Beyond 2020: Strategies and costs for transforming the European energy system

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(1) Overview

The Energy Modeling Forum 28 (EMF28) exercise systematically explores the energy system transition required to meet the European goal of reducing greenhouse gas (GHG) emissions by 80% by 2050. This scenario is compared to a reference case that aims to achieve a 40% GHG reduction target. The paper investigates mitigation strategies beyond 2020 and the interplay between different technological decarbonization options including nuclear power, carbon capture and storage, and individual renewable technologies. The 13 models present different technology pathways for the decarbonization of Europe, but a common finding across the scenarios and models is the prominent role of energy efficiency and renewable energy sources. Renewables will become the most important source of electricity, particularly as wind power and bioenergy increase considerably beyond current deployment levels. The transformation becomes more challenging after 2040. With some exceptions, our analysis agrees with the main findings of the "Energy Roadmap 2050" presented by the European Commission.

(2) Methods

A total of 13 European modeling teams—including the PRIMES team—are involved in the EMF28 project[1]. The model typology ranges from global integrated assessment models to European energy system models, which feature a greater level of spatial detail and an explicit representation of individual Member States. The EMF28 analysis builds upon the scenarios defined in the European Commission's Energy Roadmap to achieve a low carbon energy system by 2050. One set of scenarios considers the continuation of current policies, leading to a 40% reduction of GHG emissions by 2050 compared to 1990. The decarbonization scenarios aim to reduce GHG emissions by 80% by the same year. This exercise has two goals. The first is to identify common technological requirements and technology portfolios by analyzing the various low carbon pathways produced by the models. The second is to understand the extent to which variations in results are due to inherent assumptions in the input data, and the extent to which they are explained by methodological differences. The underlying research question is whether different types of models tell different stories about Europe's optimal decarbonization pathway, or whether there is a shared view about cost-effective strategies.

(3) Results

First, this study shows that, despite the models' differences, there are several pathways for achieving ambitious climate change mitigation in Europe. Nearly all the models can achieve the long-term target of reducing GHG emissions by 80% GHG, and implementation only leads to GDP loss of less than 1% until 2030 and slightly above 2% for 2040. However, some models show a sharp GDP loss after 2040 of up to 10% when the EU is mitigating unilaterally, while others show costs increasing in a rather linear manner. This allows us to conclude that the 80% GHG reduction target is indeed challenging, especially after 2040 when a substantial amount of effort is required. It is important to mention that these results are derived from models that do not consider technical and political obstacles that could hinder the technology developments prescribed by our results. This study also shows that it is critical to start a structural transformation of the fossil-fuel based energy system prior to 2030. This requires that the right price signals are set in order to prevent the energy system from being locked into long-lasting investments in carbon intensive technologies, such as coal-fired power plants. In general, policies should be designed to facilitate this transition through infrastructure development and behavioral and societal transformation.

Our findings show that the short-term target of a 20% GHG reduction by 2020 is not consistent with the cost-minimizing pathways for the long-term target of reducing GHG emissions by 80% GHG in 2050, because models show a stronger decrease of nearly 30% reduction by 2020. The model results show that a 40% GHG reduction target for 2030 could be in line with the long-term effort to reduce emissions by 80%. The power sector is crucial for the

[1] The project was performed in the context of the Stanford EMF and were documented as the EMF28 study.

decarbonization as it has the ability to reduce emissions more than any other sector. This is, in fact, already the case for the less ambitious case of 40% reduction, and as the mitigation target becomes more stringent, cutting emissions through the non-electricity sectors becomes even more important. The transport sector is the most costly sector to decarbonize, especially without significant biofuel imports to the EU. Allowing for larger biofuel imports is likely to decrease the costs of mitigation. Energy efficiency across all sectors is key for transformation across all the models, in all the scenarios, and for all levels of ambition; however, it requires much stronger policy instruments in order to be achieved.

(4) Conclusions

Despite the differences across the models, common features leading to the achievement of the 80% GHG reduction target exist, see Fig. 1:

- This model comparison shows that our results can support the general conclusions of the EU Energy Roadmap 2050. One noticeable difference is the importance of CCS: While CCS plays also an important role in the default EMF28 scenarios (as in the Energy Roadmap), the alternative technology scenarios show that CCS is not required to meet the mitigation target.
- Energy efficiency plays a key role in the mitigation strategies of both the Roadmap and the EMF28 results;
- In the EMF28 results, biomass use shows a greater than three-fold increase between 2010 and2050; non-biomass-renewables also increase considerably; all renewable energies together make up nearly 50% of electricity generation (model mean); among non-biomass-renewables, wind is the most important with an seven-fold increase until 2050, ultimately reaching a similar deployment level as nuclear, while solar PV represent a limited share;
- Nuclear is constant or moderately increases over time, but continues to make an important contribution in the electricity sector;
- Intermittent renewables such as wind and solar PV contribute 27% of the future electricity mix by 2050 (model median). Therefore, new balancing power options are required, like the development of long-term and medium-term energy storage options and/or the expansion of the European electricity grid and the increase of interconnectors between Member States.

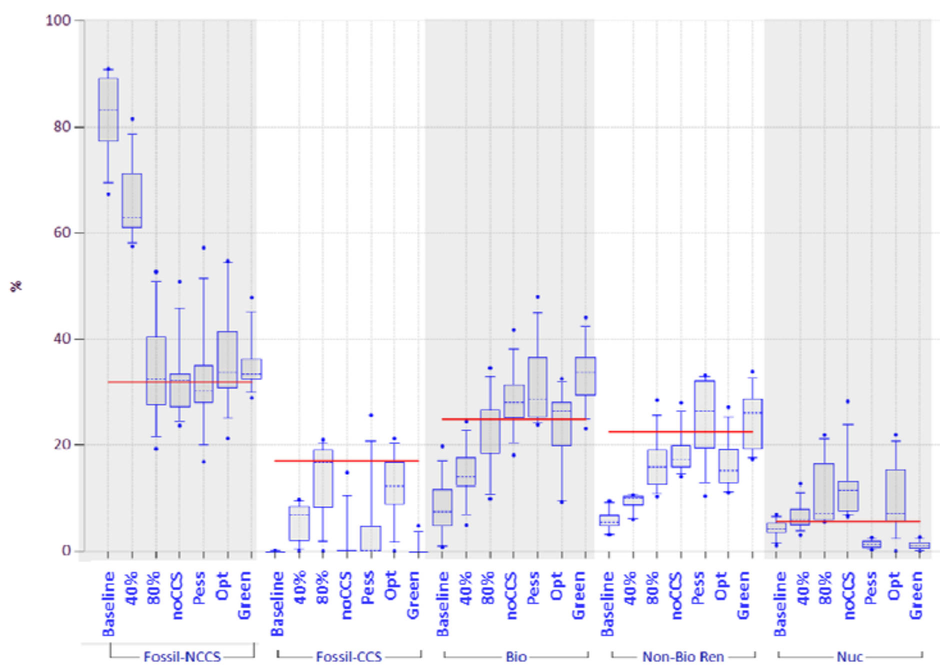

Fig. 1: Percentage share of different technologies from primary energy in 2050. The dotted line is the median over all 13 models, the box indicates the 50% interval, the whiskers mark the 90% interval, and the dots mark the extreme values. Different scenarios shown are: baseline, 40% GHG reduction by 2050 and for 80% reduction by 2050. For the latter scenario four different technology sensitivity analyses are run: no CCS, pessimistic (no new nuclear, no CCS), optimistic (all technology options included, optimistic technology learning), and green (i.e. no new nuclear, no CCS, optimistic technology learning). The red line indicates the numbers from the Energy Roadmap for the diversified technology scenario.