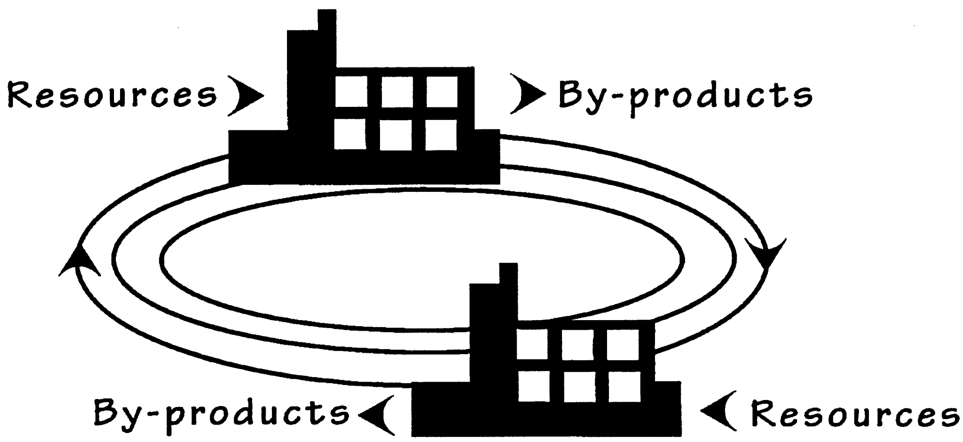
Guideline for implementing Co-generation based on Biomass waste from Thai Industries

- through implementation and organisation of Industrial Materials Networks



Ph.D. thesis

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Resumé (abstract in Danish)

Grundet den industrielle udvikling i Thailand er energiforbruget - primært baseret på fossile brændsler - steget voldsomt de seneste år, på trods af stagnation efter den økonomiske krise i 1997. Det er derfor vigtigt at reducere de miljømæssige negative effekter af dette energiforbrug, hvilket for eksempel kan ske ved energibesparelser, højere effektivitet i energiproduktionen og ved brug af forskellige typer af vedvarende energikilder. Nærværende forskningsprojekt søger derfor at udvikle strategier for udnyttelsen af spildvarme som en integreret del af den industrielle procesvarme. Gennem substituering af procesvarme, genereret via elektricitet eller i individuelle kedler ved forbrænding af fossile brændsler, med procesvarme produceret på et kraftvarmeværk - hvor de enkelte industriers affald nu i stedet konverteres - kan procesvarme distribueres til lokale industrier via et mindre fjernvarmenet. Herved kan et *'Industrial Materials Network'* blive skabt, som er fordelagtigt for de implicerede industrier og samfundet hvad angår økonomien og miljøet. Med udgangspunkt i et case studie udført i et industriområde, Navanakorn Industrial Promotion i Thailand, er strategier for effektiv materiale -, og energiforbrug søgt etableret for en række industrier i området, og har vist sig succesfuld. De implicerede industrier, samt en række lokale og nationale statslige organisationer - såvel som NGO og brancheorganisationer - har udvist interesse i implementeringen af projektet.

I projektet etableres et planlægningsværktøj - en *'Guideline'* - for en storskala implementering af disse *'Industrial Materials Networks'* i Thailand. Ved at følge en række *'Actions'* , forklarer værktøjet skridt for skridt, hvilke initiativer der må foretages for herved at sikre en sådan implementering. Kronologisk set, er 'Guidelinens' fokus først at udpege relevante aktører der kan gennemføre en sådan proces, og derefter relevante områder og industrier for implementering af *'Industrial Materials Networks'*. Herefter, vejledes der mht. hvorledes indsamling af data vedrørende forbrug af materialer og energi i industrier kan finde sted, og hvorledes data vedrørende andre relevante biomasse ressourcer fra det omkringliggende nærområde kan erhverves, og hvilke der er interessante. 'Guidelinen' viser derpå, hvorledes man ved at kortlægge *ressourcegrundlaget* og *energibehovet*, kan udvælge den mest velegnede *teknologi*, bestemmende for udformningen af energisystemets samlede *design* som derpå følger. Aspekter som ejerskab og organisatorisk opbygning er også medtaget, og udstikker guides til hvorledes den mest hensigtsmæssige ejerskabs -, og forvaltningstype kan vælges for de implicerede industrier. Et sidste emne som 'Guidelinen' berører er finansielle aspekter, hvor forskellige finansieringsformer bliver foreslået som kilde til implementering af *'Industrial Materials Networks'*.

Abstract

Due to the large scale industrial development in Thailand the consumption of energy - primarily based on fossil fuels - has increased enormously, even though the economic growth has slowed down since the economic crisis in 1997. It is, therefore, important to reduce the environmental impact of this energy consumption, which can be achieved by energy conservation, higher efficiency in the production of energy, or by the use of different kinds of renewable energy. This thesis seeks to develop new strategies for the use of waste heat as a part of the industrial process heat, which can be supplied to industries by a district heating network. By substituting process heat - produced by electricity or by boilers using fossil fuel in individual industries - with process heat, produced by a co-generation plant - using the industries own biomass waste as fuel - process heat can be supplied to industries participating in a small scale district heating network. Thus, an *Industrial Materials Network* can be created, which is environmentally as well as economically beneficial for both industry and society. On the basis of a case study of the industrial area, Navanakorn Industrial Promotion Zone in Thailand, such initiatives for efficient materials and energy uses have been conducted and proved successful, and industries - as well as local and national governmental agencies, NGOs and branch organisations etc. - have shown interest in supporting the implementation of such scheme.

In this thesis, a *Guideline for large scale implementation of Industrial Materials Network in Thailand* was developed. By following a series of Actions, the Guideline defines the initiatives that must be taken in order to ensure correct implementation. Chronologically, the emphasis of the Guideline is on pointing to relevant stakeholders who can pursue the implementation, and then appropriate areas and types of industries for Industrial Materials Network implementation. Thereafter, guidance for the collection of data regarding the consumption of materials and energy in Thai industries, as well as for biomass waste generated by the surrounding community, is emphasised. The Guideline then illustrates how to study the *resource* and *energy demand* found for an appropriate selection of conversion *technology*, determining the design of the energy system, which then follows. Organisational issues such as ownership and organisational structure are also emphasised, providing guidance for the selection of the most appropriate form of Corporate governance for participating industries. A last topic, dealt with in the Guideline, relates to financial issues, and emphasises different sources and types of financing for facilitating the implementation of Industrial Material Network.

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Interfurn; Rockwood; Sun Cabinet; B.B. Snacks; Baskin Robbins; ASAN Service; Imperial; Light House Industries; and, NMT Limited. Thank you also to the many other organisations in Thailand - governmental organisation, NGOs, branch organisations, research institutions etc. - who welcomed me during my periods of data collection.

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Table of contents

Chapter 1; Introduction p.11

1.1 Background p.11
1.1.1 Previous studies as background for this thesis p.11
1.1.1.1 Sustainability in energy production and consumption p.11
1.1.1.2 Domestic resources p.12
1.1.1.3 De-couple economic growth and increase in energy uses.................... p.12
1.1.1.4 Definition of contexts p.13
1.1.1.5 Elements of the study p.13
1.2 Thailand's development p.14
1.2.1 Resource consumption p.14
1.2.2 Energy consumption p.15
1.2.2.1 Industrial output p.15
1.2.2.2 Energy efficiency p.15
1.2.2.3 Domestic resources and waste generation p.16
1.2.2.4 Energy consumption in two sectors p.16
1.2.2.5 New conditions for renewable energy production p.16
1.2.2.6 Perspectives for energy system development p.17
1.2.2.7 Present industrial uses of biomass p.18
1.3 Purpose of the study p.19
1.4 Research question p.20
1.5 Delimitation p.20
1.6 Design of the study p.20
1.6.1 Research design - Tools and approaches p.21
1.6.1.1 Field trips p.21
1.6.1.2 Case-study p.21
1.6.1.3 Interview approach p.21
1.6.1.4 Two types of data p.23
1.6.1.5 Validity of data in the field p.23
1.6.1.6 Principles of validity p.24
1.6.2 Overall research methodology p.24

Chapter 2; Methodology p.27

2.1 Concept arrangements p.27
2.1.1 Concept arrangement - Limitation in materials use p.28
2.1.1.1 Dematerialization p.28
2.1.1.2 Industrial Ecology p.29
2.1.1.3 Important criterion for energy system development p.34
2.1.2 Concept arrangement - Biomass availability and type p.36
2.1.2.1 Cyclic materials flow p.37
2.1.3 Concept arrangement - Framework Conditions p.38
2.1.3.1 Primary framework conditions (case specific) p.38
2.1.3.2 Secondary framework conditions p.40
2.1.3.3 Important criterion for energy system development p.40

2.1.4 The Triangle Analysis p.40
2.1.4.1 The analytic platform p.41
2.1.4.2 Additional analysis p.43
2.1.5 Concept arrangement - The Guideline p.43
2.2 Morphology of the thesis p.44

Chapter 3; Theoretical pre-selection of appropriate industries and areas in Thailand p.47

3.1 Appropriate areas - Why Industrial Zones or Parks? p.47
3.1.1 Perspectives for energy system development p.49
3.2 Appropriate types of industries? p.49
3.2.1 Industries located in Phase 1 of Navanakorn p.51
3.2.2 Industries for Macro Industrial Metabolism - Food and Pharmaceutical industries p.53
3.2.3 Industries for Macro Industrial Metabolism - Wood industries p.54
3.2.4 Supporting Industries/Systems/Resources for Macro Industrial Metabolism p.55
3.2.4.1 Supporting Industries (internal) p.55
3.2.4.2 Supporting Systems (internal) p.55
3.2.4.3 Supporting Resources (internal) p.56
3.2.4.4 Supporting Resources (external) p.56
3.2.5 Overview of Supporting Industries/Systems/Resources for Macro Industrial Metabolism p.56
3.3 Energy consumption and waste generation in selected types of industries p.57
3.3.1 Pharmaceutical industries p.57
3.3.1.1 Waste generation p.57
3.3.1.2 Energy utilities and coverage of energy services p.58
3.3.1.3 Comments on energy utilities in pharmaceutical industries p.58
3.3.1.4 Waste and energy profile p.59
3.3.2 Wood and furniture industries p.60
3.3.2.1 Waste generation p.60
3.3.2.2 Energy utilities and coverage of energy services p.61
3.3.2.3 Comments on energy utilities in wood and furniture industries p.61
3.3.2.4 Waste and energy profile p.62
3.3.3 Food producing industries p.63
3.3.3.1 Waste generation p.63
3.3.3.2 Energy utilities and coverage of energy services p.64
3.3.3.3 Comments on energy utilities in food industries p.64
3.3.3.4 Waste and energy profile p.65
3.3.4 Energy potentials from biomass waste p.66
3.3.4.1 Liquid waste - Food and Pharmaceutical wastes (digest as example) p.66
3.3.4.2 Solid waste - Wood waste (incineration) p.67

Chapter 4; Navanakorn Industrial Promotion Zone and surroundings - Empirical approach p.69

4.1 Community metabolism - Resource and waste management in Navanakorn Industrial Promotion Zone p.69
4.1.1 Location p.69
4.1.2 Establishment and ownership..................... p.70
4.1.3 Infrastructure and facilities..................... p.71
4.1.4 Management objectives and Industrial Zone philosophy..................... p.72
4.1.5 Available land in the Zone p.72
4.1.6 Zoning and industries located in Navanakorn..................... p.73
4.2 Waste management and resources in Navanakorn p.74
4.2.1 Problems with present resource management - Navanakorn..................... p.76
4.3 Community Metabolism - Resources and waste management in Takhlong Municipality p.77
4.4 Community Metabolism - Resources and waste management in Pathum Thani Province p.80
4.4.2 Problems with present resource management - Takhlong Municipality and Pathum Thani Province p.81
4.4.3 Resource estimations p.81
4.4.3.1 Household waste..................... p.81
4.4.3.2 Industrial/commercial waste..................... p.83
4.4.3.4 Navanakorn Industrial Promotion Zone..................... p.84
4.4.3.5 Takhlong Municipality..................... p.84
4.4.3.6 Pathum Thani Province p.84
4.4.3.7 Evaluation of contents of organic fractions in waste..................... p.85
4.4.4 Contextual conditions for development of an energy system p.85
4.5 Micro Industrial Metabolism - Case industries..................... p.86
4.5.1 Pharmaceutical industries p.86
4.5.1.1 Imperial Industrial Chemicals p.86
4.5.2 Food producing industries..................... p.88
4.5.2.1 ASAN Service..................... p.88
4.5.2.2 B.B. Snacks..................... p.90
4.5.2.3 Baskin Robbins p.93
4.5.3 Wood industries p.94
4.5.3.1 Sun Cabinet..................... p.94
4.5.3.2 Rockwood p.96
4.5.3.3 Interfurn..................... p.99
4.5.3.4 Light House Industries..................... p.100
4.5.4 Resource estimation (waste generation) p.101
4.5.4.1 Pharmaceutical industries - Liquid waste..................... p.101
4.5.4.2 Food industries - Solid waste..................... p.101
4.5.4.3 Wood industries - Solid waste..................... p.101
4.5.4.4 Supporting Industries - Solid waste..................... p.101
4.5.4.5 Comments on industrial pre-selection p.102
4.5.5 The supply and value of biomass waste..................... p.103
4.5.5.1 Constant supply of waste..................... p.103

4.5.5.2 The value of internal/external re-use of biomass waste p.103
4.6 Perspectives for energy system development p.104

Chapter 5; Triangle Analysis - Resources p.107

5.1 Energy potentials of biomass waste p.108
5.2 Evaluation of biomass waste p.109
5.2.1 Energy potentials of waste p.109
5.2.1.1 Strategies in developing an energy system p.109
5.2.2 Character of biomass waste p.109
5.2.2.1 Strategies in developing an energy system p.110
5.2.3 Other important fuel specifications p.110
5.2.4 "Treatment" possibilities of waste p.110
5.2.4.1 Liquid waste - can be dried p.111
5.2.4.2 Liquid waste - cannot be dried p.111
5.2.4.3 Solid waste p.111
5.2.4.4 Solid waste - can be liquid p.111
5.2.4.5 Strategies in developing an energy system p.112
5.2.5 Contamination of biomass waste p.112
5.2.6 Incineration contra digestion? p.114
5.2.6.1 Heavy metals and organic compounds - incineration p.114
5.2.6.2 Heavy metals and organic compounds - digestion p.115
5.3 Strategies in developing an energy system p.116

Chapter 6; Triangle Analysis - Energy demands (industrial End-uses) p.117

6.1 Energy consumption patterns in case industries p.117
6.1.1 Heat uses p.117
6.1.2 Operation hours and heat demands p.122
6.1.2.1 Optimum size of energy plant (incineration) p.124
6.1.2.2 Estimated future energy demands p.124
6.1.3 Strategies in developing an energy system p.125
6.2 Conversions and optimisations in energy uses p.125
6.2.1 Wood industries p.126
6.2.1.1 Conversion to water based heat by district heating p.126
6.2.1.2 General optimisations by process equipment p.127
6.2.2 Food industries p.128
6.2.2.1 Conversion to water based heat by district heating p.128
6.2.2.2 General optimisations by process equipment p.129
6.2.3 Pharmaceutical industries p.130
6.2.3.1 Conversion to water based heat by district heating p.130
6.2.3.2 General optimisations by process equipment p.131
6.3 Evaluation of End-use demands p.132
6.4 Strategies in developing an energy system p.132

Chapter 7; Triangle Analysis - Technology p.135

7.1 Identification of possible technologies p.135
7.1.1 Incineration p.136
7.1.1.1 Steam Turbine Plant.. p.136
7.1.1.2 Resource and End-use demands.. p.138
7.1.1.3 Technical level and Danish experiences.. p.140
7.1.1.4 Bobbling Fluidised Bed (BFB) with Steam Engine application p.140
7.1.1.5 Resource and End-use demands.. p.142
7.1.1.6 Technical level and Danish experiences.. p.143
7.1.2 Digestion p.143
7.1.2.1 Biogas Plant with Gas Engine application.. p.143
7.1.2.2 Resource and End-use demands.. p.145
7.1.2.3 Technical level and Danish experiences.. p.146
7.2 Evaluation of technology.. p.146
7.3 Strategies in developing an energy system p.147

Chapter 8; Macro Industrial Metabolism - Design of the energy system.. p.149

8.1 Optimising the Triangle p.149
8.1.1 Steam Turbine Plant and BFB combustion plant.. p.149
8.1.1.1 Energy supply and location of the energy plant. p.149
8.1.1.2 Composition of waste and specific plant design.. p.151
8.1.1.3 Plant flexibility.. p.151
8.1.1.4 Capacity of meeting increases in End-use demands.. p.152
8.1.2 Evaluation of the most optimal design of energy system p.153
8.1.3 Strategies in developing an energy system p.154
8.2 The transformation strategy.. p.154
8.2.1 Back-up system p.155
8.2.2 Strategies in developing an energy system p.155
8.3 Environmental evaluations of options p.156
8.3.1 Performance of technologies.. p.156
8.3.2 Evaluation of technologies p.157
8.3.3 Emissions analysis.. p.157
8.3.4 Strategies in developing an energy system p.157
8.4 Contextual conditions and choice of technology.. p.157
8.4.1 Strategies in developing an energy system p.158
8.5 Pre-Feasibility Study of options p.159
8.5.1 Cost-savings analysis p.159
8.5.2 Sensitivity analysis.. p.164
8.5.3 Emissions analysis.. p.165
8.5.4 Evaluation.. p.165
8.6 Strategies in developing an energy system p.165

Chapter 9; Organisation of the Industrial Materials Network in Navanakorn p.167

9.1 Transaction costs/Risk minimisation p.167
9.1.1 Risk assessment p.167
9.1.2 Transaction costs and Risk minimisation p.169
9.1.3 Contextual conditions and Risk minimisation p.170
9.1.3.1 Case industries in Navanakorn p.170
9.1.3.2 Strategies in developing an energy system p.172
9.1.3.3 Relevant local stakeholders p.172
9.1.3.4 Co-operation benefits p.174
9.1.3.5 Strategies in developing an energy system p.175
9.2 Conditions for Inter-industrial Co-operation p.176
9.2.1 The industries' point of view p.177
9.2.2 Co-operation possibilities and barriers p.179
9.2.3 Various stakeholders' possibilities for braking down barriers p.180
9.2.4 Pre-conditions for co-operation - Overall framework p.181
9.2.5 Strategies in developing an energy system p.182
9.3 Corporate Governance p.183
9.3.1 Different types of Corporate Governance p.183
9.3.2 Economic consequences of different types of ownership p.185
9.3.2.1 Pre-conditions p.185
9.3.2.2 Economic consequences p.185
9.3.3 Pros' and con's of different types of ownership in the specific context p.186
9.3.4 Evaluation of options p.188
9.3.4.1 Transformation of power in a Limited Partnership p.189
9.3.4.2 Possibilities for setting up a Limited Partnership p.190
9.4 Strategies for developing an energy system p.190

Chapter 10; Guideline for Industrial Materials Network implementation p.191

10.1 Introduction p.191
10.1.1 Purpose of the Guideline p.191
10.1.2 Generalisation p.192
10.1.2.1 The location issue p.192
10.1.2.2 Types of industries p.192
10.1.2.3 The potentials of Industrial Materials Networks p.193
10.1.2.4 "Built-in validity" p.193

Guideline Actions

Action 1: Project *problem* approach p.195
Action 2: Stakeholder identification p.196
Action 3: Locate appropriate industries for Industrial Materials Network implementation p.197
Action 4: Map biomass waste and energy uses p.199
Action 5: First Triangle Analysis - technical feasibility p.201
Action 6: Second Triangle Analysis - corporate feasibility p.208
Action 7: Financing; How to finance and commence the construction phase p.210

Chapter 11; Conclusion p.215

11.1 Guideline Actions p.215

References p.225

Appendix's p.241

Appendix A p.241
Appendix B p.277
Appendix C p.285
Appendix D (part 1 & 2) p.291

Chapter 1; Introduction

The purpose of this study is to increase the use of biomass resources for renewable energy production in developing, or, more likely, in newly industrialised countries (NICs). In recent years, many such countries have had high economic growth rates, which have led to intensive pressure on natural resources and demands for energy services. At the same time, many NICs are blessed with a diversity of biomass resources due to their rich natural vegetation, and due to the intensive industrial production, these countries also generate large quantities of industrial biomass wastes that could be useful for renewable energy production. One such NIC is Thailand, which has experienced an economic boom starting in the middle of the 1980s and continuing to the late 1990s. This has both led to a dramatic change in life styles, and the provision of energy services. Today, big centralised fossil fuelled power plants provide energy to the Thai people, and the use of biomass for energy production has declined tremendously.

The purpose of this thesis is, therefore, to study how the use of biomass for energy production can become a part of the energy supply in modern Thailand, and how the use of such resources can be managed and by whom. The possibilities of using biomass for energy purposes, however, depend on the specific context, as energy production from biomass resources is highly context dependent. This thesis thus focuses on increasing the use of biomass for energy purposes, departing from the analysis of one single context, being the specific case under study in Thailand. By capturing this context, and transforming it to a planning tool capable of covering other Thai contexts, I hope to have contributed to some ideas and plans as to how to increase the use of biomass resources for energy purposes in Thailand, and in other NICs in South East Asia as well.

1.1 Background

Before commencing on the introduction to the research area (section 1.2 Thailand's development), I would like to explain my background for doing this study.

1.1.1 Previous studies as a background for this thesis

As a result of my work on two Master's degree projects[1], I have come to see that certain *aspects* must be valued or emphasised in order to obtain success in the implementation of renewable energy and energy efficiency in a *Danish context*. These aspects are discussed below:

1.1.1.1 Sustainability in energy production and consumption

One important conclusion arrived at, as the result of my Master's projects, is the concept of sustainability in energy production and consumption. Sustainability in energy production and consumption can be obtained by various means, by for instance increasing the efficiency of

[1] "New planning strategy for implementing windmills in the public sector in Denmark - The concept of resources as basis for windmill planning" (1998) & "Technological, - innovative and market supportive initiatives for implementation of small scale biogas plants in Denmark" (1999).

existing energy technologies (co-generation, combined cycle etc.), by limiting energy uses in general (insulation/technical equipment using less energy etc.), by increasing the use of *constant energy sources* (wind, solar etc.) or by using *re-created sources* for energy production - resources that otherwise would have been discharged or not used for energy production (industrial waste, animal manure etc.).

The focus of this thesis corresponds with the aspects of sustainability mentioned above: *Firstly*, as the priorities are uses of non-fossil fuels by means of materials, which lower the pressure on virgin materials, such as wastes from food and wood industries. The focus on re-created energy sources is therefore in line with the aspect of sustainability, as emphasising the use of materials that otherwise would be wasted or utilised inappropriately. *Secondly*, the energy must be produced as efficiently as possible so that less fuel produces more energy. Here in particular, combined heat and power production is important, leading to higher resource usage compared to power production only. *Thirdly*, the produced energy must be utilised as efficiently as possible so as to limit energy use. This can be obtained by making use of generated heat, and by making use of generated heat *and* electricity more efficiently (better household machinery and industrial equipment, district heating and cascading of heat etc.).

1.1.1.2 Domestic resources

A conclusion of previous studies of the Danish context is that surprisingly large quantities of energy can be produced, by using domestic renewable resources for fuel, thereby substituting the use of fossil fuels. These resources can be categorised as ***constant energy sources*** (wind, sun, wave and hydropower etc.) or as ***re-created energy sources***, which derive from a previous process (incineration of wood waste from furniture industries, or production of biogas made by manure deriving from the process of bringing up pigs etc.). As for both the *constant energy sources* and the *re-created energy sources*, the energy facility is often located relatively close to the energy source, and is dependent on whether the electricity and heat can be used locally or sold on a market. From experiences gained through working with biogas produced by animal manure, I have come to find the production of renewable energy deriving from a previous process especially interesting, thus re-created energy sources. This is due to the fact that this type of waste sometimes simply is discharged, and when actually used for energy purposes, it often happens quite inefficiently.

1.1.1.3 De-couple economic growth and increase in energy uses

Another aspect of importance in regards to energy production and efficiency, seen in a Danish context, is the achievement of almost no increase in the use of energy for a period of 25 to 30 years, while there was continuous economic growth at the same time. This development is quite remarkable and contrasts with many otherwise similar countries, which have experienced dramatic increases in energy demands alongside economic growth. Two important reasons for this have been the expansion of district heating networks in Denmark, and thus the utilisation of waste heat from the electricity production. Also initiatives relating to the insulation of buildings and houses etc. have saved much in the total consumption of energy.

1.1.1.4 Definition of contexts

Finally, the importance of looking at the specific context, which is intended to be changed or influenced, must be emphasised. This also includes the specific stakeholders who are a part of or will be affected by this change or influence. The specific context, including the stakeholders moving in it, is never identical from one area to another area. This means that the most optimal solution in one area might only be second best - or not work at all - in another area. It is, therefore, important to define the contexts better, as it can improve the success rate of projects.

Some of the conclusions obtained from working with the two Master's degree projects - exemplified above - can be utilised as cornerstones in this thesis, in which a planning tool will be developed for efficient production and consumption of renewable energy in Thailand. Experiences with energy planning in Denmark over the past 25 to 30 years have resulted in knowledge that can be beneficial in other parts of the world, as long as we do not try to transfer *our* context to the developing countries. As the economies and social structures of society in such countries often are very different from ours, it is especially important to analyse *their* context, before commencing the transfer of knowledge regarding renewable energy and energy efficiency.

Thus, the Danish experiences must be co-ordinated with the specific context in which they have to operate, before being implemented. From the Danish context, I have extracted some aspects that define some non-context dependent concepts. These non-context dependent concepts will be transformed into a planning tool (a Guideline) that can capture the specific and different Thai contexts where applied.

1.1.1.5 Elements of the study

In the following, I will briefly summarise which elements the thesis will work with as focal points for obtaining sustainability in energy production and consumption:

- Work with domestic biomass fuel coming from re-created energy sources (industrial biomass wastes);
- Work with the implementation of co-generation and district heating (utilisation of waste heat and cascading of heat);
- Work with limitations in energy uses by optimisation in manufacturing processes and implemented equipment (demand side management and conversion from steam to water based heat uses);
- Work with the transfer of experiences from one country to another (from Denmark to Thailand), in which the specific context is captured, and the transferred experiences co-ordinated with local conditions;

1.2 Thailand's development

The following is the introduction to the research area, which includes a presentation of Thailand's development, Purpose of the study, Research question, Delimitation and Design of the study.

1.2.1 Resource consumption

From the beginning of the 1960s, Thailand has had rapid economic growth with only a few years of decline in the 1970s and 1980s. Between 1987 and 1997 - Thailand's Golden Era - the country experienced growth rates of 9 % per year, and during the period of 1988 to 1991 growth rates of more than 10 % per year (The State of Thailand's Environment, 1997, OEPP, 1998). This rapid growth made Thailand a member of the "young tiger" economies of Asia (the 5th tiger), in line with countries like South Korea, Taiwan, Singapore and Hong Kong. During this period, the Thai economy had one of the highest growth rates in the world, and experienced the most rapid transformation from a primarily agricultural to an industrialised economy ever seen. Thus, Thailand has in many ways developed into a modern and industrialised society (Ibid.).

Throughout the last three decades this transformation process has put a dramatic pressure on natural resources in Thailand, such as water, forests and land. The population growth, rapid urbanisation and industrial development, has led to many environmental problems, such as increased water and air pollution, increased solid waste generation, as well as a growing need for energy services all of which have had negative environmental impacts. The growing need for energy services has resulted in load forecasts suggesting the need for a dramatic increase in the electricity generation capacity from 13,311 MW in 1997 to 30,557 MW in 2011 (National Power development Plan (1999-2011), Revised PDP, EGAT, 1999). This means that within a period of 15 years the electricity generation capacity will grow by 17,609 MW in order to meet the expected increase in energy demands.

The environmental impacts of an electricity generation capacity expansion of almost 18,000 MW is, within the present energy system, a large problem. In modern Thailand energy services are primarily produced by big centralised, primarily power producing, facilities based on fossil fuels, or by hydropower facilities producing electricity only. The "National Power Development Plan" therefore also focuses on fossil fuels - natural gas and imported coal - as the main source for obtaining the capacity expansion (National Power development Plan (1999-2011), Revised PDP, EGAT, 1999). The environmental impacts of this energy production will be high, due to intensified emissions of SO_2, NO_x and CO_2. But also hydropower plants can lead to environmental problems, with social and economic impacts. This is caused by the reduction in agricultural land available due to the establishment of dams, and in the decline of fish resources etc. due to the destruction of natural habitats.

1.2.2 Energy consumption

1.2.2.1 Industrial output

It is estimated that industrial activities in Thailand will grow dramatically over the next decades, as East Asian countries will increase their share of the global industrial output. By the year 2025, this part of the world is expected to obtain as much as 55-60 % of the total global industrial output (Asian's Re-emergence, S. Radelet and J. Sachs, in Foreign Affairs, Vol. 76, Number 6, 1997). Estimations of the future energy demands in East Asian countries further stress that the energy consumption will more than double within the year 2020, and that carbon emissions will increase likewise due to the industrial growth, as emphasised above (Development of Asian Mega Cities: Environmental, economic, social and health implications, US Global Change Research Program, G. Carmichael and F. Sherwood Rowland, 1998). Therefore, East Asian countries will most likely overtake the OECD economies, as the largest source of green house gas emissions world wide, sometime between 2015 and 2020 (Industrial Ecology and Clean Development in East Asia, Michael T. Rock, et. al., in Journal of Industrial Ecology, Vol. 3, number 4, 2000).

Even though some of these expectations were formed *before* the economic crises gained speed, and therefore might not be matched, the development puts great pressure on means for finding environmentally friendly solutions for materials and energy uses; Thus, to developing more sustainable production methods for the expected industrial growth in near future, hereunder usage of renewable energy.

1.2.2.2 Energy efficiency

Compared to energy figures for OECD countries (here the US and Japan), East Asian figures for energy efficiency are only 40 and 15 % respectively, of what is obtained in these countries (Industrial Ecology and Clean Development in East Asia, Michael T. Rock, et. al., in Journal of Industrial Ecology, Vol. 3, number 4, 2000), and compared to Denmark the figures for energy efficiency are even lower yet. One of the main reasons for this is the inefficiency of producing electricity only, which is common in East Asian countries, thus there is no use made of generated surplus heat that is a free "by-product". Also the transmission of electricity is quite inefficient, primarily due to large energy losses on the grid. On the transmission side, the average losses are 3 to 4 %, and on the distribution side 13 %. Compared to OECD figures (here Denmark) the average losses are 1.50 and 5 % respectively (Mission on Sustainable Energy, Thailand, Ministry of Energy, 1998).

The energy consuming part of the energy system also suffers from inefficiencies, which come from a wide range of sources, such as bad insulation in buildings, which leads to unnecessary uses of energy for air conditioning etc., and poor maintenance and use of efficient processing technologies in industries. These aspects result in an overall high energy consumption (Mission on Sustainable Energy, Thailand, Ministry of Energy, 1998).

1.2.2.3 Domestic resources and waste generation

Thailand's energy demand has for many years primarily been covered by biomass resources - as for instance wood fuel and charcoal - but the changes in lifestyle and economic growth during the 1980s and 1990s, has included Thailand in the globalised economy. Many industries during that period gave up the use of biomass for internal energy production. Today, this has lead to a large fall in the use of biomass resources for energy purposes, not only in industries but also in private households (Sustainable Energy, Sustainable Society, Thai-Danish Co-operation on Sustainable Energy, 1999).

This, in combination with growing quantities of industrial as well as household waste, has lead to intensified problems in finding appropriate landfill areas for industrial as well as household wastes in Thailand. Some industrial biomass wastes are therefore burned uncontrolled, or openly dumped and left to decompose naturally, which causes air pollution, hygienic problems and threatens to contaminate ground water capacities and the natural life (Environmental management in Thailand - Achievements, Barriers and future Trends, Mandar Parasnis, Ch. 12 in Growing Pains, TEI, 1999). Again, some other biomass waste is transported over increased distances in order to find spatial room for landfill areas. This is for example the case in Pathum Thani Province in Thailand, where increased amounts of waste in the community leads to ever longer transportation distances for industrial/household waste.

1.2.2.4 Energy consumption in two sectors

In the *transportation sector* we find the heaviest energy consumption in Thailand accounting for 787.10 PJ (18,632 ktoe) (Thailand energy situation 2001, DEDP, 2001). In the last decade, the growth in this sector has shown a 100 % increase in energy consumption from 430.90 PJ in 1989 to 798.40 PJ in 1998. The expanded use of private cars stood for more than 80 % of the energy use in the sector in late 1990s (Thailand energy situation 1998, DEDP, 1998).
The *manufacturing sector* is thus the second largest energy consumer amounting to 714.90 PJ (16,922 ktoe), or 34.20 % of total energy use in 2001. Energy consumed in this sector was primarily coal (25.90 %), petroleum products (23.60 %), renewable energy (20.60 %), electricity (20.70 %) and natural gas (9.20 %) (Thailand energy situation 2001, DEDP, 2001). In general, the use of renewable energy has declined in this sector. In 1981 it stood for about 50 % of the energy consumption (Sustainable Energy, Sustainable Society, Thai-Danish Co-operation on Sustainable Energy, 1999), but now contributes to approximately 20 %. (See Annex A for more details on the energy production and consumption in Thailand).

1.2.2.5 New conditions for renewable energy production

Economic globalisation and World Bank policies towards developing countries have initiated a movement towards deregulation, or privatisation, of former state owned or controlled institutions in Thailand, i.e. privatisation of the financial sector in the early 1990s and the ongoing process of privatising the energy sector (Sustainable Energy, Sustainable Society, Thai-Danish Co-operation on Sustainable Energy, 1999). Privatisation of the energy sector puts emphasis on private stakeholders as energy producers in the coming years. The question is, however, whether much focus will be on the utilisation of biomass for energy production in a privatised energy market. As energy made from renewable energy in general tends to cost more compared to conventional energy production, the competition between suppliers will most likely marginalise the utilisation of biomass resources for energy purposes even further.

It is, therefore, important to create strategies for the development of a more sustainable energy production and consumption in Thailand, based on *domestic biomass waste* with target stakeholders being the private sector. As the manufacturing sector is the second largest energy consumer in Thailand, after the transportation sector (Thailand's Energy Situation 2001, DEDP, 2001), it is obvious to develop sustainable energy production and consumption in the Thai manufacturing sector. Especially Small and Medium size Enterprises (SME) are of importance in this context, as these types of industries generate more than 90 % of the total industrial output in Thailand (Environmental management in Thailand - Achievements, Barriers and future Trends, Mandar Parasnis, Ch. 12 in Growing Pains, TEI, 1999).

1.2.2.6 Perspectives for energy system development

According to the previously mentioned long term energy targets set by Thailand (until 2011), the projected energy generation capacity will increase by almost 18,000 MW within a period of 15 years (see Annex A for more details regarding the Thai energy sector and its stakeholders etc.). In the "National Power development Plan", this capacity increase is, as mentioned earlier, expected to be covered by domestic and imported natural gas as well as imported coal. The share of renewable energy in the energy production has and will continue to decline over the coming year relatively, due to the expected increase in power plants fed by fossil fuels (National Power Development Plan, Revised PDP, EGAT, 1999).

There are, however, initiatives regarding the implementation of renewable energy in Thailand, for instance the Small Power Producers (SPP). As of January 2003, only 42 of 72 SPPs produced renewable energy, and in total all SPPs produced energy amounting to 2,354.94 MW (Classified Generated Electricity of SPP by type of fuel, NEPO Homepage, 2003; at www.eppo.go.th/power/pw-spp-purch-raw-E.html, per 2-6-03). The environmental effect of implemented SPPs is therefore quite limited, when compared to the total energy production in Thailand. Moreover, all Independent Power Producers (IPPs) in Thailand are solely fed by fossil fuels, primarily natural gas (Thailand's IPP award (as of January 2003), NEPO Homepage, 2003, at; www.eppo.go.th/power/pw-ipp-awards-E.html, per 29-5-03). (See Annex A for further more details on SPPs and IPPs).

The dramatic need for capacity expansion in the energy sector in Thailand also means that old and inefficient power plants, those especially fed by fuel oil and coal etc., are not phased out and replaced by more modern and efficient technologies, as for instance combined cycle technologies fed by natural gas. The energy sector in Thailand can, therefore, be characterised as completely linear, with no attempts to approach a cyclic flow - or closing the loops - in the implementation of new capacity. A more cyclic flow could, however, be obtained by substituting the most inefficient and polluting technologies with energy production from more efficient technologies based on domestic biomass resources. But how can such cyclic flow, posed by the implementation of renewable energy, be introduced in the Thai energy sector creating a "room" for the ideas behind Industrial Ecology? (to be introduced in Chapter 2).
It is my belief that the private sector in Thailand must take the lead in such developments, as lack of initiatives and power from the central administration, now act as barriers for such development (Pers.Com., Jan Andersen, 2001).

The manufacturing sector is the second largest energy consumer in Thailand, only oversized by the transportation sector. The manufacturing sector is therefore interesting as a target stakeholder in such development, firstly due to the large energy consumption appropriate for a substitution to renewable energy. Secondly, the manufacturing sector is a mix of many different lines of businesses (branches) in which appropriate biomass waste for energy production can be found. This sector is, however, not the *energy sector*. It is therefore important that appropriate means of renewable energy implementation take place, so that this group of stakeholders is willing to take on such responsibility.

1.2.2.7 Present industrial uses of biomass

Biomass resources is highly represented in Thailand, and has been a primary source of energy for many years, used in for example cooking stoves in households and in the manufacturing industries for thermal energy production. Combustion or digestion of biomass wastes is a CO_2 neutral process as emissions of CO_2 from biomass uses, equals the amounts of CO_2 consumed through the lifetime of organisms. If biomass is left to decompose, it will contribute to the same amount of CO_2 emissions as when used for energy purposes. Some analyses estimate that biomass wastes can cover up to 15 % of the energy demand in Thailand (Thailand-Danish Country Programme for Environmental Assistance 1998-2001, Ministry of Environment and Energy, 2000). These estimations are primarily made from biomass waste from the extraction part of agricultural activities, and for large scale agricultural processing of crops etc. - as for instance saw and palm oil mills - and do not include biomass wastes from SMEs in Thailand. Thus, the energy potential of biomass waste can be much larger if these resources are included.

Biomass technologies are already implemented in various manufacturing branches in Thailand. Almost all sugar mills have for example implemented co-generation technologies based on their own biomass wastes for internal process heat generation (Evaluation of conditions for electricity based on biomass, EC-ASEAN COGEN, 1998). The efficiency of implemented technologies is, however, quite low, and often compensated for by uses of fossil fuels as supplements, even though energy produced from biomass could cover internal energy demands. In some cases, the converting technologies are deliberately set to a low efficiency (energy output) in order to incinerate all the amounts of generated biomass waste, hence solving an industrial waste problem (Ibid.).

Even though some agricultural industries generate sufficient amounts of biomass wastes, as well as having a demand for internal process heat, co-generation technologies are also not always applied. Out of, for instance, 52 palm oil mills in Thailand, only 20 % have implemented co-generation technologies, and therefore depend on the purchase of electricity from the grid as well (Thailand Biomass-Based Power Generation and Co-generation within Small Rural Industries, NEPO, 2000). Many agricultural industries such as rice and palm oil mills are often located in remote areas, where there are no possibilities for selling surplus heat, either to other industries or to a district heating network. In combination with limited possibilities for selling electricity to the grid, the implementation of efficient co-generation technologies is thus not attractive.

These conditions have initiated a development in which industries produce process heat by using high qualitative energy, i.e. electricity (Thailand Power Pool and Electricity Supply Industry NEPO, 2000). This is a very inefficient method of providing process heat, as the overall energy efficiency of centralised power plants in Thailand normally are between 31 and 35 % (Mr. Ludovic Lacrosse, EC-ASEAN COGEN, Bangkok, Letter dated the 14-6-01). The energy losses, or inefficiencies, in this part of the energy production are therefore extremely high.

The existing uses of biomass for energy purposes are therefore quite inefficient and based on inappropriate technologies. The main reason for this is that biomass to a great extent are regarded as wastes, and when used for energy production it is mainly to reduce a *waste problem*, and not to produce energy by means of efficiency (Sustainable Energy, Sustainable Society, Thai-Danish Co-operation on Sustainable Energy, 1999 & Mr. Ludovic Lacrosse, EC-ASEAN COGEN, Interview, Bangkok the 14-2-00). By implementation of more appropriate co-generating technologies it is, however, possible to increase the efficiency of energy production. But in order for such a development to materialise, relevant markets for process heat must be located and small scale district heating networks between appropriate manufacturing industries be established.

1.3 Purpose of the study

I believe, that the present decline in economic growth rates in Thailand could be seen as a space for re-thinking the energy situation, and develop *changes in the energy system* towards more sustainable energy production and consumption pattern. To obtain this, a more decentralised energy system - based on domestic renewable resources and efficient energy utilisation - must be developed, as opposed to existing low efficient centralised systems based on fossil fuels.

The aim of the thesis is, therefore, to establish co-operation between private SME in Thailand, so that efficient energy production and consumption can be initiated. By using the industries own biomass waste as fuel for renewable energy production in co-generation technologies, it is possible to substitute the use of fossil fuels or electricity for process heat generation in individual industries. This will enable the use of domestic biomass resources for energy purposes and reduce the pressure on virgin materials. By establishing a small scale district heating network between industries, water based heat can be transmitted to industries, just as the produced electricity can be transmitted by uses of the national or own grid. Another aim of the thesis is, therefore, to locate industries (thus markets) having a demand for water based process heat - or find means of converting steam uses to water based uses in these industries - and generates biomass waste appropriate for energy production.

Such co-operation between different types of industries in what I call ***Industrial Materials Networks***, must, however, be established so that co-generation technologies match the actual energy needs of participating industries, and are capable of converting the biomass waste generated, as efficiently as possible. This is in line with the aspects of sustainability as emphasised earlier. It is also important that the most appropriate form of Corporate governance supports the Industrial Materials Network, for the ownership and organisation of the corporation to be made in accordance with, for example, the economic and co-operative capacities of participating industries etc.

The aim of this thesis is thus to create some guidelines concerning how to approach the implementation of Industrial Materials Network in Thailand on a general level: from the point of locating the most appropriate types of industries for such co-operation; to how the biomass waste and energy demands in industries can determine the choice of technology; to which type of corporation to establish etc. The Guideline will be established along the way that an actual energy system development takes place in a case area in Thailand. From this case relevant notions are extracted for Guideline creation. The *overall purpose* of this project is therefore to create a Guideline, which can be used for large scale implementations of Industrial Materials Networks in Thailand, as well as in other NICs in South East Asia.

1.4 Research question

- ***How can the implementation and organisation of Industrial Materials Networks be facilitated in Thailand - emphasised by an energy system development in a case area, and presented as a Guideline for large scale implementation?***

1.5 Delimitation

The focus of this thesis is how to increase the implementation of small scale electricity and heat (co-generation) producing facilities. Thus, I delimit the thesis from analysis of how to produce heat, electricity *and cooling* (tri-generation), as the latter has secondary priority when creating efficient energy systems.

Moreover, the thesis focuses on different types of industries, which generate their own biomass waste appropriate for energy production. The focus is therefore the connections between, on the one hand, the *industrial system*, and, on the other hand, the *energy system,* and how these can interact or work together for industrial self-supply of energy services. The focus is, therefore, not how and why for instance to substitute the industrial output, so that it benefits the energy production the most - or how to apply other resources as for instance energy crops - but merely how an *integration* of two systems can be developed. Most emphasis of the study is furthermore placed on fuel substitution and efficient energy uses, and to a minor extent on energy saving initiatives within industries.

1.6 Design of the study

In the following, I will elaborate on issues and thoughts behind the Design of the study as outlined in the sections on Research design - Tools and approaches and the Overall research methodology.

1.6.1 Research design - Tools and approaches

1.6.1.1 Field trips

The data in this study are gathered through three field trips to Thailand conducted in January/February 2000, January/February 2001 and April/May 2003:

At the *first* field trip (2000) - in which I also attended the DUCED I&UA Field Course at University of Mahidol, Bangkok, Salaya - I managed to establish a lot of contacts in Thailand, and to get a first impression of the country and its people. This first trip, which was placed in the first month of my employment as a PhD student, has been extremely important for my later work and actions in relation to Thailand, as it taught me a great deal about the Thai culture in an early stage of my work: *codes; customs; do's; and, don'ts* etc. In addition it produced contacts that were helpful on several occasions later on. At the *second* field trip (2001), I conducted interviews in the industries located in Navanakorn Industrial Promotion Zone and in many other relevant organisations etc., which gave me data to develop the Guideline for Industrial Materials Network implementation. This Guideline was then revised and extended according to feed back and new information obtained at the *third* field trip (2003).

1.6.1.2 Case-study

As mentioned several times, I employ a case study approach to the research area, and industries located in the specific Industrial Zone examined, will be regarded as the case material. The actual type of case can be described as a multiple case - an embedded multiple case - as the selected (embedded) study areas, are chosen for each industry being a part of the case. The industries will be examined as individual cases, but as a whole the case study design is multiple (Case Study Research - Design and Method, Robert K. Yin, 1994). The aim of choosing a multiple case is not the replication of data, as usually argued for selecting this type of design, but to illustrate how industries can work together in Networks. In seeking replication, several Industrial Materials Networks should thus be established. Thus, Thailand acts as an analytic frame and the industries as the specific case.

1.6.1.3 Interview approach

The interview method used in this thesis origin in the semi-structured qualitative approach, where approximately 2/3 of the interview period is based on bounded (pre-defined) research questions, and the remaining period left to an open discussion. This gives the interviewees a possibility to draw on aspects of personal importance or interests. I have chosen this interview form to ensure a more open approach to the research area, as interviewees can illuminate aspects that the interviewer did not know existed, or did not know the importance of.
Before each interview, I elaborated a question guide and revised it as the interview went on, because of new information and thus new questions arising.

The questionnaire technique has been to question the interviewees so they talk, and thereby "seek verbal descriptions of phenomenon and understandings". It has also been the aim not to pose questions such as "yes" or "no" could be answered, and not to "put words in the mouth" of the interviewees. The aim has further been to obtain an open and friendly interview situation, where interviewees felt that they had essential information to share. The methodologies of elaborating question guides and techniques concerning interviews in general, are inspired by Knut Halvorsen; Å forske på samfunnet. En indføring i samfunnsvitenskapelig metode, 1989: 80-88.

During the interviews, I took notes to the answers given by the interviewees, and then went straight home, to elaborate a full summary of the interview and enter my diary notes (see below). All interviews took between one and two hours. I have not used a tape recorder during my interviews in Thailand, because I have come to understand this as a barrier for Thai people. They are not as accustomed as people in the North to interviews in general, and they do not have the same tradition for revealing information that might concern others than themselves, or for instance sensitive company data about energy uses and waste generation, especially if it gets documented on tape.

All interviews, except for three, where conducted in English. I deliberately tried to "find the level of English" spoken by the interviewee, in order to create a good atmosphere and to establish a form of communicating in which we where equal individuals. I have also sought to avoid misunderstandings due to language barriers by posing the questions differently (rephrasing them etc.), if I sensed any kind of insecurity or confusion regarding the questions. In three interviews conducted, I used an interpreter from University of Mahidol (a Master's degree student). Before the interview, I made sure that the interpreter understood my research and thus the meaning and reasons for the interviews. In this way, I hoped to avoid that important information slipped away by the interpreter not understanding the focus of the research.

Besides trying to create a good atmosphere and establish an equal form of communicating in regards to language skills, as described above, I also sought to adapt to the Thai way of showing respect in the way I carried myself while being in Thailand:

First of all, I have adopted the *Wai*, which is the Thai way of greeting each other where the hands are brought together in a sort of prayer position at chest or mount level, accompanied by a slight bow. Usually, people at lower rank will *Wai* people at higher rank showing them respect and honour this way (Working with the Thais, Henry Holmes and Suchada Tangtongtavy, 1997). In the beginning it felt a bit awkward doing the *Wai* being a foreigner, but as I immediately sensed that the Thai people liked it, I did not think more of it afterwards. By reading literature about Thai culture, and of course by talking to Thais about the subject, I have come to realise how important the *Wai* is for Thai people, and I believe my approach and relations to the Thai people have been facilitated by my adoption of *Wai* combined with appropriate dress.

Second, I have sought not to be loud (as I usually can be) and for instance not show anger or other emotions, as it embarrasses and discomforts Thai people. Thais are taught that one should *"exercise restraint and maintain composure in stressful situations, avoiding extreme displays of emotion, where one is angry, sad - or even happy"* [2] (Working with the Thais, Henry Holmes and Suchada Tangtongtavy, 1997:56). *Third*, besides the aspects mentioned above, I have tried to show respect towards the interviewees during the interview situation -

[2] Own italicisation.

by for instance smiling and being forthcoming - and in the way I physically carried myself during the conversation: for instance not pointing at the informants with my feet; not being barefoot; and, not getting to close physically etc.

1.6.1.4 Two types of data

Two types of data have been collected in this thesis. Different questions have arisen, which has made it necessary to distinguish between and conduct different modes of information collection; thus quantitative and qualitative data collection. The "how much" and "how many" questions, opposed to the "how" and "why" questions, separates the quantitative data from the qualitative data. Data from research areas posing "how much" question's etc., has been collected as quantitative data by a question paper during the interview. The "how" question's etc., has been collected by semi-structured qualitative interviews.

1.6.1.5 Validity of data in the field

When being in the field a method often used by ethnographies is to keep diaries. Especially when working in another culture, and in a context where English is a second language for both parties, this can be a god idea for later evaluations of data validity. With a narrative approach to diary writing while being in the field, I have sought to capture the interview "atmosphere" from each interview, and adopted it as a personal validity criteria for further interpretations of the empirical data (Case-Studier - Af og om mennesker i organisationer, Erik Maaløe, 1999:164-165). Data analysis often begins already in the field, where a selection of "important aspects" against "not so important aspects" is made.

Maaløe thus stresses the importance of writing down analysed pre-assumptions, general thoughts about the research methodology and impressions of the interview "atmosphere" in a diary, as it can help to evaluate data validity (validity of interpretation) in a later stage of the writing process. Regarding methodologies for why and how to conduct dairy's etc. see Erik Maaløe's Case-Studier - Af og om mennesker i organisationer, 1999: 164-165.

I have also sought to increase the validity of data obtained in the field by returning interview summaries to the interviewees, which has allowed them to review what was said during the interview. If any correction or additional information, these have been added to the interview summary or full text. In a later stage - when having conducted a draft Guideline - a copy of this has also been handed out to relevant parties, with the purpose of receiving feedback on final conclusions and interpretations, with an aim of increasing the validity and usability (Case Study Research - Design and Method, Robert K. Yin, 1994).

Another aspect I have used when being in the field, is to collect data about the same topic from more than one interviewee, especially when I have questioned the validity of the data first given. When touring the factory together with floor manager's etc. later on, I have thus posed the same questions as to the director/head manager interviewed earlier. In this way it has been possible to evaluate the validity of data.

1.6.1.6 Principles of validity

In general, I have sought data validity by triangulation, which means that data concerning one aspect are collected from various sources, i.e. interviews, studies of primary and secondary literature (books, reports) and articles etc. Robert Yin calls this for Multiple Sources of Evidence (Case Study Research - Design and Method, Robert K. Yin, 1994). This approach will of course increase the validity of data, and when combined with the rules of using only authentic data - together with the inclusion rule of data - the validity increases even further:

Use of authentic data means referring to data as they were exactly reported in, for example, the interview summary, and not as we “remember” them. The inclusion rule also means including data with a contradictory view point, as opposed to most of the remaining data collected, i.e. not only focus on data that supports a specific - and maybe preferable - viewpoint. The rule of transparency has also been used in this study, which emphasis the importance of making it explicit from where data derive. This means that the reader exactly knows, from where the data referring to originates. Thus in the thesis, arguments, viewpoints - or data in general - will always refer to a source, i.e. an interview, a report etc., or to, for example, previous analysis conducted.

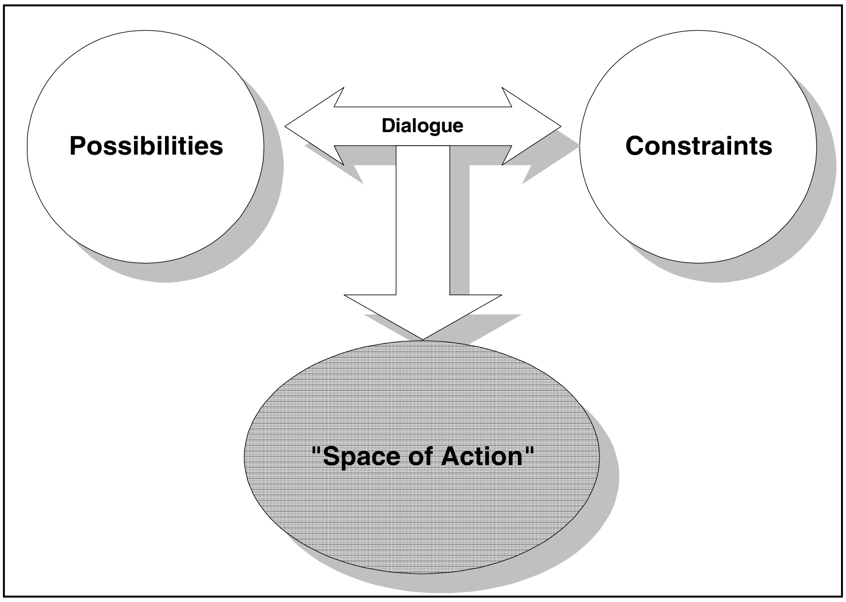
Several interviews with each - and in some cases different - interviewees have also strengthened data validity in the thesis. By returning to the interviewees it has been possibly to pose questions regarding the validity of empirical data collected earlier. Triangulation of data (for instance ‘years’, ‘figures’, ‘numbers’ etc.) has also been conducted, for example by studies of literature, by information obtained on the internet, by interviews and by telephone-interviews of relevant persons in other organisations with insight in the specific topic etc.

1.6.2 Overall research methodology

The overall methodology, which I have applied in this thesis, can be described as an *“explorative problem-identification method with a problem solving aspect”* [3] (Valg af organisations-sociologiske metoder, Ib Andersen et. al., 1990), or even more to the point a *problem and context oriented approach with a methodology generating aspect*. The overall challenge is therefore to discover and explore the possibilities and constraints for developing appropriate methodologies for implementing Industrial Materials Networks in Thailand. The empirical data will show the possibilities and barriers for such scheme.
The actual goal (to implement an Industrial Materials Network) is pre-defined, but the way to reach it is in no way linear. Possibilities, on the one hand, and constraints, on the other, will lead to a “Space of Action” - materialised by the Guideline - in which the Network will be implemented and organised etc. (see the figure below). This means that data constantly are in “dialogue” or “triangulated”, with the reality in which it exists.

[3] Own translation from Danish to English as well as italicisation.

Figure 1A: A constant dialog between data



Chapter 2; Methodology

The purpose of this chapter is to develop a methodology for energy system development, which can act as a platform for creating the Guideline, thus the development of a tool that can support the implementation of Industrial Materials Networks in Thailand and in other NICs. The methodology is developed based on a set of analytic conditions found, when, for example, looking at different areas influencing the use of biomass for energy production. These areas are, for instance, certain thoughts behind limitations in material use, different aspects acting as barriers to biomass uses according to availability and type, as well as certain framework conditions posed on the energy system as a whole.
The purpose of looking at areas of *Limitation in materials use*, *Biomass availability and type* and *Framework conditions*, acting as a platform for methodology development, is to establish a more environmental friendly energy system in which fewer resources are used to produce more energy that again are utilised efficiently. An examination of these areas creates a set of elements exposed for further analysis, leading to a methodology for Guideline development.

2.1 Concept arrangements

In the following, I will briefly describe why I have chosen to work with the types of conditions to be presented in the sections below.

What is regarded as important when creating energy systems can be quite different and depends on the people creating the system, however the technical and economic approaches are often emphasised. The focus on technical and economic aspects is very important, and is also included in this study. But prior to undertaking such an analysis, I have found it important to look at the materials flow and energy system of a given context, as this qualifies the outcome of the technical and economic analysis on a higher level. The foundation for making such an analysis will be improved, and thus the final results more appropriate for the specific context under study.

The figures showing *Limitation in materials use* and *Biomass availability and type* (Figure 2D page 32 & 2G page 36), thus deals with the materials side of energy production, i.e. how we must understand the notion of materials use etc. in order to develop an appropriate energy system, and which types of resources we preferably must utilise for producing this energy. The two figures, therefore, develop a normative standpoint for energy system development in regards to the materials side of the energy production. When the materials side is outlined, energy system development must be seen from the point of view of certain *Framework conditions* (Figure 2I page 39) given by the existing energy system (national and/or local conditions and regulations etc.). The framework conditions establish some overall and important possibilities and barriers for the outcome of the energy system to be developed in a given context - in which the biomass waste will be used.

From the above three areas that are of importance for the energy system development, some non-contextual notions can be extracted. To make these non-contextual notions contextual, a fourth figure named the *Triangle Analysis* (Figure 2J page 41) is introduced, in which the notions are transformed into mechanisms capable of embracing the specific contexts, in which the energy system has to operate. Thus, it is by means of the Triangle Analysis that the energy system development is established in the specific case under study.

2.1.1 Concept arrangement - Limitation in materials use

In the following sections, I will introduce the concepts of *Limitation in materials use* (Dematerialization & Industrial Ecology (section 2.1.1 page 28)), that act as an analytic platform in this thesis together with two other concepts. These concepts are *Biomass availability and type* (section 2.1.2 page 36), and *Framework Conditions* (section 2.1.3 page 38), which in combination create an analytic platform when joined together in the *Triangle Analysis* (section 2.1.4 page 40), and thereafter developed into a set of analytic conditions for Guideline creation (Chapter 10).

2.1.1.1 Dematerialization

Thailand is - as many NICs - moving towards Western standards of living, which has lead to an intensified pressure on resource demands. A way of reducing this pressure would be to limit economic growth, and turn away from western lifestyle and consumption patterns. This is, however, like asking Thailand to stop their development process. Instead, I recognise the need for economic development and consequently the use of resources, but in order to increase development opportunities - and at the same time limit the pressure on resources uses - dematerialization initiatives must be applied. By doing so, it is possible to achieve both economic development and a limitation in resource consumption, as we have experienced in Denmark regarding energy use.
The aim of dematerialization is to obtain a reduction in materials uses and energy intensity in industrial processing activities. Reducing the materials input - required to form a product or to perform a service as for example an energy service - limit the pressure and rate of drawings on new, and maybe non-renewable resources, which again limits the use of resources in larger materials systems. According to Iddo K. Wernick et. al.:

"…dematerialization refers to the absolute or relative reduction in the quantity of materials required to serve economic functions" (Materialization and Dematerialization: Measures and Trends, Iddo K. Wernick et. al., in Journal of the American Academy of Art and Sciences, 1996:171).

Density of products:
Dematerialization, however, is not a new phenomenon. For years, car and aircraft manufactures have conducted research on how to limit the use of raw materials (steel and consequently gasoline), and at the same time strengthen product performance. Also soft-drink can manufactures have experimented with different materials in order to reduce production and transportation costs, which have resulted in light weight aluminium cans with one-third the density of the formerly used steel products (Materialization and Dematerialization: Measures and Trends, Iddo K. Wernick et. al., in Journal of the American Academy of Art and Sciences, 1996).

The energy sector:
Dematerialization in the energy sector can be obtained by more efficient technologies, converting raw materials into "more energy" with the same amount of input, or/and by utilising "secondary energy" emerging from the primary energy production. This is, for example, the case in Denmark, where centralised combined heat and power plants (CHP) distributes district heating to communities (households) thereby utilising a "by-product". District heating dematerialises the uses of oil and natural gas in the individual heating systems of households. Substituting an old light bulb with a fluorescent light bulb is another example of how to dematerialise. Feeding the power plant with 1 kilogram of coal will now result in an energy service, which might have taken two or three kilograms of coal using the old light bulb.

Re-use of products:
Re-use of plastic and glass is another example of how to dematerialise. Due to the contamination of oil, natural gas and hydrocarbon, combined with growing limitation in waste disposals, the re-use of plastic will obviously increase. Large quantities of plastic are, for example, used in the car manufacturing business (Materialization and Dematerialization: Measures and Trends, Iddo K. Wernick et. al., in Journal of the American Academy of Art and Sciences, 1996). As the number of cars evidently will increase, re-uses - and thereby dematerialization - will only slow the now increasing use of plastic products. Thus, an actual materials substitution must take place.

Materials substitution:
This is similar to the production of energy, which mainly is based on fossil fuels throughout the world (except from many third world countries), and thereby require a materials substitution. By re-cycling, re-use and promotion of energy efficiency - emerging from new technologies or Demand Side Management (DSM) - much can be achieved, but in order to reduce the environmental impacts from uses of fossil fuels an actual substitution of the energy sources must take place. This will not necessary increase the use of other resources (now substituting fossil fuels), as for example intensifying deforestation when using biomass such as wood, but can be applied by re-use of already extracted and "used" biomass waste. Many of these resources are currently looked upon as waste and treated as so.
This is for example the case for industrial wood wastes in Thailand, where, in some cases, large amounts of waste are left to decompose on the fields, dumped on riversides, or treated as ordinary waste and dumped in landfill sites (Evaluation of conditions for electricity based on biomass, EC-ASEAN COGEN, 1998). Some examples of the latter can be found in Navanakorn Industrial Promotion Zone, which act as case study area in this thesis.

2.1.1.2 Industrial Ecology

Industrial Ecology is a concept in which an industry is understood, not only in isolation from the surrounding environment, but as a part of it. The aim of Industrial Ecology is to optimise the total materials cycle from virgin materials to final product or service. Theories of Industrial Ecology are inspired by traditional biological ecology and studies concerning the interactions that determine the distribution and abundance of organisms. Frosch and Gallopoulos have made the following comparison:

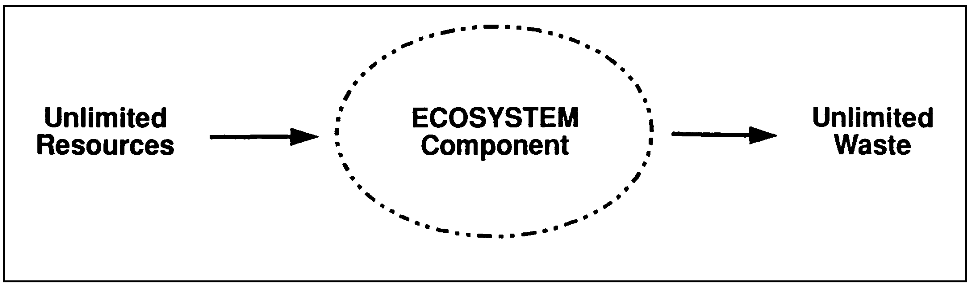
"In a biological ecosystem some of the organisms use sunlight, water, and minerals to grow, while others consume the first, alive or dead, along with minerals and gases, and produce wastes of their own. These wastes are in turn food for other organisms, some of which may convert the wastes into the minerals used by the primary producers, and some of which consume each other in a complex network of processes in which everything produced is used by some organism for its own metabolism.
Similarly, in the industrial ecosystem, each process and network of processes must be viewed as a dependent and interrelated part of a larger whole. The analogy between the industrial ecosystem concept and the biological ecosystem is not perfect, but much could be gained if the industrial systems were to mimic the best features of the biological analogue" (Strategies for Manufacturing, R. A. Frosch and N. Gallopoulos, in Scientific American, 261(3), 1989).

Gertler gives a more precise definition of Industrial Ecology:

"An industrial ecosystem is a community or network of companies and other organisations in a region who choose to interact by exchanging and making use of by-products and/or energy in a way that provides one or more of the following benefits over traditional, non-linked operations:
- *Reduction in the use of virgin materials as resource inputs;*
- *Increased energy efficiency leading to reduced systemic energy use;*
- *Reduction in the volume of waste products requiring disposal (with the added benefit of preventing disposal-related pollution);*
- *Increase in the amount and types of process outputs that have market value";* (Industrial Ecosystems: Developing sustainable industrial structures, N. Gertler, Massachusetts Institute of Technology, 1995:79).

The biological approach to Industrial Ecology is also taken by L.W. Jelenski et. al., who describes the earliest life forms on earth as being limited and characterised by large amounts of resources available. Not only were resources unlimited, but there were also unlimited possibilities for waste disposals. The existence of life was so limited, that waste disposals had practically no impact on the surrounding environment. Ecosystems, in which materials flow from one stage to another - being independent of all other flows - are so called linear materials flow. This *type 1 ecology* is shown in the figure below:

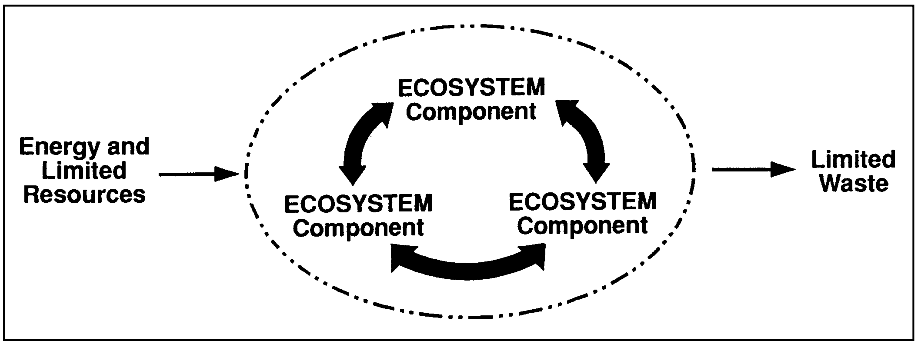
Figure 2A: Linear materials flow in type 1 ecology



Source: "Industrial Ecology: Concept and Approaches", L.W. Jelenski et. al., in Proceedings to the National Academy of Sciences, 1991:3

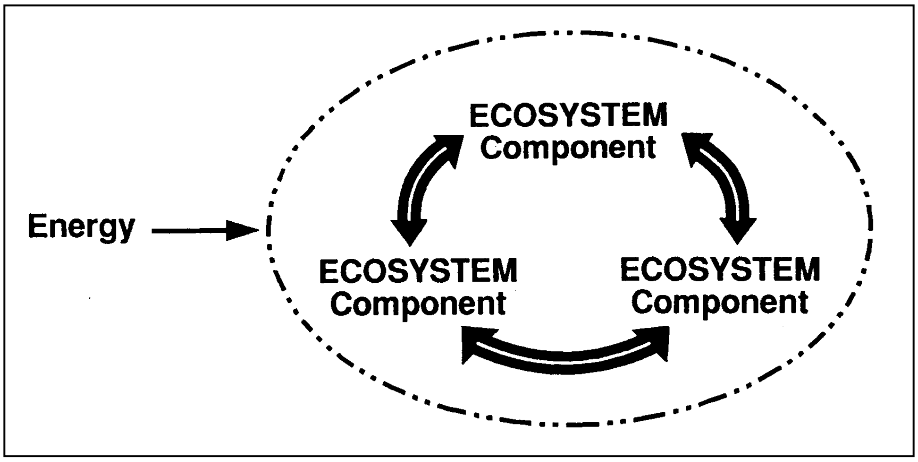
In an ecosystem with limited resources, which can be compared to a known biological community also named a biotope, life forms becomes more strongly inter-linked and depended on each other. Within such a system the materials flow may be very large, but flows of resources into, and wastes out of, the ecosystem are quite limited compared to the linear materials flow. Biological ecosystems have developed to be almost completely cyclical in nature with no waste or environmental impacts; What is seen as waste for one organism is regarded as a resource for another (only solar radiation is an exception from the overall materials cycle, as being an external resource).
According to Jelenski et. al., the cyclic system is more efficient for industrial purposes than the latter, but not sustainable in the long term because of the flow direction. Thus, the system will eventually "run down" (Industrial Ecology: Concept and Approaches, L.W. Jelenski et. al., in Proceedings to the National Academy of Sciences, 1991). The quasi-cyclic materials flow in a *type 2 ecology* is shown below:

Figure 2B: Quasi-cyclic materials flow in a type 2 ecology



Source: "Industrial Ecology: Concept and Approaches", L.W. Jelenski et. al., in Proceedings to the National Academy of Sciences, 1991:3

Figure 2C: Cyclic materials flow in type 3 ecology

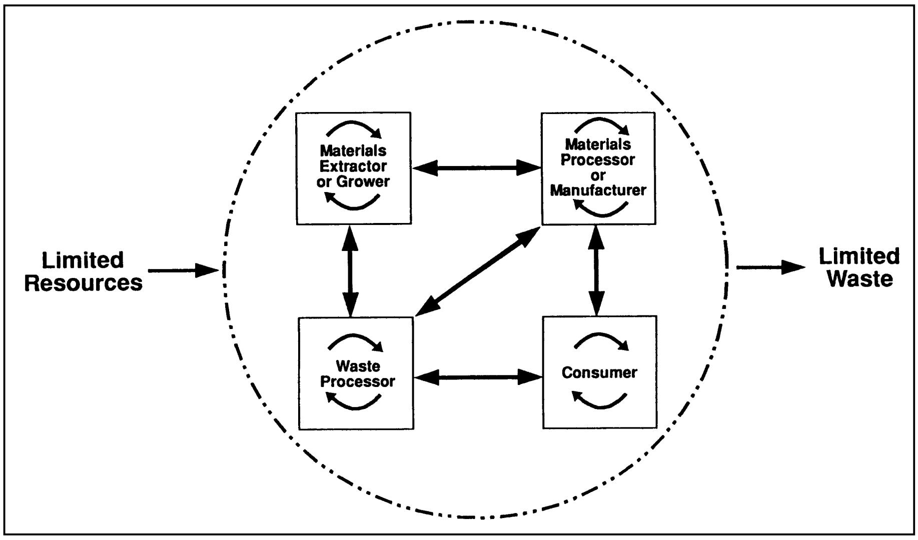


Source: "Industrial Ecology: Concept and Approaches", L.W. Jelenski et. al., in Proceedings to the National Academy of Sciences, 1991:4

An ideal use of resources in industries would, according to L.W. Jelenski et. al., be one that is similar to biological systems in which materials are produced, used and re-used in a cycle with almost no environmental impacts. The cyclic materials flow in this *type 3 ecology* are shown in Figure 2C above. As the figure shows, industries are inter-linked and the use and re-use of resources leads to increased efficiency with no waste generation, no environmental impacts and no resource extraction (except from solar energy throughputs) (Industrial Ecology: Concept and Approaches, L.W. Jelenski et. al., in Proceedings to the National Academy of Sciences, 1991).

By visiting many industries in Thailand it has been my general impression that certain can be characterised as putting great pressure on natural resources (water, air, fossil fuels etc.), by generating large amounts of wastes with limited re-cycling. This type of industrial production resemble the type 1 ecology. In this linear production flow, materials are degraded, dispersed and lost, in one single production line, which is clearly unsustainable.
However, limitation's in resource availability are now setting in (Environmental management in Thailand - Achievements, Barriers and future Trends, In Growing Pains (Ch. 12), Mandar Parasnis, TEI, 1999). Together with an increased industrial environmental awareness, some industries are moving from type 1 ecology to type 2 ecology in modes of operation. But most industrial processes and products, however, still remain largely problematic even when a more "biological" approach is taken within the industries, i.e. industries manufacturing lubricants, paints, pesticides and automobile tyres etc. (Industrial Ecology: Concept and Approaches, L.W. Jelenski et. al., in Proceedings to the National Academy of Sciences, 1991).

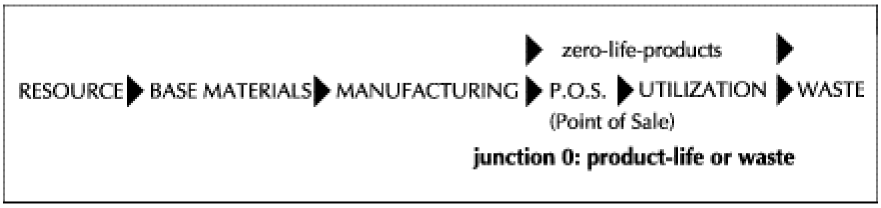
Figure 2D: Type 3 model of the industrial ecosystem



Source: "Industrial Ecology: Concept and Approaches", L.W. Jelenski et. al., in Proceedings to the National Academy of Sciences, 1991:5

When transforming *type 3 ecology* into modes of operation in industries, the figure above appears in which Industrial Ecology consists of 4 nodes; 1) The Materials Extractor or Grower, 2) The Materials Processor or Manufacturer, 3) The Waste Processor and 4) The Consumer. If industries, according to L.W. Jelenski et. al., within the specific nodes manage to perform operation practices that are cyclic - or even establish cyclic flows of materials within the entire industrial ecosystem - the industrial production will become more efficient and have less impact on the environment. This will lead to a reduction in resource demand and generated wastes, due to higher internal resource utility compared to the external system (Industrial Ecology: Concept and Approaches, L.W. Jelenski et. al., in Proceedings to the National Academy of Sciences, 1991).

Figure 2E: The linear structure of the industrial economy (or 'river' economy)



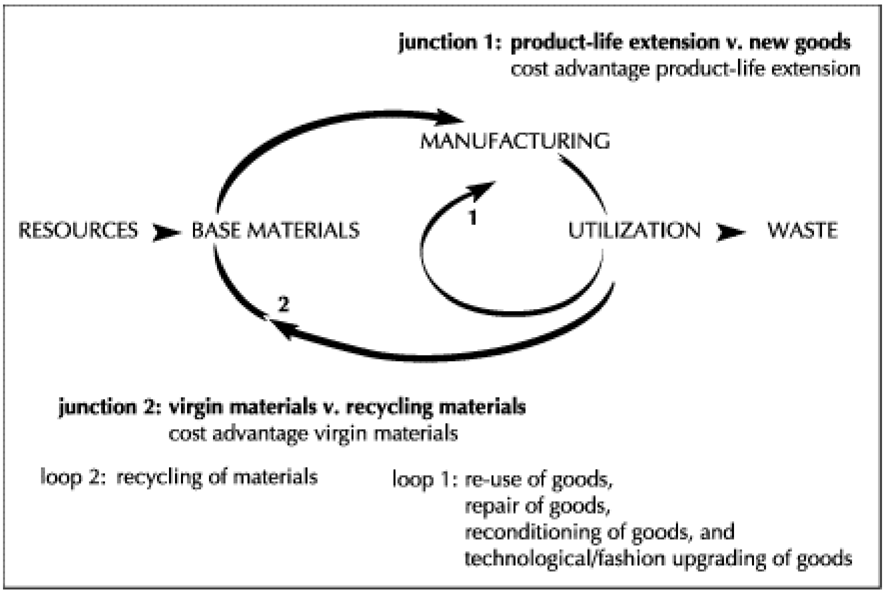
Source: "Jobs for Tomorrow, The Potential for Substituting Manpower for Energy", Walter Stahel and Geneviève Reday-Mulvey, 1976/1981

Another, but quite similar, approach to Industrial Ecology is that of Stahel and Reday-Mulvey (1976/1981), in which they work with the term "economy" as opposite to the "ecology" approach. According to Stahel and Reday, the present industrial production can be characterised as a "river" economy, where resources are extracted, manufactured, sold and utilised to finally end up as wastes. In this value-adding manufacturing process, wastes are regarded as cost-adding factors for industries, and therefore represent a loss of income. The "river" economy is shown in the figure above.

In contrast to this approach is the "lake" economy, in which "value-adding" or "waste" are not understood in a linear sense. In this system, on the contrary, there is no beginning and no end. Industries are constantly seeking ways to close the materials loops, for example by re-cycling products (loop 2 in the figure below) or by improve product life extension (loop 1), in order to reduce the use of new resource inputs. Closing the materials loops in industries is thereby a way of achieving dematerialization.

Let me emphasise the importance of understanding Industrial Ecology as a co-operation between industries in order to obtain mutual benefit from various resources within industries. Only by working together can mutual benefits for industries be obtained, and by co-operation it is therefore possible to achieve larger environmental benefits than when only looking a one industry as a separate unit.

Figure 2F: Closing the materials loops: The loops of a self-replenishing, More sustainable service economy (or "lake" economy), and the Junctions between these loops and a linear economy



Source: "Jobs for Tomorrow, The Potential for Substituting Manpower for Energy, Walter Stahel and Geneviéve Reday-Mulvey, 1976/1981

2.1.1.3 Important criterion for energy system development

When looking at Figure 2D page 32 - which is an idealised situation for industries according to Industrial Ecologists - co-operation between industries seems a very important aspect in order to achieve such a situation. This puts great emphasis on studying organisational issues, like the appropriateness and conditions for Inter-industrial Co-operation and the economic perspectives of different designs of Corporate governance, hereunder issues such as ownership and corporate economy. How can these areas be established, or designed, so that they support the implementation of Industrial Materials Network? Included in the focus on organisational issues is also the question of how to minimise the risks of participating in such Networks (and thereby the collapse of the system), that is how to maintain the co-operation between industries. How can the above aspects be designed so industries find it beneficial to participate in Industrial Materials Networks?

It is also important to locate industries that, according to the figure, are appropriate as A) Materials Extractor or Grower/Materials Processor or Manufacturer, B) Waste processor and C) Consumer, so that the aim of Industrial Ecology can be facilitated. Thus, the aim is to find industries that can both (a) generate, (b) use and (c) re-use materials, hereby mimicking the idealised situation of Industrial Ecology shown in Figure 2D. As seen from the above, two very important areas for appropriate materials use in Industrial Materials Networks are thus the ***type of industries selected for co-operation***, as well as the ***organisational conditions created for these industries.***

One advantage of Industrial Ecology as means of understanding the use and re-use of materials, is that it facilitates the transformation of one system to another system: The transformations of materials systems into energy systems. In the energy system the Materials Extractor or Grower/Materials Processor or Manufacturer are industries producing biomass wastes, which are used for energy production through a Waste Processor, being an energy plant. Finally, the produced energy is re-used by the Consumer, which are the same industries as the Materials Extractor or Grower/Materials Processor or Manufacturer *and* the responsible Waste Processor.

When mimicking the ideas behind Industrial Ecology etc. the following criterion for energy system development appears:

In order to minimise the impact of waste, which evidently will be generated (although the amounts are limited), a *first* criterion for the energy system is to utilise fuel which is based on industrial biomass waste. This can limit the negative environmental impacts of the energy production, and will reduce the utilisation of new virgin materials. A *second* criterion is to base the energy system on co-generation (combined heat and power) as this can limit the amounts of resources wasted. The efficiency of co-generation technologies is 85 %, whereas the total efficiency of producing heat and electricity separately is approximately 58 %. As electricity and heat are produced separately, fuel uses are also larger in the latter. When producing energy by means of co-generation technologies the overall materials use thus decrease.

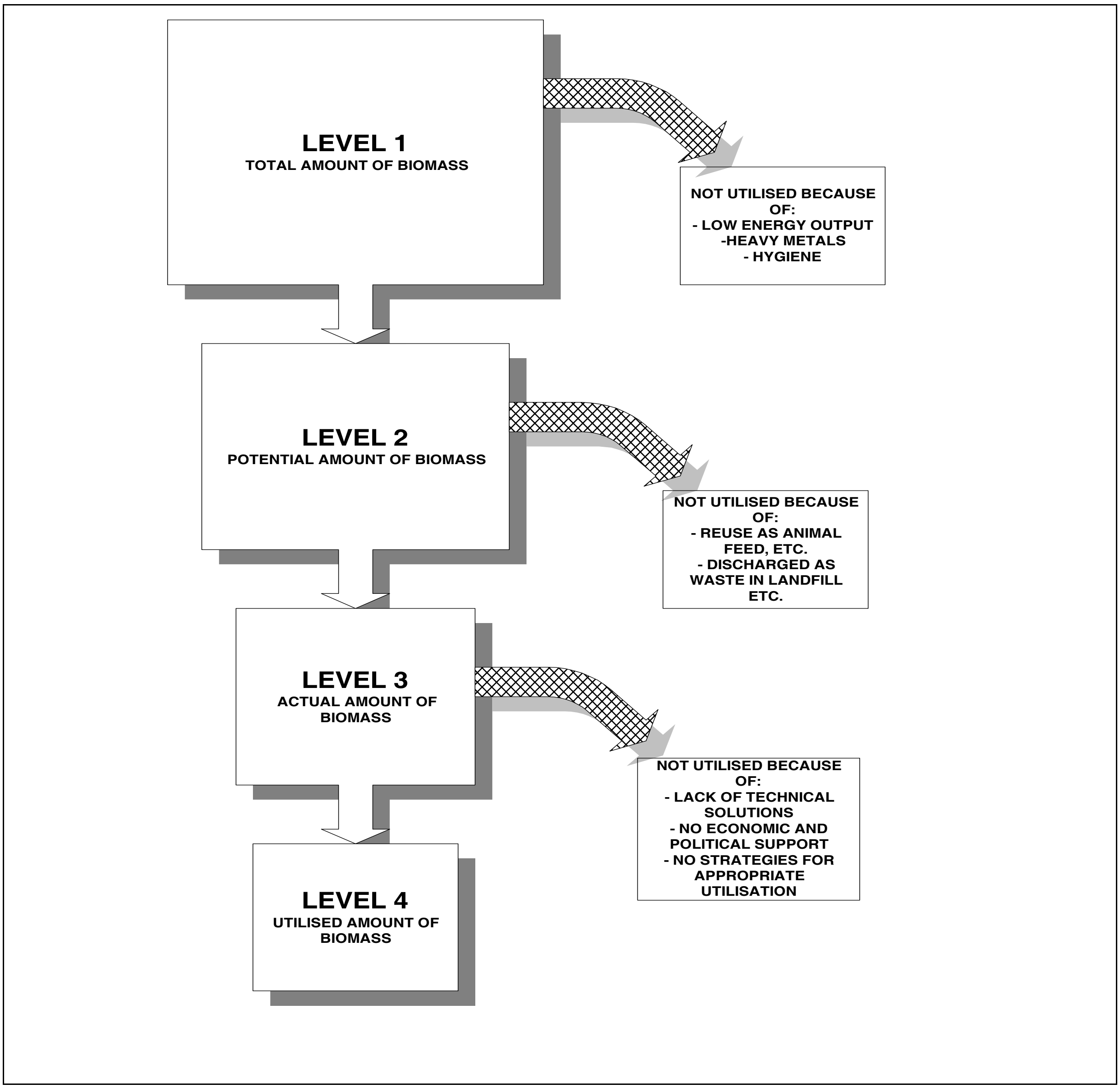
A *third* criterion is to base industrial energy uses on water based heat - district heating - when possible, as this also reduces overall materials uses. Hot water is a “by-product” of a primarily energy production, which normally is electricity production. If piped to industries using process heat in processing activities, hereby covering water based heat demands, much can be gained. If industries base their heat demands on fossil fuels converted in individual boilers, this can be phased out and now solely be covered by district heating, leading to less impacts on the environment. If industrial heat uses are based on steam - or steam made by electricity - it can be favourable to eliminate such uses by emphasising how conversion from steam to water based heat uses can be applied. In this way industries will be able to cover their process heat demands by water based heat only, and as being of a lower quality compared to steam, this can reduce the overall materials uses in the production of energy (fossil fuels as well as biomass uses for steam generation).

In order to establish a district heating system, which does not lead to great energy losses, the distance between industries participating in such co-operation should, preferably, not be too far. If so, the costs of establishing a district heating network will also be unnecessary large. It will, moreover, increase the price for transportation of biomass waste to the energy facility, if the distance between industries is too far. It is thus a *fourth* criterion that the district heating network is established between industries located relatively closely.

A *fifth* criterion is to look at possibilities for applying cascading of energy, beyond what is obtained by district heating that in itself is a cascading system (each cascading step decreases the quality of the energy). Further initiatives for cascading of energy can, for instance, be in steam uses, as one industry’s “waste steam” possibly can be used as primarily steam supply in another industry. Again, this “waste steam” can possible be re-used in the district heating network. Such cascading of energy also reduces the use of resources, as it limits pressure on virgin materials and reduces the amounts of "waste energy" produced by the energy system. A *sixth* criterion is to focus on general energy saving options within industries, for instance the implementation of more effective processing equipment leading to energy savings through DSM.

2.1.2 Concept arrangement - Biomass availability and type

Figure 2G: Regressing in possible biomass waste for energy production within a community (study area)



Source: Figure inspired by "Biogashandlingsplanen", Baggrundsrapport nr. 12, Energistyrelsen, 1991

When mimicking the thoughts of Industrial Ecology etc., in combination with aspects of Biomass availability and type, the following criterion for energy system development appears:

A *first* criterion in the analysis of Biomass availability and type is of course to examine the amounts and type of biomass waste in the study area - the *Community Metabolism* - and hereafter estimate how much is available for energy production. Within industries, the quantities of biomass waste can be reduced by means of the specific processing activities it undertakes. It is therefore important also to study the *Micro Industrial Metabolism*, in order to estimate the amounts of wastes generated.

Many production processes lead to a reduction in the quality of processed biomass, as for example being contaminated with heavy metals or hazardous organic solvents. Contaminated biomass can be difficult to re-use, and even when digested, incinerated etc., this type of waste can be problematic in relation to later disposals or uses as fertiliser. A *second* criterion for biomass use is therefore to focus on clean biomass waste (non-contaminated) in order to develop a clean biomass fuel chain.
Biomass waste can also be of low quality when leading to a low and economically insufficient energy outputs when looking at the capital costs of converting technologies, which lead to the *third* criterion, focusing on the use of waste leading to high energy outputs *(*hereunder the most appropriate means of conversion). This now means that the theoretical *total* amount of waste generated from industries is reduced to theoretical *potential* amounts of biomass waste.

When trying to use *potential* amounts of waste we might also face some constraints, as competitive sources of utilisation might appear. Here a qualitative perspective can be introduced again; Biomass wastes re-used for animal feed or fertiliser has high value, whereas wastes discharged in landfill areas, or re-used in far away location with long transportation as a consequence, have low priority. A *fourth* criterion, when planning to increase utilisation of potential biomass waste, is, therefore, to value competitive uses of biomass wastes *(internal/external re-uses)* and to estimate whether they can be utilised more appropriate for energy production locally (within the industrial area).

The *actual* amount of biomass available for energy purposes can be limited by lack of supporting strategies, combining economically, technically and organisational issues. Such lack of strategies can affect private as well as public initiatives for biomass re-use, just as lack of appropriate research or demonstration projects can prevent a necessary spin off effect. The aim of this thesis is precisely to contribute to such strategies for appropriate biomass waste utilisation, which is the purpose of the Guideline; combining economically, technically and organisational issues to a planning tool.

2.1.2.1 Cyclic materials flow

As for the concept of Industrial Ecology, also the concept of *Biomass availability and type* possesses a cyclic materials flow. The point of departure is that biomass is generated and utilised by means of a cyclic flow in which some biomass resources are used and new once created. In every type of production - industrial as well as agricultural - the generation of waste will appear, but the higher the efficiency of utility the lower the amounts of waste, which thus “step up” one level in the figure and becomes cyclic. This is due to the fact that this waste is now utilised as a primarily material for production purposes, which previously put pressure on new virgin materials.

2.1.3 Concept arrangement - Framework Conditions

Two levels of Framework conditions are considered in this study; Primary and Secondary, which both influence the price of generated energy per kWh. Below, I will shortly describe the two types of Framework conditions, which are illustrated in Figure 2I. The following section are partly based on “Green Power and Promotion of Power from Biomass”, Tyge Kjær, University of Roskilde, 1998.

2.1.3.1 Primary framework conditions (case specific)

A number of factors determine the price of energy produced by from biomass technologies, which are shown as Primary framework conditions in Figure 2I next page.

The ***biomass fuel price*** *is* either the price of buying for instance agricultural waste, the price for collecting industrial wastes generated by industries participating in Industrial Materials Networks, or the price for buying appropriate waste from other relevant industries to support the energy production (or a combination of the three). These prices are connected to the waste policy and regulation in individual countries, as well as to potential taxes and disposal fees put on waste.

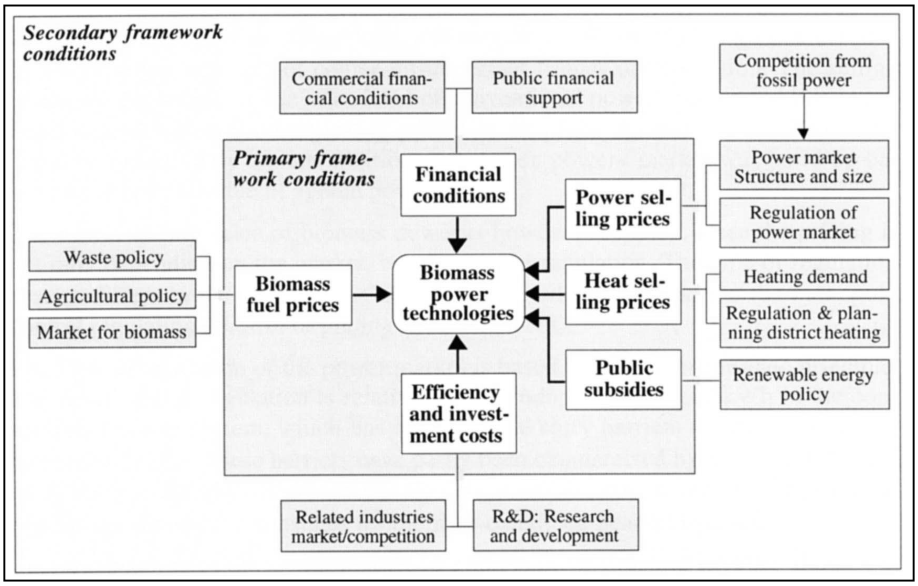
The ***energy efficiency and investment costs*** (capital costs) of biomass technologies largely depend on the maturity of technologies (technical reliability and energy efficiency), which tends to increase with increased market size, as this normally initiates competition between suppliers and thus product innovations and possible price reductions. The maturity of technologies also depends on the level of research and developing activities in general, as this also supports the process of maturing biomass technologies. It is thus favourable to pursue the implementation of mature technologies in order to secure technical reliability and energy efficiency in energy production based on biomass resources. By doing so it is presumed that the investment costs (the price of the technology) reflect sound competition between suppliers.

The ***power selling price*** is important if the electricity produced is sold to power companies (grid connected electricity sales). The selling price of biomass power normally depends on the price of conventional electricity and the bargaining power of suppliers against buyers, unless special conditions are established. This can, for instance, be a higher selling price for biomass produced electricity compared to the conventional electricity or fees put on conventional electricity production. If the electricity is solely transmitted to industries participating in an Industrial Materials Network, the price for borrowing the grid (the “wheeling” fee) is also important, and must be evaluated against establishing an individual grid connection between participating industries, increasing the total capital costs of the energy system. The selling price of electricity will thus be the substituted costs of buying commercial electricity.

The ***heat selling price*** depends on the competition between network companies, and the level of district heating network expansion in individual countries, thus the availability or access opportunities. This framework condition is therefore largely dependent on the structure of the

heat market as a whole, and thus on secondary framework condition as they determine the degree of support and regulation of district heating network implementations.
If generated heat is only supposed to be utilised by industries participating in an Industrial Materials Network - and no district heating network exists - it is, of course, necessary to implement a small scale district heating network connecting these industries. The selling price of heat will thus be substituted costs of buying commercial heat, i.e. oil, natural gas, LPG or coal.

Figure 2I: Primary and Secondary framework conditions for Implementation of biomass energy technologies



Source: "Green Power and Promotion of Power from Biomass", Tyge Kjær, University of Roskilde, 1998

Together, the framework conditions for heat and power determine the character of energy End-uses in industries and households etc., and thus the "space" for implementing alternative energy solutions based on biomass.

Public subsidies and grants can be used as financial support for biomass technologies making them competitive against commercially produced energy. Donation of grants can, for instance, take place as a governmental grant (construction grant), in which a certain percentage (for instance 30 %) of the investment costs is paid for. Public subsidies can, for example, be an electricity or heat selling subsidy (operation subsidy), which the government put on utilities, making them pay more for energy produced by biomass resources.

Finally, the ***financial conditions*** (possibilities for obtaining loan or other means of financing) have a great influence on the implementation of biomass technologies, determined by the framework conditions mentioned above. If the biomass fuel price is high, grants and subsidies limited, the selling price of power and heat low - or even a lack of heat markets and thus non-existing district heating networks - then the financial conditions are difficult for biomass technologies.

2.1.3.2 Secondary framework conditions

The Primary framework conditions are, with more or less dependencies, given by a number of Secondary framework conditions, illustrated in Figure 2I. The regulation of and initiatives taken in relation to agriculture, waste management and the market for biomass, determines the biomass fuel prices. Likewise, the electricity market structure/size, the regulation of the electricity markets, as well as the competition of commercial energy, influence the selling price of electricity. Also, heat demands and regulation of, and initiatives taken in relation to implementation of district heating networks, determine the heat selling price. And, as a last example of Secondary framework conditions, public financial support and conditions for commercial financing are important for the overall financial conditions for biomass technologies. Both Primary and Secondary framework conditions are thus determining for the biomass technology to be implemented.

2.1.3.3 Important criterion for energy system development

In order to select the most appropriate biomass co-generation technology, a *first* criterion is to look at the Primary framework conditions and thus elaborate Pre-Feasibility Studies (Cost Savings analysis) of appropriate technologies. A *second* criterion - not shown as Primarily framework conditions in the figure but included in several Pre-Feasibility Studies - is to evaluate the Environmental Performance of technologies, illustrating which technologies are more favourable than others in the specific context analysed. Together, these analysis will help in the selection of the most appropriate technology to implement.

A *third* criterion is, also according to the figure, to find out whether Public Subsidies can be granted, which can support the implementation of biomass technologies. A *fourth* criterion is to examine the local resource base regarding technology development, thus R&D, as it can especially affect the investment costs (capital costs) of technologies if produced locally (particularly in developing countries). It is therefore best to support the local manufacture of renewable energy technologies.
Finally, as *fifth* criterion, the possibilities of obtaining a loan or other means of financing must be exposed, as this has great influence on the perspectives for large scale implementations of Industrial Materials Networks.

2.1.4 The Triangle Analysis

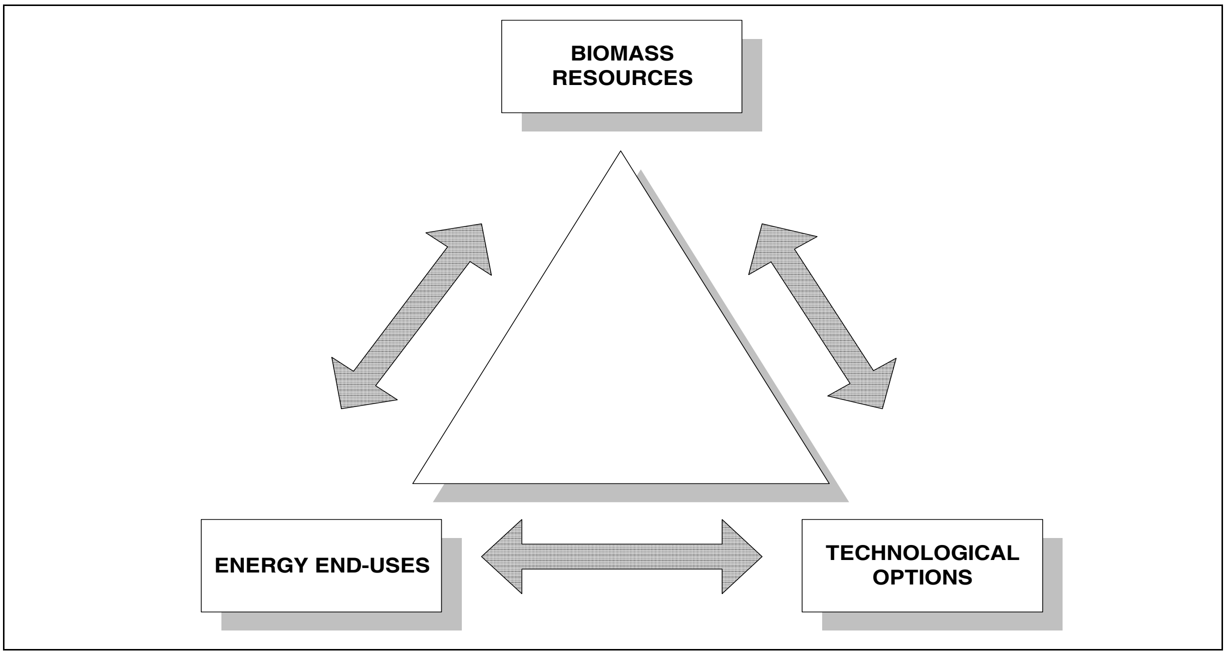
In this section, the previous areas of study will be joined together in a research methodology applied for energy system development - named the Triangle Analysis - consisting of the following areas: Biomass Resource, Energy End-use and Technological Options (Green Power and Promotion of Power from Biomass, Tyge Kjær, Roskilde Universitetscenter, 1998). The idea behind using this Triangle Analysis as a methodology is to emphasise the specific contextual conditions (given by the area of study), and thereafter optimise the Triangle by means of solutions, which integrate the three focus areas of the Triangle Analysis. Thus, creating optimisation between the specific energy needs found in industries, the type and amount of biomass waste found, and possible conversion technologies to implement.

The inter-connection between the three areas determines the outcome - the optimisation - of the Triangle. Each area cannot be regarded on as a separate unit, but must be analysed as a whole in order to develop an appropriate energy system. If, for instance, most biomass waste is on a liquid form, certain converting technologies are more appropriate than others, like for instance a Biogas Plant with Gas Engines application. As Gas Engine produce low quality heat (hot water or steam at low temperatures), energy demands requiring large quantities of steam cannot be satisfactory fulfilled. Thus, other means of conversion technologies must be evaluated, together with for instance treatment of the fuel (as drying) for appropriate coverage of the heat demands.

2.1.4.1 The analytic platform

In the paragraph below, the name of the figure from which the elements come from is noted, and the specific chapter of the thesis in which the analysis are elaborated. Note that Chapter 4 has a special status as only the results of the chapter are included in the Triangle Analysis, which are elaborated in Chapter 5 to 8. Thus, Chapter 4 has status as Pre-Triangle Analysis.

Figure 2J: The Triangle "Biomass Resources, Energy End-uses and Technological Options"



Source: Figure inspired by "Green Power and Promotion of Power from Biomass", Tyge Kjær, University of Roskilde, 1998

Biomass Resources:

The purpose of the following elements is to identify appropriate biomass waste for efficient energy production, thus lowering the pressure on virgin materials and minimise pollution:

- The *first element* in developing an energy system is to study the amounts and availability of biomass wastes for energy production in the local context examined. This can, firstly, be industrial waste appropriate for energy production, for example wood waste, flotation sludge, fermentation wastes etc. (Micro Industrial Metabolism). Secondly, it can be appropriate wastes from the community acting as Industrial Materials Network Supporting Resources (Community Metabolism). This can for instance be household wastes, agricultural wastes or sludge from WWTPs (Figure 2G, Chapter 4);
- The *second element* in the energy system development is hence to identify clean biomass wastes (non-contaminated), with a potential high energy output (calorific value) being the *third element* (Figure 2G, Chapter 5);
- The *fourth element* is to evaluate present internal/external re-use of industrial biomass wastes, as better re-use strategies might be obtained (Figure 2G, Chapter 4);
- Similar, the *fifth element* focuses on which means of conversion method (combustion, digestion etc.) is the most favourable to pursue for the energy system development, as leading to the largest energy output (Figure 2G, Chapter 5).

Energy End-use:

- The *first element* in developing the energy system is here to look at possibilities for covering industrial heat demands by district heating - thus water based heat. Also, in connection to this, to study options for converting steam uses to water based heat uses (Figure 2D, Chapter 6);
- As a *second element* is focus on efficient use of the produced energy, by strategies for cascading of energy between Industrial Materials Network participating industries, thereby creating Macro Industrial Metabolism (Figure 2D, Chapter 8);
- Finally, general options for energy efficiency (DSM) by optimisation in processing activities and equipment substitution must be studied, as a *third element* (Figure 2D, Chapter 6).

Technological Options:

- Emphasis is solely on converting technologies producing combined heat *and* power, thus mature co-generating technologies are a *first element* of studying technological options (Figure 2D, Chapter 7);
- The *second element* is to conduct Pre-Feasibility Studies (cost savings analysis) of appropriate technological options (Figure 2I, Chapter 8);
- A *third element* is, as a part of the Pre-feasibility Studies, to examine the Environmental Performance of technological options, adding to the capability of selecting the most appropriate technology for implementation (Figure 2I, Chapter 8);
- Another important and *fourth element* in developing an energy system is to look at the national resource base regarding technologies, thus Research & Development initiatives (Figure 2I, Chapter 8);
- The *fifth element* is to study national as well as local context specific conditions for receiving Public Subsidies, which can support the implementation of biomass co-generation technologies (Figure 2I, Chapter 9);

- Finally, as *sixth element*, are the possibilities of obtaining financing for Industrial Materials Network implementation, either by financial loans or by other means of financing (Figure 2I, Chapter 10).

2.1.4.2 Additional analysis

Besides the analysis made in Chapter 4, laying a foundation for the Triangle Analysis which follows, two additional areas of research must be elaborated in order to finalise the research methodology; one elaborated *before* the actual Triangle Analysis, and one *after*. These two areas are described in the following:

Pre-Triangle Analysis:

- Before commencing the Triangle Analysis focusing on amounts and types of biomass wastes generated by communities and industries (Community/Micro Industrial Metabolism), it is - as a *first element* - favourable if a pre-selection of industries in lines of business or branches can take place. Thus, locate branches appropriate both as waste generators, users and re-users for Macro Industrial development in Industrial Material Networks (Figure 2D, Chapter 3);
- Similar, it is most favourable if a pre-selection or pre-definition of appropriate types of areas for Industrial Materials Network implementation can be pointed out, securing a tight or relatively close location of industries beneficial for piping of district heating (Figure 2D, Chapter 3), being the *second element*.

Post-Triangle Analysis:

The Post-Triangle Analysis is, in itself, a small triangle analysis, stretch out between the areas shown below. As for the Triangle Analysis, the optimisation or solution is found in the sphere between the research elements:

- The *first element* is to look at how to minimise the risks of participating in Industrial Materials Network, so as the best conditions for establishment and co-operation are created (Figure 2D, Chapter 9);
- A *second element* is to focus on the contextual conditions for Inter-industrial Co-operation given by the industries in the study area, and examine how they can be improved (Figure 2D, Chapter 9);
- The final and *third element* is to emphasis on different aspects of Corporate governance, as consequences for corporate economy and ownership, embracing the elements above (Figure 2D, Chapter 9).

2.1.5 Concept arrangement - The Guideline

The methodology of the thesis is determined by the areas of *Limitation in materials uses*, *Biomass availability and type*, as well as the *Framework conditions* of the energy system, creating a set of analytic conditions. These conditions are treated further in the Triangle Analysis and used for appropriate energy system development. The conditions, given by the above mentioned areas, have further made certain Pre-Triangle Analysis necessary in order to obtain appropriate conditions for the optimisation of the Triangle.

Thus, a pre-selection of appropriate industries and areas for Industrial Materials Network implementation have been found necessary, as well as studies of waste generation in industries and the surrounding community, of which the results are included in the Triangle Analysis. The Triangle Analysis thus optimises on the conditions given for energy system development. The Post-Triangle Analysis deals with areas of energy system development that the Triangle does not embrace, but found to be important according to the set of analytic conditions created. The Post-Triangle Analysis also creates a Triangle, under which the optimisation of the elements happens in the created area of tension. The Guideline is, therefore, a result of two Triangle Analysis elaborated, in which the analytic conditions - as well as additional conditions found appropriate through the case study analysis - are transformed into a tool for Industrial Materials Network implementation.

2.2 Morphology of the thesis

Chapter 1; Introduction
This chapter introduces the Purpose of the study, the Research question, the Delimitation and elaborates on the Design of the study.

Chapter 2; Methodology
The theoretical and analytic platform of the thesis is presented in this chapter, departing from a series of concept arrangements. Limitations in material use, Biomass availability and type and Framework conditions lead to a set of analytic elements appropriate for energy system development. These elements are thus extracted and thereafter transformed into an analytic tool, capable of embracing the specific contexts in which is has to operate or function, by a Triangle Analysis. The chapters further deals with which other types of analysis it is necessary to elaborate (Pre- and Post-Triangle Analysis), in order to create an appropriate foundation for Guideline creation. Chapter 2 ends with a description of the contents of each chapter (Morphology of the thesis), illustrating how the chapters are build up according to the analytic conditions set out.

Chapter 3; Theoretical pre-selection of appropriate industries and areas in Thailand
Chapter 3 deals with two Pre-Triangle Analyses; one firstly focusing on appropriate types of areas for Industrial Materials Network implementation, enabling a relatively close location of industries appropriate for piping of heat in small scale district heating networks. Secondly, a pre-selection of industries in lines of business or branches - with the aim of locating industries both generating clean biomass waste and having a demand for water based heat to be covered by district heating - takes place. Thus, mapping of branches appropriate both as waste generators, users *and* re-users in Industrial Material Networks. Apart from industrial biomass waste, this chapter also deals with from which other relevant sources biomass waste can be applied to the energy system.

Chapter 4; Navanakorn Industrial Promotion Zone and surroundings - Empirical approach

The focus of this chapter is on the amounts, and availability, of biomass wastes for energy production in the specific context examined; Navanakorn Industrial Promotion Zone located in Pathum Thani Province. This is firstly emphasised by analysis of wastes appropriate for energy production from the community (Community Metabolism), acting as Industrial Materials Network Supporting Resources. Such resources can, for instance, be household wastes, agricultural wastes or sludge from WWTPs. Secondly, it is emphasised by analysis of industrial waste appropriate for energy production (Micro Industrial Metabolism), as for example wood waste, flotation sludge, fermentation wastes etc.

Apart from analysis of the Industrial as well as the Community Metabolism, the purpose of the chapter is also to introduce the case area, and point to the problematic waste management practices taken in the community as a whole. The chapter ends with an evaluation of the supply and value of biomass waste, as being an important aspect when planning to implement other means of use, and some introductory perspectives of how to approach the creation of an energy system in the area.

Chapter 5; Triangle Analysis - Resources

In the first part of this chapter, the theoretical energy potential (calorific value) of the biomass waste found will be emphasised, with the purpose of identifying the most appropriate conversion method for the waste. Thus, whether combustion or digestion is the most appropriate means of conversion for the energy system to be implemented, as leading to the largest energy output. Hereafter, the character (content and structure) and form (solid or liquid) of biomass wastes will be identified, with the purpose of treating it for other means of conversion, if possible. This will increase the flexibility of the energy system.
In the second part of this chapter focus will be placed on whether the biomass waste can lead to any contamination or not when converted by different means, leading to suggestions for which conversion methods to pursue for certain types of wastes. The chapter ends with some strategies of how to develop the energy system, which is uniform for all chapters being part of the Triangle Analysis/Post-Triangle Analysis, Chapter 5-9, and is undertaking as a successive development throughout the thesis.

Chapter 6; Triangle Analysis - Energy Demands (Industrial End-uses)

The purpose of this chapter is to analyse the energy consumption patterns in case industries, and look at possibilities for covering industrial process heat by water based heat, i.e. district heating. Where the industrial process heat cannot be covered by water based heat, the chapter studies options for converting steam uses to water based heat uses. Also general options for energy efficiency (DSM), by optimisation in processing activities and equipment substitution, are emphasised in the chapter. This chapter also ends with some strategies of how to develop the energy system.

Chapter 7; Triangle Analysis - Technology

The purpose of this chapter is to identify which technologies are capable of converting the biomass waste identified, and at the same time cover the specific energy demand found. The emphasis of this chapter is solely upon mature technologies producing combined heat *and* power (co-generating technologies). The chapter also ends by suggesting some strategies of how to develop the energy system.

Chapter 8; Macro Industrial Metabolism - Design of the energy system
The purpose of the first part of Chapter 8 is to establish the most appropriate design of the energy system, both technically and economically, by optimisations of the Triangle. Technically, the design will be determined by the most appropriate (technically, economically and environmentally) use of resources (biomass waste and energy), as, for instance, possibilities for establishing cascading of heat between Industrial Materials Network participating industries, beyond what is obtained by district heating. Also aspects like Plant flexibility, Composition of waste and specific plant design and Capacity of meeting increases in End-use demands, are used to determine which design of the energy system to pursue.

In the second part of Chapter 8 an environmental evaluation of technical options (Performance of technologies and Emissions analysis) is elaborated. Together with studies of the resource base in Thailand regarding manufacture's of biomass technologies (Research & Development initiatives), this will narrow down the choices of technologies to implement. Selected technical options are finally exposed for economic analysis, through a Pre-Feasibility Study (cost savings analysis) leading to a final choice of technology. Strategies for developing an energy system end this chapter.

Chapter 9; Organisation of the Industrial Materials Network in Navanakorn
This chapter has status as Post-Triangle Analysis with the aim of developing the most appropriate organisation (ownership & corporate governance) of the Industrial Materials Network in Navanakorn, when looking at various aspects of co-operation possibilities and barriers. Analysis of the most favourable organisational set-up, is based on a *second* Triangle analysis; namely the triangle that develops when looking at Transaction costs/Risk minimisation, Conditions for Inter-industrial Co-operation and Corporate governance.

In the first area focus is on how to minimise the risks of participating in Industrial Materials Network, so as the best conditions for establishment and co-operation are created. This, for instance, includes which stakeholders can support (for example economically) the implementation of Industrial Materials Networks, and how to secure the supply of wastes from industries. In the second area, some means of improving co-operating conditions for involved stakeholders are examined. This can, for instance, be by influencing the industries' attitude towards co-operation by limiting their interdependence, and by involve other stakeholders whom the industries trust. The third area emphasis different aspects of Corporate governance, each type having different consequences for the corporate economy and ownership. The chapter ends with strategies for developing the energy system.

Chapter 10; Guideline for Industrial Materials Network implementation
By a series of Actions the reader is taken through the Guideline, step by step explaining which actions there must be taken in order to implement Industrial Materials Networks in Thailand. Finally, possibilities for obtaining financing for Industrial Materials Network implementation - either by financial loans or by other means of financing - are also emphasised, facilitating the search for financing.

Chapter 11; Conclusion
Consists of a short version of the Guideline developed in Chapter 10.

Chapter 3; Theoretical pre-selection of appropriate industries and areas in Thailand

In the first part of this chapter appropriate areas for Industrial Materials Network implementation will be pointed out focusing on industrial Zones and Parks in Thailand. The second part of this chapter is an examination of, and an argument, for the adequacy of selecting certain types of industries as participants in Industrial Materials Networks. A selection of industries as lines of business (or branches) will thus take place. The adequacy of industries will be exposed by the analysis of energy needs and types of waste generated in selected industries. The benefit of pre-selecting industries is twofold, as it also establishes a better foundation for what it is possible to expect in the field. It thereby enables the collection of more detailed information while being in the case area, as more appropriate field trip preparations can be conducted.

The analysis of industrial energy consumption, raw materials input and output etc., can, as shown in Chapter 2, be called studies of the *Industrial Metabolism* (Industrial Metabolism, in Technology and Environment, Robert U. Ayres, 1989). The analysis of metabolism on the level of one industry - *Micro Industrial Metabolism* - will hereby outline possibilities for creating co-operation between several industries - *Macro Industrial Metabolism* - through the implementation of Industrial Materials Networks.

In order to support adequate quantities of biomass supply to the Industrial Materials Network for energy production, I have also found it important to focus on Network Supporting Resources and Systems in the community, which will be emphasised in this chapter. This can, for example, be agricultural or household waste from the local community, which is appropriate for energy production. Other industries in the industrial area can, for instance, also support the Industrial Materials Network through the supply of biomass waste. Through studies of such resources, the *Community Metabolism* is identified (see Chapter 4 for an actual identification) (Regional Resource Recovery and Eco-Industrial Parks; An Integrated Strategy, Indigo Development Working Paper, Ernest Lowe, 1997).

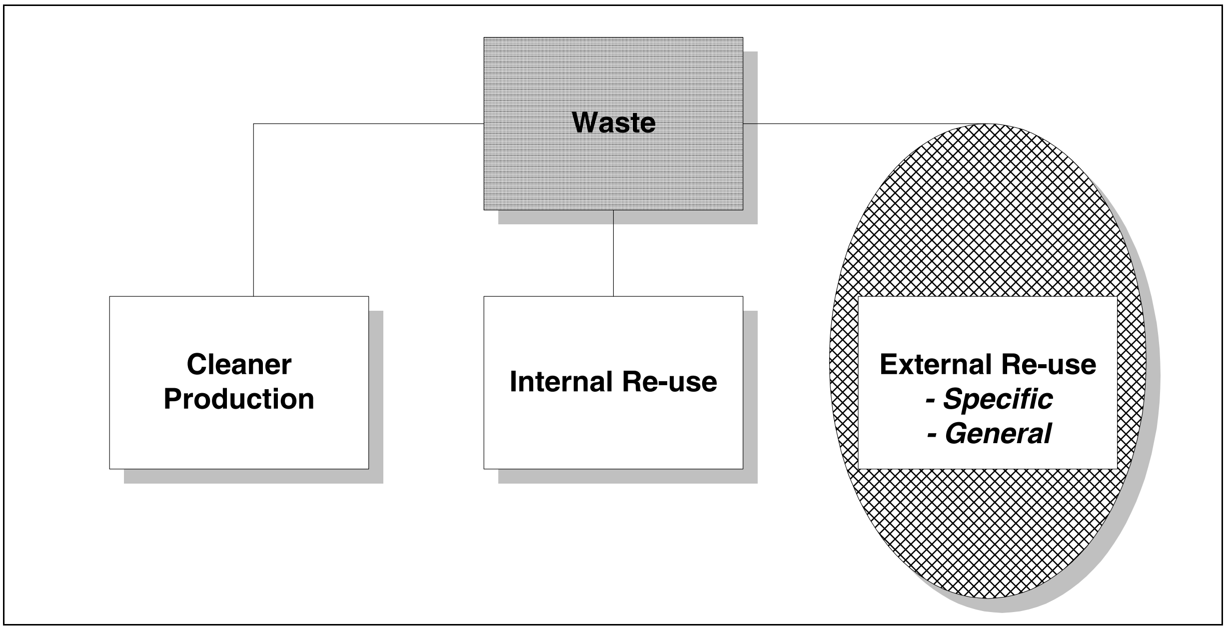
3.1 Appropriate areas - Why Industrial Zones or Parks?

Both the re-use and minimisation of wastes can happen in several ways when seeking dematerialization in production processes. By implementing ***Cleaner Production***, it is possible to reduce the amounts of waste generated, thereby minimising the environmental impacts of waste generation. It is also possible to re-use waste within the specific industry by ***Internal Re-use***, or seek value adding of generated waste by pursuing ***External Re-use*** of which the latter can happen in two ways: By *Specific External Re-use* the waste is re-used in another industry in the same line of business, and by *General External Re-use* the waste - which cannot be re-used with a specific purpose - undertakes a general re-use.

In some industries it can, however, be the *amounts* of waste generated that limits the effective re-use of waste. This is, for instance, the case in some wood industries in Thailand, where generated sawdust and wood chips not are capable of covering the internal energy demands. Therefore, some industries choose to discard the wood waste and find other means of energy

sources, even though the demand for heat exists within the industry (see Chapter 4 for a description of case area industries).
The opposite situation can be found in some large agricultural industries, where the amounts of waste are so large that the efficiency of boilers is deliberately set to a low effect in order to incinerate all waste (Evaluation of conditions for electricity based on biomass, EC-ASEAN COGEN, 1998). As these industries often are located in remote areas, there is no heat market for surplus energy or/and other relevant customers for the generated waste.

Figure 3A: Methods for resource utilisation, with the *ellipse* symbolising an Industrial Zone or Estate for materials (waste and energy) exchanges



In this thesis focus is placed on *General External Re-use* of waste within an industrial area in Thailand. *Cleaner Production, Internal Re-use and Specific External Re-use* are, however, superior strategies to *General External Re-use*, and it is therefore very important to pursue such initiatives, *before* commencing *General External Re-use*. Seen by studying a case area in Thailand, both *General and Specific External Re-use* can sometimes, however, be quite inappropriate. Industries pursuing External Re-use strategies for wastes, often add to long transportation distances for materials re-uses, as industries that can benefit from generated wastes are not often located door to door with the waste generating industry.

Empirical data shows that even within a relatively small part of an Industrial Zone in Thailand, wastes - which could have been used more appropriate within the Zone - are transported out of the area, and some of it even discharged. By appropriate co-ordination of generated waste within the Zone, it is possible to connect these industries to a network for more appropriate materials re-use. Within an Industrial Zone or Park on the contrary, industries are located close by, which means that both *Specific and General External Re-use* happens within the nearby community, possibly within the walls of the Industrial Zone or Estate.

Energy efficiency is closely connected to the production and utility of electricity *and* heat. As already argued in Chapter 1, the inefficiency of the energy supply system in Thailand is mainly caused by electricity production only. The heat market is limited due to high temperature levels, which so far has made the implementation of co-generation schemes difficult. Heat produced by power plants is therefore a resource that is wasted. In an Industrial Zone or Estate, however, it is possible to create such heat market, by looking at industries with a demand for process heat in processing activities. By district heating supply to industries, it is possible to substitute individual fossil fuel uses in boilers for thermal energy production only.

By, for example, the cascading of energy it is possible to cover energy demands in industries requiring high quality energy (process heat made by electricity or steam uses), and thereafter to cover lower quality heat demands (process heat temperatures of less than 100 ºC) in other industries. Thus, within an Industrial Zone or Estate it is possible to optimise both materials and energy uses in an External Re-use scheme, which can increase the value of wastes (materials/process heat), and transform it into new resources for the community. In an industrial area, even small amounts of waste can be re-used in this way, as being based on a collaborative scheme of networking industries.

3.1.1 Perspectives for energy system development

Using resources locally - thereby minimising environmental impacts from transportation - will not favour technologies composting biomass waste. Composting will normally lead to the transportation of the waste to dump side areas for later collection of the resultant gas for energy production, by for example a Gas Engine producing both electricity and heat. Composting the biomass wastes outside the Industrial Zone or Estate will also make the piping of process heat difficult, as the heat market is located far away (more expensive, plus heat losses due to piping distance).

3.2 Appropriate types of industries?

In order to work with large amounts of biomass wastes generated by Thai industries, which increase the possibility for successful Industrial Materials Network development, I have chosen to work with the following types of waste:

A) Wastes from agricultural processing industries, processing wood (furniture and wood floor wastes, etc.) and crops (human and animal food wastes);
B) Wastes from pharmaceutical and medical industries producing insulin, health products etc. (fermentation and liquid waste etc.);
C) Wastes from possible Supporting Resources/Systems (agricultural waste, sludge from WWTPs etc.);

Industries that generate wastes similar to A&B all produce relatively *large amounts of waste*, and are thus appropriate for energy production. Wastes from A&B industries also yield *high energy output*, and the fact that *wastes are clean* (supposedly not contaminated) makes it attractive for renewable energy production (Pers.Com., Tyge Kjær, 2001). Industries generating A&B wastes are *also energy intensive companies*, using large amounts of process heat in processing activities, thus appropriate for substitution in energy supply (section 3.3).

Other industries are also found favourable with regards to biomass production and types of energy uses, but are not included in the following analysis, as they do not have a presence in the case area of Navanakorn. This is especially the case *for Paper and Tanning industries*, which also generate clean but minor amounts of biomass wastes appropriate for energy production (paper wastes and grease). As also being energy intensive industries, using large amounts of process heat in process activities (Industrien som varmekunde, Mogens Weel Hansen, et. al., Dk-Teknik Energi og Miljø, 1988), these industries can be included as potential Industrial Materials Network participants when they are present in an area.
Apart from type A&B waste generating industries emphasis will also be on type C waste, as well as on industries acting as Industrial Materials Network Supporting Industries - industries receiving for instance surplus electricity or heat from the Network if any.

In the following, I have made a rough theoretical pre-selection of industries solely based on their appearance on the next page, in which a list of Thai case area industries can be found. Departing from an estimation of the type of biomass wastes generated by each industry (whether solid, liquid or both), and by which conversion method these resources can be used for energy purposes (incinerated or digested), industries with *estimated clean biomass waste* are shown in the figure below. The numbers in Figure 3B below, refer to the specific numbers of industries as shown in Figure 3C next page.

Figure 3B: Type of wastes appropriate for energy conversion by different technologies, and in "bold" industries selected for interviews as potential Network participants

Type of waste	Incinerate (co-generation)
Solid waste	1, **4, 7**, 8, **9, 10**, 15, 21, 22, 24, **26, 27**, 30, 32, **38**, 39, **41**, 44, **46, 47, 48**, 52, **55**, 56, **57**, 58, **59, 60**, 64, **72, 74**

Type of waste	Digest (co-generation)	Incinerate (co-generation)[4]
Liquid waste	1, **4**, 8, **9,10**, 15, **25, 26, 28**, 32, **38**, 39, **41, 42**, 47, **51, 55, 57, 60**, 64, **72, 74**	1, **4**, 8, **9,10**, 15, **25, 26, 28**, 32, **38**, 39, **41, 42**, 47, **51, 55, 57, 60**, 64, **72, 74**

Not *all* industries generating appropriate biomass wastes are relevant Industrial Materials Network participants. Some might not require process heat in production activities, and some might not generate the biomass supposed. It is, therefore, necessary to conduct interviews and site visits in all the above industries, as some might be able to contribute with biomass wastes without actually being Industrial Materials Network participant. Marked in "bold" in the figure above are industries selected as potential Industrial Materials Network participants, namely *Pharmaceutical, -Food and Wood processing industries.*

[4] Incineration is included as conversion option as possible when drying liquid waste.

These industries are theoretically found to be the *most appropriate industries* for Industrial Materials Network development. All such industries should therefore in theory become Industrial Materials Network participants, but in practise the number of industries will be reduced. Firstly, due to their unwillingness to participate, and secondly, due to theory failure: The industries were not appropriate as Industrial Materials Network participants due to the waste for instance being contaminated, or by other means not appropriate when actually visited etc.

3.2.1 Industries located in Phase 1 of Navanakorn

Figure 3C: Companies, products and owners of industries in Phase 1

Number	Company *Products* (Owner)
1	A.U.K. Co. Ltd., *Leather Goods* (Japanese).
2	Acushnet (Thailand) Ltd., *Custom Moulded Rubber Part* (American).
3	AgrEvo (Thailand) Limited, *Pesticides, Environmental Health Products* (German).
4	ASAN Service Co. Ltd., *Soy Sauce, Frozen Food, Mirin, Sake, Shochu, Whisky and Ryorishu* (Thai, Jap.).
5	B.I.S. Fastener Co. Ltd., *Bolt & Nut* (Thai).
6	B.P.I. Co. Ltd., *Printing Ink* (Thai).
7	Bangkok Veneer Co. Ltd., *Wood Flooring* (Thai).
8	Bangkok Visypak Co. Ltd., *Corrugate Box* (Thai).
9	Baskin-Robbins (Thailand) Ltd., *Ice cream*
10	B.B. Snacks Co. Ltd., *"Greennut" Crispy Green Peas* (Thai).
11	Best Rubber Co. Ltd., *Rubber Roller, Rice Mill Blake Block* (Thai).
12	BP Thai Solar Co. Ltd., *Solar Module* (Thai, English).
13	Century Electronics and Systems Co. Ltd., *Printed Circuit Board Assembly, Key Telephone* (Thai).
14	Coates (Thailand) Ltd., *Can Coatings & Printing Inks*.
15	D.H.A. Siamwalla Ltd., *File, Note Book, "Elephant"* (Thai).
16	Daikoku Electronics (Thailand) Ltd., *Coil for Electronic Parts* (Jap.).
17	Daisin Group: Daisin Kogyo Co. Ltd., Daitec Co., Ltd. Alcast Co. Ltd., MN Industry Co. Ltd., Kwang Kij Industry Co. Ltd., Nissin Brake System Co. Ltd., *Aluminium Diccasting, Brake Lining Press Parts, Hydraulic brake system for vehicle* (Thai, Jap.).
18	Duraflor Co. Ltd., *Floor covering and wall paper (polyvinyl chloride).*
19	Ecolab Ltd., *Cleaning Detergent, Sanitizer Products System* (American).
20	Environmental Tectonics International Co. Ltd., *Sterilizers, Medical Equipment*.
21	Euro Asia Manufacturing Co. Ltd., *Water Sport Suit, Diving Suit, Survival Suit, Gloves, Shoes, Boots and Equipment* (Thai, German).
22	FCT Co. Ltd., *Stuff Toy, Disney Toys*.
23	Fujikura (Thailand) Ltd. Interface, *Cable assemblies, Wire assemblies & Wire harness, Flexible flat cable (Fuji-card), Magnetic head lead wire assemblies for HDD, Metal dome switch assemblies for Mobile phone, Coaxial cable & Telecommunication cable* (Jap.).
24	Fujishinko (Thailand) Co. Ltd., *Auto Parts (Brake & Clutch)*, *Footwear*.
25	General Hospital Products Public Co. Ltd., *Intravenous Solution, Peritoneal Dialysis Solution (CAPD)* (Thai).
26	Imperial Industrial Chemicals (Thailand) Co. Ltd., *Fatty Acids and Glycerine* (India).
27	Interfurn Co. Ltd., *Cushion Cover and Sofa Set* (Thai).
28	International Capsule Co. Ltd., *Hard Empty Gelatine Capsule*.
29	Kawasumi Laboratories (Thailand) Co. Ltd., *Disposable Medical Devices* (Thai, Jap.).
30	Kongo Chemifa Thai Co. Ltd., *Adhesives for sport shoes and for leather products.*
31	Kritchai Machinery Co. Ltd., *Regulators* (Thai).
32	Light House Industries (Bangkok) Co. Ltd., *Luggage's* (Taiwan).
33	Lucent Technologies Microelectronics (Thai) Co. Ltd., *Integrated Circuit* (Thai, American).
34	Mahajak International Electric Co. Ltd., *Kilowatt hour Meter* (Thai, Jap., Korea).
35	Metoxide Thailand Co. Ltd., *Zinc Oxide (ZNO)* (Thai, English).
36	MHE-Dematic (T) Ltd., *Crane, Hoist, Lift, Racking System, Dock Leveller* (Thai, German).

37 Mitsuboshi Belting (Thailand) Co. Ltd., *Power Transmission V-Belts, Automative V-Belts, Industrial V-Belts* (Thai, Jap.).
38 MK Restaurant Co. Ltd., *Frozen Food*
39 Multi Leatherwear (Thailand) Co. Ltd., *Men and Ladies Leather Garment* (Taiwan).
40 NEC Technologies (Thailand) Co. Ltd., *Tele-Communication Products (Key Telephone Term, Personal Fax)* (Jap.).
41 Nestle Foods (Thailand) Ltd., *Milo Tonic Drink, Chocolate, "Smarties", "FOXs", "Polo"* (Swiss).
42 NMT Limited Household Products, *Wax Products, Cosmetic Products* (Thai).
43 O & C Plastic Co. Ltd., *Plastic Container* (Thai).
44 Pacific Polysack Industry Co. Ltd., *P. P. Woven Bags* (Thai).
45 PCTT Ltd., *Flexible Printed Circuit Board.*
46 Peter and Toshima Furniture Co. Ltd., *All kind and types of wooden & Furniture under specific orders.*
47 Pfizer International Corporation, *Animal Health Products*.
48 Rockwood Co. Ltd., *Office & Home Furniture* (Thai).
49 Rohm Apollo Electronics (Thailand) Co. Ltd., *Transistor, Capacitor, Diode* (Japanese).
50 Rohm Integrated Semiconductor (Thailand) Co. Ltd., *I. C., Semiconductor.*
51 RT Beauty Care Ltd., *Shampoo, Conditioner, Lotion "Revlon".*
52 Shinawatra Fashion House Ltd. Part, *Garments* (Thai).
53 Siam Aluminium Co. Ltd., *Aluminium* (Thai).
54 Siam Spokes Industrial Co. Ltd., *Motorcycle & Bicycle Spokes with Nipple, CP& UCP, Bicycle Ball Retainer, Motorcycle Steer, Bicycle Wheel, UCP, CP & Black* (Thai).
55 Sara Lee Coffee and Tea (Thailand) Co. Ltd., *Instant Coffee, Roasted and Ground Coffee* (Holland).
56 Siovest Enterprises Ltd., *Cigarette Filter* (Thai).
57 Snacky Thai Co. Ltd., *Cooked - Frozen Food.*
58 Sry Engineering & Trading Ltd. Part, *Industrial Gas (Oxygen, Nitrogen)* (Thai).
59 Sun Cabinet Co. Ltd., *Teak & Oak Office Furniture, Bedroom Furniture* (Thai).
60 Sun Foods Co. Ltd., *Cooking Wine* (Thai, Jap.).
61 T.P.W. Die Casting Industries Ltd., *Computer Hard-Disk.*
62 T.S. Polyproducts Co. Ltd., *Medicine: Aluminium Hydroxide Gel, Magnesium Hydroxide Gel* (Thai).
63 Thai Bond Industrial Co. Ltd., *Polyester Padding, Interlining*, *Thermo bond* (Thai).
64 Thai Containers Ltd., *Corrugated Box* (Thai, Jap.).
65 Thai Engineering Products Co. Ltd., *Parts for Automobile, Motorcycle, Agricultural Diesel Engine, Material-Cast Iron, Forge Parts & Aluminium Die Casting* (Thai).
66 Thai Present Co. Ltd., *Pewterware*.
67 The Siam Gypsum Industry Co. Ltd., *Gypsum Board, Gypsum Plaster* (Thai).
68 The Siam Kubota Industry Co. Ltd., *Small Diesel Engine Walk-Behind Tractor, Rice Reaper, Tractor, Oil & Spare Parts* (Thai, Jap.).
69 U.T.N. Chemicals Co. Ltd., *Chemicals for Textiles, Pigment Resin Colours, Household Products* (Thai).
70 Unichem Pharmaceutical Ltd., *Pharmaceuticals Dosage Forms* (Thai, Indian).
71 Uniplas Industry Ltd., *Biaxially Oriented Polystyrene Film, Sheet for Packing* (Thai)
72 United Pharma Antibiotics Industries Co. Ltd., *Amoxicillin, Cloxacillin, Ampicillin* (Thai, Philippines).
73 Usha Siam Steel Industries Public Co. Ltd., *Steel Wires, Ropes & Strands* (Thai, Indian).
74 Wellab International Co. Ltd., *Feed Additive and Vitamin & Minerals*, *Premix for Swine, Poultry, Cattle, Dairy Cattle, Dog, Cat and Aqua-culture* (Thai).
75 Y.M.P. Printing Co. Ltd., *Printing* (Thai).
76 Yachiyoda Alloy Wheel Co. Ltd., *Aluminium Alloy Wheels for Cars*.

Source: "Industrial Promotion Zone Directory", Navanakorn Industrial Promotion Zone Homepage, 2000, at; www.navanakorn.co.th/dir.html, per 30-10-00

3.2.2 Industries for Macro Industrial Metabolism - Food and Pharmaceutical industries

Figure 3D: Food and Pharmaceutical industries as possible Network participants, and marked in "bold" the actual industries interviewed

Food industries:	
4	**ASAN Service Co. Ltd., *Soy Sauce, Frozen Food, Mirin, Sake, Shochu, Whisky and Ryorishu* (Thai, Japanese)** (Except from soy sauce all products are import);
9	**Baskin-Robbins (Thailand) Ltd., *Ice cream***;
10	**B.B. Snacks Co. Ltd., *"Greennut" Crispy Green Peas* (Thai)**;
38	MK Restaurant Co. Ltd., *Frozen Food*;
41	Nestle Foods (Thailand) Ltd., *Milo Tonic Drink, Chocolate, "Smarties", "FOXs", "Polo"* (Swiss);
55	Sara Lee Coffee and Tea (Thailand) Co. Ltd., *Instant Coffee, Roasted and Ground Coffee* (Holland);
57	Snacky Thai Co. Ltd., *Cooked - Frozen Food*;
60	Sun Foods Co. Ltd., *Cooking Wine* (Thai, Japanese);
74	Wellab International Co. Ltd., *Feed Additive and Vitamin & Minerals*, *Premix for Swine, Poultry, Cattle, Dairy Cattle, Dog, Cat and Aqua-culture* (Thai);
Pharmaceutical industries:	
25	General Hospital Products Public Co. Ltd., *Intravenous Solution, Peritoneal Dialysis Solution (CAPD)* (Thai);
26	**Imperial Industrial Chemicals (Thailand) Co. Ltd., *Fatty Acids & Glycerine* (India)**;
28	International Capsule Co. Ltd., *Hard Empty Gelatine Capsule*;
42	**NMT Limited Household Products, *Wax Products, Cosmetic Products* (Thai)**;
47	Pfizer International Corporation, *Animal Health Products*;
51	RT Beauty Care Ltd., *Shampoo, Conditioner, Lotion "Revlon"*;
72	United Pharma Antibiotics Industries Co. Ltd., *Amoxicillin, Cloxacillin, Ampicillin* (Thai, Philippines);

Source: "Industrial Promotion Zone Directory", Navanakorn Industrial Promotion Zone Homepage, 2000, at; www.navanakorn.co.th/dir.html, per 30-10-00

Choice of industries (food industries):
Not *all* food producing industries can be case area targets in conducting my research, thus, some simple means of selections must be applied. I have therefore chosen to focus on the number of employees as an indirect measurement of production quantities (number of employees as indicator for the production size), and the energy potentials of wastes (see section 3.3.4), as method of selecting industries:

ASAN Service (4) has 43 employees: Fat and flotation sludge yields high quantities of energy. (The productions of whisky etc., also generate valuable yarn/filter cakes for energy production, but are imports);
B.B. Snacks (10) has 60 employees: Fat and flotation sludge yields high quantities of energy;
Baskin Robbins (9) has 40 employees: Fat and flotation sludge yields high quantities of energy;

MK Restaurant (38) has 200 employees: Fat and flotation sludge yields high quantities of energy. The industry was, however, not willing to participate in interviews;
Nestle Food (41) has 110 employees: Fat and flotation sludge yields high quantities of energy. The industry was, however, not willing to participate in interviews;
(Industrial Promotion Zone Directory, Navanakorn Industrial Promotion Zone Homepage, 2000, at; www.navanakorn.co.th/dir.html, per 30-10-00).

Choice of industries (pharmaceutical industries):
International Capsule (28) has 92 employees: Production sludge, consisting of gelatine wastes yield high quantities of energy. The industry was, however, not willing to participate in interviews;
Imperial Industrial Chemicals (26) has 120 employees: Fat/grease yield high quantities of energy;
NMT Limited Household Products (42) has 321 employees: Production sludge yield high quantities of energy;
(Industrial Promotion Zone Directory, Navanakorn Industrial Promotion Zone Homepage, 2000, at; www.navanakorn.co.th/dir.html, per 30-10-00).

3.2.3 Industries for Macro Industrial Metabolism - Wood industries

Figure 3E: Wood industries as possible Network participants, and marked in "bold" the actual industries interviewed

Wood industries:
7 Bangkok Veneer Co. Ltd., *Wood Flooring* (Thai);
27 Interfurn Co. Ltd., *Cushion Cover and Sofa Set* (Thai);
46 Peter and Toshima Furniture Co. Ltd., *All kind and types of wooden & Furniture under specific orders*;
48 Rockwood Co. Ltd., *Office & Home Furniture* (Thai);
59 Sun Cabinet Co. Ltd., *Teak & Oak Office Furniture, Bedroom Furniture* (Thai);

Source: "Industrial Promotion Zone Directory", Navanakorn Industrial Promotion Zone Homepage, 2000, at; www.navanakorn.co.th/dir.html, per 30-10-00

Choice of industries (wood industries):
All wood industries (7, 27, 46, 48, and 59) were intended to become case area industries. Only three of five industries were, however, willing to participate in interviews. The remaining wood industries have between 90 and 500 employees
(Industrial Promotion Zone Directory, Navanakorn Industrial Promotion Zone Homepage, 2000, at; www.navanakorn.co.th/dir.html, per 30-10-00).

3.2.4 Supporting Industries/Systems/Resources for Macro Industrial Metabolism

3.2.4.1 Supporting Industries (internal)

Electricity demands
Supporting Industries can be companies, which have a great demand for high quality energy, i.e. electricity. This industry (ore more industries) can, if large quantities of surplus electricity are produced in the Industrial Materials Network, act as a main electricity customer. An Industrial Materials Network Supporting Industry will benefit from electricity services produced as carbon free energy. The Industrial Materials Network will, on the other hand, limit the amounts of surplus electricity necessary to transmit on the national grid (which will lead to energy losses). Another possibility is also to transmit surplus electricity to households in the residential areas of Navanakorn Industrial Promotion Zone.

Heat demands
An Industrial Materials Network Supporting Industry can also be an industry with an appropriate demand for process heat, but no possibilities of contributing with biomass wastes to the Industrial Materials Network.

Figure 3F: Supporting Industries, and marked with "bold" the actual industries interviewed

Supporting Industries:	
17	Daisin Group, *Aluminium Diccation, Brake Lining Press Part etc.* (Thai, Japanese);
24	Fujishinko (Thailand) Co. Ltd., *Auto Parts (Brake & Clutch), Footwear*;
32	**Light House Industries (Bangkok) Co. Ltd., *Luggage's* (Taiwan)**;
33	Lucent Technologies Microelectronics (Thai) Co. Ltd., *Integrated Circuit* (Thai, US);
45	PCTT Ltd., *Flexible Printed Circuit Board*;
61	T.P.W Die Casting Industries Ltd., *Computer Hard-Disk*;

Source: "Industrial Promotion Zone Directory", Navanakorn Industrial Promotion Zone Homepage, 2000, at; www.navanakorn.co.th/dir.html, per 30-10-00

Choice of industries (Supporting Industries):
Daisin Group (17) has 1,800 employees;
Fujishinko (24) has 3,500 employees;
Light House Industries (32) has 1,220 employees, selected by random;
Lucent Technologies Microelectronics (33) has 1,226 employees;
PCTT Ltd., (45) has 1,500 employees;
T.P.W Die Casting Industries (61) has 3,000 employees;

3.2.4.2 Supporting Systems (Internal)

Depending on heavy metal contents in the sludge of Navanakorn WWTP, this can be digested in a Biogas Plant, and/or dried and incinerated in a co-generation plant. Analysis in the field highlights whether this might be an option.

3.2.4.3 Supporting Resources (Internal)

Household waste from the residential areas of Navanakorn Industrial Promotion Zone can also be incinerated or source separated and digested in a Biogas Plant. In order to obtain hygienic conditions, which means eliminating pathogen organisms etc., the biomass waste must be treated like follows: 70 ºC in a hygienic tank for at least one hour, or to 55 ºC in 10 hours, before pumped to the digester chamber (Smittebeskyttelse i biogasfællesanlæg, H.J. Bendixen and S. Ammendrup, Veterinærdirektoratet, 1991). Hygienic conditions for processed or non-processed products from the food producing line of business, can normally be obtained by heating biomass wastes to 55 ºC for at least two hours, or to 50 ºC in four hours (Ibid.). It might also be possible to utilise other resources than those found in case industries, for example industrial/commercial waste from other industries and the commercial areas of Navanakorn Industrial Promotion Zone.

3.2.4.4 Supporting Resources (external)

A possibility is also to combine the activities of the Industrial Materials Network, with treatment of municipal and provincial household waste and commercial/industrial waste. They can, for instance, also be agricultural wastes from cut-offs, or other available organic materials appropriate for digestion or incineration. Such initiatives can create integrated environmental and energy solutions to waste management problems in a community. Studies in the field highlighted possibilities for collecting additional biomass waste, with the aim of creating Macro level Industrial Metabolism through the implementation of an Industrial Materials Network. The uses of such resources will, however, depend on transportation distances etc. and other contextual conditions, as emphasised more in Chapter 4.

3.2.5 Overview of Supporting Industries/Systems/Resources for Macro Industrial Metabolism

Figure 3G: Possible Industrial Materials Network Supporting Industries/Systems/ Resources

Supporting Industries (Internal):	
32	Light House Industries (Bangkok) Co. Ltd., *Luggage's* (Taiwan).
Supporting Systems (Internal):	
	Wastewater treatment plant
Supporting Resources (Internal):	
	Household waste
	Industrial/Commercial waste
Supporting Resources (External):	
	Provincial and Municipality waste - Household waste/Commercial & Industrial waste
	Provincial and Municipality waste - Other resources, i.e. agricultural wastes

3.3 Energy consumption and waste generation in selected types of industries

In the following, the adequacy of Food, - Pharmaceutical and Wood processing industries as potential Industrial Materials Network participants will be discussed in detail. The Focus is on types/amounts of waste generation and energy uses in relevant industries as Industrial Materials Network participants. The description of Micro Level Industrial Metabolism thus happens for the lines of businesses mentioned above. Data on waste generation comes from specific company descriptions of resource consumption etc. - primarily in a Danish context - with comments on the Thai context. Descriptions of heat and electricity uses are on a general level, illustrating energy consumption in the lines of businesses, with comments on the Thai situation when possible.

3.3.1 Pharmaceutical industries

3.3.1.1 Waste generation

Data for pharmaceutical industry producing insulin (fermentation):
In the pharmaceutical line of business, raw material inputs primarily consist of large amounts of water, and agricultural products, for example, soy flower, sugar and starch. Non-organic materials are, for example, uses of sulphur acid and hydrochloric acid etc. Water is on any account the largest resource utilisation, and counts for approximately 94 % of total raw material input. In processing raw materials (100 %), 83 % will become liquid waste, 0.30 % solid waste, and 1.20 % will end up as final product. The remaining 15 % ends up as steam, which is lead to the outdoor environment (Data based on The Environmental and Social Report, Novo Nordisk, 1999).

When only looking at liquid waste (100 %), 26 % will be re-cycled as liquid biomass, solid waste and yarn. The remaining 74 % will be discharged to water treatment facilities. Similarly, when looking at solid waste (100 %), 25 % will be re-cycled as, for example, fertiliser, 29 % incinerated, another 29 % dumped in landfill areas, 17 % discharges by controlled destruction, and finally 1 % will become water suspension (Data based on The Environmental and Social Report, Novo Nordisk, 1999).

Data for pharmaceutical industry producing nutrition products:
Raw material input primarily consists of gelatine, lactose sugar, water and organic solvents. In processing raw materials (100 %), 2.20 % will become liquid waste, 15.70 % solid waste, 3.70 % air emissions and 74 % final products. When looking isolated at liquid waste (100 %) the total amount will become wastewater. Figures for solid waste (100 %) show that 78 % will become combustible waste, such as paper and packaging material wastes, and the remaining part (22 %) re-usable waste, such as paper and cardboard products. Air emissions consist of evaporation of ethanol (Data based on Grønt Regnskab, Bifodan A/S, 2000).

3.3.1.2 Energy utilities and coverage of energy services

Energy figures for pharmaceutical industries include manufactures producing enzymes, medicine, vitamins, fertiliser, industrial gasses and soap. The main sources of energy in pharmaceutical industries are electricity, oil and gas (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995). In the figure below, the electricity and heat consumption in these types of industries are shown:

Figure 3H: Energy utilities in pharmaceutical industries: electricity and heat

Electricity used for:	Share (%)
Pumping	12
Fine separation	3
Compressed air	6
Process air (compression)	22
Stirring	16
Cooling	14
Blowing machinery	20
Ventilation	4
Others	3

Heat used for:	Share (%)
Process heating	25
Evaporation	30
Drying	25
Distillation	10
Heating building facilities	5
Others	5

Source: "Teknologikatalog - energibesparelser i erhvervslivet", Energistyrelsen, 1995

3.3.1.3 Comments on energy utilities in pharmaceutical industries

Energy uses:
High quantities of electricity are used for generating process air and for stirring, cooling and blowing processes. ***Process air*** is, for example, used for generating vacuum in the reactor, in which the ***Stirring*** activities happen when bulk substances are being mixed (Profile of the pharmaceutical manufacturing industry, US EPA, 1997). ***Blowing machinery*** is, for instance, used for ventilation purposes. ***Cooling*** is normally produced by a cooling compression system, which in industrial processes uses ammonia as a cooling media. The ammonia evaporates, which results in a cooling effect.
Cooling is primarily obtained by electricity uses, but can also be produced by using (diesel or natural) Gas Engines. Compression cooling systems are used for producing process cooling temperatures of 18 ºC and downwards (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995). ***Pumping*** activities also demand a lot of energy, and this happens for instance when bulk and other process substances are pumped through filters or centrifuges, re-cycled within the process, or pumped to re-cycling or disposal facilities (Profile of the pharmaceutical manufacturing industry, US EPA, 1997).

In pharmaceutical industries there is a high demand for heat used for various purposes. ***Process heating*** is a general term for processes in which products are being heated. A typical process heating activity can take place when preparing a product for final thermal treatment, by heating it up to about 100 ºC from any pre-temperature. Only to a minor extent is process heating activities produced by electricity, but are normally produced in boilers, where the heat media is hot water, steam or oil. When producing enzymes, large quantities of heat are used for heating up pipes in order to avoid the development of bacteria, which will damage a new production line (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995).

Evaporation processes are the most energy intensive part of the processing activities in this line of business as a whole, and account for 30 % of the total heat consumption. When evaporating a material solvent disappears, which results in a more concentrated product, whether being medicine or food additives. Evaporation normally happens as a boiling process using steam. It is possible to use water steam compression - thermal or mechanical - in order to upgrade the energy in the steam, thereby enabling the re-use of energy losses in earlier evaporating processes. Evaporation normally happens in temperatures between 40 to more than 100 ºC (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995).

Drying activities take place with temperatures between 40 and 250 ºC, and can be obtained through two types of processes: as batch-drying or as continuous-drying[5]. ***Distillation*** activities are used in almost every chemical process, and are for example utilised for purification of solvents in pharmaceutical and food producing industries. Just like drying processes, distillation can take place as batch-distillation or as continuous-distillation. The process is, however, very energy intensive, as the efficiency of the activity is low. Distillation temperatures are between 400 to less than 100 ºC (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995).

Internal energy production:
Internal energy production is primarily obtained by individual boilers - fired by oil or gas - for the production of heat only. Electricity services are transmitted from the grid (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995). In the Thai context, the energy situation is quite similar, as pharmaceutical industries primarily use gas or oil in individual boilers for process heat generation, supplemented by electricity from the national grid (Information obtained through Ms. Sutasana Kamnerdtong, Bangkok, Letter dated the 1-12-00).

3.3.1.4 Waste and energy profile

Waste:
When utilising chemical synthesis, waste products consist of reaction wastes and reactor bottom waste, which are not appropriate for energy production. In natural product extraction processes, the waste consist of spent raw materials like plants and roots etc., whereas in fermentation processes, the waste are filter cake waste, production sludge and fermentation products. In formulation processes, wastes are packaging waste, rejected tablets and capsules etc. (Profile of the pharmaceutical manufacturing industry, US EPA, 1997). Waste from natural product extraction and fermentation processes can be digested in Biogas Plants and yield high quantities of gas. Wastes from formulation processes - for example gelatine

[5] The specific product quantities are dried in a closed environment, or as an open continuous process.

capsules - can also be utilised in Biogas Plants for energy production. As stated earlier, the waste can also be incinerated when dried first.

Energy:
In the pharmaceutical line of business 10 % of the heat utilisation is covered by temperatures of 30 to 50 ºC, another 10 % by temperatures of 50 to 75 ºC, 30 % by temperatures of 75 to 100 ºC and 40 % by temperatures of 100 to 200 ºC. The remaining part by temperatures of more than 200 ºC (Industrien som varmekunde, Mogens Weel Hansen et. al., Dk-Teknik Energi og Miljø, 1988). This means that 50 % of heat uses can be covered by water based heat, and probably more, if implementing a vacuum drying processes, which lower the temperature requirements. This will be emphasised more in Chapter 6.

3.3.2 Wood and furniture industries

3.3.2.1 Waste generation

General overview of wood processing and producing industries:
When looking at figures for materials flow from wood extraction activities to final product output, the following data appear: In the Thai context, plantation wood material (100 %) are reduced by 54 % before entering a Thai sawmill, due to cut-offs etc. The remaining wood materials (46 %) are being processed at the sawmill, which leads to a waste generation of 24 %. Now 22 % of the original 100 % wood materials enter the furniture industry, where 10 % are lost in production processes. The final product thus counts for 12 % of the total wood input. Looking isolated at the figures for sawmills and wood furniture industries, waste generations of around 50 % are seen in these lines of businesses (Evaluation of conditions for electricity based on biomass, EC-ASEAN COGEN, 1998).

This means that when processing 1,000 kilos of wood in the furniture industries that waste will amount to almost half (45 %), i.e. 450 kilos of wood will be wasted. Similarly, when processing 1,000 kilos of wood in a sawmill, the waste will amount to more than half (52 %), i.e. 520 kilo of wood will be wasted. Knowledge about materials flow in the Danish wood industry shows roughly the same figures, as representatives for this line of business estimates that around 8 to 10 % of raw materials input, ends up as final products (Ib Hansen, Hyllinge Møbler, Hyllinge, Telephone-interview the 22-11-00).

Data for wood processing industry producing wood flooring (including oil and lacquer):
In the wood processing line of business, raw material input primarily consists of large amounts of water (approximately 75 %), wood and various additive substances such as solvents, glue etc. In processing raw material (100 %), 80.20 % will end up as liquid waste, 1 % as solid waste, 0.10 % as by-products, and 18.70 % as final product (including oil and lacquer). When looking isolated at liquid waste (100 %), 99.90 % will become treated wastewater, and the remaining part water suspensions (nitrogen and phosphor) and chemical fragments, discharged in controlled destruction facilities. Solid waste (100 %) primarily consists of sawmill wastes (69 %) such as soil, sand etc., combustible wood waste (18.20 %), ash/slag (4.20 %) - which are dumped in landfill areas - MDF plates and scrap (8.50 %). Solid by-products consists of saleable wood chips (36 %), internal wood fuel (31 %) and bark materials (33 %) (Data based on Grønt Regnskab 1999, F. Junckers Industrier A/S, 1999).

3.3.2.2 Energy utilities and coverage of energy services

Wood and furniture industries are separated into two types of industries as above: 1/ Wood processing industries as for example saw mills and industries producing building materials (wood floor etc.); and, 2/ Wood industries producing furniture. The main source of energy in wood and furniture industries is wood waste, oil, natural gas and coal. Wood waste counts for about half of the total energy consumption (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995). In the figure below the electricity and heat consumption of these types of industries are shown:

Figure 3I: Energy utilities in wood and furniture industries: electricity and heat

Electricity used for:	Wood processing industries (%)	Wood furniture industries (%)
Processing wood	43	27
Drying wood	30	(-)
Compressed air	(-)	17
Removal of sawdust	21	30
Lighting	14	
Others (incl. Internal transport)	6	12

Heat used for:	Wood processing industries (%)	Wood furniture industries (%)
Treatment of surface wood	2	11
Drying wood	53	11
Heating building facilities	33	66
Others	12	12

Source: "Teknologikatalog - energibesparelser i erhvervslivet", Energistyrelsen, 1995

3.3.2.3 Comments on energy utilities in wood and furniture industries

Energy uses:
High electricity usage is seen in processing wood, drying wood and in removals of sawdust etc., with the highest energy consumption located in wood processing industries.
In ***processing wood,*** various machinery is being utilised, such as electrified saws, planes, moulding and polishing machines etc., which all are energy intensive activities (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995).
Drying wood - warm pressing wood etc. - also demands a lot of energy, and normally happens with temperatures between 100 to 200 ºC (Industrien som varmekunde, Mogens Weel Hansen et. al., Dk-Teknik Energi og Miljø, 1988).

Removal of sawdust and transportation of wood waste, to for example silo storage facilities, are also energy intensive activities in this line of business. ***Compressed air*** in furniture production is energy demanding, and is for example used for fixation of wood under production activities, and for joining wood and cover fabrics (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995).

Heat utilisation for ***drying wood*** purposes is high, and normally takes place with temperatures between 30 and 50 ºC (Industrien som varmekunde, Mogens Weel Hansen et. al., Dk-Teknik Energi og Miljø, 1988). In both wood processing industries and industries producing furniture, wood drying is obtained by using a drying kiln or oven, fired by boilers (Profile of the wood furniture and fixtures industries, US EPA, 1996). In the Danish context, large amounts of heat are used for ***heating building facilities***, thus not accurate for Thai conditions where air conditioning is more likely to take place. In the production of wood furniture, heat is also utilised for ***treatment of surface wood***, for example when hardening glue (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995).

Internal energy production:
Wood waste is utilised for co-generation on larger wood processing industries in Denmark, with the purpose of covering internal energy needs. In some cases industries are connected to the local district heating system, and thereby receive surplus heat. Producers of wood furniture normally use wood waste as a supplement to fossil fuels - primarily oil and natural gas - for thermal energy production, which are utilised for heating up building facilities, or for instance in the production of chip boards (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995).
Converting technologies for thermal energy production in Danish furniture industries typically varies from 1 to 2 MW electricity. If the wood waste consists of more than 1 % hazardous substances - primarily obtained by surface treatment activities or by glues in the chipboard production - it must be incinerated in centralised waste treatment facilities (Lene Christensen, Dk-Teknik Energi og Miljø (Ålborg), Telephone-interview the 22-11-00).

In the Thai context, wastes products generated by wood processing industries and industries producing furniture, are normally only used for thermal energy production in inefficient boilers. Only a few industries have implemented modern biomass technologies such as co-generating plants, because of inappropriate regulatory means for selling surplus electricity (Evaluation of conditions for electricity based on biomass, EC-ASEAN COGEN, 1998). Producers of wood furniture utilise wood waste for thermal energy production when the wastes are not contaminated, and when internal use can be applied (Mr. Ludovic Lacrosse, EC-ASEAN COGEN, Letter dated the 23-11-00).
According to COGEN wood furniture industries cannot cover internal energy needs by their waste alone, which means that additional biomass wastes must be applied before a possible co-generating technology can be implemented. Thus, wood producing industries supplement wood waste with fossil fuels - primarily coal or oil - for thermal energy production only (Evaluation of conditions for electricity based on biomass, EC-ASEAN COGEN, 1998).

3.3.2.4 Waste and energy profile

Waste:
Depending on previous process activities wood producing industries generates a clean and dry wood waste product - wood chips and sawdust etc. - which produces relatively low particulate emissions when properly burned (Profile of the wood furniture and fixtures industries, US EPA, 1996). Wood waste can beneficially be incinerated or gasified, of which the latter is not included here.

Energy:
Wood processing and producing industries primarily utilise heat temperatures of less than 100 ºC. 25 % of the energy uses are covered by temperatures from 30 to 50 ºC, 20 % by temperatures of 50 to 70 ºC, 35 % by temperatures of 75 to 100 ºC and the remaining part by temperatures of 100 to 200 degree ºC (Industrien som varmekunde, Mogens Weel Hansen et. al., Dk-Teknik Energi og Miljø, 1988). This means that 80 % of energy utilities can be covered by water based heat.

3.3.3 Food producing industries

3.3.3.1 Waste generation

Data for food industry producing fish products (frozen and fresh fish):
Raw materials input primarily consist of water (more than 80 %), fish products and packaging materials. When processing raw material (100 %), 61 % will become liquid waste, 0.50 % solid waste and 38.50 % will end up as the final product. Liquid waste (100 %) includes process wastewater - flotation sludge - (71.50 %) are treated internally, cooling wastewater (22.80 %) and sanitary wastewater (5.70 %), which are piped into the ocean. Similarly, when looking at solid waste (100 %), 91 % will become fish sludge - collected at an internal wastewater facility - and delivered to Johannes Pihl. The remaining 9 % are sanitary waste delivered to Bofa I/S (Data based on Grønt Regnskab, Bornfish A/S, 1999).

Data for food industry producing dairy and fresh food products (butter, cheese, milk etc.):
When processing raw materials input, of which approximately half is water, 41.90 % will become liquid waste, 0.10 % solid waste and 58 % final products. The final product comes in three categories: primary processed products (39.40 %), secondary processed products (55.60 %) and raw products (5 %). Looking isolated at liquid waste (100 %), 99.90 % is discharges to the municipality wastewater facility, where the remaining 0,01 % is grease products (whey, flotation sludge) utilised in Biogas Plants. Solid waste (100 %) consists of 62 % combustible wastes, 36.60 % re-usable material, and finally 1.40 % of the solid wastes are lead to a controlled destruction facility (Data based on Grønt Regnskab, MD Foods amba, Holstebro Mejeri- og Friskvareterminal, 1999).

Data for food industry producing pet food:
Raw materials input primarily consists of water, animal parts and vitamins, where water counts for almost 91 % of materials inputs. In processing raw materials (100 %), 83.60 % will become liquid waste, 0.90 % solid waste, and 15.50 % final products. Liquid waste (100 %) primarily consists of wastewater, whereas solid waste (100 %) is fragmented as follows: 74 % will end up as meat wastes for destruction, 18.50 % as cardboard and paper materials for re-use, 23.30 % will be transported to landfill areas, and finally 0.50 % end up as chemical substances for controlled destruction (Data based on Grønt Regnskab, A/S Arovit Petfood, 1999).

3.3.3.2 Energy utilities and coverage of energy services

Food producing industries, exemplified here, cover the following industries: Conservation of vegetables and fruit, fish processing industries, oil mills and mills in general, margarine and fish-flower industries, bakeries and bread industries, chocolate and sugar industries, animal food industries and others. In the figure below, the electricity and heat consumption in food producing industries are shown. The main source of energy in these types of industries is heat (district heating) and electricity (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995).

Figure 3J: Energy utilities in food industries: electricity and heat

Electricity used for:	Share (%)
Processing machinery	32
Ventilation	8
Cooling equipment	19
Compressed air	7
Pumping	12
Lightning	5
Others	17

Heat used for:	Share (%)
Drying	12
Process heating	21
Other process heat	40
Boiling	3
Heating building facilities	10
Hot water	4
Others	10

Source: “Teknologikatalog - energibesparelser i erhvervslivet”, Energistyrelsen, 1995

3.3.3.3 Comments on energy utilities in food industries

Energy uses:
Large amounts of electricity are used by processing machinery, cooling equipment and for pumping activities. Electricity consumption by ***processing machinery*** primarily takes place as activities in which materials are centrifuged, rolled or pressed etc. These processes account for 32 % of the electricity use in this line of business. ***Cooling equipment*** is also an energy consuming activity. As mentioned earlier, cooling activities are normally carried out by a cooling compression system, which uses ammonia as cooling media. Cooling is primarily carried out by electricity, but can also be produced by using (diesel or natural) Gas Engines. Compression cooling systems are utilised for producing process cooling temperatures of less than 18 ºC (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995).

Electricity for ***pumping*** activities is normally used for moving or circulating liquids, as for example water and flotation sludge. The energy efficiency of pumping equipment is between 50 to 70 % for larger pumps, and between 20 to 50 % for smaller pumps. The category

Others, here refers to the transportation of products in food industries, by electrified transportation slides etc., and accounts for 17 % of total electricity consumption in the line of business (Ibid.).

Heat uses in food producing industries are high, and primarily used for process heat, heating and drying purposes. The category ***Other process heat***, refers to different types of heat utilisation by various process equipment, for example, evaporation processes. It is estimated that evaporation activities account for approximately 50 % of the heat consumption in this category. ***Process heating*** takes place, when preparing food products for a final thermal treatment - like evaporation or drying - by heating it up from any pre-temperature (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995).
Drying activities are the final treatment of food products with the purpose of for example conserving the product, and take place - as mentioned - with temperatures between 40 and 250 ºC. The category ***Others*** here refers to the coverage of energy losses in the heat producing and distributing systems (Ibid.).

Internal energy production:
Only oil-producing industries, and industries conserving vegetables and fruits, normally have internal energy production units. It is estimated that this line of business can save up to 70 % of the external (district heating) energy consumption, by implementing co-generation (Teknologikatalog - energibesparelser i erhvervslivet, Energistyrelsen, 1995).
In the Thai context, district heating is not available, thus, food producing industries are producing process heat by the use of fossil fuels, primarily gas, oil and coal. Electricity is used for mechanical activities and for cooling processes, and is transmitted from the national grid (Information obtained through Ms. Sutasana Kamnerdtong, Bangkok, Letter dated the 1-12-00).

3.3.3.4 Waste and energy profile

Waste:
Most food producing industries generate liquid waste appropriate for digesting in Biogas Plants. Food producing industries produce very different products, but in general wastes consist of grease/fat, oil, intestinal parts from animals, wastes from vegetable processing, proteins and fruit juices etc. In general, wastes from food producing industries yield relatively high quantities of gas when digested in Biogas Plants. Grease products in this line of business are obtained by fat separation and collecting systems in the production process, and flotation sludge is obtained by flotation techniques, which separate and collect the organic materials as sludge. This happens by a mechanical skimming of the liquid surface. Flotation sludge consists of large amounts of grease and proteins, which can yield high quantities of gas when digested (Biogashandlingsplanen, Baggrundsrapport nr. 12, Energistyrelsen, 1991).

In Denmark flotation sludge is partly used in centralised Biogas Plants and partly as a fertiliser, but are also brought to controlled destruction facilities or digested in Biogas Plants in connection to wastewater treatment facilities (Biogashandlingsplanen, Baggrundsrapport nr. 12, Energistyrelsen, 1991). Wastes from food producing industries can also be dried as thus incinerated.

Energy:
Temperatures of less than 100 ºC cover approximately 70 % of the heat uses in this line of business. 10 % of the energy uses are covered by process heat temperatures of 30 to 50 ºC, 20 % by temperatures of 50 to 70 % ºC, 40 % by temperatures of 75 to 100 ºC and the remaining by temperatures more than 100 ºC (Industrien som varmekunde, Mogens Weel Hansen et al., Dk-Teknik Energi og Miljø, 1988). This means that approximately 70 % of the heat utilisation can be covered by water based heat. When substituting highly heat consuming processes in this line of business, which other production methods - for example vacuum for drying and evaporation purposes which at present are being covered by electricity - an even larger amount of the heat uses can be covered by process heat, as the demand for high temperatures decrease when using vacuum processes.

3.3.4 Energy potentials from biomass waste

3.3.4.1 Liquid waste - Food and Pharmaceutical wastes (digest as example)

In centralised Biogas Plants in Denmark various organic waste from industries are utilised in a combination with manure. This waste comes from grease/fat or flotation sludge from fodder and fish industries, fruit and vegetables industries, breweries, dairies, sugar and pharmaceutical industries, and from sewage sludge etc. Approximately 45 % of total biomass uses are organic waste from the industry. This co-digestion of manure *and* organic waste is an important economic factor for centralised Biogas Plants in Denmark, as the gas potential of organic waste is high (Centralised Biogas Plants, Danish Institute of Agricultural and Fisheries Economics, Kurt Hjort Gregersen, 1999).

Biomass waste from industries can, also, be digested without utilisation of manure in traditional Biogas Plants, but for pumping purposes organic dry matter (VS) must not increase 12 VS (%). Organic materials on purely liquid fractions - low content of VS - can be digested in a bio-filter system (UBS-system), in which bacteria grows on small-topped plastic constructions (Kurt Hjort Gregersen, SUC, Telephone-interview the 11-12-00). After digesting, biomass wastes can be utilised as fertiliser.
Heat uses in food and pharmaceutical industries in Thailand are mainly obtained by the use of fossil fuels for process heat generation purposes. Between 50 to 70 % of the heat uses can be covered by water based heat in these line of businesses. In general, the amounts of waste generated through processing food and pharmaceutical products are high, which means that biomass resources are technical available for the implementation of biogas technologies for energy production (heat and electricity).

Figure 3K: Organic dry matter (VS %) and methane contents (CH_4/VS) in the wastes from different lines of businesses or products[6]

Line of business/ Products	Waste materials	VS %	CH_4/VS
Slaughterhouse - pigs	Intestinal contents Fat and flotation sludge Sifted material[7]	16 to 20 4.50 to 35 12	0.46 0.50 0.30
Slaughterhouse - livestock	Intestinal contents Fat and flotation sludge Sifted material	16 36 12	0.40 0.58 0.30
Slaughterhouse - poultry	Fat and flotation sludge	7 to 40	0.61
Oil mills	Bleaching earth[8] Organic materials	40 25	1.00 0.47
Margarine	Fat sludge	90	0.81
Fish- oil/flower	Fat and flotation sludge	8 to 24	0.36
Fish fillet	Fat and flotation sludge	7 to 20	0.45
Haring conserves	Different sludge	8 to 11	0.55
Mackerel conserves	Fat and flotation sludge	17 to 23	0.55
Seafood	Fat and flotation sludge	20 to 25	0.75
Smokehouse	Fat and flotation sludge	8 to 44	0.59
Potato flower	Fruit juice	4	0.35
Pectin industry	Seaweed wastes	4 to 5	0.21
Brewery	Yarn[9] Yarn kieselguhr[10] Filter materials	10 21 11	0.26 0.26 0.26
Pharmaceutical	Production sludge	5 to 100	0.30
Tannery	Leather grease	17	0.50
Forage drying	Green and brown juice	2.50 to 5	0.45
Dairies	Flotation sludge Whey[11]	7 to 8 4 to 6	0.40 0.33

Source: ”Biogashandlingsplanen”, Baggrundsrapport nr. 12, Energistyrelsen, 1991

3.3.4.2 Solid waste - Wood waste (incineration)

Heat use in wood processing and producing industries in Thailand is mainly obtained by incineration of internal biomass waste. This energy production can, however, normally not cover all energy demands, and are therefore supplemented with fossil fuel boilers, primarily feed by coal and oil. Analysis shows that up to 80 % of heat utilities can be covered by water

[6] Own translation from Danish to English.
[7] (‘sigtegods’) ….all translations from English to Danish are from now on put in paragraphs without further indication.
[8] (‘blegejord’)
[9] (’gær’)
[10] (’kiselgur’)
[11] (’valle’)

based heat, as temperatures are below 100 ºC. Waste generation in these lines of businesses is in general high, which is why an effective combustion and collection of the waste could lead to a high energy production based on biomass resources, replacing uses of fossil fuels.

Figure 3L: Figures for wood chips[12]

Content	Content % of VS	Wood chips
Carbon	C % of VS	50
Hydrogen	H % of VS	6.20
Oxygen	O % of VS	43
Nitrogen	N % of VS	0.30
Sulphur	S % of VS	0.05
Chlorine	C % of VS	0.02
Ash	A % of VS	1
Volatile parts[13]	% of VS	81
Effective combustibility	MJ/kg VS	19.40
Water contamination	%	35 to 45
Effective combustibility	MJ/kilo	9.70 to 11.70

Source: ”Træ til energiformål - Teknik, Miljø, Økonomi”, Videnscenter for Halm og Flisfyring, Dk-Teknik Energi og Miljø, 1999

[12] Own translation from Danish to English.
[13] (’flygtige bestanddele’)

Chapter 4; Navanakorn Industrial Promotion Zone and surroundings - Empirical approach

The purpose of this chapter is to give an introduction to Navanakorn Industrial Promotion Zone and its surrounding community, Pathum Thani Province, and Takhlong Municipality in which the Industrial Zone is located. Emphasis will be on the specific context in which the Industrial Materials Network is to be implemented. The focus of the chapter is on highlighting resource management practices within the Industrial Zone and surrounding community, and identifying biomass wastes appropriate for energy production in the Industrial Zone as well as in the community; A study of Industrial/Community Metabolism.

In the first part of this chapter, I will give an overall description of resource management practices and estimate the quantities of biomass wastes in Navanakorn Industrial Promotion Zone and surrounding community, as well as comment on the present management practices. In the second part, I proceed to describe case area industries on the level of Micro Industrial Metabolism, and to expose resource management practices within case industries. This includes a description of the value of possible internal/external re-use of wastes from industries, and whether or not the wastes can be regarded as constant resources during the year with no seasonal effects.

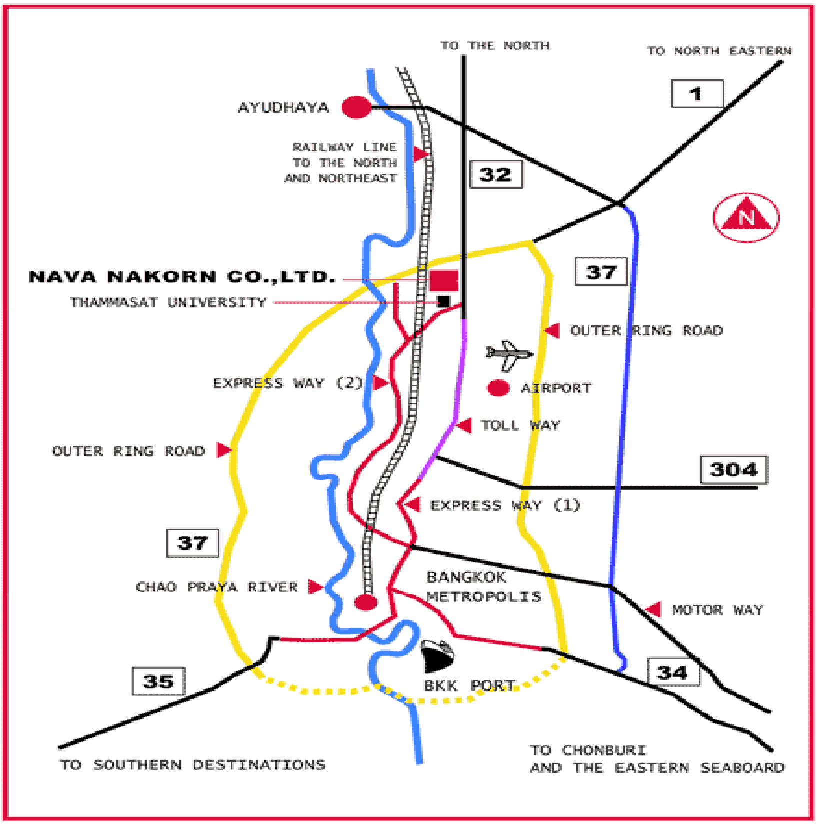
Case area industries are target objects for the development of Macro Industrial Metabolism, i.e. the creation of an Industrial Materials Network. The outcome and development of such schemes will not only depend on available wastes and energy needs within the industries, but also on additional types of wastes in the community, as well as other contextual conditions as emphasised above.

4.1 Community Metabolism - Resources and waste management in Navanakorn Industrial Promotion Zone

4.1.1 Location

Navanakorn Industrial Promotion Zone is a privately owned Industrial Town located in Pathum Thani Province on Phaholyothin Road, 46 km. North of Bangkok, 20 km. from Don Muang International Airport and approximately 60 km. from Bangkok Klongtoye Port. Due to a 10-lane road and nearby train station, projected electric railway lines (extension of the sky-train), bus connections to Bangkok and upper Central, North and Northeast Thailand, Navanakorn has a good location depicted below (Introduction, Navanakorn Industrial Promotion Zone Homepage, 2001, at; www.navanakorn.co.th/intro-p4.asp, per 19-3-01.

Figure 4A: Location of Navanakorn Industrial Promotion Zone



Source: "Introduction", Navanakorn Industrial Promotion Zone Homepage, 2001, at; www.navanakorn.co.th/intro-p4.asp, per 15-3-01

4.1.2 Establishment and ownership

Navanakorn Industrial Promotion Zone was the first Industrial Zone to be developed in Thailand, and was founded in 1971. Is has developed into a role model for the implementation of new Industrial Estates or Zones in Thailand, thus occasionally it receives delegations from other parts of the country (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01). Navanakorn Co. Ltd., which shareholders manages Navanakorn Industrial Promotion Zone, consists of the following stakeholders:

- NEP Reality and Industry Public Company Limited;
- The Charusorn family;
- The National Housing Authority;

The aim of Navanakorn Co. Ltd. is to develop and turn the 6,000 rai[14] of land into the first complete Industrial Town in Thailand. The good location of Navanakorn Industrial Promotion Zone, including implemented facilities such as flood prevention, electricity and water supply

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[14] 1 rai is equal to 1,600 m^2

etc., makes the area attractive for investors (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01).

4.1.3 Infrastructure and facilities

Electricity supply is transmitted to Navanakorn by a 115 KV transmission line, connected to a substation of the Provincial Electricity Authority (PEA), and a 22 KV line to each industrial site has the total electricity capacity of approximately 285 MVA. Water supply is provided by 12 deep well pumps and 12 water storage tanks in the area, which were provided by the Provincial Waterworks Authority (PWA) who produce and distribute unlimited water to the Industrial Zone. A wastewater treatment plant (WWTP), which has a peak capacity of approximately 26,000 m^3/day, has been implemented in the Industrial Zone in accordance with governmental regulations (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01).

Buns[15] around the area, including three large drainage stations, assist in flood prevention during rainy seasons. The Telephone Organisation of Thailand (TOT) and Telecom Asia Co. Ltd., have installed the telephone lines in the area. Roads leading to the project area, as well as roads within the Zone, are paved. All sectors of the Industrial Zone are accessible by minibus (TukTuk) service (Introduction, Navanakorn Industrial Promotion Zone Homepage, 2001, at; www.navanakorn.co.th/intro-p5.asp, per 15-3-01). Navanakorn Co. Ltd. also provides management of solid and hazardous waste from industries located in the Industrial Zone, by sub-contracts to private companies, plus maintenance of all infrastructure facilities as mentioned above (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01).

Figure 4B: Recreational area in Navanakorn Industrial Promotion Zone

[15] ('forhøjninger')

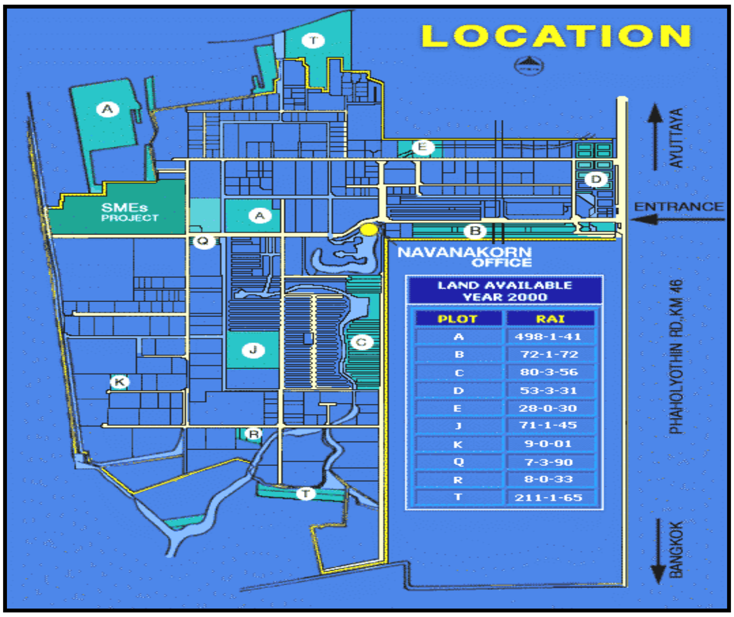
4.1.4 Management objectives and Industrial Zone philosophy

Navanakorn Co. Ltd. has the main objective to develop the area in which Navanakorn is located into a new Bangkok satellite town. This includes the development of Industrial-, Residential and Commercial Zones, combined with entertainment and recreational opportunities. Apart from shopping malls, restaurants and supermarkets etc., public utilities such as hospitals, schools etc. have also been established, in order to create an attractive community (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01).

The philosophy behind these initiatives is to create a community in which industries and workers live side by side in order to facilitate a work force for the industries, and to avoid long transportation distances for employees in the Zone (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01). There are, currently, approximately 200 industries located in Navanakorn Industrial Promotion Zone, and some 60,000 people residence within the area. Another 50,000 to 80,000 people are coming each day from surrounding municipalities to work in the Zone (Letter from Mr. Dhani Kumwongwan dated the 4-6-01), some of them being transported by organised bus services to the Industrial Zone (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01). According to Mr. Dhani Kumwongwan, the number of residents will most likely increase in the future, as new housing (houses and apartments) constantly are being built in Navanakorn Industrial Promotion Zone (Ibid.).

4.1.5 Available land in the Zone

Figure 4C: Land available including location of SMEs project



Source: "Land available", Navanakorn Industrial Promotion Zone Homepage, 2001, at; www.navanakorn.co.th/smes_eng.htm, per 15-3-01

Around 1,000 rai (1,600,000 m^2) of remaining land is available in the Zone (see Figure 4C), of which some will be managed solely as SMEs Industrial Zone, in order to support the continuing industrial growth in Navanakorn Industrial Promotion Zone (Introduction, Navanakorn Industrial Promotion Zone Homepage, 2001, at; www. navanakorn.co.th/intro-p2.asp, per 15-2-01). As the price of land has risen considerably since 1987 (Navanakorn Industrial Promotion Zone, CD ROM-info, 1999), the Industrial Zone has experienced a decline in new industries locating in the area recent years (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01).

4.1.6 Zoning and industries located in Navanakorn

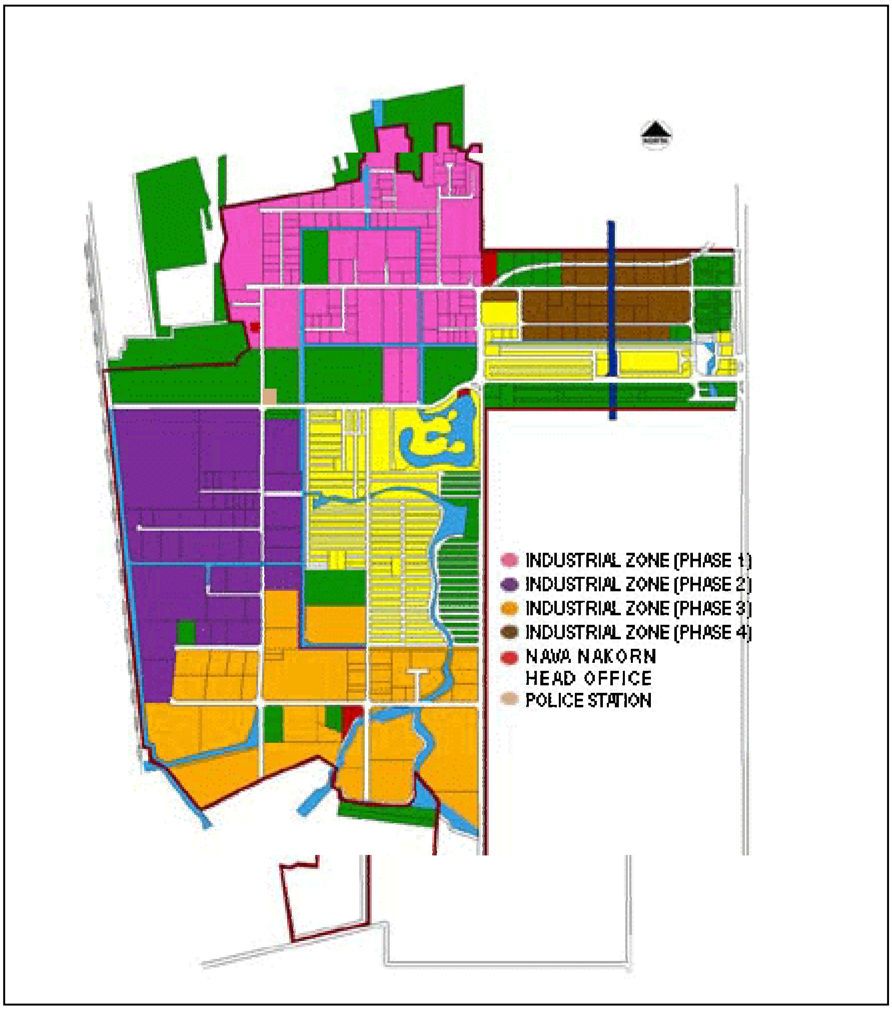
The building of Navanakorn Industrial Promotion Zone has been in four phases: one to four. Industries in Navanakorn are not located within the Zone in accordance with their product characterisations, as in some Industrial Zones or Estates in Thailand (Ms. Sukran Rojanapaiwong, Campaign for Alternative Industry Network (CAIN), Interview, Bangkok the 12-2-01), but are a mix of different types of industries in each phase. According to Mr. Dhani Kumwongwan there are approximately 200 industries located in Navanakorn at present, separated as follows (homepage not updated):

Phase 1 = 71;
Phase 2 = 38;
Phase 3 = 25;
Phase 4 = 23;

As seen on the list of industries located in Phase 1 of Navanakorn Industrial Promotion Zone, (Chapter 3 Figure 3C), industries vary between food, medical, furniture and electronic producing industries etc. Few industries are large scale businesses, i.e. having more than 2,000 employees, but can, in general, be characterised as SMEs. Phase 1 - in which selected case area industries are located - is the largest phase, and is located in the Northern part of the Industrial Zone, marked with the colour pink in Figure 4D on the next page. Just North from Phase 1, the before mentioned WWTP of Navanakorn has been implemented. South West of Phase 1, we find one (substation 3) of three substations for electricity supply in the area. The remaining two are located just East of Phase 1 (substation 1), and the last one (substation 2) in the centre of Phase 3 - marked with orange - in the Southern part of the Zone. Phases 2 and 4 - marked with purple and brown colours respectively - are located Southeast and Northeast in the Industrial Zone.

Marked with a thin black line on the figure are the implemented flood protection buns established all the way around the Industrial Zone. Canals in the Zone are marked with a blue colour. One of three drainage pumping stations was built in Phase 1 close to the WWTP, and the remaining two in the South and South East part of Phase 3. Within the complex water supply piping systems and gate value, as well as two wastewater pumping stations located in Phase 1, have been built. Sewerage pipes exist throughout the Industrial Zone. Marked with yellow on the figure is Navanakorn's Residential and Commercial Zone, in which approximately 60,000 people live. The green areas are Recreational sites and available land.

Figure 4D: Zoning in Navanakorn Industrial Promotion Zone



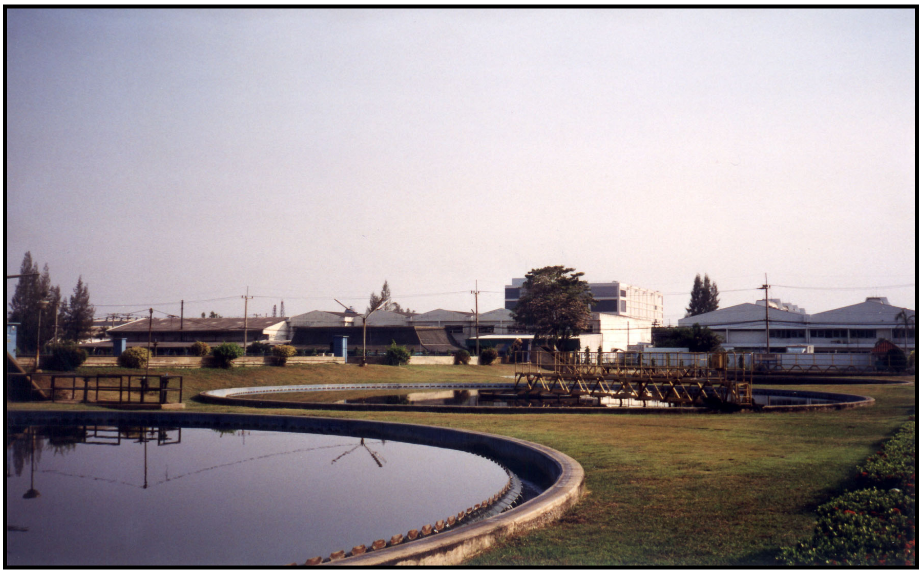
Source: "Introduction", Navanakorn Industrial Promotion Zone Homepage, 2001, at; www.navanakorn.co.th/intro-p7.asp, per 15-3-01

4.2 Waste management and resources in Navanakorn

The WWTP in Navanakorn Industrial Promotion Zone treats industrial wastewater as well as sewer sludge from the Residential areas (Letter from Mr. Dhani Kumwongwan dated the 4-6-01). Before the wastewater enters the WWTP is must have a certain standard, which can require pre-treatment of wastewater from industries in the Zone. Thus, some industries have implemented small scale WWTPs in order to live up to discharge standards.
Currently, the WWTP treats wastewater amounting to 13,000 m^3/day, thus only operating half of its capacity of 26,000 m^3/day (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01). The plant is operated as an aerobic process and requires large amounts of energy in order to provide mechanical activities for oxidation purposes etc. After treatment, the water is lead to the nearby Klong Luang. Sludge from the WWTP amounts to approximately 10 tons/day (300 m^3/day) - 3,600 tons/year - and is dried right next

to the plant, after which it is transported to a landfill area in another municipality (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01).

Figure 4E: The WWTP of Navanakorn



Navanakorn Co. Ltd. also manages solid and hazardous waste from industries, as they have implemented waste collection systems in the Zone. Up until 1999 solid waste was collected and brought to a landfill area in the Southern part of the Industrial Zone (see Figure 4D for the square area just South of Phase 3). The Ministry of Industry (MOI) has now stopped this activity, as the landfill area was located too close to the residential areas, and thus the Ministry received complaints from the community. Industrial wastes are now temporarily transported to the same area, but only to be collected by a company Better Green World (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01). This company transports it to another landfill area in Saraburi Province, approximately 120 km. from Navanakorn (Letter from Mr. Dhani Kumwongwan dated the 4-6-01).

Hazardous waste from industries is also collected by Navanakorn Co. Ltd., but is evidently transported to the only hazardous landfill area in Thailand, near the city of Rayong some 170 km. South East of Navanakorn. This is done by a company called GENCO, (Takhlong Municipality, Tambon Klong Nuang, Mr. Terapong Keawjaroon, Interview, Takhlong Municipality the 15-2-01). Household waste from Residential Zones and waste from Commercial areas, are also collected by Navanakorn Co. Ltd. - subcontracted to a company called PMS Construction - and brought to the temporary landfill area in Navanakorn (Ibid.). Then it is brought to a landfill area in Lad Lumkaew some 70 km. from Navanakorn Industrial Promotion Zone (Letter from Mr. Dhani Kumwongwan dated the 4-6-01).

According to the Main Office of Navanakorn, industrial and commercial waste amounts to approximately 15 to 20 tons/day (=17.50), of which Mr. Dhani Kumwongwan estimates that five tons/day is appropriate for energy production as being biomass wastes (organic fractions and wood etc.) (Navanakorn Main Office, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01). The actual amounts of waste are 10 to 20 % higher due to some industries moving their waste outside the Industrial Zone (Letter from Mr. Dhani Kumwongwan dated the 4-6-01). Thus, the actual waste generation is approximately (17.50+15 %) 20 tons/day. Another 30 to 50 tons of household waste are collected from the Residential areas each day, and brought to the former landfill area for later disposal (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01). Thus, an average mix of industrial, commercial and household waste amounting to 57.50 tons/day (20,700 tons/year), or separated as 6,300 tons of industrial and commercial waste per year, and 14,400 tons of household waste per year.

A document obtained from Takhlong Municipality, dated the 18-1-01, specifies that waste collection in Navanakorn Industrial Promotion Zone, undertaken by PMS Construction, derives from 160 industries, 779 households and commercial buildings and 1,077 apartments (Document obtained from Takhlong Municipality, Tambon Klong Nuang, Takhlong Municipality the 15-2-01). The remaining 40 industries (200 in total) have individual solutions to their waste management practices (Takhlong Municipality, Tambon Klong Nuang, Mr. Terapong Keawjaroon, Interview, Klong Nuang the 15-2-01).
The Main Office of Navanakorn charge industries, commerce and households for waste management. Industries and commerce pay waste fees amounting to Baht 2,500/tons wastes, and the Main Office of Navanakorn Baht 1,800/tons wastes for sub-contractions. Waste fees from households are included in the general service charge, which allocates resources to waste management (Letter from Mr. Dhani Kumwongwan dated the 4-6-01).

4.2.1 Problems with present resource management - Navanakorn

According to the Main Office of Navanakorn, the changes in waste management practices - which happened in 1999 - have lead to a lot of complaints from industries located in the Industrial Zone. One consequence in the shift in waste management practices has been a 200 % (three-doubled) increase in waste fees for industries. This has lead to massive complaints, which finally resulted in Navanakorn Co. Ltd. only charcing industries with an extra price of 60 % for waste management services, but still industries complain about the price level (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01). A possible consequence of increased waste management prices can be that industries seek alternative ways of waste disposals by, for example, pursuing illegal dumping at "unidentified locations". Increased waste management prices are thus suspected to intensify such a development in Thailand (Industrial Waste Treatment, Article in Bangkok Post the 14-3-01).

Another aspect is the increasing problem in locating appropriate landfill areas, as plans for developing such face more and more resistance throughout Thailand (Pathum Thani Provincial Office, Tambong Bang Plong, Ampur Muang, Pathum Thani, Mr. Ruangsak Padoogsilp, Interview, Pathum Thani the 22-2-01). Those who live in Navanakorn Industrial Promotion Zone are no longer exposed to a near by landfill area, but the chances that another community is now facing the same problem are high.

Resources appropriate for energy production in the Industrial Zone are also *not* being utilised. Sludge from the WWTP is not used for producing biogas, but is currently dried and transported to a landfill area. The waste management in Navanakorn Industrial Promotion Zone lack strategies for the re-use of organic fractions for energy production or for uses as valuable fertiliser. Apart from hazardous and ordinary waste - which is picked up by two different companies - there are no source separation of the waste. Industrial non-hazardous waste and household waste are dumped at the temporary landfill area in the Industrial Zone, and thereafter transported to the new dumpsite areas.

Figure 4F: Sludge being dried by the WWTP

According to the Main Office of Navanakorn, the amounts of waste from industries, Residential and Commercial areas will continue to increase and pose great problems in the future. To give an example of this, Mr. Dhani Kumwongwan stresses that the amount of waste has increased by 7 % in the period from November 2002 to January 2003 alone (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 29-4-03).

4.3 Community Metabolism - Resources and waste management in Takhlong Municipality

Takhlong Municipality is located in the Eastern part of Pathum Thani Province and covers an area of 63 km^2. Takhlong Municipality is located in Klong Luang one of 7 Ampur's (districts) in Pathum Thani Province. There are, in total, 13 municipalities (sub-districts) in Pathum Thani Province divided on 60 Tambon's. The population in Takhlong Municipality amounts to 31,815 people, living in 35 villages and 20,345 residences (Document obtained from Pathum Thani Provincial Office, Tambong Bang Plong, Ampur Muang, Pathum Thani the 22-2-01).

Apart from Navanakorn Industrial Promotion Zone, no other industries are located in Takhlong Municipality. In Pathum Thani Province, industrial activities are carried out in two industrial areas: Navanakorn Industrial Promotion Zone and Bang KaDi Industrial Park located South West of Navanakorn (Letter from Mr. Dhani Kumwongwan dated the 4-6-01). The agricultural activities in the area primarily consist of fruits and crops: oranges, vegetables and rice. Thus, the existence of animal livestock's is very limited in the community (Takhlong Municipality, Tambon Klong Nuang, Mr. Terapong Keawjaroon, Interview, Klong Nuang the

15-2-01). Except from two areas in Thaklong Municipality: Navanakorn Industrial Promotion Zone and Talaad Thai - which is a large market for vegetables, fruits etc. - the municipality is responsible for all waste management (Ibid.).

According to Mr. Terapong Keawjaroon, waste management in Takhlong Municipality is becoming an increasing problem for the community. At present, the municipality collects approximately 60 tons of household waste each day, but in total, at least 160 tons are generated per day. Thus, waste generation amounts to 57,600 tons/year and the collection capacity to 21,600 tons/year. A private company now operates the waste collection system in the municipality. Previously, household waste was dumped in a landfill area in the municipality. As the spatial room for developing such areas has been very difficult to find during recent years, the waste is now transported to another municipality, some 20 km. from the boarder of Takhlong Municipality (Takhlong Municipality, Tambon Klong Nuang, Mr. Terapong Keawjaroon, Interview, Klong Nuang the 15-2-01).

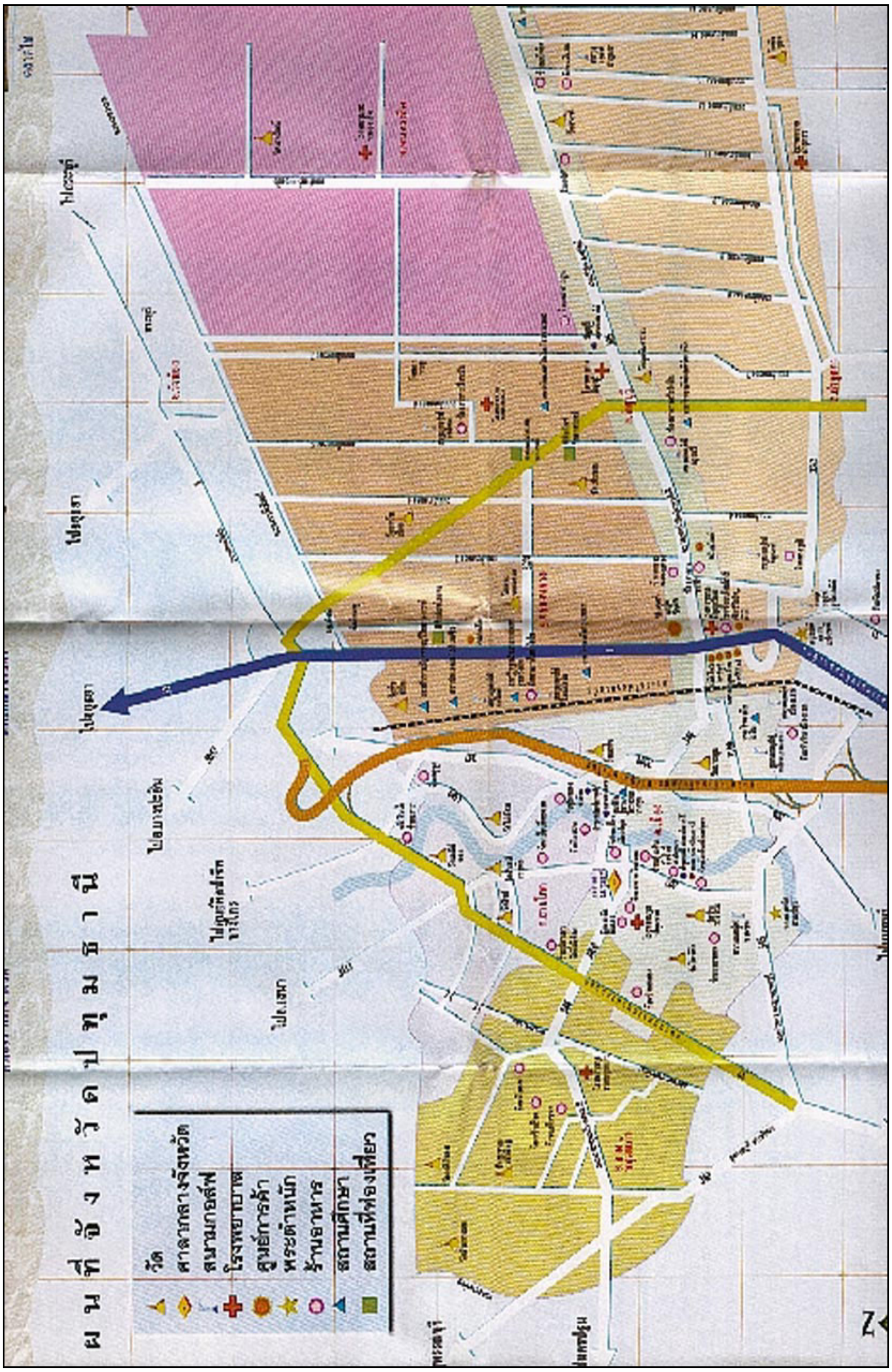
Mr. Terapong Keawjaroon expresses concern about the increasing prices of waste management in the community, which he believes will most likely increase even further in the future because of problems in finding spatial room for landfill areas. At present, the charges are Baht 200 per tons waste, which are collected from households in the municipality through a Waste-Tax according to quantity. People in the community complain about current prices for waste management, which amounts to Baht 60,000 to 70,000 (DKK 13,000[16]) per month in municipality Waste-Tax income. The actual price for maintaining the system, however, is much higher than the income from Waste-Tax's, as the municipality pays a sum of Baht 400,000 each month (DKK 80,000) for operating the waste management system (Takhlong Municipality, Tambon Klong Nuang, Mr. Terapong Keawjaroon, Interview, Klung Nuang the 15-2-01).

The Board of Takhlong Municipality would like to proceed with new waste management strategies, as the existing scheme is expensive, and because of increasing problems in developing landfill areas. According to Mr. Terapong, the Board is in favour of incinerating municipal waste, but is concerned whether such plant can live up to emission standards, as it will threaten the health of community members if it does not (Takhlong Municipality, Tambon Klong Nuang, Mr. Terapong Keawjaroon, Interview, Klong Nuang the 15-2-01). Waste incineration is not a common practice in Thailand, and the possibilities for meeting local resistance in planning such a scheme are high (Mr. Pongsak Wongwisnupong, OEEP, Interview, Bangkok the 16-2-01).

Mr. Terapong Keawjaroon stresses that Thaklong Municipality is satisfied with the present system as it is being operated professionally, but the price is too high. The municipality will be willing to participate and implement other waste management systems, as long as they are cheaper and possible benefit the environment more than the present system, which he points out not being sustainable (Takhlong Municipality, Tambon Klong Nuang, Mr. Terapong Keawjaroon, Interview, Klong Nuang the 15-2-01).

[16] Exchange rate calculated as DKK 1 equal to Baht 5, being the rate in 2001 when the empirical data in industries etc. were collected. This exchange rate is uniform for all economic calculations in this thesis.

Figure 4G: Map of Pathum Thani Province



Source: Pathum Thani Province, 2001

4.4 Community Metabolism - Resources and waste management in Pathum Thani Province

As highlighted above, it is becoming an increasing problem for municipalities in Pathum Thani Province to find spatial room for the development of new landfill areas. Because of these problems, the Province has now decided to examine the possibilities for establishing alternative solutions to present waste management systems. Thus, the authority has set up a committee in order to analyse possibilities for implementing two waste collection areas in the Province: One in the Eastern part and another in the Western part. The committee will, according to Mr. Ruangsak Padoogsilp, thus look into new management systems in order to try to solve waste problems in the Province (Pathum Thani Provincial Office, Tambong Bang Plong, Ampur Muang, Pathum Thani, Mr. Ruangsak Padoogsilp, Interview, Pathum Thani the 22-2-01).

A draft idea is, as mentioned, to develop two waste collection areas in the Province, but the idea has already met resistance from community members, especially in the Eastern part of the Province, where the amount of waste are largest. According to Mr. Ruangsak, the population fears pollution risks from the collection area, and does not trust the people responsible for managing it. It is, however, the belief of Pathum Thani Province that such a system will be better than the present one. It will most likely be cheaper and operated more efficiently (Pathum Thani Provincial Office, Tambong Bang Plong, Ampur Muang, Pathum Thani, Mr. Ruangsak Padoogsilp, Interview, Pathum Thani the 22-2-01).

One possible new solution concerning waste management practices in Pathum Thani Province can be to source separate household waste as proposed by one company. The organic fraction can then be utilised as a fertiliser, whereas the non-organic part will be mechanical pressed, in order to reduce the volume, and then put in landfill areas. Another possibility is to build an incineration plant and incinerate all the waste. Source separation of household waste can, however, be a problem in a Thai context, according to Mr. Ruangsak. The awareness of such possibilities are limited in Thailand, and only massive campaigns and awareness rising will change this (Pathum Thani Provincial Office, Tambong Bang Plong, Ampur Muang, Pathum Thani, Mr. Ruangsak Padoogsilp, Interview, Pathum Thani the 22-2-01).

The actual quantities of waste generation in Pathum Thani Province are, according to a study conducted in May 2000, as follows: In the Eastern part of the province - in which Nananakorn is situated - waste generation (household-, industrial and commercial waste) amounts to 666.80 tons/day of which 516 tons/day is collected. The Eastern part consists of the following districts: Klong Luang, Thunya Buri, Lum Look Ka and Nhong Sua.
In the Western part of the province 171.43 tons of waste/day is generated, and 157.19 tons/day are collected. Thus, generated waste amounts to 301,763 tons/year, whereas the collection capacity amounts to 242,348 tons/year. The Western part consists of the following districts: Muang district (centre district), Sam Kok and Lard Loom Gaew (Document obtained from Pathum Thani Provincial Office, Tambong Bang Plong, Ampur Muang, Pathum Thani, Pathum Thani the 22-2-01).

Present waste management practices in the Province are landfills, dumping on land and incineration, of which the latter only happens in Lum Look Ka district in combination with dumping of waste. Lum Look Ka district generated 158.80 tons waste/day of which 141.50 tons/day is collected (Document obtained from Pathum Thani Provincial Office, Tambong Bang Plong, Ampur Muang, Pathum Thani, Pathum Thani the 22-2-01).

4.4.2 Problems with present resource management - Takhlong Municipality and Pathum Thani Province

Takhlong Municipality, as well as Pathum Thani Province, is facing increasing problems in handling waste management systems in their community. One consequence of present waste management approach is the lack of available spatial room for landfill areas, which has lead to long transportation distances and increasing price levels put on households, as well as on the municipality budgets, as illustrated by the case of Takhlong Municipality. Local resistance regarding landfill areas and waste incineration makes the situation even more difficult, as appropriate land for developing such areas can meet local resistance, due to the fact that members of the community mistrust people in position to manage such projects. As we saw in the case of Navanakorn, local resistance can also lead to the closing down of landfill areas which are located to close to residential areas.

Takhlong Municipality has dealt with waste management problems by using an available landfill area in a neighbouring municipality, thus putting more pressure on landfill areas in the community. In Pathum Thani Province, there are at present attempts to come up with new solutions to problems in waste management practices, by developing two waste collection areas in the region. The strategy is to seek limitation in the volume of the wastes by using organic parts as fertiliser and reduce the volume of remaining non-organic parts; but only to continue the present model of depositing the waste in landfill areas, thus only extending the capacity of dumpsite areas. Due to problems in dealing with an increased amount of wastes in Takhlong Municipality and Pathum Thani Province, both institutions welcome and would like to support initiatives which reduce waste management problem.

4.4.3 Resource estimations

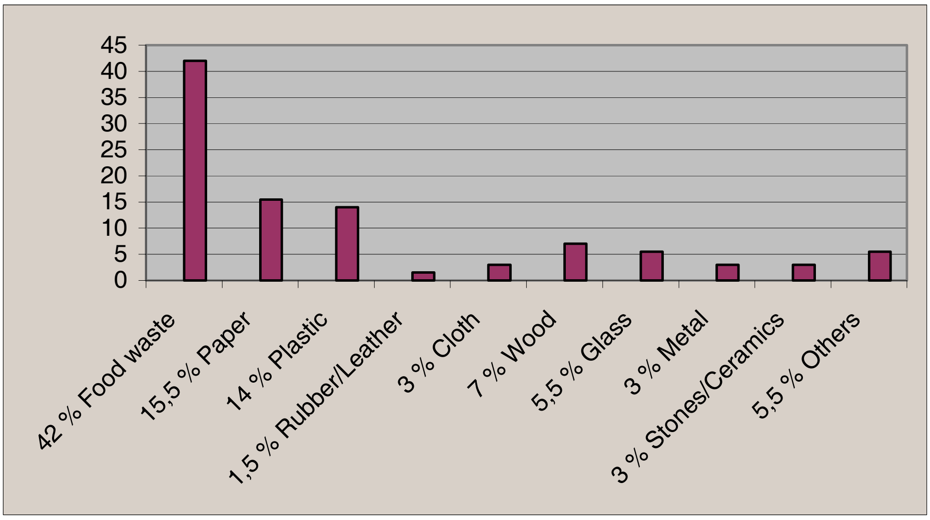
4.4.3.1 Household waste

When utilising household waste for energy production, the amounts of organic fractions are very important. There is much experience in Denmark concerning household waste, which could be useful in a Thai context. It is therefore important to estimate whether the composition of household waste in Thailand can be compared to the Danish situation. A study made at Prince of Songkla University in Hat Yai puts emphasis on the composition of household waste from urban municipalities and sanitary districts in Southern Thailand. The composition of analysed waste from this area - urbanised like the area of Navanakorn Industrial Promotion Zone - is shown in Figure 4H below.

Compared to the composition of Danish household waste (see Figure 4I) the greatest difference is seen in Food waste and Paper. Organic fractions deriving from Food wastes tend to be larger in the Thai context (42 %) compared to the Danish situation (36 %). The opposite situation is seen for Paper, where this fraction in the Danish context is larger (32 %) when compared to the Thai situation (15.50 %). Thus, Paper waste amounts to half of what is seen in a Danish context. By contrast, Plastic contents are larger in the Thai situation (14 %) compared to the Danish (7 %). The Danish category Combustible waste (13 %) can be compared to the Thai categories Wood (7 %), Cloth (3 %) and Rubber/Leather (1.50 %), which thus are quite equal compositions for the two countries.

The relatively low composition of paper in the Thai context is assumedly caused by the re-cycling price of these materials. Paper and bottles can be sold for re-use purposes, and the lower composition of this material can, therefore, be due to a source separation of paper in households, or by other people searching for sailable materials when the waste is dumped in household bins outside the houses (Industrial Office of Pathum Thani, Mr. Somjit Khunpleum, Tambon BangChang, Ampur Muang, Pathum Thani, Interview, Pathum Thani the 22-2-01).

Figure 4H: Composition of household waste in Thailand (% of content)

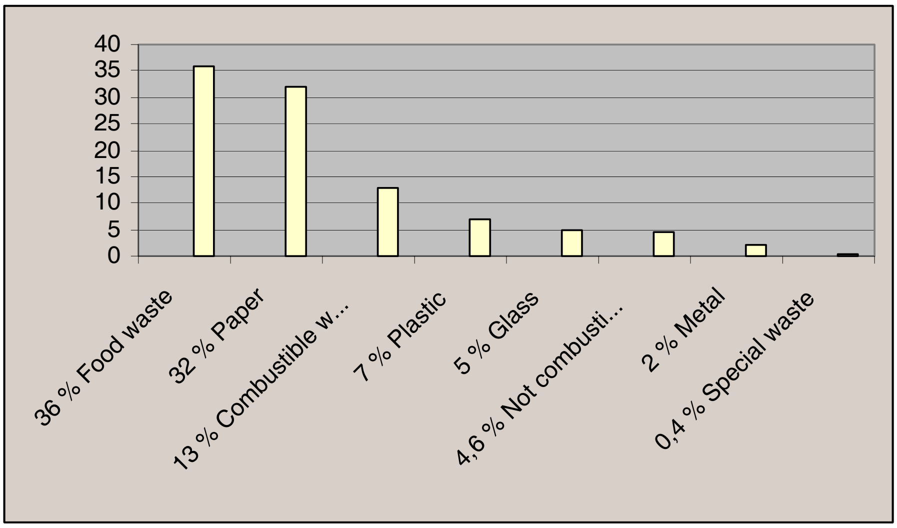


Source: "Solid Waste Management of Municipalities and Sanitary Districts in Southern Thailand", K. Thongnak, Prince of Songkla University, 1998

Paper wastes are, compared to food waste, not a specifically valuable type of waste for energy production. It is primarily the amounts of organic fractions from Food wastes, which leads to a large energy potential. The gas potential of paper is for example only 0.12 m^3 biogas/kilo VS (100 %), compared to 0.35 m^3 biogas/kilo VS (100 %) for food wastes (Biogashandlingsplanen, Baggrundsrapport nr. 12, Energistyrelsen, 1991). Seen in this light, the theoretical energy potential of household waste from Thailand is slightly higher compared to Danish household waste. Plastic contents are, as seen, larger in the Thai context compared to the Danish context. This is possible due to the fact that the Danish regulatory authorities have required substitutions of such materials, and put taxes on certain types of wrapping and packaging. Due to the higher content of plastic components in Thai household waste, the chances for an incorrect separation when source separating the waste is higher. This can, however, be counteracted by the higher amounts of food waste in the household waste. On the basis of the figures above, concerning Thai and Danish household waste, I will assume that the composition of waste can be regarded as approximately similar.

There is a lot of experience in Denmark relating to the collection and digestion of organic fractions from household waste. In the Danish context, these fractions are usually calculated as being approximately 30 % of the total amount (Poul Lyhne, EnergiGruppen Jylland A/S, Herning, Telephone-interview the 10-5-01), which is slightly lower than what was found in Figure 4H and 4I. According to experiences obtained by EnergiGruppen Jylland A/S in operating Herning Værket[17], a 30 % organic fraction is set too high.

Figure 4I: Composition of household waste in Denmark (% of content)



Source: "Indsamling og anvendelse af organisk dagrenovation i biogasanlæg", Miljøstyrelsen, 1998

A more realistic quantification of organic fractions for energy purposes should be calculated as 25 % in order to make appropriate estimations of energy potentials (Poul Lyhne, EnergiGruppen Jylland A/S, Herning, Telephone-interview the 10-5-01). From experiences obtained by EnergiGruppen Jylland A/S it is also estimated that only 75 to 80 % of source separated household wastes can be utilised for energy production, due to wrong separations, plastic and metal parts etc. (Letter from Karl Stefansen, EnergiGruppen Jylland A/S, Herning, dated the 30-4-01).

4.4.3.2 Industrial/commercial waste

Compared to Danish experiences with wastes from industrial and commercial activities (waste from industries, restaurants and markets etc.), this will normally have an organic fraction of

[17] A Joint Biogas Plant digesting animal manure and organic household wastes in Denmark.

30 % of total amount. Furthermore, it is estimated that 75 to 80 % of source separated waste can be utilised for energy purposes, as for household wastes (Letter from Karl Stefansen, EnergiGruppen Jylland A/S, Herning, dated the 30-4-01).

4.4.3.4 Navanakorn Industrial Promotion Zone

On the basis of the empirical data collected at the Main Office of Navanakorn, Takhlong Municipality and Pathum Thani Province - as well as documents obtained at Takhlong Municipality - the quantities of waste appropriate for energy production are summarised in the following:

Industrial/Commercial waste:
The collection of industrial/commercial waste amounts to an average of 17.50 tons/day or 6,300 tons/year. The Main Office estimates that five tons/day is appropriate for energy production (1,800 tons/year). 6,300 tons/year, calculated in accordance with a 30 % organic fraction, gives 1,890 tons/year appropriate for energy production. This is approximately the same amount as estimated by the Main Office. Set to the lowest amount of possible use (75 %) 1,417.50 tons/year can be utilised for energy production. The amounts of waste generated are in average 15 % higher than what is collected, thus approximately 20 tons/day or 7,200 tons/year. A 30 % organic fraction gives 2,160 tons/year appropriate for energy production. Set to the lowest amount of possible use (75 %) 1,620 tons can be utilised for energy production.

Household waste:
An average of 40 tons of household waste is collected each day (14,400 tons/year) from the residential areas of Navanakorn. Calculated on the basis of a 25 % organic fraction 3,600 tons/year can be used for energy purposes. Set to the lowest amount of possible use (75 %) 2,700 tons/year can be utilised for energy production.

Sludge from WWTP:
The WWTP of Navanakorn receives wastewater amounting to 13,000 m^3/day (4.7 million m^3/year). Sludge from the treatment activity amounts to 3,600 tons/year.

4.4.3.5 Takhlong Municipality

Household waste:
The collection of household waste amounts to 60 tons per day (21,600 tons/year), and the organic fraction (25 %) is estimated to 5,400 tons/year. Possible use (75 %) is estimated to 4,050 tons/year. The actual amounts generated are 160 tons/day (57,600 tons/year), where the organic fraction (25 %) is estimated to 14,400 tons/year. Possible use (75 %) gives 10,800 tons/year utilised for energy production.

4.4.3.6 Pathum Thani Province

Industrial/commercial/household waste:
Generated waste amounts to 838.23 tons/day (301,763 tons/year). The actual collections of waste is 673.19 tons/day (242,348 tons/year). Organic fractions (30 %) are estimated to be

60,587 and 75,441 tons/year respectively. Possible use (75 %) gives 45,440 tons/year and 56,581 tons/year respectively utilised for energy production.

4.4.3.7 Evaluation of contents of organic fractions in waste

The population of Navanakorn Industrial Promotion Zone and Takhlong Municipality are modern Thais with a western ways of living. It is very unlikely that there are competitive uses of the organic fractions in the household wastes (Main Office of Navanakorn, Mr. Dhani Kumwongwan, Interview, Navanakorn the 2-2-01). In regards to wastes generated in the remaining part of Pathum Thani Province, this matter is difficult. No data can, however, support the presence of the organic fractions estimated. In the development of an Industrial Materials Network, I will therefore not work with these *only possibly existing resources*.

Figure 4J: ***Summary*** **of generated and actually collected waste in Navanakorn, Takhlong Municipality and Pathum Thani Province, and estimated amounts appropriate for energy production**

Waste (tons/year)	Navanakorn	Takhlong Municipality	Pathum Thani Province
➢ **Collected industrial/ commercial waste** **-Estimated organic parts** **-For energy production**	6,300 1,890 **1,417.50**		
➢ **Generated industrial/ commercial waste** **-Estimated organic parts** **-For energy production**	7,200 2,160 **1,620**		
➢ **Collected household waste** **-Estimated organic parts** **-For energy production**	14,400 3,600 **2,700**	21,600 5,400 **4,050**	
➢ **Generated household waste** **-Estimated organic parts** **-For energy production**		57,600 14,400 **10,800**	
➢ **Collected industrial/ commercial/household waste** **-Estimated organic parts** **-For energy production**			242,348 60,587 **(45,440)**
➢ **Generated industrial/ Commercial/household Waste** **-Estimated organic parts** **-For energy production**			301,763 75,441 **(56,581)**
➢ **Sludge from WWTP**	**3,600**		

Own figure based on data in this chapter (see text)

4.4.4 Contextual conditions for development of an energy system

As seen in the previous sections there are certain local conditions regarding the development of the energy system in Navanakorn. One main condition for development of a successful energy system is that a traditional waste incineration system should not be built, as local

resistance most likely will lead to the rejection of such plans. So, when planning to develop an energy system based on biomass wastes, it is important not to develop new environmental problems as for instance emissions from incineration of biomass wastes. The energy system must therefore be based on clean biomass wastes, which requires an examination of possible emissions from uses of biomass by different conversion methods. Such examinations, and resulting uses of non-contaminated wastes only, can possible prevent a local resistance from the population in Navanakorn Industrial Promotion Zone regarding the energy system.
In addition, landfill of wastes, and possible extraction of landfill gas are difficult strategies seen in the local context. It is possible to pursue such extraction of already established landfill areas in the community, but the building of new landfills areas is in general becoming more and more difficult. It is therefore important to reduce the amounts of wastes for landfill areas by using the contents of biomass for energy purposes. This will reduce the amounts of wastes dumped in landfill areas.

It is likely that Takhlong Municipality and Pathum Thani Province will support the development of an Industrial Materials Network based on clean energy production in order to limit waste management problems. Both waste incineration and landfill initiatives are facing serious resistance in the community, thus strategies that promote sustainable solutions, which can be adopted by the population, are welcomed. It is also likely that industries will welcome new practices in waste management, as they have faced - and possible will face even further - increases in costs of waste disposals.

4.5 Micro Industrial Metabolism - Case industries

The purpose of this section is to introduce case industries located in Navanakorn Industrial Promotion Zone Phase 1 with emphasis on Micro Industrial Metabolism. All case area industries are located within an area of 1.50 km^2 in Phase 1 of Navanakorn Industrial Promotion Zone. In the following focus is on: Ownership, employees and markets; Raw materials input and waste; Re-use of resources; Energy; Efficiency of machinery.

4.5.1 Pharmaceutical industries

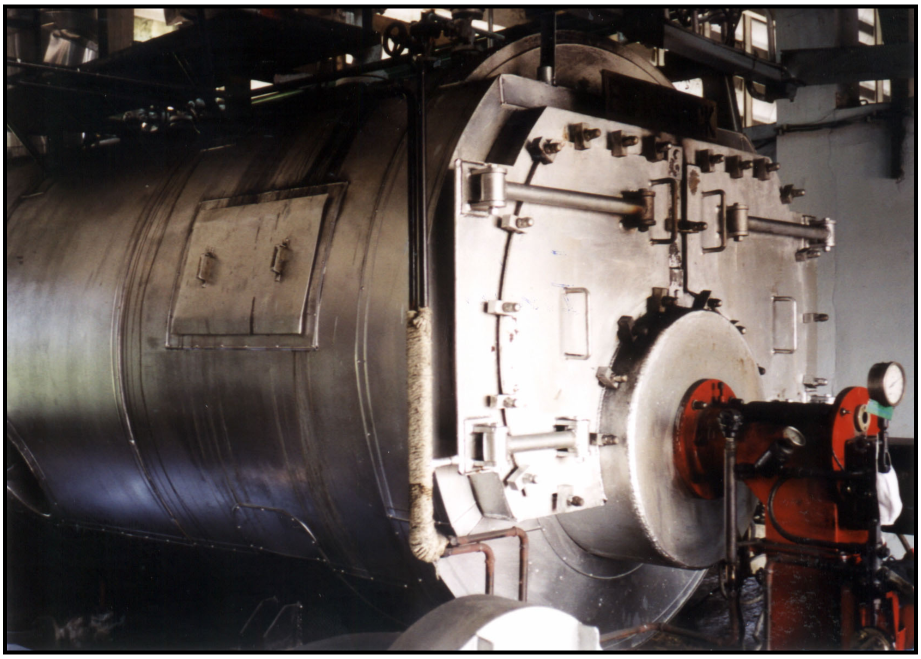
4.5.1.1 Imperial Industrial Chemicals

Ownership, employees and markets:
Imperial Industrial Chemicals was established in Navanakorn Industrial Promotion Zone in 1980 and is 100 % Indian owned. There are at present 90 employees in the factory. The main production consists of fatty acids and glycerine, and a minor part of, for example, stearine wax and methyl esters. According to Mr. Deshpande, 90 % of the industry's products are targeting the domestic market, whereas the remaining 10 % are exported to the US, EU, South Korea, India and the Middle East. There are currently no plans for increasing the production output in the industry by introducing more equipment, but to produce more efficiently by optimising/ renovate existing technologies (Imperial Industrial Chemicals, Mr. S.G. Deshpande, Interview, Navanakorn the 20-1-01).

Raw materials input and waste:
Raw materials input accounts for 6,000 tons/year, and consists of materials such as sunflower, ricebran, rubber,- rape and cottonseed and soybean[18]. Product output make up for 90 % of raw materials input (5,400 tons/year), whereas the remaining 10 % is wasted (600 tons/year). Water consumption amounts to 100 tons/day, and is pre-treated before send to the WWTP of Navanakorn (Imperial Industrial Chemicals, Mr. S.G. Deshpande, Interview, Navanakorn the 20-1-01).

Re-use of resources:
Currently, no resources are being re-used within the industry except from process water, which is cooled and re-cycled. Almost all waste, which is on a liquid basis, is sold to a company producing bricks, as it is a cheap fuel for heating up stoves (Imperial Industrial Chemicals, Mr. S.G. Deshpande, Interview, Navanakorn the 20-1-01). It is filled in customers' road tankers, and sold for between Baht 1 to 3 per kilo, depending on the demand (Letter from Mr. S. G. Deshpande dated the 1-6-01). Biomass wastes thus have a value between Baht 600,000 and 1,800,000 per year. Nickel, extracted from the catalyst process, is sold to other industries outside the industrial area for re-use (Imperial Industrial Chemicals, Mr. S.G. Deshpande, Interview, Navanakorn the 20-1-01).

Figure 4K: The 30 bar steam boiler at Imperial



Energy:
Imperial Industrial Chemicals have implemented two boilers of Indian origin. The boilers are fuelled with oil, which produces steam equal to 600 kcal/h. The two boilers have a capacity of 2 and 6 tons/h, and a pressure of 20 and 30 bar respectively (Letter from Mr. S.G. Deshpande dated the 12-12-01). Generated steam is primarily used for heating, vacuum and reaction purposes (Imperial Industrial Chemicals, Mr. S.G. Deshpande, Interview, Navanakorn the 20-

[18] ('solsikke, risklid, gummi,- raps og bomuldsfrø og soyabønner')

1-01), but also for cleaning reactors and pipes (Jan sandvig Nielsen, Dk-teknik Energi og Miljø, Interview, Gladsaxe the 18-1-02).

According to Mr. Deshpande, approximately 80 % of the energy uses occur at a temperature of 250 ºC, and the remaining 20 % by temperatures of less than 100 ºC. He stresses that the industry has lowered heat temperature requirements, from 400 to 250 ºC, by implementing a vacuum system. The amount of oil used in the industry is 150 tons/month or 1,650 tons/year. Electricity consumption amounts to 1.44 million kWh/year. Electricity is mainly used for operating pumping activities (Imperial Industrial Chemicals, Mr. S.G. Deshpande, Interview, Navanakorn the 20-1-01). The industry operates 24 hours a day six days a week, except from 14 days of national holiday per year (6,900 hours/year) (Letter from Mr. S.G. Deshpande dated the 12-12-01).

Efficiency of machinery:
Production machinery is 14 to 15 years old and the industry has no plans to implement new equipment. According to Mr. Deshpande, new technical innovations in this line of business are very slow. The industry would, however, like to utilise biomass wastes for internal energy production, but lack the knowledge about appropriate technologies. The specific waste product generated by the industry has a high flash point, which requires a lot of the boiler. Also problems related to corrosion of the boiler are of Mr. Deshpande's concern.

4.5.2 Food producing industries

4.5.2.1 ASAN Service

Ownership, employees and markets:
ASAN Service is a Thai/Japanese owned industry, which was established in Navanakorn in 1986. It produces soy sauce and imports Japanese products such as mirin, sake, shochu, whisky and ryorishu for further sales. ASAN Service currently has 43 employees, and 98 % of the products are sold to the domestic market, whereas the remaining part is exported to France. ASAN Service has no plans of increasing the production, as the market in Thailand is saturated (ASAN Service, Mr. Kyohei Omura, Interview, Navanakorn the 16-1-01).

Raw materials input and waste:
Raw materials input consists of soy been and wheat of which the industry utilise 280 tons/year. After adding water to the mix, yeast and mould[19] goes through a fermentation process of six months and finally ends up as soy sauce, amounting to 600 tons/year. According to Mr. Omura waste products from the production process is 280 tons/year (ASAN Service, Mr. Kyohei Omura, Interview, Navanakorn the 16-1-01).

Re-use of resources:
No resources are re-utilised in the production process. Waste products from ASAN Service are sometimes discharged (Information obtained through Ms. Sutasana Kamnerdtong, Letter dated the 29-5-01), and other times sold to a company making pig food as the nutritional value is high due to protein contents (ASAN Service, Mr. Kyohei Omura, Interview, Navanakorn the 16-1-01). The industry in average receives Baht 1,000 per month for waste

[19] ('gær og skimprodukt')

sold as animal feed (Information obtained through Ms. Sutasana Kamnerdtong, Letter dated the 6-4-01). This means that the waste has a yearly maximum commercial value of Baht 12,000 (DKK 2,400).

Figure 4L: Wheat as raw materials input

Figure 4M: Thai worker showing sacks of fermentation waste

Energy:
Process heat is generated by a boiler using oil - which amounts to 36,000 litres per year - and produce heat for sterilisation purposes. Mr. Omura has no knowledge about the size and pressure of the boiler, but stresses that process heat demands never increase the temperature

of 100 ºC, but in general is between 75 and less than 100 ºC. He estimates that approximately 40 % of process heat uses are covered by temperatures of 75 ºC, and the remaining 60 % by temperatures just below 100 ºC. Mr. Omura has no information regarding electricity consumption, as ASAN Service rent the factory buildings from another company (Sun Foods) for a fixed price, which includes water and electricity use (ASAN Service, Mr. Kyohei Omura, Interview, Navanakorn the 16-1-01).

Information obtained from Sun Foods, however, shows that ASAN Service on average uses 18,000 kWh/month (approximately 216,000 kWh/year) (Information obtained through Ms. Sutasana Kamnerdtong, Letter dated the 9-6-01). Electricity consumption is primarily used for cooling down the fermentation area, but also for providing other mechanical activities within the industry (ASAN Service, Mr. Kyohei Omura, Interview, Navanakorn the 16-1-01). According to Mr. Omura ASAN Service run one shift a day six days a week, thus operates approximately 2,400 hours per year.

Efficiency of machinery:
Mr. Omura stresses that the industry is in a process of implementing new technology as the present machinery are very old and inefficient. This process has lead to the implementation of new fermentation equipment, and there are also plans for changing the old mechanically machine for pressing mould and yarn with a new one, based on hydraulic. This machine will be more efficient and result in energy savings (ASAN Service, Mr. Kyohei Omura, Interview, Navanakorn the 16-1-01).

4.5.2.2 B.B. Snacks

Ownership, employees and markets:
B.B. Snacks is a Thai company established in Navanakorn in 1982 and currently has 75 employees. The industry produces snacks; crispy green peas of which 96 % goes to the Thai market, and the remaining part to export markets such as Spain, Holland and England. This year (2001) the industry plans a production increase of 20 % because of a new product; a new green peas flavour. Within the next five years, the industry expect a production increase of 5 to 10 % yearly (Mr. Kritsakhorn Dolcharumanee, Letter dated the 13-12-01). Thus, a total increase of between 45 and 70 % ≈ 55 % (including the 2001 increase) within coming years. In general, the production output depends on the market conditions. It is, however, possible to increase the production output by 200 % when utilising two production lines - of which only one is operated today - and by using two-shifts (B.B. Snacks, Mr. Pichai Burapavong, Interview, Navanakorn the 1-2-01).

Raw materials input and waste:
At present B.B. Snacks uses approximately 1,000 tons of green peas per year, plus 250 tons rice powder yearly. For flavouring the peas, the industry also uses small amounts of colour products. Nearly the same quantity as raw materials input ends up as a final product. According to Mr. Pichai Burapavong, wastes amount to 3 to 4 % of raw material input (excluding water), which is equal to 30 to 40 tons/year (B.B. Snacks, Mr. Pichai Burapavong, Interview, Navanakorn the 1-2-01).

Re-use of resources:
No internal re-use of resources happens at B.B. Snacks, and generated waste is sold as pig-food (B.B. Snacks, Mr. Pichai Burapavong, Interview, Navanakorn the 1-2-01). B.B. Snacks receive Baht 2,000/tons waste sold as animal feed (Letter from Mr. Kritsakhorn Dolcharumanee, dated the 28-5-01). The value of wastes thus amounts to approximately Baht 70,000 per year (DKK 14,000).

Figure 4N: Quality check at B.B. Snacks

Source: B.B. Snack brochure

Figure 4O: Automatic transportation of peas in the processing activity

Source: B.B. Snack brochure

Energy:

Process heat is generated by two boilers - 1.20 and 1.50 tons respectively - where the latter is a back-up boiler (Letter from Mr. Kritsakhorn Dolcharumanee, dated the 28-5-01), and is fuelled by oil of which 100 tons are used per year. Generated steam is used for cooking activities as the green peas require a cooking process before being fried, which happens through the use of liquid petroleum gas (LPG) amounting to 36 tons/year (B.B. Snacks, Mr. Pichai Burapavong, Interview, Navanakorn the 1-2-01). Cooking occurs at temperatures of 140 to 150 ºC, whereas frying happens at 160 to 180 ºC. Approximately 70 % of all energy uses is at temperatures of 140 to 150 ºC and 30 % at temperatures of 160 to 180 ºC (own calculation) (B.B. Snacks, Mr. Pichai Burapavong, Interview, Navanakorn the 1-2-01).

According to Mr. Pichai Burapavong, it is not possible to implement a vacuum in frying activities, which would lower temperature requirements, as the industry operates continuous and not bach processing. In order to provide pumping and mixing activities, the industry uses approximately 31,000 kWh/month, i.e. 341,000 kWh/year (B.B. Snacks, Mr. Pichai Burapavong, Interview, Navanakorn the 1-2-01).
B.B. Snacks operate their production in one shift, which amounts to 2,400 hours per year (Mr. Kritsakhorn Dolcharumanee, Letter dated the 13-12-01).

Efficiency of machinery:

Mr. Pichai Burapavong stresses that the production equipment is very efficient, and argues that it is even better than in Japan. For example, a modern heat exchanger for the process of frying the green peas has been implemented. Thus, B.B. Snacks has no plans to implement new technology (B.B. Snacks, Mr. Pichai Burapavong, Interview, Navanakorn the 1-2-01).

Figure 4P: Thai worker supervising the boiling of green peas

Source: B.B. Snacks brochure

4.5.2.3 Baskin Robbins

Ownership, employees and markets:
Baskin Robbins is a Thai/US industry making ice-cream products. It was established in Navanakorn in 1994 and has 40 employees. 95 % of the products are sold on the domestic market and the remainder is exported to markets in the region, for example Vietnam. Currently, the industry only operates on day shifts, but will most likely start two-shifts in the nearest future to increase the production output (Baskin Robbins, Mr. Rastam B. Raheem, Interview, Navanakorn the 18-1-01).

Raw materials input and waste:
According to Mr. Rastam B. Raheem, raw materials input consists of the following substances: Cream 100 tons/year (44 % fat); Sugar 150 tons/year; Stabilisation 4 tons/year; Glucose 60 tons/year; Skimmed milk powder 120 tons/year and water 2,500 m^3/year. The production output amounts to 1,400 tons of ice cream per year. Flotation sludge is pre-treated in a small WWTP at the site, which generates 0.50 to 1 tons of solid sludge per month, thus between 6 and 12 tons/year (Baskin Robbins, Mr. Rastam B. Raheem, Interview, Navanakorn the 18-1-01). After pre-treatment the water is send to Navanakorn WWTP who charge Baskin Robbins Baht 5,000/month for WWT (Letter from Mr. Rasham B. Raheem dated the 1-6-01).

Re-use of resources:
Farmers usually use the sludge as pig feed (Baskin Robbins, Mr. Rastam B. Raheem, Interview, Navanakorn the 18-1-01), and as the industry gives it away for free (Letter from Mr. Rasham B. Raheem dated the 1-6-01), the biomass wastes has no commercial value for the industry.

Figure 4Q: Factory buildings of Baskin Robbins

Energy:
In order to cover internal heat demands Baskin Robbins has implemented a 2 ton boiler fuelled by oil of which the industry uses 300 to 360 tons/year. Process heat temperatures are between 60 to 90 ºC, and are mainly used in the PHE heat exchanger (Baskin Robbins, Mr. Rastam B. Raheem, Interview, Navanakorn the 18-1-01). Approximately 25 % of process heat uses happens at temperatures of 60 ºC, and the remaining 75 % at 90 ºC (Letter from Mr. Rastam B. Raheem dated the 19-10-01). Electricity consumption amounts to 130,000 kWh/month or 1.56 million kWh/year, and is primarily used for mechanical processes and cooling storage facilities (Baskin Robbins, Mr. Rastam B. Raheem, Interview, Navanakorn the 18-1-01).
At present, the industry operates 2,496 hours per year (Letter from Mr. Rastam B. Raheem, dated the 12-12-01), but this will most likely be doubled in the near future.

Efficiency of machinery:
As the company is only seven years old (in 2001) the technology is quite efficient, thus Baskin Robbins has no plans for purchasing new production equipment. 60 to 70 % of the machinery is technology produced in Denmark (Baskin Robbins, Mr. Rastam B. Raheem, Interview, Navanakorn the 18-1-01).

4.5.3 Wood industries

4.5.3.1 Sun Cabinet

Ownership, employees and markets:
Sun Cabinet is a Thai owned industry established in Navanakorn in 1988. At present, the company has 250 employees, and produces wood furniture for offices and private homes. One part of the production is based on solid wood, which is imported from Burma (Union of Myanmar), and another on chip board and laminate products[20], of which the latter also are imported from Burma. Almost all products (99 %) are exported to countries such as the US, Canada, Japan and England. According to the export manager, Ms. Supranee Sripawadkul, Sun Cabinet is constantly working on increasing the production output (Sun Cabinet, Ms. Supranee Sripawadkul, Interview, Navanakorn the 30-1-01). Sun Cabinet thus plan to increase the production output by 25 % within the next 5 years (Letter from Ms. Supranee Sripawadkul, dated the 21-12-01).

Raw materials input and waste:
Sun Cabinet uses 600 tons solid wood per year and approximately 4,700 tons chip board annually, thus a total wood consumption of 5,300 tons/year. Production Manager Mr. Somyos Yamtgasorn estimates that the industry generates wood waste corresponding to 10 %[21] of all wood uses (530 tons/year). He further estimates that 1 to 2 % of this wood waste is generated as sawdust (between 5.30 and 10.60 tons/year). The remaining (8 to 9 %) wood waste is in the form of small wood pieces, and amounts to between 519.40 and 524.70 tons/year. The wood wastes primarily consist of waste from the processing of chip boards (Sun Cabinet, Mr. Somyos Yamtgasorn, Interview, Navanakorn the 30-1-01).

[20] ('spånplade og træ-laminat')
[21] This is quite low when looking at the data for waste generation in wood industries, as outlined in Chapter 3.

Re-use of resources:

Sun Cabinet utilises all sawdust wastes for internal energy production, whereas the remaining wood wastes are given to a company outside the Industrial Zone, which makes small wooden frames (Sun Cabinet, Mr. Somyos Yamtgasorn, Interview, Navanakorn the 30-1-01). Thus, except from sawdust, the wood waste has no commercial value for the industry.

Figure 4R: The 130 ºC fossil fuel steam boiler at Sun Cabinet

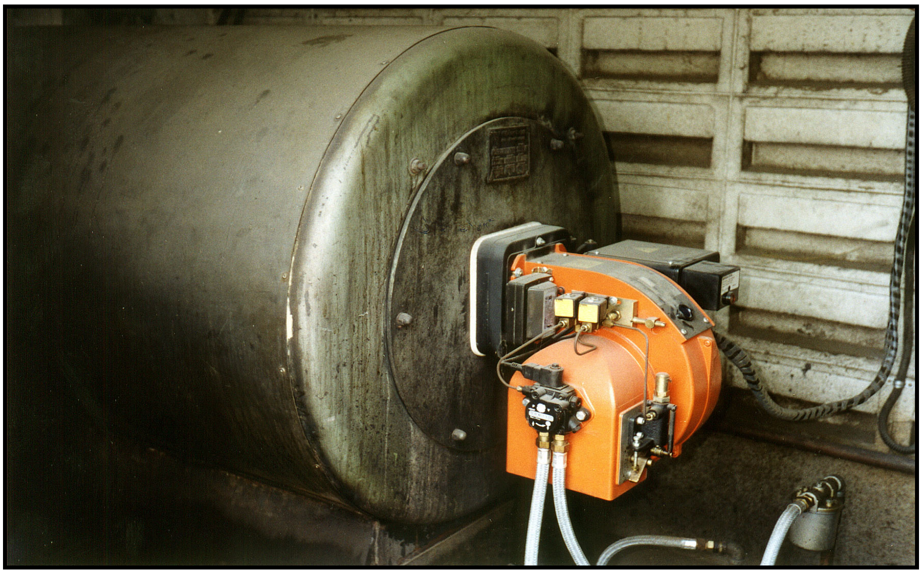


Figure 4S: The glue-hardener at Sun Cabinet using steam at 120 ºC

Energy:
An implemented boiler (a 100 ºC hot water Stoker boiler) burns sawdust wastes from the industry, but as the internal energy demand exceeds this energy production, Sun Cabinet has also implemented a second boiler with a process temperature of 130 ºC. This boiler is fuelled by oil of which the industry uses 24,000 litre/year. Process heat is primarily used to provide activities such as pressure and to hardening glue in the production process (Sun Cabinet, Mr. Somyos Yamtgasorn, Interview, Navanakorn the 30-1-01).

According to Mr. Somyos Yamtgasorn process heat requirements never exceed a temperature of more than 120 ºC. Heat temperatures are normally between 95 to 120 ºC, which is just below the temperatures of the boiler. He estimates, that 50 % of process heat usage is undertaken at temperatures just below 100 ºC and another 50 % of temperatures above 100 ºC. Approximately half of the energy demand is provided by the Stoker boiler, and the remaining share by the fossil fuel boiler (Sun Cabinet, Mr. Somyos Yamtgasorn, Interview, Navanakorn the 30-1-01). Electricity consumption amounts to 2 million kWh/year, and is mainly used for mechanical activities, compressed air etc. (Ibid.).
The industry operates in one shift per day six days a week, thus approximately 2,400 hours per year (Letter from Ms. Supranee Sripawadkul, dated the 21-12-01).

Efficiency of machinery:
The industry estimates that approximately half of installed machinery is efficient technology, and the remaining part old and inefficient. Sun Cabinet has, however, no plans of implementing new technology in the nearby future.

4.5.3.2 Rockwood

Ownership, employees and markets;
Rockwood was established in Navanakorn Industrial Promotion Zone in 1983, and is a Thai owned industry. Currently, there are 180 employees and all products are sold to the domestic market. But as from next year, the industry plans to start an export of 15 % of the products to Singapore and the Middle East. Rockwood produces 10 different types of laminated chip board products for offices and private homes. The industry can increase the production output by 30 % if the demand from customers appears (Rockwood, Mr. Paotep Chotinuchit, Interview, Navanakorn the 26-1-01). Currently, the industry plan to achieve this gold within the next three year (Mr. Paotep Chotinuchit, Letter dated the 4-1-02).

Raw materials input and waste:
Rockwood utilise 1,500 tons of chip boards per year, which generate a production output of 1,250 tons/year. 15 to 20 % of materials input ends up as waste (Rockwood, Mr. Paotep Chotinuchit, Interview, Navanakorn the 26-1-01) (between 225 and 300 tons/year - here set to an average of 262.50 tons/year). Mr. Paotep Chotinuchit estimates that the industry generates sawdust amounting to 12 tons/month (approximately 144 tons/year) (Letter from Mr. Paotep Chotinuchit dated the 1-6-01). The remaining waste is small pieces of wood (Rockwood, Mr. Paotep Chotinuchit, Interview, Navanakorn the 26-1-01), which accounts for 118.50 tons/ year.

Figure 4T: Cut-offs at Rockwood

Figure 4U: Sawdust storage tank at Rockwood

Re-use of resources:
None of the generated wood waste is re-used within the industry. Rockwood gives away the sawdust, but for small pieces of wood they charge between Baht 65 and 75/tons (Letter from Mr. Paotep Chotinuchit dated the 29-5-01). The company, who buys the wood wastes, uses it for thermal energy production (Rockwood, Mr. Paotep Chotinuchit, Interview, Navanakorn the 26-1-01). Thus, sawdust has no commercial value for the industry, whereas wood wastes can provide the industry with (118.50*70) Baht 8,000 per year.

Energy:
Energy services are solely provided by electricity at Rockwood, thus utilised for generating air compression, heat and to operate motors and provide lightening. Electricity use amounts to approximately 1.20 million kWh/year. Heat generation by electricity uses provides process heat at temperatures between 60 and 200 ºC. Gluing activities for adding laminate takes place at temperatures of 60 ºC, and hardening of lacquer is done in an oven operating at 200 ºC (Rockwood, Mr. Paotep Chotinuchit, Interview, Navanakorn the 26-1-01). Approximately 50 % of generated process heat by the use of electricity is used at temperatures of 200 ºC, and the remaining 50 % at temperatures of 60 ºC (Mr. Paotep Chotinuchit, Letter dated the 22-10-01).
The industry works one shift a day six days a week, thus operating approximately 2,400 hours per year (Mr. Paotep Chotinuchit, Letter dated the 4-1-02).

Figure 4V: Thai worker at Rockwood operating an old moulding machine

Efficiency of machinery:
According to Mr. Paotep Chotinuchit the technology used at Rockwood is very efficient. Nearly all equipment is imported from Italy or Germany, nevertheless, the industry is replacing not so efficient equipment with new technology. In general they replace 1 to 2 machines every year, thus this year Rockwood has implemented a new CNC computer based

moulding machine[22] for processing wood (Rockwood, Mr. Paotep Chotinuchit, Interview, Navanakorn the 26-1-01).

4.5.3.3 Interfurn

Ownership, employees and markets:
Interfurn was established in 1981 and is a 100 % (Chinese-) Thai owned industry, which produces covers for sofa-sets, and to a minor extent also the wooden frame. There are at present 600 employees at Interfurn. Covers are mainly made of leather, but the company also uses artificial fabrics like nylon etc. Furniture and covers are sold to the US and European markets, mainly England, Germany and Sweden. Interfurn would like to increase their market shares, but as for the textile industries, this line of business is dependent on the price of labour. If the production cannot survive in Thailand, they will set up a production in China as well (Interfurn, Mr. John Barrow, Interview, Navanakorn the 1-2-01).

Raw materials input and waste:
Interfurn uses around 700,000 square food fabric per year, which is equal to approximately 65,032 kg/year (65 tons/year). Of wood materials, the industry uses 162.72 m^3 timber, 37.16 m^3 plywood and 273.57 m^3 MDF plates per year (Letter from Mr. John Barrow dated the 7-6-01), which is equal to approximately 90, 20.50 and 150.50 tons/year respectively (261 tons/year in total). According to Mr. John Barrow wood waste amounts to 20 % of raw materials input (52.20 tons/year).
All wood waste is discharged with the ordinary waste and collected by the Main Office of Navanakorn. At Interfurn they assume that the wood waste is dumped after collection (Interfurn, Mr. John Barrow, Interview, Navanakorn the 1-2-01). Thus, discharges of wood wastes are an economic cost for Interfurn.

Re-use of resources:
Larger pieces of wood are utilised as construction support for the production of the wooden frames. Leather wastes are utilised by a company making key rings etc. (Interfurn, Mr. John Barrow, Interview, Navanakorn the 1-2-01).

Energy:
Interfurn uses electricity in their production processes to supply energy for sewing and polishing machines, and for providing air-conditioning and compressed air activities. According to Mr. John Barrow, Interfurn uses electricity amounting to 447,770 kWh/year. At Interfurn there is no heat utilisation (Interfurn, Mr. John Barrow, Interview, Navanakorn the 1-2-01).
The industry operates in two shifts (approximately 5,000 hours per year).

Efficiency of machinery:
Implemented technologies - primarily sewing machines - are all new equipment from Japan. The sewing machines are not high-technology computer based equipment, but more labour intensive machinery. The lifetime of sewing machines is very short, which is why new equipment is implemented constantly (Interfurn, Mr. John Barrow, Interview, Navanakorn the 1-2-01).

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[22] ('fræsemaskine')

Figure 4X: Factory building's of Interfurn

4.5.3.4 Light House Industries

Ownership, employees and markets:
Light House Industries was established in Navanakorn Industrial Promotion Zone in 1986 and produce luggage's for the US market. It is a Taiwanese industry, which currently has 1,220 employees. The industry would like to increase the production output, which primarily depends on the market conditions and the competition from Chinese produced luggage's. If China succeeds in taking a leading market share due to cheap labour, Light House Industries will open a factory in China as well (Light House Industries, Mr. Allen Shih, Interview, Bangkok the 31-1-01).

Raw materials input and waste:
Light House Industries produce luggage's in different fabrics and sizes. Of raw materials input PVC, nylon, PVC sheet, plywood as button material and metal zips are used. These materials accounts for 5,040 tons/year, of which 4,788 tons/year end up as final products. According to Light House Industries the company generates waste amounting to approximately 252 tons/year, which is divided as follows: Plywood 100 tons/year; Fabric wastes 26 tons/year; Metal wastes 126 tons/year (Light House Industries, Mr. Allen Shih, Interview, Bangkok the 31-1-01).

Re-use of resources:
Plywood wastes are re-cycled and used by another company, just as metal wastes which are sold to a company for re-melting (Light House Industries, Mr. Allen Shih, Interview, Bangkok the 31-1-01). Plywood wastes are given away for free (Letter from Mr. Allen Shih dated the 1-6-01), so the biomass wastes have no commercial value for the industry.

Energy:
There is no internal energy production at Light House Industries. Energy uses are solely based on electricity, which provides the energy for sewing machines, air-pressure for drying glue and for operating air-conditioning. According to Mr. Allen Shih, Light House Industries uses electricity amounting to approximately 1.13 million kWh/year (Light House Industries, Mr. Allen Shih, Interview, Bangkok the 31-1-01).
The industry operates in two shifts (approximately 5,000 hours per year).

Efficiency of machinery:
Sewing machines do not have a long lifetime, which is why new machines are constantly being introduced at Light House Industries.

4.5.4 Resource estimation (waste generation)

4.5.4.1 Pharmaceutical industries - Liquid waste

Imperial Industrial Chemical: Waste amounts to 600 tons/year and consist of a liquid substance, based on vegetable products, appropriate as fuel oil (bio-fuel).

NMT Limited: This industry has been found *not* to be appropriate as Industrial Materials Network participant, due to inadequate waste (therefore not presented in the previous and included in Figure 4Y below).

4.5.4.2 Food industries - Solid waste

ASAN Service: Waste amounts to 240 tons/year, and consists of fermentation sludge.

B.B. Snacks: Waste consists of production wastes amounting to 30 to 40 tons/year (35 tons/year).

Baskin Robbins: Waste consists of production sludge and amounts to between 6 and 12 tons/year (9 tons/year).

4.5.4.3 Wood industries - Solid waste

Sun Cabinet: Between 5.30 and 10.60 tons of sawdust is generated annually, and of smaller wood wastes between 519.40 and 524.70 tons/year (530 tons/year).

Rockwood: 144 tons/year of sawdust is generated, and of smaller wood wastes 118.50 tons/year (262.50 tons/year).

Interfurn: Mixed wood wastes amounts to 52.20 tons/year.

4.5.4.4 Supporting Industries - Solid waste

Light House Industries: Plywood wastes from bottom luggage’s materials amounts to 100 tons/year.

Figure 4Y: ***Summary* of the energy uses and raw materials consumption etc. in case industries (Industrial Metabolism)**

	Imperial	ASAN S.	B.B. Snacks	Baskin	Sun Cab.	Rockwd.	Interfurn	Light H.
Raw materials input (tons/y)	6,000	600	1,000	434	5,300	1,500	261	5,040
Solid biomass waste (tons/y)		280	=[23]35	=9	=530	=262.50	52.20	100
Liquid biomass waste (tons/y)	600							
Internal re-use of resources	Re-cycle water				Biomass fuel; Sawdust;			
External re-use of resources	Biomass fuel; Animal feed; Re-cycle nickel;	Animal feed	Animal feed	Animal feed	Biomass fuel	Biomass fuel		Re-cycle metal; Re-cycle plywood;
Use of fossil fuels per year	1,650 tons oil	36,000 l. oil	100 tons oil + 36 tons LPG	330 tons oil	24,000 l. oil			
Electricity uses - (mill. kWh/y)	1.44	0.216	0.34	1.56	2.00	1.20	0.45	1.13
Process heat temp. (°C) -Highest -Lowest	250 <100	<100 75	180 140	90 60	120 95	200 60	-	-

Own figure based on data in this chapter (see text)

4.5.4.5 Comments on industrial pre-selection

Light House Industry, NMT Limited and Interfurn prove the adequacy of combining the theoretical pre-selection of industries with actual interview and site visits. Light House Industry was selected as a Supporting Industry, which could receive surplus electricity if any. Interviews, however, showed that this industry generated biomass waste appropriate for energy production. NMT Limited was selected as a potential Industrial Materials Networks participant, but was found inappropriate due to inadequate waste (not organic materials). This industry can, on the contrary, act as Supporting Industry receiving surplus heat if any, as all heat uses happens at temperatures below 100 ºC (NMT Limited, Mr. Wattanin Kaewketthong, Interview, Navanakorn the 19-1-01).

At Interfurn, there was surprisingly no uses of process heat in production processes, which is rare in industries producing furniture. This is, however, caused by the fact that Interfurn uses already processed wood, and that the activities primarily are stuffing of and gluing fabric in the production of cushion and sofa sets. Interfurn can, however, supply wood wastes for the production of energy. Imperial and B.B. Snacks have both proved to be differently compared

[23] Approximate figures

to what could be expected by the theoretical pre-selection. Both industries use large amounts of steam and only small amounts of water based heat (in B.B. Snacks no use of water based heat happens at all). Further analysis will show whether conversion to water based heat is possible, at least for some of the energy uses, in these industries.

4.5.5 The supply and value of biomass waste

4.5.5.1 Constant supply of waste

No case industries are “seasonal industries” depending on, for instance, harvesting periods. The production outputs are thus constant during the year, and the only variation depends on market conditions. Except from ASAN Service and Imperial all industries plan to increase the production output, within the coming years. This will lead to increasing uses of raw materials input, and thus biomass wastes from the production. As the processing of raw materials increases, so does the energy requirement.
A constant supply of biomass is important when planning to implement an energy system, as industries require energy services on a constant and everyday basis. If great variations happen in the biomass supply from some industries, it can be difficult to cover a steady energy demand in the remaining industries.

4.5.5.2 The value of internal/external re-use of biomass waste

The economic value of biomass waste varies greatly in case industries, as seen by the company descriptions. Especially in wood industries there is a tendency for inefficient - if any - use of biomass wastes. At Sun Cabinet sawdust are used in a hot water boiler for internal process heat generation, whereas the remaining wood wastes has no commercial value. At Rockwood, on the contrarily, sawdust has no commercial value as it is given away for free, whereas sales of wood waste has a limited commercial value for the industry. At Rockwood there is no use of wood waste for internal energy production, as heat generation happens by electricity use.

At Interfurn wood wastes even have a negative impact on the industry’s economy, as Interfurn pays the Main Office to collect the wood wastes. Interfurn has no demand for process heat, where a possible internal re-use could materialise, and there has not been established any sales/give away of wastes, or by other means re-uses of the biomass. At Light House Industries no internal heat demand occur and the biomass waste no commercial value, as it is given away for free.

In food producing industries, most of the biomass wastes have limited commercial value. At ASAN Service, wastes are even sometimes discharges and thus collected by the Main Office. When sold the price is not very favourable. At Baskin Robbins, wastes are given away for free, thus having no commercial value for the industry. At B.B. Snacks, sales of wastes has a certain commercial value, as the industry receive Baht 70,000 per year.
At Imperial Industrial Chemicals, the commercial value of wastes amounts to between Baht 600,000 and 1,800,000 per year (DKK 120,000 to 360,000). According to the empirical data, Imperial would like to increase the commercial value of wastes by internal re-uses as bio-fuel, but lack the technological knowledge in doing so. Compared to the price of 1 litre oil, which is Baht 9 (2001-data), sale prices of Baht 1 to 3 are not favourable. Biomass wastes will most

likely account for a higher commercial value, when re-used within the Industrial Zone for energy production.

What can also be seen from the empirical data is that all re-uses of wastes happens outside the Industrial Zone, and that there is no co-ordination of the re-uses. Sun Cabinet has implemented a fossil fuel boiler as supplement to the biomass boiler, for coverage of internal energy needs. At the same time biomass wastes are discharged by other industries in the Zone, or transported over long distanced for external re-use. Similarly with Rockwood, which produces process heat by electricity uses, instead of using a biomass boiler for coverage of at least *some* of the internal energy demand. One consequence of all the wastes being re-used outside the Industrial Zone - seen in a Provincial context - is the long transportation distances. Wastes used as animal feed also means long transportation distances, as the livestock in Pathum Thani Province is very limited (Document obtained from Pathum Thani Provincial Office, Tambong Bang Plong, Ampur Muang, Pathum Thani, Pathum Thani the 22-2-01).

All this means that biomass wastes are transported to other municipalities or provinces in the region, which have environmental impacts on the local community (noise, dust and pollution), as well as on the emissions of CO_2, which must be seen in a global context. The re-use of biomass as fuel for energy production outside the Industrial Zone can also be questioned. Again, transportation distances are important in order to minimise other environmental impacts. As Navanakorn Industrial Promotion Zone is the only industrial area in Takhlong Municipality, it is evident that wastes must be transported to another municipality in Pathum Thani Province - or maybe even further - for external re-uses.
It is, however, more convenient and environmentally friendly if this wastes could be re-used for energy production within the Industrial Zone by in-site industries instead, in order to avoid long transportation distances, to areas with animal livestock's or industrial sites. If possible generated wastes (ash, digested sludge etc.) from the production of energy in Navanakorn, can be more appropriately utilised as a fertiliser for the growing of vegetables and fruits in Pathum Thani Province. By such a strategy, resources are utilised locally, and for purposes, which are actually needed in the community.

Both economic and environmental conditions related to biomass re-uses show that internal re-use strategies within the Industrial Zone - and possibly in an Industrial Materials Network - can be beneficial. The commercial value of present biomass re-uses are in general low, which means that industries could benefit more if internal re-use strategies are established, facing out uses of fossil fuels.

4.6 Perspectives for energy system development

In this section I will shortly name some possible strategies for re-use of wastes in an energy system, which will be the focus of the following chapters.

One strategy is to build a large co-generating Biogas Plant in connection to the WWTP, and thus digest sludge from the WWTP, sorted organic household waste from the community, as well as collected industrial/commercial waste and wastes from case industries. Wood wastes - which are not appropriate for digesting - can be utilised in a boiler for heat generation only. The implementation of more than one co-generation system is expensive, and the amounts of wood wastes not sufficient for this. *Another strategy* is to implement a co-generating combustion plant thus dry the sludge, and hence incinerate it together with collected industrial/commercial waste, sorted household wastes from the community and wastes from case industries.

From both of the above energy facilities, it is possible to pipe surplus heat to industries participating in the Industrial materials Network, thus establishing a Small Scale District Heating Network, thereby substituting fossil fuel boilers placed at the individual industries. At the same time, electricity can be transmitted on the grid to industries.
Which possibly scenario, or initial energy system, to pursue, depends on opportunities for utilising wastes efficient for energy production, thus for instance the energy potentials of wastes (calorific value). Also questions like whether certain types of waste are more appropriate for digestion than incineration are interesting. And whether it is possible to transform or treat wastes, so they can be utilised by means of more than one conversion method. Also whether certain wastes found create environmental problems when converted must be emphasised. These questions are topics for further analysis in the chapters to come.

Chapter 5; Triangle Analysis - Resources

The purpose of the first part of this chapter is to estimate non-converted *theoretical energy potentials of biomass wastes* (calorific value) from Navanakorn Industrial Promotion Zone and surroundings. The overall purpose of such an analysis is to *evaluate which conversion method is the most optimal for the biomass waste found*. Estimations will be made for wastes that are likely to be utilised for energy production, i.e. available resources, as well as for wastes that could be utilised for energy production, if appropriate initiatives are established, i.e. potential resources (as illustrated by Figure 2G Chapter 2). Energy potentials of wastes, whether being incinerated or digested, are important to estimate for appropriate selection of conversion methods (incineration or digestion systems). Biomass wastes can be used more efficiently for energy purposes if the most appropriate means of conversion method is selected.

In the second part of this chapter, focus will be on biomass waste and its possibility for conversion by different methods, which includes an examination of the *character of biomass wastes*: the actual composition (content and structure) and on which form (liquid or solid) it is found. Thereafter, *treatment possibilities of wastes* are emphasised, which focuses on possibilities for changing the character of the waste. Such "treatment" will enable biomass wastes to be converted by means of more than one conversion method, and can, therefore, increase the flexibility - and possible future expansion - of the energy system (see further Chapter 8). Together with data for energy potentials, the result of this analysis will provide knowledge about which type of conversion method to pursue in the case area. Finally, an estimation of *possible waste contamination* will be elaborated, which enables a priority of resources to be utilised in the initial energy system.

5.1 Energy potentials of biomass waste

Figure 5A: ***Summary*** **of theoretical energy potential of wastes from Navanakorn, Takhlong Municipality and Pathum Thani Province**

Type of biomass waste	Energy potential (MWh/year)
Solid waste - Wood wastes	
-incineration	4,400
Solid waste - Fermentation and production sludge	
-digestion	200
-incineration	1,400
Liquid waste - Bio-fuel	
-digestion	4,000
-incineration	6,300
Liquid waste - Sludge from WWTP	
-digestion	11,900
-incineration	8,000
Solid waste – Household	
⇒ ***Collected amounts:***	
-digestion	5,500
-incineration	6,600
⇒ ***Generated amounts:***	
-digestion	10,900
-incineration	13,100
Industrial/commercial waste	
⇒ ***Collected amounts:***	
-digestion	850
-incineration	6,300
⇒ ***Generated amounts:***	
-digestion	1,000
-incineration	7,200

(Data source Chapter 4 and calculations in Annex B)

5.2 Evaluation of biomass waste

5.2.1 Energy potentials of waste

In terms of ***theoretical energy potentials*** only, the most energy efficient method of conversion for biomass wastes is incineration. Except from WWTP sludge, energy potentials are in general higher when incinerated than when digested. From a resource perspective - meaning to utilise resources most efficiently - the method of conversion by incineration is thus more favourable than digestion.

5.2.1.1 Strategies in developing an energy system

Analysis of energy potentials of wastes puts emphasis on the implementation of incineration technologies, as it provides efficient conversion of wastes.

5.2.2 Character of biomass waste

Even though the energy potential of biomass wastes is utilised more efficiently when incinerating, it is important to analyse, whether the waste actually *can* be converted in this manner, or whether it is inappropriate for incineration purposes. This puts emphasis on the ***character of biomass wastes***: what is the composition of the wastes (content and structure) and in which form is it found (liquid or solid)? As seen in previous sections, biomass wastes *are* of a very different composition regarding both content and structure, and consist of *both* solid and liquid fractions. This can affect the choice of conversion methods, as emphasised below.

Solid wastes are wood wastes, organic household waste, and production and fermentation sludge. These wastes are all very different in composition. *Wood wastes* consist for instance of both sawdust, larger and smaller pieces of wood, which again can consist of plywood, chip board or mixed hardwood. Thus, the structure can vary but the actual content can be characterised as uniform.

Production and fermentation sludge is, on the contrary, a more homogeneous waste both in structure and in content. It is unlikely that any changes will happen in the composition of these types of wastes, as raw materials input and production methods are stable.
This is, however, not the case for *organic household wastes*, which can be characterised as being inhomogeneous in content, as well as in structure. The contents depend on which product is being consumed by households, which of course can vary. As the content can be variable so can the structure of this type of waste. *Industrial/commercial wastes* can also vary greatly in content and structure. No empirical data exposes the composition of this waste, and it is therefore likely that certain fractions of this material can be on liquid basis, or at least contain relatively high moisture contents.

Liquid wastes consist of *bio-oil* and *WWTP sludge*. As opposed to the solid biomass found, these types of waste are very homogeneous in structure as well as in content. It is, therefore, relatively easy to predict how these wastes will reach when converted for energy purposes.

Digestion as conversion method is unable to handle solid wastes, unless, for instance, mixed with an appropriate amount of liquids, in this case sludge from the WWTP and bio-oil. Digestion of solid wastes as wood is not possible. Incineration as a conversion method is, on the other hand, rarely capable of combusting liquid wastes, unless it is pre-treated (for instance dried). If the energy potential of wastes are much higher when incinerating than when digesting, it is favourable to analyse whether it is possible to pre-treat the wastes for incineration purposes.

5.2.2.1 Strategies in developing an energy system

The conversion method applied must be capable of converting wastes of a very different content and structure and possibly withstand certain fractions containing relatively high moisture contents. Thus, preferably a multi-fuel conversion method or at least a method, capable of converting a wide range of different fuels. Both incineration and digestion as conversion methods are suitable for this, but not appropriate for conversion of *all* the wastes found when seeking implementation of one conversion method only. Thus, whether to pursue digestion, or incineration, depends on the possibilities for "treating" the wastes to be used by means of one conversion method only, and not solely on the outcome of the energy potential analysis. This will be emphasised below.

5.2.3 Other important fuel specifications

Apart from the biomass *moisture content*, *composition* (content and structure) and *energy potentials* (which also are influenced by the first), it is important to analyse the following issue for appropriate determination of fuel specification.

Ash content:
The amounts of ash in the biomass wastes, and the chemical composition of the ash, are important factors for the quality of the fuel. The composition of ash, for instance, affects its behaviour under high temperature combustion. Melted ash can, for example, lead to problems during incineration, as the development of agglomeration - due to "slagging" ash - might occur. This may require the temporary closure of the plant for the removal of agglomerated ash. When for instance incinerating, by means of the fluidised bed principal (see Chapter 7), the agglomeration of ash can make the process impossible as it is based on fluid dynamic principles of smaller fuel particles (Energy from biomass: a review of combustion and gasification technologies, Peter Quaak et. al., World Bank, 1999).

5.2.4 "Treatment" possibilities of waste

In this section "treatment" possibilities of wastes will be emphasised. In the first section of this chapter we saw, that the energy potentials of wastes were highest when pursuing incineration. On the other hand, it was also found that large amounts of wastes were in a liquid form, thus not appropriate for incineration purposes. In the following, the focus will be on possibilities for treating biomass wastes for uses by means of more than one conversion method, which are currently determined by the composition of wastes (liquid/solid).

When emphasising treatment possibilities, the costs must also be included. In the sections above, the focus has been on feasibility ‘energy-economically’ (calorific value etc.), and not on feasibility ‘economically’ (in for instance DKK). In a Danish context, biomass drying, for instance, is relatively expensive, as it requires an industrial heating process in which water is evaporated[24] (for instance utilised when drying straw or corn). In Thailand many types of waste (such as the wastes from case area industries for example) can preferably be dried on land, as the climate is warm and dry. To cope with the rainy season, a simple and inexpensive open shed can be constructed. In this way, the treatment of biomass wastes can be carried out with limited costs, and the energy plant can be supplied with fuel on a continuously basis.

5.2.4.1 Liquid wastes - can be dried

If wastes on a liquid basis are dried, it is possible to incinerate it together with solids. Sludge from Navanakorn WWTP can be dried and then incinerated. As found, the energy potential of dried incinerated sludge is approximately 4,000 MWh/year less than when digested. Dried sludge from WWTPs are an attractive fuel for incineration purposes, as it is a very homogeneous material, and it is therefore relatively easy to predict how it will reacts in a conversion situation (Stig Dalum, Spildevandscenter Avedøre I/S, Telephone-interview the 10-5-01). Even when drying biomass wastes, the moisture content can still be relatively high. This means that conversion method applied must be capable of handling such moisture content (discussed in Chapter 7).

5.2.4.2 Liquid wastes - cannot be dried

The bio-fuel generated at Imperial cannot be dried, but is appropriate both for incineration and for digestion purposes. The energy potential of bio-fuel is slightly higher when incinerated than when digested. Bio-fuel is attractive for incineration purposes, as it - just like sludge - is a homogeneous material, and thus relatively predictable in uses as fuel.

5.2.4.3 Solid waste

As shown, solid wastes are of a very different composition and consist of wood, fermentation and production wastes, organic industrial/commercial and household waste. In order to prepare the wastes for efficient conversion - here incineration - it is possible to downsize it, and make it more convenient as fuel material. This will, however, add additional costs to the energy production (not included in the Pre-Feasibility Study Chapter 8).

5.2.4.4 Solid waste - can be liquid

Only production sludge from Baskin Robbins can be applied as liquid waste also. Currently, the solid form is obtained by drying the ice-cream wastes, which initially are of a liquid form when discharged. At ASAN Service, the liquid fractions *are* the final product (soy sauce), and the solid fractions waste. At B.B. Snacks, both the wastes and final product are on a solid basis, and the water used for boiling the peas is cleaned at the WWTP. Thus, the possibilities of transforming solid wastes to liquid wastes are limited.

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[24] (’fordampet’)

5.2.4.5 Strategies in developing an energy system

From the Resource analysis elaborated above, it can be seen that the wastes to a large extent can be converted by means of both incineration and digestion. Some wastes are - according to energy potentials - more appropriate for digestion than for incineration (and opposite). In the initial phase of the implementation of the energy system, one single conversion method is, however, favourable, as more than one conversion method will increase plant expenses unnecessarily. Thus, in the initial phase, the most optimal solution is to implement one single conversion method for *all* biomass wastes, and "treat" them in accordance with the capability to be converted by this method. If biomass wastes increase later on, due to for instance growth in the industrial output, it is thus possible to expand the energy system by a new conversion method, and thus apply certain wastes in accordance with their "original" composition (liquid or solid).

By drying liquid wastes - here production sludge - it is possible to convert all wastes by means of incineration. If pursuing digestion as a conversion method, wood wastes cannot be converted. When mixing solid and liquid wastes (liquids being sludge, bio-oil and non-dried production sludge), it is, however, possible to digest the remaining biomass.
Even though the energy potential is higher when incinerated than when digested, this conversion method will not be eliminated as a possibility, as it - with few exceptions - is found to be appropriate as a conversion method for many different kinds of fuel. In the following, emphasis will thus be on possible environmental problems caused by treating and using wastes by different means of conversion.

5.2.5 Contamination of biomass waste

Wood industries:
No industries use impregnation of raw materials input, which can contain chromium, copper and tin (Erhvervsaffald og udvalgte affaldsstrømme, Miljøstyrelsen, 1997). Possible contamination of wood wastes will solely derive from gluing activities. As the majority of case industries work with laminate, chip boards and MDF plates, and to a minor extent with solid wood (for instance noble wood) as raw materials input, it is likely that the wood wastes contain fractions of glue.

Glue contents of less than 1 % are accepted in Denmark, but when exceeding this amount the wood are regarded as waste and thus treated as so in municipal waste incineration plants. Glue contamination leads to emissions of nitrogen dioxide (NO_x), which will be emitted by a factor 2 or 3 when contained in the wood. A slight increase in emissions of nitrogen dioxide - caused by the incineration of such wood - is, however, not a serious environmental problem (Anders Evald, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 5-12-01). Even though emissions of nitrogen dioxide do not represent a major global threat - as for CO_2 emissions - it *can* affect the local environment. It is therefore important to pursue the implementation of conversion technologies that can minimise this emission if possible.

Food industries:
Wastes from food processing industries rarely contain contaminated components, as raw material input and processing activities have human foods as the final product. There was no data to contradict this, when looking at the raw materials input, emphasised in Chapter 4.

All materials are natural products based on agricultural products (vegetables materials). According to Anders Evald, there is no risk that wastes from case industries in this line of business contain contaminants (Anders Evald, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 5-12-01).

Pharmaceutical industries:
In addition, pharmaceutical wastes - from the one industry in this line of business analysed - contain only natural products. Vegetable oil is extracted from the raw material and the only reactions, which take place, are in principal exchanges of long organic based chains, where some end up as bio-oil and some as methyl esters etc. There are no additives such as heavy metals or other environmentally unfriendly substances. Thus, this biomass waste is appropriate for energy purposes (Anders Evald, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 5-12-01).

Sludge from WWTP:
Sludge from Navanakorn WWTP can be a problematic waste in regards to energy production, due to its possible content of heavy metals and organic compounds. As this waste is from industry and households, such contamination is very likely.

When the wastewater is treated at WWTPs, it results in removal and demolition[25] of certain substances, while others are concentrated further and some even created. On average 93 % of the organic compounds, 64 % of the nitrogen and 76 % of the phosphor, which are substances contained in the wastewater, is eliminated when the wastewater has passed the WWTP. Sludge from WWTPs thus contains substances that are usable as, for instance, fertilizer: organic compounds, nitrogen and phosphor. Unfortunately, it also contains compounds such as bacteria, germs, heavy metals and organic environmentally unfriendly compounds, which can have serious effects on humans and animals (Erhvervsaffald og udvalgte affaldsstrømme, Miljøstyrelsen, 1997).

Heavy metal contamination can, for instance, be cadmium, mercury, lead, chrome, copper and zinc. Organic compounds are, for example, LAS (linear alkylene-benzene sulphonates), PAH (polycyclic aromatic hydro-carbonates) and DEHP (bis(2-ethylhexyl) phthalat), which are suspected of having oestrogen like effects on humans and animals (Erhvervsaffald og udvalgte affaldsstrømme, Miljøstyrelsen, 1997).

Industrial/commercial organic wastes:
Industrial/commercial organic wastes can be wastes of a very different composition, but here it is assumed to be of a, primarily, solid basis (or contain a high level of dry matter), only with certain fractions being liquids. It can, for instance, be wood wastes and solids from different food or medical industries. In general, industrial/commercial wastes are relatively easy to control and separate into different fractions for appropriate use, as opposed to, for example, household wastes (se below) (Anders Evald, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 5-12-01). Thus, industrial/commercial wastes are in principle a relatively easy resource to map for possible contaminants regarding further uses. As mentioned, there are no empirical data on the specific composition of industrial/commercial wastes in Navanakorn, except from figures for the amounts, which are obtained from the manager of Navanakorn Industrial Promotion Zone Mr. Dhani. It is, however, possible to influence industries regarding the

[25] ('nedbrydning')

composition of wastes and a more optimal sorting of this for appropriate re-use (Anders Evald, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 5-12-01).

Household wastes:
Organic source separated household waste contains, in principle, no contamination. In reality, it is very difficult to separate with 100 % reliability the source of organic fractions. Possible contamination can thus be heavy metals from for instance discharge of batteries and plastic from wrap-ups etc., which can lead to contamination with, for instance, dioxin. The separation of organic compounds is much more problematic for household waste than, for example, industrial/commercial wastes, where the behaviour of stakeholders is easier to influence (Anders Evald, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 5-12-01).

5.2.6 Incineration contra digestion?

In evaluating possible biomass wastes to be converted either, by incineration or by digestion, it is also important to analyse the point source of possible contamination. Where do the contaminants go? When for example incinerating certain wastes, do contaminants end up in the incineration ash (button ash), in the fly ash, or as uncontrollable volatiles? If contaminants, for instance, end up in the incineration ash, it is possible to use the biomass waste for incineration purposes as the ash can be collected and deposited. In this way, the biomass resources can be utilised for energy purposes.

Sludge from WWTP:
Sludge from WWTPs, as seen above, normally contains heavy metal contaminations as cadmium (Cd), mercury (Hg), lead (Pb), chromium (Cr), copper (Cu) and zinc (Zn). Organic compounds are, for example, LAS (linear alkylbenzensulfonater), PAH (polycycliske aromatiske hydrocarbonater) and DEHP (bis(2-ethylhexyl) phthalat) (Erhvervsaffald og udvalgte affaldsstrømme, Miljøstyrelsen, 1997). Apart from these possible substances sludge also consists of a great amount of ash, and as much as 50 % can be ash contents (Jesper Cramer, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 17-12-01).

Household wastes:
Sorted organic household waste can contain substances like plastic, which can contain PVC and metal wastes, the latter from possible surface-treated with cadmium in order to prevent the development of rust. Organic bound chorine from, for instance, PVC wastes can develop dioxin emissions, which is a highly toxic substance. Dioxin is not a part of PVC but develops in the flue gas during combustion, if contents of, for instance, chlorine, dust and catalyst's as, for example, copper, are present. Dioxin is developed during the combustion process at a temperature level between 250 and 450 ºC. Therefore, it is important that the combustion process is very well controlled (Jesper Cramer, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 17-12-01).

5.2.6.1 Heavy metals and organic compounds - incineration

Incineration technologies' potential emissions of ***organic compounds*** - like the ones mentioned above - will be eliminated if high temperatures can be obtained in the furnace. By obtaining a temperature of 850 ºC - for at least two seconds - organic compounds will be eliminated (Jesper Cramer, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 17-12-01).

Analyses conducted as both literature study and experimental works, puts emphasis on point sources for waste contaminated with ***heavy metals*** when incinerated. From the results of this analysis it can be seen that:

- Fe, Cu, Cr, Ni and Mn almost only end up in the incineration ash (bottom ash);
- Zn and Pb primarily end up in the incineration ash;
- As and F in almost equal amounts end up in the incineration ash and un-cleaned flue gas;
- Cd and S primarily end up in the un-cleaned flue gas;
- Hg og Cl almost only end up in the flue gas;
- Data for Si, Al, Ca and Na are of a less reliable quality, but assumed to end up in the incineration ash; (Tungmetallers adfærd ved affaldsforbrænding, Peter Bliksbjerg and Søren Dalager, Dk-Teknik Energi og Miljø, 1994).

In electro-filter or filter bag removal equipment's the majority of Fe, Cu, Cr, Ni, Mn, Zn, Pb, Cd and As (possible also Si, Al, Ca, Na), which reaches the filter along with the flue gas, will be collected. It is thus possible to collect these specific contents of heavy metals by filter installations, as they solely separates as incineration ash and flue gas respectively. This means that S, F, Hg and Cl are present contaminants *after* such filter treatment. They can, however, be removed by two-step washing of the flue gas. If treated this way, F and Hg end up in the waste product, while Cl stays in the treatment water. S partly ends up in the waste and partly remains in the treatment water (Tungmetallers adfærd ved affaldsforbrænding, Peter Bliksbjerg and Søren Dalager, Dk-Teknik Energi og Miljø, 1994). Such two-step treatment is commonly applied on waste incineration plants, but not on biomass applications.

When applying a dry (or semi-dry) cleaning by lime uses, contaminants, which primarily or solely end up in the un-cleaned flue gas, will be found in the cleaning product (Tungmetallers adfærd ved affaldsforbrænding, Peter Bliksbjerg and Søren Dalager, Dk-Teknik Energi og Miljø, 1994). This means that Cd, S, As and F end up in the cleaning product when applying this method. It is, however, difficult to eliminate emissions of Hg effectively this way, as Hg is very volatile. Thus, when applying biomass cleaning equipment - an electro filter or a filter bag - emissions of Cd, S, As, F and Hg will appear. Except from Hg these emissions can be reduced by implementation of dry cleaning by lime uses. Also Cl - which was not collected by the electronic filter or filter bag - can be removed by lime uses, as being an acid.

Thus, when applying traditional biomass CHP cleaning equipment, emissions of Hg and dioxin will appear. As SO_2 are an acid gas, lime uses can also reduce the amounts of emissions from this substance. A temperature of 850 ºC, obtained in the furnace for at period of at least two seconds, will eliminate PAH etc. Emissions of dioxin and Hg can be eliminated by uses of a carbon filter, which is a cost full technology and not implemented on biomass fired co-generation plants in Denmark (Jesper Cramer, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 17-12-01).

5.2.6.2 Heavy metals and organic compounds - digestion

According to an analysis made at DTU in Denmark, Biogas Plants can have an effect on the demolition of *organic compounds* in household waste and sludge from WWTPs. Four important organic compounds - which normally are contained in such wastes - were examined: LAS, PAH, NPE and DEHP. It was found, with a relatively constant supply of these compounds, that an effective reduction of these compounds could be obtained. After a 30 day residence period in the digestion chamber, the following results were observed: a 80 % reduction in PAH, 82 % reduction in LAS, a 94 % reduction in NPE and a 78 % reduction in DEHP (Biogasanlæg nedbryder de miljøfremmede stoffer, Birgitte K. Ahring, Rena Angelidaki and A.S. Mortensen, Article in Dansk BioEnergi, number 44, April, 1999). These analyses show that Biogas Plants can have an effect on organic compounds under certain conditions regarding the operation of the plant.

If Biogas Plants treat sludge from WWTPs, intended to be used as fertiliser afterwards, it must be hygienic-sized[26] to prevent spreading of for instance pathogenic organisms. For sorted household waste (Category C) and sludge from municipal WWTPs (Category D), it will require a residence time and temperature level in the digestion chamber, as follows: 70 ºC in 1 hour or 55 ºC in 10 hours (or combinations alike), of which the latter for instance can be obtained in a Biogas Plant operated at a mesophilic temperature level[27] (Smittebeskyttelse i biogasfællesanlæg, H.J. Bendixen og S. Ammendrup, Veterinærdirektoratet, 1991).

Regarding *heavy metals* there are no advantages in implementing Biogas Plants, as no type of demolition takes place. Thus, heavy metals still remain in the organic wastes after a digestion has taken place. Uses of digested organic wastes as fertiliser can thus be problematic, which has been the case in Denmark where many farmers reject distributing digested organic wastes from Biogas Plants digesting, for instance, sludge from WWTPs. In 1997 only 66 % of the generated sludge from WWTPs in Denmark could live up to environmental standards regarding contents of heavy metals in sludge for agricultural uses (Teknologisk Innovative - og Markedsunderstøttende Strategier for fremme af Gårdbiogasanlæg, Rikke Lybæk & Poul Møller, Master's thesis, TekSam, RUC, 1999).

5.3 Strategies in developing an energy system

When looking at possible sources for contamination of biomass wastes to be converted in a renewable energy system, sludge from the WWTP and sorted household wastes are the most difficult and exposed resources. As for creating a renewable energy system, it is not the intention here to develop *new* environmental problems. Especially when incinerating, sludge and household wastes are difficult resources to use for energy purposes, as they lead to unwanted emissions. These resources could, however, be used for digestion and the waste products dumped - as it happens now - *after* the gas has been extracted. It this way the resources can be utilised for energy purposes before being dumped.
Thus, which initial energy system to pursue - 1/digestion of household waste, sludge and liquid industrial wastes or 2/incineration of dried liquid industrial wastes and solid industrial wastes - depends on the capabilities of conversion technologies in covering energy demands in case industries. This will be the focus of Chapter 6.

[26] ('hygiejnisering')
[27] From 50 ^{0}C to 60 ^{0}C.

Chapter 6; Triangle Analysis - Energy Demands (industrial End-uses)

The purpose of the first part of this chapter is to analyse the character of energy demands in case industries for an appropriate design of the energy system. Energy characteristics will be analysed regarding the *quantity* and *quality* of energy uses. In quantity analyses it will be emphasised how much energy case industries actually require in MWh/year. In quality analysis, the focus will be on which type of energy requirement we find in industries, whether the demands are *steam* or *water based heat*, and if both, the specific quantity of each demand.

If End-use demands, for instance, are characterised by large steam requirements, it will influence the choice of conversion technology. If steam requirements, for instance, are non-existent or low, it is possible to cover End-use demands by the implementation of a technology producing low quality heat. This is possible as steam can be extracted from certain technologies by different levels. If, on the contrary, steam requirements are high and primarily based on energy uses by one single industry, it is possible to implement a steam technology for the cascading of energy to other industries. Thus, the specific character of steam contra process heat End-uses must be analysed further. As we saw in Chapter 4, End-use demands in case industries *are* characterised by steam demands. It is thus important to emphasise the actual amount of steam contra water based heat needed, for the selection of the most appropriate conversion technology.

The last section of this chapter will discuss possibilities for conversion and optimisation of energy uses in case industries, with the purpose of introducing energy savings. Energy efficiency can be obtained not only by using the energy more efficiently but also by reducing the ‘calorific value’ of energy services. Much can be gained if industries can cover their energy demand by process heat based on water based heat substituting steam, and even more, by water based heat substitution process heat produced by electricity. Economic and environmental impacts of the present energy uses within case industries, as well as other background data to this chapter, can be found in Annex C.

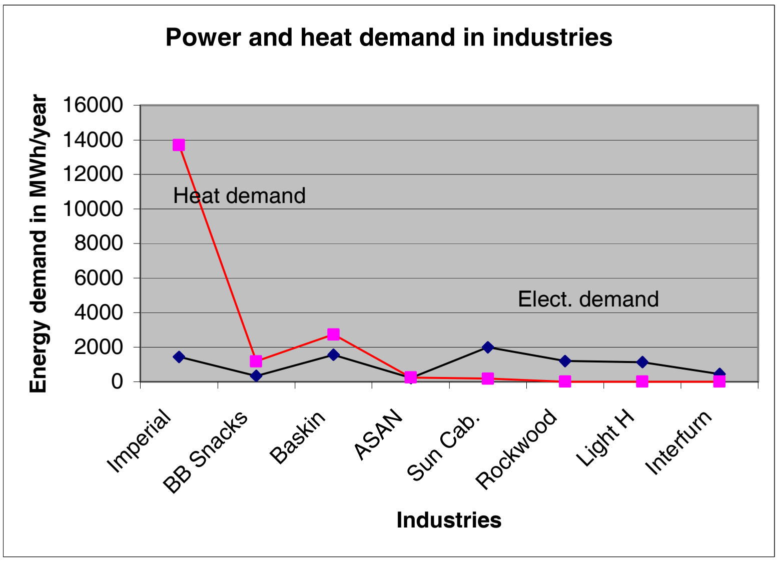
6.1 Energy consumption patterns in case industries

As mentioned in the introduction, this section will focus on the character of energy uses within the case industries. Thus, more specific analysis related to the *quantity* and *quality* of End-use demands will be emphasised in the following. As outlined in Annex C, electricity and heat uses in case industries are calculated to be 8,300 MWh/year and 18,100 MWh/year respectively, of which the latter is separated as follows within the industries:

6.1.1 Heat uses

Figure 6A below, shows the total energy consumption patterns in case industries, illustrating the total electricity and heat use in MWh/year for each industry. As the figure shows, quantities of electricity uses in each industry do not exceed 2,000 MWh/year. This is also the case regarding the quantities of heat uses. Except from Baskin Robbins - which exceeds the use of 2,000 MWh/year slightly - one industry differs dramatically from the others in End-use demands, namely Imperial, with a total heat demand of 13,700 MWh/year. Thus, Imperial make up for more than 75 % of total heat uses in case industries.

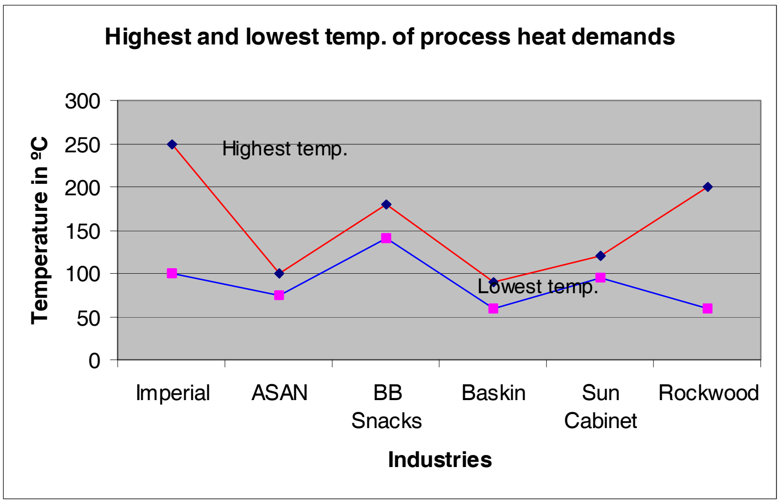
Figure 6A: Energy consumption patterns in case industries



(Data source Chapter 4 and calculations in Annex C)

Figure 6B illustrates the temperature (ºC) of heat uses in case industries by highest and lowest temperature needed, thus the quality of process heat uses. As seen, the largest variation between lowest and highest temperatures of heat requirement is found at Imperial and Rockwood, with variations of 250 % and 333 % respectively. Thus, the differences between lowest and highest temperatures in these industries are a factor 2.5 to 3.33. In the remaining industries lowest and highest temperatures only vary between 25 and 50 % maximum.

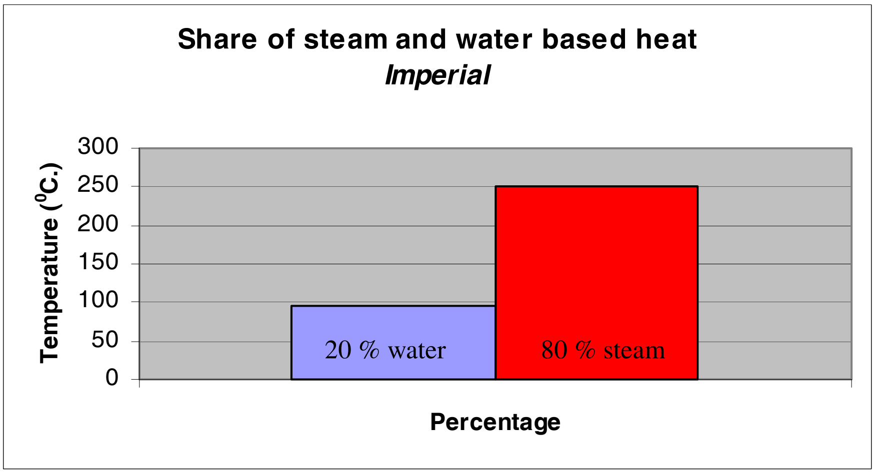
Figure 6B: Heat temperature requirements in case industries

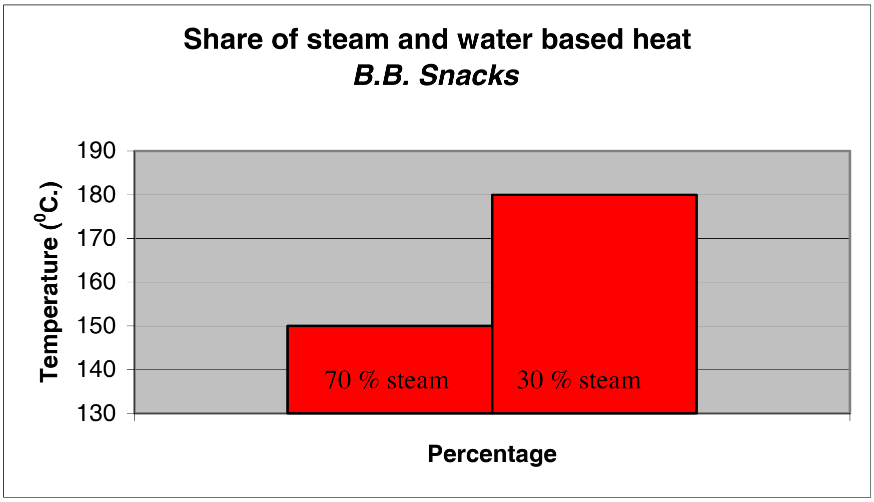


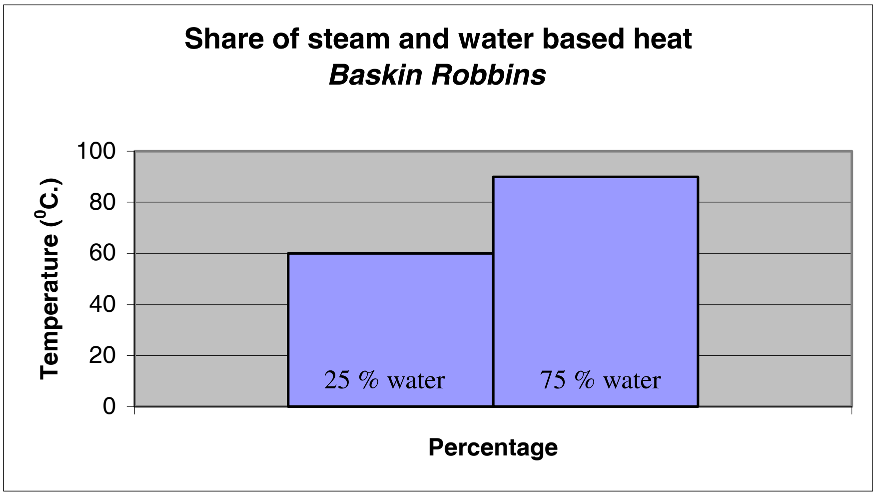
(Data source Chapter 4)

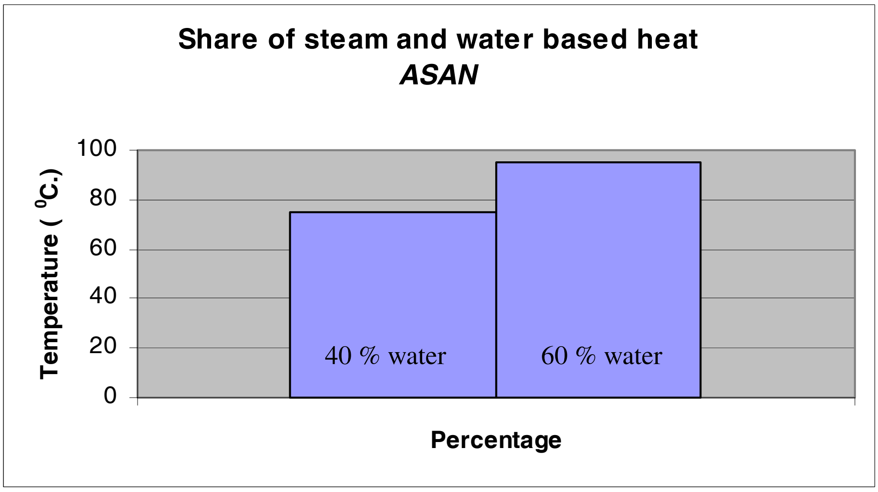
At Imperial and B.B. Snacks, peak heat demands are covered by steam and at Rockwood by electricity uses only. As seen, only ASAN Service and Baskin Robbins can cover their lowest and highest heat demands by water based heat, hence district heating temperatures of around 95 ºC. Except from B.B. Snacks, all industries can cover their lowest heat demand by district heating temperatures. Especially for industries using both steam and water based heat, it is interesting to analyse how much energy (in MWh/year) is utilised as steam and how much as water based heat, as this can influence the choice of technology. It is also interesting to point to areas where technical changes might convert steam uses to water based heat uses instead. The following figures for each industry illustrate, at which temperatures and percentage of total heat uses, the process heat demands are covered in case industries. Note that the figures are "static" illustrations, and as such do not illustrate natural temperature variations in heat uses. They are based on the knowledge available of process heat uses given by the Thai interviewees, referred to in Chapter 4.

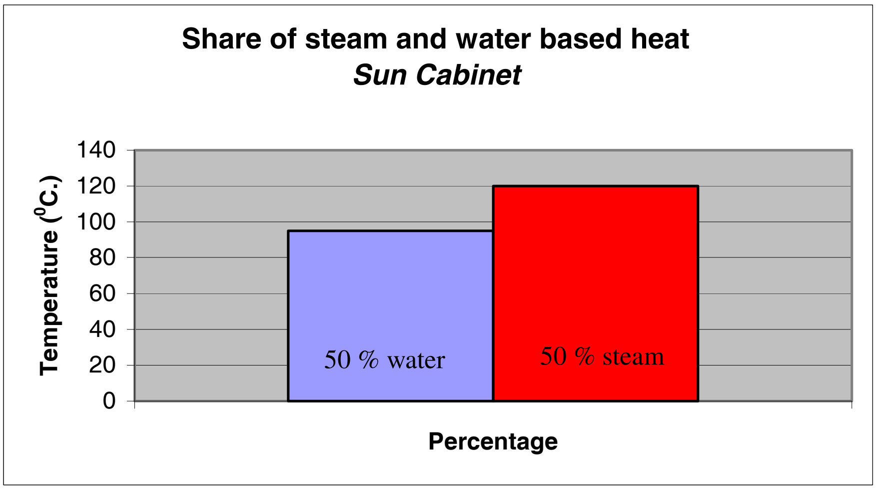
Figure 6C: Process heat uses in case industries now covered by fossil fuels (Red = steam & blue = water based heat)





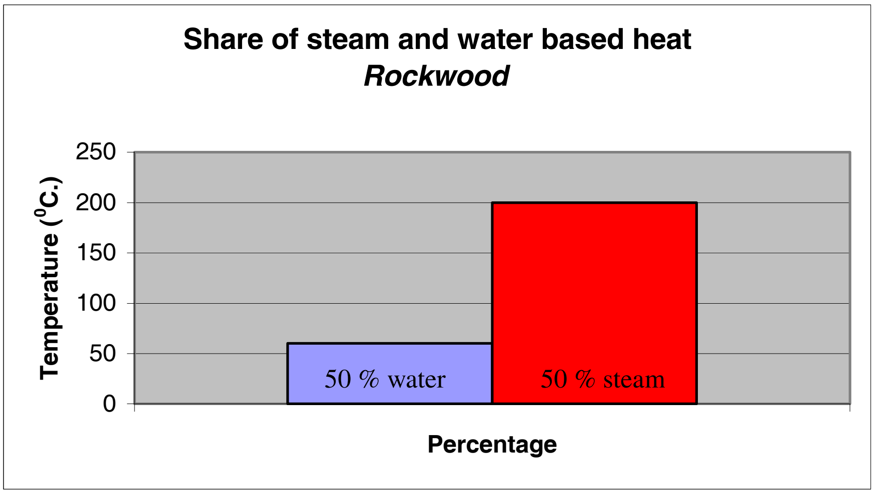






(Data source Chapter 4)

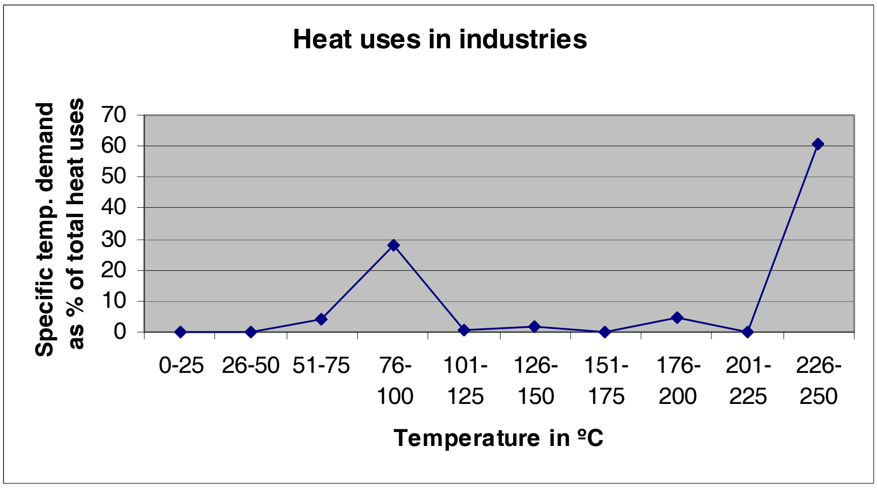
Figure 6D: Process heat uses in case industries now covered by Electricity (Red = steam & blue = water based heat)



(Data source Chapter 4)

As seen from the above, it is obvious to pursue technical changes at Rockwood for conversion of process heat produced by electricity, to process heat supplied as water based heat through district heating. At Sun Cabinet peak heat use is steam utilisation at 120 ºC. Here it would be interesting to convert this high quality heat (steam) to a low quality heat (water based heat) by technical changes. It would also be beneficial if Imperial and B.B. Snacks could decrease high quality heat uses (steam) to uses of low quality energy (water based heat), or by other means pursue optimisation in energy uses.

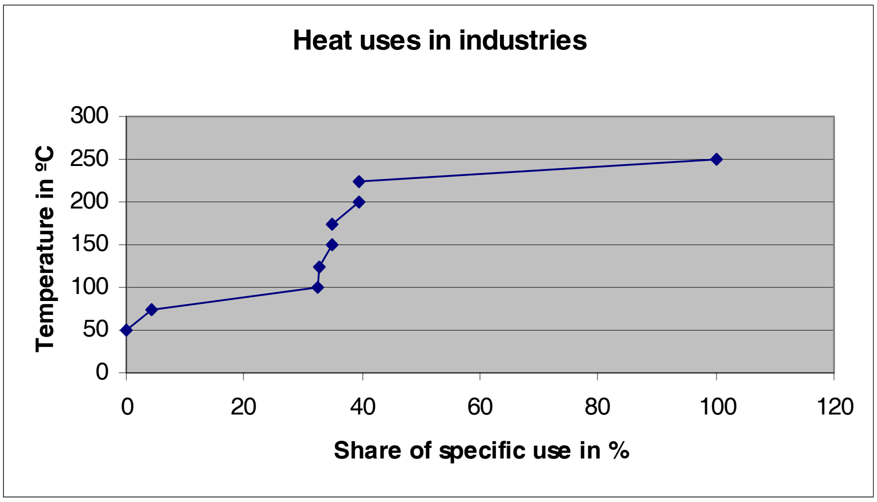
Figure 6E: Heat uses in industries by specific temperature levels in % of total heat demand (excl. Rockwood)



(Data source Chapter 4)

Only 20 % of Imperial's heat demands can be covered by water based heat, as approximately (13,700-2,740) 10,960 MWh/year are steam requirements. This amounts to 60 % of total heat use in case industries. At B.B. Snacks, no End-use temperatures are currently appropriate for water based heat supply. It is thus interesting to find technical solutions to lower the temperature requirements. In Figure 6E above, all data on heat uses are summarised and illustrates, how many percent of total heat uses are covered by which temperature level. As we can see, approximately 5 % of the heat use is covered by temperatures between 51 to 75 ºC, 30 % by temperatures between 76 to 100 ºC, approximately 5 % by temperatures between 101 to 225 ºC and finally 60 % by temperatures between 226 to 250 ºC. Figure 6F below shows the same data arranged differently.

Figure 6F: Heat uses in industries (excl. Rockwood)



(Data source Chapter 4)

Approximately 30 % of the total heat use in case industries can currently be covered by water based heat supply with temperatures of less than 100 ºC, whereas the remaining industries require higher temperature levels. This thus makes steam applications necessary, unless DSM strategies can be implemented to reduce temperature requirements. Another approximately 5 % of the total heat uses is in the temperature range of 101 to 225 ºC, and thus make up for a relatively small amount of the total energy uses.

6.1.2 Operation hours and heat demands

Figure 6H shows the use of water based heat and steam in case industries as a 'duration curve', based on Figure 6G. Until 2,400 operation hours/year, the data are for all case industries, and from 2.400 hours per year and onwards, the data are only from Imperial. Within the first 2,400 operation hour/year steam uses equal approximately 3 MW and includes Imperial and B.B. Snacks. Beyond 2,400 hours/year, and until 7,000 hours/year, steam uses only include Imperial and amounts to 1.60 MW. Until 2,400 hours/year water based heat uses includes all case industries - except B.B. Snacks who only use steam - which equals 1 MW. Beyond 2,400 operation hours per year, water based heat uses are only that of Imperial, which accounts for 0.40 MW.

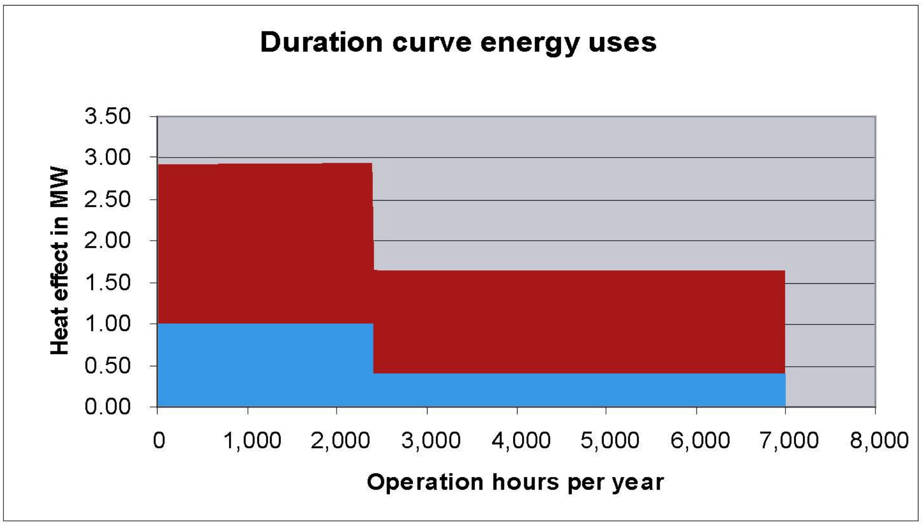
Figure 6G: Operation hours per year and heat uses to be covered in industries

Imperial:	**7,000 hours/year**	**13,699.80 ≈ 13,700 MWh/year in total**
		Steam ≈ 11,000 MWh/year (≈1.60 MW[28])
		Water based heat ≈ 2,700 MWh/year (≈ 0.40 MW)
Baskin Robbins:	**2,400 hours/year**	**830.28 ≈ 800 MWh/year in total**
		Water based heat ≈ 800 MWh/year (≈ 0.33 MW)
B.B. Snacks:	**2,400 hours/year**	**3,091.20 ≈ 3.100 MWh/year in total**
		Steam ≈ 3,100 MWh/year (≈ 1.30 MW)
Sun Cabinet:	**2,400 hours/year**	**(112+168 = 280) ≈ 300 MWh/year in total**
		Water based heat ≈ 300 MWh/year[29] (0.13 MW)
ASAN:	**2,400 hours/year**	**252 ≈ 250 MWh/year in total**
		Water based heat ≈ 250 MWh/year (0.10 MW)
Rockwood:	**2,400 hours/year**	**(Conversion to uses of water based heat)**

(Data source Chapter 4 and calculations in Annex C)

Steam and water based heat uses are approximately divided by a factor 3, which means that if steam demands are 3 MW, water based heat demands are 1 MW. The duration curve shows us that the conversion technology must have an operation period of minimum 7,000 hours/year. This is necessary in order to cover the energy demands at Imperial, who has a 24-hour demand.

Figure 6H: Duration curve for energy End-uses per year (Red = steam & blue = water based heat)



(Data source Figure 6G)

[28] 11,000 MWh per year divided by 7,000 operation hours per year = 1.60 MW.
[29] The calculations are made to cover energy needs in Sun Cabinet by water based heat only.

All industries, except from Imperial, operate in day shifts. It is therefore possible to accumulate surplus heat during the night and either utilise it during the day, make it act as back-up energy supply or pipe it to another or more industries operating at night. Such accumulation of surplus water based heat, produced at night where the demand for energy decrease, can be obtained by implementing a heat accumulation tank.

It might also be possible to cover some of the steam uses in B.B. Snacks by the cascading of "waste steam" from Imperial. Peak heat temperatures at Imperial are 250 ºC (30 bar pressure), and within the first 2,400 operation hours per year steam uses are almost separated equal between Imperial and B.B. Snacks (approximately 1.50 MW each). This gives an opportunity to cover the lowest (pressure and temperature) steam demands in B.B. Snacks, by the cascading of "waste steam" from Imperial.
Thus, Imperial can become a host industry for the conversion technology, due to a large demand for steam and the large number of operation hours per year. This will reduce the economic burden of piping steam, and place the co-generation plant where the energy demand is highest. From Imperial, steam is cascaded to B.B. Snacks, returned, and hereafter cooled down by the district heating network supplying energy to the remaining industries.

6.1.2.1 Optimum size of energy plant (incineration)

With 7,000 hours of operation per year and the cascading of steam and water based heat as district heating - corresponding to a primarily steam production of 11,000 MWh/year - the optimum total size of the energy plant is calculated to 2.63 MW (0.40 MW electricity and 1.66 MJ/s thermal output). The fuel supply fed to the plant must be in the range of 18,400 MWh/year (see Annex D, Part 1). These data will be used in Chapter 8 for Pre-Feasibility Study calculations.

6.1.2.2 Estimated future energy demands

As seen from the empirical data in Chapter 4, ***Imperial*** has no plans for increasing production output, but rather to seek improvements in the efficiency by internal optimisations in production processes. Both Baskin Robbins and B.B. Snacks, on the contrary, are planning to increase the production output, which can be initiated by implementation of for instance two shifts, the operation of more than one production line or by increasing the number of staff during one shift operation. ***B.B. Snacks*** plan to increase production by approximately 20 % in 2001 by increasing the number of one-shift staff, and thereafter pursue an increase of 5 to 10 % annually in coming years (Predictions for energy uses at B.B. Snacks in coming years, as illustrated in Figure 6I below, includes the expected 2001 increase in production output). ***Baskin Robbins*** will increase production by one more shift, and thus a 100 % increase in energy and waste generation can be expected.

Sun Cabinet is constantly seeking to increase production output, but plan to achieve a 25 % increase during the next five years. ***ASAN Service*** has no intention to increase production, as the market for soy sauce in Thailand is saturated[30]. There are no plans for activities regarding the optimisation in heat uses, but on the electricity side, implementation of more modern equipment can lead to reduced consumption. At ***Rockwood,*** they expect to increase production output by 30 % within the next three years. Figure 6I illustrates the expected increase in industrial output within the next five year as predicted by case industries, and the corresponding (theoretically linear) increase in energy uses:

Figure 6I: Increases in industrial output and heat energy uses within the coming 5 years

Imperial:	None (improve energy efficiency)	13,700 MWh/y.	⇒	< 13,700 MWh/y
ASAN:	None	250 MWh/y.	⇒	250 MWh/y.
B.B. Snacks:	≈ 55 % increase	3,100 MWh/y.	⇒	4,800 MWh/y.
Baskin Rob.:	100 % increase	800 MWh/y.	⇒	1,600 MWh/y.
Sun Cabinet:	25 % increase	300 MWh/y.	⇒	375 MWh/y.
Rockwood:				
Total increase:		***18,150 MWh/y.***	⇒	***20,700 MWh/y.***

(Data source Chapter 4 and calculations in Annex C)

6.1.3 Strategies in developing an energy system

According to the duration curve for energy uses in case industries, we have learned that the energy system must be based on a conversion technology operating at full load with the production of large amounts of steam. The duration curve shows that sufficient water based heat for industries will be generated through piping district heating. It can also be seen that Imperial can possibly cover steam demands in B.B. Snacks with “waste steam”, as they produce steam at a factor approximately 3 to 1.

The quantity of steam at B.B. Snacks, to be covered by “waste steam” from Imperial, is, however, 30 % lower than shown in the figure, as steam used for frying peas are not to be covered by “waste steam”, but only the steam needed for boiling activities. This amount is, however, the largest. Increases in future energy demands as emphasised in this section, can possibly be reduced by DSM strategies as described in the following section.

6.2 Conversions and optimisations in energy uses

This section will discuss whether it is possible to reduce peak heat temperatures in case industries, in order to implement water based heat supply (a district heating system), and whether conversion from ‘process heat made by electricity’ to ‘process heat supplied as district heating’ is possible. In addition, other means of energy savings will be highlighted.

[30] (’mættet’)

6.2.1 Wood industries

6.2.1.1 Conversion to water based heat by district heating

Sun Cabinet:
The peak heat demands of 120 ºC are used for hardening glue in a "glue presser", when adding laminates on chip board's. This use of steam can, however, be subsidised with utilisation of lower heat temperatures of approximately 70 ºC, thus by a water based district heating system (Sparet er tjent, Træets Arbejdsgiverforening Homepage, 2001, at; www. sparetertjent.dk/front.cmf, per 27-6-01). According to Træets Arbejdsgiverforening, such production change requires a relatively small investment. Heat piping must be prolonged to the "glue presser", and there must be storage of glue at temperatures of around 10 ºC, as it will be subsidised with a low temperature hardening glue (Sparet er tjent, Træets Arbejdsgiverforening Homepage, 2001, at; www.sparetertjent.dk/front.cmf, per 27-6-01).

Rockwood:
According to experiences obtained in a Danish wood industry, Lyby Møbelfabrik A/S, it is possible to save up to 82 % of the heat expenses by conversion from electricity based process heat to water based process heat in gluing activities. The industry has decreased heat temperatures of 100 ºC - made by electricity - to 70 ºC, by uses of water based heat supply instead. If the heating system falls out for a period, an electronic system will activate the former heating system by electricity uses (Sparet er tjent, Træets Arbejdsgiverforening Homepage, 2001, at; www.sparetertjent.dk/front.cmf, per 17-9-01).

At Rockwood the "glue presser" equipment is operated at electricity and heat temperatures of 60 ºC are generated in this process. Thus, Rockwood might benefit from uses of water based heat in the gluing activities. Currently, the peak heat demands of 200 ºC are also covered by electricity uses, and happen as the oven for lacquer hardening is heated up. Also here it is possible for Rockwood to decrease heat temperatures by conversion to process heat by water based heat, and prolonging heat pipes to the lacquer oven. In this case it might also be necessary to subsidise the type of lacquer used, in order to obtain a lower hardening lacquer temperature.

Effective insulation, warm caps and adjustments of warm air ventilators in the oven, can assist in lowering heat requirements and make process heat by water based heat effective (Elbesparelser ved Elsyn, Thomas Pedersen, Dk-Teknik Energi og Miljø, 1991). As for Sun Cabinet, Rockwood can also design the system to be operated on electricity in the case of fall-outs. When substituting process heat made by electricity with process heat supplied by water based heat - and convert to low temperature hardening glue/lacquer - it does *not* impact on the quality of the final product (Sparet er tjent, Træets Arbejdsgiverforening Homepage, 2001, at; www.sparetertjent.dk/front.cmf, per 27-6-01).

6.2.1.2 General optimisations by process equipment

In wood industries many technical options can be considered to save energy. In the following, emphasis will be on some of the most obvious possibilities for achieving energy savings. When looking at Figure 3I in Chapter 3, it is obvious that electricity savings can be beneficial in the areas of Processing wood, Compressed air and the Removals of sawdust.
In ***Processing wood***, it is possible to reduce electricity expenses for *ventilation air* activities in wood industries, by implementation of for instance more efficient *local exhaust ventilation systems*[31]. Traditionally, effective elimination of wood chips from moulding and drilling machines[32] has been difficult, as generated chips leave the equipment with high speed, and thus hurled away from the area of ventilation. This inefficiency has led to a need for additional cleaning activities, by for instance using highly compressed air and other means of additional ventilation (Reduktion af energiforbruget til udsugning i træindustrien, DTI Træteknik, 1994).

By implementation of a ventilation air bow[33], it is possible to avoid these problems, as the equipment is capable of removing generated wood chips more efficient. The ventilation air bow is designed to create an area around the opening of the ventilation point with high air speed, aiming at the ventilation point. This means that chips, which normally are spread to this area, now are forced into the ventilation air bow instead (Reduktion af energiforbruget til udsugning i træindustrien, DTI Træteknik, 1994). The system can lead to electricity savings of 50 %, as well as savings in additional cleaning activities by electricity uses (see below). Moreover, experience has shown that local exhaust ventilation systems also improve the dust content in the air by as much as 32 %. This, again, can lead to improvements in the final products as the wood surfaces finish increases (Ibid.).

Electricity expenditure on ***Compressed air*** activities can also be reduced by as much as 57 %, due to optimisations in these activities. Polishing and moulding sections, for instance, normally use large amounts of compressed air to conveyor belts and product cleaning activities (Sparet er tjent, Træets Arbejdsgiverforening Homepage, 2001, at; www. sparetertjent.dk/front.cmf, per 27-6-01). By monitoring air uses in a Danish wood industry, Nitex Møbler A/S, it has been possible to optimise uses of compressed air by:

- Reductions in the overall air compression level of the compressor;
- Optimisation in the compressor control unit;
- Separating the compressed air net in sections to avoid leakage;
- Optimisation of the air intake to the compressor, so air intake temperatures has been reduced;
- Making conveyor belts and product cleaning activities on polish equipment demand-controlled; (Sparet er tjent, Træets Arbejdsgiverforening Homepage, 2001, at; www. sparetertjent.dk/front.cmf, per 27-6-01).

[31] ('lokal punktudsugning')
[32] ('fræse- og boremaskiner')
[33] ('luft-bov')

Energy saving can also be obtained in mechanical ***Removals of sawdust***, which can be optimised by the utilisation of a Redler transportation system based on a "trough-snail"[34], as opposed to the more traditional ventilator based transportation system. A Danish wood industry, PLUS A/S, who produces wood fences, has obtained energy saving amounting to 88 % by implementation of the Redler transportation system (Sparet er tjent, Træets Arbejdsgiverforening Homepage, 2001, at; www.sparetertjent.dk/front.cmf, per 27-6-01). The main reason for energy savings is, that the Redler transportation system - as opposed to the ventilator based system - does not move sawdust with uses of highly compressed air. Thus, at PLUS A/S, it has been possible to substitute the old 55 kW motor with a new 5.50 kW, and reduce energy uses in effect from 42 kW to 5 kW (Sparet er tjent, Træets Arbejdsgiverforening Homepage, 2001, at; www.sparetertjent.dk/front.cmf, per 27-6-01).

6.2.2 Food industries

6.2.2.1 Conversion to water based heat by district heating

B.B. Snacks:
According to B.B. Snacks, vacuum implementation is not possible at the industry as processing activities partly happens by continuous-processing (the frying). Vacuum *can*, however, be implemented in continuous-processing's, but it is likely to be very costly (Pers.Com., Tyge Kjær, 2001). Thus, conversion to water based heat in other parts of the process not based on continuous-processing, including other means of energy savings, might be favourable. Such initiatives will be emphasised in the following separated into possibilities for energy optimisations at B.B. Snacks, when looking at boiling and frying activities:

At B.B Snacks ***boiling*** activities takes place at 140 to 150 ºC in large batch reactors or vessels containing the green peas. Depending on the structure of the peas, and whether the vessel creates a closed environment or not, the temperature of the boiling process can possibly be lowered by operating in a vacuum. If such production changes can be implemented, boiling processes can be covered by water based heat only, as provided by a district heating network. If vacuum operation is not possible, the processing of peas can partly be built on a water based system. This can be established, as the initial temperature increase (from 25 to 95 ºC) is achieved by the water based heat system, and the remaining temperature increase (from 95 to 140 ºC) by a fossil fuel based system or possible by "waste steam" from Imperial. If the latter heating process is based on fossil fuels, it is applied quite late in the process, and can thus lead to energy savings (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 18-1-02).

More favourable to this system is implementation of heat exchangers and re-circulation of hot water between vessels. "Waste heat" from one vessel can partly heat up new feed-water in the next vessel, where "waste heat", again, heats up feed-water in the vessel after that etc. "Waste heat" from one vessel can theoretically reach a temperature level of 100 ºC, and by heat exchange heat up the water in the next vessel (For reasons of hygiene it is not possible to utilise the same boiling water twice). Peak heat temperatures (95 to 140 ºC) are again provided by fossil fuel uses or by "waste steam" from Imperial. This system is superior to the latter above, as it decreases the total energy uses as providing the lowest heat temperatures by

[34] ('trugsnegl')

re-circulation of heat, and not by uses of district heating. The heat recovery system can also be combined with the vacuum boiling system, where a large part of the energy is recovered and the remaining energy demand covered by district heating (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 18-1-02).

A final possibility for obtaining energy savings (not to convert to water based heat) in boiling activities at B.B. Snacks, is to utilise the heat from the water evaporated in the boiling process. If the vessels consist of a closed environment, water will evaporate at 100 ºC, and the heat of evaporation subsequently be recovered in a heat exchanger in which the vapour is condensed. The heat can thus be used for water pre-heating. In case the vessels are not a fully closed environment, the heat recovery will drop because the condensation temperature falls to 70 to 90 ºC. Still, both temperature levels can be used for, for example, heating up the feed-water in the vessels (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 18-1-02).

At B.B. Snacks, ***frying*** activities are also included in the processing of green peas (at 170 to 180 ºC), and this happens by using LPG in a *continuous-processing*. Also, here, the development of water vapour occurs, which can be utilised for internal uses. At the top of the fryer, a ventilation system is installed, through which the vapour disappears. With a heat exchanger it is possible to collect this vapour at perhaps 70 ºC for further use in the industry. Currently, this is done to heat up the oil, in which the peas are fried (Letter from Mr. Kritsakhorn Dolcharumanee, B.B. Snacks, dated the 15-2-02). By implementation of all the examples mentioned above, it is in principle possible to save at least 40 to 50 % of total energy uses at B.B. Snacks (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 18-1-02). However, practical and economic limits might reduce this number significantly. For a realistic picture it is necessary to make more detailed energy analysis.

6.2.2.2 General optimisations by process equipment

At we saw it in Chapter 4, ASAN Services and Baskin Robbins uses ***Cooling*** in processing activities and for storage purposes. Electricity savings related to cooling/freezing (hereafter cooling) activities can often be obtained by relatively small investments (Elbesparelser ved Elsyn, Thomas Pedersen, Dk-Teknik Energi og Miljø, 1991). Suggestions for areas in which energy savings can be obtained are:

- Adjustment of cooling-demands to the turnover speed of goods in cooling storage facility and use of as high cooling temperature as possible;
- Limiting cooling needs by for instance improvements in insulation;
- Optimisation of the compressor operation;
- Lowering of condensation temperature;
- Effective maintenance of condensation's;
- Use of natural cooling with dry coolers'; (Elbesparelser ved Elsyn, Thomas Pedersen, Dk-Teknik Energi og Miljø, 1991).

The use of ***Pumping*** activities occurs in both the Food and Pharmaceutical industries, but the share of expenses for this task is in general larger in the food producing line of business. Electricity expenses for pumping activities can be reduced by:

- Adjustments to pumping-demands;
- Correct fitting of pumps;
- Regulation principles,
- Optimise the effect of the pump;
- Optimise the effect of the engine; (Elbesparelser ved Elsyn, Thomas Pedersen, Dk-Teknik Energi og Miljø, 1991).

Ventilation (See below)

6.2.3 Pharmaceutical industries

6.2.3.1 Conversion to water based heat by district heating

Imperial:
Peak temperatures at Imperial are already decreased from 400 to 250 ºC by operating the process under vacuum. It is unlikely that the temperature demand can be decreased further by this method. Steam accounts for 80 % of the total energy uses in Imperial, and it is thus a significant amount of energy that cannot be converted to water based heat. One strategy can therefore be, to utilise the "waste heat" to cover internal water based heat uses (Jan Sandvig Nielsen, Interview, Dk-Teknik Energi og Miljø, Gladsaxe the 27-11-01), accounting for 20 % of total heat use. This assumes that "waste heat" at the right temperature level is available. Imperial can therefore either receive water based heat from the district heating network, or/and even supply the network with surplus "waste energy". As mentioned earlier, re-use of high quality energy from Imperial, by the cascading of steam to B.B. Snacks, is another possibility. The possibilities mentioned above will be emphasised further in the following.

At Imperial, the batch operation happens in reactor tanks or large vessels, in which water evaporates and the specific product are concentrated further and sterilised. In the ***top of the reactor***, water vapour is extracted, or given free, on a constant basis. When collecting this energy by implementation of a heat exchanger, it is possible to re-use the energy either internally or externally: For coverage of low temperature heat demands elsewhere in the process or/and provide hot water to the district heating network. Depending on the vacuum installed (pressure level of the vacuum pump) the temperature of water vapour can be between 40 and 100 ºC (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 18-1-02).

At the ***bottom of the reactor***, it is also possible to extract "waste energy" for further re-use, as for instance in B.B. Snacks for coverage of boiling demands. "Waste heat" from heating of reactor tanks at Imperial - by uses of steam at 250 ºC - can realistically reach a level of 150 ºC (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 18-1-02). It is, therefore, a candidate for re-use in other parts of the plant, or for export to the water based district heating system or as source for the cascading of steam in separate pipes. Currently, however, this surplus energy is cooled down (lost) and therefore not collected for further uses. By implementation of the initiatives mentioned above, it is theoretically possible to save at least 50 % of the current energy uses at Imperial. In practice, the realistic energy savings must be expected to be lower. For a complex industry as Imperial, the above mentioned options must be considered systematically and simultaneously. The typical approach is thus to conduct a process integration study, in which all energy recovery options are exploited in a systematic way (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Letter dated the 31-5-02).

6.2.3.2 General optimisations by process equipment

In pharmaceutical industries many technical solutions can be applied in order to save energy. In the following, emphasis will be on some general and obvious possibilities for achieving energy savings in this line of business. When looking at Figure 3H in Chapter 3, it is obvious that electricity savings would be beneficial in the areas of Process air (compression) and in the area of Blowing machinery, Stirring and Cooling activities. As no cooling activities happen at Imperial, this matter is excluded in the following.

When substituting several small vacuum systems in the production process with one single central vacuum system, it can reduce electricity uses for ***Process air (compression)***. Existing vacuum pumps can be moved to a central facility and interconnected. A piping system can be established, which connects the machines to the central vacuum plant. By doing this, it is possible to reduce the amounts of vacuum pumps in operation, due to a limitation in tick-over periods[35] (Sparet er tjent, Træets Arbejdsgiverforening Homepage, 2001, at; www.spareter tjent.dk/front.cmf, per 27-6-01). This normally happens on the decentralised pumps, in periods where there is no need for them.

At Imperial, however, a vacuum is applied at different levels depending on the specific batch operated. A vacuum is thus utilised as a process control mechanism, and as such it is difficult to interconnect all vacuum pumps. Decentralised pumps are also often over-dimensioned. In one department processing plastic components in a Danish loudspeaker industry, it has been possibly to reduce electricity expenses in vacuum activities by 54 %, due to the centralising of 4 of 6 vacuum pumps (Sparet er tjent, Træets Arbejdsgiverforening Homepage, 2001, at; www.sparetertjent.dk/ front.cmf, per 27-6-01).

One "low hanging fruit" in the reduction of electricity expenses for operating ***Blowing machinery*** and ***Ventilation*** activities - here discussed together - is to make uses demand-controlled. It is possible to reduce expenses by up to 50 %, only by shutting down machinery's when the production is closed down (Elbesparelser ved Elsyn, Thomas Pedersen, Dk-Teknik Energi og Miljø, 1991). Some pharmaceutical industries operate ventilation machinery and other ventilation activities at night or in weekends when the industry is closed down, to remove humidity and assure a clean air environment. Experiences show, however, that this activity only is necessary three hours before re-starting the operation, thus further ventilation activities only leads to unnecessary energy uses (Elbesparelser ved Elsyn, Thomas Pedersen, Dk-Teknik Energi og Miljø, 1991).

Air intake by blowing machinery and ventilation equipment in general also leads to secondary energy uses, as it - especially in a Thai context - is cooled by air conditioning. Thus, when limiting these activities, it is also possible to save energy resources for either heating or cooling the air intake (Elbesparelser ved Elsyn, Thomas Pedersen, Dk-Teknik Energi og Miljø, 1991). As for wood industries, it is also here possible to limit the overall air intake by

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[35] ('ude-tid')

optimisations in specific local exhaust ventilation activities, as the general air quality improves by optimisations in the systems.

Other technical solutions for obtaining efficiency in these activities are for instance improvements in the technical design of ventilation channels. If, for instance, high air speed is needed, it is important that the channels system is shaped to match the air pressure, in order to reduce pressure losses and thereby energy expenses. Leakage in and sharp corners in the ventilation channels can lead to unnecessary large energy uses (Elbesparelser ved Elsyn, Thomas Pedersen, Dk-Teknik Energi og Miljø, 1991). Appropriate regulation of the numbers of revolution made by the ventilation machinery, thus air volume, can also save energy resources. Typically, such adjustments can lead to electricity saving of 20 to 50 %. Inlet regulation with guardrail[36] - substituting throttle regulation[37] - can also lead to energy savings of approximately 40 % (Ibid.).

Electricity uses for ***Stirring*** activities can be reduced by optimisations of, for instance, the motor (Elbesparelser ved Elsyn, Thomas Pedersen, Dk-Teknik Miljø og Eneregi, 1991), or by implementing stirring equipment as for instance propeller's or "worm-screws"[38], with the capability to mix substances effectively without great electricity uses. As for pumping activities it is important to look at the stirring-demand, and analyse whether stirring activities are over-dimensioned, or for instance can be provided in a shorter period of time with a reduces density. New stirring equipment can lead to significantly energy savings. One Danish pharmaceutical industry has obtained savings in the range of 20 to 40 %, just by implementation of new stirring equipment (Jan Sandvig Nielsen, Interview, Dk-Teknik Energi og Miljø, Gladsaxe the 18-1-02).

6.3 Evaluation of End-use demands

In the case industries there is a need for *both* water based heat and steam. In this chapter, the specific quantity of process heat requirements - divided into water based heat and steam - has been analysed. It was found that conversion from steam to water based heat, and general optimisation of processing activities could reduce both the quantity and quality of energy uses. Still, however, process heat demands based on steam accounts for the majority of energy uses.

6.4 Strategies in developing an energy system

Analyses have shown that technical solutions must be based on conversion technologies capable of producing large amounts of steam, and supply water based heat by a district heating network, in order to cover energy demands in the case industries.

As found in the second part of this chapter, certain steam demands can in a relatively simple way be converted to water based heat demands, which can be supplied by a district heating network. In addition, uses of electricity for heat generation have proved to be possible in order to convert to water based heat. By optimisations in production processes, it has furthermore

[36] ('ledeskinne')
[37] ('spjældregulering')
[38] ('snegleomrører')

proved possible to reduce the total amount of steam and water based heat used by the industries. Thus, the quality of the required heat can to a large extent be reduced to a lower quality: converting steam to water based heat and converting process heat made by electricity to water based heat. Which types of technologies are appropriate to meet this challenge is the focus of Chapter 7.

Chapter 7; Triangle Analysis - Technology

The purpose of this chapter is to point to technologies that can fulfil case specific conditions regarding the character of biomass wastes (Resources) and energy demands in case industries (End-uses), as found in Chapter 5 and 6. End-use demands were found to be a need for both steam and water based heat, with a large amount being steam - approximately 60 % of total heat uses. The Resource analysis further showed that the composition of biomass wastes could be described as: inhomogeneous in structure and content, on both liquid and solid basis, and with possible moisture contents of 10 to 15 % (even when pre-dried).

It was also found that certain biomass wastes (Industrial Materials Network Supporting Resources) were inappropriate as fuel for incineration purposes, due to possible contamination, which was the case for sludge and sorted organic household wastes. The remaining biomass wastes were found to be unproblematic. Wood wastes, however, were found to have contents of glue, which lead to higher emissions of nitrogen oxide (NO_x) (capabilities of different conversion technologies in regards to NO_x reduction will thus be emphasised in the next chapter).

Whether to pursue digestion of sludge and household waste, or incineration of industrial wastes as initial energy system in the case area, depends on the technical possibilities for covering End-use demands in case industries. This chapter thus places emphasis on which Technologies are capable of covering specific End-use demand, by the specific biomass Resources identified. This includes which Danish experience exists in operating different biomass technologies, regarding fuel composition and application as both steam and water based heat supplier (district heating). In addition, the technical level on which the specific technologies are placed is important, and only mature technologies are included in the analysis, as being a precondition for the technologies under study. In the next chapter, a more detailed discussion of how actually to design the energy system will be elaborated. This also includes environmental and economic issues.

7.1 Identification of possible technologies

As mentioned, the choice of possible technologies to implement must be made in accordance with their capability to generate both *steam* and *water based heat*. In the following, emphasis will be on ***incineration*** and ***digestion*** technologies, which are well known technical applications. Gasification technologies are excluded here as they are still on an experimental level (Ole Madsen, Vølund, Brøndby, Interview the 24-10-01 & Niels Bjarne Rasmussen, DGC, Interview, Hørsholm the 12-10-01). Incineration and digestion technologies will be analysed for their capability to generate water based heat as well as steam, by conversion of biomass wastes with possibilities for a relatively high moisture content and an inhomogeneous composition.

As the *first* ***incineration*** technology a Steam Turbine Plant is chosen, as being the most commonly implemented co-generation technology particularly in industries and for district heating purposes. The technology is, for instance, well proven in sugar and paper mills, having demand for both electricity and large quantities of steam at high or low pressures

(Co-generation as a means of pollution control and energy efficiency in Asia, United Nations, Undated). In Denmark Steam Turbine Plants have also demonstrated to be appropriate for biomass conversion in CHP Pants for electricity and district heating supply (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 3-12-01).

As the *second* incineration technology is selected a Bubbling Fluidised Bed (BFB) combustion plant with Steam Engine application, being a developed alternative at the industrial level due to its reliability and simplicity in operation (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 3-12-01).
BFB combustion is normally selected before CFB combustion, when biomass wastes have a relatively high moisture content and thus possible lower calorific value (Steam - its generation and use, S.C. Stultz and J.B. Kitto, Babcock & Wilcox, 1992). Finally, as ***digestion*** technology, a Joined Biogas Plant (Centralised) with Gas Engine application (motor-generator unit) is chosen. This technology can be used for conversion of a wide range of different biomass wastes in combination.

7.1.1 Incineration

7.1.1.1 Steam Turbine Plant

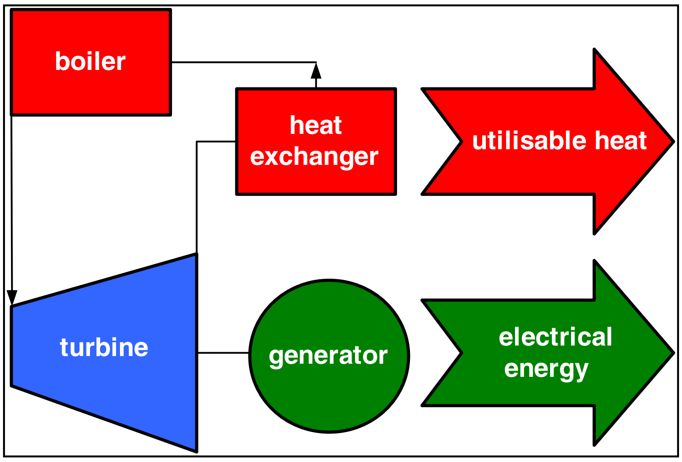
Steam Turbine Plant:
A Steam Turbine Plant consists of a Boiler, a Turbine, a Heat exchanger and Pump. In the Turbine, incoming high pressure steam is expanded to a lower pressure, converting thermal energy of high pressure steam to kinetic energy through nozzles[39], and then to mechanical power through rotating blades. In a Steam Turbine Plant, the energy is contained in the steam developed in the furnace walls constructed as water, shell or fire tubes. Modern high capacity boilers are of the water tube type, where water and steam flow inside the tubes and the hot flue gases on the outside surface (Steam - its generation and use, S.C. Stultz and J.B. Kitto, Babcock & Wilcox, 1992).

Steam developed in the tubes is hence converted to a rotational motion by the Turbine, which runs a generator for electricity production. Thermal energy (steam) from the Turbine can now be transferred to another fluid, water or air etc. by the heat exchanger, providing heat to different processes (Co-generation as a means of pollution control and energy efficiency in Asia, United Nations, Undated). In a re-heat cycle, steam can also be extracted from the Turbine and re-heated in the boiler during the expansion process (super-heated[40]). Re-heat cycles improve the overall thermal efficiency of the plant and eliminate any moisture that may develop, as steam pressure and temperature are lowered in the Turbine.
Steam Turbine Plants may also include a re-generative cycle where steam is extracted from the Turbine, and used to pre-heat the boiler feed-water (pre-heaters) (Co-generation as a means of pollution control and energy efficiency in Asia, United Nations, Undated). Such applications can increase the efficiency of the Steam Turbine Plant, but also the investment costs. For plants operating on full load, however, such equipment is favourable (Technologies for Small Scale Wood-fuelled Combined Heat and Power Systems, Søren Houmøller et. al., Dk-Teknik Energi og Miljø, 1998).

[39] ('dyser')
[40] ('over-ophedet')

The steam cycle is based on the closed Rankine process in which the boiler water is heated, evaporated - and possible super-heated - forming steam, which then expands through the Turbine. After this expansion the steam is lead through a condenser, where heat can be transferred to a district heating network by a heat exchanger, in which the steam is cooled and turned into liquid water again - and hence the cycle begins again (Technologies for Small Scale Wood-fuelled Combined Heat and Power Systems, Søren Houmøller et. al., Dk-Teknik Energi og Miljø, 1998).

Figure 7A: Steam Turbine Plant and principal diagram



Source: Ms. Christina Widjaya, COGEN, 2003

The Turbine:
In the Turbine, steam is moving relatively slowly into some stationary blades working as nozzles, thereby increasing the steam velocity[41], hence lowering the pressure and forming a whirl. The next set of blades is converting the velocity into a rotating motion, while the steam leaves the set of blades in axial directions, ready for the next step. The enthalpy drop over a step is relatively small, which means that a Turbine must consist of several steps, depending on the conditions under which is has to work (Technologies for Small Scale Wood-fuelled Combined Heat and Power Systems, Søren Houmøller et. al., Dk-Teknik Energi og Miljø, 1998).

Size & efficiency:
Small scale Steam Turbine Plants vary from 0.25 to 10 MW electricity and can reach high efficiencies. In general, however, the efficiency decrease the smaller the plant gets, and the lower the pressure (quality of steam) (Technologies for Small Scale Wood-fuelled Combined Heat and Power Systems, Søren Houmøller et. al., Dk-Teknik Energi og Miljø, 1998).
The price of Steam Turbine Plants also increases significantly for smaller plants, and as such it is favourable to implement larger Steam Turbine Plants (> 5 MW total). The efficiency of Steam Turbine Plants also falls if the plant is over-dimensioned, and thus not constructed to be operated on full load (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Pers.Com., Gladsaxe the 23-2-01).

7.1.1.2 Resource and End-use demands

Steam and water based heat generation:
Steam can be converted in either a topping cycle or in a bottoming cycle. In a topping cycle, the fuel is used for electricity production in a steam boiler, and generated waste heat supports an industrial process. The most common sort of topping cycle is one in which a boiler produces steam at a higher pressure, than that actually needed in the industrial process. The high pressure steam is then expanded in a Turbine to a pressure that is appropriate for the industrial application, producing electricity in the process (Steam - its generation and use, S.C. Stultz and J.B. Kitto, Babcock & Wilcox, 1992). In a bottoming cycle, the fuel is not supplied directly to the power producing cycle. The steam is rather produced from a waste heat source, and *then* expanded in a Turbine to produce electricity. Steam is often used in the bottoming cycle, because of its availability to condense at low temperatures in the closed Rankine cycle (Ibid.).

If End-use demands can be covered by water based heat only, a topping cycle is appropriate. Topping cycles are therefore convenient when generating process heat at low temperatures, as, for example, district heating. In topping cycles, the fuel is firstly used to produce electricity and then secondly to generate thermal energy, and thus improves the energy efficiency by generating low-qualitative steam. Topping cycles are widely used in pulp and paper, food processing and textile industries, for district heating and in hotels and hospitals etc. If End-use demands, on the contrarily, includes large amounts of steam, a bottoming cycle is more appropriate. In a bottoming cycle, high temperature thermal energy is generated, and rejected heat is used to produce electricity in a recovery boiler and Turbine generator. This technology is thus suitable for industrial processes where steam is required at high

[41] ('hastighed')

temperatures. Cement, steel, ceramic, gas and petrochemical industries are commonly users of bottoming cycles (Co-generation as a means of pollution control and energy efficiency in Asia, United Nations, Undated).

Mixed biomass fuel:
Traditional Steam Turbine Plants are capable of converting a wide range of different fuels, conventional as well as renewable. Coal, natural gas, oil, waste (organic as well as non-organic), and in principle all kinds of biomass wastes, can be converted in this technology. There are, furthermore, no specific requirements regarding the composition of fuels (Ole Madsen, Vølund, Interview, Brøndby the 24-10-01), and the Steam Turbine Plant can therefore be regarded as multi-fuel technology. At Masnedø CHP Plant - which is designed as a Steam Turbine Plant - the fuel is composed by wood chips and straw, which is mixed before entering the boiler. Plant manager Jesper Bolin stresses, that especially with a very different composition of biomass fuels, it is important to make an appropriate mixture before feeding to the plant. This will enable a better combustion in the boiler, as the biomass become more homogeneous. Thus, different biomass fuels are not a problem in Steam Turbine Plants, if the right fuel mix and appropriate air intake - which vary according to the specific biomass fuel - are applied (Jesper Bolin, Masnedø CHP Plant, Interview, Vordingborg the 4-10-01).

It is, however, important to emphasise *how* the biomass wastes react together when converted, in order to avoid the development of agglomeration, as well as to avoid the use of other means of inappropriate fuel (Per Lyngsø Nielsen, Haslev CHP Plant, Interview, Haslev the 9-10-01). At Masnedø CHP Plant they operate with only one boiler, as the biomass is relatively homogeneous. If great variations in the composition of biomass appear, a possibility is to implement more than one boiler - designed for the specific biomass fuel - and connect them to the same Turbine (Jesper Bolin, Masnedø CHP Plant, Interview, Vordingborg the 4-10-01). Thus, Steam Turbine Plants are capable of converting many different kinds of biomass wastes, but if the waste vary greatly in composition, the actual combustion can happen at different temperatures and thus affect the steam generation.

High moisture biomass fuel:
The moisture content of biomass wastes to be converted in Steam Turbine Plants can be as high as 55 to 60 %. They can, however, be designed to meet moisture contents that are much higher - which is the case on for instance sludge incineration plants - but this will evidently affect the energy output of the plant (Henrik Houmann Jakobsen, DK-Teknik Energi og Miljø, Interview, Gladsaxe the 3-12-01). At Haslev CHP Plant, for instance, high moisture contents in the straw lead to the development of sulphur, which has meant maximum moisture contents of 22 to 24 % (Per Lyngsø Nielsen, Haslev CHP Plant, Interview, Haslev the 9-10-01).

The moisture contents' influence on the quality of the biomass waste at Haslev is also partly caused by the fuel feeding system, which is a cigar system. If the waste, alternatively, were mixed *before* entering the boiler, the problem would not be as significant (Per Lyngsø Nielsen, Haslev CHP Plant, Interview, Haslev the 9-10-01). In general, high moisture biomass fuel affects the energy required to evaporate water contents. This, again, influences the final amount of energy to be extracted from the fuel, and as such it is favourable to seek reduction in the moisture content (Per Lyngsø Nielsen, Haslev CHP Plant, Interview, Haslev the 9-10-01).

7.1.1.3 Technical level and Danish experiences

The Steam Turbine Plant is a well-proven and developed technology, and can therefore be characterised as highly *mature*. Thus, most decentralised biomass-fuelled CHP Plants in Denmark are also based on this principle (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 3-12-01). Technical problems related to incineration of biomass wastes using this technology, are mainly corrosion in the boiler due to combustion of wastes with, for instance, chlorine contents (as for example straw). New alloys[42] and experiments with temperature levels have, however, reduced these problems in recent years (Jesper Bolin, Masnedø CHP Plant, Interview, Vordingborg the 4-10-01).

7.1.1.4 Bobbling Fluidised Bed (BFB) with Steam Engine application

The BFB Plant presented below is designed as a combustion plant with Steam Engine application.

Bobbling Fluidised Bed:
In a BFB combustion plant sand forms a bed material in the bottom of the furnace, which is lifted (suspended) by air injected from below, thereby fluidising the bed material (sand and fuel). The flow of air and fuel to the bed is controlled, so that the desired amount of heat is released to the furnace on a constant basis. Typically, the fuel is burned with 20 % excess air. The biomass fuel fed into the furnace quickly ignites[43], when it gets into contact with the bed material. The heat transfer surface is placed in the bed, in order to achieve the desired heat balance and bed operating temperature, and normally consists of water tubes as in the Steam Turbine Plant. In BFB plants, the combustion primarily happens in the bed due to lower gas velocity and larger fuel size (compared to the CFB Plant). The residence time of the more fine fuel particles - carried out of the bed by the flue gas - is in many cases increased by collecting and re-cycling the particles to the furnace (Steam - its generation and use, S.C. Stultz and J.B. Kitto, Babcock & Wilcox, 19929.

The fuel particles remain in the bed, until they are lifted by the flue gas or removed with the bed drain solids. As the fuel particles burn, their size falls below a given value where the terminal and gas velocities[44] are equal, which allows them to be entrained[45]. Therefore, the residence time is decided by the initial fuel particle size, and by the reduction of the initial size resulting from combustion and attrition[46]. Due to a relatively long fuel residence time in the boiler, and high intensity of the mass transfer process, the biomass wastes can be efficient burned in this technology, and by temperatures considerable lower than in a conventional combustion processes. The bed temperature is preferably in the range of 815 to 875 ºC (Steam - its generation and use, S.C. Stultz and J.B. Kitto, Babcock & Wilcox, 1992).

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[42] ('legeringer')
[43] ('antændes')
[44] ('hastigheder')
[45] ('løftet op')
[46] ('slidtage')

Steam Engine:
The Steam Engine is based on the original Thomas Newcome design from 1711 used for the draining of tin mines. The Steam Engine used the atmospheric pressure to work the engine's power stroke. Later James Watt improved the Steam Engine to work with higher pressure making it more compact and usable, for example, as locomotive engines. The principle behind the Steam Engine is similar to that of an ordinary internal combustion engine know from cars. The main difference is that in the Steam Engine the working fluid is steam, while it is hot combustion products in the internal combustion engine (Technologies for Small Scale Wood-fuelled Combined Heat and Power Systems, Søren Houmøller et. al., Dk-Teknik Energi og Miljø, 1998).

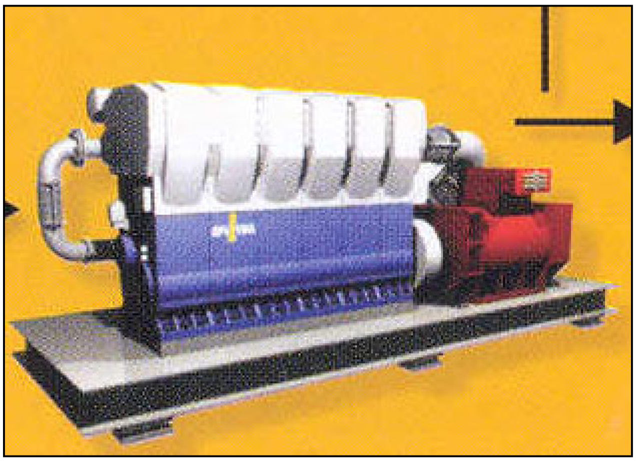
After leaving the Steam Engine cylinder the steam is condensed to water by extraction of the heat - for instance through a district heating system - and returned to the boiler. In contrast to the internal combustion engine - where the forces of the hot combustion products only act in one direction of the piston[47] movement - most Steam Engines are double acting. This means that the steam expands in both the forward and backward stroke of the piston. Therefore, the double acting Steam Engine is lighter and smaller than the internal combustion engine at a given output (Technologies for Small Scale Wood-fuelled Combined Heat and Power Systems, Søren Houmøller et. al., Dk-Teknik Energi og Miljø, 1998).

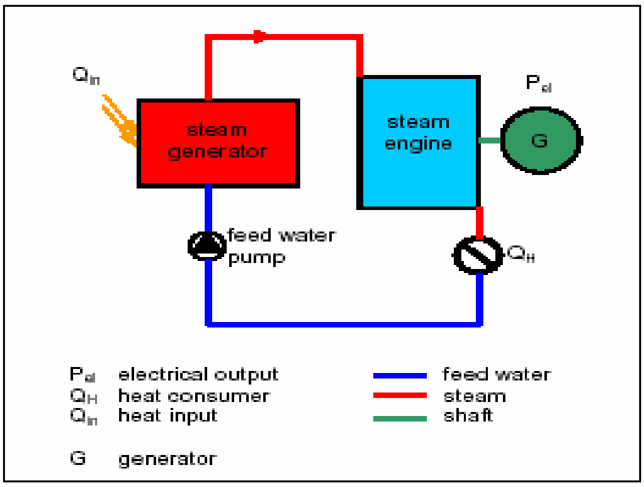
Size/efficiency:
The Steam Engine is a well-proven application capable of withstanding constant operation in industrial environments, and as such a reliable technology that only requires small maintenance costs. The efficiency of Steam Engines depends more on the quality of the steam, than one the actual engine design. As a result of this the efficiency can be increased by uses of boilers with better steam data, as for instance water tube boilers. Even when using low pressure steam in the engine, high efficiencies can be obtained. Pressure and temperature must, however, preferably not reach a level lower than 10 bar and 180 ºC, as it affects the efficiency of the engine.
Small Steam Engines are produced on commercially basis in the size of 0.25 to 1.50 MW electricity (Technologies for Small Scale Wood-fuelled Combined Heat and Power Systems, Søren Houmøller et. al., Dk-Teknik Energi og Miljø, 1998).

As for the Steam Turbine Plant, the efficiency of Steam Engines fall if not operated on full load, but are in general not affected as much by this factor as the Steam Turbine Plant. The costs (per MW) of implementing small Steam Engines are relatively higher than when implementing larger units, but, again, Steam Engines are not affected as much by this factor as the Steam Turbine Plant (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Pers.Com., Gladsaxe the 23-2-02).

[47] ('stempel')

Figure 7B: Steam Engine and principal diagram





Source: Ms. Christina Widjaya, COGEN, 2003

7.1.1.5 Resource and End-use demands

Steam and water based heat generation:
Steam generated in the BFB combustion plants is lead to the Steam Engine for electricity production, and steam outtakes can be applied as for the Steam Turbine Plant. The steam is lead to a condenser, where a heat exchanger provides water based heat to the district heating network.

Mixed biomass fuel:
The BFB combustion plant is appropriate for incinerating different kinds of wastes, such as wood wastes, bark, paper and sewage sludge, as well as different organic materials, oil and natural gas etc. (Bubbling Fluidised Bed, Babcock & Wilcox, 1999). The BFB combustion plant can thus be regarded as a multi-fuel technology, but large quantities of wastes on a liquid form feed to the plant are not favourable (Ole Madsen, Vølund, Interview, Brøndby the

24-10-01). As the biomass is fed into the furnace in which it is combusted, there is limited internal circulation of bed and fuel materials which makes the BFB more reliable, especially where the fuel has an inhomogeneous composition. In the BFB, the biomass are mixed by the "bobbling" effect in the furnace, which increases the fuel mixture and thereby the homogeneity (Niels Bjarne Rasmussen, DGC, Interview, Hørsholm the 12-10-01). If the biomass is also pre-mixed and downsized the technology is capable of incinerating almost any kind of waste (Ole Madsen, Vølund, Interview, Brøndby the 24-10-01).

High moisture biomass fuel:
As designed as BFB *combustion* plant, the technology is capable of incinerating wastes with moisture contents equal to that of a traditional Steam Turbine Plant.

7.1.1.6 Technical level and Danish experiences

The BFB combustion plant with Steam Engine application is a *mature* technology. The combustion and Steam Engine principles are well-know technical applications, and have proven reliable. As opposed to the circulating principle, the BFB combustion process is relatively simple, and only to a minor extent based on fluid dynamic principles, which makes the technology less vulnerable (Ole Madsen, Vølund, Interview, Brøndby the 24-10-01).
In Denmark, the FB combustion technology is, for instance, implemented at Grenå CHP Plant, supplying district heating to residencies and process heat (steam) to local industries. Here, it has been possible to implement the FB combustion technology based on the circulating principle, as the fuel (coal and wood chips) has a very homogeneous composition (The analysis report of the Plant Grenaa Kraftvarmeværk - Denmark, Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, 2000).

For industrial uses only, the BFB combustion plants are not commonly implemented in Denmark, as opposed to, for instance, Japan where it is widely used in industries (Tom Wismann, Dk-Teknik Energi og Miljø, Pers.Com., Gladsaxe the 12-1-02 & Ole Madsen, Vølund, Interview, Brøndby the 24-10-01).

7.1.2 Digestion

7.1.2.1 Biogas Plant with Gas Engine application

Biogas Plant:
A Biogas Plant is technically a relatively simple technology in which organic materials are mixed in one or more pre-processing tanks. The biomass mix is then pumped into a digestion chamber (or reactor), in which it is heated by internal process heat and digested anaerobic (without oxygen). Most larger Biogas Plants in Denmark - so called Joined or Centralised Biogas Plants - are operated at mesophilic (30 to 40 ºC) or thermophilic (50 to 60 ºC) levels of temperature (Danish experiences with small scale decentralised biogas plants, Rikke Lybæk, Proceedings to the Polish-Danish Workshop on Biomass, Gdansk, 2000).

The digestion chambers are fully stirred gas-tight tanks, and the digestion process is ensured by a bacterial culture consisting of natural bacteria, which adapts to the individual plant environment over a few weeks or months. In the biological decomposition process, the bacteria produce biogas, which consist of approximately 55 to 65 % methane (CH_4), 35 to

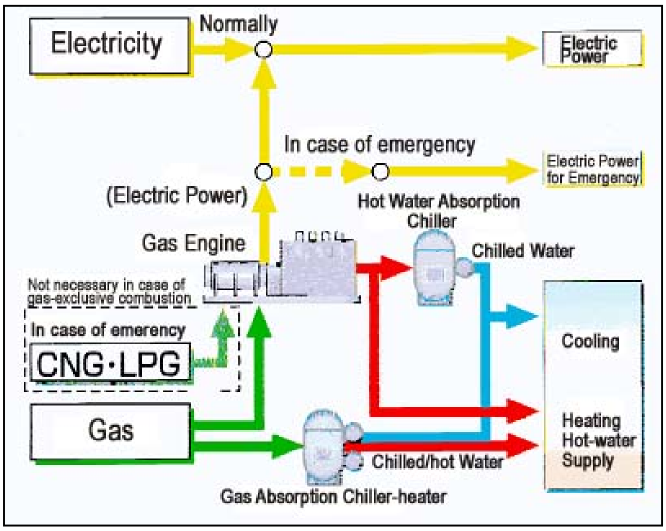
45 % carbon dioxide (CO_2) and 0 to 0.50 % sulphur (H_2S) (Fokus på Biogas, DTI, 1996). All Centralised Biogas Plants are operated as a continuous process, which means that a certain amount of digested biomass is continuously pumped out of the reactor, while a new un-digested amount is pumped into the reactor. Normally, the biomass remains in the reactor between 12 and 25 days, depending on the process temperature (the lower temperature the longer residence). The developed gas is collected in a "gas-bell", or in a gas secures PVC-bag in a technical container, and burned in a Gas Engine for electricity and heat production (Danish experiences with small scale decentralised biogas plants, Rikke Lybæk, Proceedings to the Polish-Danish Workshop on Biomass, Gdansk, 2000).

Gas Engine (reciprocating engines):
Gas engines are internal combustion engines operating on the same familiar principles as petrol and diesel engines for automobiles. In general, reciprocating engines have high electricity efficiency, but generated heat does not reach high temperature levels. There are two sources of heat recovery for reciprocating engines: engine exhaust gas, which can reach temperatures of 400 ºC and represents up to half of the generated thermal energy, and an engine jacket cooling water system reaching lower temperatures. In many applications, the heat recovery from the engine and cooling equipment is cascaded together to produce one single heat output, normally generating hot water at around 100 ºC (A guide to Co-generation, COGEN Europe, 2001).

Heat recovery can be quite efficient for small Gas Engines and therefore often implemented at low energy consuming facilities, particular at those having a larger demand for electricity than heat. Gas Engines are, therefore, appropriate for production of low pressure/temperature steam as well as water based heat (Co-generation as a means of pollution control and energy efficiency in Asia, United Nations, Undated).

Size/efficiency:
Gas Engines are produced in the range of 0.25 to 50 MW electricity (Mogens Weel Hansen, Dk-Teknik Energi og Miljø, Pers.Com., Gladsaxe the 18-1-02). Even when not operated on full load, thus for instance over-dimensioned, the efficiency is close to optimum. The costs of implementing Gas Engines are, furthermore, not determined by the size, thus small Gas Engines are not relatively more expensive (per MW) than larger Gas Engines (Pers.Com., Jan Andersen, 2002).

Figure 7C: Gas Engine and principal diagram



Source: Ms. Christina Widjaya, COGEN, 2003

7.1.2.2 Resource and End-use demands

Mixed biomass fuel:

The Biogas Plant is technical optimal for biomass fuels being of a mixed composition, and except from solid wastes it can convert almost any kind of wastes, thus a multi-fuel technology. On Danish Joined Biogas Plants - as well as on some Small scale Decentralised Biogas Plants - the biomass consists of manure (primarily) plus various other organic materials such as, for instance, organic household waste, sludge from WWTPs and organic industrial waste. This can be flotation and fermentation sludge from food industries, gastrointestinal substances from slaughterhouses, waste from fish, brewery and dairy industries etc.

Only limited amounts of industrial wastes from case industries - except from bio-oil - can be converted when applying the Biogas Plant scheme, unless the wastes, which currently are dried, are kept on a liquid form (as the fermentation and production sludge). Thus, sludge from the WWTP, household wastes and bio-oil can be applied to this technology. The Biogas Plant with Gas Engine application cannot, however, cover End-use demands in industries, as the amounts of steam generated by this technology is limited.

High moisture biomass fuel:
At Biogas Plants the problem is not as much moisture contents of the utilised biomass, but rather the amounts of dry matter, which may not exceed approximately 12 %, as it limits the possibilities of pumping the biomass.

7.1.2.3 Technical level and Danish experiences

Biogas Plants are *mature* technologies even though the actual implementation has been limited in Denmark. Danish experiences with operating Biogas Plants on sludge from WWTPs, in combination with for example household wastes, are, however, limited. The only plant in Denmark operating by this concept is Grindsted WWTP, which digests sewage sludge in a combination with source separated municipal solid waste and industrial organic waste (Grinsted Municipal Waste Water Treatment Plant, M. Hedegaard et.al., Proceedings of the 9th European Bioenergy Conference; Biomass for energy and the Environment, Vol. 2, 1996). In Denmark, digestion of household waste is primarily done at Joined Biogas Plants in combination with pig manure.

7.2 Evaluation of technology

The ***Bobbling Fluidised Bed with Steam Engine application*** as well as the ***Steam Turbine Plant***, are well-proven and *mature* technologies that - with certain limitations - can be described as multi-fuel technologies with capabilities to produce both steam and water based heat. The sensitivity regarding fuel compositions - structure and content - is relatively low compared to other technologies. As opposed to the Steam Turbine Plant, a pre-treatment of the wastes is necessary if implementing the BFB combustion plant, as a size-specification of the fuel occurs. Both the Steam Engine and Turbine applications are mature, and widely utilised in industrial as well as district heating environments around the world.

The ***Biogas Plant with Gas Engine application*** faces difficulties in covering End-use demands in case industries, as the amounts of steam generated is limited. Thus, End-use demands in case industries cannot be covered when applying this technology. When looking at the industrial wastes available, the Biogas Plant also lacks the capability to convert solid wastes (for instance wood), which make up for a relatively high-energy potentials of the total amount of industrial wastes. Apart from the lack of capability to convert solid wastes, the Biogas Plant can be regarded as a multi-fuel technology. The Biogas Plant is also regarded as a *mature* technology, even though the actual implementation of the scheme is quite limited in Denmark, when looking at the potentials (amounts of organic wastes and animal manure).

7.3 Strategies in developing an energy system

Analysis has showed that Steam Turbine Plants, as well as BFB combustion plants with Steam Engine application, are appropriate technologies for coverage of End-use demands in case industries, by conversion of industrial wastes - both factors determined by the specific local context.

The Biogas Plant with Gas Engine application has proved inappropriate for coverage of End-use demands, and in conversion of *all* industrial biomass waste found. The technology might, however, be appropriate for conversion of sludge and sorted household waste in a later stage of the development of an energy system in Navanakorn Industrial Promotion Zone. In this initial phase, however, uses of this waste have second priority. Thus, the Industrial Materials Network Supporting Resources and Systems can, in the specific context of Navanakorn, not be used in the initial build-up of an energy system. Thus, the further analysis to be elaborated in Chapter 8 will be focusing on the Steam Turbine Plants and the BFB combustion plants with Steam Engine application.

Chapter 8; Macro Industrial Metabolism - Design of the energy system

As a part of optimising the Triangle, the *first section* of this chapter will describe how to design the supply of district heating for efficient transmission and cascading of energy. Then there will be an analysis of how conversion of certain wastes from case industries can be adopted by the different technologies, and whether a flexible plant operation can be established. The latter issue is important as industries greatly depend on energy services from the plant, and it is therefore beneficial if the energy production can be re-established relatively soon after close down etc.
The technologies will also be discussed in relations to their capabilities of meeting changes (increases) in energy consumption within industries, as emphasised in Chapter 6. A strategy for design of the energy system will thus be discussed, which for instance includes whether or not the energy system must be over-dimensioned in order to meet future energy demands, and how to establish the district heating network. Transformation possibilities of the energy system will be emphasised, starting with the creation of an initial energy system, which is expanded later, as the energy demands increase.

In the *second part* of this chapter an environmental evaluation of technical options (Emission analysis and Performance of the two technologies), will be included to narrow down the final choice of which technology to use. Contextual conditions and choice of technologies, when looking at the local resource base regarding manufactures of energy technologies, are also emphasised in this section. In the *third section*, a Pre-Feasibility Study will emphasise economical issues of two technologies studied.

8.1 Optimising the Triangle

In the following an optimisation of the Triangle will be developed, building on the results of the analysis made in previous chapters.

8.1.1 Steam Turbine Plant and BFB combustion plant

8.1.1.1 Energy supply and location of the energy plant

When using a Steam Turbine Plant or a BFB with Steam Engine application, it is possible to cover different levels of process heat requirements by the extraction of steam at different levels in the energy production. By using a separate steam outtake, in which steam temperatures are lowered to the actual End-use demand by electricity production, steam can be supplied to customers by the district heating system (Niels Bjarne Rasmussen, DGC, Interview, Hørsholm the 12-10-01). Return steam (or "waste steam") from one or more steam customers, which now has a lower temperature level, re-enters the plant and is thereafter cooled by the district heating network, supplying water based heat to the remaining industries (Jesper Bolin, Masnedø CHP Plant, Interview, Vordingborg the 4-10-01).

Steam must be piped in separate high pressure steam pipes to industries requiring this type of energy service. Normally, steam will be piped at a constant temperature (for instance at 250 ºC as required by Imperial), and industries thus extract the energy needed (amount and temperature) from the pipe by individual service lines[48]. If steam is required at temperatures lower than 250 ºC also, it can be obtained by adjustment of the valve at the individual industry (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 27-11-01). As B.B. Snacks, however, will receive "waste steam" from Imperial, this system must preferably be designed as piping of *heat in series*, in order to create the cascading effect. "Waste steam" from Imperial - supplied to the steam pipe by a service line - is thus transmitted for further use in B.B. Snacks.

The water based heat supply must preferably be implemented as a *parallel system* with the application of transmissions and return-water pipes. If piping water based heat in series, the temperature of the hot water will constantly be lowered - due to the industries extracting heat - whereas the parallel system provides a constant temperature of the water based heat. Thus, by transmissions from the condenser, water based heat are extracted by individual service lines in industries, which enables a constant high temperature in the district heating network (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 27-11-01).
As described in Chapter 6, Imperial can possibly also supply "waste heat" to the district heating network, hence contributing to deliverance of water based heat. The cascading of energy firstly happens via the cascading of steam from Imperial to B.B. Snacks, and then secondly as the condensing of steam by the cascading of water based heat to the remaining industries through the district heating network.

The production of electricity can, however, be influenced negatively when energy is extracted for large steam customers, as it affects the CV-value (losses in capability to generate electricity due to a large steam outtake) (Pers.Com., Jan Andersen, 2002). It is therefore important to extract the steam as late in the process as possible, in order to utilise the energy in the steam for electricity production also (Per Lyngsø Nielsen, Haslev CHP Plant, Interview, Haslev the 9-10-01). In order to provide steam at the required temperature, the steam temperatures in the Turbine or Engine are lowered to the necessary level by electricity production. As peak heat (steam) temperatures are relatively low (250 ºC), it is also possible to produce electricity (Ibid.). The outlet temperature of district heating produced by co-generation plants can be approximately 95 ºC (3 to 4 bar), which is sufficient to cover water based heat requirements in case industries (Per Lyngsø Nielsen, Haslev CHP Plant, Interview, Haslev the 9-10-01). In Denmark, such transmissions of steam *and* district heating have, for instance, taken place at H.C. Ørsted CHP Plant (Pers.Com., Jan Andersen, 2002).

As energy demands are, by all means, largest at Imperial, it is favourable to implement the technology at, or close to, this industry. This will reduce expenses in high pressure steam pipes, and reduce eventual losses of steam due to piping.

[48] ('stikledninger')

8.1.1.2 Composition of waste and specific plant design

The actual composition of biomass wastes in the case area makes it possible to use a burner (or an over-heater) in the ***Steam Turbine Plant***, which can increase and stabilise the combustion of mixed fuel, by burning bio-oil. A burner is placed over the grate where the biomass wastes are incinerated, and it spits-in (distributes) and atomise the bio-oil by an oil-pump. Together with air-injections this process stabilises the combustion of biomass waste, and as such, reduces the negative effect of a fuel with variable energy potential (calorific value). Even when biomass wastes are mixed appropriately, there is always a risk that the temperature will decrease due to a variable composition of the fuel, which can influence the total efficiency of the plant (Niels Bjarne Rasmussen, DGC, Interview, Hørsholm the 12-10-01).

Especially when incinerating biomass wastes with relatively high moisture content - plus wastes with a very inhomogeneous composition in regards to content and structure - a burner can be efficient when operating a Steam Turbine Plant (Ole Madsen, Vølund, Interview, Brøndby the 24-10-01). Another possibility, when applying relatively high moisture biomass fuel, is to pre-heat the air - from for example 30 to 200 ºC - and inject it into the furnace for combustion support. This will affect the overall temperature in the combustion zone, and thus enable the development of a higher temperature level in the furnace, which again can result in improvements in steam generation, and thus electricity production (Ibid.).
The bio-oil can also be utilised with a specific purpose in the ***BFB combustion plant***. The bed material, placed at the bottom of the furnace, is normally heated up by uses of fossil fuels during start-ups. The bio-oil can thus be used with this specific purpose (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 27-11-01), or as fuel in a burner for combustion support, as for the Steam Turbine Plant.

When using a burner, the bio-oil must reach at least 10 to 20 % of the total burning value in order to be efficient, and the supply of bio-fuel must be constant (Niels Bjarne Rasmussen, DGC, Interview, Hørsholm the 12-10-01). For fuel flexibility the burner can be implemented as a dual-fuel technology, as being capable of incinerating (fossil and bio) oil as well as (natural and bio) gas (Ibid.).

8.1.1.3 Plant flexibility

Steam Turbine Plants are not an optimal technology if the energy production must be closed down or re-started on a daily basis, for example due to sales of tariff electricity as seen in Denmark. It will take a Steam Turbine Plant a minimum of 12 hours to reach a stable energy production (Ole Madsen, Vølund, Interview, Brøndby the 24-10-01). Thus, Steam Turbine Plants must preferably be operated on full load to be efficient (The Danish follow-up programme for small-scale solid biomass CHP Plants, Energistyrelsen, 2000).

If the plant has to be closed down in certain periods - for instance during weekends - the before mentioned burner operating on bio-oil can also affect the flexibility of the technology, as increasing the plant's capability to re-start due to injections of fuel (Anvendelse af naturgas sammen med fast biobrændsel, DGC, 2000). The reduction in operation loads on Danish Steam Turbine Plants is primarily caused by the decrease in heat requirements during summer periods. It is only possible to produce electricity corresponding to the size of the heat market (unless water based heat is stored in accumulation tanks) (Jesper Bolin, Masnedø CHP Plant, Interview, Vordingborg the 4-10-01).

The ***BFB combustion plant*** shows higher flexibility in start-up and close down compared to the Steam Turbine Plant. Once it has reached a steady temperature, the plant can be closed down - for instance during the weekend or at nights - and relatively easily re-started. The bed material reaches a temperature of approximately 850 ºC and relatively slowly looses the high temperature level, as the bed material tends to keep it warm. Thus, if the plant must be closed down for the night, or even during the weekend, it can relatively quickly be operated on full load again. The bed material will still be so warm that any biomass wastes fed into the furnace will ignite immediately (Ole Madsen, Vølund, Interview, Brøndby the 24-10-01).

As seen in the End-use analysis in Chapter 6, the conversion technology must be operated at full load or 7,000 operation hours per year, to cover End-use demands. Thus, the technology will not be closed down during nights, but only for service checks and possibly on Sundays, when Imperial closes down production. Still, it is important that the energy production can be re-established relatively quickly, as industries depend on the energy services. If the duration curve showed fewer operation hours per year, due to for instance close downs at nights or the entire weekend etc., the plant's capability of re-establishing the energy production were even more important to emphasise than in this case. This would for instance have put stronger focus on the implementation of Gas Engines or Gas Turbines, as being quick start-uppers.

8.1.1.4 Capacity of meeting increases in End-use demands

The ***Steam Turbine Plant*** can be over-dimensioned in order to meet future energy demands. This can, for instance, be applied as over-dimensioning in or implementation of more than one boiler, just as the Turbine application can be used with a larger capacity in the initial phase. Furthermore, facilities regarding handling and storage of wastes can be prepared for larger amounts of wastes. This can be done, for instance, by increasing the depth of the waste storage facility already from the beginning. The use of boilers in modules, and extra capacities regarding handling and storage of wastes, is relatively inexpensive arrangements in future energy capacities (Pers.Com., Tyge Kjær, 2001). The use of more than one boiler - designed in accordance with the specific fuel - can also increase the efficiency of converting, for instance, wood wastes, as the combustion happens more effectively when not being mixed with other types of waste. As the amounts of biomass waste increases, wood wastes can thus be separated and applied to an individual boiler for more efficient combustion.

Over-dimensioning of the technology must preferably be applied to parts where a substitution later on is unnecessarily expensive, as for instance the Turbine application. As emphasised in Chapter 7, it is, however, not favourable to over-dimension the Turbine by more than 10 to 20 % as it affects the efficiency of the plant (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 27-11-01 & Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 3-12-01). This happens as the over-dimensioning causes non-full load operation of the plant, and thus low efficiency in fuel uses. This, again, leads to a reduction in the furnace temperature and thereby affects the steam production (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 3-12-01). Thus, Steam Turbine Plants are not favourable when pursuing over-dimensioning of more than 10 to 20 % of the capacity needed.

The ***BFB combustion plant*** can also be over-dimensioned in the initial phase of the energy system, to meet future increases in energy consumption. The size of the BFB combustion plant normally varies between 2 and 10 MW thermal output, as a further up-scaling has proved difficult. If End-use demand exceeds this figure, the use of more than one unit is usually approached, especially in industries (Ole Madsen, Vølund, Interview, Brøndby the 24-10-01).

Steam Engines can also be implemented as modules, which, for instance, have been promoted by a company called Spilling, which produces Steam Engines. The Spilling Engine is based on a single cylinder module, which can be put together with other modules making larger engines. With three different module sizes, it is possible to create 5 or 6 modules in combination, which can have an effect ranking from 0.27 MW to 1.40 MW electricity. Spilling Steam Engines are primarily introduced for industrial uses (Technologies for Small Scale Wood-Fuelled Combined Heat and Power Systems, Søren Houmøller, et. al., Dk-Teknik Energi og Miljø, 1998). As emphasised in Chapter 7, Steam Engines are less sensitive to over-dimensioning compared to Steam Turbine Plants.

According to Henrik Houmann Jakobsen the only area, in which it is quite favourable to pursue over-dimensioning, is in pipes for ***district heating*** purposes. Thus, the only technical application in which an up scaling is appropriate is in the transmission system; the district heating pipes. In order to prepare the energy system for future increases in heat transmissions - for instance to other industries as well - the main pipeline can be scaled up. This will facilitate a future increase in heat transmissions, and reduce the relatively large expenses in doing so at a later stage (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 3-12-01).

8.1.2 Evaluation of the most optimal design of energy system

In regards to plant flexibility, the BFB combustion plant is more favourable compared to the Steam Turbine Plant. As the energy plant will be operated 7,000 hours per year, close down and re-starts will not happen so often. Still, close downs for inspection and maintenance will take place, and it is therefore important that industries can be supplied relatively fast with energy again. In regards to the design of the district heating system, as well as capabilities of meeting future increases in energy demands, there are no advantages in either of the technologies. Except from the Steam Engine, which can be over-dimensioned slightly more than the Turbine - without causing inefficiencies - there are no advantages of either of the two technologies. In general, over-dimensioning of the technologies has proved to be an unfavourable strategy, as it affects the efficiency of the technologies and thus plant economy.

Both technologies can benefit significantly from uses of the bio-oil as combustion support, by use of a burner, and the BFB plant can even utilise this biomass for heating up the bed, thus phasing out the use of fossil fuel for this purpose. In regards to size-specification of the fuel, the BFB combustion plant require a certain pre-treatment. This will make the energy production more costly, but possibly increase the energy output due to the use of a more homogeneous fuel.

8.1.3 Strategies in developing an energy system

The energy system will be based on the piping of steam in a *parallel system* and water based heat *in series*. Over-dimensioning will not be pursued on technical parts, as it affects the efficiency and costs of the energy plant. In regards to the issues analysed above, there is no significant argument for selecting one of the two technologies just yet.

8.2 The transformation strategy

It is the overall wish in the development of an energy system in Navanakorn Industrial Promotion Zone, to create a flexible system in regards to both investment and further expansion. Such flexibility can be obtained by the creation of an initial energy system, which opens up the possibility for transforming and expanding the system by additional energy production in a later stage.
As emphasised earlier, this can, for example, include the implementation of a multi-fuel technology for conversion of all wastes, including "treated" waste (from liquid to solid form). Later the energy system can be expanded by an additional technology, which is capable of converting certain wastes in accordance with their "original" form. A *multi-fuel incineration plant* will, therefore, be beneficial in the initial stage of the energy system, and then later expanded by a Biogas Plant for conversion of liquids from industries and Industrial Materials Network Supporting Resources/Systems (household waste and sludge). But how must the initial energy system be designed? And how will the transformation take place?

As seen in Chapters 5 to 7, it is possible to cover End-use demands in case industries, only by uses of industrial wastes in combination with industrial/commercial waste collected by the Main Office of Navanakorn. By using these wastes, matching the specific End-use demand, it is possible to implement a technology, which can be operated on a full load basis. This again improves the plant economy and can provide a "good example" of implementation of biomass technologies in industries. As stated earlier, over-dimensioning will not be pursued in the development of an energy system, as it affects the plant efficiency and thus economy.

Future short-term energy increases must preferably be dealt with by DSM strategies, as emphasised in Chapter 6, where significant energy saving could be obtained. By district heating and the cascading of steam and "waste steam", increases in future energy requirements can be delayed or "eaten up". As biomass wastes increase (supposedly) linear to increases in energy uses, surplus wastes will evidently be developed. As this surplus grows larger, the foundation for a new energy technology takes place, and a transformation of wastes in accordance with their "original" form - and thus conversion technology - can take place. Therefore, when the amounts of wastes consisting of wood, fermentation and production sludge, as well as bio-oil, increases significantly, the expansion or transformation can take place:

The ***first transformation*** is to utilise (former treated) liquids, as well as household waste etc., in their "original" form, and thus only apply "natural" solids (as for instance wood) to the multi-fuel incineration plant. As the amounts of wood wastes increase the implementation of a separate wood boiler, in connection to the multi-fuel incineration plant, will be advantageous. This can enable a more efficient combustion of wood wastes, compared to wood incinerated together with other solid biomass wastes. For co-generation purposes, the flue gas from the wood boiler can be mixed with the flue gas developed in the incineration plant, thus producing more steam (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 27-11-01).

As low quality heat (water based heat) mainly is the outcome on Biogas Plants, emphasised in Chapter 6, a ***second transformation*** of the energy system can now take place. As DSM strategies are eventually "eaten up" by long-term increases in energy uses, the need for water based heat (and possibly also steam) will evidently increase. Thus, low quality heat, produced at the Biogas Plant, can now solely provides coverage of district heating demands (water based heat), whereas high quality heat (steam) is produced on the (former) multi-fuel incineration plant.

8.2.1 Back-up system

Case industries must have a back-up system in case the energy technology breaks down, or for other reasons cannot provide energy services. One possibility is to maintain the individual fossil fuel boilers placed at each industry (except at those converting from process heat by electricity to process heat by district heating). This will, however, require a certain stand-by operation of the boilers and thus fossil fuel uses on a constant basis, as the boilers cannot be closed down completely. If so, it will affect the boiler's capability to produce process heat (Jan Sandvig Nielsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 18-1-02).
It is also possible to supply some sort of Back-up of water based heat, by the piping of surplus heat - produced during night - to storage in accumulation tanks, as emphasised earlier.

Another back-up system is to use a Steam Boiler for process heat generation only, and let industries receive electricity from the grid. The Steam Boiler can, for instance, be operated on natural gas or fuel oil, and thus relatively fast reaching peak efficiency for thermal energy production. As pipes for natural gas supply most likely will be prolonged to Navanakorn Industrial Promotion Zone (Mr. Vijit Tangnoi, Petroleum Authority of Thailand (PTT), Interview, Bangkok the 14-2-01), it is relatively simple to install a service line to the Steam Boiler providing natural gas. Depending on the "stand-by" fee for natural gas uses etc., it might be more favourable to utilise fuel oil. A Steam Boiler producing process heat can be implemented as a low cost back-up system, whether being new or second hand equipment. The costs of implementing such back-up system can thus be regarded as included in the Pre-Feasibility Study presented in section 8.5, as general data insecurities (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 10-4-02).

8.2.2 Strategies in developing an energy system

The initial energy system will be based on coverage of End-use demand, and is thus a match of the current energy requirements. No over-dimensioning will be pursued - except from the heat transmission system - as it affects the efficiency of the plant and thus the plant economy. The initial energy system is based on the "good example" of using renewable energy technologies with a sound economy. The transformation of the energy system starts in a multi-fuel incineration plant, which in the initial phase converts all biomass wastes (dried liquids and solids). But as the energy demand, and generated biomass wastes, increase - beyond what can be limited by DSM - a Biogas Plant is implemented, for conversion of dried liquids in their “original” form, together with household waste and sludge. The transformation now continues, as low quality energy is to be covered by the Biogas Plant, and high quality energy by the (former) multi-fuel technology, optimised for incineration of solids only.

8.3 Environmental evaluation of options

8.3.1 Performance of technologies

Reduced SO_2 and NO_x

Because of lower operating temperatures in ***BFB combustion plants***, it is possible to use inexpensive materials such as limestone or dolomite[49] as media for removal of SO_2 from the flue gas. Normally, cleaning with dry scrubber is a very expensive way of limiting emissions, and is not usually applied on biomass co-generation technologies. When limestone or dolomite is added to the bed material in the bottom of the furnace, it is, however, possible to obtain the same cleaning standard by means of an inexpensive method. As the limestone is mixed with the bed in the furnace, a reaction, between the resulting calcium oxides (CaO) and SO_2, occurs in the flue gas. Emissions of SO_2 can be reduced by 90 % or more, depending on the sulphur content of the biomass wastes and the amount of limestone added (Steam - its generation and use, S.C. Stultz and J.B. Kitto, Babcock & Wilcox, 1992).

When nitrogen and oxygen react at high temperatures (above 1,480 ºC) nitric oxide (NO) is formed. NO is the primary nitrogen compound formed in the high temperature combustion process, where nitrogen - present in the biomass wastes or in the combustion air - combines with oxygen to NO_x. The rate of this reaction decreases rapidly, as the temperature is lowered from this level. With an bed temperature of 820 to 870 ºC, the amounts of NO_x - formed in the BFB Plant - is lower than in conventional plants (for instance Steam Turbine Plants) operating at higher temperature levels (Steam - its generation and use, S.C. Stultz and J.B. Kitto, Babcock & Wilcox, 1992).

In BFB combustion plants, additional suppression of NO_x can also be obtained by air staging[50]. Staged combustion uses low excess air levels in the primarily combustion zone, with the remaining air (over-fire air) injected higher in the furnace for complete combustion. The staging of air delays the adding or injection of excess air, until the flue gas has transmitted (radiated) heat to the water walls in the furnace, thereby obtaining a lower temperature level and thus preventing NO_x emissions (Steam - its generation and use, S.C. Stultz and J.B. Kitto, Babcock & Wilcox, 1992).

In traditional ***Steam Turbine Plants***, it is not possible to use low-cost SO_2 reduction by limestone uses, as in BFB plants. Here, at dry or semi-dry lime cleaning equipment must be implemented, which is very costly (Jesper Cramer, DK-Teknik Energi og Miljø, Interview, Gladsaxe the 17-12-01). Staged air can also reduce emissions of NO_x in Steam Turbine Plants, and, for example, designed as injections of excess air by ‘under grate-fire air’ or ‘over-grate fire air’, hence creating staged air in the furnace. The deeper the staging, the larger reduction in NO_x emission can be obtained (Steam - its generation and use, S.C. Stultz and J.B. Kitto, Babcock & Wilcox, 1992).

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[49] (’kalksten og bitterspalt/dolomit’)
[50] (’stillestående luft’)

Apart from air staging and low temperature levels in the furnace, NO_x emissions can be controlled by the quantities of nitrogen and oxygen available, the temperature in the furnace and the level of mixing and the reaction time in the furnace (Ibid.).

8.3.2 Evaluation of technologies

As seen from the above analysis of Performance of technologies it is evident that the BFB Plant is superior in environmental performance. By inexpensive means of SO_2 and NO_x removals, it is possible to reduce the amount of SO_2 and NO_x emitted to the atmosphere. As the temperature in the BFB Plant furnace is relatively low, it prevents the development of NO_x. Due to this low temperature level, air staging is obtained quite efficiently by this technology, compared to the Steam Turbine Plant, which operates at much higher temperatures.

8.3.3 Emissions analysis

(See the results of the Pre-Feasibility Study, which ends this chapter)

8.3.4 Strategies in developing an energy system

When looking at environmental performance only, it is evident that the BFB combustion plant is superior to the Steam Turbine Plant. As both the costs of the technology, and whether a local production of the technologies mentioned, are unknown factors, a specific selection cannot be made just yet.

8.4 Contextual conditions and choice of technology

Seen in the Thai context both Steam Turbine Plants and BFB combustion plants are modern and advanced technologies, which require skilled workers to operate - just as in the West. The furnace part of the BFB combustion plant is slightly more advanced, compared to the traditional grate fired furnace in the Steam Turbine Plant. The biomass fuel requires a certain pre-treatment when applying the BFB Plant, due to (minor) size-specifications of the fuel, which is not required by the Steam Turbine Plant. As the BFB is designed with Steam Engine application, it is, however, more simple compared to the Steam Turbine Plant based on the Turbine principle. Steam Engines are relatively simple in operation and maintenance is limited (Technologies for Small Scale Wood-Fuelled Combined Heat and Power Systems, Søren Houmøller, et. al., Dk-Teknik Energi og Miljø, 1998).

Very important for the choice of technology is the resource base in Thailand, as Steam Engines are actually being manufactured in Thailand (Technologies for Small Scale Wood-Fuelled Combined Heat and Power Systems, Søren Houmøller, et. al., Dk-Teknik Energi og Miljø, 1998), which means that a resource base already exists for further use and development of this technology. At least three manufactures of Steam Engines can be found, of which one produces quite efficient engines (Mr. Chainchai Limpyakorn, ATA, Interview, Bangkok the 24-4-03). Such a resource base does not exist in Thailand for the production of Turbines, which is a more complicated and advanced applications compared to Steam Engines. When using a BFB Plant based on combustion principles, it is, also, possible to utilise a traditional boiler (Mogens Weel Hansen, Dk-Teknik Energi og Miljø, Interview the 4-2-02), when applying certain technical adjustments, especially in regards to the air supply in the bottom of the furnace.

Traditional boilers are already manufactured in Thailand, and therefore it can also be possible to utilise Thai manufactured boilers. Most Thai boiler manufactures produce the traditional fire tube boilers, but there are also manufactures of the more efficient water fire tube boilers (Mr. Somkiat Sutiratana, DEDP, Interview, Bangkok the 24-4-03). One manufacturer of water tubes boilers is for instance Bangkok Industrial Boilers, which produces both fire and water tube boilers. Both designs are licence manufacturing based on an Australian company's products (Mr. Chainchai Limpyakorn, ATA, Interview, Bangkok the 24-4-03).

If a Steam Turbine Plant is selected, at least the Turbine part of it must be imported. Turbines are, however, a very significant cost when implementing a Steam Turbine Plant (Pers.Com., Tyge Kjær, 2002). It is therefore favourable to pursue full supply of technical solutions from the home country if possible, or at least technical solutions from the South East Asia region (Mr. Somkiat Sutiratana, DEDP, Interview, Bangkok the 24-4-03). Thus, by means of supply and independence from Western countries - including Denmark - Thailand could benefit significantly by expansion and further improvements of domestic technologies, as opposed to import of technologies from the West. All previous analysis show that the BFB Plant with Steam Engine application can cover energy demands in case industries.

According to Swaay et. al., developing countries can benefit significantly from promoting manufacturing and use of national technologies. Investment costs in equipment and technologies produced in the countries themselves, can reduce the costs by a factor of four compared to that manufactured in the West (Quoted in; Energy from biomass: a review of combustion and gasification technologies, Peter Quaak, et. al., World Bank, 1999). It is, therefore, very important to promote a national resource base in technology development; especially in this case where the foundation is already laid for such national manufacturing of energy technologies.

8.4.1 Strategies in developing an energy system

According to analysis of contextual conditions for technology use, the BFB Plant with Steam Engine application has shown to be favourable, as a domestic production of these technologies are present in Thailand (adjustments of the traditional water tube boiler must, however, be applied). A final selection, however, will depend on the financial situation, as emphasised below.

8.5 Pre-Feasibility Study of options

Background calculations and pre-conditions for the Cost-savings analysis etc. are outlined in Annex C and D (part 1) - Excel work sheet.

8.5.1 Cost-Savings analysis

In the Cost-savings analysis, it is assumed that biomass wastes can be applied without costs (expenses). Wastes from case industries are thus applied freely. Certain industries can even benefit economically from applying the wastes to the energy plant, as they currently pay a fee for waste management services. These savings are not included in the Cost-savings analysis, as it is assumed that another form of waste collection must be established. It is likely that this waste collection will be significantly cheaper, as no actual profit must be generated from the collection of biomass waste. In the Cost-savings analysis it is also assumed that industrial/commercial wastes can be applied freely, as it now represents a cost for the stakeholders. In the Sensitivity analysis, however, an "Upper price limit for biomass wastes" is calculated, in case some sort of price level develops.

As opposed to establishing an individual grid connection between Industrial Materials Network participating industries in Navanakorn, it is further assumed that the electricity is transmitted on the national grid, and that a "wheeling" fee for this is charged by the Electricity Generation Authority of Thailand (EGAT). Moreover, the energy saving options and strategies for converting steam uses to water based heat uses by district heating, as emphasised in Chapter 6, are not included in the economic calculations. This is due to the fact that such calculations will be based on too many assumptions and thus insecurity in data validity. Costs for storing the biomass wastes as well as sorting it - for instance when size-specifications are required (as for the BFB combustion plant) - are also not included for the same reasons.

From the Cost-savings analysis - Figure 8A next page - it can be seen that the BFB combustion plant is more expensive than the Steam Turbine Plant. The ***"Capital Costs"*** are DKK 2.83 Mill. per year for the BFB combustion plant and DKK 2.24 Mill. per year for the Steam Turbine Plant. Thus, the BFB Plant is approximately 25 % more expensive than the Steam Turbine Plant. Due to the difference in Capital Costs between the two technologies, figures for "***Total contribution from energy production"*** as well as "***Marginal contribution of 1 kWh electricity"*** also differs.

Hence, the "Total contribution from energy production" produced by the BFB Plant is slightly smaller, than what can be produced by the Steam Turbine Plant: DKK 2.7 and 3.28 Mill. per year respectively. This again influences the "Marginal contribution of 1 kWh electricity" produced by the two technologies, which are found to be DKK 0.95 and 1.16 per kWh respectively. This means that the energy plant provide industries (earn them) DKK 0.95 and 1.16 each time 1 kWh is produced, when compared to the reference system.

Figure 8A: BFB combustion plant & Steam Turbine Plant

Bubbling Fluidised Bed Plant

Cost-savings analysis

Price of biomass waste per MWh in = none

				Mill. DKK per year					DKK per kWh
Electricity efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Bubbling Fluidised Bed Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.06	1.7	0.77	2.83	2.7	0.95

Sensitivity analysis

Upper price limit of biomass waste per MWh in = DKK 146.50

				Mill. DKK per year					DKK per kWh
Electricity efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs Of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Bubbling Fluidised Bed Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.06	1.7	0.77	2.83	0	0

Price of electricity = 25 % increase
Price of biomass waste per MWh in = none

				Mill. DKK per year					DKK per kWh
Electricity efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs Of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Bubbling Fluidised Bed Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.06	2.13	0.77	2.83	3.12	1.1

Price of fuel oil = 25 % increase
Price of biomass waste per MWh in = none

				Mill. DKK per year					DKK per kWh
Electricity efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Bubbling Fluidised Bed Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.83	1.7	0.96	2.83	3.65	1.29

Price of electricity = 25 % increase
Price of biomass waste per MWh in = DKK 146.50

				Mill. DKK per year					DKK per kWh
Electricity efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Bubbling Fluidised Bed Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.06	2.13	0.77	2.83	0.43	0.15

Price of fuel oil = 25 % increase
Price of biomass waste per MWh in = DKK 146.50

				Mill. DKK per year					DKK per kWh
Electricity efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Bubbling Fluidised Bed Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.83	1.7	0.96	2.83	0.96	0.34

Emissions analysis

Ash = 43.47 Tons TS/year
SO_2 = 0.2 Tons/year
NO_x = 2.17 Tons/year

(Data source based on calculations in Annex C & D)

Steam Turbine Plant

Cost-savings analysis

Price of biomass waste per MWh in = none

				Mill. DKK per year					DKK per kWh
Electricity Efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Steam Turbine Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.06	1.7	0.77	2.24	3.28	1.16

Sensitivity analysis

Upper price limit of biomass waste per MWh in = DKK 178.50

				Mill. DKK per year					DKK per kWh
Electricity Efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Steam Turbine Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.06	1.7	0.77	2.24	0	0

Price of electricity = 25 % increase
Price of biomass waste per MWh in = none

				Mill. DKK per year					DKK per kWh
Electricity efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Steam Turbine Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.06	2.13	0.77	2.24	3.71	1.31

Price of fuel oil = 25 % increase
Price of biomass waste per MWh in = none

				Mill. DKK per year					DKK per kWh
Electricity efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Steam Turbine Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.83	1.7	0.96	2.24	4.24	1.5

Price of electricity = 25 % increase
Price of biomass waste per MWh in = DKK 178.50

				Mill. DKK per year					DKK per kWh
Electricity efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Steam Turbine Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.06	2.13	0.77	2.24	0.42	0.15

Price of fuel oil = 25 % increase
Price of biomass waste per MWh in = DKK 178.50

				Mill. DKK per year					DKK per kWh
Electricity efficiency (brut)	**Energy input (MWh/year)**	**Size of Plant (MW electric)**	**Electricity output (MWh/year)**	**Subst. Costs of fossil fuel**	**Subst. Costs of electricity**	**Subst. Costs of Boiler-M&0**	**Capt. Costs (incl. M&0..)**	**Total contribution from energy prod.**	**Marginal contrib. of 1 kWh elect.**
Steam Turbine Plant: THERMAL MATCH									
[18%]	18,400.00	0.4	2,834.00	3.86	1.7	0.96	2.24	0.96	0.34

Emissions analysis

Ash = 43.47 Tons TS/year
SO_2 = 2.03 Tons/year
NO_x = 4.35 Tons/year

(Data source based on calculations in Annex C & D)

8.5.2 Sensitivity analysis

Due to the difference in "Capital Costs", the "Upper price limit for biomass wastes" also differs by approximately 22 %. This means that it is possible to pay 22 % more for biomass wastes when using the Steam Turbine Plant, than when using the BFB combustion plant. The "Upper price limit for biomass wastes" is defined as the price, in which the "Total contribution from energy production" is zero (or no economic surplus is generated). Thus, the BFB plant is slightly more sensitive towards fuel prices than the Steam Turbine Plant. Figures are found to be DKK 146.50 and 178.50 per MWh in respectively.

The Sensitivity analysis also focuses on increases in energy prices; a 25 % increase in electricity and heat prices is thus emphasised. Electricity prices are likely to increase in the near future, as Thailand possibly will introduce a CO_2 fee (Mr. Boonthongu Ungtrakul, DEDP, Interview, Bangkok the 7-2-01). Increases in oil prices are also very likely to be introduced, as the remaining oil and natural gas resources in the very near future are overtaken by the rate of which they are extracted (Energi- og klimapolitik i EU og i Danmark, Det Økologiske Råd, 2003).

If the price of electricity increases 25 %, the "***Substituted costs of electricity"*** will increase likewise. As the BFB combustion plant is more expensive than the Steam Turbine Plant, this will of course influence the latter technology more in regards to "Total contribution of energy production" (and of course the price of producing 1 kWh). Figures for a 25 % increase in the electricity price are thus found to be DKK 3.12 and 3.71 Mill. per year.
Also increasing oil prices affect the "Total contribution of energy production", and even more compared to the changes in electricity prices. This is due to the fact that a Thermal Match is applied (total coverage of heat demand), whereas only approximately 34 % of the total electricity demand is covered (when all case industries are included). Again, the BFB combustion plant show a smaller benefit compared to the Steam Turbine Plant, which is due to the initial higher plant expenses. Figures for "Total contribution of energy production", when applying a 25 % increase in oil prices, are found to DKK 3.65 and 4.24 Mill. per year respectively.

Is it also possible to generate an economic surplus when paying the "Upper price limit for biomass wastes", in combination with a 25 % increase in costs of heat and electricity?

When calculating with the "Upper price limit for biomass wastes", in combination with a 25 % increase in electricity prices, the following results are obtained for the BFB combustion plant and the Steam Turbine Plant in regards to "Total contribution of energy production"; DKK 0.43 and 0.43 Mill. per year respectively. And when calculating with the "Upper price limit for biomass wastes", in combination with a 25 % increase in heat prices, the following results are obtained for the BFB plant and the Steam Turbine Plant in regards to "Total contribution of energy production"; DKK 0.96 and 0.96 Mill. per year respectively.

From the above it can be seen, that if the "Upper price limit for biomass wastes" must be paid, in combination with 25 % increases in heat or electricity prices, the largest flexibility are obtained by selecting the Steam Turbine Plant, as the "roof" is more than 100 % larger than for the BFB combustion plant.

8.5.3 Emissions analysis

	BFB Plant	Steam Turbine Plant
Ash (tons TS/year)	(43,47) =[51] 43	(43,47) = 43
SO_2 (tons/year)	(0,2) = 0,2	(2,03) = 2
NO_x (tons/year)	(2,17) = 2	(4,35) = 4

As seen from the Emissions analysis above, the BFB combustion plant is superior to the Steam Turbine Plant in emissions reduction. Emissions calculations are made theoretically based on straw and wood, assumable containing average NO_x contents. It is thus likely that emissions of NO_x are higher when converting wood waste from case industries, as containing glue fractions. Thus, the BFB combustion plants capability to reduce NO_x emissions is a very important performance skill in this specific situation.

8.5.4 Evaluation

Seen from an economic point of view, the Steam Turbine Plant show better results in the Cost-savings analysis compared to the BFB combustion plant. Due to the initial lower plant expenses, the Steam Turbine Plant also show slightly better results when increasing heat and electricity prices in the Sensitivity analysis. This reduced sensitivity also affects the "Upper price limit for biomass wastes", as the Steam Turbine Plant can withstand a higher price per MWh applied. Thus, the economic figure suggests implementation of the Steam Turbine Plant. This changes, however, when looking at the Emissions analysis. The BFB combustion plant can reduce SO_2 emissions by a factor 10 compared to the Steam Turbine Plant. Emissions of NO_x can be reduced by more than 50 %. This is an important factor, seen in the local context, in regards to the population in Navanakorn; their approval of and benefit from the implemented technology.

8.6 Strategies in developing an energy system

The "Total contribution of energy production" is smaller for the BFB combustion plant, compared to the Steam Turbine Plant when manufactured in the West (thus imported to Thailand). It is, however, likely that this cost can be lowered by a factor of four, when the technology is produced by Thai manufactures. Due to the production of Steam Engines in Thailand, and its simplicity compared to the Turbine application, this technology is chosen for implementation in the case area. The technology is also selected for its superiority in environmental performance, compared to the traditional grit fired biomass boiler.

[51] Approximate figures.

Chapter 9; Organisation of the Industrial Materials Network in Navanakorn

The purpose of this chapter is to develop the most appropriate organisation of the Industrial Materials Network in Navanakorn, after examining various aspects of co-operation possibilities and barriers between potential participants. The analysis of the most favourable organisation of the Industrial Materials Network is based on a second Triangle analysis; namely the triangle that develops when looking at 1) Transaction costs/Risk minimisation, 2) Conditions for Inter-industrial Co-operation, and 3) Corporate governance.

The purpose of *Transaction costs/Risk minimisation* analysis is to reduce the overall costs and risks posed on the scheme, which, for instance, can be done by an appropriate inclusion of various stakeholders with potential influence on the project. Through Transaction costs/Risk minimisation analysis, it is possible to make proposals to the most appropriate composition of Industrial Materials Network participants, owners, and financial contributors etc. *Conditions for Inter-industrial Co-operation* covers which possibilities and barriers the case industries pose for co-operation in an Industrial Materials Network. The conditions, uncovered by these analyses, are, for instance, case industries' attitudes towards a close co-operation and economic possibilities or lack of them for joining the scheme.

Through analysis of Transaction costs/Risk minimisation and Conditions for Inter-industrial Co-operation a "space of action" is developed, which make up some pre-conditions or overall frameworks for the most appropriate type of *Corporate governance* needed in the given context. Emphasis on how to organise the *type* of corporation behind implemented energy facilities, so the most favourable organisation of the Industrial Materials Network in Navanakorn Industrial Promotion Zone, is thus pursued. This part of the chapter therefore *exemplifies* different types of Corporate governance, and thus seeks to define an appropriate match in regards to the set of pre-conditions posed on the corporation, as defined by previous analysis. This also includes economic calculations of consequences for the corporate economy, when set-up differently.

9.1 Transaction costs/Risk minimisation

This section begins with a general description of risks posed on energy projects based on local biomass wastes, and continues with how these risks can be minimised when looking at Transaction costs. Transaction cost analyses put emphasis on optimal relations between selected stakeholders, and through this achieve Risk minimisation by, for instance, ensuring that case industries not will find other markets for biomass wastes.

9.1.1 Risk assessment

This section describes, in general terms, which risks renewable energy schemes based on local industrial biomass wastes can face.

Fuel supply risk:
When implementing an energy plant based on biomass fuel several risks can emerge, which can influence the plant's capability to generate and transmit energy. First, is the risk of fuel supply. Will industries involved supply the fuel? Or will they find other markets for the wastes, which make the supply of fuel uncertain? When relying, for example, on local industrial wastes as fuel, the risk increases due to a higher sensitivity towards this specific supply of fuel. The supply risk of, for instance, coal is still much lower, as it can be delivered from various sources such as South Africa or Australia etc. Thus, when connecting the energy production to a specific type of fuel that increase the fuel supply risk, the fuel supply is more sensitive and must, therefore, somehow be made reliable.

Reliable energy production:
The specific production of energy is of course also important, as industries rely on the energy service in their production activities. Coverage of energy services, especially in industries, must be followed by assurances of a stable and reliable supply, as the industrial sector is extremely sensitive toward energy supply (Ole Madsen, Vølund, Brøndby, Interview the 24-10-01). Risks connected with the energy production can, for instance, be 'stop-down' caused by corrosion of the boiler due to the composition of biomass fuels. Actual 'breakdown' can also make the energy production impossible for longer or shorter periods of time, until re-established. In general, renewable energy technologies are regarded as less reliable technologies compared to conventional technologies, even when proved mature and reliable as an energy supplier. To ensure the supply of energy to industries - when 'stop-downs' and 'breakdowns' occur - a back-up system is normally implemented, which can be operated on full load preferably within a few hours (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 3-12-01).

Transmission of electricity:
Transmission of energy can also face certain risks, which can vary depending on the energy services produced. Usually, transmissions of electricity on the grid have limited risks, as it often - as in Thailand - are established and owned by the national electricity company or the public as in Denmark. Unless in very remote areas, it is rarely necessary to establish new grid connections for the transmission of electricity produced. One risk connected with the transmission of electricity on the grid is the price. If the grid - used for distributing electricity from the co-generation plant to industries - is owned by an electricity company, a "wheeling" fee must be paid in order to utilise the grid. Such a fee can be a potential risk on the energy facility if not controlled by certain rules or legislation determining the price. A sudden and unexpected price jump in "wheeling" fees can thus undermine the economic benefit of transmitting electricity to industries on the national grid.

Piping of heat:
It is often necessary to establish a network of pipes for heat transmission, as district heating networks are only widespread in the Northern European countries (i.e. Britain, Germany, Scandinavia). There is no, or a very limited, tradition for district heating in warm countries like in the south of Europe and in Asia for instance. A district heating network is relatively expensive, and it is, therefore, important that the network is utilised optimally throughout its lifetime. There are no other meaningful or alternative uses of such networks, unless for transmission of heat. The risks, connected with implementation of district heating networks,

are of course the lack of customer, i.e. no demand for heat transmitted through the network, or a sudden relocation of the demand elsewhere.
As district heating networks lack mobility, it is not possible to change heat customers without economic consequences, but merely to include new ones by expanding the network. This is, for instance, possible for transmission of electricity, which is much more flexible in regards to End-use customers. It is, therefore, important that the initial heat customers *stay* heat customers, and that new district heating pipes are only established when, for instance, including additional heat customers.

9.1.2 Transaction costs and Risk minimisation

To reduce or eliminate the risks connected with the production and transmission of energy, it can be beneficial to look at the Transaction costs. Transaction costs are costs on the market, and industries are thus interested in reducing or eliminating Transaction costs. As there are costs connected with each transaction that takes place, industries will seek to minimise these costs, either via “take over” - produce the goods or service themselves - or by for instance contracts, thereby ensuring the price or deliverance’s of goods or services to the industry (Transaktionsomkostningsteori: En introduktion til Williamson, Martin Lippert-Rasmussen & Niels Peter Mols, 1994).

Energy production can be connected with Transaction costs for appropriate Risk minimisation by, for instance, *inclusion* of various stakeholder interests, and by limiting the number of trading partners leading to lower price levels etc. Transaction costs are, therefore, important when looking at possible ownership of the implemented energy plant, as pointing to relevant stakeholders who should be included through the approach of minimising the Transaction costs. In Williamson’s approach to Transaction costs, emphasis is primarily on the signing of contracts for maintaining business relations, thereby minimising risks. In the following, other types of Risk minimisation approaches than contract signing will also be included.

As seen from the general presentation in the previous section, there are several risks connected with production and distribution of energy: (1) fuel supply risk; (2) stable and reliable energy supply; (3) transmissions of electricity; (4) and heat, which can be characterised as transactions, or Transaction costs. The risk connected with (1) fuel supply, (3) transmissions of electricity (4) and heat, can for instance be minimised by signing contracts and assurances, by including various stakeholders as owners of the energy plant or by supplying energy at favourable prices, thereby seeking to maintain the business relations.

By, for instance, making case industries owners of the energy plant, it is - according to the ideas behind Risk minimisation - possible to limit the risk of alternative uses of the biomass wastes. Or by distributing electricity and heat to industries at a lower price than the alternative, it is also possible to maintain the biomass supplier in a business relation. High Transaction costs are, for instance, placed on energy facilities depending on another or more outside companies for fuel supply. The use of fuel supply companies will increase the overall price of fuel deliverance to the energy facility, through the additional charge that must be paid. A more vertical integrated fuel supply can eliminate such additional charges by making the fuel suppliers partners or owners of the energy facility.

9.1.3 Contextual conditions and Risk minimisation

The focus of the following section is on the possibilities of Risk minimisation in producing and distributing energy, as exemplified by the general presentation in the previous section (9.1.1), but here utilised in the specific context of Navanakorn and its surroundings. The focus will first be on *case industries* in Navanakorn, and then, in the following section, on *other relevant stakeholders* from the surrounding community. Through the Risk minimisation approach, which focuses on appropriate elimination/reduction of possible project risks, relevant Industrial Materials Network participants, possible owner(s), financial contributors and prime initiators are sought defined in the following sections.

9.1.3.1 Case industries in Navanakorn

In case industries, two out of eight companies do not require heat in their production activities, which means that pipes for the transmission of heat not are required (it is here assumed that Rockwood converts to process heat by water based heat). Two industries - Light House and Interfurn - generate biomass wastes, which are supposed to be converted in the energy plant for electricity and heat production. The six case industries using process heat in their production activities, can cover internal heat demands by the energy facility only, but the production of energy is not sufficient to cover electricity demands in *all* case industries. Apart from the supply of fuel from case industries, a minor additional fraction of wastes, from other diffuse industries in Navanakorn, must be supplied to generate the amount of heat required. Today, the Main Office of Navanakorn collects these additional fractions of commercial/industrial waste, which is dumped in landfill areas. As emphasised in Chapter 4, industries in Navanakorn have recently complained about the price level of waste management in the Zone, which has increased by 200 % (three-double) within the last few years.

As stated, two case industries will not be heat customers (Light House and Interfurn), but merely potential electricity customers. This can create problems concerning the biomass supply, as the energy production is partly based on wastes from these industries. One possibility for maintaining the supply of wastes, is thus to offer these industries the produced electricity at a lower price than the alternative (grid electricity). In this way the business relation becomes interdependent; the fuel supply to the energy facility is secured, and the two industries receive electricity at a lower price than what can be transmitted from the national grid. This method of securing fuel supply is very flexible, as it eliminates any plant ownership by the two industries, and can be proposed to other biomass generating industry in the Zone with a demand for electricity. The disadvantages is that generated electricity is not utilised by participants in the Industrial Materials Network, but “lost” to other industries for the sake of fuel supply.

Fuel deliverance can also be secured by letting Light House and Interfurn become co-owners of the energy facility. This will also prevent alternative uses of biomass wastes and foster a commitment for successful plant operation, and thus appropriate collection and quality control of the wastes. The ownership will eventually lead to economic return, which is the driving force behind becoming co-owners. Another possibility is to sign contracts to secure the supply of fuel, and thus completely eliminate the industries from any kind of ownership or special benefits (as for instance electricity supply). Such contracts are, seen in a Thai context, not very reliable, as contracts seem to be made for breaking! Various cases in Thailand have, for example, shown that farmers break contracts for fuel delivery by increasing the price by several hundred percentage *after* the contracts have been signed and the energy plant implemented (Mr. Ludovic Lacrosse, EC-ASEAN COGEN, Interview, Bangkok the 14-2-00).

Many case industries, however, are Private Limited Companies with business head quarters located outside Thailand, for example the US, India, Japan and Taiwan. It is, therefore, likely that contract signing is a more appropriate business politics in these industries. The two case industries only requiring electricity, are from Taiwan and Thailand, the latter owned by Chinese Thais who generally have a different business culture than Thais. Chinese Thais are more service minded and have a more Western way of thinking business and business relations. According to COGEN, Chinese Thais are more loyal towards maintaining business relations, as, for instance, agreements concerning fuel supply (Mr. Ludovic Lacrosse, EC-ASEAN COGEN, Interview, Bangkok the 14-2-00), and it is therefore likely, that contracts of fuel delivery can be trusted.

There is also a potential but minor risk of basing the energy production on wastes from diffuse industries in Navanakorn, collected by the Main Office. By making the Main Office co-owners does not solve this problem, as they have no influence on decisions taken in industries. One alternative is to make contracts of biomass supply. The Pre-Feasibility Study demonstrated that the energy plant has economic room for buying wastes if necessary. As industrial/commercial waste make up for a minor part of the total fuel use, it is, therefore, possible to pay diffuse industries for deliverance of biomass wastes if required. It is, however, not possible to evaluate whether such contract signing is relevant for diffuse industries, as no empirical data cover these stakeholders. Another, and more likely possibility, is to eliminate the increased economic burden of waste management posed on diffuse industries in the Zone, by simply collecting the waste for free.

It is not favourable to make diffuse industries co-owners of the energy facility; Firstly because no surplus energy can be transmitted, and, secondly, because co-ownership by many diffuse industries - solely based on economic return - does not create a real commitment towards the project. Co-ownership by many industries also leads to a very complex composition of the corporate power, which can be unfavourable for the decision-making capabilities of the corporation (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Pers.Com., Gladsaxe the 18-1-02). If the supplies of biomass from diffuse industries fails/disappears, it can be beneficial to substitute it by biomass collected outside the Zone, or seek deliverance of wastes from one or more industries within the Zone, which today transport biomass waste out of the Industrial Zone. A co-owner outside the Industrial Zone, acting as fuel back-up supplier, is thus a possibility. This could, for example, be Takhlong Municipality or Pathum Thani Province, the latter having the capacity to supply biomass wastes from, for instance, Tahlad Thai Market (see Chapter 4).

Problems created through the implementation of district heating pipes and industries, for instance, pulling out of the co-operation due to various reasons (bankruptcy, other heat supply etc.), are very important issues, and can, for example, be minimised by favourable heat prices and by insurance. The force of the proposed co-operation is caused by the unity of industries, which again is dependent on participation by *all* industries. By signing insurance large economic problems can be prevented if industries pull out of the corporation, but insurance is often quite expensive. The optimal situation is, therefore, that no industries see benefits in *not* participating (This of course cannot prevent bankruptcy).

It goes against the decentralisation and privatisation beliefs to make the electricity company co-owners of the plant, to minimise the risks of electricity transmission on the grid. The price, which must be paid for borrowing the grid, will be settled as a fixed price valid throughout Thailand (Mr. Pinij Siripuekpong, EGAT, Letter dated the 4-1-02). It is, therefore, possible that a price - stable over for instance 10 years - will be settled, and industries thus know the conditions in a certain period of time. Afterwards the specific “wheeling” conditions are unsure. If “wheeling” fees are high, or expected to become so, it may be beneficial simply to establish an individual grid connection only between industries co-operating.
This has, for instance, been done in Map Ta Phut Industrial Estate South East of Bangkok, for transmission of electricity from an implemented coal fired co-generation plant to industries in the Estate. Electricity cables are installed under earth thereby reducing the maintenance costs over time (Leif Mortensen, EC-ASEAN COGEN, Interview, Bangkok the 29-4-03).

9.1.3.2 Strategies in developing an energy system

In defining Industrial Materials Network participants and owners, the following are found. It is assumed that contracts of fuel deliverance from Light House and Interfurn can be signed, and that alternative wastes, to that supplied by diffuse industries in Navanakorn, can be found outside or within the Zone. The latter is likely to be achieved, as waste management in the Zone is relatively costly. It is, therefore, possible that industries will consider giving the biomass away for free, instead of paying for waste management themselves.
Alternatively, it is assumed that the biomass wastes can be supplied from the surrounding community. This means that *Industrial Materials Network participants* are solely defined by the six industries using *both* electricity and heat. As the electricity produced is *not* used for securing the biomass supply, it can solely be transmitted to Industrial Materials Network participants, thereby reinforcing the benefits of the co-operation by supply of less expensive electricity. It is also beneficial to make Industrial Materials Network participants owner or co-owners of the scheme, as this will increase the commitment for successful operation and management.

9.1.3.3 Relevant local stakeholders

The following section describes various local stakeholders in Pathum Thani Province and emphasises which co-operation benefits they can have in implementation of an energy facility in Navanakorn. Benefits are uncovered by analysis of possible *stakeholder motivation/interests* in the scheme to be implemented. Also possible *stakeholder support* will be exposed, which can be economic, legislative etc. The purpose of the analyses is to point to other relevant stakeholders, who could be possible co-owners, financial contributors and/or prime initiators in the process of implementing and organising the Industrial Materials Network in Navanakorn.

Pathum Thani Province and Takhlong Municipality:
Pathum Thani Province and Takhlong Municipality face increased problems in managing industrial/commercial and household waste, as emphasised in Chapter 4. The largest problems connected with waste management in Pathum Thani Province, are the lack of spatial room for landfill areas, and a massive resistance towards waste incineration. Industrial/commercial and household waste from Navanakorn, is thus a Provincial problem.
According to Mr. Terapong Keawjaroon, Takhlong Municipality can only support the implementation of an Industrial Materials Network in Navanakorn if a political hearing takes place. The Municipality has political power to force such co-operation on industries if decided by the hearing. The only other power possessed by the Municipality is the capability to lower property taxes on industries joining the scheme. Mr. Terapong Keawjaroon stresses that the Municipality would like to participate in seminars, workshops and training etc., in order to support the implementation of Industrial Materials Networks in Navanakorn Industrial Promotion Zone (Mr. Terapong Keawjaroon, Takhlong Municipality, Ampur Klong Luang, Klong Nuang, Interview, Klong Nuang the 15-2-01).

It is not possible to receive financial support for implementation of the Industrial Materials Network from the Province of Pathum Thani. The only financial support can come through different funds, like the Environmental Fund, which the Province can make applications for (Mr. Ruangsak Padoongsilp, Pathum Thani Provincial Authority (City Hall), Interview, Pathum Thani the 22-2-01). According to Mr. Ruangsak Padoongsilp, the Industrial Materials Network in Navanakorn is likely to receive support from Pathum Thani Province, as it both builds on renewable energy production and waste minimisation initiatives (Ibid.). Pathum Thani Province is included as one of Thailand's *Pollution Control Zones*, and it is, therefore, likely that such initiatives will face special interests.

Main Office of Navanakorn:
According to Mr. Dhani Kumwongwan, Main Office of Navanakorn, the organisation behind Navanakorn is probably willing to support the implementation of an Industrial Materials Network in the Zone. If required, the Main Office can contribute economically to such a scheme, and they will also be willing to organise this development project if needed. Mr. Dhani stresses that the Main Office has no power over industries located in the Zone, but merely acts as a service organ. But if industries commence such initiatives, the Main Office would like to join and support it (Mr. Dhani Kumwongwan, Main Office of Navanakorn, Interview, Navanakorn the 2-2-01). The Main Office of Navanakorn own stocks in Navanakorn Distribution Centre (NNDC), which is a central distribution point in the Zone for all products produced. The Main Office owns 10 % of the stocks in NNDC, whereas a Japanese company owns the remaining 90 % (Ibid.). Thus, it is not unlikely that the Main Office will join such scheme, as they already have experiences in joining different projects.

Industrial Office of Pathum Thani Province (local MOI):
The tasks of Pathum Thani Industrial Office (sub-office of Ministry of Industry in Bangkok) is to inspect industries in the Province, and, for instance, take samples of industrial wastewater and register industries in the Province etc. According to Mr. Somjit Khunpleum, Head of Industrial Control of Pathum Thani, the local MOI can support the project in various ways. The local MOI can promote economic incentives for industries to participate in Industrial Materials Networks, by, for example, a reduction in factory taxes, which industries pay once a year. Also new tax incentives can be initiated by the local MOI, which currently is

used in industries who have implemented ISO 14000. By such tax incentives, the local MOI can promote the ideas of Industrial Materials Networks in Navanakorn (Mr. Somjit Khunpleum, Industrial Office of Pathum Thani (local MOI), Interview, Pathum Thani the 22-2-01).
Another initiative that can be promoted by the local MOI is to establish an Environmental Board for the implementation of the scheme. Mr. Somjit Khunpleum proposes potential Board members to be the local MOI, Bangkok MOI and MOSTE, and will have the task of planning the implementation of the energy system in Navanakorn. Thus, the Industrial Office can, according to Mr. Somjit Khunpleum, be an important stakeholder in the Industrial Materials Network development (Ibid.).

Federation of Thai Industries (FTI) - FTI local chapter:
Pathum Thani chapter (FTI Sub-Club) is one of several sub-organisations to FTI, and presently there are 56 Sub-Clubs throughout Thailand (Mr. Kidkla, FTI, Interview, Bangkok the 28-4-03). According to Ms. Dominica Dacera, Senior Environmental Engineer of the Industrial Environmental Institute at FTI, such FTI local chapters can support the implementation of an Industrial Materials Network in Navanakorn. The FTI local chapter can promote the idea of Industrial Materials Network development in Navanakorn by awareness campaigns held as seminars, by workshops and meetings between industries. Ms. Dominica Dacera stresses that the promotion of this first must be initiated in the specific branch organisations or lines of businesses, and then later to potential networking industries across different branches by a sub-chapter in the Zone (Ms. Dominica Dacera, FTI, Interview the 19-2-01).

According to Ms. Dominica Dacera, Pathum Thani Sub-chapter has the capacity to establish awareness raising within industries in Navanakorn, and initiate industrial co-operation across different branches. The FTI local chapter has a great influence on the opinion formation of industrial leaders, and thus is a very important stakeholder when commencing initiatives similar to those proposed in Navanakorn (Ms. Dominica Dacera, FTI, Interview the 19-2-01).

9.1.3.4 Co-operation benefits

Motivation/interests:
Pathum Thani Province and Takhlong Municipality have vital interests in the implementation of the Industrial Materials Network, as it can act as a *waste treatment facility*, and thus lower the pressure on the Municipal and Provincial waste management systems. Waste from Navanakorn is only indirectly a municipal problem, as the Main Office is responsible for and provides management of all waste in the Zone. But Takhlong Municipality must point to appropriate landfill areas, which is becoming an increased problem. As Pathum Thani Province is a Pollution Control Zone, not only waste minimisation, but also renewable energy production, must be of vital interest for the Province.
It is, therefore, primarily a materials (waste and energy) motivation that drives the interest for project support. The management of waste is an important factor for project support.

No waste management problems within the industrial Zone of Navanakorn - unless the complaints about the price level - make the Main Office especially interested in the project. It is, supposedly, a question of prestige and promotion of the Industrial Zone, which already face interests from stakeholders all over Thailand, as emphasised in Chapter 4. As the Main

Office already acts as a service and facilitating organ for industries, it is very likely that they can act as a prime stakeholder in implementing and operating the energy plant. The Main Office is, very likely, capable of collecting the biomass wastes, as already processing this task today, and employ trained staff for plant operation and maintenance. The Main Office is - very importantly - also a *well know* stakeholder by industries in the Zone, and thus most likely possesses the capability to aid in the build up of Inter-industrial Co-operation between certain industries in the Zone.
The motivation behind the project support is, therefore, the continuous service and facilitation of industries, combined with aspects of promotion of the Zone, which the project can support.

The local office of MOI has no direct interest in the project, unless as a source of achievements towards the overall national goals of waste minimisation and re-use in the Province. As for Pathum Thani and Takhlong Municipality, it is, therefore, also here a materials motivation that lies behind a possible support, combined with national political goals. FTI local chapter has likewise no specific interests in the project. The motivation for joining it could, at least in the initial phase of the planning and implementation, be overall economic and prestigious reasons; to show the business world that Thai industry cares about the environment, and achieve business advantages in the globalised economy by doing so, and that it actually is economically beneficial to do so. In this way, the FTI local chapter can have a facilitating role, and thus influence the opinion of business leaders, which was found to be very important.
The motivation is thus the increased industrial competitiveness through appropriate handling and uses of materials in industries.

Support:
Both Pathum Thani Province and Takhlong Municipality have no financial resources for supporting the project in Navanakorn, but Pathum Thani Province can apply for financial resources through the Environmental Fund (ENCON), thereby supporting the implementation of the Industrial Materials Network. Only indirect financial support can be obtained from the Municipality through reduction in property taxes. The Municipality can, however, support the project through training and workshops etc., thus the planning and implementation process. The Main Office is willing to support the project both financially and through implementation and operation. The local MOI can also indirectly support the project financially, by lowering of factory taxes and by establishment of new tax incentives for Industrial Materials Network participants. In addition, the planning and implementation phase can be supported by MOI, for instance, through the creation of a Board for project implementation. The FTI local chapter can also help in the planning and implementation phase by increasing the awareness among industrial leaders in the Zone through seminars, workshops etc., and facilitating Inter-industrial Co-operation.

9.1.3.5 Strategies in developing an energy system

In defining important stakeholders, possible co-owners and financial contributors, the following were found: Pathum Thani Province and Takhlong Municipality have no possibilities of giving financial support to the project, unless transmitted from national Funds. If this succeeds, Pathum Thani will most likely require some sort of influence if not co-ownership of the project in order to support it (at least a position on the Board). As no financial aid can come from the Municipality - merely tax reductions - Takhlong Municipality has no special interests or power to be included as an important stakeholder for project success. The Main Office is regarded as a very important stakeholder as well known by industries in the Zone, and as already managing and facilitating different tasks in Navanakorn. The Main Office can possibly build bridges between industries, and manage the waste collection and energy production. Moreover, the Main Office can support the project financially, which means that it most likely will seek to manage it correctly. As for the case of Takhlong Municipality, the local MOI has no capacity to support the project. Only indirect support through tax reduction can be applied. The MOI can, by setting up a Board, support the initial planning process and implementation of the idea.

According to the analysis, all stakeholders can contribute to and support the project. Most important is awareness raising in industries and thus the modelling of opinion formation among industrial leaders. Even though - according to the empirical data - there seems to be no economic support from FTI, the “power-through-influence” make the FTI local chapter a stakeholder that must be included in the initial phase. The analysis thus shows that the Main Office of Navanakorn, FTI local chapter and Pathum Thani Province are the most important stakeholders in the initial phase of implementing an Industrial Materials Networks in Navanakorn. FTI local chapter can thus fulfil the tasks of building bridges and links between industries, and facilitate Inter-industrial Co-operation.

Economic support can be obtained from the Main Office and Pathum Thani Province (through ENCON). A reliable and supposedly discrete (especially concerning business matters within case industries) waste collector and responsible plant operator is preferably the Main Office (plant operation will be contracted to professionals). Supporting initiatives from local MOI (unless establishment of a Board for project implementation) and Takhlong Municipality, are underlying support, which can be implemented at a later stage.
Beneficial co-owners can be the Main Office, as they have the capability to co-finance the project, and as economic commitment can lead to increased interest in appropriate waste collection and plant operation. Another co-owner or financier can be Pathum Thani Province as large financial resources can follow this stakeholder, and due to its capacity to supply alternative biomass wastes to the energy plant if the supply within the Zone fails.

9.2 Conditions for Inter-industrial Co-operation

Nonetheless, there are several questions: Are case industries interested in joining the Industrial Materials Network? Which problems do they see in such Inter-industrial Co-operation? How does the Thai business culture suit such co-operation set-up? Do they have the capacity (finance and knowledge) themselves to commence such initiatives, or do they point to specific stakeholders as prime or leading initiators for establishing the co-operation? In the following section, the emphasis is on some of the statements made by case industries in relation to co-operation possibilities and barriers. The focus will, hereafter, be on how to break down barriers and promote Inter-industrial Co-operation by the inclusion of support from various stakeholders presented in the previous section.

9.2.1 The industries' point of view

Imperial:
Mr. Deshpande is interested in the company participating in an Industrial Materials Network, but stresses that the development of such a scheme is difficult as industries in the area don't know each other. Thus, the communication between industries is very scarce. He also points out, that an outside firm must be responsible for waste collection and operation of the energy facility etc, as industries only have knowledge about their own production area. He stresses that the Main Office of Navanakorn must take the initiative in developing such scheme, if it is to be implemented, as; "*Industries are to busy with their own businesses, and they don't know anything about such things"* (Mr. S.G. Deshpande, Imperial Industrial Chemical's, Interview, Navanakorn the 20-1-01).

He further stresses, that is must be profitable for industries to participate in the Industrial Materials Network in order to obtain support for the idea. But, as he further stresses, environmental regulation will most likely increase in the future - for example regarding standards of solid and liquid waste plus air emissions - and more industries will, therefore, possible find the scheme interesting. Thus, a more aggressive environmental legislation will push industries to find new solutions, as, for example, development of Industrial Materials Network's (Mr. S.G. Deshpande, Imperial Industrial Chemical's, Interview, Navanakorn the 20-1-01).

ASAN Service:
According to Mr. Omura, the development of an Industrial Materials Network in Navanakorn can be difficult regarding the communication between industries in the Zone; "*Companies are very different from one another, and they don't talk to each other. There are Associations for industries here, but I newer go"*. To support this statement, he was not aware of the existence of other food producing industries in Phase 1 of Navanakorn, except from a few located very near. Another barrier for the implementation of Industrial Materials Network's is the created dependency between industries;" *What if some industries go bankrupt...What will happen to the other industries, who have planned their energy supply on that waste?"* (Mr. Kyohei Omura, ASAN Service, Interview, Navanakorn the 16-1-01).

He further stress, that an appropriate organisation of the Industrial Materials Network should be organised, so that industries obtain a share of the ownership in accordance with their supply of biomass. If the scheme is to be implemented, it must also contribute to economic profit for participating industries. Legislation or Command and Control initiatives are not enough, because industries can make "pay off's" to government officials and thereby avoid environmental obligations. This, he argues, is a big problem in Thailand. Thus, the willingness to implement such schemes must come from industries themselves; *"But they only think of money"* (Mr. Kyohei Omura, ASAN Service, Interview, Navanakorn the 16-1-01).

B.B. Snacks:
Mr. Pichai Burapavong would like to participate in the Industrial Materials Network, but argues, that someone else must be responsible for waste collection etc.
As the Main Office of Navanakorn already provides this service to industries in the Zone, he is in favour of letting this stakeholder be responsible for developing the scheme, and to

transport biomass wastes to the implemented energy facilities; "*They must set up a plan for this, and send the energy to the industries or to the residential areas*" (Mr. Pichai Burapavong, B.B. Snacks, Interview, Navanakorn the 1-2-01).

He further stresses that economic benefits from such a scheme will make industries interested in participating. Increases in energy or waste management prices can motivate industries to commence re-se of resource in the industrial area (Mr. Pichai Burapavong, B.B. Snacks, Interview, Navanakorn the 1-2-01). Mr. Pichai Burapavong would like to see the Main Office as owners of such a scheme, and do not see any problems in regards to the fuel supply, thus inter-dependence between industries; *"If one company close down it is no problem…the waste can just be collected from another company in the Zone"* (Ibid.).

Baskin Robbins:
Mr. Rastam B. Raheem argues that implementation of an Industrial Materials Network to some extend depends on the Thai Government, as state support concerning financial and technology issues are a necessity for the plan to materialise. He further stresses that the collection of biomass from industries is a simple task, and thus something industries can put in the hands of an outside stakeholder (Mr. Rastam B. Raheem, Baskin Robbins, Interview, Navanakorn the 18-1-01).

Sun Cabinet:
Regarding the co-operation possibilities between industries in Navanakorn Ms. Supranee Sripawadkul stresses that; *"Thai people are not very good in joining together and working for a case…only if there is something wrong politically, they will join and make protests. Here [in the Industrial Zone] nothing is wrong, so why should they do something together. They mind their own business…they don't want to spend time on doing anything else…they only look at their own company"*. She also refers to the lack of business Associations in the Zone, which *could* make industries work more closely together, but only as specific lines of businesses or branches, thus not as a mix of different industries (Ms. Supranee Sripawadkul, Sun Cabinet, Interview, Navanakorn the 30-1-01).

Ms. Supranee further stresses the importance of reaching the owners or the top management in the industries, as Thai business culture is very hierarchical. Even when people just below the management are in favour of some specific changes or initiatives within the company, they will never happen unless the top manager or owner is in favour of them too. Also, financial and technical issues are important as industries lack technical knowledge, and will be concerned whether or not they can make money - or save money - by participating in the Industrial Materials Network. Financial and technical support must be implemented in order for the project idea to succeed (Ms. Supranee Sripawadkul, Sun Cabinet, Interview, Navanakorn the 30-1-01).

Rockwood:
Mr. Paotep stresses that an outside stakeholder with technical knowledge must be the prime initiator for development of the Industrial Materials Network in Navanakorn, as industries in the Zone only know about their own production area. Except maybe from Japanese industries in the Zone, there is no communication between industries. Only workers are in dialogue, mostly about working conditions and salaries. Stakeholders outside the Zone must take the

leading role in such schemes, as there is a lack of knowledge about such matters in industries (Mr. Paotep Chotinuchit, Rockwood, Interview, Navanakorn the 26-1-01).

Interfurn:
According to Mr. John Barrow, it can be difficult to organise an Industrial Materials Network, when it comes to sharing resources. Industries will be very determined that other industries do not benefit more from the co-operation than they do. For example, that industries do not benefit more from the energy production, than what they provide in amounts of biomass wastes; "*Even if companies did not make money on their waste before, they will be very concerned whether some industries now benefit more than they do*" (Mr. John Barrow, Interfurn, Interview, Navanakorn the 1-2-01).
Mr. Barrow also finds that Thai industries are very inward. They tend to be quite closed and not open towards other companies, which can be a barrier for Inter-industrial Co-operation. In addition, economic issues, like the cost of participating in the Industrial Materials Network, will be of their concern. Therefore, industries must be able to save money on the scheme otherwise they will not be willing to participate (Ibid.).

Light House:
Mr. Shih stresses that the implementation of waste re-uses through Industrial Materials Networks not will succeed if initiatives comes from Command and Control regulation; *"Such schemes must come from a good planning process in which industries have seen that they can save money and obtain a better image…If the government provides economically and technically support, industries can manage for themselves"* (Mr. Allan Shih, Light House, Interview, Bangkok the 31-1-01).

9.2.2 Co-operation possibilities and barriers

Motivation/interests:
Most case industries in Navanakorn expressed interest in participating in the Industrial Materials Network when interviewed. They found the production of renewable energy interesting, especially as it is combined with management of industrial waste. In regards to increasing prices of energy services and waste management - in combination with stronger focus on environmental issues in Thailand in coming year - they saw great, especially economic, benefits in becoming participants in such co-operation. However, some case industries also saw several barriers for such Inter-industrial Co-operation, which must be dealt with as being important pre-conditions for successful co-operation between industries. These are outlined in the following.

Barriers:
Firstly, as stressed by several industries, there is no communication between industries in the Zone, which is a barrier for industrial initiated co-operation. Industries tend to be very inward and do not share information with each other. In addition, there seems to be a very hierarchical decision-making process in Thai industries, which makes it important, for project support, to approach industries in a specific manner. *Secondly*, industries only have knowledge about their own businesses, which makes support from an outside stakeholder regarding waste collection and plant operation etc., very important. Thus, a third party must preferably manage the daily operation of the plant and waste collection in the Zone. *Thirdly*, several case industries call for economic as well as technical aid in developing the scheme.

Fourthly, the created inter-dependence between industries is stressed as a potential problem by several case industries, in regards to sharing and counting on biomass waste deliverance's from other participating industries.

9.2.3 Various stakeholders' possibilities for breaking down barriers

(1) Business culture:
One issue uncovered by the empirical data is that industries seem to be closed, understood in the sense that they primarily focus on internal management issues and practices. Inter-industrial communication seems to be very limited, and if it happens, it is most likely to be among industries in the same line of business, i.e. for example food producing industries. This tendency to be closed, as mentioned by two (expatriate) stakeholders, is often related to keeping business practices - and possible weaknesses - out of the knowledge of other stakeholders.
Another issue related to business culture is the very hierarchical decision making processes in Thai industries, compared to for instance Denmark. One Thai stakeholder with experiences in different business cultures - obtained by business trips to European countries including Denmark - stressed this. As decision-making tends to be very top-down, she argued for the importance of reaching the top management, if changes were to materialise. Only by approval at high levels could such schemes as Industrial Materials Network be initiated.

As seen above, the lack of communication between industries, and the limited sharing of information concerning internal business issues and practices, calls for an organisational structure based on *structured* and *firm* principles, where participation not only requires mutual openness between industries, but the corporation facilitated by another stakeholder (see (2)). The very hierarchical culture present in the Thai industries, which makes it necessary to reach the top management, also calls for a stakeholder with some kind of industrial authority to promote participation. According to the analysis made in the previous section, it could be appropriate if FTI local chapter undertook the role of building bridges between industries, and as an authority, promote the co-operation among industries.

(2) Waste collector and plant operator:
As argued by most case industries, the Industrial Materials Network will hardly become a reality without one or more leading stakeholders being prime initiators. This aspect can to some extent be connected to the inwardness of industries, as inter-industrial issues solely occupy industries, and the outward communication therefore weak. As seen, industries especially ask for the Main Office of Navanakorn to take the leading role in such a development, as they already have experience with waste management and provide other services in the Industrial Zone. Industries are, according to the empirical data, not capable of handling such complex issues by themselves.
It is, therefore, important that a stakeholder with motivation or interests in the project becomes the prime initiator for the project to materialise. Several case industries points to the Main Office of Navanakorn as an important stakeholder in supporting Industrial Materials Network development, and, as stressed by one case industry, not only as plant operator and waste collector, but also as possible owners of the scheme. As they already managing and facilitating various tasks in the Zone, it seems that industries trust this stakeholder to be a leading initiator.

(3) Economic and technical support:
In order for the Industrial Materials Network to materialise in Navanakorn Industrial Promotion Zone, it is important that industries benefit economically from the co-operation. This can, for example, be by energy savings obtained by the self-supply scheme, and by elimination of increased waste management costs. Several industries call for governmental support regarding economy and technology, as a pre-condition for the project to be implemented. Case industries lack the financial and technological capacity and capability to commence such implementation themselves. Financial aid to project implementation, can, as emphasised in the previous section, be given by the Main Office of Navanakorn and Pathum Thani Province. Other outside stakeholders than those mentioned here, must supply the technical support necessary (see Chapter 10).

(4) Inter-dependence between industries:
The created inter-dependence between industries is stressed as a potential problem in regards to sharing and counting on biomass waste deliverance from participating industries. As stressed by one expatriate stakeholder, it is important that industries mutually benefit from the co-operation, as they will be very concerned whether some industries benefit more from the scheme than they do. A second industrial stakeholder further stresses, that industries must benefit economically from the corporation corresponding to the amounts of biomass they contribute.
A third stakeholder emphasises a potential fragility of the scheme, by pointing to the situation in which a case industry stop its participation in the Industrial Materials Network, thereby leaving the remaining industries with a lack of fuel (and heat market). These statements emphasise the importance of the Risk minimisation initiatives presented earlier. Still, the design of the organisational structure to be determined, also leads to some means of Risk minimisation in regards to the inter-dependence between industries participating in the Industrial Materials Network.

9.2.4 Pre-conditions for co-operation - Overall framework

The possibilities for creating an Industrial Materials Network have been defined by some *pre-conditions* for its implementation, and by a definition of Industrial Materials Network participants, possible co-owners, financial contributors and prime initiators.
The pre-conditions for Industrial Materials Network implementation thus imply, that other stakeholders than case industries become initiating or leading actors in developing the scheme, due to their vital interest in the project at different levels. This is caused by the lack of inter-industrial communication between industries.
Also, the lack of economic and technical capacity has lead to a search for and inclusion of other stakeholders than case industries. As case industries do not have the necessary “business culture” to commence such co-operation themselves, focus has also been on other stakeholder to take a leading role in the project promotion and implementation. The inclusion of other stakeholders than case industries as members of the Industrial Materials Network, has resulted in an overall enlargement of stakeholders that it is necessary to involve. Thus, important “third part stakeholders” or “initiator stakeholders” are pointed to fulfil various tasks at different levels.

Industrial Materials Network co-operation evidently forces industries closer to each other, but must also - according to the framework above - seek to maintain the industrial independence somewhat intact, as found to be important for case industries. How can these interests be combined? Which type of Corporate governance can fulfil and cope with the differentiated interests and demands exposed by the empirical data? How must the ownership be separated between case industries and other relevant stakeholders to ensure an initial and continuous interest and thus participation by case industries? As already noted in the previous analysis, Corporate governance based on structured and firm principles, can be preferable when looking at the conditions for co-operation. As seen by the above analysis, the conditions for Inter-industrial Co-operation between case industries are relatively weak. This means that industries will be reserved in joining the scheme, unless flexible and favourable conditions for joining it are established. But how is it possible to overcome such barriers? These matters will be outlined in the following section.

One way of promoting case industries' participation is to limit the economic risks of joining the scheme. This can, for instance, be cost placed on industries for necessary technical changes, when converting from uses of process heat by electricity or steam to process heat by the supply of district heating. Technical equipment for heat recovery and the cascading of steam can also be expensive, and perhaps result in industries not wanting to participate due to such initial costs (These costs are not included in the economic calculations made in section 9.3.2.2 Figure 9A, as they are based on too many assumptions).

Also the actual implementation of the energy plant, including district heating pipes and back-up system etc., are of course potential high costs posed on industries, which - as we have seen - lack economic capabilities. To meet such economic burdens, which most likely will hold back industries from participating in the Industrial Materials Network, these costs can, for example, be paid for by an organisation behind the Industrial Materials Network, thus eliminating the economic barriers of industrial participation. It is beneficial to pursue a successive take over of the corporate ownership by case industries, along with the development of a favourable (positive) corporate economy. This means that a corporate partner will take the initial economic costs and risks by implementing the scheme, which later on is put in the hands of case industries, as the corporate economy proves successful.
The corporate responsibility is, thereafter, successive transformed from the partner to case industries in the Industrial Materials Network, along with economic benefits, which will increase the engagement of participating industries. It is, however, favourable that case industries are also owners of the implemented energy facility, in order to maintain the necessary interest in an optimal plant operation (to eliminate white elephants).

9.2.5 Strategies in developing an energy system

It has proved beneficial to pursue a successive takeover of the corporate ownership by case industries, along with the development of a favourable (positive) corporate economy. This means that a corporate partner takes the initial economic costs and risks by implementing the Industrial Materials Network, which then later is put in the hands of case industries as the corporate economy proves profitable. The responsibility is, thereafter, successive transformed from the partner to case industries in the Industrial Materials Network, along with economic benefits, which will increase the engagement of participating industries. In the specific context of Navanakorn, Pathum Thani Province and Main Office can therefore be partners to the case industries, who in the initial phase are mainly passive stakeholders with limited economic responsibility and corporate power. As the energy facility proves successful, they can become more active stakeholders with increased economic responsibility and power.

9.3 Corporate Governance

The pre-conditions for the organisation of the Industrial Materials Network, as outlined above, must be transformed into an appropriate type of Corporate governance. In this section, emphasis will thus be on finding such a match, through analysis of different types of Corporate governance. Many other types of Corporate governance, than those presented in the following, exists (Pers.Com., Tyge Kjær, 2002), so the presentation is merely an example of *how* such analysis can be approached. In the following discussions of appropriate types of ownership for co-operations, similar to that exemplified in Navanakorn, I assume that the scheme primarily depends on external financing (no ENCON funding). The purpose of this is to show which consequences different forms of ownership have on the corporate economy, if implemented in a situation where no financial resources were present.

9.3.1 Different types of Corporate Governance

In the following, a general description of different types of Corporate governance will be presented, which afterwards will be linked to the pre-conditions for co-operation found earlier as well as economic calculations of consequences for the corporate economy. There are, in principle, five types of ownerships for businesses, of which the main difference are characterised by the type of liability towards creditors:

- **One-man firm**[52]**;**
- **Partnerships:** Partnership[53], Limited Partnership[54], Limited Partnership Company[55]**;**
- **Private Limited Company**[56]**;**
- **Co-operative Society**[57]**;**
- **Tradesman Fund**[58]**;**

One-man firms are characterised by companies, which are run by a person who is the one and only responsible owner of the company. The owner has liability for the company's obligations with all her or his capital. One-man firms are not obliged to report annual accounts, and there are no requirements of general public knowledge of the company's relations and accounts (Debatoplæg om aktivt ejerskab - Maj 1999, Finansministeriet, 1999).

[52] ('enkeltmandsvirksomhed')
[53] ('interessentskab'),
[54] ('kommanditselskab'),
[55] ('kommandit-aktieselskab').
[56] ('aktie- og anpartsselskab')
[57] ('andelsselskab')
[58] ('erhvervsdrivende fonde')

In ***Private Limited Companies***[59] none of the investors or shareholders has liability towards the company's obligations, with more than their capital deposit. The minimum sum when setting up a Private Limited Company is DKK 500,000. As opposed to One-man firms, the public has right to information regarding the companies' relation, the investor's legal position and specified demands of the management (Debatoplæg om aktivt ejerskab - Maj 1999, Finansministeriet, 1999).
A variant of Private Limited Companies is called ***"Share-Companies"***[60]. As for Private Limited Companies, mentioned above, no shareholders have liability towards the company's obligations with more than their capital deposit, unless the shareholders has decided to 'dissolve the company by surrender the ability to pay'[61]. The flexibility of "Share-Companies" is higher than traditional Private Limited Companies, as it, for instance, to a large extend is up to the shareholders to decide upon internal matters within the company. The minimum sum when setting up a "Share-Company" is DKK 125,000 (Ibid.).

Two or more partners, who can be physical or legal persons but normally consists of a narrow group, can set up a ***Partnership***. The partners are each fully responsible for the company's obligations, i.e. each partner has liability (unlimited by all her or his capital) together with the other partner(s). There are in other words 'joint and several liabilities'[62], which means that a creditor can raise a demand for all outstanding debt towards all partners in a Partnership (Debatoplæg om aktivt ejerskab - Maj 1999, Finansministeriet, 1999). A variant of a Partnership is a ***Limited Partnership***, which can be applied, if certain stakeholders find the economic risk of the traditional Partnership *too* high. In a Limited Partnership one or more partners, named *General Partners*[63] have 'personnel, unlimited and joint and several liabilities' (similarly to the model above), while other partners, named the *Limited Partners*[64], only have liability toward their capital deposit.
Also a Limited Partnership has a variant called ***Limited Partnership Company***, in which a Private Limited Company (with all its capital) are Limited Partner, or in which the Limited Partner has deposited a certain amount of capital distributed on stocks. There is no requirement of a minimum sum when setting up Partnerships (Debatoplæg om aktivt ejerskab - Maj 1999, Finansministeriet, 1999).

As opposed to the above-mentioned types of ownership, ***Co-operative Societies*** are characterised by a different way of organising the ownership. The actual form, on which the corporation is based, is explicitly formulated in the 'purpose of Co-operatives'[65]: Involved stakeholders must be active in the Co-operative Society's production and/or marketing of products. The profit generated by involved stakeholders is calculated in accordance with their contribution of goods to the society. Furthermore, all stakeholders have one vote: the "one-man-one-vote principle". It takes minimum two stakeholders, who can be physical as well as legal persons, to set up a Co-operative Society. The circle of participating members and the ground capital can be variable (Debatoplæg om aktivt ejerskab - Maj 1999, Finansministeriet, 1999).

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[59] ('aktieselskaber')
[60] ('anpartsselskaber')
[61] (…..'opløse virksomheden ved afgivelse af betalingserklæring').
[62] ('solidarisk hæftelse')
[63] ('komplementarer')
[64] ('kommanditister')
[65] ('andelsformålene')

No specific liability is characterised for this type of ownership, and as such there exists a wide range of forms of liability within this type of ownership. Varying, for example, from personnel liability to no liability at all, and to joint and several liabilities, but today most Co-operative Societies are set up with limited liability (Selskabsformerne - en lærebog i selskabsret, Noe Munch et. al., Jurist -og Økonomiforbundets Forlag, 1997). There is no requirement of a minimum capital deposit when setting up Co-operative Societies (Pers.Com., Tyge Kjær, 2002).

9.3.2 Economic consequences of different types of ownership

In the following, some examples of economic consequences on the corporate economy, when using different types of ownership's, will be emphasised. The purpose of the examples is to evaluate which type of ownership is the most favourable for case industries, when looking at their lack of economic as well as co-operation capabilities, as found in the previous sections. It is important that the ownership reflects the capabilities of potential participants, and incorporate possibilities for making dynamic changes in the ownership, i.e. increased economic and decision-making responsibility taken by case industries at a later stage.

9.3.2.1 Pre-conditions

Calculations are made for three types of ownership's: 1/ Private Limited Company, 2/ Limited Partnership and 3/ Co-operative Society. It is presumed that five case industries (the once using both electricity and heat), as well as the Main Office and Pathum Thani Province, are owners of the implemented scheme, which was found to be beneficial in previous analysis. There are thus seven participants in the circle of Industrial Materials Network owners. Calculations are made for the BFB combustion plant as found to be the most appropriate technology for the given context in Navanakorn (primarily due to the Emissions analysis and fuel flexibility as highlighted in Chapter 8). Interests rates and conditions for repayments etc. are the same as used in the Pre-Feasibility Study. These, as well as background calculations regarding the following, can be found in Annex D (part 1 & 2).

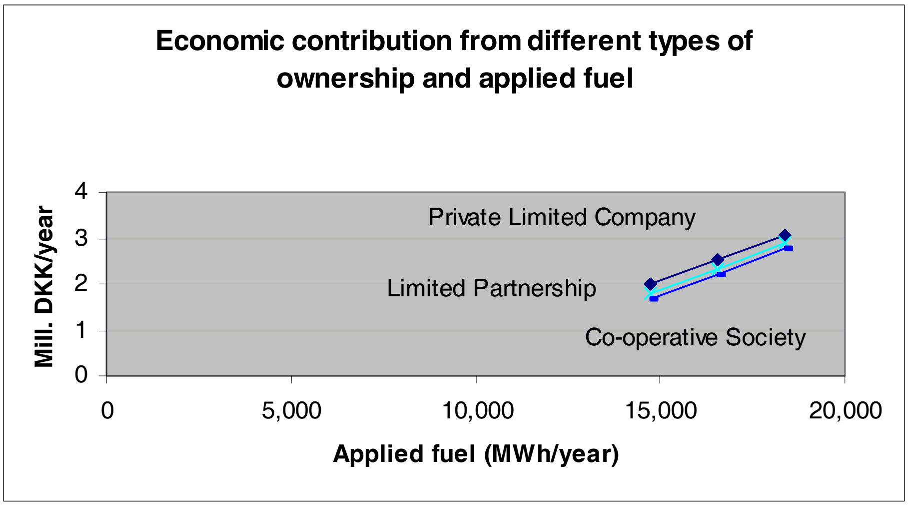
Calculations for an ownership organised as Private Limited Company, are made with a 20 % self-financing share, as required by the World Bank as maximum share (Pers.Com., Tyge Kjær, 2002). This means that participants must come up with 20 % of the total sum required for implementing the scheme. For the Limited Partnership calculations are made with a 10 % self-financing share, and for the Co-operative Society a contribution of DKK 100,000 per participants are used as an example. To illustrate the importance of an adequate fuel supply for the corporate economy, I have shown the results of the total economic contribution with a 10 and 20 % fuel deficit.

9.3.2.2 Economic consequences

In Figure 9A below, the economic consequences are shown. It is seen, that the high economic contribution (self-financing share) by industries when setting up a ***Private Limited Company***, reduces the total costs for external financing. For the corporate economy, this is of course beneficial, and the Private Limited Company scheme also contributes to the best economic results of the three.

The total contribution of DKK 3.08 Mill. per year, are reduced by as much as 36 % if a 20 % deficit fuel supply appears. As the share of self-financing are reduced, in the example used for a ***Limited Partnership***, the total contribution is thus lower. The result is, however, still favourable and only differs 6 % from what is obtained when pursuing the Private Limited Company as type of ownership. The difference between full and 20 % deficit fuel supply are, however, a 38 % decrease in total contribution of the corporate economy.

Figure 9A: Different ownership's (Corporate governance) versus the amount of biomass fuel supply



(Data source based on calculations in Annex D (part 1 & 2))

When setting up a ***Co-operative Society***, calculated with a contribution of DKK 100,000 per participant, the lowest total contribution is obtained. This is, of course, due to the high rate of external financing needed. The difference between the best result - which was obtained for the Private Limited Company - and the present, are, however, only 10 %. The corporate economy's sensitivity towards fuel supply increases, however, as the total contribution are reduced by 40 % when a 20 % fuel deficit occur.

9.3.3 Pros' and con's of different types of ownership in the specific context

This section will emphasise benefits and constraints of each type of ownership mentioned, in regards to creation of a flexible ownership for participating industries. This means limiting the economic responsibility of case industries in the initial phase, and then successive - as economic profits are gained and the co-operation shows fruitful - hand over the responsibility to these stakeholders. But it, however, also means looking at the lack of economic capability of case industries, and the limited (cultural) conditions for co-operation.

In a ***Private Limited Company,*** participants are required to make a relatively high capital deposit to establish themselves in this type of corporation. Unless certain stakeholders, for instance the Main Office and Pathum Thani Province, can contribute to the majority of this deposit, it is unlikely that case industries have such economic capacity. At the constituting

general meeting a Board of Directors and Committee are appointed, who thus possess the power of the corporation. At the general meeting, the stakeholders' share of economic profit generated by the corporation etc. is decided, which - as for all other decisions - are made by majority vote (Selskabsformerne - en lærebog i selskabsret, Noe Munch et. al., Jurist -og Økonomiforbundets Forlag, 1997).
When organising the ownership in the form of a Private Limited Company, case industries have - already in the initial phase - the possibility to exert corporate power (for instances the right to vote) and economic responsibility (liability towards own capital deposit). As shareholders they can also be selected as members of the Board of Directors or the Committee, influencing corporate strategies and daily management from the beginning.

An ownership organised as a ***Limited Partnership*** can be more beneficial for case industries, as the economic liability is limited to a reduced capital deposit, and due to the possibility of differentiating the corporate power when setting up the company. Case industries can thus be Limited Partners, while the Main Office and Pathum Thani Province will act as General Partners, each party contributing with, for instance, 50 % of the total capital deposit. The difference in power between the two parties - the General and Limited Partner - is significantly differentiated. The General Partner roughly have the same power as the Board of Directors and the Committee in a Private Limited Company, and thus responsible for the corporation in regards to both internal and external issues (Selskabsformerne - en lærebog i selskabsret, Noe Munch et. al., Jurist -og Økonomiforbundets Forlag, 1997).

The power of Limited Partners are, therefore, reduced to a right of veto against decisions taken by the General Partner, which goes *beyond* the agreements formulated in the corporate contract by the parties. Limited Partners *can* have certain economic power, which, for instance, can be shares of the economic profit paid to industries in accordance with their share of capital deposit (Selskabsformerne - en lærebog i selskabsret, Noe Munch et. al., Jurist -og Økonomiforbundets Forlag, 1997). In the example above, the capital deposit is set to an equal share by all participants, but can also be differentiated so that case industries only contribute with for instance DKK 20,000 each and Main Office and Pathum Thani Province with DKK 300,000 each.

In a ***Co-operative Society*** the corporate economy is supposed to 'pay for itself'[66], but *is* allowed an economic profit. Often, such economic profit stays within the corporation (Pers.Com., Tyge Kjær 2002), but can also be paid to industries in accordance with their turnover with the company. Participants are obliged to either contribute to or take back/buy goods/services produced by the society. As opposed to Private Limited Companies and Limited Partnerships, the power of participants joining Co-operative Societies is not dependent on their share of capital deposit paid to the corporation. This also means that any profit paid to participants, for instance when closing down a Co-operative Society, solely depends on their turnover within the corporation (Selskabsformerne - en lærebog i selskabsret, Noe Munch et. al., Jurist -og Økonomiforbundets Forlag, 1997).

[66] ('hvile-i-sig-selv')

Co-operative Societies are, as mentioned above, characterised by "one-man-one-vote" principles. This means that case industries, only contributing with limited biomass waste (fuel) or limited needs to take/buy generated energy, have equal power to industries' contribution to large amounts of fuel and a large need for generated energy. Thus, there is no differentiation in the right to exert power by means of contribution to the corporation.

9.3.4 Evaluation of options

When setting up a ***Private Limited Company,*** case industries must come up with a relatively high capital deposit if the share of self-finance (20 %) is spread equally between participants. Such an economic obligation is not favourable for case industries, which lack financial resources, and will most likely end their willingness to become participants in the Industrial Materials Network. If industries manage to raise the required (high) capital deposit, the economic liability might pose *too* high a risk for them to be willing to participate. Also potential influence through the rights to vote in accordance with shares, are most likely handed to industries at a *too* early stage. In the initial phase, an ownership based on a passive role by industries is more beneficial.

As seen from the empirical data case industries are concerned, as to whether other industries benefit more from the co-operation than they contribute with. This, in combination with the "one-man-one-vote" principles, makes ***Co-operative Societies*** unfavourable as a type of ownership for the Industrial Materials Network. Also regarding the decision-making capability within the corporation, a high right of veto (do to the "one-man-one-vote" principles) is unfavourable, as it can limit the speed and rate of decisions taken by the corporation, i.e. incapability to make decisions. Despite case industries' possibility for contributing a lower capital deposit, which could promote increased participation, a Co-operative Society is not an optimal type of ownership. It is clear that the corporation must built on participating industries' individual contribution to the corporation in order to avoid conflicts, which could happen when pursuing a scheme based on "soft" Corporate governance", as found in Co-operative Societies.

A ***Limited Partnership*** is found to be the most favourable type of ownership of the three mentioned. This is firstly due to a lower total capital deposit (compared to the Private Limited Company), secondly, due to the reduced economic liability of case industries, and, thirdly, due to the possibilities of differentiating the power of participants through the General and Limited Partner scheme. Fourthly, it is also possible to differentiate the economic contribution from participants, so that, for instance, only half of the total required capital deposit is paid by participating industries (the Limited Partners), and the remaining by the Main Office and Pathum Thani Province (the General Partner). Case industries then have limited liability towards their share, whereas 'all personnel, unlimited and joint and several liabilities' are taken by the General Partner, who in return possesses all the corporate power when the company is established. Later, as emphasised in the next section, the corporate power can be transformed and come in the hands of the Limited Partners.

The individual economic contribution (size of capital deposit) by case industries can, for example, be organised in accordance with their energy consumption. Imperial, for instance, contributes large amounts of biomass waste (fuel) and is also a large energy consumer. Imperial can contribute a relatively large capital deposit (for instance what equals the costs of operating the former energy system at the industry on a yearly basis), whereas ASAN Service, for instance, only will contribute a minor capital deposit, due to less biomass waste generation and energy requirement. Thus, the industries' shares of the economic profit, generated by the corporation, can be calculated in accordance with their capital deposits, based on former costs for operating their individual energy systems. Such differentiation of capital deposits is intended to create a fair system, where no industries profit to the detriment[67] of other industries.

9.3.4.1 Transformation of power in a Limited Partnership

But how can the corporate power be transformed and change hands, as the renewable energy scheme proves economic profitable?

One possibility is to make 1/ ***"Share Emissions"***[68], which means that any economic profit generated by the company are converted to new shares, instead of paid to participants as a profit in accordance with their capital deposit as normally pursued. New shares can now be bought at a favourable price by case industries (the Limited Partners), who have purchase priority as being the partner who gradually must take over the corporate power. Another possibility is to distribute new shares among all participants (in accordance with their capital deposit), and then let the Limited Partners buy shares from the General Partner, also at a favourable price. In both cases more and more shares will end up in the hands of the Limited Partners, phasing out the influence of the General Partner. As more and more new shares "emissions", the General Partner losses corporate power and can eventually pull completely out of the corporation. Then, the company can be converted to an ordinary Private Limited Company.

The actual transformation of power can happen as the General Partner's right to vote are locked to the amounts of shares, which this partner owns in the initial phase. As more shares are "emissioned", for the benefit of the Limited Partner, the large amounts of shares - earlier owned by the General Partner - are reduced relatively. This is, in principle, the same as deciding that the General Partner must only have 100 votes (due to initially possessing 100 shares), even when the amounts of total shares have "emissioned" to be more than 500 and separated equal between the two parties.

It can also happen as the Limited Partner 2/ ***"Buy Out"***[69] the "emissioned shares" by the General Partner - for example every third year - which then lock the General Partners' right to vote at a new (lower) level, again, successive favouring the Limited Partner.
Another possibility is simply to 3/ ***Formulate certain conditions in the corporate contract***, signed by the participants, in which it is explicit stated that the Limited Partner have special conditions for taking over the corporate power in due time. But, if the economic profit is to be transformed automatically, it is beneficial to link it to the economic profit generated by the corporation, as exemplified above.

[67] ('på bekostning af..')
[68] (' "Emissioner" af aktier eller "Emissionerede" aktier')
[69] ('opkøbe eller købe dem ud')

9.3.4.2 Possibilities for setting up a Limited Partnership

In the case of Thailand, Limited Partnership is a legal type of Corporate governance (Markedsorientering - Thailand, Undenrigsministeriet, Sekretariatet for Udenrigshandel, 1997). There might, however, be countries where such organisation of the ownership is not possible, and if so, this type of company can be established under the legal frames of a Private Limited Company, but as a Limited Partnership Company (limited by stocks) (Pers.Com., Tyge Kjær, 2002). It requires, as being the case for Thailand (Corporate Governance in Asia - A Comparative Perspective, OECD, 2001 & Pers.Com., Tyge Kjær, 2002), that Private Limited Companies are attached to the same regulatory rules as, for instance, in Denmark.

9.4 Strategies in developing an energy system

A ***Limited Partnership*** is seen here as the most favourable type of ownership of the three mentioned. This is firstly due to a lower total capital deposit (compared to the Private Limited Company), secondly, due to the reduced economic liability of case industries, and, thirdly, due to the possibilities of differentiating the power of participants through the General and Limited Partner scheme. Fourthly, it is also here possible to differentiate the economic contribution from participants, so that, for instance, only half of the total required capital deposit is paid by participating industries (the Limited Partners), and the remaining by the Main Office and Pathum Thani Province (the General Partner). Case industries then have limited liability towards their share, whereas 'all personnel, unlimited and joint and several liabilities' are taken by the General Partner, who in return possesses all the corporate power when the company is established. Later, the corporate power can be transformed and come in the hands of the Limited Partners, by *"Share Emissions"* and *"Buy-out"* of "Emissioned shares".

Chapter 10; Guideline for Industrial Materials Network implementation

The aim of this chapter is to present the Guideline for appropriate implementation of Industrial Materials Networks in Thailand, which has been developed throughout this study. Under each Action, which follows, the Guideline contains the following aspects: *Purpose of the action; Actions to be taken; The source of information;* and, finally, *Important stakeholders.* Before presenting the Guideline, I will elaborate on the purpose of the Guideline and discuss some generalisation aspects of it, as outlined in the introduction below.

10.1 Introduction

10.1.1 Purpose of the Guideline

This chapter will develop a Guideline with the aim of establishing Industrial Materials Networks in Thailand. The purpose of the Guideline is thus to create a platform from which new Industrial Materials Networks can emerge, thereby moving from the "pilot-project-level" of Navanakorn, to a level, which generally supports the implementation of such schemes. The Guideline consists of several *Actions*, each poses different assignments to be conducted by different stakeholders. Most of the actions outlined below are identical to the analysis made in this thesis, in which an Industrial Materials Network was established in Navanakorn Industrial Promotion Zone. Other actions, than those, are a consequence of further elaboration on the topic. As mentioned, each action in the Guideline consists of *four parts*:

1/ The overall purpose of the action; 2/ The actual action to be taken; 3/ Important stakeholders for completing the action; and, 4/ The source of information. The four parts also consist of different *steps* to be taken under each action. The Guideline is, furthermore, approached on a general level, and only when found important for understanding the actions and steps taken, will examples from the actual case study be introduced.

The intention with the Guideline is to develop a *dynamic* approach to the implementation of Industrial Materials Networks. Certain actions taken can, therefore, provide knowledge that result in feedback and thus reconsideration of former actions taken. The Guideline is meant to be an inspiration for stakeholders wanting to pursue the implementation of Industrial Materials Networks in Thailand or in other NICs, and as such not a recipe, which followed slavish, ends in the successful implementation of Industrial Materials Networks. Many important areas and aspects of such implementations cannot be predicted with any precision, and a countless number of variables make it impossible to include every possible situation, which can emerge. I therefore assume that stakeholders utilising the following Guideline are capable of catching the ideas behind it, and add relevant actions when found to be important.

The target group for the present Guideline is all levels of stakeholders interested in exploring the potentials for Industrial Materials Network implementation in their community. This can be a municipality or a province facing increased pressure from waste generation in their community, or a more stable team of stakeholders (for instance industries and/or owners/managers of industrial areas) wanting to pursue the implementation of Industrial

Materials Network for re-use of wastes and renewable energy production. The cause of motivation can thus be different, but the methods by which the potentials can be exploited are the same, and are outlined in the Guideline Actions that follows.

Figure 10A below, gives an overview of the different actions and steps which must be taken when implementing Industrial Materials Networks. Under each of the seven actions is a reference to the specific chapter in the thesis, in which the background analysis is elaborated, as well as references to the similar action, outlined in the Guideline (the present Chapter 10). In this way it is possible to get a more thorough description of how to approach Industrial Materials Network implementation, when studying the thesis, and a quick overview of the implementation process when looking at the Guideline Actions only.

10.1.2 Generalisation

The results of this Guideline have been developed through a case study conducted in Navanakorn Industrial Promotion Zone in Thailand, and 'transformed' into some indicators as to how to implement Industrial Materials Networks throughout Thailand. What, however, justifies such a generalisation of data to other contexts than the one studied?
Let me emphasise that I understand the term "generalisation", as the Guideline's general usability as a planning tool. I will, therefore, look into the following aspects in regards to its usability, as they can have a great effect on the results obtained when using the Guideline: *The location issue; Types of industries;* and, *The potentials of Industrial Materials Networks*. Below, I will elaborate on this issue, as well as on the *Built-in validity*, before presenting the Guideline Actions.

10.1.2.1 The location issue

The co-operation between industries proposed for Navanakorn Industrial Promotion Zone facilitates the distribution of energy and collection of biomass from industries, as the physical location of industries is close. Most industries in Thailand are located in Industrial Estates or Zones, caused by re-location of for instance Bangkok industries, and all new industries establishes themselves in such locations. There are 55 industrial Estates or Zones in Thailand (List of Industrial Estates/Industrial Parks/Industrial Zones, BOI Homepage, 2003, at; www.boi.go.th/english/business/ind_estates_zone3.html, per 4-6-03), providing the same opportunities for a close location as found in Navanakorn Industrial Promotion Zone.

10.1.2.2 Types of industries

A few Industrial Estates or Zones have a majority of Petrochemical industries (for instance Map Ta Phut Industrial Estate), but most Estates or Zones are a mix of industries as found in Navanakorn Industrial Promotion Zone (Your guide to investment in Thailand's Industrial Estates, IEAT, 2001 & Three decades of IEAT (1972-2002), IEAT, 2002).
These, theoretically contain the same possibilities for establishing Industrial Materials Networks as found in Navanakorn. Typically, Industrial Estates or Zones are thus established as a mix of different industries, as, for instance, food, wood, pharmaceutical, electronic, textile, leather and paper industries (Ibid.), creating great opportunities for implementing some sort of materials and energy co-operation between them.

10.1.2.3 The potentials of Industrial Materials Networks

I expect the potentials for implementing Industrial Materials Networks to be larger than that shown in the case of Navanakorn. This is due to the limited possibilities of getting every single relevant industry in the Zone in speak, due to some resistance towards participating in interviews, and of course due to the fact that not all industries could be approached.
The empirical data also show that industries, which I had expected not to contribute with relevant biomass, actually generated appropriate waste for energy production. This shows that the biomass waste potentials can be larger than expected, and that "door-to-door studies" *must* be made. Therefore, by making appropriate stakeholders approach the industries with relevant information about the potentials of Industrial Materials Network, I expect the interests from industries to be much larger than what I could identify.

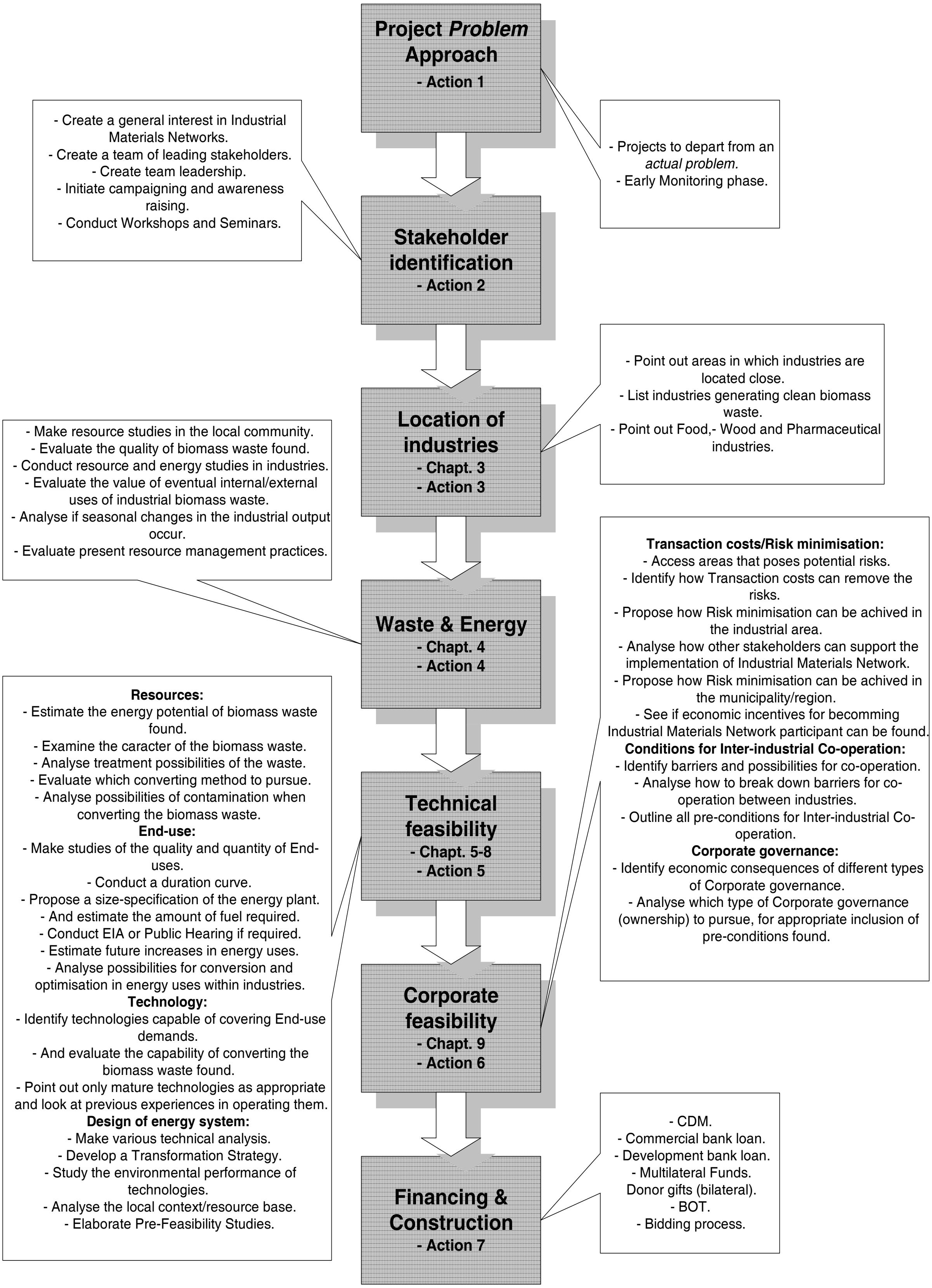
10.1.2.4 "Built-in-validity"

Moreover, the Guideline contains a Monitoring phase in Actions 2 and 3 in order to avoid the possibility, that an implementation continues on wrong premises. The usability of the Guideline is thus integrated in the Guideline Actions themselves, as parameters for moving from one Guideline Action to the next.

If, for instance, no Leading Stakeholders (see Action 2) can be found in the specific area, where it would be favourable to implement Industrial Materials Networks, then the purpose of moving on to the next action disappears. Thus, the Guideline has no usability in this situation and therefore is not appropriate in the specific case. Likewise, if no relevant (defined by the Guideline) industries can be located in an industrial area, in which industries are located relatively close to one another (see Action 3), then it makes no sense to continue to the next step, as the argumentation for doing so is undermined. And further, if the quality of biomass wastes from industries located in an industrial area is bad, it could, for some unexpected reason, contain too many contaminants etc. - and by no means can be either digested or incinerated (see Action 5) - then it gives no meaning to continue, and the Guideline has no usability in this specific context.

As seen from the above, the Guideline is meant to be a dynamic tool and not a manual, ready to fit any given situation. It is a step-by-step approach, taken by the Leading Stakeholders implementing the Industrial Materials Network, showing whether or not the Guideline is valid in the specific context where it is sought implemented.

Figure 10A: Guideline Actions



Guideline Actions

⇒ **Action 1: Project *problem* approach;**
⇒ **Action 2: Stakeholder identification;**
⇒ **Action 3: Locate appropriate industries for Industrial Materials Network implementation;**
⇒ **Action 4: Map biomass waste and energy uses in relevant industries, as well as biomass waste from the community etc.;**
⇒ **Action 5: Make 1.Triangle Analysis - technical feasibility: 'Resources, End-use and Technology';**
⇒ **Action 6: Make 2.Triangle Analysis - corporate feasibility: 'Transaction costs/Risk minimisation, Conditions for Inter-industrial Co-operation and Corporate governance';**
⇒ **Action 7: Financing: How to finance and commence the construction phase;**

Action 1: Project *problem* approach

Purpose of the action

- A first criterion for project proposals is to evaluate whether the project can help in solving an actual *problem* or *unsustainable practice*. It must thus be a problem or a critical situation, which initiates the project identification. Often, projects are simply initiated by, for instance, looking at which technologies developed countries *can* transfer, and not whether this technology actually helps in solving an actual *problem* in the specific context examined (Pers.Com., Tyge Kjær, 2003). When an appropriate identification of the project has taken place, it is important to emphasise whether the project potentials, which now are drafted, have a reasonable *validity* before proceeding with the project. Therefore, a *Monitoring phase* must be introduced very early in the project, so as to determine whether the project can succeed (and not *after* the implementation).

The Monitoring phase must be introduced in Actions 2 and 3, in which stakeholders are identified and relevant areas and industries are pointed out for Industrial Materials Network implementation. The Monitoring phase will, in Action 2, identify if relevant stakeholders actually *can* be identified, and *whether* project support can be found among the local stakeholders. If not succeeding in this task, the project must be cancelled as it will be continued on unsustainable premises. If, on the contrary, relevant stakeholders are found, the project can proceed to the next phase.
In Action 3, emphasis is placed on industrial areas and relevant waste generating industries. The Monitoring phase will identify *whether* it is possible to find appropriate areas for Industrial Materials Network implementation, and whether the most appropriate types of industries for such co-operation *could* be identified. If the Monitoring phase indicates validity or usability of the project until this stage, the project can continue.

Action 2: Stakeholder identification

Purpose of the action

- The purpose of Action 2 is to *identify* relevant stakeholders to initiate the process, and stakeholders capable of acting as leaders in the implementation of Industrial Materials Networks. The purpose is, however, not only to identify stakeholders but also to *create* the interest, as a prior interest in the project cannot be expected. The stakeholders are not aware of the benefits of participating in Industrial Materials Networks in advance. It is, therefore, also important to take actions to *develop* the interest of various stakeholders, and by campaigning activities etc. build bridges between different stakeholders so that the Inter-industrial Co-operation can find its roots.

Campaigning activities can also be used if the stakeholders resist or are reluctant to participate. Furthermore, if the target group is large, campaigning activities can be an appropriate means of communicating, for instance, the benefits of participating in Industrial Materials Networks. Such activities can be used, whenever the project faces difficulties in delivering messages about the project. Campaigning and awareness activities are, therefore, used as a dynamic tool. As the Guideline must be understood and used as a *process*, such a dynamic tool is beneficial. If the project is not ready to proceed, due to for instance lack of support, campaigning activities can be initiated and the project continues afterwards.

Campaigning and awareness raising activities can, for instance, be in the form of written material or web sites presented to industries, as well as factory visits by governmental agencies or NGOs etc. participating in the development of Industrial Materials Network implementation. This information can contain economic and environmental benefits for industries when joining an Industrial Materials Network. Later, workshops and seminars can gather potentially interested industries for further information and discussion.
The most important aspect when looking for participants to join the Industrial Materials Network is campaigning and awareness raising activities, and through such initiatives, find industries who wants to participate on a voluntary basis (Mr. Chaiwat Pollap, NEPO, Interview, Bangkok the 9-2-01 & Mr. Tannerat Worasute, DIW, Interview, Bangkok the 21-2-01).

However, prior to any actions taken a ***Team of leading stakeholders must be created*** to pursue these initiatives. A stakeholder identification must be elaborated by stakeholder analysis, emphasising organisations/institutions etc. who can be prime initiators, and thus appropriate members of the Leading Team, and which of them who can take on leadership. Below, potential Leading Team stakeholders are suggested. The criteria for pointing to these specific stakeholders are their views upon the increasing amounts of waste, as being a *problem.*

Important stakeholders

- -Stakeholders already collecting/treating waste in the area examined;
  -Local governmental institutions that see waste as a problem;
  -Non Governmental Organisations who see waste as a problem;
  -National governmental or quasi-national governmental institutions that see waste as a problem;

Example:
Create a Leading Team
In Navanakorn three stakeholders were found to be very important for Industrial Materials Network implementation, namely the *Main Office of Navanakorn*, *Pathum Thani Province* and finally the *Local FTI* (FTI local chapter). The Main Office of Navanakorn was found to be an important stakeholder due to its positive and trustful relation to industries - providing various service tasks to industries as for instance waste collection - and its financial capacity to support the project, as being owners of the Industrial Zone. Pathum Thani Province was found to be an important stakeholder due to its knowledge of local biomass resources, its interest in finding new waste management practices, and as being a potential Fund contributor (i.e. can apply for economic resources through ENCON).

The Local FTI (Pathum Thani Local Chapter) was found to be a powerful stakeholder with the capacity to build bridges between industries, and promote the idea of Industrial Materials Networks. First, by promoting the implementation of Industrial Materials Networks in different lines of business in the region, then, later, in sub-chapters across branches in the industrial areas pointed out. A Leading Team must, therefore, preferably consist of at least:
1) Owners/leaders of the industrial site or area who service industries; 2) The province in which the industries are located; and, 3) Local FTI. If owners/leaders of the industrial area do not possess the same relation to industries as in the case of Navanakorn, it is important to find stakeholders who can undertake this role instead.

Create Team Leadership
How must the Leading Team be built? The Local FTI must, together with for instance a large and powerful NGO - for example Thai Environmental Institute (TEI) or Energy for Environment Foundation (EFE) - take on Team Leadership and create the Leading Team. They must present the ideas of Industrial Materials Networks for owners/leaders of industrial areas, and representatives of the provinces in which the sites are located. Stakeholders who find the idea of Industrial Materials Networks useful, and support the ideas behind it, must preferably be Leading Team members. When the Leading Team by means of this approach is established, it will pursue an identification of appropriate industries, as emphasised below.

Action 3: Locate appropriate industries for Industrial Materials Network implementation

Purpose of the action

- The purpose of this action is to locate appropriate industries for Industrial Materials Network implementation. Materials uses and energy requirements are the main criteria for selection of industries, as emphasised more fully in the following.

Materials use:
Regarding materials usage, there are, in principle, four types of re-use strategies. The first strategy is *Internal Re-use*, which, for instance, can be small pieces of wood re-used as construction support in the production of wooden furniture. The second strategy is *Cleaner Production*, which, for instance, can be a new moulding machine only removing

the top surface of wood in processing activities. This leads to an overall reduction in wood uses and thus pressure on virgin materials. Another strategy is *External Re-use,* which can be sub-divided in two: Specific External Re-use - being the <u>third</u> strategy - and General External Re-use. By *Specific External Re-use* materials are, for instance, re-used in another industry in the same line of business. Using wood industries as an example again, sawdust from one industry can be re-used as materials for producing chip boards in another industry. By *General External Re-use* - being the <u>fourth</u> strategy - materials are re-used in a general matter, this not necessarily attached to the specific line of business. This can, for instance, be wood waste used for producing energy.

The purpose of this action is to focus on General External Re-use, thus re-use of materials that cannot be re-used elsewhere. This is, however, not a first priority, as Internal Re-use, Cleaner Production and Specific External Re-use rank higher. It is, therefore, a pre-condition in the following actions that appropriate initiatives are taken on this behalf, *before* commencing the actions as outlined below.

Energy requirement:
Industrial demand for energy, here heat, is an important criterion for the selection of industries. By substituting uses of fossil fuels for process heat generation, with the use of clean biomass waste as fuel for supply of heat in district heating networks, economic and environmental benefits can be obtained for industries and society. By means of this approach a heat market is "created", and the energy efficiency of the energy production will increase dramatically, as no "waste heat" is produced.

The selection of industries is thus made theoretically in accordance with estimations of energy uses and biomass waste generation in different lines of businesses. Thus, certain types of industries are pointed out as being appropriate as Industrial Materials Network participants. This is due to the fact that a majority of process heat uses in these industries happens by temperatures of less than 100 ºC, which can be covered by water based heat (i.e. district heating), and that large amounts of mainly "clean" biomass waste are generated thus appropriate as fuel.

Food,- Pharmaceutical and Wood processing industries are identified as the most appropriate industries for Industrial Material Network development, using this method. Paper and tanning industries are also relevant industries, but the amounts of generated wastes are inferior compared to the industries above.

Focus on industrial areas:
In order to find both waste generating industries and heat markets within a narrow spatial area, Industrial Estates or Zones are found favourable locations for pursuing Industrial Materials Network implementation.

Actions to be taken

- ***Point out areas in which industries are located relatively closely to one another***. This can preferably be in Industrial Estates or Zones, or other industrial areas that provides the same possibility for a close location of industries. ***List industries that presumably generate clean biomass wastes***. If not actually becoming Industrial Materials Network participants, some of these industries can supply biomass wastes to the co-operating industries.

- Finally, ***point out Food,- Pharmaceutical and Wood processing industries*** (paper & tanning industries), as being especially relevant as Industrial Materials Network participant, but conduct further studies and site visits in *all* industries found above (see Action 4).

Important stakeholders

❖ Location of appropriate industrial areas not being Industrial Estates or Zones can be done by the Leading Team in co-operation with the Ministry of Industry (MOI), who is responsible for registering all industries in Thailand. MOI can also support analysis regarding which line of business (branches) the industries belong to, by which a first theoretical selection of industries is made. The Leading Team can thus draw on knowledge from governmental institutions in their information gathering.

The source of information

❑ *Theoretical analysis* (paperwork) based on knowledge concerning waste generation and energy uses in different lines of businesses.

Action 4: Map biomass waste and energy uses

Purpose of the action

➢ From an industry's view generated by-products are regarded as *waste*, but when re-used for energy production it become a new resource with value. As mentioned earlier, this re-use can happen as *General* or *Specific Re-use*, here with emphasis on General Re-use. Thus, the focus of the following section is on analysis and estimations of *amounts and types of waste for further re-use*. A condition for appropriate Industrial Materials Network implementation is namely studies, which emphasise biomass waste generation and energy uses in the types of industries found by the action above, in detail, as well as biomass waste from the community (for instance household and agricultural waste). In this action, the theoretical selection of industries (which happened in Action 3) will be supplemented empirical data, making it possible to point out the most appropriate industries for Industrial Materials Network development, as well as industries supplying for instance biomass wastes to the Network.

Actions to be taken

- Make ***resource studies*** of Industrial Materials Network Supporting Resources or Systems within and outside the industrial area. These can, for instance, be relevant agricultural wastes as well as organic household wastes and commercial/industrial wastes from the community (Supporting Resources). It can, for instance, also be the presence of a WWTP within the industrial area, contributing to sludge generation appropriate for energy production (Supporting Systems). Then specify the type and amounts of resources found.

- ***Evaluate the quality of biomass wastes*** that comes from Supporting Resources, or Systems, when used for energy purposes. How large are the fractions of organic materials in household waste and commercial waste, and how much can be utilised when sorted? Are there other means of uses, which makes it inappropriate as fuel? This issue can be very context-dependent, as organic fractions in household waste seem to "disappear" in certain countries or parts of countries, usually for uses as animal food or fertiliser. Thus, it is not sufficient to *estimate* the presence of biomass fractions, as an actual collection and analysis must be made in order to conclude whether these resources can be utilised for energy purposes.

- Make ***resource and energy studies*** in industries pointed out as relevant Industrial Materials Network participants. Identify types and amounts of biomass wastes by studies of Raw materials input and waste, as well as Re-use of resources. Identify types and amounts of energy uses by studies of electricity and fuel uses (for process heat generation). Note the temperature of process heat uses. How much is based on steam uses and how much is water based heat uses? Also expose important issues such as Operation hours per year, Efficiency of machinery in use, Expected increases in production output and Ownership, employees and markets.

- Determine the ***value of internal/external uses of biomass wastes from industries***. If the wastes have a very high commercial value, it is not likely that industries will utilise it for internal energy production. If the commercial value, however, is low - or even sometimes negative as being a cost factor - it is more likely that industries will seek other ways to improve the value of biomass wastes, as, for instance, through an Industrial Materials Network for energy production. If external re-use happen far away from the industrial area, with long transportation distances as a consequence, preferably seek re-use within the industrial site.

- Find out whether there are ***seasonal changes in the industrial output***, which can affect the quantities of biomass available for energy production. This must be studied for all types of biomass found, but especially where agricultural wastes are applied, seasonal changes can occur (due to harvesting periods). A constant output of biomass waste also means a constant demand for energy, which is preferable when designing an energy system (compared to a very fluctuating output of biomass and energy demand).

- Evaluate present ***resource management practices*** within and outside the industrial site, i.e. in the Province, the Municipality and in the industrial area. If weaknesses, or problems, are found in these practices, the biomass wastes are more likely to be canalised to the industrial area for energy uses, as they represent a "problem" for various stakeholders. For instance, if the management of industrial waste is expensive for industries, they are more likely to pursue new means of waste management.

Important stakeholders

❖ Several stakeholders have proved interested in participating in the process of elaborating resource and energy studies. The Department of Industrial Works (DIW) has initiated data collection in Thai industries, where the focus is on the amounts of waste generated (Mr. Tannerat Worasute, DIW, Interview, Bangkok the 21-2-01). This analysis can be used as background material for further studies, as the credibility can be questioned when conducted by a governmental body (Pers.Com., Jan Andersen, 2002).

The Leading Team must, therefore, take action in conducting the resource and energy studies, which now has to take place. The "mother organisation" of the Local FTI, Bangkok FTI, has the capacity (technical, personal, and economic) to pursue this task. The organisation has also proved to be interested in commencing such analysis. FTI has the capacity and interests in conducting energy and biomass waste audits in Thai industries, thereby laying the foundation for Industrial Materials Network implementation (Ms. Dominica Dacara, FTI, Interview, Bangkok the 19-2-01). Also the Province, in which the industrial area or site is situated, can provide important information regarding Industrial Materials Network Supporting Resources i.e. agricultural wastes, household waste, commercial/industrial waste etc. and its potential availability. Managers/owners of the industrial sites must also contribute with knowledge regarding biomass wastes.

The National Science and Technology Development Agency (NSTDA) can - through the University Consortium - also support such data collection by collaborating with universities, in which students, lectures and professors at universities all over Thailand join forces in data collection. Especially students - whom traditionally are used for various data collection in Thai industries - will be able to help in providing this task, whereas lectures and professors can finalise and sum up the analysis (Mr. Bundit Fungtammasan, NSTDA, Director of Energy and Cleaner Technology Center & Ass. Professor at King Mongkut's Institute of Technology, Interview, Bangkok the 13-2-01). Also in regards to, for instance, amounts and contents of organic fractions in household waste etc., within or outside industrial areas, the academia can provide such analysis, which can support the implementation of Industrial Materials Network further.

The source of information

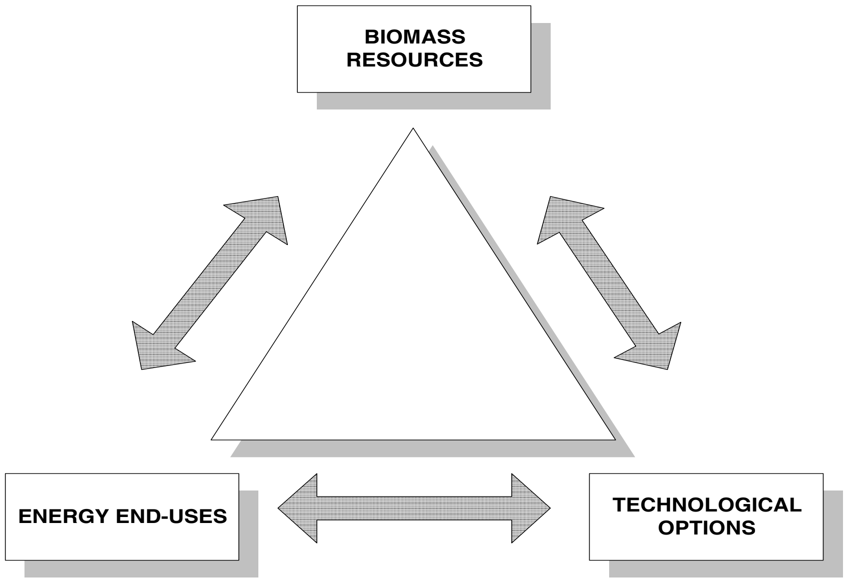
- *Interviews/site visits in industries* will expose biomass waste generation and energy uses etc. in industries, as well as aspects like; Seasonal changes, Operation hours per year, The efficiency of machinery in use etc. Information about Industrial Materials Network Supporting Resources and Systems will be *exposed by the knowledge given by Leading Team members* i.e. the Province and Managers/owners of the industrial site.
  Collecting and sorting of wastes must be initiated, where the amounts and availability of organic fractions are in question.

Action 5: First Triangle Analysis - technical feasibility

Purpose of the action

- The results of the energy and resource studies conducted in Action 4 must now be examined for further analysis, which ends in an optimisation of the Triangle: 'Resource; End-use and Technology' as outlined below. The consequences of this optimisation are actions that determine the Design of the energy system, which will end Action 5.

Figure 10B: Triangle Analysis



The ideas behind the Triangle is to create optimisation between the specific need for energy found in industries, the type and amount of waste found and the conversion technologies. The inter-connection between the three determines the outcome - the optimisation - of the Triangle. If, for instance, most biomass waste is on a liquid form, certain conversion technologies are more appropriate than others, as, for example, Gas Engines (motor-generator unit) in this case. As Gas Engines produces low quality heat, energy demands requiring large quantities of high quality heat (steam), cannot be fulfilled satisfactory. Thus, other means of conversion technologies must be examined, together with a possible "treatment" of the fuel, in order to cover the heat demands found.

Biomass Resource

As emphasised earlier, waste can be re-used by means of External Re-use, divided as Specific or General Re-uses, of which the latter can be raw materials - fuels - for energy production. This fuel can be on a solid or a liquid form. The focus of the section below is to study the *energy system* by which the energy will be generated, which depends on the waste characterisation. If the waste is liquid, it will normally be converted in a Gas Engine, which cannot generate high quality heat for industrial uses. If the waste is solid, Technologies producing high quality can, on the contrary, be implemented. How to approach the study of waste for appropriate selection of an energy system will be emphasised in the following, which for instance will include, how to transform liquid waste to solids for high quality heat production.

Actions to be taken

- Estimate which conversion method is the most optimal when examining the ***theoretical energy potential of all biomass wastes found*** (in MWh/year). If the energy outputs differ, according to the way of conversion (whether for instance being *incinerated* or *digested*), preferably chose the method providing the largest energy output. This will improve the utilisation of biomass wastes for efficient energy production.

- ***Examine the character of biomass wastes*** (composition; content/structure and type; solid/liquid), which is important in order to determine, whether it can be converted by the method most efficiently as emphasised above. If biomass wastes are found to be most appropriate for digestion - according to the energy potential - then analyse whether such conversion is possible when looking at the specific biomass character; Can all the wastes be converted by this method, or are there large quantities of wastes, which cannot? Is it, furthermore, possible to obtain the right mix of liquid contra solid organic waste for appropriate digestion?

  If the energy potential, as well as the composition of biomass waste, points to digestion as method, this would be an appropriate conversion method to pursue. And, the other way round, if the energy potential, as well as the composition of wastes, favour incineration as method, this will preferably be the method to pursue. If, on the contrary, large amounts of wastes are on both liquid and solid form - and energy potential of wastes is not very ambiguous - one way of determining the most appropriate conversion method is by looking into ”treatment” possibilities of the wastes, as emphasised in the step below.

- ***Analyse treatment possibilities of wastes*** with the purpose of preparing or transforming it for other means of conversion. If, for instance, digestion is found to be the most favourable conversion method, according to the composition of wastes (large amounts of wastes on liquid form), but the energy potentials low when using this type of conversion, a "*treatment*" can be applied. Is it, for instance, possible to dry liquid wastes with the purpose of incineration? If large amounts of liquid wastes can be dried for incineration purposes, or kept on liquid form for digestion with improvements in energy output, the latter method is superior. Treatment possibilities also depend on the economy; what is feasible ‘energy-economically’ might not be feasible ‘economically’ (in DKK). Therefore, analyse whether such treatment is feasible in the local context before continuing.

- ***Evaluate which conversion method to pursue*** if biomass wastes are of both liquid and solid composition. If the amounts of liquid and solid wastes are almost the same, preferably select a multi-fuel conversion method. If the energy system is enlarged later on, then expand it with a conversion method more in accordance with the “original nature” of the wastes. Whether the multi-fuel conversion technology should focus on liquid or solid wastes (digestion or incineration) mainly depend on which energy demand to cover, as different conversion methods provide different energy services. It also depends on which possible environmental problems that can occur when applying different conversion methods, as emphasised below.

- ***Analyse whether biomass wastes can lead to contamination when converted in certain ways*** and, therefore, more appropriate for other means of conversion. In order not to create unwanted emissions through the development of an energy system, such analysis is a necessity. The results *can* change focus away from the most appropriate conversion method initially found, at least for some of the wastes. The energy potential of household waste is, for example, highest when incinerated, but emissions of dioxin (caused by contents of organic bound chlorine), which can develop under incineration, make this an inappropriate conversion method (two-step treatment are only applied on waste incinerating plants, not on biomass technologies). In this case, biological digestion is more appropriate as a conversion method.

The source of information

- The tasks to be conducted are primarily *theoretical studies and analysis* (paperwork), combined with studies of biomass wastes in the field, in order to evaluate its character.

<u>Energy End-uses</u>

Purpose of the action

- Besides further analysis of "heat market" potentials and energy uses within industries, which is the purpose of the section below, it is also important to find out whether there is a local district heating network by which generated surplus heat could be transmitted. It can also be favourable to find out whether other large heat customers, as, for instance, a local hospital, are located in the area, or whether other types of heat using facilities are located in the area. These activities can add "heat market" potentials to that found in industries, as emphasised below, if the need for industrial process heat not is sufficient.

Actions to be taken

- Elaborate more ***detailed analysis on the quality and quantity of End-use demands*** from the data given by Action 4, in which the quantity and quality of energy uses were exposed. Study the energy consuming patterns in industries, showing, for instance, total uses of heat and electricity (in MWh/year), and by which temperatures (highest and lowest) process heat are required in the production processes, to get a thorough picture of the energy demands. Note industries that are obvious for an substitution in energy supply, as using process heat by temperatures below 100 ºC, i.e. conversion from high quality heat uses (steam made by electricity or fossil fuel) to low quality heat uses (water based heat by district heating). Also note industries using process heat above 100 ºC, and, therefore, *could* convert to water based process heat by means of technical changes in processing activities.

- Departing from knowledge about operation hours per year and the quality and quantity of End- use demands, ***conduct a duration curve for industrial energy uses***, showing the heat effect in MW and the operation hours per year. The purpose of such a curve is to develop a tool appropriate for estimating how energy End-uses can be covered, according to the energy consuming patterns in industries; is it possible to cover energy demands solely by district heating? Or if steam uses are required; can cascading of steam to other industries be established? Is it, furthermore, possible to cascade "waste steam" from these industries to other industries again? As a result of the above analysis, now ***propose a size-***

specification of the energy plant (in MW heat and electricity) and ***estimate the amounts of fuel required*** (MWh/year).

- If the proposed energy plant exceeds 10 MW then an Environmental Impact Assessment (EIA) must be conducted. If the energy plant will be established as a Firm-SPP, a Public Hearing must rightfully be initiated (Mr. Somkiat Sutiratana, DEDP, Interview, Bangkok the 24-4-03).

- ***Estimate the consequence of future increases in energy uses within industries*** (in MWh/year), which are important for appropriate design of the energy system regarding, for instance, plant flexibility. Expected increases in energy uses can partly be complied with by implementation of DSM strategies, which is the next step to be taken.

- Make a thorough analysis of possibilities for implementing ***conversion and optimisation initiatives in industries***, the latter especially relevant in industries using process heat exceeding 100 ºC, and, therefore, not just adequate for conversion in energy supply. Thus, by conversion initiatives it is possible to transform energy demands, consisting primarily of steam uses, to energy demands consisting primarily of water based heat uses. Combined with efficient uses of energy through optimisation initiatives, as for instance effective uses of machinery etc., this can lead to large reductions in total energy uses: both quantitative and qualitative.

  To give an example of *conversion and optimisation* strategies possible to implement, wood industries using process heat produced by electricity can be emphasised. In wood industries, process heat is often used for drying glue in "glue pressers" at temperatures just above 100 ºC. By connecting the "glue presser" to a water borne system, and using a glue that hardens by lower temperature levels, a conversion of the energy supply can take place. Optimisations strategies can be achieved by various activities in wood industries. Especially in the areas of Processing wood, Compressed air and Removals of sawdust, such strategies are beneficial (see Chapter 3 of this thesis). In the latter, large energy savings can be obtained by implementation of a more adequate transportation system for sawdust removals.

The source of information

- The tasks to be conducted are *theoretical studies and analysis* of data and information given by the steps in Action 4 (paperwork), as well as additional studies and monitoring in industries, as the information needed might exceed what is obtained in Action 4.

<u>Technological Options</u>

Purpose of the action

- The purpose of the following section is to look into technologies capable of converting biomass wastes found into the type of energy required by industries. When the biomass waste and energy End-use has determined the energy system, i.e. by which means the conversion must take place (process), an appropriate selection of converting technologies can take place. This task is emphasised below.

Actions to be taken

- ***Identify which technologies are capable of producing energy services as required by industries*** (steam, water based heat or both). If no steam but only water based heat is required, Gas Engines might for instance be a technical option. Looked at it the other way round, Steam and Gas Turbines are more appropriate technologies where steam demands appear.

- ***Now evaluate the technologies in accordance with their capability to convert biomass wastes*** as found in the Resource analysis. The composition of biomass wastes can be very different, thus analyse which technologies that are capable of converting the specific wastes found. The composition can, for instance, vary according to the content of wastes, and in regards to the moisture levels. Some combustion technologies, for instance, require fuel of a very homogeneous structure (size-specification's of fuel), whereas the moisture level can be relatively high. If the wastes are very different in composition, preferably select a multi-fuel technology as being the most appropriate application. If, on the contrary, biomass wastes are very homogeneous, as, for instance, being wood wastes only, the number of possible conversion technologies to choose between increases.

- ***Finally, point out mature technologies and look at experiences in operating the specific technology***, when emphasising the energy demand to be covered and the composition of biomass fuels. Are there, for example, previous experiences in operating the technology - fed by this specific fuel - that points to potential weaknesses? The maturity of technologies is very important to bear in mind, as it affects plant reliability and thereby the creation of a stable energy production. Analysis must only be elaborated on technologies fulfilling this criterion.

The source of information

- *Theoretical studies* of different conversion technologies for biomass wastes, combined with *expert interviews* and *interviews with plant operators etc.*, emphasising the most appropriate technology for implementation in the specific context analysed.

<u>Design of energy system</u>

Purpose of the action

- An optimisation of the energy system as a whole will appear in the following section, as opposed to the optimisations, which happens under each action (Resource, Technology and End-use) of the Triangle.

Actions to be taken

- ***Make various technical analysis*** emphasising the set-up in the Energy supply and location of energy plant, as, for instance, how to design the district heating network so all levels of energy requirements can be fulfilled, and how to implement the cascading of energy practically. In the analysis of Composition of waste and specific plant design, it is possible to emphasise how certain types of biomass wastes can be utilised especially beneficially, compared to for instance traditional combustion. This could, for example, be uses of liquid bio-oil (if any) as combustion stabilisation in a burner placed in the furnace, thereby reducing the influence of high moisture biomass or biomass with a very inhomogeneous content.

In Plant flexibility the potential technologies for implementation are evaluated in accordance with their capability to start up and close down. If the conversion technology must not be operated on full load (emphasised in the duration curve), it is especially important to find a technology, which has such flexibility. Also elaborate analysis of Flexibility in the capacity of meeting increases in End-use demands, which expose whether technologies can be over-dimensioned in order to prepare for future energy increases.

Normally, over-dimensioning of biomass technologies is inappropriate as it affects plant economy relatively more than when implementing traditional technologies.
A slight over-dimensioning *can*, however, be pursued by for instance up-scaling the Steam Turbine Plant slightly (must not exceed 20 %). Otherwise, "up-scaling" - or more appropriate *preparation* for energy increases - can happen as implementation of, for instance, boilers or certain engines in modules. Further, elaborate Back-up system analysis, which includes how to utilise existing fossil fuel boilers in industries as such, and whether other types of fuel in the area can feed an individual back-up boiler for energy production.

- If energy increases are expected in the future, and biomass wastes are found to be of both solid and liquid nature, then preferably ***develop a Transformation Strategy for the energy system***. This will successive expand the energy system by implementation of other technologies using the biomass fuel in their "original form", as the energy demand expands beyond what can be limited by DSM initiatives. ***Study the environmental performances of technologies*** proposed for implementation (including Emissions analysis). Are there certain environmental advantages in implementing one technology over another? This could, for instance, be technologies favourable as capable of emitting lower levels of SO_2 or NO_x to the environment, compared to others.

- ***Analysis of the local context must now be conducted*** which includes studies of the local resource base regarding manufacturing of energy technologies. Are there appropriate technologies produced locally? If domestic manufactured technologies are available preferably select these, as it lower the technology costs (compared to imports from the West) and support the national industries. Now several technologies might be appropriate for implementation, but are they equal feasibly? ***Elaborate a Pre-Feasibility Study of selected technologies for implementation,*** showing the economic consequences of the different technical opportunities (including Cost-Savings analysis and Sensitivity analysis). The Pre-Feasibility Study provides information that enables a final choice of technology to implement.

The source of information

- *Theoretical technical analyses* emphasising the most appropriate energy system to implement, including the performance of technologies. *Economic and environmental analysis* illustrating the feasibility of implemented technology and the emissions.

Important stakeholders

- Optimisation of the first Triangle can be elaborated by the Department of Energy Development and Promotion (DEDP) under MOSTE, or academia. The main duties of DEDP are to develop and promote renewable energy and energy conservation, and to implement energy conservation programmes. DEDP has 12 regional offices for energy development and promotion in regions throughout Thailand, which can provide assistance with such an analysis (Mr. Somkiat Sutiratana, DEDP, Interview, Bangkok the 24-4-03). Also large NGOs can be included in these analyses, as for instance TEI or EFE, who has the capacity to conduct technical feasibility studies, energy audits, training, campaigns etc. (Ms. Patcharin Worathanakul, TEI, Interview Bangkok the 28-4-03 & Mr. Lars Ivarsson and Mr. Chaiwat Pollap, EFE, Interview Bangkok the 30-4-03).

The staff at the Asian Institute of Technology (AIT) and King Mongkut's University will also be very interested in helping with analysis in this phase (Mr. Bundit Fungtammasan, NSTDA, Director of Energy and Cleaner Technology Center & Ass. Professor at King Mongkut's Institute of Technology, Interview, Bangkok the 13-2-01). Again, this must be done as a collaborative effect between the Leading Team and the stakeholders mentioned.

Several stakeholders have also expressed interests in providing the tasks as required in designing the energy system. This, for instance, includes making feasibility studies. Again, the staff at the Asian Institute of Technology (AIT) and King Mongkut's University will be able to provide this task. Also governmental agencies like NEPO (National Energy Policy Office) and DEDP, will like to participate with their knowledge in this phase (Mr. Chaiwat Pollap, NEPO, Bangkok, Interview the 9-2-01 & Mr. Boonthong Ungtrakul, DEDP, Interview the 7-2-01). As for the analysis above, it must be done in collaboration with the Leading Team.

Action 6: Second Triangle Analysis - corporate feasibility

Purpose of the action

- When interested industries are pointed out, the organisational build-up can commence. This include which stakeholders (industries) are the most relevant to embrace as Industrial Materials Network participants and owners, and which other stakeholders to include in the co-operation as, for instance, being potential financial contributors etc. The purpose of this action is thus to minimise the economic risks of joining the project, and to establish appropriate co-operation between the stakeholders, including which ownership to pursue.

Transaction costs/Risk minimisation

Actions to be taken

- ***Access which areas of the energy system that poses potential risks***. These risks can, for instance, be a potential lack in fuel supply, turbulent conditions for transmission of electricity on the grid or lack of a stable heat market. ***Identify how Transaction costs etc. can be used in removing potential risks*** (Risk minimisation) by, for instance, inclusion of certain stakeholders or by limitations in the number of (vertical) trading partners, thereby reducing costs.

- Now ***propose how Risk minimisation can be achieved in the specific context examined (Industrial Estate or area etc.),*** which can also point to important members and potential owners of the Industrial Materials Network. Risk minimisation can, for instance, be obtained by including only industries using process heat (district heating) as Industrial Materials Network participants and possible owners. This is important due to the creation of a stable heat market, and thus optimal uses of the district heating network, where heat customers have incentives to remain heat customers. Another example can be unfavourable high "wheeling" fees for transmission of electricity on the grid, which can be met by establishing an individual electricity supply system between Industrial Materials Network participating industries for Risk minimisation.

- ***Analyse how other outside stakeholders can support the implementation of Industrial Materials Network*** by examining which interests/motivations they have in the scheme, again using the Risk minimisation approach. Then ***propose how Risk minimisation can be achieved in the specific context examined (municipality/region etc.)***, which can also point to the most important outside stakeholders to include, as well as to possible co-owners and financial contributors. If the province in which the industrial area is located, for instance, faces difficulties in managing waste, it is likely that the implementation of Industrial Materials Network will receive support from this stakeholder. Risk minimisation in regards to fuel supply, for instance, can here be obtained by the province supplying biomass fuel to the Industrial Materials Network if other sources fail.

- Analyse whether local/provincial ***economic incentives*** for participating in Industrial Materials Network can be found, and which will support the implementation of an Industrial Materials Network. This can, for instance, be as a property tax reduction from the municipality in which the industrial area are located, or as reduction in factory tax given by the local MOI (which is now given to industries implementing ISO 14000). It can, for instance, also be economic support from the province by means of sources from ENCON, which can amount to 30 % of project costs (and 100 % for pilot projects) (Mr. Chaiwat Pollap, Energy For Environment Foundation (EFE), Interview, Bangkok the 30-4-03).

Conditions for Inter-industrial Co-operation

Actions to be taken

- Emphasise potential Industrial Materials Network members (the industries), their interests in joining the scheme and which ***barriers and possibilities for co-operation*** they see (lack of financial and technical capacity for instance). Then propose how participation by other stakeholders than case industries (analysed above), can ***break down some barriers found***, by, for instance, acting as leaders, prime initiators or financial contributors. ***Outline all pre-conditions for co-operation*** in Industrial Materials Networks, as emphasised above. Discuss how the pre-conditions can be fulfilled so that industries are willing to join the Industrial Materials Network. Which financial and organisational scheme must be established in order to secure participation etc.?

<u>Corporate governance</u>

Actions to be taken

- Create an overview of ***different types of Corporate governance***, and analyse ***which economic consequences*** this has on the corporate economy. ***Analyse which type of Corporate governance (and thus ownership of the Industrial Materials Network) to create***, in order to incorporate the pre-conditions as found above. This can also include strategies for transformation of power in the corporation established etc.

The source of information

- Action 4 data is used as background information for *theoretical analysis* (paperwork) of Transaction costs/Risk minimisation possibilities, which can be supplemented by *interviews* elaborated for further *analysis*, emphasising the pre-conditions for Industrial Materials Network implementation. *Theoretical studies* (paperwork) also outline different types of Corporate governance, whereas *economic calculations* are used for illustrating the corporate economy when applying different types of Corporate governance.

Important stakeholders

- Organisational issues can also be supported by NSTDA, and especially in the area of how to organise and manage the Industrial Materials Network they can be helpful (Mr. Bundit Fungtammasan, NSTDA, Director of Energy and Cleaner Technology Center & Ass. Professor at King Mongkut's Institute of Technology, Interview, Bangkok the 13-2-01). It might also be beneficial to involve NSTDA in the area of conducting interviews and mapping potential outside stakeholders, who could have an interest, or by other means be beneficial for the Industrial Materials Network (Risk minimisation through fuel supply for instance).

  A Leading Team member, FTI, is also very important in this phase, as proved interested in elaborating *corporate feasibility studies* showing the expected economic results for involved industries, as a means of identifying potential participants. This can provide a very important incentive for industries to participate in Industrial Materials Networks (Ms. Dominica Dacara, FTI, Interview, Bangkok the 19-2-01). As for the previous steps taken, it is the specific situation (context) that determines which stakeholders to pursue the different tasks proposed.

Action 7: Financing: How to finance and commence the construction phase

Purpose of the action

- When both Triangle Analyses are finalised the energy facility is ready for implementation. This firstly requires financing and then secondly the actual construction. The purpose of the following section is to focus on some means of financing Industrial Materials Networks, as well as suggestions for how to commence the construction phase.

Financing

Clean Development Mechanism (CDM):
Economic support for projects mitigating green house gasses in developing countries is the concept of CDM. Two countries (developed and developing) working together can thus find new options in reducing their green house gas emissions, by, for instance, implementing a renewable energy facility in the developing country, financed by the developed country (Co-generation Project Developing Guide, EC-ASEAN COGEN, Romel M. Carlos et. al., 2002). The credits for resulting mitigation of green house gasses are, thereafter, transferred to the developed county for a minimum of 7 years and a maximum of 21 years.

CDM as a source of financing the implementation of Industrial Materials Networks in Thailand faces quite promising perspectives. Several bilateral donors have expressed interests in establishing Industrial Materials Networks in Thailand financed by means of the CDM. The combination of efficient renewable energy production and consumption, as well as waste minimisation initiatives - which happens within the Industrial Materials Network - are initiatives bilateral donors would like to support in Thailand, especially if the carbon certificates are acquired by the donor country (Mr. Dieter Brulez, GTZ, Interview, Bangkok the 30-4-03 & Mr. Akira Shibuya, JICA, Interview, Bangkok the 6-5-03 & Mr. Karsten Gasseholm, DANIDA, Interview, Bangkok the 7-5-03).

Multilateral Funds:
It is also possible to acquire financing for Industrial Materials Network implementation through Multilateral Funds, as, for example, by funds under the UN. The major source of multilateral funding is the International Bank for Reconstruction and Development (IBRD) - better known as the World Bank - and its affiliates. From the World Bank Group Multilateral funding handed over as gifts to developing countries (by IDA) is not an option for Thailand, as being one of the richer developing countries. Multilateral gifts are solely given to the poorest countries of the world (Mr. Martin C. Spicer, IFC, Interview, Bangkok the 5-5-03). Funding from the World Bank Group, particularly directed to support the private sector, is as follows:

1. Guarantees from the World Bank to support loans to the private sector;
2. Investment and loans provided by the International Finance Corporation (IFC) exclusively to private sector enterprises;
3. Political risk insurance offered by the Multilateral Investment Guarantee Agency (MIGA) to promote private investment flows to developing countries; (Co-generation Project Developing Guide, EC-ASEAN COGEN, Romel M. Carlos et. al., 2002).

According to the International Finance Corporation (IFC) in Bangkok, the World Bank Group is interested in supporting the implementation of an Industrial Materials Network in Thailand. The implemented energy facility must not be lower than 40 MW if the loans are to come directly from IFC, as the evaluation of the proposal will be to costly. Alternatively, the IFC can support an Industrial Materials Network implementation indirectly, by lending resources to an external finance organisation - similar to for instance the America based *Fondelec* supporting renewable energy projects in Latin America and Eastern Europe - which then manage the evaluation of the projects etc. Another possibility is to apply IFC for support by “clustering” the applications of several similar project proposals, thereby lowering the costs of evaluating individual proposals. Today the IFC practices this in the field of WWTP implementations in Thailand (Mr. Martin C. Spicer, IFC, Interview, Bangkok the 5-5-03).

In Asia, the Asian Developing Bank (ADB) is another source of multilateral Funds. ADBs mission is to promote investment and foster economic growth in Asia and the Pacific by lending funds and providing technical assistance to its developing member states (Co-generation Project Developing Guide, EC-ASEAN COGEN, Romel M. Carlos et. al., 2002).

Donor gifts (bilateral):
From bilateral sources, it is also possible to help financing the implementation of Industrial Materials Networks, by means of donor gifts and partnerships between the two countries (the developed and the developing country). Where the above types of financing belong to the category Project Financing[70], donor gifts belong to the category Project Programmes[71]. For the idea of Industrial Materials Networks to become a part of the Project Programmes by donors in Thailand, it must normally be included in the Country Programmes negotiated between the developed and the developing country.

If not included in the Country Programmes, another type of donor gift supporting the implementation of Industrial Materials Networks, can, for instance, be technical assistance or other means of facilitation by donors. Hence, donors are not financing the energy plant etc., but facilitating its implementation (initiate training, awareness raising, communication between stakeholders, technical analysis etc.) (Mr. Dieter Brulez, GTZ, Interview, Bangkok the 30-4-03 & Mr. Akira Shibuya, JICA, Interview, Bangkok the 6-5-03).

Developing Bank Loans:
If local financing is pursued for Industrial Materials Network Implementation especially developing banks like Industrial Finance Corporation of Thailand (IFCT) are appropriate. Support for renewable energy projects and focus on SME are business objective for the bank, which is perfectly in line with Industrial Material Network schemes. According to Mr. Anat Prapasawad, Vice President of IFCT, the corporation will be interested in contributing with up to 60 % of the project expenses, and possible more, if positive show cases are implemented in Thailand (Mr. Anat Prapasawad, IFCT, Interview, Bangkok the 8-5-03).

Commercial Bank Loans:
Commercial banks still remain the most popular and largest source of financing energy projects in general; due to the ability of the bank to understand and appraise the credit risk exposures involved. It is common that international and even local large banks employ staff of engineers to assist in the structuring of financing the project. The banks also have experienced and professional loan staff with experience as to the acceptable practices and risks of particular industries. Commercial bank loans can be secured or unsecured loans, but may also involve a single lender, several lenders, or they may be syndicated. The

[70] (’projektfinansiering’)
[71] (’projektleverancer’)

different types of commercial loans may vary depending on their use, such as construction loans, term loans, and bridge loans, mortgage loans or working capital loans (Co-generation Project Developing Guide, EC-ASEAN COGEN, Romel M. Carlos et. al., 2002).

Build Operate and Transfer (BOT)

BOT projects can be established both by donor gifts and by traditional Project Financing. In a BOT project a private company is given concession to build and operate for instance an energy facility, which normally would be built and operated by the government. The private company is also responsible for financing and designing the project. At the end of the concession the private company returns ownership of the energy facility to the government (BOT Guidelines, UNIDO, 1996). This system can also be utilised for Industrial Materials Network implementation, as a private company as the Leading Team can hold the concession, thereby getting the energy facility implemented. At the end of the concession, the ownership is transferred to industries participating in the Industrial Materials Network.

BOT is therefore relevant when a passive ownership is found appropriate in the initial phase. Later, the ownership can become active and more responsible, when it is transferred to industry. This level of responsibility depends on whether the financing happens as loans or donor gifts, and which Corporate governance is selected for participating industries. BOT is especially relevant when the Industrial Materials Network is based on a Co-operative Society, as the type of Corporate governance, as this is based on a low initial financial contribution from participating industries, and all risks taken by the donor. Project Financing, Donor gifts (Project Programme), CDM, Commercial and Developing Bank Loans, can be sources of BOT financing. When BOT is based on donor gifts it is not required that the loans are paid back, but some kind of economic surplus must be generated to the circle of owners (Pers.Com., Tyge Kjær, 2003).

Bidding[72] process:
When the organisational build-up is finalised and the size and type of energy system decided upon, as well as the source of financing determined, an actual implementation of technical equipment etc. must begin, i.e. construction. To promote competition between interested tenders[73] - thereby promoting effectiveness and efficiency - a process of competitive bidding can be initiated. Within such a bidding process, tenders compete in order to acquire the project contract. Bidding, as a tool, is thus a means of getting the project implementation started. It is for the Leading Team to initiate this bidding process, which is briefly described below:

1. The first step in a competitive bidding process is to elaborate a project description in which all specifications are outlined (invitation to tenders). These specifications can, for instance, be size specifications, timing issues and performance requirements etc. Clear and transparent conditions for the evaluation process must also be emphasised in the project description;

[72] ('udbud')
[73] ('udbydere af tilbud')

2. After the invitation-to-tender-document is finalised, a group of interested investors or sponsors normally form a consortium to put together a responsive bid. The consortium elaborate their own studies of the project feasibility, and seeks tentative loan commitments and preliminary contract prices from potential lenders, contractors and suppliers in order to structure the bids;
3. Then an actual selection of bidders is pursued, which must be undertaken by highly qualified technical, financial and legal advisers. Other factors than price will normally be included in the selection of bidders, as for instance reliability and experience;
4. Project development can now take place, which includes a formation of the project company, loan agreements and financial closing, construction and supply contracts, off-take and insurance contracts, M&O agreements etc;
5. When the project reaches final closing the construction work and delivery of important pieces of construction equipment can begin. This ends with a specified completion test, which ends in a final acceptance;
6. In a BOT-project the following phases are also included: Operation and Transfer; (Unido BOT Guidelines, UNIDO, 1996).

Chapter 11; Conclusion

To support the implementation and organisation of Industrial Materials Networks in Thailand a Guideline has been elaborated, containing several initiatives - or Actions - with this specific purpose in mind. Apart from the Guideline Actions presented below, the Guideline - as outlined in Chapter 10 - suggests which stakeholders are to become a part of the Industrial Materials Network implementation in Thailand, it also suggests how to collect/acquire the information or data needed. These aspects are, however, not included in this short version of the Guideline, but can be studied further in the Guideline presented in Chapter 10, which also elaborates on the importance of looking at projects with the aim of solving *problems*. The latter is outlined as Action 1 in the Guideline of Chapter 10. In the following, the Guideline Actions will be presented with the starting point being Action 2. An overview of the different actions and steps to be taken can be found in Figure 11A next page.

11.1 Guideline Actions

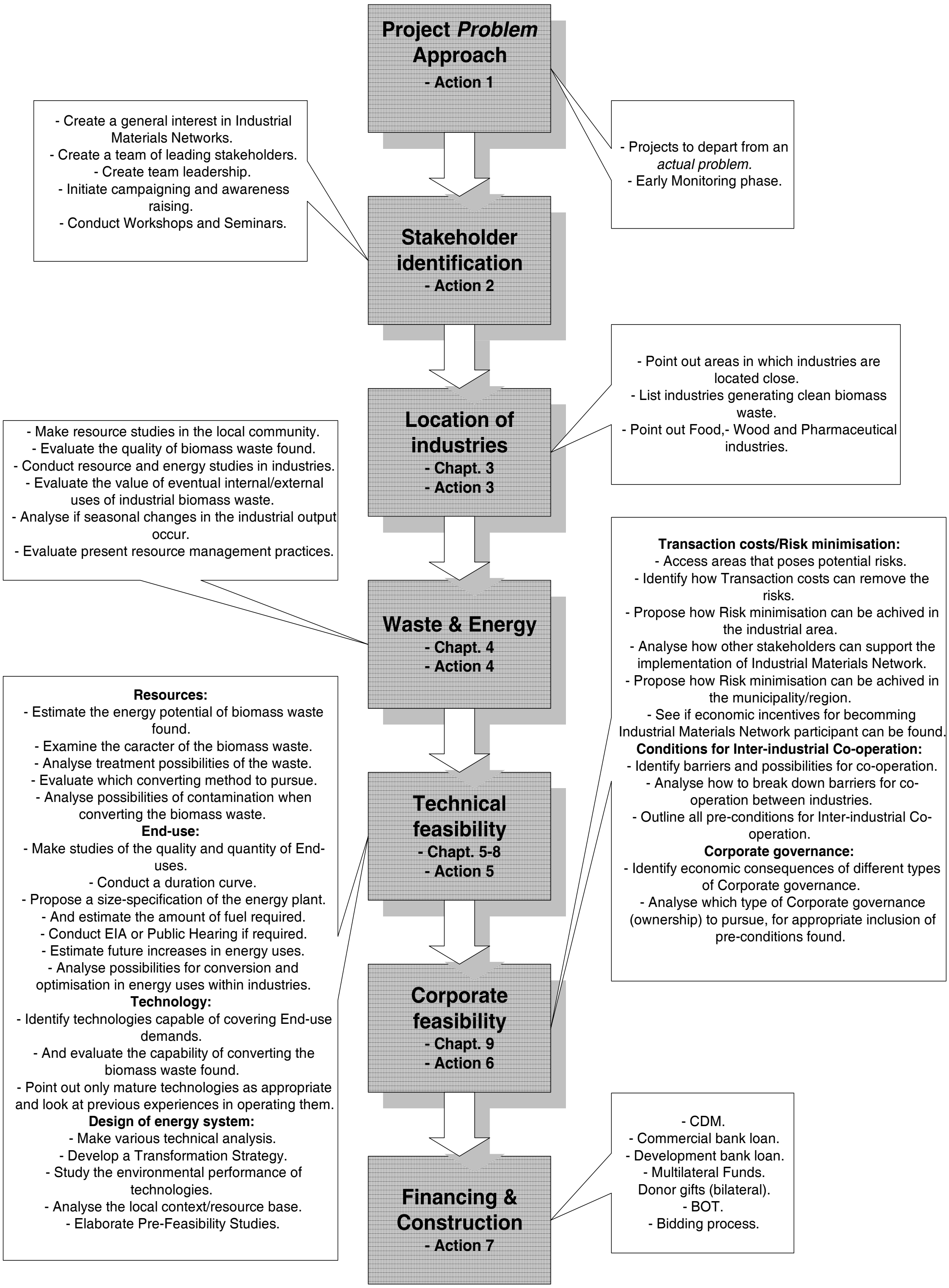
Action 2

Firstly, it is important ***to identify relevant stakeholders to initiate the process*** of implementing Industrial Materials Networks. First, to create a general interests in the ideas behind Industrial Materials Networks, and then, second, to motivate a leadership which would push for its implementation. Important organisations/institutions in creating such leadership are stakeholders being affected - or by other means having interests - in new waste management practices, for instance limiting the amounts of waste in the community.
Third, after the ***Team Leadership*** has been established, campaigning and awareness raising activities must be initiated, followed by ***workshops and seminars*** joining potential participants or overcoming resistance. When interested stakeholders are pointed out and Team Leadership established, the project proceeds to the stage in which appropriate areas and industries for Industrial Materials Network development are pointed out.

Action 3

Secondly, the most appropriate types of areas for Industrial Materials Networks implementation are pointed out. Such areas are identified to be Industrial Parks or Zones in which industries are located closely, thereby facilitating the implementation of district heating networks between participating industries. As types of industries (branches) the most appropriate as Industrial Materials Network participants, especially Food,- Wood and Pharmaceutical industries are pointed out.
This is due to the fact that these types of industries generate clean biomass waste, and require large amounts of process heat below 100 ºC. Thus, this type of energy demand are appropriate to be covered by district heating generated by biomass waste, instead of individual fossil fuelled boilers producing heat only. It is also important to point out that other industries in the areas, which presumably generate clean biomass waste, might join the Network, or supply biomass waste to the it. The following steps, shown after Figure 11A below, must be taken:

Figure 11A: Guideline Actions



Point out areas in which industries are located relatively closely to one another. This can preferably be in Industrial Estates or Zones, or other industrial areas that provides the same possibility for a close location of industries. ***List industries that presumably generate clean biomass wastes***. If not actually becoming Industrial Materials Network participants, some of these industries can supply biomass wastes to the co-operating industries.
Finally, ***point out Food,- Pharmaceutical and Wood processing industries*** (paper & tanning industries), as being especially relevant as Industrial Materials Network participant, but conduct further studies and site visits in *all* industries found above.

Action 4

Thirdly, energy and waste studies must now be conducted, the latter also on a community level in order to identify Supporting Resources and Systems being additional wastes - household waste, agricultural wastes, sludge from waste water treatments plants (WWTP) etc. Within industries, energy *and* waste audits are conducted to identify the energy consumption patterns, as well as relevant sources of biomass waste. The following steps are taken:

Make ***resource studies*** of Industrial Materials Network Supporting Resources or Systems within and outside the industrial area. These can, for instance, be relevant agricultural wastes as well as organic household wastes and commercial/industrial wastes from the community (Supporting Resources). It can, for instance, also be the presence of a WWTP within the industrial area, contributing to sludge generation appropriate for energy production (Supporting Systems). Then specify the type and amounts of resources found.

Evaluate the quality of biomass wastes that comes from Supporting Resources, or Systems, when used for energy purposes. How large are the fractions of organic materials in household waste and commercial waste, and how much can be utilised when sorted? Are there other means of uses, which makes it inappropriate as fuel? This issue can be very context-dependent, as organic fractions in household waste seem to "disappear" in certain countries or parts of countries, usually for uses as animal food or fertiliser. Thus, it is not sufficient to *estimate* the presence of biomass fractions, as an actual collection and analysis must be made in order to conclude whether these resources can be utilised for energy purposes.

Make ***resource and energy studies*** in industries pointed out as relevant Industrial Materials Network participants. Identify types and amounts of biomass wastes by studies of Raw materials input and waste, as well as Re-use of resources. Identify types and amounts of energy uses by studies of electricity and fuel uses (for process heat generation). Note the temperature of process heat uses. How much is based steam use and how much is water based heat uses? Also expose important issues as Operation hours per year, Efficiency of machinery in use, Expected increases in production output and Ownership, employees and markets.

Determine the ***value of internal/external uses of biomass wastes from industries***. If the wastes have very high commercial value, it is not likely that industries will utilise it for internal energy production. If the commercial value, however, is low - or even sometimes negative as being a cost factor - it is more likely that industries will seek other ways to improve the value of biomass wastes, as, for instance, through an Industrial Materials Network for energy production. If external re-use happen far away from the industrial area, with long transportation distances as a consequence, preferably seek re-use within the industrial site.

Find out whether there are ***seasonal changes in the industrial output***, which can affect the quantities of biomass available for energy production. This must be studied for all types of biomass found, but especially where agricultural wastes are applied, seasonal changes can occur (due to harvesting periods). A constant output of biomass wastes also means a constant demand for energy, which is preferable when designing an energy system (compared to a very fluctuating output of biomass and energy demand).

Evaluate present ***resource management practices*** within and outside the industrial site, i.e. in the Province, the Municipality and in the industrial area. If weaknesses, or problems, are found in these practices, the biomass wastes are more likely to be canalised to the industrial area for energy uses, as they represent a "problem" for various stakeholders. For instance, if the management of industrial waste is expensive for industries, they are more likely to pursue new means of waste management.

Action 5

Fourthly, the technical feasibility will be outlined consisting of Resources, End-use & Technology, finally leading to the Design of the energy system. In this action the following steps must be conducted:

Resources:
Estimate which conversion method is the most optimal when examining the ***theoretical energy potential of all biomass wastes found*** (in MWh/year). If the energy outputs differ, according to the way of conversion (whether for instance being *incinerated* or *digested*), preferably chose the method providing the largest energy output. This will improve the utilisation of biomass wastes for efficient energy production.

Examine the character of biomass wastes (composition; content/structure and type; solid/liquid), which is important in order to determine, whether it can be converted by the method most efficiently as emphasised above. If biomass wastes are found to be most appropriate for digestion - according to the energy potentials - then analyse whether such conversion is possible when looking at the specific biomass character; Can all the wastes be converted by this method, or are there large quantities of wastes, which cannot? Is it, furthermore, possible to obtain the right mix of liquid contra solid organic waste for appropriate digestion?
If the energy potential, as well as the composition of biomass waste, points to digestion as method, this would be an appropriate conversion method to pursue. And, the other way round, if the energy potential, as well as the composition of wastes, favour incineration as method, this will preferably be the method to pursue. If, on the contrary, large amounts of wastes are on both liquid and solid form - and energy potential of wastes not very ambiguous - one way of determining the most appropriate conversion method is by looking into "treatment" possibilities of the wastes, as emphasised in the step below.

Analyse treatment possibilities of wastes with the purpose of preparing or transforming it for other means of conversion. If, for instance, digestion is found to be the most favourable conversion method, according to the composition of wastes (large amounts of wastes on liquid form), but the energy potentials low when using this type of conversion, a "*treatment"* can be applied. Is it, for instance, possible to dry liquid wastes with the purpose of incineration? If large amounts of liquid wastes can be dried for incineration purposes, or kept on liquid form for digestion with improvements in energy output, the latter method is superior. Treatment possibilities also depend on the economy; what is feasible 'energy-economically' might not be feasible 'economically' (in DKK). Therefore, analyse whether such treatment is feasible in the local context before continuing.

Evaluate which converting method to pursue if biomass wastes are of both liquid and solid composition. If the amounts of liquid and solid wastes are almost the same, preferably select a multi-fuel conversion method. If the energy system is enlarged later on, then expand it with a conversion method more in accordance with the "original nature" of the wastes. Whether the multi-fuel conversion technology should focus on liquid or solid wastes (digestion or incineration) mainly depend on which energy demand to cover, as different conversion methods provide different energy services. It also depends on which possible environmental problems that can occur when applying different conversion methods, as emphasised below.

Analyse whether biomass wastes can lead to contamination when converted in certain ways and, therefore, more appropriate for other means of conversion. In order not to create unwanted emissions through the development of an energy system, such analysis is a necessity. The results *can* change focus away from the most appropriate conversion method initially found, at least for some of the wastes. The energy potential of household waste is, for example, highest when incinerated, but emissions of dioxin (caused by contents of organic bound chlorine), which can develop under incineration, make this an inappropriate conversion method (two-step treatment are only applied on waste incinerating plants, not on biomass technologies). In this case, biological digestion is more appropriate as a conversion method.

End-use:
Elaborate more ***detailed analysis on the quality and quantity of End-use demands*** from the data given by Action 4, in which the quantity and quality of energy uses were exposed. Study the energy consuming patterns in industries, showing, for instance, total uses of heat and electricity (in MWh/year), and by which temperatures (highest and lowest) process heat are required in the production processes, to get a thorough picture of the energy demands. Note industries that are obvious for an substitution in energy supply, as using process heat by temperatures below 100 ºC, i.e. conversion from high quality heat uses (steam made by electricity or fossil fuel) to low quality heat uses (water based heat by district heating). Also note industries using process heat above 100 ºC, and, therefore, *could* convert to water based process heat by means of technical changes in processing activities.

Departing from knowledge about operation hours per year and the quality and quantity of End- use demands, ***conduct a duration curve for industrial energy uses***, showing the heat effect in MW and the operation hours per year. The purpose of such a curve is to develop a tool appropriate for estimating how energy End-uses can be covered, according to the energy consuming patterns in industries; is it possible to cover energy demands solely by district heating? Or if steam uses are required; can cascading of steam to other industries be established? Is it, furthermore, possible to cascade "waste steam" from these industries to other industries again? As a result of the above analysis, now ***propose a size-specification of the energy plant*** (in MW heat and electricity) and ***estimate the amounts of fuel required*** (MWh/year).

If the proposed energy plant exceeds 10 MW then an Environmental Impact Assessment (EIA) must be conducted. If the energy plant will be established as a Firm-SPP, a Public Hearing must rightfully be initiated (in Thailand).

Estimate the consequence of future increases in energy uses within industries (in MWh/year), which are important for appropriate design of the energy system regarding, for instance, plant flexibility. Expected increases in energy uses can partly be complied with by implementation of DSM strategies, which is the next step to be taken.

Make a thorough analysis of possibilities for implementing ***conversion and optimisation initiatives in industries***, the latter especially relevant in industries using process heat exceeding 100 ºC, and, therefore, not just adequate for conversion in energy supply. Thus, by conversion initiatives it is possible to transform energy demands, consisting primarily of steam uses, to energy demands consisting primarily of water based heat uses. Combined with efficient uses of energy through optimisation initiatives, as for instance effective uses of machinery etc., this can lead to large reductions in total energy uses; both quantitative and qualitative.

To give an example of *conversion and optimisation* strategies possible to implement, wood industries using process heat produced by electricity can be emphasised. In wood industries, process heat is often used for drying glue in "glue pressers" at temperatures just above 100 ºC. By connecting the "glue presser" to a water borne system, and using a glue that hardens by lower temperature levels, a conversion of the energy supply can take place. Optimisations can be achieved by various activities in wood industries. Especially in the areas of processing wood, Compressed air and Removals of sawdust, such strategies are beneficial. In the latter, large energy savings can be obtained by implementation of a more adequate transportation system for sawdust removals.

Technology:
Identify which technologies are capable of producing energy services as required by industries (steam, water based heat or both). If no steam but only water based heat is required, Gas Engines might for instance be a technical option. Looking at it the other way round, Steam and Gas Turbines are more appropriate technologies where steam demands appear.

Now evaluate the technologies in accordance with their capability to convert biomass wastes as found in the Resource analysis. The composition of biomass wastes can be very different, thus analyse which technologies that are capable of converting the specific wastes found. The composition can, for instance, vary according to the content of wastes, and in relation to the moisture levels. Some combustion technologies, for instance, require fuel of a very homogeneous structure (size-specification's of fuel), whereas the moisture level can be relatively high.

If the wastes are very different in composition, preferably select a multi-fuel technology as being the most appropriate application. If, on the contrary, biomass wastes are very homogeneous, as, for instance, being wood wastes only, the number of possible conversion technologies to choose between increases.

Finally, point out mature technologies and look at experiences in operating the specific technology, when emphasising the energy demand to be covered and the composition of biomass fuels. Are there, for example, previous experiences in operating the technology - fed by this specific fuel - that points to potential weaknesses? The maturity of technologies is very important to bear in mind, as it affects plant reliability and thereby the creation of a stable energy production. Analysis must only be elaborated on technologies fulfilling this criterion.

Design of the energy system:
Make various technical analysis emphasising the set-up in the Energy supply and location of energy plant, as, for instance, how to design the district heating network so all levels of energy requirements can be fulfilled, and how to implement cascading of energy practically. In the analysis of Composition of waste and specific plant design, it is possible to emphasise how certain types of biomass wastes can be utilised especially beneficially, compared to for instance traditional combustion. This could, for example, be uses of liquid bio-oil (if any) as combustion stabilisation in a burner placed in the furnace, hereby reducing the influence of high moisture biomass or biomass with a very inhomogeneous content.

In Plant flexibility the potential technologies for implementation are evaluated in accordance with their capability to start up and close down. If the conversion technology must not be operated on full load (emphasised in the duration curve), it is especially important to find a technology, which has such flexibility. Also elaborate analysis of Flexibility in the capacity of meeting increases in End-use demands, which expose whether technologies can be over-dimensioned in order to prepare for future energy increases.

Normally, over-dimensioning of biomass technologies is inappropriate as it affects plant economy relatively more, than when implementing traditional technologies. A slight over-dimensioning *can*, however, be pursued by for instance up-scaling the Steam Turbine Plant slightly (must not exceed 20 %). Otherwise, “up-scaling” - or more appropriate *preparation* for energy increases - can happen as implementation of, for instance, boilers or certain engines in modules. Further, elaborate Back-up system analysis, which includes how to utilise existing fossil fuel boilers in industries as such, and whether other types of fuel in the area can feed an individual back-up boiler for energy production.

If energy increases are expected in the future, and biomass wastes are found to be of both solid and liquid nature, then preferably ***develop a Transformation Strategy for the energy system***. This will successive expand the energy system by implementation of other technologies using the biomass fuel in their “original form”, as the energy demand expands beyond what can be limited by DSM initiatives. ***Study the environmental performances of technologies*** proposed for implementation (including Emissions analysis). Are there certain environmental advantages in implementing one technology over another? This could, for instance, be technologies favourable as capable of emitting lower levels of SO_2 or NO_x to the environment, compared to others.

Analysis of the local context must now be conducted which includes studies of the local resource base regarding manufacturing of energy technologies. Are there appropriate technologies produced locally? If domestic manufactured technologies are available preferably select these, as it lower the technology costs (compared to imports from the West) and support the national industries. Now several technologies might be appropriate for implementation, but are they equal feasibly? ***Elaborate a Pre-Feasibility Study of selected technologies for implementation,*** showing the economic consequences of the different technical opportunities (including Cost-Savings analysis and Sensitivity analysis). The Pre-Feasibility Study provides information that enables a final choice of technology to implement.

Action 6

Fifthly, the corporate feasibility will be exposed consisting of 'Transaction costs/Risk minimisation, Conditions for Inter-industrial Co-operation and Corporate governance'. The following steps must be taken:

Transaction costs/Risk minimisation:
Access which areas of the energy system that poses potential risks. These risks can, for instance, be a potential lack in fuel supply, turbulent conditions for transmission of electricity on the grid or lack of a stable heat market. ***Identify how Transaction costs etc. can be used in removing potential risks*** (Risk minimisation) by, for instance, inclusion of certain stakeholders or by limitations in the number of (vertical) trading partners, thereby reducing costs.

Now ***propose how Risk minimisation can be achieved in the specific context examined (Industrial Estate or area etc.),*** which can also point to important members and potential owners of the Industrial Materials Network. Risk minimisation can, for instance, be obtained by including only industries using process heat (district heating) as Industrial Materials Network participants and possible owners. This is important due to the creation of a stable heat market, and thus optimal uses of the district heating network, where heat customers have incentives to remain heat customers. Another example can be unfavourable high "wheeling" fees for transmission of electricity on the grid, which can be met by establishing an individual electricity supply system between Industrial Materials Network participating industries for Risk minimisation.

Analyse how other outside stakeholders can support the implementation of Industrial Materials Network by examining which interests/motivation they have in the scheme, again using the Risk minimisation approach. Then ***propose how Risk minimisation can be achieved in the specific context examined (municipality/region etc.)***, which can also point to the most important outside stakeholders to include, as well as to possible co-owners and financial contributors. If the province in which the industrial area is located, for instance, faces difficulties in managing waste, it is likely that the implementation of Industrial Materials Network will receive support from this stakeholder. Risk minimisation in regards to fuel supply, for instance, can here be obtained by the province supplying biomass fuel to the Industrial Materials Network if other sources fail.

Analyse whether local/provincial ***economic incentives*** for participating in Industrial Materials Network can be found, and which will support the implementation of Industrial Materials Network. This can, for instance, be as a property tax reduction from the municipality in which the industrial area are located, or as reduction in factory tax given by the local MOI (which is now given to industries implementing ISO 14000). It can, for instance, also be economic support from the province by means of sources from ENCON, which can amount to 30 % of project costs (and 100 % for pilot projects).

Conditions for Inter-industrial Co-operation:
Emphasise potential Industrial Material Network members (the industries), their interests in joining the scheme and which ***barriers and possibilities for co-operation*** they see (lack of financial and technical capacity for instance). Then propose how participation by other stakeholders than case industries (analysed above), can ***break down some barriers found***, by, for instance, acting as leaders, prime initiators or financial contributors. ***Outline all pre-conditions for co-operation*** in Industrial Materials Networks, as emphasised above. Discuss how the pre-conditions can be fulfilled so that industries are willing to join the Industrial Materials Network. Which financial and organisational scheme must be established in order to secure participation etc.?

Corporate governance:
Create an overview of ***different types of Corporate governance***, and analyse ***which economic consequences*** this has on the corporate economy. ***Analyse, which type of Corporate governance (and thus ownership of the Industrial Materials Network) to create***, in order to incorporate the pre-conditions as found above. This can also include strategies for transformation of power in the corporation established etc.

Action 7

Sixth, the possibilities for obtaining financing and commencing the construction of Industrial Materials Networks are exposed, with the aim of facilitating the implementation of such schemes in Thailand. The analysis has shown, that sources of financing can be achieved as loans from multilateral funds (IFC etc.) and from developing banks (IFCT etc.). Sources of financing can also be bilateral aid, if included in the specific country programmes of donor countries, and through the CDM, which have proved a popular means of implementing the scheme. The construction phase is suggested commenced by uses of BOT and Bidding process.

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Annex A

The purpose of Annex A is to provide an introduction to the energy sector in Thailand, and highlight background information regarding the sector and its stakeholders, as well as point out aspects of the environmental and industrial regulation in the country. In the first part of Annex A, some aspects of the energy situation and energy sector in Thailand are outlined, for instance, the status of energy consumption, short and long term energy targets for the country, and a presentation of the most important stakeholders within the energy sector is made. In the second part, environmental and industrial regulations in Thailand are presented more broadly, including important policies and laws, as well as relevant governmental bodies and NGOs.

The Thai energy sector

In the following an introduction to the energy sector and most important stakeholders will be outlined.

Energy highlights

Production

In 2001 Thailand's total primary energy production amounted to 1,797.20 PJ[74] (42,543 ktoe[75]), whereof commercial energy counted for 69.40 % of the domestic energy production and renewable energy for 30.60 %. Domestic energy production derives primary from fossil fuels such as crude oil, natural gas, condensate and lignite. In 2001 they amounted to 10.50 %, 57.70 %, 8.00 % and 19.10 % of the domestic primarily energy production respectively (Thailand energy situation 2001, DEDP, 2001). Renewable energy also contributes to the domestic energy production. From hydropower the energy production amounted to 58.90 PJ (1,395 ktoe) or 4.70 % of the total energy production in 2001. From geothermal, solar cells and wind power - which is included under commercial energy production - the energy production amounted to 0.08 PJ (2 ktoe). Also biomass energy resources as fuel wood and paddy husk contribute to the energy production, and counts for 550.20 PJ (13,025 ktoe) separated as 74.10 %, 16.60 % and 9.30 % respectively (Thailand energy situation 2001, DEDP, 2001).

Imports

Almost all energy imports in 2001 where based on commercial energy, and only a small part on imported renewable energy. The total energy imports amounted to 1,900.50 PJ (44,989 ktoe) - rose for the third year in a row at a rate of 13.30 % over 2000 - and was primary based on crude oil, natural gas, petroleum products, coal and its products and electricity. These products contributed to 79.10 %, 12.60 %, 0.90 %, 6.90 % and 0.50 % respectively of the energy supply based on imports (Thailand energy situation 2001, DEDP, 2001). Renewable energy imports were mainly based on charcoal and small amounts of wood fuel, representing 0.34 PJ (8 ktoe) - a decline of 42.90 % compared to previous years (Ibid.).

[74] Peta Joule
[75] Tons of oil equivalents

Exports

In 2001 Thailand exported energy counting for 316.40 PJ (7,490 ktoe), consisting of petroleum, crude oil, natural gasoline, electricity and renewable energy, which contributed to 74.20 %, 24.40 %, 1.10 %, 0.30 % respectively of the total energy export (Thailand energy situation 2001, DEDP, 2001).

Final energy consumption

The total final energy consumption in 2001 was 2,092.90 PJ (49,542 ktoe), an increase of 3.60 % compared to 2000. Commercial energy had a share of the total consumption of 83.00 % and the remaining 17.00 % renewable energy. Petroleum products are the main contributors to the final energy consumption with a share of 66.40 % of total final energy consumption. Hereafter follows natural gas, coal and its products, electricity and renewable energy, with shares of 3.80 %, 10.70 %, 19.10% and 17.00 % (Thailand energy situation 2001, DEDP, 2001). The energy consumption can be separated into different sectors like the transportation sector, the industrial sector and the residential and commercial sector:

In the ***transportation sector*** we find the heaviest energy consumption accounting for 787.10 PJ (18,632 ktoe), or 37.60 % of the total energy consumption. The energy consumption consists of petroleum products, mainly diesel (51.20 %), gasoline (27.10 %), jet fuel (16.30 %), fuel oil (3.80 %) and LPG (1.60%) (Thailand energy situation 2001, DEDP, 2001). In the last decade the development in the transportation sector has shown a 100 % increase in the energy consumption from 430.90 PJ in 1989 to 798.40 PJ in 1998. The expansion of private cars stood for more than 80 % of the energy use in the sector in late 1990s (Thailand energy situation 1998, DEDP, 1998).

The ***manufacturing sector*** is the second largest energy consumer amounting to 714.90 PJ (16,922 ktoe), or 34.20 % of total energy use in 2001. Energy consumed in this sector was primarily coal (25.90 %), petroleum products (23.60 %), renewable energy (20.60 %), electricity (20.70 %) and natural gas (9.20 %) (Thailand energy situation 2001, DEDP, 2001). In general, the use of renewable energy in this sector is decreasing. In 1981 it stood for about 50 % of the energy consumption (Sustainable Energy, Sustainable Society, Thai-Danish Co-operation on Sustainable Energy, 1999), but now contributes to only approximately 20 %.

In 2001 the ***residential and commercial sector*** consumed energy equal to 461.30 PJ (10,920 ktoe), or 22.00 % of total energy consumption. The energy sources in this sector primary consist of renewable energy (45.20 %), electricity (39.10 %) and petroleum products (15.70 %) (Thailand energy situation 2001, DEDP, 2001).

The ***mining and agricultural sector*** consumed energy corresponding to 124.20 PJ (2,940 ktoe), or 4.70 % of the total energy consumption in 2001. Energy sources are primarily electricity in the mining sector and petroleum products in the agricultural sector (Thailand energy situation 2001, DEDP, 2001).

Future plans for the energy supply

Short-term energy targets

“Thai Energy Development Plan under the Eight National Economic and Social Development Plan (*1997-2001)”* lists a series of activities, which have the overall purpose to secure the Thai energy supply (selected quotation):

”1.1 Increase commercial primary energy production at an annual growth rate of 5.00 per cent during the Eight National Plan period.
1.2 Maintain the growth rate of the domestic primarily commercial energy consumption at a similar level to the growth rate of the gross domestic product during the Eight National Plan period.
1.3 Maintain the level of energy import dependence at below 75 per cent by the year 2001.
1.4 Set targets for domestic production of natural gas (excluding those in the Malaysia-Thailand Joint Development Area: JDA), crude oil, condensate and coal/lignite as follows:

	1996	2001
Natural gas (million cubic feet/day)	1,270	2,424
Condensate (barrels/day)	35,700	68,500
Crude oil (barrels/day)	26,500	28,050
Coal/lignite (million tons/year)	21.30	21.90
- For electricity generation	16.40	14.40
- For industrial use	4.90	7.50

1.5 Set targets for energy imports as follows:

	2001
Power purchase from new projects (megawatt)	
- The Lao People’s Democratic Republic (Lao PDR)	313
- Malaysia (purchase/exchange)	300
Natural gas (million cubic feet/day)	
- The Union of Myanmar [Burma]	729
- Thailand-Malaysia JDA resources	503

1.6 Increase the electricity generating capacity by power plants of the Electricity Generating Authority of Thailand during the Eight National Plan period by 6,000 megawatts; purchase power from Independent Power Producers (IPP), totalling 4,120 megawatts, and from Small Power Producers (SPP) using non-conventional energy or co-generation system totalling 2,500 megawatts.
1.7 Reduction of consumption through demand side management measures by 1,400 megawatts during the Eight National Plan period, and reduction of energy consumption through the implementation of the Energy Conservation Promotion Act of approximately one million tons per year of crude oil equivalence by the end of the Eight National Plan period” (Thai Energy Development Plan under the Eight National Economic and Social Development Plan (1997-2001), NEPO, 1997:2-3).

Strategies to reach the energy targets

"2.1 Provide an adequate amount of energy to satisfy demand at reasonable prices while ensuring quality and security of supply as follows:

2.1.1. Speed up exploration and development of petroleum and coal resources.

- *Promote and encourage the exploration and development of domestic petroleum resources, and encourage the application of petroleum information and modern technology, so that the petroleum exploration and development of the country would be more efficient.*
- *Speed up petroleum resource development under the Malaysia-Thailand Joint Authority as stipulated in the Malaysia-Thailand Joint Authority Act, B.E. 2533 (1990) to encourage exploration and development of natural gas in the Joint Development Area.*
- *Speed up exploration for additional coal resources to ensure adequate primary energy reserves for future use (…).*
- *Accelerate the feasibility study for developing the oil shale resources at Mae Sod Basin, Tak province.*

2.1.2 Speed up negotiations and energy development with neighbouring countries.

- *Encourage joint feasibility studies of hydropower projects in the Mekong Basin, Salawin Basin and other basin in neighbouring countries as well as encourage investors/governments of those countries to submit their proposals for power sale to Thailand. Serious consideration and negotiations should be made so that the power purchase agreements could be agreed upon.*
- *Negotiate with the governments of Vietnam and Cambodia to determine the maritime boundary line in the contiguous or overlapping zones in the Gulf of Thailand and/or to seek common benefits from petroleum resources.*
- *Negotiate and find a conclusion on further purchase of natural gas from the union of Myanmar (…).*
- *Negotiate with Malaysia on the purchase of electricity and/or natural gas.*
- *Negotiate with Indonesia on the purchase of natural gas from Natuna field.*

2.1.3 Consider the feasibility's and determine regulatory framework for the use of nuclear energy for electricity generation and speed up energy procurement from foreign sources, in particular that of liquefied natural gas (LNG), orimulsion and coal, to ensure sufficient supply of energy to satisfy the domestic demand. This will help to diversify both sources and types of fuels and ensure competitive prices of fuels" (Thai Energy Development Plan under the Eight National Economic and Social Development Plan (1997-2001), NEPO, 1997:4-6).

Long term energy targets

The *"National Power Development Plan (1999-2011)"*, launched by EGAT, is a long-term plan covering a period of 15 years. The Plan serves as an investment framework for EGAT in its investment in the expansion of the electricity generation and transmission system. Changes to the Plan will only be carried out if aspects of the national economy affect the energy demands. The National Power Development Plan (1999-2011) - or the so-called EGAT Power Development Plan (99-01) - was introduced in January 1999, based on electricity demand projections made by the Thailand Load Forecast Sub-Committee in September 1998. The forecast conducted, suggested a growing demand for electricity from 13,311 MW in 1997 to 30,557 MW in 2011, during the period of the 8th to the 10th National Economic and Social Development Plans (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001).

Figure AA: Planned 'electricity generation expansion' (1997-2011)

Fuel	Unit	1999	2001	2006	2011
Hydropower	GWh	3,925	3,925	5,388	5,972
Natural gas	GWh	51,696	65,676	84,440	103,076
Fuel oil	GWh	15,501	3,915	4,008	5,354
Diesel	GWh	484	542	-	-
Lignite	GWh	12,361	13,915	16,821	16,4571
Imported coal	GWh	-	-	14,764	33,848
Purchase	GWh	9,211	15,711	17,5582	32,452

Source: "National Power Development Plan", Revised PDP, EGAT, 1999:69

Thus, in the "National Power Development Plan", EGAT described the need for implementing additionally 21.20 GW to secure the electricity demand at the end of the period, due to an expected increases in energy demands form 18.20 GW in 1997 to 39.40 GW in 2001. The figure above shows the planned 'electricity generation expansion' by different types of fuel. As a consequence of this forecast, EGAT has planned the following activities:

- Install 4,070 MW thermal power based on natural gas and fuel oil;
- Install 2,175 MW combine cycle plants based on natural gas and diesel;
- Construct 2 pumping storage hydro power plants with a total capacity of 1,660 MW;
- Install 100 MW steam turbine in connection to an existing gas turbine plant at Surat Thani; (National Power Development Plan, Revised PDP, EGAT, 1999).

From IPP and SPP (se explanation further below) the electricity purchase will be as follows:

- Purchase 10,444 MW from IPPs, of which 5,944 MW from 7 producers have already been contracted, and some of which are currently under construction. 4 of these producers will use natural gas; the other will use imported coal. The additional 4,500 MW is outlined as combined cycle power plants, but has not yet been specified in terms of fuel;
- Purchase 1,535 MW from 20 firm SPPs based on natural gas (940 MW), coal (420 MW), wood (180 MW) and rice straw (5 MW);
- Purchase 3,426 MW from hydropower projects in Laos and 300 MW from Malaysia; (National Power Development Plan, Revised PDP, EGAT, 1999).

The projected amount of investments to be made during the 8th Plan (1997-2001) is estimated to Baht 207,900 mill., and to Baht 213,000 mill. during the 9th Plan (2002-2006). The total investment outlay covering both Plans is projected to Baht 420,900 mill. (calculated at a currency exchange rate of Baht 40 per U.S. Dollar) (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001).

As of August 2002 the Load Forecast Sub-Committee has revised its load projection for Thailand again, and adjusted the plan in accordance with the overestimation of the energy demands, which had occurred. In 2002 Thailand's power demand only increased by 3.40 % to 16,681 MW installed capacity against the projected 17,388 MW (Total EGAT generation requirement, Thailand Load Forecast Sub-committee, Aug. 2002, NEPO Homepage, 2003, at; www.eppo.go.th/power/load2002/pw-BaseCase-GrossGen.html, per 29-5-03).

Power purchase from neighbouring countries

Lao People's Democratic Republic (Lao PDR)

The Royal Thai Government and the Lao PDR Government have jointly signed a Memorandum of Understanding on the Co-operation in Power Development in the Lao PDR on June 19, 1996 to purchase 3,000 MW of electricity from the Lao PDR by the year 2006. The Lao PDR has proposed eight projects, totalling 3,576 MW at the points of delivery, to the Thai Government for consideration. Two of the projects, Nam Theun-Hin Boun Project and the Houay Ho Project, have already provided commercial supply of electricity to the EGAT system. For the remaining six non-contracted power projects, the Thai Government has negotiated with the Lao PDR Government and both have agreed to delay the purchasing period, divided into two phases, due to the economic recession in the Thai national economy, which has greatly lowered the domestic demand for electricity. The first phase of the power purchase will commence with three projects in December 2006, including Nam Theun 2, Nam Ngeum 2 and Nam Ngeum 3 projects. The other three projects for the second phase, commencing in March 2008, will be Hongsa Lignite Project, Xepian-Xe Nam Noi Project and Xekaman 1 Project (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001).

Union of Myanmar (Burma)

On July 4., 1997, the Thai Government and the Myanmar Government jointly signed a Memorandum of Understanding on the Power Purchase Program from the Union of Myanmar. Under this MOU, the Thai Government would purchase 1,500 MW of electricity from Myanmar by the year 2010. Currently, negotiation and agreement on details of individual projects are being made on four projects from which the Union of Myanmar has proposed to sell electricity to the Royal Thai Government, namely:

- Three hydropower projects, consisting of Nam Kok, Hatgyi and Tasang Projects, with installed capacities of 42 MW, 300 MW and 3,300 MW respectively;
- One combined-cycle project - Kanbauk Project - with an installed capacity of 1,500 MW; (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001).

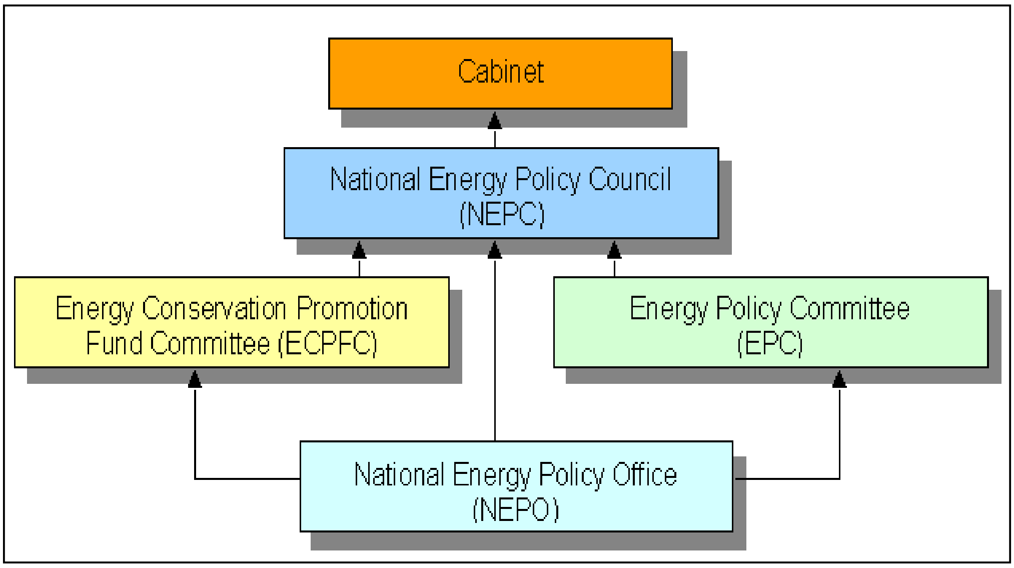
People's Republic of China

The Thai Government and the government of the People's Republic of China (PRC) jointly signed a Memorandum of Understanding on the Power Purchase Program from the PRC on November 12- 1998. The Thai Government agreed to purchase 3,000 MW of electricity from power projects in the PRC by the year 2017. It is expected that the Chinese government will initially suggest to the Thai Government, the Jinghong hydropower project, which could supply up to 1,200 MW of electricity. This is due to the fact that the feasibility study, on the routing of the 1,055 km. transmission-line already has been completed. The line will originate in the Yunnan Province of China, passing through Muang Sing and Muang Luang Nam Tha in Lao PDR, crossing Mekong River, heading on into the Thai border via Chiang Khong District in Chiang Rai Province, and end at the Ta Wung district in Lop Buri Province (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001).

Stakeholders in the Thai energy sector

Energy policy-makers

Figure AB: Organisation chart for energy policy stakeholders



Source: "Roles and Responsibilities of the National Energy Policy Office", NEPO, 2001:7

The energy sector in Thailand is managed by the *National Energy Policy Council (NEPC),* established under the *National Energy Policy Council Act, B.E. 2535* (1992), with the *National Energy Policy Office (NEPO)* acting as the Secretariat. To assure an efficient energy sector management, the *Energy Policy Committee (EPC)* has been established to assist the works of NEPC. NEPC is responsible for the promotion of energy conservation and the management of the *Energy Conservation Promotion Fund*, as of the *Energy Conservation Promotion Act B.E. 2535* (1992). Therefore, the *Energy Conservation Promotion Fund Committee* has been established to assist the management of the *Energy Conservation Promotion Fund,* and to ensure that allocations are made, in compliance with the regulations stipulated in the *Energy Conservation Promotion Act B.E. 2535* (1992) (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001). The figure above shows the governing bodies.

National Energy Policy Council (NEPC)

The authority and duties of the National Energy Policy Council (NEPC) are as follows:

- *"Recommend national energy policies, energy management and development plans to the cabinet;*
- *Establish rules and terms in determining energy prices that will be consistent with the national energy policies and energy management and development plans;*
- *Monitor, supervise, co-ordinate and support the efforts of all energy-related committees, government authorities, state-enterprises and the private sector on energy matters to ensure consistency with the national energy policies and energy management and development plans;*
- *Evaluate the implementation of the national energy policies and energy management and development plans;*
- *Perform any other task that may be assigned by the Prime Minister or by the cabinet";* (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001:7-8).

The Energy Policy Committee (EPC)

The authority and duties of the Energy Policy Committee (EPC) are as follows:

- *"Recommend to the NEPC energy policies, energy management and development plans and energy measures;*
- *Provide comments on energy-related plans and projects of various agencies, including their priority;*
- *Determine oil prices and levies to be collected for the Oil Fund, and perform other functions with respect to the Oil Fund management as may be assigned by the Prime Minister and as prescribed under the Royal Decree on the Solution and Prevention of Fuel Oil Shortage;*
- *Recommend policies and measures on energy pricing and regulate changes in electricity tariffs in accordance with the automatic (price) adjustment mechanism;*
- *Consider and provide recommendations to the NEPC concerning royal decrees, ministerial regulations and measures to be issued under the Energy Conservation Promotion Act;*
- *Liase with government agencies, private and public bodies and individuals to submit technical, financial, statistics information and/or other necessary details related to national energy policies, energy management, and development plans;*
- *Perform other duties as may be assigned by either the NEPC or its Chairman;*
- *Appoint sub-committees to assist with particular tasks as deemed necessary";* (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001:8).

The Energy Conservation Promotion Fund Committee (ECPFC)

The authority and duties of The Energy Conservation Promotion Fund Committee (ECPFC) are as follows:

- *"Suggest to the NEPC guidelines, criteria, terms, and priorities in dispensing the Energy Conservation Promotion Fund (ENCON Fund) in accordance with the objectives stipulated under Section 25 of the Energy Conservation Promotion Act, B.E. 2535 (1992);*
- *Allocate appropriations from the ENCON Fund in accordance with the objectives prescribed under Section 25 of the Act, and ensure that they conform to the guidelines, criteria, conditions and priorities prescribed by the NEPC;*
- *Establish regulations on the criteria and procedures for submissions for grants, grant allocations or subsidies from the ENCON Fund;*
- *Propose to the NEPC the appropriate rates of contribution to be imposed on oil for the ENCON Fund;*
- *Recommend to the NEPC the types of oil to be exempted from the above contribution to the ENCON Fund;*
- *Prescribe surcharges to be levied, with the approval of the NEPC and determine exceptional cases where surcharges should be exempted;*
- *Consider for approval requests for support and/or assistance in accordance with the guidelines, criteria and conditions laid down by the NEPC;*
- *Prescribe regulations on the criteria and procedures for making requests for support and/or assistance;*
- *Perform other duties as stipulated under the Energy Conservation Promotion Act, B.E. 2535 (1992)";* (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001:9).

National Energy Policy Office (NEPO[76])

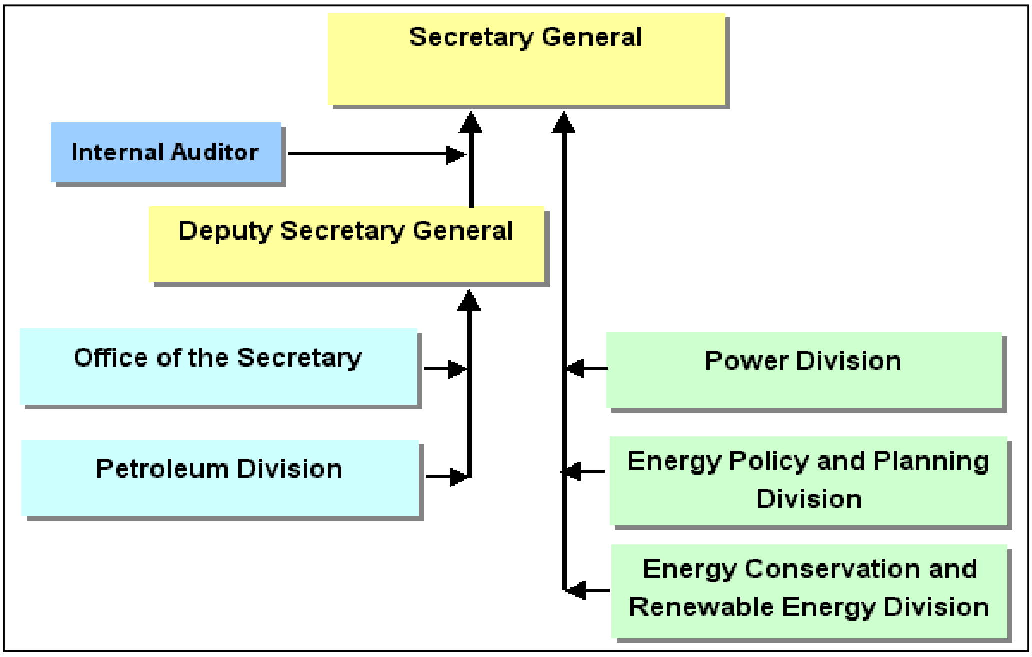
NEPO acts as the Secretariat to the NEPC and was established in 1986 to promote the co-ordination of the governments overall plans and policies related to energy matters. The authority and duties of NEPO derived from three acts; the *National Energy Policy Council Act, B.E. 2535* (1992), the *Royal Decree on the Solution and Prevention of Petroleum Oil Shortage, B.E. 2516* (1973), and the *Energy Conservation Promotion Act, B.E. 2535* (1992) (Energy sector management in Thailand, NEPO, 1997). NEPOs role can be summarised as follows:

- *"Study and analyse energy policies, management and development plans of the country to be presented to the National Energy Policy Council;*
- *Monitor, evaluate, and act as the focal point for co-ordinating and supporting the implementation of energy policies, management and development plans of the country;*
- *Compile information and keep abreast of changes in the energy situation;*

[76] NEPO has, due to an ongoing restructuring of the central administration in Thailand, changed name to Energy Policy and Planning Office (EPPO) under the newly created Ministry of Energy.

- *Analyse trends and evaluate any possible effect in order to make recommendations on energy policies, management and development plans, as well as disseminate energy statistics;*
- *Perform any other task as may be assigned by the Prime Minister or the National Energy Policy Council";* (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001:4).

Figure AC: Organisation chart for NEPO



Source: "Organisation of National Energy Policy Office", NEPO, 2000

As shown, NEPO is an important stakeholder in the Thai energy sector, because it has its own responsibility and authority to develop new energy policies. NEPO decides on the financial support in regards to energy conservation and renewable energy development.

Energy implementing stakeholders

Department of Energy Development and Promotion (DEDP[77])

DEDP was transformed from National Energy Administration to Department of Energy Development and Promotion in 1991 (Department of Energy Development and Promotion, MOSTE publication, Date unknown). While NEPOs status is a permanent department under the Office of the Prime Minister - taking charge of energy policies - DEDP is designed to manage the operational works under the *Ministry of Science, Technology and Environment.* DEDPs authorities and duties derive from two acts: The *Energy Development and Promotion Act, B.E. 2535* (1995), and the *Energy Conservation Promotion Act, B.E. 2535* (1992) (Ibid.). DEDPs role can be summarised as follows:

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[77] DEDP has, due to an ongoing restructuring of the central administration in Thailand, changed name to Department of Alternative Energy Development and Efficiency (DEDE).

- *"To conduct surveys, collect data, analyse, test and examine the energy activities regarding the sources of energy, the production, transformation, transportation and utilisation;*
- *To study, plan and formulate the project concerning energy and related activities;*
- *To research and develop, demonstrate as well as generate pilot projects on the production, transformation, transportation, utilisation and conservation of energy sources;*
- *To design, construct and maintain the production and transformation of energy sources, the transportation and utilisation of energy systems such as the utilisation of new and renewable energy to generate power, biomass to produce energy and electrical pumping irrigation;*
- *To determine regulations and standards on the production, transportation, transformation, utilisation and conservation of energy as well as to regulate and supervise the implementation of such regulations and standards;*
- *To determine remuneration rates for the utilisation of energy operated by the Department of Energy Development and Promotion;*
- *To acquire, regulate, construct, buy, sell, rent, lease out, transfer or accept transferrals of the production and transformation of energy sources as well as the transportation and distribution of energy systems and to issue licenses for the production or expansion of capacity of energy;*
- *To transfer technology, promote, train, disseminate information on production, transformation, transportation, utilisation and conservation of energy sources as well as to act as a centre of the collaboration for co-operation on related activities";* (Responsibilities, DEDP Homepage, 2003, at; www.dedp.go.th/eng/default.htm per 29-5-03).

The main duties of DEDP are to develop and promote renewable energy and energy conservation, and to implement energy conservation programmes. Moreover, DEDP also takes charge of electric water pumping stations, the Khong-She-Mun Irrigation Project and the implementation of small Hydro Power Plants up to 12 MW (Mr. Somkiat Sutiratana, DEDP, Interview, Bangkok the 9-2-00). In relation to the promotion of renewable energy there are two main bureaus: *Bureau for Energy Control and Conservation* and *Bureau for Energy Research and Development*. Furthermore, DEDP has twelve regional offices for energy development and promotion in regions through out Thailand (Mr. Somkiat Sutiratana, DEDP, Interview, Bangkok the 24-4-03). Although DEDP do not have a role in determining the energy policies, it is an important stakeholder in implementing desirable energy policies in Thailand, and the success of these policies are largely depending on the efficiency of DEDP (Sustainable Energy, Sustainable Society, Thai-Danish Co-operation on Sustainable Energy, 1999).

Other important energy stakeholders

State owned stakeholders in the power sector (EGAT, MEA and PEA)

Before the privatisation of the energy sector in Thailand, three state enterprises EGAT, PEA and MEA almost completely dominated the energy sector. EGAT took charge of electricity production, transmission and direct sale to large customers, while Metropolis Electricity Authority (MEA) covered the greater Bangkok area, and Provincial Electricity Authority

(PEA) the provincial areas. Before the beginning of 1990s the power sector were thus completely monopolised by these three stakeholders. Up until the privatisation process began, EGAT was the biggest state owned stakeholder, not only in the power sector but also in Thailand as a whole, with approximately 30,000 employees. The power of EGAT covered the control of all power plants, the national grid as well as the country's lignite resources (Sustainable Energy, Sustainable Society, Thai-Danish Co-operation on Sustainable Energy, 1999).

During the last 30 to 40 years, EGAT has expanded Thailand's power generating capacity dramatic, from less than 500 MW in the 1960s to a total generating capacity of approximately 17,850 MW today (2003) (Total EGAT generation requirement, Thailand Load Forecast Sub-committee, Aug. 2002, NEPO Homepage, at; www.eppo.go.th/power/load2002/pw-BaseCase -GrossGen.html, per 29-5-03). EGATs capacity expansion has mainly been due to the implementation of large condensing Power Plants, as for example Mae Moh Power Plant (2,400 MW), Wang Noi Power Station (1,774 MW) and Bang Pakong Power Station (3,697 MW). Typically fuel uses in these Power Plants are natural gas and diesel oil, oil or lignite (EGAT Power Plants, EGAT Homepage, 2003, at; www.egat.or.th/english/powerplants/ thermal.html, per 29-5-03).

EGATs capacity expansion is mainly financed through international finance institutions, such as the World Bank Group and Japan's Overseas Economic Co-operation Fund, as well as funding from bilateral aid (Sustainable energy alternatives to the 1,400 MW coal-fired Power Plant under construction in Prachuap Khiri Khan, Thai-Danish Co-operation on Sustainable Energy & SENT, 1999). In the 1990s the privatisation were firstly introduced by the World Bank Group - as seen, an important financial supporter for EGAT - thereby challenging the monopolised power of the organisation. The labour union of EGAT made protests against this policy, the whole 1990s, especially when the government assigned the person to promote the privatisation process to be on the executive board of EGAT (Sustainable Energy, Sustainable Society, Thai-Danish Co-operation on Sustainable Energy, 1999). The labour union feared that the consequences of the privatisation would be a reduction in EGATs staff by more than 20,000 employees (Thoop Kerjedee, EGAT, Interview, Bangkok the 15-2-00). However, little did it help and the privatisation of the energy sector is now an ongoing process.

Increasing the private sector role in energy production

Up until now, the privatisation process has resulted in EGAT selling out of its capacity of old and inefficient power plants. EGAT plan to take charge of the transmission net (the grid), and thereby control the power distribution from various producers (Mr. Pinji Siripuekpong, EGAT, Interview, Bangkok the 16-2-01). EGAT is therefore interested in a highly competitive energy market with low energy prices leading to growth in energy consumption, and thereby be able to collect more resources on the transmission of energy (Pers.Com., Jan Andersen, 2000).

The privatisation of some parts of EGAT by establishing EGCO (Electricity Generating Public Company Limited) is part of the strategy to increase the private sector's role in power production and distribution in Thailand, and planned to bring along many advantages. The public investment burden can for instance be reduced, and a public offering in the stock market, in particular, can help reduce the public sector's liabilities. Moreover, the competition is expected to enhance the quality of services. At the initial stage, EGCO divested EGAT of a 1,232 MW combined cycle power plant in Rayong (at the price of Baht 17,180.60 mill.), and made a public offering in the stock market by diluting EGATs shareholding to 48 % (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001).

In addition, it was specified in the Rayong combined cycle power plant purchase contract that EGAT should grant EGCO the option of purchasing Khanom Power Plant (Roles and Responsibilities of the National Energy Policy Office, NEPO, 2001). Fund raised through a second public offering thus further reduced EGATs shareholding to 40 %, when this power plant was sold to EGCO. A further diluting of EGATs shareholding has taken place after this, and their shares in EGCO are now at approximately 20 % (EGAT Privatisation, NEPO Homepage, 2003, at; www.eppo.go.th/doc/idp-02-10Q&A-E.html, per 2-6-03).

Private stakeholders in the power sector

In response to the privatisation process, and the overall government policies to encourage the private sector in power development, EGAT has established a program for *Independent Power Producers* (IPP) and *Small Power Producers* (SPP). This program allows private stakeholders to construct and operate energy facilities and sell power to EGAT. The power production from IPP and SPP is incorporated in the "National Power Development Plan" Revised PDP (1999-2011), as shown earlier.

IPPs are mainly the results of joint ventures between Thai industrialists and Trans-national power companies. All of the IPPs are using fossil fuels mainly imported coal or domestic natural gas (Independent Power Producers, EGAT Homepage, 2000, at; www.egat.or.th/ english/asean_cc/ project/cc_thiipp.htm, per 27-4-00). There are currently contracted seven IPPs with a total power production of almost 6,000 MW (Thailand's IPP award (as of January 2003), NEPO Homepage, 2003, at; www.eppo.go.th/power/pw-ipp-awards-E.html, per 29-5-03)). To promote electricity production from biomass EGAT also issued (in 1992) an *Announcement for the Purchase of Power from Small Power Producers*, initiated by the implementation of *Energy Conservation Promoting Act B.E. 2535* (1992). By 1999 more than 60 SPP had offered to sell electricity to EGAT, amounting to 1,700 MW and an installed capacity of 3,100 MW. SPP can be divided into two groups:

- Firm SPPs;
- Non-firm SPPs;

Firm-SPPs can supply power to EGAT all year with high reliability in terms of quantity. The total hours of electricity production supply must be no less than 7,008 hours per year. If the SPP is using renewable energy (biomass) the annual hour must be no less than 4,672 hours per year.
Non-firm SPPs usually rely on their agricultural wastes, like rice, sugar and palm oil industries. They are non-firm SPPs because they cannot deliver a stable amount of power to the grid all year, due to the seasonally supply of biomass. Because of that, the SPPs receive a lower price per kWh produced compared to *Firm-SPPs* (Small Power Producer info, EGAT Homepage, 2000, at; www.egat.or.th.dppd/eng-info_spp.html, per 27-4-00).

As of January 2003 there are 72 SPPs (received notification of acceptance) in Thailand - 36 firm and 36 non-firm SPP - with a generation capacity of 4,440.96 MW and power sales to EGAT amounting to around 2,354.94 MW (Classified Generated Electricity of SPP by type of fuel, NEPO homepage, 2003, at; www.eppo.go.th/power/pw-spp-purch-raw-E.html, per 2-6-03). As for both the firm and non-firm SPPs the power sales may be no less than 60 MW and no more than 90 MW, according to the capacity and reliabilities of the system (Small Power Producer info, EGAT Homepage, 2000, at; www.egat.or.th.dppd/eng-info_spp.html, per 27-4-00). 42 of 72 SPPs use non-conventional fuel (renewable energy), 26 use commercial fuel (natural gas, coal, oil) and four use mixed fuel (for instance coal and eucalyptus bark) (Classified Generated Electricity of SPP by type of fuel, NEPO homepage, 2003, at; www. eppo.go.th/power/pw-spp-purch-raw-E.html, per 2-6-03).

Private and state owned stakeholders in the petroleum sector

At present, there are three state-owned stakeholders in the petroleum sector; The Petroleum Authority of Thailand (PTT) and the Bangchak Petroleum Public Co. Ltd. who takes charges of petroleum business from refinery, transportation, wholesaling, to retailing business. The third state-owned stakeholder in the petroleum sector is PTT Exploration and production Co. Ltd. (PTTEP), which is responsible for investment in petroleum exploration and production. Moreover, the government has the following shares in energy-related companies:

- Thai oil Co.: PTT holds 49 %;
- Fuel Pipeline Transportation Co., Ltd. (FPT): PTT, Bangchak, Thai Airways International Public Co., Ltd. and Airport Authority of Thailand altogether holds 44 %;
- Thai Petroleum Pipeline Co., Ltd. (THAPPLINE): PTT holds 30,6 %;
- Esso (Thailand) Public Co., Ltd.: The Ministry of Finance holds 12,5 %;
- Rayong Refinery Company (RRC): PTT holds 36 %;
- Star Petroleum Refining Co., Ltd.: PTT holds 36 %;
- Bangkok Aviation Fuel Services Co., Ltd. (BAFS): PTT, Thai Airways and Airport Authority of Thailand hold 49 %. Thailand; (Privatisation and Liberalisation of the Energy Sector in Thailand, NEPO, 1999).

The list excludes a number of petrochemical companies in which PTT is also a shareholder, for example National Petrochemical Public Co., Ltd. and Thai Olefins, Ltd. (TOC) (Privatisation and Liberalisation of the Energy Sector in Thailand, NEPO, 1999). Because high investment costs acts as a barrier for new stakeholders in the petroleum market, it is an oligopoly in all stages; from the exploration and production stage, refining and distribution stage to the retailer stage. Unlike the electricity sector, however, this market is based on competitive market principle, especially after the deregulation of the petroleum market in 1992. According to NEPO, the Thai government will promote free and fair competition in all sub-sectors, including refinery market, LPG market, and wholesale market.

The competitions in the petroleum market - which mainly are trans-national companies (like the Royal Dutch Shell) - are very strong. The present policy on privatisation of the energy sector, and the focus on the economic crises, has led the Thai government to reduce its shareholding in these enterprises: For example in Bangchak, Esso (Thailand) and BASF by selling out to the private sector and/or make public offering, and/or seek strategic investors to buy its shares (Privatisation and Liberalisation of the Energy Sector in Thailand, NEPO, 1999). In general, this sector has many fewer conflicts in entering a competitive market structure compared with the power sector. But because of the heavy investments in the petroleum sector, these enterprises - both state and private owned enterprises - might not have a strong interest to develop renewable energy as alternative fuels.

Environmental regulations

In the following, the focus will be on environmental regulation in Thailand by emphasising key responsible Departments and Ministries etc.

Key responsible Ministries, Departments and Enterprises

National Environmental Board (NEB)

The National Environmental Board (NEB) is an inter-ministerial body at Cabinet level, and has since 1992 - with the introduction of the *Enhancement and Conservation of National Environmental Quality Act, B.E. 2535* (NEQA) - been represented by all major ministries headed by the Prime Minister, with the deputy Prime Minister and the Minister of Science, Technology and Environment (MOSTE) acting as vice chairman's. This 1992 rearrangement was an attempt to empower NEB in order to make ministries respect the decisions made by the board (Oral presentation by Mr. Amnat Wongbandit, University of Mahidol, Salaya Campus the 27-1-00).

NEB has the authority to prescribe environmental quality standards, action plans, and to recommend strategies to the Cabinet regarding monetary, fiscal and other measures for implementing NEQA. NEB also manages and administrates the *Environmental Fund* (see later) placed under the Ministry of Finance (Enhancement and Conservation of National Environmental Quality Act, B.E. 2535, Department of Environmental Policy Promotion (DEQP), 1992).

Ministry of Science, Technology and Environment (MOSTE[78])

MOSTE are responsible for two State Enterprises and nine Departments, of which three are directed by the *National Environmental Quality Act, B.E. 2535* (NEQA). These departments are the *Office of Environment Policy and Planning* (OEPP), the *Pollution Control Department* (PCD) and the *Department of Environmental Quality Promotion* (DEQP):

[78] MOSTE is ultimo 2002 transformed into Ministry of Science and Technology and Ministry of Environment, due to an ongoing reorganisation of the central administration in Thailand. As the final outcome of this reorganisation has long prospects, I will present the previous and known structure of the administration.

Figure AD: Departments and State Enterprises under MOSTE

Source: "Ministry of Science, Technology and Environment", The Royal Thai Government Homepage (date unknown), at; www.thaigov.go.th/em-org.htm, per 30-8-00

Office of Environmental Policy and Planning (OEPP)

The Office of Environmental Policy and Planning (OEPP) shall, in collaboration with all government agencies concerned, formulate the national policy and plan for enhancement and conservation of national environmental quality. OEPP also gives advice to the governors of each province for the preparation of the provincial environmental action plans, for submission to the National Environment Board for approval. Within its mandate, OEPP will examine the environmental impact assessment reports of private or governmental activities or projects, before they can be submitted to the NEB for consideration.
Furthermore, OEPP acts as a national focal point for various international organisations and programs, i.e. UNEP, GEF, ASEAN Senior Official on the Environment (ASOEN), United Nations Framework Convention on Climate Change, etc. and is a secretariats office for several national committees, i.e. NEB, National World Heritage, Committee for the Environmental Fund Committee, etc. (MOSTE Thailand, MOSTE publication (Date unknown)).

At present, OEPP has four regional offices, located in Chiang Mai, Khon-Khaen, Songkla (Had-Yai) and Chonburi Provinces. These four regional offices have the main duties to provide technical advice to the provinces in preparing their environmental action plans, and help to co-ordinate the various central environmental policies with local governments. OEPPs highest priorities are water and air pollution, emphasising water re-cycling and reductions of air emissions (MOSTE Thailand, MOSTE publication (Date unknown)). According to the NEQA the following duties of OEPP is mandated:

"1. To formulate as well as monitor and evaluate the Policy and Prospective Plan for Enhancement and Conservation of National Environmental Quality, in accordance with the sector policies of the country;
2. To co-ordinate the formulation of Environmental Quality Management Plan in accordance with the Enhancement and Conservation of National Environmental Quality Act of 1992;
3. To monitor, audit and formulate the State of the Environment Report;
4. To co-ordinate the natural resources management in accordance with the Policy and Prospective Plan for Enhancement and Conservation of National Environmental Quality, the National Economic and Social Development Plan, and the Environmental Quality Management Plan;
4. To carry out environmental impact assessment from projects and activities, likely to have environmental impact, of any governmental agency or individual, which are tendentious to damage the environment quality;
6. To formulate position, direction, and co-ordinate international co-operation and obligate acceptance related to the environment;
7. To propose policies, guidelines, and co-ordinate the Environmental Fund administration and management, as well as mobilising the fund for Environmental Fund in accordance with the Enhancement and Conservation of National Environmental Quality Act;
8. To perform other functions, provided by the law, which are the mandate of the Office of Environmental Policy and Planning, or carry out matters which have been assigned by the Ministry of the Cabinet"; (Responsibilities, OEPP Homepage, 2003, at; www.oepp.go.th/ eng/about_oepp2. html, per 4-6-03).

The Pollution Control Department (PCD)

The Pollution Control Department formulates and evaluates pollution control measures which include measures to control, prevent and remedy environmental problems caused by pollution. The Department is also responsible for setting national environmental quality standards, and for monitoring the quality of the environment. It develops systems, methodologies and means to improve water and air quality, noise pollution, and hazardous substances and solid waste management. The department also acts as a technical advisor and manager to the local governments in handling environmental problems. In addition, the department takes action on public complaints related to pollution any performs and other tasks as designated by the law (MOSTE Thailand, MOSTE publication (Date unknown)). PCD has the following mandate:

"1. To support the formulation of national policy and plans of environmental quality conservation and promotion in respect to pollution control;
2. To formulate and recommend environmental quality and emission/effluent standards;
3. To formulate environmental quality management plans, which include measures to control; prevent and remedy environmental problems caused by pollution;
4. To monitor the national environmental quality and prepare an annual report on the state of the pollution;
5. To develop systems, methodologies and technologies, which are appropriate in application to the better management of water quality, air quality, noise pollution, hazardous substances and solid waste;
6. To perform any activities specified in the Enhancement and Conservation of National Environmental Quality Act B.E. 2535 (1992) concerning pollution control;
7. To take actions on public complaints related to pollution;

8. To perform other functions as may be designated by other laws" (About PCD, PCD Homepage, 2003, at; www.pcd.go.th, per 4-6-03).

Department of Environmental Quality Promotion (DEQP)

The Department of Environmental Quality Promotion (DEQP) is responsible for specifying measures to strengthen and foster co-operation and co-ordination among government agencies, state enterprises and the private sector in matters concerning the promotion and conservation of environmental quality. DEQP supports and performs research and development for appropriate technologies in pollution control and environmental management, certifies environmental laboratories, and transfers technology to professional and technical staff at all levels in both government and non-government agencies. Moreover, DEQP is serving as the co-ordination body for the dissemination of information or data to promote public awareness, proper understanding and knowledge about environmental protection and conservation of environmental and natural resources (MOSTE Thailand, MOSTE publication (Date unknown)). DEQP has the following mandate:

"1. To provide public education and liase with media on environmental protection;
2. To collect and establish database on environmental information and technology;
3. To provide environmental knowledge to other government agencies and the private sector;
4. To perform other functions specified by law"; (About US, DEQP Homepage, 2003, at; www.deqp.go.th, per 4-6-03).

Thailand Institute of Scientific and Technological Research (TISTR)

TISTR was established in 1963 and initiates and conducts R&D to help achieve the goals of the country's development plans. Special emphasis is placed on the fields of bio-science, industrial materials, energy and environment, while engineering and business development are also areas of main concern. Other activities include scientific and technological services in terms of testing and standards, metrology, information and other technical affairs (MOSTE Thailand, MOSTE publication (Date unknown)). The responsibilities of TISTR are as follows:

"1. To conduct research and development programs that help solve the problems of industries and rural communities;
2. To transfer technology to small and medium [size] enterprises;
3. To render scientific and technological services to industries to help increase productivity and to develop export potential"; (State enterprises, TISTR Homepage, 2003, at; www.moste.go.th/moste_eng/file/state.htm#tistr, per 4-5-03).

Industrial regulations

In the following, the focus will be on industrial regulation in Thailand by emphasising key Departments and Ministries etc. which are responsible for the regulation.

Key Ministries, Departments and Enterprises

Ministry of Industry (MOI)

Figure AE: Departments and State Enterprises under MOI

Source: "Ministry of Science, Technology and Environment", The Royal Thai Government Homepage (date unknown), at; www.thaigov.go.th/em-org.htm, per 30-8-00

Thai Industrial Standard Institute (TISI)

Thai Industrial Standard Institute (TISI) was established in 1969 - as a result of MOIs *Industrial Product Standards Act B.E. 2511* (1968) - and is responsible for Thailand's standardisation activities. According to the Act mentioned above, the governing body for TISI is the *Industrial Product Standards Council* responsible for the policy making, for setting the priority of standards to be prepared, for recommending the qualified persons for the Minister to appoint to the technical committees, and finally for arbitrate and award licenses under its certification scheme (About TISI, TISI Homepage, 2003, at; www.tisi.go.th/eng/tisi.html, per 5-6-03). The purpose of TISI is to:

”1. To establish the national policy and master plan in standardisation to be in line with the international practices with systematic participation of the public and private sectors;
2. To carry out standardisation work according to the Industrial Products Standards Act and the resolutions of the Cabinet for the purpose of consumers protection, safety, environmental protection, energy saving as well as industrial development of the country to be competitive in the world market;
3. To protect the national interests in the area of standardisation so that it does not become barrier to trade”; (About TISI, TISI Homepage, 2003, at; www.tisi.go.th/eng/tisi.html, per 5-6-03).

Through the *National Accreditation Council*, TISI has the authority to certify firms under the Thai Industrial Standards for ISO 9000 and 14000. The responsibilities of the *National Accreditation Council* are as follows:

“1. To develop national accreditation policy benefiting co-operative operation of all bodies concerned, as well as aiming the mutual recognition with other countries;
2. To establish the process of Thai accreditation in line with international standard;
3. To co-operate and co-ordinate with concerned parties on accreditation;
4. To grant, cancel and withdraw of accreditation as well as establish accreditation fees;
5. To arrange for mutual recognition of test reports and conformity assessment with trading partners;
6. To appoint accreditation sub-committee for assisting the conduct of accreditation process;
7. To perform other tasks assigned by the Cabinet”; (National Accreditation Council, TISI homepage, 2003, at; http://www.tisi.go.th/nac/nac3_e.html, per 5-6-03).

Department of Industrial Works (DIW)

DIW monitors and enforces standards on industrial operations in accordance with the *Factory Act B.E. 2535*, and has for example the authority to pull back a factory’s operating license. Opposite to the PCD - which are concerned about industrial outlets - DIW is concerned with issues within the industries. DIW has the following responsibilities:

“1. To control, oversee, and engage in industrial business in the area of environmental preservation, sanitation, and energy savings;
2. To enhances the capacity and efficiency of industrial operation in Thailand to grow and remain competitive in the world market;
3. To be the centre of information on industrial machines, chemicals, hazardous substances, and volatile substances; and,
4. To represent and protect the benefits of the Kingdom in international relations, concerning issues on environment, safety, and security of the country”; (Vision, DIW publication (Date unknown)).

Department of Industrial Promotion (DIP)

The major target groups for DIP policies are small and medium-scale industries including cottage industries and handicraft, rural industries and personnel of public and private organisations. DIP has the following mission:

"1. To implement support measures for the development of Thai entrepreneurs and SM[E]s in compliance with the National and Ministry of Industry's policies and plans;
2. To promote and develop networks between public and private agencies involved in SM[E] development;
3. To provide inputs in entrepreneurship development and SMI promotion for policy formulation and planning"; (Mission, DIP Homepage, 2003, at; www.smethai.net/th, per 4-6-03).

Industrial Estate Authority of Thailand (IEAT)

The IEAT is a state enterprise under the jurisdiction of the Ministry of Industry founded in 1972 to carry out the country's industrial development policy. The IEAT policies is to *"ensure orderly and systematic development of industries that will bring mutual benefit to the nation, all Thai people and the people who chose to invest here"* (Introduction to IEAT, IEAT Homepage, 2000, at; ieat.go.th/introduct%20ieat.htm, per 30-8-00). IEAT has the regulative authority of all Industrial Estates in Thailand, developed and regulated by the authority, or developed by private stakeholders and regulated by IEAT.

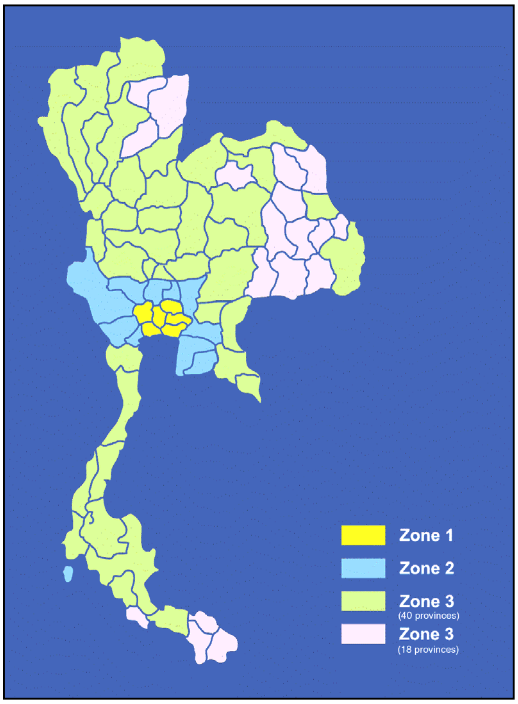
At present there is 29 Industrial Estates in Thailand regulated by IEAT of which some also are developed by the organisation (Your guide to investment in Thailand's Industrial Estates, IEAT, 2001 & Three decades of IEAT (1972-2002), IEAT, 2002). Industries located in IEAT Industrial Estates can receive incentives and government promotional privileges from IEAT. Moreover, 26 industrial Zones and Parks are established in Thailand, which add up the total number of Industrial sites to 55 (List of Industrial Estates/Industrial Parks/Industrial Zones, BOI Homepage, 2003, at; www.boi.go.th/english/business/ind_estates_zone3.html, per 4-6-03).

Board of Investment (BOI)

BOI is the primary agency responsible for providing fiscal and non-fiscal incentives to stimulate the investments in Thailand. BOI is placed under the *Prime Ministry's Office*, but are closely linked to MOI and MOSTE through overlapping board memberships of government officials. BOIs policy focuses today on high technology industries, low polluting or pollution controlled industries, and the placement of industries outside Bangkok. BOI has established a line of incentives for industries located outside Bangkok, like incentives for foreign investments in export production, tax privileges for industries locating in Industrial Estates with pollution control and location in remote areas (BOI Incentives, BOI Homepage, 2003, at; www.boi.go.th/english/boi/incentives.html, per 4-6-03). Thailand has three regional industrial zones, in which the incentives improve the further distance to Bangkok:

Zone 1: Includes Bangkok, Samut Prakan, Samut Sakhon, Nakhon Pathom, Nonta Buri and Pathum Thani (Bangkok and 5 provinces);
Zone 2: Includes Samut Songkhram, Ratchaburi, Kanchanaburi, Suphanburi, Angthong, Ayutthaya, Saraburi, Nakhon Nayok, Chachoengsao, Chonburi, Phuket and Rayong (12 provinces);
Zone 3: Includes the remaining 61 provinces plus Laem Chabang Industrial Estates; (BOI privileges by location, BOI Homepage, 2003, at; http://www.boi.go.th/english/boi/incentives_location.html, per 5-6-03).

Figure AF: Industrial Estates zoning



Source: "BOI privileges by location", BOI Homepage, 2003, at; www.boi.go.th/english/boi/incentives_location.html, per 25-6-03

Other regulative authorities

In the following section, the focus is on quasi governmental organisations and NGOs with importance in regards to environmental and industrial regulations.

Quasi governmental Organisations

Federation of Thai Industries (FTI)

The Federation of Thai Industries (FTI) is an upgraded body of the Association of Thai Industries, which was created in 1967. The transformation took place in 1987 by the implementation of the *Federation of Thai Industries Act* (1967), requiring FTI to be under the supervision of the Minister of Industry. The Federation of Thai Industries Act, aims at strengthening the private sector institution, which - according to FTI - will help to make the industrialisation in Thailand more sustainable, and synchronising with other ongoing national economic development processes, as well as ensuring a proper protection of the national interest in the world economic environment. The FTI is authorised by the law to pursue the objectives as set forth in the Federation of Thai Industries Act (Organisation, FTI Homepage, 2003, at; www.fti.or.th/nfti/org/index_e.htm, per 26-6-03). The responsibilities of FTI are as follows:

"1. To act as the sole representative of all industrial enterprises in Thailand in co-ordinating with the state in both the policy and operation matters;
2. To promote and develop the industry;
3. To identify, analyse and solve problems and issues arising in the conduct of industrial enterprises;
4. To encourage, support the study, research, training and disseminating technical knowledge and technology related to industries;
5. To conduct product test and issue certificate of origin and certificate of quality assurance;
6. To offer appropriate advice, recommendations to the Government for the overall benefits of the industrial circle;
7. To encourage industrialists and acts as a focal point for exchanging of views among industrialists for the mutual benefits of the entire industrial community;
8. To exert control and oversee the operation of all members to ensure the compliance to the respective laws relating to industrial enterprises;
9. To conduct any other business as the law may prescribe"; (Organisation, FTI Homepage, 2003, at; www.fti.or.th/nfti/org/index_e.htm, per 26-6-03).

The membership of Federation of Thai Industries is as follows:

*"1. **Ordinary Member**: any industrial enterprises in the country, who must comply with the Factory Act or the trade association in the industrial sector;*
*2**. Associate Member:** those individuals and juristic persons not in the industrial sector or other trade associations. These members are grouped into:*

1. Industry clubs.
2. Country-wide provincial chapters: This grouping allows the F.T.I. to strengthen the unity and organise its work systematically by focussing on F.T.I. as a centre enhancing the inter - industry groups relations, and among the industrialists themselves as well as maintaining its relations with the consumers and other members of the Thai business community" (Organisation, FTI Homepage, 2003, at; www.fti.or.th/nfti/org/index_e.htm, per 26-6-03).

Non governmental Organisations

Thailand Environment Institute (TEI)

TEI is a non-profit, non-governmental organisation focused on environmental management established in 1993. The Institute aims to play a catalytic role concerning environmental issues in Thailand, and interacts with governmenta2l institutions, universities, the private sector, the media and the general public, etc. TEI helps to formulate environmental policies at the national level and collaborates, with various international organisations, to promote environmental awareness at the global level (General intro at TEI Homepage, 2003, at; www.tei.or.th/main.htm, per 25-6-03).

The vision of TEI is;
".....to be a centre of excellence in environmental issues; a source of up-to-date and reliable data; equipped with highly qualified personnel able to promote initiatives towards the sustainable development of our natural resources and the environment; and as such well recognised both locally and internationally" (Vision, TEI Homepage, 2003, at; www.tei.or.th/main.htm, per 25-6-03). TEI has six programme areas:

- Grassroots Action Program (GAP);
- Environmental Education and Human Resources Development Center (EEHRDC);
- Energy Industry and Environment Program (EIP);
- Urbanisation and Environment Program (UEP);
- Environmental Information Center (EIC);
- Business and Environment Program (BEP); (Mission, TEI Homepage, 2003, at; www.tei.or.th/main.htm, per 25-6-03).

TEI aims at serving as a respected research institute, a centre of high-quality information and meaningful action, committed to sustainable human development:

- *"1. By conducting research activities within and outside the country to benefit the conservation of natural resources and the environment, and by supporting and participating in the practical application of the research findings;*
- *2. By establishing up-to-date and reliable information systems and through providing for extensive dissemination of quality information on environmental issues;*
- *3. By developing and enhancing the knowledge and capabilities of the staff so that they can be proud of their work and their organisation; and,*
- *4. By producing quality research publications to be made available to relevant institutions and the general public, both locally and internationally;*
- *5. And further, in line with its social obligations towards the Thai society, TEI will undertake environment related capacity building activities among the more vulnerable groups of society in support of the national poverty alleviation goals and within the overall framework of sustainable development";* (Mission, TEI Homepage, 2003, at; www.tei.or.th/main.htm, per 25-6-03).

Appropriate Technology Association (ATA)

ATA was established in 1978 as a group of lecturers and students from the Faculty of Engineering at Chulalongkorn University, as well as some professional engineers, established a study and research group. The group aims at strengthen the development in Thailand by implementing appropriate technologies. The objectives and strategies of ATA are as follows:

- *"To collect and disseminate appropriate technology to publics;*
- *To conduct research and develop appropriate technology in order to easier usage, saving and safety by applying local resources and local wisdom;*

- *To transfer appropriate technology to target group in the form of different activities, demonstration, training and building different mass media and also to consult technical devices to the publics";* (Objectives, ATA Homepage, 2003, at; www.ata.or.th/ata/aboutus/aboutus_frameeng.html, per 25-6-03).

Strategies:

- *"1. Increase awareness on Energy and Environment as well as develop sustainable energy technology through strengthening capacity of NGOs in identifying, organising and co-operation with end-users groups, governments, research institute and private sector in Thailand and South East Asia;*
- *2. Enhance community self-reliance by developing entrepreneurship of the community in order to apply production and management technology to improve their economic situation;*
- *3. Develop institutional quality of ATA through co-operation with NGOs, GO communities and private sector in compiling knowledge on appropriate technology and develop itself with quality and self sustain";* (Strategies, ATA Homepage, 2003, at; www.ata.or.th/ata/aboutus/aboutus_frameeng.html, per 25-6-03).

During the past years, ATA has worked jointly with OVE (The Danish Organisation for Renewable Energy) in operating *Thai-Danish Co-operation on Sustainable Energy*, which is supported by DANIDA. The target areas are different provinces located Northeast of Thailand, as well as the opening of an environmental office in Korat. The co-operation aims at increasing the awareness on energy issues among Thai people, and replace conventional energy sources with renewable energy (Chanchai Limpiakorn, ATA, Interview, Bangkok the 15-2-00 & Finn Tobiesen, OVE, Interview, Århus the 14-6-00).

ATA is the largest NGO in Thailand working with renewable energy. The amounts of energy-related NGOs are currently quite limited, compared to other areas like for example Agricultural and Human Rights NGO's. As of 1998 there were registered some 500 NGOs, whereof only a few were working with energy related matters (Directory of Non-Governmental Organisations, Thai Development Support Committee (TDSC), 1997). Energy NGOs will, however, become more represented in the next decades, as the awareness of energy related matters becomes more strongly integrated in the Thai society (Mr. Chatri Moonstan, DANIDA, The Royal Danish Embassy, Interview, Bangkok the 11-2-00).

Campaign for Alternative Industry Network (CAIN)

CAIN in an NGO which mostly works with pollution from industries and awareness rising. They help and guide people who are exposed to pollution from industrial sites in Thailand, and are active in resistance towards waste incineration. CAIN regards themselves as the "watchdogs of the environment" (Ms. Penchom Tang, CAIN, Interview, Bangkok the 12-2-01). CAIN is not regarded as an official NGO in Thailand as they have found it difficult to raise Baht 200.000 which is a governmental registration fee for obtaining NGO status. So far, CAIN has received support from, for instance, DANIDA in its activities (Ibid.).

Thailand Development Research Institute (TDRI)

TDRI was established in 1984 to conduct policy research and disseminate results to the public and private sectors. TDRI is Thailand's first policy research institute, created and registered as a non-profit, non-governmental foundation (recognised as such by the Royal Thai Government). The tasks of TDRI is to provide technical and policy analysis supporting the formulation of policies with long-term implications for sustaining social and economic development in Thailand (About TDRI, TDRI Homepage, 2003, at; www.info.tdri.or.th.htm, per 25-6-03).

Users of TDRI research - mainly different local and foreign donors - normally fund the Institute's research. In its earliest period, the Institute were funded by the following fundamental supporters: the National Economic and Social Development Board, the Department of Technical and Economic Co-operation, the Canadian International Development Agency, and the United States Agency for International Development (About TDRI, TDRI Homepage, 2003, at; www.info.tdri.or.th.htm, per 25-6-03). TDRI conducts the following objectives:

"1. To conduct and promote policy research;
2. To establish information centre containing updated information on relevant policy issues;
3. To create a research network linking institutions and individuals engaged in policy research issues; and,
4. To disseminate the results of policy research to maximise their impact on decision-making and public opinion"; (Objectives, TDRI Homepage, 2003, at; www.info.tdri.or.th.htm, per 25-6-03).

To meet its objectives the Institute has established six research programs and two non-program research projects. The six TDRI Programs are as follows:

- Human Resources and Social Development;
- International Economic Relations;
- Macroeconomic Policy;
- Natural Resources and Environment;
- Science and Technology Development;
- Sector Economics;

Supporting facilities to the research programs is provided by three non-research divisions, namely the Information Services Division, the Financial Services Division, and the Administrative Services Division (About TDRI, TDRI Homepage, 2003, at; www.info. tdri.or.th, per 25-6-03).

Energy for Environment Foundation (EFE)

The Energy for Environment Foundation (E for E) is an independent non-profit organisation established in 2000 by sources from the Global Environment Facility (GEF) (Mr. Chaiwat Pollap, EFE, Interview, Bangkok the 30-4-03). EFE objectives are to promote, demonstrate and disseminate efficient use of renewable energy in an environmental friendly manner, as well as the utilisation of energy efficient technologies. Its activities in the promotion of the use of renewable energy to produce electricity and other forms of energy include knowledge and information dissemination, technical and financial consultation, and policy recommendation (About E for E, EFE Homepage, 2003, at; www.efe.or.th/index_efe.htm, per 25-6-03). The objectives of EFE are as follows:

1. *"To support the work of public and private sectors in energy and environment conservation;*
2. *To demonstrate and disseminate energy conservation technology including the designing of building materials for efficient use of energy;*
3. *To demonstrate and disseminate the use of renewable energy in an efficient and environmental-friendly manner;*
4. *To promote the use of renewable energy to produce electricity and other forms of energy;*
5. *To promote and disseminate knowledge of energy and environment conservation through training, public relations campaign and administer projects supported by the ENCON Fund;*
6. *To disseminate knowledge, concepts, and new technology to promote the efficient use of energy,*
7. *To co-operate and co-ordinate with governmental agencies and other organisations both in Thailand and other countries to promote renewable energy and energy conservation;*
8. *To support the welfare of the Energy Policy and Planning Office;*
9. *To conduct activities and co-operate with other charitable organisations for the benefits of the public;*
10. *To promote democracy under the Thai constitution with non-partisan interest";* (About E for E, EFE Homepage, 2003, at; www.efe.or.th/index_efe.htm, per 25-6-03).

North-South co-operation

EC and ASEAN

The EC-ASEAN COGEN Programme is an economic co-operation, which is instantiated by the European Commission (EC) and the Association of Southeast Asian Nations (ASEAN). The European Commission funds it. Below, is Phase I-III of the project shown. All information is taken directly from the COGEN Homepage.

"COGEN Phase I:
COGEN Phase I, which took place between 1991 and 1994, was essentially a technically focussed identification phase for what was to become COGEN Phase II.

COGEN Phase II:
COGEN Phase II (1995-1998) was a demonstration phase combining technical and business expertise. The purpose of COGEN Phase II was both to demonstrate that proven European Technologies are available to support biomass-based co-generation in ASEAN countries, and to enhance the EU-ASEAN economic co-operation. COGEN II focused on 16 Full Scale Demonstration Projects promoting real reference projects using proven biomass-based technologies.

COGEN Phase II:
Directly increased EU-ASEAN economic co-operation by

- *Approximately 60 million Euro*
- *Contributing 354 MWth/74MWe to the ASEAN energy supply,*
- *Avoiding 250,000 tonnes of carbon equivalent/year of emissions,*
- *Increasing ASEAN awareness of indigenous biomass resources (up to 6,000 MW electricity total capacity),*
- *Increasing the availability of European technologies,*
- *Increasing European supplier's competitiveness and the European image in the ASEAN market*

COGEN Phase III:
COGEN III is the third phase of the EC-ASEAN co-operation programme. COGEN 3 is an enlargement both in terms of new member countries within ASEAN and in terms of an expanded range of fuel. Now, in addition to biomass, also co-generation technologies for Coal and Gas are promoted. The programme is co-ordinated in ASEAN by the Asian Institute of Technology (AIT), Bangkok, Thailand and in Europe by Carl Bro International AB, Sweden. COGEN III started its operation in January 2002 and will continue until December 2004.

The objective of COGEN 3 is to promote and create business opportunities for the use of co-generation to generate power and heat using biomass, coal or gas as fuel. This will be achieved through partnerships between ASEAN industries and power producers and European equipment suppliers. COGEN 3 is endowed with a team of experts covering the different aspects of co-generation. These experts are committed to help accelerate the implementation of co-generation projects. COGEN 3 acts as a facilitator serving the co-generation market in South East Asia, in defining and matchmaking appropriate technology supplied by European Equipment Suppliers to ASEAN end-users. In addition assistance is provided throughout the process to ensure smooth implementation of the projects" (About COGEN, COGEN Homepage, 2003, at; www.cogen3.net/aboutcogen.html, per 25-6-03).

Environmental and industrial policies and laws

In the following emphasis is on environmental and industrial policies and laws in Thailand, staring with a presentation of Thailand's 5-year plans for economic and social development, followed by highlights of the "Enhancement and conservation of National Environmental Quality Act B.E. 2535" (1992) and the "Energy Conservation Promotion Act B.E. 2535" (1992).

National Economic and Social Development Plan (NESDP)

From 1961-1991

Since 1961, Thailand has conducted 5-year plans for the country's economic and social development. During the period of the first 3 plans (1961-1976) natural resources were exploited fundamentally for economic development, and only little emphasises were put on environmental conservation. Except from establishment of natural resource plans and watershed development plans - which were unclear in its environmental goals - emphasises were on resource exploitation. In 1977 - with the introduction of the 4th National Economic and Social Development Plan (1977-1981) - emphasises on environmental conservation were clearly stated and included in the plan. The focus was now put on soil and water conservation, reforestation, and protected areas, and on water resource allocation (Oral presentation by Dr. Nawarat Krairapanond, MOSTE (OEPP), University of Mahidol, Salaya Campus, Bangkok the 25-1-00).

In the 5th plan (1982-1986), an integrated management approach was introduced for natural resource Development, and emphasises was put on forest resources (watershed protection), soil resources (soil erosion control), water resources (watershed development), and the introduction of "Science Technology" for natural resource development. With the introduction of the 6th National Economic and Social Development Plan (1987-1991) an important step was taken in decentralising the management of natural resource, as the authorities were placed at provincial and local levels with the development of "Provincial NRED Plans". Also the creation of "Natural resources and environmental development Plan" and pollution prevention - which focused on environmental friendly technologies - put more emphasises on resource management (Oral presentation by Dr. Nawarat Krairapanond, MOSTE (OEPP), University of Mahidol, Salaya Campus, Bangkok the 25-1-00).

From 1992-2006

The 7th National Economic and Social Development Plan (1992-1996) focused on encouraging participation by the public, NGOs and the local communities in natural resource conservation and management. Furthermore, it focused on creating a balance between environmental protection and socio-economic development. The plan was written in accordance with the "*Enhancement and conservation of National Environmental Quality Act B.E. 2535*" (1992), which will be presented below. The following aspects were introduced in the 7th plan: Land use plan to reduce natural resource use conflict, 25 watersheds management plans and a natural resource information system. A 'Financial Mechanism' was also introduced in order to manage natural resources (Oral presentation by Dr. Nawarat Krairapanond, MOSTE (OEPP), University of Mahidol, Salaya Campus, Bangkok the 25-1-00). It was explicitly stated in the 7th plan that more emphasises would be put on domestic biomass resources for electricity production, and on energy conservation. The plan also focused on the involvement of the private sector in the energy production.

The 8th National Economic and Social Development Plan (1997-2001) focuses on sustainable development and quality of life. The thrust of the plan is on holistic people-centred development and sustainable development; a major shift from the previous plans that emphasised growth and equity. The approach is to empower the people and create an enabling environment that allows the people to realise their full potential and play a leading role in development activities that benefit themselves and their communities. The plan outlines 7 strategies: human development, social development, regional and rural development, economic development, environmental and natural resource management, good governance, and development administration. The 8th plan also focuses on poverty alleviation and social sector programmes, for protection and regeneration of the environment, for the advancement of women and for more equitable development of society at large (8th NESDP, NESDB

Homepage, 2003, at; www.nesdb.go.th/plan/data/plan8_Eng/data/summary. doc, per 26-6-03).

Regarding energy development, it is stated in the 8th plan - similar to the 7th plan - that more emphasises must be put on domestic energy resources and on energy conservation, and that participation by the Thai people is important. The following strategies are set for the conservation of natural resources and for environmental management in the 8th plan.

⇒ Rehabilitate degraded soil:
- acid soil and low organic soil = 160,000 ha/yr.;
- soil erosion =160,000 ha/yr.;
- marine resources (fish, coral, reef, sea grass);

⇒ Reduce pollution in the local environment:
- 25 river basins;
- wastewater treatment and garbage disposal;
- green technology;

⇒ Promote participation by the public, NGOs and the local community:
- social/community forestry;

⇒ Ensure sound management of community environments and green areas etc.;
(Oral presentation by Dr. Nawarat Krairapanond, MOSTE, (OEPP), University of Mahidol, Salaya Campus, Bangkok the 25-1-00).

The 9th National Economic and Social Development Plan (2002-2006) is a strategic plan that serves as a framework for medium term national development, consistent with the long-term vision. It builds on the 8th plan that advocated a holistic people-centred development approach. In the Ninth Plan, major emphasis is placed on balanced development of human, social, economic, and environmental resources. A priority goal is pursuance of good governance at all levels of Thai society in order to achieve real sustainable people-centred development. The objectives of the plan are as follows:

*"**To promote economic stability and sustainability.** Measures will be taken to strengthen the financial sector and fiscal position of country, along with economic restructuring, to create a strong and self-reliant economy at the grassroots level. The overall economy will be made more competitive through development of the knowledge base;*

***Establishment of a strong national development foundation** to better able Thai people to meet the challenges arising from globalisation and other changes. Human resource development, education and health system reforms, the setting up of a social protection system is priorities to be implemented. At the same time, popular participation in communities and rural areas will be enhanced to create sustainable urban and rural development networks, improve management of natural resources and the environment, as well as development of appropriate science and technology;*

Establishment of good governance at all levels of the Thai society. *Good governance will be fostered based on the principles of efficiency, transparency, and accountability. Emphasis will be placed on the reform of government management systems, the promotion of good corporate management in the private sector, and public participation in the development process, as well as the creation of a political system that is accountable to the public and does not tolerate corruption;*

Reduction of poverty and empowerment of Thai people. *Thai people will be empowered through equal access to education and social services. Employment generation will be supported, leading to increases in incomes. Quality of life will be upgraded. Public sector reform will be undertaken to create an enabling environment for public participation";* (9th NESDP, NESDB Homepage, 2003, at; www.nesdb.go.th/plan/data/plan9_Eng/data/ summary.doc, per 28-7-03).

"Enhancement and conservation of National Environmental Quality Act B.E. 2535" (1992)

As mentioned earlier, the environmental law *Enhancement and conservation of National Environmental Quality Act B.E. 2535* (NEQA) was implemented in 1992 in order to empower NEB, and thereby substituting the "Enhancement and conservation of National Environmental Quality Act B.E. 2518" (1975), and B.E. 2521 (no. 2) as well as B.E. 2522 (no. 3).

Public participation in environmental protection

With the *Enhancement and conservation of National Environmental Quality Act B.E. 2535* (1992) public participation was introduced in Thailand. According to the Act a person has the rights:

"1. To be informed and obtain information and data from the government service in matters concerning the enhancement and conservation of environmental quality, except the information or data that are officially classified as secret intelligence pertaining to national security, or secrets pertaining to the right to privacy, property rights, or the rights in trade or business of any person which are duly protected by the law;
2. To be remedied or compensated by the State in case damage or injury is sustained as a consequence of dangers arisen from contamination by pollutants or spread of pollution, and such incident is caused by any activity or project initiated, supported or undertaken by government agency or state enterprise;
3. To petition or lodge complaint against the offender in case of being a witness to any act committed in violation or infringement of the laws relating to pollution control or conservation of natural resources;
4. To co-operate and assist government officials in the performance of duty relating to the enhancement and conservation of environmental quality;
5. To strictly observe the provisions of this Act or other laws concerning the enhancement and conservation of environmental quality"; (Enhancement and conservation of National Environmental Quality Act B.E. 2535, (1992), DEQP, 1992:3).

Under Section 8 of the Act it is stated how the government will help NGO's in for example organising, and how they can receive governmental resources, when they - as stated in Section 7 - have been registered as legally NGO's within MOSTE.

The Environmental Fund

There has been an Environmental Fund set up in order to strengthen the environmental management. According to the Act, resources from the Environmental Fund - controlled by the Fund Committee - may be used for the following purposes:

- Grants for the governments central wastewater or waste treatment plants;
- Loans to local administrations or state enterprises for their pollution control and prevention system;
- Loans to private investors for pollution control and prevention system;
- Grants for environmental promotion and conservation activities; (Enhancement and conservation of National Environmental Quality Act B.E. 2535, (1992), DEQP, 1992: Chapter 2:8).

Environmentally protected areas/Pollution control areas

The Act states furthermore that the Minister of MOSTE, with approval from NEB, shall formulate an action plan; an Environmental Quality Management Plan (EQMP) - in order to implement the *National Environmental Quality Act B.E. 2535* - and that all governmental agencies must take action in order to implement the management plan. EQMP (1999-2006) has how been completed and adopted, and function as a framework for the conservation of the environment, and incorporates environmental quality management plans to cover various sectors as specified in Article 36 like for example:

- Management of air, water and environmental quality;
- Point sources pollution control;
- Conservation of the natural environment, natural resources or cultural environment pertaining to aesthetic values; (Enhancement and conservation of National Environmental Quality Act B.E. 2535, (1992), DEQP, 1992, Part 2:12).

EQMP outlines the works of government agencies, state enterprises and also relevant stakeholders in the private sector, and sets up frameworks for the implementation of environmental conservation at the provincial level: When the plan has been published in the Government Gazette it is the duty of province Governor's, who are residents in environmental protected areas or pollution control areas, to conduct a plan for environmental quality management at provincial level - a Changwat Action Plan - and submit it to NEB for approval (Enhancement and Conservation of National Environmental Quality Act B.E. 2535, (1992), DEQP, 1992, Part 2:13). These initiatives open up for decentralisation of environmental management to provincial and local levels. The ministerial regulation may prescribe, among other things, the following protective measures:

- Land use control;
- Prohibition of acts or activities harmful to the ecosystem of the area;
- Requirement of environmental impact assessment (EIA) reports for certain types of sizes of projects or activities;
- Other proper protective measures; (Enhancement and Conservation of National Environmental Quality Act B.E. 2535, (1992), DEQP, 1992, Part 3:14).

Environmental Impact Assessment (EIA)

With the implementation of the Act, the EIA process has been improved; the report approval period has shortened, and there has been set up a expert committees.

MOSTE has power to issue a ministerial notification requiring the preparation of reports on environmental impact assessment (EIA), before undertaking certain types or sizes of projects or activities. An EIA report will be reviewed by the OEPP within 30 days with preliminary comments. The report will then be submitted to the Committee of Experts that will render its decision within 45 days. In case of total or partial denial of approval, the Committee shall complete the review of the resubmitted EIA report within 30 days (Enhancement and conservation of National Environmental Quality Act B.E. 2535, (1992), DEQP, 1992, Part 4). In the following section is an outlined example of projects, which requires an EIA:

- Dams or reservoirs;
- Irrigation;
- Hotels or resorts near rivers, lakes or beaches;
- Express ways;
- Mining;
- Industrial Estates etc.;
- Commercial ports;
- Thermal Power Plants (> 10 MW);
- Petrochemical industry;
- Oil refinery;
- Steel industry;
- Cement industry;
- Pulp and paper industry;
- Dwelling buildings;

When implementing energy producing facilities an EIA is only required when the installed effect passes 10 MW (Environmental Impact Assessment in Thailand, Environmental Impact Evaluation Division, OEPP, 1998).

Pollution Control

The Pollution Control Committee (PCC) is created to give advises to NEB and MOSTE, particular on issues dealing with pollution control and prevention, including other related matters as specified by the Act. The committee has the Permanent Secretary of MOSTE as Chairman. With the implementation of the Act the "Polluter Pays Principle" has been introduced. PCC set measures and standards for the following areas:

- Emissions or effluent standards;
- Pollution control areas;
- Air and noise pollution;
- Water pollution;
- Other pollution and hazardous waste;
- Monitoring, inspection and control;
- Service fee and penalty;
- Promotional measures;
- Civil liability;
- Penal provisions;
- Interim provisions; (Enhancement and conservation of National Environmental Quality Act B.E. 2535, (1992), DEQP, 1992: Chapter 4).

"Energy Conservation Promotion Act B.E. 2535" (1992)

The purpose of the *Energy Conservation Promotion Act B.E. 2535* (ECPA) from 1992 is to promote energy conservation and to encourage investment in energy conservation in factories and buildings. To promote energy conservation an *Energy Conservation Promotion Fund* (the ENCON Fund) - managed by the ENCON committee - has been established in order to support energy conservation, together with enforced legislative measures, such as the *Royal Decree on Designated Buildings B.E. 2535* (1995) and the *Royal Decree on Designated Factories*, which focuses on energy conservation inside specified buildings and factories. The ENCON Fund supports government agencies, state enterprises, NGOs, etc., who works with measures to increase efficiency in energy uses (ECPA, NEPO Homepage, 2000, at; www. nepo.go.th/doc/doc-NEPO-ACT2.html, per 13-9-00). Regarding energy conservation in factories, Section 7 of the Act states the following measures:

"1. Improvement in combustion efficiency of fuels;
2. Prevention of energy loss;
3. Recycling of energy wastes;
4. Substitution of one type of energy by another type;
5. More efficient use of electricity through improvement in power factors, reduction of maximum power demand during the period of the electricity system's peak demand, use of appropriate equipment's, and through other approaches;
6. The use of energy-efficient machinery or equipment as well as the use of operation control systems and materials that contribute to energy conservation;
7. Other means of energy conservation as stipulated in the Ministerial Regulations"; (ECPA, NEPO Homepage, 2000, at; www.nepo.go.th/doc/doc-NEPO-ACT2.html, per 13-9-00).

The *Energy Conservation Program* is a program under the ENCON programmes, which aims at promoting energy conservation. It is divided into three sub-programs, which now has entered the second period of duration (1995-1999 and 2000-2004):

(1) *Compulsory Program* which relates to the legislative and regulatory implementation of energy conservation programmes in buildings;
(2) *Voluntary Program* which relates to renewable energy in rural and small and medium size industries - both agricultural and industrial - and on research and development, focusing on energy conservation related technologies; and,
(3) *Complementary Programs*, which relates to the educational and training programmes on energy conservation, and increasing of operational efficiency; (Energy conservation promotion fund during the fiscal period 2000-2004, NEPO publication (Data unknown)).

Demand Side Management (DSM)

To promote energy conservation the Thai government also launched a Demand Side Management plan in 1992, deriving from a cabinet solution of December 3., 1991. The DSM program aim at encouraging economic use of electricity and reduce energy consumption in general. NEPO has supported the DSM project by taking the following actions:

- "Liase with EGAT in carrying out campaigns to urge the public to use energy-saving lighting equipment and to use 11W or 7W compact fluorescent tubes instead of normal incandescent light bulbs;
- Liase with EGAT in promoting the energy-efficiency labelling of 5-6 cubic-foot refrigerators manufactured as of January 1, 1995, which has met with success. The expansion of the No. 5 efficiency-level labelling for refrigerators of other sizes has been encouraged;
- Liase with EGAT in promoting the No. 5 energy-efficiency level labelling for air-conditioners of no larger than 13,300 BTU since early 1996;
- Encourage government agencies to use high-efficiency air-conditioners and compact fluorescent tubes on an exceptional basis. In this regard, the Bureau of the Budget shall consider revising median prices of large-sized air-conditioners so that government agency may procure No. 5 efficiency-level labelled air-conditioners. It shall also lower the median price of 13,300 BTU split-typed air-conditioners to correspond with the market price"; (The Demand Side Management (DSM) program, NEPO Homepage, 2003, at; www.eppo.go.th/admin/NEPO-Roles-E.html#4, per 21-7-03).

In 2000 the Thai government spend Baht 200 mill. (DKK 40 mill.) on advertisement for energy conservation, and Baht 180 mill. are planned to be spend in 2001 (Thailand Energy Direction: Public Participation and Campaigns in Thailand, Dr. Chirapol Sintunawa, Paper handed out at University of Mahidol, Salaya Campus, Bangkok the 28-1-00).

Annex B

All calculations are based on information about amounts of wastes etc. as given in Chapter 4. The terms 'collected' compared with 'generated', used in the following, refers to whether or not the waste actually are collected by the community, or simply resources that are generated but *could* be collected for further re-use.

Solid waste - Wood wastes

Biomass resources:	Wood wastes	
Amounts of wastes (tons/y):	Interfurn	52.20
	Sun Cabinet	530
	Rockwood	262.50
	Light House	100
	Total ≊	***945***

Incineration:
The combustibility of wood wastes must be calculated for three types of wood: 1/ Chip boards (including sawdust); 2/ Plywood; 3/ Mixed wood. According to the company visits, all wood wastes appeared as dry biomass resources, and as such, I assume moisture contents of approximately 10 to 15 % (Anders Evald, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 5-12-01).

1/ Chip boards
Sun Cabinet and Rockwood generate wood wastes amounting to 792.50 tons/year. The combustibility of chip boards, including sawdust, is 17 MJ/kg (Letter from Hans Falster, Dk-Teknik Energi og Miljø, dated the 14-5-01). Energy potentials of wood wastes are therefore (792,500*17) 13,472,500 MJ/kg, or (13,47,500/3,600) 3,742.40 MWh/year.

2/ Plywood
Light House generates 100 tons of plywood annually and Interfurn (20.50*0.20) 4.10 tons/year. The estimated combustibility of plywood is 16 to 17 MJ/kg (Letter from Hans Falster, Dk-Teknik Energi og Miljø, dated the 14-5-01), here set to 16.50 MJ/kg. The energy potentials of wastes is therefore (104,100*1.50) 1,717,650 MJ/year, or (1,717,650/3,600) 477.10 MWh/year.

3/ Mixed wood
Interfurn also generated mixed wood waste amounting to 48.10 tons/year. The estimated combustibility of mixed industrial wood waste is 15 to 16 MJ/kg (Letter from Hans Falster, Dk-Teknik Energi og Miljø, dated the 14-5-01), here set to 15.50 MJ/kg. Energy potentials of wastes is therefore (48,100*15.50) 745,550 MJ/year, or (745,550/3,600) 207.10 MWh/year.

Total energy potential of wood wastes: ≈ <u>4,400 MWh/year.</u>

Solid waste - Fermentation and production sludge

Biomass resources:	Fermentation and production sludge	
Amounts of wastes (tons/y.):	ASAN Service	280
	B.B. Snacks	35
	Baskin Robbins	9
	Total	***324***

Digestion:
As the VO (%) - dry matter - of this wastes appeared relatively high when examined during the company visits, they can only be digested - if not dried or when mixed with liquid wastes with a lower content of VO (%).

According to Energistyrelsen (see Chapter 3 Figure 3K) 1,900 tons VS (100 %) of fermentation sludge[79] is equal to 18 TJ, which means that 1,900,000 kilo is equal to 18,000 GJ or 18,000,000 MJ. 1 kilo VS (100 %) of fermentation sludge is, therefore, equal to (18,000,000/1,900.000) 9.47 MJ/kg VS (100 %) (Biogashandlingsplanen, Baggrundsrapport nr. 12, Energistyrelsen, 1991). Dry matter contents (VS (%)) of wastes from this kind of industry is 21 (Ibid.), which means that is takes (100/21) 4.76 kilo of ordinary fermentation sludge to generate 1 kilo VS (100 %).

As there is no specific data for wastes generated from industries, which are similar to B.B. Snacks, I have set the energy potential and VS (%) as the same figures as for ASAN Service. The amounts of wastes from this industry are limited, which means that estimated figures not will have a significant influence on the calculations for energy potentials. As the wastes are utilised as animal feed, I assume it is a protein rich material, and as such, contain a high gas potential. The gas potential of sludge from Baskin Robbins is also set to that of ASAN Service.

Altogether ASAN Service, B.B. Snacks and Baskin Robbins generates 324,000 kilo of biomass waste per year, which gives a total of (324,000/4.76) 68,067.20 kilo VS (100 %) per year. As 1 kilo VS (100 %) is equal to 9.47 MJ, wastes has an energy potential of (9.47*68,067.20) 644,596.60 MJ/year. Estimated energy potentials of resources are thus (644,596.60/3,600) 179.10 MWh/year.

Total energy potentials of wastes: ≈ <u>200 MWh/year.</u>

Incineration:
The combustibility of organic industrial wastes with a relatively high content of VO (%) is approximately 16 MJ/kilo (‘Biobib’, University of Technology, Vienna, Homepage, 2001, at; www.vt.tuwien.ac.at/biobib/fuel281.html, per 3-7-01). As stated, the biomass wastes appeared on a relatively dry basis. Therefore, the above figures for combustibility will be used in the following.

[79] (’gær/bærme/kieselgur’ m.v.)

All together ASAN Service, B.B. Snacks and Baskin Robbins generates 324,000 kilo of organic material per year, which is equal to an energy potential of (324,000*16) 5,184,000 MJ/year or (5,184,000/3,600) 1,440 MWh/year.

Energy potentials of wastes: ≈ <u>1,400 MWh/year.</u>

Liquid waste - biofuel

Biomass resources:	Liquid vegetarian waste (bio-oil)	
Amounts of wastes (tons/y.):	Imperial	600
	Total	***600***

Digestion:
As there is no specific data for wastes equal to that generated by Imperial in Figure 3K Chapter 3, I will utilise data for margarine grease as reference. According to Energistyrelsen, 252 tons VS (100 %) of margarine grease is equal to 7 TJ, which means that 252,000 kilo is equal to 7,000 GJ or 7,000,000 MJ. 1 kg VS (100 %) of margarine grease is, therefore, equal to (7,000,000/252,000) 27.80 MJ/kg VS (100 %) (Biogashandlingsplanen, Baggrundsrapport nr. 12, Energistyrelsen, 1991). VS (%) is 90 for this type of industry, which means that it takes (100/90) 1.11 kilo of ordinary waste to generate 1 kilo VS (100 %) (Ibid.).

Generated waste amounts to 600,000 kg/year, which gives a total of (600,000/1.11) 540,540.50 kilo VS (100 %) per year. As 1 kilo VS (100 %) is equal to 27.80 MJ, this waste has an energy potential of (27.80*540,540.50) 15,027,027 MJ/year, or 15,027,027/3,600) 4,174 MWh/year. As figures are rough estimations the energy output are set to 4,000 MWh/year.

Energy potentials of wastes: ≈ <u>4,000 MWh/year</u>.

Incineration:
The combustibility of bio-fuel is approximately 38 MJ/kg (Letter from Hans Falster, Dk-Teknik Energi og Miljø, dated the 14-5-01). This gives an energy potential of (600,000*38) 22,800,000 MJ/year, thus (22,800,000/3,600) 6,333.30 MWh/year.

Energy potentials of wastes: ≈ <u>6,300 MWh/year</u>.

Liquid waste - sludge from Navanakorn WWTP

Biomass resources:	Sludge from N.N. WWTP	
Amounts of wastes (tons/y):	WWTP of N.N.	3.600
	Total	***3.600***

Data for digestion and incineration of sludge from WWTPs are based on figures from Spildevandscenter Avedøre I/S. This plant is chosen as reference for theoretical calculations of energy potentials, as the wastewater at Avedøre are generated by both industrial and residential costumers. This is similar to the situation at Navanakorn Industrial Promotion Zone, which is a mix of industries and households.

Digestion:
According to average energy potentials of digested sludge, obtained at Spildevandscenter Avedøre I/S, it is possible to generate 0.55 m^3 biogas/kg sludge (Stig Dalum, Spildevandscenter Avedøre I/S, Telephone-interview the 10-5-01). As 1 m^3 biogas is equal to 6 kWh (Fokus på Biogas, Dansk Teknologisk Institut, 1996), it is possible to produce (0.55*6) 3.30 kWh/kg sludge. As generated sludge amounts to 3,600,000 kg/year it is, theoretically, possible to produce (3.30*3,600,000) 11,880,000 kWh/year, or 11,880 MWh/year.

Energy potentials of wastes: ≈ <u>11,900 MWh/year</u>.

Incineration:
Sludge from WWPTs can also be dried before or after the gas is extracted and then incinerated. The combustibility of digested sludge is approximately 22 MJ/kg VS (%) 32, which can be regarded as average figures under Danish conditions (Stig Dalum, Spildevandscenter Avedøre I/S, Telephone-interview the 10-5-01). If not digested the energy potential is slightly higher due to the intact contents of carbon. At Spildevandscenter Avedøre I/S they treat wastewater amounting to 25 mill. tons/year, and generated sludge is digested in a biogas plant. Hereafter, digested sludge is dried to VS (%) 32 and incinerated (Ibid.).

According to data from Spildevandscenter Avedøre I/S, 1 tons of dry sludge VS (%) 32 is generated for every 3,571 tons of wastewater passing through the WWTP. Using these figures for estimating theoretical energy potentials of generated sludge at Navanakorn WWTP, it gives the following results. The WWTP treats wastewater corresponding to 4.68 mill. tons per year, which can yield dry sludge VS (%) 32 estimated to (4.68/0.003571) 1,311 tons/year. Energy potentials of dry sludge are therefore (22*1,311,000) 28,842,000 MJ/year, thus (28,842,000/3,600) 8,012 MWh/year.

Energy potentials of wastes: ≈ <u>8.000 MWh/year</u>.

Solid waste - Household wastes

The following examples are made for Navanakorn (N.N.) and Takhlong Municipality only.

Navanakorn

Biomass resources:	Organic source separated household wastes	
Amounts of wastes (tons/y.)	Collected wastes N.N.	14,400
	For energy production	***2,700***

Digestion:
Collected amounts of source separated household waste (2,700 tons/year):
As 1 ton of source separated household waste contains energy potentials between 120 to 150 m^3 gas (Poul Lyhne, EnergiGruppen Jylland A/S, Telephone-interview the 10-5-01) - here set to an average of 135 m^3 - we can produce (135*2,700) 364,500 m^3 biogas/year. As 1 m^3 biogas is equal to 6 kWh (Fokus på Biogas, Dansk Teknologisk Institut, 1996), the energy potential of source separated waste is (364,500*6) 2,187,000 kWh/year or 2,187 MWh/year.

Energy potentials of wastes: ≈ 2,187 MWh/year.

Incineration:
Collected amounts of source separated household waste (6,750 tons/year):
The combustibility of organic source separated household waste is, according to experiments conducted by Dk-Teknik Energi og Miljø, approximately 3,500 MJ/tons, thus 20-25 % of the combustibility of ordinary non-separated household waste (Indsamling og anvendelse af organisk dagrenovation i biogasanlæg, Miljøstyrelsen, 1998). Organic fractions amount to 2,700 tons/year, which equals an energy potential of (2,700*3,500) 9,450,000 MJ/year. This is equal to (9,450,000/3,600) 2,625 MWh/year.

Energy potential of wastes: ≈ 2,625 MWh/year.

Navanakorn and Takhlong Municipality

Biomass resources:	Organic source separated household wastes	
Amounts of wastes (tons/y.)	Collected wastes N.N.	14,400
	Collected wastes Takhlong M.	21,600
	Total (collected amount)	*36,000*
	For energy production	***6,750***
	Generated waste Takhlong M.	57,600
	Total (generated amount) incl. N.N.	*72,000*
	For energy production	***13,500***

Digestion:
Collected amounts of source separated household waste (6,750 tons/year):
As show in Chapter 4 Figure 4J, the theoretical amounts of household waste for energy production from Navanakorn and Takhlong Municipality, equals 6,750 tons/year. As 1 tons of source separated household waste has an energy potential of 135 m^3, we can produce (135*6,750) 911,250 m^3 gas/ year. As 1 m^3 biogas is equal to 6 kWh energy potentials of source separated waste is (911,250*6) 5,467,500 kWh/year, or 5,467.50 MWh/year.

Energy potentials of wastes: ≈ 5,500 MWh/year.

Generated amounts of source separated household waste (13,500 tons/year):
If the came calculations are made for the generated amounts of household waste, which is calculated to 13,500 tons/year, we get the following result. Gas potentials are (135*13,500) 1,822,500 m^3, which is equal to (1,822,500*6) 10,935,000 kWh/year, or 10,935 MWh/year.

Energy potentials of wastes: ≈ 10,900 MWh/year.

Incineration:
Collected amounts of source separated household waste (6,750 tons/year):
Organic fractions amount to 6,750 tons/year, thus an energy potential of (6,750*3,500) 23,625,000 MJ/year. This is equal to (23,625,000/3,600) 6,562.50 MWh/year.

Energy potentials of wastes: ≈ 6,600 MWh/year.

Generated amounts of source separated household waste (13,500 tons/year):
Organic fractions are estimated to 13,500 tons/year, which gives an energy potential of (13,500* 3,500) 47,250,000 MJ/year, thus (47,250,000/3,600) 13,125 MWh/year.

Energy potentials of wastes: ≈ 13,100 MWh/year.

Industrial/Commercial waste

Biomass resources:	Industrial/commercial waste	
Amounts of waste (tons/y.)	Collected waste N.N.	6,300
	For energy production	***1,417.50***
	Generated waste N.N.	7,200
	For energy production	***1,620***

The following calculation must be regarded as a rough estimation of energy potentials of these materials, as there are no empirical data available for more specific calculations. When looking at the industries located in Phase 1 of Navanakorn Industrial Promotion Zone (See Figure 3C in Chapter 3), it is evident, that there are many industries that can generate appropriate biomass wastes.

Digestion:
Possible wood fractions in the organic industrial/commercial waste are here included in the calculation of energy potential when digesting. Wood fractions are, however, not appropriate for digestion and must be separated from the remaining organic wastes, if digestion is pursued. According to Rena Angillidakki, DTU, the average gas potential of industrial/commercial waste varies greatly depending on type. It can vary from 30 to 300 m^3/tons, but for calculating energy potentials, she estimates that 100 m^3/tons is an appropriate figure (Rena Angillidakki, DTU, Telephone-interview the 6-6-01). The following calculations are based on this estimate.

Collected amounts of source separated industrial/commercial waste (1,417.50 tons/year):
We have 1,417.50 tons of industrial/commercial waste, which can generate a gas potential of (1,417.50*100) 141,750 m^3 gas/year. 1 m^3 biogas generates 6 kWh, which gives an energy potential of (141.750*6) 850.500 kWh/year, or 850,50 MWh/year.

Energy potentials of biomass wastes: ≈ 850 MWh/year.

Generated amounts of source separated industrial/commercial waste (1,620 tons/year):
We have 1,620 tons of industrial/commercial waste, which can generate a gas potential of (1,620*100) 162,000 m^3 gas/year. 1 m^3 biogas generates 6 kWh, which gives an energy potential of (162,000*6) 972,000 kWh/year, or 972 MWh/year.

Energy potentials of biomass wastes: ≈ 1,000 MWh/year.

Incineration:
Organic industrial/commercial wastes can also be incinerated. The combustibility of organic industrial/ commercial wastes with a relatively high VO (%) is, as stated earlier, approximately 16 MJ/kilo. This figure is also appropriate for making estimations of energy potentials of wastes, containing fractions of dry wood wastes as well (10 to 15 % moisture content) (Andres Evald, DK-Teknik, Miljø og Energi, Interview, Gladsaxe the 5-12-01), as claimed by the management of Navanakorn.

Collected amounts of source separated industrial/commercial waste (1,417.50 tons/year):
1,417.50 tons per year is equal to 1,417,500 kilo waste per year, thus an energy potential of (1,417,500*15.90) 22,538,250 MJ/year, or (22,538,250/3,600) 6,260.60 MWh/year.

Energy potentials of wastes: ≈ 6,300 MWh/year.

Generated amounts of source separated industrial/commercial waste (1,620 tons/year):
1,620 tons per year is equal to 1,620,000 kilo waste per year, thus an energy potential of (1,620,000*15.90) 25,758,000 MJ/year, or (25,758,000/3,600) 7,155 MWh/year.

Energy potentials of wastes: ≈ 7,200 MWh/year.

Annex C

All calculations are based on information regarding energy consumption etc. as given in Chapter 4.

Present energy End-uses, costs and environmental impacts

Heat demands in case industries

…Covered by fossil fuels

Utilisation of fuels (tons oil/y):

Imperial	1,650
B.B. Snacks	100
Baskin Robbins	330
Total	***2,080***

Energy needs (MJ):
1 tons of oil is equal to 42,7 GJ, which means that the energy demand is (2,080*42,7) 88,816 GJ, or 88,816,000 MJ/year.

Utilisation of fuels (litre oil/y):

ASAN Service	36,000
Sun Cabinet	24,000
Total	***60,000***

Energy needs (MJ):
1,000 l. of oil is equal to 36 GJ, which means that the energy demand is (60,000/1,000*36) 2,160 GJ, or 2,160,000 MJ/year.

Utilisation of fuels (Liquid petroleum gas, LPG, in tons/y);

B.B. Snacks	36
Total	***36***

Energy needs (MJ):
1 l. of LPG is equal to 0.53 kilo and 26.60 MJ, which means that the energy demands is (36,000 l./0.53*26.60) 1,806,793 MJ/year.

…Covered by biomass wastes

As seen from the empirical data in Chapter 4, Sun Cabinet covers approximately 40 % of total heat uses by an implemented Stoker boiler based on incineration of sawdust wastes. Calculated in accordance with fossil fuel uses - which amounts to 24,000 l./year or 168 MWh/year and covers 60 % of energy uses - the total theoretical energy demand amounts to (168/60*100) 280 MWh/year.

In case the amounts of sawdust used for generating process heat are reliable data, it is not possible to cover the remaining 40 % of the heat demands by the Stoker boiler, as this maximum generates (8,000 kg sawdust*17 MJ/kg) =136,000 MJ. This equals (136,000 MJ/3,600) = 38 MWh/year (120 MWh/year deficit). Thus, I assume that more biomass wastes actual are feed into the boiler, and that the actual heat demand equals 280 MWh/year.

Total heat demand

Total energy needs (MJ):
From *fossil fuel* uses a total heat demand of 92,782,793 MJ/year are found in case industries, which equals a non-converted energy demand of (92,782,793/3,600) 25,773 MWh/year. From uses of *biomass wastes* we found a heat demand equal to (280-168) 112 MWh/year. This gives a total heat demand in case industries amounting to (25,773 + 112) 25,885 MWh/year. As no empirical data exposes the effect of installed boilers in case area industries, the total effect of all boilers are set to an average of 70 % (Pers.Com., Tyge Kjær, 2001). As the boilers were found to vary greatly in size and age, this figure is found appropriate for further calculations. This means that estimated heat demand in case industries equals (25,885*0.70) 18,119.50 MWh/year, divided as follows:

Heat demands (MWh/year):

Imperial	13,699.80
ASAN Service	252.00
B.B. Snacks	3,091.20
Baskin Robbins	830.28
Sun Cabinet	280.00
Rockwood	Process heat by electricity uses; conversion to water based heat
Interfurn	No process heat demand
Light House Industry	No process heat demand

Total heat demand: ≈ 18,100 MWh/year.

Electricity demand

Electricity demands (mill. kWh/year):

Imperial	1.44
ASAN Service	0.21
B.B. Snacks	0.34
Baskin Robbins	1.56
Sun Cabinet	2.00
Rockwood	1.20
Interfurn	0.45
Light House Industry	1.13

Total electricity demand: ≈ 8.3 mill. kWh/year ≈ 8,300 MWh/year

Environmental impacts

Fossil fuel utilisation

It is found that fossil fuel utilisation in case area industries amount to 92,782,793 MJ/year, divided in uses of 1,806,793 MJ LPG and 90,976,000 MJ oil annually, thus 1,806.79 and 90,976 GJ/year respectively. In the following, I will estimate emissions from the use of the above mentioned fuels. Calculations are made from data given in Miljøstyrelsens report: Denmark's Second National Communication on Climate Change, Miljøstyrelsen, 1997. In Annex D of that report, figures for emissions from 'Industrial Combustion' are used as data for calculations.

Figure CA: Estimated emissions from uses of fossil fuels in case industries

Component	Emission Factor [kg/GJ] (LPG)	(Oil)	Yearly emission [kg/year] (LPG)	(Oil)	⇒ Total
CO_2	65.00	74.00	117,441.40	6,732,224.00	6,849,665.40
CO	0.013	0.012	23.50	1,091.70	1,115.20
NO_x	0.100	0.100	180.70	9,097.60	9,278.30
UHC	0.0021	0.0015	3.80	136.50	140.30
SO_2	0.000	0.234	0.00	21,288.40	21,288.40

Source: Own calculation based on data from: "Denmark's Second National Communication on Climate Change", Miljøstyrelsen, 1997

Electricity production

Electricity services transmitted to industries in Navanakorn is here calculated as being generated at a modern power plant, similar to for instance Wang Noi Power Plant located close to Ayuthaya North of Navanakorn. Rather then comparing with emissions generated by average power producing technologies in Thailand (based on coal, oil, lignite etc.), I have chosen to compare with emissions produced on technologies *to be* implemented in Thailand in coming years, of which some already are established. In doing so, the Wang Noi Power Plant is an appropriate technology for comparison, as it reflects the choice of technologies to be implemented. Wang Noi Power Plant is a Combined Cycle natural gas fired plant with a capacity of 2,031 MW (divided on three block's) (Annual Report 1999, EGAT, 2000).

In order to estimate CO_2 emissions from the production of 8,336 MWh of electricity, as utilised by case industries, the electricity efficiency of the Wang Noi power plant is set to 48 % (Mr. Lodovic Lacrosse, EC-ASEAN COGEN, Bangkok, Letter dated the 14-6-01). Electricity needs in case industries amount to (8,336*3,600) 30,009,600 MJ/year. With an electricity efficiency of 48 %, it is necessary to utilise natural gas amounting to (30,009,600/0.48) 62,520,000 MJ/year, or 62,520 GJ/year to cover energy demands. Figures for emissions are shown below.

Figure CB: Emission figures for estimated amounts of natural gas used at Wang Noi to cover electricity demands in case industries

Component	Emission Factor [kg/GJ]	Yearly Emission [kg/year)
CO_2	57.00	3,563,640.00
CO	0.01	625.20
NO_x	0.05	3,126.00
UHC	0.03	1,875.6
SO_2	0.0003	18.76

Source: Own calculation based on emission factors given by Dansk Gasteknisk Center Homepage, 2001, at; www.dgc/publikationer/katalog/miljoe_1000.htm, per 19-7-01

Estimated total emissions from energy uses

Emissions, caused by the heat and power production to cover energy demands in case industries, are shown below:

Figure CC: *Summary* - Estimated total emissions in case industries

Component	Yearly Emission [kg/year]
CO_2	10,413,305.00
CO	1,740.40
NO_x	12,404.30
UHC	2,015.90
SO_2	21,307.16

Costs of present energy uses

The costs of present energy uses within industries, shown below, is, apart from its informative status, used as background data for calculating 'substituted costs' of energy as shown in the Pre-Feasibility Study, Annex D Part 1.

Electricity

All together industries utilise electricity amounting to 8,336,000 kWh/year. Industries pay approximately Baht 3 per kWh incl. taxes (data for May 2001) (Mr. S.G. Deshpande, Imperial, Letter dated the 8-5-01), thus the price ads up to Baht 25,008,000 per year.

Fossil fuels

To calculate oil prices, I will convert all figures to l. oil uses per year. As 0.843 tons oil is equal to 1,000 l. oil, 1 tons oil equals 1,186.24 l. oil. We have 2,080 tons uses of oil per year, which thus equals (1,186.24*2,080) 2,467,378.40 l./year. Added utilities of 60,000 l./year

(ASAN Service & Sun Cabinet), we get a total of 2,527,378.40 l./year. Industries pay Baht 9.25 per l. oil (data for May 2001) (Mr. Kritsakhorn Dolcharumanee, B.B. Snacks, Letter dated the 28-5-01). Thus, expenses for oil uses amounts to (9.25*2,527,378.40) Baht 23,378,250 per year.

The use of LPG amounts to 30 tons per year. Industries pay Baht 10,476 per tons LPG (data for May 2001) (Mr. Kritsakhorn Dolcharumanee, B.B. Snacks, Letter dated the 28-5-01), which means that the price ads up to (36*10,476) Baht 377,136 per year. Thus, prices for fossil fuel utilisation in case industries amount to Baht <u>23,755,386 per year</u>. Total energy expenses in case area industries are <u>Baht 48,763,386 per year</u>. As we can see, electricity and fossil fuel expenses are almost the same.

Costs of 1 MJ of energy

Fossil fuels:
1 MJ energy equals uses of 0.0278 l. of oil. As the efficiency of boilers is set to 70 %, we must utilise (0.0278/0.70) 0.0397 l. of oil to generate 1 MJ. The price for producing 1 MJ is therefore (0.0397*9.25) <u>Baht 0.367</u>. Thus, 1 GJ equals Baht 367, and 1 MWh (0.367*3,600) Baht 1,321.20 (data for May 2001).
1 MJ energy equals uses of 0.0199 kilo of LPG. As the efficiency of boilers is set to 70 %, we must utilise (0.0199/0.70) 0.0284 kilo LPG to generate 1 MJ. The price for producing 1 MJ is therefore (0.0284*10,476) <u>Baht 0.298</u>. Thus, 1 GJ equals Baht 298, and 1 MWh (0.298* 3,600) 1,072.80 Baht (data for May 2001).

Electricity:
1 MJ equals 0.000278 MWh electricity. As the price of 1 kWh is Baht 3 (data for May 2001), the price of 1 MWh is Baht 3,000. The price of 1 MJ is therefore (0.00278*3,000) <u>Baht 0.833.</u> Thus, 1 GJ equals Baht 833.33, and 1 MWh (0.833*3,600) Baht 3,000 (data for May 2001).

Annex D (part 1)

Calculations

Steam data: 420 to 450 ℃ and 65 bar.

Conversion technology: 'Bubbling Fluidised Bed combustion plant'

Energy data:				
Applied waste	**18,400.00**	MWh/year		
	66,240.00	GJ/year	**1**	
	2.63	MJ/s in	**2**	
Availability factor	87.5%			
Total efficiency	90.0%			
Net energy input	16,100.00	MWh/year	**3**	
	57,960.00	GJ/year	**4**	
Internal process electricity	0.40%			
	64.40	MWh/year	**5**	
Brut Electricity efficiency:				
Minimum	20.00%			
Maximum	40.00%			
Self-providing, heat & electricity	29.53%			
Applied	**18.00%**			
Electricity output	2,833.60	MWh/year	**6**	
Heat output	11,592.00	MWh/year	**7**	
Operation hours	7,000.00	Hours/year		
Total size of plant;	2.63	MW	**8**	
	0.40	MW el.	**9**	
	1.66	MJ/s th.	**10**	
Economy:				
Plant expenses	7.00	Mill. DKK/MJ/s	**11**	
	18.40	Mill. DKK	**12**	
Cost of piping	10%	of plant exp.	**13**	
	1.84	Mill. DKK	**14**	
'Wheeling' fee	0.09	Mill. DKK/y	**15**	
Maintenance & operation	4.5%	/y of plant exp.	**16**	
	0.83	Mill. DKK/y	**17**	
Total plant expenses	20.24	Mill. DKK	**18**	
Lifetime	20.00	Years		
Emissions:				
Ash	43.47	Tons TS/year	**19**	
SO_2	0.20	Tons/year	**20**	
NO_x	2.17	Tons/year	**21**	
Feasibility:				
Yearly interest rate	7%		**22**	
Capital costs	1.91	Mill. DKK/y	**23**	
(including M&O + 'wheeling' fee)	2.83	Mill. DKK/y	**24**	
	0.00	DKK/MWh in	**25**	<u>151.5</u>

Cost of biomass waste (fuel)						
	0.00	Mill. DKK/y		**26**		
Substituted cost, heat	264.24	DKK/MWh out	264		330.3	198
	3.06	Mill. DKK/y		**27**		
Substituted cost, Boiler-M&O	0.77	Mill. DKK/y		**28**		
Sales, heat	**0.00**	DKK/MWh out				
	0.00	Mill. DKK/y		29		
Substituted cost, electricity	600.00	DKK/MWh out	600		750	450
	1.70	Mill. DKK/y		**30**		
Sales, electricity	**0.00**	DKK/MWh out				
	0.00	Mill. DKK/y		**31**		
Total contribution of energy production	2.70	Mill. DKK/y		**32**		
Marginal contribution of 1 kWh elec.	0.95	DKK/kWh/y		**33**		

Coverage of energy demand:

Electricity uses	8,336.00	MWh/year		
Coverage (% of demand)	**33.99%**			**34**
Primarily Steam uses/substituted heat	17,200.00	MWh/year (11,000)		
Coverage (% of demand)	**105.00%**		**35***	

*At 11,000 MWh primary steam supply 105 % of the total heat demand are covered, as the remaining part are being covered by district heating.
In the cell 17,200 MWh/y are noted, as this express the amount of heat substituted. For B.B. Snacks 30 % of the heat uses are not included, as it is covered by LPG, which means that the substituted heat ends at 17,200 MWh/year.

Pre-conditions

Industrial wastes (case industries)		
Energy potentials of waste for incineration:		
Solid waste		
Wood	4,427	MWh/year
Fermentation and production sludge	1,431	MWh/year
Sub-total	5,858	MWh/year
Liquid waste		
Bio-fuel	6,117	MWh/year
Total energy potential	***11,974.3****	MWh/year
Internal[80] Supporting Systems		
Energy potentials of waste for incineration:		
Dried liquid waste		
Sludge from WWTP	8,012	MWh/year
Total energy potential	8,012	MWh/year
Internal Supporting Resources		
Energy potentials of waste for incineration:		
Solid waste		
Collected industrial/commercial waste	6,261	MWh/year
Generated industrial/commercial waste	***7,155****	MWh/year
Total energy potential	7,155	MWh/year
Internal/external Supporting Resources		
Energy potentials of waste for incineration:		
Solid waste		
Collected internal household waste	2,625	MWh/year
Collected internal/external household waste	6,563	MWh/year
Generated internal/external household waste	13,125	MWh/year
Total energy potential	13,125	MWh/year
Sum of total energy potential	**40,266**	**MWh/year**

*** Applied waste**

Data inputs:

1 Energy input MWh per year*3,600/1,000 (to GJ).
2 Energy input MWh per year*3,600/Operation hours/3,600.
3 Energy input MWh per year*(Availability factor/100).
4 Net energy input MWh per year*3,600/1,000 (to GJ).
5 4kWh*Net energy input GJ per year/1,000 (to MWh).

[80] 'Internal versus external' refers to whether the biomass waste comes from within or outside Navanakorn Industrial Promotion Zone.

6 Net energy input MWh per year*(Electricity efficiency/100)-Internal process electricity.
7 Net energy input MWh per year*(Total efficiency-electricity efficiency)/100).
8 Energy input MWh per year/Operation hours.
9 Electricity output/Operation hours per year.
10 Heat output/Operation hours per year.
11 7 mill. DKK*MJ/s in (Mogens Weel Hansen, Dk-Teknik Energi og Miljø, Pers.Com., Gladsaxe the 4-2-02).
12 Plant expenses*MJ/s in.
13 Plant expences*10 % (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 10-4-02).
14 Plant expenses*Cost of piping.
15 Between 0.12 to 0.20 Baht/kWh transmitted = an average of 32 DKK/MWh (Mr. Pinij Siripuekpong, EGAT, Letter dated the 4-1-02).
16 Plant expenses/100*4.50 DKK
17 Plant expenses*M&O.
18 Plant expenses+Cost of piping.
19 0.75kgTS*Net energy input GJ per year/1,000 (to tons).
20 3.50g*Net energy input GJ per year/1,000,000 (to tons) (35g/GJ reduced by 90 % due to adding of limestone) (Mogens Weel Hansen, Dk-Teknik Energi og Miljø, Pers.Com., Gladsaxe the 4-2-02).
21 37,50g*Net energy input GJ per year/1,000,000 (to tons) (75g/GJ reduced by at least 50 % due to low temperature combustion) (Mogens Weel Hansen, Dk-Teknik Energi og Miljø, Pers.Com., Gladsaxe the 4-2-02).
22 Set to a fixed 7,00 % p.a.
23 Yield (interest rate;nper;-nv;fv;type).
24 Capital costs+M&O.
25 Variable prices per MWh.
26 Cost of biomass waste*Energy input MWh/year/1,000,000.
27 Reflects price of 1 MWh produced by uses of oil.
(Baht 1,321.20/MWh=DKK 264.24/MWh)
: 264.24*Heat output/1,000,000 (to mill. DKK).
28 In operating oil boilers average expenses are 80 % fuel and 20 % hardware (boiler).
Of the 80 % fuel expenses another 20 % is normally M&0.
Substituted cost of heat/80*100*20 %.
29 MAKS(Heat output-Primarily steam uses;0)*Sales heat/1,000,000.
30 Reflects price of 1 MWh electricity pursued from the grid (Baht 3,000/MWh = DKK 600/MWh) :600*Electricity output/1,000,000 (to mill. DKK).
31 MIN(Electricity output-Electricity uses;0)*Sales electricity/1,000,000).
32 Capital costs (including M&O)+sub.cost of heat+sub.cost of electricity+ (cost of biomass waste*energy input MWh per year)/1,000,000.
33 Total costs of energy production/Electricity output*1,000,000.
34 100*(electricity output/8,336)-1.
35 100*(heat output/18,041)-1.

Source for data input: Teknologidata for vedvarende energiteknologier, Energistyrelsen 1996, plus other sources as referred to.

Calculations

Steam data: 420 to 450 ºC and 65 bar.

Conversion technology: Combustion in 'Steam Turbine Plant'

Energy data:			
Applied waste	**18,400.00** MWh/year		
	66,240.00 GJ/year		**1**
	2.63 MJ/s in		**2**
Availability factor	87.5%		
Total efficiency	90.0%		
Net energy input	16,100.00 MWh/year		**3**
	57.960,00 GJ/year		**4**
Internal process electricity	0.40%		
	64.40 MWh/year		**5**
Brut Electricity efficiency:			
Minimum	20.00%		
Maximum	40.00%		
Self-providing, heat & electricity	29.53%		
Applied	**18.00%**		
Electricity output	2,833.60 MWh/year		**6**
Heat output	11,592.00 MWh/year		**7**
Operation hours	7,000.00 Hours/year		
Total size of plant:	2.63 MW		**8**
	0.40 MW el.		**9**
	1.66 MJ/s th.		**10**
Economy:			
Plant expenses	5.50 Mill. DKK/MJ/s		**11**
	14.46 Mill. DKK		**12**
Cost of piping	10% of plant exp.		**13**
	1.45 Mill. DKK		**14**
'Wheeling' fee	0.09 Mill. DKK/y		**15**
Maintenance & operation	4.5% /y of plant exp.		**16**
	0.65 Mill. DKK/y		**17**
Total plant expenses	15.90 Mill DKK		**18**
Lifetime	20.00 Years		
Emissions:			
Ash	43.47 Tons TS/year		**19**
SO_2	2.03 Tons/year		**20**
NO_x	4.35 Tons/year		**21**
Feasibility:			
Yearly interest rate	7%		**22**
Capital costs	1.50 Mill. DKK/y		**23**
(including M&O + 'wheeling' fee)	2.24 Mill. DKK/y		**24**
	0.00 DKK/MWh in	178,5	**25**

Cost of biomass waste (fuel)					
	0.00 Mill. DKK/y		**26**		
Substituted cost, heat	330.00 DKK/MWh out	<u>264</u>		<u>330</u>	<u>198</u>
	3.83 Mill. DKK/y		**27**		
Substituted cost, Boiler-M&O	0.96 Mill. DKK/y		**28**		
Sales, heat	**0.00** DKK/MWh out				
	0.00 Mill. DKK/y		**29**		
Substituted cost, electricity	600.00 DKK/MWh out	<u>600</u>		<u>750</u>	<u>450</u>
	1.70 Mill. DKK/y		**30**		
Sales, electricity	**0.00** DKK/MWh out				
	0.00 Mill. DKK/y		**31**		
Total contribution of energy production	4.24 Mill. DKK/y		**32**		
Marginal contribution of 1 kWh elec.	1.50 DKK/kWh/y		**33**		

<u>Coverage of energy demand:</u>

Electricity uses	8,336.00 MWh/year		
Coverage (% of demand)	**33.99%**		**34**
Primarily Steam uses/substituted heat	17,200.00 MWh/year (11.000)		
Coverage (% of demand)	**105.00%**	**35***	

*At 11,000 MWh primarily steam supply 105 % of the total heat demand are covered, as the remaining part are being covered by district heating.
In the cell 17,200 MWh/y are noted, as this express the amount of heat substituted. For B.B. Snacks 30 % of the heat uses are not included, as it is covered by LPG, which means that the substituted heat ends at 17,200 MWh/year.

Pre-conditions

Industrial wastes (case industries)	
Energy potentials of waste for incineration:	
Solid waste	
Wood	4,427 MWh/year
Fermentation and production sludge	1,431 MWh/year
Sub-total	5,858 MWh/year
Liquid waste	
Bio-fuel	6,117 MWh/year
Total energy potential	***11,974.3**** MWh/year
Internal Supporting Systems	
Energy potentials of waste for incineration:	
Dried liquid waste	
Sludge from WWTP	8,012 MWh/year
Total energy potential	8,012 MWh/year
Internal Supporting Resources	
Energy potentials of waste for incineration:	
Solid waste	
Collected industrial/commercial waste	6,261 MWh/year
Generated industrial/commercial waste	***7,155**** MWh/year
Total energy potential	7,155 MWh/year
Internal/external Supporting Resources	
Energy potentials of waste for incineration:	
Solid waste	
Collected internal household waste	2,625 MWh/year
Collected internal/external household waste	6,563 MWh/year
Generated internal/external household waste	13,125 MWh/year
Total energy potential	13,125 MWh/year
Sum of total energy potential	**40,266 MWh/year**

*** Applied waste**

Data inputs:

1 Energy input MWh per year*3,600/1,000 (to GJ).
2 Energy input MWh per year*3,600/Operation hours/3,600.
3 Energy input MWh per year*(Availability factor/100).
4 Net energy input MWh per year*3,600/1,000 (to GJ).
5 4kWh*Net energy input GJ per year/1,000 (to MWh).
6 Net energy input MWh per year*(Electricity efficiency/100)-Internal process electricity.
7 Net energy input MWh per year*(Total efficiency-electricity efficiency)/100).
8 Energy input MWh per year/Operation hours.

9 Electricity output/Operation hours per year.
10 Heat output/Operation hours per year.
11 5.50 mill. DKK*MJ/s in.
12 Plant expenses*MJ/s in.
13 Plant expences*10 % (Henrik Houmann Jakobsen, Dk-Teknik Energi og Miljø, Interview, Gladsaxe the 10-4-02).
14 Plant expenses*Cost of piping.
15 Between 0.12 to 0.20 Baht/kWh transmitted = an average of 32 DKK/MWh (Mr. Pinij Siripuekpong, EGAT, Letter dated the 4-1-02).
16 Plant expenses/100*4.50 DKK.
17 Plant expenses*M&O.
18 Plant expenses+Cost of piping.
19 0.75kgTS*Net energy input GJ per year/1,000 (to tons).
20 35g*Net energy input GJ per year/1,000,000 (to tons) (50 % of the sulphur contained in the ash).
21 75g*Net energy input GJ per year/1,000,000 (to tons).
22 Set to a fixed 7.00 % p.a.
23 Yield (interest rate;nper;-nv;fv;type).
24 Capital costs+M&O.
25 Variable prices per MWh.
26 Cost of biomass waste*Energy input MWh/year/1,000,000.
27 Reflects price of 1 MWh produced by uses of oil.
(Baht 1,321.20/MWh=DKK 264.24/MWh)
:264.24*Heat output/1,000,000 (to mill. DKK).
28 In operating oil boilers average expenses are 80 % fuel and 20 % hardware (boiler).
Of the 80 % fuel expenses another 20 % is normally M&0.
:Substituted cost of heat/80*100*20 %.
29 MAKS(Heat output-Primarily steam uses;0)*Sales heat/1,000,000.
30 Reflects price of 1 MWh electricity pursued from the grid (Baht 3,000/MWh = DKK 600/MWh)
:600*Electricity output/1,000,000 (to mill. DKK).
31 MIN(Electricity output-Electricity uses;0)*Sales electricity/1,000,000).
32 Capital costs (including M&O)+sub.cost of heat+sub.cost of electricity+
(cost of biomass waste*energy input MWh per year)/1,000,000.
33 Total costs of energy production/Electricity output*1,000,000.
34 100*(electricity output/8,336)-1.
35 100*(heat output/18,041)-1.

Source for data input: Teknologidata for vedvarende energiteknologier, Energistyrelsen 1996, plus other sources as referred to.

Annex D (part 2)

Private Limited Company:	**18,400 MWh/year**	**16,560 MWh/year (-10%)**	**14,720 MWh/year (-20%)**
Overview of costs:			
Total Plant expenses	20.24 Mill. DKK	20.24 Mill. DKK	20.24 Mill. DKK
Internal financing (max. 20% of total costs)	4.05 Mill. DKK	4.05 Mill. DKK	4.05 Mill. DKK
External financing (bank loan etc.)	16.19 Mill. DKK	16.19 Mill. DKK	16.19 Mill. DKK
Budget:			
Capital cost	1.53 Mill. DKK/year	1.53 Mill. DKK/year	1.53 Mill. DKK/year
(including M&O+ ‘wheeling’ fee)	2.45 Mill. DKK/year	2.45 Mill. DKK/year	2.45 Mill. DKK/year
Substituted costs	5.53 Mill. DKK/year	4.98 Mill. DKK/year	4.42 Mill. DKK/year
Total contribution	***3.08 Mill. DKK/year***	***2.53 Mill. DKK/year***	***1.98 Mill. DKK/year***

Limited Partnership:			
Overview of costs:			
Total Plant expenses	20.24 Mill. DKK	20.24 Mill. DKK	20.24 Mill. DKK
Internal financing (10% of total cost)	2.02 Mill. DKK	2.02 Mill. DKK	2.02 Mill. DKK
External financing (bank loan etc.)	18.22 Mill. DKK	18.22 Mill. DKK	18.22 Mill. DKK
Budget:			
Capital cost	1.72 Mill. DKK/year	1.72 Mill. DKK/year	1.72 Mill. DKK/year
(including M&O+ ‘wheeling’ fee)	2.64 Mill. DKK/year	2.64 Mill. DKK/year	2.64 Mill. DKK/year
Substituted costs	5.53 Mill. DKK/year	4.98 Mill. DKK/year	4.42 Mill. DKK/year
Total contribution	***2.89 Mill. DKK/year***	***2.34 Mill. DKK/year***	***1.78 Mill. DKK/year***

Co-operative Society:			
Overview of costs:			
Total Plant expenses	20.24 Mill. DKK	20.24 Mill. DKK	20.24 Mill. DKK
Internal financing (100,000 DKK each)	0.70 Mill. DKK	0.70 Mill. DKK	0.70 Mill. DKK
External financing	19.54 Mill. DKK	19.54 Mill. DKK	19.54 Mill. DKK
Budget:			
Capital cost	1.84 Mill. DKK/year	1.84 Mill. DKK/year	1.84 Mill. DKK/year
(including M&O+ ‘wheeling’ fee)	2.76 Mill. DKK/year	2.76 Mill. DKK/year	2.76 Mill. DKK/year
Substituted costs	5.53 Mill. DKK/year	4.98 Mill. DKK/year	4.42 Mill. DKK/year
Total contribution	***2.77 Mill. DKK/year***	***2.21 Mill. DKK/year***	***1.66 Mill. DKK/year***