Project BiNe: Results of the Energy-Information-Cost Model

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Als Mitglied des Fachverbandes vertreten bei

Results of the Energy-Information-Cost Model

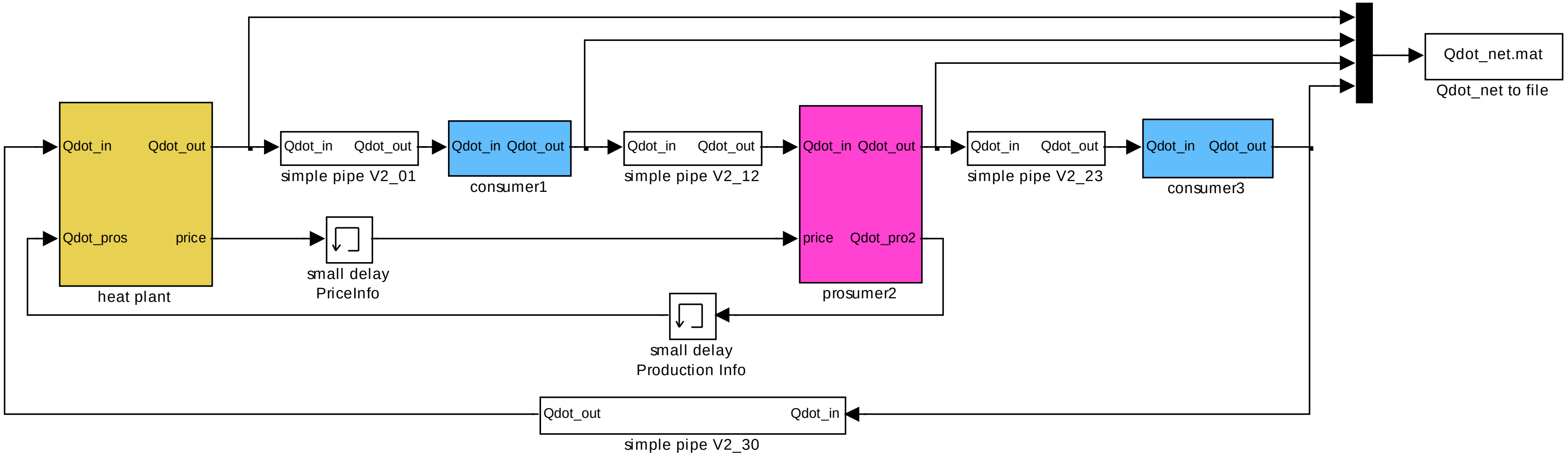
- Why an energy-information-cost model?
- General structure of the model
- Emission model
- Economic model
- Parameter optimisation
- Some results

Why an Energy-Information-Cost Model?

- High quality control strategies (both technical and economic) are essential for the success of de-centralized heat supply and inclusion of prosumers.
- Technical and econmic control can influence each other and thus should be modeled and simulated in a combined approach.
- On the other hand, many aspects of technical and economic control are almost independent of physical details of the implementation.
- Analyse interplay between control systems → simplify physical system and technological implementation as far as possible.

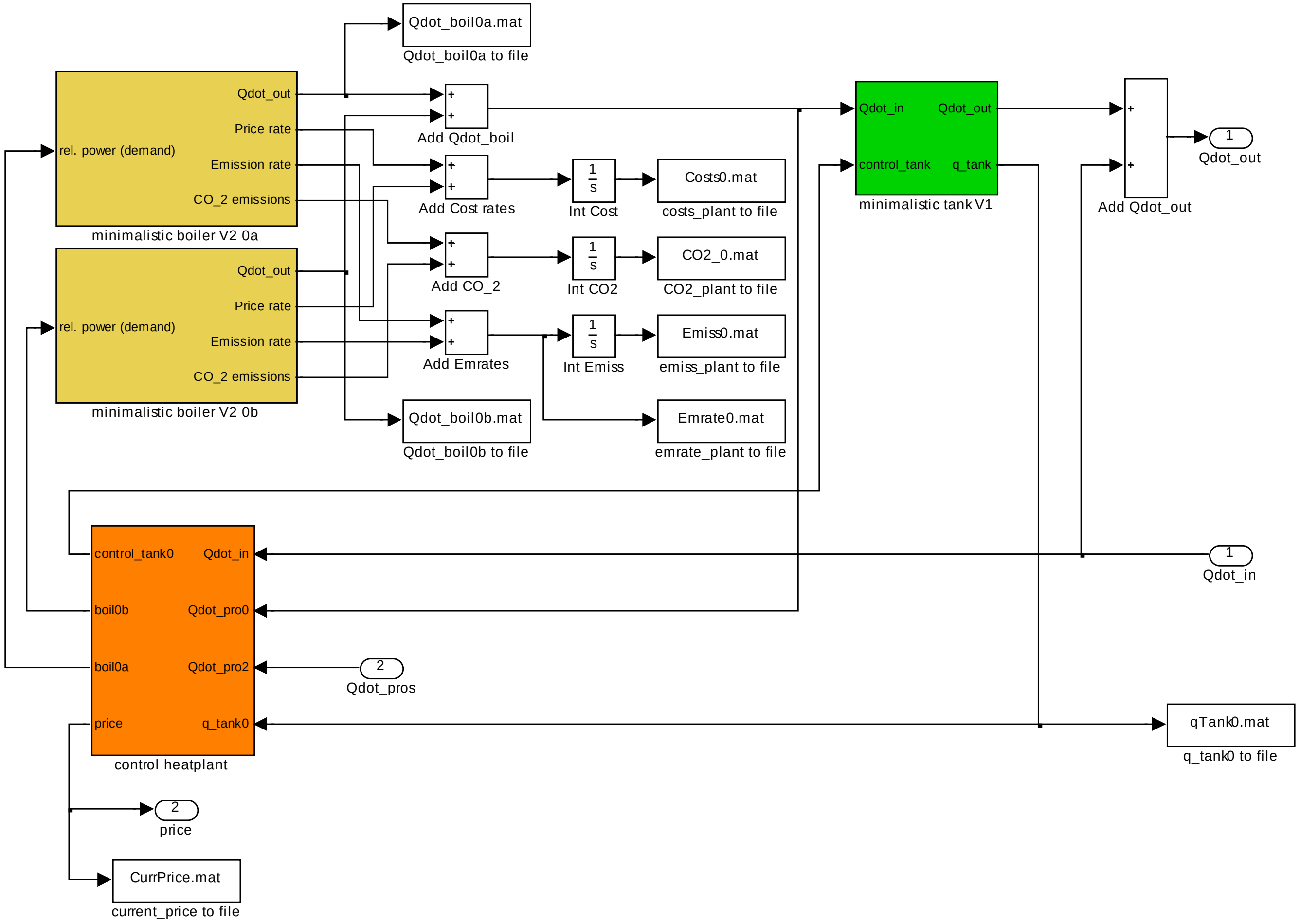
General Structure of the Model (1/3)

- Heat plant, two aggregated consumers and a prosumer
- Employ energy and information flow, but no further physical quantities (like pressure and temperature)
- Implementation in MATLAB/Simulink:



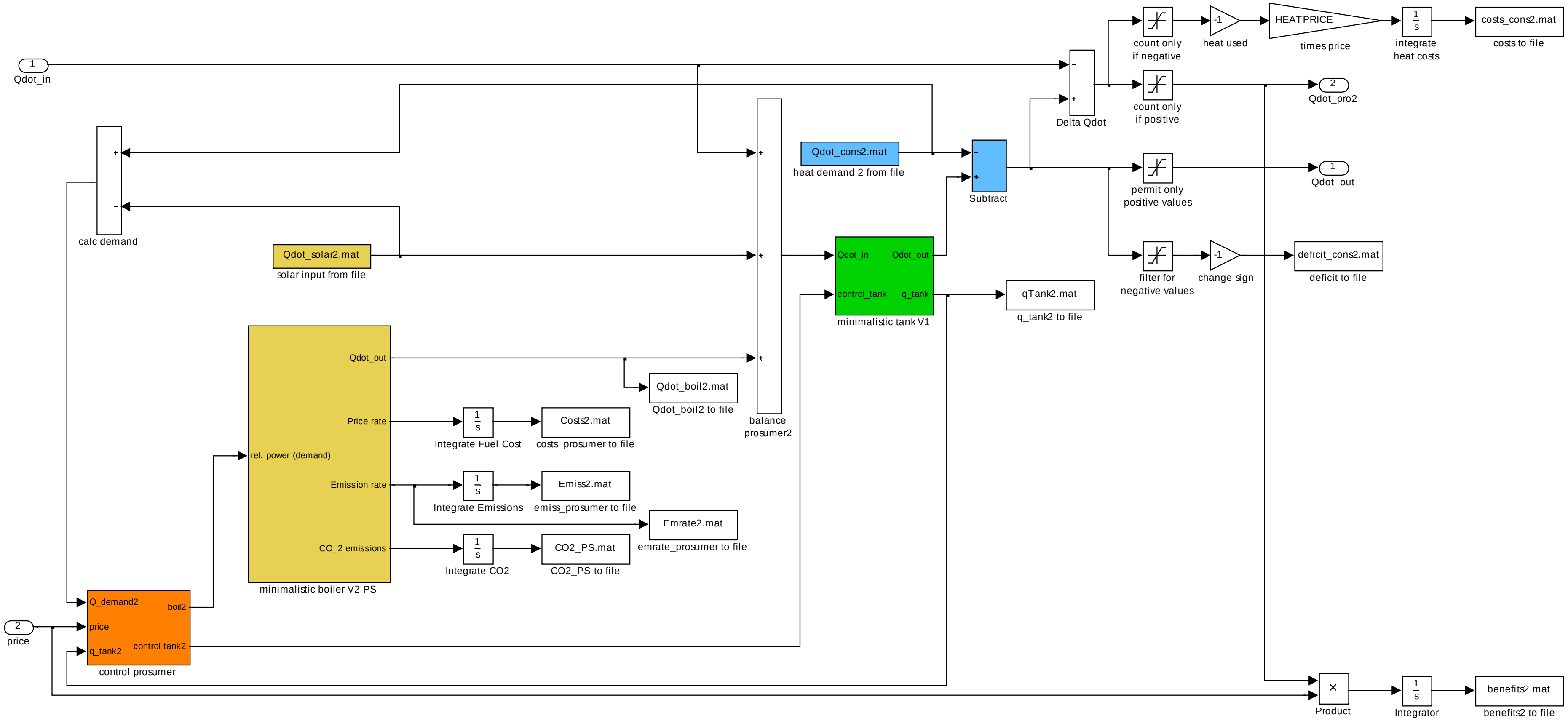
General Structure of the Model (2/3)

- Heat plant (base and peak load boiler, storage tank):



General Structure of the Model (3/3)

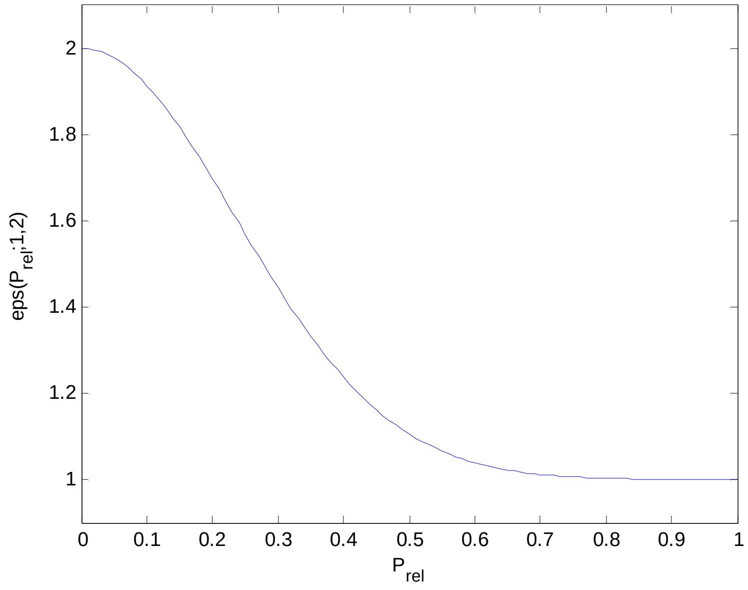
- Prosumer (boiler, solar thermal, storage tank):



Emission model

- Emission charakteristics of boilers very different, in particular in partial load mode
- For this simulation simple analytic model, emissions only depend on boiler power:
- $Em(P) = P \times \varepsilon(\frac{P}{P_0})$ with

$$\varepsilon(P_{rel}) = \epsilon_{min} + (\epsilon_{max} - \epsilon_{min}) \times e^{-9 \times P_{rel}^2}$$

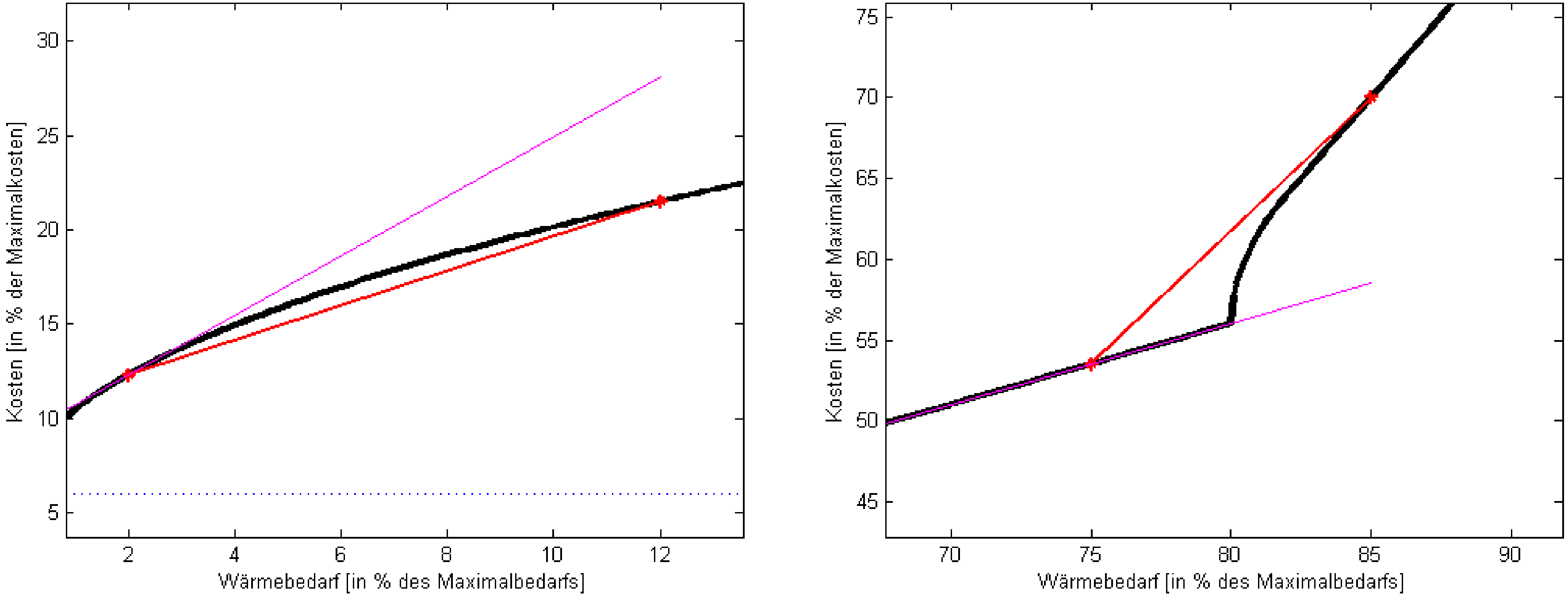


Economic Model (1/3)

- Fundamental approaches to economic system:
  - Complete central control
  - Market-based model with situation-dependent prices for heat in-feed → presumably more attractive for prosumers (who retain decision autonomy)
- How to calculate price payed for heat in-feed?
  - Savings of heat plant due to de-central heat supply?
  - Define upper and/or lower limit for prices?
  - Upper limit for total compensation with defined periods of time?

Economic Model (2/3)

- Price estimated as tangent or secant to cost function:



- Secant yields (almost) exact cost reduction
  Tangent can under- oder overestimate the fair price

Economic Model (3/3)

- Upper limit for prices:
  - advantageous for heat plant
  - not problematic, as long as limit price is high enough
- Lower limit for prices:
  - advantageous for prosumer
  - problematic if limit price is too high
    → provokes unnecessary energy in-feed
- Limit for total compensation :
  - also problematic: risk of missing heat supply at the end of the relevant period

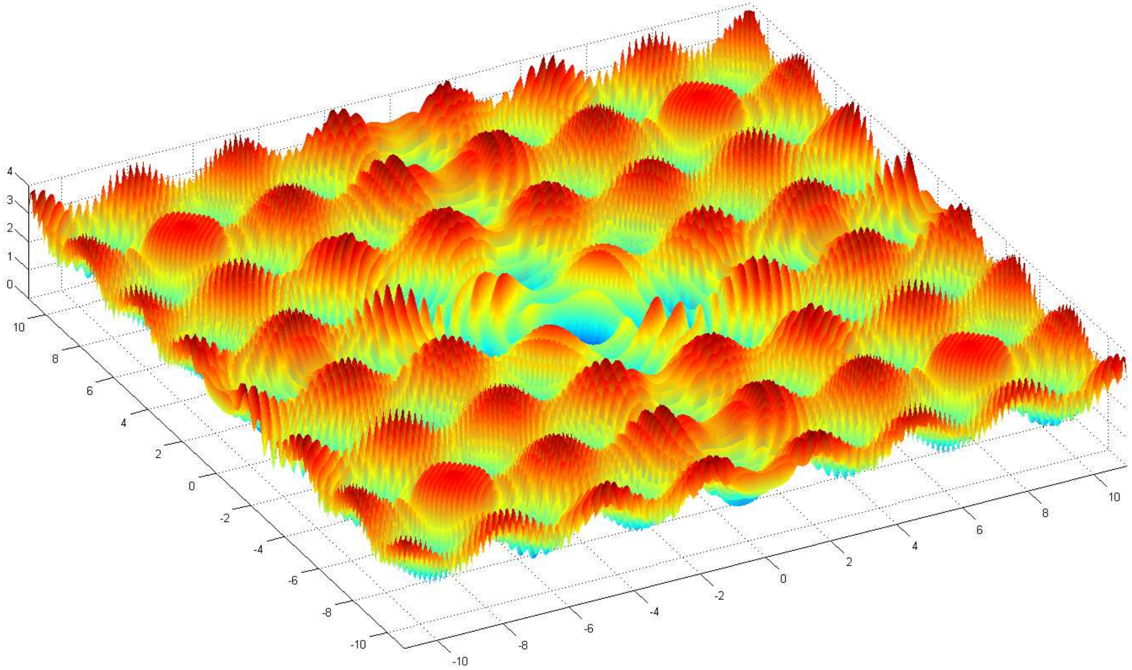
Parameter Optimization (1/3)

- Current control strategy contains14 free parameters
- Various goals: Reduction of costs (which mostly stem from fuel consumption), reduction of CO_2 and toxicological emissions, reliability of the grid
- Define *cost function*: emissions and missing heat are artificially endowed with a price (corporate or political decision) → weighting as compared to fuel and other „real“ costs

Parameter Optimization (2/3)

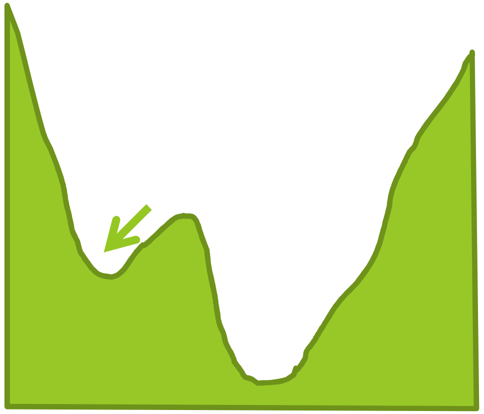
- Minimize cost function with respect to the parameters. Simulations for pre-defined periods of time (one week in winter, during transition time and in summer)

- Task: Find global minimum of function of several variables, each evaluation computationally very expensive.



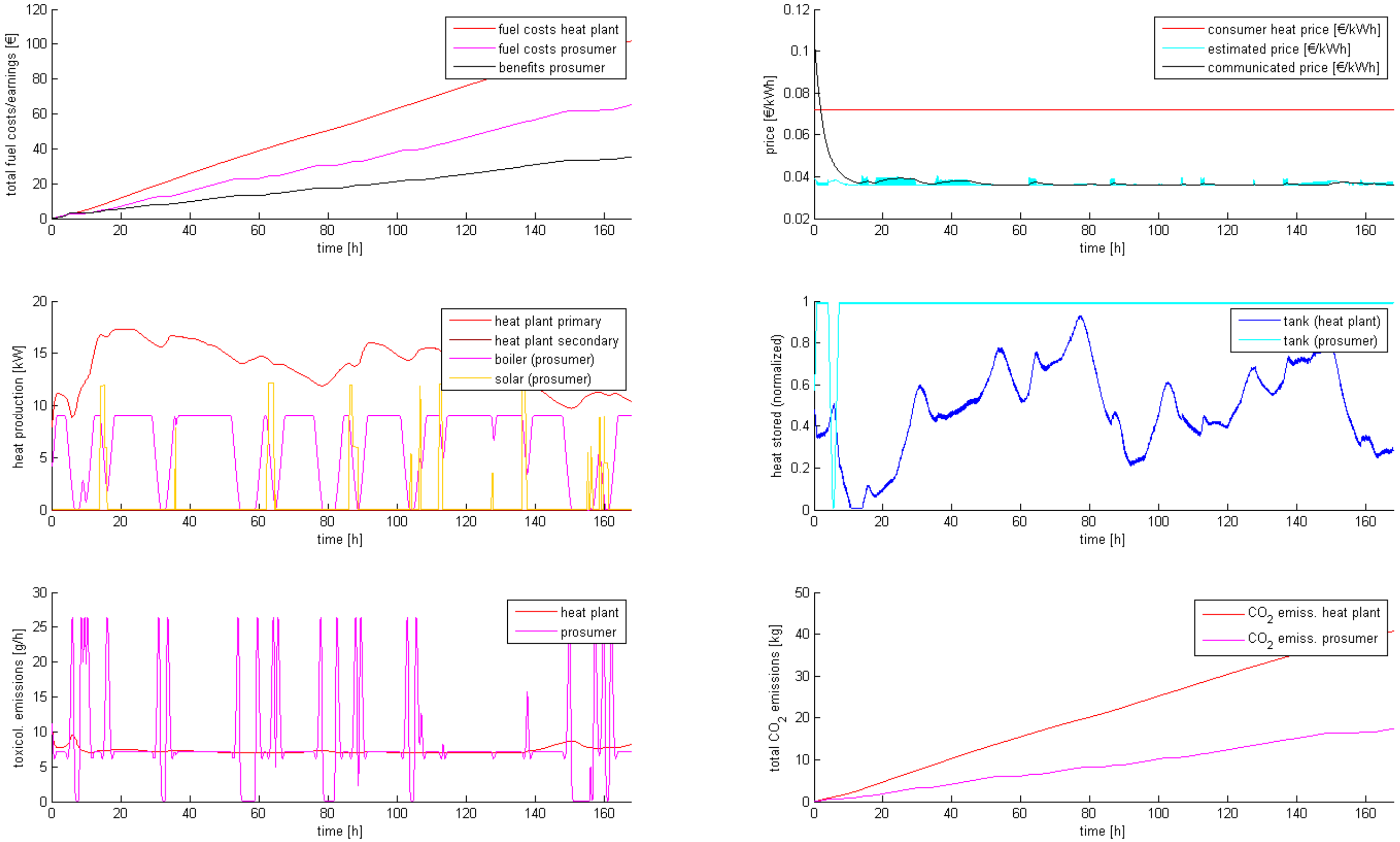
Parameter Optimization (3/3)

- Methods:
  - *Steepest descent* and related methods (e.g. *conjugate gradients*): few evaluations necessary, here O(100), but usully finds only local minimum close to initial guess.
  - Grid-based systematic („brute-force“) optimization: would require O(10^{28}) evaluations for a reasonably fine grid.
  - Resort: Employ stochastic methods, e.g. *simulated annealing*: Local minima can be left again, usually good results with O(1000) evaluations.



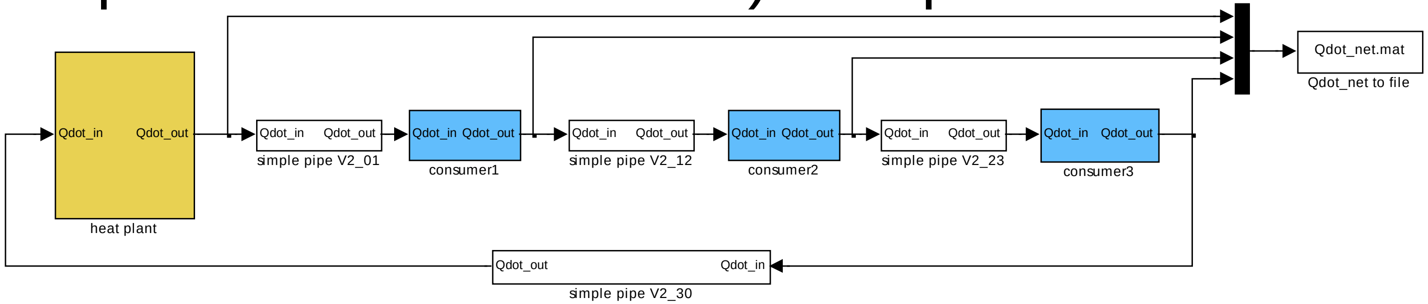
Results (1/4)

- Typical simulation run (one week in spring):

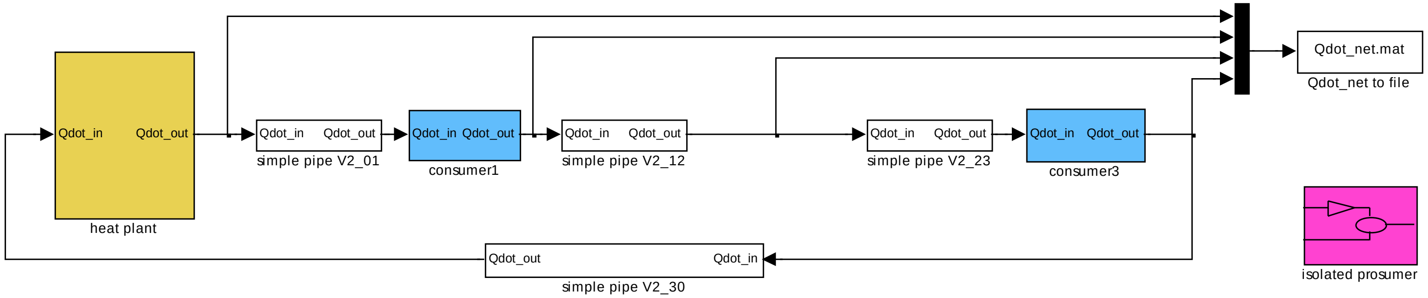


Results (2/4)

- Comparison with similar model, but with pure consumer (i.e. prosumer → consumer): `simple`



- Comparison with similar model, but with isolated producer (neither heat in-feed nor extraction): `split`



Results (3/4)

- Comparison with `split` scenario (assuming 20 cold, 18 transition and 14 warm weeks), prosumer with 10 kW boiler and 13 kW solar thermal device:

Vergleich mit Szenario `split`*:*

bPS	second boiler	PS_price	Fuel Pl	Fuel PS	Net earn Pl	Net earn PS	emiss [kg]	CO_2 [kg]	Heat def.	SumDiff
0	Gas	normal	-€ 283,10	-€ 41,35	-€ 153,52	+€ 479,20	-10,34	-124,29	+18,51	**€ 325,68**
1	Gas	normal	+€ 647,40	-€ 951,12	-€ 376,63	+€ 682,05	+12,10	+5,29	-119,44	**€ 305,43**
-1	Gas	normal	-€ 229,76	-€ 929,91	+€ 188,95	+€ 944,20	-29,42	-328,65	-102,59	**€ 1.133,15**
0	Holzabfälle	normal	-€ 627,30	+€ 220,78	-€ 1.832,19	+€ 2.238,24	+131,70	+467,11	-21,63	**€ 406,05**
1	Holzabfälle	normal	-€ 616,67	+€ 220,78	-€ 1.914,19	+€ 2.309,24	+131,94	+520,92	-16,32	**€ 395,05**
-1	Holzabfälle	normal	-€ 689,75	+€ 220,78	-€ 1.733,14	+€ 2.200,18	+131,87	+368,39	-0,64	**€ 467,04**
0	Gas	billig	-€ 1.114,96	+€ 279,93	-€ 1.269,00	+€ 2.103,76	+88,90	+300,24	-114,79	**€ 834,77**
1	Gas	Billig	-€ 1.156,17	+€ 279,93	-€ 1.278,52	+€ 2.150,86	+89,34	+283,76	-59,84	**€ 872,34**
-1	Gas	Billig	-€ 1.135,18	+€ 279,93	-€ 1.192,26	+€ 2.046,87	+90,49	+292,15	-106,17	**€ 854,62**
0	Holzabfälle	billig	+€ 986,59	-€ 1.210,57	-€ 899,52	+€ 1.123,37	-19,84	+96,20	-20,27	**€ 223,86**
1	Holzabfälle	billig	+€ 512,59	+€ 494,83	-€ 2.537,92	+€ 1.530,57	+1,98	+653,38	+68,02	**-€ 1.007,34**
-1	Holzabfälle	billig	+€ 154,59	-€ 1.210,57	+€ 40,28	+€ 1.015,37	-24,72	-260,98	+20,69	**€ 1.055,66**

Results (4/4)

- Economic balance in market model can be difficult. Often improvements for whole system, but higher costs or lower incomes for one player (usually heat plant) → economic model has to be improved.
- Next steps:
  - Improve economic and control approach (also with predictive elements, including weather forecasts),
  - Transfer control strategies to more realistic model (including temperature and pressure levels),
  - Increase size of model system in order to simulate more realistic district heating systems.