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Scheduling and Dimensioning Optimization of Electric Energy Storages with GOMES®

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Motivation & Methods

For the integration of the increasing share of renewable energy sources at the energy supply (especially wind energy and photovoltaics) the energy supply system needs more flexibility in the future. In that context energy storage devices are important components. They can be deployed at many different sites (close to renewable power plants, close to end consumers, close to substations or other neuralgic points in the electric grid) and offer a wide range of storage services, e.g. system stability, system reliability, investment deferral, arbitrage as well as balancing of load and generation.

In the last years Fraunhofer UMSICHT developed GOMES® - a generic model for the scheduling and dimensioning optimization of grid-coupled energy storage devices. Due to the modular layout of the model, it is possible to analyse and evaluate the economic and technical relevance of numerous storage services.

Generic Optimization Model for Energy Storage

GOMES® is formulated as mixed-integer linear optimization model with the objective function of revenue maximziation resp. cost minimization. Optimization variables are the current charge and dischare power in each time step. The model bases on the software GAMS in combination with the solver CPLEX. Due to its generic nature the model can be applied to different storage technologies and to different power markets by parameterisation. The input parameters as well as the resulting output are presented in Figure 1:

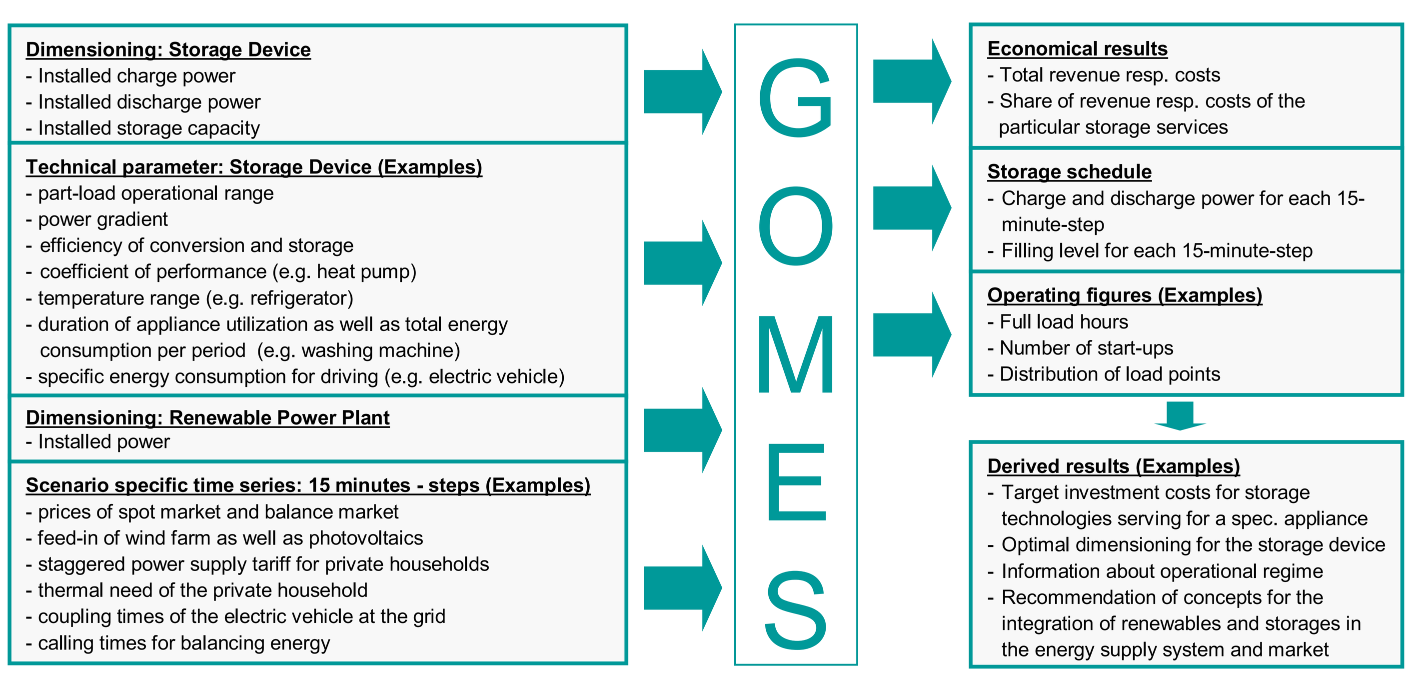

Figure 1: GOMES® : input parameters and optimization results

In addition Figure 2 shows the different modular components that can be combined in GOMES® to build up a scenario for the evaluation of a specific storage service. There exist three main groups: renewable power plants, storage devices and potential revenue sources.

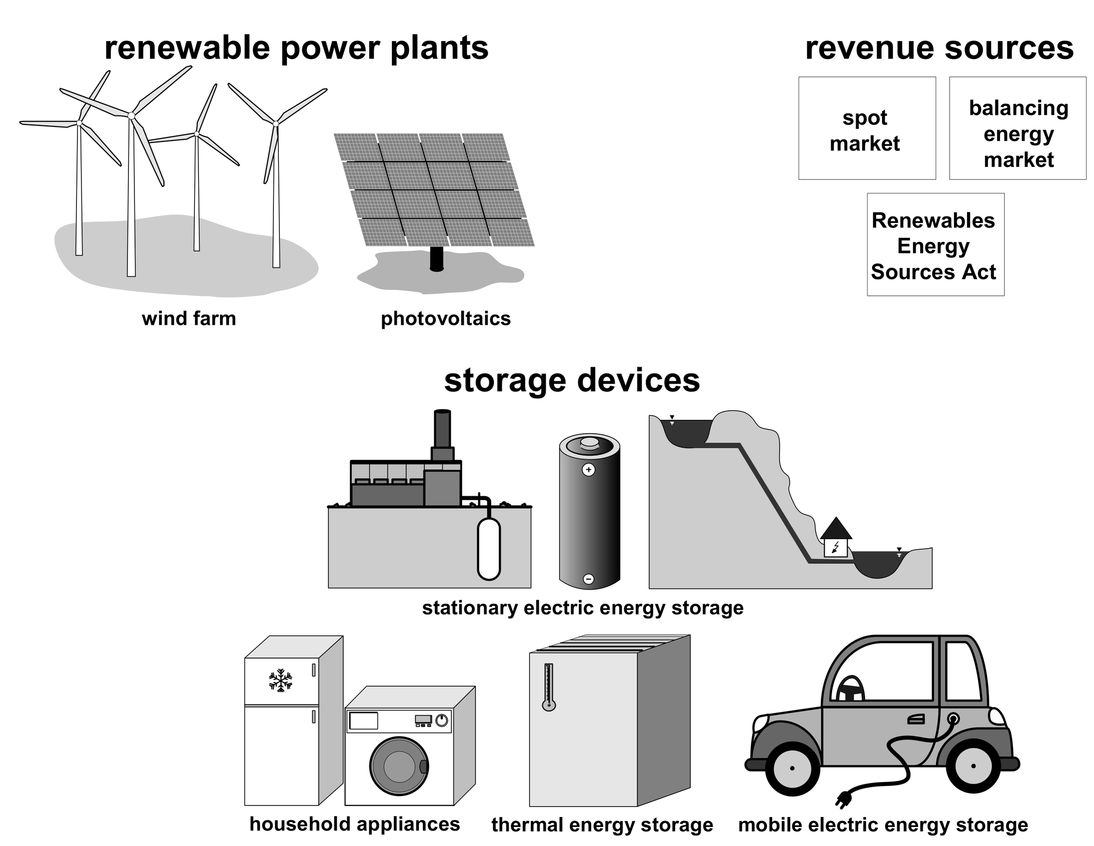

Figure 2: Modular components of GOMES®

In the last years several studies led to the conclusion that electric energy storages are in many cases - current investment costs assumed - not yet competive when they only offer a single storage service. Besides the expectation of decreasing investment costs there is the chance to improve the revenues by offering several storage services at the same time. GOMES® allows the evaluation of such multi-functional operation modes which is illustrated in the example in the next section.

Case study: Wind energy & A-CAES

In this case study an adiabatic compressed air energy storage which is co-located to a wind farm will be examined. The installed wind farm capacity (= 350 MW) exceeds the capacity of the connected 110kV transmission line (= 260 MW), so that wind energy curtailment would sometimes take place, according to the current situation in northern Germany. Besides storing the wind energy surplus the storage is allowed to participate in the spot market as well as to provide tertiary reserve power simultaneously. The first question to answer is what storage size is most economic for the specified application. For that purpose several runs are performed with GOMES® with different storages sizes. While the installed charging power (compressor) is fixed to 70 MW, the installed discharging power (turbine) and storage volume are varied.

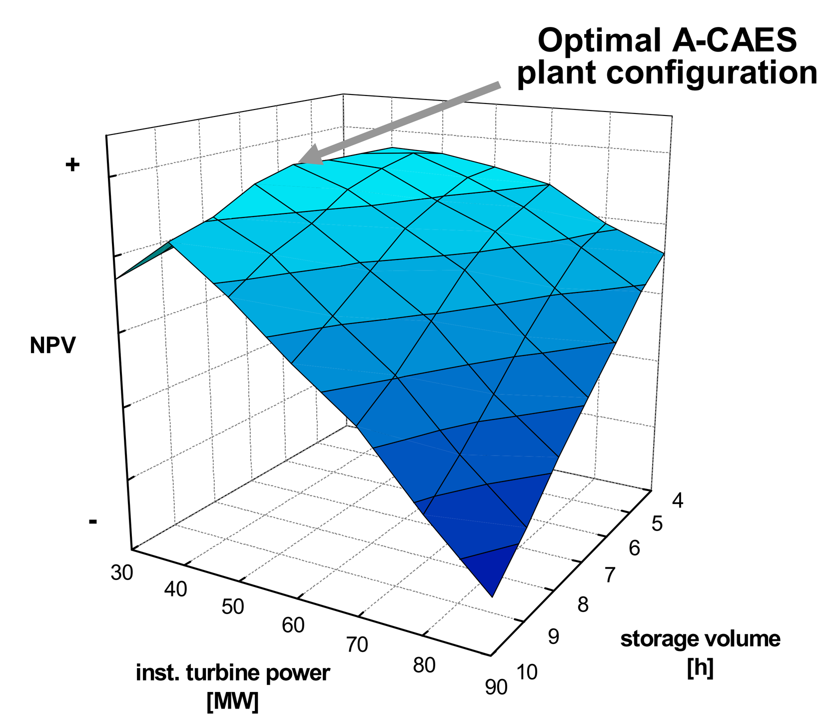

Figure 3: Dimensioning results

Figure 3 shows the results of the GOMES® runs. As can be seen the economic performance (NPV) is far more sensitive to the compression/turbine power ratio than to the storage volume. The best performance results with a turbine power of 40 MW and a storage volume of 7 full load hours.

The operational regime for the identified storage size at 5 examplarily days is illustrated in Figure 4. It is demonstrated that the storage harvests the wind energy surplus as well as trading at the market. Buying of energy goes along with low spot prices, selling of energy with high spot prices. For the provision of tertiary reserve the upper two diagrams show that the storage restricts its operation (power as well as storage volume) about the offered amount of balancing energy. Another interesting finding concerning the operational regime is the high share of part-load operation. About half of the compressor's operating hours is carried out at minimal load point (here: 50%).

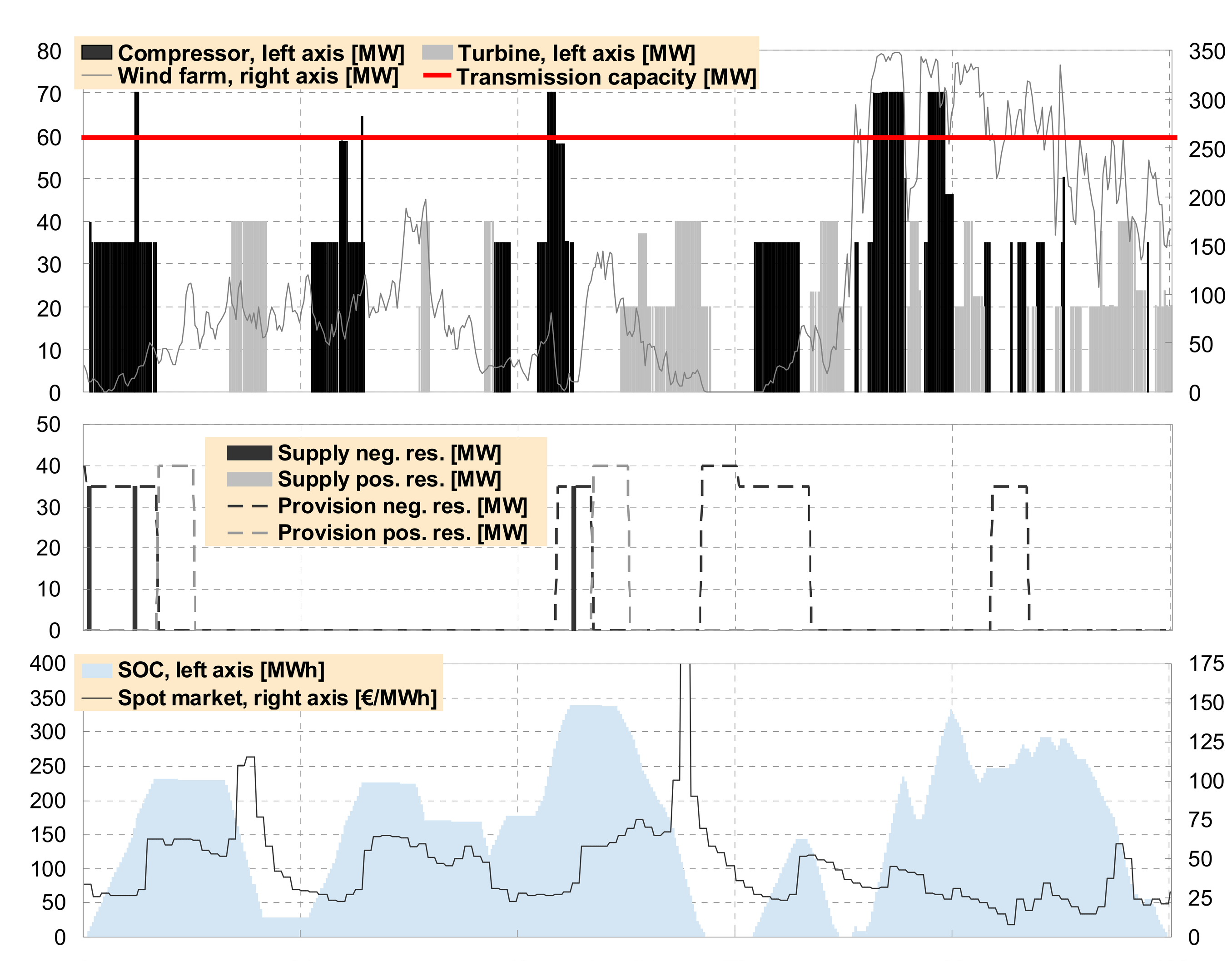

Figure 4: Operational regime for five examplarily days

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