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LIFE CYCLE ENGINEERING

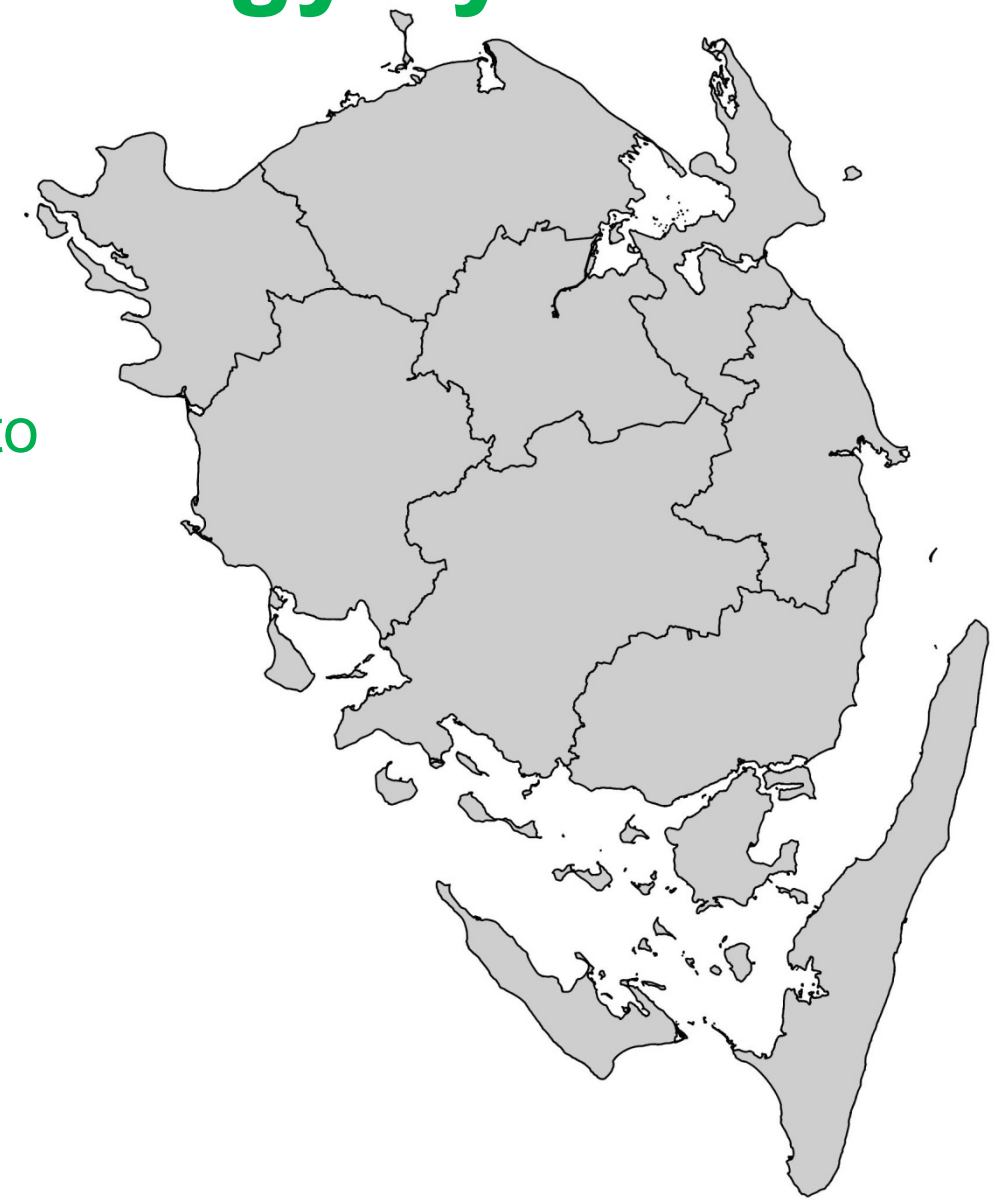
The carbon balance of techo-sphere

Henrik Wenzel, Professor SDU

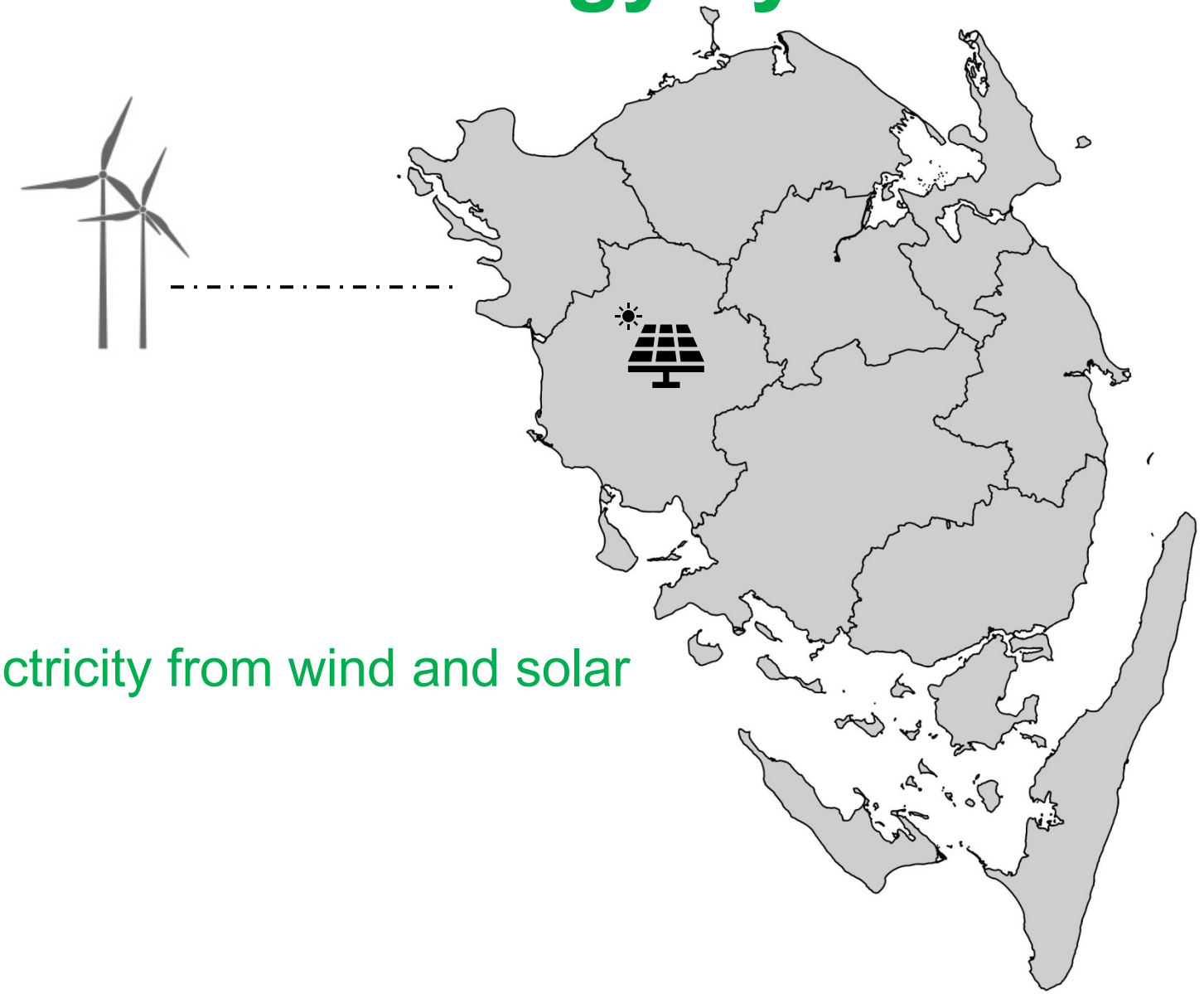
Climate Thursdays
Thursday, October 12th, 2023

The future energy system – the basics

Let us use this model of the world to illustrate the points

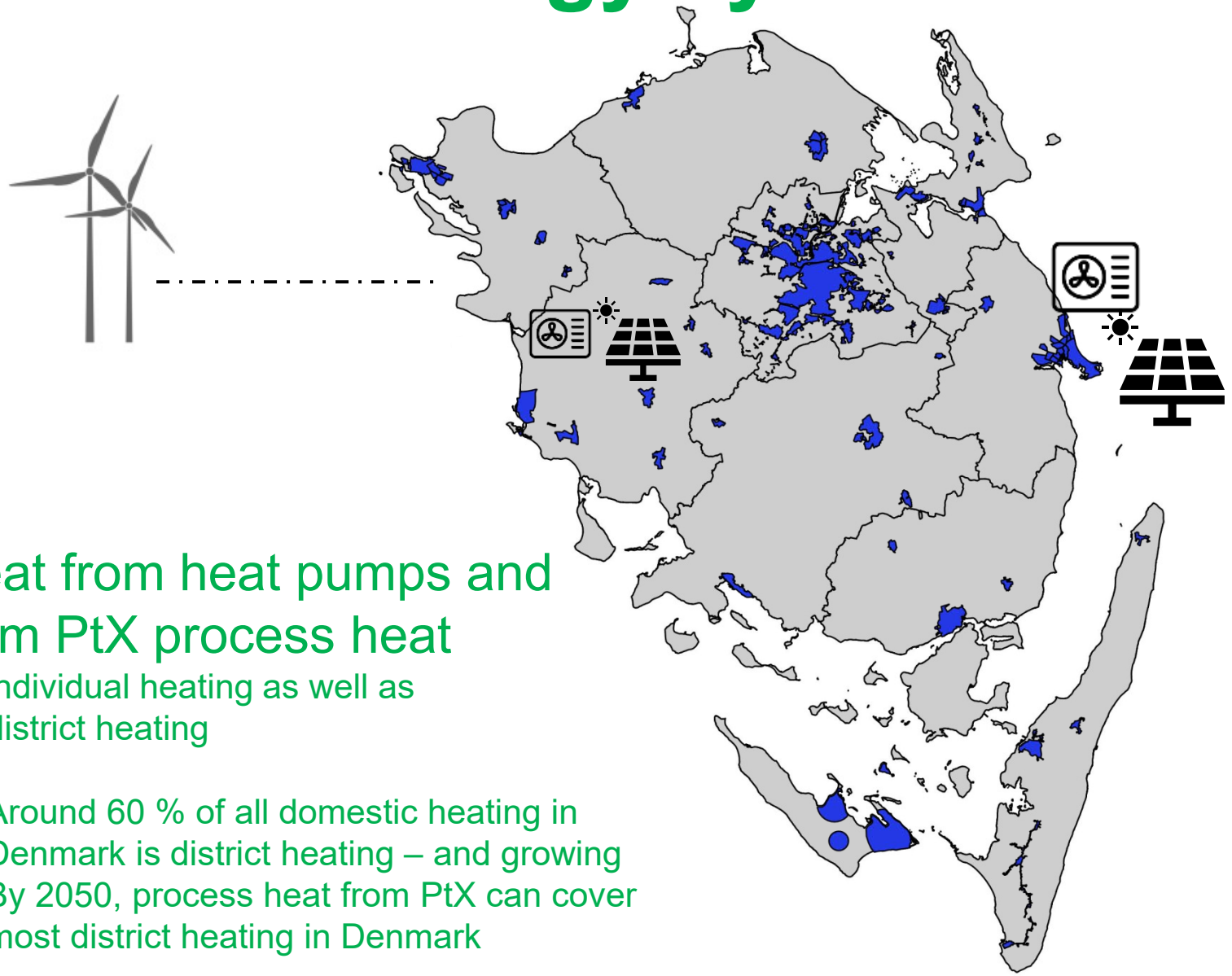


The future energy system – the basics



Electricity from wind and solar

The future energy system – the basics



Heat from heat pumps and from PtX process heat

- individual heating as well as
- district heating

- ❑ Around 60 % of all domestic heating in Denmark is district heating – and growing
- ❑ By 2050, process heat from PtX can cover most district heating in Denmark

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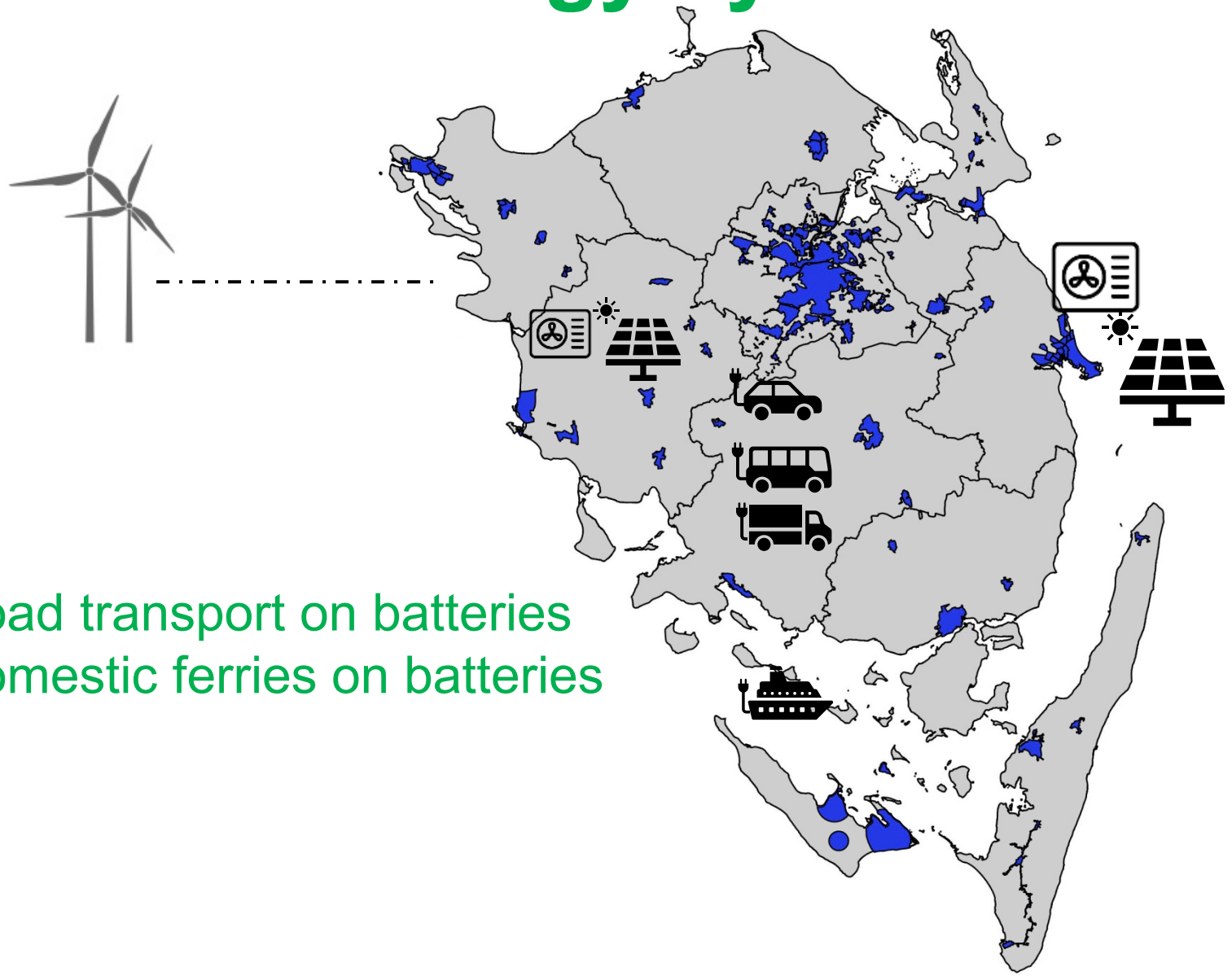
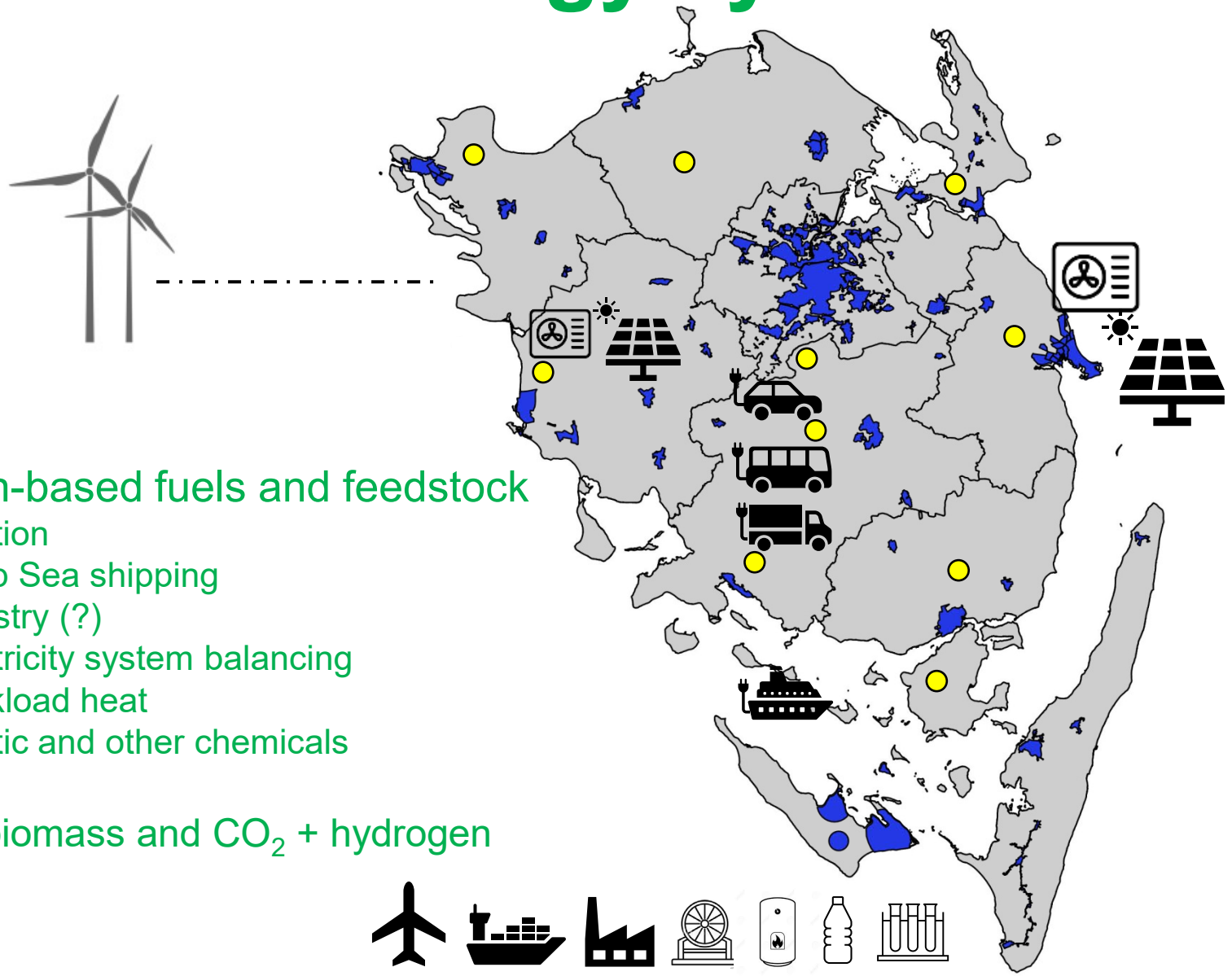


Road transport on batteries
Domestic ferries on batteries

The future energy system – the basics



Carbon-based fuels and feedstock

- ❑ Aviation
- ❑ Deep Sea shipping
- ❑ Industry (?)
- ❑ Electricity system balancing
- ❑ Peakload heat
- ❑ Plastic and other chemicals

- from biomass and CO_2 + hydrogen

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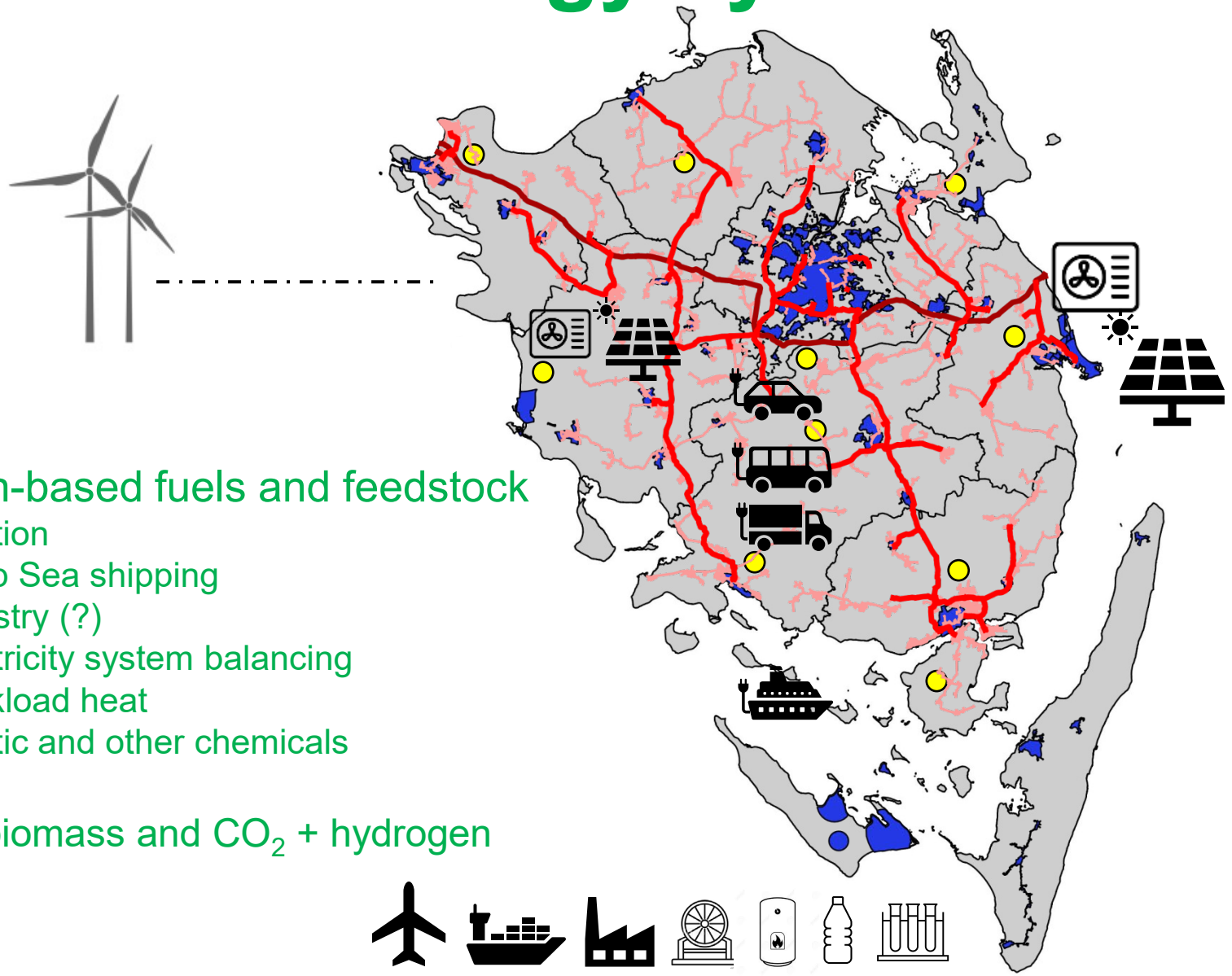

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Demand for carbon-based substances (fuel and feedstock) ≈ one third of energy and materials system

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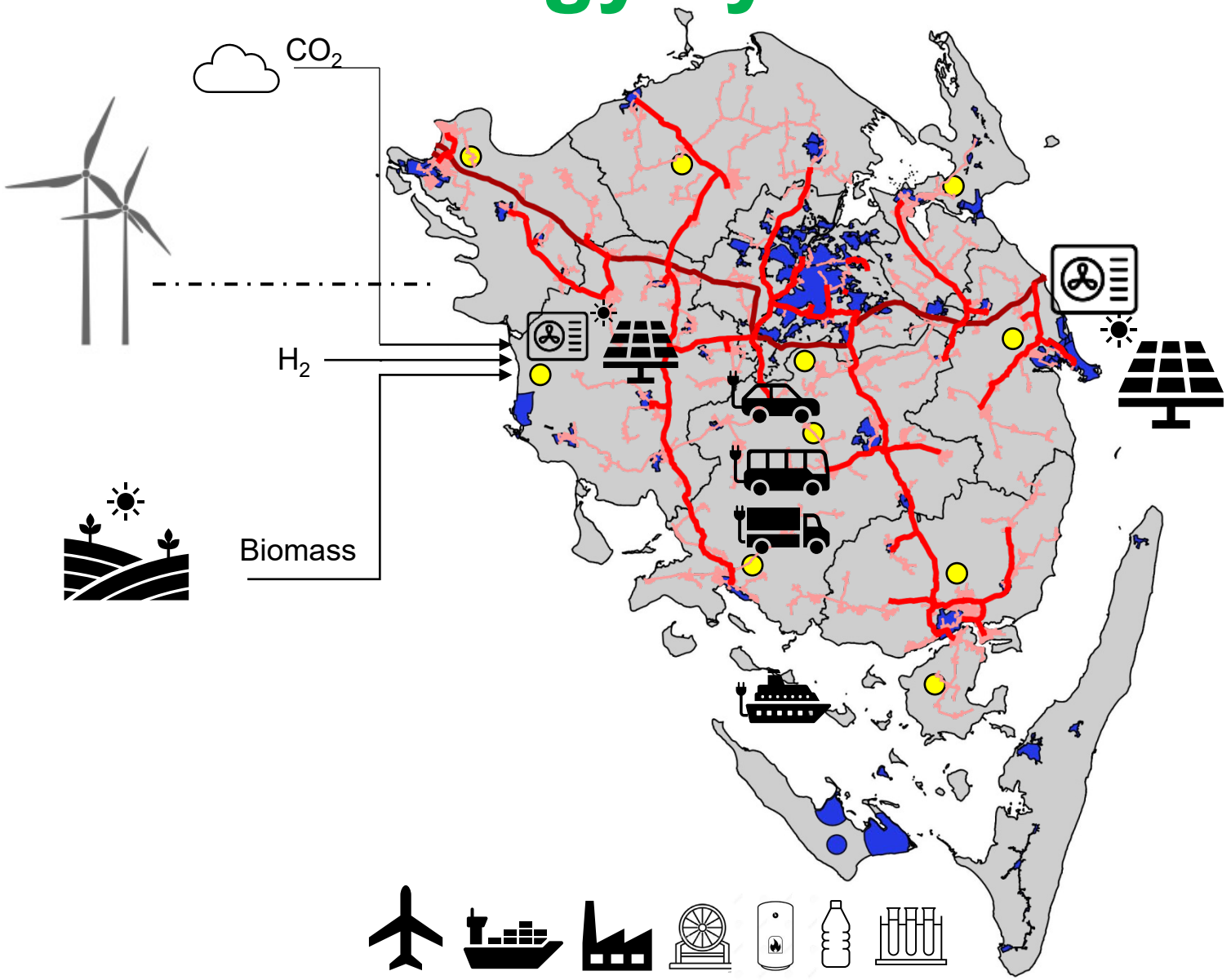

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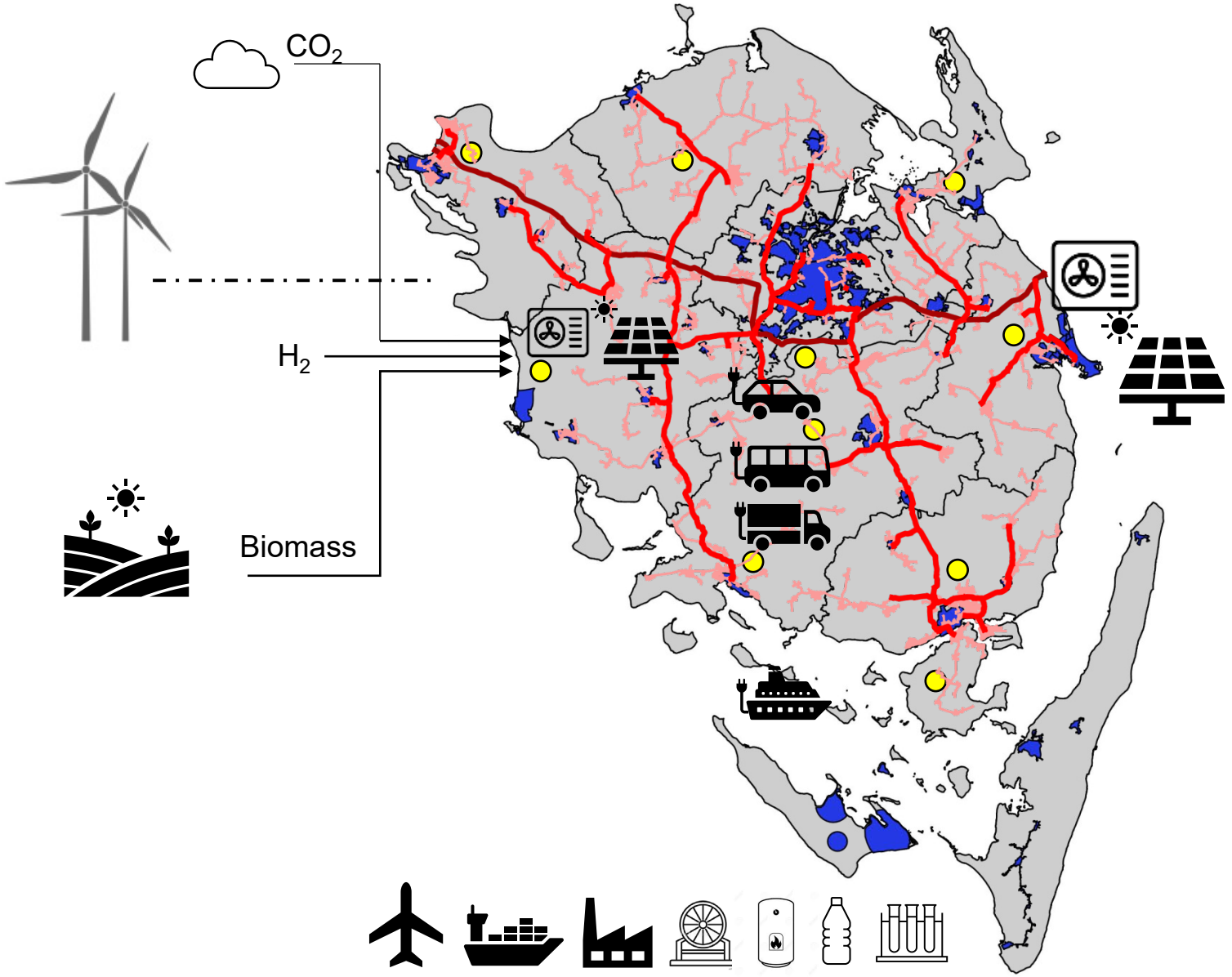
The sector integration



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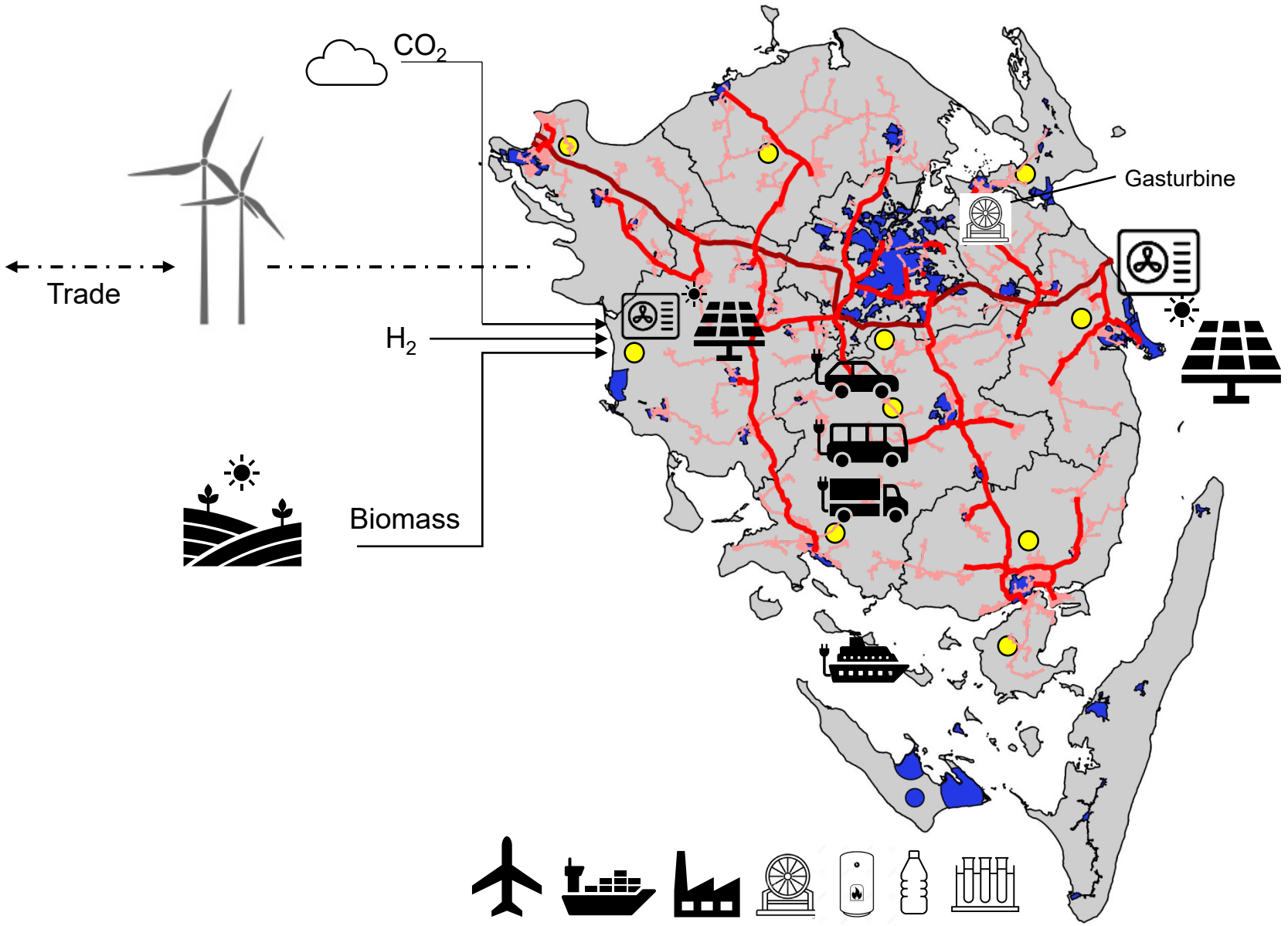

1. The electricity sector

1.1 Trade – incl. Norwegian hydropower

1.2 At low wind, flexible supply: Gas turbines – running on biogas, bio-methane and/or e-methane

1.3 At high wind, flexible demand:

- Battery electric vehicles
- Heat pumps
- Hydrogen production
- Electric boilers
- Curtailment

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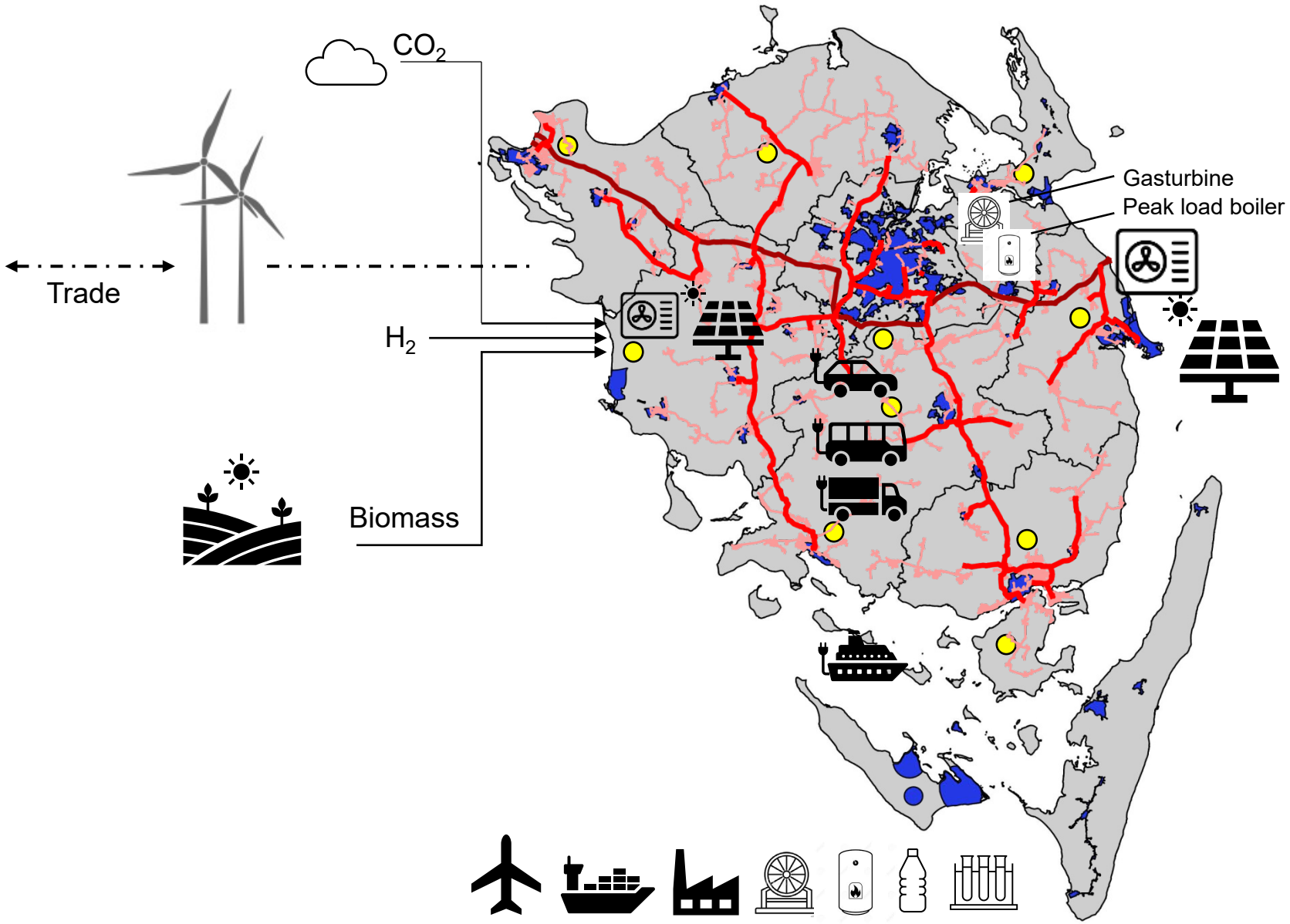
The sector integration

2. The heat sector

2.1 Peak load boiler for the coldest days

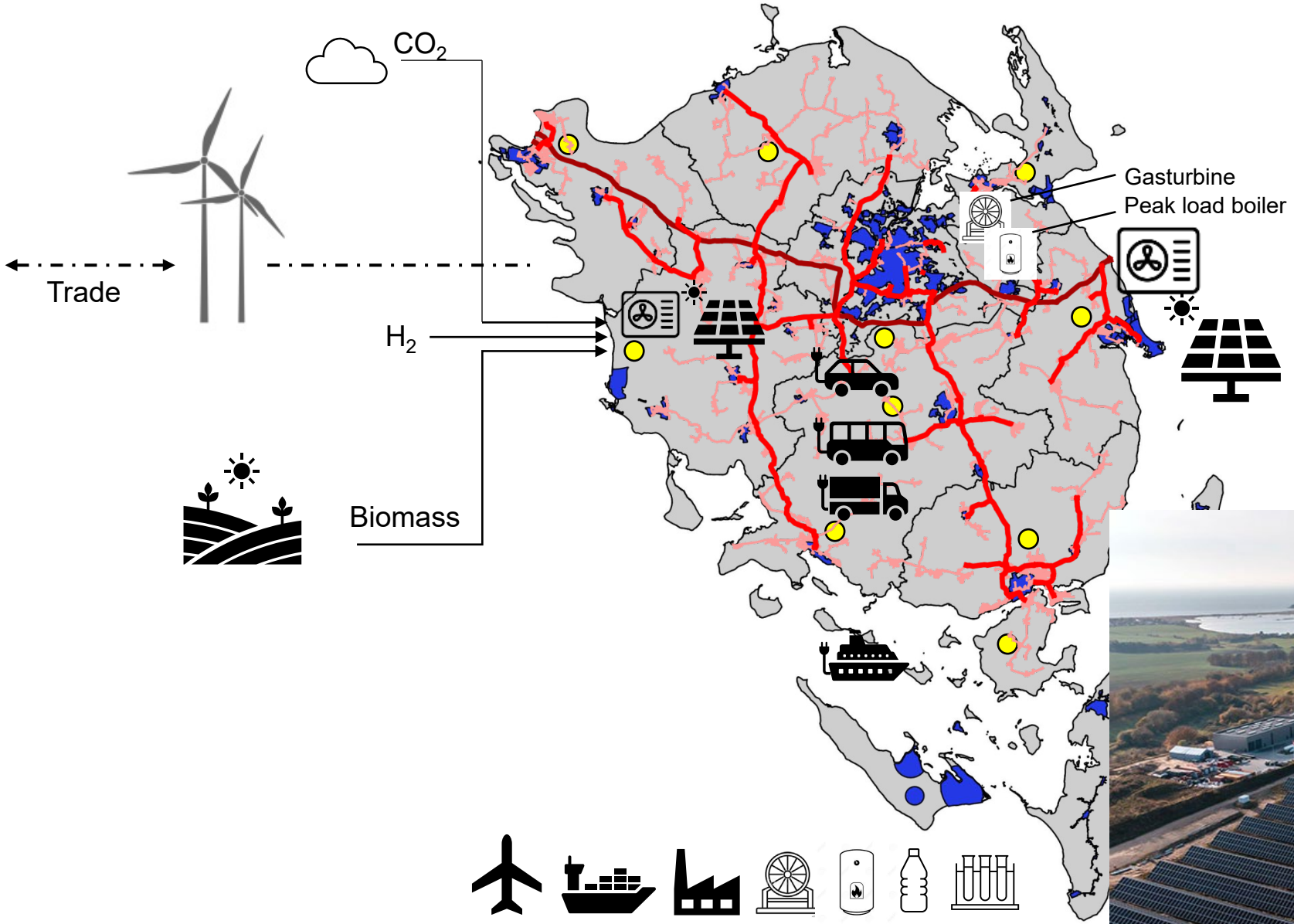


The sector integration

2. The heat sector

2.1 Peak load boiler for the coldest days

2.2 Combining solar park, wind turbine(s), large heat pump and heat storage => cheap and attractive district heating



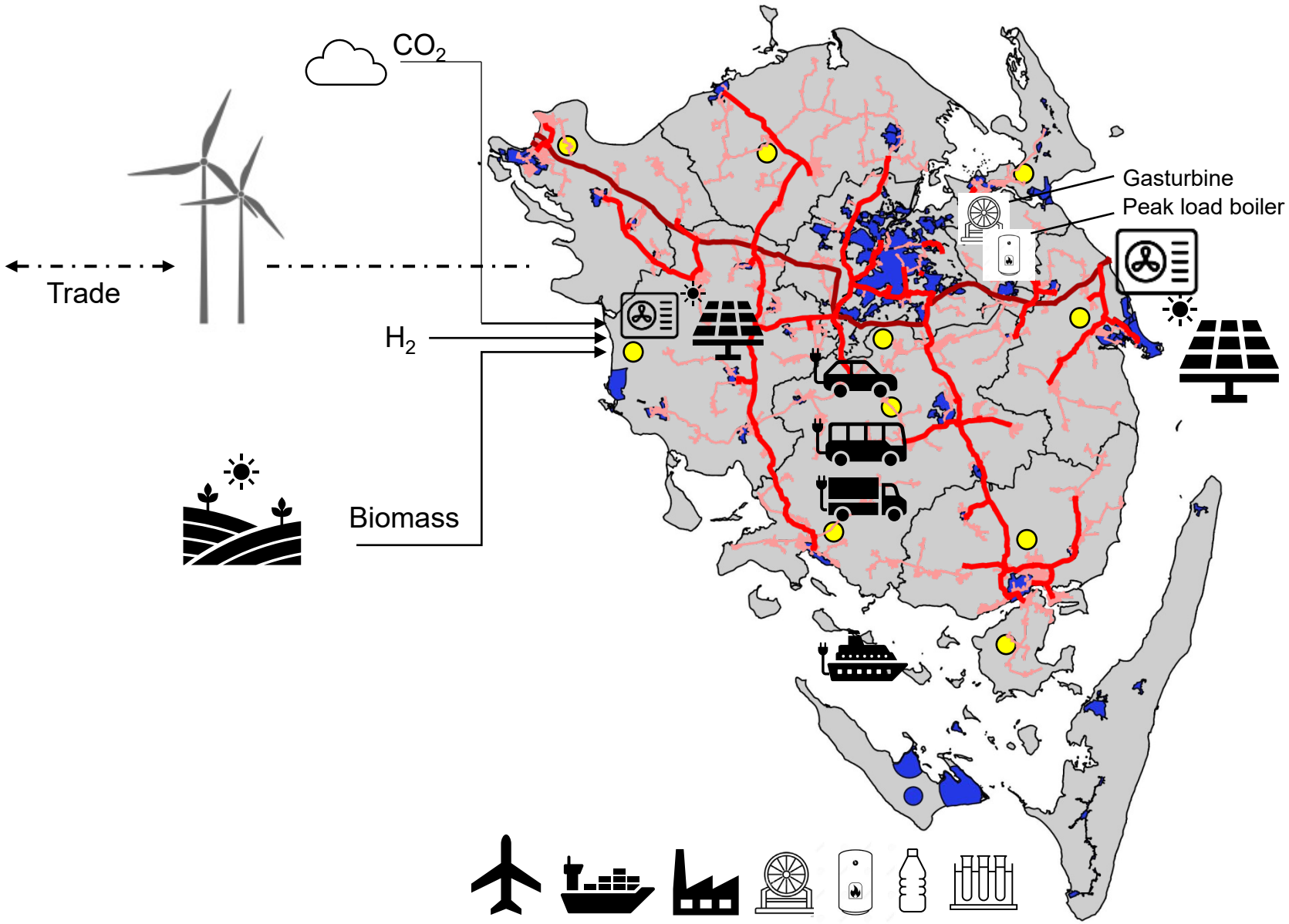
The sector integration

2. The heat sector

2.1 Peak load boiler for the coldest days

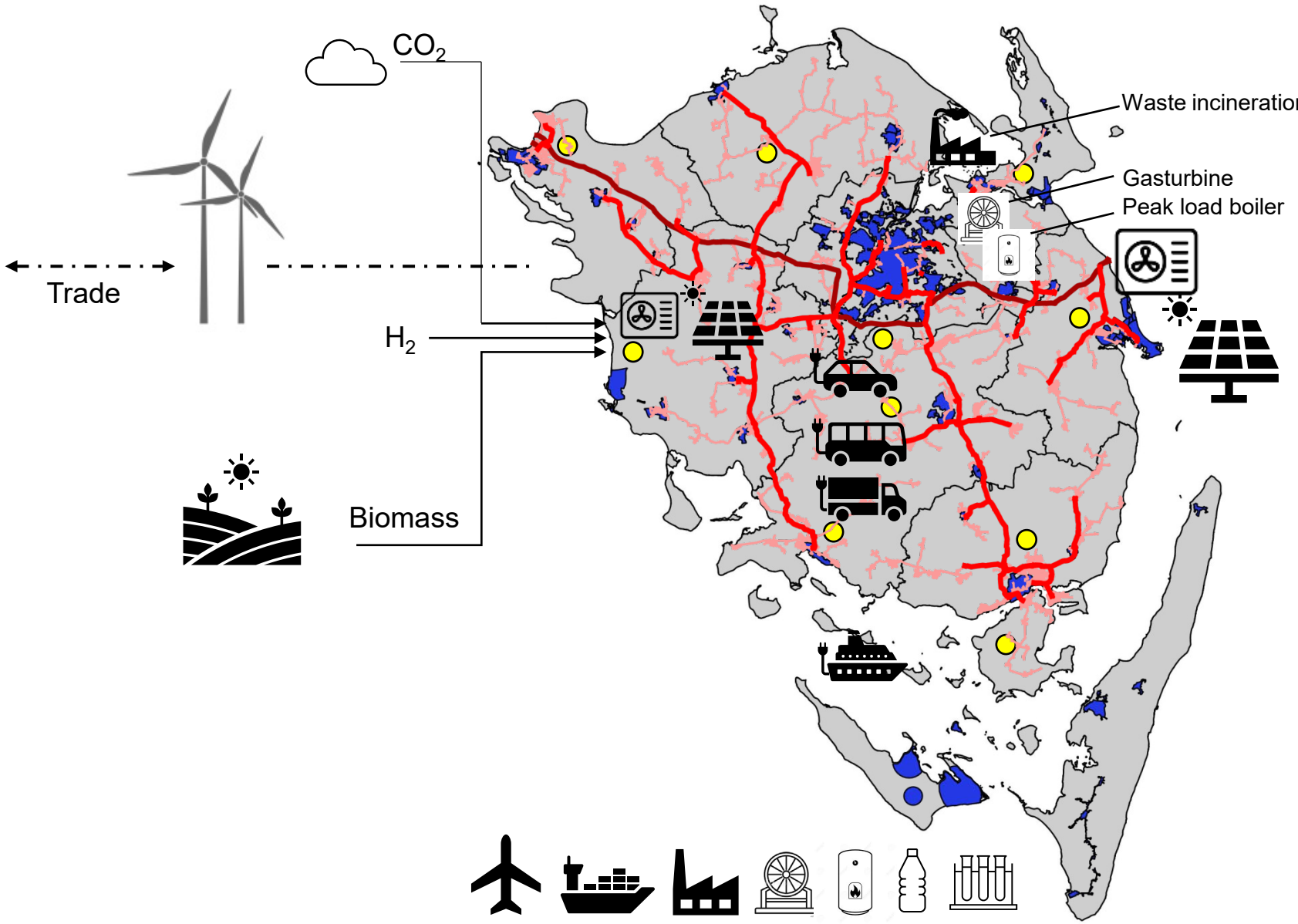
2.2 Combining solar park, wind turbine(s), large heat pump and heat storage => cheap and attractive district heating

2.3 Integrating waste heat from industry, data centers and – most importantly – PtX



The sector integration

3. Waste management, plastic and fuel production



3.1 Process integration of CO_2, heat, carbon capture and hydrogen production

3.2 Waste sorting incl. making a storable waste-based fuel (RDF) => burn only waste in the winter season => room for PtX heat

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The sector integration

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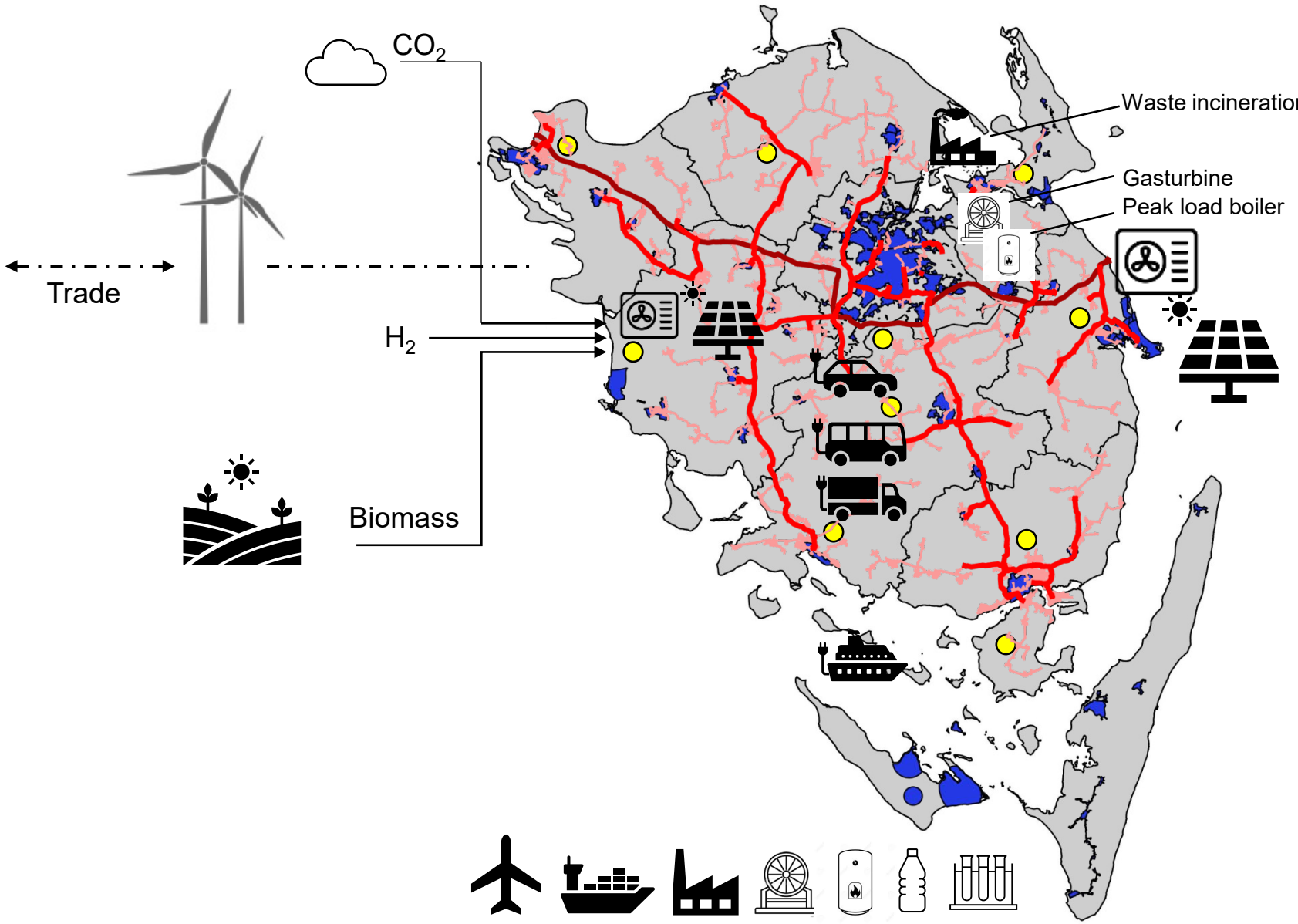

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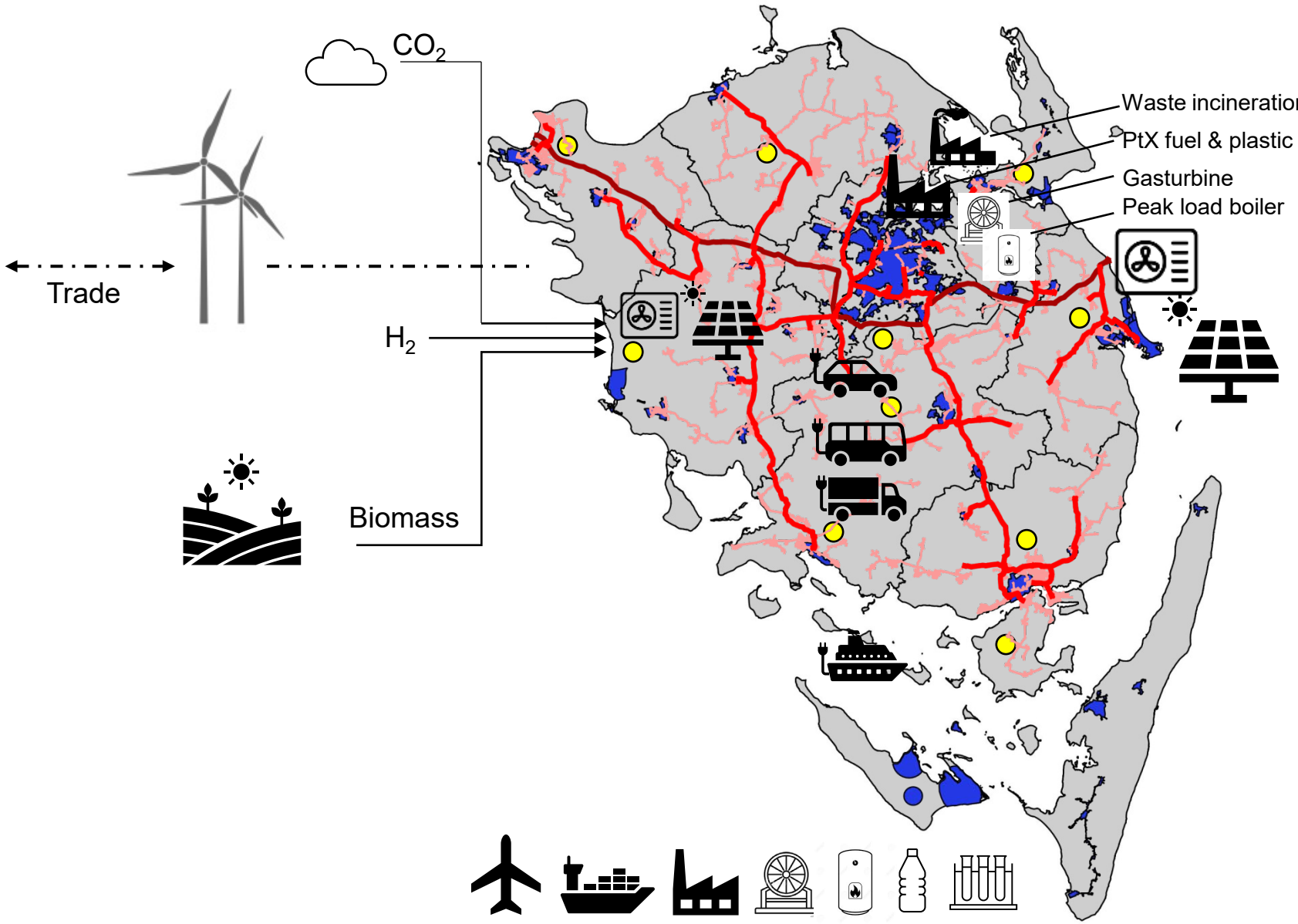

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3.2 Waste sorting incl. making a storable waste-based fuel (RDF) => burn only waste in the winter season => room for PtX heat

3.3 Burn waste in pure oxygen (oxyfuel combustion) from electrolysis => cheaper carbon capture

3.4 Co-production of PtX aviation fuel and naphta for plastic from waste-CO_2 => allow burning the dirtiest plastic, closing the plastic system fully

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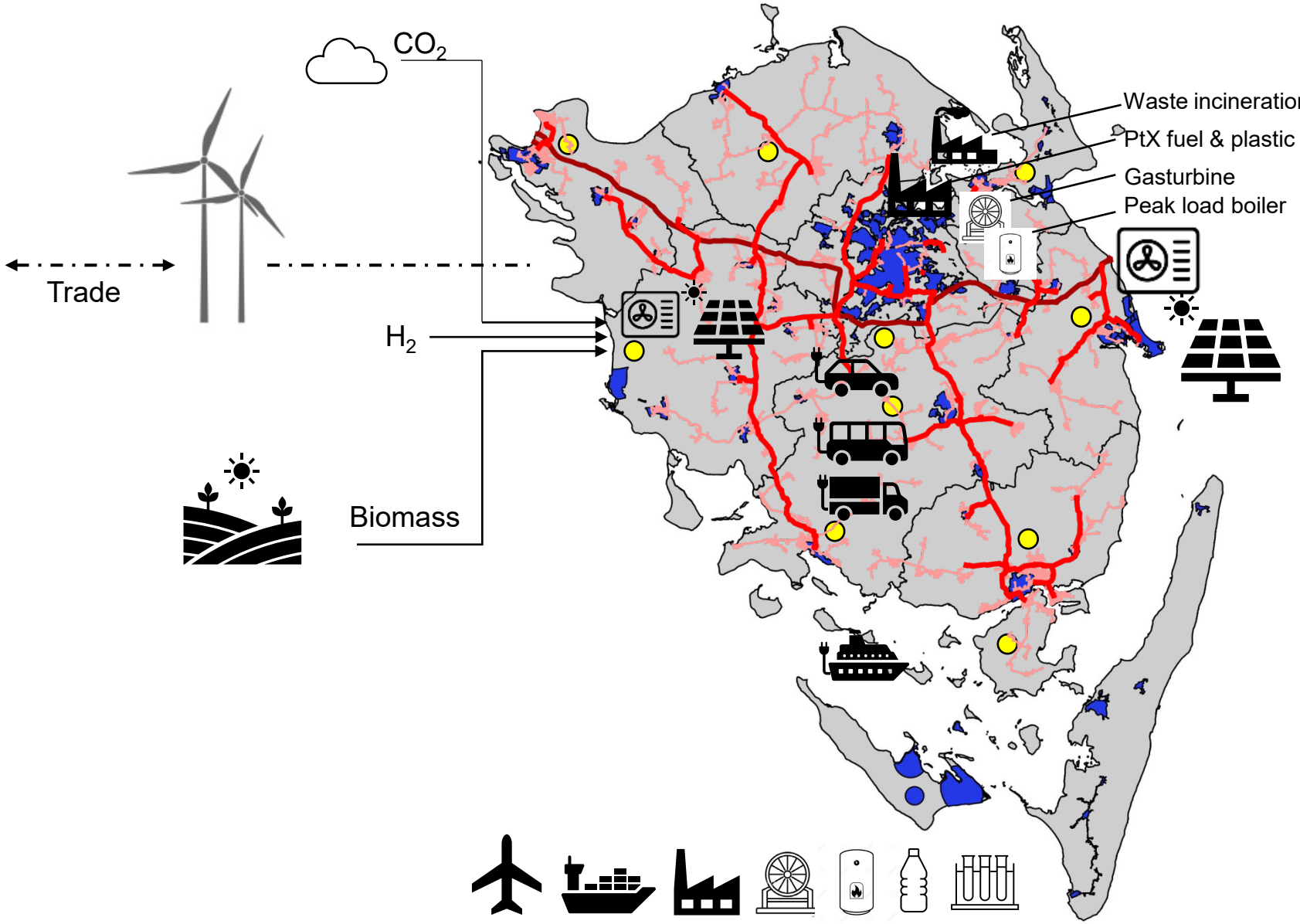
The sector integration

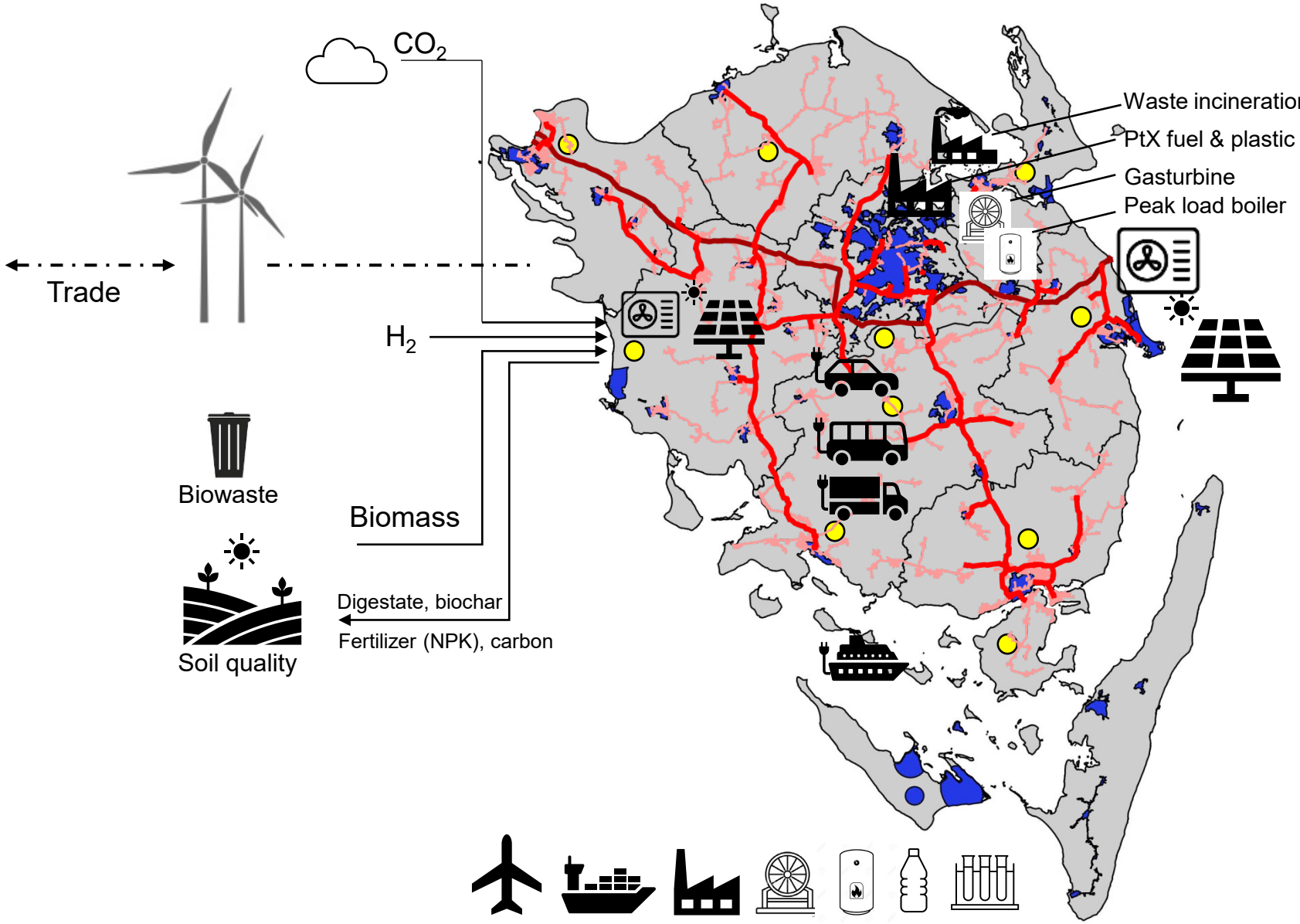
4. The agricultural sector



4.1 Concern for soil quality and fertilizer re-distribution

The sector integration

4. The agricultural sector



4.1 Concern for soil quality and fertilizer re-distribution

4.2 Supporting waste management of biowaste

4.3 Co-optimization of cropping schemes towards both food/feed and energy/materials. Transition from cereals to grass/clovergrass (Ref.: Uffe Jørgensen, Århus University)

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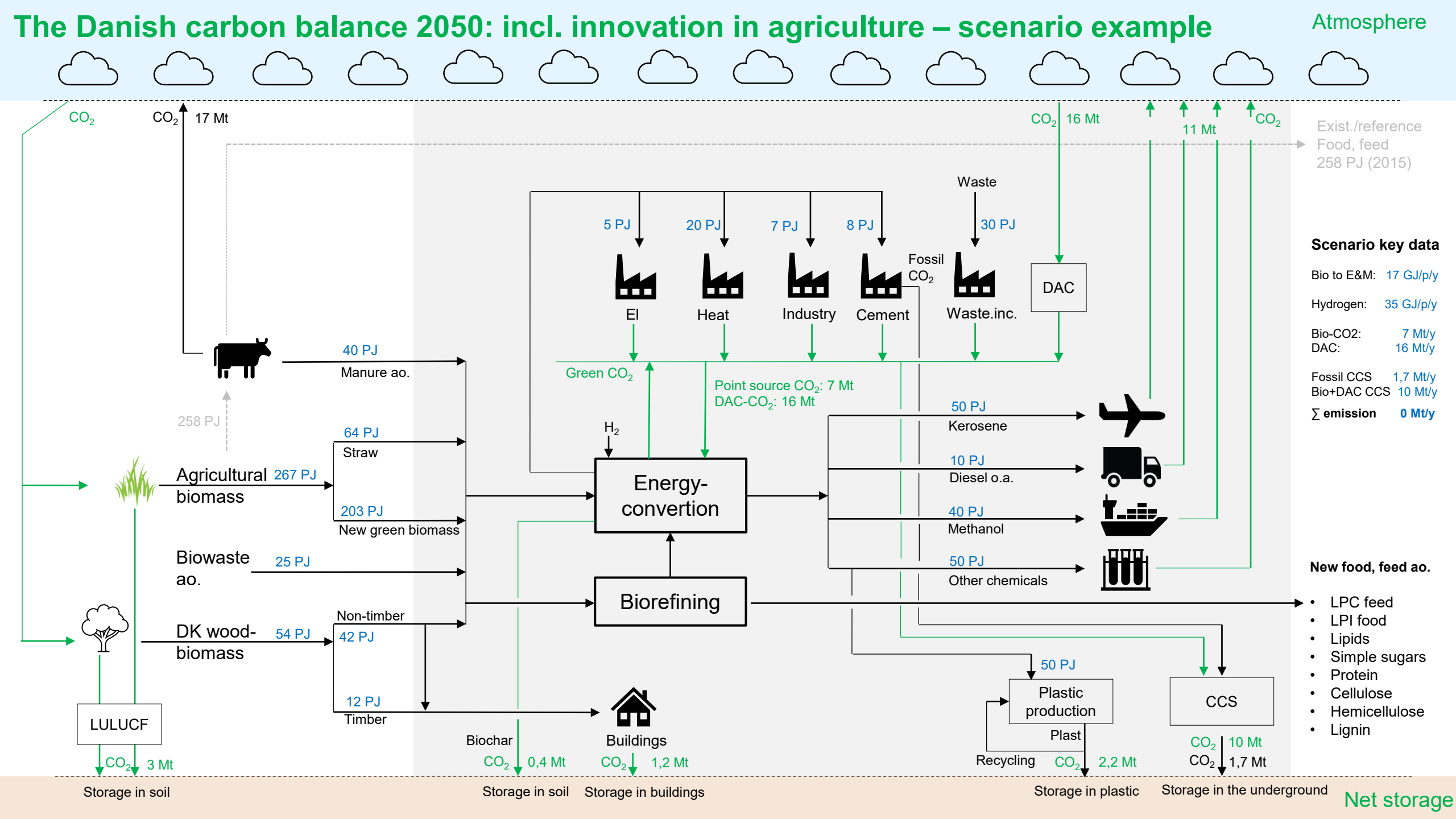
The Danish carbon balance 2050: incl. innovation in agriculture – scenario example



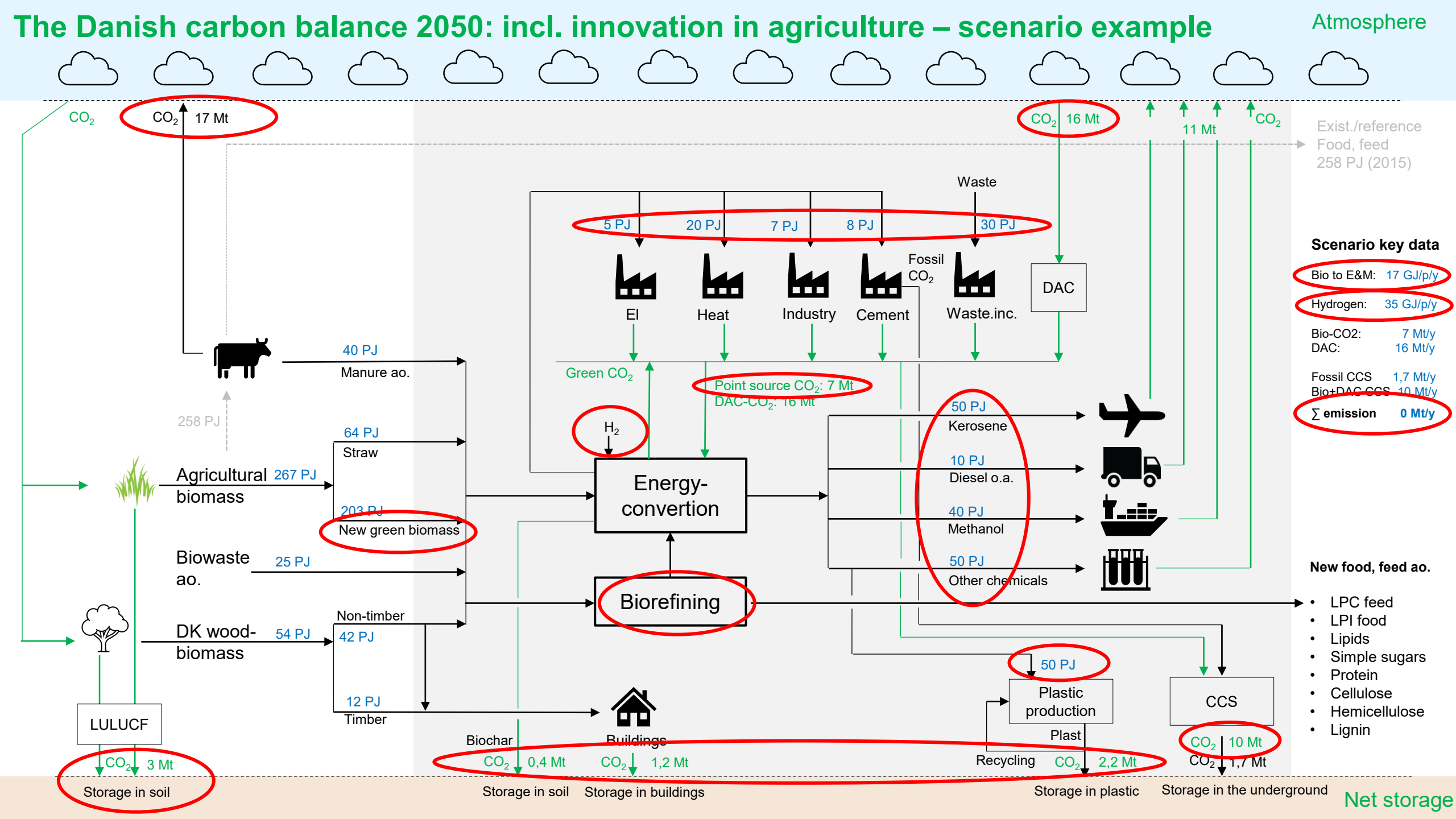
Scenario key data

Bio to E&M:	17 GJ/p/y
Hydrogen:	35 GJ/p/y
Bio-CO2:	7 Mt/y
DAC:	16 Mt/y
Fossil CCS	1,7 Mt/y
Bio+DAC CCS	10 Mt/y
∑ emission	**0 Mt/y**

New food, feed ao.

- LPC feed
- LPI food
- Lipids
- Simple sugars
- Protein
- Cellulose
- Hemicellulose
- Lignin

The Danish carbon balance 2050: incl. innovation in agriculture – scenario example

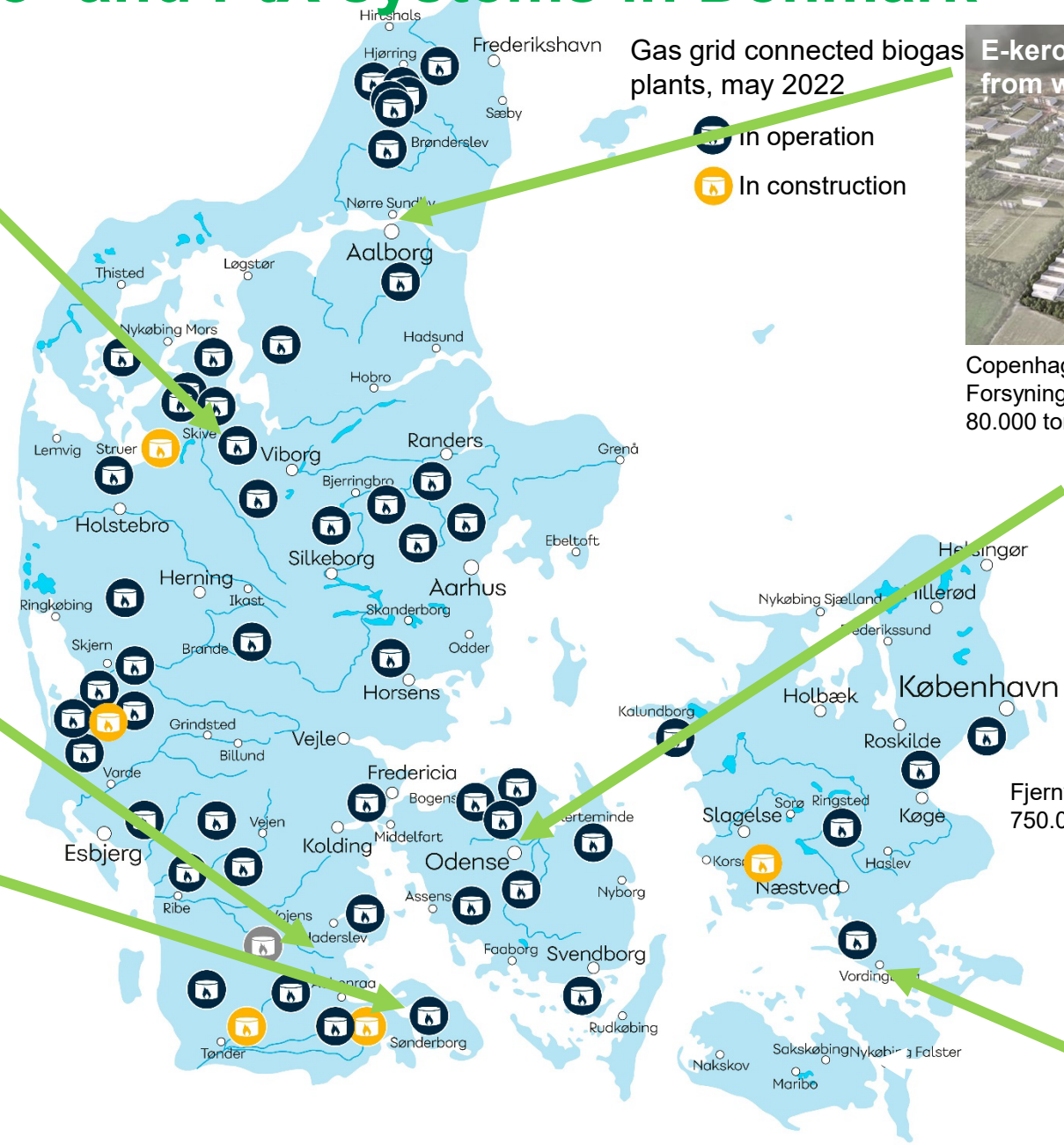


Latest news on bio- and PtX systems in Denmark

Stiesdal – SkyClean, Skive, Denmark (2023)

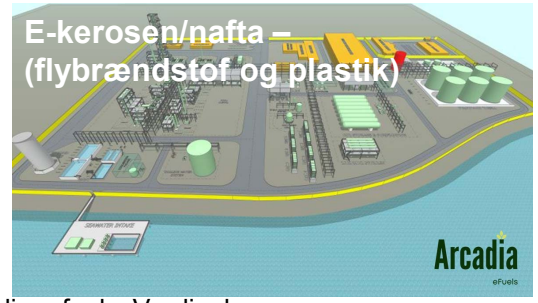
European Energy, LEGO, Novo
Kassø, near Aabenraa, Denmark
32.000 tons/year (2024) – to be used for POM plastic

Nature Energy, Biogasclean, Andel, SDU, DTU
Glansager, near Sonderborg, Denmark
Starting full scale (2023), 13 million m3/year (2024)



Copenhagen Infrastructure Partners, Reno Nord, Aalborg Forsyning. Aalborg, Denmark
80.000 tons e-kerosene/y + 17.000 e-naphta/y (2027)

Fjernvarme Fyn and Fortum, Odense, Denmark
750.000 tons CO2/y for plastic production through methanol



Arcadia e-fuels, Vordingborg,
75.000 tons e-kerosene/y + 25.000 e-nafta/y (2026)

PtX fuels cost minimum 3 times fossil fuels

- but what is the implication on end product price and consumer economics?

Price increase, if the fuel were e-methanol or e-ammonia?

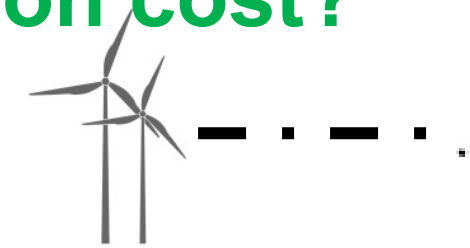
End product < 0,1 % increase

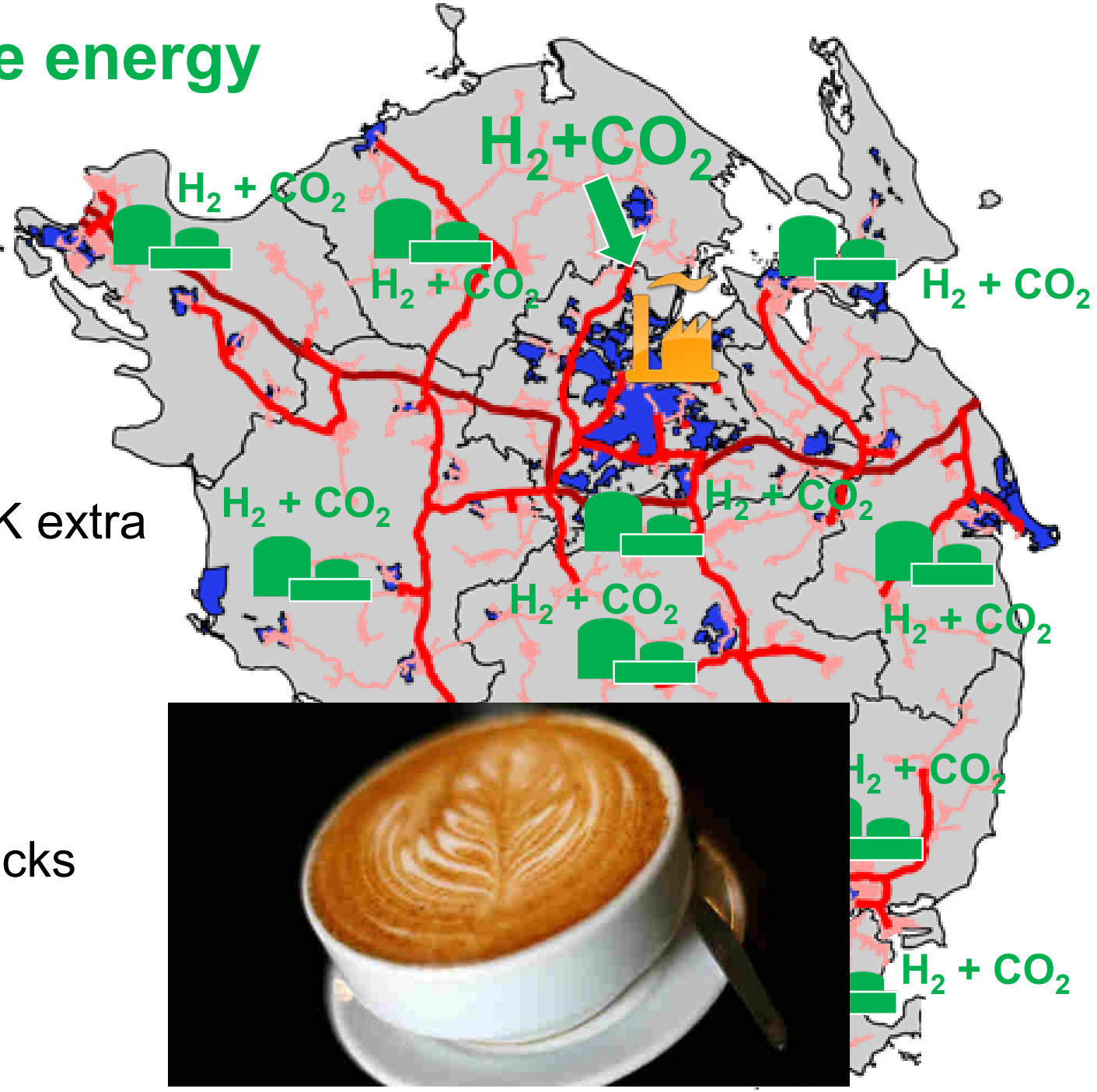
Price increase, if the fuel were made of CO2 and hydrogen?

Flight price < 30 % increase
… and still cheaper than flying by 2013 and earlier

Price increase of plastic-containing products, if the plastic were made of CO2 and hydrogen?

…and what does the whole energy system transition cost?





- Danish Energy Agency: 10 bill. DKK extra
- Ca. 0,3 % of GDP
- Ca. 150 DKK/person/month
- Less than 40 DKK/person/week
- Less than a cup of coffee at Starbucks per person/week