TradeRES

New Markets Design & Models for 100% Renewable Power Systems

Backbone

Energy system modelling tool

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

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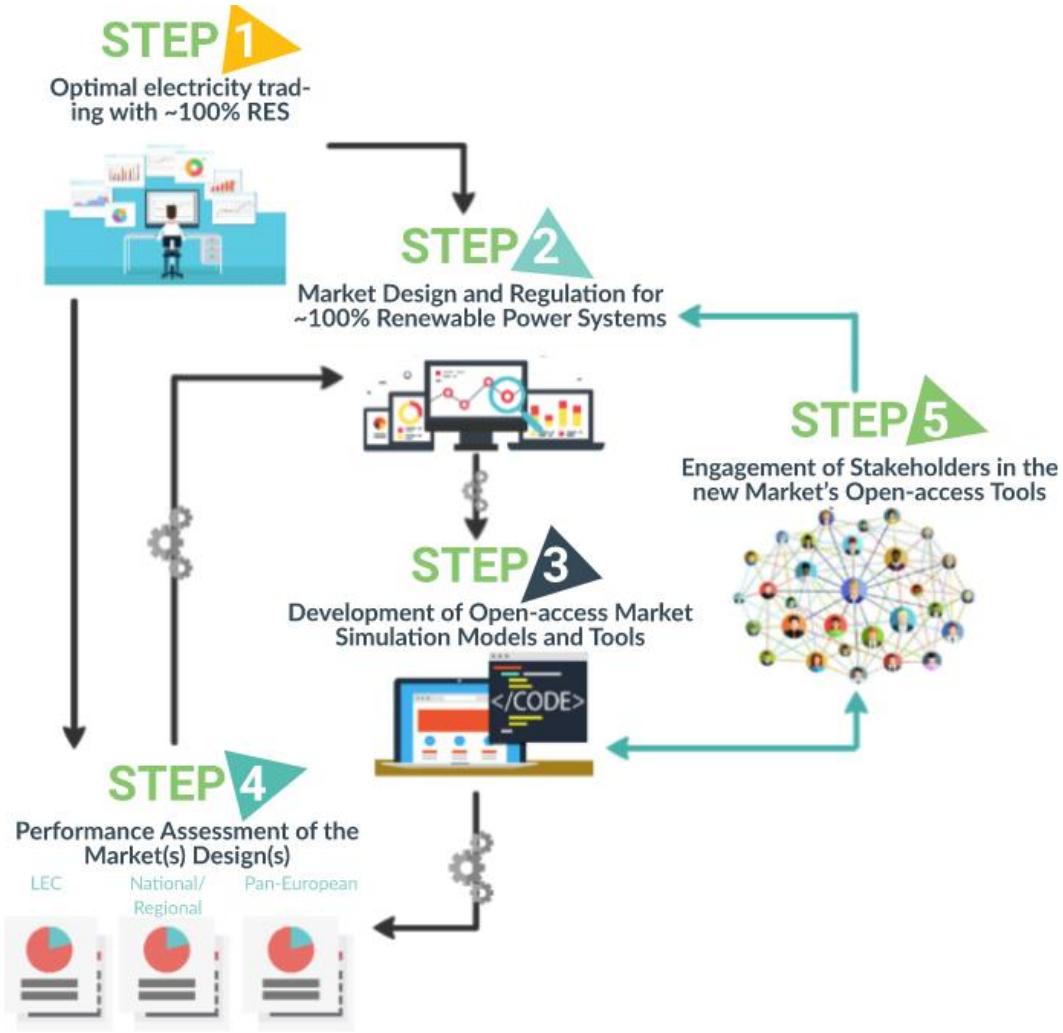
1 TradeRES Develop and test an electricity market design for a near 100% renewable power system



Spatial levels

Pan-European National Local

Model levels

Backbone COMPETES

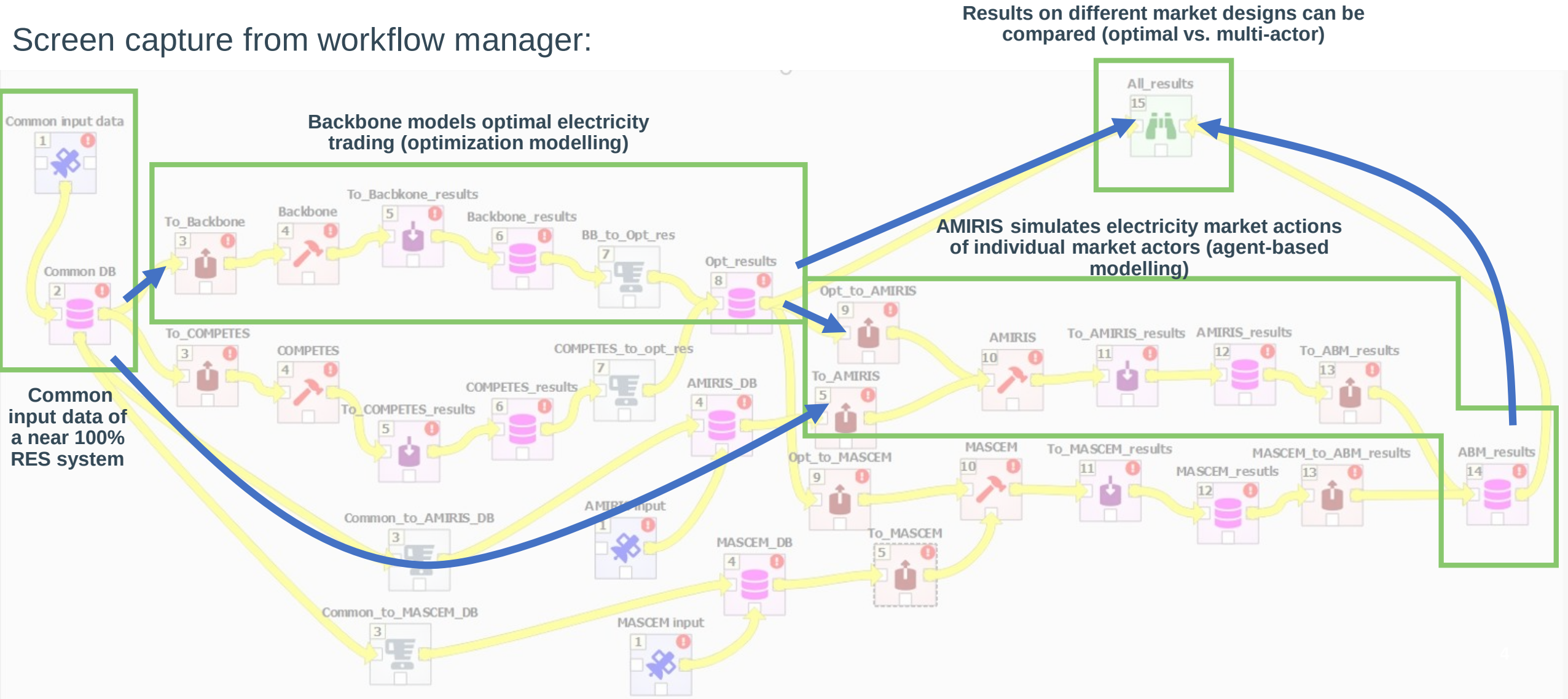
Optimization models

Agent-based market models

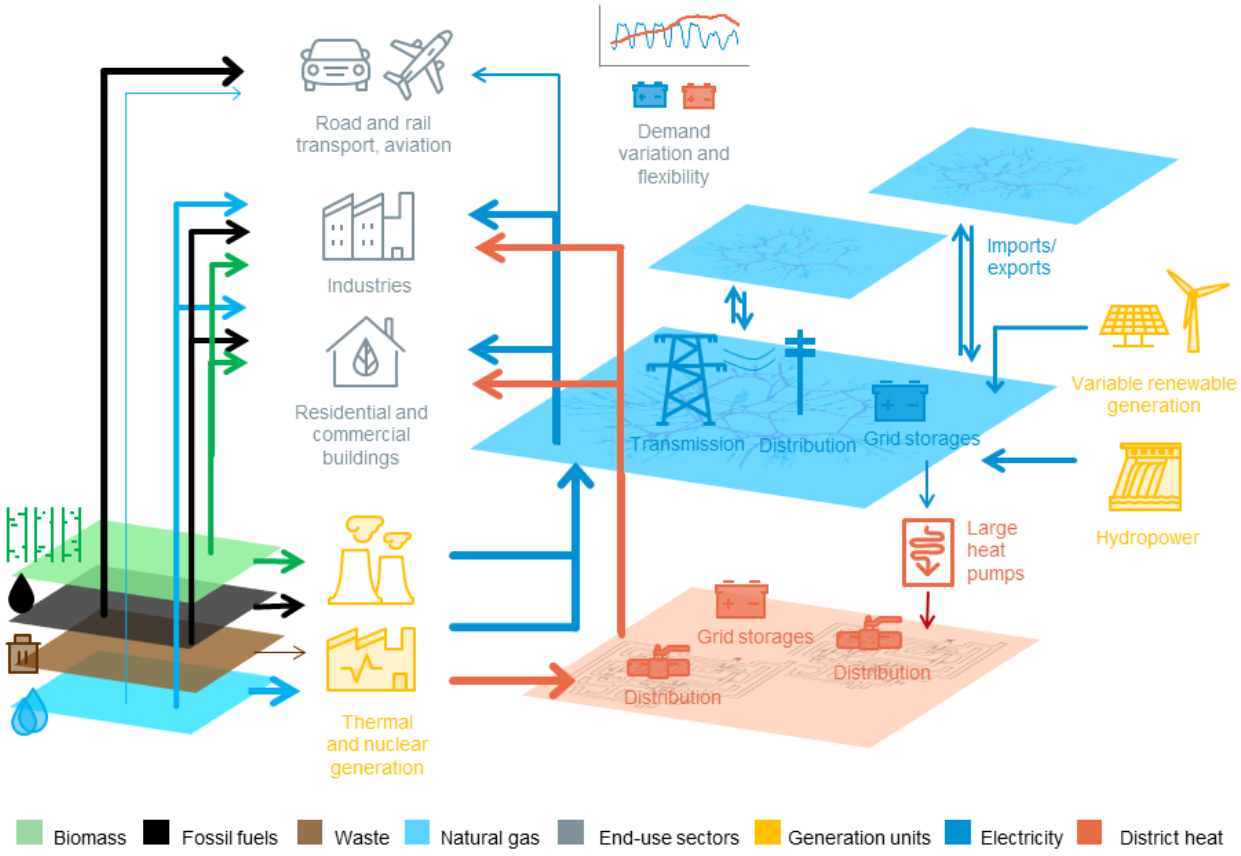
AMIRIS MASCEM RESTrade EMLab

1 Interaction of different models

Screen capture from workflow manager:



2 Backbone modelling approach



Cost-optimization

bottom-up

for multiple energy sectors

in local, national and regional scales.

INVEST PLANNING / CAPACITY EXPANSION

What would be the most cost-optimal investments for a certain system in a certain future setting?

OPERATIONAL PLANNING / SCHEDULING

How a certain future system would operate with given investments according to least-cost unit commitment?

2 Backbone modelling approach

INPUTS

Technology data
(as unit sets with parameters)

Spatial data
(in nodes and transfers)

Stochastic data
(in forecasts and long-term variability timeseries)

Temporal settings

Market design
(in price timeseries, reserve settings)

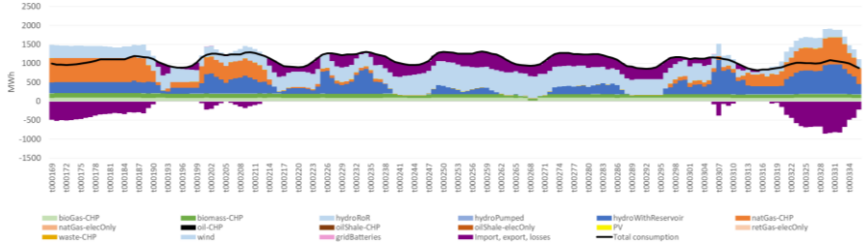
OUTPUTS

INVEST PLANNING

Invested amount of each type of generation, other technology and transmission

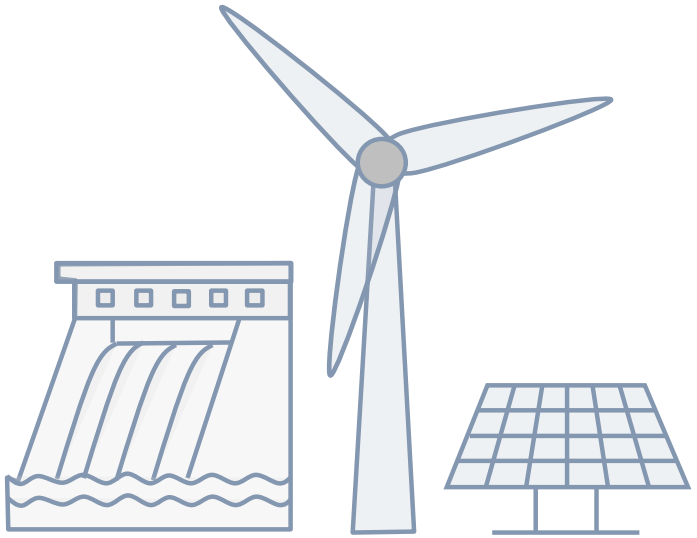
SCHEDULING

Unit commitment and dispatch



Emissions
Costs
Prices
Flexibility indicators

3 Story of Backbone



16 Mar, 2016 1 commit

First commit as Backbone. A working version for scheduling that probably contains several bugs.
unknown authored 6 years ago

8f4ac29e

Realized that existing models were unable to represent stocasticity related to hydropower

Wanted to combine these features into a flexible and general model to address unknown future modelling needs

2015 2016 2017 2018

Long history with open-source optimization and unit commitment models in GAMS (General Algebraic Modeling System)

Need to model decision making under variable generation conditions – to improve the value of VRE generation

3 Story of Backbone

Backbone started to be "ready" – was able to do the things old models did and more

Currently we are working on new tools, but currently we continue using Backbone because of stability, active development and sufficient features

Biggest unsolvable issue remains with GAMS licencing not allowing for full open-source use

2018 2019 2020 2021 2022

For a couple of years still, modellers in our team used combinations of old tools, but by 2020 everyone had changed to Backbone

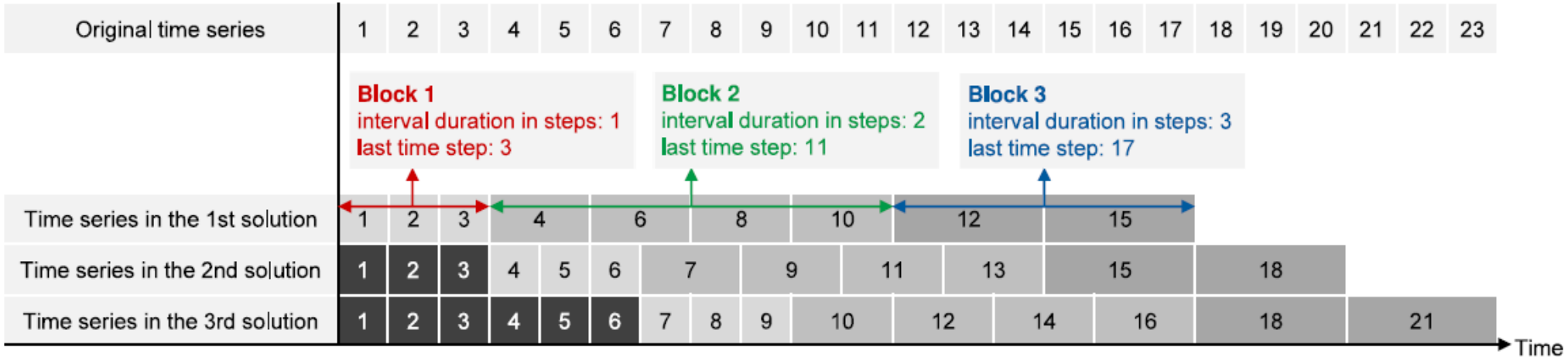
Advancing market design features with TradeRES project

Building tools for data and scenario management – ease-of-use & interaction of tools

4 Features: Temporal

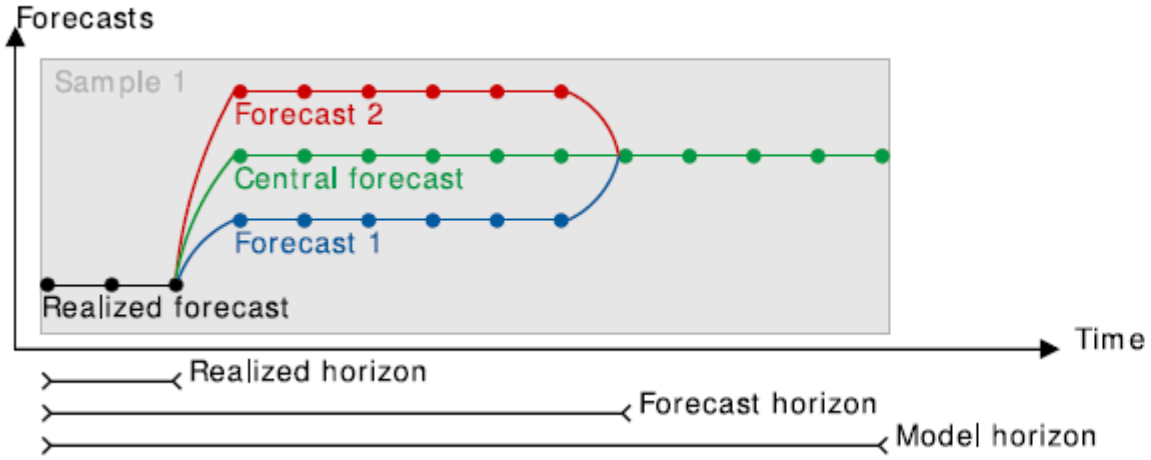
- Typical use case is one year in hourly time steps
  - Invest planning uses representative periods, typically few weeks in hourly resolution
  - Operational planning uses full year in hourly time steps
- Free to choose other time step lenght and amount of timesteps or model multiple years in pathway modelling
- Free to choose from ’one solve with perfect foresight’ to ’rolling horizon with limited foresight’

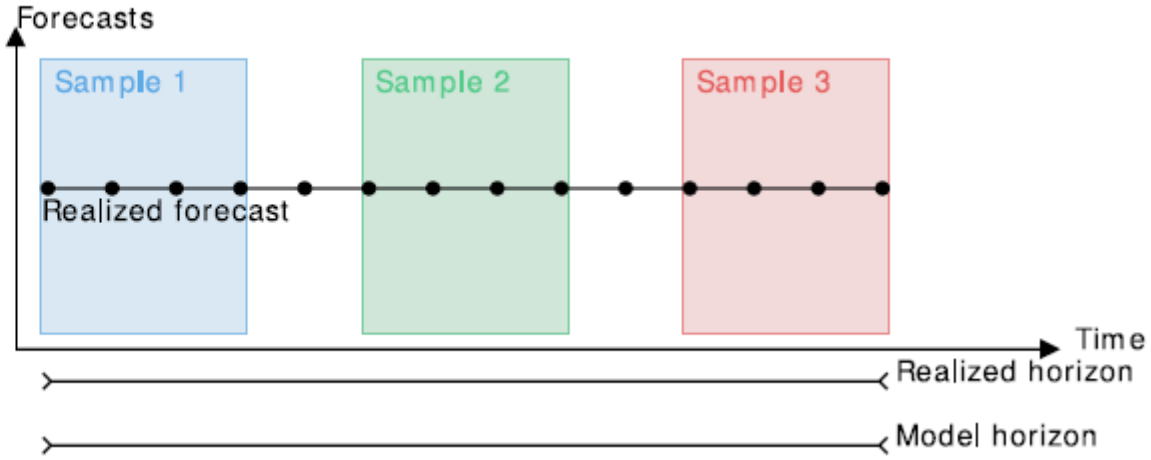
EXAMPLE:
Lenght of solve 3 h.
Model always sees:
- next 3 h in 1h time resolution,
- next 8 h in 2 h resolution, and
- next 4 h (or rest of time series) in 3 h resolution



4 Features: Stochastic

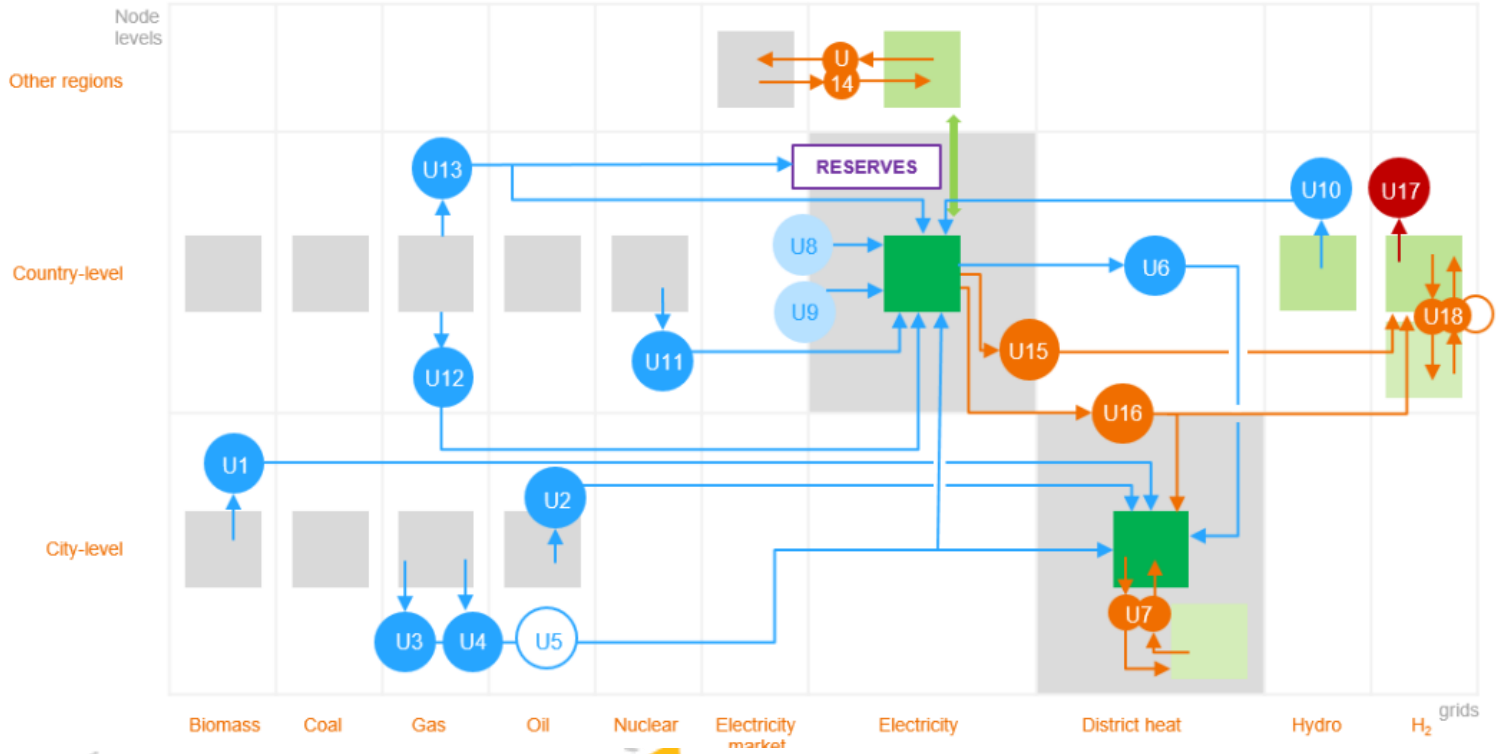
- Possibility to use short term forecast (hours-days) – typical use case for wind forecasts
- Long-term variability (seasons-years) – typical use case for different weather years or hydrological inflows





4 Features: Spatial & technology

- Flexible node-unit structure allows for flexible representation of different spatial scales and technologies
  - Typical use case is that nodes are used for both country- and city-level and also as storages or demands



- Multiple efficiency representation and aggregation possibilities to control level of detail vs. run time
- Predefined and user-defined constraints

4 Features: Market design

- Optimized market conditions, ”each player acts in the best interest of the system”
  - Predefined: Multilevel *reserve* requirements and provision configurations, gate closures as well as *inertia* and *capacity adequacy* constraints
  - User-built: Market designs can be described using units, nodes and prices

5 Example

Example data set: Spain-Portugal system from 2013 (3 nodes) with existing capacity and possibility to invest in existing technologies or solar PV

Question: How can you test different renewable support market designs and how they impact generation mix?

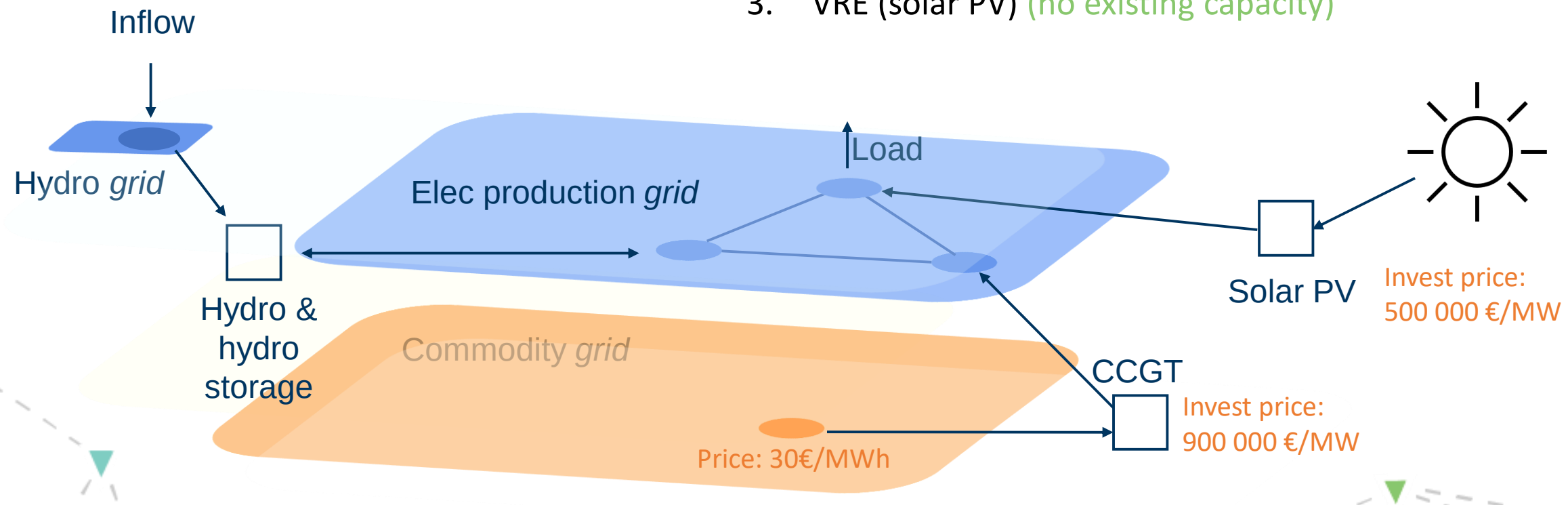
1. Optimize investments
2. Optimize operation

(Example by: Silke Johanndeiter – EnBW, Germany)

5 Example: Building the base model

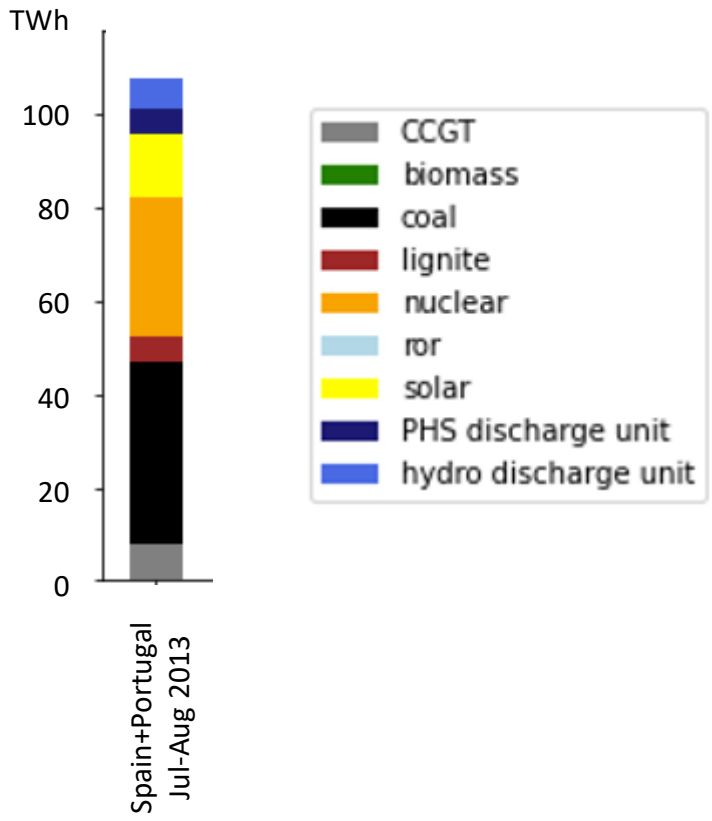
Three types of units:

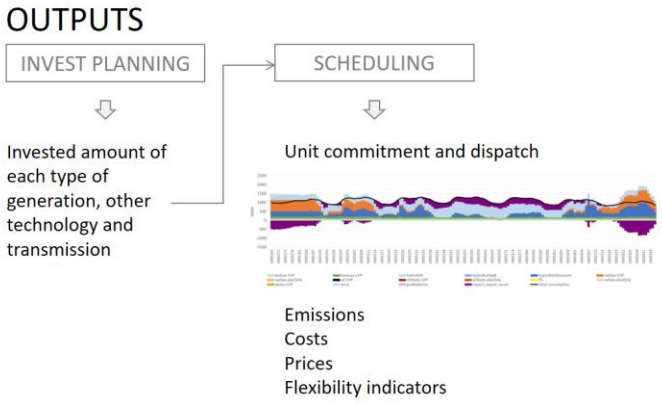
1. Thermal (CCGT, coal, lignite, nuclear) (existing capacity)
2. Hydro (ROR, reservoir, storage) (existing capacity)
3. VRE (solar PV) (no existing capacity)



5 Example: Running base case results

Optimized generation mix

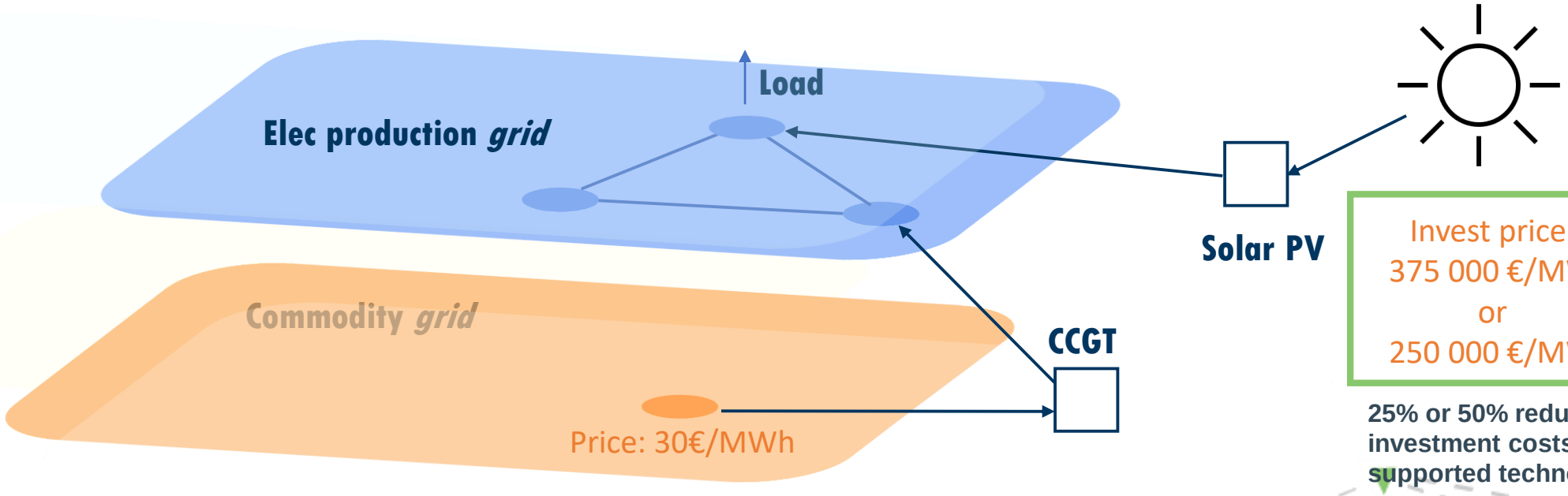




Modelling four market designs:

A. Capacity premium for VRE
B. Market premium for VRE
C. Prosumers with dynamic consumer prices
D. Prosumers with static consumer prices

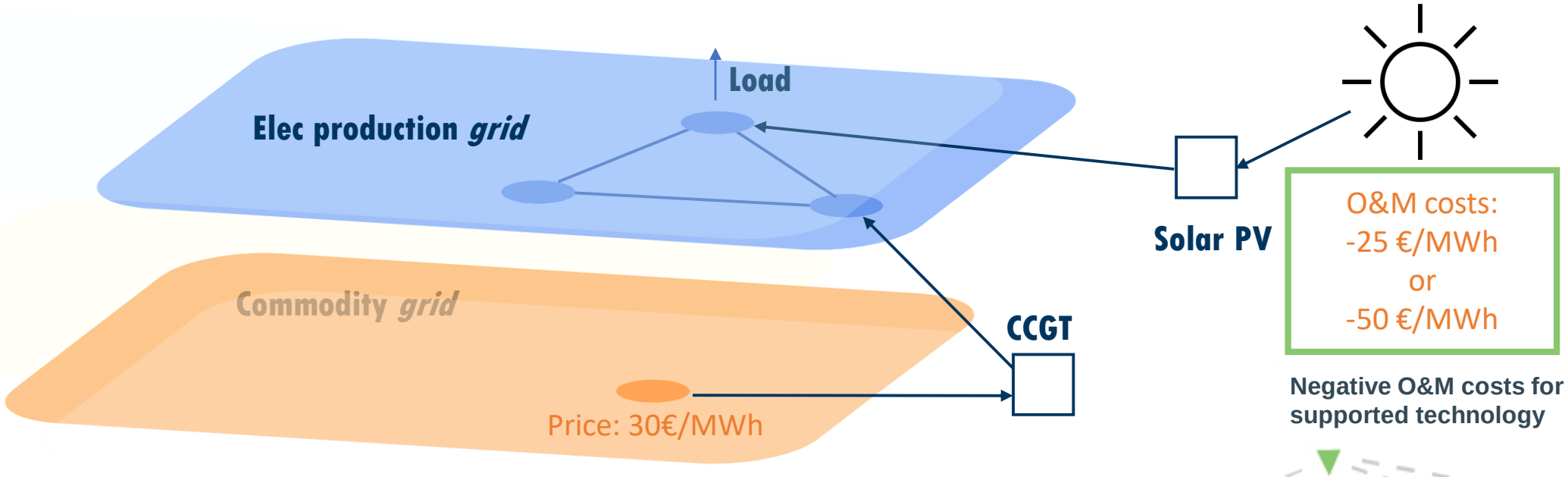
4 Example: A. Capacity premium for VRE



Invest price:
375 000 €/MW
or
250 000 €/MW

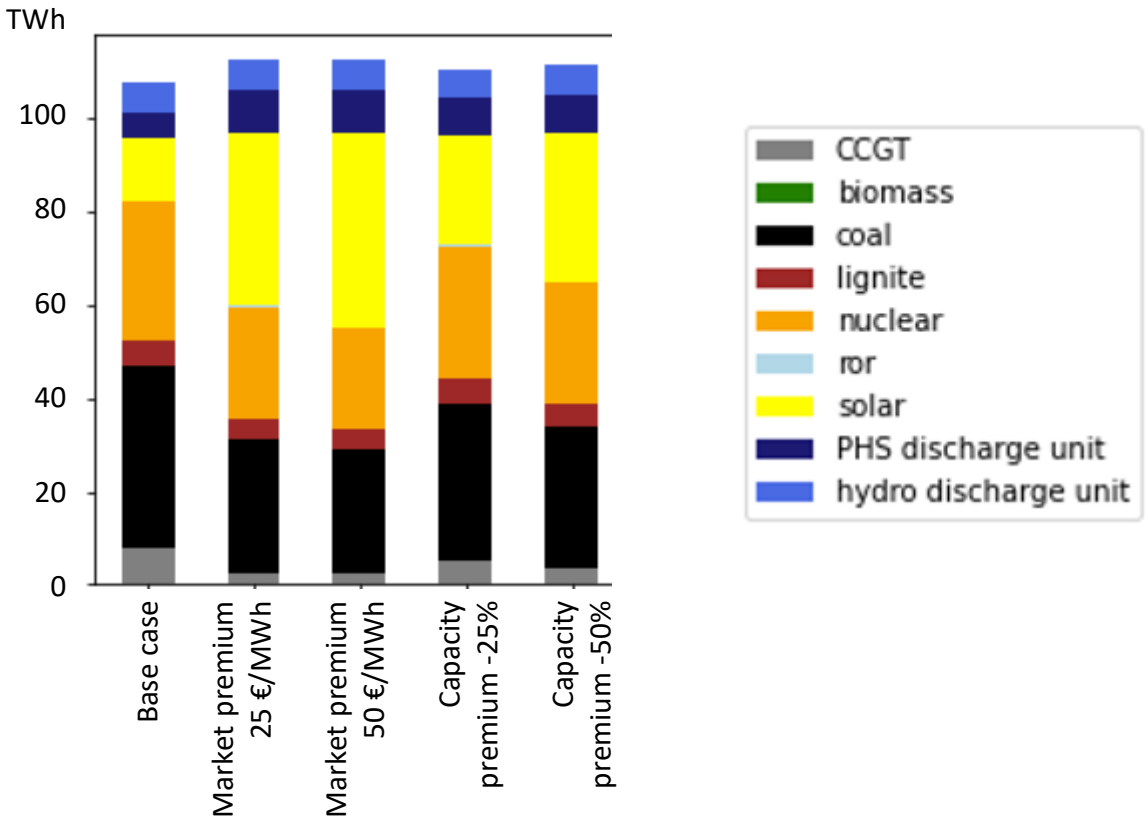
25% or 50% reduced investment costs for supported technology

5 Example: B. Market premium for VRE

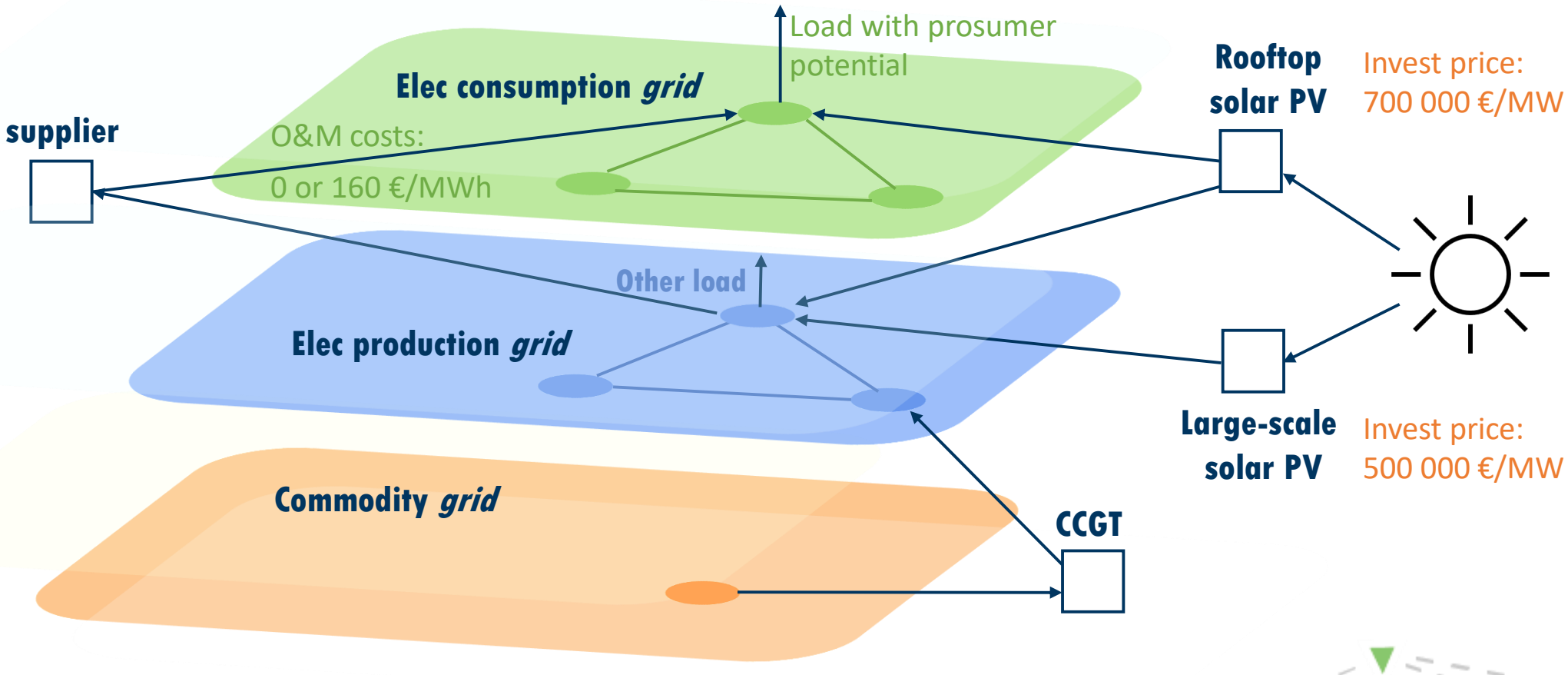


4 Example: Market design impact (A. & B.)

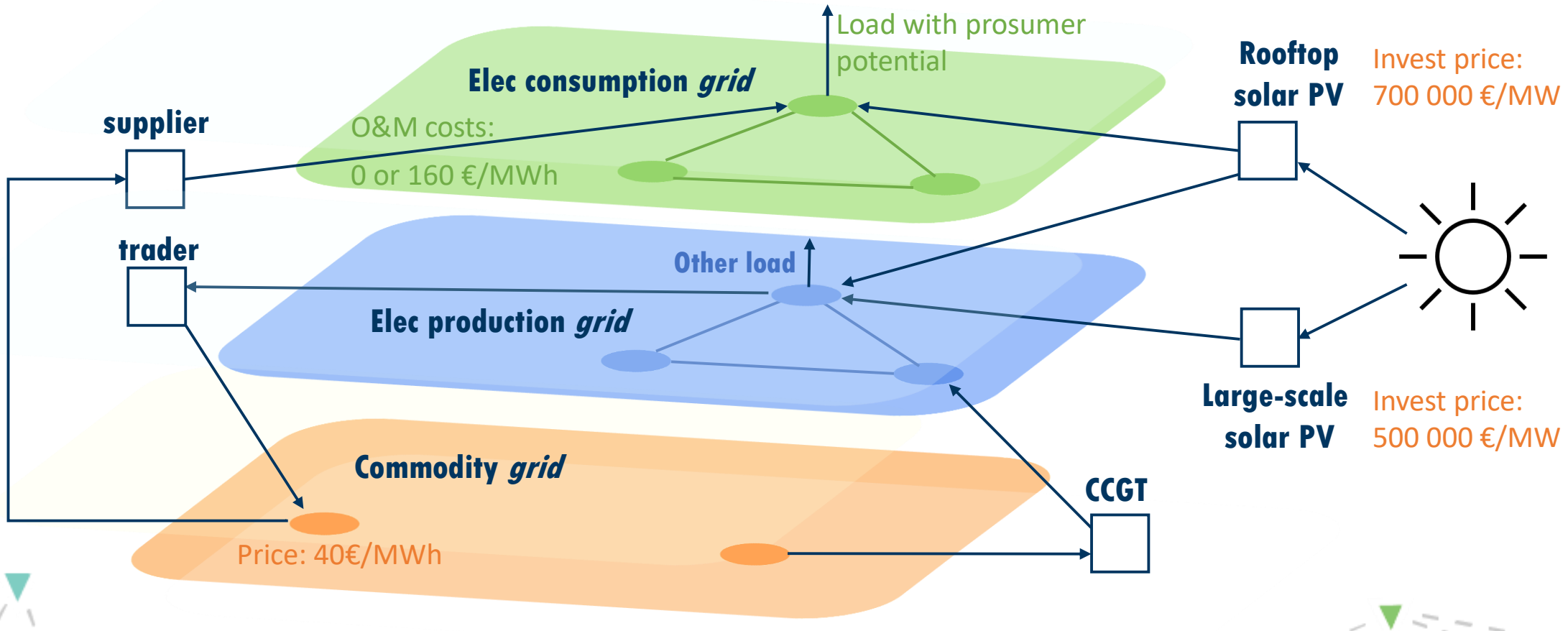
Optimized generation mix



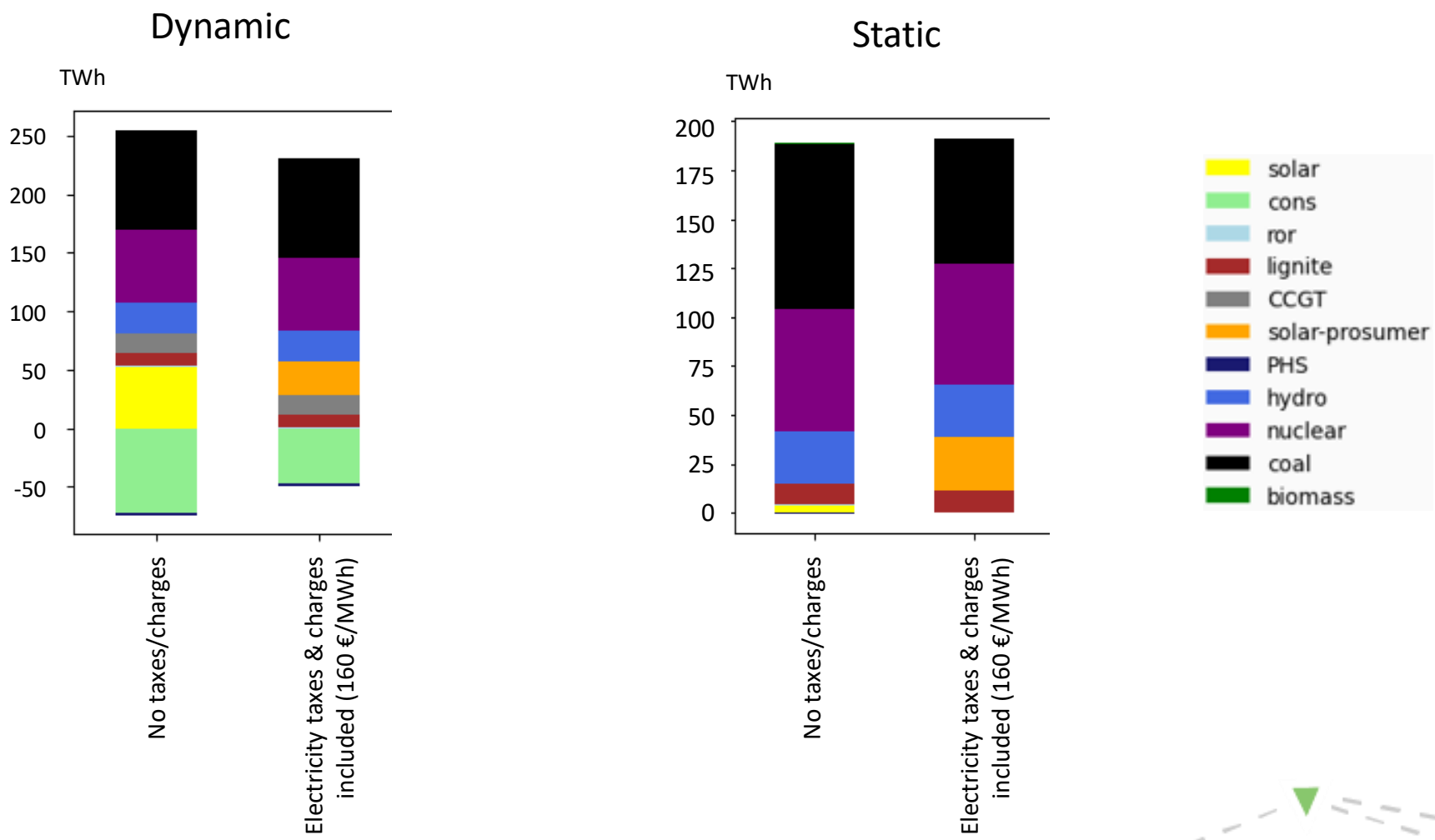
5 Example: C. Prosumers with *dynamic* consumer prices



5 Example: D. Prosumers with *static* consumer prices



5 Example: Market design impact (C. & D.)



6 Where to get started

- Install from gitlab.vtt.fi/backbone/
  - Clone Backbone to your local repository using git:
    git clone --branch release-2.x https://gitlab.vtt.fi/backbone/backbone.git
  - To get started, see Backbone Wiki (gitlab.vtt.fi/backbone/backbone/-/wikis/)
    - Download Demo1 from “Example models” - new and updated
    - Note that Wiki is still under construction
- Tutorials in Youtube (search for “Backbone energy system modelling”)
- Join biweekly calls by contacting juha.kiviluoma@vtt.fi or nelli.putkonen@vtt.fi