Chair of Energy Systems
TUM School of Engineering and Design
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Utilisation of Poly-generation Plants Considering Local Feedstock Potentials in Germany

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Motivation and Methods

Modelling energy systems is of central importance for the optimal use of technologies in future energy systems. Scenarios with different technologies, energy demands and policies are used to discuss sustainable transition paths. In particular, the integration of technologies such as Power-to-X, Waste-to-X and Biomass-to-X is important for the supply of synthetic energy carriers and base chemicals.

The aim of this paper is to discuss an evaluation framework for benchmarking innovative technological concepts. Using a residue-based poly-generation plant as an example, the performance, dynamics and localisation of the plant in Germany are evaluated. In order to gain valuable insights, the proposed assessment framework is shown in Figure 1.

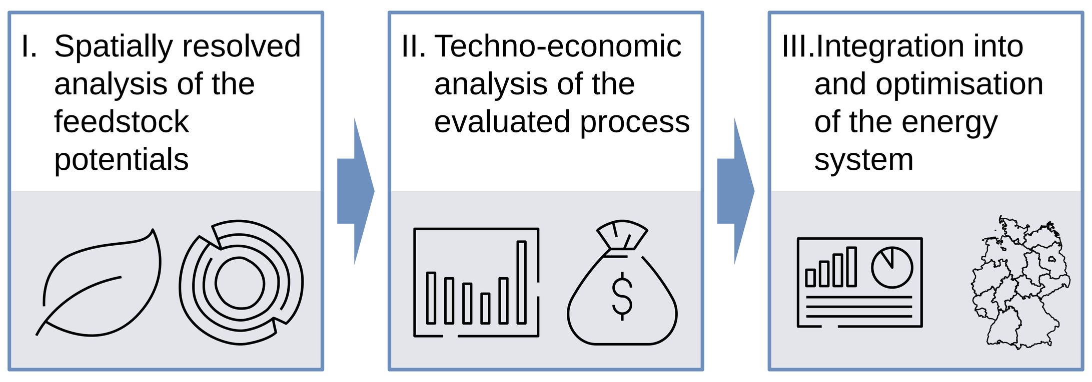

Figure 1: Proposed workflow of the energy system optimisation based technology benchmark method.

I. Feedstock Potential

Considering biogenic and non-biogenic residues, the annual potential of solid feedstock in Germany is summarised to more than 800 TWh, neglecting competing applications, e.g., the food or construction industry [1-3]. Their spatially resolved occurrence can be determined using GIS data openly published by the statistical offices of the federal and state governments and the 'Fachagentur Nachwachsende Rohstoffe e.V.'.

Figure 2 summarises the annual technical potential of twelve chosen feedstocks, showing the strong dependence on population density and the characteristics and use of non-urban land. However, a large share is already used for energetic applications, e.g., domestic heating, which shows the importance of using currently unused residue potentials.

Figure 2: Potential of (biogenic) residues in Germany with NUTS3 resolution.

II. Techno-Economics

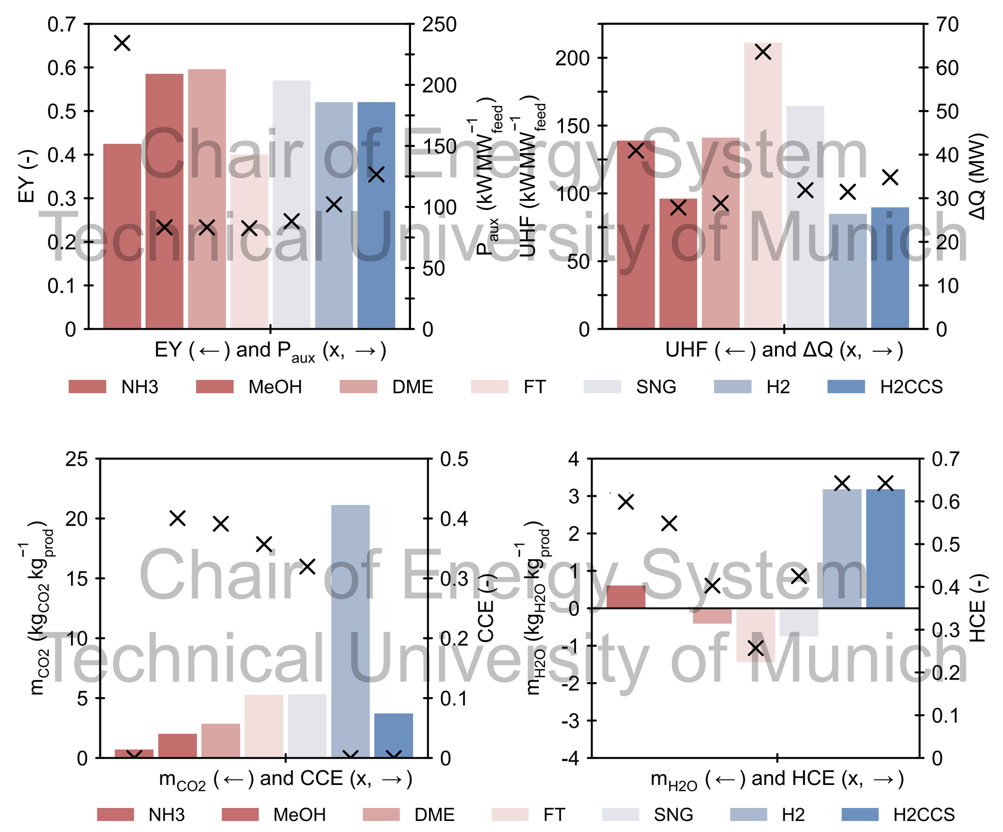

Figure 3: Results of the technical and energetic analysis , taken from [4].

The evaluated concept is the poly-generation of electricity, heat and a synthesis product in one plant. Considered are Methanol, Fischer-Tropsch crude, SNG, DME and hydrogen as energy carriers and thus as products. For an in-depth description of the technical process, Aspen Plus® models have been created for each of the process variants. A technical and energetic comparison shows methanol production's advantages (Figure 3) [4].

Additionally, economical key performance indicators are needed to compare the process routes in the context of an overarching system. This has been done by the authors in [5] using established factor-based methods to calculate investment, operational and specific product costs. Again, methanol shows its advantages compared to other products.

III. Energy System Analysis

Based on the techno-economic parameters of the poly-generation concept and the potential of the residual materials available in Germany, energy system optimisation methods can be used to evaluate their use. Here, the questions regarding the use as a poly-generation or only single- or co-generation plant, as well as the choice of feedstock-product combination and the time-resolved operation of the plant can be determined.

As described in [6,7], the model framework uses a node- and link-based formulation to simulate energy systems (Figure 4a). The feedstock potentials are implemented in a NUTS3 resolution (Figure 2), whereas the power-, heat- and mobility sectors are aggregated to larger nodes (Figure 4b and c). The model describes the scenario of a near emission-free system in 2040, considering all main demand and supply technologies.

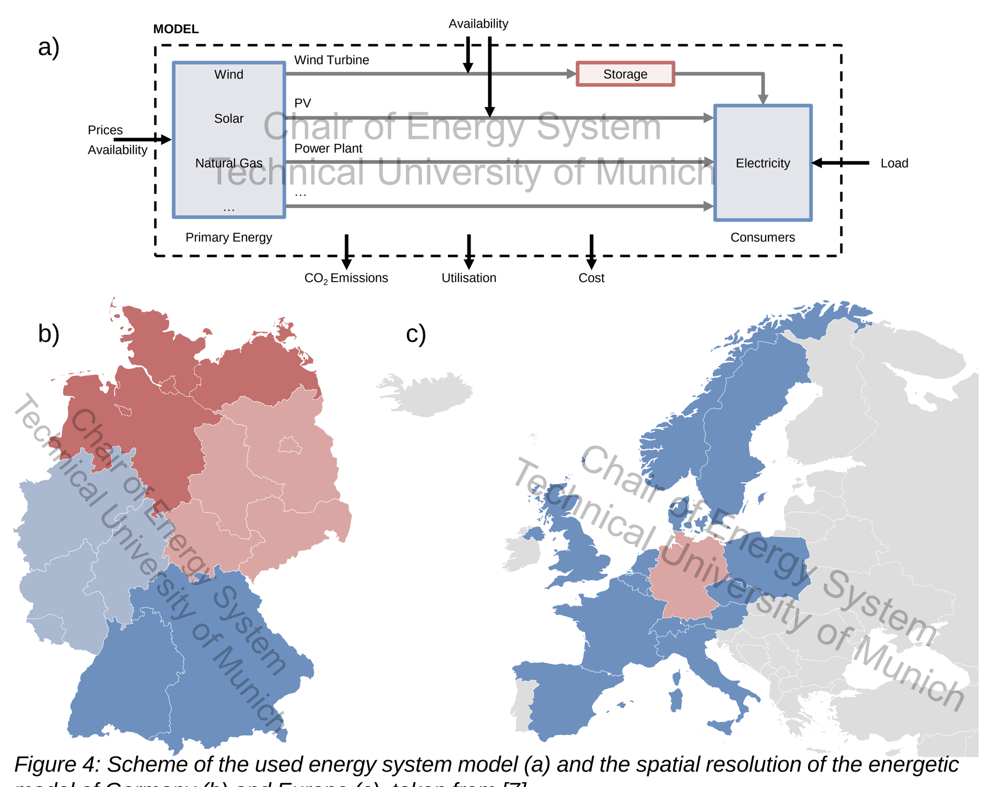

Figure 4: Scheme of the used energy system model (a) and the spatial resolution of the energetic model of Germany (b) and Europe (c), taken from [7].

Results, Conclusion and Outlook

Preliminary results show that the already high use of biogenic feedstock for heat supply and biogas production uses a large share of the biomass potential. B/WtX plants only become economically viable when currently unused residual materials are considered. Furthermore, the results of the techno-economic analysis are confirmed in the system optimisation as far as product selection is concerned. Particularly in regions with high chemical industry, methanol is increasingly used, with SNG production being highest across the board due to the scenario definition (Figure 5). The use of poly-generation plays only a minor role in the given scenario compared to co-/single-generation plants. The main reason is that the market costs of chemicals and fuels are higher than the average electricity costs in an almost entirely renewable energy system. Although PtX plants are increasingly used in times of high renewable electricity generation, the re-conversion into electricity is not profitable due to the poor efficiency chain. However, increasing natural gas prices highly influence this result until a 100% renewable system is achieved.

In summary, the framework shows a good methodology for benchmarking new technologies. The results available from the optimisation can also be used in further post-processing for a time-resolved analysis of the plant operation. For this purpose, however, the next step will be to optimise based on new scenarios and consider the uncertainties that still need to be discussed in detail, as well as a more extensive selection of configurations within the poly-generation concept.

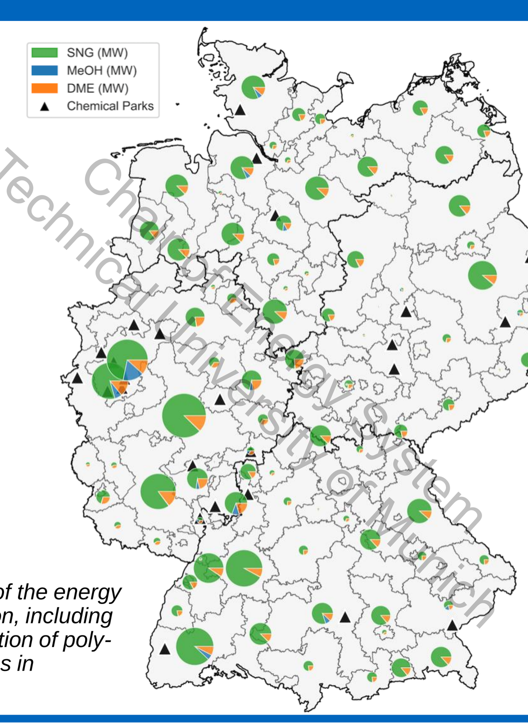

Figure 5: Results of the energy system optimisation, including the spatial distribution of poly-generation systems in Germany.

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