Heat Roadmap Europe 2050
A low-carbon heating and cooling strategy

4DH
4th Generation District Heating Technologies and Systems

reINVEST

3RD INTERNATIONAL CONFERENCE ON

SMART ENERGY SYSTEMS AND 4TH GENERATION DISTRICT HEATING

COPENHAGEN, 12–13 SEPTEMBER 2017

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1949

Smart hybrid renewable energy for communities (SHREC)

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Background


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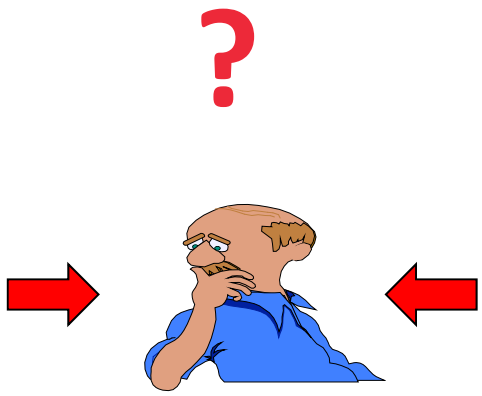
FUEL
E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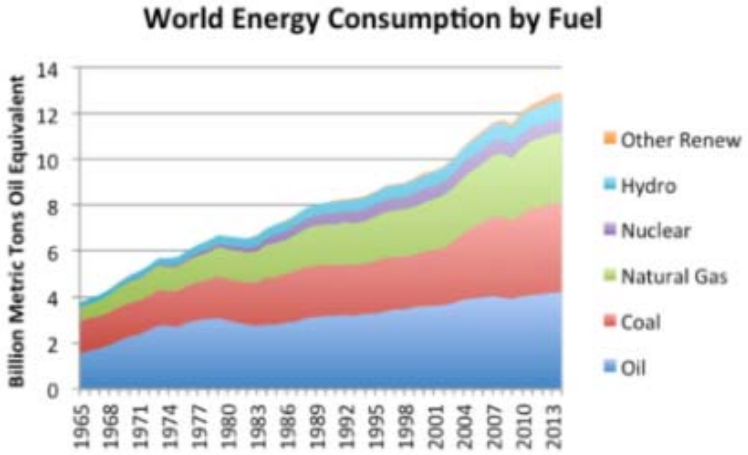
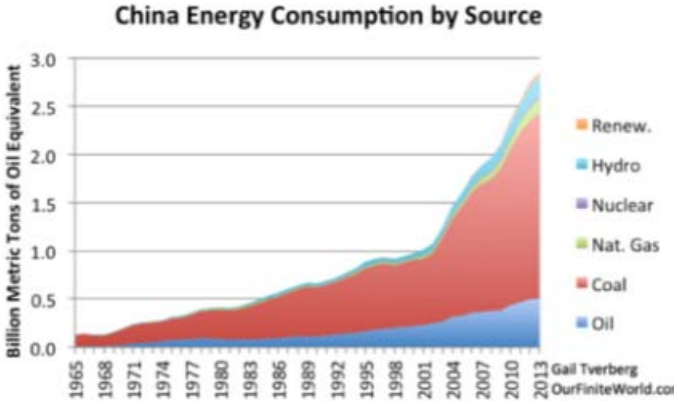

World Energy Consumption by Fuel
Billion Metric Tons Oil Equivalent
0
2
4
6
8
10
12
14
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Other Renew
Hydro
Nuclear
Natural Gas
Coal
Oil


China Energy Consumption by Source
Billion Metric Tons of Oil Equivalent
0.0
0.5
1.0
1.5
2.0
2.5
3.0
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Renew.
Hydro
Nuclear
Nat. Gas
Coal
Oil
Gail Tverberg
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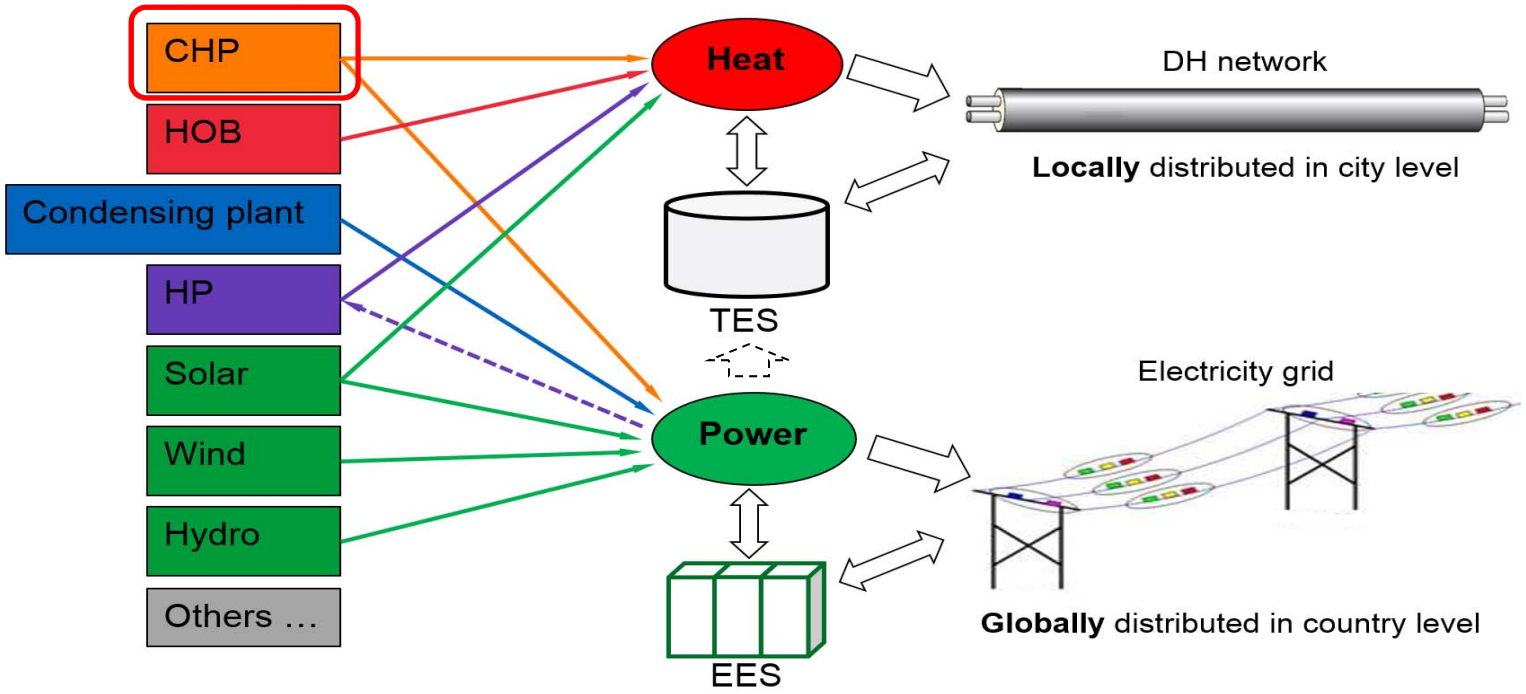
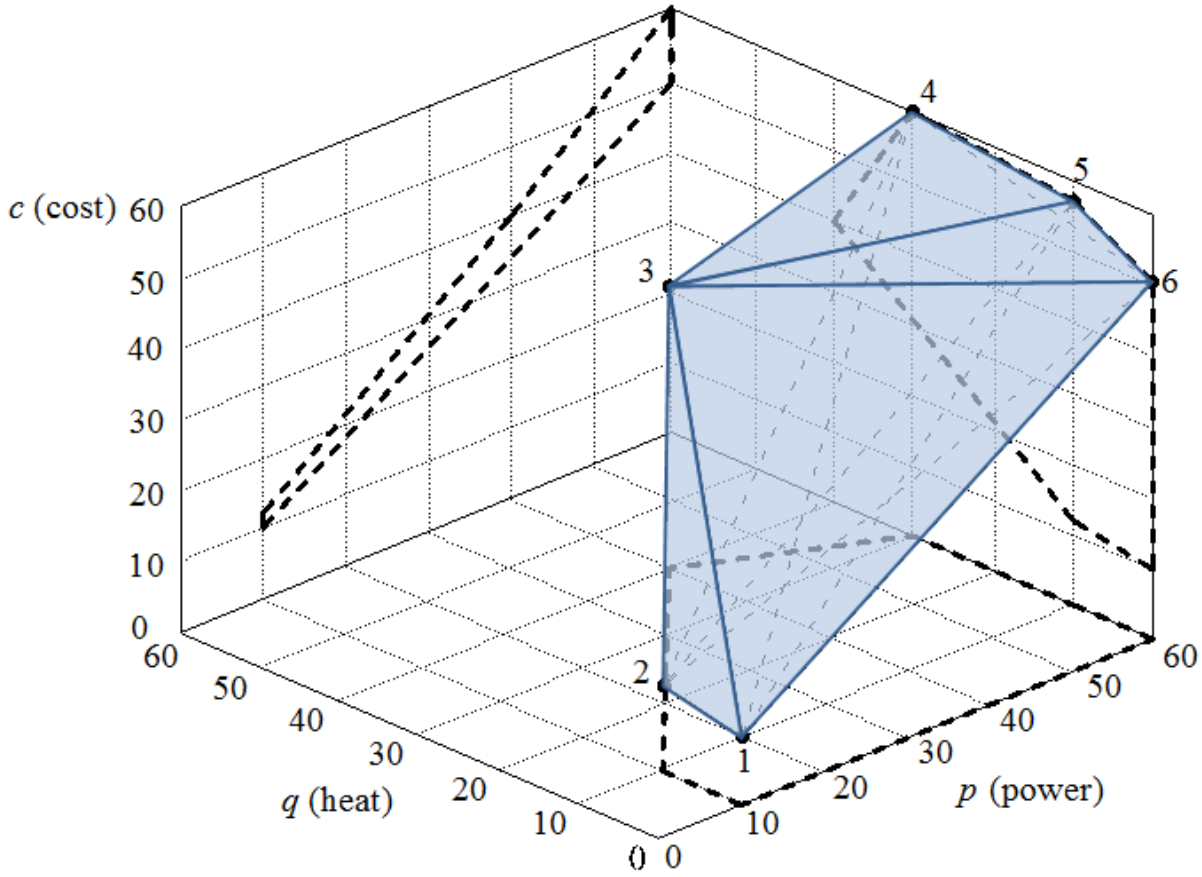
SHREC system



CHP – Combined heat and power; DH – District heating; HOB – Heat only boiler;
HP – Heat pump; TES – Tehermal energy storage; EES – Electricity energy storage.

Schematic energy flow in one model region, different regions may have different components and it is not necessaryt to have all components in one region.

Modelling of ONE CHP



Characteristic points and feasible operating region of a CHP.

Modelling of ONE CHP

- Basic formulation for ONE CHP
  - E.g. to minimize the energy production cost over a planning period.

$$\min Z = \sum_{j \in J} c_j x_j$$

s.t.

$$\sum_{j \in J} x_j = 1$$

Power balance $$\sum_{j \in J} p_j x_j = P$$

Heat balance $$\sum_{j \in J} q_j x_j = Q$$

$$x_j \geq 0,\ j \in J$$

where,

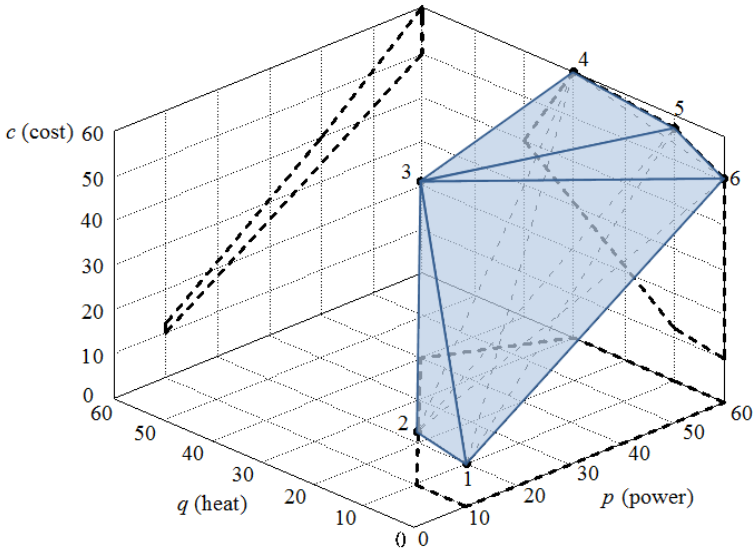
J - index s
of CHP

c_j - cost c

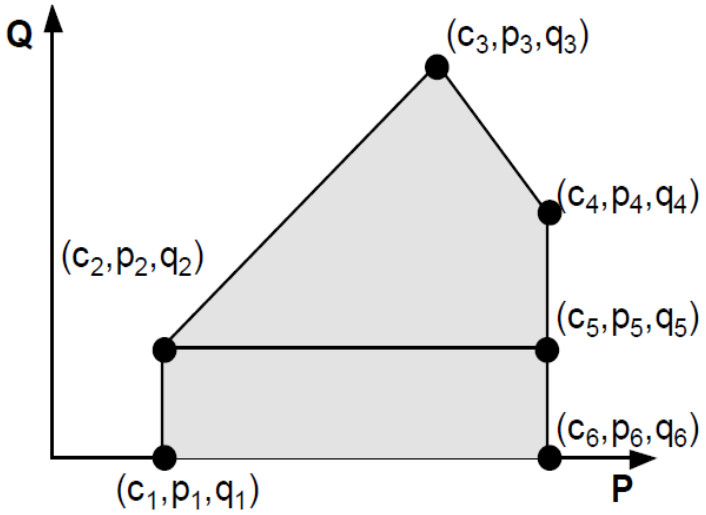
x_j - decisic
extrem

p_j, q_j – pow
chara

P,Q – powe



- Long term planning → Hourly models→LP



Modelling and optimization of SHREC

To minimize the overall costs of the net acquisition for heat and power in deregulated power market over a period.

Objective function $\min Z = \sum_{t=1}^{T}\left[\left(\sum_{j\in J_u} c_j x_j\right) - c_p^t P_G^t\right], t = 1,\ldots,T.$

Convexity constraint $\sum_{j\in J} x_j = 1$

Power balance $\sum_{j\in J_u, u\in U^p \cup U^{pq}} (p_j x_j)^t - p_{chr}^t + p_{dis}^t = P_G^t = P^t$

Heat balance $\sum_{j\in J_u, u\in U^q \cup U^{pq}} (q_j x_j)^t - q_{chr}^t + q_{dis}^t = Q^t$

Storage balance $S_q^t = \eta_{qs} S_q^{t-1} + q_{chr}^t - q_{dis}^t \;;\; S_p^t = \eta_{ps} S_p^{t-1} + p_{chr}^t - p_{dis}^t$

Storage level constraint $S_q^{\min} \le S_q^t \le S_q^{\max} \;;\; S_p^{\max} \le S_p^t \le S_p^{\max}$

Time steps $t = 1,\ldots,T.$

Non-negativity constraint $x_j \ge 0,\ j \in J_u, u \in U^{pq}$

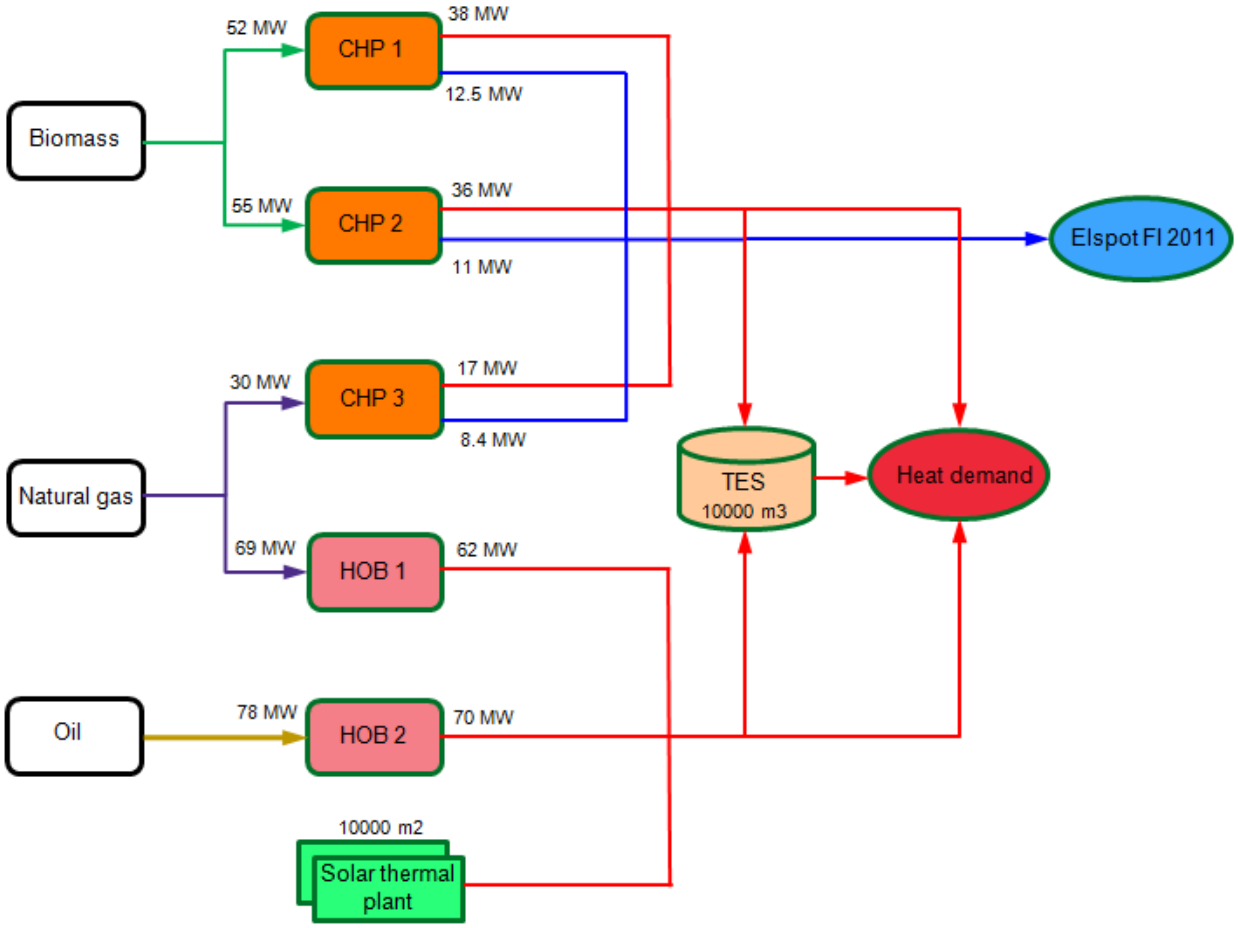
$0 \le x_j \le 1,\ j \in J_u, u \notin U^{pq}.$

- Ramp

$$\left|(p_j x_j)_u^t - (p_j x_j)_u^{t-1}\right| \le p_{u,ramp}$$

LP2 was developed and used to solve this problem.

Modelling and optimization of SHREC



1. **Planning period**
   One week
2. **Model input data**
   Characteristic points of CHPs
   Meteorological data
   Heat demands
   Nordpool electricity price
   Fuel price
   Storage efficiency
3. **Model output**
   Optimal planning and operation of each plant and TES
   Total cost optimum

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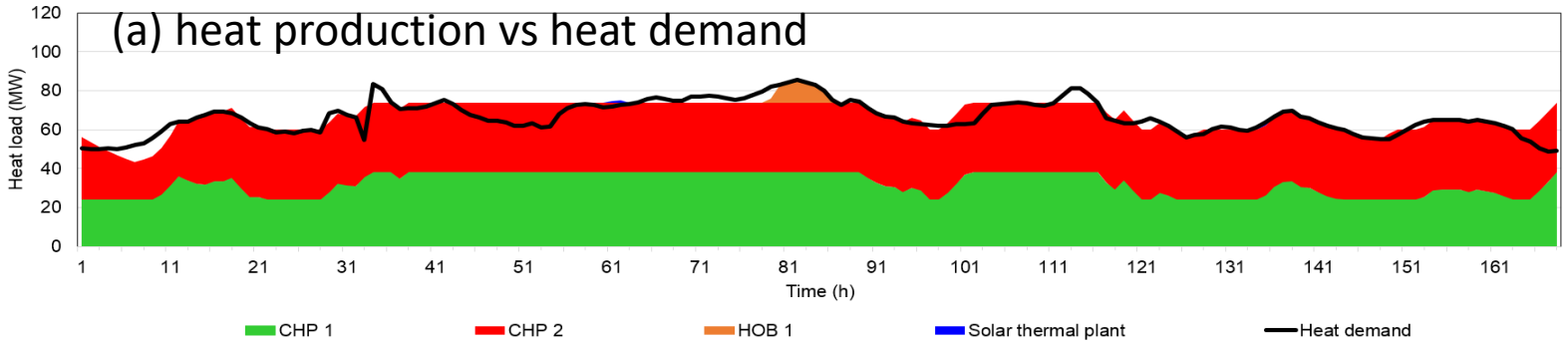
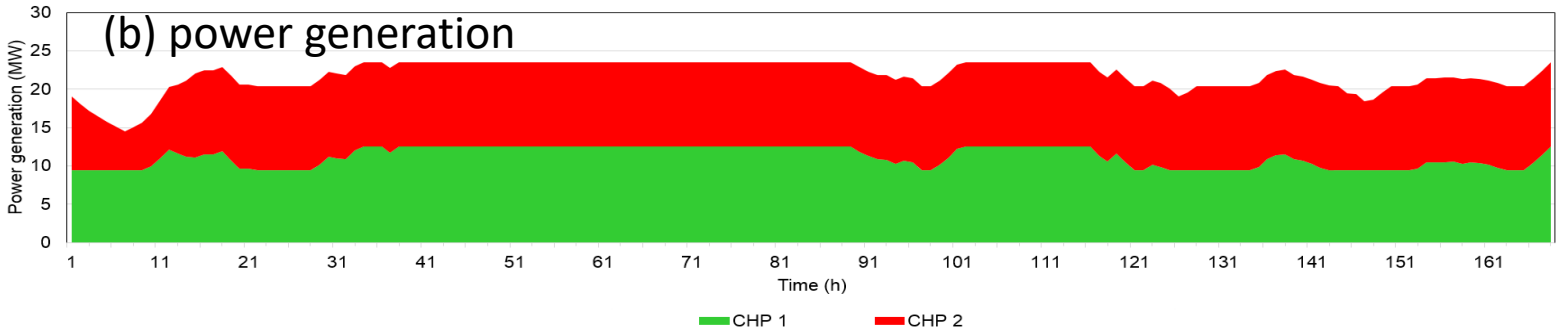
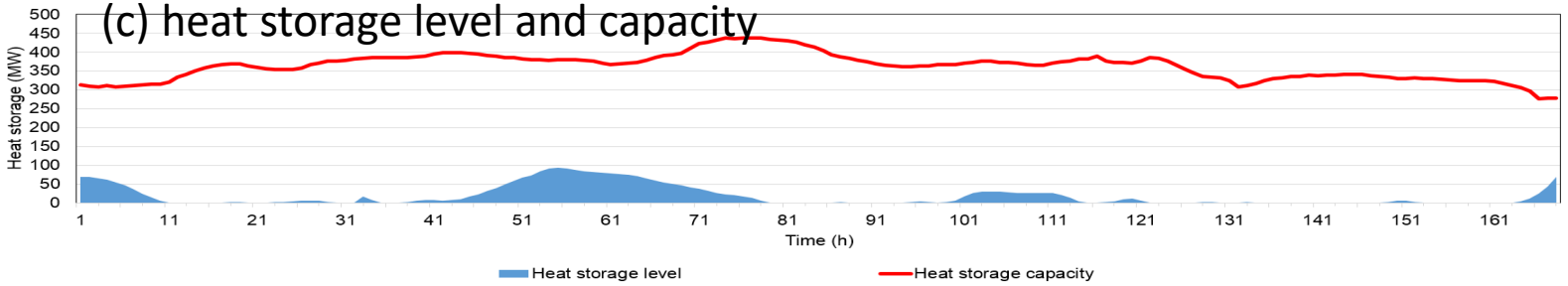
Modelling and optimization of SHREC



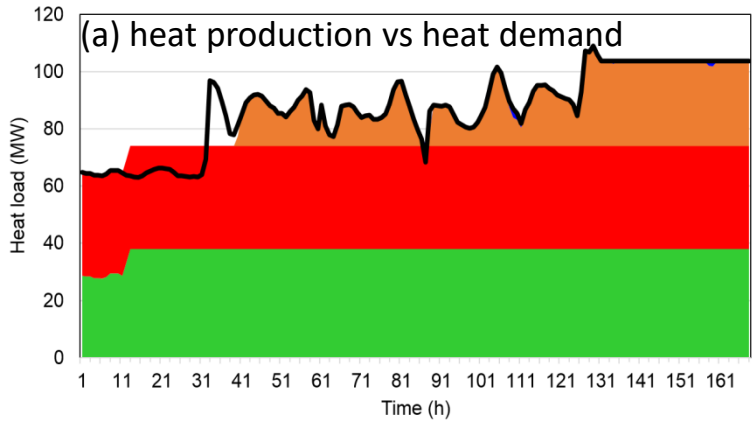


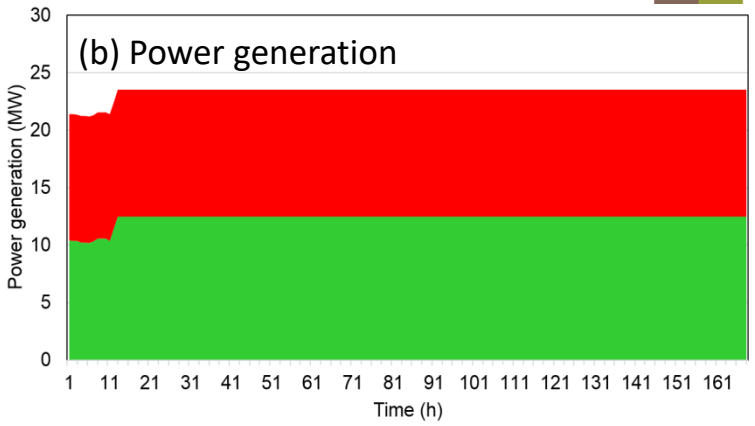


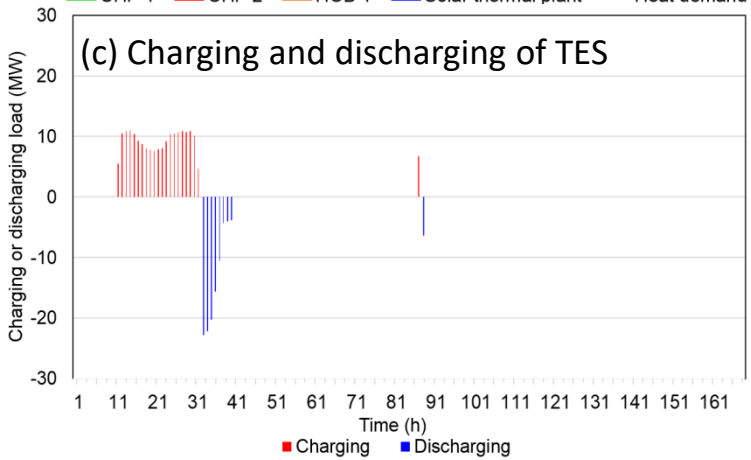
Model validation

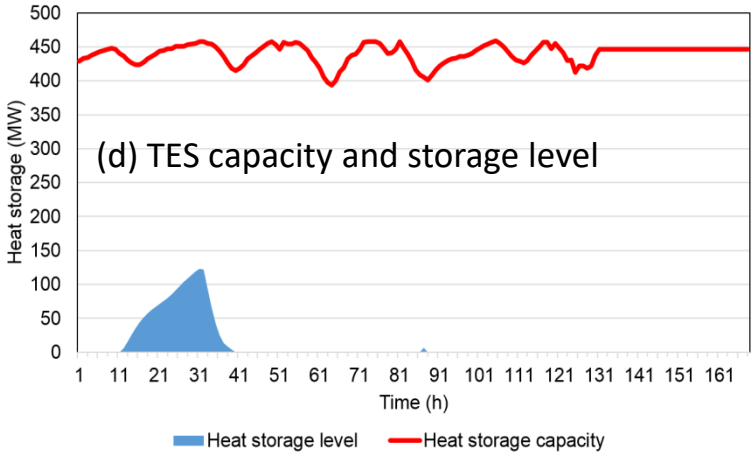
Results and conclusion

Cold season - February 13-19 when the maximum peak heat demand occurred.









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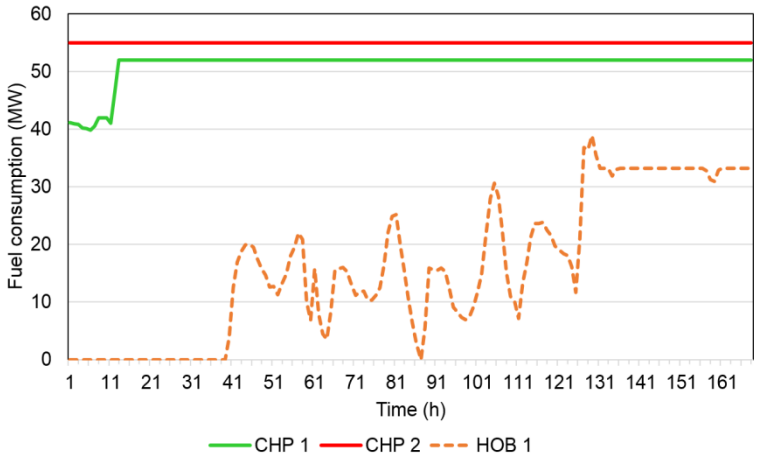
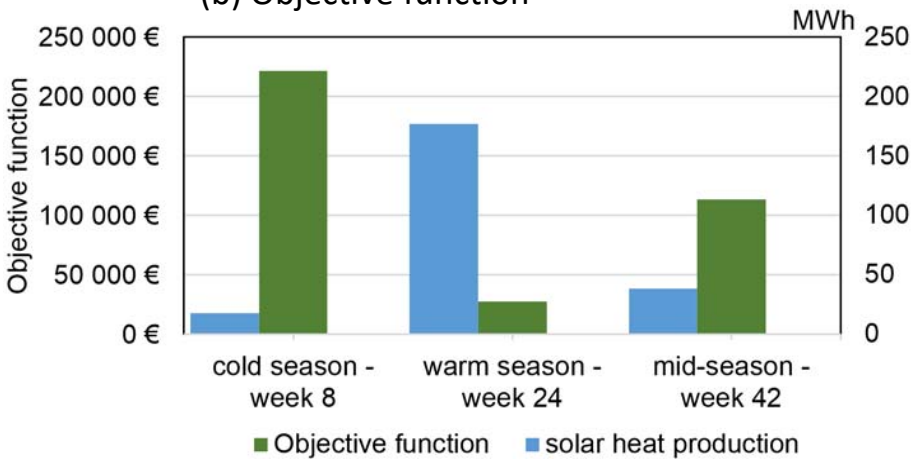
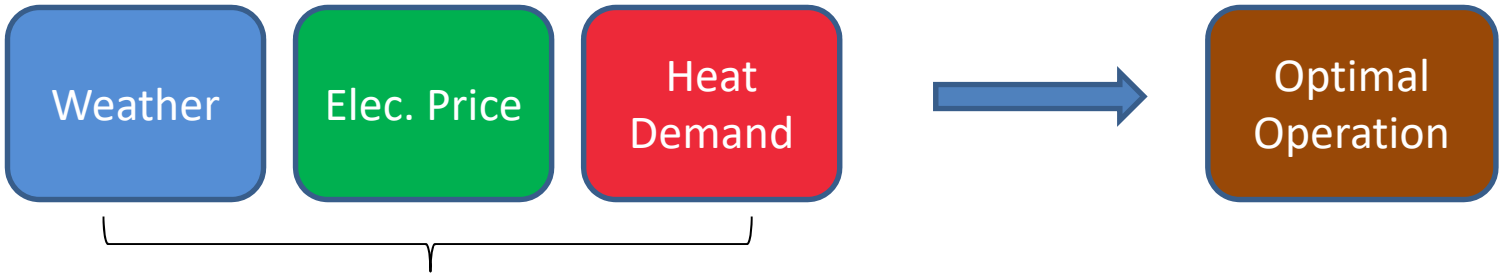
Results and conclusion

(a) Fuel consumption



(b) Objective function





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Results and conclusion

SHREC can be seen as part of 4DH or a step to realize it.

It is a very demanding task to design and operate the SHREC system. Therefore, a mathematical planning mode was developed based on the CHP modelling technique and a more efficient linear programming algorithm named LP2 was developed to solve it.

The developed model is more efficient for modelling and optimizing the SHREC system and it can provide more detailed information on charging and discharging heat load and fuel consumption of each plant, which are very important for operating the SHREC system.

The modeling and optimization of the SHREC system in day ahead level is more meaningful to facilitate an optimal real life operation rather than long term planning.

Thank you for your attention