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Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Dominkovic, D. F., Baekovi, I., Sveinbjörnsson, D. Þ., Pedersen, A. S., & Krajai, G. (2016). Benefits of Integrating Geographically Distributed District Heating Systems [Sound/Visual production (digital)]. 29th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, Portorož, Slovenia, 19/06/2016

Benefits of Integrating Geographically Distributed District Heating Systems

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ECOS coference Portorož

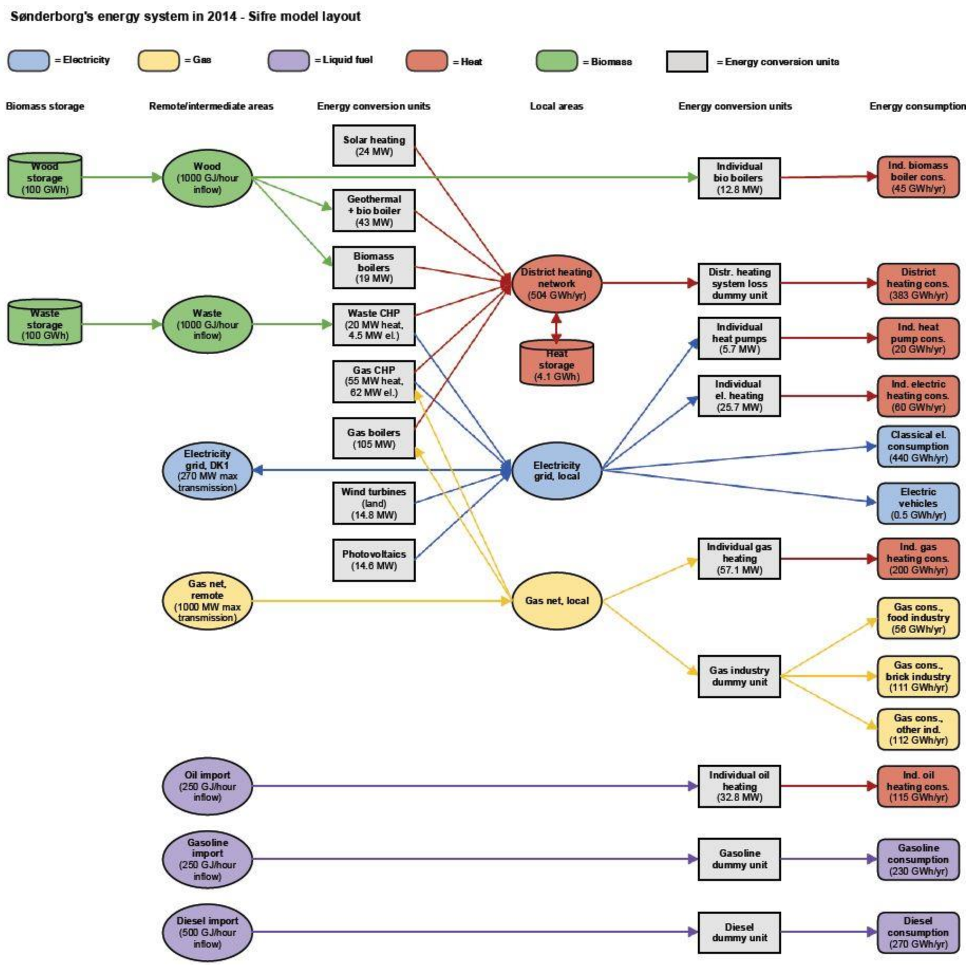
21 June 2016

DTU Energy
Department of Energy Conversion and Storage

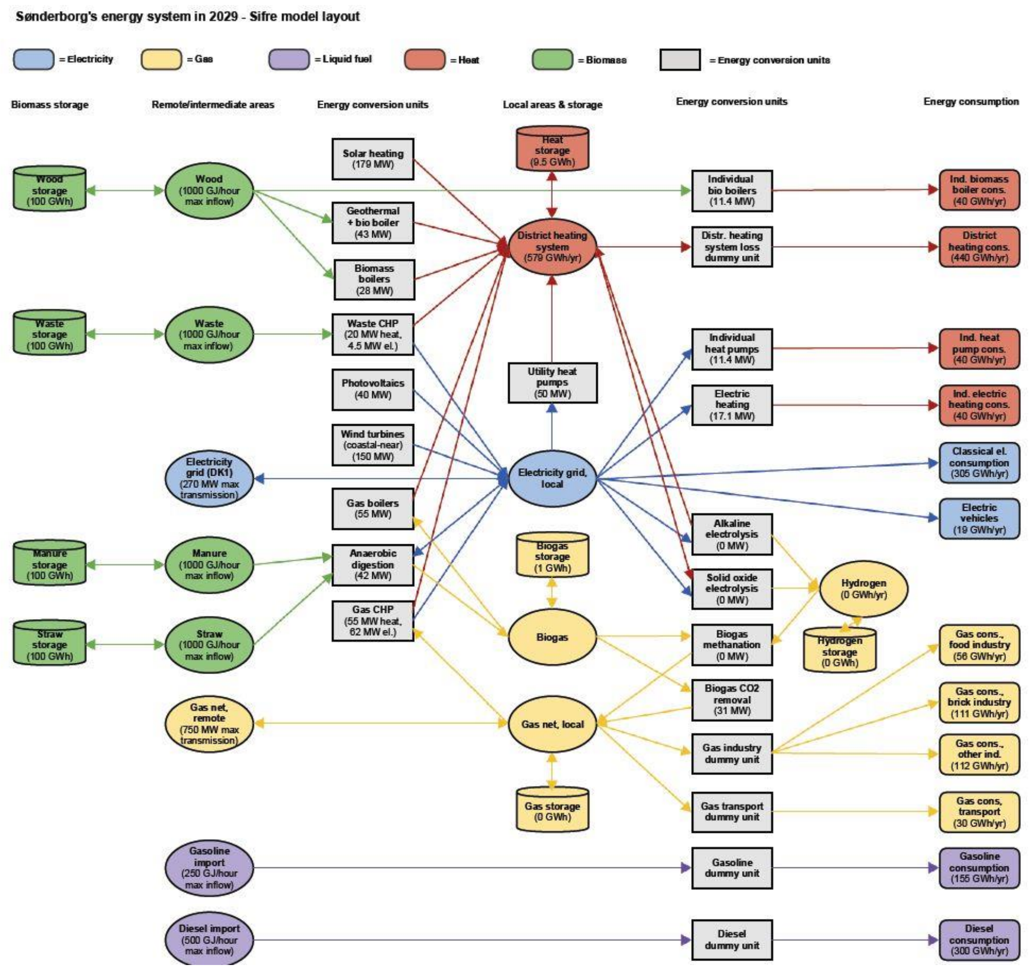
Outline

- Sønderborg – the current status of DH systems
- Model description
- Description of indicators used for evaluation
- Case study description
- Results
  - Model validation
  - Results of the case study for the current state of the system
  - Results of the case study for the energy system in 2029
- Conclusions

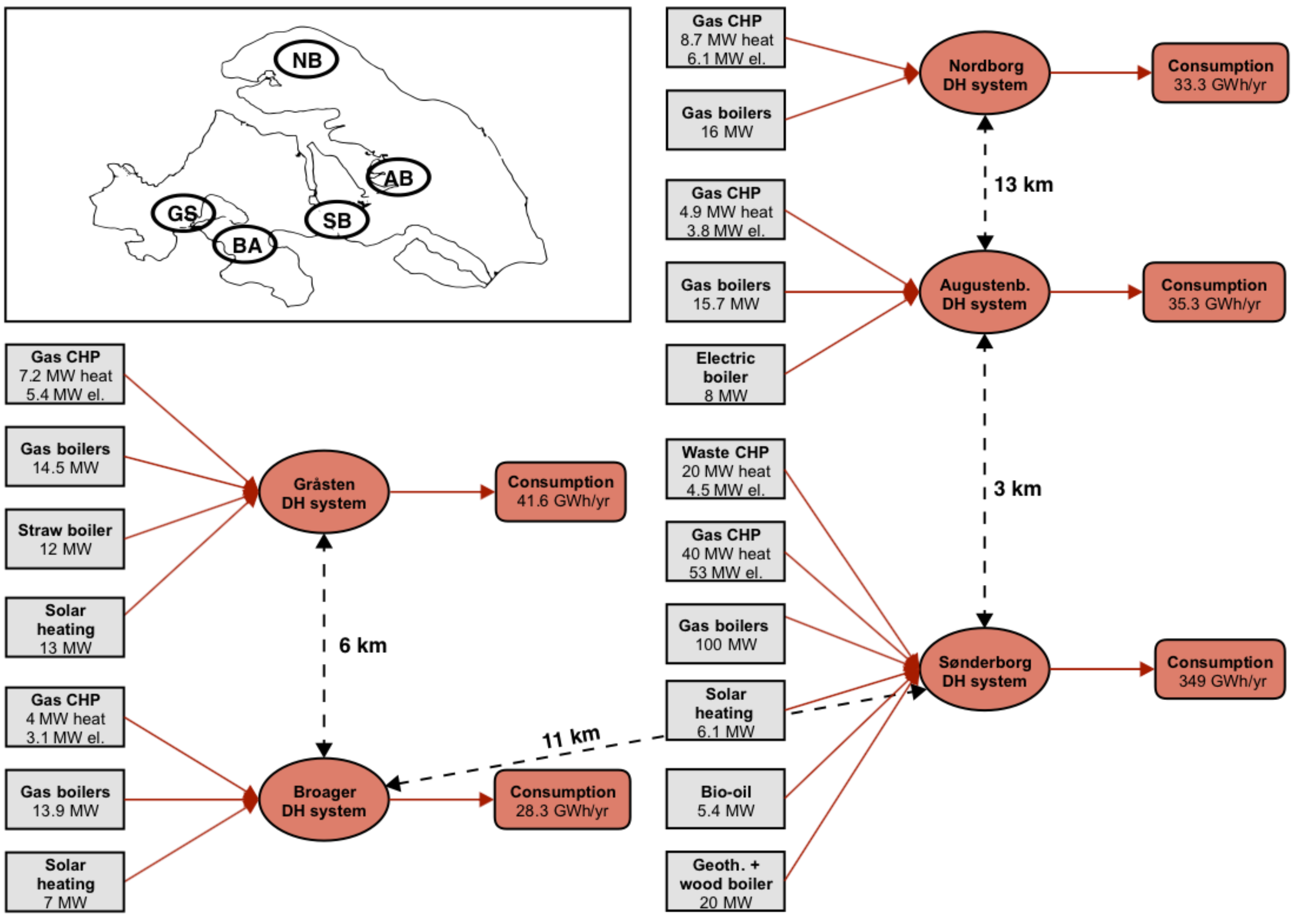
Sønderborg – energy system in 2014



Sønderborg – anticipated energy system in 2029



Sønderborg – DH systems



Connecting DH systems – the model

- Linear continuous optimization model

- Objective function: to minimize total annual socio-economic costs
  - Levelized investment costs, fixed and variable O&M, fuel costs and import/export of different energy carriers

- Possibility of using CO2 and biomass consumption cap

- Exogenous variables:
  - Demand for different types of fuel

- All sectors included in calculation (power, heating, gas and mobility)

Indicators

- Economic: the total annual socio-economic costs
- Technical: CO_2 emissions (calculated post-optimization)
- Feasibility of interconnections: NPV, IRR, dynamic payback time
  - NPV – sum of all the payments (positive and negative) related to the investment
  - IRR – discount rate at which NPV is equal to zero
  - Dynamic payback time – time needed for NPV of income to cover the investment

Case study

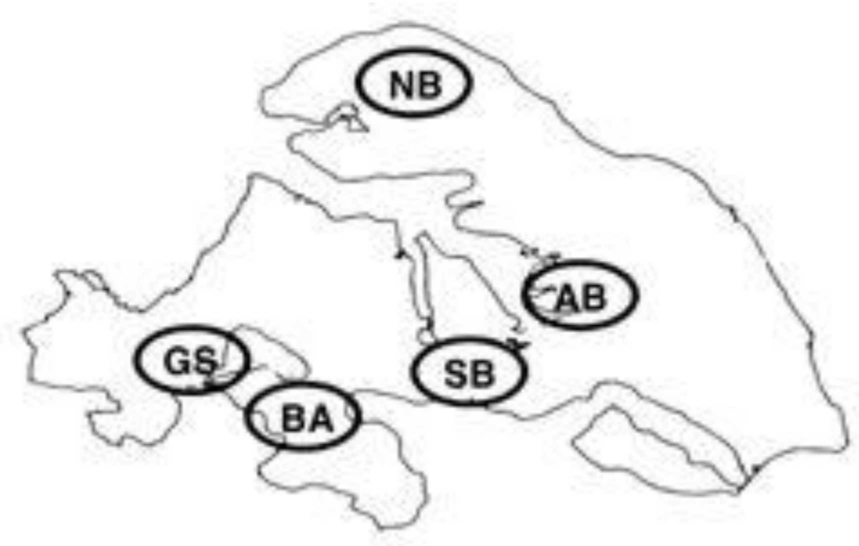
- Population: 75,000
- Area: 496 km^2
- Carbon neutrality by 2029
- 5 different DH systems

TOTAL FINAL ENERGY CONSUMPTION	CONSUMPTION (GWH/YR)	CO2 EMISSIONS (KTON/A)
DISTRICT HEATING	488	42
INDIVIDUAL HEATING	438	104
ELECTRICITY (CLASSICAL)**	442	158
PROCESS ENERGY	270	64
TRANSPORT	510	133
TOTAL	2148	500 (528.57)*

DH systems

DH PRODUCTION BY NETWORK*	INSTALLED CAPACITY (MW)	PRODUCTION (GWh/YEAR)	STORAGE CAPACITY [m^3]
SØNDERBORG	201.5	349.0	4000
GRÅSTEN	46.7	41.6	8500
AUGUSTENBORG	28.6	35.3	-
NORDBORG	24.1	33.3	-
BROAGER	24.9	28.3	4500
TOTAL	325.8	487.6	-

Case study (II) – system today



Case	Interconnected DH systems
I	5 separated DHs
II	Merged Sønderborg (town) and Augustenborg
III	Merged Broager, Sønderborg and Augustenborg
IV	Merged Gråsten, Broager, Sønderborg and Augustenborg
V	Merged all five DH

Case study (III) – system in 2029

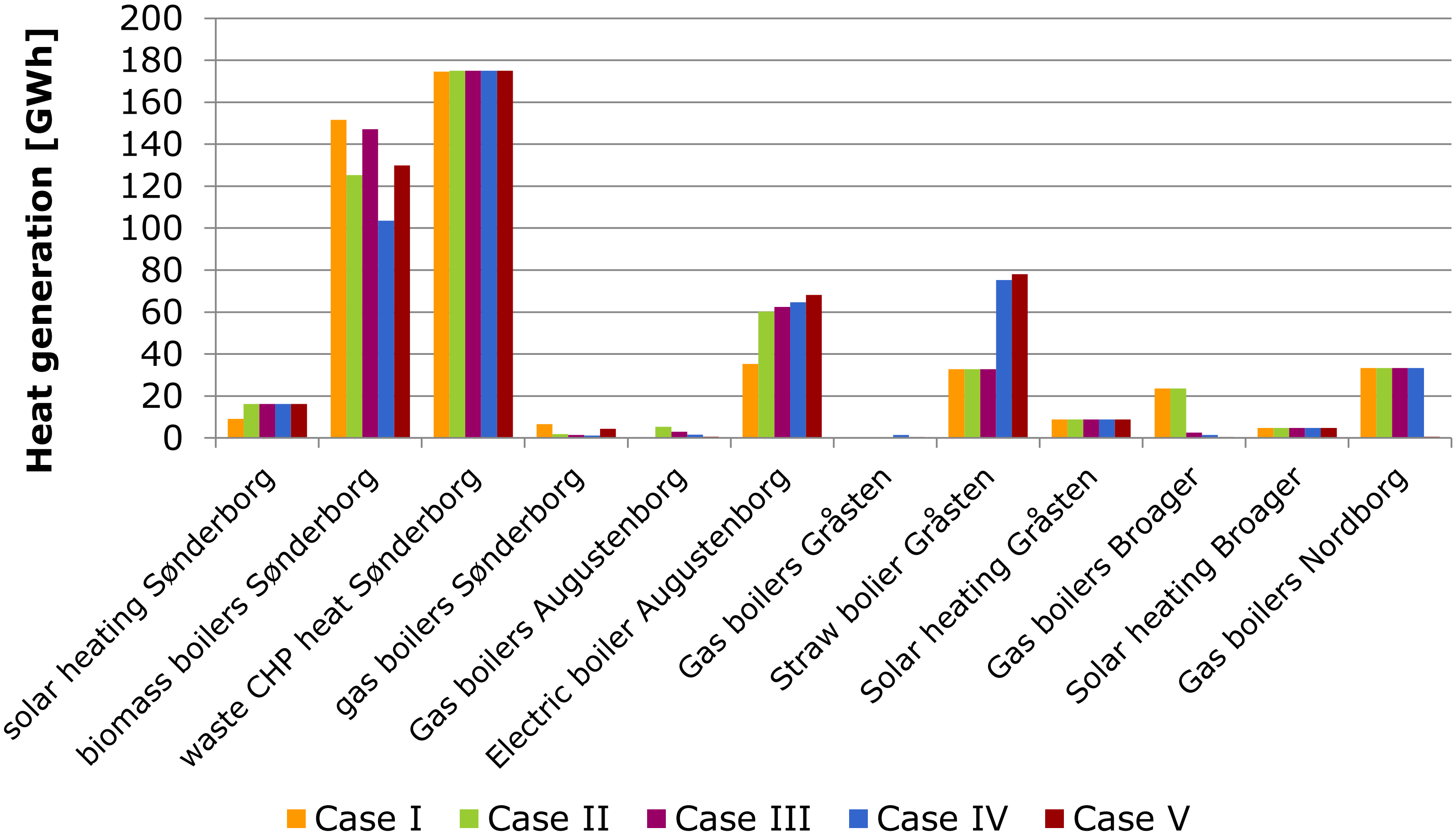
	Installed capacity 2013 (MW)	Installed capacity 2029 (MW)
Anaerobic digestion	0	42
Gas boilers	105	55
Biomass boilers	19	28
Large scale heat pumps	0	50 (electrical capacity)
Solar heating	24	179
Heat storage	4,100 MWh	9,500 MWh
Wind turbines	14.6	180
Photovoltaics	14.8	60

Case	Interconnected DH systems
VI	5 separated DHs
VII	Merged all five DH

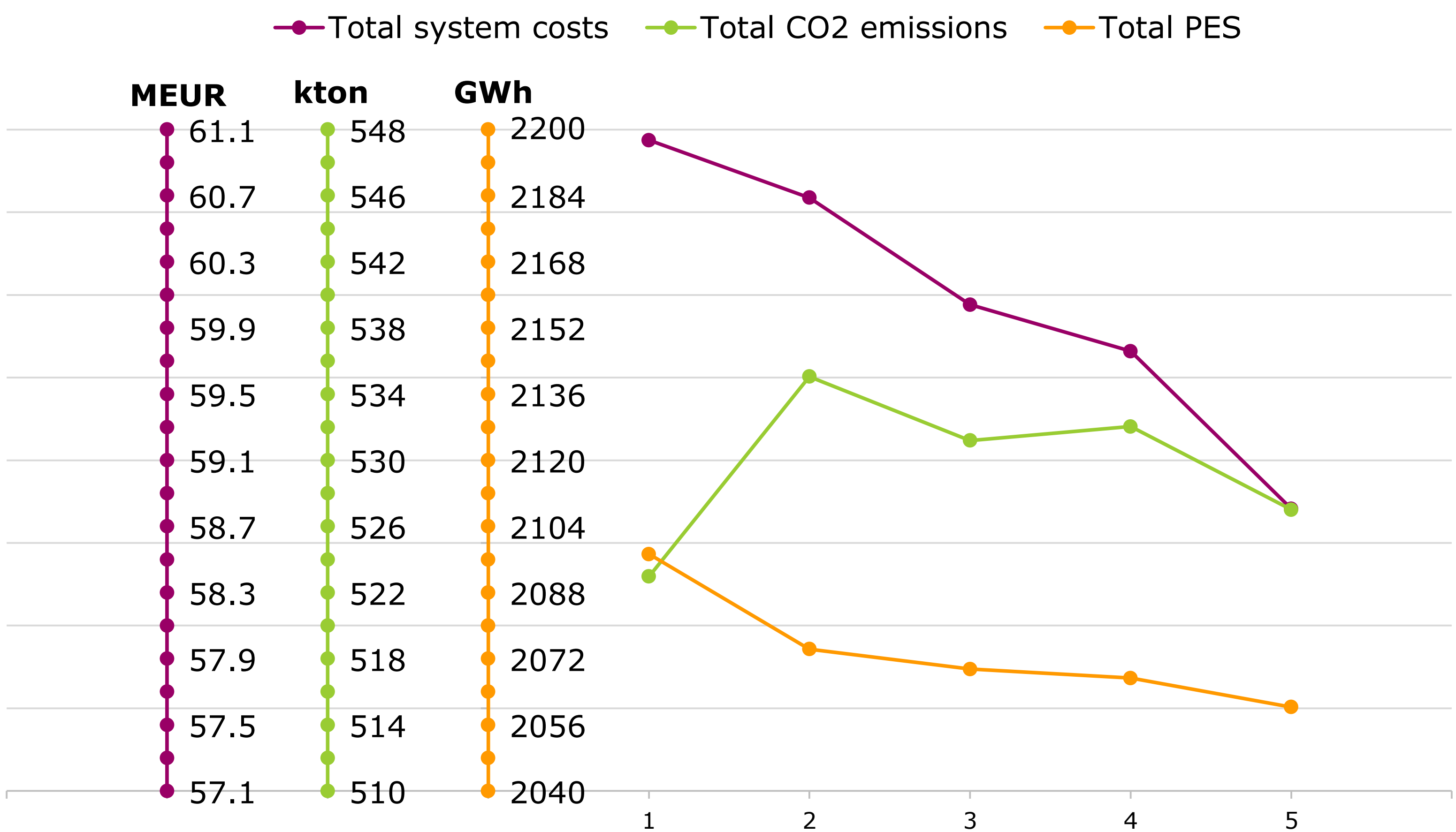
Results – model validation

Total energy consumption	Reference consumption (GWh/yr)	Reference scenario (case I) (GWh/yr)	Difference [%]	Referent CO_2 emissions (including waste) (kton/yr)	Reference scenario (case I) (kton/yr)
Gas	571.87	554.82	-2.98%	528.57	525.05
Coal	13.6	13.6	0.00%		
Heating oil	116	116	0.00%		
Wood and straw	188.09	201.27	7.01%		
Individual heat pumps	21.238	21.24	0.01%		
Individual electric heating	53.534	53.54	0.01%		
Waste consumption	212.5	214.81	1.09%		
Classical electricity	451.5	466.89	3.41%		
Diesel and gasoline	506.8	506.6	-0.04%		
Other and unknown	12.87	0	-100.00%		
Total	2148	2149	0.05%		

Sønderborg – today's system (I)



Sønderborg – today's system (II)

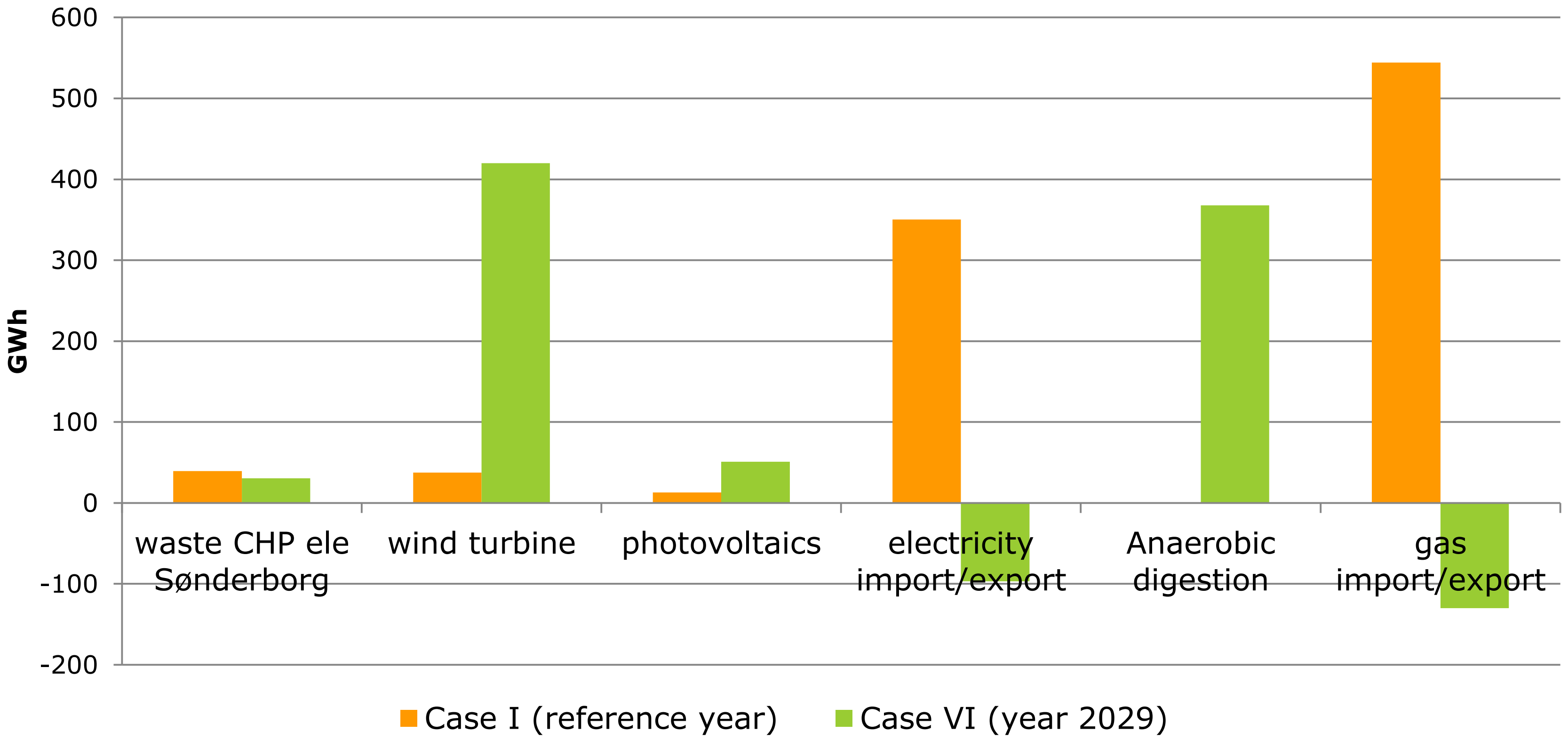


Sønderborg – today's system (III)

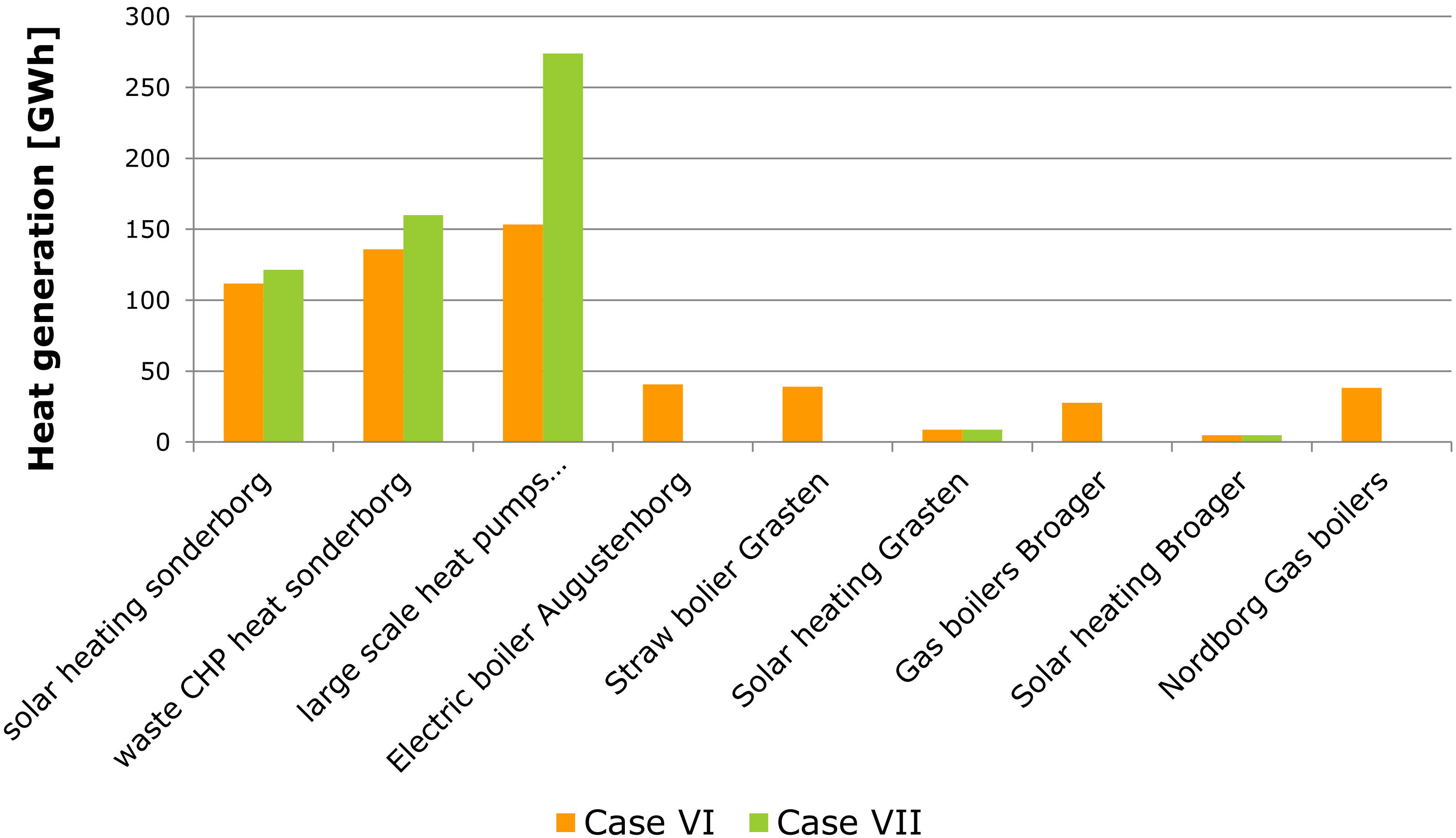
	I	II	III	IV	V	
TOTAL SYSTEM COSTS	61.039	60.653	59.934	59.621	58.563	MEUR
DIFFERENCE (SAVINGS)	Reference	0.386	0.719	0.313	1.058	MEUR
PIPE LENGTH	-	3,000	11,000	6,000	13,000	m
PIPE COST	-	2.25	8.25	4.5	9.75	MEUR
NPV		3.00	1.52	-0.25	4.63	MEUR
IRR		16.32%	5.99%	3.36%	8.86%	
PAYBACK TIME		6.77	15.66	21.82	11.72	
PAYBACK TIME		7	16	22	12	years

Sønderborg – 2029 (I)

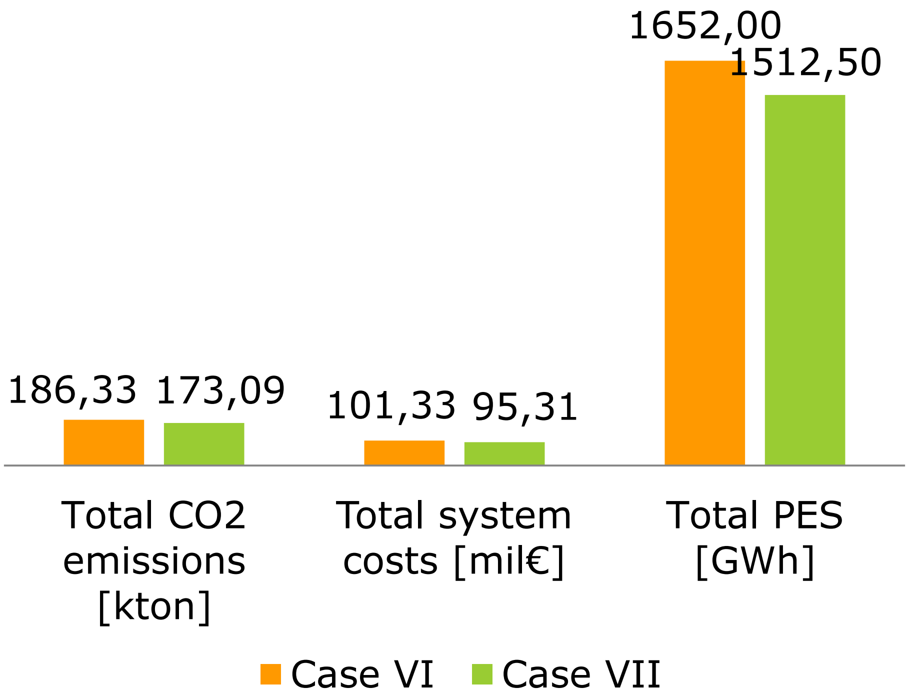
- Generation and power sectors:



Sønderborg – 2029 (II)



Sønderborg – 2029 (III)



	CASE VI	CASE VII	
TOTAL SYSTEM COSTS	101.33	95.311	MEUR
DIFFERENCE (SAVINGS)	0	6.019	MEUR
PIPE LENGTH	0	33,000	m
PIPE COST	0	24.75	MEUR
NPV		57.05	MEUR
IRR		23.98 %	
PAYBACK TIME		4.58	
PAYBACK TIME		5	years

Conclusions (I)

- ✓ For the current energy systems, three out of four DH interconnections are economic feasible with the dynamic payback times of 7, 12 and 16 years, while one of the interconnections has a dynamic payback time of 22 years which is more than considered project lifetime of 20 years. After the last interconnection is being set in place, the total socio-economic costs are 4.1 % lower than in the reference case.

- ✓ For the anticipated energy system of the year 2029, connecting all five DH systems has a payback time of only 5 years. Moreover, the investment proposed leads to the savings in PES of 8.4 %, lower CO_2 emissions for 7.1 % and reduced total system costs for 5.9 %.

- ✓ There is no correlation between the lengths of the interconnections and the economic indicators of the investments. Thus, the investment in interconnection is dependable upon the structure of the DH supply plants being interconnected.

Conclusions (II)

- ✓ In the system of today, with the current electricity and fuel prices, between the three boiler technologies, electric boiler has the lowest running costs, followed by biomass and gas boilers. Gas driven CHPs do not have economic benefits of running in the DH systems with the current electricity prices on day-ahead markets. The model shows that they do not operate a single hour either in the reference year or the year 2029.
- ✓ Large-scale heat pumps, with the average electricity price levels similar to current ones, completely replace the production of all the boilers, including the electricity, biomass and gas ones.
- ✓ Finally, interconnecting the DH systems is beneficial in both the current energy system and the anticipated system in the year 2029; however, greater benefits are achieved in the system of the future.
- ✓ Connecting DH grids brings more flexibility to the system, making it cheaper, less environmentally harmful and more energy efficient to integrate intermittent energy sources in the power sector.

Thank you for your attention!