System studies of energy infrastructure options and development trajectories over time; methodology development and strategy design with inclusion of uncertainty analyses from techno-economic perspective

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Aanleiding

The energy infrastructure is critical to the functioning of modern socio-economic systems. The current Dutch energy infrastructure is result of decisions and efforts made over the previous decades. So will the future energy infrastructure be result of decisions and efforts made in the upcoming decades. However, large uncertainties exist of how the energy infrastructure will evolve in the future. Moreover, the evolution of the energy infrastructure involves long-lived capital stocks and it is prone to irreversibility along with path-dependency. The capital-intensive and long-lived nature of the energy infrastructure and most of the energy capital stock lead to technological inertia in the form of slow capital stock turnover rates. In addition, previous choices and developments constrain the set future opportunities to change. Once the system is moving towards a given path, the transition from one path to another is burdensome, perhaps even impossible. There are a vast number of uncertainties surrounding these processes. The uncertainties include amongst others:

- Technological uncertainties (e.g. availability of technologies, technological properties, speed of technological learning etc.)
- System uncertainties (e.g. interoperability of existing and new technologies)
- Political uncertainties (e.g. GHG emission targets, subsidies, taxes, energy sector regulations, geopolitics etc.)
- Resource uncertainties (e.g. availability and prices of primary energy carriers, availability and costs of capital etc.)
- Uncertainties about the evolution of societal preferences (e.g. acceptance of new technologies)

The issue of uncertainty is complicated by the fact that the different uncertainties interact. For instance, the future competitiveness of a renewable energy source such as wind energy is subjected to its intrinsic technological uncertainty, technological uncertainties of its competitors, political uncertainties, and uncertainties about its interoperability with existing technologies in the system.

The complex interdependencies of the various uncertainties are exactly the focus of this research. From a techno-economic system perspective this project analyses the implication of key uncertainties on the long term development of the Dutch energy and infrastructural system. The overall approach has been split up into case studies, which are dedicated to the built environment and the electricity sector respectively.

Methodiek

Key to the methodological approach in this project is the explicit incorporation of uncertainties into energy system analyses. Strong focus is laid on quantitative energy system modelling methods. Technology explicit, quantitative models are applied and developed to simulate the development of the Dutch energy system on the longer term (i.e. up to 2050). Most commonly in energy system analyses it is dealt with uncertainties in the framework of scenarios analyses. However, while there is no way to treat all the uncertainties associated with the future, there are alternatives other than conventional scenarios for analyzing them. Different approaches of uncertainty (and sensitivity) analysis, such as Monte Carlo analyses, Design of Experiment, Stochastic optimization, are employed.

These analyses aim to create strategic insights on the uncertainties associated with potential development trajectories of the energy infrastructure and an understanding of how these uncertainties interact over time. Furthermore, these findings are used to identify strategies that are robust across uncertainties, allow for a maximum degree of flexibility, and disclose critical points in development (such as lock-inn situations).

Conclusies tot nu toe

Insights from the first case study on the residential built environment confirm the importance of uncertainty and sensitivity analyses. We developed a model (DREM) for systematically analysing future energy use and associated carbon emissions from the Dutch dwellings across a variety of uncertainties such as demographics, investment behaviour, fuel prices, energy policy and technological development. The analyses show that dwelling stock turnover, technology learning, energy prices, energy policy (subsidies, building codes), and heating degree days are among the most significant uncertainties with respect to the development of the residential built environment up to 2050. Furthermore, we found that multiple sets of conditions may lead to similar results, i.e. a similar emission level can be reached as result of different system realisations in terms of technology deployment, stock turnover rate, demographic activity etc.. However, we also identified the relevance of path dependency and the need for early action. Once the system is moving towards a particular direction, it is difficult to adjust the development path. The development depends on the chain of historical events and action omitted in the near future are difficult compensate later on.

Meer informatie

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http://www.nwo.nl/nwohome.nsf/pages/NWOP_5WCHCK