SIXTH FRAMEWORK PROGRAMME

Neptune FP6 Project

Life Cycle Assessment of nutrient removal in wastewater treatment

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with acknowledgements to

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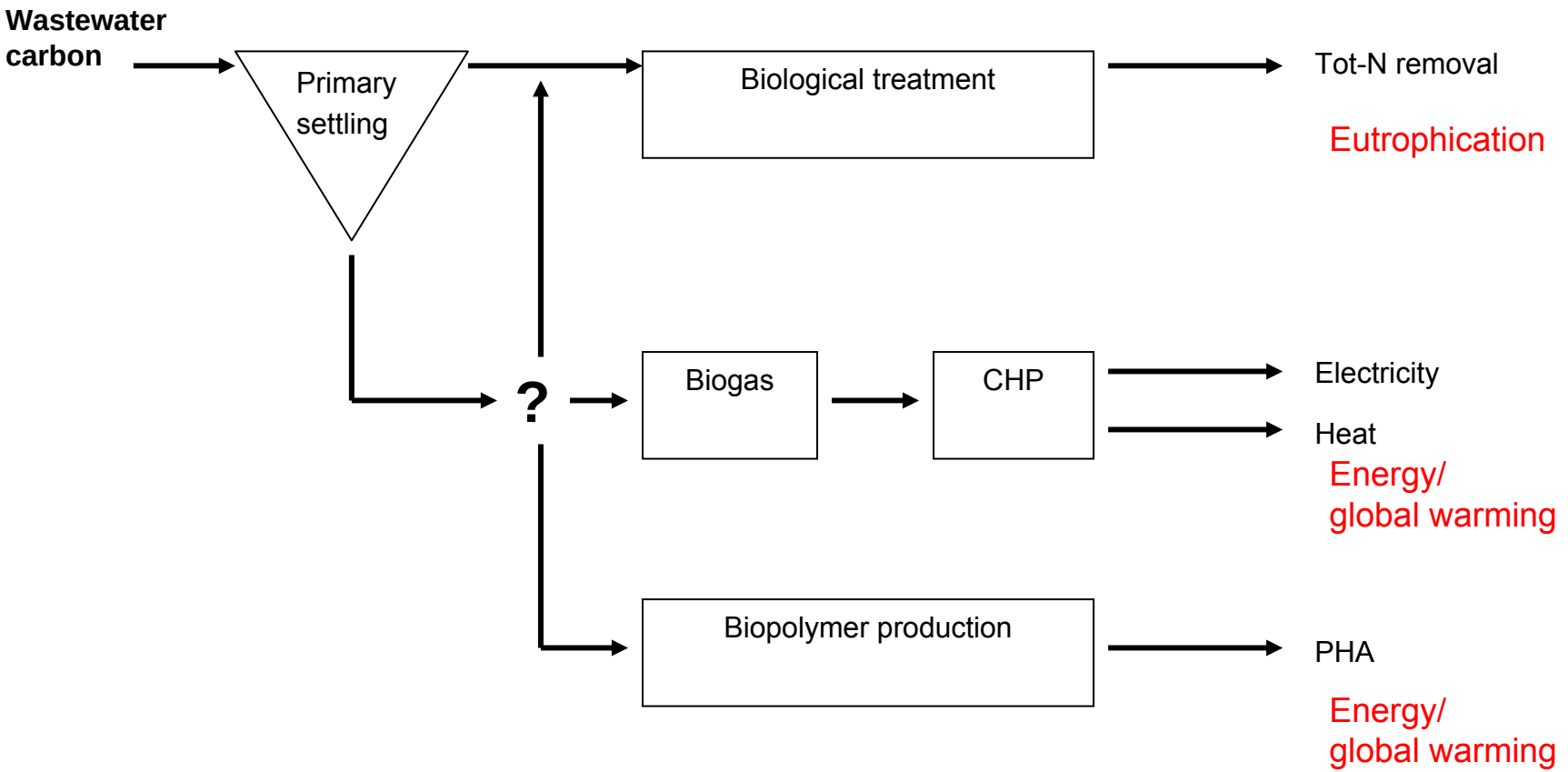
AnoxKaldnes

Water Framework Directive and Emerging Pollutants
Workshop 21-22 April 2009
Koblenz, Germany

Nitrogen, energy or materials?
- that is the question



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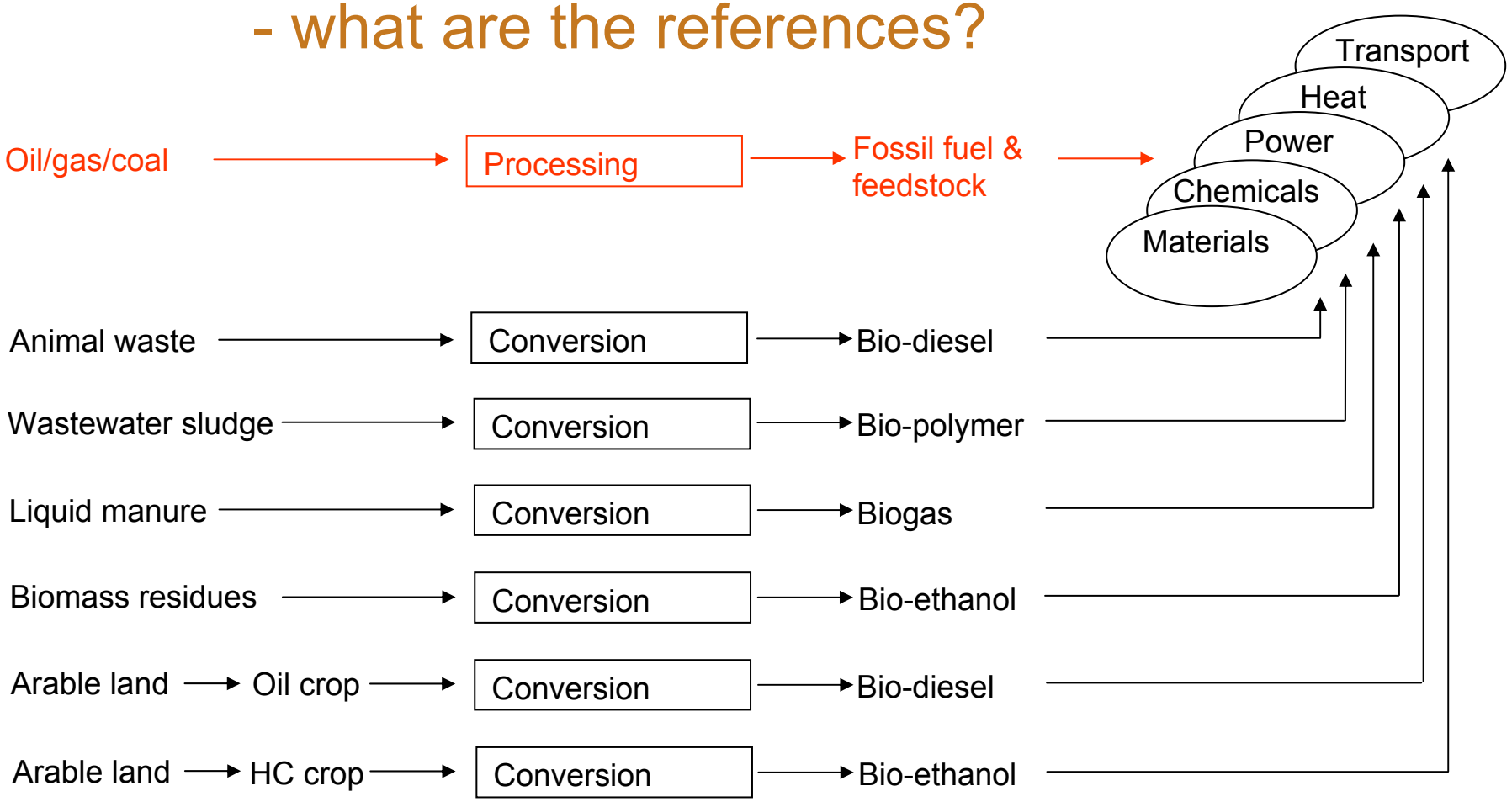
Scope definition of the comparison
- what are the references?



Two types of references: 1) Functional reference, 2) Competing uses of the waste/resource

1. Alternative provision of the same product/service – existing and/or future alternatives
2. Alternative use of the same waste/resource – existing and/or future alternatives

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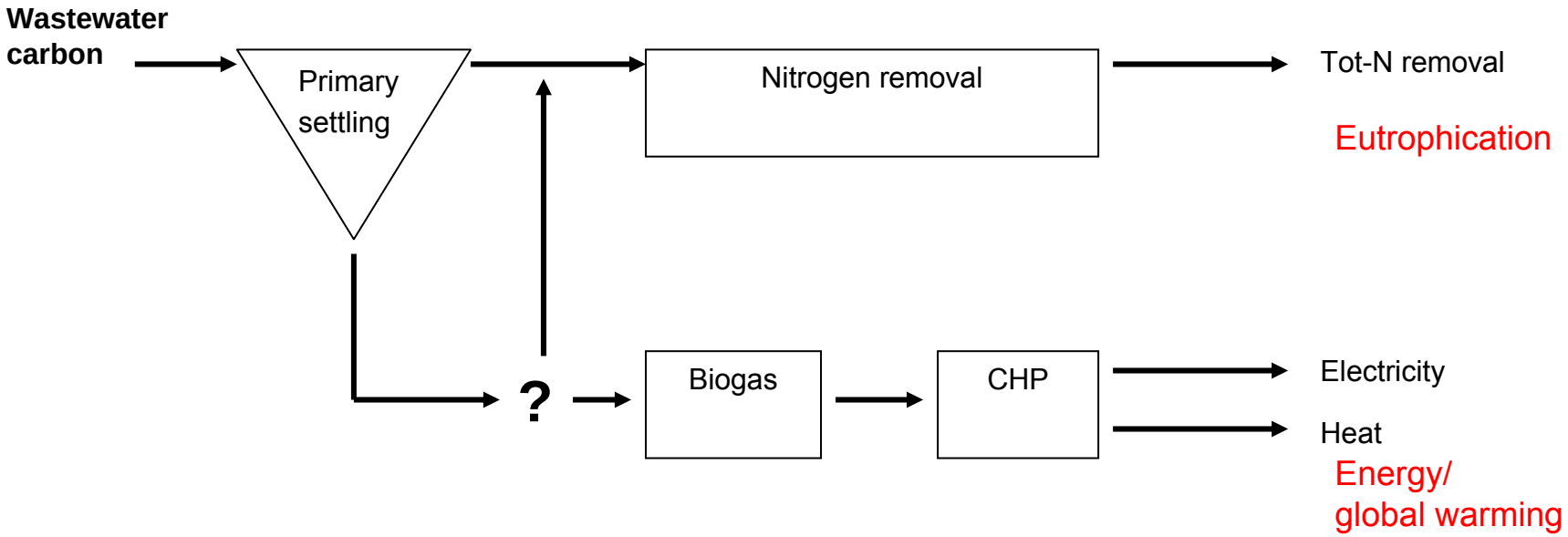
Study 1:
Nitrogen removal versus biogas



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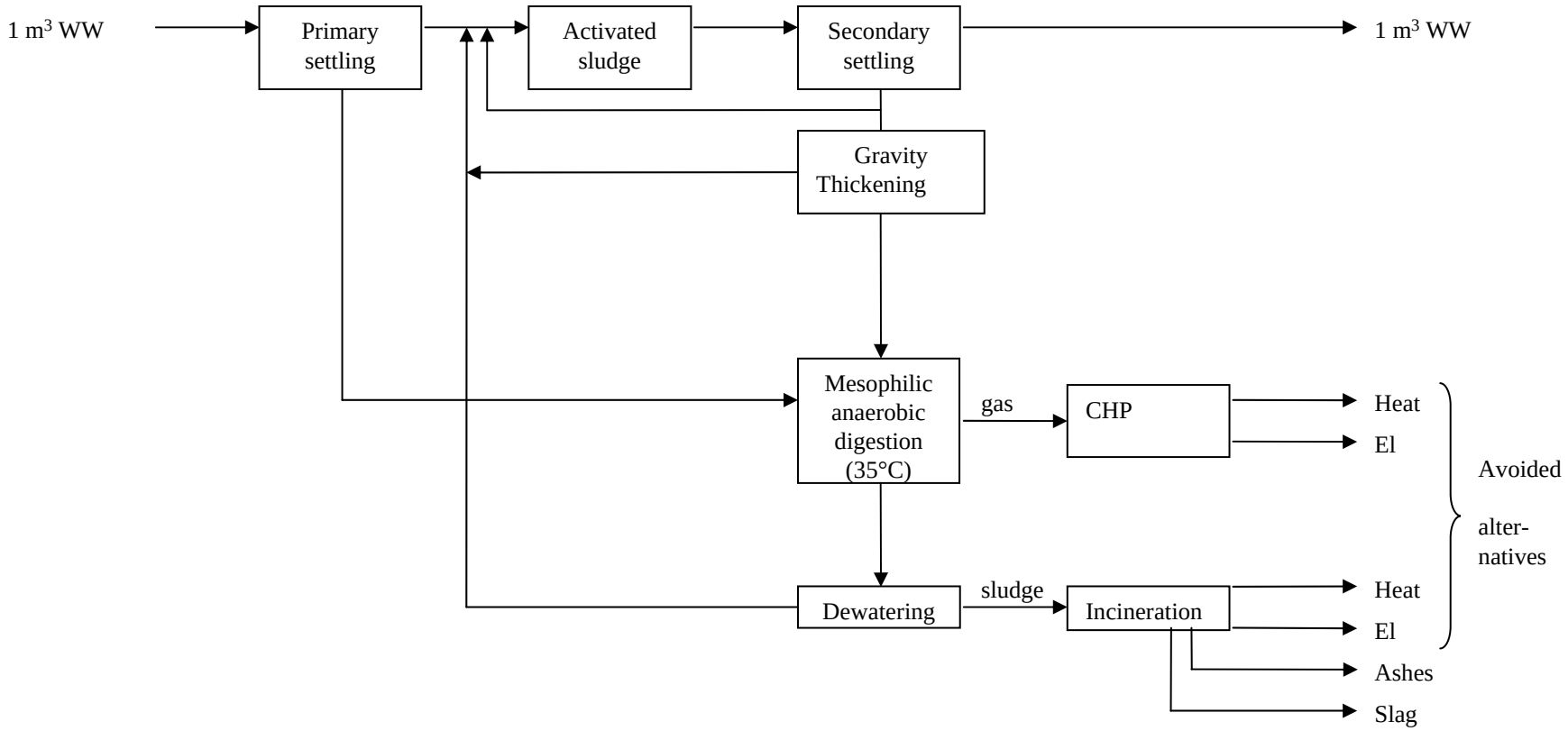
Biogas: the reference system
- system scope



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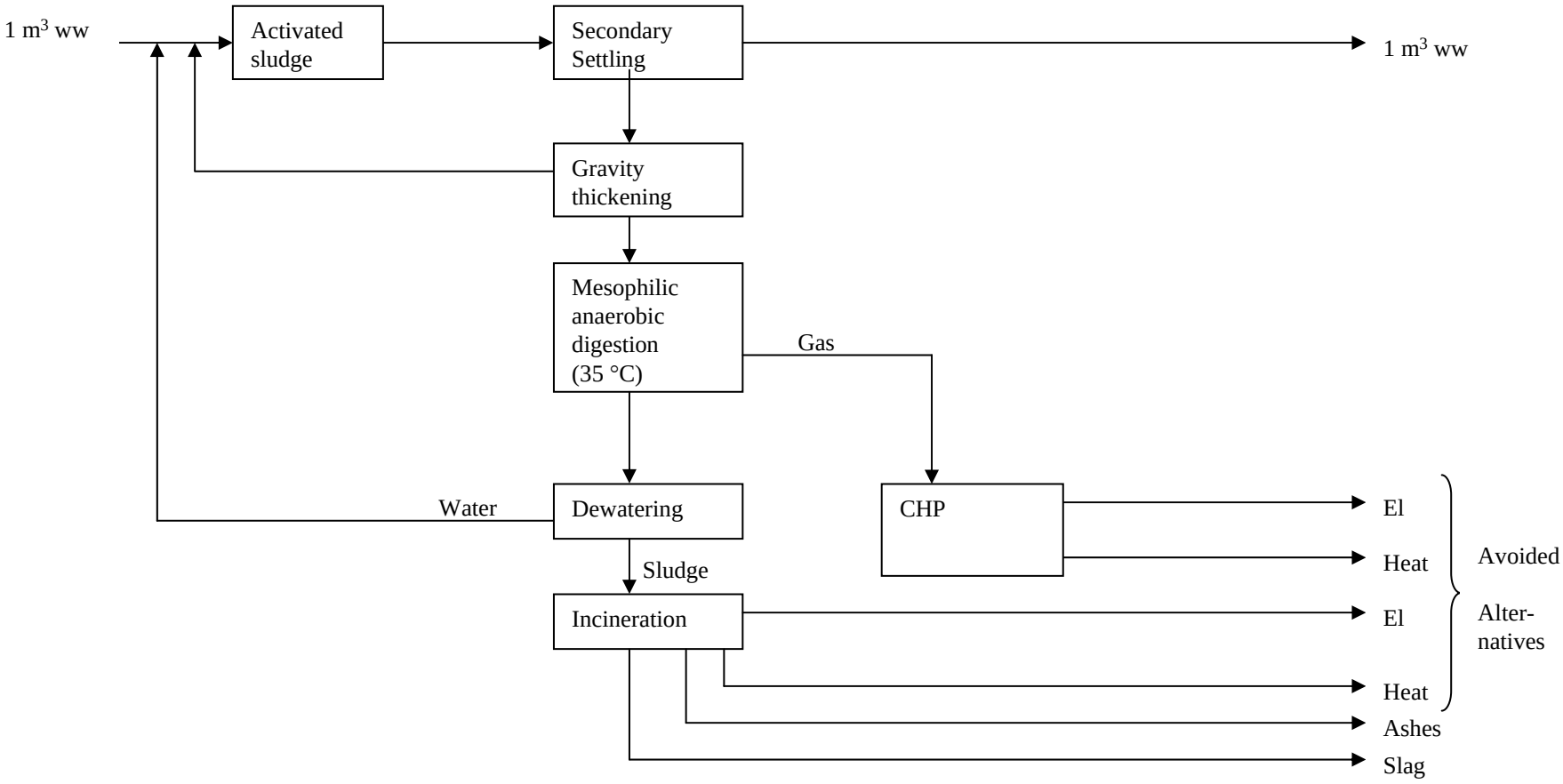
Nitrogen removal

- system scope



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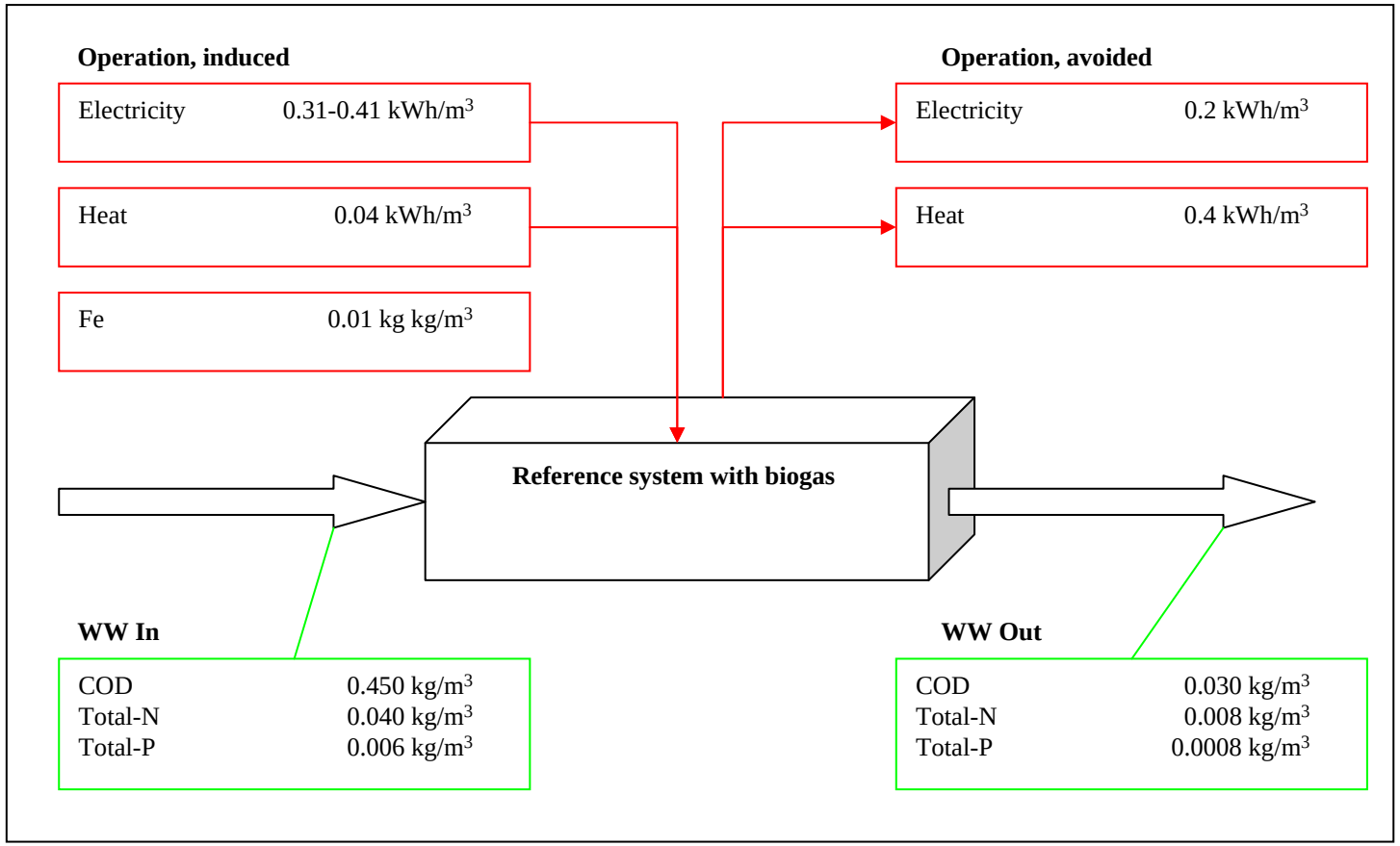
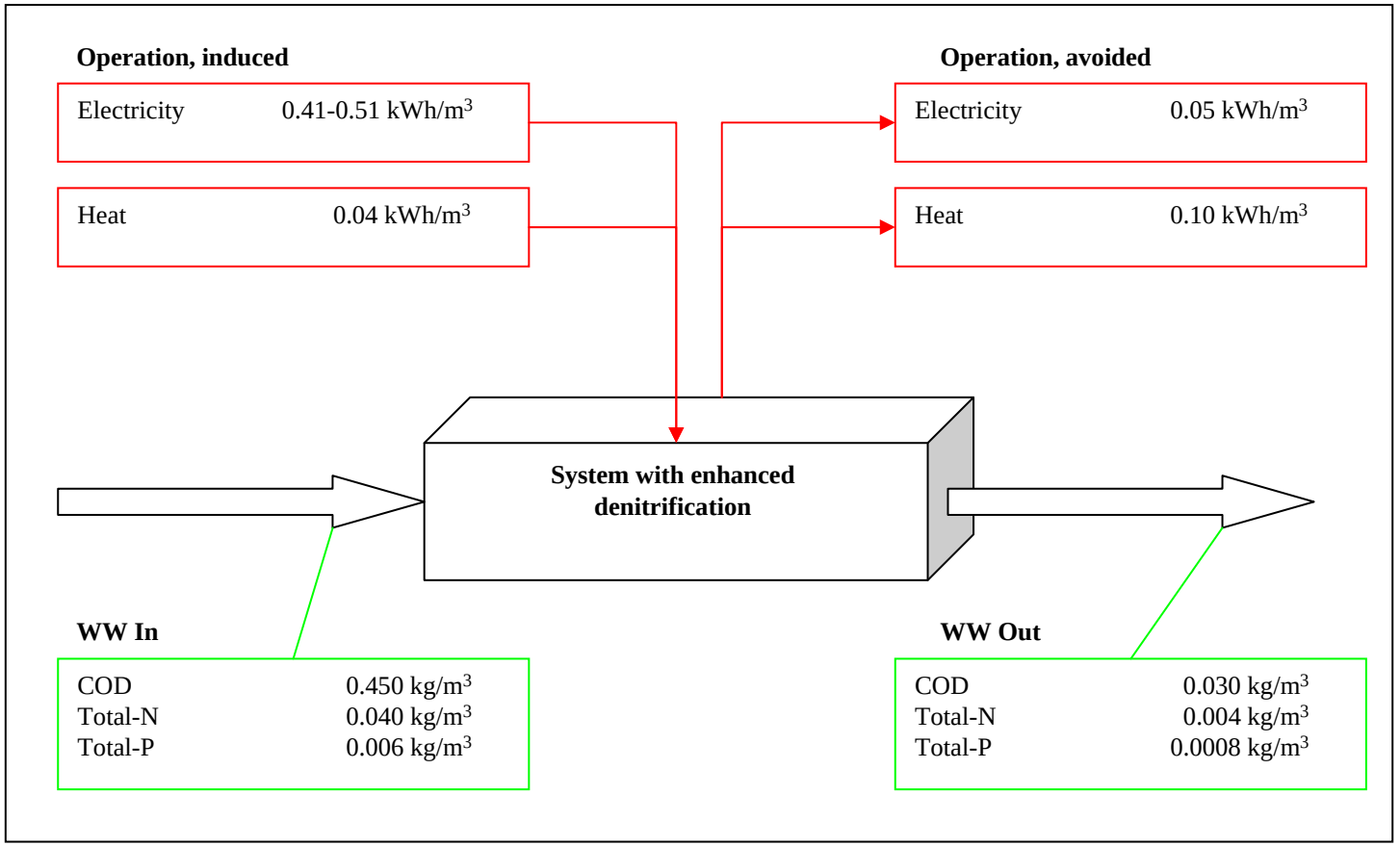
Biogas

- key inventory data



Nitrogen removal

- key inventory data



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Nitrogen removal

- key trade-off

Electricity consumption

- 0.25 kWh/m3 more for the enhanced denitrification

Nitrogen discharge

- 4 g/m3 less for the enhanced denitrification

So energy efficiency of nitrogen removal:

- **16 g N/kWh**

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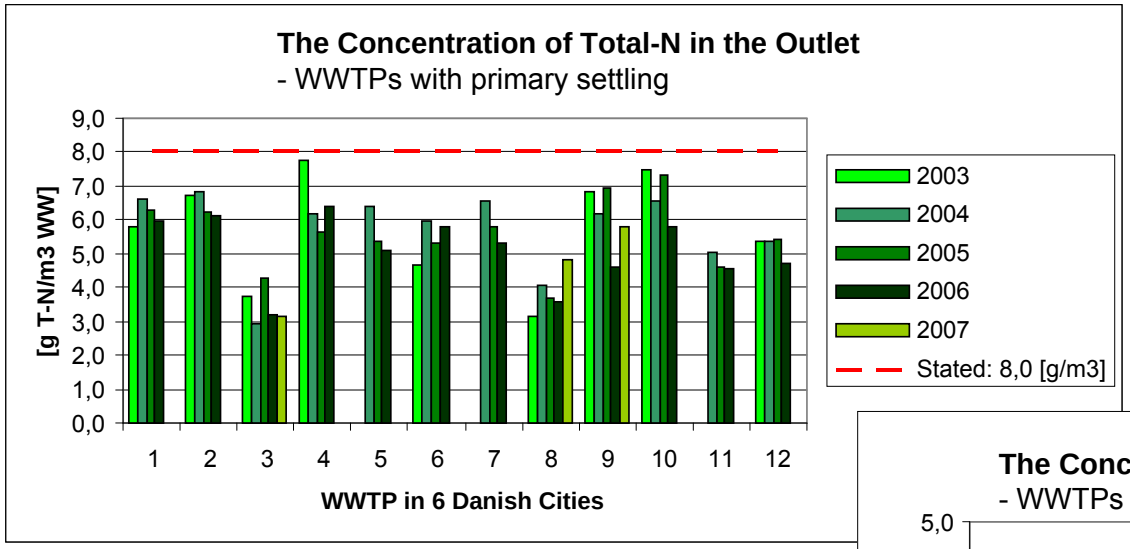
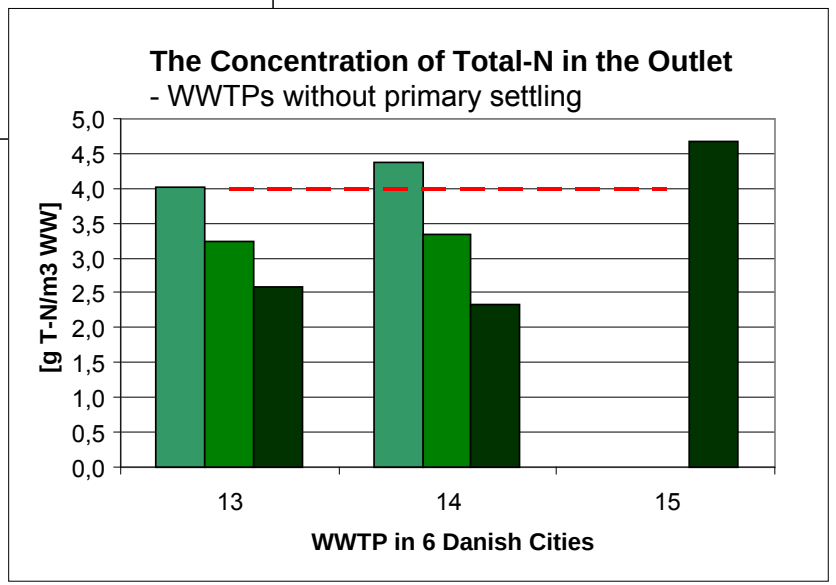
Nitrogen removal versus biogas

- assumption check



Assumption

With PS: 8 g/m3
Without PS: 4 g/m3



Check:

With PS: 3-7 g/m3 (average 5,5)
Without PS: 2,5-4,5 g/m3 (average 3,5)

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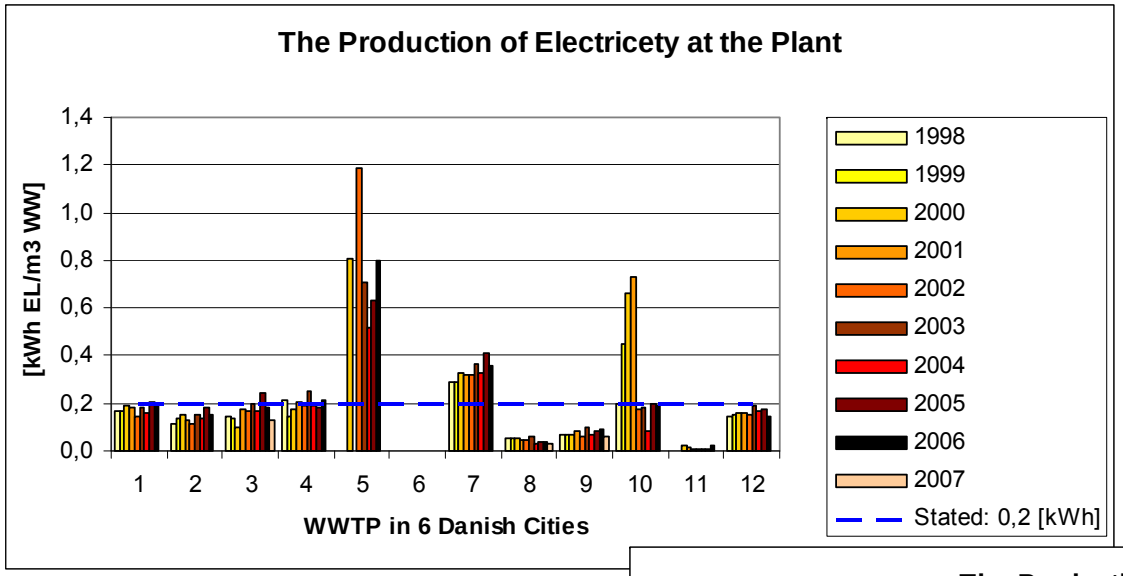
Nitrogen removal versus biogas

- assumption check

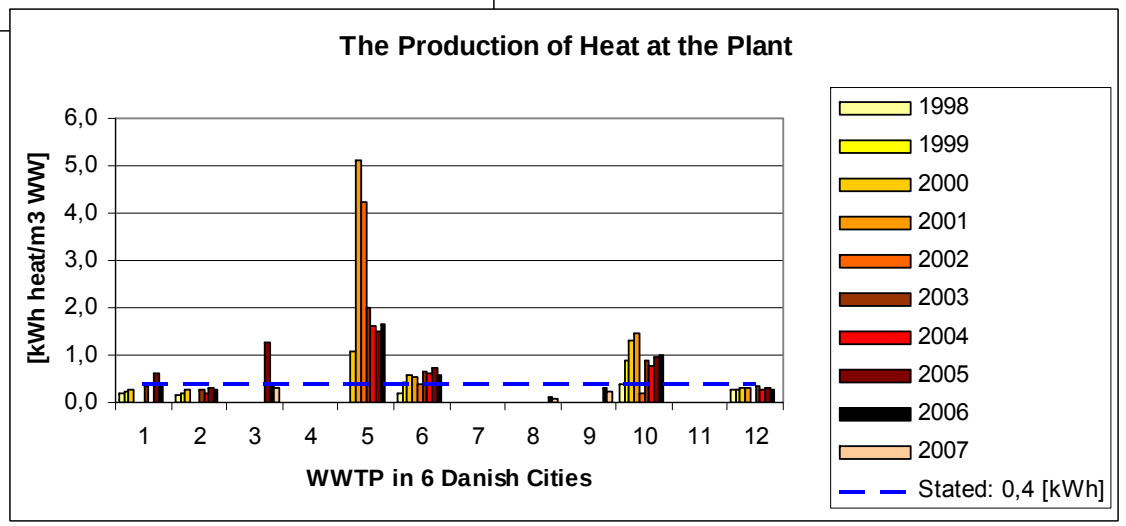


Assumption (with PS)

Electricity: 0.2 kWh/m3
Heat: 0.4 kWh/m3

Check (with PS)

Electricity: 0.1-1.2 kWh/m^3 (0.2)
Heat: 0.2-5.0 kWh/m3 (0.5)



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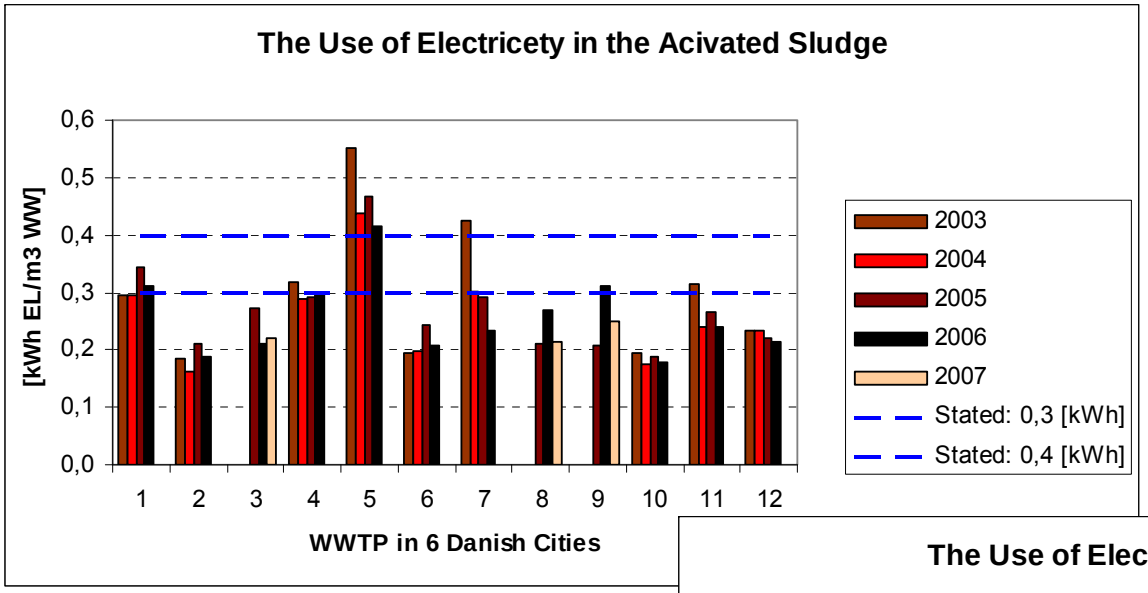
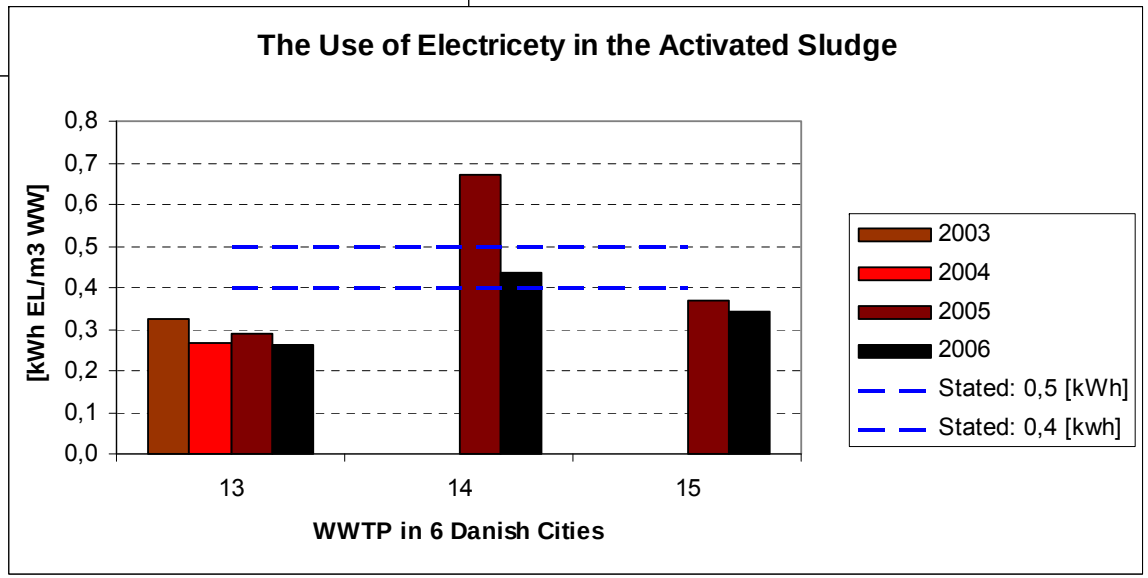
Nitrogen removal versus biogas

- assumption check



Assumption

With PS: 0.3-0.4 kWh/m3
Without PS: 0.4-0.5 kWh/m3



Check

With PS: 0.2-0.5 kWh/m3 (0.3)
Without PS: 0.3-0.6 kWh/m3 (0.35)

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Nitrogen removal

- key trade-off checked by data for 6 Danish plants

Electricity consumption

• 0.20 kWh/m3 more for the enhanced denitrification

Nitrogen discharge

• 3 g/m3 less for the enhanced denitrification

So energy efficiency of nitrogen removal:

• **15 g N/kWh**

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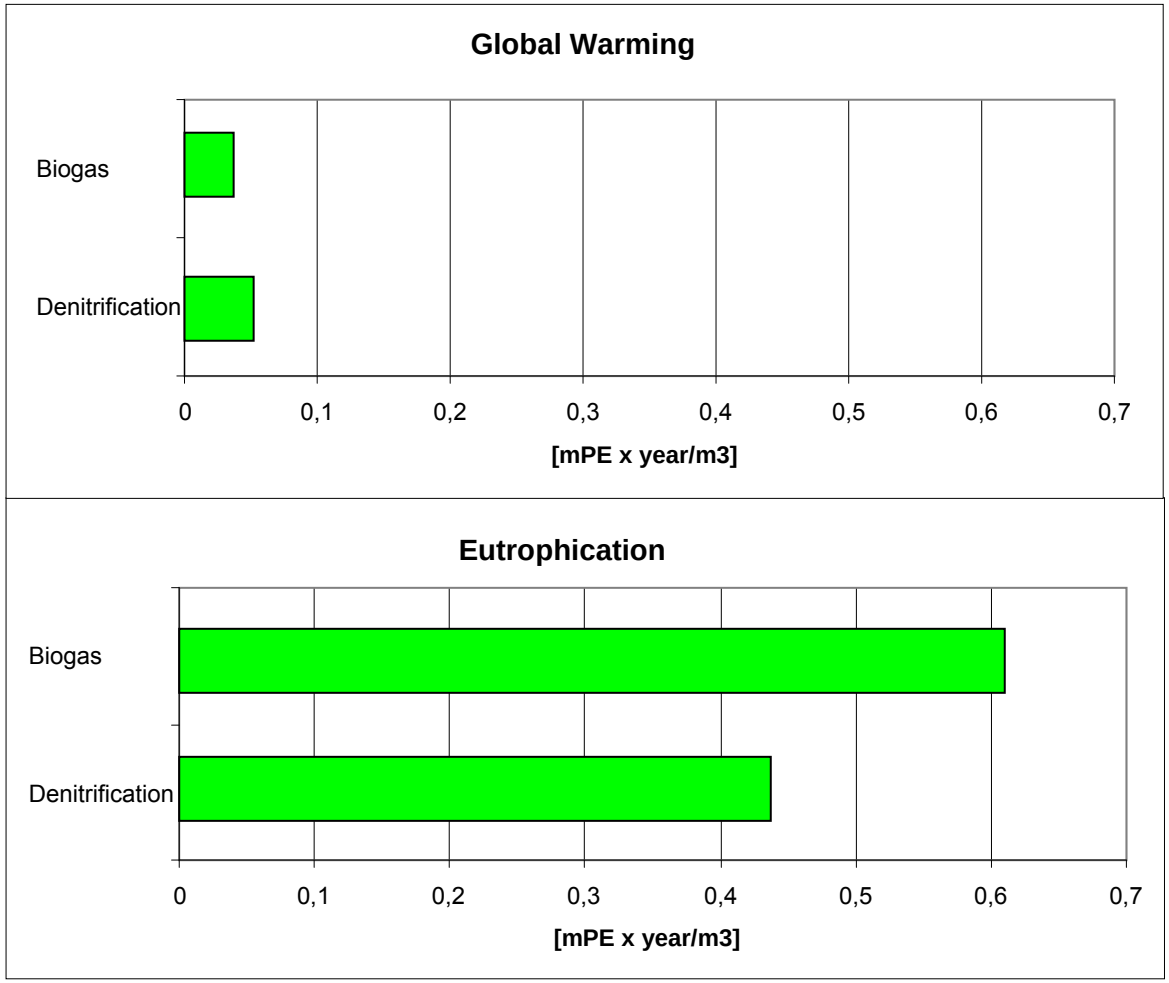
Nitrogen removal versus biogas

- key results



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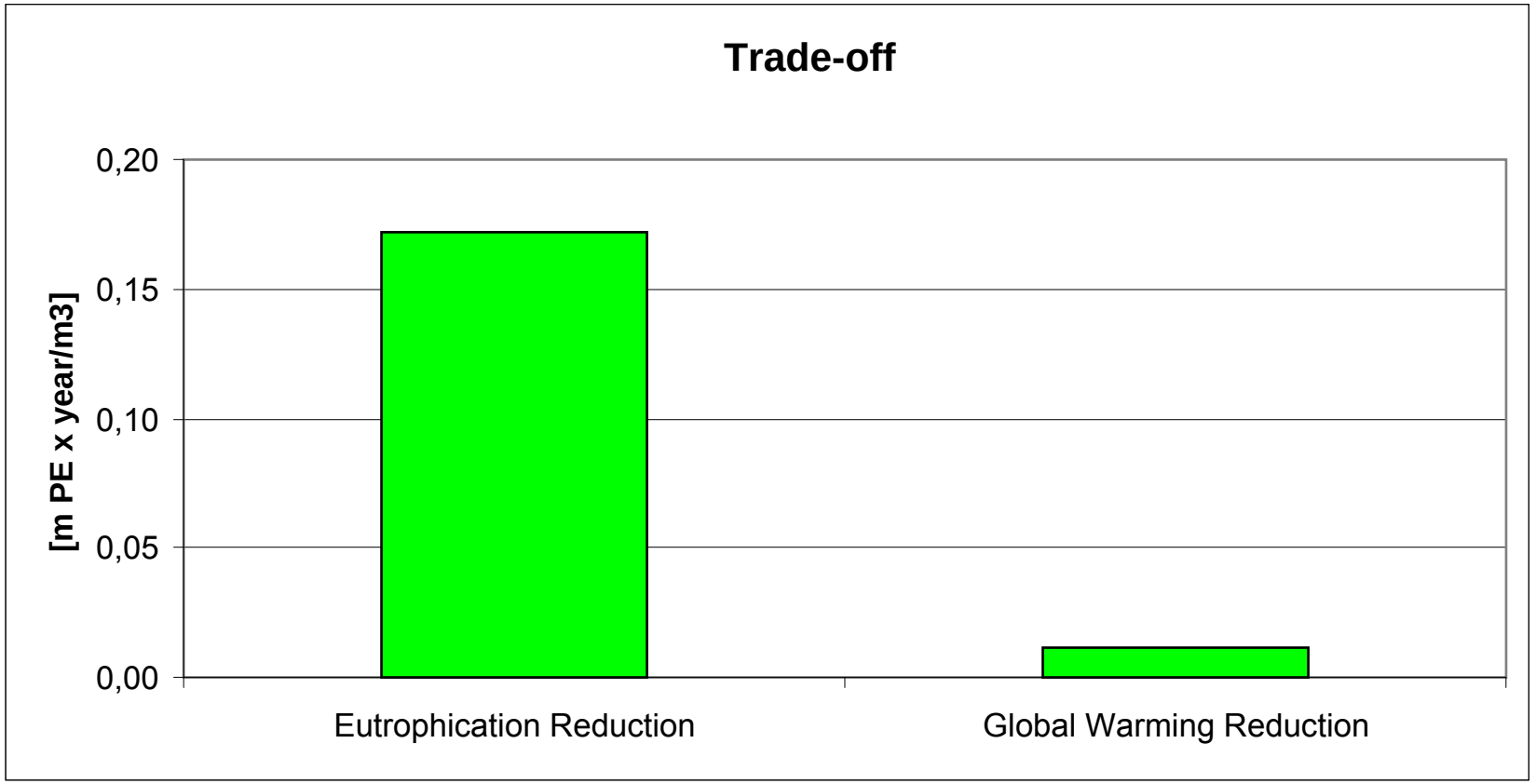
Nitrogen removal versus biogas

- key results



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Nitrogen removal versus biogas
- interpretation

- Wastewater carbon for denitrification removes 10 PE of nutrient enrichment potential per PE of global warming potential induced
- Today's political weighting in terms of policies for nutrient enrichment and global warming reduction both require around 10-20% over 10 years
- In a 'distance-to-target' based weighting, nitrogen removal, thus, has priority over biogas formation from the primary sludge
- Global warming needs about 10 times higher weight to change the priority
- But following the IPCC 2 ^{o}C scenario this may be the case looking over 100 years instead of 10 years

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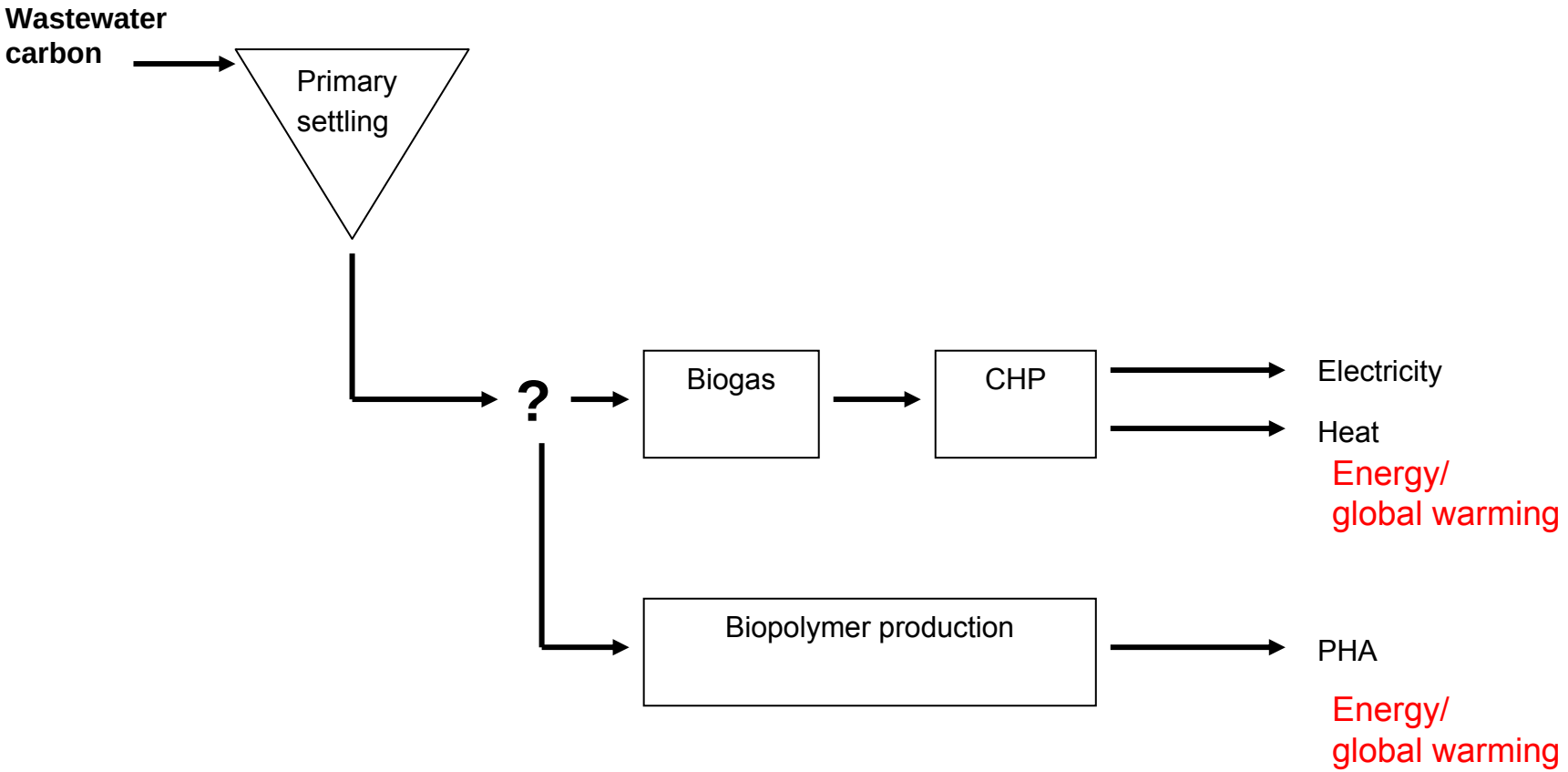
Study 2: PHA versus biogas



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Scope definition of the comparison
- what are the assessment criteria?

Scope issue	Included	Not included
Functional reference	Petrochemical polymer	Other biopolymer
Temporal scope	Short term	Longer term
Technological scope - data	Early in PHA technological development	Already existing efficiency improvement potentials
Competing resource use	Biogas for heat and electricity Denitrification	Gasification Other fermentation processes Other conversions
Competing resource replacement	Natural gas, oil and coal	Other biomass
Assessment criteria	Energy consumption Global warming Nutrient enrichment	Non-degradable waste Eco-toxicity Human toxicity Other

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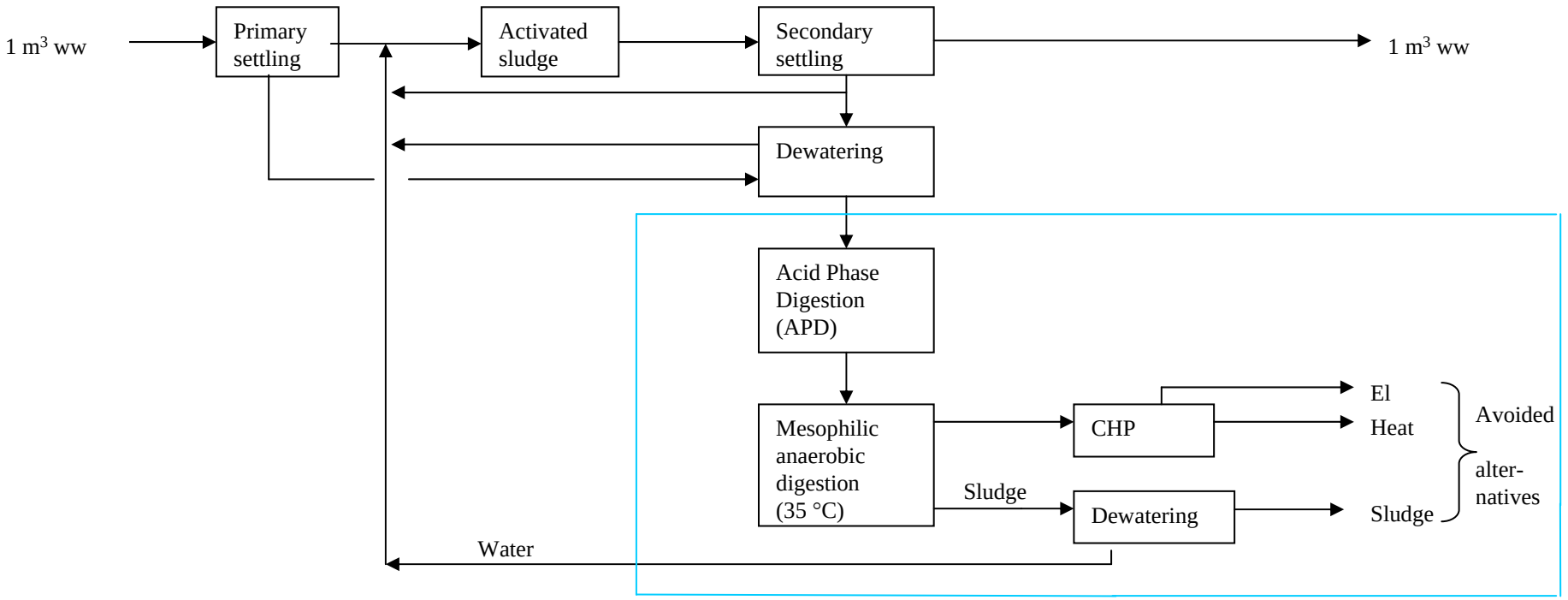
Biogas with APD

- system scope



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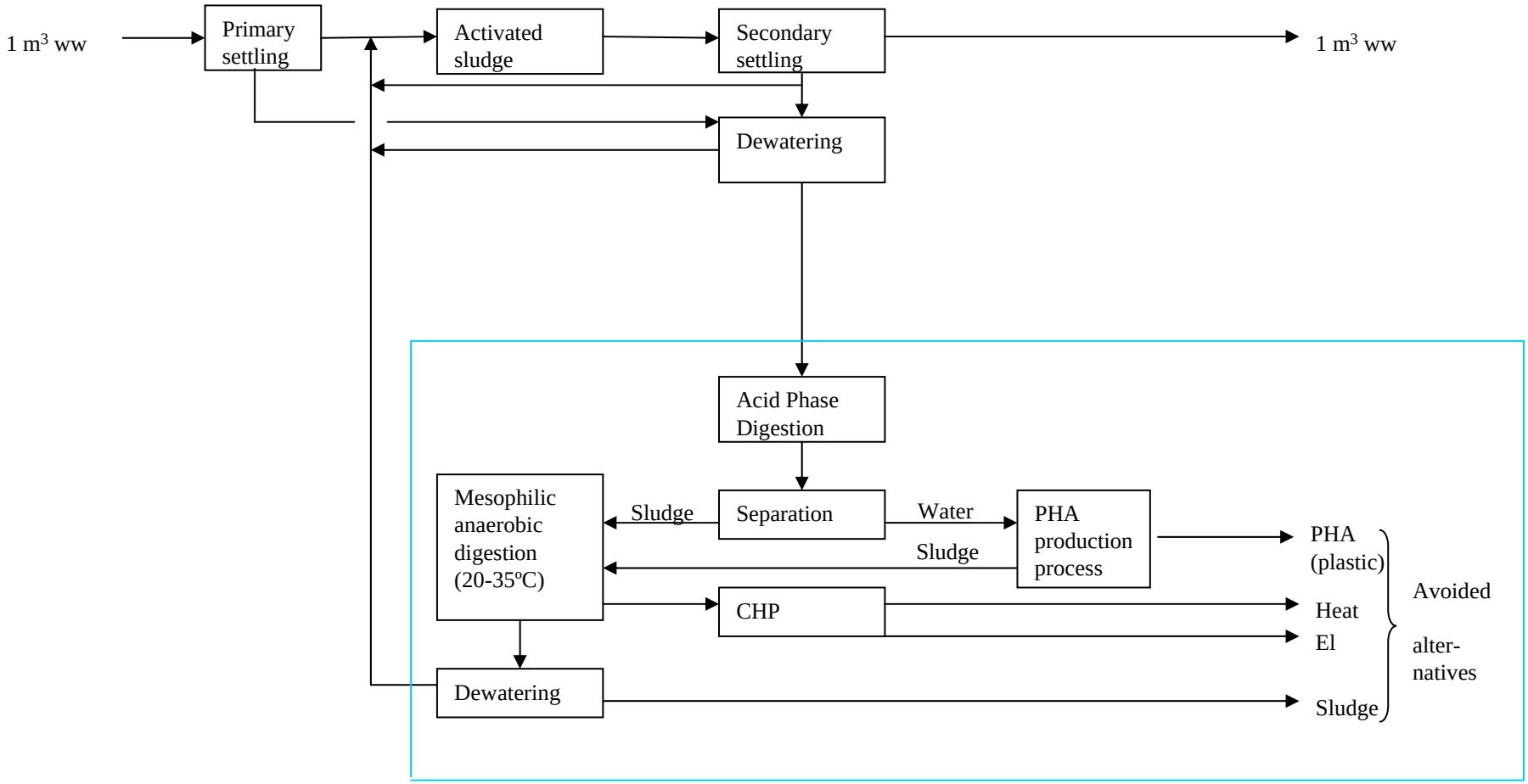
PHA production

- system scope



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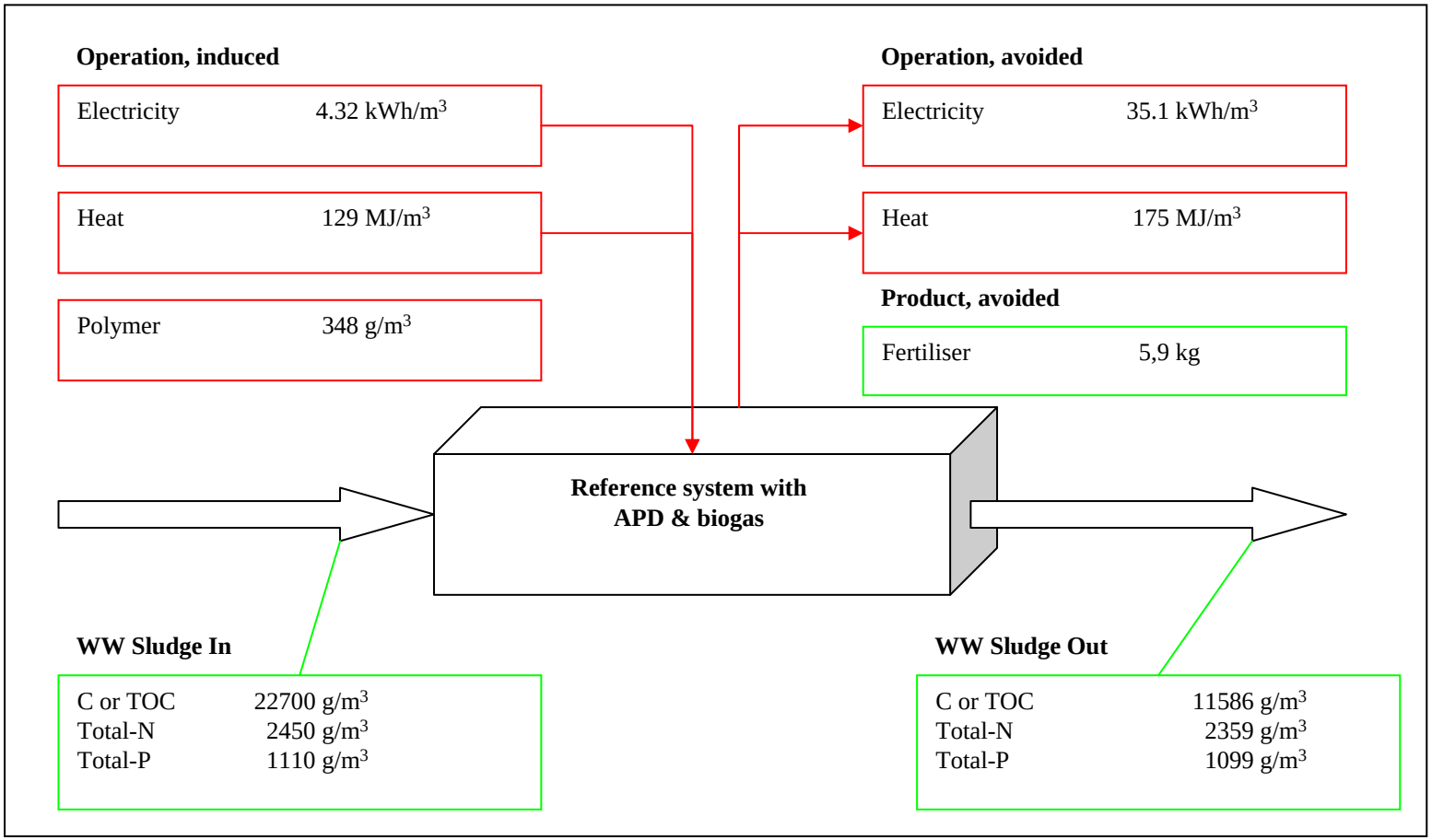
Biogas with APD

- key inventory data



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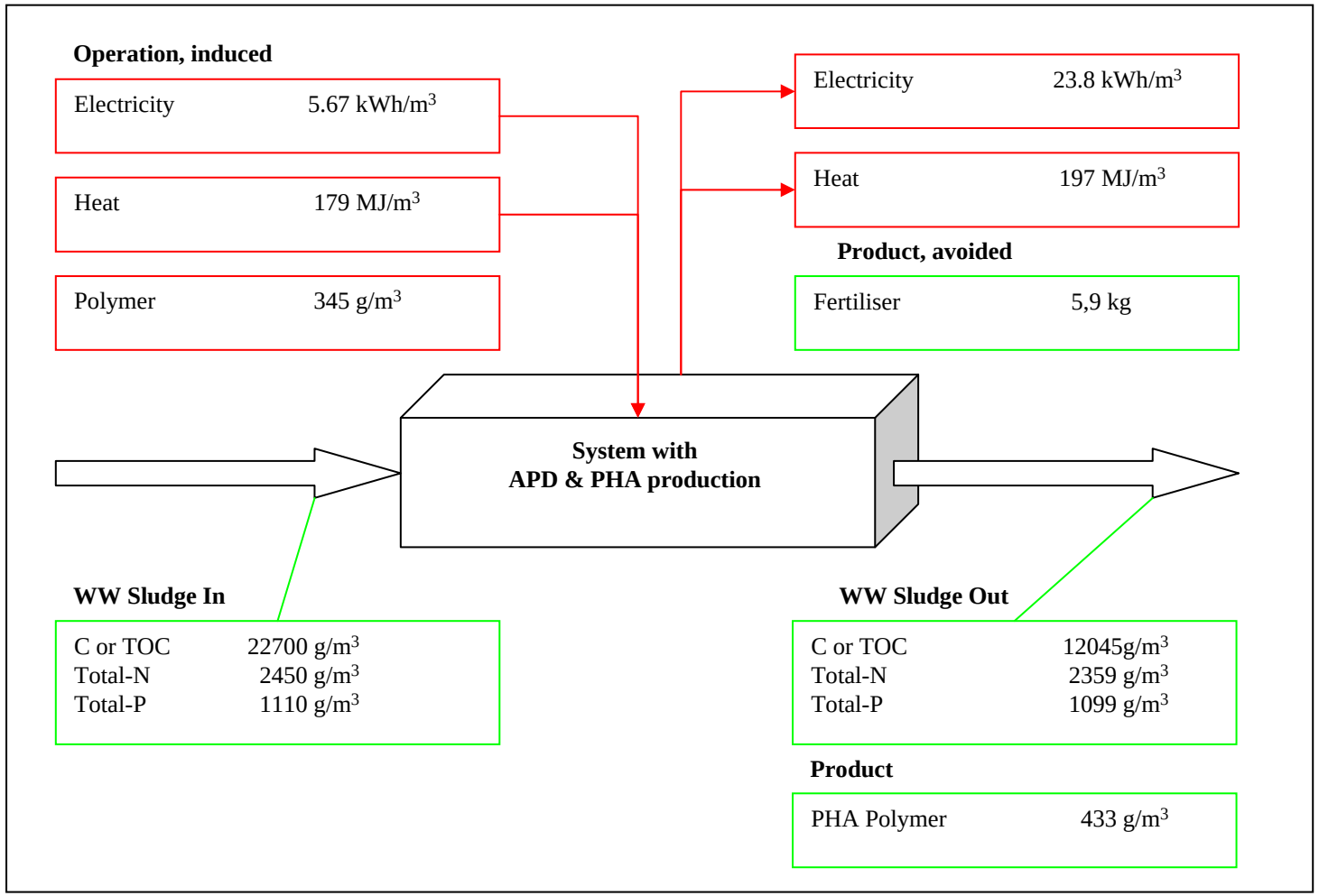
PHA production

- key inventory data



agw3

PHA versus biogas

- key results: energy balance

Energy balance

	ADP + PHA	ADP + Biogas
Net heat	18 MJ	46 MJ
Net electricity	18.6 kWh	31.25 kWh
Net electricity in MJ	67 MJ	112.5 MJ
Net electricity primary energy (x 2-3)	134 – 201 MJ	225 – 338 MJ
PHA	0.433 kg	-
PP primary energy substitution (80 MJ/kg)	35 MJ	-
Total energy production	**187 – 254 MJ**	**271 – 384 MJ**

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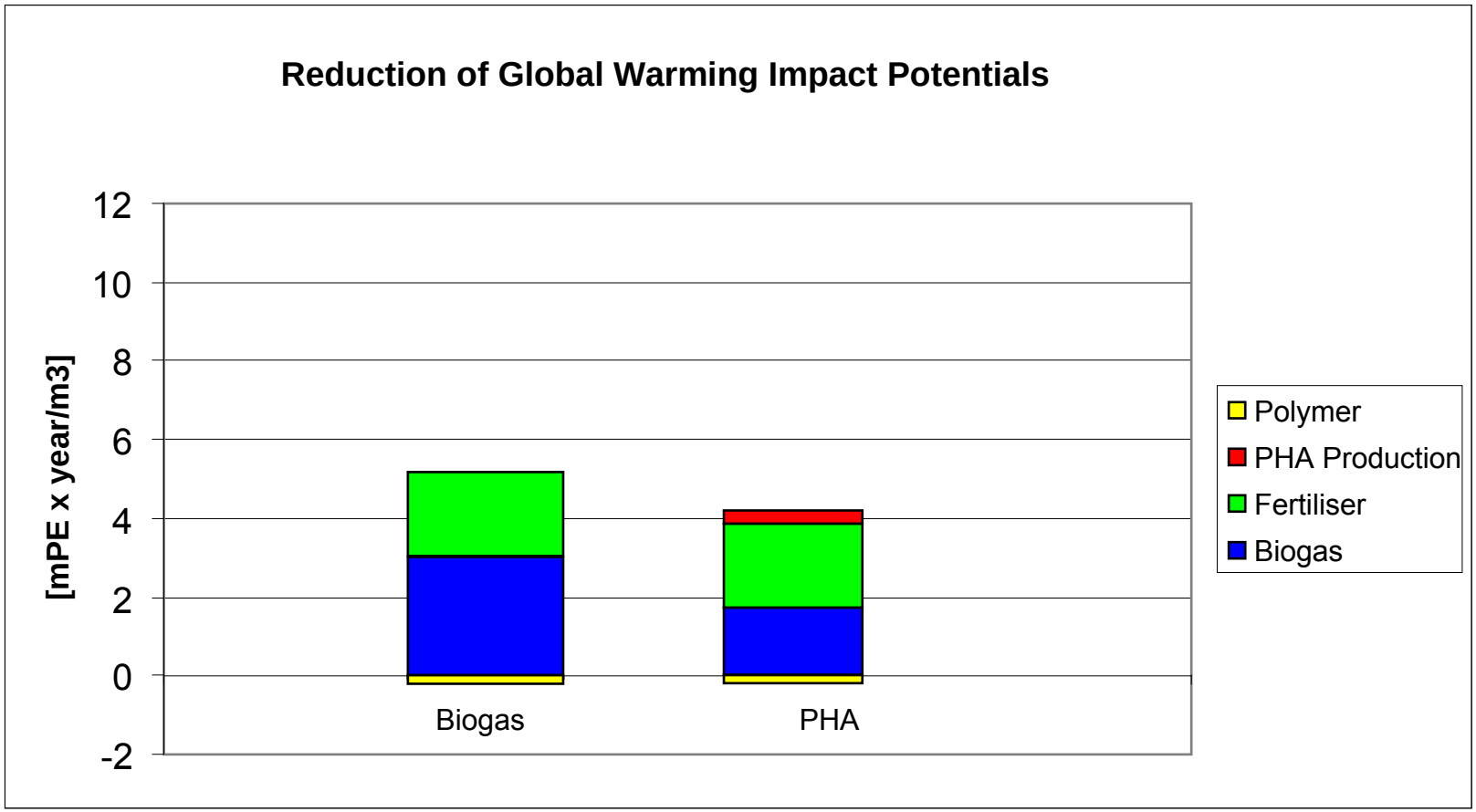
agw3 basis - m3 treated?

alan.werker; 23.10.2008

agw4

PHA versus biogas

- key results: global warming



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agw4 is the difference significant given some of the uncertainties??

alan.werker; 23.10.2008

PHA versus biogas

- explanation of key results

- PHA production is aerobic → electricity consumption
- Biomass production aerobic → higher sludge production

  Both of the above to be eliminted by intended Process Integration with the activated sludge reactor.

- Low yield of PHA compared to methane
- Equal or higher primary energy replacement from biogas than from PHA per MJ
- Higher CO2 replacement from biogas per MJ when substituting coal based electricity

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PHA versus biogas

- interpretation

Based on presently available data on PHA production, biogas CHP has a better energy balance and better global warming balance than PHA

- under boundary conditions where PHA replaces petrochemical polymer and biogas CHP replaces heat and power based on natural gas and coal, and with the used early staqe data on PHA

The comparison does not cover conditions where:

- PHA replaces other biodegradable polymers on the market
- Biogas CHP does not replace fossil fuels
- Impacts of non-degradable waste or other impacts are of priority
- Future integration of PHA into the AS aeration step and other technological alterations

Further: On the long term – when/if fossils fuels become heavily constrained – material production will be a priority customer for biomass

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Acknowledgement

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- AnoxKaldnes provided data and support for the study on PHA