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Effects of retrofitting on the operation and deployment of technologies within a decentralized system

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Leading Questions

- How can part load be integrated adequately in an cost minimizing expansion and unit-commitment optimization model for the heat and power sector
- What is an adequate methodology to integrate building retrofit in the optimization model
- What are qualitative findings can be drawn from modelling an exemplary system in terms of system costs, technology portfolio, and operation of technologies?

Modell Boundaries

Optimization model in General Algebraic Modelling System (GAMS)

The model covers:

- Heat and Power Coupling Technologies
- Generation, Storage and Grid technologies (heat and power)
- Building Retrofit
- Energy efficiency
- Trade at the EEX
- Demand Side Management

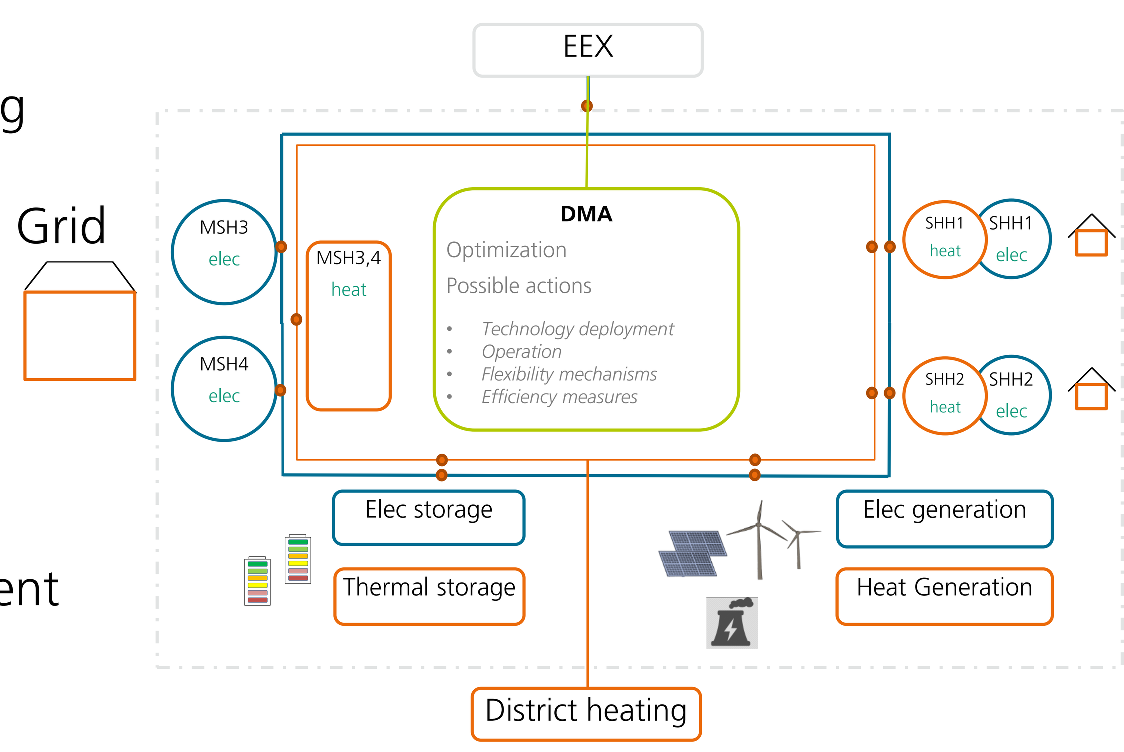


Figure 1 System boundaries of the model

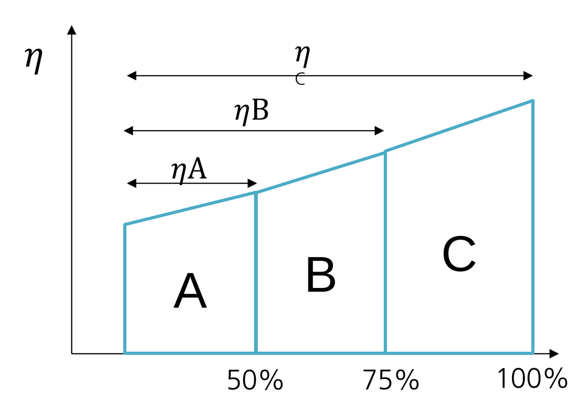
Partload

The overall performance of a combustion technology is split into three partial load ranges A, B and C with different efficiencies.

Conditions:

- Calculate auxiliary efficiencies:

$$\eta auxB_{tec} = \frac{percentB_{tec} - percentA_{tec}}{\frac{percentB_{tec}}{\eta blockB_{tec}} - \frac{percentA_{tec}}{\eta blockA_{tec}}}$$



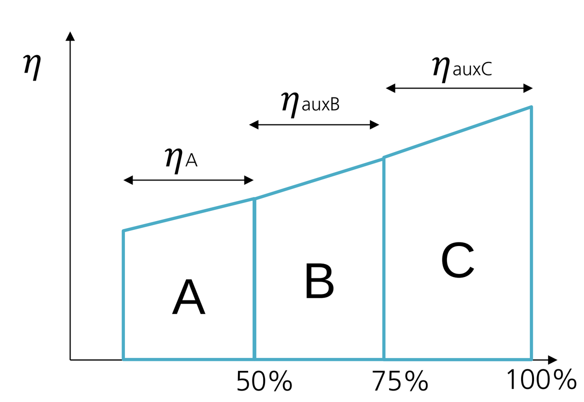
- Binaries integrated to assure the sequence of blocks turned on:

$\nabla(A)_{t,h,pec} \geq \nabla(B)_{t,h,tec}$ and $\nabla(B)_{t,h,tec} \geq \nabla(C)_{t,h,tec}$

$$PB_{t,h,tec} \leq \nabla(B)_{t,h,tec} * bigM$$
$$PC_{t,h,tec} \leq \nabla(C)_{t,h,tec} * bigM$$

- Power of each block:

$$PB_{t,h,tec} \leq cap_{t,h,tec} * (percentB_{tec} - percentA_{tec})$$
$$PC_{t,h,tec} \leq cap_{t,h,tec} * (percentC_{tec} - percentB_{tec})$$

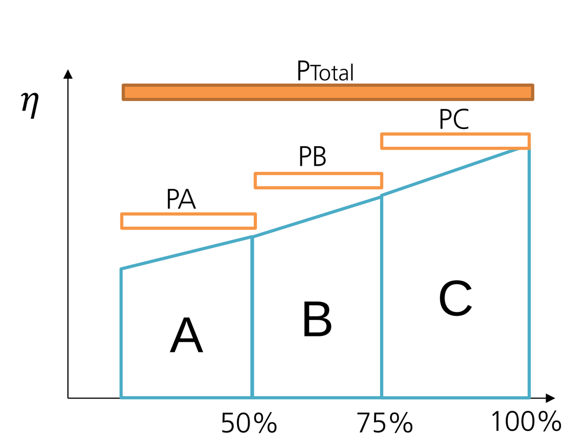


For PA the following equation applies

$$PA_{t,h,tec} = cap_{t,h,tec} * percentA_{tec}$$

- To allow block A to be off

$$PA_{aux_{t,h,tec}} \geq PA_{t,h,tec} - (1 - \nabla(A)_{t,h,tec}) * bigM$$
$$PA_{aux_{t,h,tec}} \leq PA_{t,h,tec} + (1 - \nabla(A)_{t,h,ptec}) * bigM$$
$$PA_{aux_{t,h,tec}} \geq -PA_{t,h,tec} * bigM$$
$$PA_{aux_{t,h,tec}} \leq PA_{t,h,tec} * bigM$$



- Total power output

$$P_{primary} = \left(\frac{P_{Total}}{\eta_{Total}}\right) = \frac{PA}{\eta_{blockA}} + \frac{PB}{\eta_{auxB}} + \frac{PC}{\eta_{auxC}}$$

Retrofit

Within the model one retrofitting measure for a building can be chosen according to a certain KfW standard. For each building three different standards or the option of no retrofitting are implemented. Within the optimization time horizon (typically 10 years) only once a new standard can be deployed. Retrofit is modelled as a generation technology and is therefore added in the sum of the heat balance

Conditions:

- Deploy only one standard:

$\sum_{rt} bin\ retrofit_{t,h,rt} \leq 1$

The model cannot retrofit at T=1:

$\sum_{rt} bin\ retrofit_{t=0,h,rt} = 0$

- New demand calculated

$$retrofit\ gen_{t,h} = \sum_{rt} generation\ retrofit_{t,h,rt} * bin\ retrofit_{t,h,rt}$$

- Investment decision

$$diff\ bin\ retrofit_{t,h,rt} = bin\ retrifit_{t,h,rt} - bin\ retrofit_{t-1,h,rt}$$

Exemplary Results

Advantages of the partload methodology:

- It is possible to present the operation of the technologies in more detail.
- This method of implementing partload allows the calculation to stay a Mixed Integer Problem.

Advantages of presenting retrofit as a generation technology:

- Calculation time is saved by subtracting the saved demand through retrofitting in the heat balance equation to avoid a non linearity through reading in a new demand every time retrofit is implemented.

The methodology was tested in the following calculation *[1]:

- 8 Residential buildings, each 2000 m² area with District heating
- Heating demand: 1,229 MWh/a — Renovated: 627 MWh/a
- Hot water demand: 527 MWh/a — Power demand: 733 MWh/a

First results show that retrofitting has a systematic effect, reducing the required temperature levels from the heating grid and therefore saving gas boilers and deploying heat pumps. *[1]

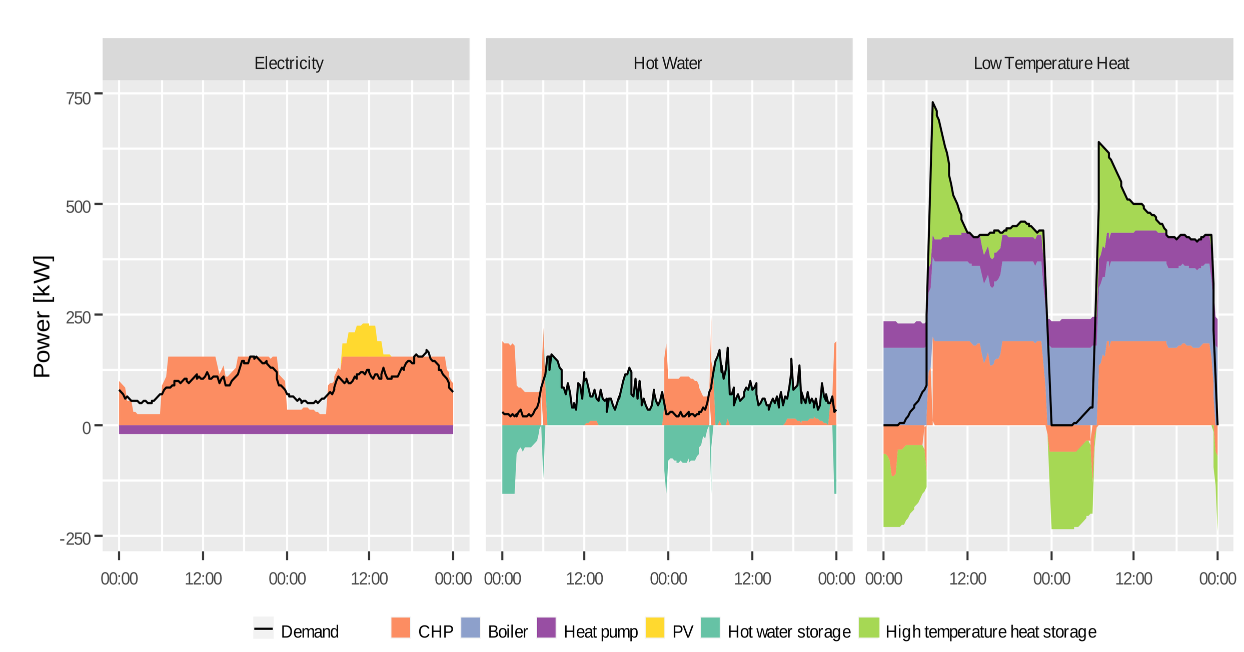


Figure 2
Load and generation profiles for DMA case on January 6th and 7th

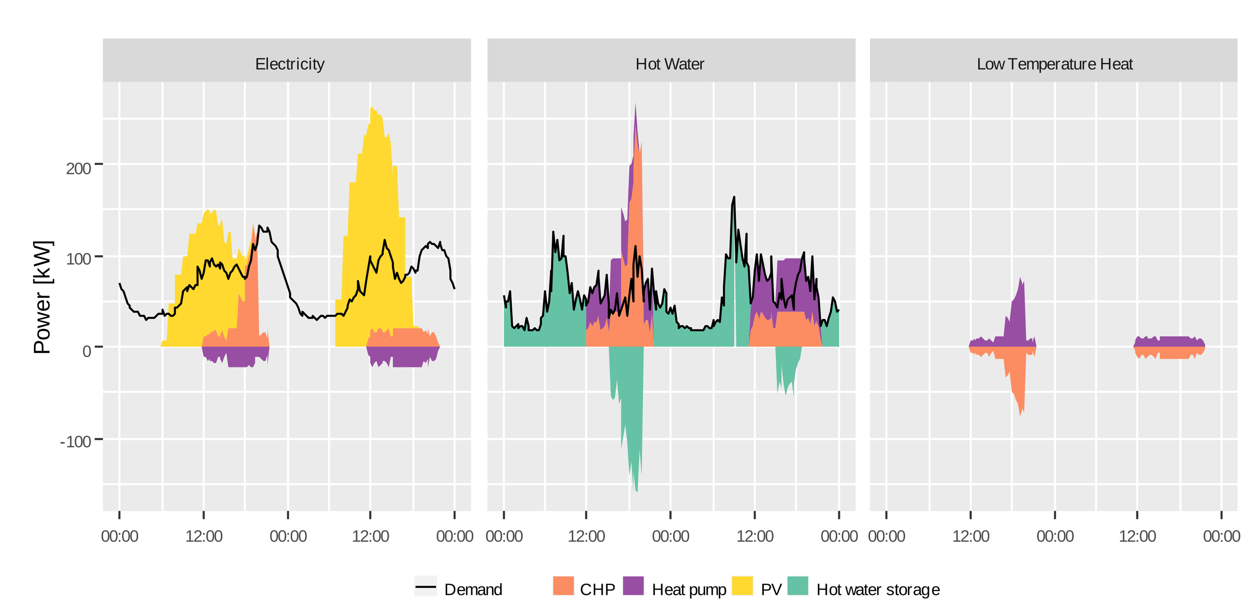


Figure 3
Load and generation profiles for DMA case on July 4th and 5th

*[1] N.S. Hussein et al., Possible actions to maximize the flexibility usage in a decentral energy system for the heating and electricity sector, 14th symposium Energieinnovation, 10-12.2 Graz, 2016