eurac research

Renewable energy high penetration scenarios using bottom-up modelling

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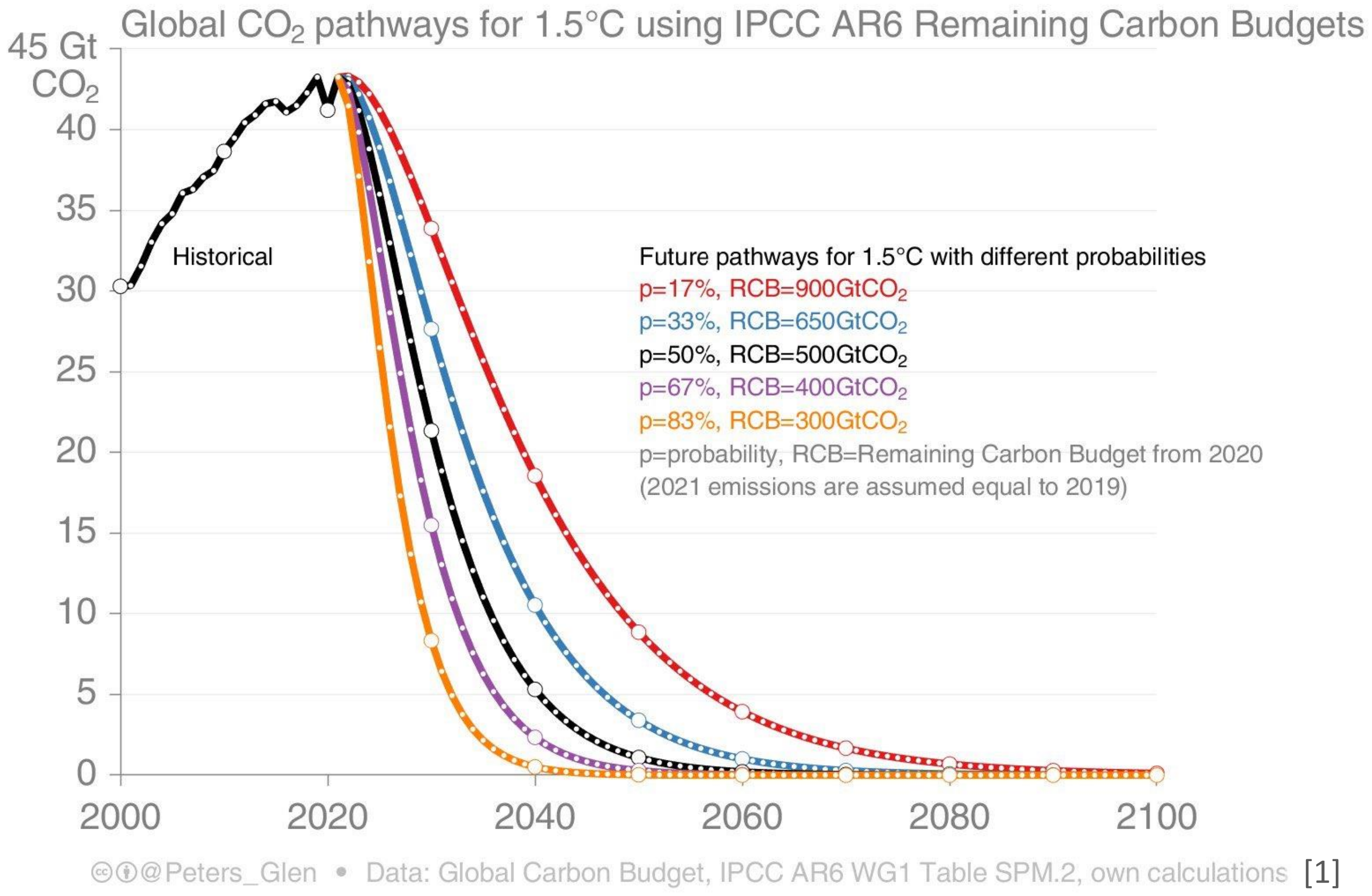
Euregio Young Researcher Award 2021

Why we need to change?

The later the decarbonization process will take place the higher will be the probability for an increase of temperature above 1.5°C within 2100 above pre-industrial levels, 1850-1990.

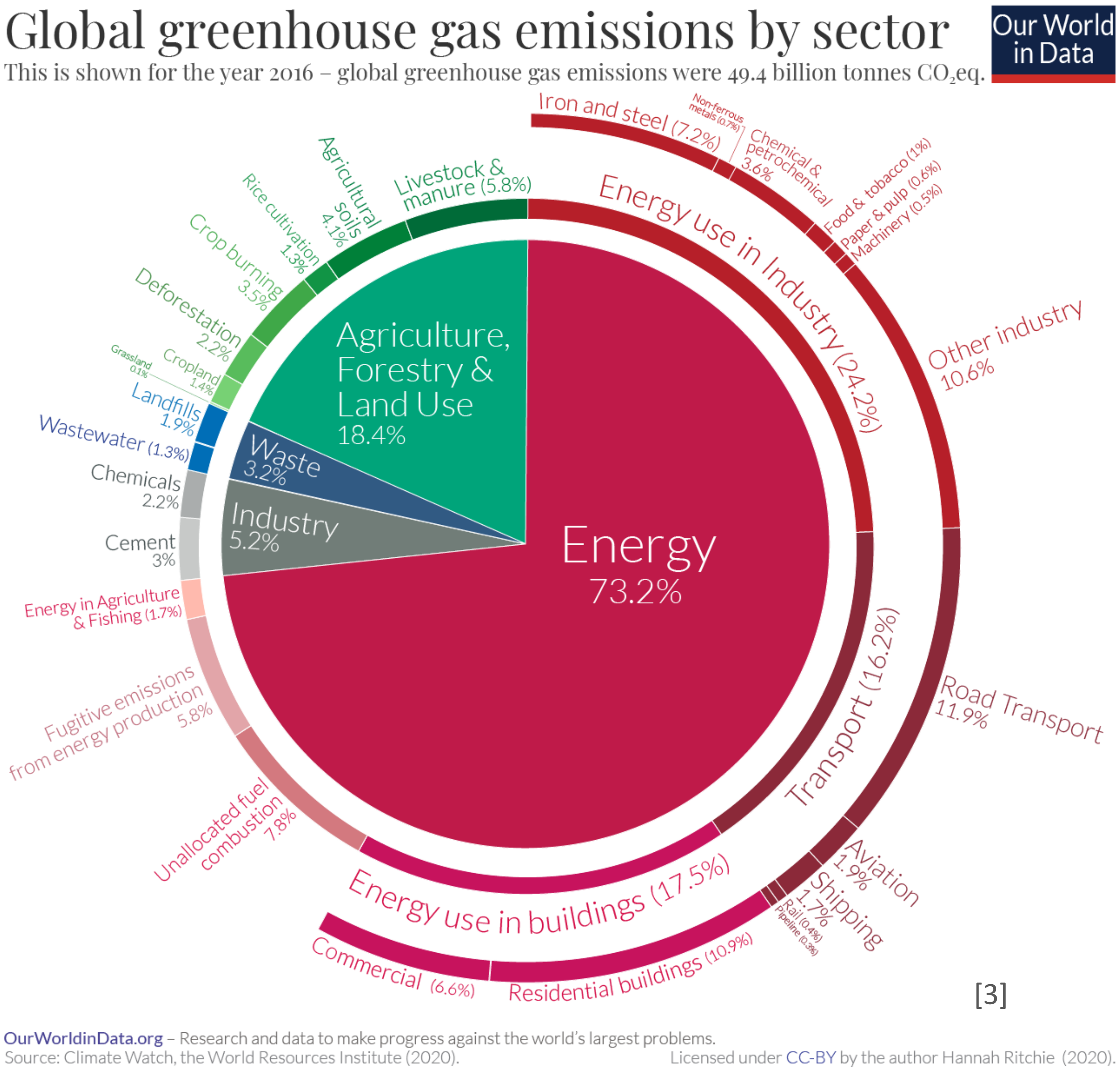


[1]

[1] Elaboration of IPCC results by Glen Peters, 2021. [2] IPCC 2021 report https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

Why the energy sector?

The majority of the GHG emissions globally comes from the energy sector.



[3] Emissions by sector, OurWorldInData. https://ourworldindata.org/emissions-by-sector

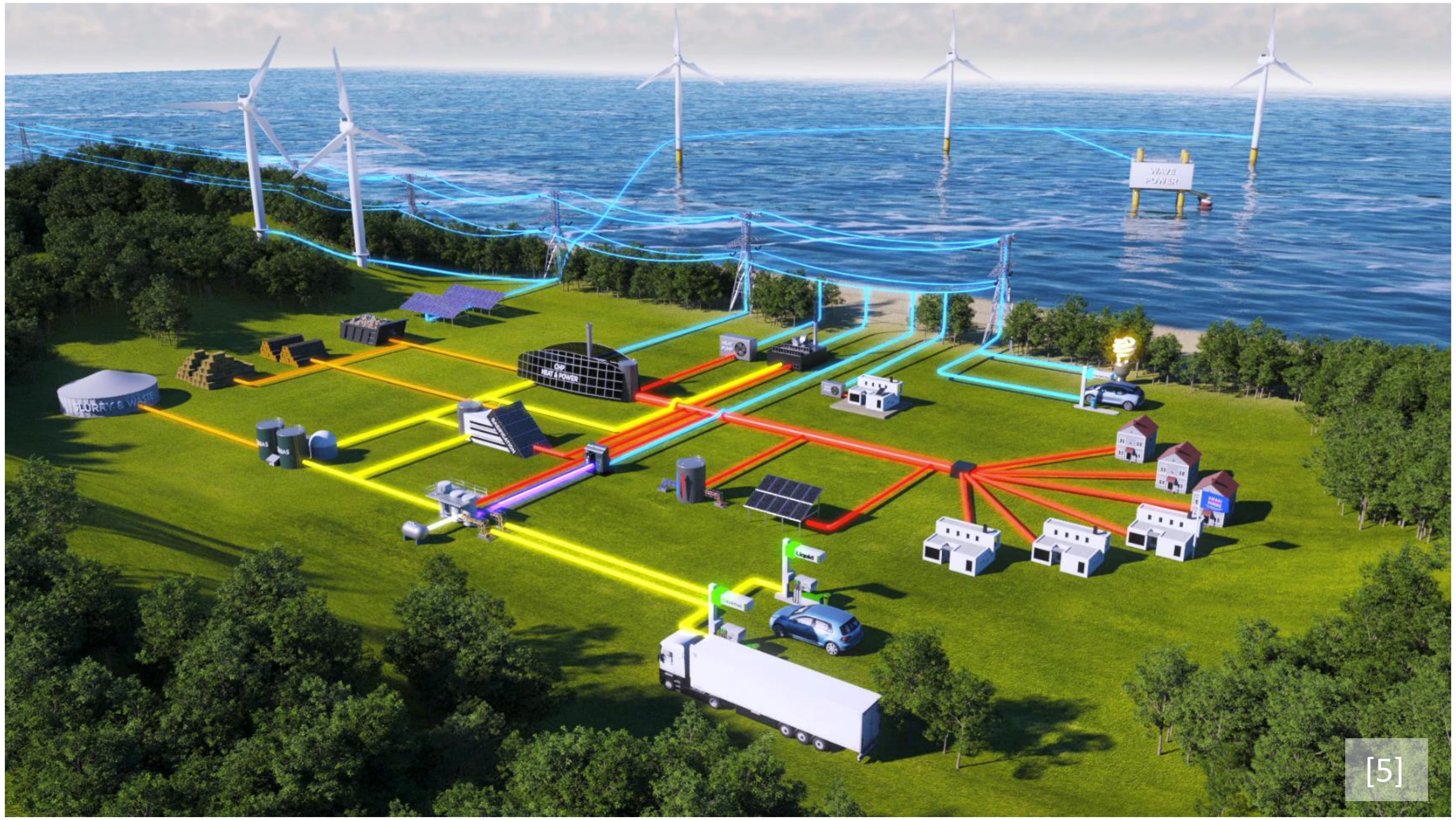
Energy system modelling

Definition:

It is the process of building **computer models** of energy systems in order to **analyze** them and **inspect future scenarios.**

Scope [4]:

- to provide **orientation** and material for discussion about **energy futures**
- to **support decision makers** in developing short and long-term strategies in energy sectors



[5]

[4] Cao K-K et al. Raising awareness in model-based energy scenario studies—a transparency checklist, [5] picture: https://www.en.plan.aau.dk/research+groups/SEP/

Bottom-up versus Top-down approach

	Bottom-up	Top-down
Developed and used by	• Engineers • Natural Scientists • Energy supply companies	• Economists • Public administrations
Scope	To inspect **best technology options** for a future energy system	To **test** a **certain energy policy** and evaluate its future impacts (macro-economic, environmental, societal)
Type	Simulation model, Optimization model	Macroeconomic model
Advantages and limitations	**+** High degree of technological detail (Timestep: hour) **-** Heavily dependent on data availability and credibility	**+** Application of feed-back loops to **walefare**, **employment** and **social growth** **-** Lack of technological detail (Timestep: year)
Examples	- **energyPLAN** - MARKAL/TIMES - REMod-d	- PRIMES - ENPEP-BALANCE - MARKAL/TIMES (partly) - LEAP

[6] Herbst et al. Introduction to Energy Systems Modelling 2012

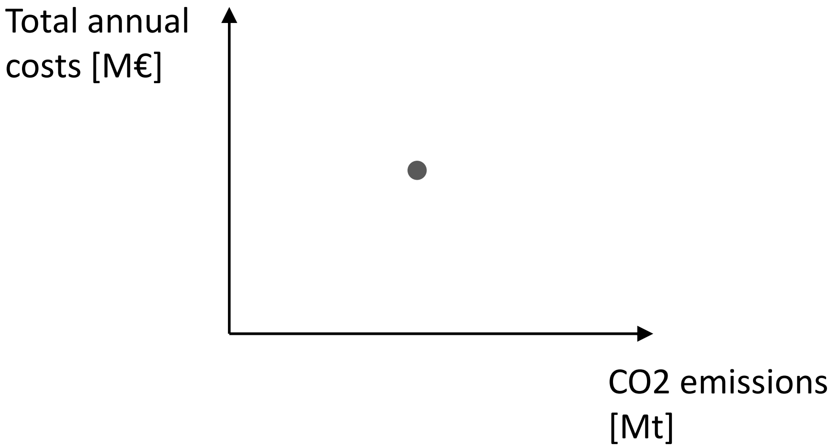
Problem in bottom-up energy system modelling

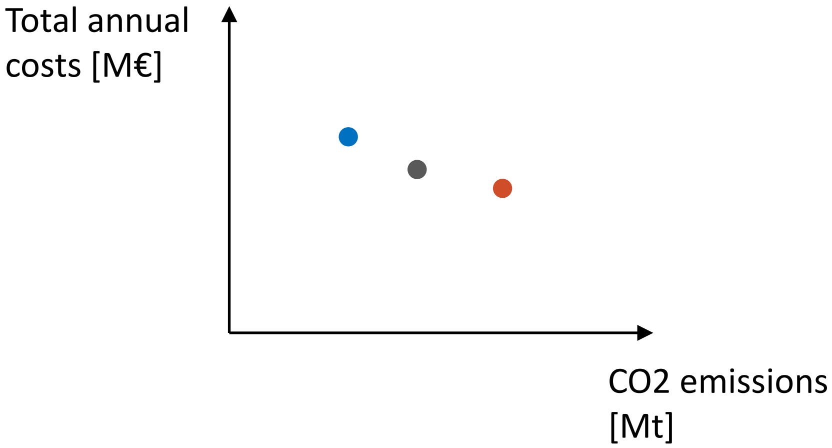
Single optimum method
Energy system models typically provide a single optimal best solution to policy makers

- Large infrastructure projects
- visual impact
- land-use conflicts
- problematic concentration of renewables in single regions

are all **political implications** which are **difficult to be quantified in energy system models** [7].

These implications could justify a policy-makers choice towards a solution which is slightly more cost expensive than the unique optimal one.





[7] Neumann F, Brown T. The near-optimal feasible space of a renewable power system model. 2021

How to go beyond the single optimum method?

Scope of my PhD and research activity**:** to **go beyond** the ”**single optimum method**” with the aim to better **support** and guide **policy makers** in the selection of the **best future alternatives** of the energy system from a techno-economic point of view.

[7] Neumann F, Brown T. The near-optimal feasible space of a renewable power system model. 2021

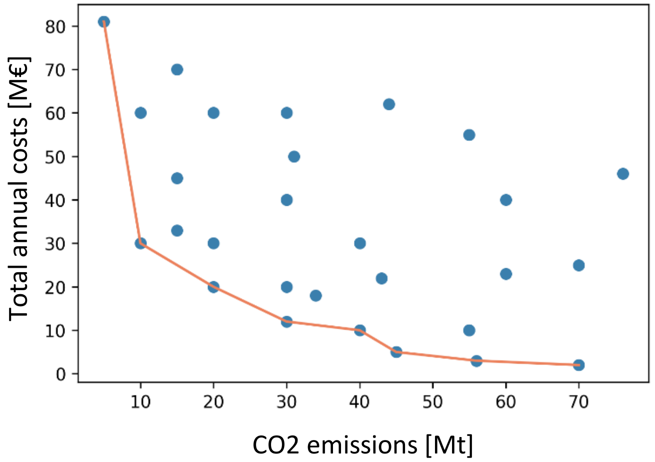
How to go beyond the single optimum method?

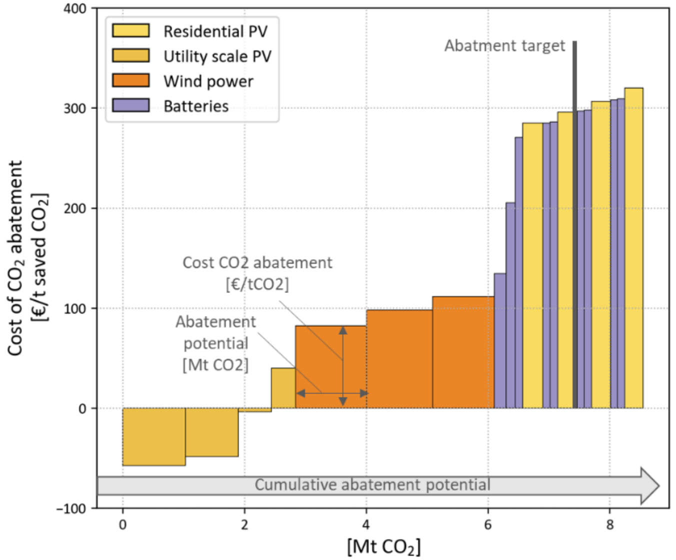
Techniques to assess this challenge:

i) Identification of multiple near-optimal solutions

ii) Multi-objective optimisation approach → - **EPLANopt** - **Oemof-moea**

iii) Marginal abatement cost (MAC) curves → - **EPLANoptMAC**



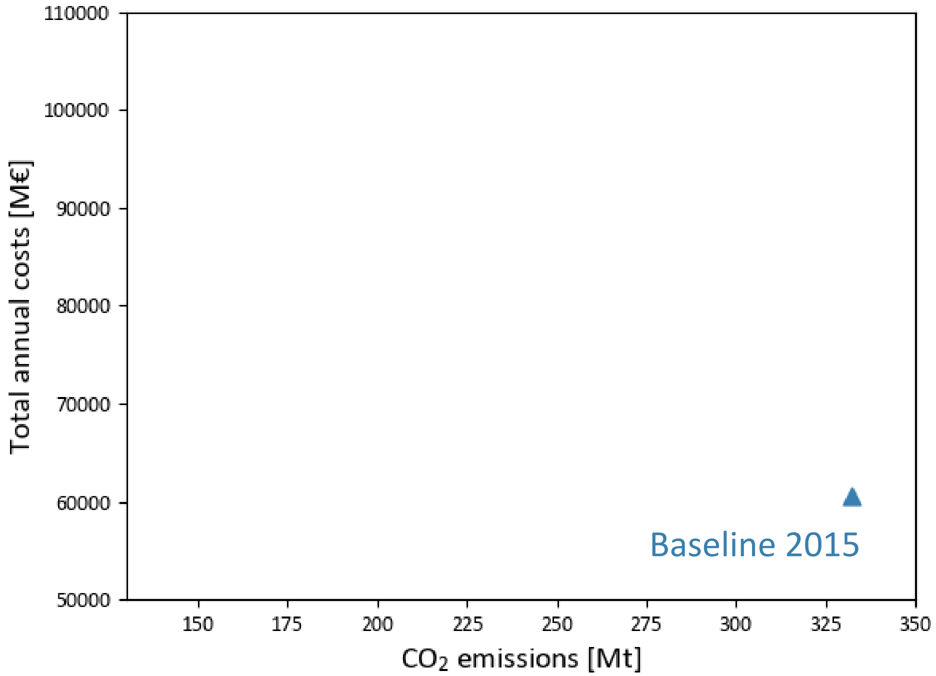


[7] Neumann F, Brown T. The near-optimal feasible space of a renewable power system model. 2021

EPLANopt

Model n objectives - Eurac Research

Simulation model		Optimization model
EnergyPLAN (Aalborg University)	+	Multi objective evolutionary algorithm MOEA

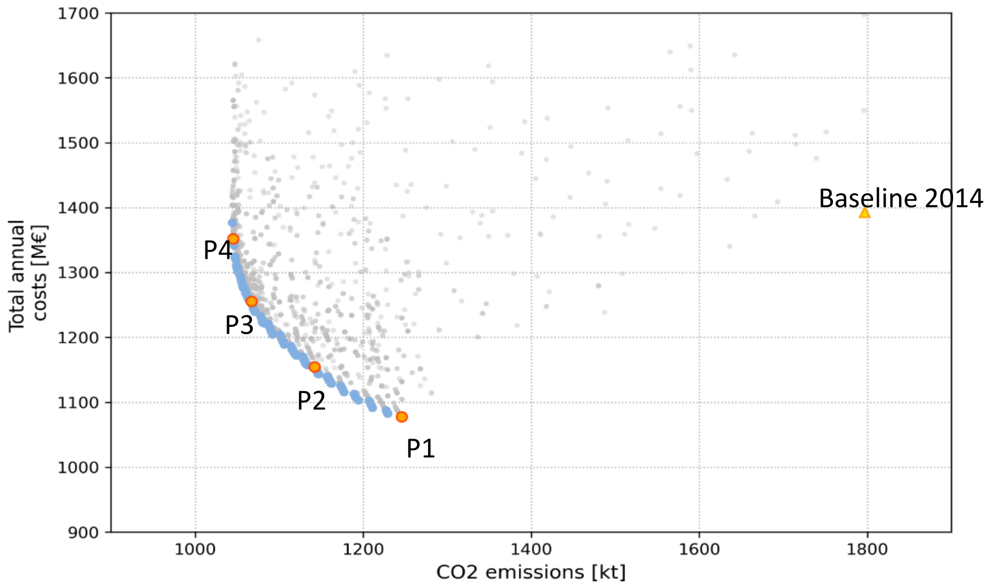


Each point on the chart shows total costs and CO_2 emissions per each combination of technologies of the energy system.

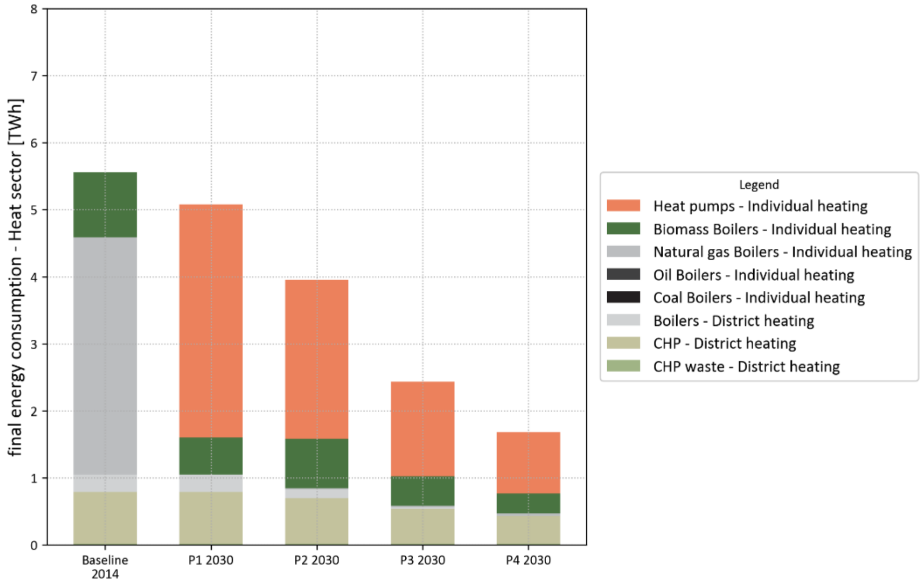
For each combination of technologies of the energy system, hourly energy production and consumption have been simulated.

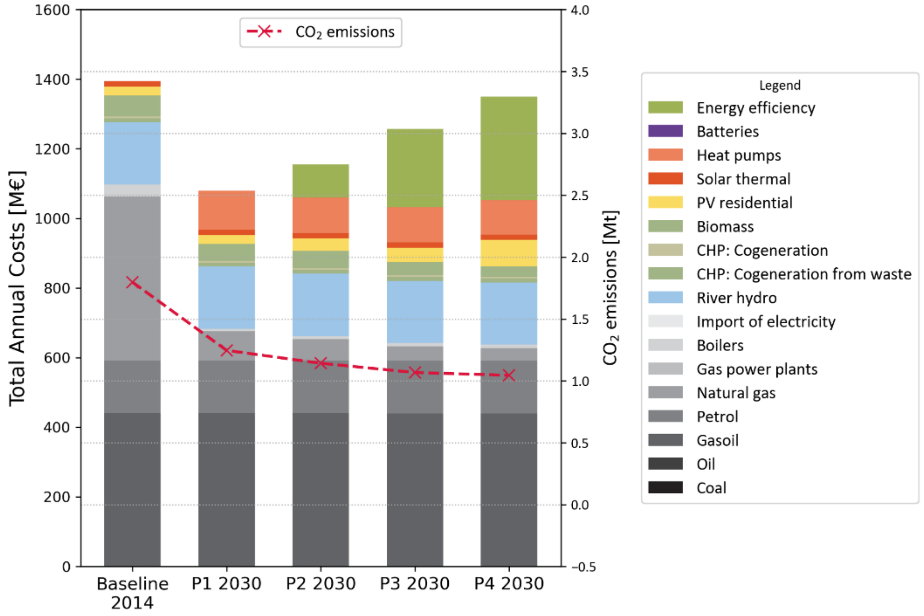
[8] Prina et al. Multi-objective optimization algorithm coupled to EnergyPLAN software: The EPLANopt model. 2018

EPLANopt: results for South Tyrol



	PV	Batteries	Energy efficiency of buildings	Beta, HPs with energy efficiency	Gamma, HPs without energy efficiency
Baseline 2014	50 MW	0 MWh	0 %	0 %	0 %
P1 2030	50 MW	0 MWh	0 %	0 %	90 %
P2 2030	750 MW	0 MWh	25 %	60 %	80 %
P32050	1500 MW	0 MWh	55 %	100 %	60 %
P4 2050	1450 MW	0 MWh	70 %	70 %	30 %

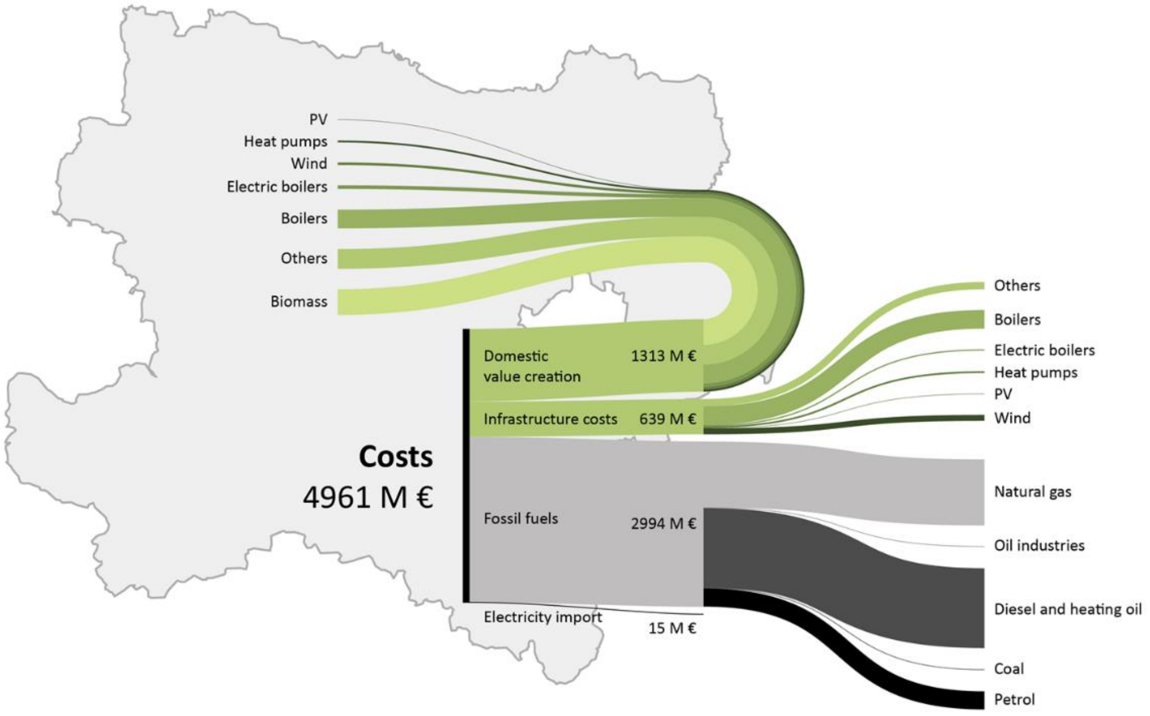




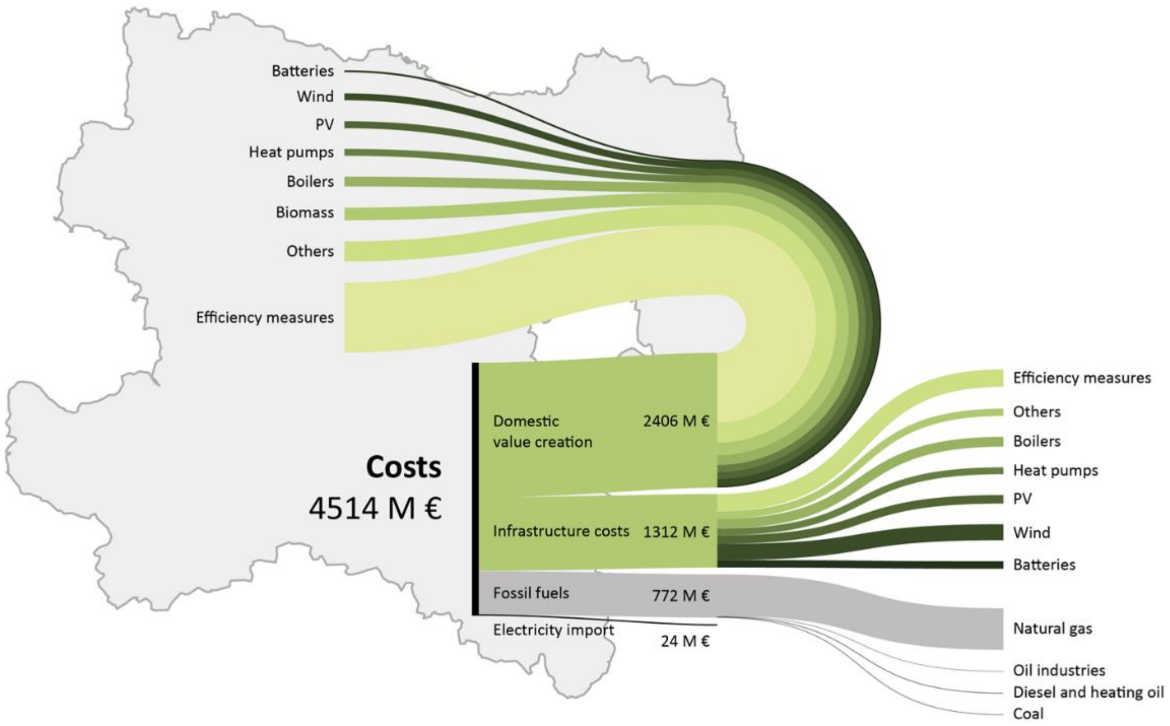
[8] Prina et al. Multi-objective optimization algorithm coupled to EnergyPLAN software: The EPLANopt model. 2018

EPLANopt: results for Niederösterreich

Baseline

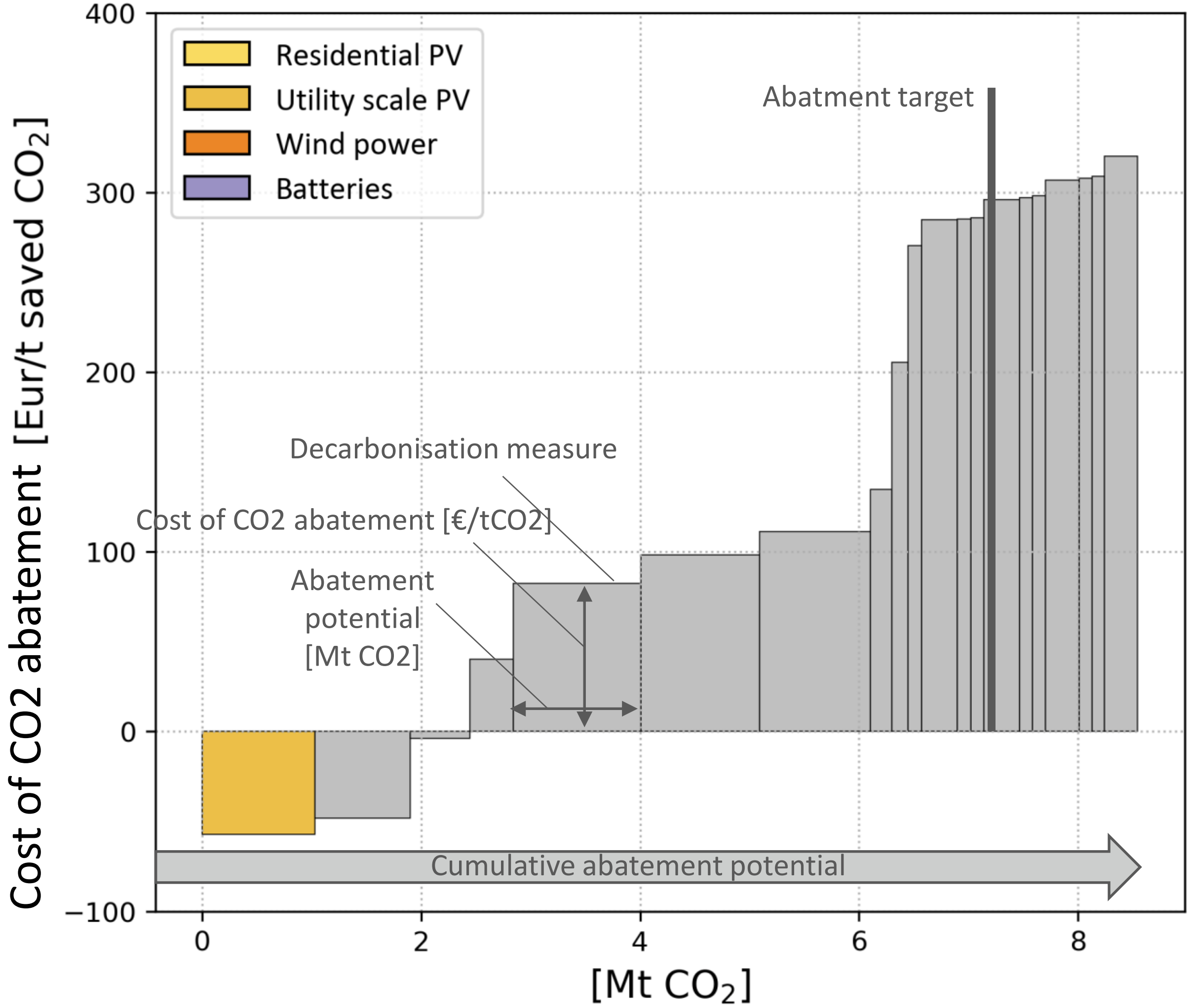


Advanced scenario



[10] Prina et al. EPLANopt optimization model based on EnergyPLAN applied at regional level: the future competition on excess electricity production from renewables. 2020

EPLANoptMAC

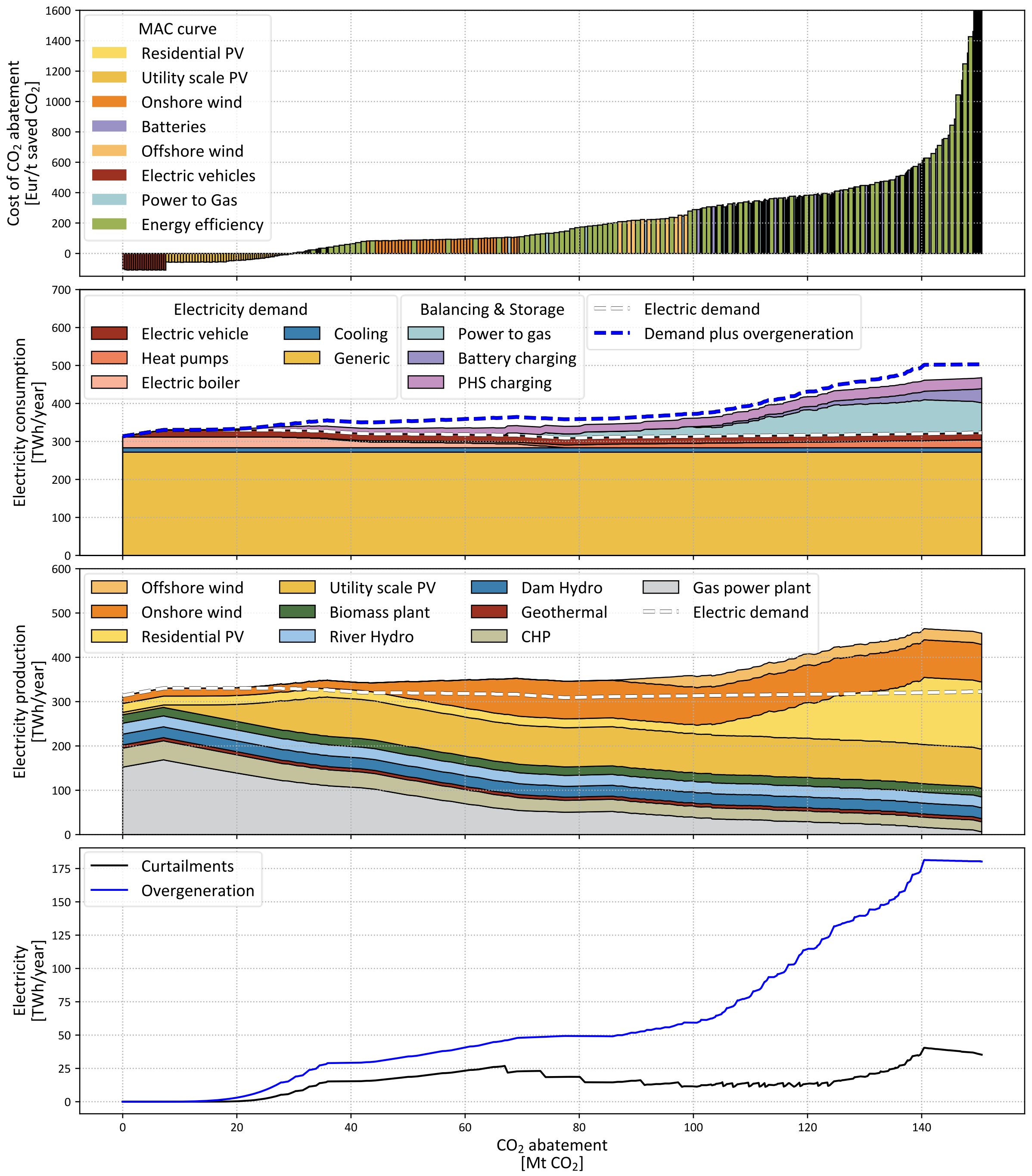


	Utility scale PV	Wind power	Residential PV	Batteries
step 1	+1 GW	+1 GW	+1 GW	+1 GWh
step 2	+1 GW	+1 GW	+1 GW	+1 GWh
step 3	+1 GW	+1 GW	+1 GW	+1 GWh
step 4	+1 GW	+1 GW	+1 GW	+1 GWh
step 5	+1 GW	+1 GW	+1 GW	+1 GWh
step 6	+1 GW	+1 GW	+1 GW	+1 GWh
step 7	+1 GW	+1 GW	+1 GW	+1 GWh
step 8	+1 GW	+1 GW	+1 GW	+1 GWh
step 9	+1 GW	+1 GW	+1 GW	+1 GWh
step 10	+1 GW	+1 GW	+1 GW	+1 GWh
step 11	+1 GW	+1 GW	+1 GW	+1 GWh
step 12	+1 GW	+1 GW	+1 GW	+1 GWh
step 13	+1 GW	+1 GW	+1 GW	+1 GWh
step 14	+1 GW	+1 GW	+1 GW	+1 GWh
step 15	+1 GW	+1 GW	+1 GW	+1 GWh
step 16	+1 GW	+1 GW	+1 GW	+1 GWh
step 17	+1 GW	+1 GW	+1 GW	+1 GWh
step 18	+1 GW	+1 GW	+1 GW	+1 GWh
step 19	+1 GW	+1 GW	+1 GW	+1 GWh
step 20	+1 GW	+1 GW	+1 GW	+1 GWh

[9] Prina et al. Optimization method to obtain marginal abatement cost-curve through EnergyPLAN software. 2021

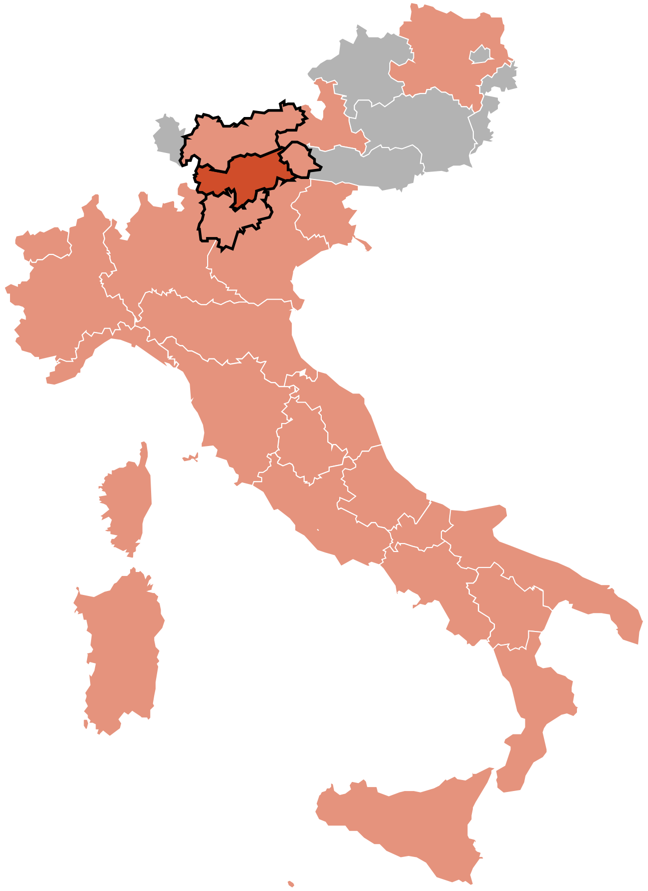
EPLANoptMAC: results for Italy

MAC curve at 2030 for the Italian case study (first subplot on the top), different contributions to the electricity consumption (second subplot from the top), electricity generation from different sources (third subplot from the top) and comparison between curtailments and overgeneration (subplot on the bottom).



[9] Prina et al. Optimization method to obtain marginal abatement cost-c

Relevance for EUREGIO



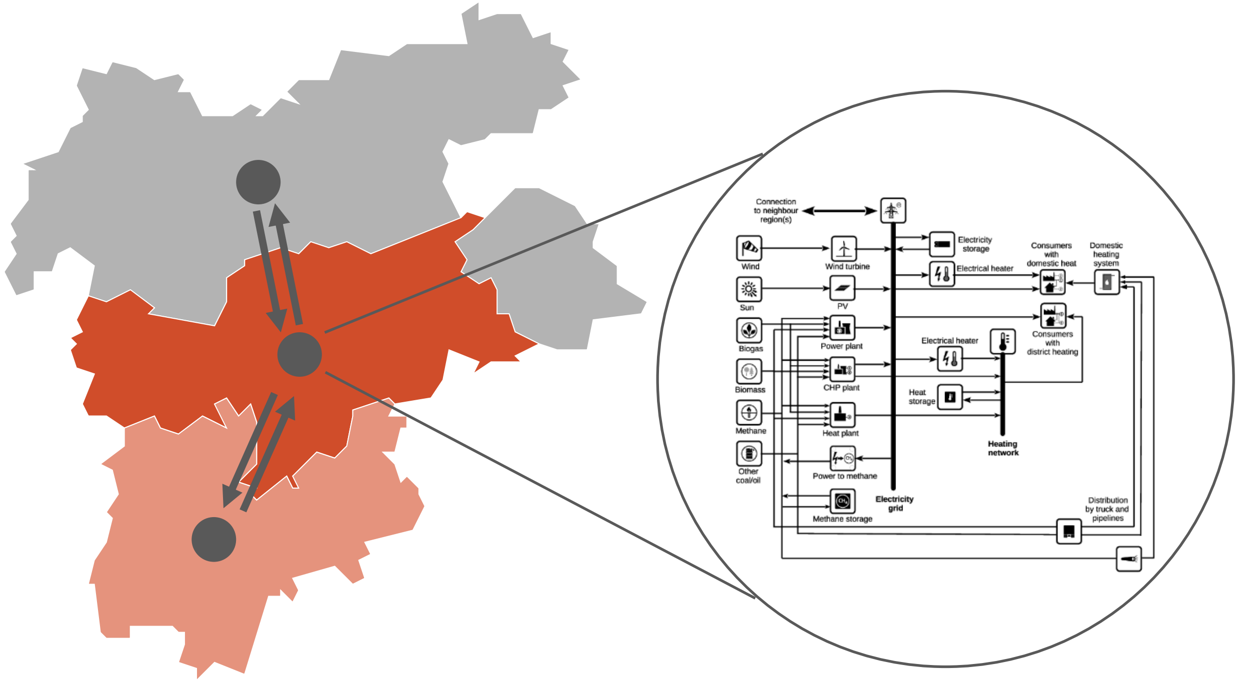
Case study	Type of study	Title	Year
South Tyrol	Journal article	Multi-objective optimization algorithm coupled to EnergyPLAN software: The EPLANopt model	2018
Bressanone-Brixen	Journal article	Smart energy systems applied at urban level: The case of the municipality of Bressanone-Brixen	2016
Italy	Journal articles	i) Transition pathways optimization methodology through EnergyPLAN software for long-term energy planning ii) Electrification of transport and residential heating sectors in support of renewable penetration: Scenarios for the Italian energy system iii) Multi-objective optimization model EPLANopt for energy transition analysis and comparison with climate-change scenarios	2018-2021
Niederosterreich	Journal article	EPLANopt optimization model based on EnergyPLAN applied at regional level: The future competition on excess electricity production from renewables	2020
Salzburg	Final report	In progress	2020-2021
Tyrol	Study in phase of evaluation	In progress	2020-

In energy system modelling an added value is certainly transparency. The codes of the developed models are open to everyone (on Gitlab/Github) and available on different repositories: EPLANopt [10], Oemof-moea [11], EPLANoptMAC [12].

[10] EPLANopt, 2016. https://gitlab.inf.unibz.it/URS/EPLANopt. [11] Oemof-moea, 2019 https://github.com/matpri/oemof-moea. [12] EPLANoptMAC, 2021 https://github.com/matpri/EPLANoptMAC

Next steps

The creation of a **model** for the whole **EUREGIO** based on the **multi-node tool Oemof-moea** to study the beneficial exchanges of energy flows between regions.



Final aim:

The results of this study support policy makers in the definition of a shared energy strategy 2050 for EUREGIO.

Tirol 2050 (Tyrol)

Klimaplan 2050 (South Tyrol)

Piano energetico ambientale (Trentino)

Shared energy strategy 2050

Thank you
for your attention

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