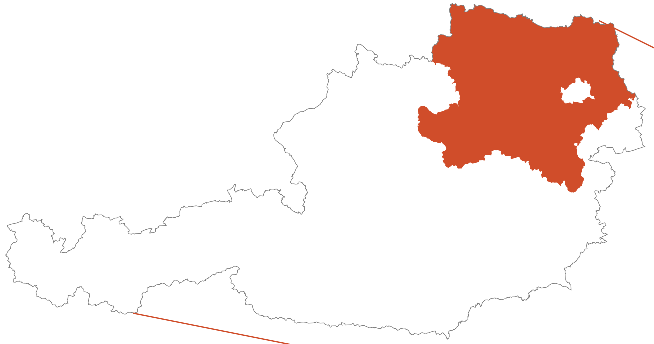
eurac research

EPLANopt optimization model based on EnergyPLAN applied at regional level: the future competition on excess electricity production from renewables

Matteo Giacomo Prina, David Moser, Roberto Vaccaro, Wolfram Sparber

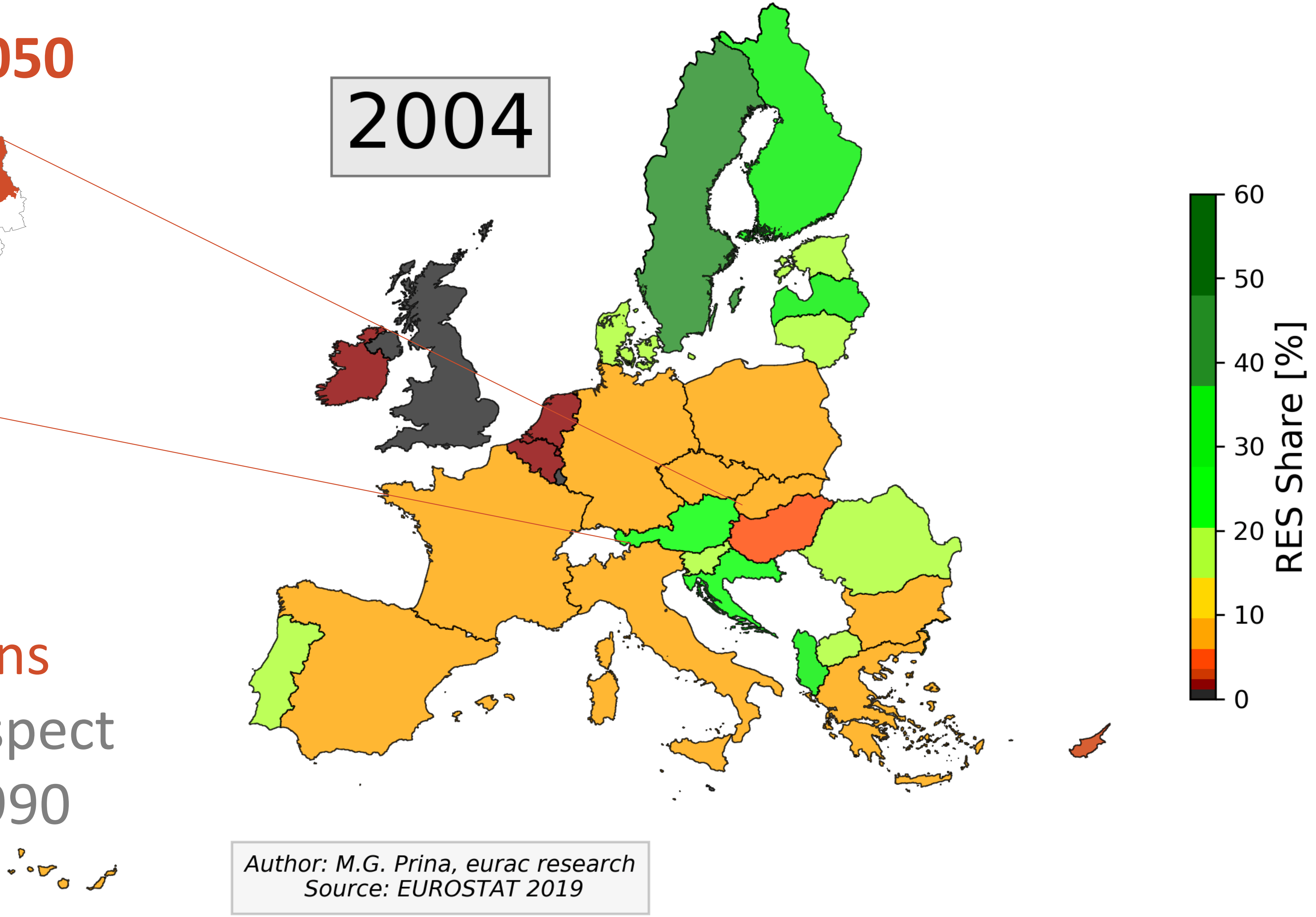
NÖ Climate plan 2050



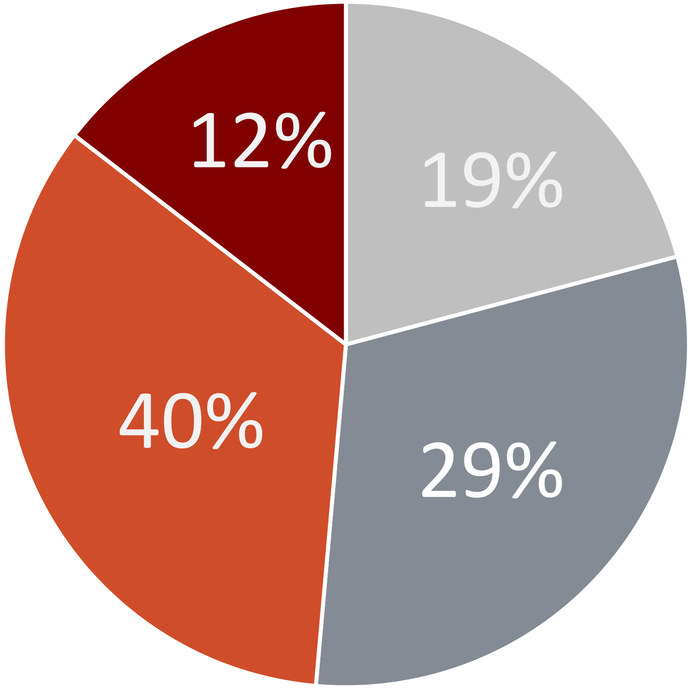
Target

-80% emissions

at 2050 in respect
to value of 1990



Starting energy system in Niederösterreich: 2016



Heat
19.9 TWh

Transport
22.2 TWh

Electricity
13.6 TWh

Industrial heat
9.5 TWh

Total final energy consumption
65.1 TWh

*Including distribution losses and consumption of the energy system itself for heat fuels and electricity

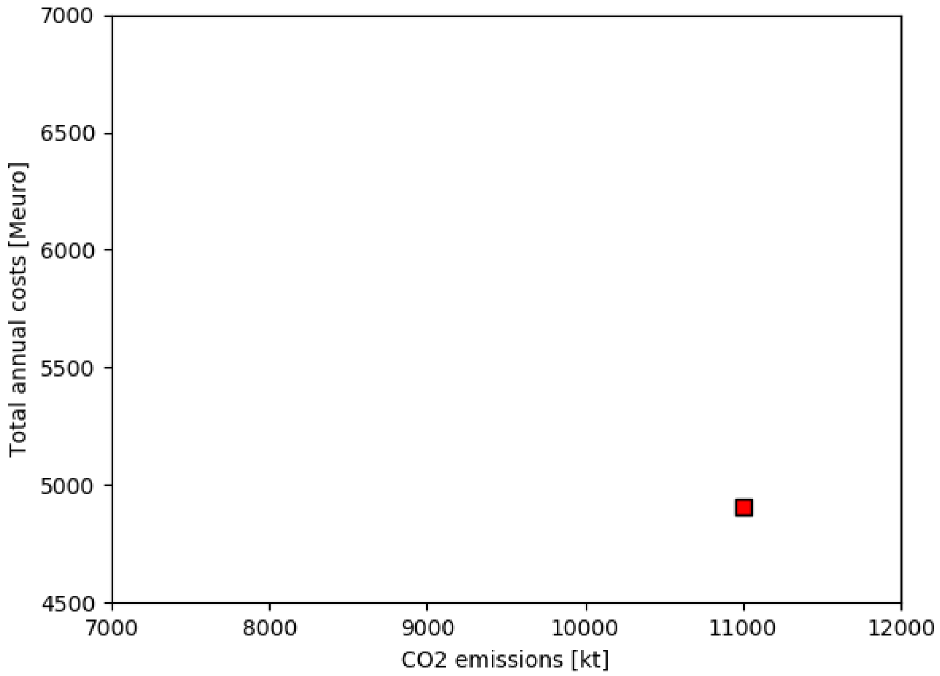
The model

Model n objectives - Eurac Research

Simulation model + **Optimization model**

EnergyPLAN (Aalborg University)

Multi objective evolutionary algorithm MOEA



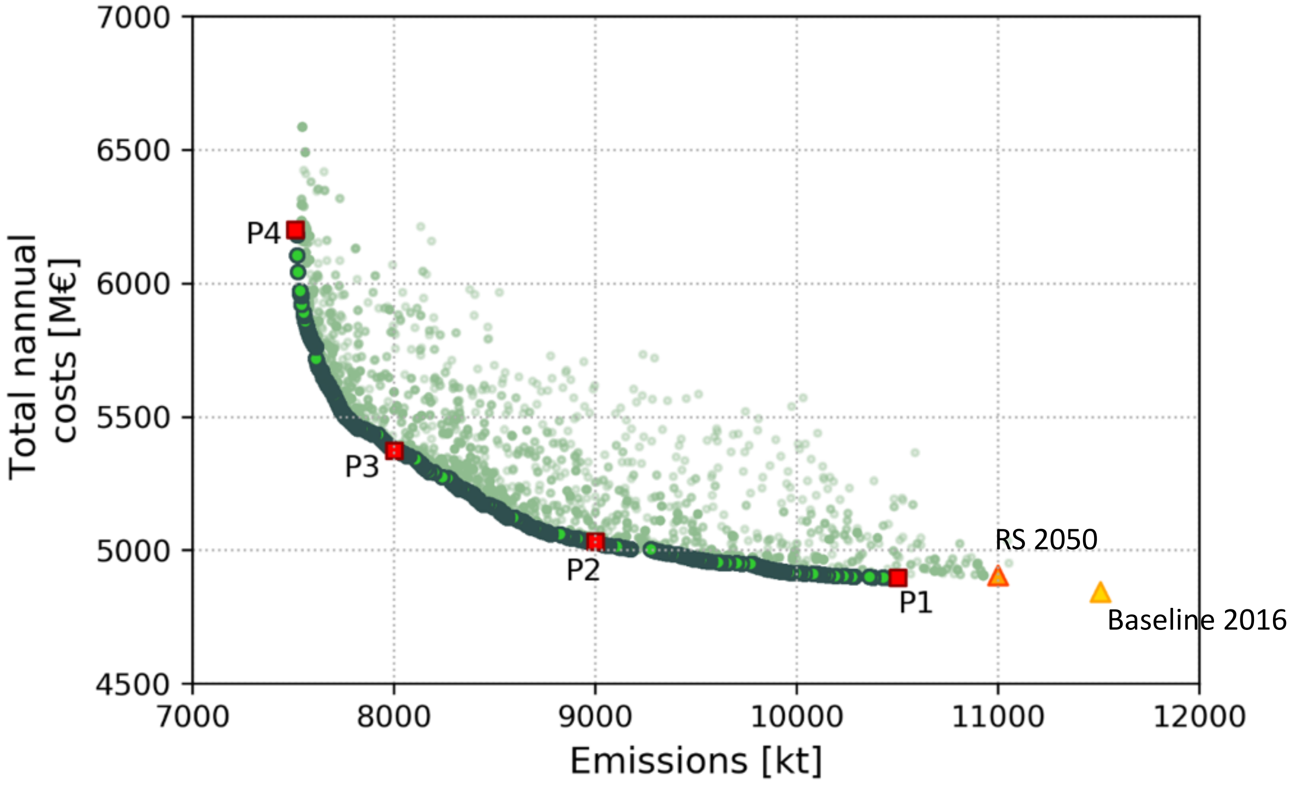
The algorithm tries to find the combination of technologies that reduces **CO_2 emissions** and **costs**. Each point in the graph represents the total cost and total annual CO_2 emissions of a specific combination of technologies of the energy system.

Prina MG, Cozzini M, Garegnani G, Manzolini G, Moser D, Filippi Oberegger U, et al. Multi-objective optimization algorithm coupled to EnergyPLAN software: The EPLANopt model. **Energy** 2018;149:213–21. doi:10.1016/j.energy.2018.02.050.

The decision variables

Decision variables	Current value (2016)	Maximum potential
Residential PV [MW]	250	4750
Wind power [MW]	1500	4000
Lithium-ion batteries [GWh]	0	20
Power to gas, H2 produced [%]	0	15
Power to gas, Electrolyser max capacity [MW]	0	250
Solar thermal [GWh]	450	800
Energy efficiency of buildings [%]	0	75
Heat pumps [%]	0	100

Results of system simulation by optimizing the power and heat sectors

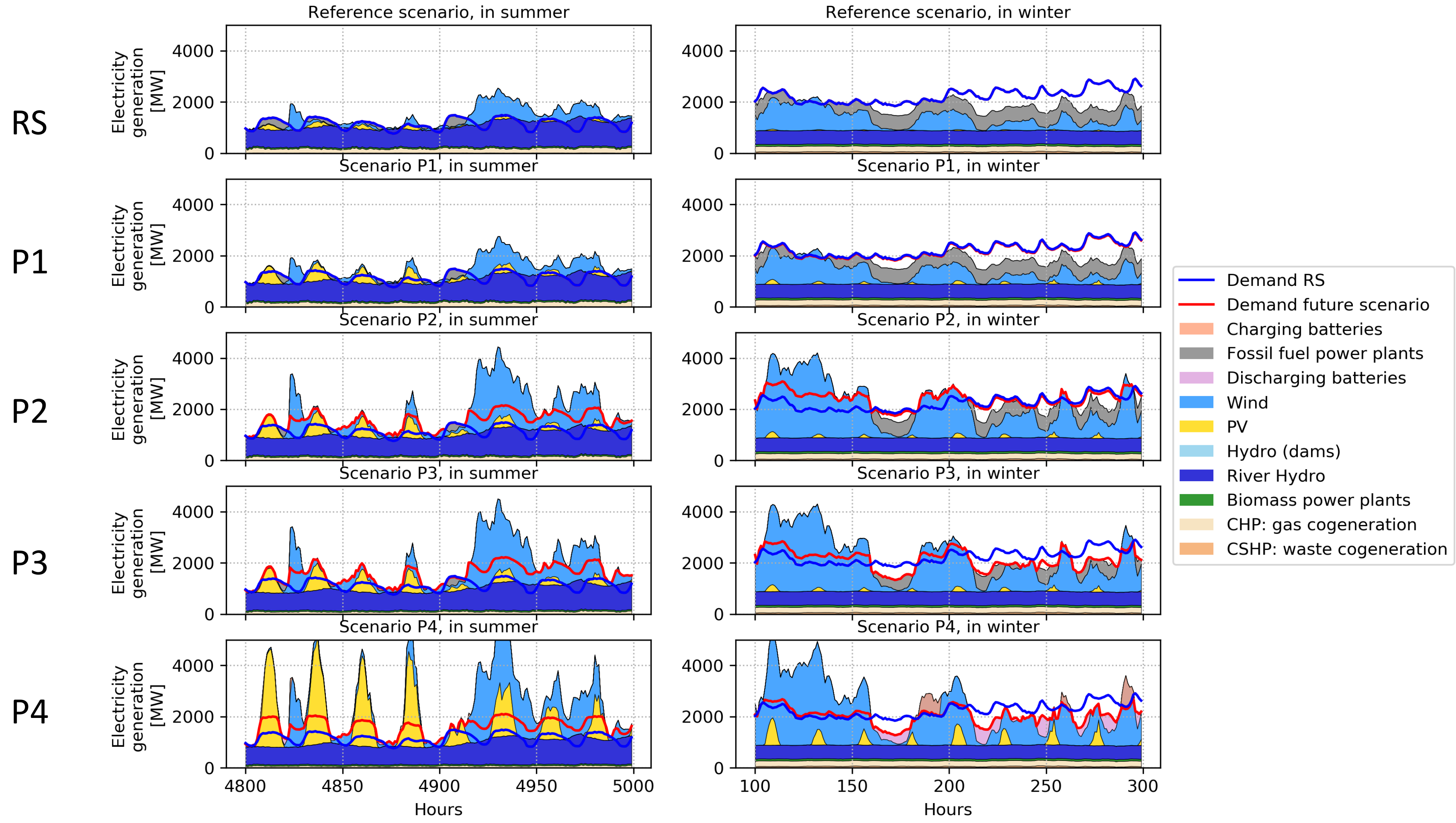


- Each point in the cloud represents the **annual cost** and **CO_2 emissions** of a specific energy system scenario (combination of exploited potential of each renewable energy sources and energy efficiency measures).

Baseline = reflects the current state of the energy system (for this study is the **year 2016**).

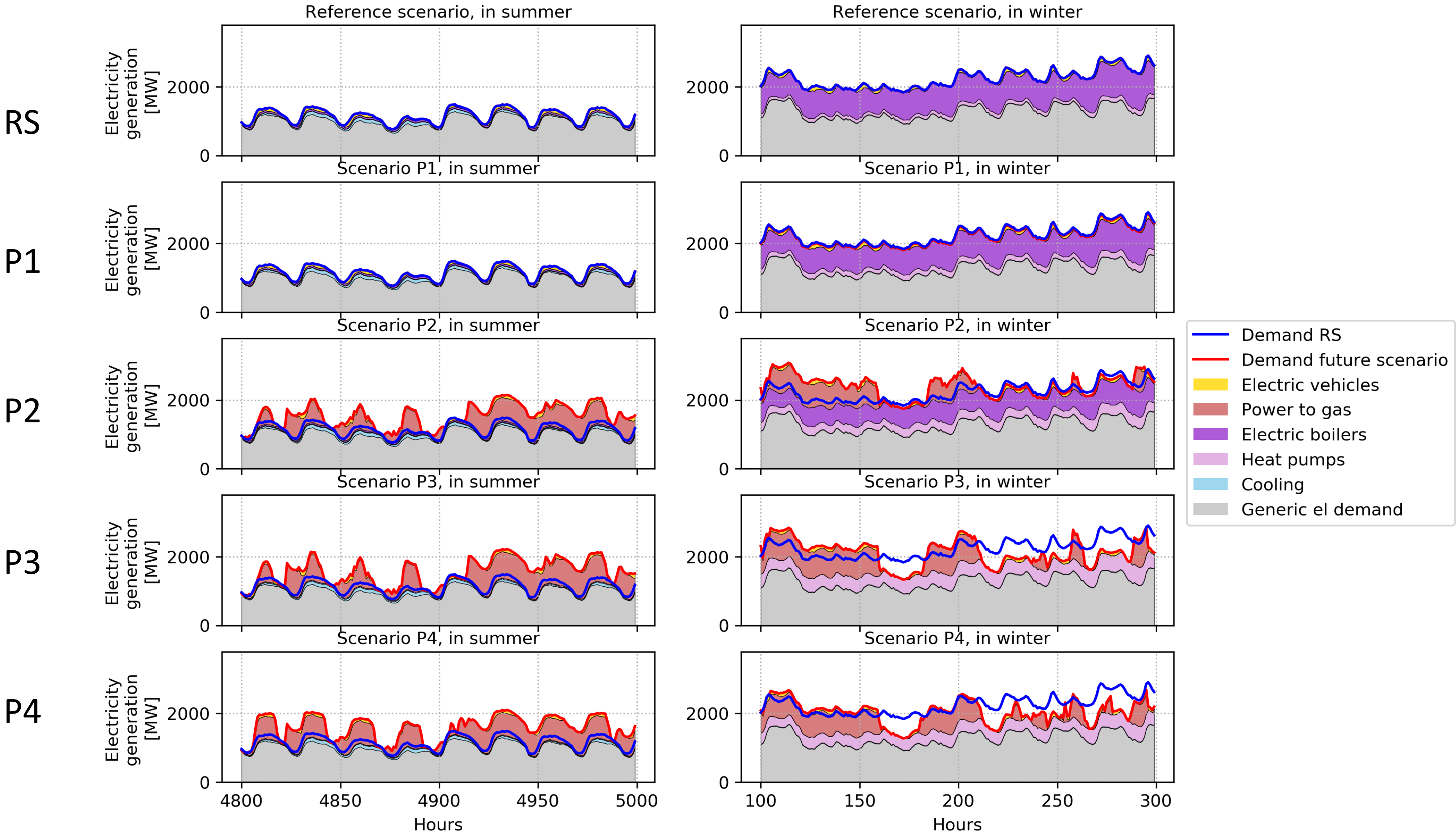
Reference scenario (RS)= describes the future energy system (for this study is the **year 2050**) preserving the energy mix of the baseline.

Electricity production in various scenarios



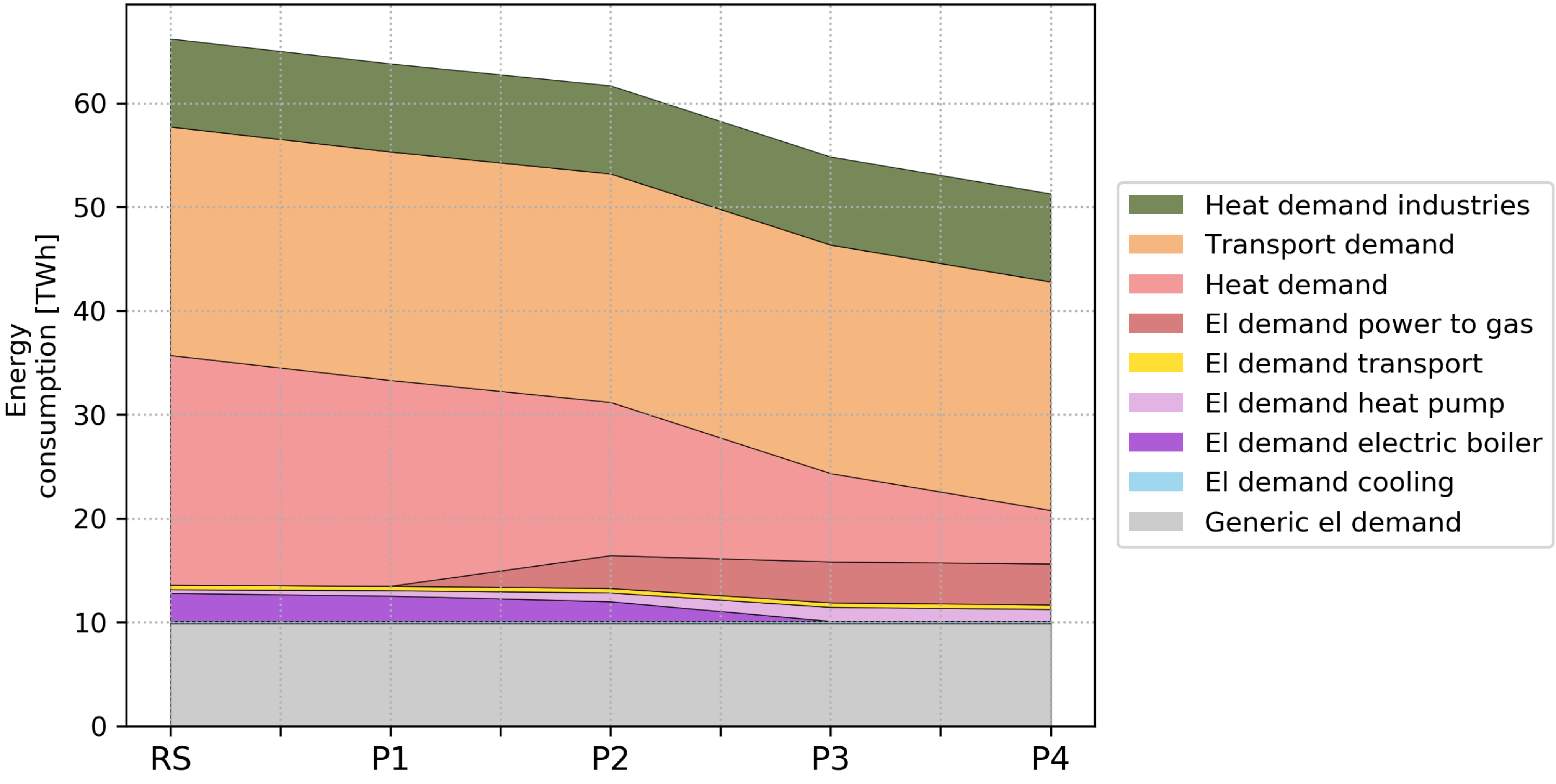
Scenarios P1 - P4 are characterised by the gradual increase in the use of renewable resources, in particular wind and solar energy (shown in light blue and yellow)

Electricity demand in various scenarios



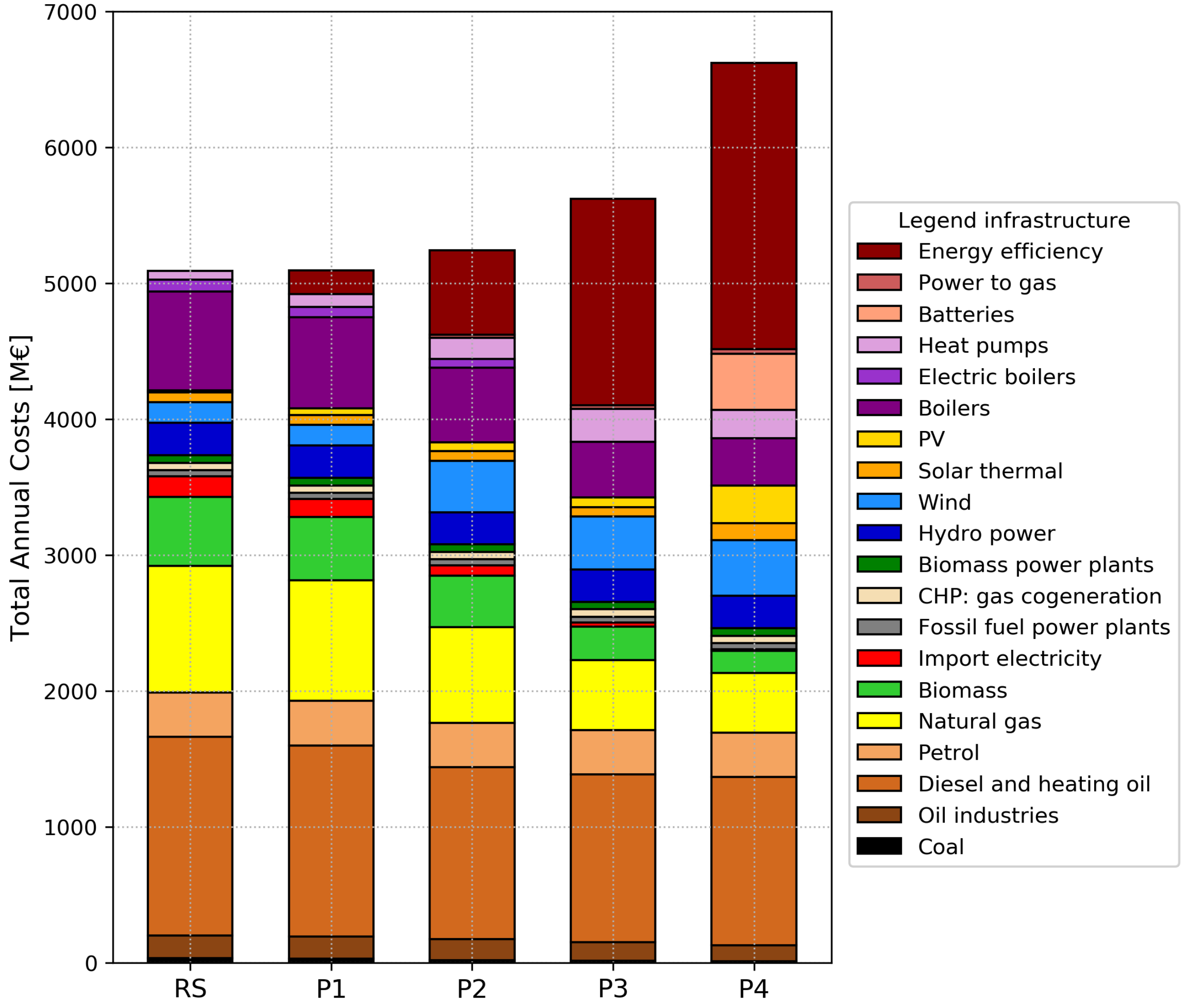
Scenarios P1-P4 are characterised by a decrease of the electricity consumption of electric boilers and an increase of the consumption of heat pumps and power to gas

Total energy consumption – a focus on electricity and heat



The graph shows the significant reduction of heat demand due to the gradual increase of passive energy efficiency measures in buildings. Electricity demand increases with heat pumps and power to gas. EVs in the transport sector are yet not considered.

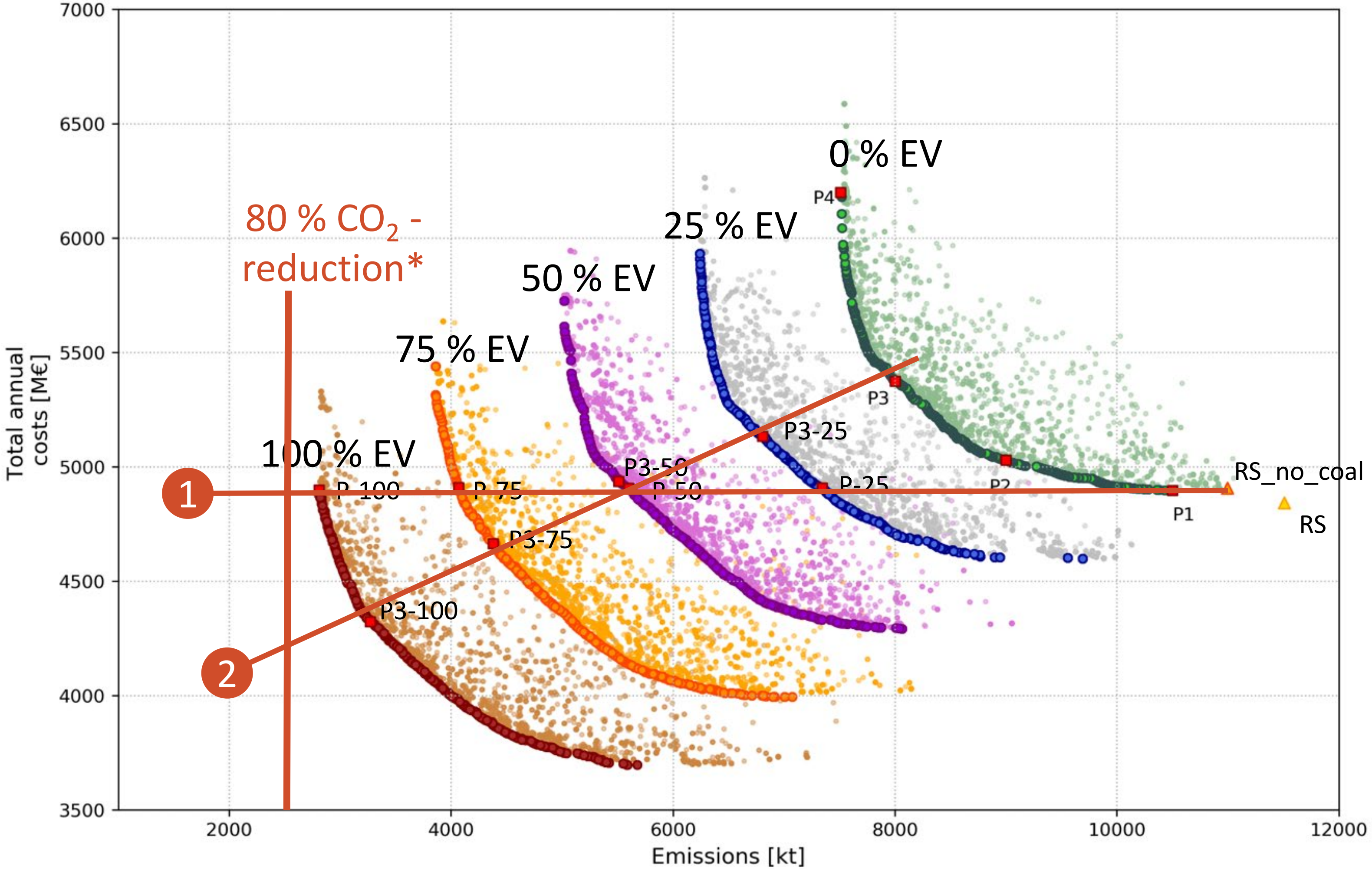
Cost structure changes in the different scenarios



Energy efficiency measures and **heat pumps** investments costs **raise** gradually thus inducing a significative **reduction** of purchasing costs for **natural gas** and heating **oil**. A cost **increase** in the electricity sector is visible due to **solar** and **wind** energy, in scenario P4 also by the use of batteries. Power to Gas is barely noticeable from a cost viewpoint. The transport sector has not yet been considered.

Considering zero emission mobility

Results System Simulation - Integration of E-Mobility

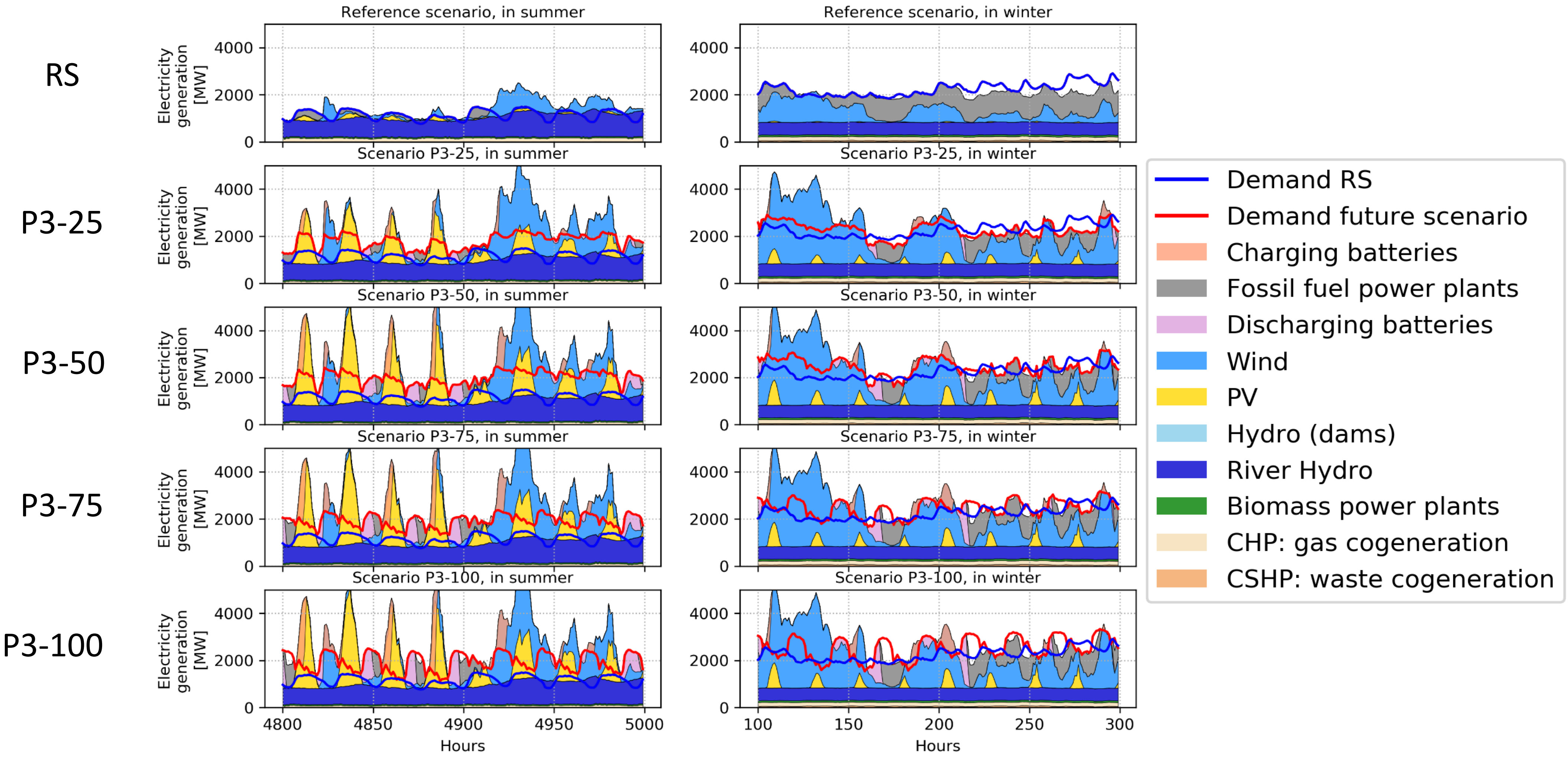


The individual curves result from a gradual increase in e-mobility of 0, 25%, 50%, ... of the total annual driven kilometres.

The increase in e-mobility leads to a gradual reduction of emissions and to a reduction of the total costs based on the high efficiency of electric motors and the reduction of fossil fuels.

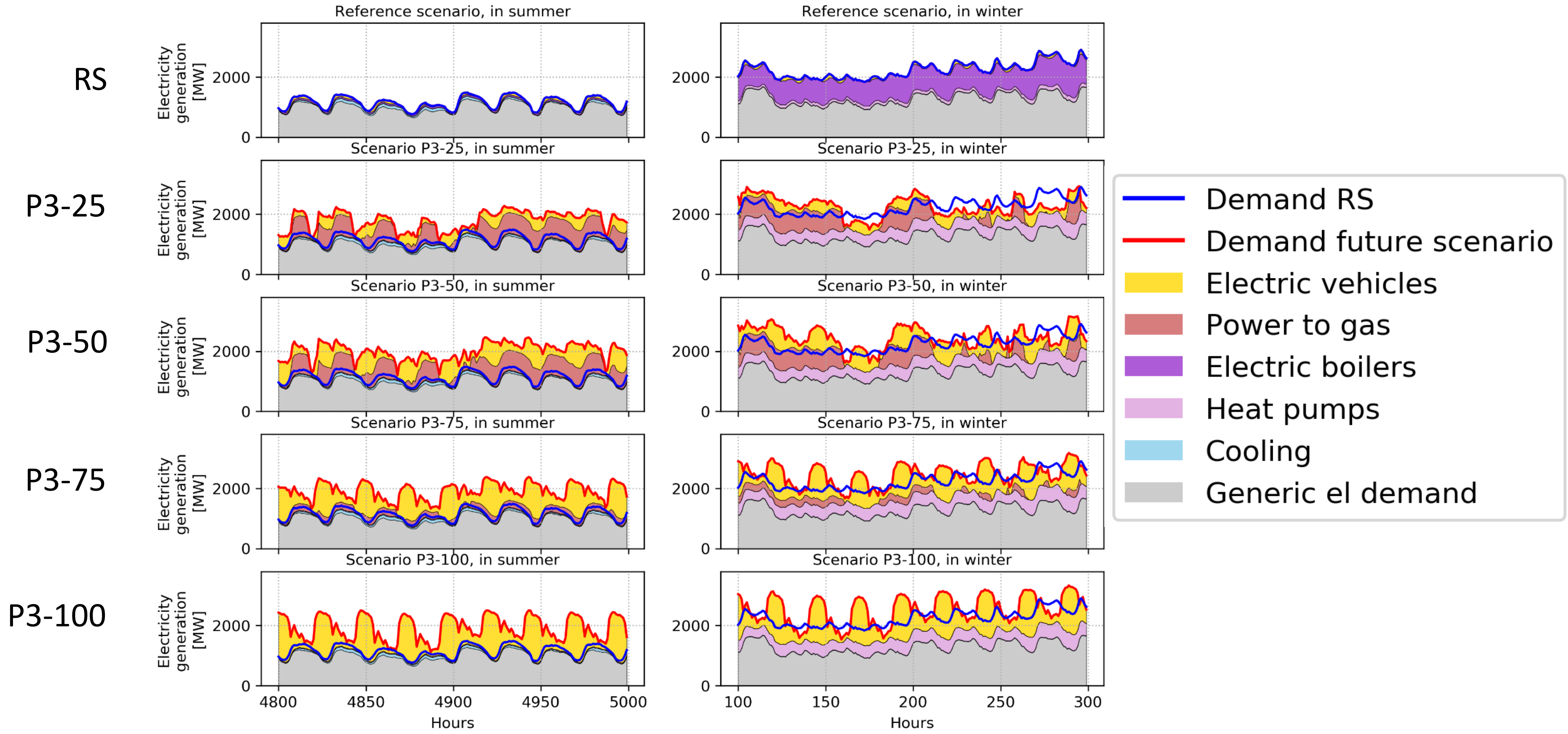
Even in the final scenario, the target set cannot be achieved without the inclusion of energy efficiency measures in the industry sector.

❷ Path 2: Electricity production in different scenarios including transport sector



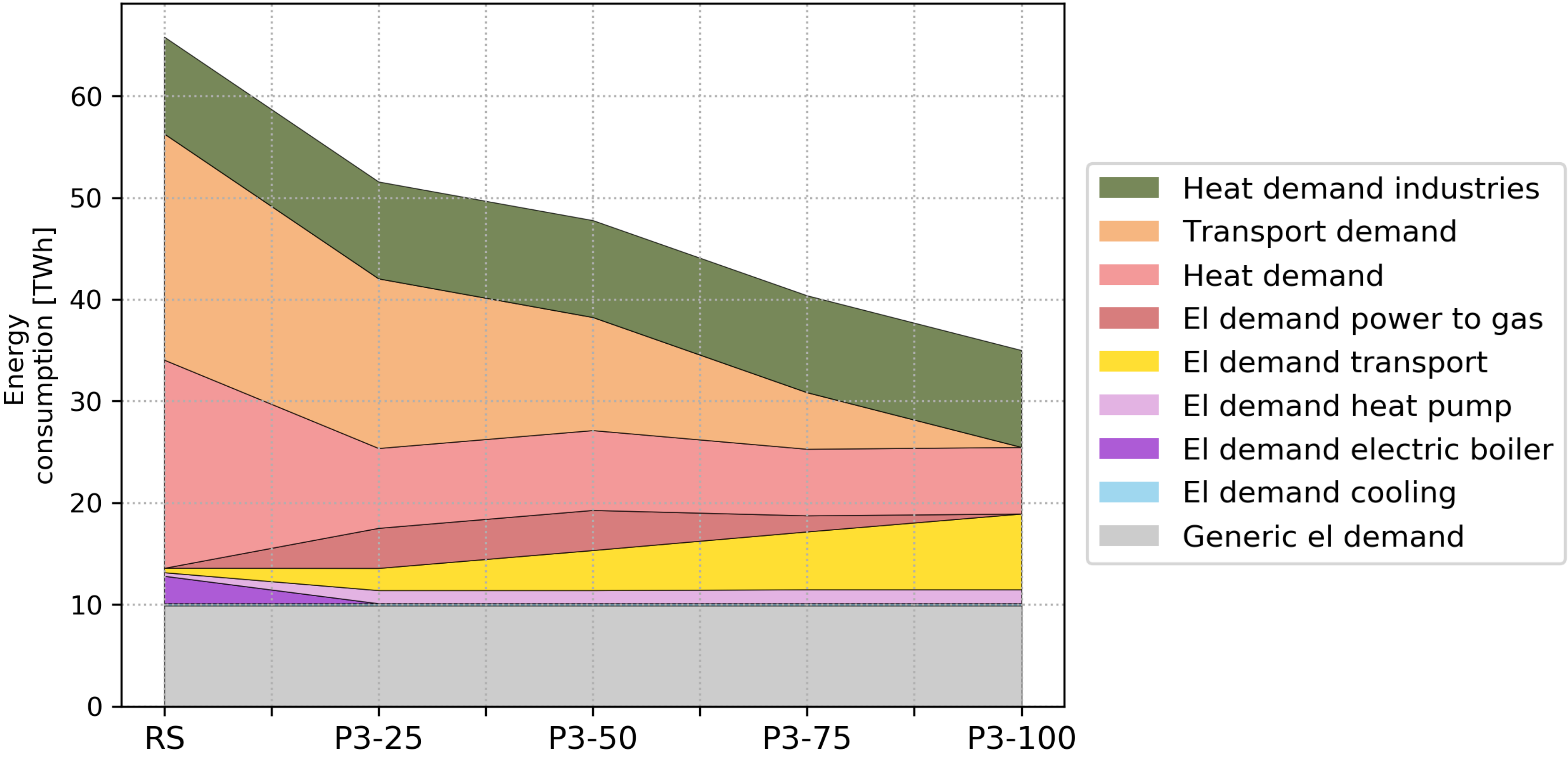
The scenarios with 25% to 100% electrified transport sector are characterised by a even greater use of the existing solar and wind energy potential with corresponding high production peaks

② Path 2: Electricity demand in different scenarios including transport sector



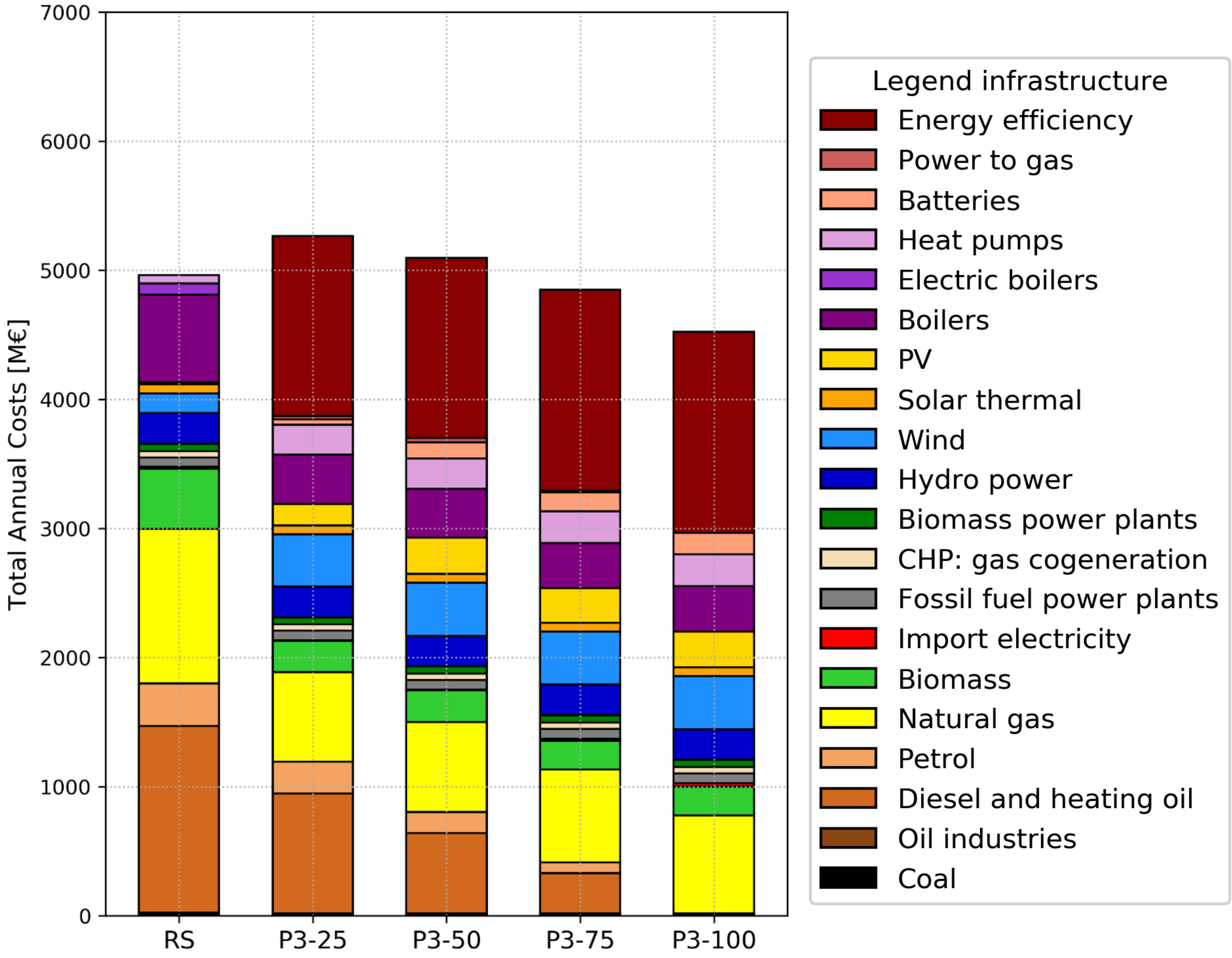
The scenarios with 25% to 100% electrified transport sector are characterised by an increasing demand for electricity, and a demand for power to gas that initially assume a relevant role for then disappearing at high penetration of e-vehicles

❷ Total energy consumption – a focus on electricity, heat and transport



The graph shows the significant reduction in heat demand and the decreasing fuel consumption due to increasing electrification of the transport sector. Power-to-gas rises and falls, the electricity demand in the transport sector increases.

② Change in the cost structure – a focus on electricity, heat and transport

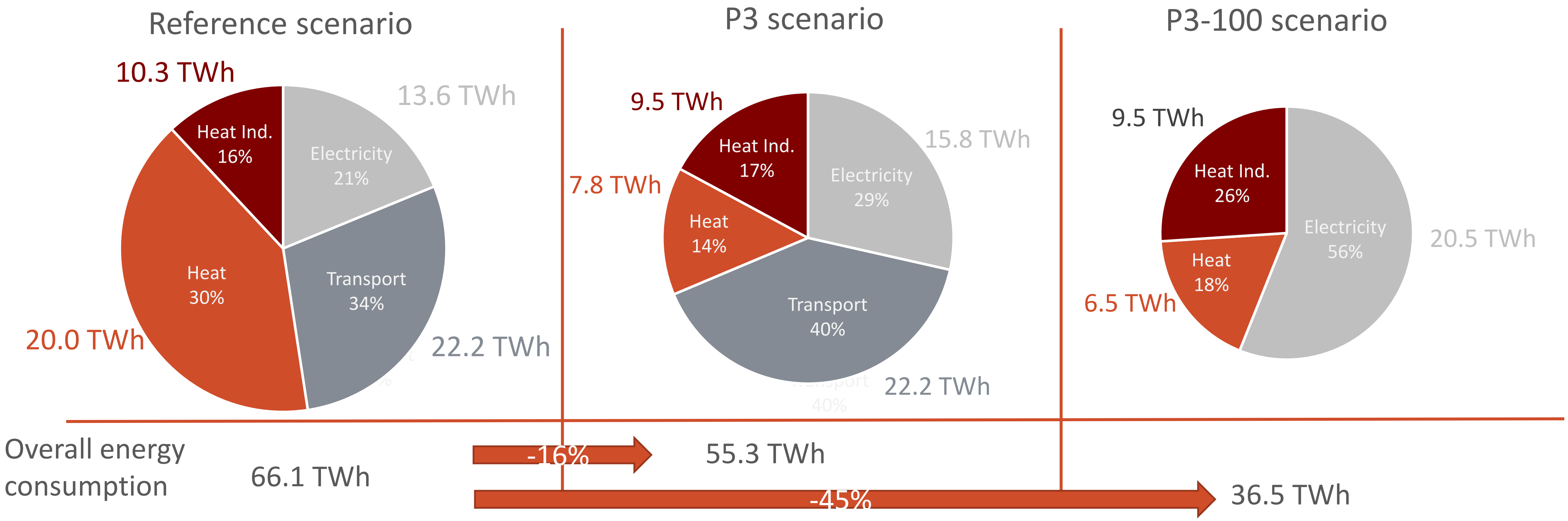


The graph shows the change in the total cost of the energy system in each scenario.

The gradual increase in electrified transport sector causes a significant reduction in gasoline and diesel consumption in addition to the decline of fossil heating fuels due to buildings renovation.

Due to the high efficiency of electric vehicles, the necessary increase in power consumption and associated costs is much lower, resulting in a step-by-step reduction in the total energy system cost of approximately 10%.

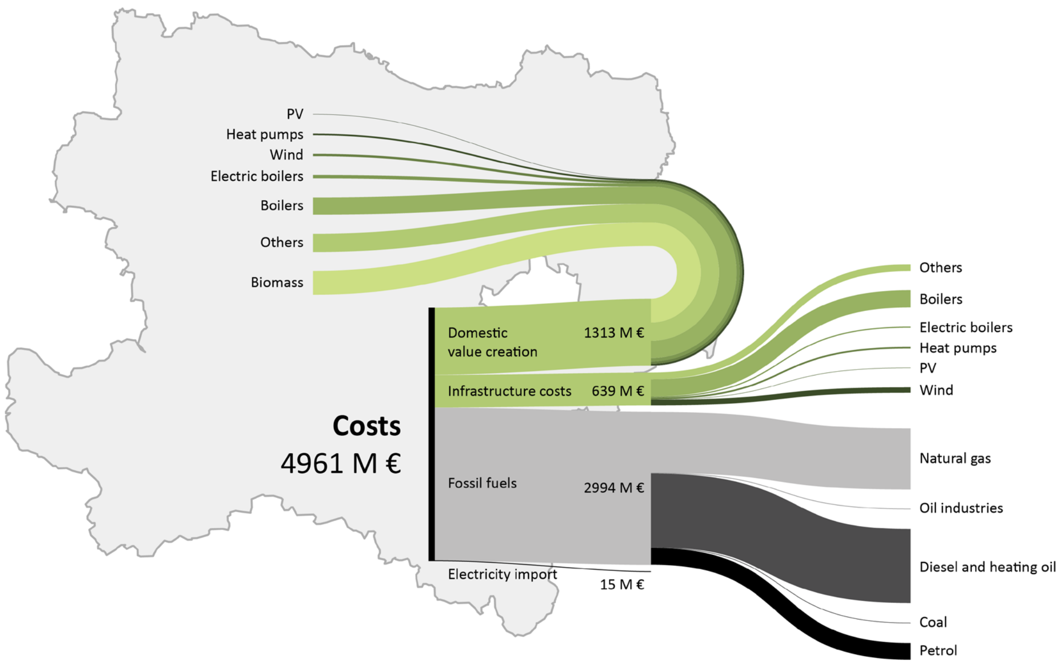
Evolution of total energy consumption in three scenarios



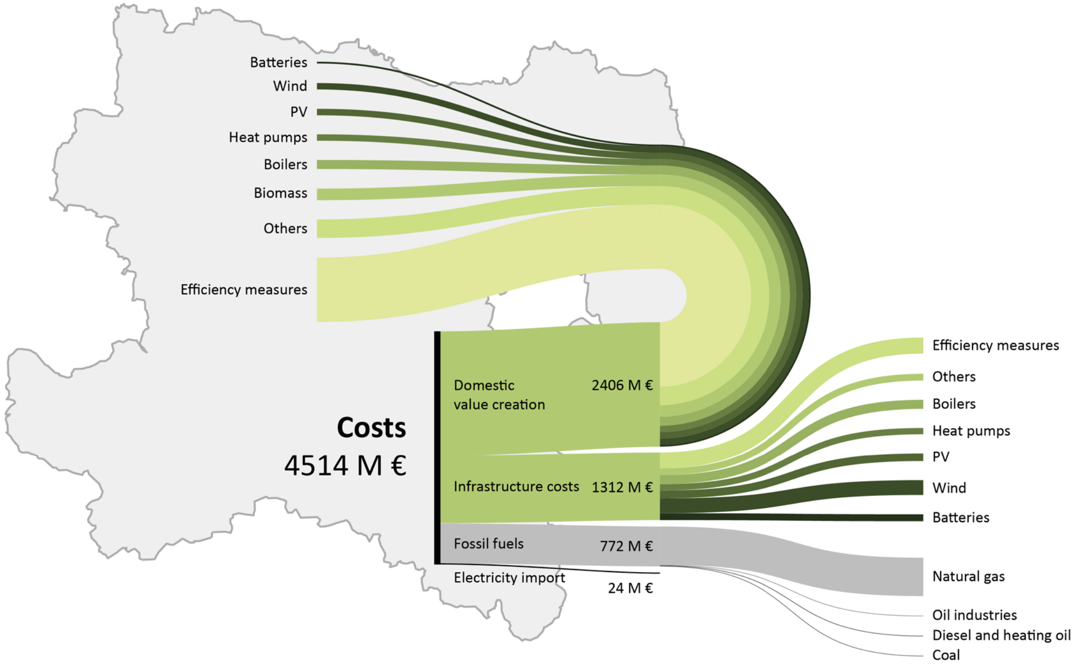
The graph shows the **reduction of total energy consumption** in the three scenarios. The share of the individual energy sectors changes significantly showing: decreasing heat demand and decreasing energy demand from transport by internal combustion engines with related **increasing electrification** of the energy system

Cost Structure - Reference Scenario

Reference Scenario



P3-100



Subdivision of investments in the region and import of technology and raw materials

Key messages (1/2)

- The objective of 80% emission reduction is an ambitious target that can be met only with a strong sustainable transformation of the energy system

- The key transformations are
  - Energy efficiency of buildings
  - Electrified transport sector
  - A deep exploitation of the renewable energy potential
  - Contribution to decarbonisation from the industry sector

Key messages (2/2)

- Electric mobility cannibalizes power to gas due to the reduction of the available overgeneration from RES

- The transformation is a relevant economic opportunity as a large shift from costs for fossil fuels to investments in on place technologies and infrastructures is taking place

Thank you for your attention

M. G. Prina, R. Vaccaro, D. Moser, W. Sparber
matteogiacomo.prina@eurac.edu

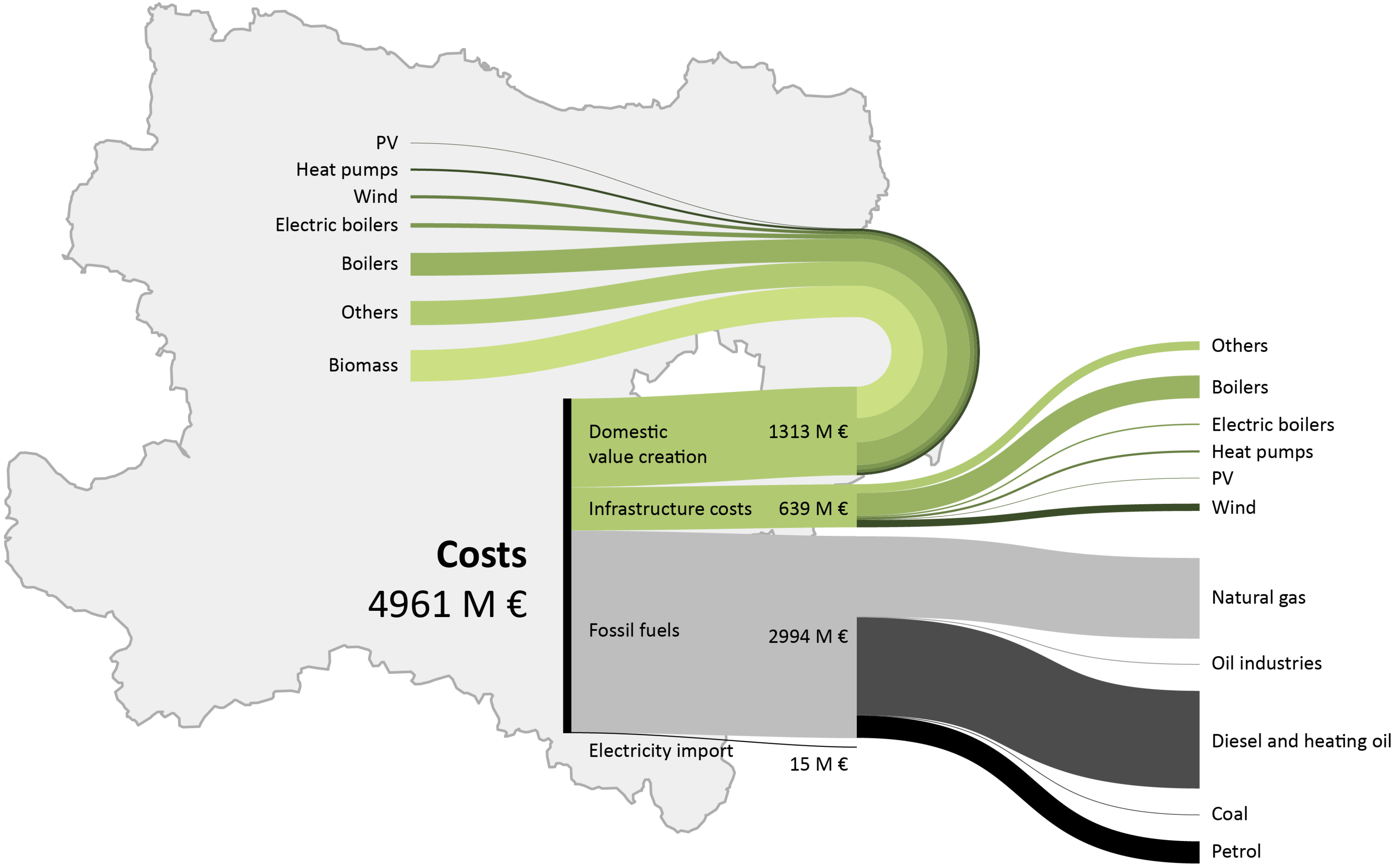
Our thanks to A. Segata (Eurac research) for taking care of this presentation from the graphical point of view (particularly, slides 2 and 18)

Our thanks also to the public administration of Niederosterreich for the permission of publishing these results.

KLIMA- UND ENERGIEPROGRAMM

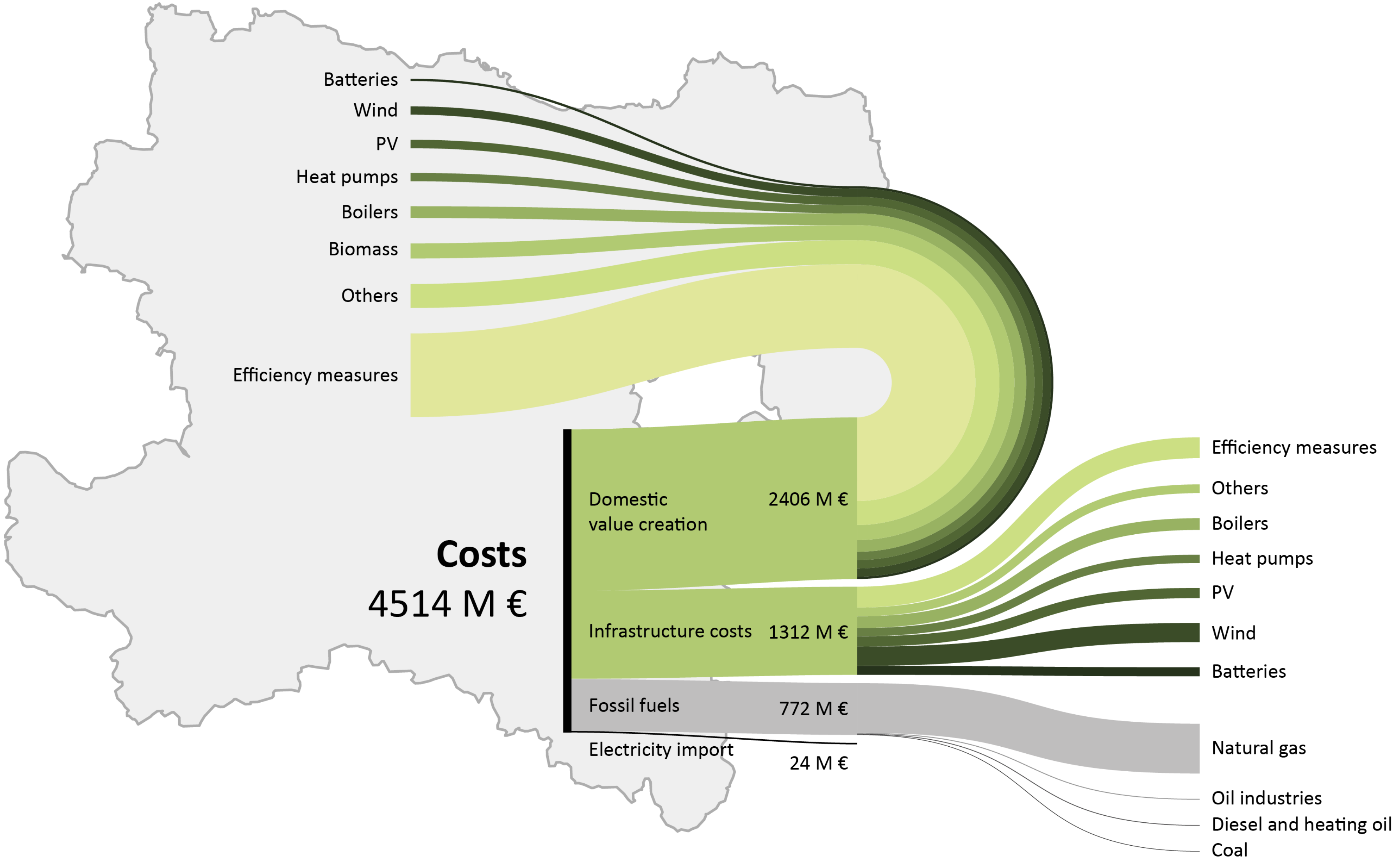
eurac
research

Cost Structure - Reference Scenario



Subdivision of investments in the region and import of technology and raw materials

Cost structure - target scenario (P3-100)

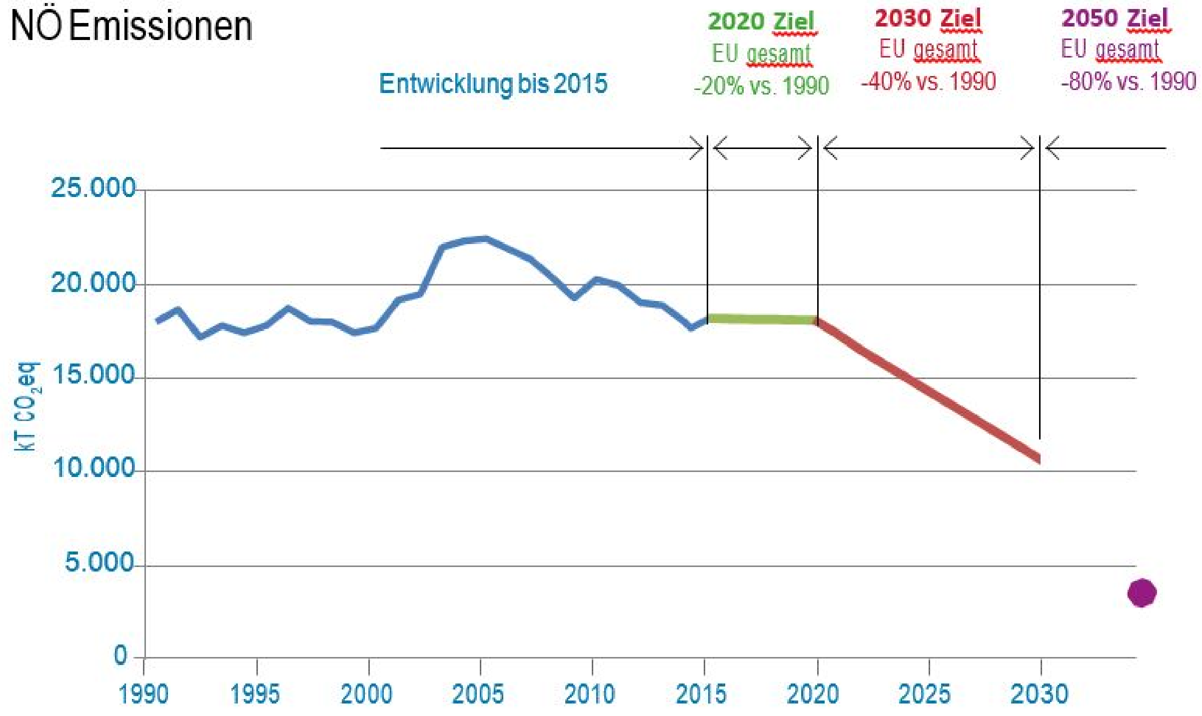


Subdivision of investments in the region and import of technology and raw materials

NÖ Climate plan

Target

-80% emissions
at 2050 in respect
to value of 1990



Source: Klima- und EnErgiEprogramm, November 2017

Niederösterreich 2050

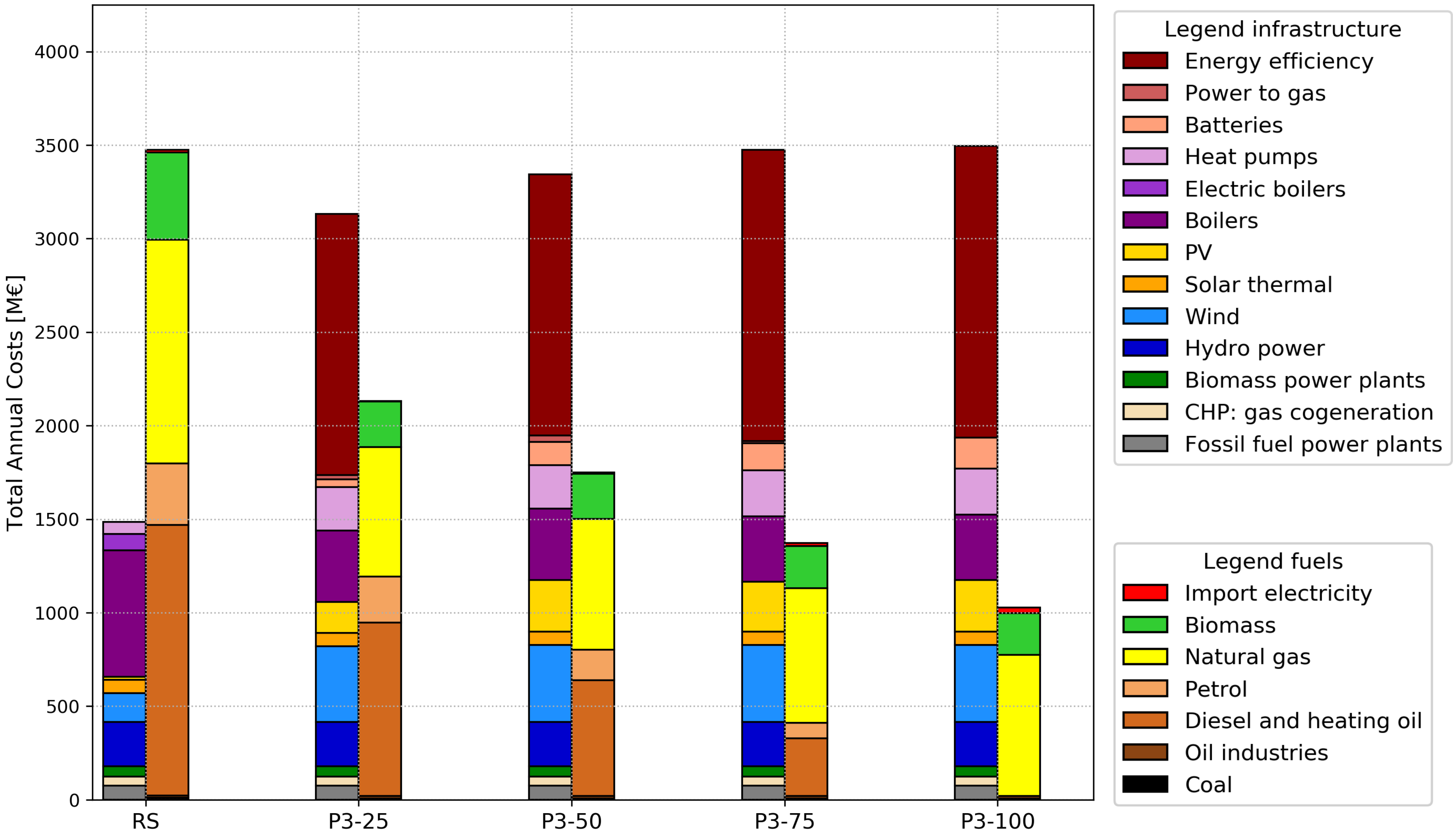
Durnstein Niederösterreich | Source: Chris De Wit, www.goodfreephotos.com

Reference year: 2016

Variable	Source	Source year
Capacity, generation of different sources renewable and not	Niederösterreich, Energiebilanz 2016	2016
Overall annual electric and thermal energy consumption	Nutzenergieanalyse 2016	2016
Hourly profiles: District heating demand, electricity demand, wind power, PV, Hydro and biomass	Data provided by NÖ Landesregierung - RU3	2017
Energy efficiency curve in the building sector	EURAC research elaboration from different sources – details reported in annex 1	2014
Costs	EnergyPLAN database	2050

Appendix 1 contains a detailed list of hourly profiles and sources

❷ Analysis - Development of raw material costs and investment costs

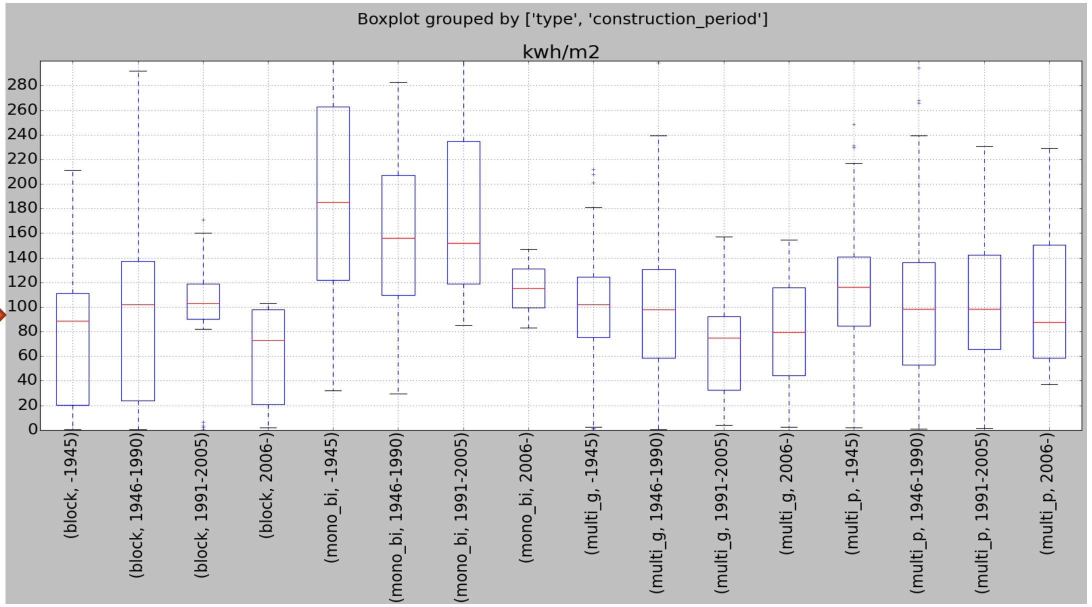


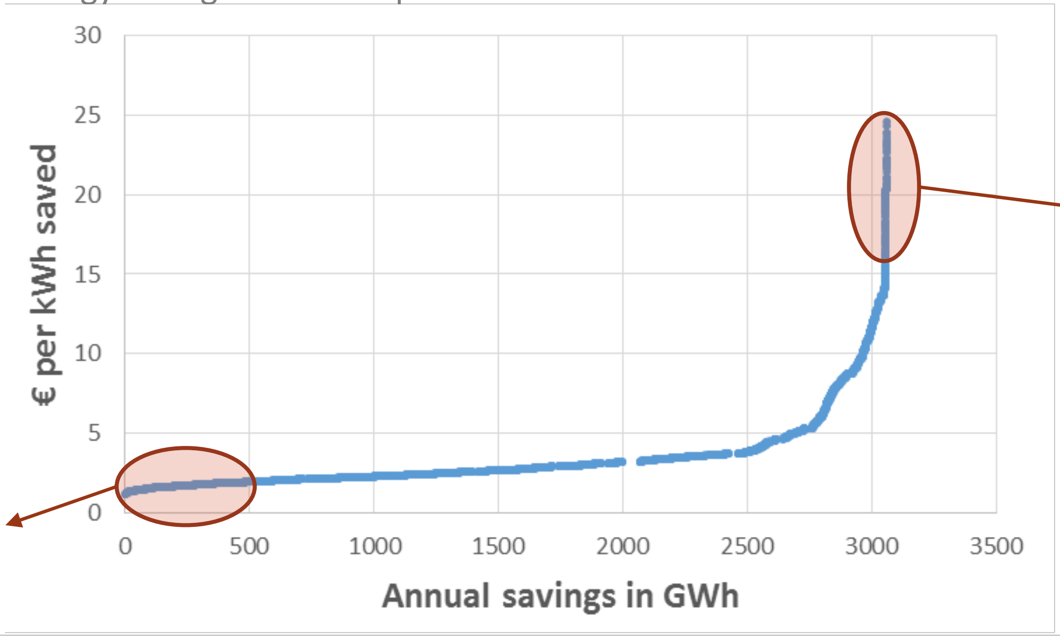
The chart shows how the gradual decrease of energy system emissions reduces fossil raw material costs while increasing investments in regional infrastructures (especially building efficiency and renewable energy production).

Thus also significantly increase the economic added value remaining in the region.

Energy efficiency

1. **Analysis and classification** of the provincial residential **building stock: construction period**, the **types of buildings** (single family house, multi family house, detached, block) and the heating degree days (**HDD**).
2. **Evaluation** of the **specific heat consumption** for each municipality, construction period, and type of buildings.
3. **Assessment of the cost of retrofit** and the **actual energy savings** associated to retrofit measures (through Passive House Planning Package (**PHPP**) **simulations** launched to evaluate the thermal energy consumption in post-retrofit conditions)
4. **Assumption** that the **energy saving percentage** is **the same regardless** of the **municipality** and the **construction period** of the buildings.
5. Possible to calculate the **annual thermal energy savings** for each construction period and type of building and also the value of the **euro per kWh saved**. The results obtained show therefore higher values of energy savings for municipalities with colder climates.





Measures that produce low energy savings compared to the costs (window replacement for new houses)

Measures that produce high energy savings compared to the costs (roof insulation for old SFH built before 1946, façade insulation and basement insulation)