Ecological driven Energy Management: how to build up the active load shifting in LCA

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Introduction & Objectives

Refrigeration technology exhibits a share of approx. 14% of the total electrical energy demand in Germany and it is responsible for approx. 5 % of the direct and indirect green house gas emissions.(a)

Sustainable cooling supply solutions therefore are one important step towards reaching the 2 degree Celsius target for the limitation of global warming.

In the German public funded project “Energienetz Berlin Adlershof – Smart Grid Allianz” an energy management system for cooling networks is under development which addresses both, economical and ecological optimization.

The heart of the cooling network considers an ice storage unit (Fig. 01) which allows the decoupling of cooling production and cooling demand.

The ice storage unit can be used to integrate a higher share of renewable energy by shifting the cooling production to times with high electricity production from wind power or photovoltaic.

Otherwise energy efficiency of cooling supply can be increased by shifting the cooling production to periods with more favorable temperature conditions.

(a) Carsten Heinrich et. al, CLIMATE CHANGE 25/2014: Nachhaltige Kälteversorgung in Deutschland an den Beispielen Gebäudeklimatisierung und Industrie, Umweltbundesamt, Dessau, 2014

Fig. 01: Ice storage, Center of Photonic and Optics © TU Berlin

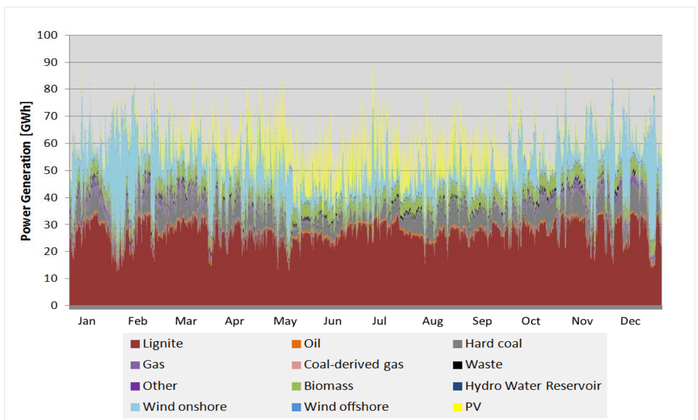

Fig. 02 Power Generation in German 50Hertz zone in 2016 according to ENTSO-E transparency platform

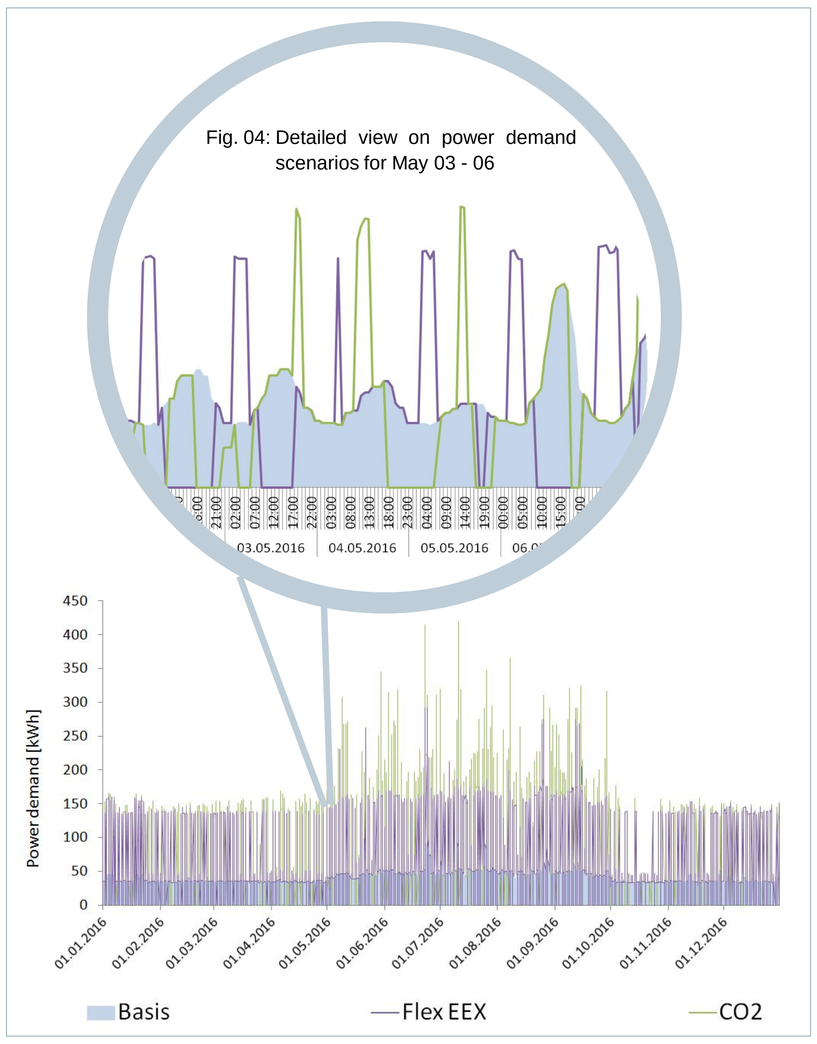

Fig. 03: Power demand scenarios for 2016

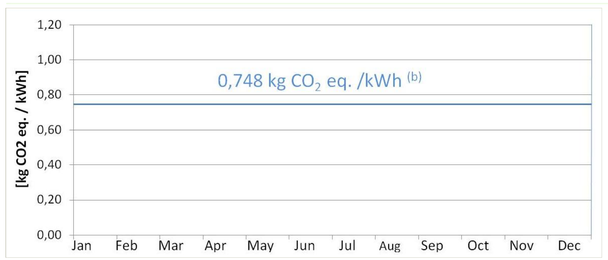

Fig. 06: Average Global Warming Potential of electricity production in German 50Hertz zone 2016

Evaluation of electricity demand

Fig. 05: Annual electricity demand and electricity costs

Evaluation of electricity demand

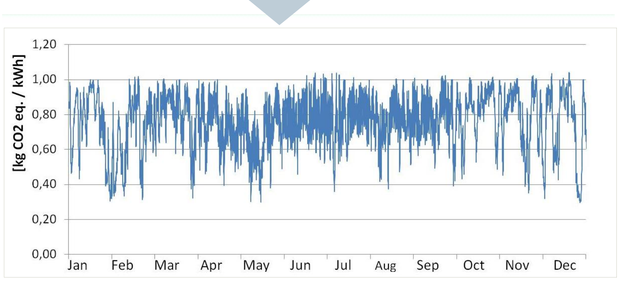

Fig. 06: Global Warming Potential of electricity production in German 50Hertz zone 2016 in hourly resolution

Methodology

Ecological optimization:

Goal: Lowering carbon footprint of power demand by shifting cooling to periods with high shares of renewables

Based on hourly given power generation mix (Fig. 02) an hourly Global Warming Potential (GWP) profile (Fig. 06) can be build up that serves as target function.(b)

Economical optimization:

Goal: Lowering costs of power demand by shifting cooling to periods with low electricity prices

Optimization is using the given EEX spot market prices in 2016 plus 15 % margin and 11 ct/kWh for taxes, levies or charges as a target function.

- **Basic**: Direct cooling without load management (basic scenario)
- **Flex EEX**: Economical optimization of cooling by using of ice storage (Scenario: Flex EEX)
- **CO2**: Ecological optimization of cooling by using of ice storage unit (Scenario: CO2)

Annual cold supply: 2150 MWh_{th}

All scenarios consider storage losses and outdoor temperature related efficiency of chillers.

(b) LCA background data: ecoinvent 3.3, SimaPro 8.3

Calculation base: Average annual power mix

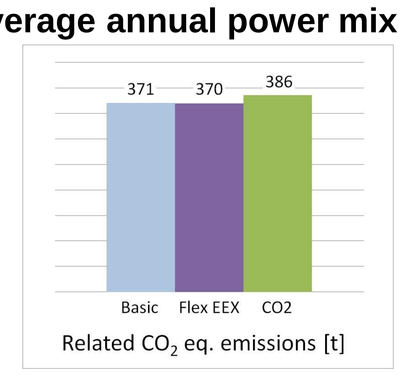

Fig. 07: Global Warming Potential of annual power demand using average annual power mix

Calculation base: Hourly resolution of power mix

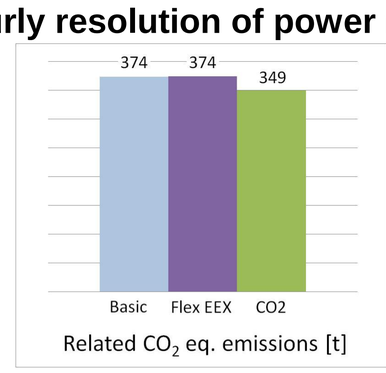

Fig. 08: Global Warming Potential of annual power demand using hourly resolution of power mix

+ 4 %

GWP

LCA view of ecological optimization

- 7 %

GWP

Results & Discussions

Economical optimization under the prevailing conditions only effects a smaller reduction in costs but has no significant influence on electricity demand or power related GWP.

Ecological optimization has the potential to lower the power related CO_2 emissions despite higher total electricity demand but results in higher costs in comparison with the basic scenario. Without breaking down the power grid mix on an hourly resolution the positive effects of the ecological optimization on the GWP would not be visible in Life Cycle Assessment due to the higher electricity demand.

In both scenarios with load management around 28 percent of cooling will be shifted to other time periods.

A detailed view on the optimization results shows that in economical optimization and ecological optimization often different time slots for the charging of the ice storage are chosen (= times when power demand is higher than for the basic scenario). (Fig. 04)

This behavior is in contrast to qualitative similar curves for flexible price and GWP of power.

For ecological optimization efficiency losses when operating the chillers at noon time often can be overcompensated due to the higher elasticity of the GWP curve.

On the other hand economical optimization gets the most out of efficiency wins from operating the chillers at low outdoor temperatures in the night. Nevertheless no energy efficiency increase for the cooling supply can be reached in total due to the higher energy demand of ice production in comparison to cold water production by 15 up to 30 percent .

Conclusions

- Ecological driven load management for cooling supply using ice storage units
  - Ø can shift energy demand in periods with lower GWP of power generation.
  - Ø can lower carbon footprint of electricity supply for cooling at the expense of energy efficiency.
  - Ø will not pay off under current market conditions.
- For complex optimization tasks higher energy demand does not necessarily correlate with higher GWP.
- Effects of ecological load management only can be made visible in LCA by handling the electricity generation as a foreground process.

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