Open modelling: Transmission network needs for Paris-compliant European energy scenarios

Jonas Hörsch, Veit Hagenmeyer, **Tom Brown**; tom.brown@kit.edu, https://nworbmot.org/
Karlsruhe Institute of Technology (KIT), Institute for Automation and Applied Informatics (IAI)

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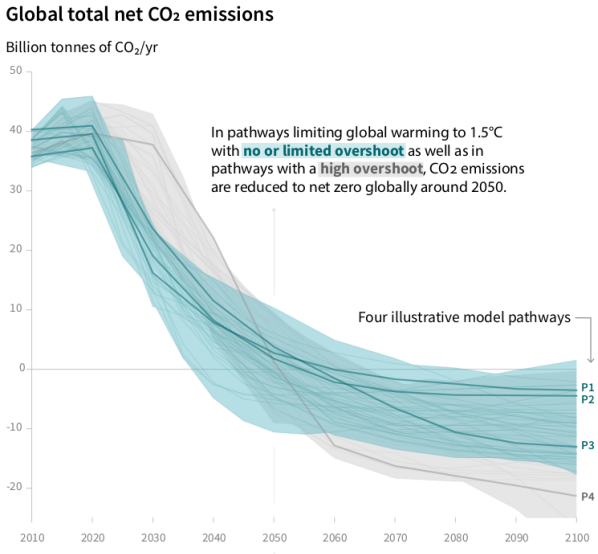
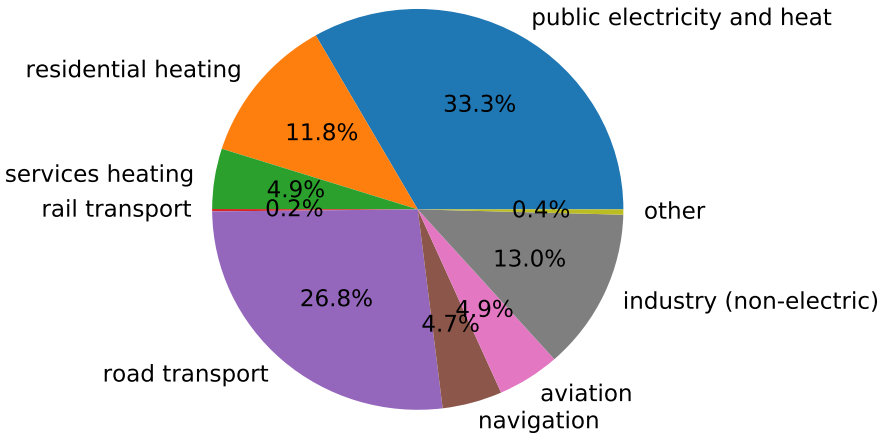
The Global Carbon Dioxide Challenge: Net-Zero Emissions by 2050



Source: IPCC SR15 on 1.5C, 2018

It's not just about electricity demand...

EU28 CO_2 emissions in 2015 (total 3.2 Gt CO_2, 8% of global):



Source: Brown, data from EEA

...but electrification of other sectors is critical for decarbonisation

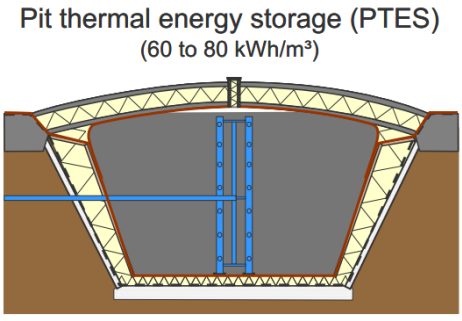
Electrification is essential to decarbonise transport, heating and industry.

Some scenarios show a **doubling or more of electricity demand**.

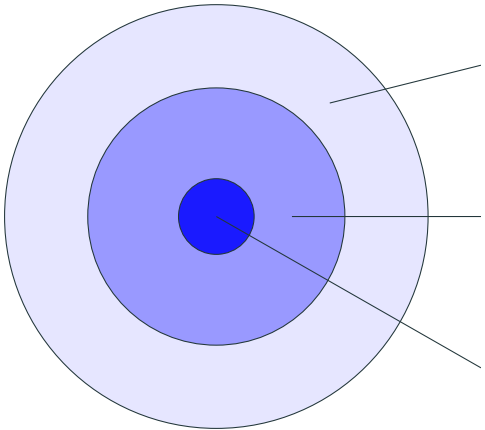
Source: Tesla; heat pump: Kristoferb at English Wikipedia

Fortunately other sectors offer flexibility back to grid

Other sectors offer **flexibility** (e.g. battery electric vehicles, power-to-gas, thermal storage), enabling energy to be **stored cheaply** and **transported easily** (e.g. using natural gas network).



Different levels of planning



Researchers: bold modelling with wide scope, but rough on details

Network Development Plan: more precise, but restricted scope

Specific construction project: very concrete, no additional scope

Research approach

Avoid too many assumptions. Fix the **boundary conditions**:

- Meet demand for energy services
- Reduce CO_2 emissions
- Conservative predictions for cost developments
- No/minimal/optimal grid expansion

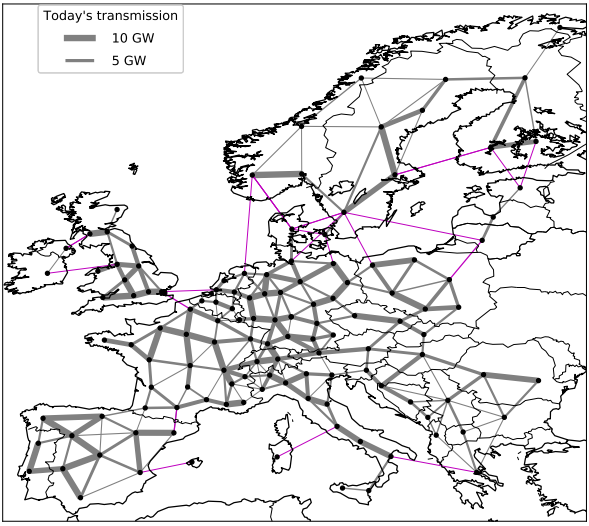
Then **let the math decide the rest**, i.e. choose the number of wind turbines / solar panels / storage units / transmission lines to minimise total costs (investment **and** operation).

Generation, storage and transmission optimised **jointly** because they are **strongly interacting**.

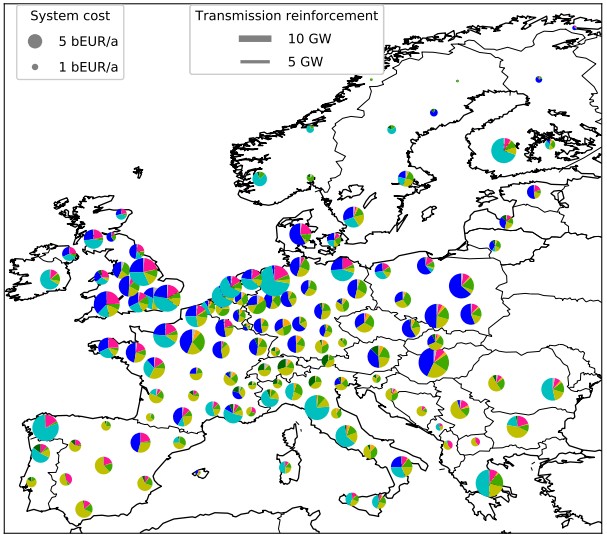
Application to zero-CO_2 European sector-coupled model

In this model we:

- Meet **all demand** for electricity, space and water heating, and land transport
- Reduce CO_2 emissions **to zero**
- Assume **smaller bidding zones** and **widespread dynamic pricing**
- Examine effect of **grid expansion** on technology choices and costs

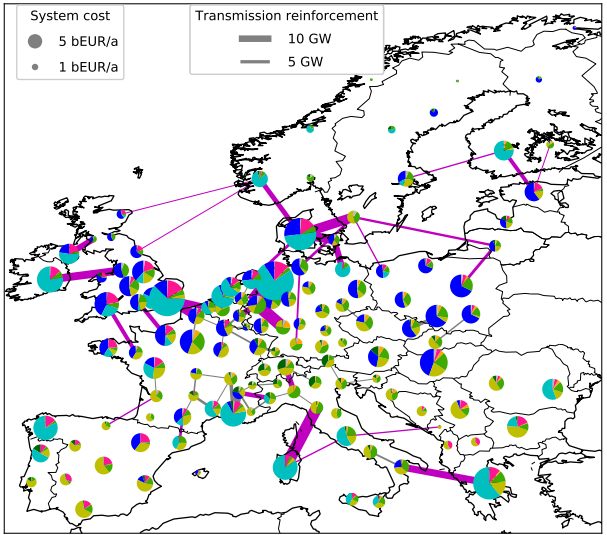


Distribution of technologies: No grid expansion



- hydroelectricity
- onshore wind
- offshore wind
- solar
- power-to-heat
- gas-to-power/heat
- power-to-gas
- hot water storage

Distribution of technologies: 25% more grid volume - similar to TYNDP



- hydroelectricity
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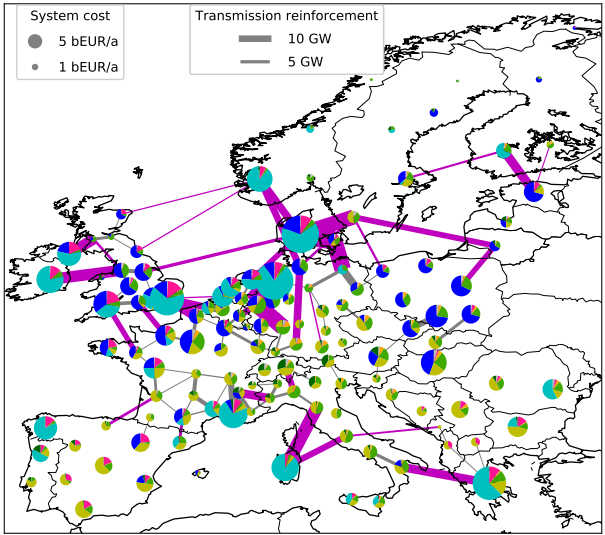
- hot water storage

Distribution of technologies: 50% more grid volume - double the TYNDP



- hydroelectricity
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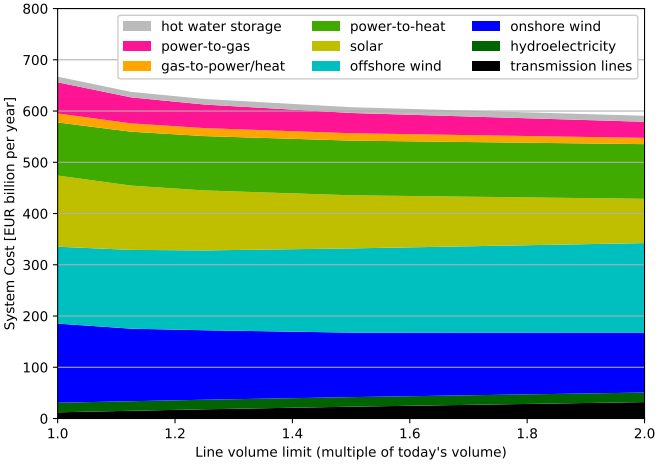
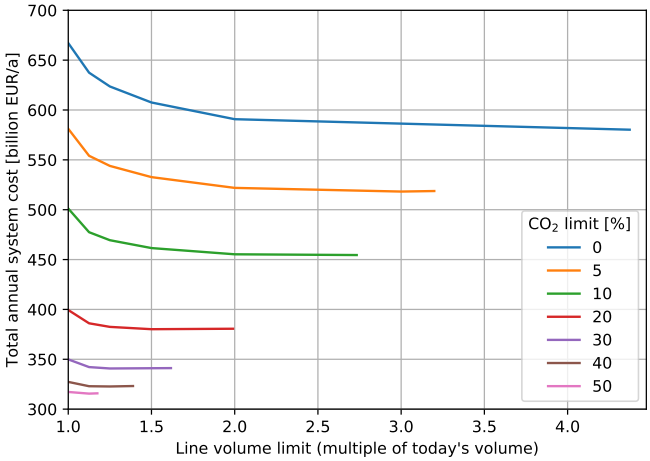
Benefit of grid expansion for sector-coupled system



- Costlier than today's system (€ 380 billion per year with same assumptions), but big health and climate benefits
- As grid expands, **costs reduce** from solar and power-to-gas; more offshore wind
- Total cost benefit of extra grid: $\sim$ € 87 billion per year
- **Over half of benefit available at 25% expansion** (like TYNDP)

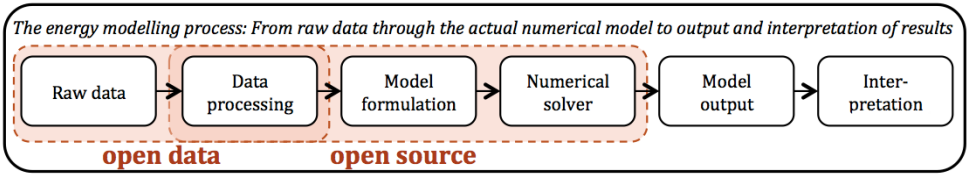
Benefit of grid depends on level of carbon dioxide reduction



- Optimal grid (rightmost point of each curve) grows successively larger
- Benefit of grid expansion grows with depth of CO_2 reduction
- Can still get away with no transmission reinforcement (if the system is operated flexibly)

Idea of Open Energy Modelling

The whole chain from raw data to modelling results should be open:



Open data + free software ⇒ Transparency + Reproducibility

There's an initiative for that! Sign up for the mailing list / come to the next workshop at Aarhus University, Denmark, 22-24 May 2019:

openmod open energy modelling initiative

openmod-initiative.org

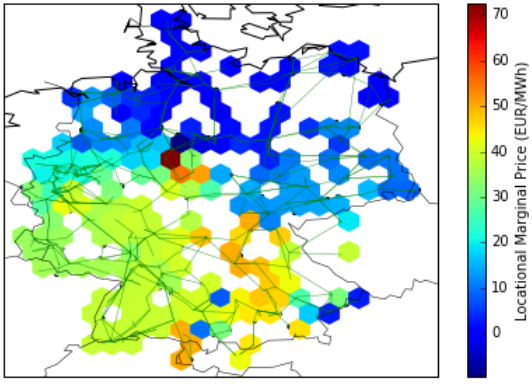
Source: openmod initiative

Python for Power System Analysis (PyPSA)

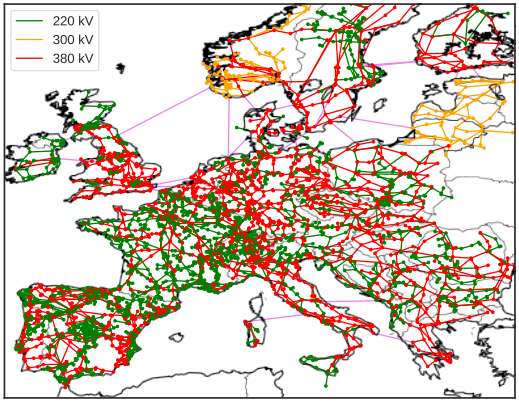
Our free software PyPSA is online at `https://pypsa.org/` and on github. It can do:

- Static **power flow**
- **Linear optimal power flow** (LOPF) (multiple periods, unit commitment, storage, coupling to other sectors)
- **Security-constrained LOPF**
- Total electricity system **investment optimisation**

It has models for storage, meshed AC grids, meshed DC grids, hydro plants, variable renewables and sector coupling.



PyPSA-Eur: Open Model of European Transmission System



- Grid data based on **GridKit** extraction of ENTSO-E interactive map
- **powerplantmatching** tool combines open databases using matching algorithm DUKE
- Renewable energy time series from open **atlite**, based on Aarhus University REatlas
- Geographic **potentials** for RE from land use
- Basic **validation** described in Hörsch et al 'PyPSA-Eur: An Open Optimisation Model of the European Transmission System'
- `https://github.com/PyPSA/pypsa-eur`

Conclusions

- Meeting Paris targets is **urgent** and requires addressing **all energy sectors**
- **Cross-sectoral** approaches are important to reduce CO2 emissions **and** for flexibility
- Without grid expansion, deep CO_2 reductions are possible but **expensive**
- In our model, TYNDP-level expansion delivers $\sim$ €44 billion per year benefit; a bigger expansion could deliver double the benefit, but is unlikely to find public acceptance
- Our results broadly **agree** with location of TYNDP projects
- **Policy prerequisites**: high, increasing and transparent **price for CO_2 pollution**; to manage grid congestion better: **smaller bidding zones** and **more dynamic pricing**
- All results depend strongly on assumptions and modelling approach - therefore **openness and transparency are critical**, guaranteed by open licences for data and code

More details?

For more details, see publications, code and data listed at:

`https://www.nworbmot.org`

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