



TradeRES

New Markets Design & Models for
100% Renewable Power Systems

Backbone

Overview

Backbone represents a highly adaptable energy systems modelling framework, which can be utilised to create models for studying the design and operation of energy systems, both from investment planning and scheduling perspectives. It includes a wide range of features and constraints, such as stochastic parameters, multiple reserve products, energy storage units, controlled and uncontrolled energy transfers, and, most significantly, multiple energy sectors. Both high-level large-scale systems and fully detailed smaller-scale systems can be appropriately modelled.

The framework has been implemented as the open-source Backbone modelling tool using General Algebraic Modeling System (GAMS). The tool minimizes the total investment and operating costs of the system. The formulation is based on mixed-integer programming and takes into account unit commitment decisions for power plants and other energy conversion facilities.

The adaptability of Backbone extends to several dimensions: temporal, spatial, technology representation and market design. Stochastic inputs can be represented with short-term forecasts and longer-term statistical uncertainties. It is possible to vary time step durations, select representative periods, and define rolling optimization structures. Due to the modifiable node-unit structure, multiple efficiency representation alternatives, and aggregation possibilities, technologies can be modelled with appropriate accuracy. From the market design perspective, Backbone supports, for example, different reserve requirement and provision configurations as well as gate closures.



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Inputs

Main input data sets and parameters are given in the `inputData.gdx` file. Backbone sets and parameters are documented in the files `1b_sets.gms` and `1c_parameters.gms`, respectively, as well as `1a_definitions.gms`, which describes hard-coded sets, such as parameter definitions, in more detail. Some sets and parameters are not in the input data – they are calculated from the input data.

The Backbone model is initialized by the `modelsInit.gms` file (a model definition file) in the input data folder. This file sets, for example, the temporal structure of the model. It often just points to a specific model version that is described by another file (for example, `scheduleInit.gms`). This way it is easier to change between different model definition versions. There are templates for different model versions in the Backbone/defModels folder.

Global system parameters to control the solution process are given in `1_options.gms` and temporal index ranges are given in `timeAndSamples.inc`. Templates for these files are available in the main Backbone folder.

The main input data types are tabulated below.

Table 1

Output group	Main output types
Investments	Invested amount of each type of generation or other technology as well as transmission
Unit commitment and dispatch	Start-ups and shutdowns, online status, production or consumption, ramping, and reserve provision of of each unit
Transmission between nodes	Use of transmission links
Emissions	Emissions from fuel consumption
Costs	OPEX: fuel costs, other O&M costs, emission costs, penalty costs from inflexibilities



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Outputs

Backbone writes results in the results.gdx file. Result parameters are described in 1d_results.gms. The main output data types are tabulated below.

Output group	Main output types
Investments	Invested amount of each type of generation or other technology as well as transmission
Unit commitment and dispatch	Start-ups and shutdowns, online status, production or consumption, ramping, and reserve provision of each unit
Transmission between nodes	Use of transmission links
Emissions	Emissions from fuel consumption
Costs	OPEX: fuel costs, other O&M costs, emission costs, penalty costs from inflexibilities CAPEX: generation capacity and other technology investments, transmission link investments
Prices	Marginal cost of commodities (electricity, gas, heat, etc.)
Flexibility indicators	Loss of load, reserve shortages, spillage, VRE curtailment



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Find out more

Backbone is available at <https://gitlab.vtt.fi/backbone/backbone>. The README file and Wiki pages <https://gitlab.vtt.fi/backbone/backbone/-/wikis/home> give more instructions for installing and using the tool. Backbone documentation and other publications are listed at <https://gitlab.vtt.fi/backbone/backbone/-/wikis/More-information/List-of-publications>.

If you use Backbone in a published work, please cite the following publication, which describes the Backbone energy systems modelling framework:

Helistö, N., Kiviluoma, J., Ikäheimo, J., Rasku, T., Rinne, E., O'Dwyer, C., Li, R., & Flynn, D. (2019). Backbone—An Adaptable Energy Systems Modelling Framework. *Energies*, 12(17), 3388. <https://doi.org/10.3390/en12173388>

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Info

The TradeRES project will develop and test innovative electricity market designs that can meet society's needs of a (near) 100% renewable power system. The market design will be tested in a sophisticated simulation environment in which real-world characteristics such as actors' limited foresight into the future and risk aversion are included.



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Start date

1 February 2020

End date

31 January 2024

Overall budget: € 3 988 713,75



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864276