Fostering local and wide area efficiency by HomePower

Distributed and intelligent micro-generation

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RWE Effizienz

RWE Effizienz is part of the RWE group, a leading European supplier of gas, electricity an water which also has upstream gas interests. The entire RWE group generated € 53 billion in revenue in 2010, producing 3 bcm of gas and supplying eight million gas customers.

RWE Effizienz as Innovator & Integrator of energy efficiency plays its part in the RWE Group by promoting highly efficient technologies and energy saving products. A three-fold approach aims at …

- consistent enhancement of economical efficiency potential across all areas,
- contribution towards a less CO_2-intensive energy mix through the development of distributed generation and demand,
- increased emphasis on electricity e.g. for vehicles or heating.

All products developed and distributed by RWE Effizienz are based on innovative technologies and provide economic sound benefits for private households while satisfying their daily needs. Charging Infrastructure for E-Mobility (1), secure and affordable plug'n'play "SmartHome" house automation (2) and intelligent "HomePower" cogeneration-systems (3) are some examples for the innovative range of the company's product portfolio.

Background

Gas is the first choice for growing power generation in private households. The still enormous potential of gas is sustained and exploited by modern appliances such as combined heat- and power-devices (CHP). Additional developments in the gas market, for example CO_2-neutral biogas or enriching gas with hydrogen, underline the high relevance of gas infrastructures for sustainability.

CHPs downscaled for residential homes with less than $5kW_{el}$ (so called “micro-CHP”) are technologically maturing rapidly, yet still operated isolated and based on simple operating rules. A strong stakeholder environment is driving the innovation known as “micro-CHP”:

- Politics in Europe promote energy efficient applications by introducing new laws, regulations and supportive subsidies.
- Society is increasingly raising concerns over large-scale central generation, whilst private households are becoming small-scale power producers (so-called “Prosumers”).
- Manufacturers of innovative building-systems technology are increasingly focussing on micro-CHP as the next evolutionary step. New micro-CHP-systems, especially developed for single-family houses (1 kilowatt electrical power), are market-ready since autumn 2011 and those systems for multi-family houses (approx. 5 kilowatt electrical power) have already shown high reliability as well as market acceptance for many years.

Enriching micro-CHPs with smart and grid-connected control will be an innovation for several reasons. The HomePower-system based on an proven “ecopower 4.7” cogeneration device has an efficient combustion engine with an effective output of 4,7 kW_{el} and 12,5 $kW_{th.}$ Smart control and operation algorithms have been developed inside of the project.. As a base result, CO_2 emissions are reduced by up to 50% and fuel consumption is simultaneously reduced by more than a third, both compared to today’s conventional electricity production in Germany.

Aims

Photovoltaics in Germany has demonstrated both the potential and the acceptance of distributed power generation. An innovative and sound business idea as well as a reliable implementation is needed in the area of micro-CHP, if the enormous success of residential photovoltaics shall be repeated. For that reason, we are currently improving both technical system efficiency and marketing strategy.

Economical and ecological improvements in supplying private homes with electricity and heat are possible if a micro-CHP system does not only run based on the momentary local heat demand but preferred in an optimised manner based on local and wide area electrical demand.

Local optimisation defines a high percentage of the electrical energy generated being consumed locally by the residents. In this manner, energy supply from the electricity grid is substituted and both CO_2 emissions and costs are being reduced.

Wide area optimisation potential for operating micro-CHPs is seen in contributing to ancillary services and taking part at the balancing energy market. Especially

- using energy from wind and solar power, exceeding the demand at times of surplus and
- smoothing the rising volatility in electricity grids caused by the enormous rise in capacities of renewable energies (promoted by increasing gaps in production & demand forecasts)

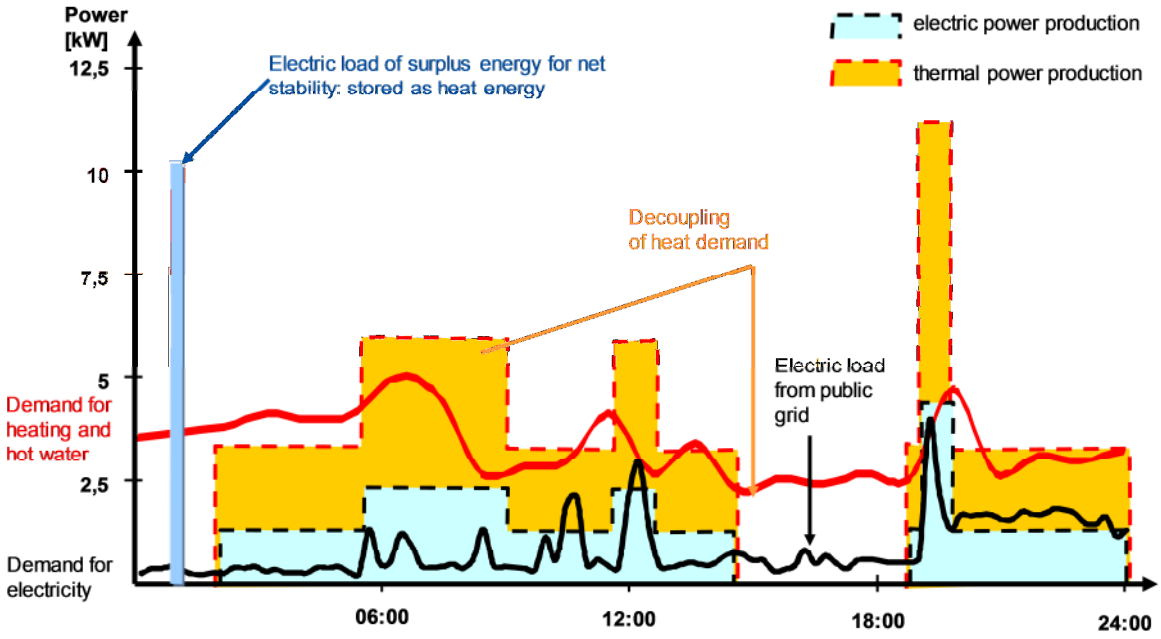
Pilot micro-CHP

have to be mentioned. We are thus convinced that we can achieve efficiency gains through more flexible and better connected operation of the micro-CHPs. Flexibility in operation is therefore increased by expanding the boiler capacity. Both local and wide area potentials are currently analysed and developed in the HomePower-system.

Besides the technical and operative aspects mentioned above, sound offers to the costumers as well as implementation of newest regulatory options are crucial for market diffusion. First, Contracting, a very new concept in the sphere of private consumers is going to be the driving force for higher penetration rates and thus may speed up overdue modernisation cycles by lowering the investment, commodity costs and by providing a full maintenance service to the customer. Second, new regulatory frameworks have been set during the last years. In combination with the market-ready smart meter technology new billing concepts for distributed power producers such as photovoltaic- and micro-CHP-systems have been developed. In the area of residential buildings, especially the “combined heat and power generation act” (KWK-Gesetz) as well as current “technical connection requirements” (TAB), are to be mentioned for the German market environment. The combination of the mentioned regulatory frameworks for the first time enables efficient and standardized billing processes in multi-family houses which can also cope with change of the supplier. These new processes (so called virtual metering points) have been included to the HomePower-system as well.

Methods

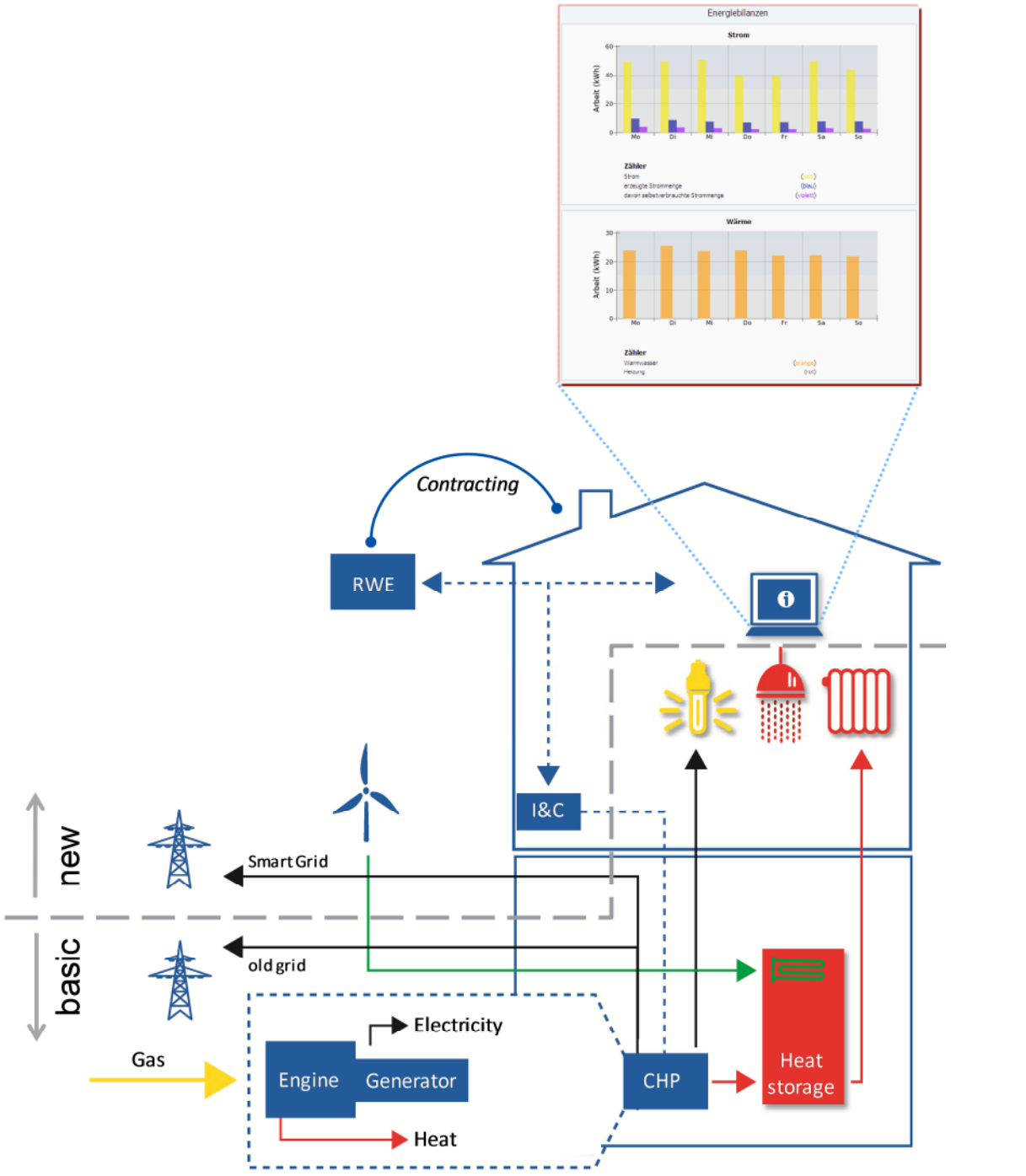
Efficient operation of micro-CHPs depends on both sound design for the particular building as well as on strategies for energy and load management. Energy management in this context means cost-efficient supply of all (electrical and thermal) loads by intelligent operation of all interacting system components, in particular the micro-CHP unit. Load management means the controlled arresting and releasing of the operation of devices, especially larger electro-thermal loads with a significant power demand.



Simplified system operation on a spring day

The concept of HomePower and its components is shown in the picture below. The micro-CHP-system is based on an efficient combustion engine with an effective output of 4,7 kW_{el} and 12,5 $kW_{th.}$ The thermal storage enlarged volume of 850 l decouples electrical and thermal generation and thus creates more operation flexibility.
As shown in the picture below, smart meter values for domestic hot water, heating circuits and electrical demand are regularly read out via internet by an Instrumentation and Control unit (so called “control-box”). Due to the high resolution of just one minute, load behaviour is available for optimising the plant operation and visual illustration. The visualisation gives transparency about the demand curves and the plant operation to the customer.
The demand curves are being analysed every day and load forecast for the next day are being generated.
Also taking into account the technical characteristics of the micro-CHP-system (including thermal storage) and the tariff structure optimised set points for the CHP-plant are being calculated. This optimized operation ensures that a high percentage of consumption of the electrical energy generated with the CHP inside of the house.
By this means energy supply from the electricity grid is substituted and both CO_2-emissions and costs are being reduced.

All control strategies depicted below have been developed and tested with the ecopower engine described above. Due to modular design of software algorithms and meter concept, all newly developed strategies can also be applied to different micro-CHP-systems for single and multi-family houses.The following sections “results” shows the significant efficieny gains due to optimised operation.



I&C: Instrumentation and Control
CHP: Combined heat and power
System concept of distributed production as an integral part of the public grid

In a first step, the current heat-oriented strategies for chp plants have been simulated for residential houses. Simulation results have been analysed and validated.

In a second step, the newly developed management algorithms have been tested on the mentioned pilot installation by means of emulation and test runs. It has been evaluated and confirmed that the described smart management strategies enhance the operating times of the micro-CHP while using less than 13 % of additional heat peak demand to satisfy the specific resident's heating needs.
The heat-oriented control of CHP-plants runs by measuring current hot water temperatures inside of the thermal storage. This ensures primarily the heat comfort (heating circuits and

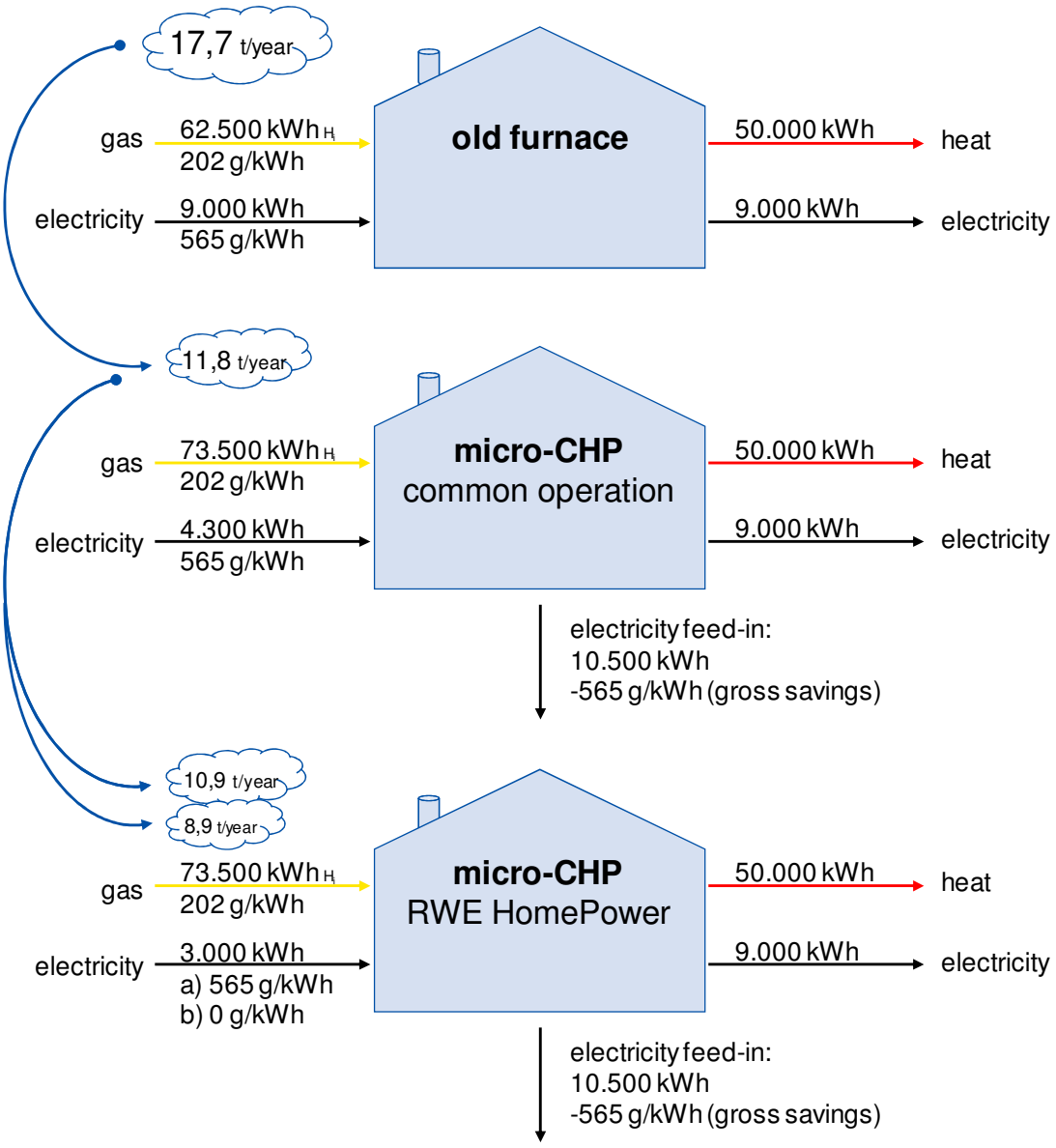
domestic hot water) of the specific house but electricity is generated just a secondary output. Electrical production and electrical demand do not correlate. The new adaptive control algorithms is also monitoring the temperatures inside of the thermal storage in order to ensure heat comfort at all time. Furthermore the described forecast for electricl power demand and the tariff structure are exploited in order to calculate optimized CHP-set-points.

Results

Local efficiency

Conventional micro-CHP-systems do have fairly rough optimisation systems based on temperature parameters: the CHP device starts and stops simply according to the temperature levels inside of the storage unit. A new adaptive optimization algorithm has been developed and put into operation. Thus, the HomePower-system simultaneously analyses electrical and thermal demand patterns and continuously optimises time schedules resulting in smarter operating cycles and boiler management.

For each hour a micro-CHP-system runs, the specific CO_2 emissions of electrical power are reduced by up to 50%. So it makes sense to increase the operating time of the micro-CHP rather than switching on an conventional furnace.



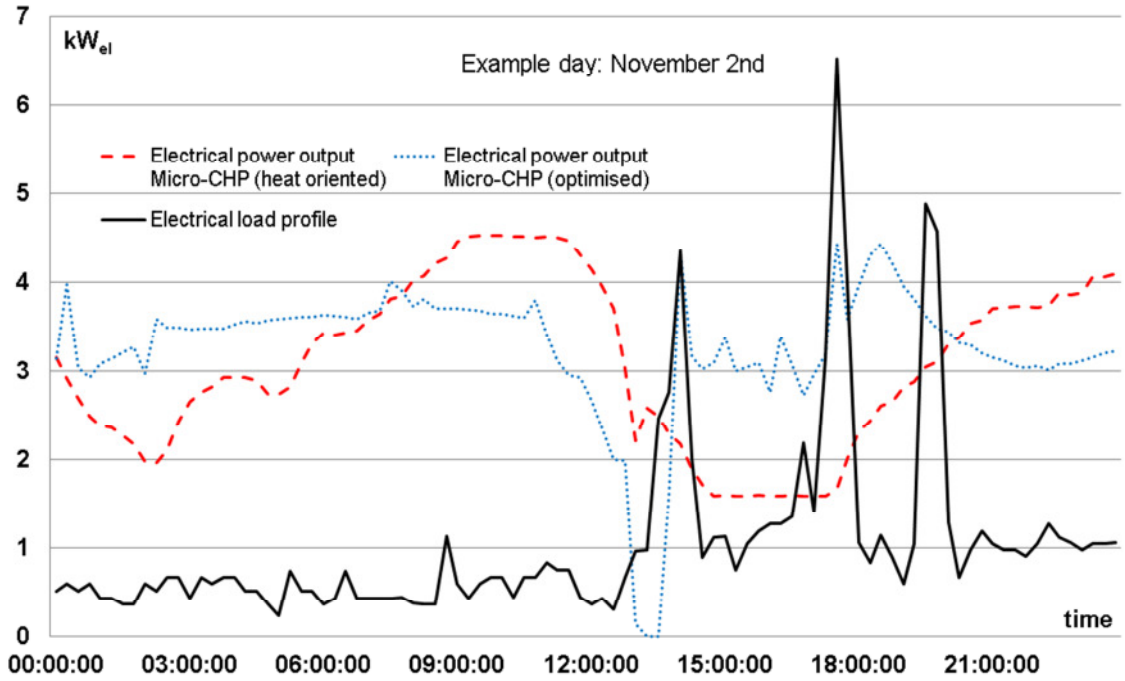
Savings in CO_2-emissions

The figure above shows that total CO_2-emissions are reduced by approximately 40% (optimised HomePower-system: 10,9 t/year) compared to conventional patterns consisting of an old furnace without any cogeneration (17,7 t/years). Additional improvements may easily be realised by switching to electricity from renewable ressources with zero CO_2-emissions, resulting in just 8,9 t CO_2 per year or 50% CO_2-reduction compared to the old furnace-system.
Thus, the optimised HomePower-system helps to improve the existing ecological benefits of conventional micro-CHPs, operated just in accordance to head demand (from 17,7 down to 11,8 t/years = 33%).

Wide area efficiency

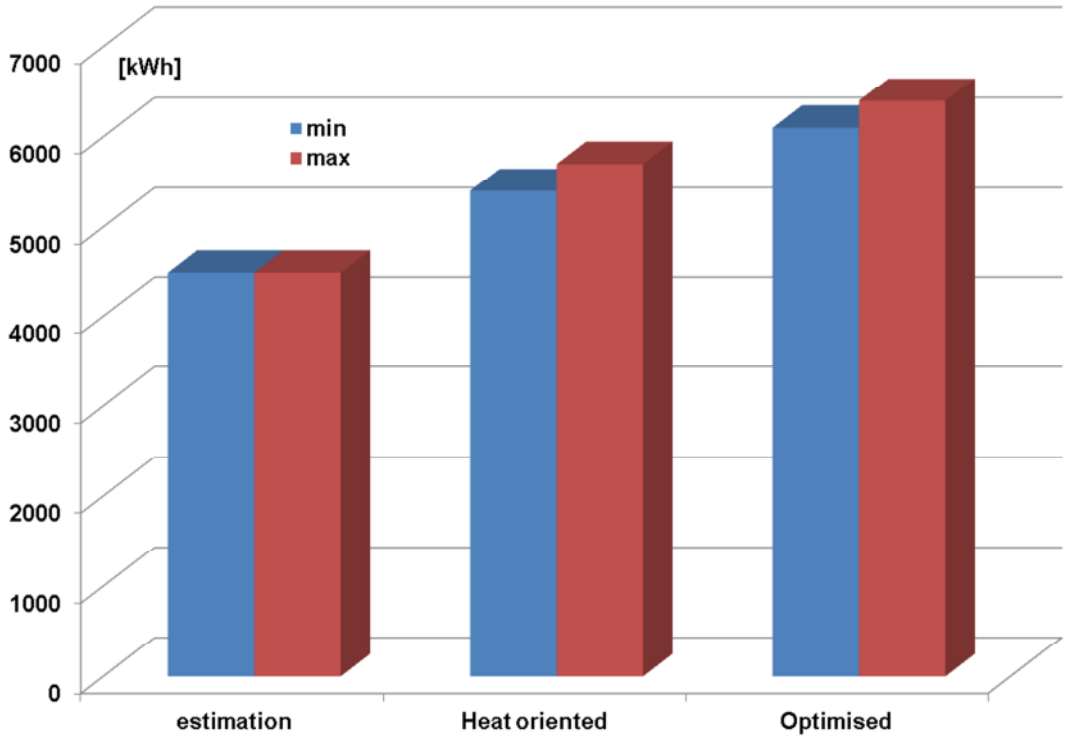
Loading of surplus renewable energy not only stabilizes the electricity grid and therefore diminishes the need for costly infrastructure upgrades, but also makes use of new distributed production capacities with almost zero carbon dioxide. The figure in section “methods” a short timeframe of heavy wind power overflow being directed into the boiler.

Emulation results have been collected at the pilot plant for specific days in sprint, summer, autumn and winter. The following diagram shows the electrical demand on “November 2nd” representing a certain demand pattern in autumn. Furthermore, it gives the electrical power output based simple temperature control (heat-oriented”) and optimised operation of the micro-CHP. In comparison to the heat-oriented control the percentage of the electrical energy generated in the Micro-CHP and used inside of the house could be increased by 5,5%. By this means energy supply from the electricity grid is substituted and both CO_2 emissions and costs are being reduced. Especially the electrical peaks at midday and in the evening have been well forecasted and transferred into CHPset-points. In this example, the energy content of heat storage has been reduced after noon in order to provide the electrical peak demands during late afternoon and evening.



Emulation results for a November day

In further investigations the simulation results have been compared to heat-oriented and optimised control by extrapolating the results gained for the specific days in spring, summer, autumn and winter to a complete year. Since the extrapolation is being based on single days both a minimal and maximal potential for the percentage of the electrical energy generated in the CHP plant and used inside of the house is given.



Emulation results over one year, extrapolated

Summary/Conclusions

So far, micro-CHPs are operated according to heat demand oriented and do not fully harnesses their ecological and economical potentials.

In the RWE HomePower project powerful strategies for energy and load management structures including automatic adaptation of the CHP operation to the individual customer behaviour, given tariffs and local infrastructure have been developed. A pilot plant installation has been launched successfully in December 2010. Computed simulation results have been analysed and validated by means of emulations at the pilot plant.

First results of studies and operation show that – in harmony with growing renewable generation (wind & photovoltaics) – local efficiency gains are highly realistic. Ongoing efforts for connecting micro-CHP-systems will ensure wide area efficiency and contribute to security of electricity supply. The management systems will continuously being improved over the next years and will result in more efficient real-life products, sold by RWE since autumn 2011

Efficiency gains of 15% compared to conventional micro-CHPs are a first step. Further technical as well as market evolution will increase profitability of the HomePower-system realising smart meters, innovative billing concepts and the fruitful German regulatory framework. Contracting for private households as an innovative and sound business idea, as well as a reliable implementation for the mass market will be the driving forces of ongoing market diffusion.