Merit Order of Energy Storage by 2030 – Executive Summary

Aim and approach

The study "Merit Order of Energy Storage by 2030" aimed at the analysis and systematical assessment of measures for flexibilisation via functional energy storage. Therefore, power to heat, flexibilisation of load in industrial and private household applications, electromobility, stationary battery storage, pumped hydro storage as well as power2gas were investigated. In the context of the study, the term "Merit Order" is understood as a comparative ranking of different storage technologies. This ranking of storage technologies is done with respect to their added value from a system as well as business perspective by means of storage expansion. For this purpose, an innovative approach was used: multiobjective technology rankings were combined with a spatially and highly time resolved energy system analysis.

For Germany and Austria a linearized unit commitment model was used to perform hourly resolved simulations on the transmission system level. Exchange within Europe was considered with a country specific resolution. Every weather dependent input data was modeled with meteorological data from the year 2012. Renewable energy capacities in Germany were taken from the grid development plan 2015 which results in 60 GW photovoltaic, 76 GW onshore- and 14 GW offshore-wind power for 2030. In contrast to the grid development plan, technological advances of onshore wind power turbines are taken into account, which leads to full load hours of newly installed units of 3000 instead of 2000. Hereby, the capacity-directed expansion corridor results in a renewable energy share of up to 75 % in electrical supply by 2030 which is significantly more than stated in the coalition contract of the federal government of Germany (55 % by 2035).

Statements on the added value of storages for the energy system and its implications for curtailment as well as on power plant operation can be derived from the results of the study. Additionally, aspects of market design are addressed.

1. **Power to heat in public and industrial district heating systems as well as flexibilisation of load in industrial processes offer the largest benefit on the transmission level from a system perspective.**

   Thermal storages used for the flexibilisation of chp-production and in particular electrical heaters in district heating systems offer a significant added value for the system. Electrical heaters are installed up to a capacity of close to 10 GW whereas their full load hours reach approximately 1200. The same is true for industrial processes as they offer a notably cheap exploitation potential regarding capacity which is determined as approximately 2 GW. Investigations also show that functional energy storages are suitable to reduce overall system costs; this effect increases with the share of renewable energy. The contribution of flexibilisation of electromobility has a minor effect on the transmission level. Electromobility as well as heat pumps and night storage heaters are likely to play a more important role on the distribution level. According to the evaluations Power2Gas does not offer an added value to the system. However the results would look different if hydrogen from Power2Gas would be used in the mobility sector.

2. **In the study, expansion of functional energy storage reduces curtailment of up to 8 TWh.**

Depending on grid expansion and load scenario, curtailment raises up to 12 TWh by 2030 without storage expansion. In any case, more than 85 % of curtailed energy is wind power. Storage expansion and commitment reduces curtailment to less than 4 TWh.

3. **Calculations show that usage of functional energy storage increases operation hours of base load power plants.**

   The energy system of the future demands a flexible operation of power plants. Hence storages do not only contribute by a reduction of curtailment but they also reduce costly and inefficient power plant start-ups. This in turn increases operation hours of base load power plants and leads to an increased production of electrical energy which is also used in the heat sector.

4. **Advances in technology and changes in market design will guarantee system stability in the future.**

   In the future, enough flexibility for the intraday and frequency reserve markets will be available. Storages which offer an added value elsewhere in the system are also capable of fulfilling the requirements of short term markets at the same time. Amongst others, additional factors promoting this flexibility are the improvement of renewable energy and demand forecast, the strengthening of the European internal energy market, reduction of lead-times on the intraday market and changes in tender periods for frequency reserve. Moreover, batteries and the use of wind power for frequency reserve are likely to reduce balancing costs even further.

5. **The existing regulatory framework leads to non-negligible additional costs for the system.**

   To model the business perspective, taxes and fees e.g. grid charges were taken into account. Results show that the utilization of existing flexibility potential is reduced as well as barely any power to heat expansion is applied. By 2030, this leads to an increase of costs of around one hundred million euros per year when compared to the system perspective.

Conclusion

In conclusion, the investigations demonstrate that enough low cost flexibility potential might be available in terms of electrical heaters in district heating systems and flexibilisation of industrial processes. However, its assessment and the usage of existing flexibility options like pumped hydro storage is restricted by taxes, fees and further regulatory framework. Possible adjustments might comprise the allocation of primary energy factors in district heating and time variable tariffs. For example, fees like the ones existing for final consumption could be temporally varied in the case of system beneficial behavior.

The study does also demonstrate the necessity of enhanced energy awareness in companies to access the flexibility potential in industrial processes. Furthermore, additional changes in market design are required to use flexibility potentials to a better extend, e.g. shortening of tender time as well as a reduction of product slice in terms of time for frequency control and the creation of liquid 15-minute day-ahead and intraday markets.

In the course of the digitalization of the energy system, costs for information and communication are likely to fall. If the regulatory framework will be adapted at the same time flexibilisation of small scale devices like heat pumps, night storage heaters and electromobility are likely to play a much more important role.

Outlook

The new modeling environment offers the opportunity to investigate the interdependencies between storage expansion, grid expansion, efficiency measures and expansion of renewable energies as well as the opportunity to prioritize these measures. In order to analyze differences between system and business perspective, incentives for prosumers will have to be explored in more detail. Considering the continuously changing political and market based constraints in energy economics, the model allows for a dynamic assessment of these changes. For example, sectoral targets for emission reduction and achieving objectives of emission-reduction measures can be put on the test bench taking energetic, economic and ecological criteria into account.

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