IMPACTS OF HEAT SECTOR TRANSFORMATION ON GERMANY'S POWER SYSTEM THROUGH INCREASED USE OF POWER-TO-HEAT

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Overview

Ambitious political targets by the Federal Government of Germany and comprehensive energy policies based on incentive schemes led to strong increases in energy production from renewable energy sources (RES) in recent years [1]. In Germany's power sector RES reached an important share of 31.7 percent by 2016 [2]. Nevertheless, also other energy consumption sectors are required to transform in order to reduce the use of conventional CO_2 emitting fossil fuels. In this respect the energy consumption in the mobility sector and the heat supply sector are developing a lot slower and endanger reaching the 18 percent target share of RES in primary consumption in 2020 and 60 percent in 2050 resepctively. Compared to the power sector, where the share increased starting from 3.4 percent in 1990 the share of RES in Germany's heating supply grew only moderately starting from 2.1 to reach 13.4 percent in 2016.

Due to few alternative technologies and limited availability of biomass as RES for heat energy supply, electricity generated from RES will play a crucial role in order to replace fossil fuels and make the heat energy supply transform in a sustainable way. This necessarily leads to an increase in the demand for electricity, which some studies estimate to be from 550 TWh nowadays to 788 TWh in 2050 including important energy consumption reductions [3]. The implications of such a development would lead into a failure of achieving a reduced gross power consumption of 480 TWh in 2050 and to ever higher amounts of installed capacity for wind power and photovoltaics in order to cover 80 percent of this power consumption with RES in 2050 according to the governmental targets. On the other hand new power consumers in the heating sector, such as electric boiler units or heat pumps in combination with heat storages, can provide flexibility on the power sector's demand side and hence, assist integrating RES for electricity (RES-E) into the energy system as a whole [4]. Commonly discussed integration measures are transmission expansion, electric storages, demand-side-management within the power sector and flexibilization of conventional generators [5]. In contrast sector coupling through power-to-heat [6] is often neglected and is hence focused on in this work.

Methods

The techno-economic effects on investment and generation between various energy conversion technologies in different interacting energy sectors and countries analysed over time bear a high degree of complexity. In order to track these effects an existing electricity sector model named dynELMOD [7] has been extended to the German heat supply sector and is employed for this object of inquiry. dynELMOD is a dynamic large-scale techno-economic linear optimization model. It covers the power generation infrastructure constisting of power plants and transmission capacities of all European countries and combines long-term investment with short-term hourly generation decisions of various power generation technologies, transmission capacities, power storages and demand-side-management technologies under CO_2 emission allowance constraints until 2050. The heat sector extension as depicted in figure 1 covers the individual heat supply for space and domestic hot water heating as well as the district heating networks comprising of various types of combined heat and power (CHP) plants.

In order to estimate the increase in power consumption through power-to-heat, the impacts on capacity installations of wind power and photovolataics as well as of power storages in Germany between 2015 to 2050 various scenarios with different assumptions concerning heat demand development, CO_2 emission constraints and technology availability are analysed and compared to each other.

Results

Preliminary results indicate strong increases of annual electric energy demand for heating purpuses in the order of several hundred TWh additionally to the 550 TWh of conventional electricity demand per year in Germany throughout all computed scenarios. Until 2050 a domination of power-to-heat technologies in the individual heating demand sector seems possible. In contrast in the district heating supply also ground-sourced heat pumps are employed, but overall electricity demand resulting from power-to-heat seems to stay limited here. Furthermore, the required installed capacities for RES increase significantly, whereas heat storages can obviously reduce the need for other power storage capacities.

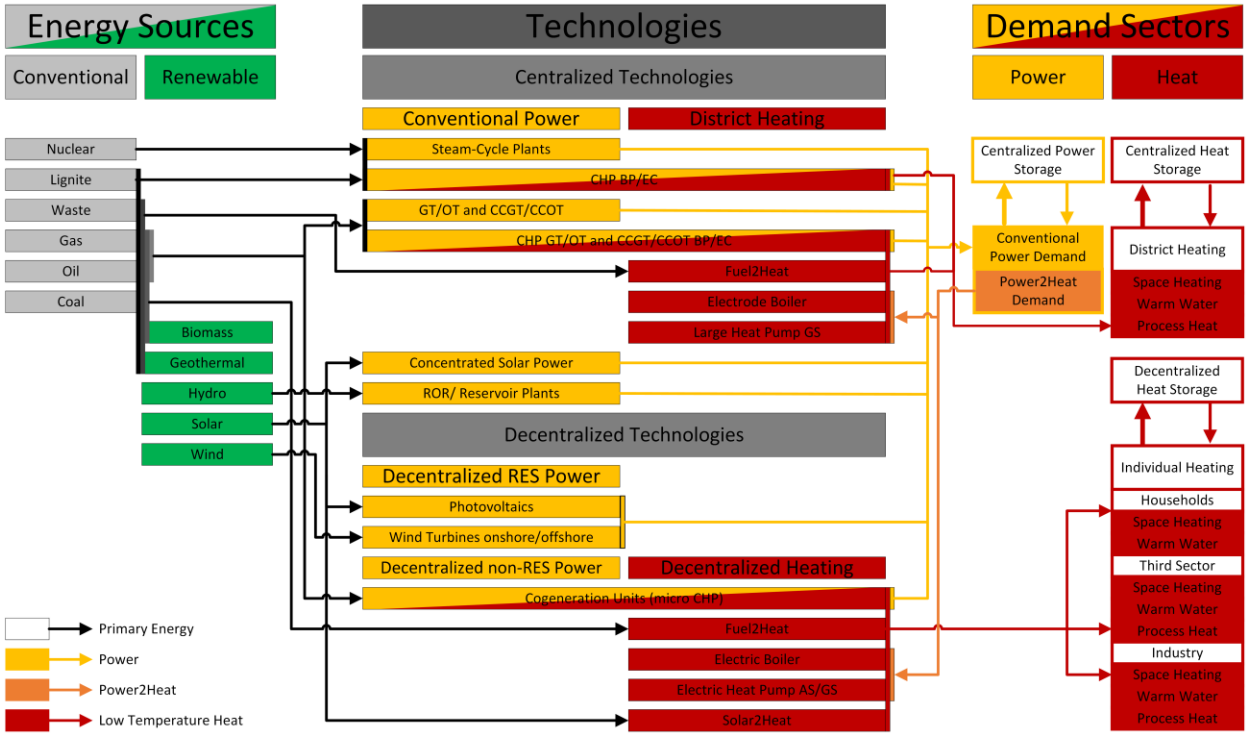

Fig 1: Cross-sectoral power and heat model.
Source: Own depiction.

Conclusions

Significant differences in results between employing power and heat sector coupling versus neglecting the heating sector indicate the importance of conducting such cross-sector analysis. The dominant employment of power-to-heat technologies even in scenarios, where fossil fuels in the individual heating sector are not restricted by CO_2 emission constraints, supposes the economic affordability of even higher amounts of installed RES capacities. Furthermore, even very conservative assumptions about the technical progress of heat pumps do not significantly decrease their installed capacities. However, these assumpitons seem to be crucial for the estimated electricity demand for heating purposes and hence for the extra RES capacities.

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