How to (not) succeed in the German energy transition: Some insights from modeling electrical storage technologies

Germany was long mentioned a prime example of the energy transition[1] because of the nuclear phase-out and a rapid diffusion of renewables (Michaelowa 2003). But lately the growth of renewables declined because of negative effects of the transition including (a) negative prices, (b) high prices for household consumers, (c) needed but slow grid expansion, (d) growth in natural gas and lignite power plants and (e) less subsidies for renewables.

Most of these negative effects are attributed to the volatile electricity generation by wind and solar which account for more than 60% of all renewables in Germany (BMWi 2018). The share of renewables in the total electricity generation amounts to over 30% (Burger 2018a). In order to manage these negative effects, several solutions are discussed. The first option is a more flexible generation capacity which is also promoted by the Federal Ministry for Economic Affairs and Energy (BMWi 2018). It focusses on balancing oscillations in the generation by flexible conventional generation capacities and therefore guarantee a stable electricity generation. Flexible generation capacities are mainly natural gas fired power plants[2] (Näsäkkälä & Fleten 2005) and lignite power plants[3] (Bugge et al. 2006).

The second option is demand site management (Strbac 2008) which focusses on the consumption of electricity. Research shows that demand side management raises concerns about privacy protection (Laupichler et al. 2011) and the diffusion of technologies for demand side management may be very slow (Wissner and Growitsch 2010). A third option in energy storage. Energy storage may focus on each stage of the value chain (Chen et al. 2009). A fourth option is a smart grid that may be described as a combination of the aforementioned options (Blumsack and Fernandez 2012).

This paper focuses on energy storage, especially electrical storage, i.e. the use of electricity to provide electricity at a later point in time. The aim of the paper is to (1) analyze electrical storage technologies with system dynamics and (2) assess the capabilities of energy storage technologies in the Germany electricity market.

Our analysis shows that the volatile electricity generation provides an incentive for electrical storage but also to more generation by conventional power plants. Further, electrical storage capacity – when charged – can be seen as electricity generators and therefore compete with other generation capacities. Concerning the assessment of the capabilities of electrical storage technologies, we show a possibility to incorporate them in system dynamics models. However, we show also the arising issue of competing time horizons: building storage capacities range over several years while the capabilities of the different technologies come into operation due to volatile generation that will be on basis of minutes.

Sterner and Bauer (2017) define energy storage as an energy technology for storing energy in form of internal, potential or kinetic energy. It covers three processes that include charging, storing and

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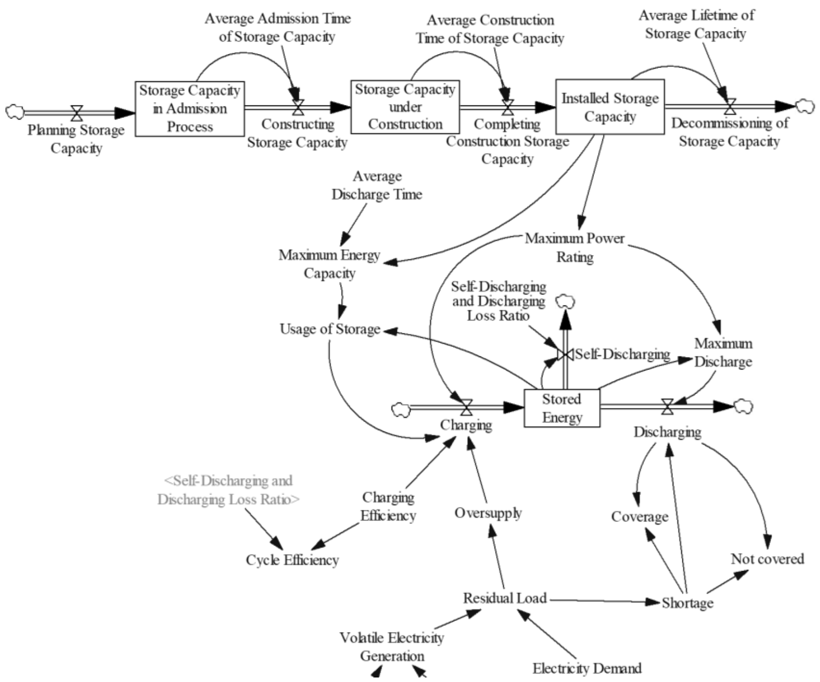
[1] Michaelowa (2003) attributes Germany's leading role in the energy transition to a chaos of different influences of lobbyists and policies but nevertheless states that Germany somehow achieved significant level of CO2 reductions and a growth in renewables.

[2] See EON power plant Irsching Block 4 and 5

[3] See EnBW power plant RDK 8

discharge in one cycle. Energy storage can be generally divided into primary and secondary energy storage. Summarizing all operational characteristics of different technologies, we created a generic structure that include all criteria:



Model 2: Operation of Electrical Storage with technical characteristics

This Model can then be integrated in the context of the electricity market structure:

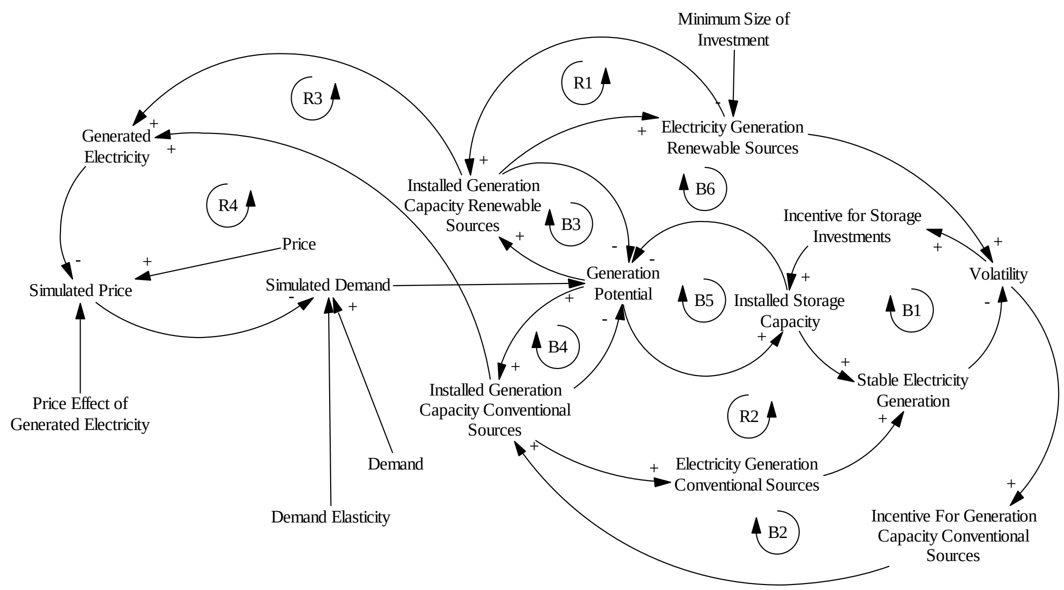


Figure 1 - Causal Loop Diagram

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