Country-level energy demand modelling in support of Europe's climate neutrality target

[Gabriel David Oreggioni, Imperial College London, g.oreggioni@imperial.ac.uk]
[Iain Staffell, Imperial College London, i.staffell@imperial.ac.uk]

Overview

The European Union and the United Kingdom have legally committed to become climate neutral economies by 2050, along with intermediate targets to be met in the next decade. Reaching these emission reduction targets requires substantial transformations within final energy uses, such as: electrification of heat supply, uptake of renewable energy vectors, significant deployment of electromobility, incorporation of H_2 for heating, transport and industrial feedstock; and carbon capture and utilisation within heavy industries. Official scenarios present the requirements for technology incorporation, but only aggregated at the EU-wide level. There is still a significant gap in highly sectoral and national granular decarbonisation pathways for demand in the context of the mid-century net zero objective and intermediate milestones. This work intends to contribute to providing meaningful insights for the national feasibility, challenges, and opportunities derived from the implementation of climate change mitigation measures to meet overall continental carbon budgets by 2050 and emission cuts by 2030.

Methods

A bottom-up approach for energy demand modelling has been followed, distinguishing among several final energy uses and different subcategories – residential and commercial buildings (heating, cooling, and appliances); road transport (passenger cars and motorbikes, light duty vehicles, trucks, and buses); light industries; heavy industries (steel, cement, and chemicals); rail; navigation; and aviation. Service demand has been quantified using national projections for socio-economic indicators and other demand drivers for 2030 and 2050 from the EU Reference Scenario.[1] Country-level fuel baskets, efficiency measures, and road transport fleet shares were downscaled from continent-wide scenarios [2,3] on the basis of present circumstances and by developing functional relationships that account for national income indicators and technology penetration rates (especially for electromobility). In addition, post-2030 efficiency standards [4] for road transport and different trajectories for 2050 have been considered. The scenario runs have been conducted using the DESSTINEE (Demand for Energy Services, Supply and Transmission in EuropE) model, which is a free and open-source full energy system modelling tool that enables to forecast yearly and hourly energy and power consumption.[5,6]

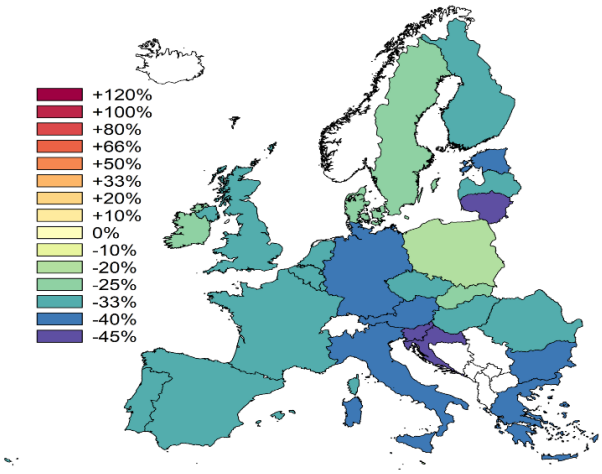

Figure I. Country-level final energy consumption, expressed in percentage of change, between 2015 and 2050

Results

We have modelled decarbonisation trajectories compatible with both 2030 and 2050 targets. Here, we present results for 2050 – due to the word count of the abstract – however at the conference results for the 2030 time horizon will also be discussed. Our estimates show that the implementation of measures enabling emission reduction targets would lead to a decrease of 34% of final energy consumption by 2050 at the continental level, compared with 2015. Country-level reductions between 4% and 42% translate into significant decreases in the energy intensity of the economy, close to 59% at the bloc level, with figures ranging between 52% and 64% across the 28 countries. Final energy consumption per capita will go down by 32% at the EU27+UK level, with national reductions between 7% and 49%.

This evolution in energy consumption is expected to be driven by cumulative lower energy usage within the road transport. Such a decrease is expected to occur despite a significant increase in service demand, ranging

between 8% and 47% among the 28 countries. This is consequence of electric vehicles exhibiting higher fuel economy efficiencies – two or three times larger than combustion engines. Industries, especially heavy industries, are the second contributor to the downward trends in final energy consumption, with reductions between 11% and 50% across the 28 countries. This is due to efficiency improvements, electrification of steel production and low enthalpy heat provision. It must be noted that, when accounting for energy consumption, we have computed power used for in-situ H_2 production as an input for the supply sector when developing the energy balances for these scenarios.

Electrification plays a key role in enabling emission reductions, with electricity becoming the most used energy vector across end users. This will lead to a bloc-wide increase in power consumption of 52% by 2050, compared with 2015. National increases are modelled to range between 8% and 113% across the 28 countries. Such a wide span is a consequence of different industrial subcategories, different compositions of the road transport fleet, and electrification levels.

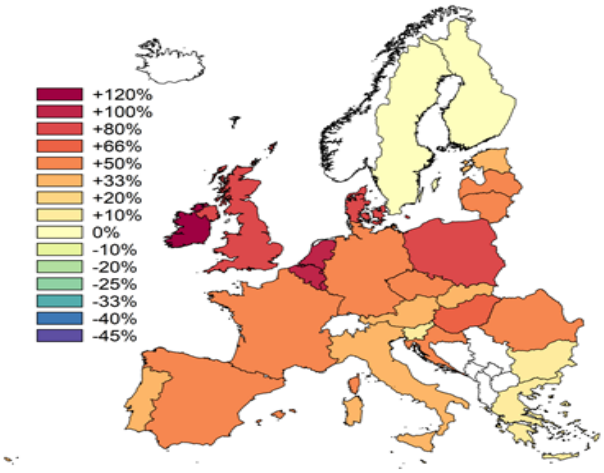

Figure II. Country-level final energy consumption, expressed in percentage of change, between 2015 and 2050

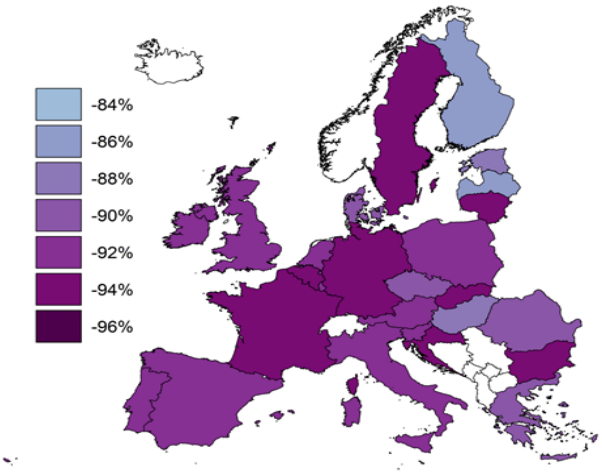

Figure III. Country-level demand related fossil CO_2 emissions expresses as percentage of change, between 2015 and 2050

Decarbonisation measures within end uses will allow a reduction of 89% in demand-related fossil CO_2 emissions between 2015 and 2050. These decreases will be larger than 84% across the 28 countries, mostly driven by reductions in emissions from road transport and lower emissions from combustion in heavy industries (fuel swapping and efficiency) and process CO_2 emissions (feedstock change and CO_2 capture). By 2050, residual emissions from the different sectors are quite similar – close to 20 $MtCO_{2eq}$ for transport, heating in commercial buildings and aviation – whilst combustion and process emissions from heavy and light industries account for 50 $MtCO_{2eq}$. Germany will account for 19% of continental energy demand related fossil CO_2 emissions, followed by Italy (13%) whilst the shares for Spain, Poland and France will range around 8%.

Conclusions

Reaching climate neutrality will lead to unprecedented changes within final energy uses, translating into changes in fuel baskets which will have a significant impact on the whole energy system. These transformations will be dissimilar across countries, depending on the current fuel basket, industrial matrices, road transport fleet and electrification shares. This will lead to significant reductions in final energy consumption at the bloc level (34%) and a rise of 52% in final power demand. Electricity is modelled to become the most consumed energy carrier, being electrification the main diver for the emission and energy consumption downward trends. Balancing power supply and demand, at hourly and yearly level, will be one of the most important challenges that the future energy system will go through in addition to charging infrastructure development and investments on CO_2 capture in industries. Having detailed and national granular tools to evaluate these changes is key for policymakers, industrial stakeholders, and citizens.

References

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