MODELLING OPTIMAL REGIONAL ENERGY SUPPLY BASED ON 3D GEODATA FOR BUILDINGS AND RENEWABLE ENERGIES

Philipp Theile, University of Cologne, +49 221 277 29-210, philipp.theile@ewi.uni-koeln.de
Amir Ashour Novirdoust, University of Cologne, +49 221 277 29-321, amir.ashour@ewi.uni-koeln.de
Michael Moritz, University of Cologne, +49 221 277 29-202, michael.moritz@ewi.uni-koeln.de
Johannes Wagner, University of Cologne, +49 221 277 29-302, johannes.wagner@ewi.uni-koeln.de
Chris Kesnar, Hochschule für Technik Stuttgart, +49 711 8926 2807, chris.kesnar@hft-stuttgart.de
Bastian Schroeter, Hochschule für Technik Stuttgart, +49 711 8926 2371, bastian.schroeter@hft-stuttgart.de
Volker Coors, Hochschule für Technik Stuttgart, +49 711 8926 2708, volker.coors@hft-stuttgart.de

Overview

The Building sector plays a crucial role in achieving German national CO2 targets. In 2019, the building sector's share of total energy consumption amounted to 27%, with over 84.1% used for heating (both space and water heating). Therefore, a rigorous understanding of the building sector is crucial for effective climate policy. There is great amount of research modelling energy systems with consideration of the building sector as well as renewable energies from a top-down perspective. To do so, renewable potentials typically are aggregated and building characteristics are fed in for representative buildings on the system level. However, this branch of research does not give insights into the measures that need to be taken for CO2 abatement on the regional level, the regionally specific costs of CO2 abatement or costs for gaining energy autarky. Energy Communities have been discussed in the EU Clean Energy Package as a means to, among other things, mobilise private capital needed for an energy transition and increase public acceptance of renewable energy. Therefore, the question remains, how to model energy systems on the regional level, while accounting for regionally specific characteristics regarding the building stock and renewable potentials.

This research project aims at providing a suitable framework for the regionalisation of energy system analysis by bridging the gap between bottom-up building energy system models and regional energy system models, including modelling of renewable energy sources. Doing so, the framework allows policymakers and researchers to analyse regional energy systems while accounting for the specific building stock characteristics and regional potentials for renewable energies. This approach allows for analysis of regionally specific cost structure as well as estimating the costs of autarky and the abatement costs of greenhouse gas emissions of the regional system. For this purpose, the project aims to couple a physical 3D model with an economic simulation both at the individual building level and the regional energy supply level. A comparison of energy supply costs with existing supra-regional energy system models allows for the assessment of regional cost structures. This is particularly relevant regarding regional efforts to gain energy autarky or carbon neutrality.

Methods

We aim to couple a 3D geodata model with an energy system model, optimizing regional heat and power markets. SimStadt is an urban energy simulation model (Nouvel et al., 2015). SimStadt takes spatial information about the building configurations and the geographical character of a predefined area as input; including the 3D outline of the buildings. In combination with reference weather data and estimations of the occupancy of the buildings based on statistical inference, SimStadt computes the corresponding electrical and heat demand as well as regional renewable energy potential. The results are used as inputs for COMODO which determines the optimal technology set-up and operation to satisfy these demands given the generation potential of the house and the characteristics of the market environment like electricity prices and subsidies (Frings & Helgeson, n.d). COMODO's and SimStadt's results combined serve as inputs for a bottom-up regional energy system model. This framework allows for the computation of installed capacities of power plants necessary to meet regional energy demand under detailed consideration of demand adjustments in the building sector. Commodity prices will be regarded as exogenously given, as we treat the region as a price taker on the national level. By expanding COMODO by an endogenous energy market model, we cover feedbacks between the regional electricity price and household's technology investment and operation.

We will consider a set of representative houses to compute the technology diffusion within an entire region via COMODO. Clustering of the households will be performed on the regional building stock, prefiltered by year of construction and usage type. This allows for a high number of representative houses and a reliable representation of the building stock. Thus, using a cost-minimization approach, the energy system model delivers expansion and dismantling of various renewable and fossil technologies and associated costs to meet regional demand. This framework allows for the analysis of the system costs of regional energy system with high level of autarky as well as the assessment of CO_2 abatement costs on a regional level.

Results

The model coupling methodology will deliver regional energy demands and optimal (renewable) power plant expansion, both on the building level and the system level with consideration of detailed regional characteristics. The analysis will be conducted for a set of model regions in Germany. The model regions represent structurally different regions, such as urban, sub-urban and rural. Based on the model framework and the case studies implications for optimal structures of regional energy systems for different types of regions can be derived. Currently, we are in the conceptual phase, implementing the coupling of the existing models with the regional energy model. We aim at presenting first results at the IAEE Online Conference.

Conclusions

Our model framework allows for the comparison of local CO_2 abatement costs of a set of German model regions. The comparison can be conducted both between regions as well as between a specific region and the national level. By this, policymakers and researchers can assess energy systems concerning regional peculiarities and draw conclusions about local optimal energy supply. Our research contributes to the existing literature on energy system models by combining local potentials for renewable energies (supplied by the 3D geodata model SimStadt), individual household cost optimization problems and regional energy system optimization.

References

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