7th International Conference on Smart Energy Systems
21-22 September 2021
#SESAAU2021

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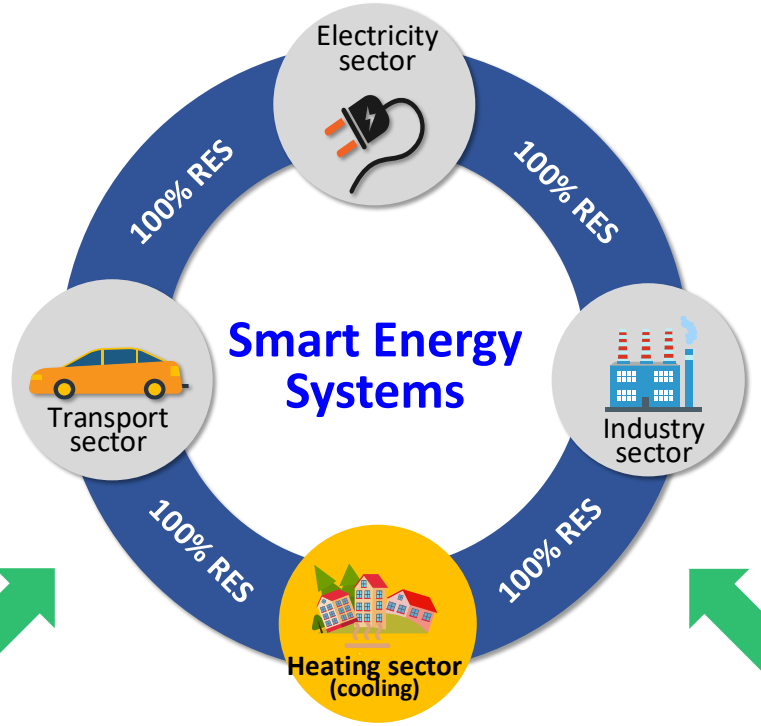
Funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement no. 846463

District heating in 100% renewable energy systems: Combining industrial excess heat and heat pumps

Meng Yuan*, Jakob Zinck Thellufsen, Peter Sorknæs, Henrik Lund, Yongtu Liang

[1] Yuan M , Thellufsen J Z , Sorknæs P, Lund H, Liang Y. District heating in 100% renewable energy systems: Combining industrial excess heat and heat pumps. Energy Convers Manag. 2021;244:114527. https://doi.org/10.1016/j.enconman.2021.114527

Trade-off problem between IEH and HP



- (+) Positive effects on RES integration
- More flexible

- (-) Negative effects on RES integration
- Cheaper in general

Key enabling techs

4th Generation District Heating

Key enabling techs

Heat pumps (HP)

Trade-off

Industrial excess heat (IEH)

Research questions

100% renewable smart energy systems

- How to determine 1) the optimal share of IEH and HP in a given DH system, 2) associated RES capacity in a 100% RE system?
- What are the techno–economic impacts on the integrated energy system caused by the integration of IEH and HP under the smart energy systems context?

Methodology

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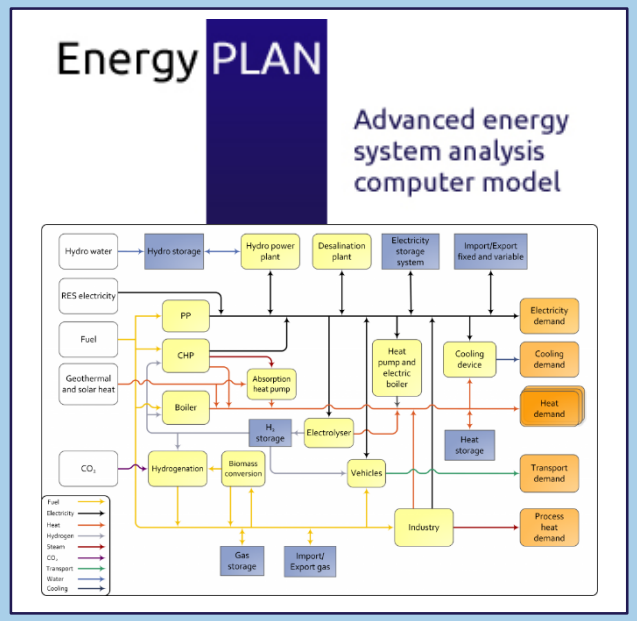
AALBORG UNIVERSITY
DENMARK
中国石油大学(北京)
CHINA UNIVERSITY OF PETROLEUM

Smart energy system modelling



EnergyPLAN

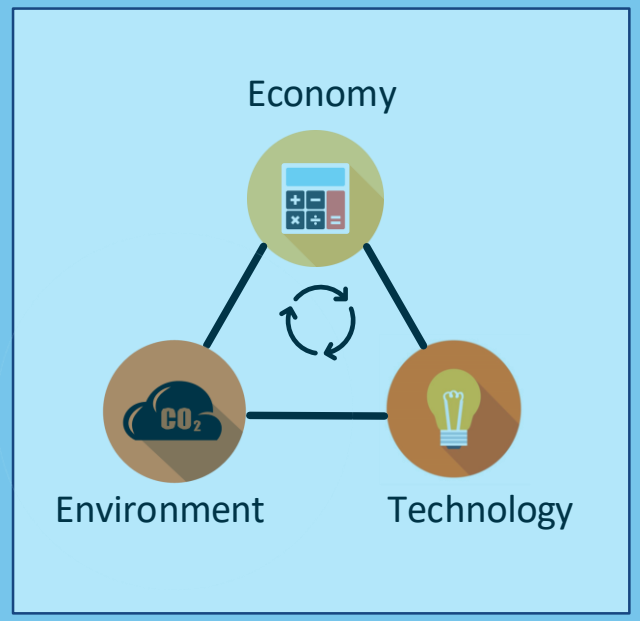
www.energyplan.eu

- Hourly operation simulation of the 100% RE system in a defined year

Capacities of techs

System operation results

Multi-objective optimization



MOPSO

Multi-objective particle swarm optimization

- Three-objective minimum: total annual cost, CO_2 emissions, and CEEP
- Decision variables: HP, IEH, PV & wind

Pareto solutions

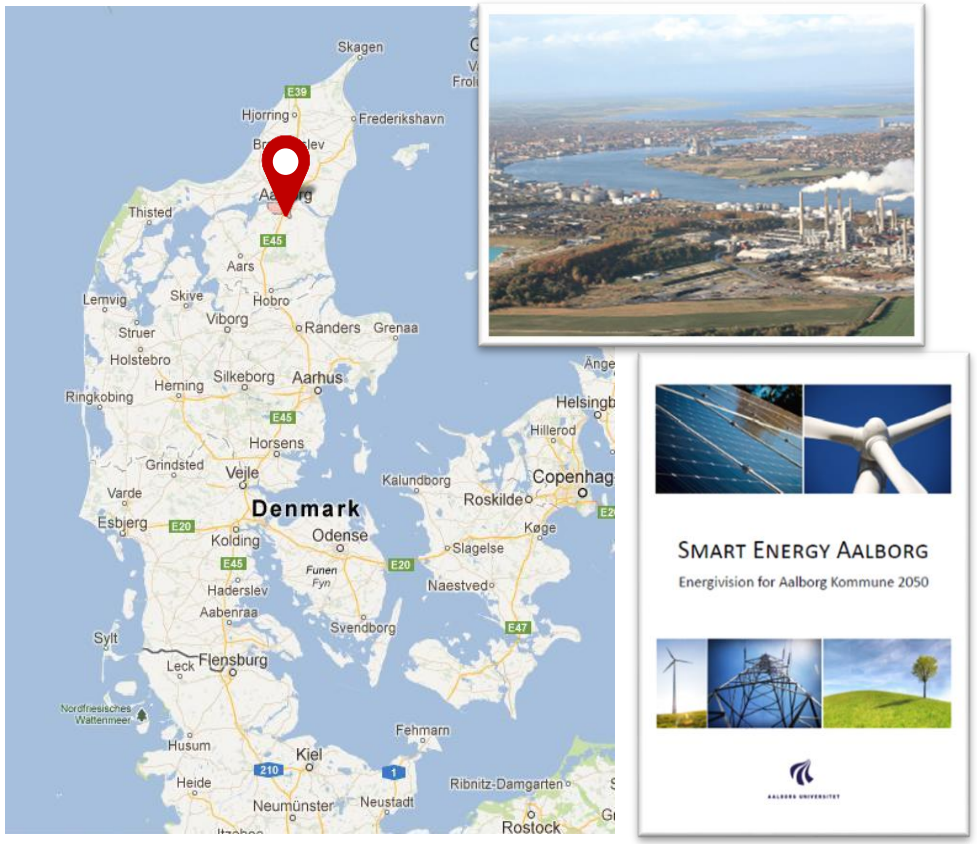
Multiple-criteria decision-making

Improved TOPSIS

Technique for Order of Preference by Similarity to Ideal Solution

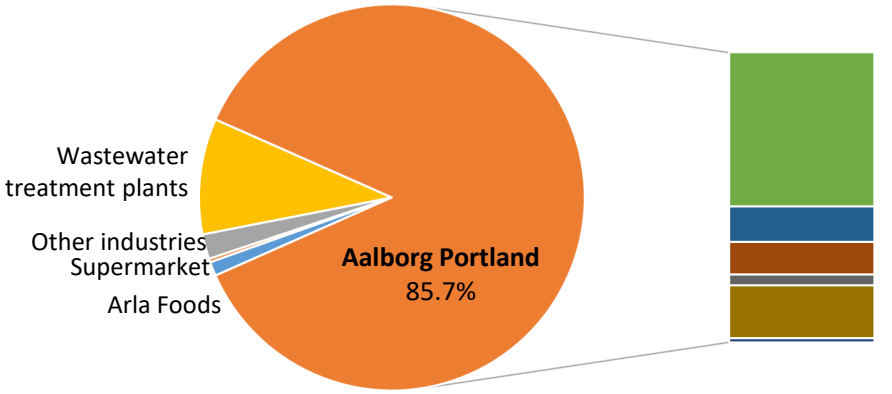
- Post-process of Pareto front
- Determine an optimal solution considering the **weights** of 3-objectives

2050 Smart Energy Aalborg



- Based on the "Smart Energy Aalborg" project* in AAU, which aims to transit Aalborg to 100% RE in 2050
- The BAU scenario and Energy Vision scenario are adopted as the baseline of this study

Technical potential of IEH in Aalborg

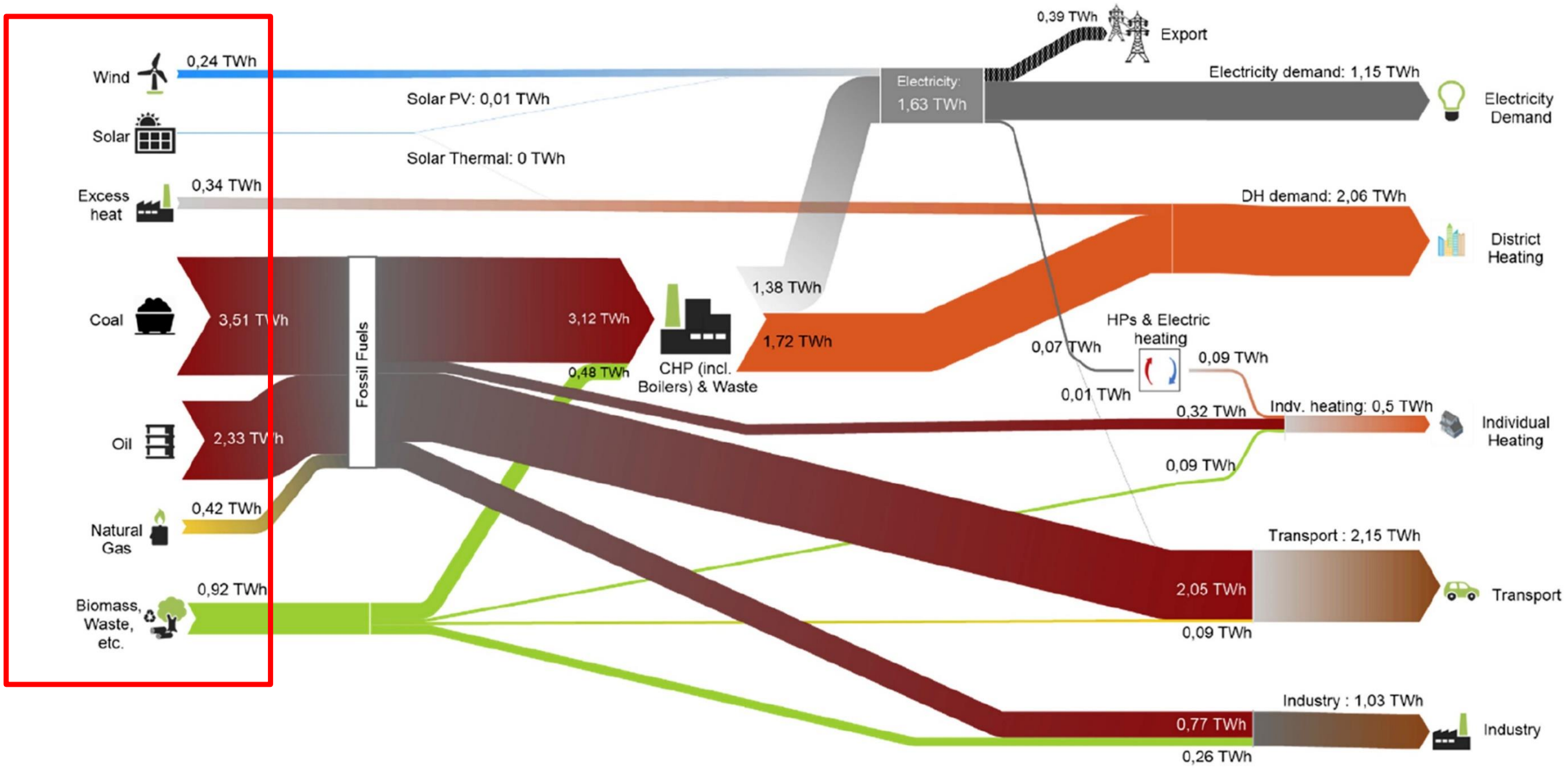


- Output from existing units
- Optimization of existing units
- Heat recovery from grey cement kiln
- HP reducing return temperature to existing units
- Collecting radiant heat from the white cement kiln with heat shields
- Exploiting heat from filtrate water using HP

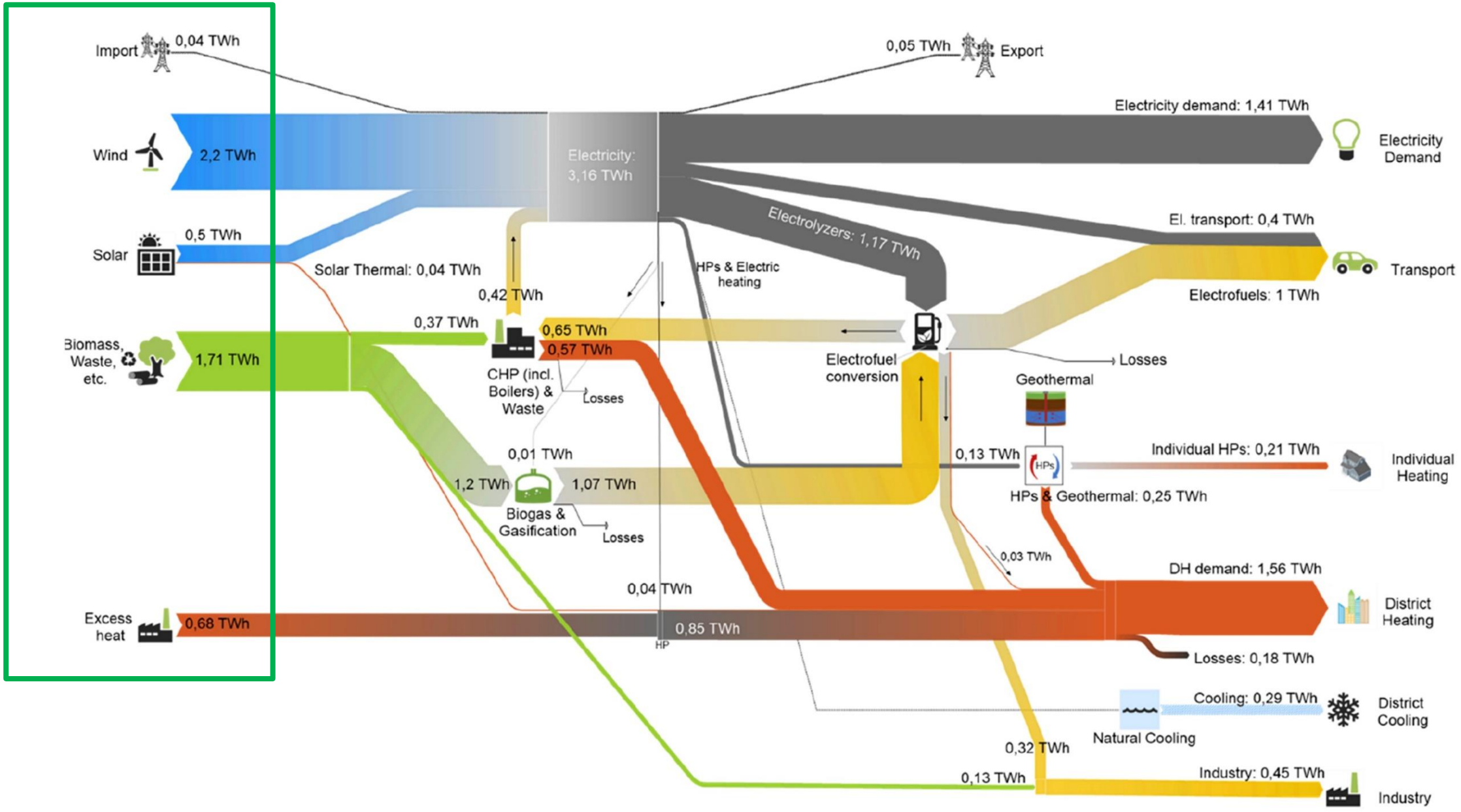
Total IEH potential: 1023 GWh
IEH in Energy Vision: 850 GWh

* "Smart Energy Aalborg" research was conducted by the Sustainable Energy Planning Research Group Aalborg University at the request of the city council of Aalborg Municipality and the local municipality-owned utilities and authorities. https://vbn.aau.dk/en/publications/smart-energy-aalborg-energivision-for-aalborg-kommune-2050-2

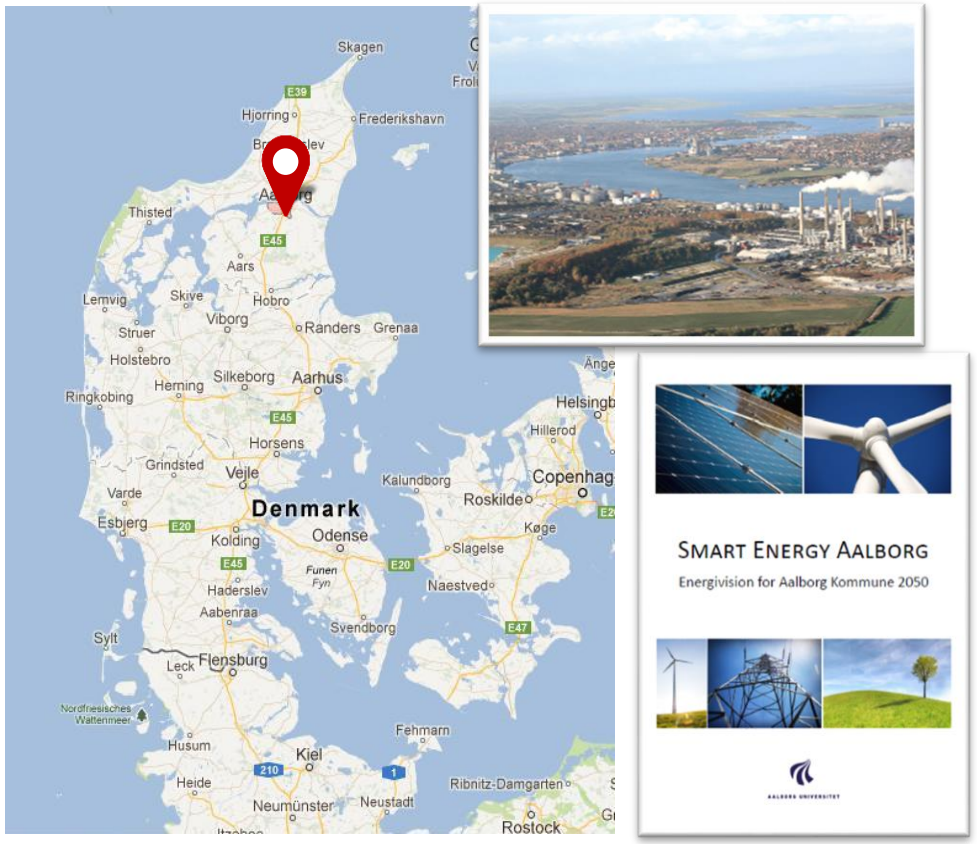
2050 BAU scenario



2050 Energy Vision scenario



2050 Smart Energy Aalborg



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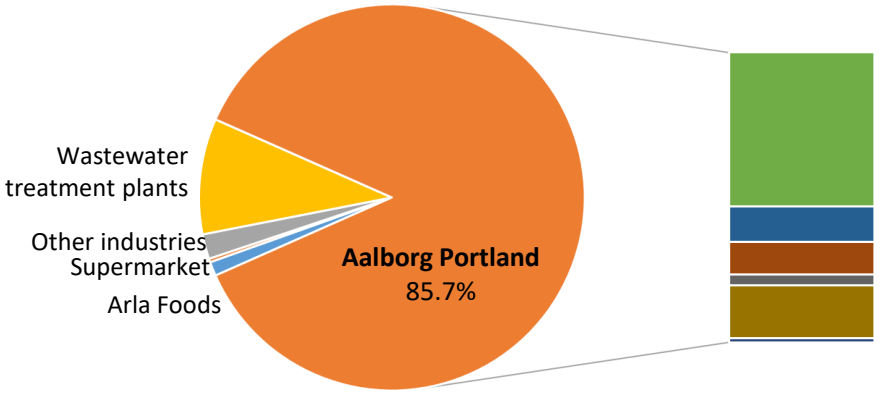

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Results - Optimal DH planning

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中国石油大学(北京) CHINA UNIVERSITY OF PETROLEUM

Scenarios

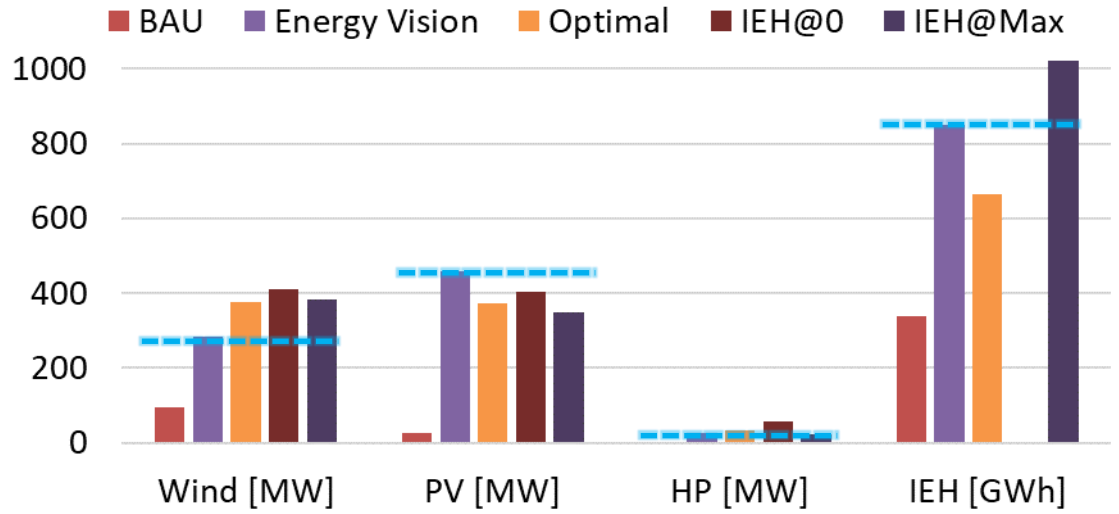
REF

- **BAU**: Maintain the status quo of the energy system of 2018 in the year 2050
- **Energy Vision**: The 100% RE system defined in Smart Energy Aalborg
- **Optimal**: The optimal 100% RE system obtained by using the proposed approach
- **IEH@0**: The 100% RE system does not utilize IEH in DH
- **IEH@Max**: The 100% RE system utilizes the max technical potential of IEH in DH

Results of the three-objectives in different scenarios

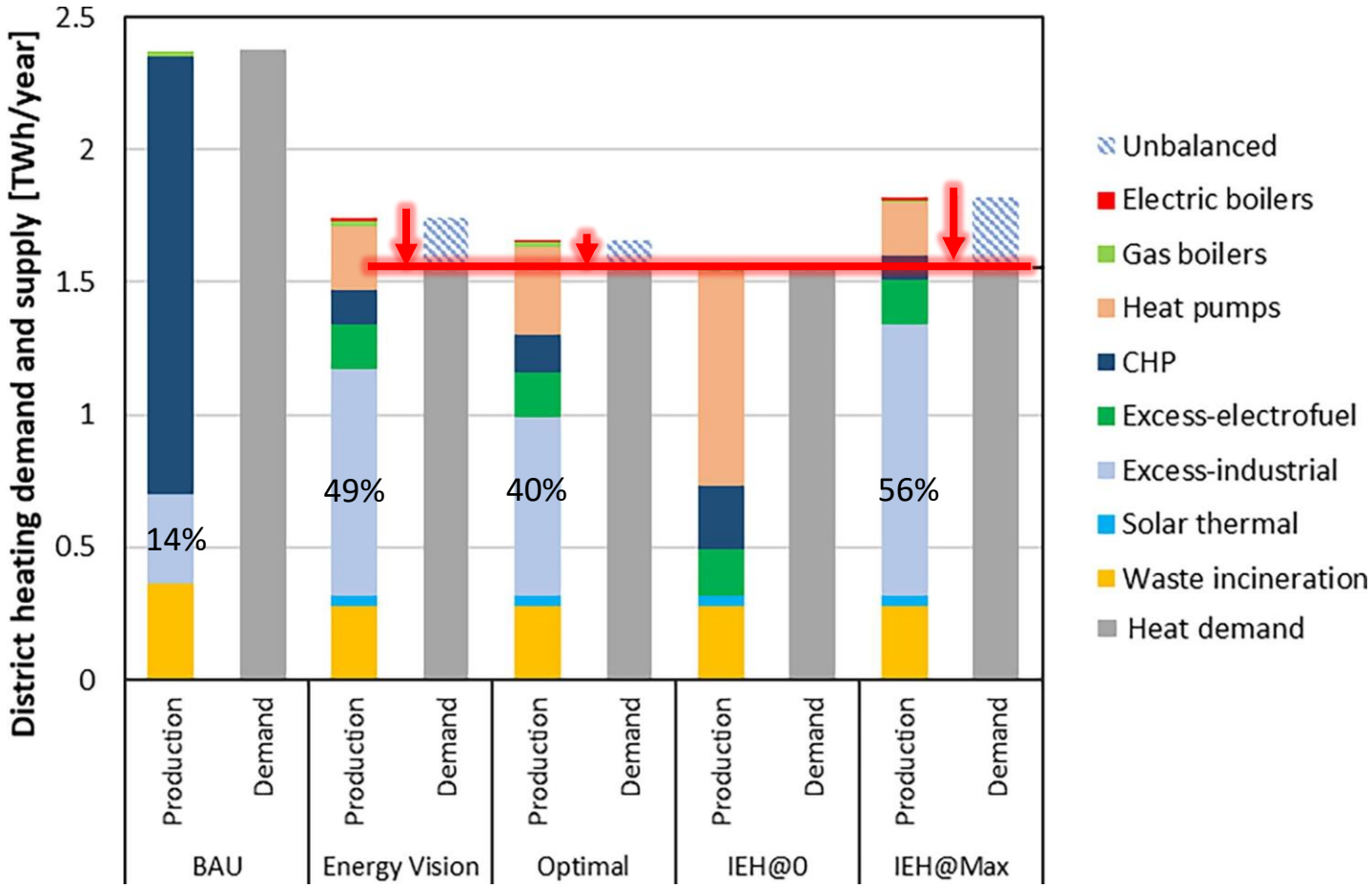
Scenarios		Cost [MEUR]	CO_2 [Mton]	CEEP [TWh]
Smart Energy Aalborg	BAU	673	2.374	0.47
	Energy Vision	626	0.044	0.05
This study	Optimal	621	0.001	0.07
	IEH@0	628	0.001	0.09
	IEH@Max	624	0	0.07

Results of the decision variables in different scenarios

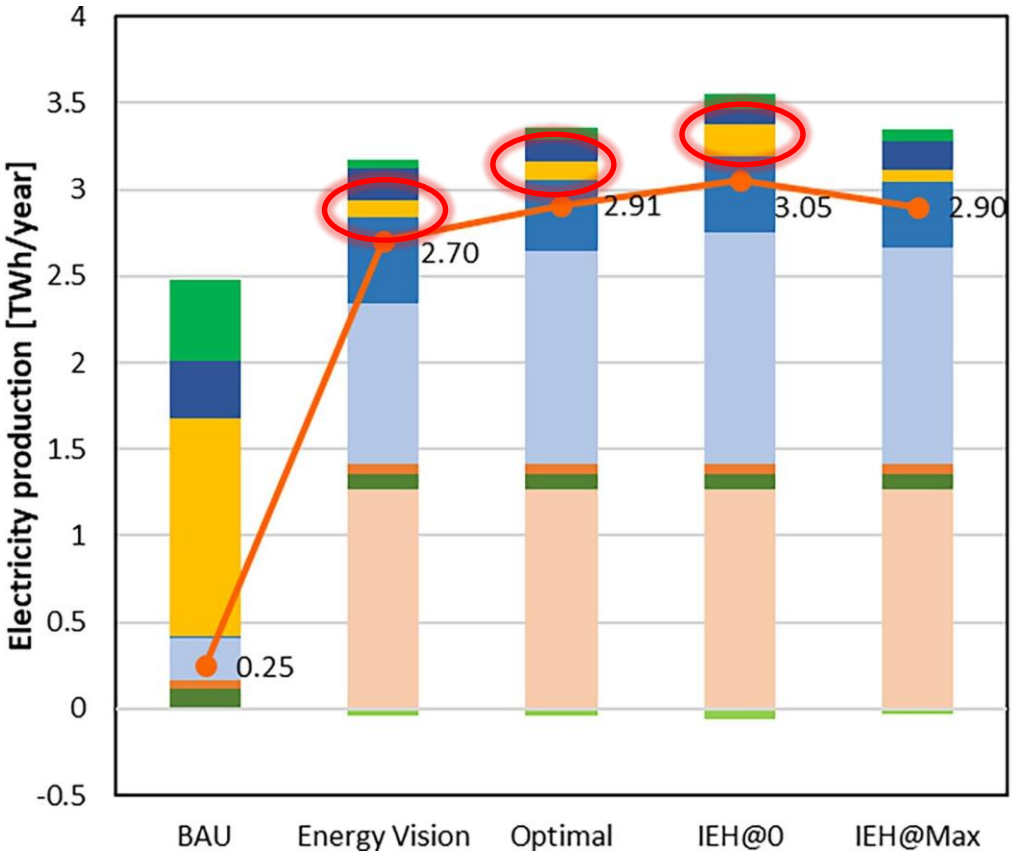


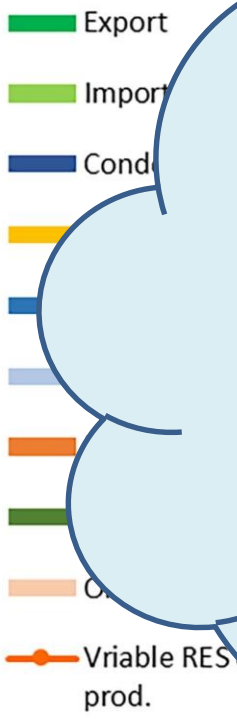
Results - District heating systems

- 20% HP and 40% IEH in the total DH supply under the Optimal scenario
- The larger-scale integration of HP will bring a more balanced DH system



Results - Structure of electricity generation





Other results and analysis

- Sector synergies between heating, electricity, and gas grid
- Sensitivity analysis of the gas prices
- Technology choice impacts of each single IEH resource
- Sensitivity analysis of the weights of three-objectives

Key points

- A **proper mix** of both HP and IEH technologies in the DH supply will bring larger benefits
- While IEH is a key resource for future low-temperature 4GDH and smart energy systems, it is vital to emphasize that the **HP solution is also feasible**
- This work has provided a reference and a methodology for policymakers and system operators in the design of district heating systems under multiple feasible technical options

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Thank you for your attention!

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More info:

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