PATHFNDR Project

Calliope and Euro-Calliope

Stefan Pfenninger (TU Delft)

ETH zürich Empa PAUL SCHERRER INSTITUT PSI zhaw HOCHSCHULE LUZERN UNIVERSITÉ DE GENÈVE EPFL

Calliope and Euro-Calliope

Calliope

www.callio.pe

A tool to build
energy system models

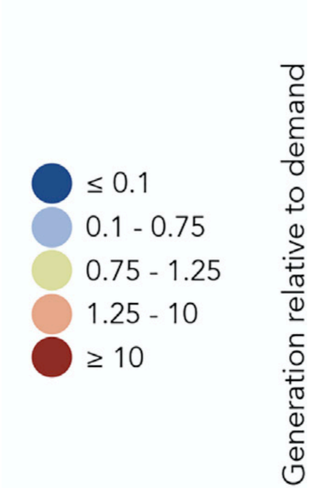
Euro-
Calliope

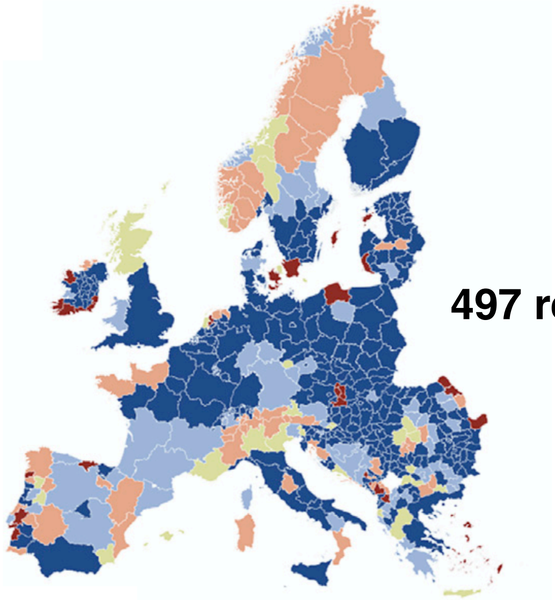
github.com/calliope-project/euro-calliope

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

An example application: Continental or regional scale supply?

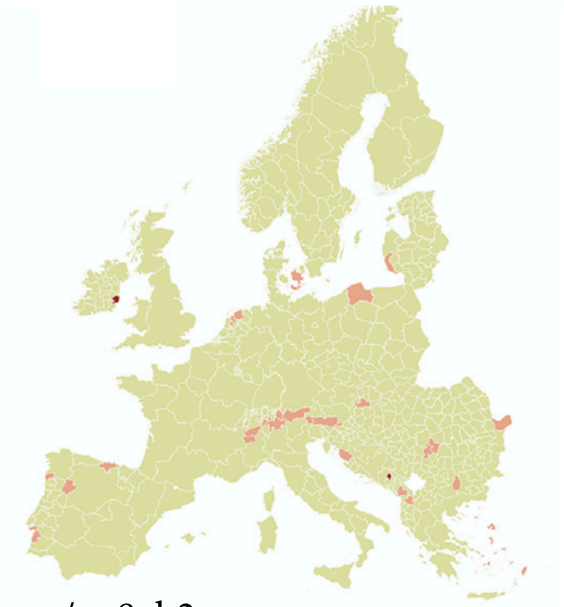
Continental supply: Wind and PV at best locations





497 regions

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

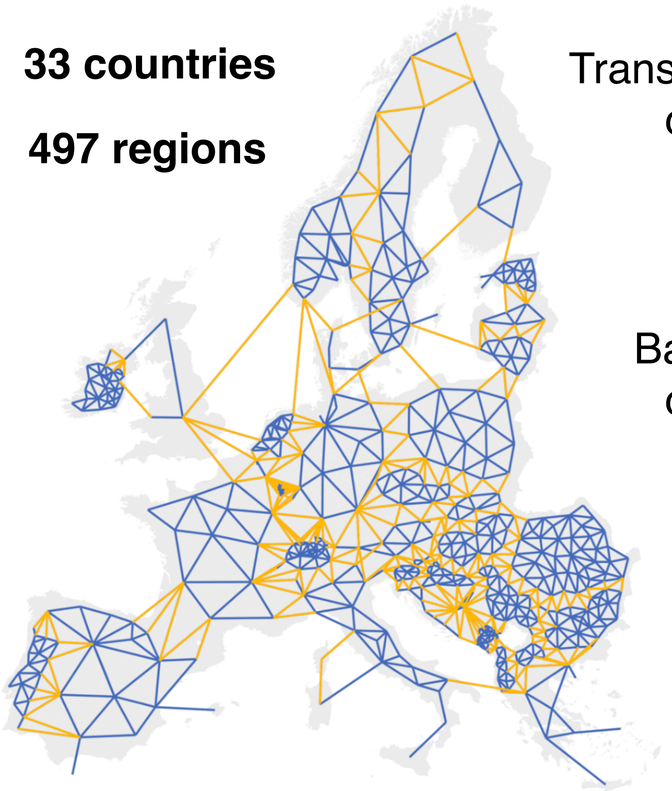


Continental supply requires 2.5x the capacity of today's electricity transmission system

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

Tröndle et al. (2020). *Joule*. https://doi.org/gg8zk2

Less integrated systems are possible, but cost more



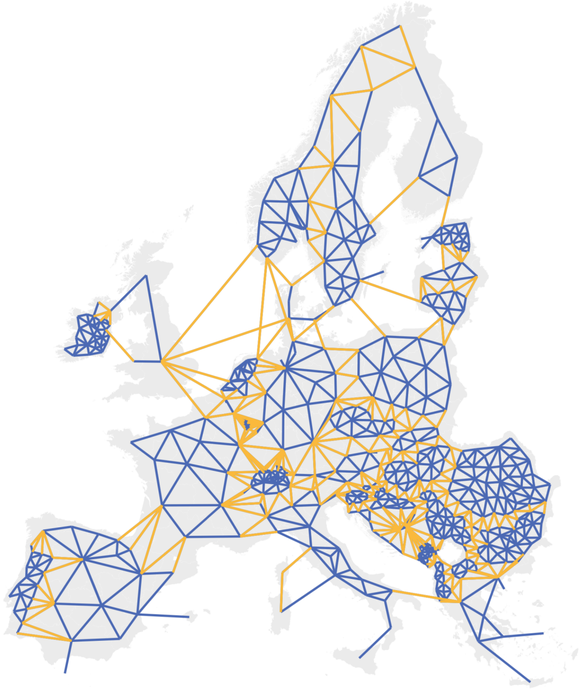
	Continental	Countries self-sufficient on average	Regions self-sufficient on average	Countries cut off	Regions cut off
Transmission capacity	100%	120%	80%	50%	0%
Balancing capacity	100%	116%	121%	138%	151%
Cost	100%	107%	122%	140%	170%

Tröndle et al. (2020). *Joule*. https://doi.org/gg8zk2

Tim Tröndle

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)

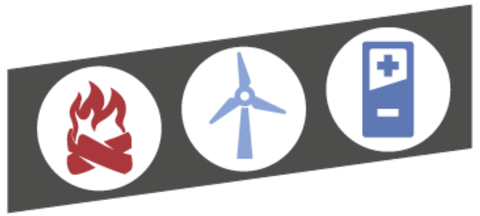
Open-source and reproducible

Calliope code: www.callio.pe
Model/data: github.com/calliope-project/euro-calliope

Tröndle et al. (2020). *Joule*. https://doi.org/gg8zk2

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

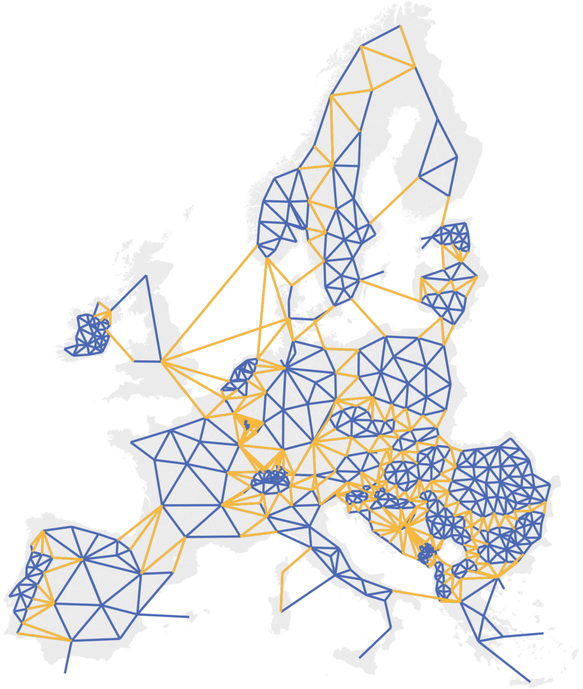
Derived Outputs

- Capacity factors
- Levelised costs

Tim Tröndle

Model used

Spatial resolution



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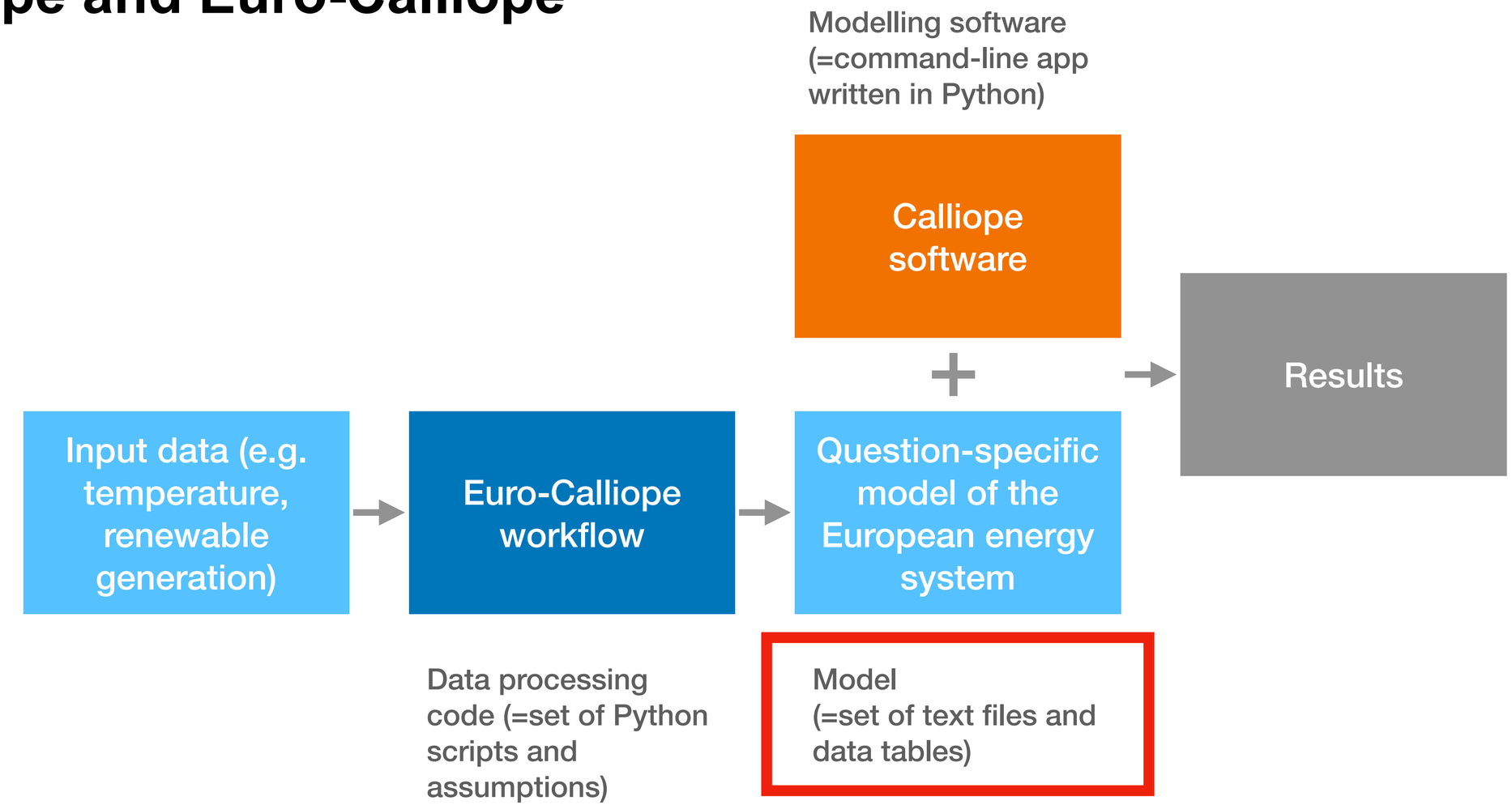
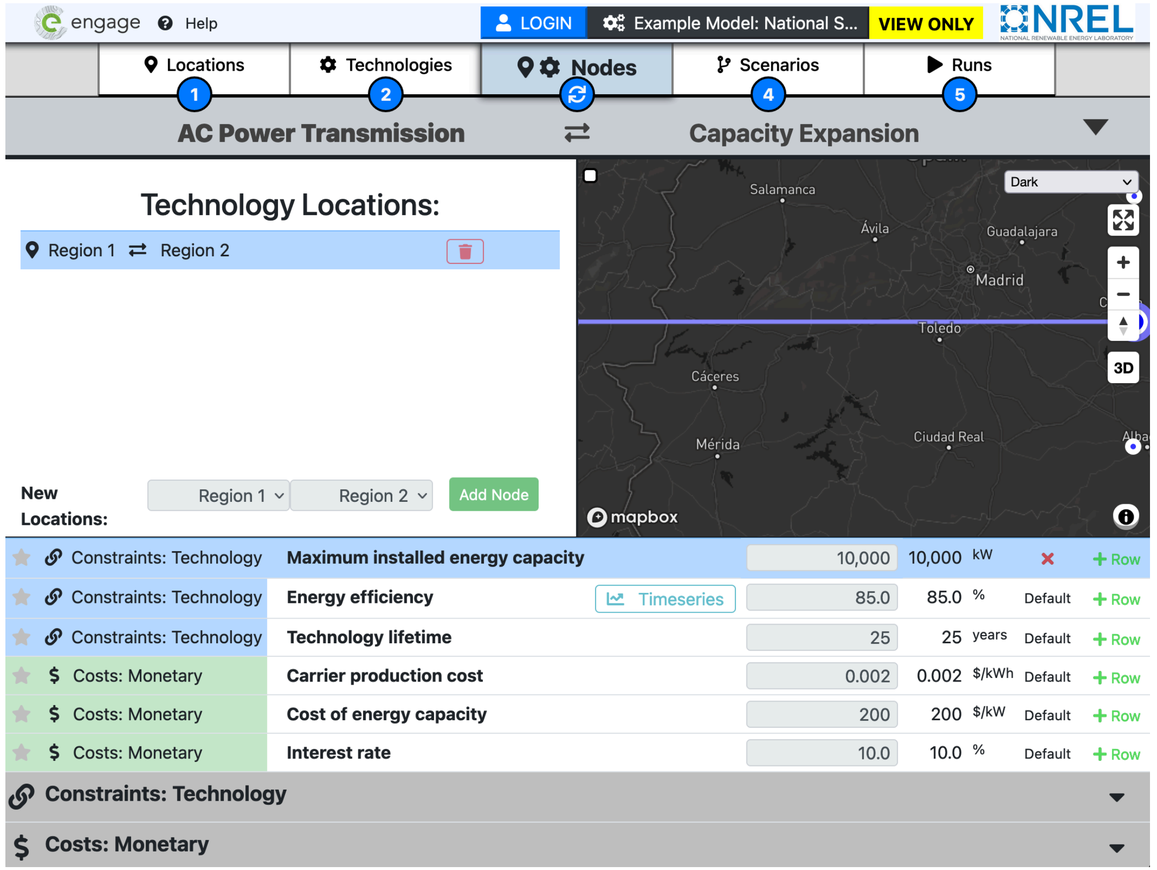
Calliope and Euro-Calliope



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
```

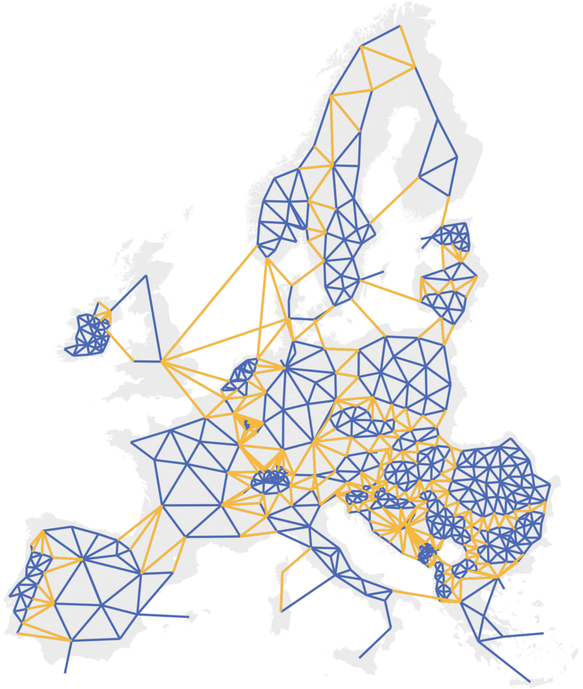


Our interface: text files

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

Euro-Calliope version 1: electricity only

Spatial resolution



497 first-level administrative units

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Temporal resolution

4 hours, single year, 2007–2016

We want to go beyond just electricity!

Tröndle et al. (2020). *Joule*. https://doi.org/gg8zk2

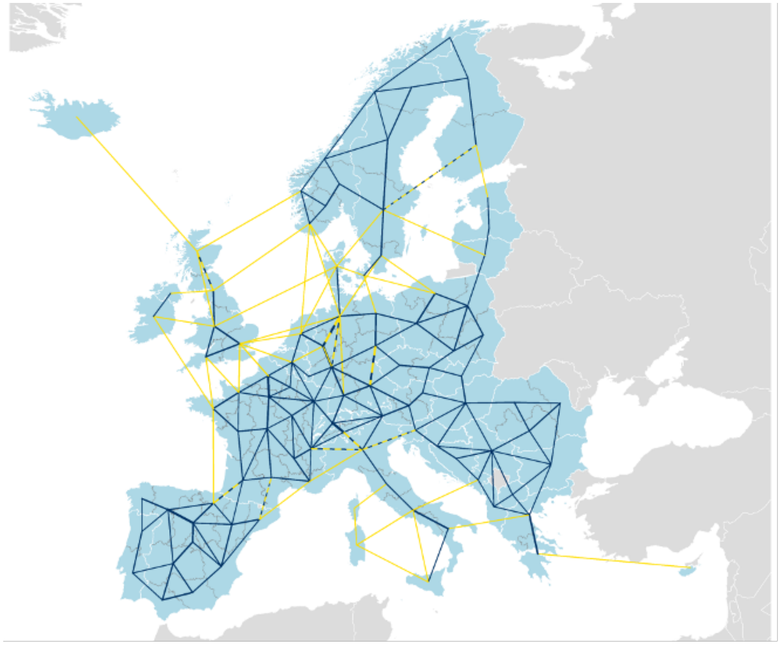
Euro-Calliope v2.0 workflow

Bryn Pickering

Tim Tröndle

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)



Possible spatial configurations:

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

Temporal resolution: 1 hour

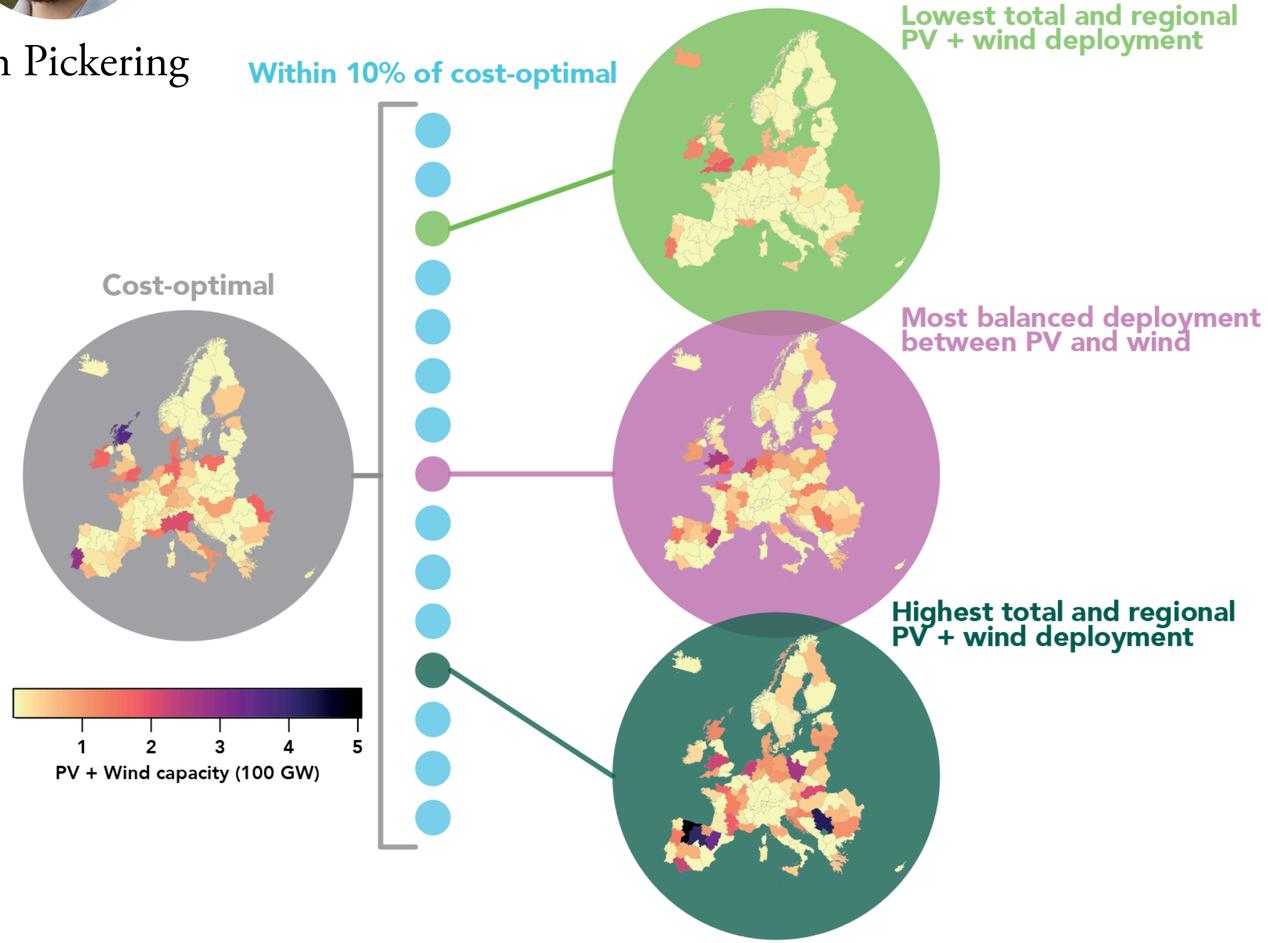
PATHFNDR

The SENTINEL project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 837089.

Current models built with the Euro-Calliope 2.0 workflow

Bryn Pickering

Euro-SPORES



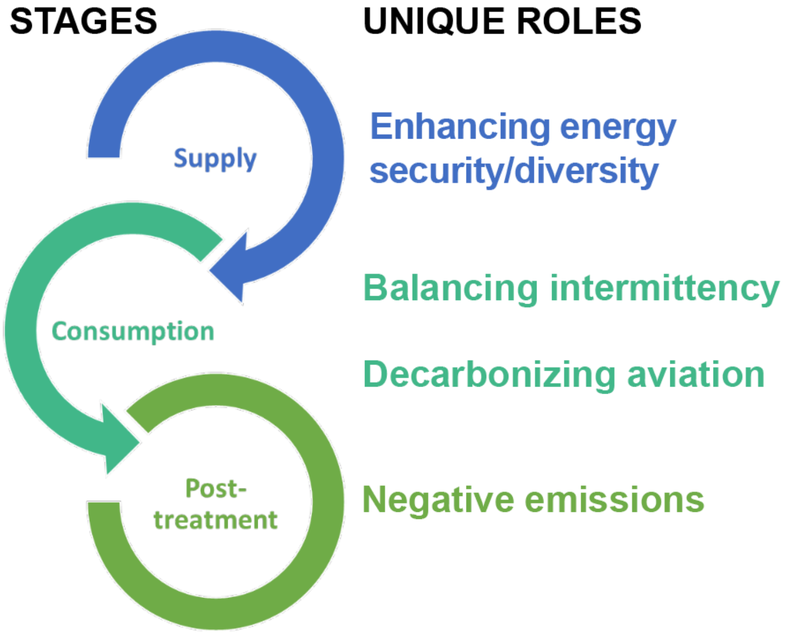
Based on Lombardi et al. (2020). *Joule*. https://doi.org/gg8z6v

PATHFNDR

ABBIE

Fei Wu

Role of bioenergy



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

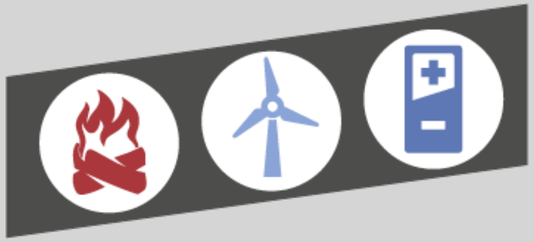
Euro-Calliope and Calliope

Euro-Calliope v2.0

Euro-Calliope v1.0

Full energy system
(will be used
in PATHFNDR)

Electricity sector only



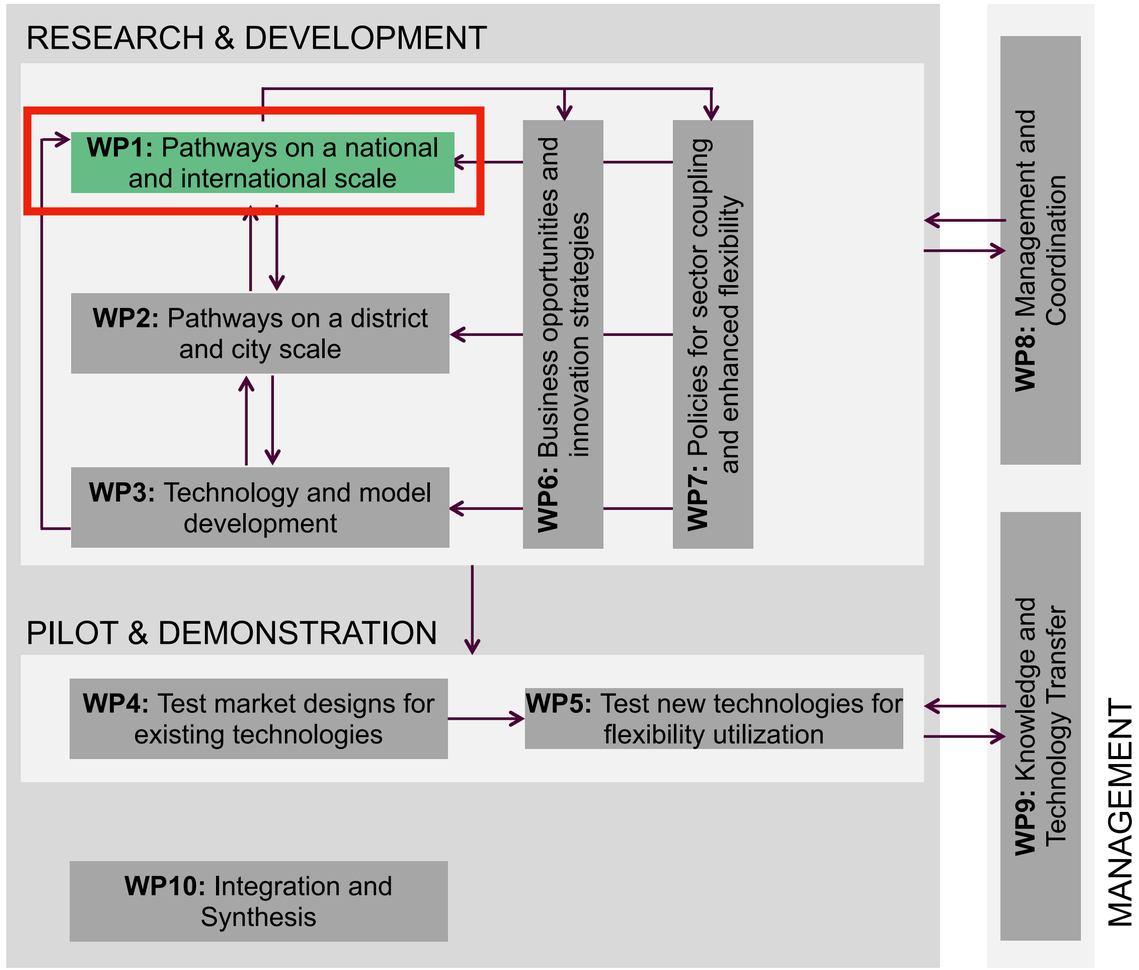
Calliope

www.callio.pe

A tool to build
energy system models

Future development under the PATHFNDR project

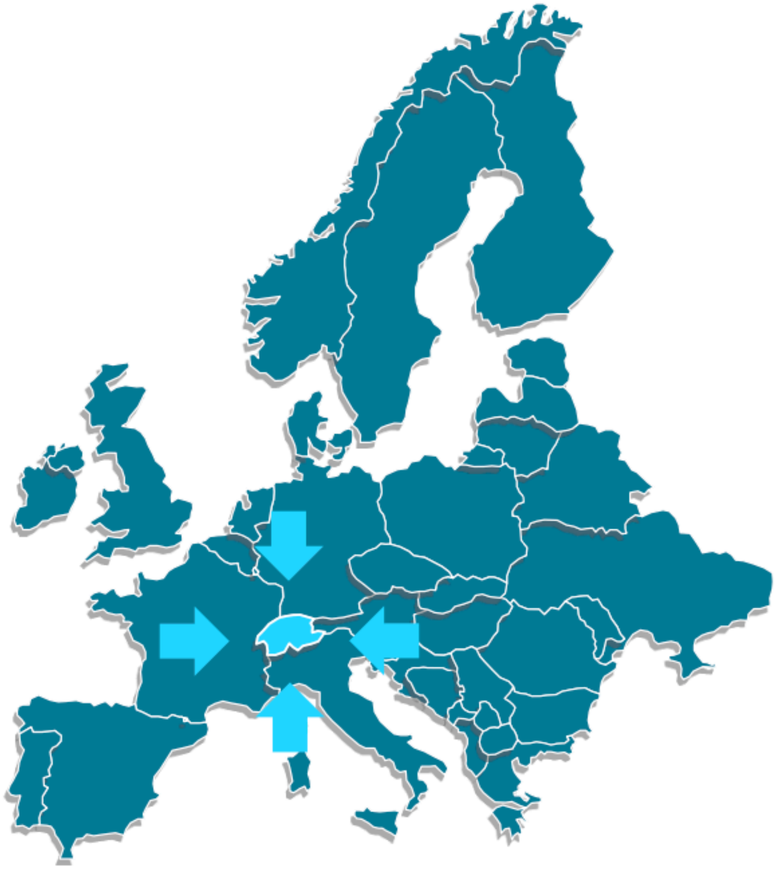
- A model to assess pathways for Switzerland within the context of decisions taken Europe-wide



Linkage to other tools of the PATHFNDR project

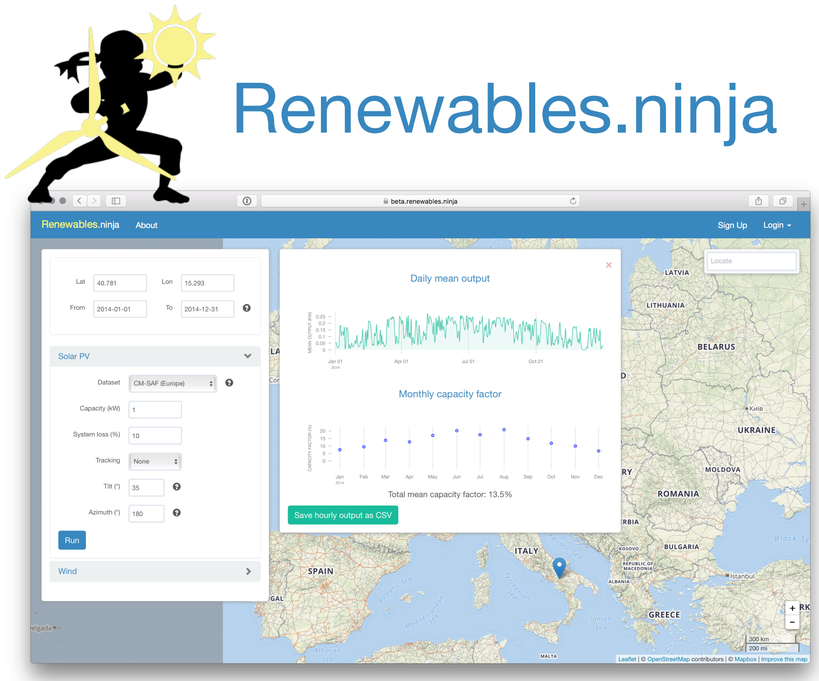
- Provide boundary conditions for the detailed modelling of the Swiss energy system with nexus-e

- Explore integration of operational constraints from the more detailed models, e.g. Ehub and ReMaP



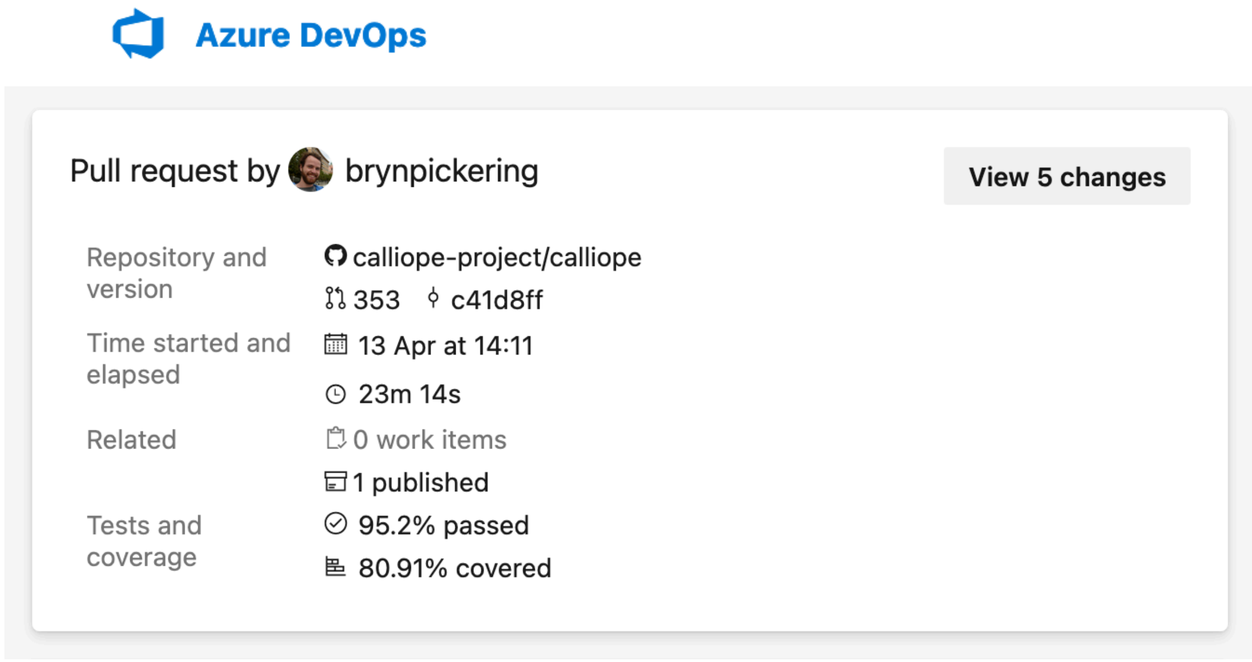
Validation / calibration

- 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



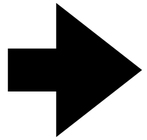
https://dev.azure.com/calliope-project/calliope/_build/results?buildId=242&view=results

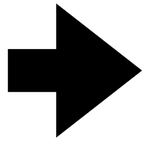
Limitations - there are many!

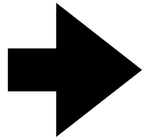
- It is a (usually cost-minimising) linear/ mixed-integer optimisation model, fed with a range of assumptions which may or may not be “correct”.

- 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

Calliope

www.callio.pe

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

Euro-Calliope

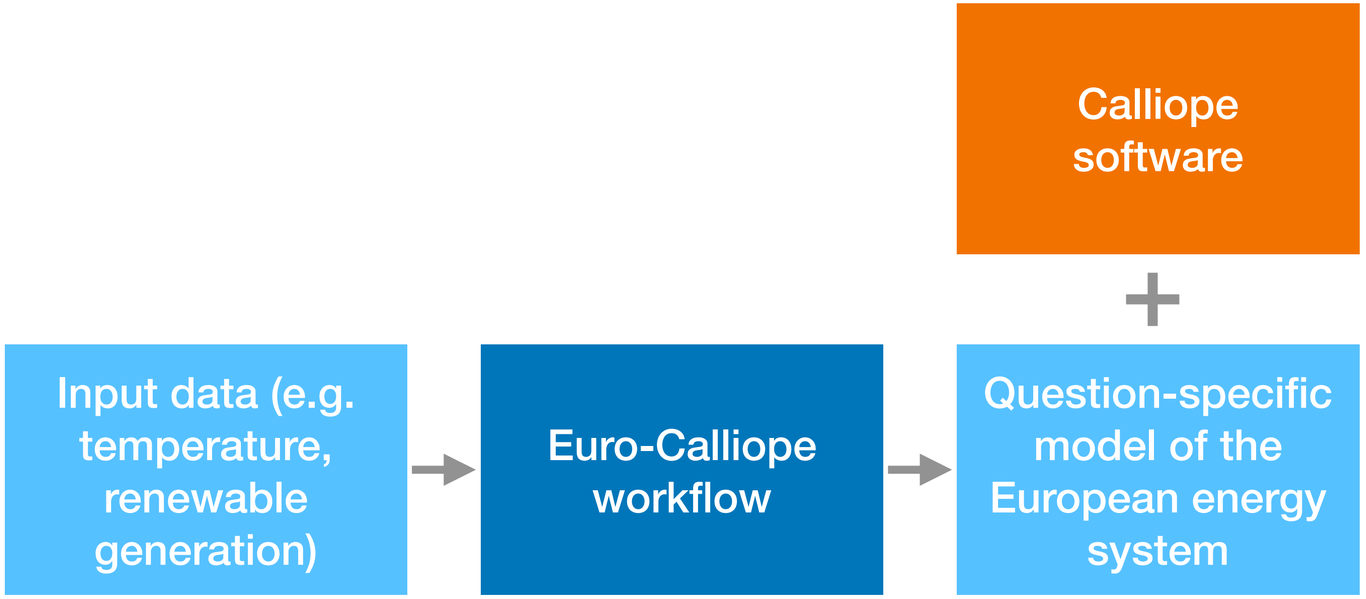
Current users:

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

Potential users:

- Quite a few

Licenses: everything is free and open-source



Apache 2.0 license:

github.com/calliope-project/calliope

with a few exceptions, open data

MIT license:

github.com/calliope-project/euro-calliope

e.g. Tröndle et al. 2020, Creative Commons CC-BY license:

doi.org/10.5281/zenodo.3949552

sweet swiss energy research for the energy transition

PATHFNDR

Calliope

www.callio.pe

Stefan Pfenninger
s.pfenninger@tudelft.nl
Faculty of Technology, Policy and Management
TU Delft

PATHFNDR: https://sweet-pathfndr.ch/

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