Production and application of char in agriculture - in a system perspective

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Production and application of char in agriculture **in a system perspective**

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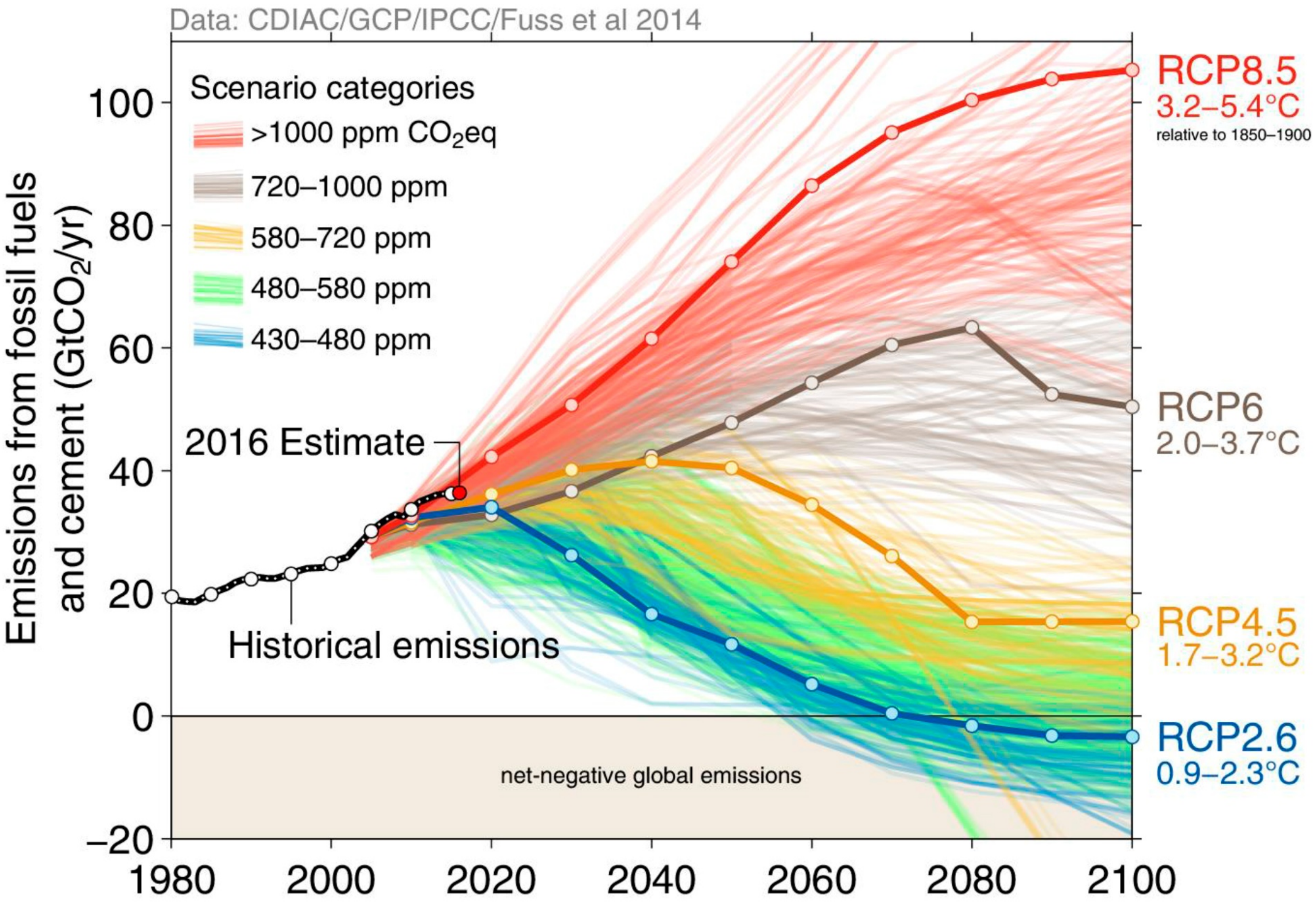
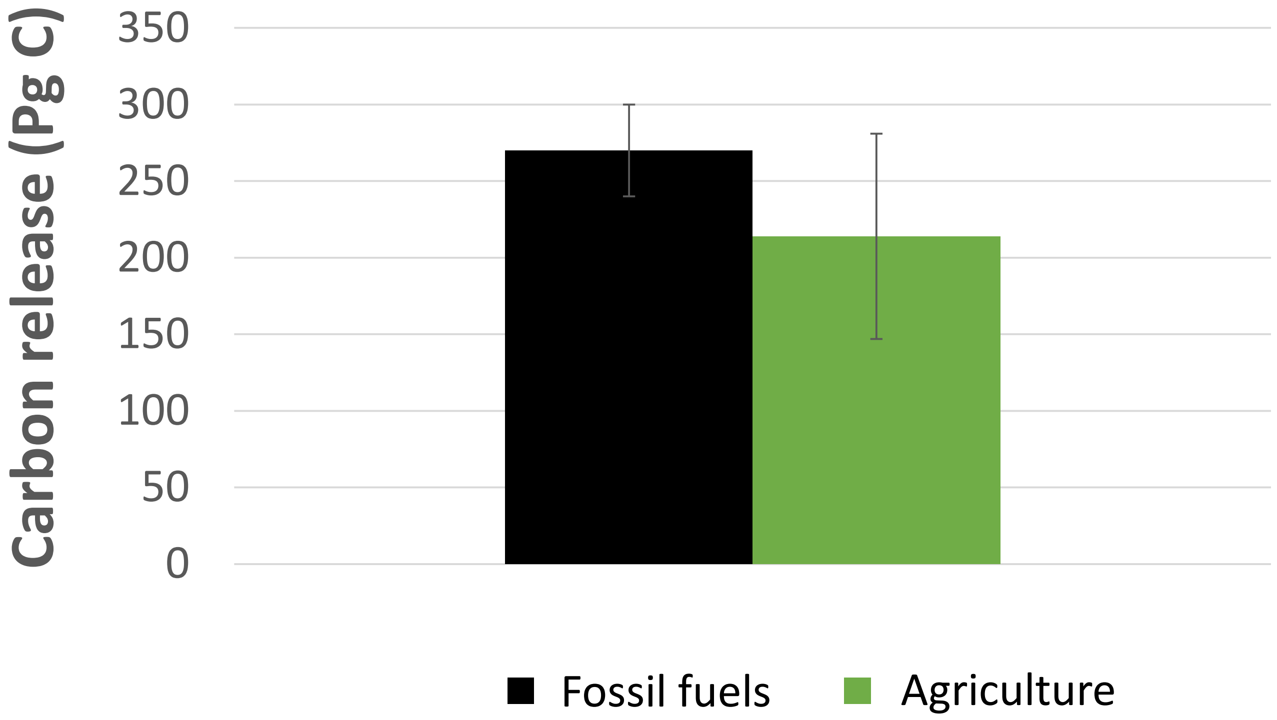


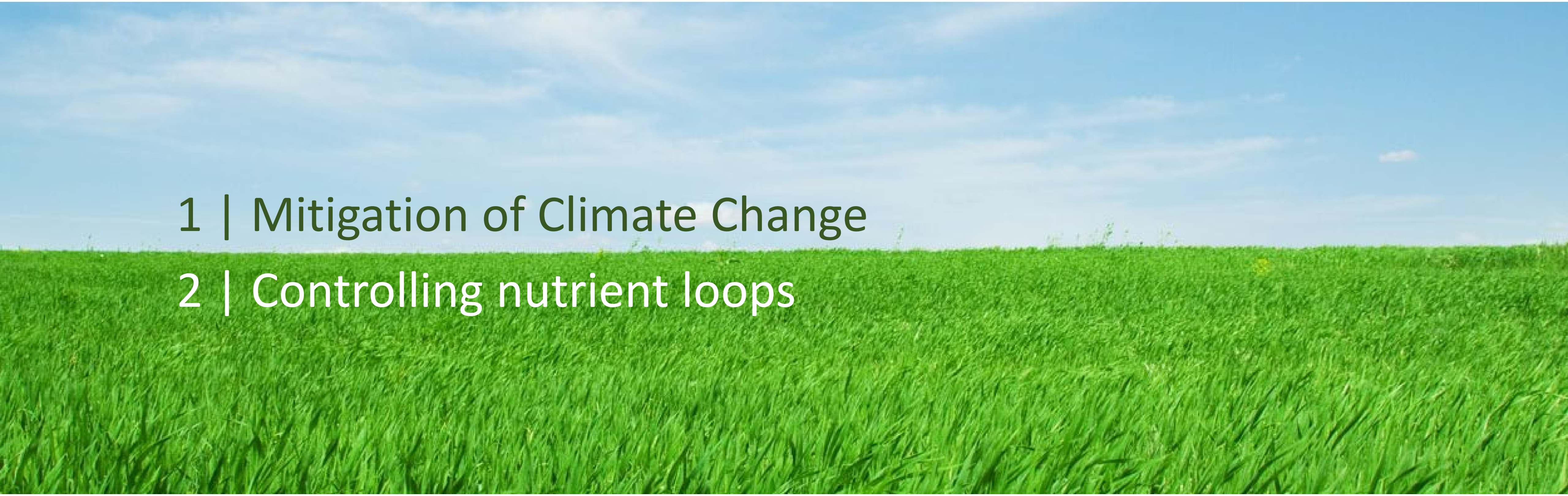
Source: The IPCC Fifth Assessment Report

Accumulated **anthropogenic carbon release**



Source: Zomer et al., 2017, Global Sequestration Potential of Increased Organic Carbon in Cropland Soils

Focus on potential environmental benefits within:



1 | Mitigation of Climate Change

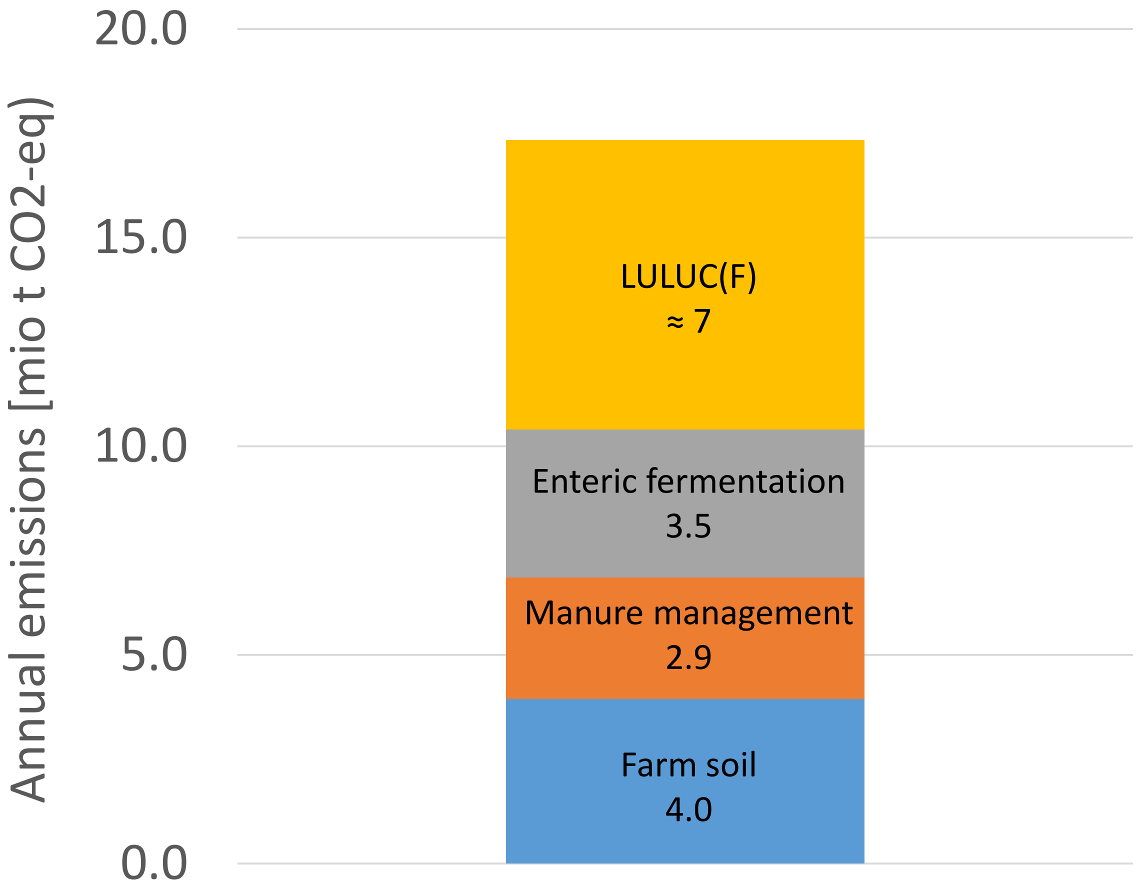
2 | Controlling nutrient loops

Status | **greenhouse gas emissions from Danish agriculture**

- 21% of total greenhouse gas emissions
  - 89% of total N_2O
  - 81% of total CH_4
  - 1% of total CO_2

(≈ 4.7, 5.5 and 0.2 mio t CO2-eq/year)

- + LULUC(F), around 14% of DK emissions



Source: AU ”DENMARK'S NATIONAL INVENTORY REPORT 2018” and AU ” DANISH EMISSION INVENTORIES FOR AGRICULTURE, Inventories 1985 – 2015” and Klimarådet (2018) “Effektive veje til drivhusgasreduktion i landbruget”

Potentials | Abatement of field N_2O emissions

- Char often contains very small amounts of N
- Manure char + mineral N -> lower emissions than raw or composted manure fibers (Zhu et al 2014)
- Soil-N and fertilizer-N N_2O emissions inhibition up to 30% by use of e.g. wood pyrolysis char (e.g. Borchard et al 2018 and Cayuela et al 2014)
- NH_3 emissions avoided -> precurser for N_2O in adjecent systems

Potentials | Stabilization and improved management

Pyrolysis of organic residues and wastes

-> Stabil storage and improved transportation and handling

-> Severely reduce emissions of methane and nitrous oxide (+ NH_3 and odor)

Characterization factors for CH_4		
Normal approach	100 years	28
New normal?	20 years	84

Perspective: Apply char on/under stable floors, on ventilation air or in storage tank to adsorp NH_3, add value to char and reduce emissions

Source: IPCC "Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change", Appendix 8A

Potentials | **Char as dietary supplement?**

- Carbon as pharmaceutical or dietary supplement already commercial in pure form in several countries
- May stabilize digestion and reduce CH_4 release from cows
- May increase meat quality in boar pigs
- Can also stabilize human digestion system

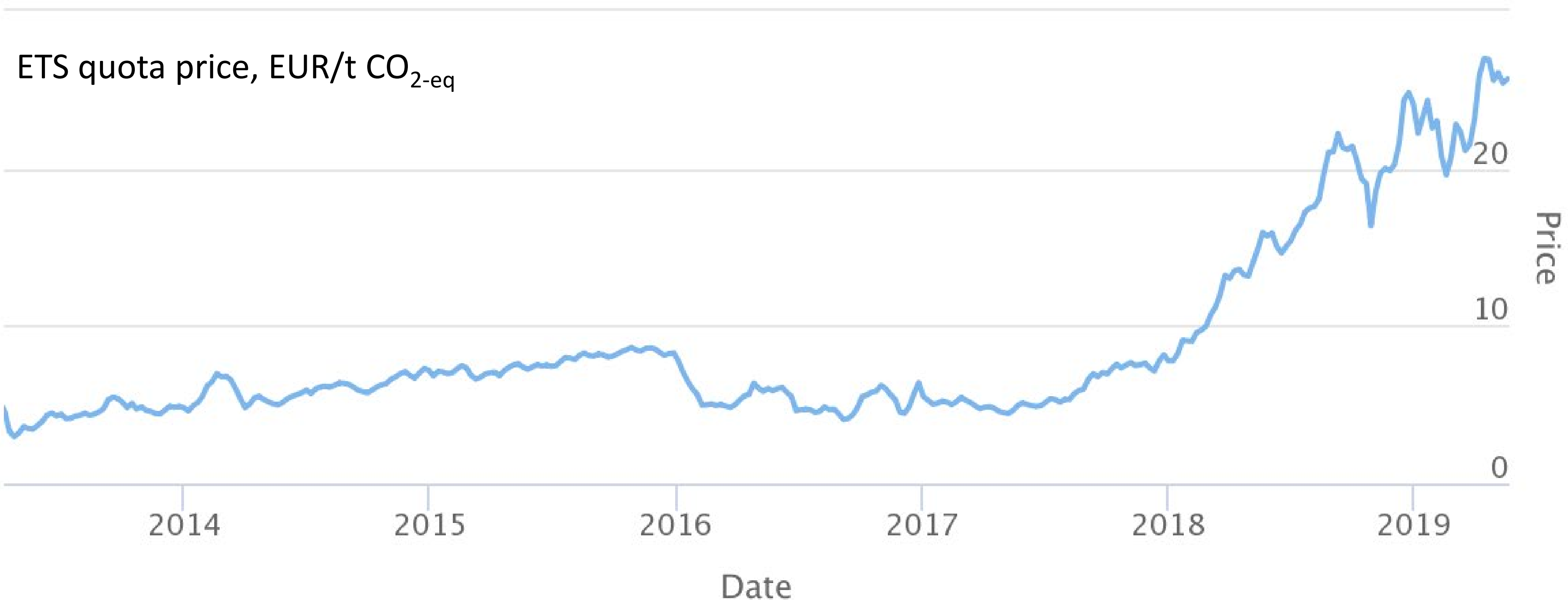
Potentials | **C-sequestration**

- Highly recalcitrant carbon char matrix (Sander B.)

  -> Carbon sequestered, low tech and highly efficient

- Char in soil is more than carbon sequestration
  - Improves water infiltration and water retention
  - Retain nutrients from leaching
  - Increase pH
  - Improves soil structure -> reduce field work energy requirements
  - Increase quality and robustnes of biom by creating shelter
  - More, on the next workshop?
- Carbon credit prices may be a ”new” incentive?

Potentials | **C-sequestration**



Source: https://sandbag.org.uk/carbon-price-viewer/

Potentials | Energy production - a <u>bonus</u> mitigation mechanism

- Hard case - Sludge, manure fibers, digestate and similar: Around 25 PJ heat products < 100 C due to high moisture content and drying requirements
- Easy case - Straw: Around 50 PJ, heat, gas or oil products used e.g. for process heat, peak load in boilers – or as bunker fuel?
- Mixed case: Straw + sludge etc.: 75 PJ with good fuel and char characteristics - and no need for drying
- Total DK pyrolysis bioenergy product potential (excl char) 70-120 PJ.

Substituting 10 PJ bunker fuel reduce GHG emissions with almost 1 mio t CO2-eq!

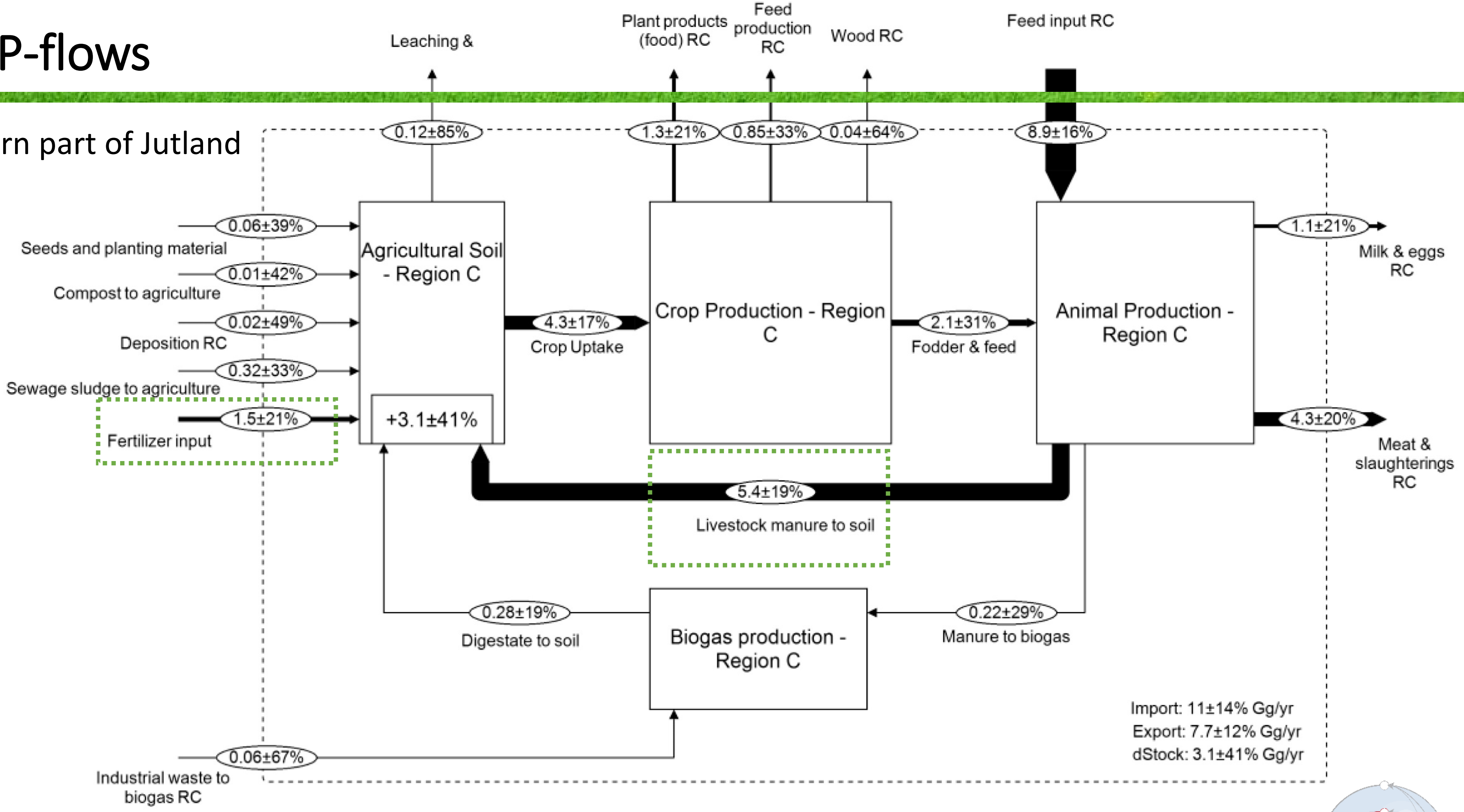
Focus on potential environmental benefits within:

1 | Mitigation of Climate Change

2 | Controlling nutrient loops

Status | **P-flows**

Case: Northern part of Jutland



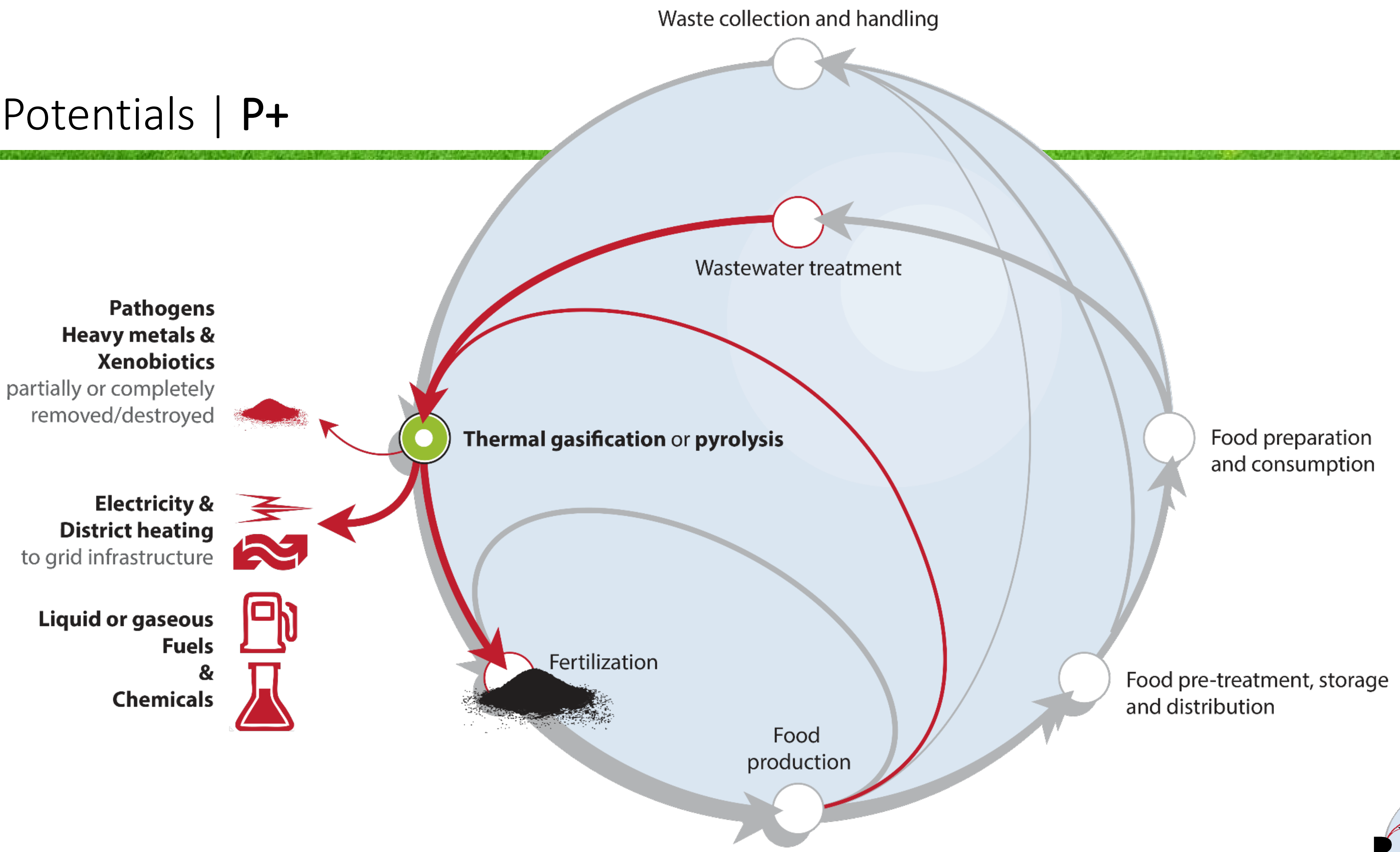
Source: Klinglmair, M. (2016) Anthropogenic phosphorus flows in Denmark: Quantification and critical analysis

Status | Current management strategies

Controlling nutrient loops by management of organic residues and wastes:

- Direct field application
- Composting
- Anaerobic digestion
- Separation
- Incineration

Potentials | **P+**



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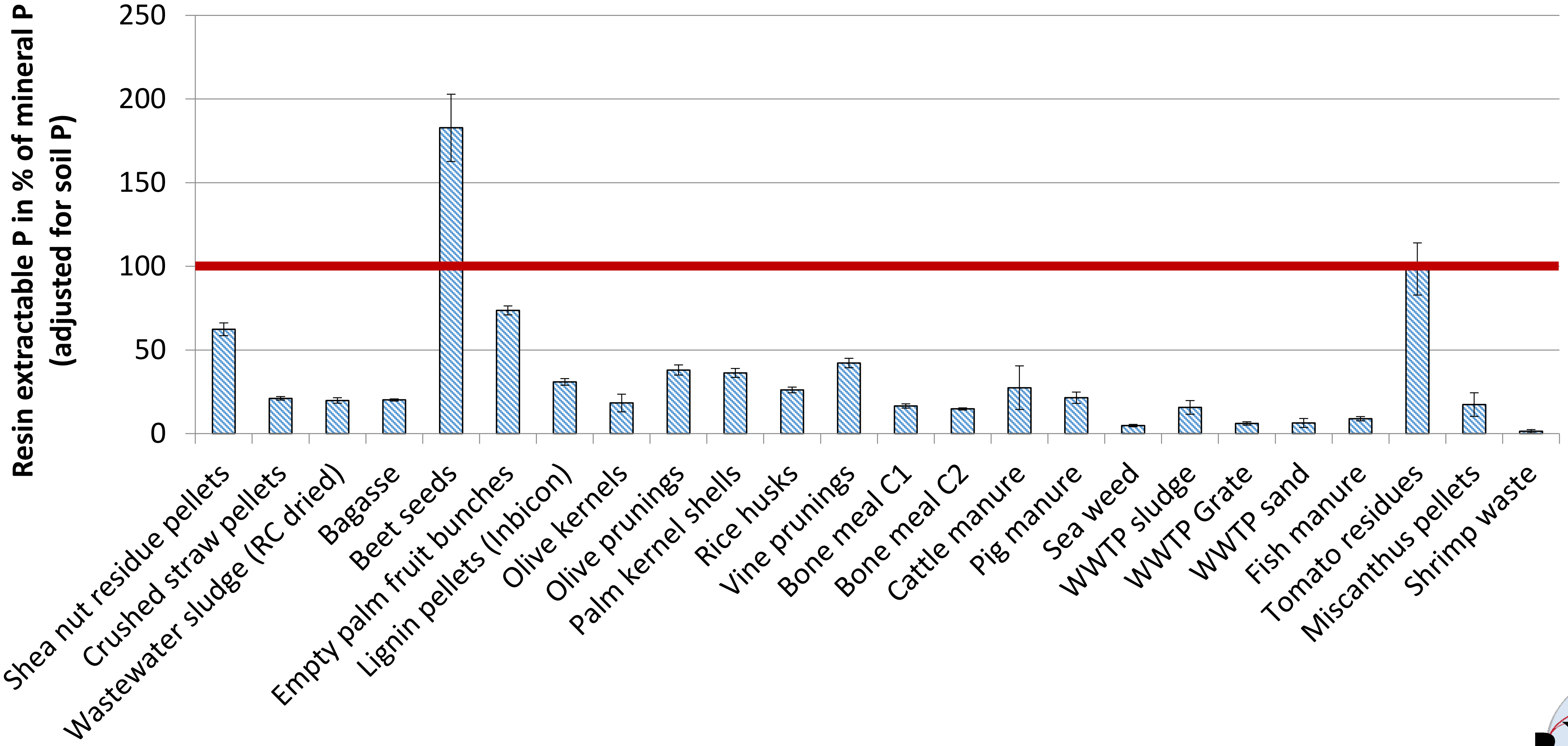

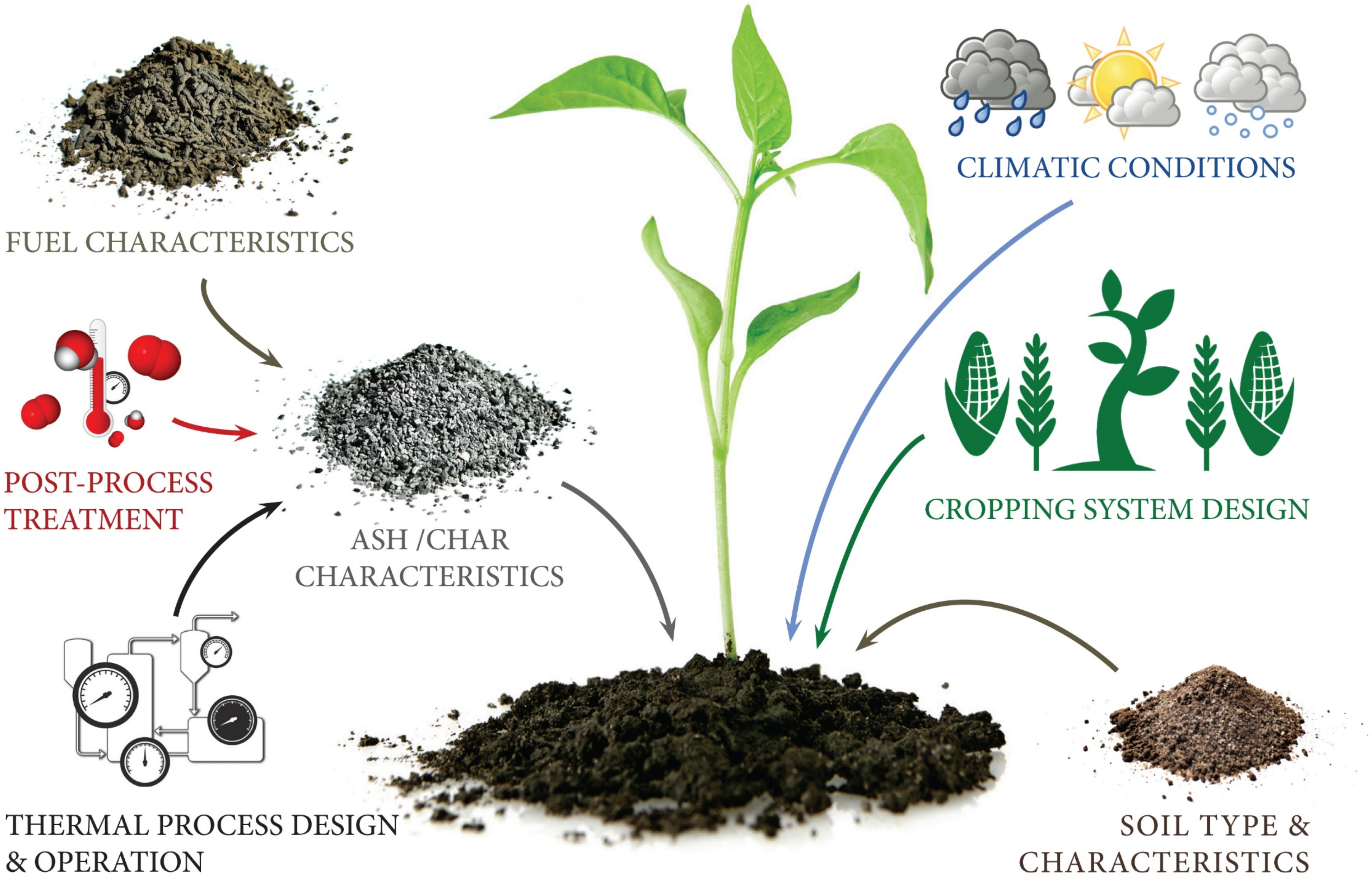

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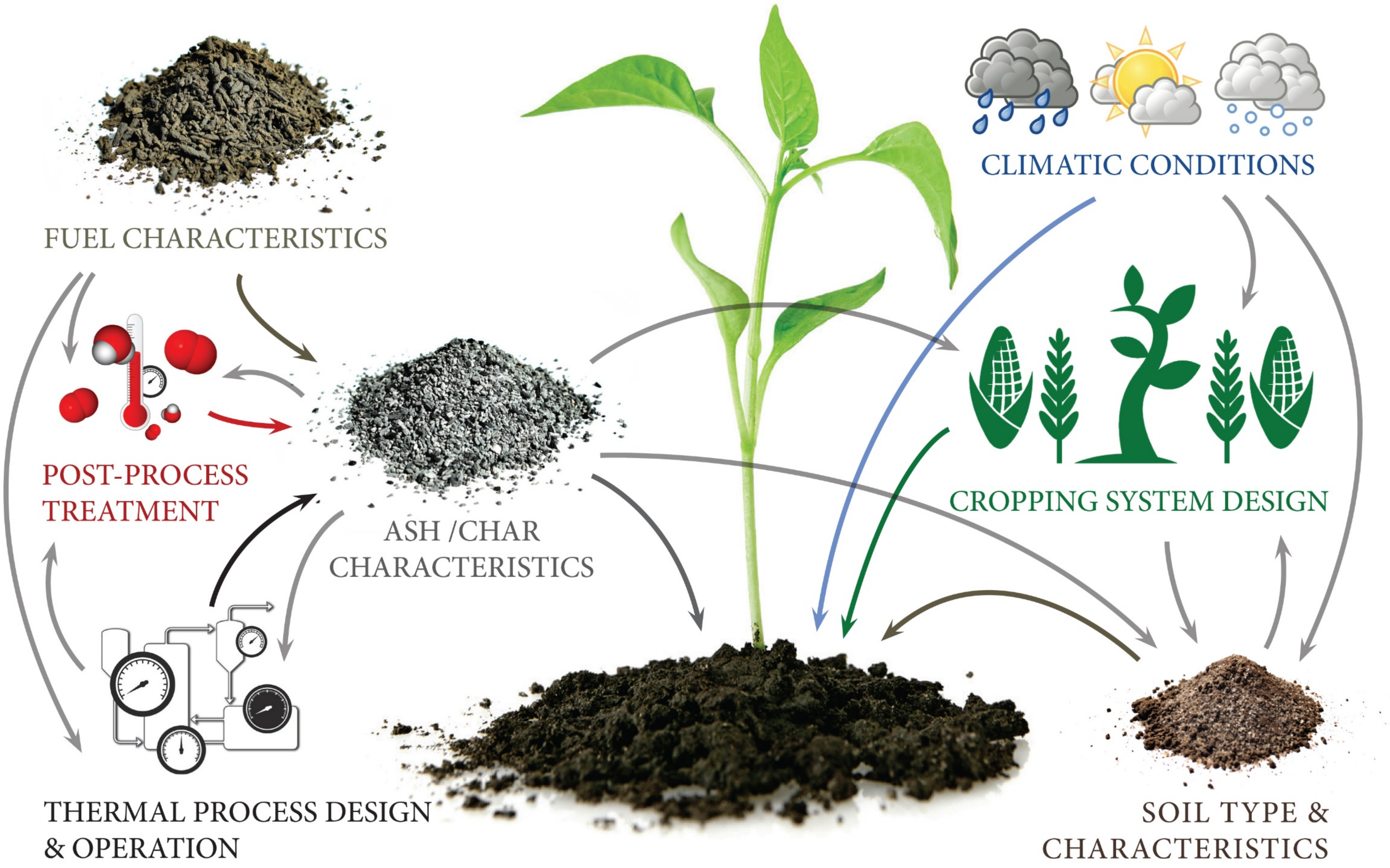

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Potentials | **P+**

- Thermal purification
  - Removing or reducing heavy metals e.g. Hg, Cd, As, Zn
  - Destroying pathogens
  - Destroying other xenobiotics in manure, sludge and digestate e.g.
    - Antibiotics, growth hormones and other pharmaceuticals
    - Pesticides, fungicides, herbicides
    - Dewatering polymers (Polyacrylamide)
    - Surfactants, phthalates, solvents
    - etc.

Issues | N-loss in thermal processes

- N loss is a common downside of thermal processing of biogenic materials
- Losses of 60-80% are common and residual N is not plant available
- N is essential for plant growth
- The value loss is associated with the N quality in the feed stock

- However, N is not a critical, or even limited, resource (like P)
- N can be sourced from the air to the soil by growing e.g. legumes
- Fueling a Haber-Bosch process with hydrogen from electrolysis can provide sustainable replenishment
- Using char to adsorb NH_3 will reduce net loss

Pyrolysis in agriculture

One size fits all?

Applicable? | **Climate change mitigation**

High level of knowledge and certainty:

- Stabilization
- Carbon sequestration
- Energy production

More R&D required and/or higher level of uncertainty:

- N_2O emission inhibition and NH_3 adsorption
- Soil functionalities and services (safe but varying efffects)
- Dietary supplement effects

Applicable? | **Material loop control**

High level of knowledge and certainty:

- Nutrient recovery levels
- K fertilizer value
- Fate of most elements incl. heavy metals
- Fate of common organic xenobiotics

More R&D required and/or higher level of uncertainty:

- Quality of micronutrients
- P uptake efficiency
- Fate of exotic xenobiotics