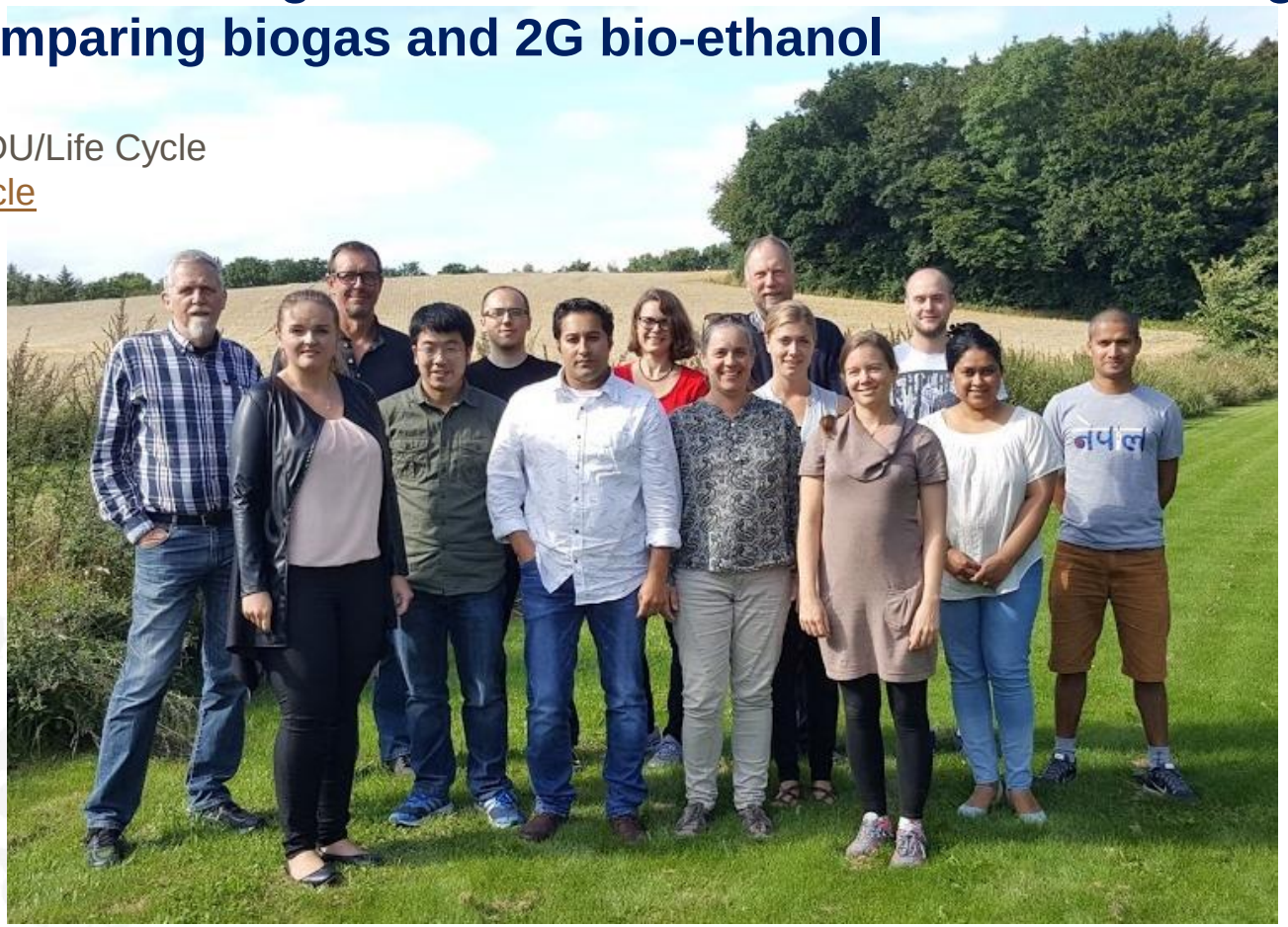
Prioritizing the use of agricultural straw in the Renewable Energy system – comparing biogas and 2G bio-ethanol

Henrik Wenzel, SDU/Life Cycle
www.sdu.dk/lifecycle



2nd International Conference on
Smart Energy Systems and 4th Generation District Heating
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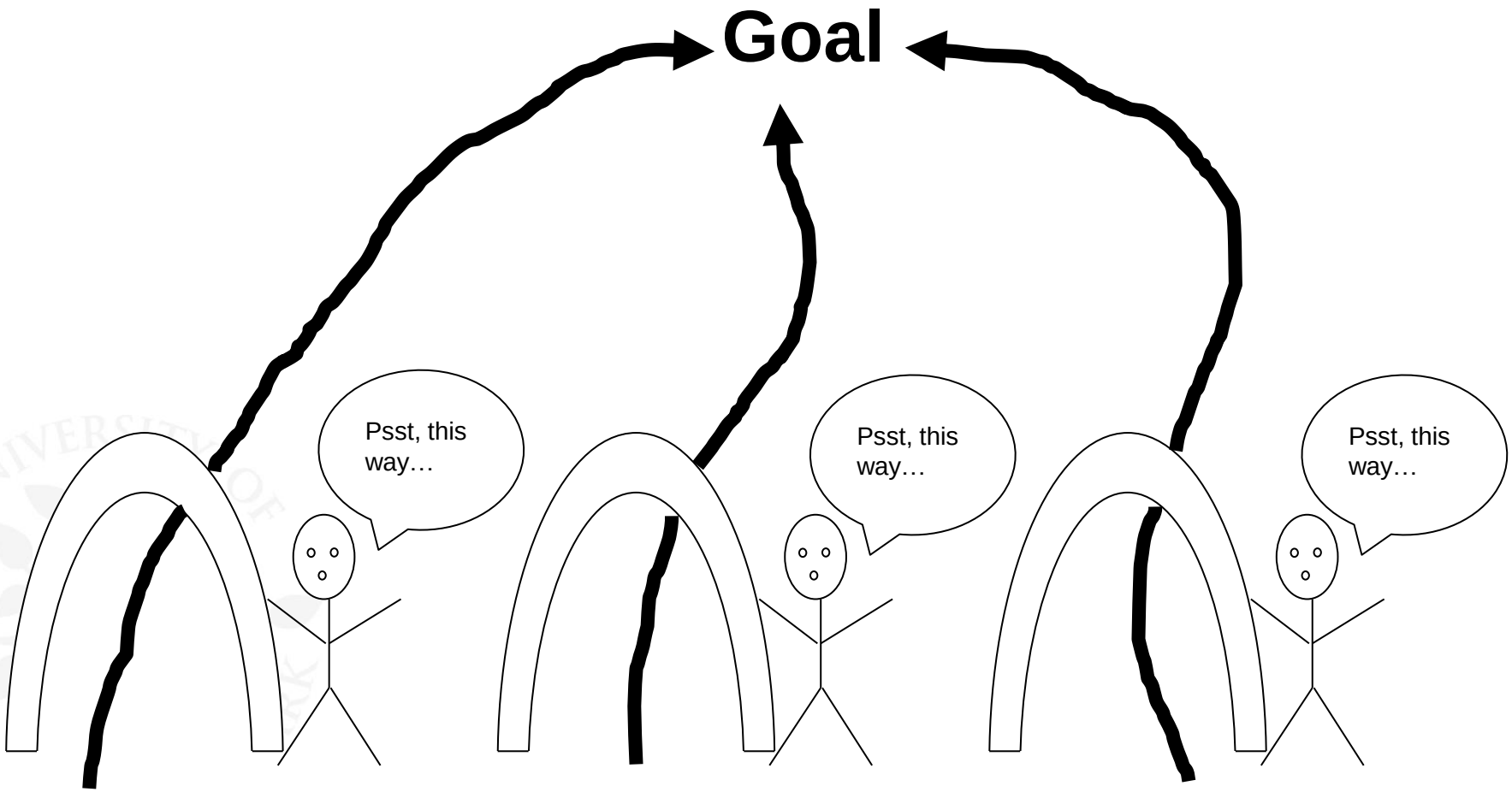
We are at a crossroad

- which path shall we follow towards the renewable energy system?



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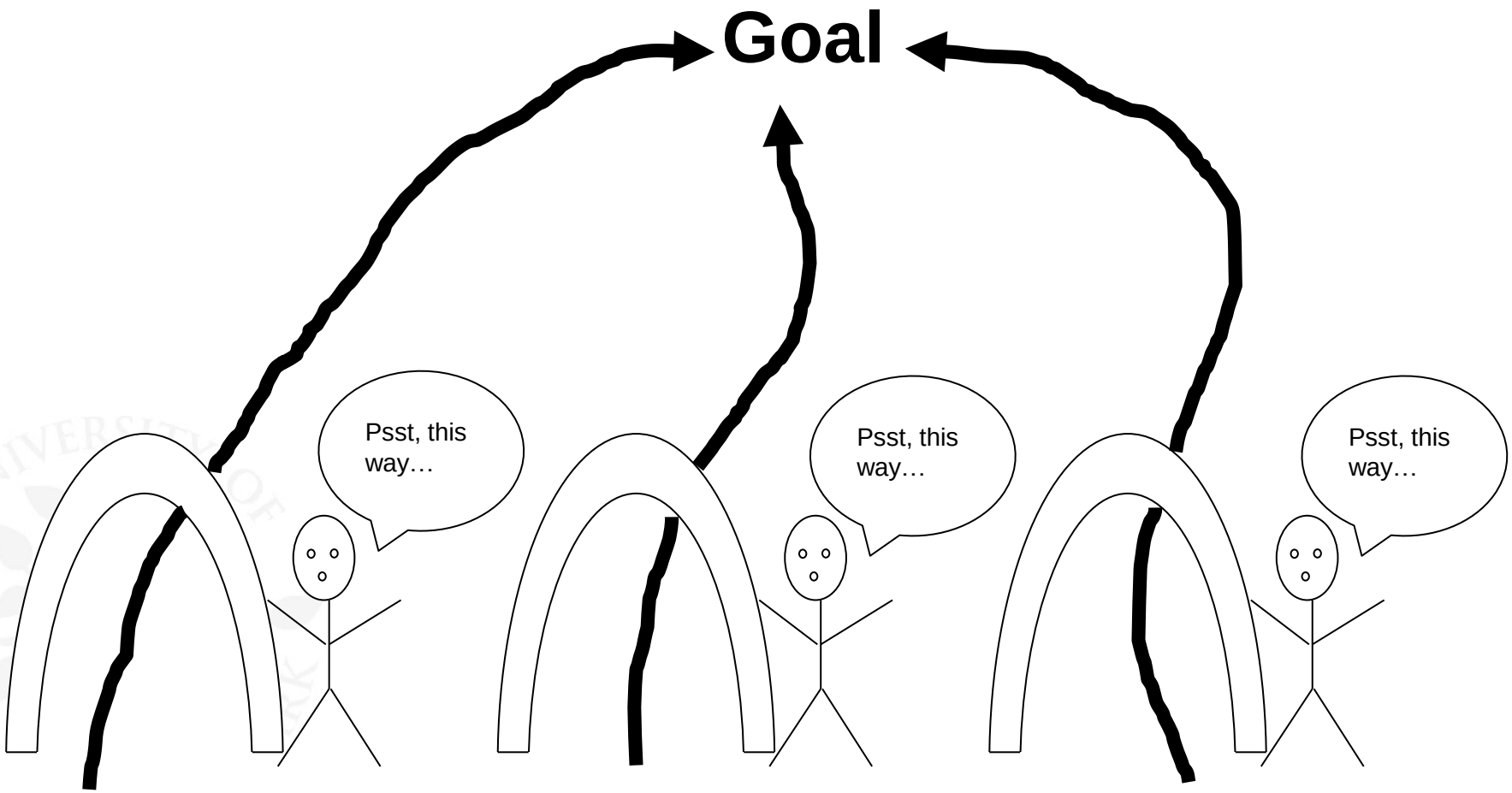
- how should we use our agricultural straw residues?



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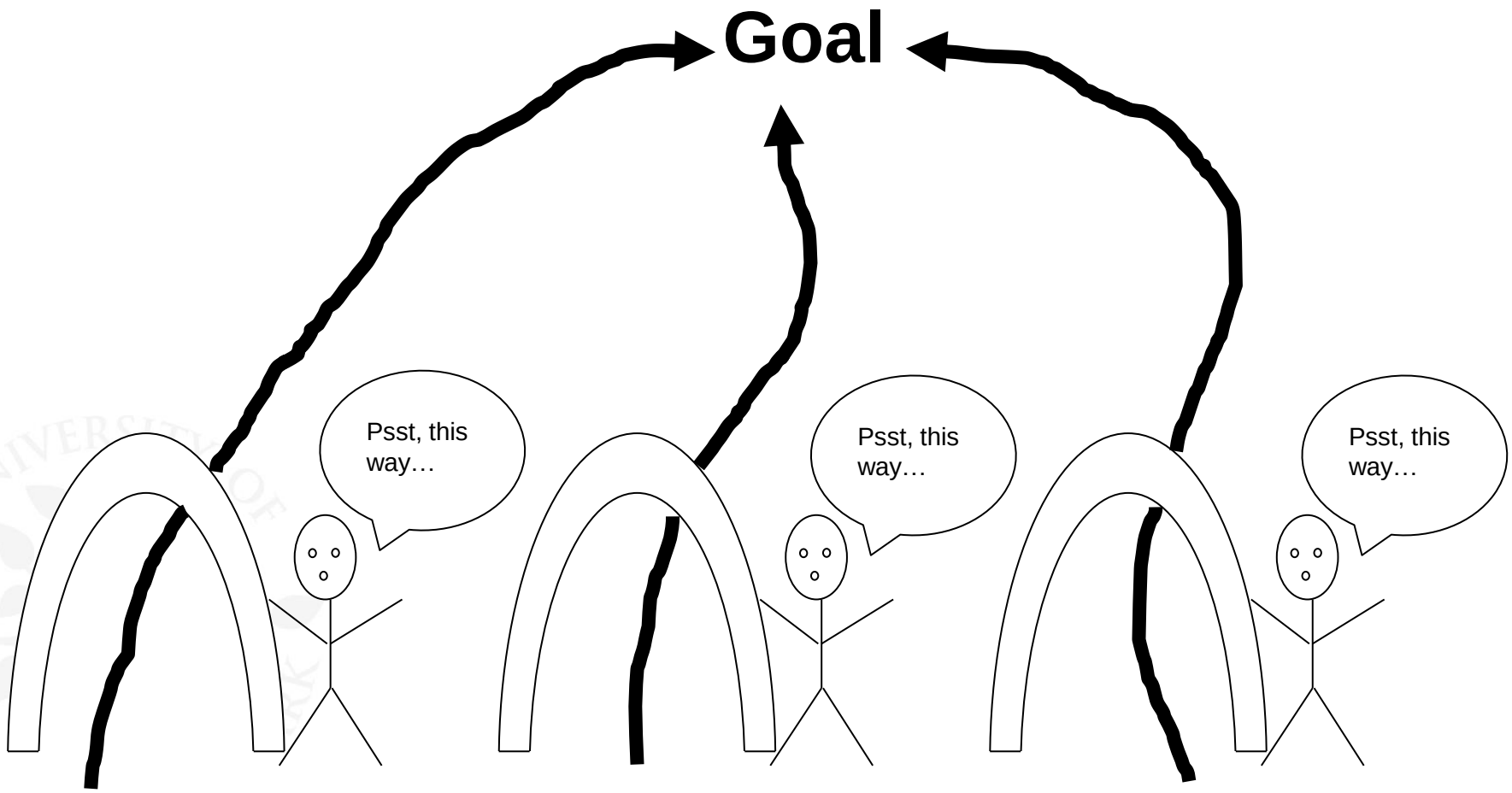

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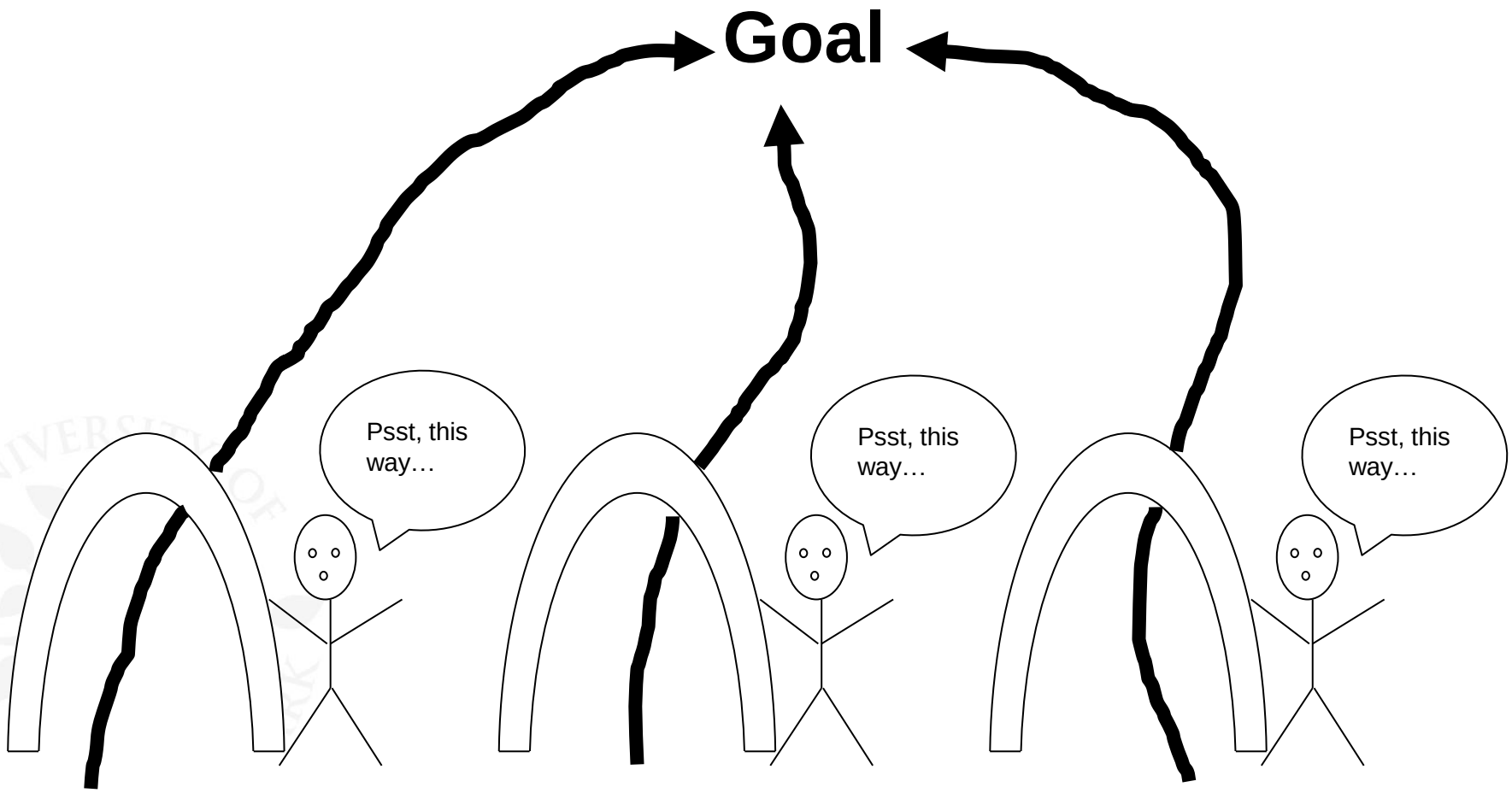

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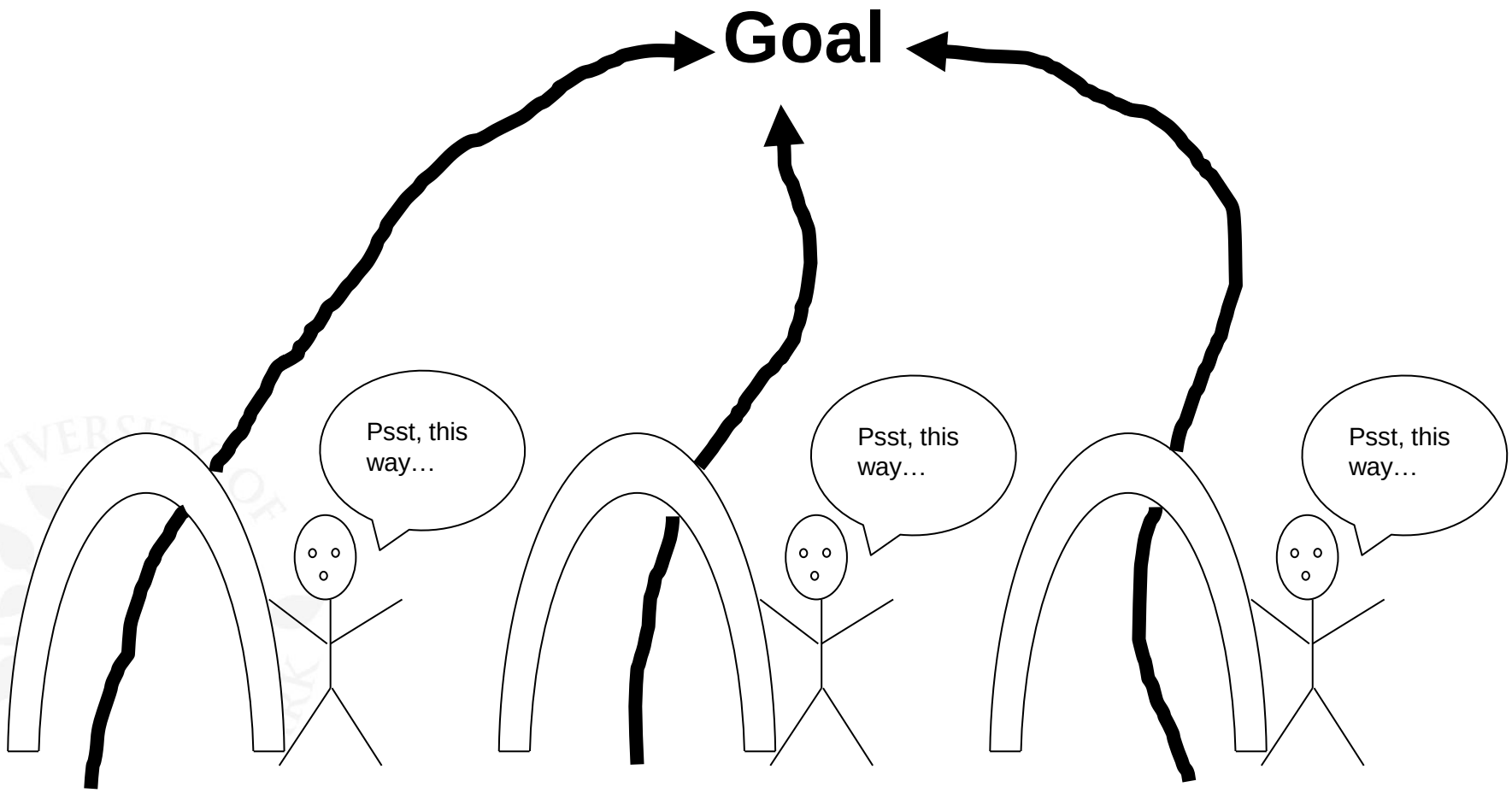

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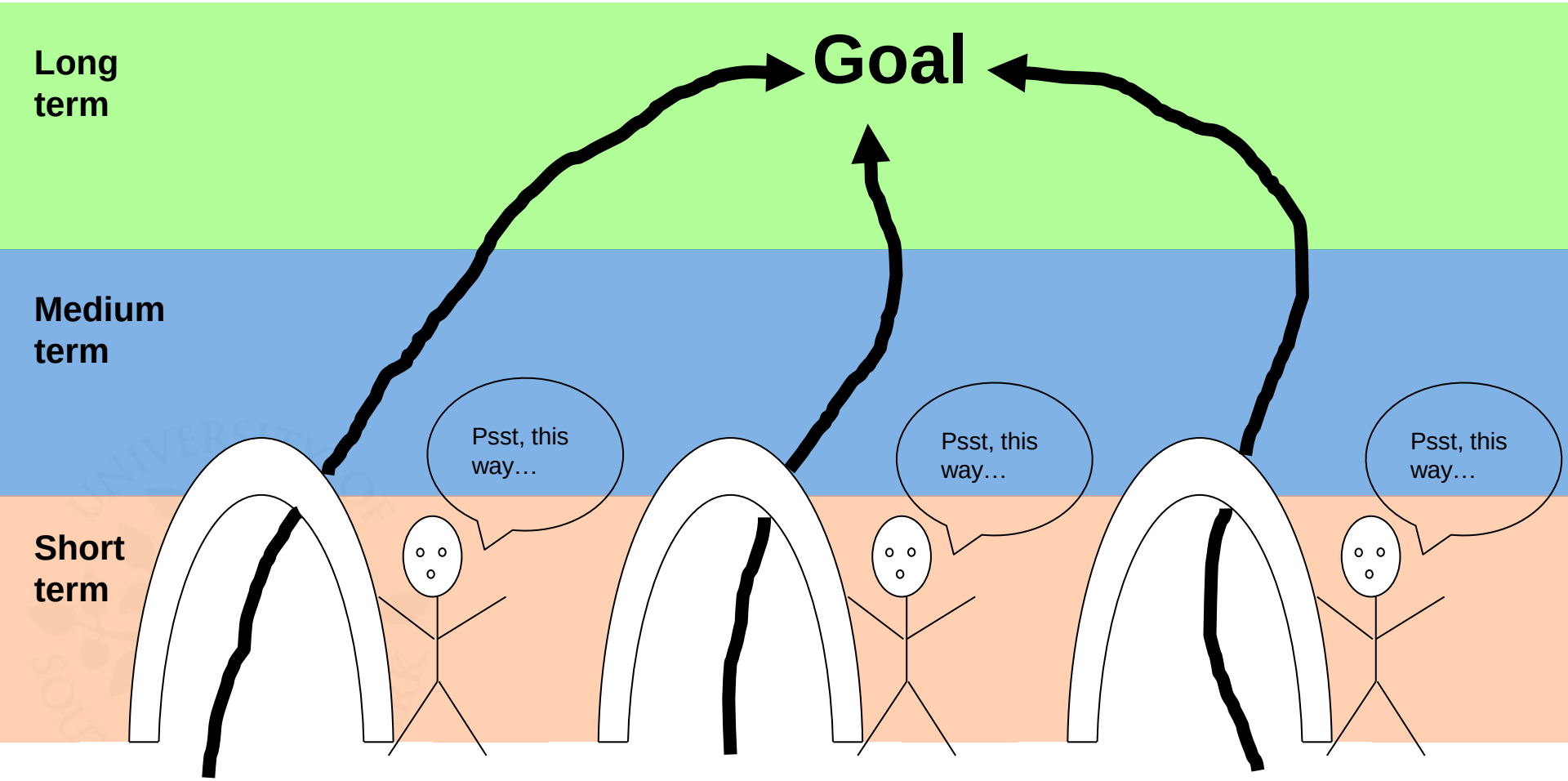

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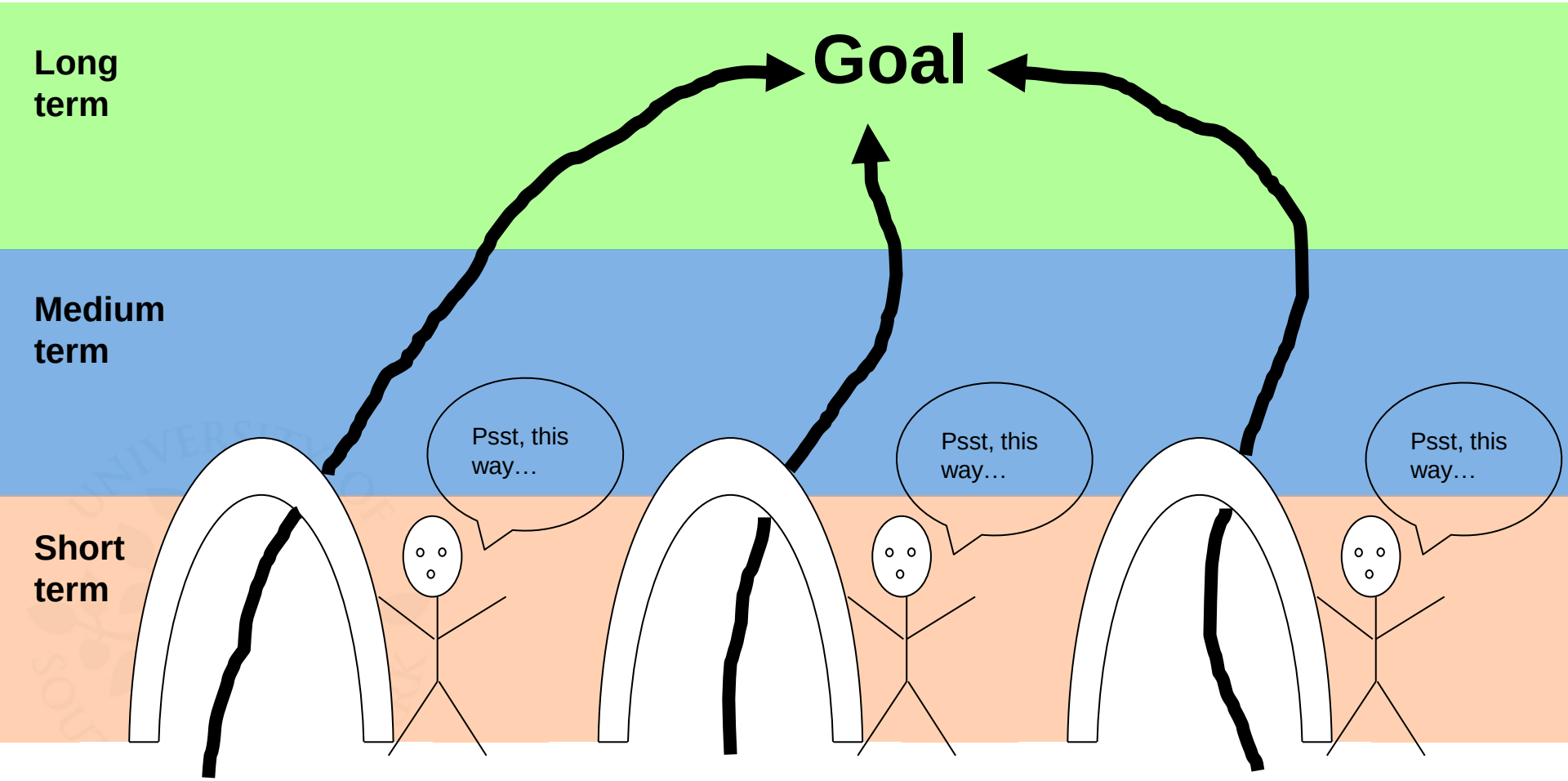

Dilemma: optimal use of biomass on the short and long term is very different

Optimizing use of straw on the short term

- convert or exchange to transport fuels?

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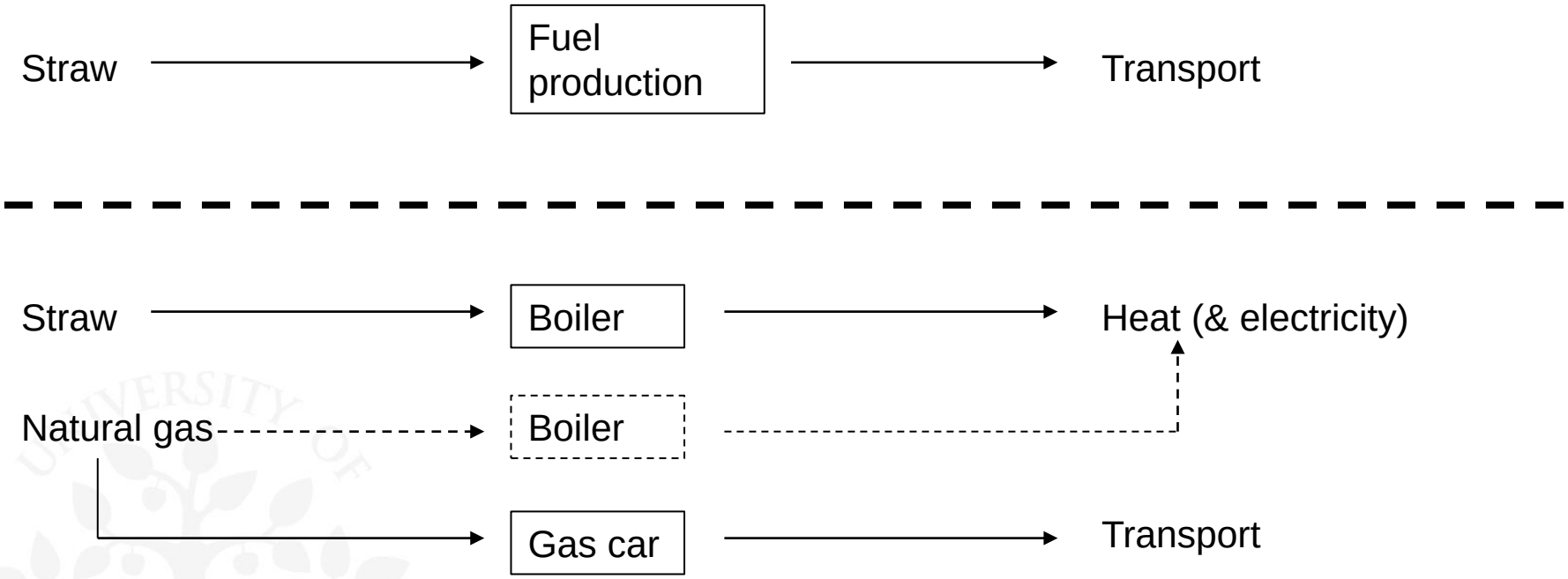

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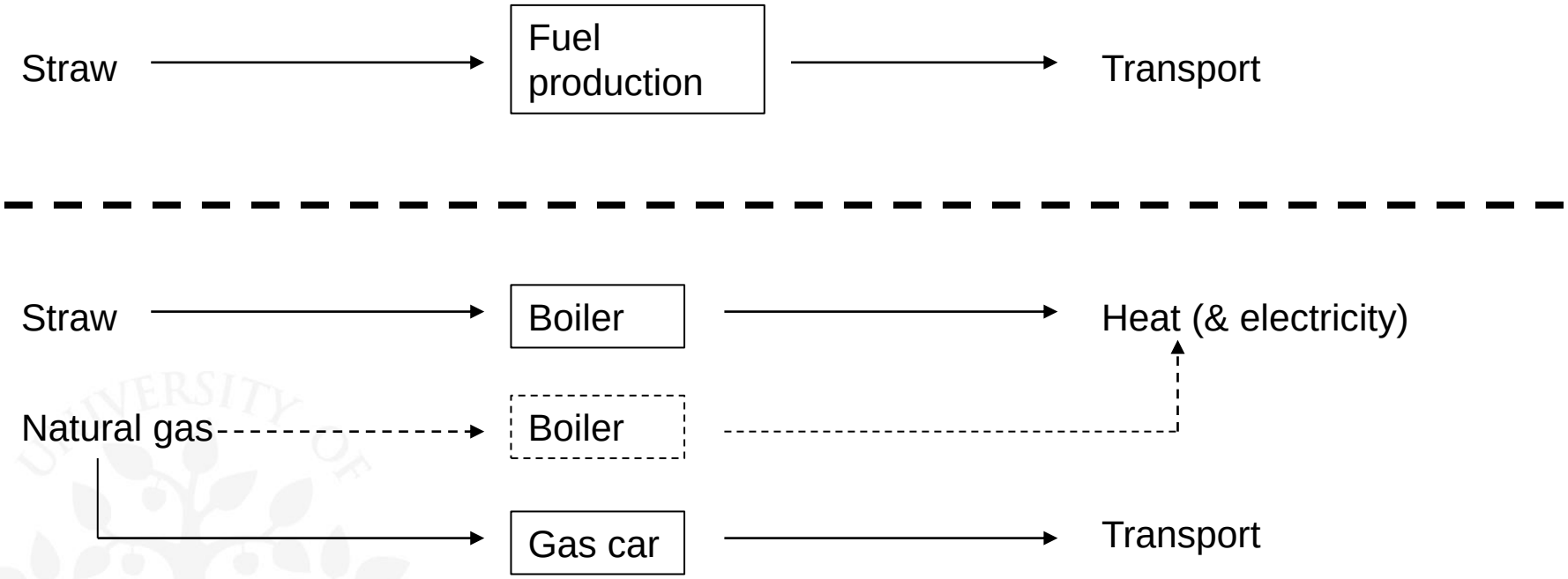

- As long as we can *exchange* straw for natural gas or oil through a boiler, it is much more efficient, both environmentally and economically, compared to *converting* straw to fuels

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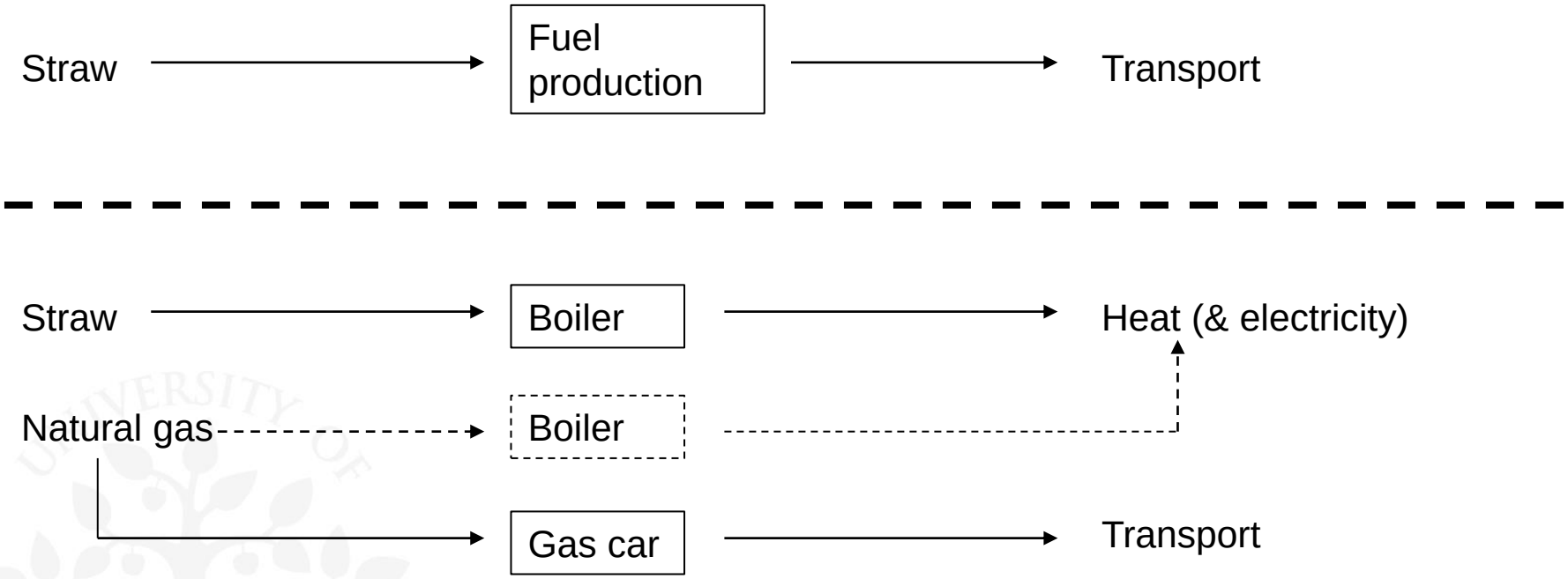
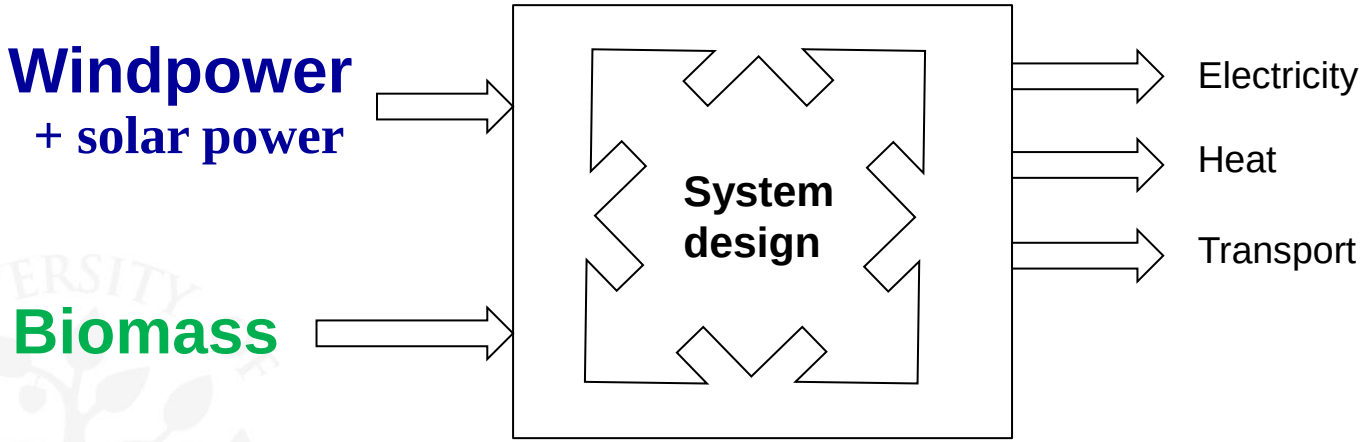


- As long as we can *exchange* straw for natural gas or oil through a boiler, it is much more efficient, both environmentally and economically, compared to *converting* straw to fuels
- But for how long can we do that? And when do we start on the road towards the long term fully renewable system?

Optimizing use of straw on the long term

- how do we design the future renewable energy system?



…and how do we optimize the system's use of bio-energy?

Optimizing use of straw on the long term

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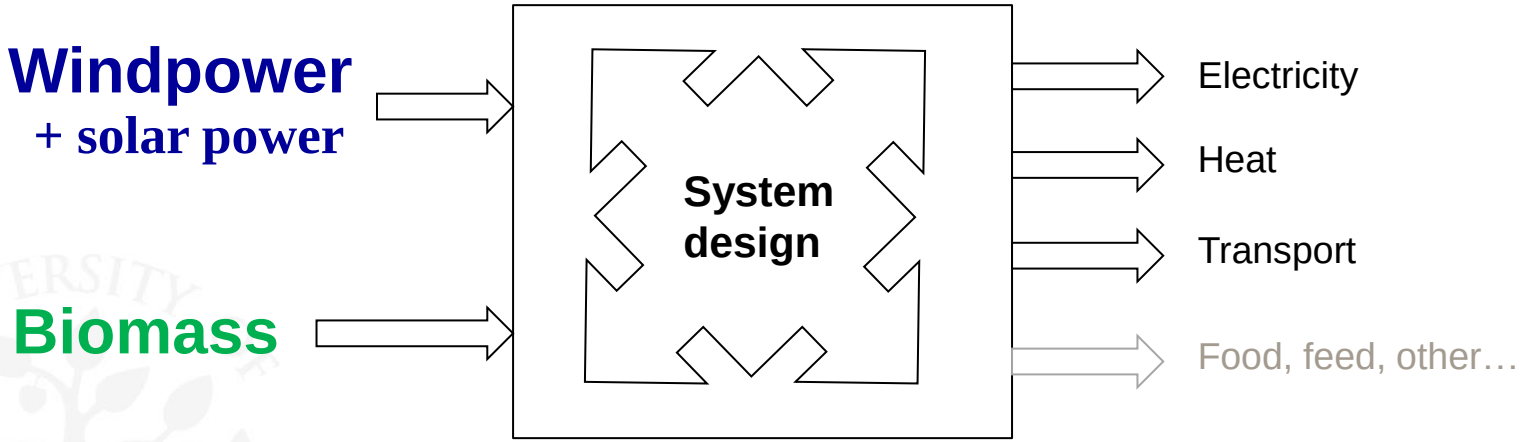

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Renewable energy scenarios

– Danish Energy Agency 2014, energinet.dk 2010, energinet 2015, Climate Commission 2010, IDA 2015, AAU 2011, SDU 2014

3 basic philosophies:

- **Biofuels**
- **Electrification**
- **Hydrogen**

Conv. el-use

Small DH-net

Large DH-net

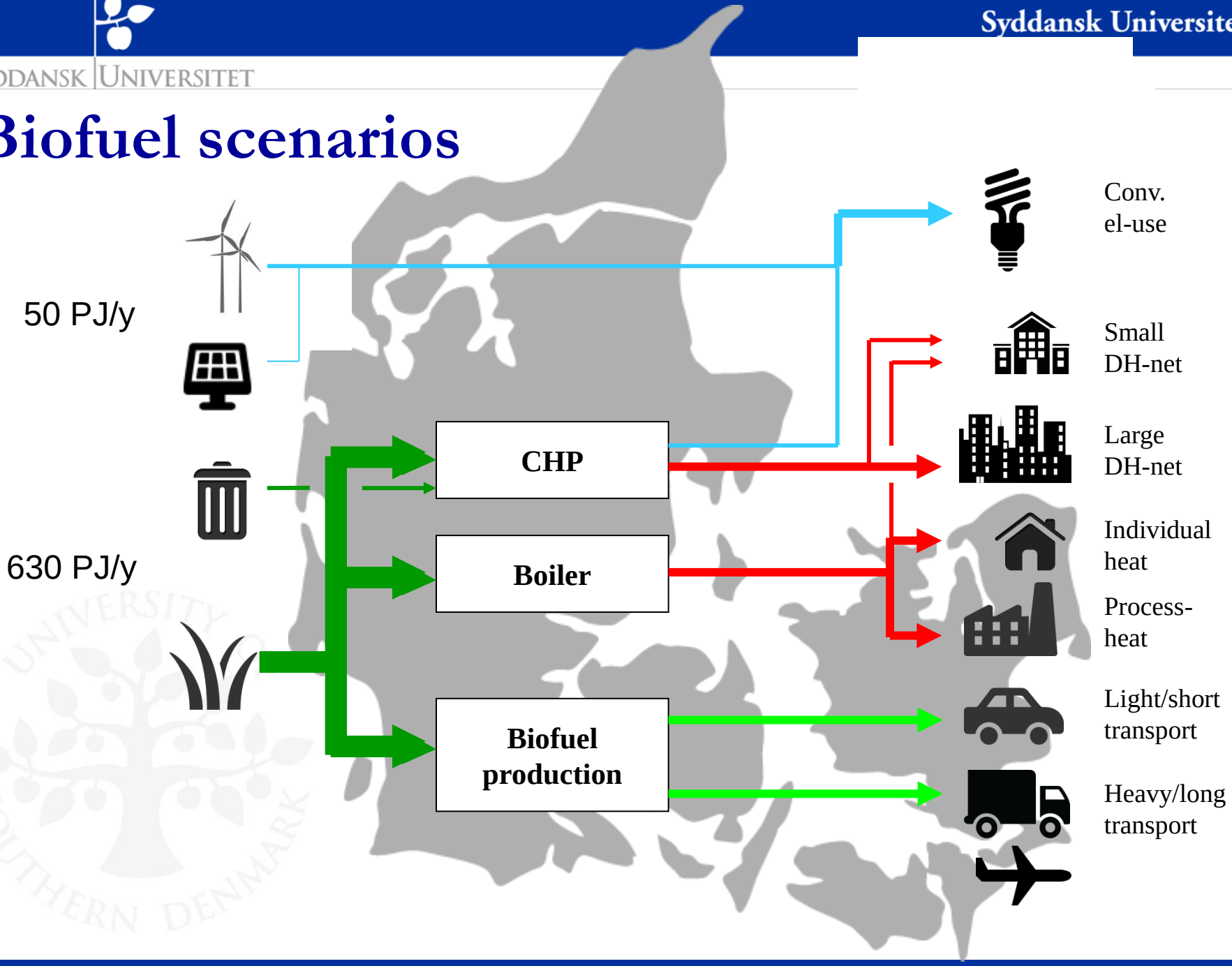
Individual heat

Process-heat

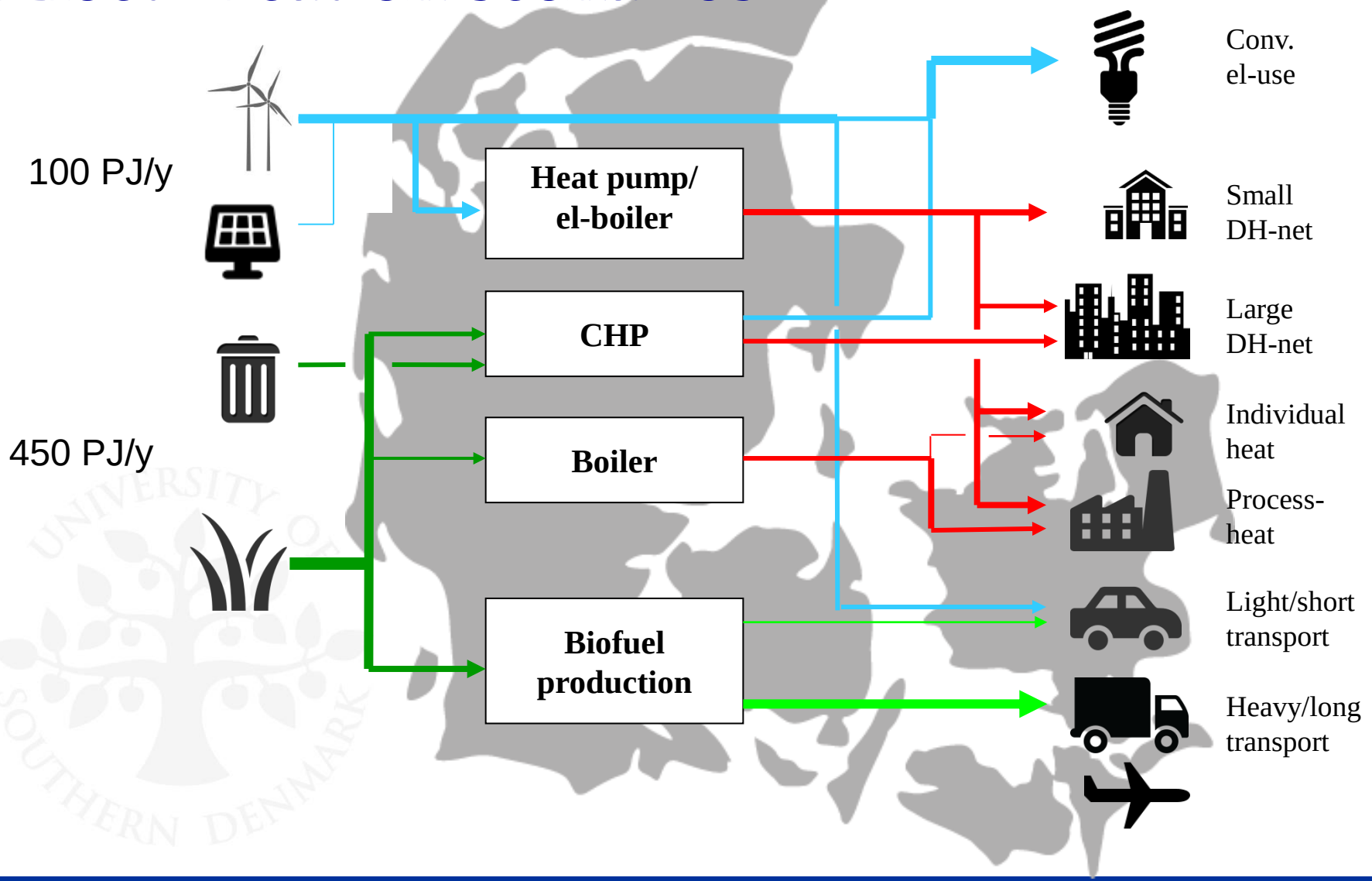
Light/short transport

Heavy/long transport

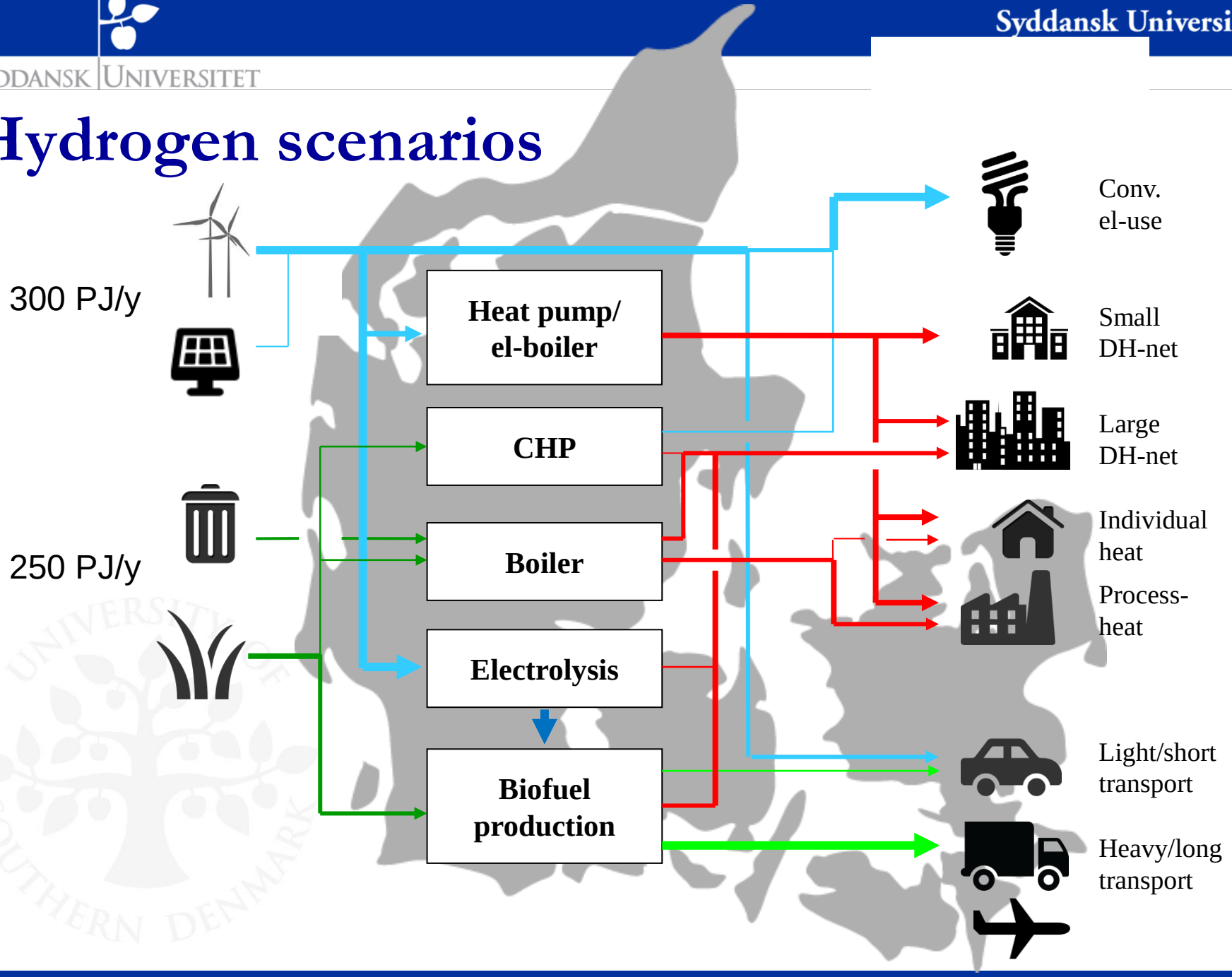
Biofuel scenarios



Electrification scenarios



Hydrogen scenarios



Comparison of key figures

Scenario name	Author	Wind + solar power	Biomass input	Hydrogen	Biomas input/prs/y
		PJ/y	PJ/y	PJ/y	GJ/prs./y
Bio+	ENS	80	738	0	130
Standard Bioenergy	SDU	50	625	0	115
Bio	ENS	120	470	0	85
Electrification	SDU	90	450	0	80
Wind	ENS	250	284	63	50
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IPCC 2011 (Chum et al., 2011):
Global biomass potential = 100-300 EJ/y in 2050 equivalent to 10-30 GJ/person/y

The origin of biomass

- in a global Renewable Energy scenario?

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Plantation on savannah and cerrado is likely at medium biomass consumption increase of 5-10 GJ/person/year (Wenzel et al., 2014: Carbon footprint of bioenergy pathways for the future Danish energy system).

At higher biomass consumtion, plantation on or harvest from forest land may happen

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Eucalyptus harvest

The origin of biomass

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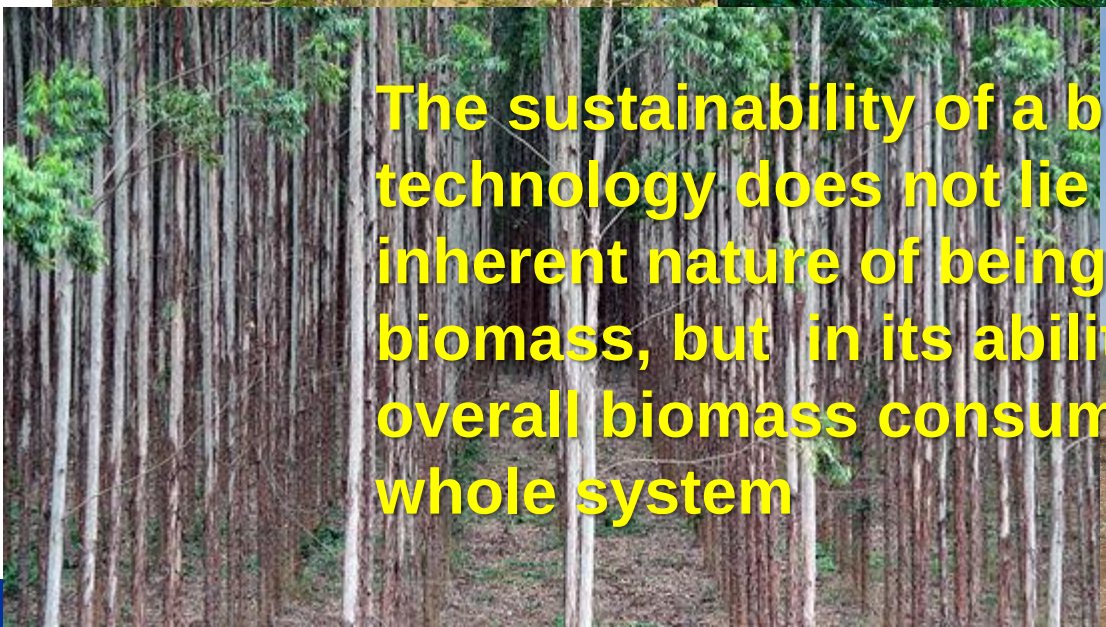
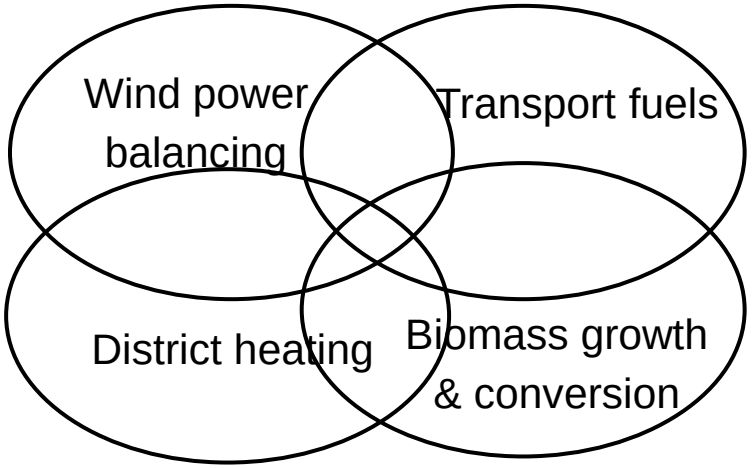


The sustainability of a bio-energy technology does not lie in its inherent nature of being BASED ON biomass, but in its ability to SAVE overall biomass consumption in the whole system

System integration – a key to success

- el, heat, transport and agriculture integration



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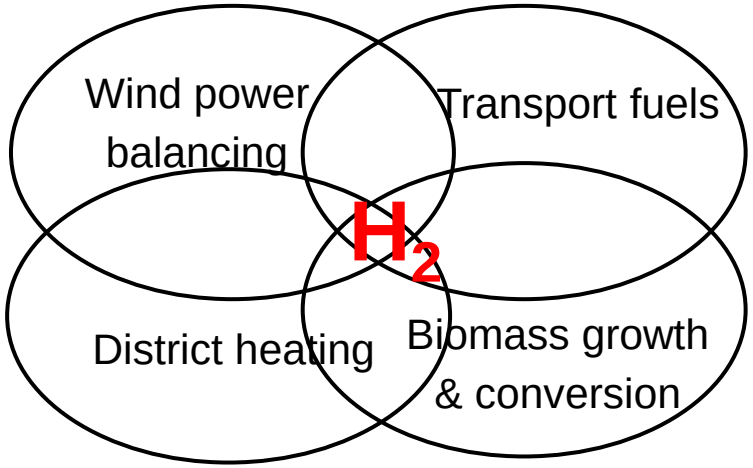

Succes criteria for the use of biomass

- in a fully renewable energy system

In general

1. Respect an overall prioritization of biomass and land: 1) Food/feed, 2) Materials/chemicals, 3) Some transport fuels, 4) Stand-by electricity for wind and solar power, 5) Some industrial process heat
2. Match conversion process to the inherent character of the biomass: 1) wet and easily degradable biomass, suitable for fermentation, 2) dry and hard degradable biomass, suitable for incineration/gasification
3. Make room for wind and solar power: up to 250 – 300 PJ/year = 45-55 GJ/person/year for DK
4. Integrate hydrogen, keep biomass consumption below 40 GJ/person/year

System integration of co-products from conversion processes

5. Utilize process heat from: 1) biomass conversion, 2) hydrogen production, 3) fuel production
6. Create flexibility – between fuel production, industrial process heat, district heating and stand-by electricity production
7. Ensure synergy with agriculture:
    1. Cropping optimization and co-production of food/feed and energy (e.g. clover refining)
    2. Co-substrate for biogas – avoid losing manure biogas potential
    3. Return nutrients to soil (N, P, K)
    4. Return degradable carbon (C) to soil

Criteria for a sustainable RE system

- comparison of ethanol and biogas

Systemintegration success criteria	Upgraded biogas (CH4)	Ethanol
Cost of production (CAPEX + OPEX)	130 DKK/GJ	230 DKK/GJ
Wind power integration	+	-
Integrate hydrogen	+	-
Utilize process heat	+	-
Create flexibility – transport fuel – el – industri	+	-
Create synergy with agriculture	+	-
- N, P, K og C	+	-
- Co-substrat til gyllebiogas	+	-
GHG proces emissioner	-	+

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Integration of wind and hydrogen

- Methane, CH_4, assimilates 4 hydrogen per carbon, ethanol assimiltaes, C_2H_5OH, assimilates 2 hydrogen per carbon (the rest is H_2O)

- CO_2 is easily available from biogas. In fact, it is available in a pure stream from biogas upgrading

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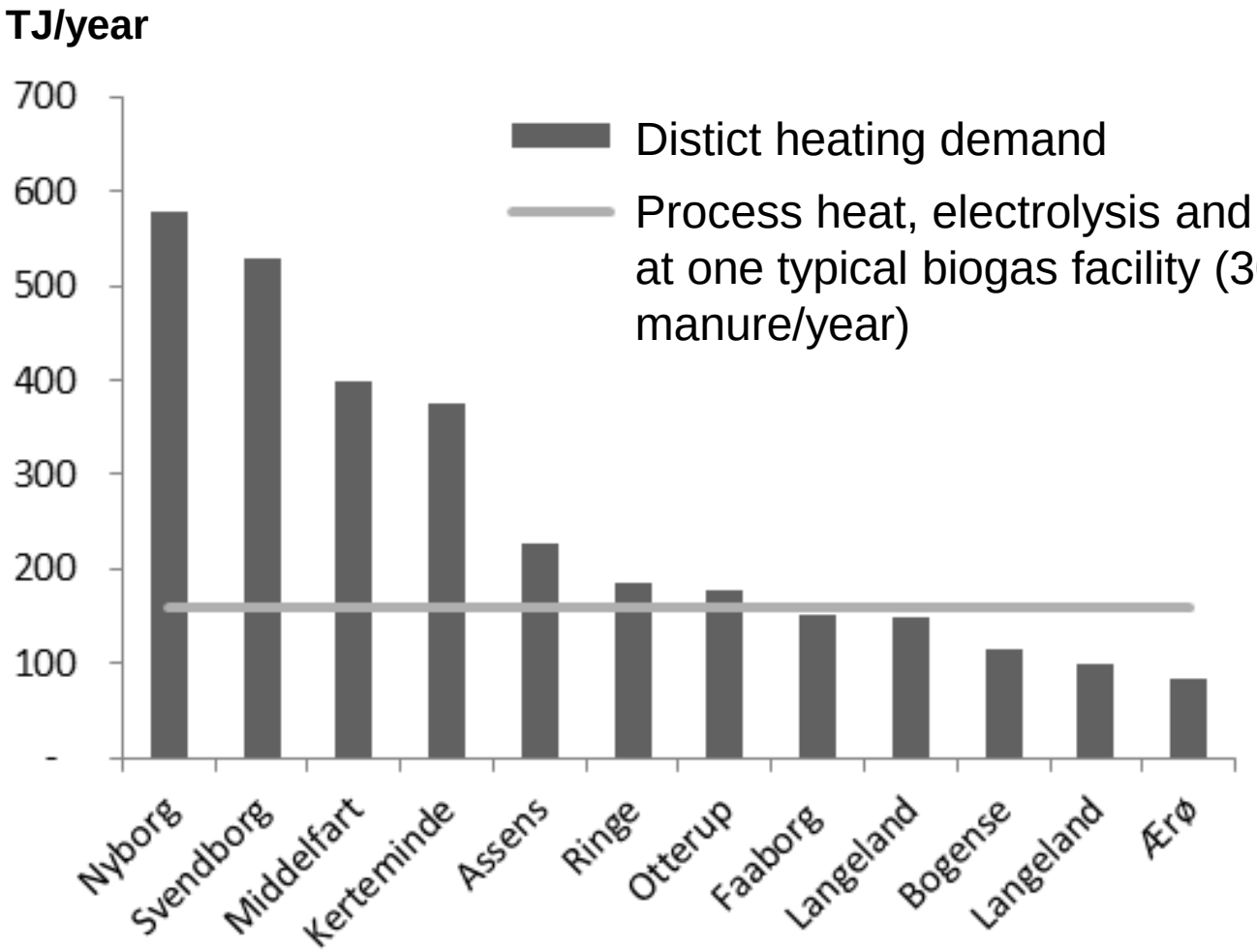
Integration of process heat, Funen DK

- from electrolysis (alcaline) and methanation of biogas CO_2



District heating system on the Island of Funen, DK

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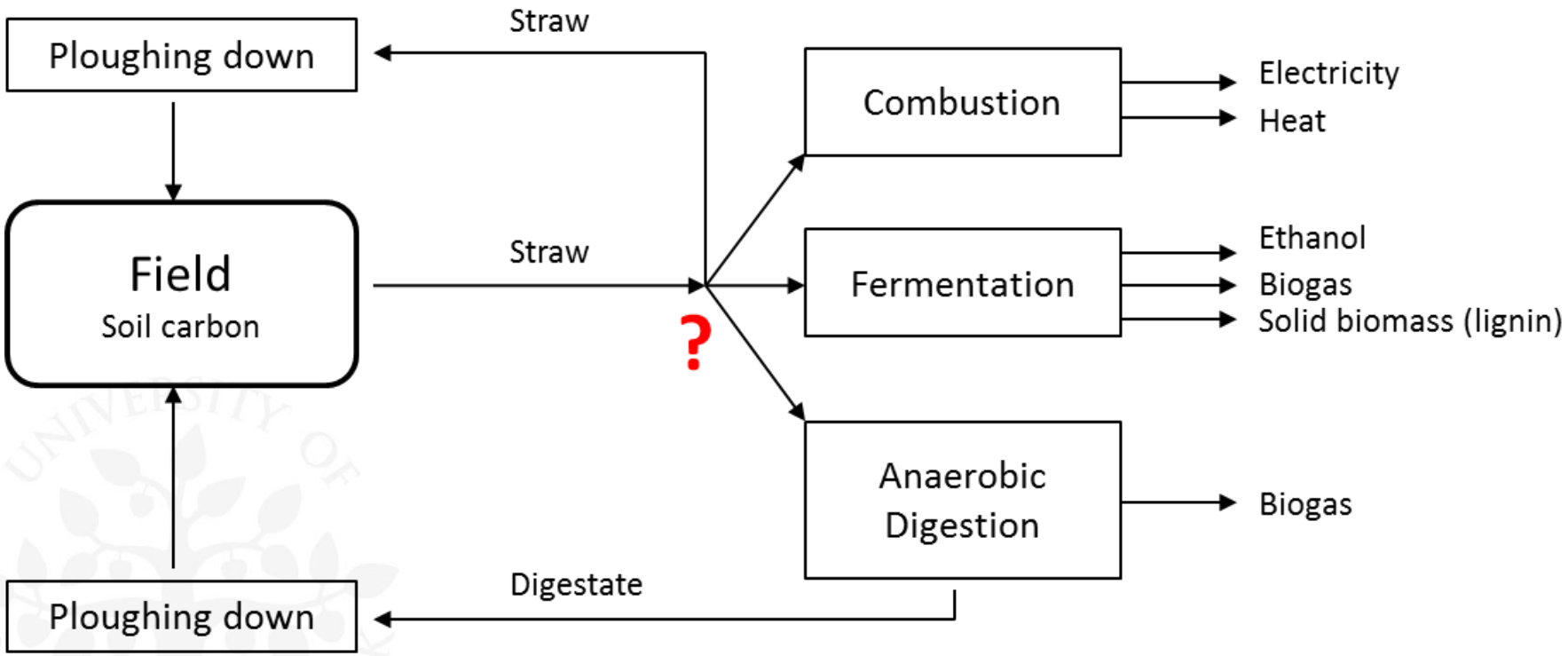
Synergy with agriculture



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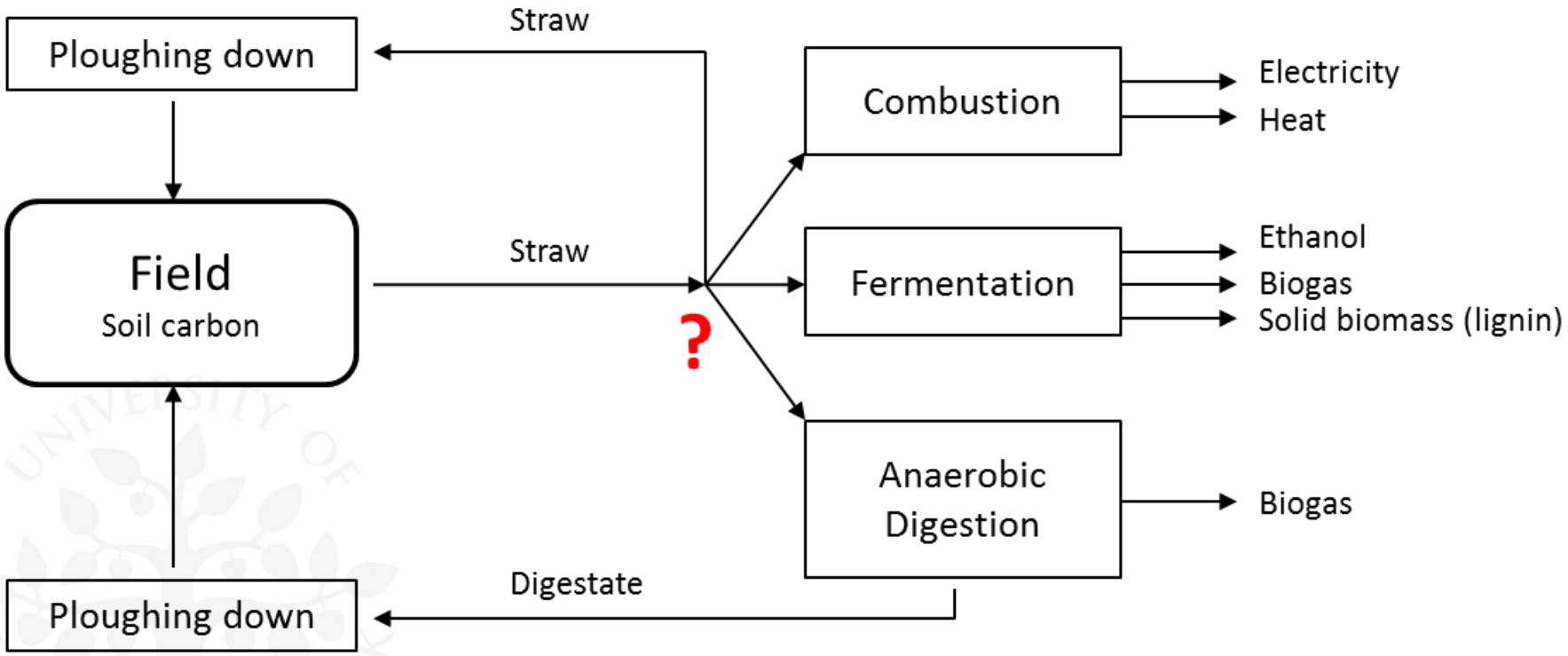

If the SAME soil carbon level is to be maintained, the amount of straw for biogas is 4 times higher than the amont of straw for CHP or 2G ethanol, where NO carbon is returned to soil (ongoing reasearch, J.H. Hansen, SDU)

Conclusion

- on prioritizing straw for renewable energy

- Short term: substitute fossil fuels for heat and/or electricity. But in a fully renewable system, biomass for heat and power leads to excessive biomass demands. Will new investments have enough time for pay-back?
- Long term: Prioritize straw for biogas:
  - Cheapest renewable transport fuel
  - Supports manure biogas
  - Maximum integration of hydrogen and wind/solar power
  - Best integration of heat co-products
  - Best flexibility between fuel production, stand-by electrivity, industry process heast supply
  - Best integration with agriculture
- 2G ethanol does not seem justified in the short term nor the long term

Thanks for the attention!