Karlsruher Institut für Technologie

Institut für Industriebetriebslehre und Industrielle Produktion
Lehrstuhl für Energiewirtschaft

Master Thesis

What is the optimal scale for fully autonomous municipal energy systems?

Contents of the thesis

The German energy transition (Energiewende) requires the integration of large amounts of fluctuating, heterogeneously-spatially-distributed electricity into the energy system. Some characteristics of renewable energy resources means that their decentralised exploitation is necessary. These characteristics of renewables have led to discussions about energy autonomy. This is the idea that a region can become more or less independent from its surroundings by providing much or all of its energy from indigenous resources. However, most of these regions aim for so-called "balanced electricity autonomy", meaning they generate enough electricity over the year in order to meet their annual demand, using the electricity network to balance out excesses and deficits. Arguably, this type of energy autonomy can result in inefficient reallocation of costs (at least under existing network cost redistribution systems), as the network is only used as a backup option (McKenna 2018). Hence the high costs of the capital infrastructure would need to be distributed across an ever-decreasing number of customers.

Complete energy autonomy relates to an island or off-grid solution, whereby a region can meet its energy demand at all times, perhaps with backup generators to ensure security of supply. Some islands already achieve this, based on 100% renewable energy sources, but in that case, the motivation is mainly technical due to a lack of interconnector. In other contexts such as Germany, this concept could also be economically attractive, however, given the right framework conditions.

On the one hand, economies of scale and the "portfolio effect", whereby pooling larger areas ensures a smoother generation profile for renewable energies, are arguments for a higher aggregation of the energy (supply) system. On the other hand, higher aggregation results in more requirements for transmission and distribution network infrastructure, resulting in higher investments and energy losses that are proportional to the distance. The research hypothesis for this Masters Thesis is that there is an optimal scale at which it makes economic sense, under specific framework conditions, to implement an autonomous local energy system. It is the objective of this Masters Thesis to test this hypothesis, by carrying out a quantitative analysis that considers the above as well as the following aspects:

- Costs and potentials for renewable energies, and available area for these (provided by supervisors)
- Size of the region, in terms of population and area
- Type of region, e.g. urban/rural, type of network
- Existing energy system and infrastructure characteristics
- Consideration of existing network, i.e. "greenfield" or not

The output from the Thesis should be in the form of a quantative model (regression and/or simulation) that captures these interdependencies and is validated with empirical data for German municipalities (to be provided), which is therefore able to test the above hypothesis. Examples of similar functions for distribution networks relate the total costs to the number of customers, the length of the network and amount of transmitted energy (Kuosmanen 2012).

Kuosmanen, T. (2012): Stochastic semi-nonparametric frontier estimation of electricity distribution networks: Application of the StoNED method in the Finnish regulatory model, Energy Economics, 34, 2189-2199

McKenna, R. (2018): The double-edged sword of decentralized energy autonomy, Energy Policy, Volume 113, February 2018, Pages 747–750, https://doi.org/10.1016/j.enpol.2017.11.033.

Prerequisites

- Enthusiasm for topics related to renewable energies and renewable energy policy
- Willingness to work independently
- Experience programming languages would be advantageous, but is not mandatory

Start / Duration / Language

from now on / 6 months / German or English (preferred)

Contact persons

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