Modelling Energy Transition in the Netherlands

Data Collection and Preparation

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1 METHODOLOGY

Energy sector, considered to be a complex system, is characterized by non-linear dynamic relations and feedback loops. This constitutes a reason why its behavior is not easily predictable. However, the prediction of the system performance and its side effects is required in order to regulate the decisions that define it.

In order to explore the system behavior, answer the research question, identify and comprehend the different scenarios of achieving or directing the energy transition in the Netherlands, a model is created. During this project, a system dynamics model that depicts the energy sector in the Netherlands is developed based on publicly available time-series data.

System dynamics simulation models provide a promising instrument to support decision making. The (potential) contribution of the model created relies on the following aspects:

- Identifying patterns among the system's components.
- Understanding dynamic system behaviours and the structures that generate them.
- Exploring paths into the future.
- Assessing different strategies and directing the energy transition in the Netherlands.

Overview of the process. Firstly the necessary data is gathered and analysed. The model is created based on the dynamical patterns that are identified within the data. Then, the model is subject to sensitivity analysis, based on real-life data in order to fine tune it. After the sensitivity analysis, the model is simulated and data are produced. Finally, the produced data are analysed and compared to real-life data available. In this way the validity of the model can be assessed. The overview of the process is illustrated in figure 1.

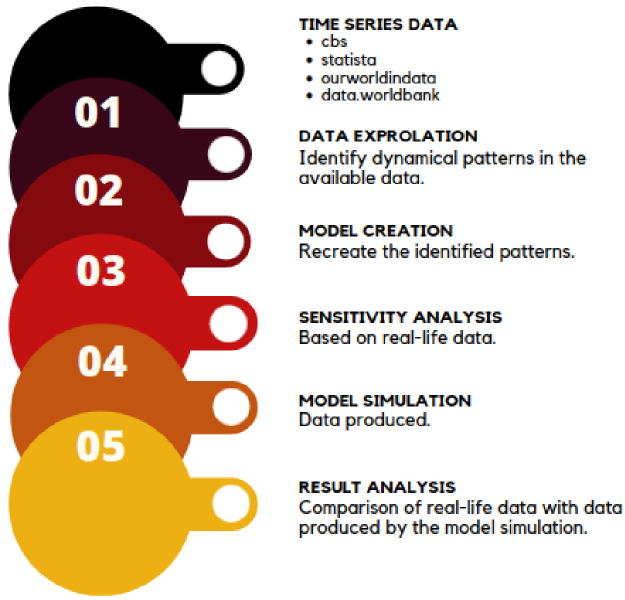

Figure 1: Overview of data flow

1.1 Data Collection

Most of the data used for the development and validation of the model is already collected by the dutch Central Bureau for Statistics (CBS)[1]. The CBS provides a branch with datasets on the energy sector. The data provided are time-series since they form a collection of the observations gathered through repeated measurements over time. The CBS also has a department that focuses primarily in Renewable energy; consumption by energy source, technology and application. The available data date from 1990 until 2022 and is broken down into energy source/technique and into energy application (electricity, heat, transport). In addition there is data available on Renewable electricity; production and capacity, dating from 1990-2022. The data is broken down according to the type of energy source and the technique used to obtain the electricity. A distinction is made between four main categories: hydro power, wind energy, solar power and biomass. However, the available data are not gathered for the purpose of this specific project, therefore it is important that this data is critically analysed before it is used in the model.

During the data exploration it became evident that not all the data that are required for the development and validation of the model are available in CBS. Those data are collected from various other sources such as Statista [2], Our World in Data [3] and the World Bank [4]. Data related to the CO2 production (annual, per capita) per fuel type (coal, oil, gas, other sources) is gathered from Statista and The World Bank, available from 1960. Data on the electric power consumption is provided by The World Bank and dates back to 1960. Finally, data on the different renewable energy sources capacity is provided by Statista.

[1] CBS

[2] Statista

[3] Our World in Data

[4] World Bank Group

1.2 Data Analysis

Data is used to identify the dynamical patterns the model is required to be able to recreate. Additionally, data can provide the bounds to the parameters and form the the range of their inputs/ outputs during the sensitivity analysis of the model.

1.3 Model Development

The main aim of this thesis is the construction of a generic model that depicts the dynamics within the energy sector and the impact of different scenarios; in this case different ways to achieve the energy transition. The appropriate modeling approach to use depends on the assumptions about the stocks and flows in the system that are applicable to a specific purpose. During this case study two different types of models will be used. The system modeling will be firstly approached by a causal loop diagram and then by a stock and flow diagram.

The diagrams that are going to be constructed will be grounded on the available data. In particular, after the analysis of the data the patterns among the various elements of the sector are going to be identified. The relations and feedback loops within the models are going to be established based on the patterns identified. Therefore, the models are going to depict the interconnections among the available data.

1.4 Sensitivity Analysis

The development of a basic model does not recreate the precise behavior of the system presented. The stock and flow diagram that is created includes equations that determine the value of its elements. The equations of the basic model only depict the relations among the various components of the system and do not provide realistic results.

In order to fine tune the model and produce accurate results a sensitivity analysis will be conducted. During this process, the available data are going to be analysed meticulously in order to determine the equations that can recreate the actual behavior of the system. The sensitivity analysis of the model will propose and evaluate different scenarios that outline the direction and speed of the energy transition.

1.5 Model Simulation

The mathematical model produced by this thesis has a predictive function since the initial objective is to use the simulated model to guide the energy transition. The simulation constitutes an experiment that is performed on a model with the objective to generate insight that enhances the understanding of the behaviour of the system. The change of the conditions (the experimental frame) enables the analysis of the system for different scenario's. The simulation of the model produces data that is later analysed. Mainly, growth and saturation rates of different points of the system are going to be examined.

The model is going to be calibrated in order to quantify the relationships among its elements and explore its projection into the future. In this way, insight on the parameters that fulfil the requirements of the Paris Agreement will be provided.

1.6 Model Evaluation

One of the last stages of the research is the evaluation of the results that it has produced. The real life data that will be used during the calibration of the model can be also used to show that the data produced by the model is valid. Therefore, the comparison of the data produced with the real life, available data is going to form the main evaluation method of this thesis. However, the model might have limited accuracy due to its limitations.

More information on model evaluation...success requirements of the model?