

PATHFINDER Project

Calliope and Euro-Calliope

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ETH zürich



HOCHSCHULE
LUZERN



UNIVERSITÉ
DE GENÈVE

EPFL

Calliope and Euro-Calliope



A tool to build
energy system models



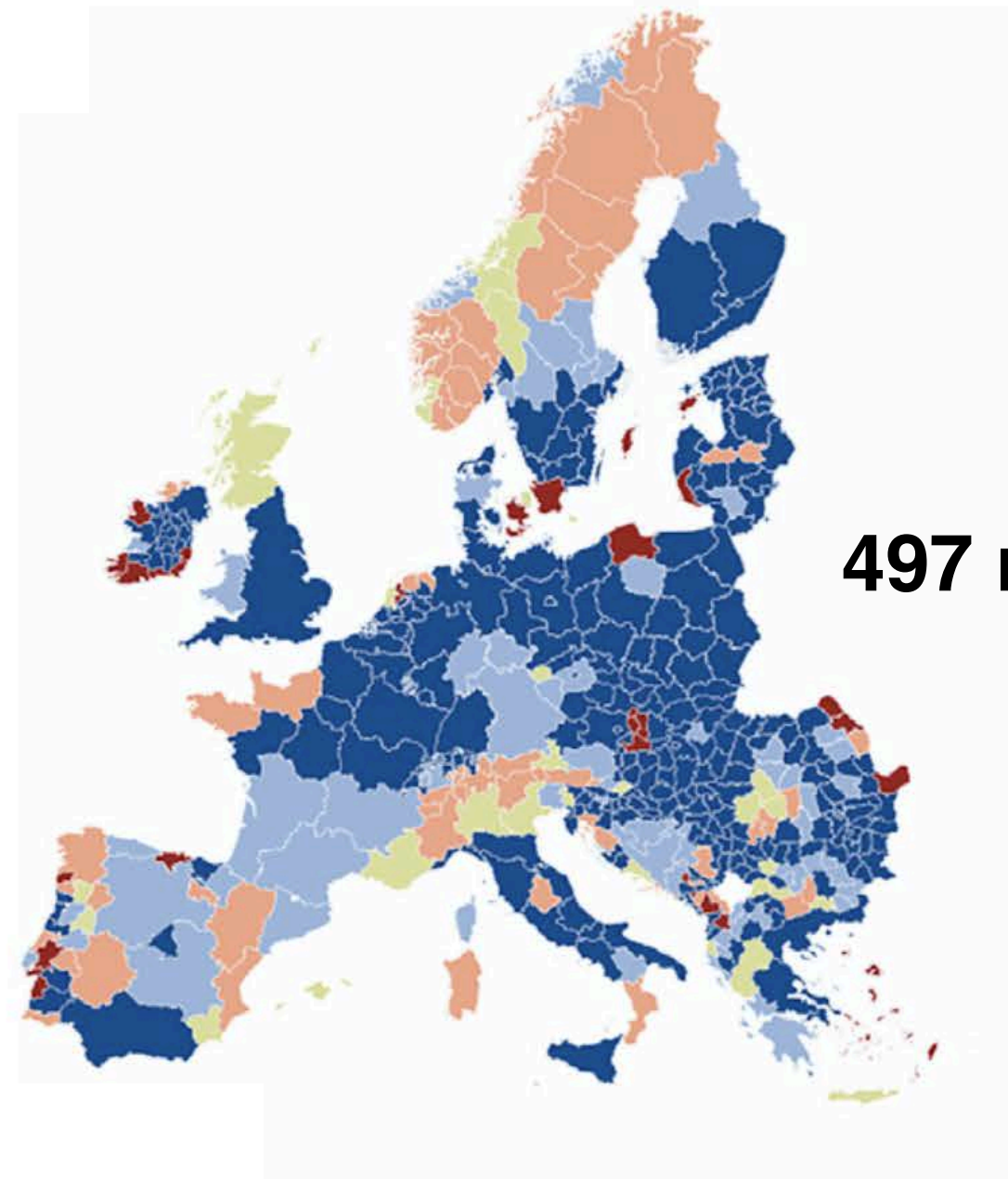
Data and workflows
to build models of the
European energy system
using Calliope

An example application: Continental or regional scale supply?

Continental supply:
Wind and PV at
best locations



Generation relative to demand



497 regions

Regional supply:
Regions self-supply
*on average over
the year*

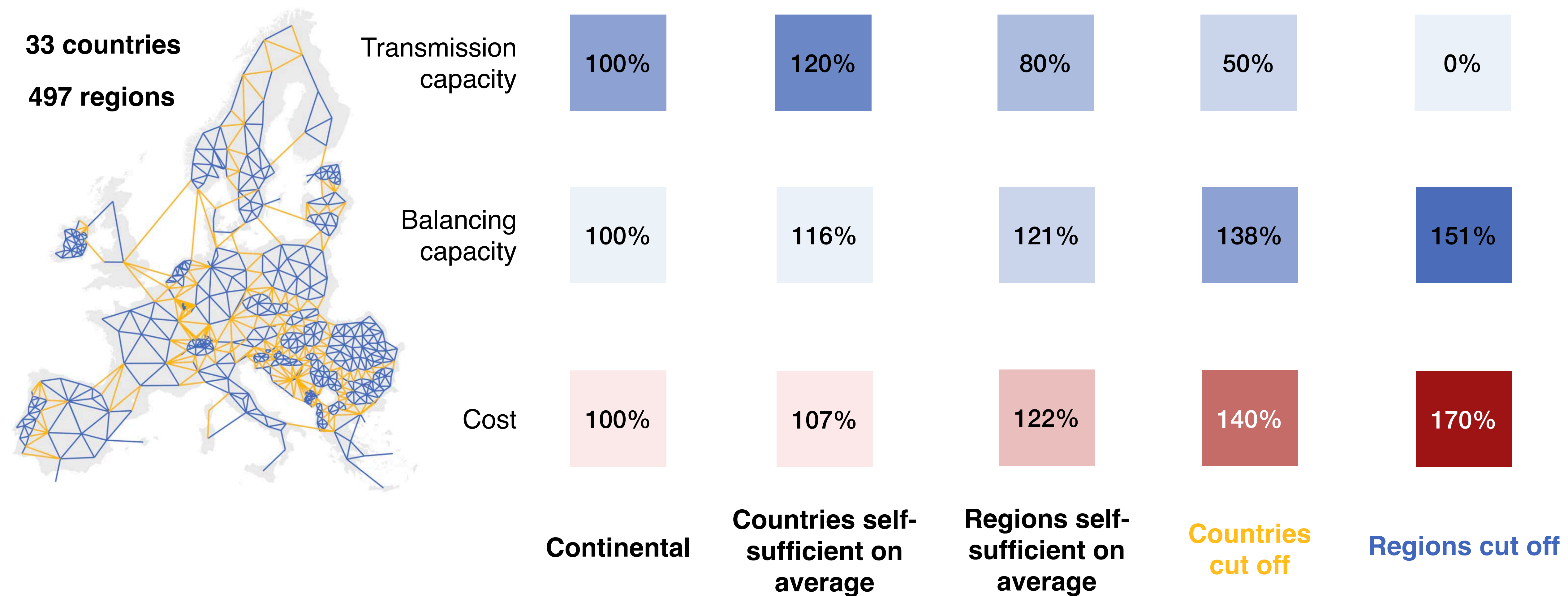


**Continental supply
requires
2.5x the capacity of
today's electricity
transmission system**



What if I don't want to
build so many new
transmission lines?

Less integrated systems are possible, but cost more

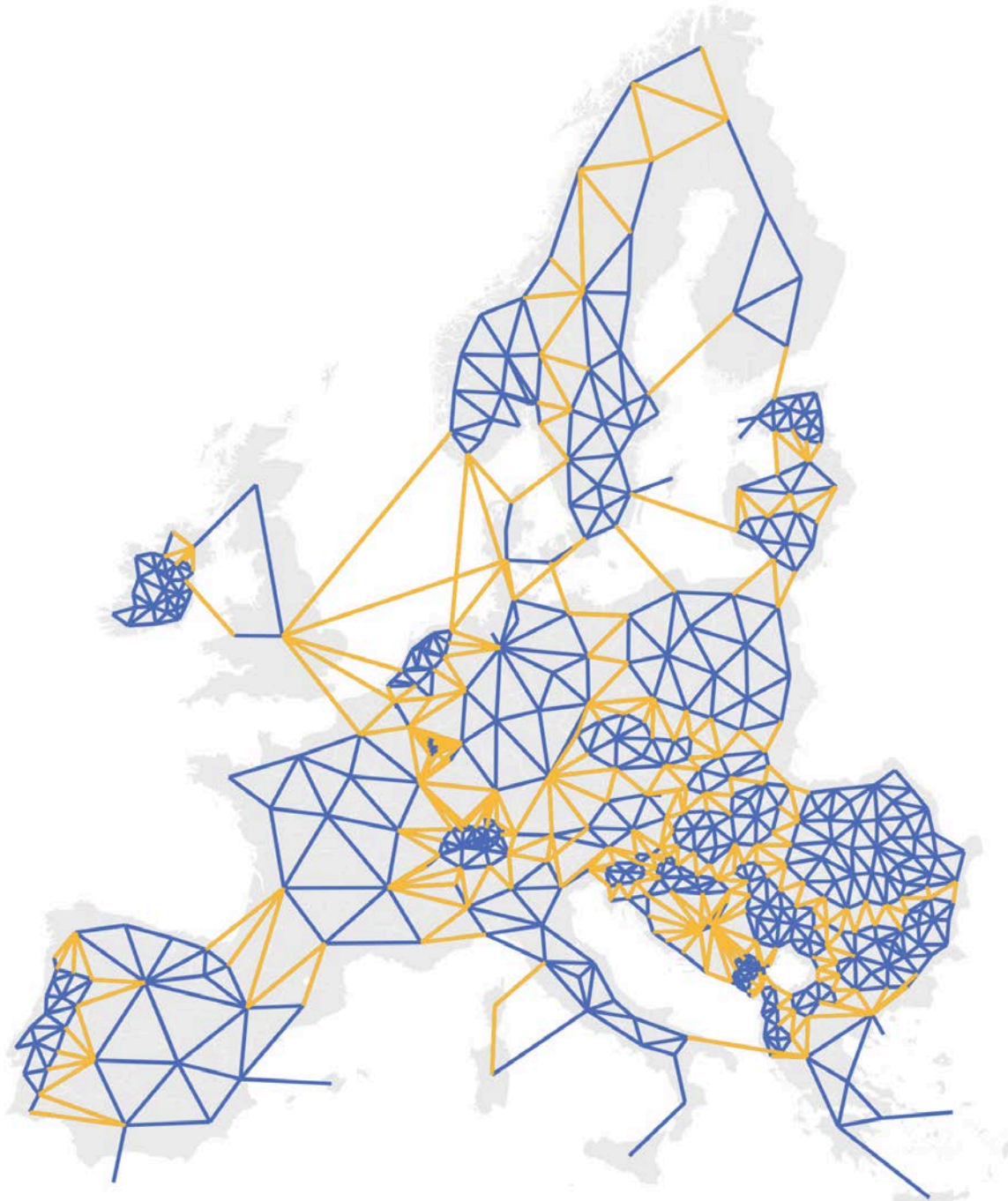




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Model used

Spatial resolution



497 first-level administrative units

Technologies

- PV
- Wind
- Biofuel
- Hydro
- Short and long-term storage

Temporal resolution

4 hours, single year,
2007–2016

Sensitivity analysis

- 10 weather years
- Uncertainty in technology costs, capital cost, bioenergy availability (by sampling a surrogate model)

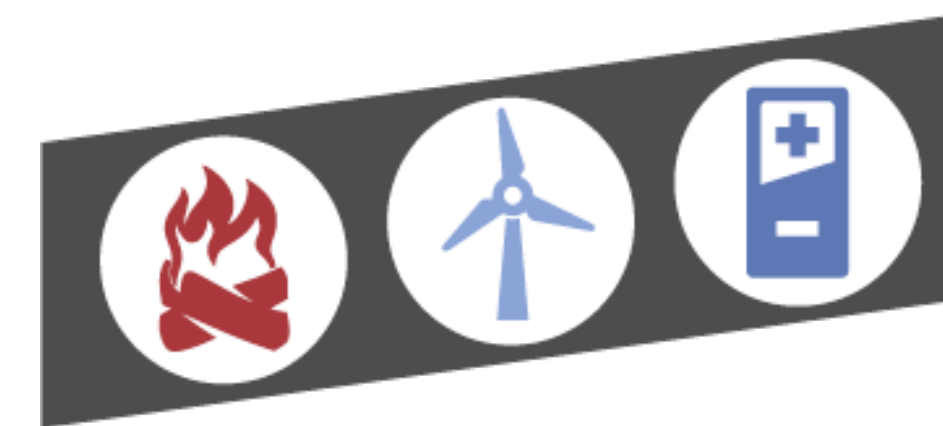
Open-source and reproducible

Calliope code: www.callio.pe

Model/data: github.com/calliope-project/euro-calliope

Purpose of Calliope

- A tool to build energy system optimisation models at any scale (urban to continental)
- Allow high resolution in time and space in order to adequately model renewables
- Human-readable models in the form of text files; Calliope translates these into a mathematical model and solves it
- Range of built-in functionality like time series aggregation, modelling to generate alternatives (MGA) algorithms, ...
- 100% free and open-source



Calliope

www.callio.pe

Process: inputs and outputs for a typical Calliope model

Model Inputs

- Model regions/locations and possible transport/transmission connections between them
- Demand, wind, PV, hydro generation time series
- Technologies including their performance parameters and costs
- Technology capacity constraints
- Policy constraints like emissions caps or renewable targets

Model Outputs

- Technology capacities
- Investment and variable costs
- Emissions
- Technology operation decisions
- Energy transport and transmission decisions
- Storage levels
- Consumed resources

Derived Outputs

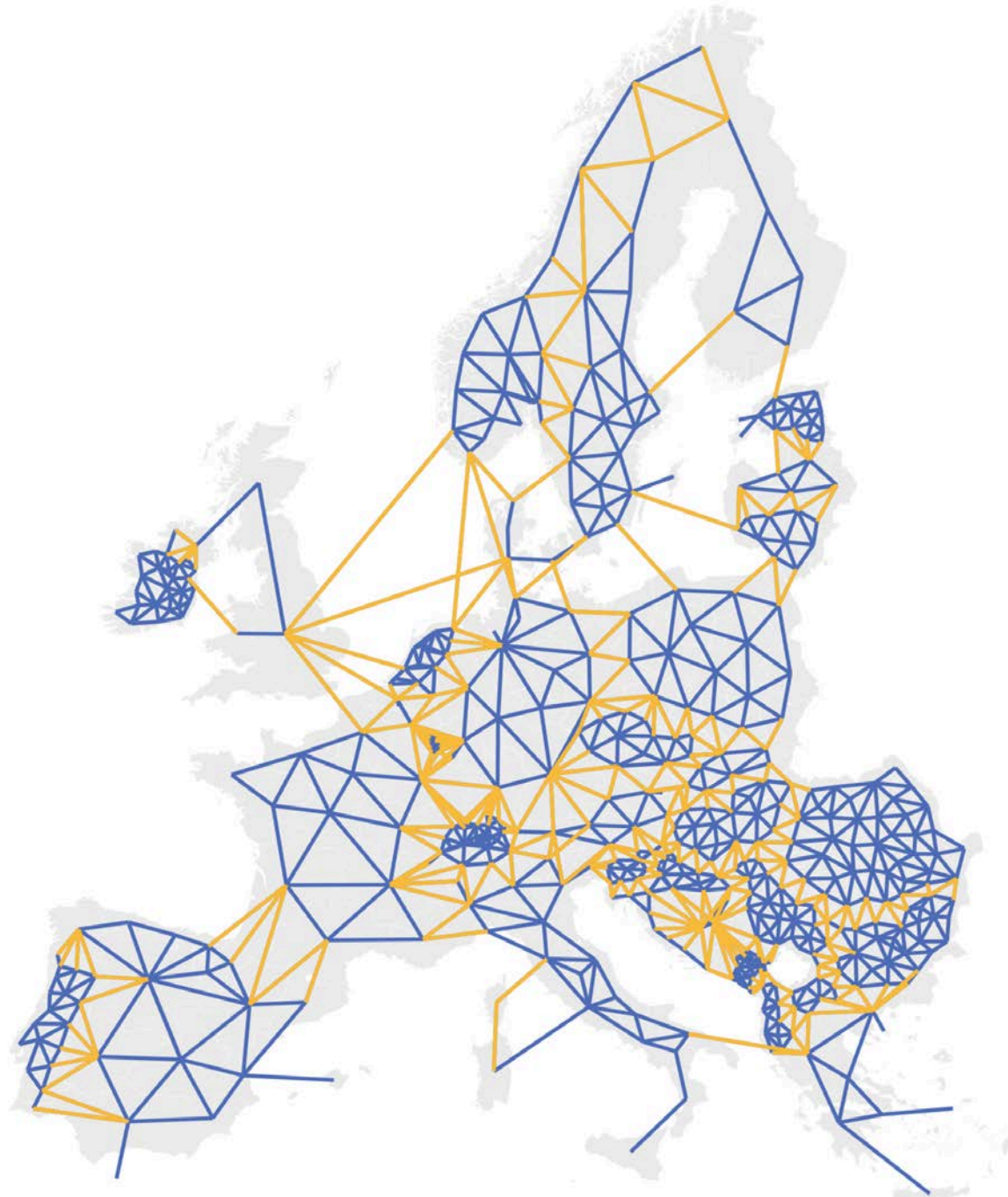
- Capacity factors
- Levelised costs



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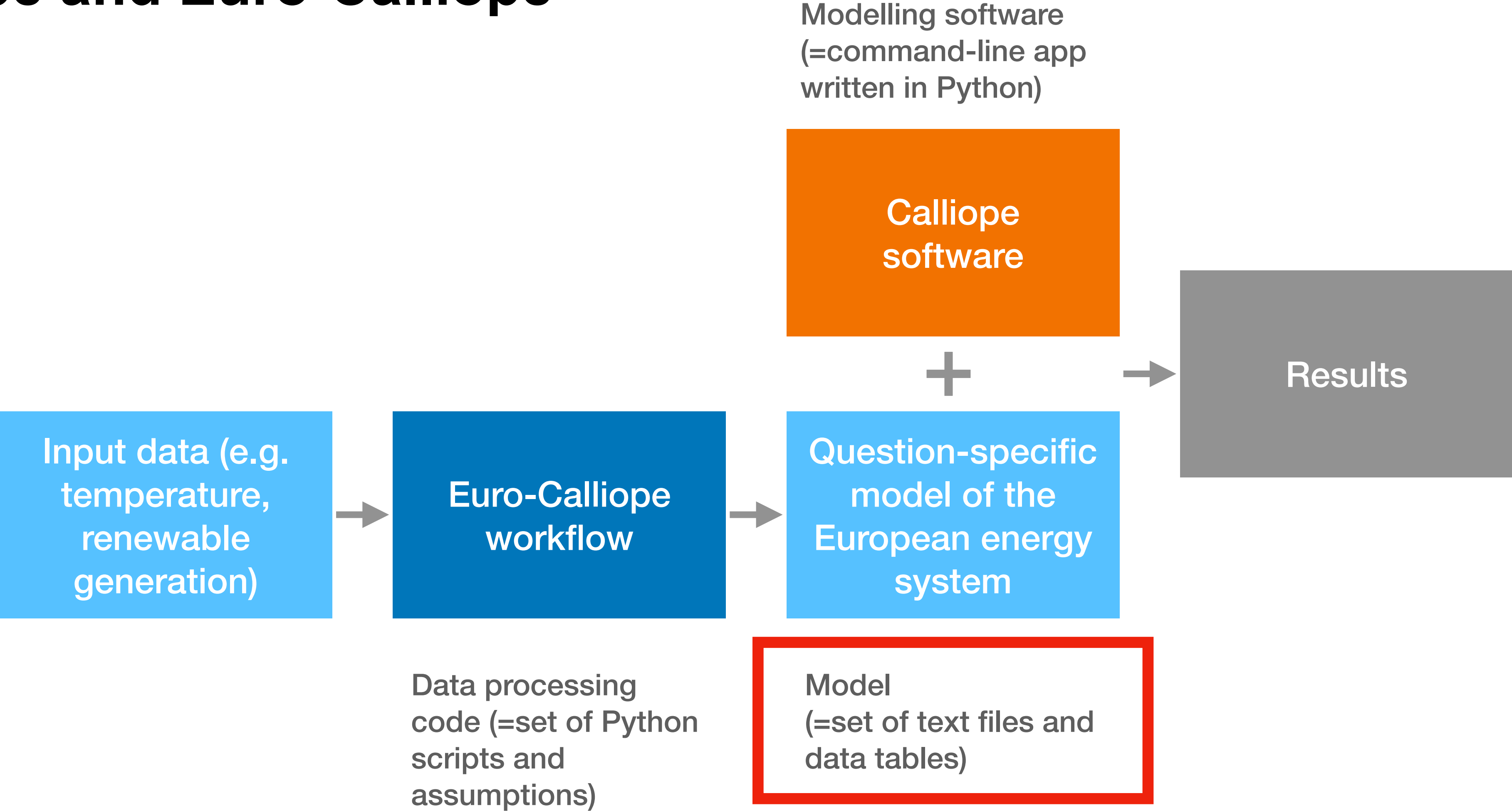
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Calliope and Euro-Calliope



User interface of Calliope

```
ccgt:
  essentials:
    name: 'Combined Cycle Gas Power Plant'
    color: '#FDC97D'
    parent: 'supply'
    carrier_out: 'electricity'
  constraints:
    resource: inf
    energy_cap_max: 40000 # kW
    energy_ramping: 0.8
  costs:
    monetary:
      energy_cap: 750 # USD per kW
      om_con: 0.02 # USD per kWh
```

Our interface: text files



engage

Help

LOGIN

Example Model: National S...

VIEW ONLY

NREL

Locations

Technologies

Nodes

Scenarios

Runs

AC Power Transmission

Capacity Expansion

Technology Locations:

Region 1 Region 2

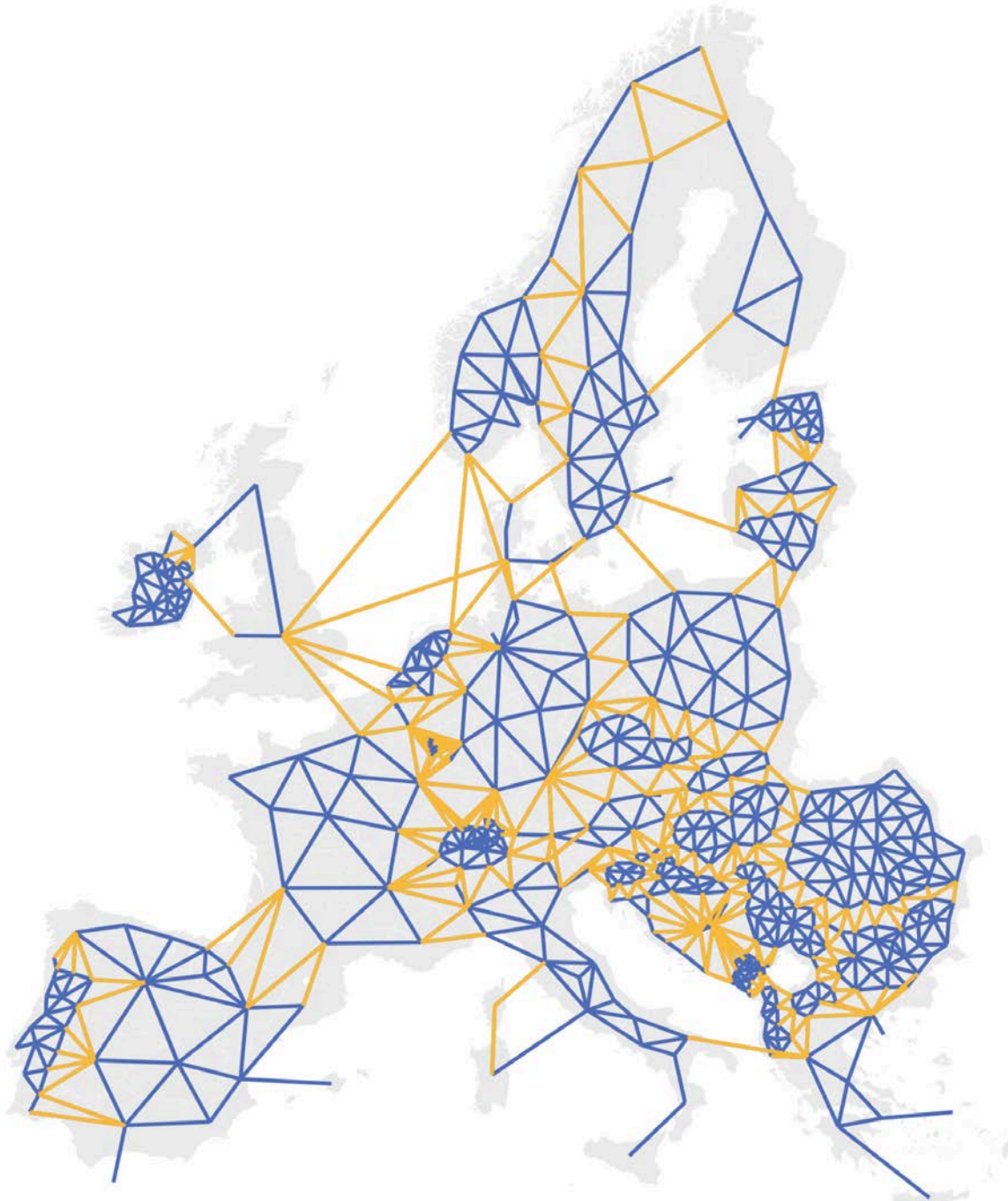
New Locations: Region 1 Region 2 Add Node

Constraints: Technology	Maximum installed energy capacity	10,000	10,000	kW		Row
Constraints: Technology	Energy efficiency	85.0	85.0	%	Default	Row
Constraints: Technology	Technology lifetime	25	25	years	Default	Row
Costs: Monetary	Carrier production cost	0.002	0.002	\$/kWh	Default	Row
Costs: Monetary	Cost of energy capacity	200	200	\$/kW	Default	Row
Costs: Monetary	Interest rate	10.0	10.0	%	Default	Row

NREL built an open-source web UI:
<https://engage.nrel.gov/>

Euro-Calliope version 1: electricity only

Spatial resolution



497 first-level administrative units

Technologies

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We want to go beyond just electricity!

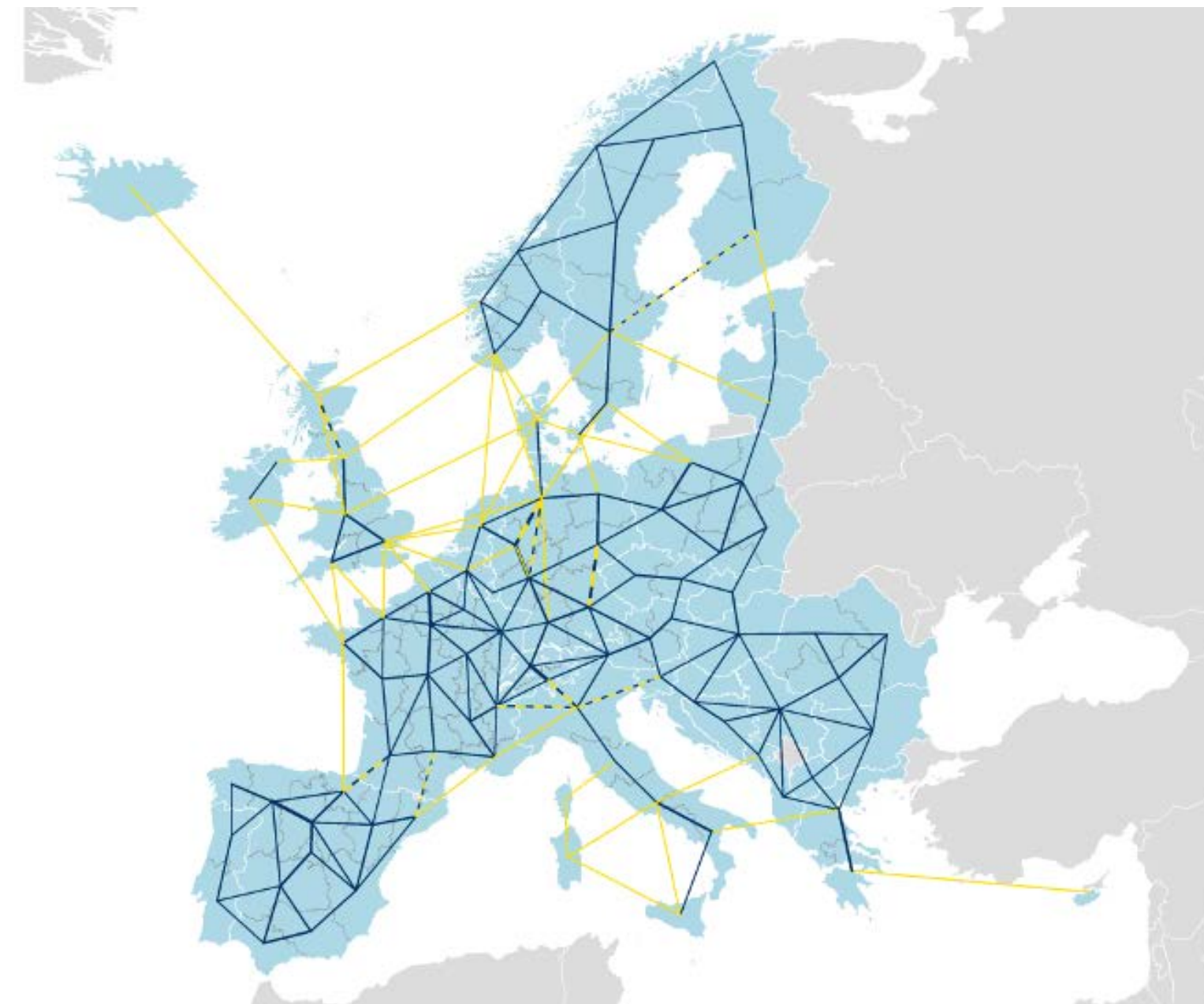
Temporal resolution

4 hours, single year,
2007–2016

Euro-Calliope v2.0 workflow

Research focus: trade-offs in building
100% renewable all-sector European energy system

- Electricity
- Household and commercial heat
- Passenger and freight transport
- Industry process heat and feedstocks (e.g. for chemicals)



Bryn Pickering



Tim Tröndle

Possible spatial configurations:

- 98 nodes based on transmission system
- All European countries
- Single country

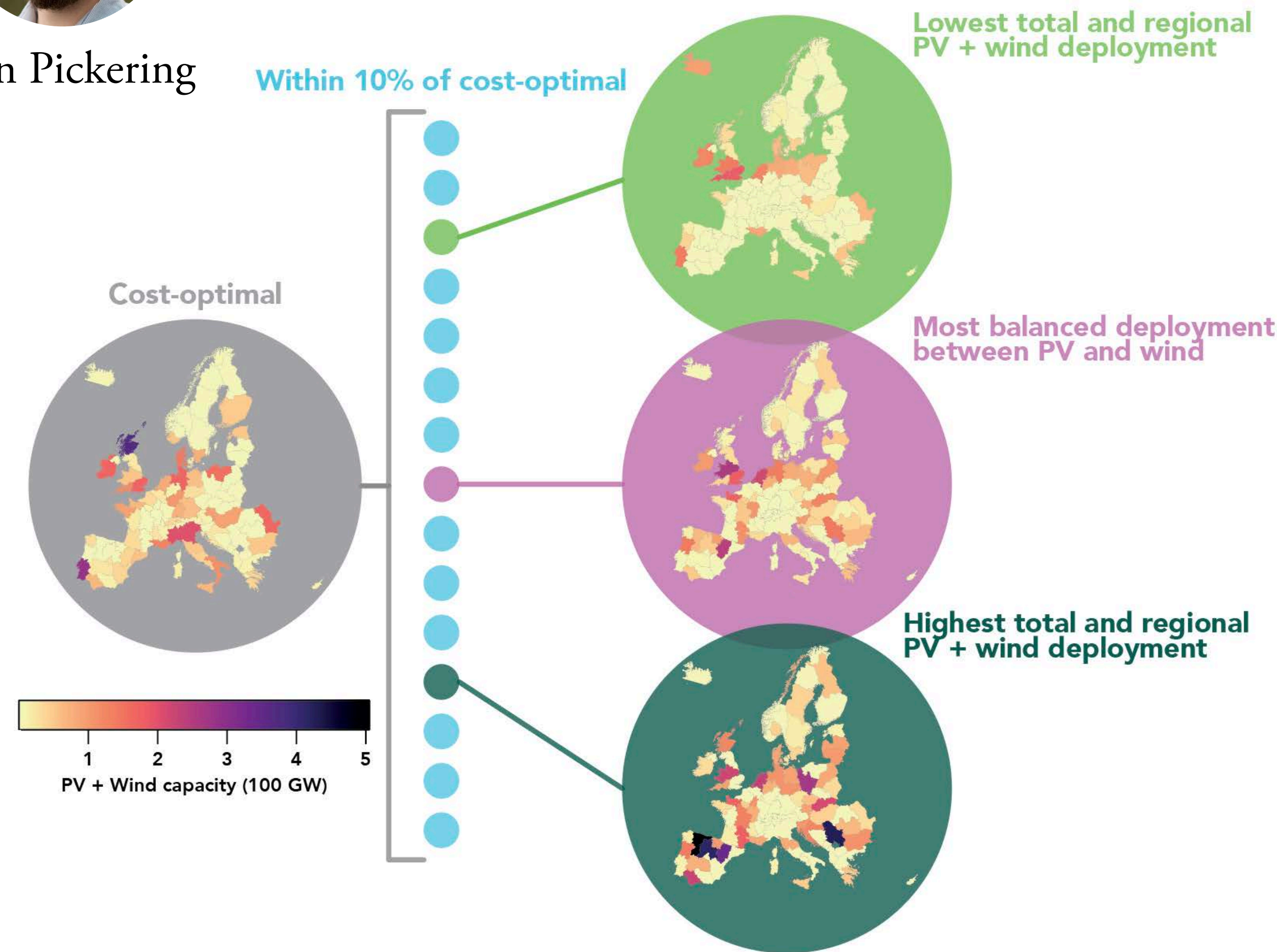
Temporal resolution: 1 hour

Current models built with the Euro-Calliope 2.0 workflow



Bryn Pickering

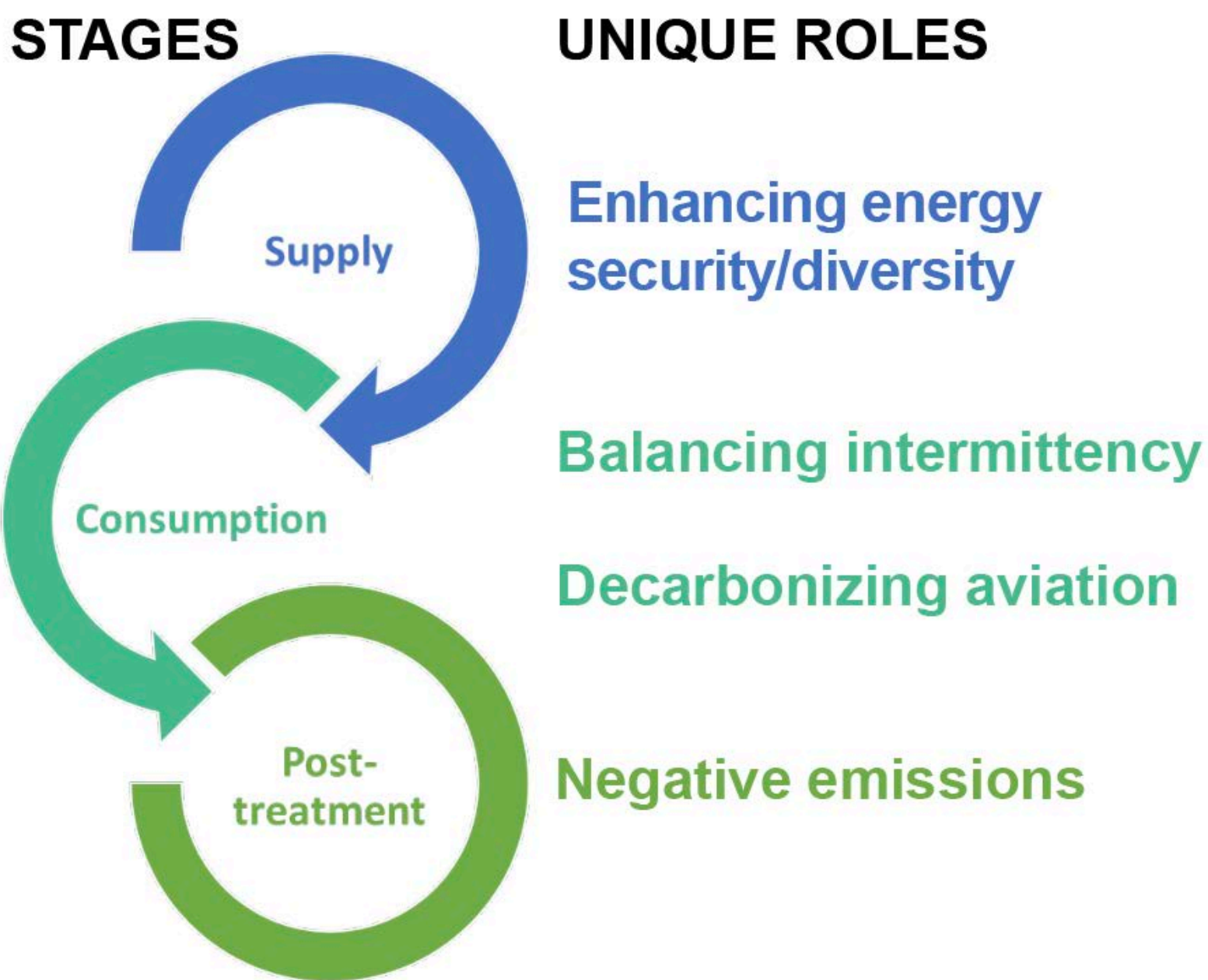
Euro-SPORES



Fei Wu

ABBIE

Role of bioenergy



Based on Lombardi et al. (2020). *Joule*. <https://doi.org/gg8z6v>

PATHFINDER

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie (MSC) grant agreement No. 847585.

Euro-Calliope and Calliope

Euro-Calliope v2.0

Euro-Calliope v1.0

Full energy system
(will be used
in PATHFNR)

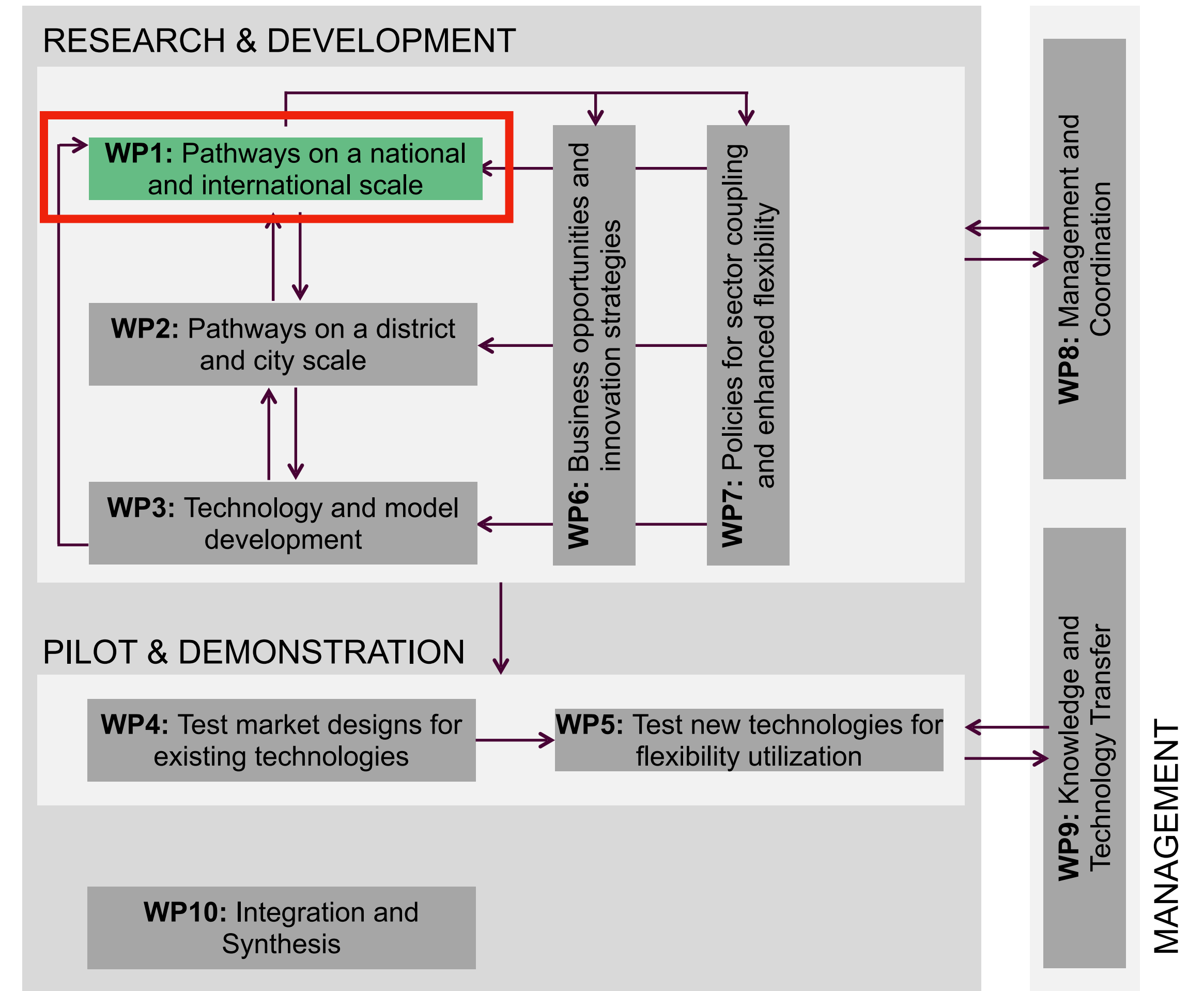
Electricity sector only



A tool to build
energy system models

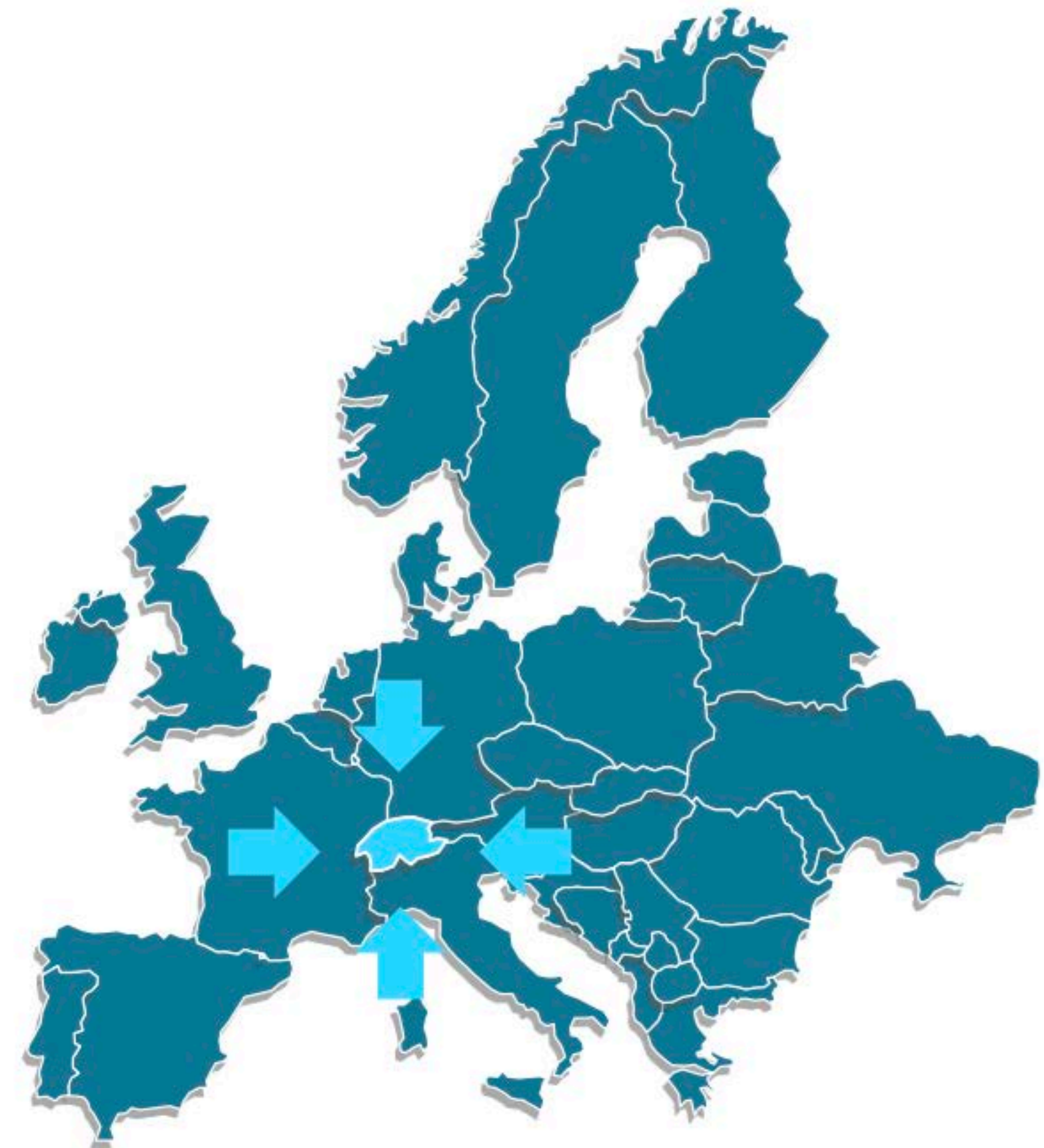
Future development under the PATHFNDR project

- A model to assess pathways for Switzerland within the context of decisions taken Europe-wide



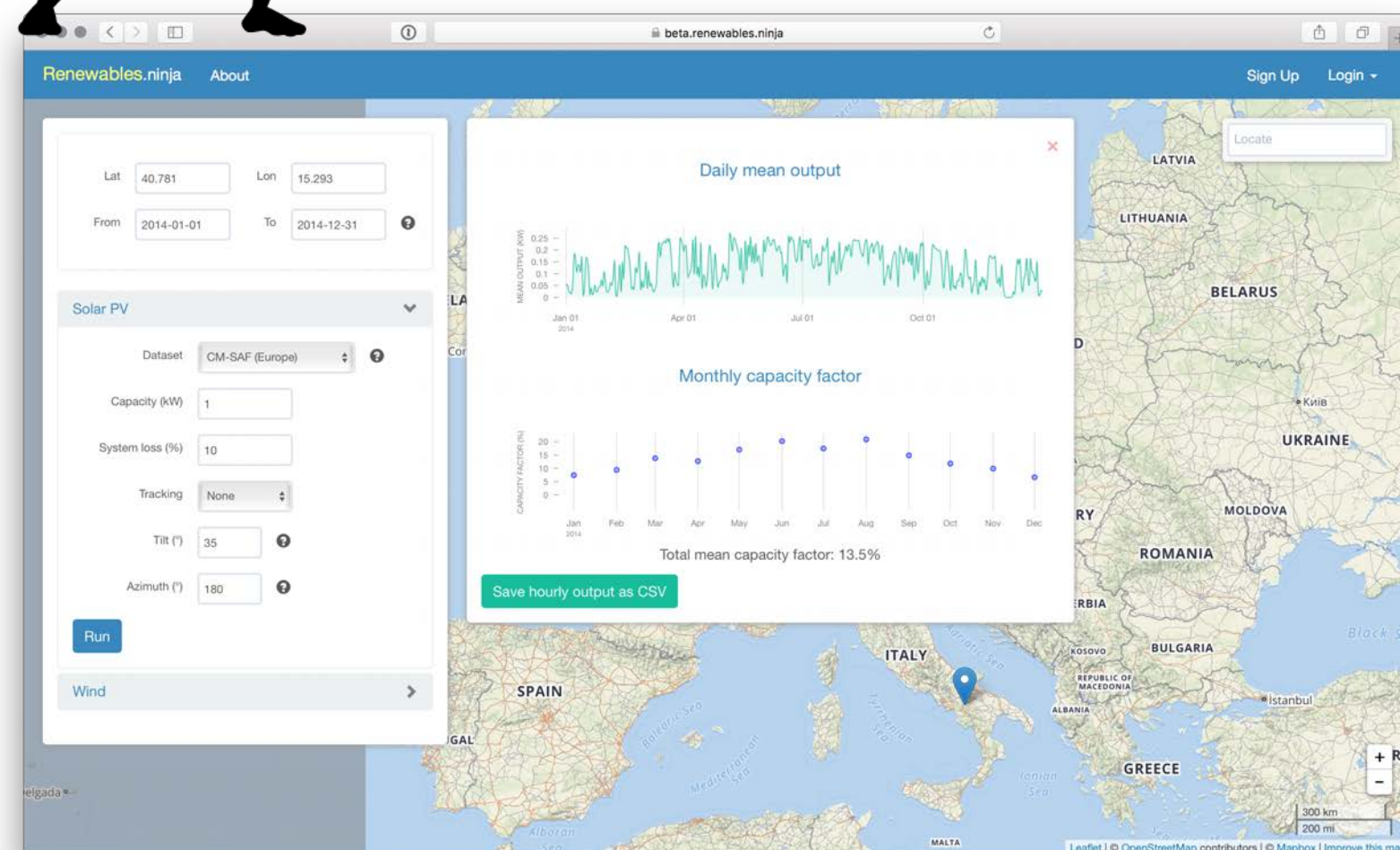
Linkage to other tools of the PATHFINDER project

- Provide boundary conditions for the detailed modelling of the Swiss energy system with nexus-e
- Explore integration of operational constraints from the more detailed models, e.g. Ehub and ReMaP



Validation / calibration

- Input data is validated or checked, e.g. renewable generation data, cost data, ...




Validated renewable generation data

- Calliope has extensive automated tests to ensure that the code does what we think it does



Pull request by  brynpickering

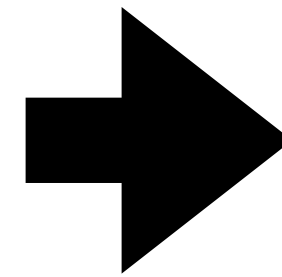
[View 5 changes](#)

Repository and version	 calliope-project/calliope 353 c41d8ff
Time started and elapsed	13 Apr at 14:11 23m 14s
Related	0 work items 1 published
Tests and coverage	95.2% passed 80.91% covered

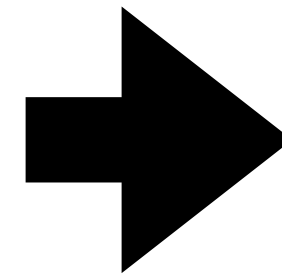
https://dev.azure.com/calliope-project/calliope/_build/results?buildId=242&view=results

Limitations - there are many!

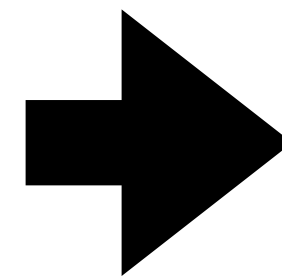
- It is a (usually cost-minimising) linear/mixed-integer optimisation model, fed with a range of assumptions which may or may not be “correct”.
- It requires some technical flair to operate both Calliope and Euro-Calliope.
- It requires a high-performance computing cluster for its full capabilities.



- User must be aware of what it can and cannot do.



- Third-party graphical user interface (NREL) and we are working on accessibility for both Calliope and Euro-Calliope.



- We are working on model formulation and algorithm improvements to reduce computational needs.

Users



Current users:

- A range of academic and industrial users
- e.g. Imperial College London, University of Cambridge, University of Reading, University of Strathclyde, FZ Jülich, Politecnico di Milano, NREL, PBL, IASS Potsdam, ITA Brazil, University of Lisboa, ...
- Major energy companies and engineering consulting firms



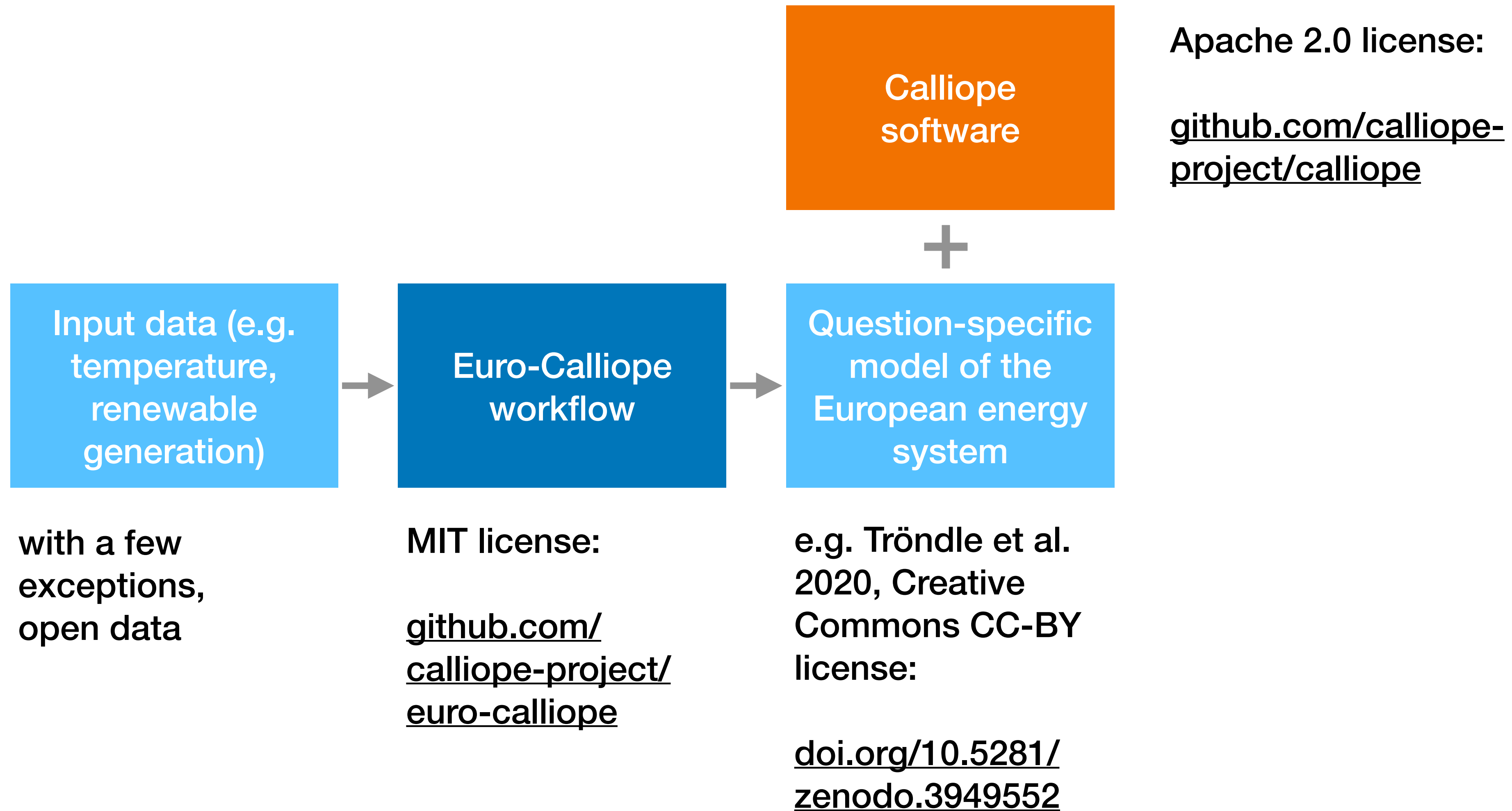
Current users:

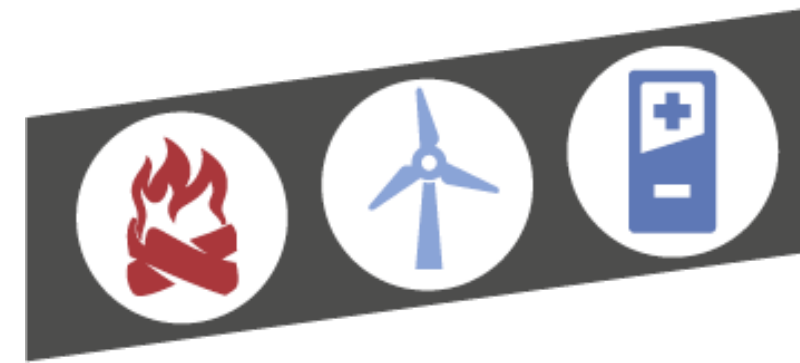
- ETH Zürich and TU Delft (as far as we know)

Potential users:

- Quite a few

Licenses: everything is free and open-source





Calliope
www.callio.pe

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TU Delft

PATHFNR: <https://sweet-pathfndr.ch/>

Calliope: <https://www.callio.pe/>

Euro-Calliope: <https://github.com/calliope-project/euro-calliope>

ETH zürich



Empa



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