FLEXIBILITY REQUIREMENTS AND INCENTIVES FOR STORAGE INVESTMENTS IN FUTURE EUROPEAN POWER SYSTEMS

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Overview

The transition to a climate neutral energy system is accompanied by an increasing share of renewable energy sources in European electricity grids. As the production of renewable energy sources is inherently variable, flexibility needs to balance supply and demand are expected to grow in the years to come. In this work, we study the flexibility requirements and incentives for investing in storage technologies in the 2030 and 2050 European power system using the METIS energy system model. We find the flexibility needs to increase significantly, with variable renewable energy output the main driver behind growing flexibility requirements at different timescales. We address which technologies, including storage, may provide flexibility solutions in addressing the flexibility needs and assess the economic value of financial arbitrage for such flexibility technologies in the spot market. We further study, in relation to storage investment costs and available interconnection capacity, the optimal fleet of electricity storage solutions to accommodate flexibility needs in future European power systems.

Methods

We model the European power system with METIS, a mathematical model simulating the operation of the European energy system, representing each Member State of the EU and relevant neighbouring countries. The model enables us to optimise (technological) parameters from a system cost perspective, by jointly performing capacity expansion and hourly dispatch simulations.

The METIS energy model simulates the clearing of the short-term power market, using fundamental input data on installed production capacities and commodity price costs, on an hourly basis over a given year. In the context of this study, the model allows us to address flexibility needs in relation to the variable nature of demand and variable renewable energy sources (VRES) supply. Next to their variable nature, VRES is also inherently difficult to predict and this uncertainty may create profitable arbitrage trading strategies between sequential short-term markets. As the focus of METIS on a single spot market does not allow to incorporate such benefits, the results on the economic value of flexibility technologies should be considered as a lower bound, targeting flexibility needs arising from variability in production and supply rather than uncertainty in production and supply.

Results

Flexibility requirements estimates in this work are derived based upon the residual load curve. The residual load curve is defined as the load served by technologies that can be dispatched flexibly, and is derived by subtracting the must-run and VRES generation from the realised demand curve. The residual load curve as such indicates which part of the demand needs to be met by flexible technologies (e.g. thermal generation units, hydro-power, interconnectors, storage etc.). We define FR^T as the yearly flexibility requirements with a granularity of time *T* by:

$$FR^T = \sum\nolimits_T \frac{1}{2} \sum\nolimits_t |RL_t - \overline{RL_t}| \qquad (1)$$

Where RL_t represents the residual load at time step *t*. Note that by definition, positive and negative flexibility requirements have to be equal. In this report, we focus on the absolute value of these flexibility requirements, taking half of the sum of both the positive and negative requirements. In other words, the sum of the positive differences over *T* between the residual load at *t* and the average residual load over *T* renders the flexibility requirements over *T*. We sum over all timescales *T* in a year to compare flexibility requirements with a different timescale *T* over one specific year.

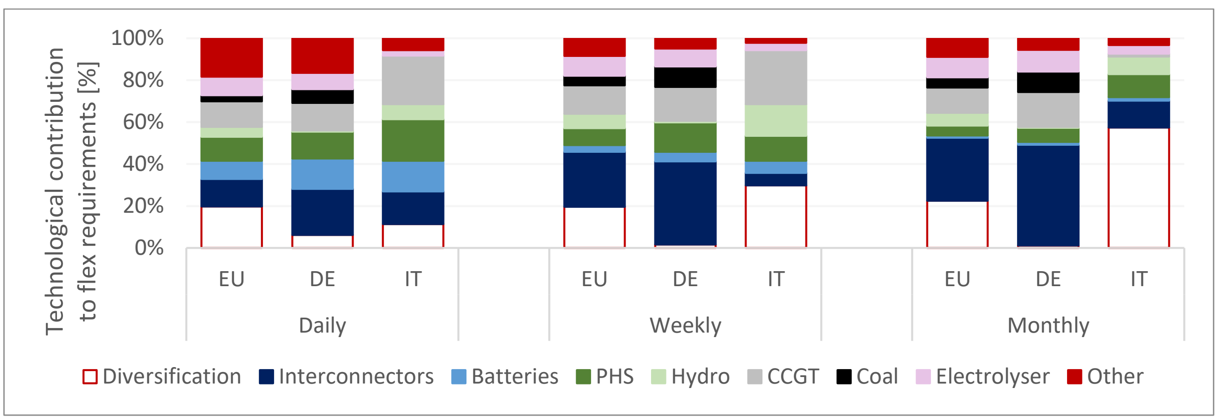
Comparing the flexibility requirements across the three different timescales, we observe daily flexibility requirements to be the largest across the EU in 2030 with 287.7 TWh compared to 258.4 TWh on a weekly and 172.7 TWh on a monthly basis. In 2050, these flexibility requirements respectively increase on EU level to 919 TWh, 775.4 TWh and 494.4 TWh. In 2030, the Netherlands, with the largest relative MS share of wind to total demand in 2030, experiences the highest flexibility requirements relative to the total demand on all three timescales. In 2050, the picture is more dispersed, with next to the Netherlands, also Ireland and the Baltic States ranking high in terms the relation between flexibility requirements to total demand. We find however that the relative share of flexibility requirements for these countries may only increase slightly or even decrease between

2030 and 2050, while countries with a relative low share of flexibility requirements to total demand may see a more pronounced increase of that share moving towards 2050. Comparing the relative share of flexibility requirements to total demand to 2021 however does present pronounced increases, for both 2030 and 2050, across all timescales and for all Member States.

Next, we study the effect of VRES on flexibility requirements by increasing the share of VRES across the entire EU under ceteris paribus conditions. While such a high degree of control allows us to isolate the effect of VRES on flexibility requirements, one has to bear in mind that in reality this would distort the equilibrium in energy systems, resulting in an adaptive shift in underlying production technologies. We find that for the EU, with more VRES installed, the flexibility requirements increase. The increasing trend seems to accelerate for the daily and weekly flexibility requirements, with the inflection point for the EU around a VRES capacity share of 74% to total installed capacity, related to the inability of the 2030 power system to cope with the sharp increase of VRES of the following decades. We find an increasing share of installed solar PV capacity to correlate only with an increase in daily flexibility requirements, while the increase in installed wind capacity correlates only with weekly and monthly flexibility requirements.

We conclude by studying which technologies contribute to addressing the flexibility requirements. These technologies include dispatchable units, which are able to adjust generation flexibly according the residual demand, but also storage, interconnectors and demand-side management technologies may contribute in relieving the flexibility needs. Figure 1 shows the contributions of the main flexible technologies to the flexibility requirements in the context of our study for the EU, Germany and Italy. We find that interconnectors are one of the main sources offering flexibility, mainly as imports and exports vary according to MS specific flexibility needs. Their relative contribution increases for the EU from 15% for the daily requirements to 33% for the monthly requirements, signalling the important role of interconnectors in dealing with longer duration flexibility needs in the residual load curve. Short-term storage technologies like batteries also offer a considerable amount to relieve the daily flexibility requirements, but much less so for the weekly and monthly requirements. Pumped hydro storage (PHS) follows a similar pattern, although their role in addressing flexibility needs is an important factor across all three timescales. From the thermal generation units, Combined Cycle Gas Turbines (CCGT) contribute a significant amount in addressing the daily and weekly flexibility needs. Finally, electrolysers provide a considerable contribution to the flexibility requirements on EU level, consistently addressing 10% of the flexibility requirements across all timescales. The combined role of other technologies, like for example OCGT, oil and biomass, only seems to be of certain relevance in addressing the daily flexibility requirements.

Figure 1: Technological contribution to flexibility requirements in the EU, Germany and Italy, 2030.



Conclusions

In this study, we address the flexibility requirements and storage solutions by simulating operations in a 2030 and 2050 EU energy system with the METIS energy model. We find that compared to today's levels, flexibility requirements will increase significantly in all EU Member States. The numbers present considerable flexibility requirements, indicating the need for both short-term and long-term flexibility solutions in future European power systems. We further observe that the market share of VRES directly affects the share of flexibility requirements to total demand, while the type of VRES affects on which time suration energy system flexibility is needed. Efficiently integrating both sources of renewable energy sources in the power system thus requires an adequate evaluation of necessary related short-term or long-term flexibility solutions. Finally, the results show that multiple technologies are needed to address the flexibility needs at different time scales, showing that while new storage solutions become increasingly important, conventional assets may also remain important in addressing flexibility needs.