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Published in:
Journal of Transdisciplinary Environmental Studies

Publication date:
2012

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Czeskleba-Dupont, R. (2012). A secular carbon debt from atmospheric high temperature combustion of stem wood? *Journal of Transdisciplinary Environmental Studies*, 11(2), 37-47. <http://www.pfpi.net>

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A Secular Carbon Debt from Atmospheric high Temperature Combustion of Stem Wood ?

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Abstract: Basically, the combustion of woody biomass in high temperature processes results in a long lasting addition of carbon dioxide to the atmosphere. When harvesting large extra amounts of stem tree for energetic use, a global as well as secular time frame is needed to assess overall consequences if due attention is to be given to biosphere processes, including the complex productivity of whole ecosystems. Analytically, a time dependent variable of carbon neutralization can be traced by a simple carbon neutrality or CN factor. Using the (forgotten) Marland approach, project managers should document how a pay-back of the whole carbon debt incurred by their projects proceeds over time. As recommended by the European Parliament in May 2011, this methodology should be applied consistently in climate and energy policies when revising the failures of the 'instant carbon neutrality' approach for smokestack emissions that was propagated within the Kyoto process, the first phase of which is ending in 2012. Otherwise, we allow that the substitution of wood pellets for coal or other fossil fuels creates long lasting extra emissions of carbon dioxide. This is a climate policy mistake which carbon trading systems such as that of the EU ETS do not compensate for, but instead amplify by giving extra credits for further pollution. This contradicts the very purpose of the UNFCCC, namely to prevent environmental degradation.

Keywords: *Critical realism, global warming, wood fuels, carbon accounting, lag time, life cycle analysis, carbon credits, Kyoto process, carbon neutrality factor, project evaluation, resistance*

1. Introduction

Physicist Bent Sørensen has pointed to the critical climate implications of the combustion of woody biomass: “The lag time for trees (regrowth compared with combustion, red.) may be decades or centuries, and in such cases the temporary carbon dioxide imbalance may contribute to climatic alterations” (Sørensen 2000, p. 477). In recent years, this potentiality has been called upon in reflections upon geologic and biogenic sources of atmospheric CO₂: “It is indisputable that emissions from fossil fuels contribute to the atmospheric pool by releasing carbon from the geologic

pool and are therefore new emissions to the atmosphere. However, the same is functionally true, in terms of climate implications, for any biological carbon emission with a low likelihood or a delayed return (>50 years) to the biogenic or oceanic pools. If alternatives to fossil fuels include use of forests where C is emitted and resides in the atmosphere for long periods of time (e.g. decades or longer), a reduction of atmospheric concentrations of CO₂ (e.g. to 350 ppm) will be difficult to achieve and may contribute to some degree of irreversible climate change.” (Gunn et al. 2012, p. 240). Obviously, this climate problem is not a question of resource scarcity

regarding the number of trees available for burning, but of a secular carbon dioxide waste accumulation in the atmosphere.

When NASA's James Hansen recommended reducing coal firing in the energy sector in order to return to a goal of 350 ppm CO₂ in the atmosphere, he never meant that we should substitute it with the combustion of woody biomass, but recommended inter alia an increased sequestration of carbon from forests by the pyrolytic production of charcoal (Hansen et al. 2008, p. 217). Contrary to low or medium temperature oxygenation of biomass in other technical (pyrolysis) or biological processes (fermentation, anaerobic digestion) atmospheric high temperature combustion of stem wood consumes considerable amounts of combustion air. On a massive scale, it can, therefore, contribute to abrupt changes in the composition of the atmosphere. In the light of a beginning public awareness of the resulting threats to both climate policy and forest carbon pools (EP 2011, EEA 2011), this article focuses on, why and how such global warming effects have to be identified and accounted for.

2. Methodology

Critical realism gives insight into the ontology of real issues by connecting real, actual and empirical domains. This allows us to orchestrate trans-disciplinary analysis from findings of basic science via their socio-ecological implications to policy issues. Epistemologically, uncertainties in knowledge bases are seen as unavoidable: "*Critical realism continuously reminds us of the enormity of the unknown and unproven: the world does not correspond to our knowledge of it*" (Cornell and Parker 2010, p. 30f). Policies of trial and error are therefore rejected in ecological questions: "*These concepts support the case for the precautionary principle in relation to the risks of human intervention in ecological systems*" (ibid).

Human intervention in forest ecosystems is clearly a point in case with respect to the application of the precautionary principle as defined in the Rio Declaration on Environment and Development of 1992: "*Where there are threats of serious or irreversible damages, lack of full scientific certainty shall not be used as a reason for post-posing cost-effective measures to prevent environmental degradation*" (UNCED 1992a, principle 15; see also EEA 2001).

This contribution starts within the real domain by highlighting selected basic science facts regarding biomass as a substitute for fossil fuels and the consequences for global warming of its indiscriminate use. Moving to the actual, fact finding domain, inconsistencies between the original UNFCCC (UN Framework Convention on Climate Change) intentions and practices evolving throughout negotiations regarding the Kyoto Protocol and European Union climate policies are stressed. Loopholes in carbon accounting are discussed. Undifferentiated language on biomass fuel from forest resources is confronted with evolving knowledge about how to evaluate effects of both fossil fuel substitution and biosphere losses of carbon resulting from interventions in forest ecosystems. Within the empirical domain the emergence of contests and conflicts over practical policies is presented in selected cases from the Northern hemisphere that call for more sustainable practices.

Through this chain of reasoning, it should become clear what Gregg Marland meant when he stated that "*biomass energy is only 'carbon neutral' if we get the system boundaries right*" (Marland 2010, p. 866). The motivating question for his research approach was: "*What happens when a forest is harvested for fuel but takes 60 years to regrow or when biomass is harvested in a country that is not party to an international accord but is burned in a country that is?*" (ibid).

2.1 Research Question

In reality, the still operative Kyoto Protocol has generated Marland's, and our, problem: (a) Although the UNFCCC intended a global coverage of regulations, one of the main parties to this convention and of the authors as well as subscribers of the Kyoto Protocol, the United States of America, refrained in 2001 from ratifying the protocol. This poses a serious problem of the spatial system boundaries with one economically important party of the Convention (The U.S.A.) acting from an 'outpost' position, see the selected cases below. That the position of the U.S.A. as well as the withdrawal of Canada from the Kyoto Protocol in 2011 are blatantly undermining the principle of the Climate Convention of 'common but differentiated responsibilities and respective capabilities' is evident and will not be dealt with here at length; (b) most governments and state administrations as well as business companies adhere to the a-temporal dogma of instant CO₂-neutrality

as applied to all biomass combustion, although it overlooks the divergence in time between actual CO₂ emissions from smokestacks and tailpipes and the decade-long compensating reproduction of forest resources. This poses a problem of the temporal system boundaries, originally created by a last-minute decision in Kyoto 1997 to include climatically ambivalent land use changes as compensating mechanism (Flannery 2006, ch. 24). In this way the Kyoto regulatory framework has become both fragmented and temporally uncertain.

Together, spatial fragmentation and temporal uncertainty mean that the high temperature 'instant' combustion in Europe of woody biomass from all over the world does not contribute to the solution, but is part of the global warming problem. Can this entangled knot of problems be made accessible for remedial action or is it inevitably leading to a secular carbon debt?

3. Real Domain

3.1 Waste Accumulation

Although global and long-lasting in their nature, CO₂ accumulating effects result from a myriad of historically developed local activity-related uses of carbon-based energetic potentials which originally stem from solar energy inputs to the Earth (Sørensen 2000, p. 2012). Through photosynthesis and with nutrients taken up from the Earth, green biomass produces *carbohydrates* with energy-rich bonds between carbon and hydrogen as well as oxygen and vital trace components, e.g. nitrogen, phosphorous and sulfur (NOAH 1972). Through oxygenation – be it at low temperature as in digestion of food items, at medium temperature levels as in pyrolysis or at high temperature as in open fire - CO₂ is again set free together with H₂O. This applies also to the combustion of fossil fuels which, however, in geological time have been refined to *hydrocarbons*. The original fossil biomass has been decomposed into the more pure components of carbon and hydrogen, the bindings between them being decisive for energy release by combustion. Methane gas (CH₄) is the most energy-efficient hydrocarbon of all, because all four valence bonds of its carbon atom are occupied by hydrogen, see table 1 for structural variants. Biogenic methane (biogas) has the same properties only after purification.

Table 1. Heat of combustion per molecular unit of carbon fuels

Fuel	Heat of combustion [GJ/mole]	Carbon-hydrogen relation
Natural gas (methane)	0,8	CH ₄
Gasoline	0,63	---CH ₂ ---
Coal (Anthracite)	0,52	---(CH)---
Biomass: Straw	0,48	---(CH ₂ O)---
Biomass: Firewood	0,48	---(CH ₂ O)---

Source: SIPI 1979, table II-1

Per unit of energy produced methane also emits least waste in the form of CO₂ - followed by gasoline and coal. On the other hand, straw and firewood emit more CO₂ as they are more complex hydrocarbons:

Table 2. CO₂ emission factors of fossil fuels and solid biomass

Fuel	CO ₂ [kg/GJ]
Natural gas (methane)	57,12
Gasoline	74
Coal	96
Biomass: Straw	102
Biomass: Firewood	102

Danish NERI Technical Report 632, Denmark's National Inventory Report 2007 to UNFCCC

It follows that the substitution of biomass for natural gas, oil or coal necessarily produces an overshoot of CO₂ per unit of energy delivered, so that the build-up of a carbon debt is basically inevitable (Czeskleba-Dupont 2009a, ch.1.1 and 4.1). In the case of woody biomass from long-standing forests, this build-up of a carbon debt can be accelerated. This is because the two phases of the otherwise reversible process of carbon assimilation in plant matter and the emission of carbon to the atmosphere diverge in both space and time.

In historical time, the foundations of this debt have been laid both before and after Euro-centric industrialization. Compared to deforestation by pre-industrial, agrarian land clearing, the urban-industrial

fuel use of “*fossil forests*” or “*subsurface woodlands*” (Matoon 1998, Sieferle 2010) has accelerated the release of CO₂ to the atmosphere by a factor greater than ten (Erb et al. 2008, p. 698). A pronounced biomass combustion strategy that enacts a massive conversion of combustion facilities from fossil fuels to woody biomass threatens, however, to become counter-productive in relation to the CO₂ reduction goals of climate policy. To deliver 20% of current global energy supply from woody biomass would be totally counterproductive, as it “*is likely to miss its main objective, i.e. to reduce greenhouse gas (GHG) emissions, because it would result in a reduction of biomass pools that may take decades to centuries to be paid back by fossil fuel substitution, if paid back at all*” (Schulze et al. 2012, p. 611). Therefore, more CO₂ would accumulate as atmospheric waste.

3.2 Unabated Trends of Global Warming

Ongoing net emissions of CO₂ – whether fossil or biogenic - cause elevated atmospheric levels of concentration of this greenhouse gas for up to 1000 years (Solomon et al. 2009, p. 1704). Seen within a decade-long or secular time scale, they thus contribute to irreversible accumulations and to cumulative real damages. It is therefore problematic that according to the Scientific Committee of the European Environment Agency “*several European Union energy directives encourage a switch from fossil fuels to renewable energy derived from biomass based upon the premise that biomass combustion, regardless of the source of the biomass, would not result in carbon accumulation in the atmosphere.*” As the Committee points out, “*this mistaken assumption results in a serious accounting error*” (EEA 2011, p. 1).

Already shortly after the adoption in 1997 of the Kyoto Protocol critical voices as those of the German Advisory Council on Global Change warned against this outcome. They evaluated the short time slot of the first commitment period from 2008 to 2012 as a step backwards in relation to the task of the UNFCCC: “*The accounting of terrestrial sources and sinks in the form of changes in carbon stocks over a 5-year commitment period fails to do justice to the differing dynamics over time of carbon stocks and fluxes*” (WGBU 1998, p. 1). They differentiated between the usual criterion of net primary productivity and net ecosystem productivity. Whereas the growth of above-ground biomass in a forest two decades after clear-cutting may be substantial (3 t C ha⁻¹ year⁻¹), the net carbon

flow of the ecosystem may still be negative, releasing 1/3 t C ha⁻¹ year⁻¹. The exclusive use of net primary productivity as a measure of carbon additions for what has also been criticized on biological grounds, because indicative measurements have shown a much higher carbon assimilation in old forests than otherwise predicted (Carey et al. 2001). After all, the Kyoto accounting methods fall short of measuring the real consequences of different climate mitigation strategies by forest management.

When climate mitigation actions as the transition to woody biomass fuels postpone essential reductions in the atmospheric concentration of greenhouse gases, it is relevant to apply a secular time frame. This makes it possible to take account of eventual tipping points leading to abrupt global warming. The IPCC 2007 report contained such early warnings of a feedback loop from warming saying that the net carbon assimilating service of forests globally will tip into net carbon release, when or if the mean surface temperature on Earth increases by more than 2.5°C over its pre-industrial level (Fischlin et al. 2007, fig.4.4, Czeskleba-Dupont 2009b). In boreal as well as tropical biomes, which together cover the overwhelming part of woodlands – and in the boreal case of subsurface carbon - on Earth, this process is already well underway (IUFRO 2009). This more and more probable tipping point undermines the faith into a timely 100% binding of carbon dioxide emitted from burning wood. After all, the prospective growth of forests is not assured by life insurance systems. On the contrary, the secular trend of global warming and its feedback upon the climate regulating ecosystem-service of woodlands make the financial emission of massive carbon credits for the energetic use of forests inherently uncertain. This uncertainty undermines any ‘*rational expectation*’ that assumes a continual net carbon uptake by the growth of forests globally (Sedjo 2011). When it is taken into account, the financial emission of tradable carbon pollution rights to the amount of the substituted fossil fuels is deeply problematic: Within the EU Emissions Trading System (EU-ETS) these sub-prime carbon credits can even be sold further to known polluters, thus more than doubling real emissions up to the year 2050 instead of drastically reducing them (Concito 2011, 2012).

4. Actual Domain

4.1 Accounting Loopholes

The actual climate mitigation strategy of burning forest biomass has been jeopardized by a loophole in carbon accounting that eliminates the facts: a) that massively expanded extraction of wood products from forests causes external carbon costs in the form of net losses to the atmosphere (Searchinger et al. 2009; McKechnie et al. 2011); and b) that CO₂ emissions from a globally expanding combustion of woody biomass therefore cannot be instantly carbon neutral.

Theoretically, it would be “straightforward...to fix the accounting of bioenergy. That means tracing the actual flows of carbon and counting emissions from tailpipes and smokestacks whether from fossil energy or bioenergy” (Searchinger et al. 2009, p. 528). In political-administrative practice, however, this is not so easy.

After the adoption of the UNFCCC at the Rio Conference on Environment and Development in 1992 no consistent scheme of reporting has been developed. UNFCCC receives yearly inventories from nearly all countries separately reporting on emissions from energy use and from land-use change. “This accounting principle does not assume that biomass is carbon neutral, but rather that emissions can be reported in the land-use sector. This accounting system is complete and accurate because emissions are reported from both land and energy sectors worldwide”, as the EEA Scientific Committee has noted (EEA 2011, p. 5). But “these conditions do not apply to any treaties and regulations, such as the Kyoto Protocol, that seek to limit emissions from energy use but do not limit emissions from land-use, or do so only weakly and that do not apply worldwide...The accounting regime adopted for the Kyoto Protocol improperly maintained the exemption of carbon from burning biomass. This error was followed by...the European Union’s Emissions Trading System (EU-ETS) which ignores CO₂ emissions from biomass combustion...(and) the Renewable Energy Directive which implicitly sets CO₂ emissions from biomass combustion to zero” (ibid).

Life cycle analysts do not necessarily avoid the accounting error. In an editorial of the International Journal of Life Cycle Analysis Rabl et al. (2007) explained the missing link: “In a part of the LCA community, a special convention has been established

according to which CO₂ emissions need not be counted if emitted by biomass.” The authors see this as a mistake: “The logic of such a practice would imply absurd conclusions, e.g. that the CO₂ emitted by burning a tropical forest, if not counted, would equalize the climate impact of burning a forest and preserving it, which is obviously wrong. Likewise, the benefit of adding carbon capture and sequestration (CCS) to a biomass fuelled power plant would not be evaluated because that CO₂ is totally omitted from the analysis.” (Rabl et al. 2007, p. 281) The last point has been considered practically by energy companies in Denmark (Czeskleba-Dupont 2011). Also, the UK Advisory Committee on Climate Change has proposed CCS to be made mandatory for biomass burning power plants.

In the literature, Rabl et al.’s (2007) critique was confirmed by LCA analyst Eric Johnson stating that “most published footprint or life-cycle assessment studies take the same approach; they automatically exclude carbon dioxide emitted in the combustion of biomass. [...] In an early 2008 survey of over 100 publications by 56 researchers about solid biomass fuels, 25 researchers were identified who had estimated footprints of wood fuel (in log, pellet or chip form). Of those 25 researchers, only one did not presume wood to be carbon neutral” (Johnson 2009, p. 165).

4.2 Forgotten Methodology

As an analytic alternative developed through more than 15 years, Johnson 2009 referred to the ‘Marland approach’. In 1992, Scott and Gregg Marland based their approach upon the observation that “to date, tree planting is the only active component of the official U.S. strategy for responding to increasing anthropogenic emissions of CO₂” (Marland and Marland 1992, p. 181). They formulated a principle of equivalence between trees as a living and trees as a dead resource saying “that trees are equally effective in preventing the accumulation of CO₂ in the atmosphere if they remove a unit of C from the atmosphere or if they supply a sustainable source of energy that substitutes for a unit of C discharged by burning fossil fuels.” (p. 181) They established, thus, a hypothetical equivalence between a process in the biosphere and a process in the technosphere which, however, is more complex than it may seem.

In 1997, Marland and Schlamadinger pointed to this complexity: “Factors like fuel moisture and plant

size generally result in lower net conversion efficiency” for biomass, which they set at a maximum of 60% (p. 390). Even huge plant sizes can, however, not compensate for lower combustion efficiency: When Europe’s biggest carbon polluter, German-based electricity company RWE, recently converted the Tilbury power plant near London with 1100 MW electrical output from coal firing to wood pellets, plant electric output capacity fell to 750MW, that is by 68%.

The Marland approach identified several critical factors regarding uses of the forest base: “The model shows that the most effective strategy for using forest land to minimize increases in atmospheric CO₂ will depend on

- the current status of the land (e.g. forest density, history of land use etc.),
- the productivity that can be expected,
- the efficiency with which the forest harvest is used to substitute for fossil fuels, and
- the time perspective of the analysis” (Marland and Marland 1992, p. 181).

At an upper limit of forest density, Marland and Marland recommended a protection strategy: “For forests with large standing biomass and low productivity the most effective strategy is to protect the existing forest.” On the other hand: “Where high productivity can be expected, the most effective strategy is to manage the forest for a harvestable crop and to use the harvest with maximum efficiency either for long-lived products or to substitute for fossil fuels” (Ibid.).

Regarding the time dimension, the Marland approach started optimistically: “The longer the time perspective, the more likely that harvesting and re-planting will result in net C benefits” (Marland and Marland 1992, p. 181). However, when present net C benefits are preferred in order to accomplish emission reductions in the near future, later benefits should be discounted into a diminished present value. Applying a 4% discount rate to carbon fluxes to and from the biosphere, a critical threshold of the initial carbon debt to be incurred was identified: “There is no gain at all in terms of net present value of C to harvest forests with an initial C storage greater than about 150 Mg C ha⁻¹ [tons of C per ha]” (Schlamadinger and Marland 1999, p. 323). A value of 160 Mg C ha⁻¹ was said to represent “mature forest with no expected change in C storage over time”

(*ibid.*, p. 318). The discounting perspective makes it clearly preferable not to mobilize this carbon pool.

4.3 Accounting for Carbon Neutralization

Based upon the Marland approach, Schlamadinger and Spitzer (1994) proposed to calculate a carbon neutrality (CN) factor as a “time dependent characteristic value to describe carbon balance of bioenergy systems”. The CN factor includes carbon losses of the biosphere by forming a “ratio of the net emission reduction (fossil carbon substitution minus carbon losses of the biosphere) to the fossil carbon substitution without any biosphere losses. CN = 1 if bioenergy is completely ‘CO₂-neutral’” (Schlamadinger and Spitzer 1994, p. 317).

After the death of Bernhard Schlamadinger in 2008, other researchers of Joanneum Research used the CN-factor methodology to formulate a model of CO₂ emission neutralization over time. It accounted for the upfront carbon debt incurred by forest clearing (Zanchi et al. 2010). In June 2010 their paper was presented to the Committee on the Environment, Public Health and Food Safety of the European Parliament. Zanchi et al. recommended to make the use of CN factors mandatory: “[the] use of a CN factor in directives on renewable bioenergy could align bioenergy with its greenhouse gas consequences with respect to unified targets. CN factors could also be used to calculate biomass emissions within EU-ETS, thus removing the undesirable effects of lack of coordination between the two systems” (Zanchi et al. 2010, p. 48). Applied to forest based bioenergy, a ‘break-even point’ between C uptake and C releases was estimated as lying in the range of centuries.

In response, the Parliament’s Committee incorporated this view in its report on the Commission’s Green Paper on forest protection and information in the EU (‘Preparing forests for climate change’), adopted by Parliament on May 9, 2011. The European politicians were “concerned that the short time-frames used in the current greenhouse gas (GHG) calculation methodology, and the resulting carbon neutrality assumption for woody biomass, could hinder the achievement of the EU 2020 renewable energy target and the 2-degree Celsius climate change target.” Therefore, they called upon “the EU Commission to consult the IPCC and to establish a new GHG calculation methodology, controlling for longer time horizons and for biomass emissions from land use,

land use change and forest management" (European Parliament 2011, § 71).

Seen from the viewpoint of critical realism, the inclusion of a secular time perspective and of external effects from land use change into criteria of sustainability is essential in order to integrate partial assessments of 'stylized facts' into a more full-fledged evaluation of real trends: By adding to global warming in the short and medium term, the rapidly expanding practice of substituting woody biomass for fossil fuels contributes to the erosion of its own forest base. The only acceptable response to this is the precautionary principle, i.e. not to await the emergence of the disastrous fact itself, but to oppose the causal mechanisms leading up to it. As argued above, they result from the twin problem of spatial fragmentation of the regulatory system and the denial of its temporal uncertainties. Climate and energy policies have to become more consistent, before they can help to realize the originally intended world-wide mitigation of climate change.

5. Empirical Domain

5.1 Regulators under Cross-Pressure

In an Open Letter to the U. S. House of Representatives, 90 leading scientists tried to avert the counterproductive results of the promotion of biomass energy by stating: "*Although fossil fuel emissions are reduced or eliminated, the combustion of biomass replaces fossil emissions with its own emissions (which may even be higher per unit of energy because of the lower energy to carbon ratio of biomass)*" (Schlesinger et al. 2010, p. 13). Please note the understatement in brackets. - Shortly after the Schlesinger initiative over 100 U.S. forest scientists offered counter-arguments in a Letter to several House committees (Lippcke et al. 2010). They built on the assumption that biogenic and geologic CO₂ have different effects on atmospheric concentrations and laid most weight upon long-term effects.

In a critical examination of these propositions Gunn et al. (2012) evaluated the premise of the latter letter that carbon emissions from regional forests need not be related to global carbon cycles. When wood burning for heating purposes in temperate climate boosts regional CO₂ emissions, they occur in seasons with minimum photosynthesis and add to hemispheric peaks of CO₂. This is shown in the

well-known Mauna-Loa/Hawaii observations of CO₂ concentrations in the Northern hemisphere (NOAH 1972). Since measurements began in the context of the 1958 International Geophysical Year, these seasonal oscillations have been registered as seasonal variations around a rising trend of atmospheric CO₂ – which after all is at the core of the global warming problem.

Comprehensive strategies of de-carbonization of the technosphere are, therefore, needed in order to reduce additions to the atmospheric carbon pool from both geologic and from biogenic sources. Switching from fossil to non-fossil fuels derived from living forests would only contribute to this transition, if it. counter-factually, could be demonstrated that resource extraction on the forest floor as well as atmospheric combustion of woody biomass do not lead to decade-long or even secular net losses of carbon to the atmosphere.

5.2 Conflicts and Controversies, Selected Cases

As the following review indicates, climate and energy policies are not characterized by either consistency or effectiveness as long as dogmatic premises of carbon accounting abstract from the spatial-temporal dimensions of global warming.

(a) *Denmark: Carbon Neutrality in Question*

In the run-up to COP15, the Danish state owned electricity company DONG built upon its experience with co-firing of straw, mandated by parliament in 1994, when Denmark had its own CO₂-tax. In 2009, DONG published its plans to install the combustion of 100% wood pellets in its power generators (Berg-Hansen 2009). Although there were no binding sustainability criteria for solid biomass in the pipeline, green organizations such as Nordic Greenpeace applauded this. However, in autumn of 2011 this optimism was questioned by Greenpeace's Canadian sister organization reporting misuse of forests in its own sourcing area (Greenpeace Canada 2011). Although wood pellets had to be imported from North America and Baltic countries, energy companies and municipal leaders laid pressure upon the Danish government to support the change-over from coal to forest biomass. When a Danish energy plan was announced in 2010, the then Minister of Climate and Energy, Lykke Friis, announced that most big power stations should change over to woody biomass to in order to achieve a CO₂-

reduction of 2-3 million tons per year – the gross amount of emissions from the fossil fuels replaced. It was clear that neither smokestack emissions nor biosphere losses of CO₂ to the atmosphere would be reported domestically. Since the implementation of the EU Emission Trading Directive in Denmark in 2005, wood combustion was dogmatically “considered to have an effective emission factor of zero” (Illerup 2009).

The center-left government which came into power in 2011 was on November 25 confronted with a basically critical analysis of these projects by the environmental think-tank Concito (Concito 2011). The very same day, the minister for climate, energy and buildings, Martin Lidegaard, proposed a new energy plan incorporating a massive conversion of power plants to wood pellet fuels. Based upon these proposals, a broad political energy consensus was formed in spring 2012. As part of this political compromise, 1 million euro were reserved for “an analysis of the application of bioenergy in Denmark. The analysis shall focus upon, whether appropriate conditions are given in Danish energy supply for an effective and environmentally sustainable application of biomass resources” (DMCEB 2012, p. 3, our translation). It was added that “The analysis shall furthermore shed light upon CO₂ displacement” (ibid.). Concito (2012) remarked that it is the opposite of an optimal sequence first to enact changes and then to ask whether they are sustainable.

(b) United States: Contested Forest Resources

Regarding the sourcing of wood pellets, around 500 pellet factories have been established in the United States. Already from 2008 to 2011 more than 50 wood combustion projects with an electricity generating capacity of more than 3000 MW were proposed and partly enacted. Building upon local democratic institutions over one-tenth of these projects were finally stalled or withdrawn after campaigns by local citizens and critical scientists (Biomass Accountability Project, July 2011). Even from forests with FSC certificates, destructive effects from large-scale clearing have been reported (www.maforests.org). Concerned scientists conclude that “Much of what you’ve probably heard about biomass energy - that it’s clean, carbon neutral, and friendly to forests - is untrue” (Partnership for Policy Integrity www.pfpi.net).

In a study on carbon accounting loopholes that threaten U.S. forests, the NGO Environmental Working Group summed up: “Burning trees is worse than burning coal...Cutting of US forests will sharply increase, and when this wood is burned in power plants, it will produce a huge surge in carbon emissions that will be kept off the books and, even worse, will be counted as an emissions reduction” (EWG 2010, p. 31). When such sub-prime credits moreover can be sold in Europe, they attract transnational carbon trading interests, see below.

Citizens of the municipality of Springfield/Western Massachusetts insisted upon their democratic right to repeal a preliminary license given in 2008 by town authorities for the construction of a 50 MW electricity plant with wood combustion. Focusing upon local environmental and health effects on the ground that children in this area already showed a significant extra level of asthma incidence, they succeeded in 2011 (Tuthill 2011).

State governmental policies contributed to this change in stance concerning local policies. In June 2010, the government of Massachusetts received a 'Biomass Sustainability and Carbon Policy Study' from the Manomet Center for Conservation Sciences (Walker et al. 2010). It gave the Secretary of Energy and Environmental Affairs “a deeper understanding that the greenhouse gas impacts of biomass energy are far more complicated than the conventional view that electricity from power plants using biomass harvested from New England natural forests is carbon neutral” (Bowles 2010, p. 1). Despite remaining uncertainties, government officials were “confident that we now have enough information [...] to take the next step in changing the way in which the Commonwealth (of Massachusetts, red.) provides incentives for biomass energy” (ibid.). In 2011, Massachusetts revised its rules of eligibility for state support to bioenergy. Their enactment in August 2012 was correctly described as a tightening of rules that pushes the profitability of wood burning power plants further into doubt (Scheck 2012).

c) Transatlantic Differentials exploited: Forest Energy for Profits

Amidst this contested U.S. environment, German electricity giant and Europe’s biggest polluter with CO₂, RWE, invested, via its subsidiary Innogy, in the State of Georgia to build one of the world’s biggest

wood-pellet factories with 750 000 tons of output pr. year. It is located in forested areas but not used for local electricity generation, at least “*as long as the US is not part of the CO₂-emissions trading scheme*”, as RWE explains (Kessler 2010). In order to earn carbon credits, the Danish shipping company D/S Norden transports the manufactured pellets to Europe where they e.g. are burnt in the U.K. Tilbury power plant. RWE defends its Georgia project by pointing to the reduced demand for wood in the American pulp and paper industry and the windfall profits from power production in Europe with its tradable carbon credits (www.renewable-energy-sources.com/2010/01/21/).

5.3 *Consciously Incomplete Accounting?*

In the RWE case as in other cases of wood pellet burning companies within EU member countries, neither the easily measurable CO₂ emissions from the end-of-pipe combustion of wood are accounted for; nor the negative soil carbon stock changes or foregone CO₂ sequestration caused by bottom-up resource extraction in forests (cp. Searchinger et al. 2009). For economic agents as RWE Innogy (operating in Georgia) or RWE npower (operating in U.K.) these deep regulatory faults are non-existent, as long as the political-administrative rules laid down in the European Emissions Trading Scheme allow for the making of windfall profits because of these loopholes. Such a half-blind view of economic agents is, what critical realism conceives of as an experienced, but chaotic empirical view upon apparent reality. This means that it is not the full story, because there are unaccounted, but societally relevant facts that can be identified by a more comprehensive analysis, as indicated above.

In order to contest the apparent legitimacy of RWE's and other companies' actions, a growing social resistance movement backed by scientists from many fields points at alternative strategies, until a new, spatially-temporally consistent systems design is implemented, where the basic proposition of instant carbon neutrality is nullified and global coverage achieved. - Because of an enduring extremely low quota price (down to 6 euro pr. ton CO₂), the informal EU Energy and Climate Ministers Council at Horsens/Denmark decided in March 2012 prematurely to renegotiate the quota scheme. At the same time, a Commission Press Release explained: “*Following the decision of the United Nations Framework*

Convention on Climate Change on revised accounting rules from soils and forests adopted in December 2011, the EU is determined to close the gap in common accounting in its climate policy” (Comm. Press 2012). The gap was said to be due to lacking coverage of the agriculture and forestry sectors (Comm. Press 2012). It would be a reasonable first step to enact the precautionary principle and to eliminate any environmentally sub-prime credits given in power generation for substituting woody biomass for fossil fuels from the system. A system that maintains these counterproductive incentives should otherwise be replaced by direct carbon taxation.

6. Conclusion

The two combined shortcomings of the way, in which the UNFCCC has been implemented by the Kyoto Protocol, spatial fragmentation by the withdrawal of North America; and temporal uncertainties in the relation between technosphere and biosphere processes in the combustion of woody biomass, have strong implications for the remaining chances to reach the politically desired outcome of stabilising the global climate below critical increases of 2 to 2.5 °C over pre-industrial levels. As remedial action it is crucial to re-evaluate the extended use of woody biomass for energy purposes, because Europe with its premium on fossil fuel substitution acts as a chaotic attractor point. Technical issues and biosphere processes indicate that a time-sensitive analytic approach as the calculation of varying C/N factors is mandatory for the evaluation of local projects, where CO₂ neutralisation must be documented as a process over decades and/or centuries. In this way, the loopholes in carbon accounting can be eliminated that were created by the assumption of instant carbon neutrality for all biomass combustion. A more realistic outlook is mandatory in order to prevent a use of forest products that accelerates global warming and on the ground undermines the very stabilisation of vulnerable ecosystems and spaces for human livelihood, which is a policy target.

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