1 Executive summary

The Pentalateral Energy Forum (short Penta) is a framework for regional cooperation between Austria, Belgium, France, Germany, Luxembourg, Switzerland and the Netherlands. The participating countries have been working since 2005 on a voluntary basis towards more closely integrating their domestic electricity markets and are thereby taking the lead in Europe. In 2021 Penta countries ministers agreed that **a joint 2050 vision for a decarbonised electricity system will keep Penta at the forefront of the energy transition**.

The present study shall help to create a common vision for a decarbonised electricity system at the latest by 2050, as part of the Pentalateral Energy Forum's endeavour for regional integration towards a European and reliable electricity market. The present study builds on previous work and broadens and deepens the analysis to work towards a common understanding and vision on a decarbonized electricity system by 2050, with intermediate steps in 2030 and 2040.

The preparation of the study relied on a 4-step approach, which is illustrated in Figure 1.

Figure 1 - Four-step approach underlying the preparation of this study

A review of existing scenario assessments and technical reports identified likely developments and remaining uncertainties in the different energy system transformation pathways published by national and international stakeholders. The analysis of the scenarios and technical reports was organised along four major dimensions: power demand, supply, power system stability and methodologies underlying the scenario assessments. For each dimension, a set of major **observations** was identified, which indicate likely developments and remaining uncertainties in the transformation pathways analysed. Subsequently, the observations were condensed and translated into twelve **convictions**, which may be understood as *necessary conditions* to facilitate the decarbonisation of the power sector and ultimately of the entire economy by 2050 at the latest. Finally, a non-exhaustive list of exemplary, indicative **actions** illustrates how the convictions could be put into effect**. The twelve convictions are as follows**:

1. **Power sector decarbonisation** needs to be decarbonized as early as possible, ideally by 2035;
2. **Renewables** are the main pillar of power sector decarbonisation, with solar power and wind representing the biggest share – but requiring an accelerated deployment;
3. "**Energy efficiency first**" reduces the expected increase in power demand and releases pressure from the power system;

4. **Direct electrification** is a no-regret option in various domains and comes with immediate benefits;
5. **Decarbonised molecules** will play a limited but crucial role in hard-to abate sectors;
6. The **hydrogen economy** needs to be established now, and Penta is particularly well placed to initiate and drive forward this process;
7. **Power grid capacities** need to increase substantially, through more efficient operation and grid reinforcement, at all grid levels: distribution, transmission and cross-border;
8. A **coordinated approach to energy system planning** is key to achieve a timely and cost-efficient system transformation avoiding stranded assets;
9. **Flexibility** is a key element of the energy transition and flexibility needs for power system stability will significantly increase in the future on all time scales;
10. Additional **power demand can and must be flexible** (i.e., operated in an electricity price sensitive way) in particular for electric vehicles, heat pumps and electrolysers;
11. **Energy storage** facilitates RES integration, yet storage potentials (e.g., for hydro and hydrogen) are not equally distributed and require regional cooperation for a coordinated exploitation;
12. The transition **requires a future-proof market design**, to trigger the investments into the beforementioned technologies and to efficiently ensure resource and transmission adequacy.

These building blocks may be used by the Pentalateral Energy Forum for the building of a joint 2050 vision.