Scenarios for decarbonizing an integrated European energy system - First results from a top-down-bottom-up modelling approach

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Overview

With the “Clean Planet for all” initiative, the European Union (EC, 2018) has developed a comprehensive roadmap for a carbon-neutral energy system by 2050, that updates the “Energy Roadmap 2050”, dating back to 2011(EC, 2011). This paper presents a similar agenda, i.e. an integrated top-down-bottom-up model to analyse scenarios for decarbonizing te European energy system. One of the foci is sector coupling: While in the power sector transition from fossil fuels to renewables is progressing, in the heat and mobility sector it still is in its initial stage. Decarbonizing these sectors is challenging: Since the sustainable potential of biomass is limited, there are few renewable energy sources available to use directly. Consequently, decarbonization in the heat and mobility sector implies to increasingly rely on renewable electricity as an energy carrier. This can be achieved by either converting electricity into synthetic fuels or direct use of electricity in electric cars or heat pumps. However, both ways result in major sectoral interdependencies and, thus, the integration of the energy system.

Against this background, we analyze conceivable developments of the European energy system until 2050 for three different scenarios. Final results with a high degree of detail, especially for the power sector, are obtained by transferring results of an energy system model to a electricity system model as inputs. In previous researcher similar practise has been referred to as “soft-linking” models.

Methods

We couple a top-down energy system model (GENeSYS-MOD, Löffler et al., 2017; Hainsch et al., 2018) with a bottom-up electricity model (dynELMOD, Gerbaulet and Lorenz, 2017), to which two more sectoral modules are currently added, a transport and a heating module for the industry. The applied method can be subdivided into three steps illustrated in the energy flow diagram in Figure 1: First quantitative scenarios regarding final demand for energy services, as displayed on the left, and climate protection efforts are derived. These assumptions are based on qualitative storylines sketching global and European political and economic developments.

However, there are many conceivable technological options to cover final demands and decrease emissions: In the transport sector, for example, cars could be powered by renewable electricity (directly or indirectly by synthetic fuels generated from electricity) or bio fuels. The same applies for the heating sector. Therefore, in the second step, the energy system model GENeSYS-MOD is applied to determine what technologies and fuels are used to what extent to cover final demand. This corresponds to the demands for secondary energy (synthetic fuels and electricity) in the middle and primary energy on the very right of the diagram.

From the key role electricity plays in most concepts to decarbonize the heat and mobility sector, it is apparent, that how demand is covered in these sectors will greatly impact the electricity system. Furthermore, accurately modelling (renewable) power generation and transport requires high spatial and temporal resolution. Therefore, the electricity model dynELMOD “zooms in” on the part of the energy flow diagram dedicated to electricity as secondary energy carrier to achieve a more detailed view. On a practical level, this is implemented by setting the electricity demand and relevant capacities as computed by the energy system model.

Both models applied are formulated as cost-minimizing optimization problems computing investments until 2050 in 5-year steps.

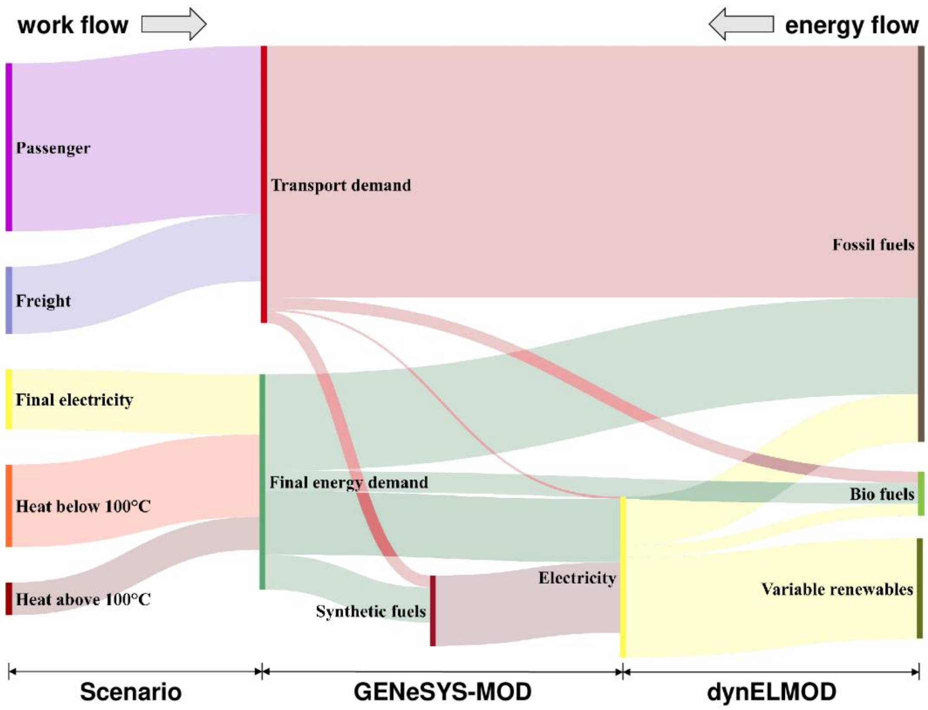

Figure 1: Stylized energy flow diagram

Preeliminary Results

Preeliminary results indicate, that strategies for decarbonising the heat and transport sector have a major impact on the power sector. Mostly due to additional demand from heatpumps and electric vehicles, the overall demand for electricity greatly increases with the level of climate protection. Also, more complex interdependencies between the use of electricity and its optimal generation portfolio can be observed: For example, if more electricity is used to produce synthetic fuels, invesments into renewables shifts from wind to solar. This is, because less favourable generation profiles of solar are increasingly outweighed by its smaller generation costs, if synthetic fuels facilitate the storage of excess generation.

Conclusions

Compliance with emission targets requires integration of sectors within the European energy system. The method applied in this papers identifies interdepencies arising from this and sketches a range of conceivable developments until 2050. Overall, the highest level of detail is dedicated to the power sector since it is expected to play a key role in this process.

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