Policy brief: Modelling Energy Systems Synergies and Quantification of EEFP Impacts

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Key messages

- *sEE 2030 and sEE 1.5 represent robust system redesigns paired with the Energy Efficiency First Principle, which allow for better integration of variable electricity and the cross-sectorial connections unfold flexibility, i.e., electric vehicles, electrofuels.*
- *sEE 1.5 demonstrates that applying the Energy Efficiency First Principle, focusing on energy conservation, energy efficiency, energy supply changes and resource security can bring Europe to become fully decarbonised by 2050 using 100% renewable energy.*
- *The scenarios combine cost-effective energy efficiency measures in transport, industry, and buildings with a highly interconnected renewable energy system with increased synergies and reduced primary and final energy consumption.*
- *This re-design also provides an opportunity to integrate more cost-effective renewable energy such as solar PV and wind, which in turn allows us to balance the overall energy system with energy storage and transfer technologies such as thermal storages, district heating and PtX.*
- *As a result, primary and final energy demand can be reduced significantly compared to a 2015 reference energy system (comparable to the EU Commission's PRIMES scenarios), by 44% and 40% respectively, as shown in the figure below.*

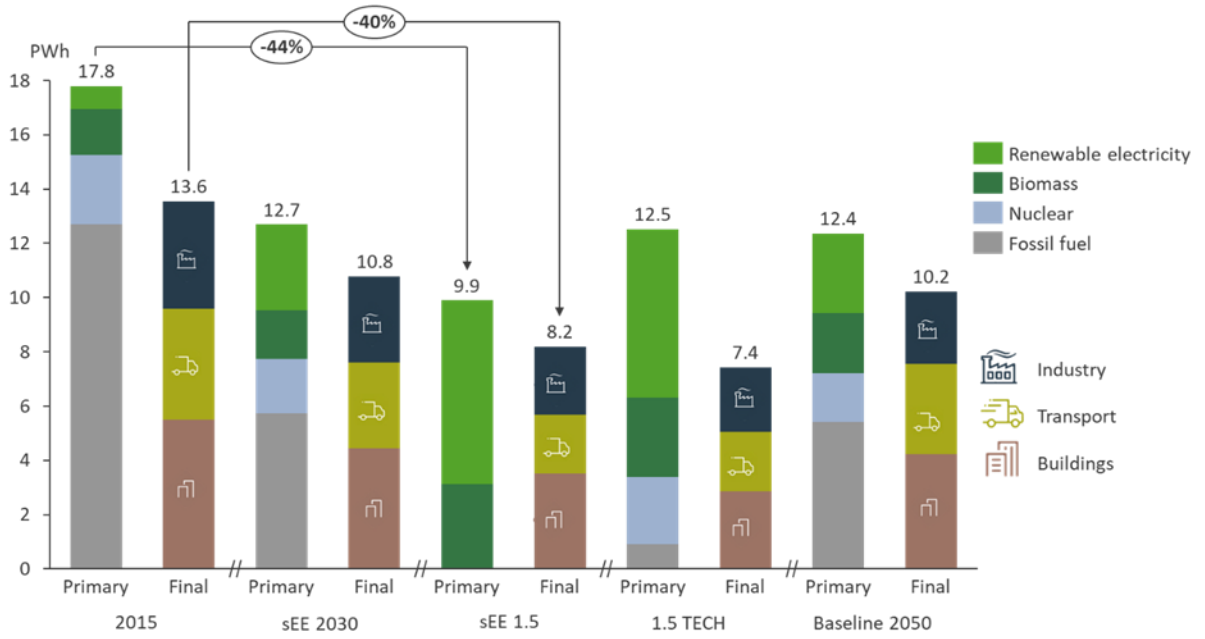

Figure 1. Primary and final energy consumption in reference, sEE and 'A clean planet for all scenarios'

- *This is possible by building renovations and supply measures, and extensive electrification of the transport and the industry sectors both via direct and indirect electrification among other measures.*
- *This enables a 2050 system to be supplied with 100% renewable energy for all the EU27 and the UK.*

Key findings and key recommendations

- In traditional energy systems, fuels represent the highest share of costs. In future renewable smart energy systems, technology investments are prioritised over variable costs. Our analysis shows that there is a need for over **5 trillion € investments in EE measures** in buildings, transport and industry, out of a total of approximately 9 trillion €. More than 2 trillion € should be dedicated to renewable energy and over 1 trillion € spent on system redesign measures. While investments are higher in energy efficiency compared to supply and system redesign measures, it is important to note that all investments should be initiated and implemented simultaneously.

- **40% reduction of final energy demand** can be achieved by saving about 2 PWh in both buildings and transport sectors, and 1.5 PWh within industry, out of a total final demand of 13.6 PWh.
- **Building stock refurbishment costs represent the largest investment** related to energy savings, followed by investments in the electrification of the transport sector and industry as well as in renewable capacities, primarily wind and solar.
- The sEE2030 recommendations demonstrates a **14-22% larger natural gas reduction** compared REPowerEU and Fitfor55 for EU27.
- **Health costs from air pollution** can be reduced to approximately 71 billion EUR/year in sEE 1.5 towards 2050, down from approximately 299 billion EUR/year in 2015 and 154 billion EUR/year in the PRIMES 2050 Baseline.

The building sector

- An investment of **2.2 trillion € is required to reach the final target of 40% heat savings in the building stock by 2050**. Such savings enable synergies with our system redesign as it increases the energy efficiency of the supply system and increases the possibilities to integrate renewable heat and low-temperature heat sources.
- One of the system redesign components is **district heating**, which requires an investment of 420 billion €, and can unlock the potential of using cheaper heat sources. About 1 PWh or half of the energy savings achieved in the buildings sector is a result of end-demand savings due to building stock refurbishments and the other half is a result of system redesign measures and changes in the heat supply.
- Half of the **heat demand** (47%) is supplied by district heating in 2050, the remaining half is covered by individual heat pumps.
- **Excess heat and low-temperature** heat sources such as industrial waste heat, geothermal, solar thermal, large-scale heat pumps and electrolysis, can supply 60% of district heating, while the remaining 40% is supplied by CHP, waste incineration and boilers.
- **Individual heat pumps** are an important energy efficiency measure, representing the fourth largest investment of over 1 trillion € to achieve more than 100 million units installed in Europe. However, as with unlocking excess heat and low temperature heat in district heating systems, where expansions are in the district heating grids, individual heat pumps also require new infrastructure investments in electricity grids.

The transport sector

- The transport sector can deliver the same magnitude of **energy savings** (2 PWh) as the building sector or about a **50% reduction**. This requires an energy-efficient urban development as well as high levels of electrification and includes energy inefficiency in the use of hydrogen-based fuels (electrofuels) for heavy-duty transport in aviation and navigation. This will reduce the primary energy demand for the transport sector in Europe by around 50% compared to the baseline in 2050.
- **Energy-efficient urban development** will **reduce the passenger kilometres driven by a car by 16%** compared to traditional urban development. In order to achieve this, new investments need to be made predominantly in more efficient modes of transport, so that higher transport demands are not induced in in-efficient modes of transport. This entails a dedicated investment of 784 billion € in predominantly railroad infrastructure as well as e-roads and cycling infrastructure.
- **Electrification of the transport sector** is done through direct and indirect electrification, where direct electrification wherever possible should be prioritised. Majority of passenger cars and vans (95%) are shifted to battery electric vehicles in 2050. In 2030, the number of electric vehicles is estimated to be 95

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million and 254 million in 2050. This requires 1.3 trillion € in additional investments compared to not switching to electric vehicles, and this is the second largest investment after heat savings. Electrification of heavy-duty trucks is prioritised with the implementation of e-road systems.

- The use of **hydrogen and electrofuels** should be reserved only for the difficult to electrify modes such as aviation and shipping. Major investments in electrolysis capacities and hydrogen storage of 327 billion € need to be made to provide hydrogen and e-fuels for transport and industrial demands. An additional 161 billion € is needed for e-fuel production. Almost 456 GW of electrolyser capacity is needed in 2050 to cater to this demand. By 2030, the electrolyser capacities are low, since the focus is on implementing energy efficiency measures.

The industry sector

- The implementation of **innovative energy efficiency measures and electrification** in industry enables **reductions in final energy by 36%** from today to 2050, and which requires 209 billion €. This includes and assumption of increasing production in line with the past trends. Emphasis on EE improvements and electrification are of high importance in order to avoid extensive biomass consumption when pursuing 100% renewable energy.
- Careful considerations must be taken in the implementation levels of electrification and **hydrogen-based technologies** paired with energy efficiency to minimize the costs and energy losses.
- By 2050 **electrification increases to 66% of the total final energy demand up from 25% in 2015**. This is largely in the “others” category for lower temperature sub-sectors such as engineering and the food industry. District heat demand in the industry falls from 5% to 1.5% of the energy mix from 2015 to 2050.

Renewable Energy and System Redesign

- It is expected that by 2030 the **electricity demand will increase by around 32%** from 3,051 TWh due to the electrification of transport, industry, and heating in buildings, **and 158% by 2050** to 7,860 TWh, as a result of high hydrogen production in Europe.
- Targeted energy efficiency and the **smart energy system**, with **flexible storage options**, can enable the primary energy demands to be kept within sustainable biomass levels and **limit the GW wind power and PV to the potentials available in the EU**. With another system design, with no considerations of more energy-efficient infrastructure investments in transport and with lower utilisation of best practise in industry, the renewable energy installations would be higher.
- The smart energy system requires abandoning silo thinking in each sector and consider **energy storage** options between energy vectors to move the storages towards heating, fuel production and transport sectors rather than keeping it in the power sector. The main three energy storage options are electrofuels (>2,000 TWh), storage of electricity in vehicles (~15 TWh) and large-scale thermal storages (~6 TWh). This way, rounds trip losses will be avoided (electricity to hydrogen and back to electricity) and flexible storage should be enabled e.g., 40-60% operation time of electrolysers and large-scale heat pumps.
- **System redesign with high electrification levels requires large investments in establishing renewable energy capacities**. Wind power represents the third-largest investment towards 2050 of 1.3 trillion €, which amounts to 1,135 GW onshore capacity and 265 GW offshore capacity. In addition, 521 billion € are required to be invested in photovoltaics, amounting to a capacity of 1,400 GW. Investments in gasification and biogas production as well as solar thermal and geothermal are also required.
- The bioenergy consumption is in line with the reference scenario from the JRC ENSPRESO project (2019) of 3,200 TWh (EU27+UK). **Both sEE 2030 and sEE 1.5 are within the sustainable bioenergy levels**. Countries with large amounts of bioenergy and renewable electricity could become the main producers of electrofuels for transport due to shortfall in some countries. Furthermore, due to the inefficiency of

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biofuels, biofuel quotas should be phased out with increased focus on e-fuels for sectors not suitable for electrification.

- Redesign of the energy system based on Energy Efficiency First Principle allows a **phase-out of nuclear by 2050**. Replacing nuclear at the end of life with renewable electricity gives lower cost. By 2030, nuclear capacities only decrease marginally to support the quick phase out of Russian natural gas.

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