Flex4RES
Flexible Nordic Energy Systems

Design of tariffs for power-to-heat generation to increase system flexibility

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norden
Nordic Energy Research

The Flex4RES project

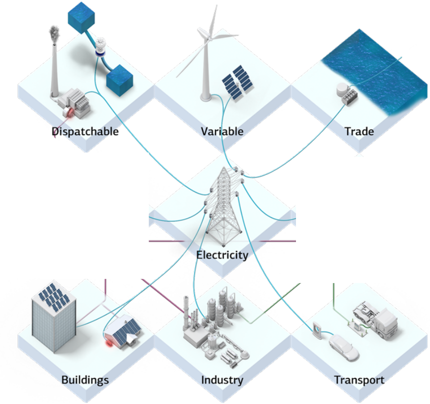
Flex4RES

Flexibility for Variable Renewable Energy Integration in the Nordic Energy System

Resource

System

Service



Supply flexibility

Demand responds

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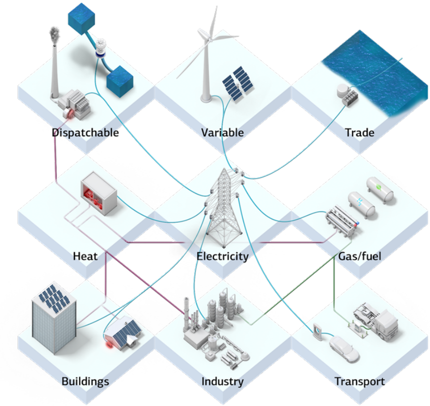

Supply flexibility

Sector coupling/ Electrification

Demand responds

System flexibility and tariffs?

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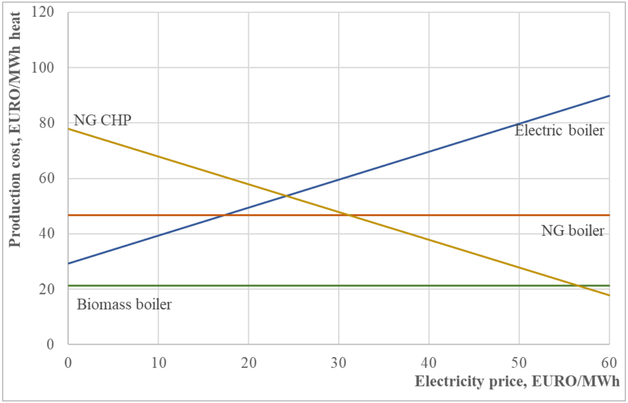
- Analysing the impact of alternative electricity grid tariff design on the flexibility potential in a DH system



System flexibility and tariffs?

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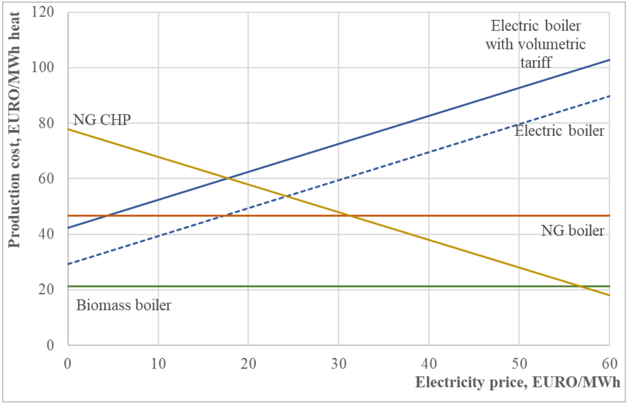

The general idea

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The model is a unit commitment model minimising costs with:

- A heat demand equality constraint
- Minimum and maximum production limits
- Storage capacity constraints
- Start-up constraints
- No investments

Variables used in objective function:

- $q_{i,t}$: Heat production on unit i in time t
- $p_{i,t}$: Power production on unit i in time t
- $v_{i,t}$: Start-up status of unit i in time t

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The objective function

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Minimise

Heat-only boilers: $$\sum_{i \in \mathcal{I}^{HO} \setminus \mathcal{I}^{P2H}} \sum_{t \in \mathcal{T}} \left(\frac{fp_{i,t} + ft_i}{\eta_i} + c_i^{OM} \right) q_{i,t}$$

CHP units: $$+ \sum_{i \in \mathcal{I}^{P}} \sum_{t \in \mathcal{T}} \left(\frac{fp_{i,t} + ft_i}{\eta_i} + c_i^{OM} - ft_i \, \tau_i \right) p_{i,t}$$

Electric boilers: $$+ \sum_{i \in \mathcal{I}^{P2H}} \sum_{t \in \mathcal{T}} \left(\frac{fp_{i,t} + ft_i + ec_t}{\eta_i} + c_i^{OM} \right) q_{i,t}$$

Start-up cost: $$+ \sum_{i \in \mathcal{I}} c_i^{start} \, q_i^{max} \, v_{i,t}$$

Elecitricity sold: $$- \sum_{i \in \mathcal{I}^{P}} \sum_{t \in \mathcal{T}} ep_t \, p_{i,t}$$

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The system under consideration

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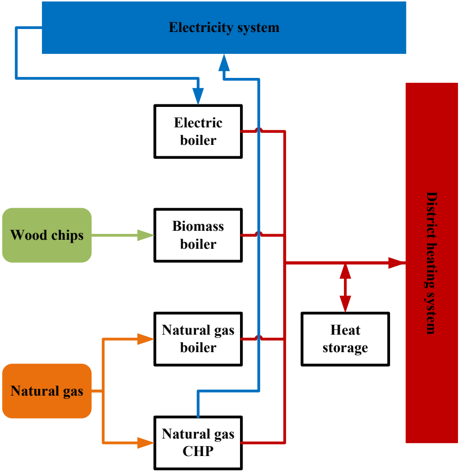
We assume a representative DH system of Denmark with demand covered using:

- A biomass boiler
- An electric boiler
- A natural gas boiler
- A natural gas CHP
- A heat storage tank



Assumptions and data

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- Yearly heating demand is 19 GWh
- Storage capacity is 36 MW (approx. 8 hours of maximum demand)
- Storage efficiency is 99.97%

	Unit	Electric boiler	Wood chips boiler	NG boiler	NG CHP
Capacity	MW	4.20	1.70	6.72	4.95
Minimum production level	% of capacity	5	20	15	50
Efficiency	%	99	117.3	103	44
Average fuel cost	€/MWh input	55.1	22.86	51.61	51.61
O&M cost	€/MWh	0.5	0.94	1.1	5.4
Start-up cost	€/MW/start-up	1	80	10	10
Heat-to-power ratio	-	-	-	-	0.9

Tariff designs

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- Business-as-usual (BaU): a volumetric tariff of 12.9 €/MWh
- Flat tariff: capacity-based tariff paid per billing period (not included in optimisation)
- Peak-event tariff (PE): a volumetric tariff with two rates: 0 and 12.9 €/MWh
- Dynamic tariff (DT): a volumetric tariff ranging from 1 or a fixed lower rate to 12.9 €/MWh

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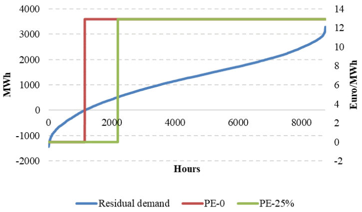

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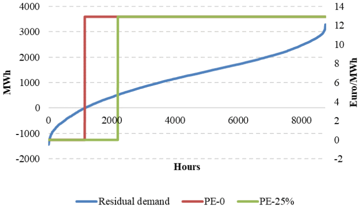

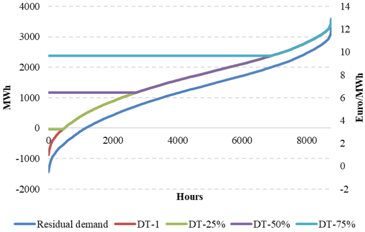

Results: expenses for the plant owner

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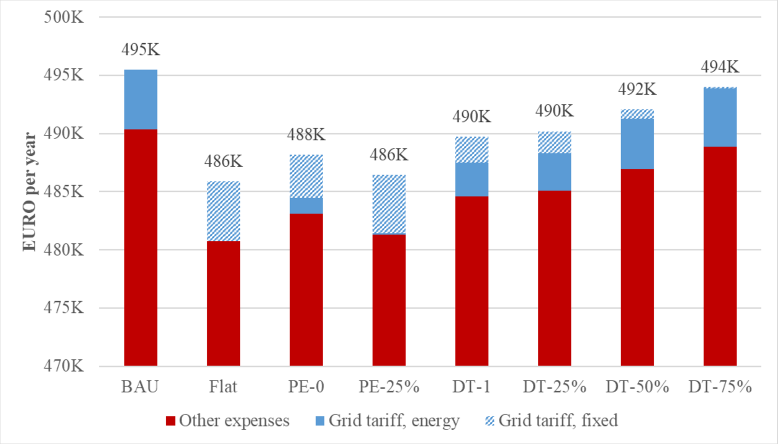

- All the alternative grid tariff designs results in a cheaper system for the owner

Results: production

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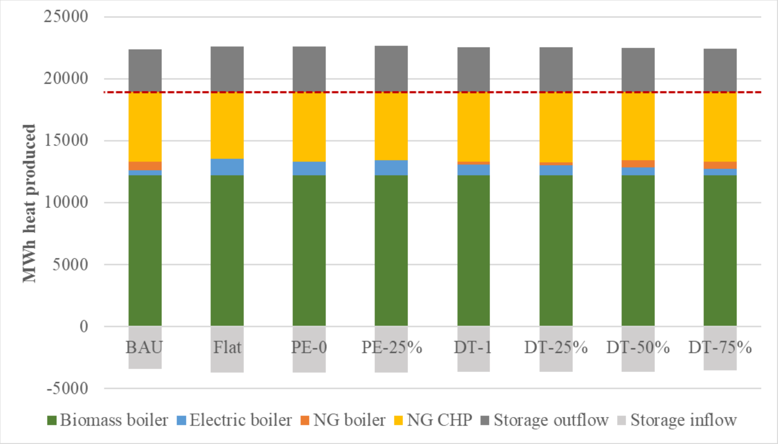

- All the alternative grid tariff designs results in less usage of the NG boiler with no usage in the flat and peak event tariff scenarios

Results: production pattern

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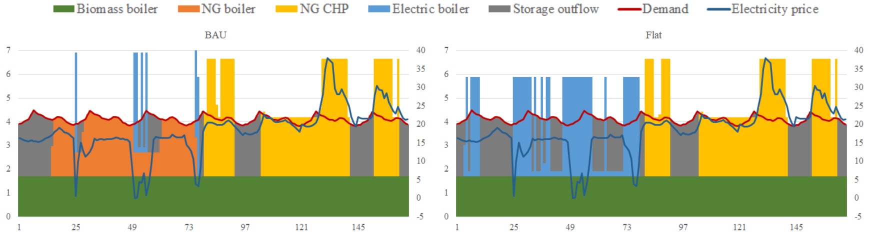

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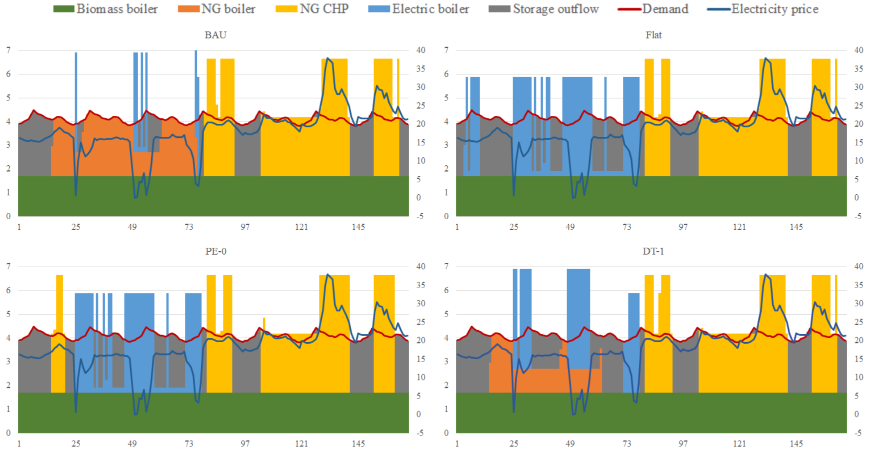

Conclusion

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- Current electricity tariffs represent a barrier to flexibility in decarbonised energy systems
- Alternative grid tariffs are necessary to activate flexibility from DH operators
- The flat tariff is most promising for flexible usage of the electric boiler given that the fixed component is set adequately by the regulator
- The peak-event and dynamic tariffs also provide flexibility but their draw-back is complexity

Thank you for your attention

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