COMPETES-EMLabpy

COMPetition in Electric Transmission and Energy Simulator & Energy Modelling Laboratory

Overview - COMPETES

COMPETES is a power system optimisation and optimal dispatch model that seeks to minimize the total power system costs of the European power market whilst accounting for the technical constraints of the generation units and transmission constraints between the countries. COMPETES model can be used to perform simulations for two types of purposes:

- Least-cost capacity expansion to optimise generation and transmission capacity additions.
- Day-ahead markets, through least-cost planning and dispatch of generation and demand.

The COMPETES model covers 28 EU Member States and some non-EU countries (i.e., Norway, Switzerland, and the Balkan countries), including a representation of the cross border transmission capacities interconnecting these European countries. The Balkan and Baltic countries are each aggregated in one node. Denmark is split into two nodes due to its participation in two non-synchronous networks. The model assumes an integrated EU market where the trade flows between countries are constrained by 'Net Transfer Capacities (NTC)'.

EMLabpy – COMPETES soft linking

COMPETES doesn't consider Capacity mechanisms and doesn't model CO_2 endogenously, hence in a first attempt, we soft-linked the COMPETES optimization model with the capacity market and CO_2 market modules of EMLabpy. Figure D - 1 shows the workflow of one simulation year. The CO_2 market uses the costs and the short-term market results. The CO_2 price is used to simulate the Market Clearing and generation expansion in COMPETES. Finally, the capacity market module is done in EMLabpy.
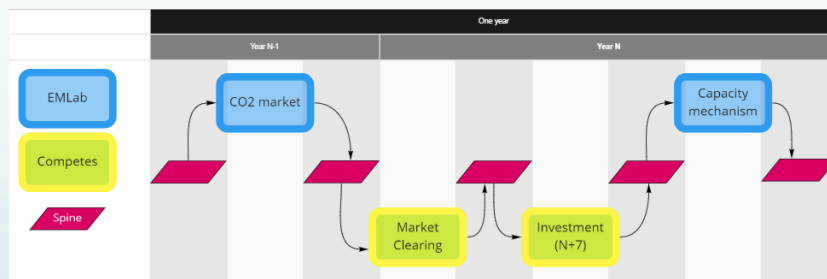

Figure D - 1. EMLabpy-COMPETES soft coupling workflow.

Inputs

This list contains the data that is exchanged between COMPETES and EMLabpy.

EMLabpy

- Average unit production costs (EUR/MWh).
- Fuel prices (EUR/MW).
- Fixed O&M costs (EUR/MW).

Data from COMPETES

- Yearly revenues per power plants (EUR).
- Yearly unit emissions (ton CO_2/MWh).
- Operational plants, Unit capacity (MW).

COMPETES

The input data of COMPETES involves a wide range of generation technologies. There are 14 types of fossil-fuel power plants which can operate with CCS or as a combined heat and power (CHP) plant – nuclear, geothermal, biomass, waste, hydro, wind, and solar technologies. These can be detailed out with unit by unit generation in the Netherlands.

The main inputs for electricity supply can be summarised as:

- Operational and flexibility characteristics per technology per country:
    - Efficiencies.
    - Installed power capacities.
    - Availabilities (seasonal/hourly).
- Emission factors per fuel/technology.
- Fuel prices per country.
- Hourly time series of VRE technologies (wind, solar, etc.).
- Overnight costs for conventional generation (EUR/MW).
- Transmission capital expenditures (CAPEX; EUR/MW).
- Fixed O&M costs (EUR/MW).
- Hourly demand (MWh).

Data from EMLabpy

- Capacity Market Clearing Price (EUR/MWh) -> Translates to a CAPEX and OPEX reduction in COMPETES input data.
- CO_2 prices (EUR/ton CO_2) and Extrapolated CO_2 price year N + T (EUR/ton CO_2).

Outputs

COMPETES

The COMPETES model calculates the following main outputs for the EU28+ as a whole, as well as for the individual EU28+ countries and regions:

- Investments in cross-border transmission (interconnection) capacities (capacity expansion module output).
- Investments in conventional generation capacities (capacity expansion module output).
- The allocation of power generation and cross-border transmission capacity.
- Hourly and annual power generation mix – and related emissions – in each EU28+ country and region.
- The supply of flexibility options, including power generation, power trade, energy storage and VRE curtailments.
- Hourly competitive electricity prices per country/region.
- Power system costs per country/region.

EMLabpy

- CO_2 Market Clearing Price (EUR/MWh).
- Capacity Market Clearing Price (EUR/MWh).

How to run it

Requirements and Installation Instructions

To run and install the soft-linking, the following software is required:

- Python.
- Spine Toolbox.
- Advanced Interactive Multidimensional Modeling System (AIMMS) – (license required, academic license available).
- COMPETES (obtainable in accordance with TNO).
- Microsoft Access (or Microsoft Access Ready Driver).
- The source code is openly available and can be downloaded through the Github (J. Hommes, Github repository for this project. [Online]. Available: https://github.com/TradeRES/Spine_EMLab_COMPETES).

Once downloaded, the folder can be opened as a Spine-project in the Spine Toolbox.

Running Instructions

To run a case study, first the input data has to be defined. Under the 'resources/data/' folder, template files have been supplied. These should be filled and the 'template_' should be removed from the file names.

If the Spine Toolbox is showing red exclamation marks, this indicates that there are problems that need to be fixed before running. Most likely, this will be fixed by the following actions:

1. File references should be checked. The blocks should refer to the correct paths, e.g., the 'EMLAB Init Data'-block should refer to the 'EMLAB Init.xlsx' file.
2. The SpineDB databases have to be initialized. This is done by clicking 'New Spine DB' on the 'DB EMLAB', 'DB COMPETES' and 'Simulation Configuration Parameters' blocks.

Once the Spine Toolbox shows no red exclamation marks, it is ready to be executed. However, to be able to run the full coupling, COMPETES has to be initialized. This is done by launching AIMMS and loading COMPETES. Once loaded, the procedure 'Setup_RESTAPI' has to be run. This procedure enables the HTTP request module from the AIMMS DataExchange library. This enables the Spine Toolbox to communicate with AIMMS and is necessary to let Spine Toolbox run COMPETES. The soft-linking is now ready to be executed.

The entire loop in Spine Toolbox entails one year of execution time. The Spine Toolbox workflow shown in Figure D - 2 represents one simulation year. This implementation was developed before the looping functionality of Spine Toolbox was available and thus, as a workaround, the Clock module indexes the data in the Databases and triggers the next year iteration. Note that when running multiple years, the import blocks should not be run again. To run multiple years, the blocks from 'Init EMLAB Clock' should be run.
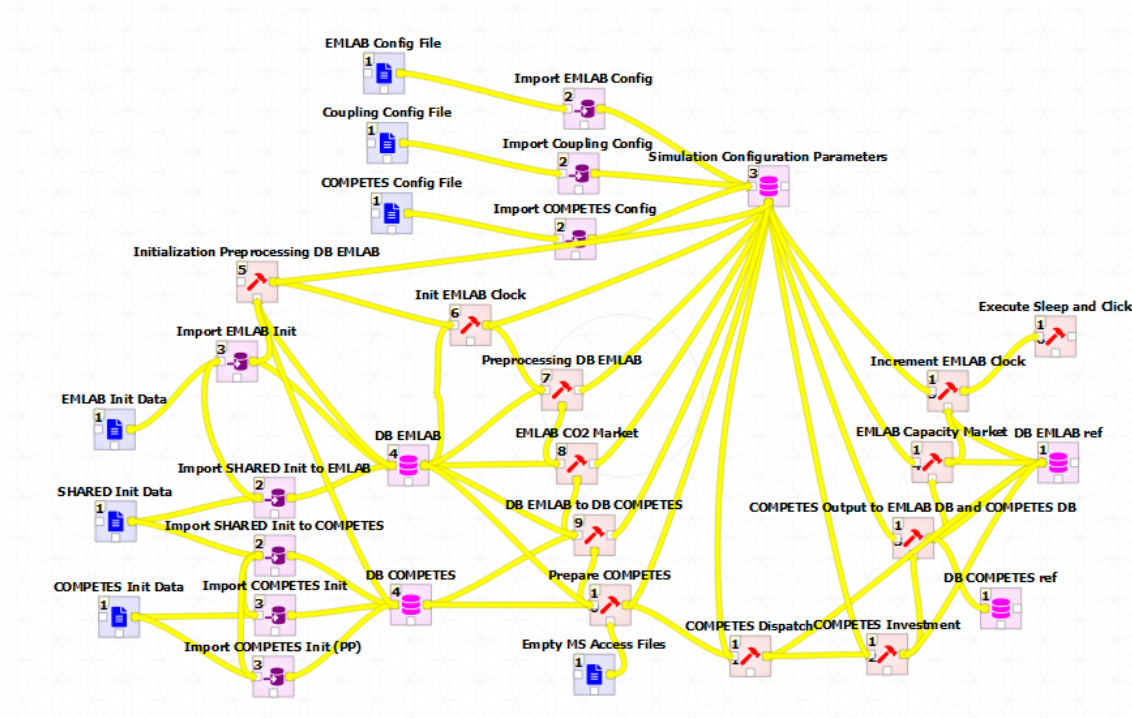
Figure D - 2. COMPETES implementation in the Spine Toolbox.

The "EMLAB Config File" and "COMPETES Config file" contain configurations to specify the model runs. The "Coupling Config File" specifies the order in which the data has to be imported into the databases. The Init data-blocks (in blue) point to the excel sheets to run the respective models. These resources are intended to be replaced by the TradeRES database. The connected importer-blocks (in purple) serve to map the input data to the Spine databases (pink). The translation script "DB EMLab to DB Competes" collects the CO_2 and capacity market results into COMPETES and similarly the "COMPETES Output to EMLAB" transfers the dispatch and investment results into EMLabpy.

After preprocessing the data to be imported to EMLabpy, the CO_2 Market is run, the CO_2 price is then fed to COMPETES which simulate the market clearing of the current year. Then the COMPETES investment block computes an optimal capacity mix seven years ahead. The new power plants are then added to the power mix considering the building times. Finally, the capacity market is simulated in EMLabpy considering the current year dispatch results.

Find out more

The following publications describe the model in further detail and some examples of its use:

- EMLab general purpose description: http://emlab.tudelft.nl/.
- Chappin, E. J. L. et al. (2017) 'Simulating climate and energy policy with agent-based modelling: The Energy Modelling Laboratory (EMLab)', Environmental Modelling and Software. Elsevier Ltd, 96, pp. 421-431. doi: 10.1016/j.envsoft.2017.07.009.
- COMPETES-EMLabpy first implementation. Master Thesis of Jim Hommes http://resolver.tudelft.nl/uuid:63691862-9a26-4df3-b6dd-57bed6c9d8a5.
- Ö. Özdemir, B.F. Hobbs, M. van Hout, P. Koutstaal (2019), Capacity vs energy subsidies for promoting renewable investment: Benefits and costs for the EU power market, Energy Policy, In Press, Available online 18 December 2019, https://doi.org/10.1016/j.enpol.2019.111166.
- Sijm J., Hout M. van, Özdemir Ö, Stralen J van., Smekens K., Well A. van der, Werner W. van, Musterd M. (2017), The supply of flexibility for the power system in the Netherlands, 2015-2050, ECN-E-17-044, November 2017. https://www.tno.nl/media/12356/e17044-flexnet-the-supply-of-flexibility-for-the-power-system-in-the-netherlands-2015-2050-phase-2.pdf.
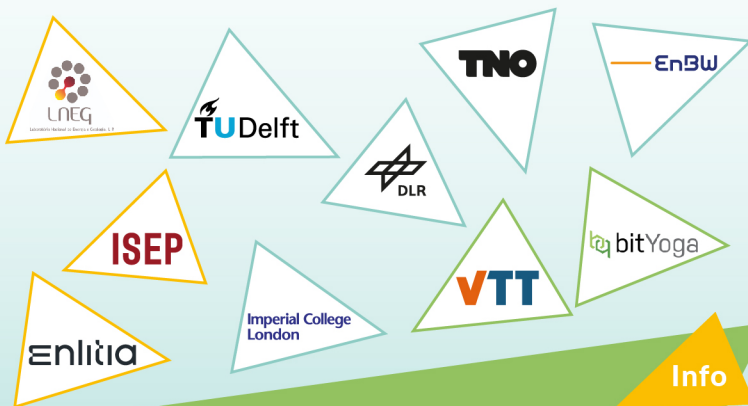
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Info

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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