Joint Activity Scenarios & Modelling

Schweizerische Eidgenossenschaft
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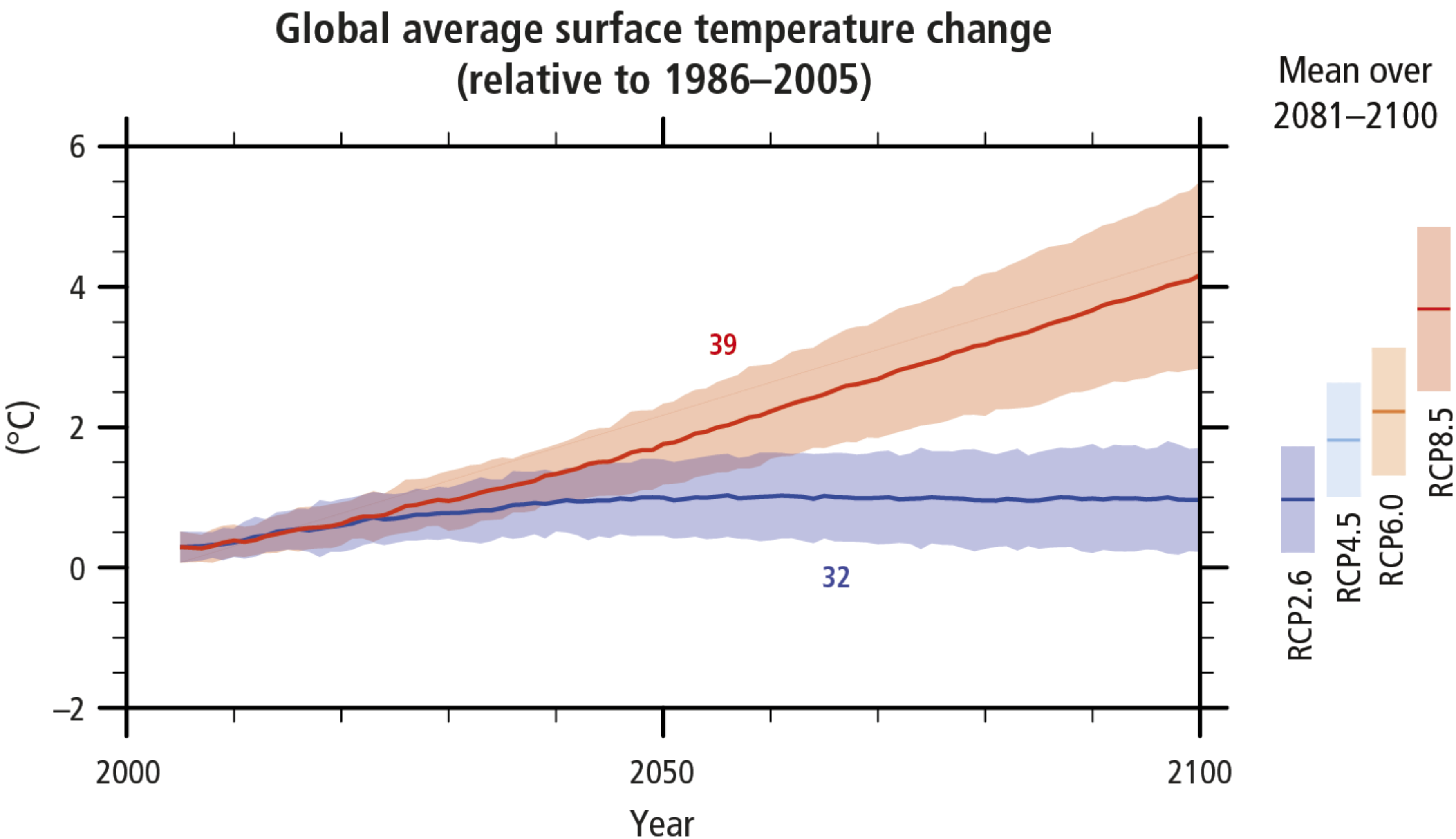
Agenda

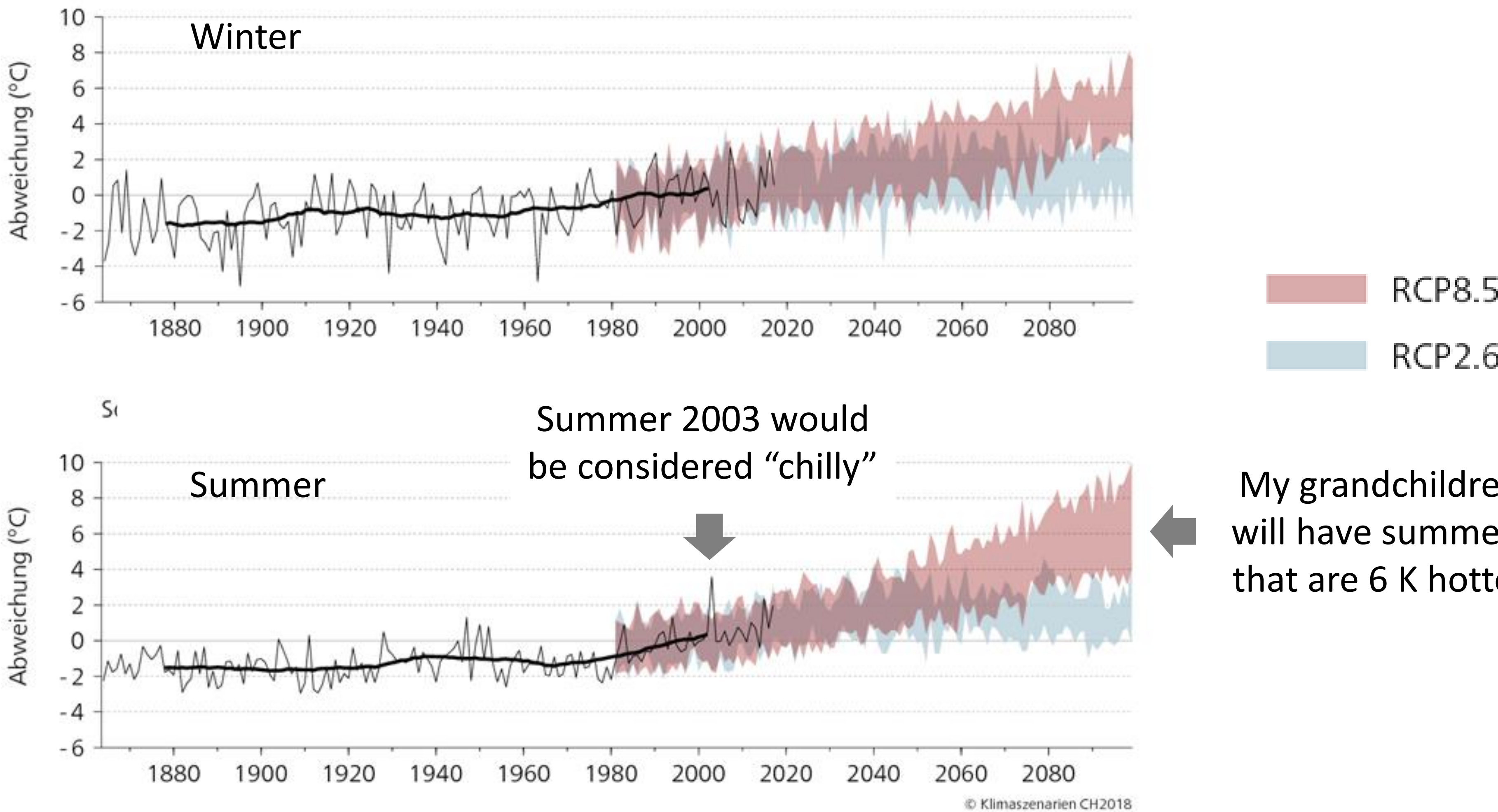
10:00	**Registration and coffee**	
10:15	Welcome	Domenico Giardini (ETHZ)
10:20	Energy Strategy 2050: Perspectives and Policies	Anne-Kathrin Faust (SFOE)
10:40	Joint Activity Scenarios & Modelling: Approach and first	The JASM team
12:00	**Lunch**	
13:30	Seasonal Heat Storage: the Underestimated Pillar of our Future Energy System	Stefan Brändle (Amstein + Walthert AG)
13:50	Alpiq - Energy with a future	Olivier Chène (Alpiq)
14:10	Integrated Energy System Modelling (Nexus) - Need for scenario inputs and data	Christian Schaffner (ESC)
14:30	National and Local Pathways of the Energy Transition	Ndaona Chokani (ETHZ)
14:50	Heat scenarios in Geneva by 2035: which role can geothermal energy play?	Loic Quiquerez (SIG)
15:10	Seeing beyond total system cost: Welfare effects of technology-based climate policies in liberalized electricity	Frank Vöhringer (econability)
15:30	Panel discussion: How can scenario modelling support the energy transition?	T. Kober, A.-K. Faust, O. Chène, Ch. Schaffner, N. Chokani, F. Vöhringer, D. Giardini, L. Quiquerez
17:00	**End of meeting & Apero**	

Global climate change



Source: IPCC

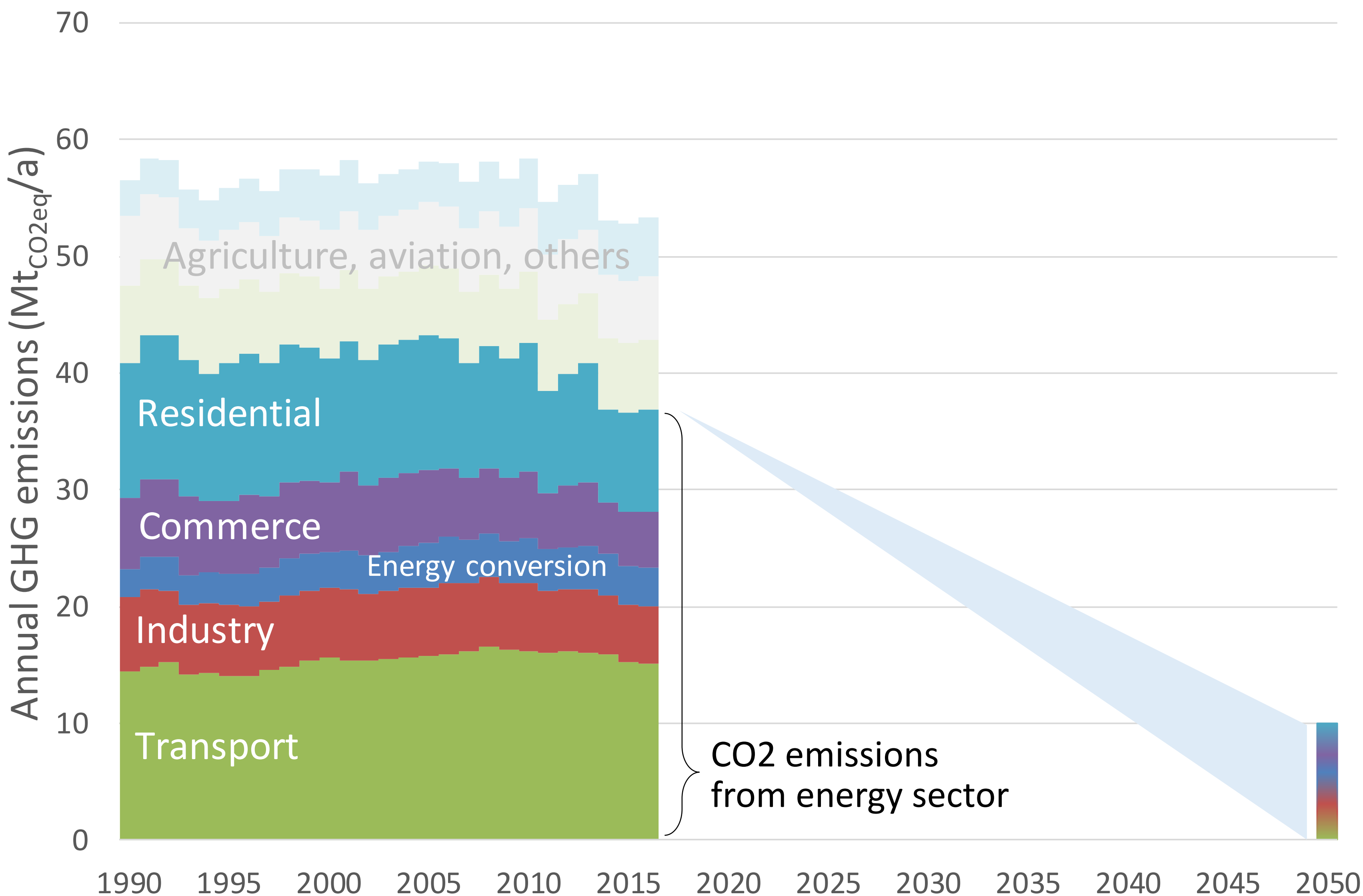
Swiss climate change



Summer 2003 would be considered “chilly”

My grandchildren will have summers that are 6 K hotter

Scope and mission of JASM



Deliver scenarios how Switzerland can reach near zero CO_2 emissions in 2050

Technology

New renewables, storage, efficiency, sector coupling, e-mobility, grids, etc

Measures

Efficiency targets, CO_2 price, feed-in tariffs, ban of technologies, etc

Impact

Micro- and macro-economy, society, landscape, industry

How will energy demand develop?

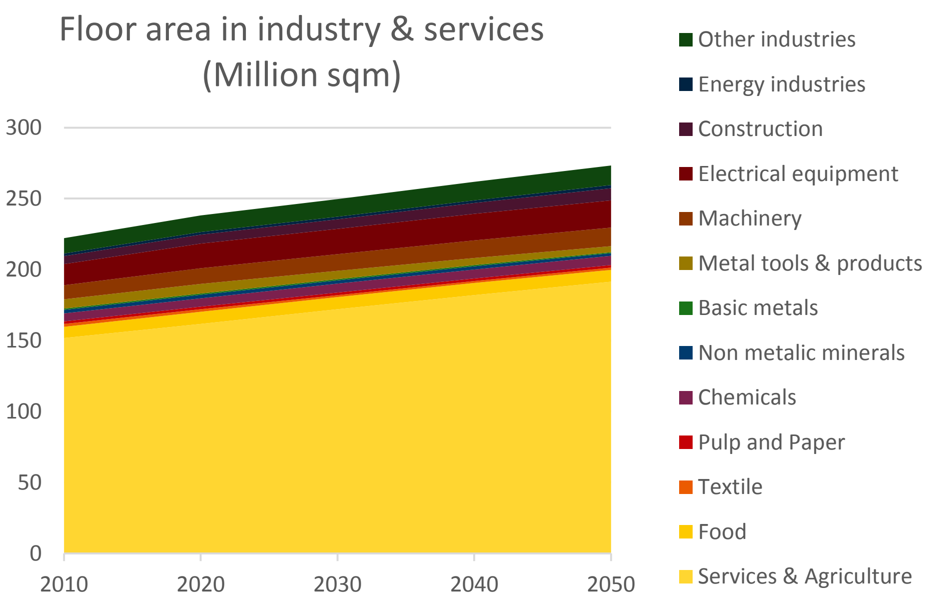
Space heat
Growth of energy reference area, building standards & renovations, change of HDD & CDD with climate

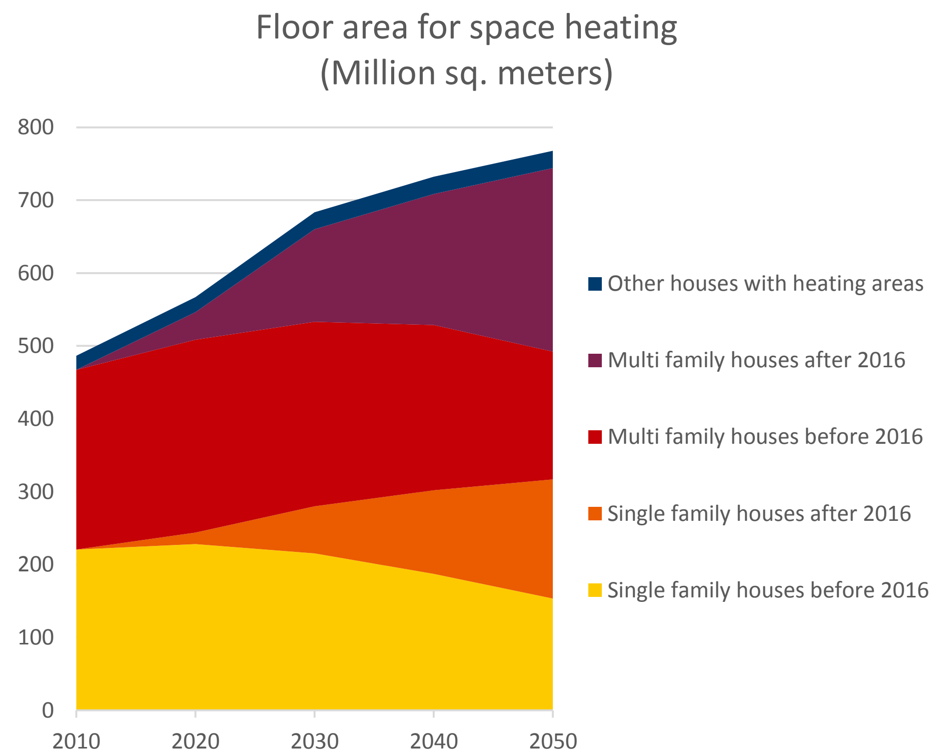
Process heat
Efficiency of industrial processes

Electricity
Development of appliance efficiency standards

Mobility
Following ARE scenarios

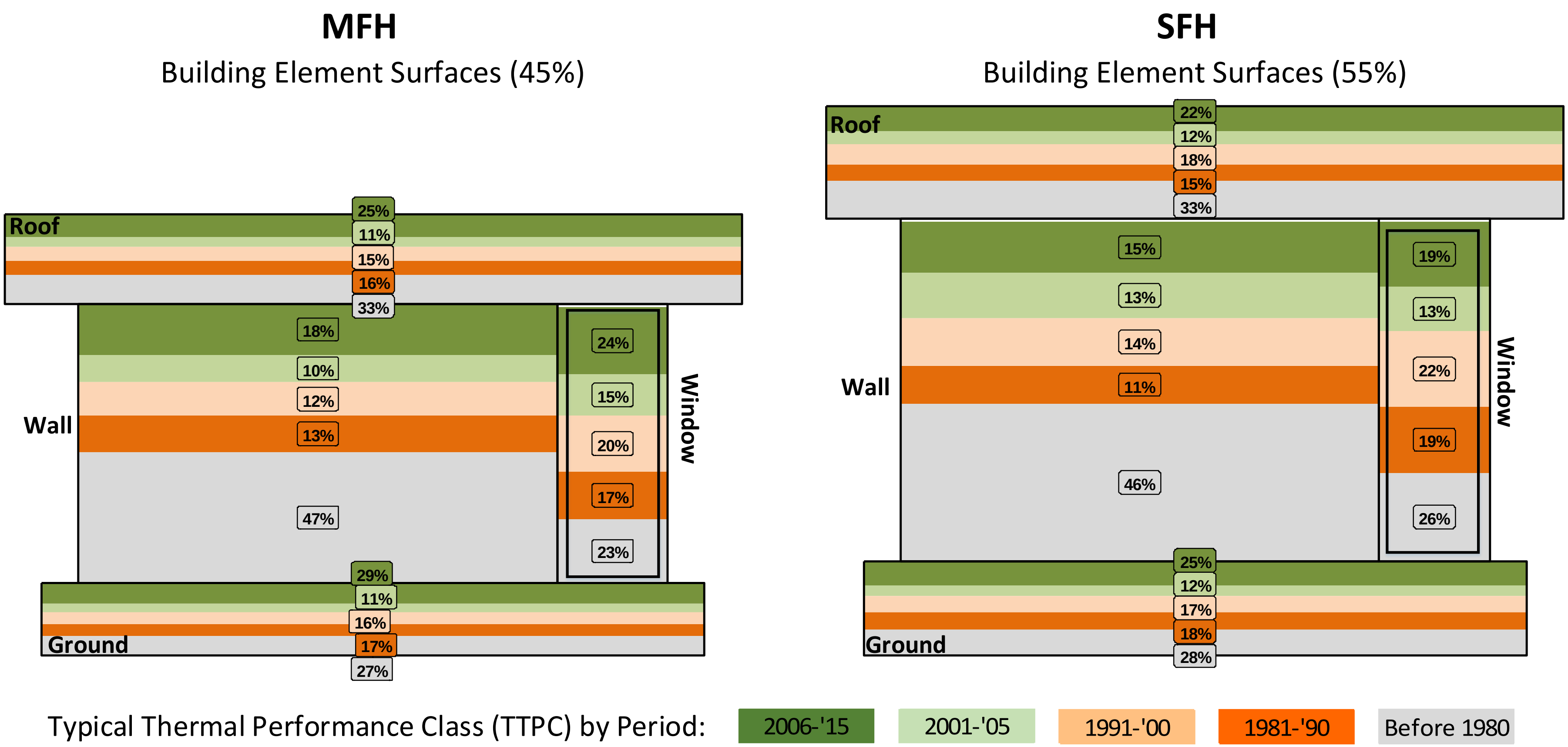
Growth of energy reference area



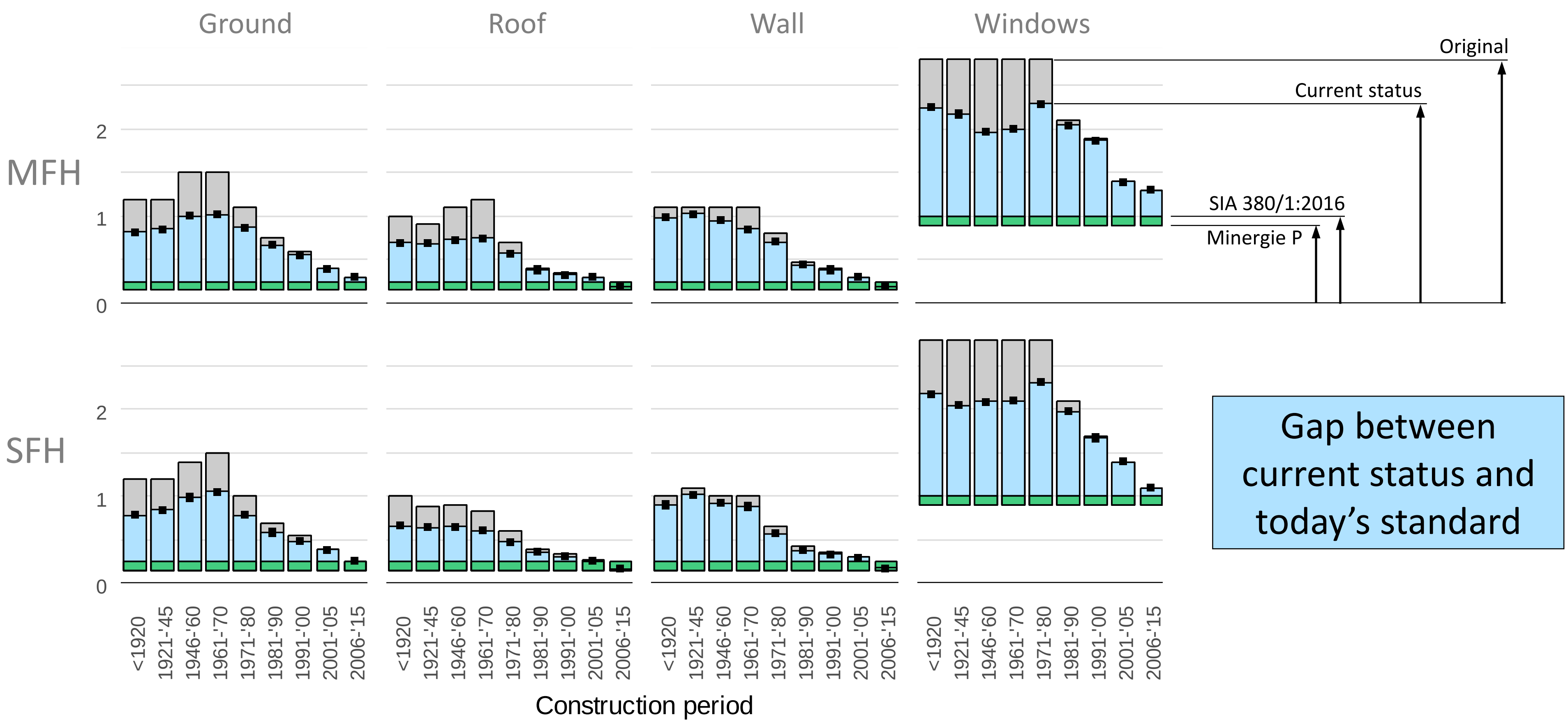


How will building heating demand develop?

Current breakdown of building surfaces



U-values of building surfaces (W/m²K)



Specific space heating demand (kWh/m²a)

JASM

Average Space Heating Demand per ERA and year [kWh/m²a] (FINAL ENERGY)

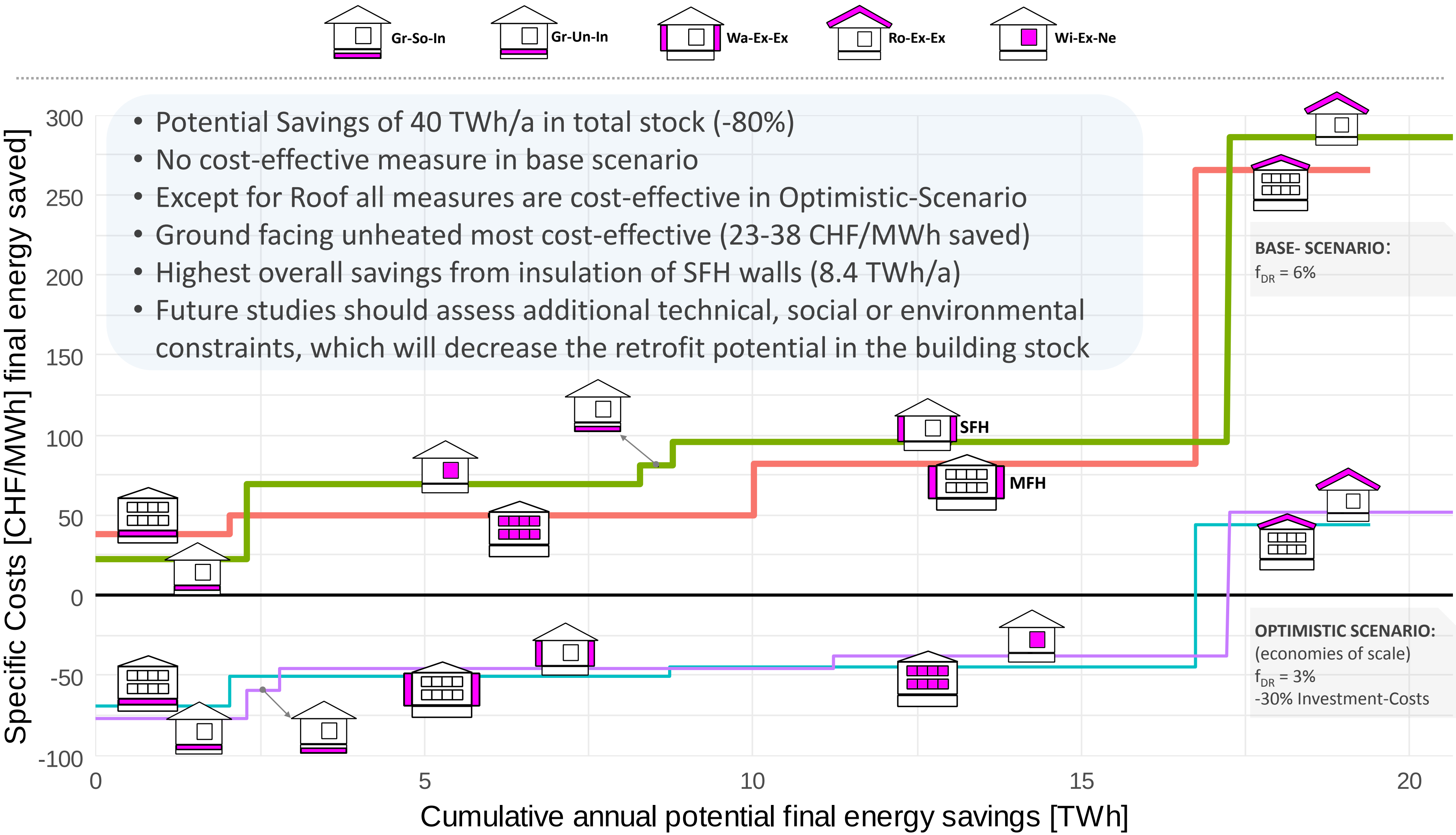
	AGE	URBAN	SUBURBAN	RURAL	AVERAGE	
MFH	≤1920	112	121	145	124	94
	1921-'45	125	144	169	136	
	1946-'60	124	134	151	130	
	1961-'70	104	120	130	115	
	1971-'80	100	111	119	108	
	1981-'90	83	89	92	88	
	1991-'00	72	76	76	75	
	2001-'10	47	48	46	48	
	2011-'18	25	23	22	24	
SFH	≤1920	163	180	199	189	134
	1921-'45	174	182	189	182	
	1946-'60	171	187	197	187	
	1961-'70	178	188	194	189	
	1971-'80	147	150	164	155	
	1981-'90	104	104	112	107	
	1991-'00	79	82	86	83	
	2001-'10	56	50	50	51	
	2011-'18	26	25	25	25	
AVERAGE		103	108	126	112	

Share of Total Swiss Space Heating Demand per year [%] (FINAL ENERGY)

	AGE	URBAN	SUBURBAN	RURAL	TOTAL	
MFH	≤1920	2.5%	2.5%	2.2%	7.3%	46%
	1921-'45	2.6%	1.5%	0.8%	4.8%	
	1946-'60	3.4%	2.6%	0.7%	6.6%	
	1961-'70	2.8%	4.1%	1.1%	8.1%	
	1971-'80	2.1%	3.6%	1.1%	6.8%	
	1981-'90	1.1%	2.5%	0.9%	4.6%	
	1991-'00	0.8%	2.1%	0.9%	3.8%	
	2001-'05	0.8%	1.7%	0.5%	3.0%	
	2006-'15	0.3%	0.6%	0.2%	1.1%	
SFH	≤1920	1.0%	4.4%	7.6%	13.0%	54%
	1921-'45	1.5%	3.3%	2.4%	7.2%	
	1946-'60	1.0%	3.6%	2.3%	6.9%	
	1961-'70	0.5%	3.5%	2.4%	6.4%	
	1971-'80	0.6%	4.0%	2.7%	7.4%	
	1981-'90	0.5%	3.0%	2.3%	5.8%	
	1991-'00	0.3%	2.1%	1.7%	4.1%	
	2001-'05	0.2%	1.3%	1.0%	2.5%	
	2006-'15	0.0%	0.2%	0.3%	0.5%	
TOTAL		22.2%	46.7%	31.1%	47 TWh/a	

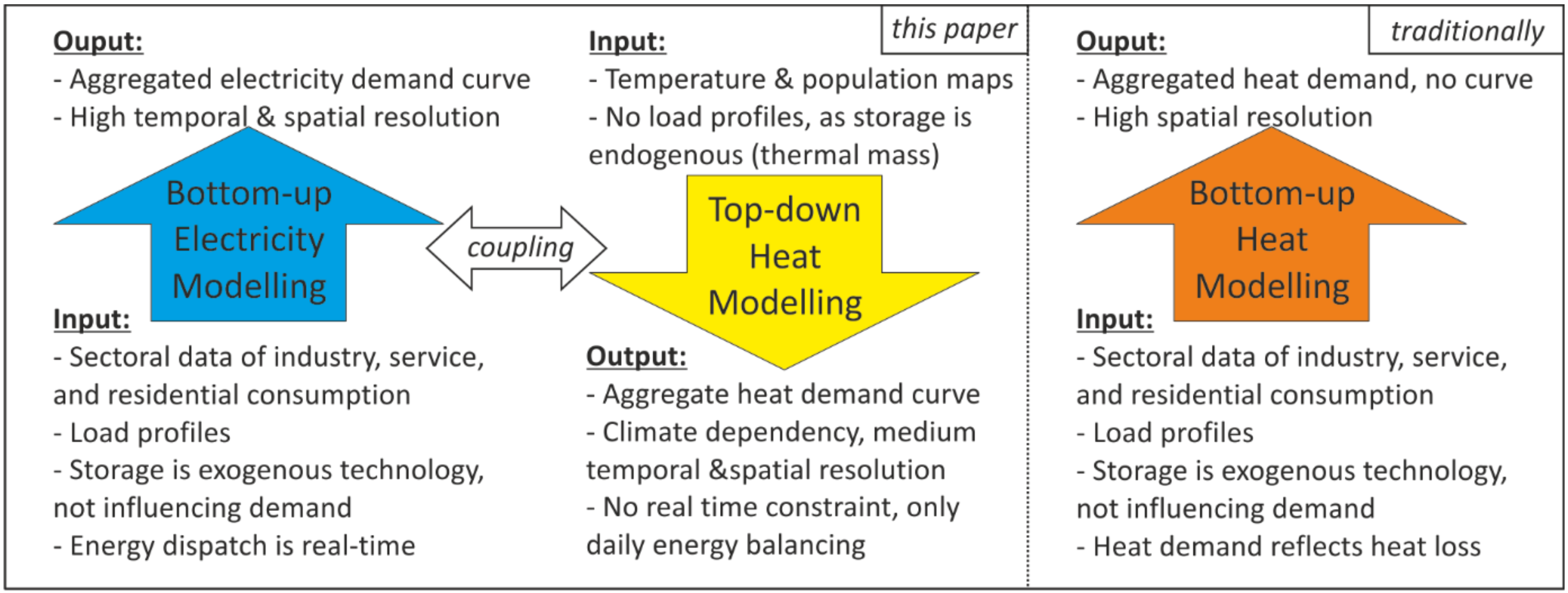
Large-scale retrofit potential

- Potential Savings of 40 TWh/a in total stock (-80%)
- No cost-effective measure in base scenario
- Except for Roof all measures are cost-effective in Optimistic-Scenario
- Ground facing unheated most cost-effective (23-38 CHF/MWh saved)
- Highest overall savings from insulation of SFH walls (8.4 TWh/a)
- Future studies should assess additional technical, social or environmental constraints, which will decrease the retrofit potential in the building stock



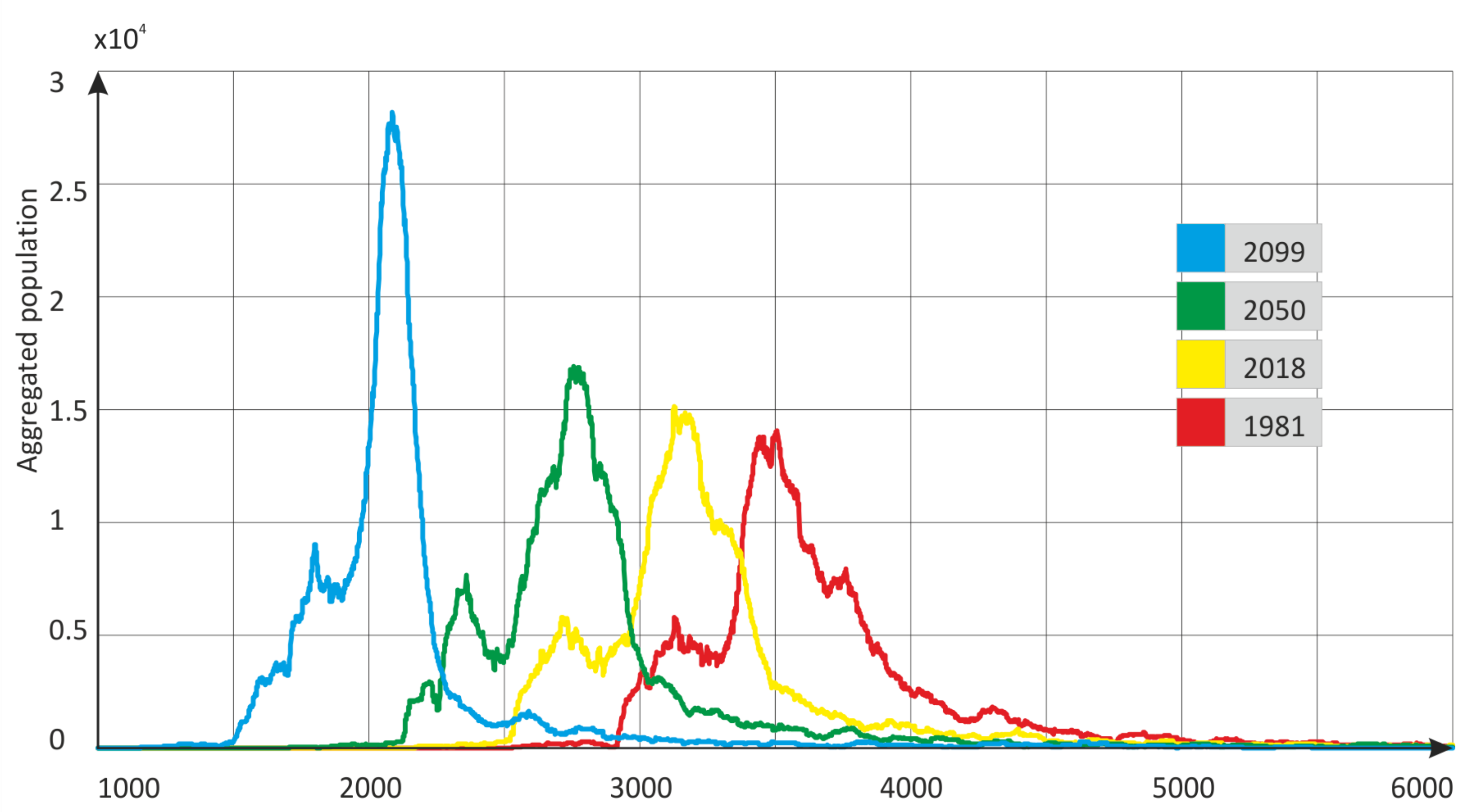
The HDD & CDD method

How will space heating and cooling demand change?



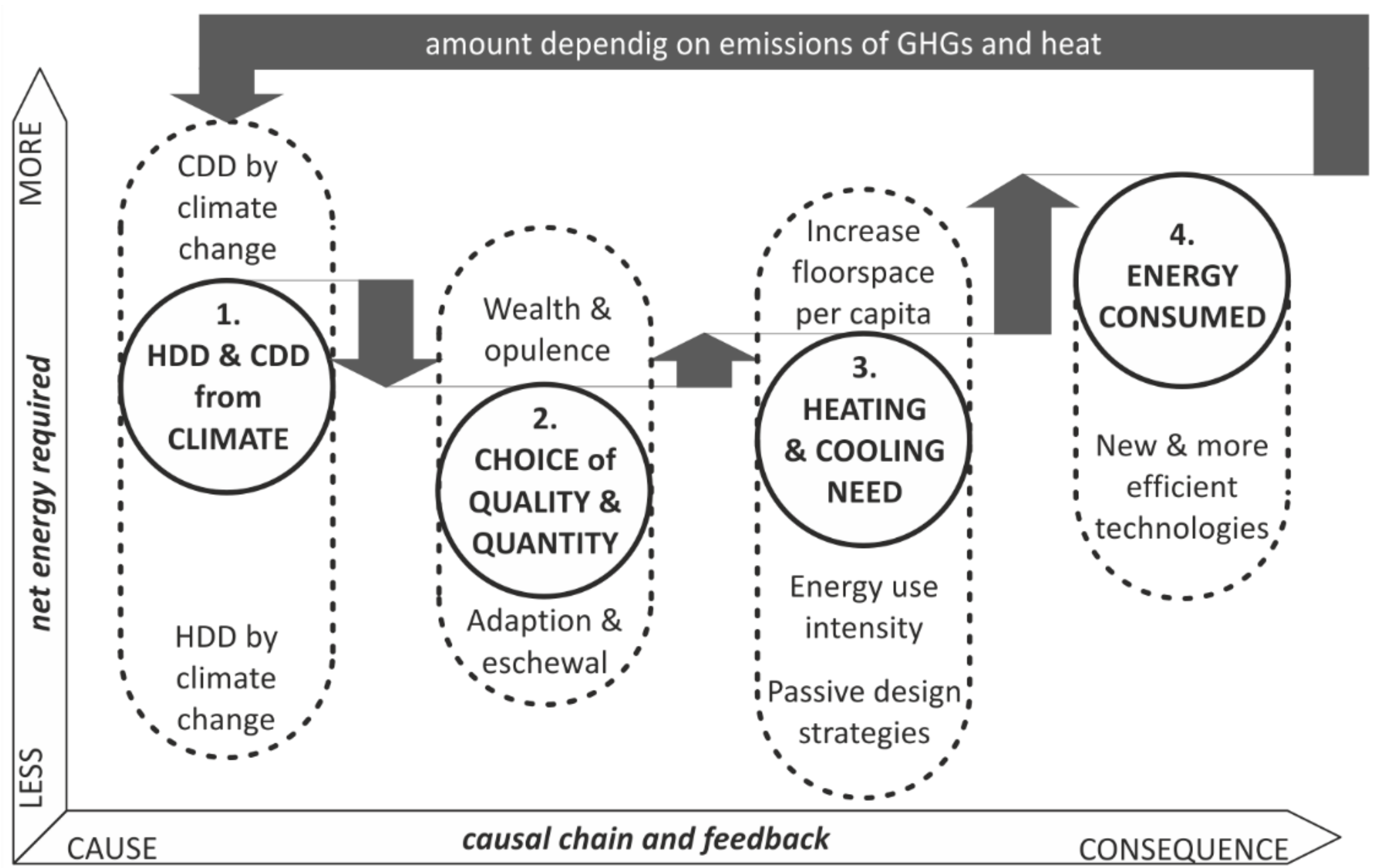
The HDD & CDD method

Combine population and temperature (past/future) maps



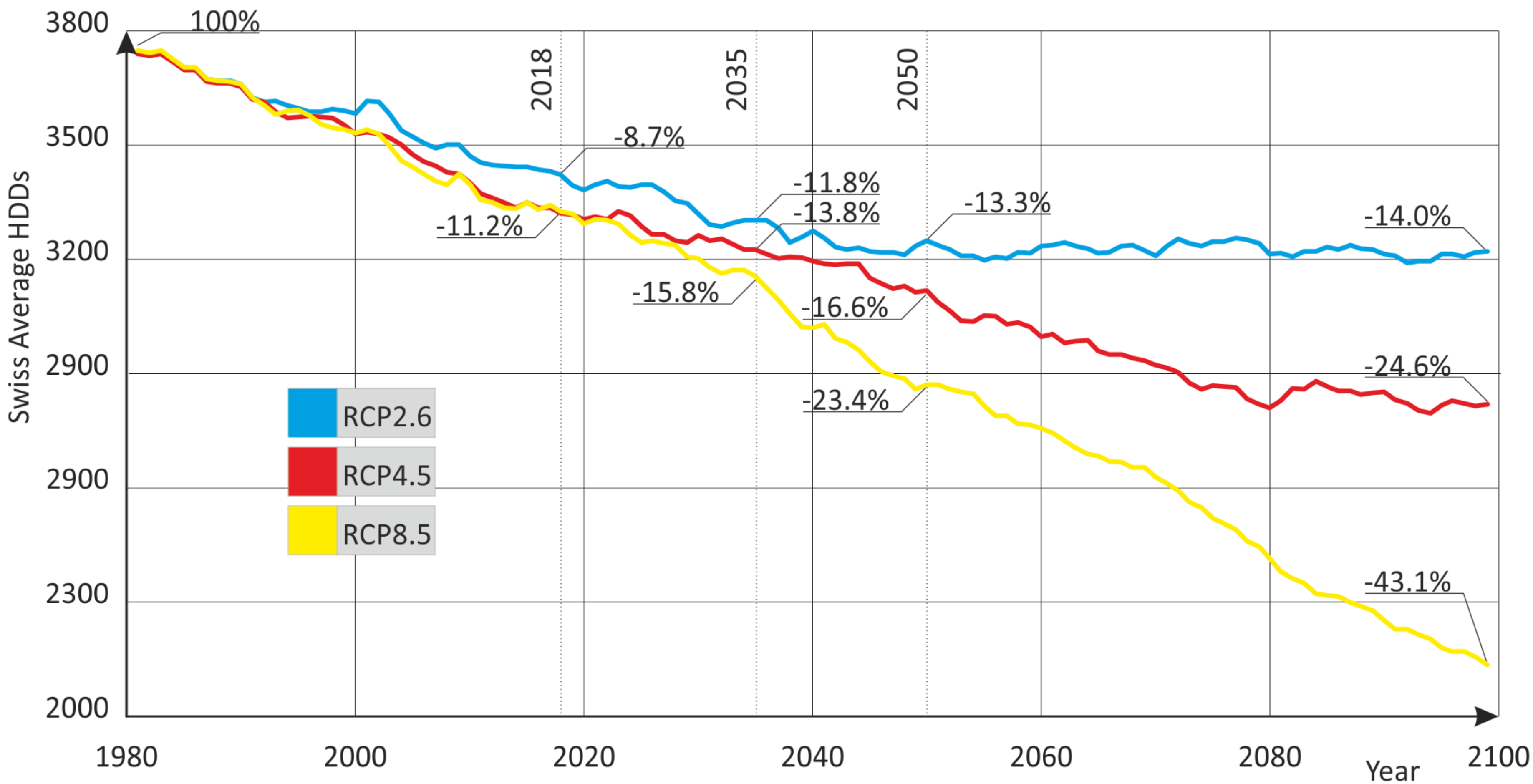
HDDs for RCP8.5 climate scenario

Trends in heating and cooling demand

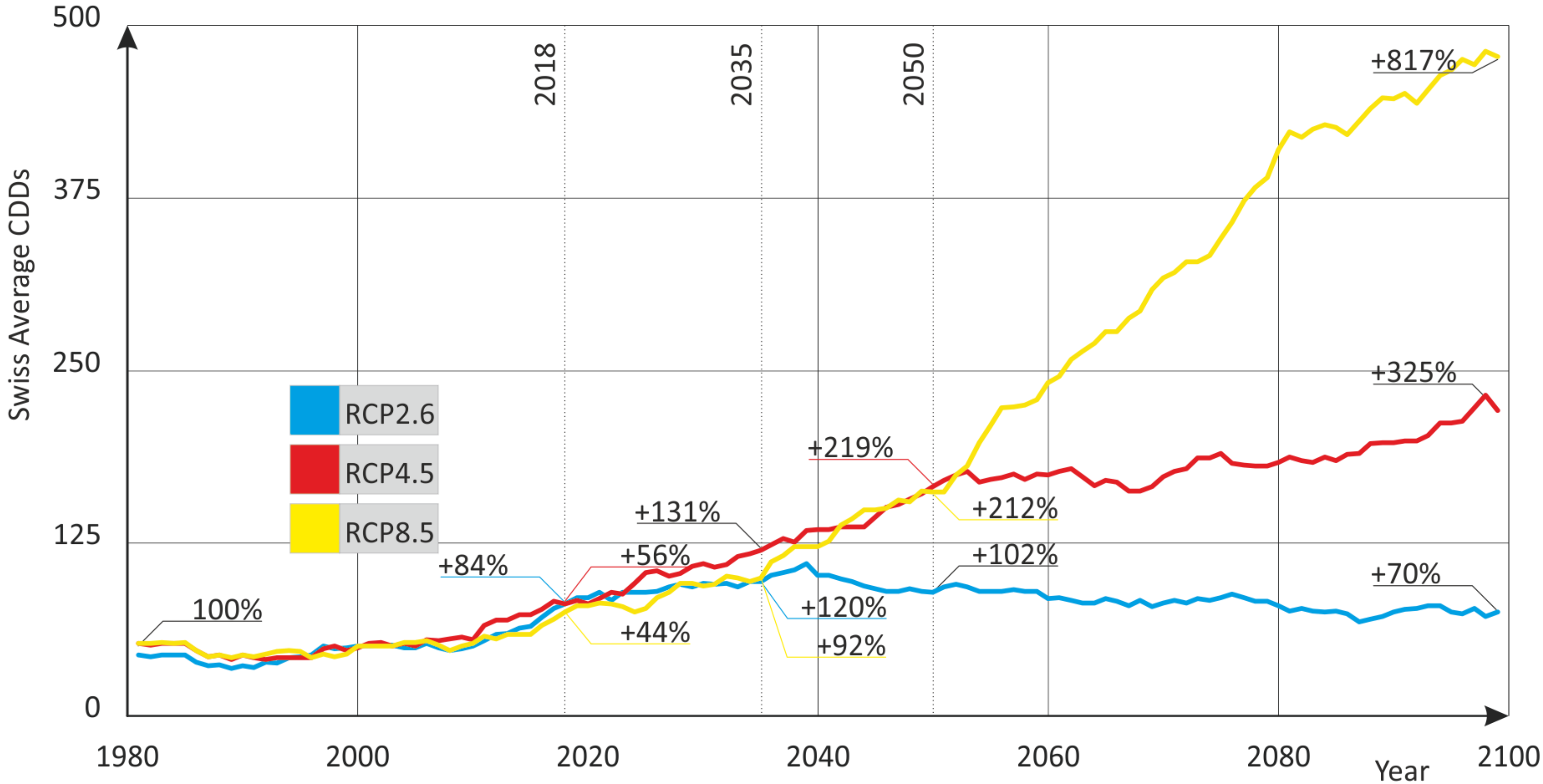


M. Berger, J. Worlitschek, "The influence of climate trends on heating and cooling demand", Weather and Climate Extremes, [in review].

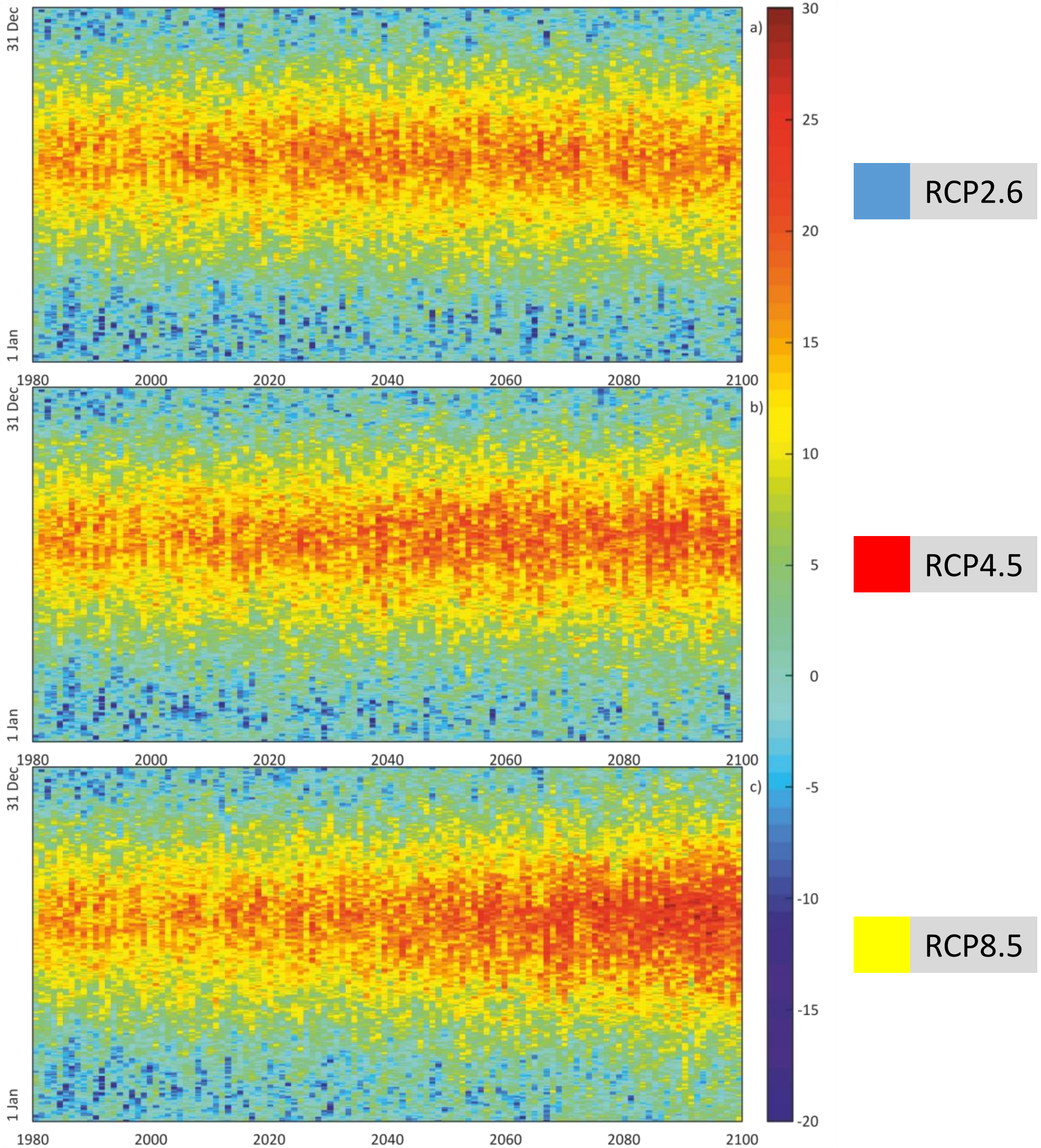
Space heating demand will go down…



… while cooling demand will grow

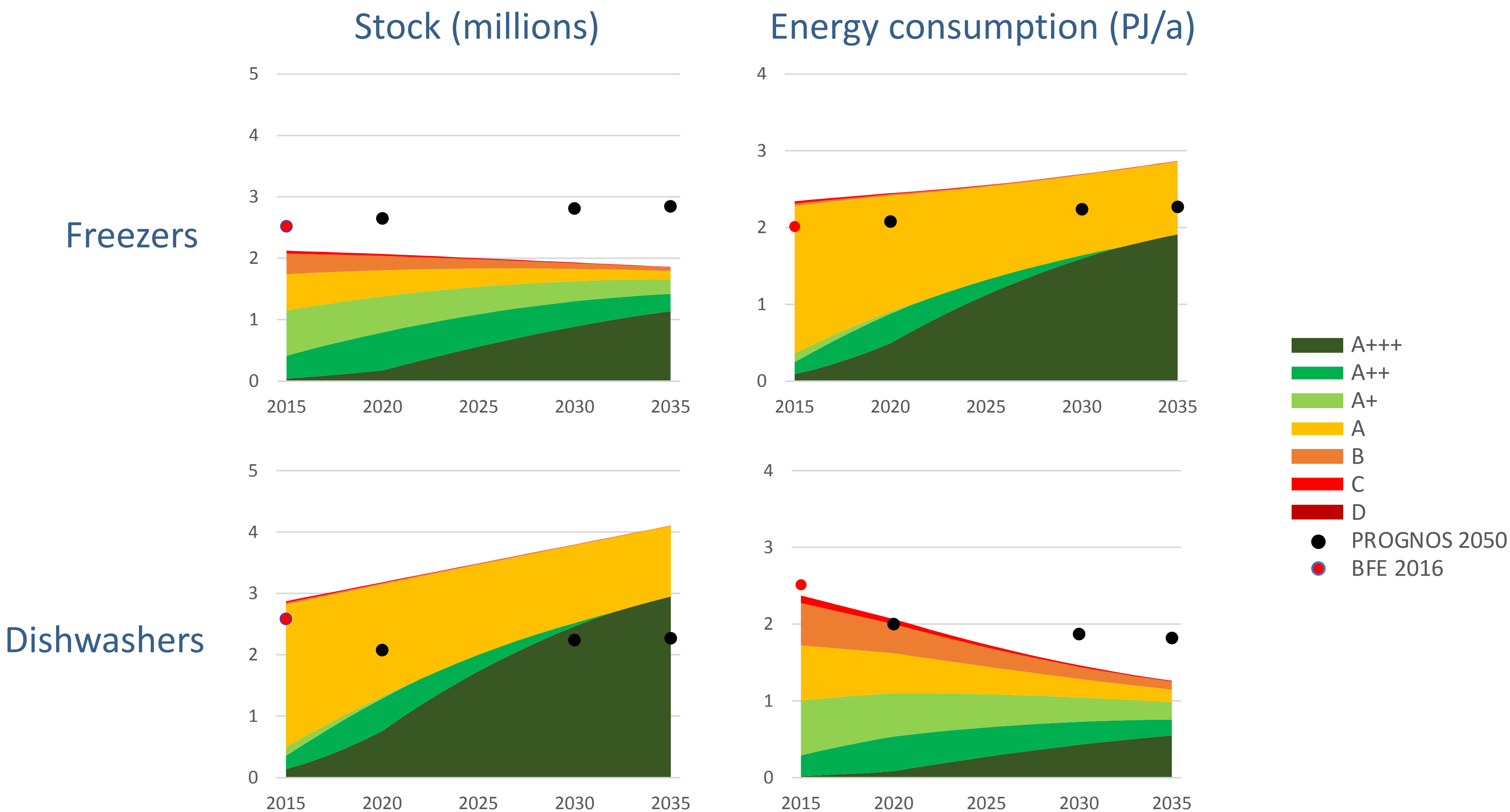


Trends in heating and cooling demand

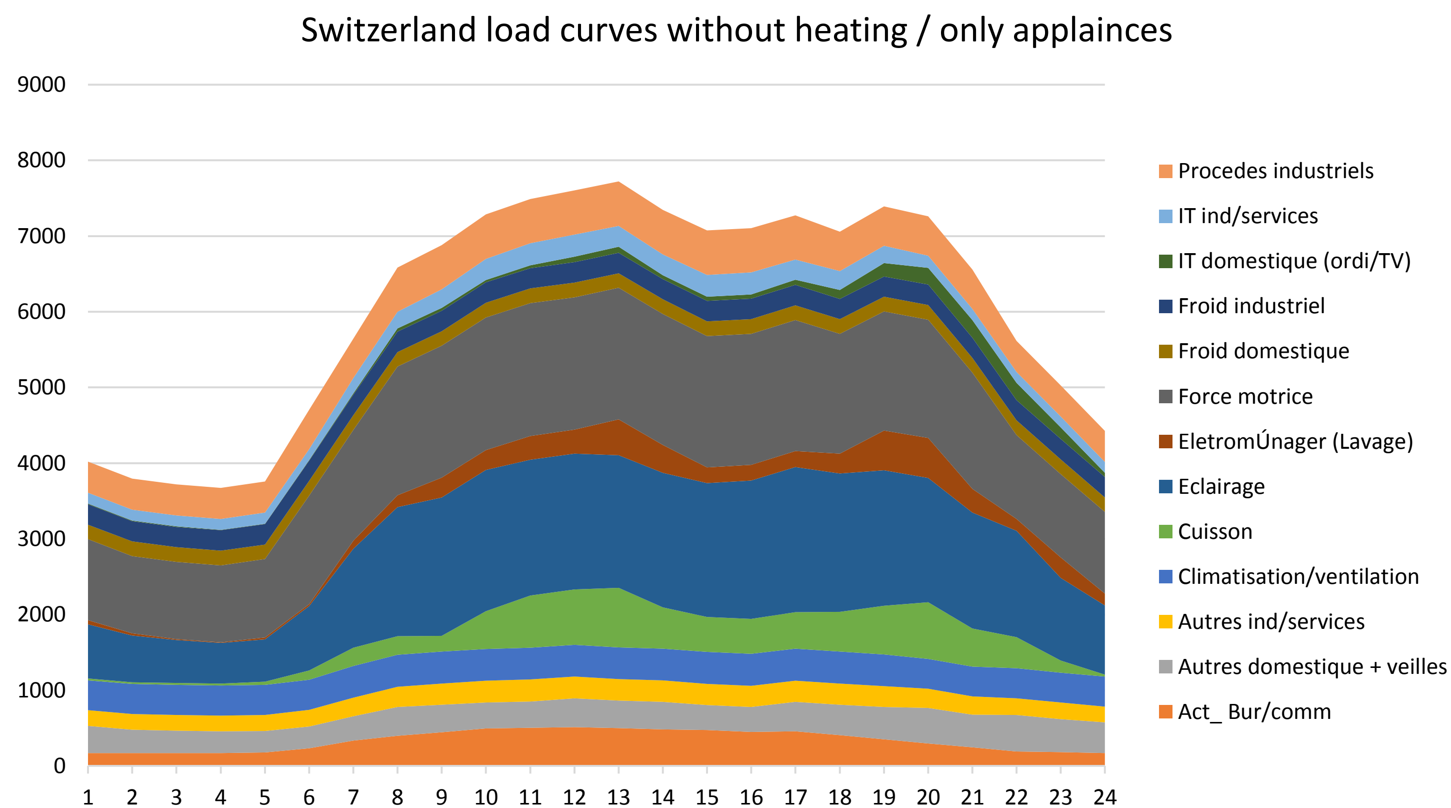


There will be longer and hotter summers – but still cold winter days

How will electricity consumption evolve?
White goods, lighting, ICT



Electrical load profiles
Residential, service, industrial sectors



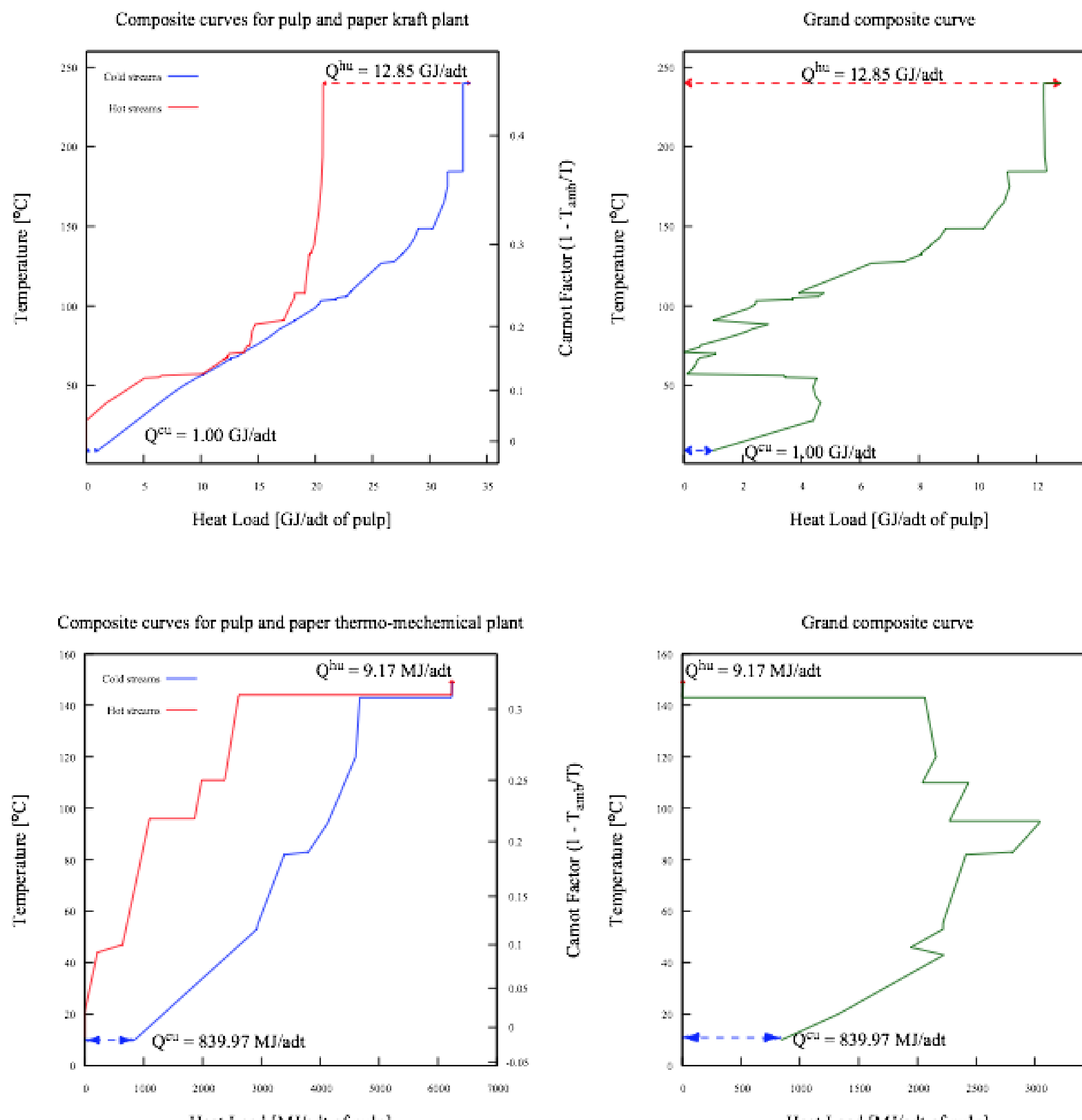
Typical weekday/weekend for 12 months and 13 end-use types

Will be available on www.electrowhat.ch in 2019

Industrial sector

How will process heat & electricity demand develop?

- Processes in the main industrial sectors were modeled covering >80% of the total energy consumption
  - Steel (1)
  - Pulp & Paper (5)
  - Refinery (1)
  - Food & beverage (6)
  - Cement (1)



Process heat & electricity demand
Approach

Detailed literature review → BaU from multiple sources

Thermodynamic models → energy savings potential for processes

Extrapolation to sector/national energy system levels

- Comparison with multiple sources: different SFOE reports, PROGNOS, BREF, etc.
- **Minute documentation of data sources**
- Extrapolation allows integration in energy system models (STEM, SES)

Process heat & electricity demand

Example for the food & beverages sector

Main processes in the sector are modeled

BaU consumption per ton → can change production volume

% energy savings at process level

Sector / process specifications				CH annual consumption					Spec. consumpt. BAU[00]		Saving potential ΔMER[01]		Δdirect[02]		EO[03]
Sector	SFOE No.	Process	NOGA	Electricity (EL) TJ/y	(% Total SFOE)	FUEL TJ/y	(% Total SFOE)	Flow rate t/y	EL MJ/t	FUEL MJ/t	EL $\%_{red}$	FUEL $\%_{red}$	EL $\Delta\%_{red}$	FUEL $\Delta\%_{red}$	☆☆☆
Food & beverage	1	Dairy	10.1501,3,.52	303[05]	(4%[04])	524[05]	(6%[04])	2,021,983[10]	150[11]	259[12]	3%[12]	29%[12]	-8[13]	30%[13]	★★☆[14]
	1	Cheese	10.1502	132[05]	(2%[04])	869[05]	(10%[04])	188,806[10]	698[15]	4600[16]	20%[17]	30%[17]	-42%[18]	22%[18]	★★☆[14]
	1	Brewery	11.05	90[05]	(1%[04])	310[05]	(3%[04])	346,364[19]	260[1a]	894[1b]	15%[1c]	72%[1c]	-3%[1d]	18%[1d]	★★☆[1e]
	1	Sugar	10.81	235[05]	(3%[04])	1,436[05]	(16%[04])	233,600[1f]	1,008[1g]	6,145[1g]	N/A[1h]	N/A[1h]	45%[1i]	42%[1i]	★★★[1k]
	1	Total (calc.)[06]	10, 11	761	(10%[04])	3138	(35%[04])				9% (8%)[0a]	37 (30%)[0a]	3% (5%)[0a]	32% (30%)[0a]	
	1	**Total (SFOE)**[07]	10, 11, 12	7,381	(14%[08])	9,108	(14%[08])				1%[0b]	6%[0b]	1%[0b]	10%[0b]	

Benchmark with todays data in CH

Expert opinion → extrapolation to process/system level

How will energy supply develop?

Hydro power

Assess the impact of climate change on runoff and on hydro power production

Photovoltaics

Where to place large amounts of generation – in urban and/or mountain areas?

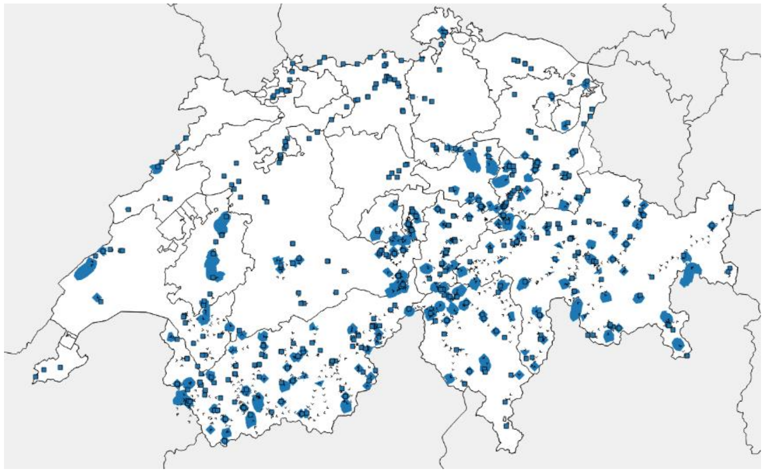
Climate & hydropower

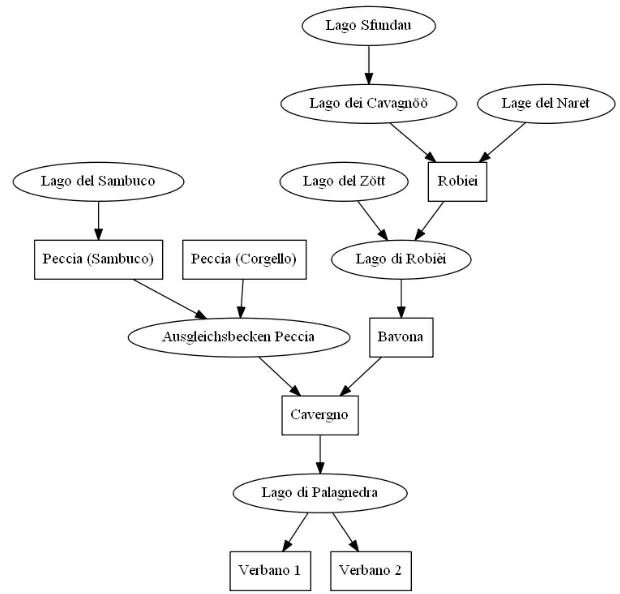
How will climate change impact Swiss hydropower?

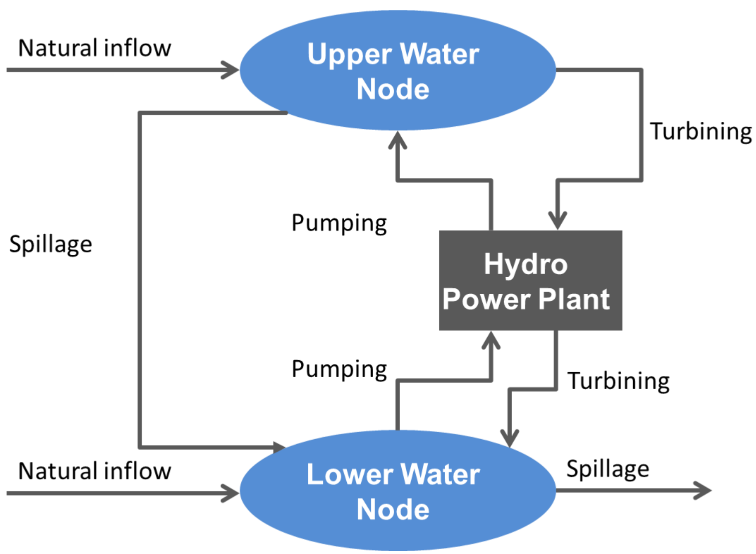
Data and methods

- Data for three climate periods
  - Historic (1980-2009)
  - 2021-2050
  - 2070-2099
- Runoff data with high geographical and temporal resolution (by WSL)
- Swissmod electricity market model

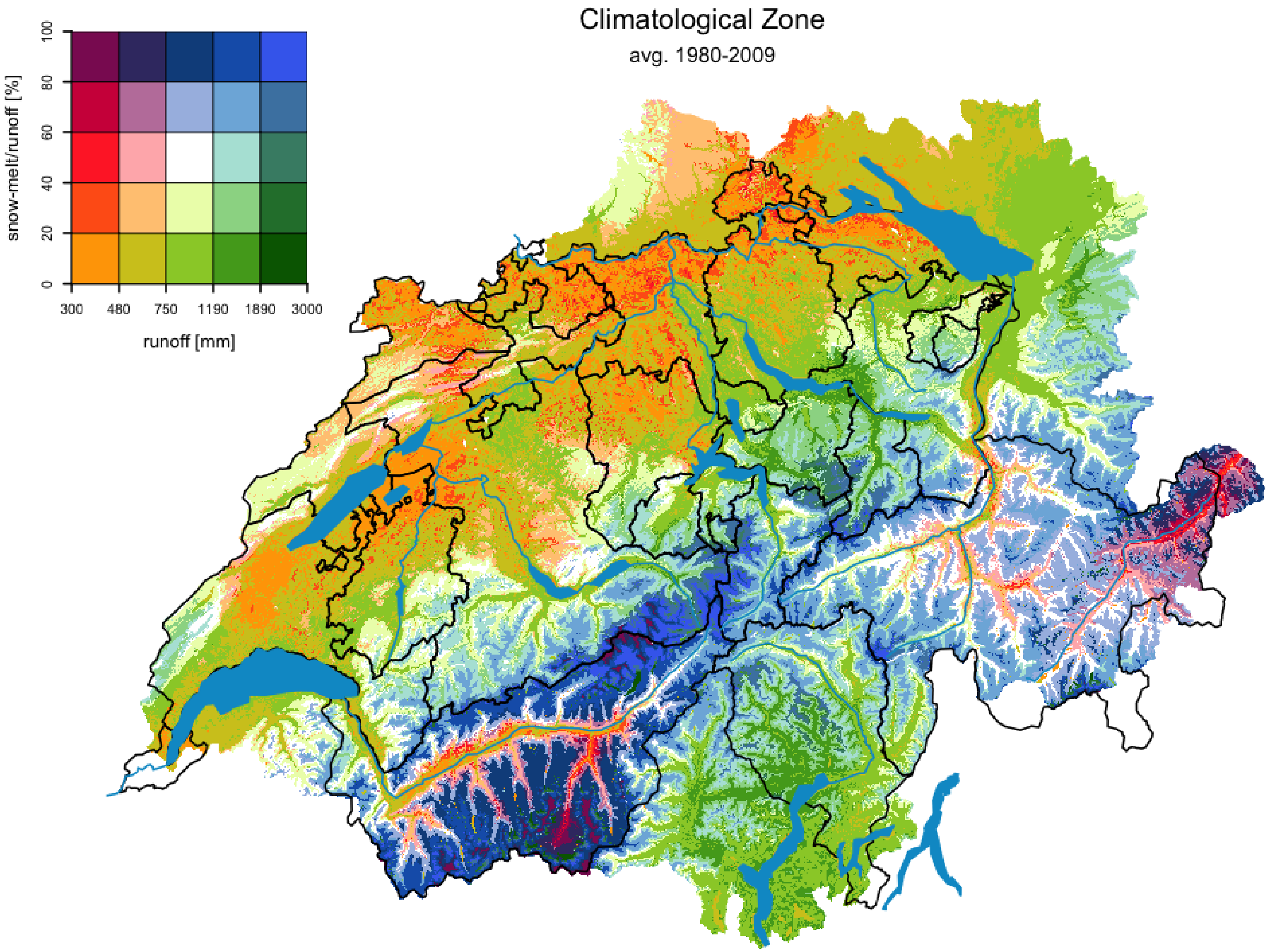
Hydropower in Swissmod



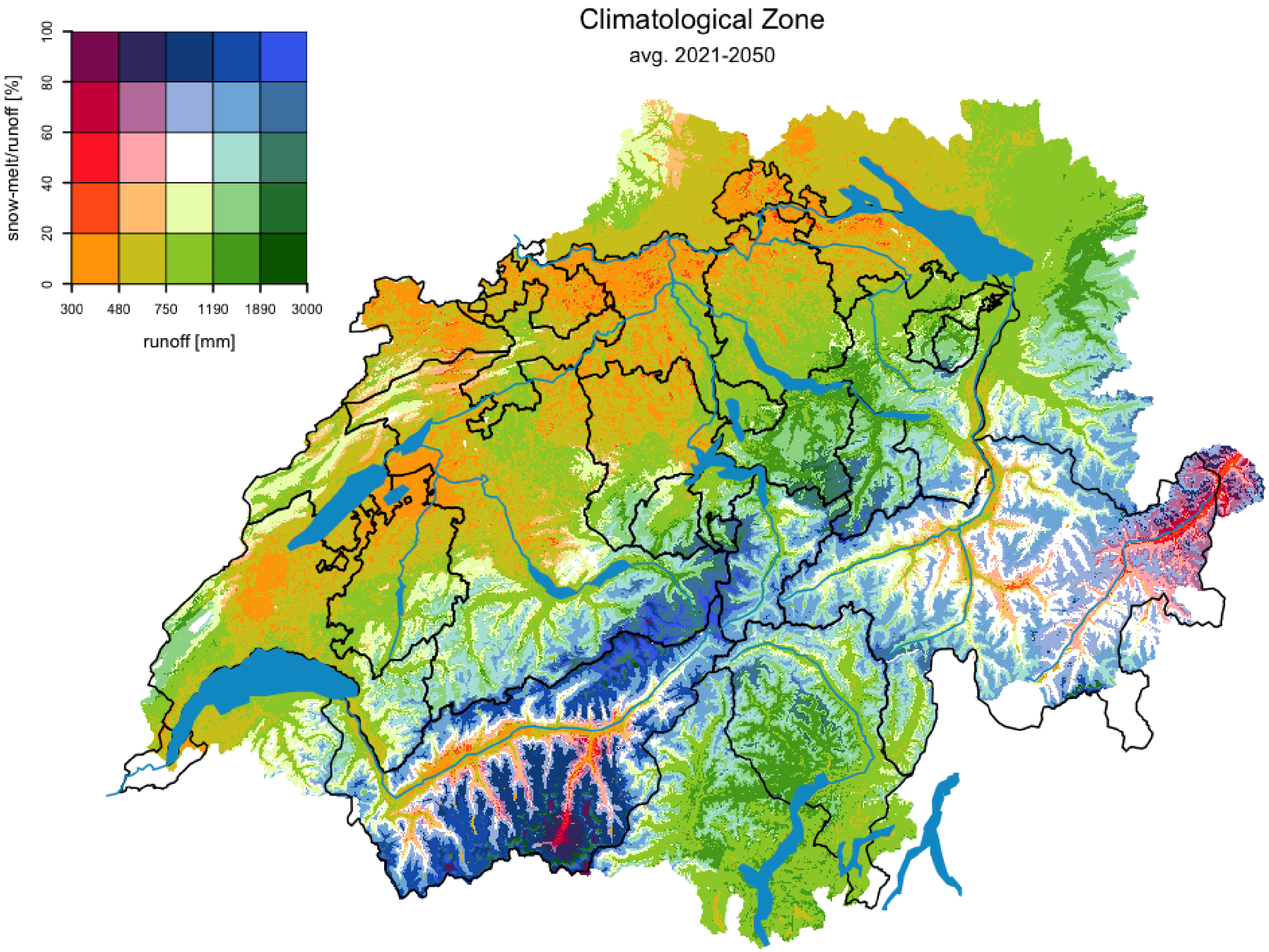




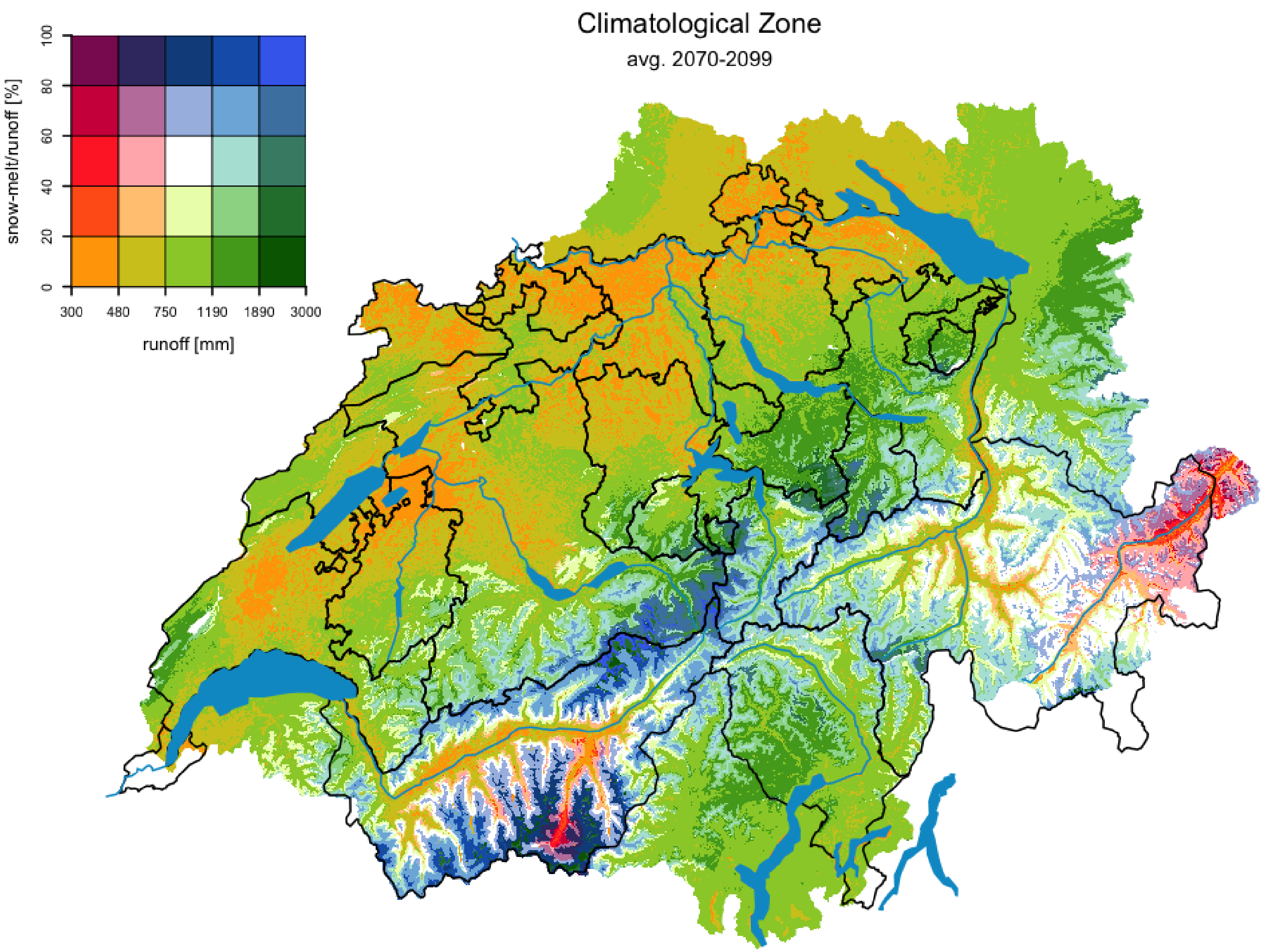
Climate data: Runoff (historic)



Climate data: Runoff (2021-2050)

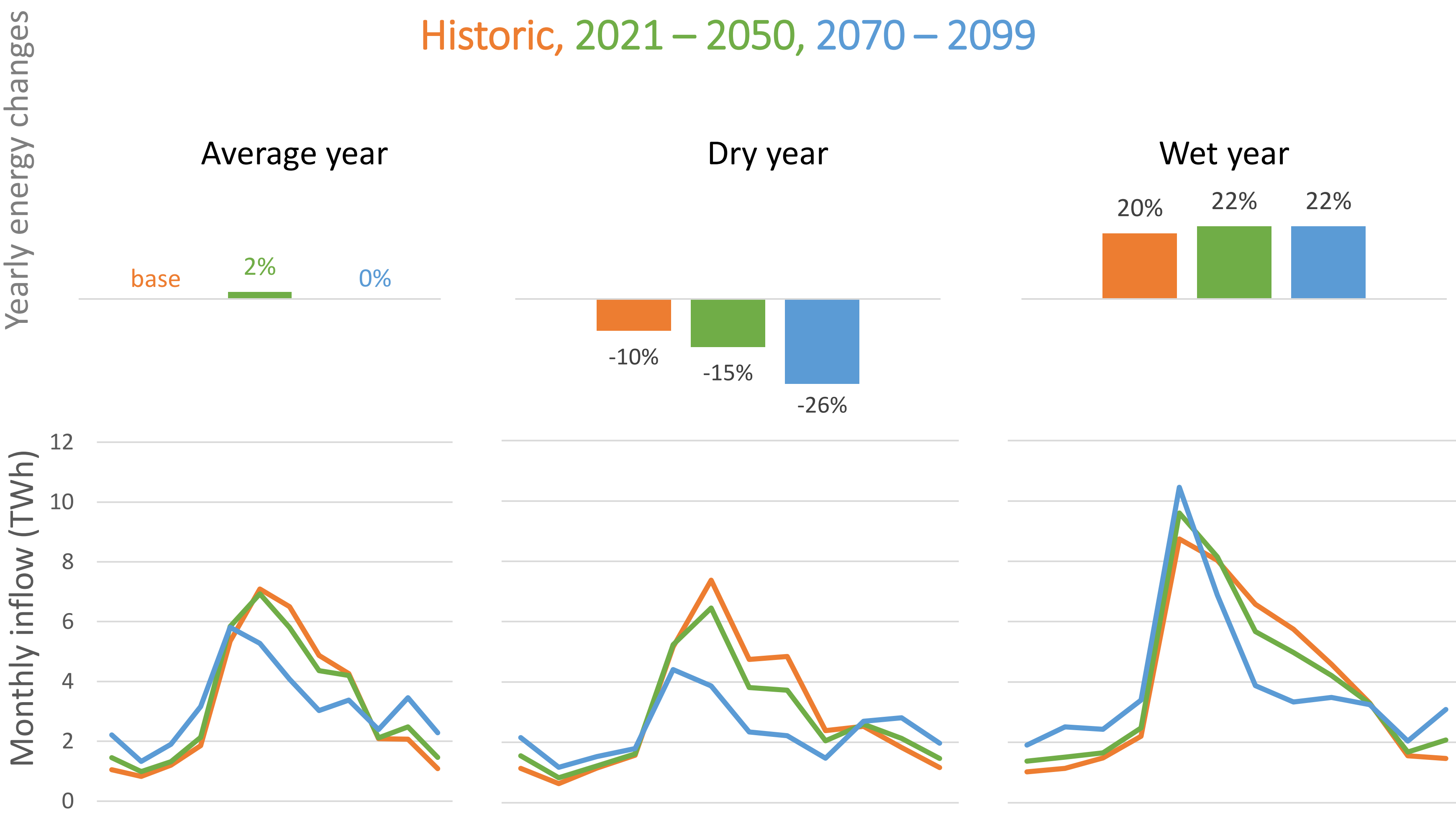


Climate data: Runoff (2070-2099)



Inflow change by climate

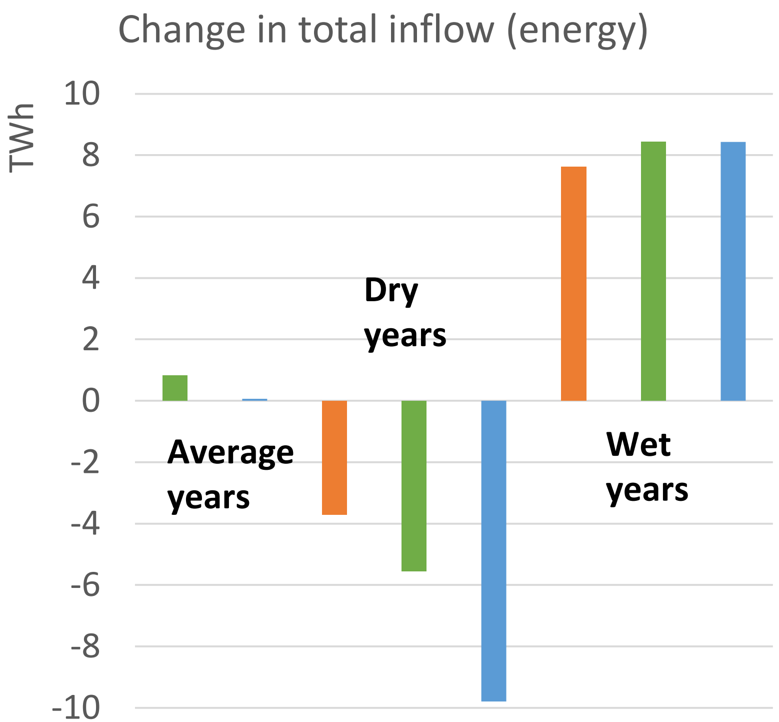
Historic, 2021 – 2050, 2070 – 2099

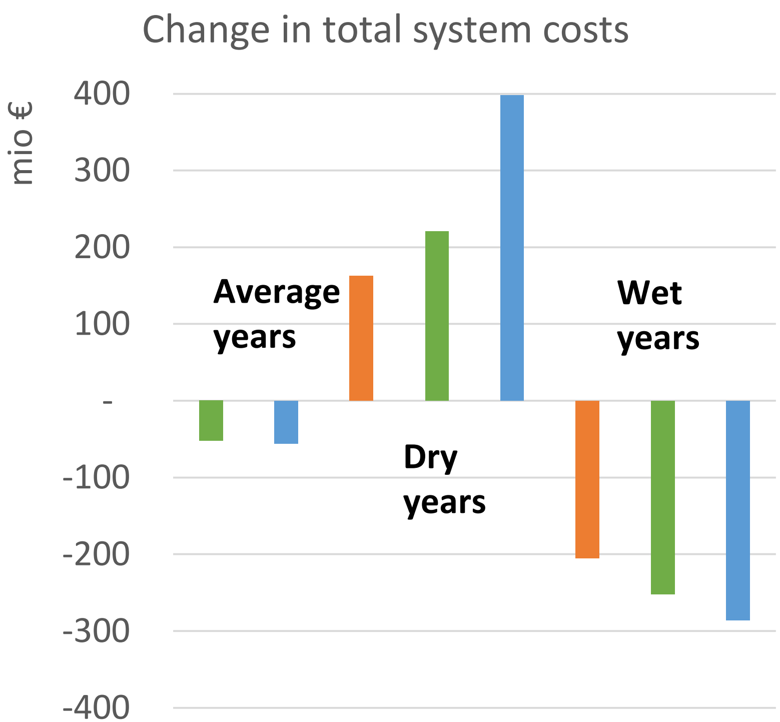


Results: Overall impact

Absolute difference in Total System Cost relative to historic base year

Historic, 2021 – 2050, 2070 – 2099

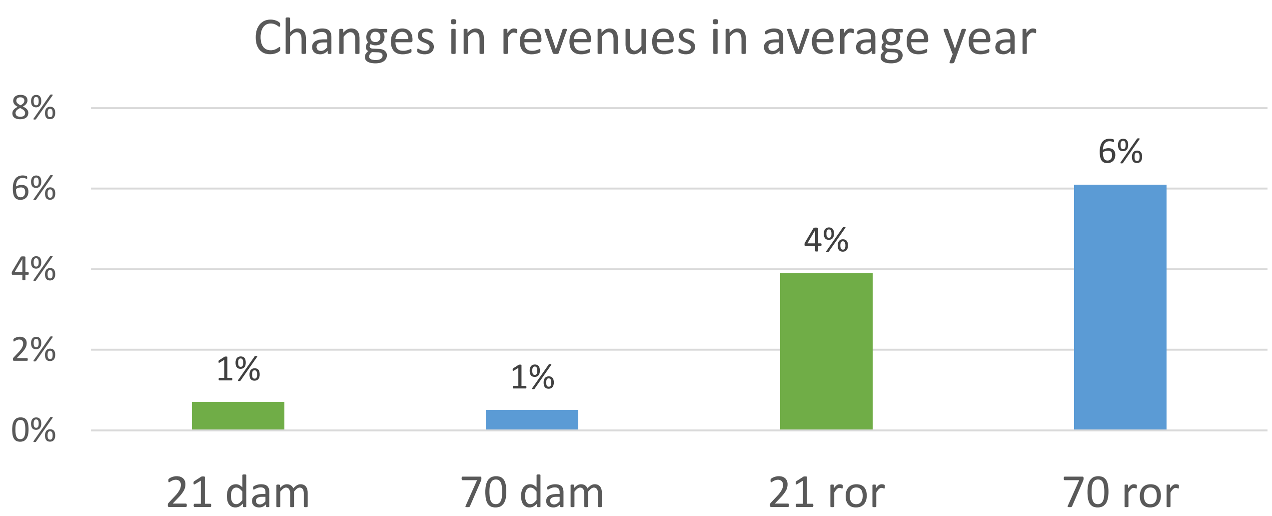




Results: Revenues in average years

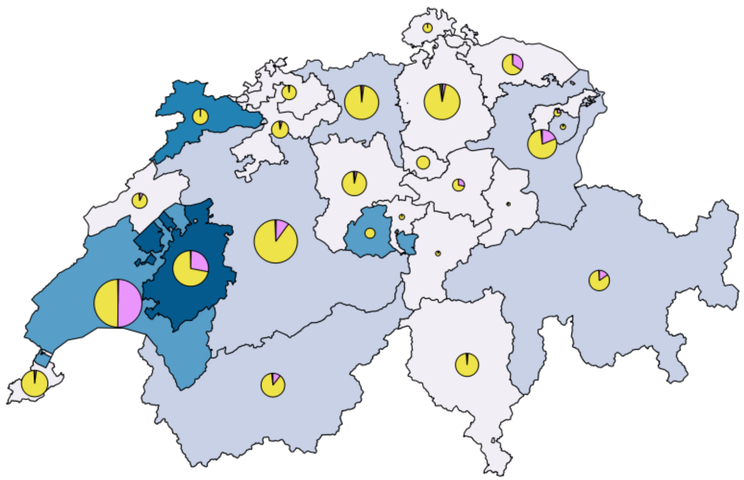
- RoR benefits significantly more from better seasonality than dam

2021 – 2050, 2070 – 2099

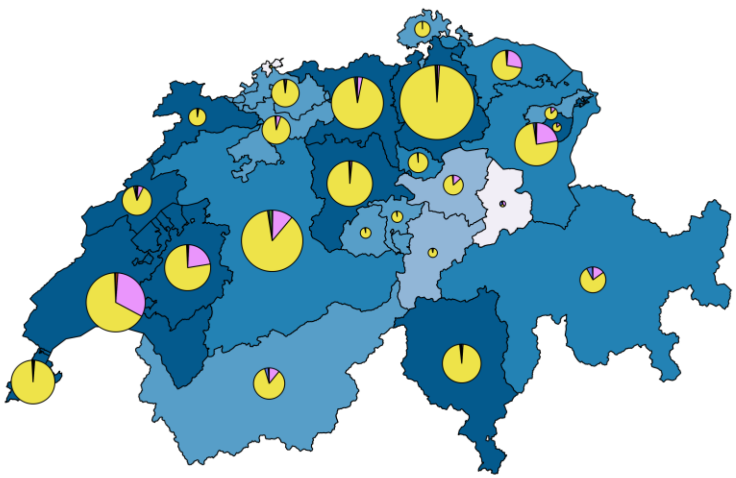


- For other weather conditions:
  - Dry years get worse
  - Wet years get better

Where to place renewables?



Cost-optimal



Regionally equitable
(Proportional to population or el. demand)

Goal:

Assess electricity generation cost and regional equity tradeoffs between various spatial allocation strategies

EXPANSE

Spatially-explicit bottom-up power system model

Pre-processing (GIS-based)

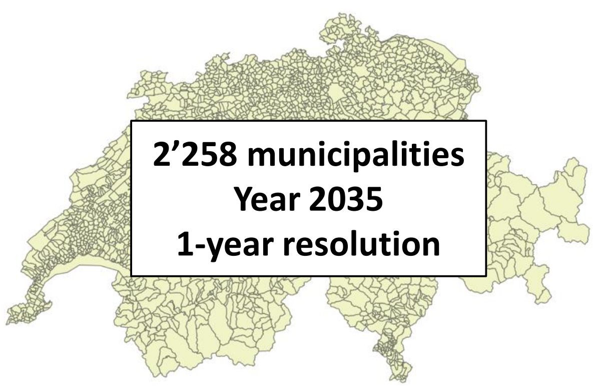
- **Resource assessment** (e.g. solar potential)
- **Power plant characteristics** (e.g. LCOE, capacity)
- **Electricity demand** (per municipality)

Optimization run (on HPC cluster)

- **Cost-optimal scenario** (1 scenario)
- **Near-optimal scenarios** (2’000 scenarios)

Trade-off analysis

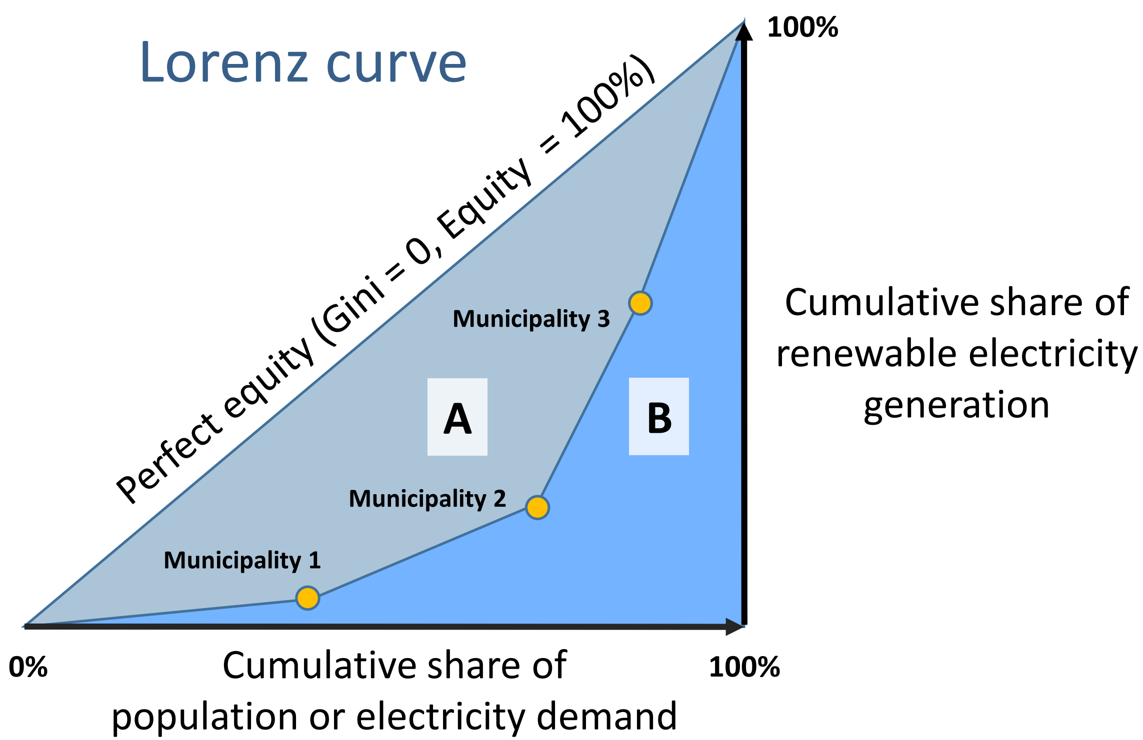
- **Regional equity**
- **Generation costs**
- **Investment**
- **Installed capacity**



Modelled Technologies

Hydro, Solar PV, Wind, Gas, Geo-Thermal, Woody biomass, Biogas, Waste incineration, Imports, Efficiency

The Gini index
A measure for regional equity

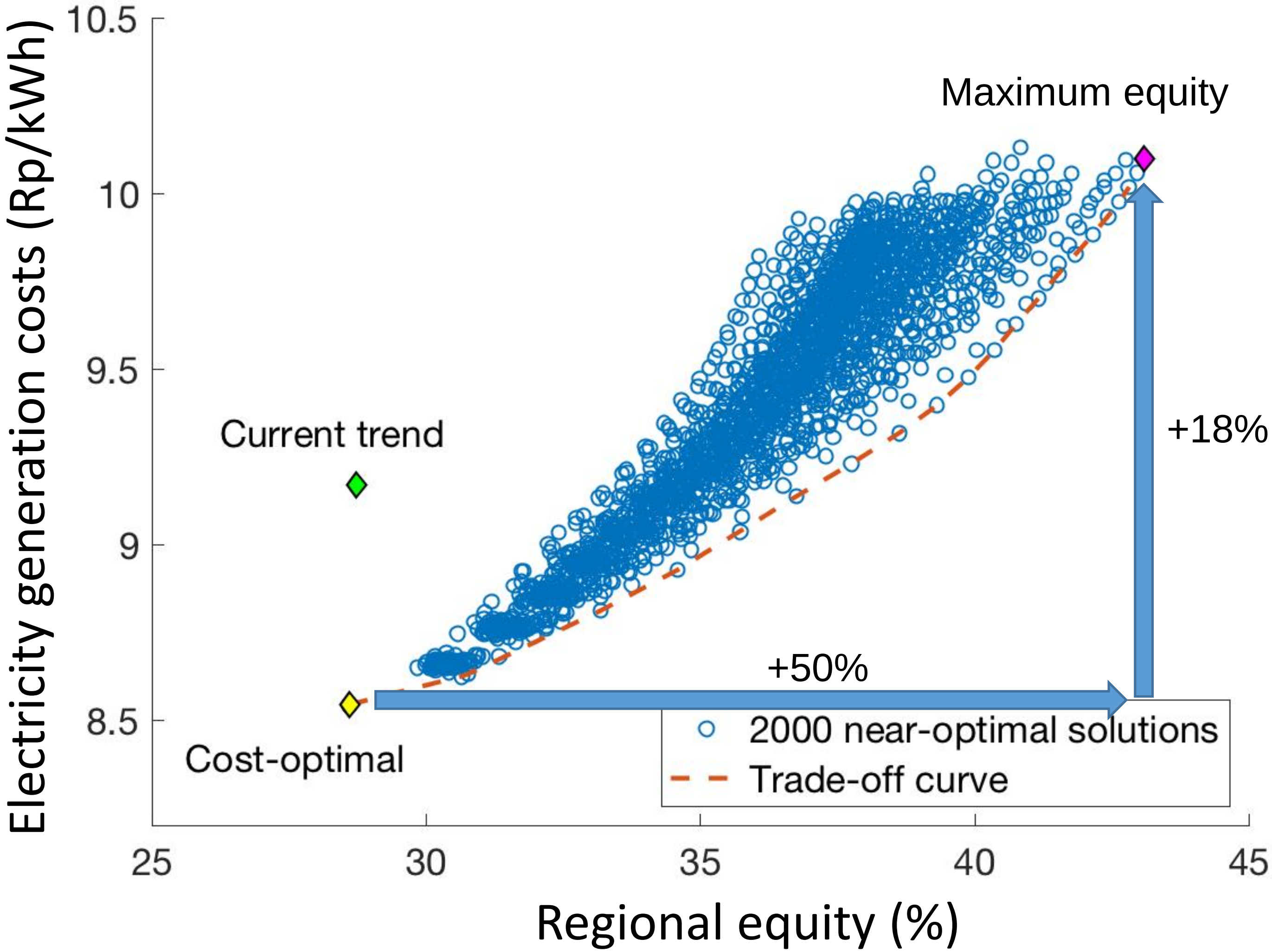


$$Gini = \frac{A}{A+B}$$

$$Equity = 100 - Gini\ [\%]$$

Optimization results

Trade-off between costs and regional equity

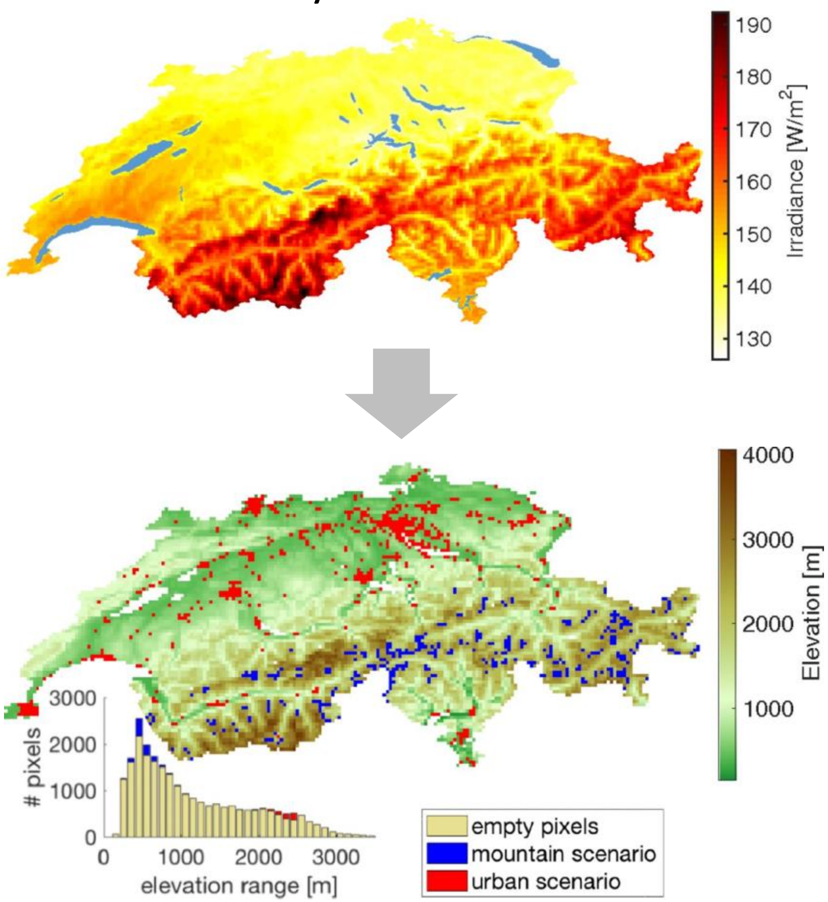


Key findings

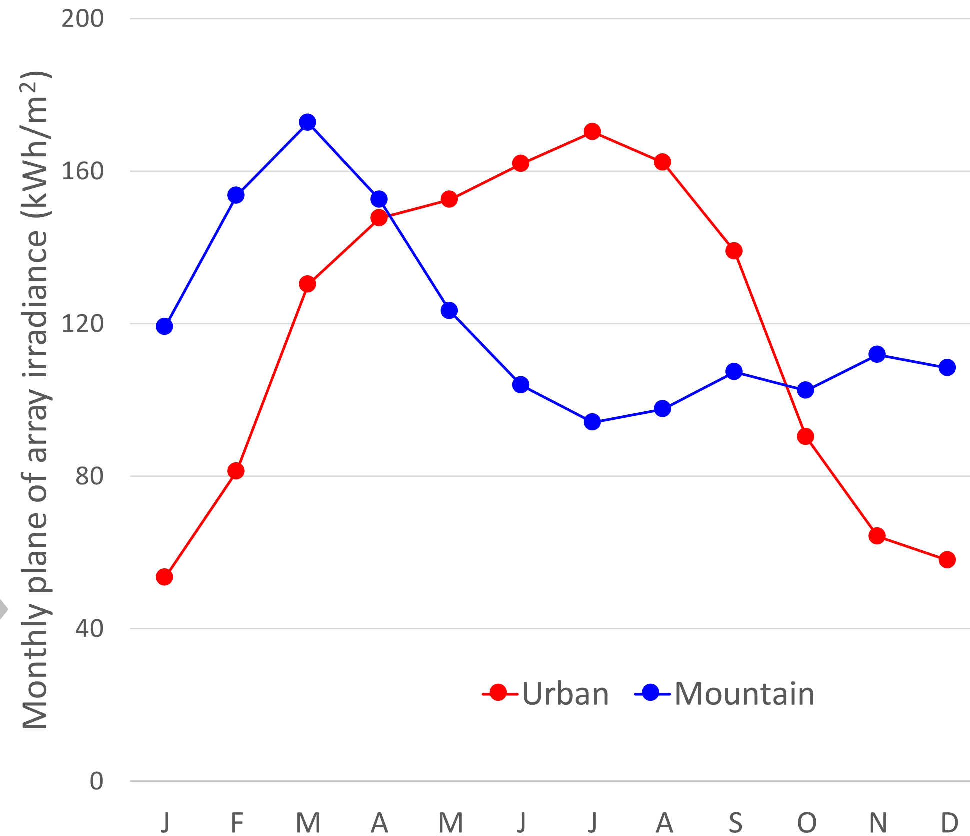
- A regionally equitable distribution of renewable generation capacity in proportion to population or electricity demand can lead to significant increases in electricity generation costs
- Focus on cost-optimality leads to spatial concentration of investments to a few locations (such as canton Vaud)
- Spatial allocation strategies have to be well planned and discussed at federal level – in order to avoid intra-cantonal conflicts

PV production in snow-covered mountains

Yearly irradiance



Optimized placement
of PV panels



Better match to yearly
electricity consumption profile

Scenario definition

Core scenarios

Mix of explorative and normative scenarios

Variants

Skepticism, market integration, increasing acceptance of new technologies

Strategy needs policy, policy needs markets and users

Energy policy & Climate policy

Market integration & operation

Companies Consumers

Main strategic objectives

Per capita energy consumption:
-16% in 2020 from 2000
-43% in 2035 from 2000

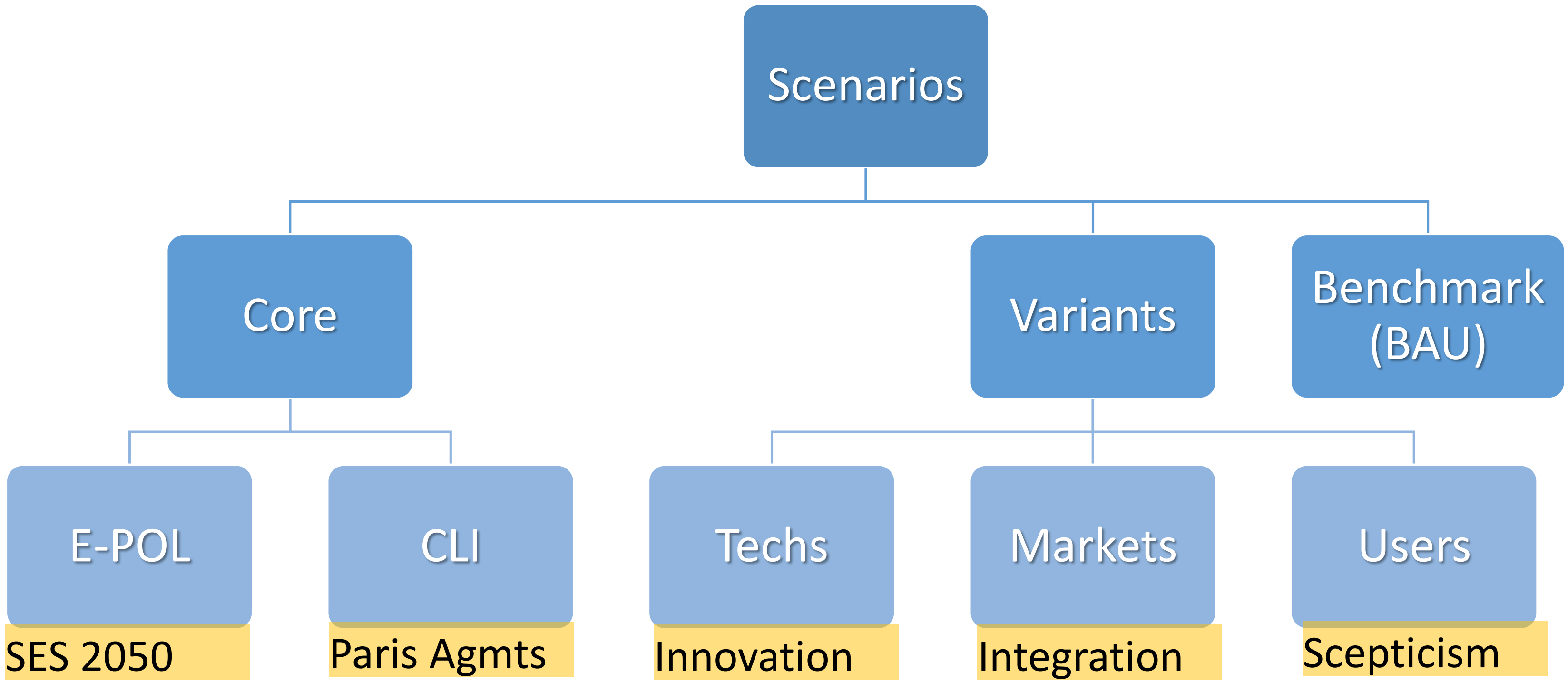
Per capita electricity consumption:
-3% in 2020 from 2000
-13% in 2035 from 2000

Domestic electricity production from RES:
In 2020: 4.4 TWh (RES other than hydro)
In 2035: 11.4 TWh (RES other than hydro)
Hydropower: 37.4 TWh in 2035

CO_2

GHG emissions:
-20% in 2020 from 1990
-50% in 2030 from 1990
-70-85% in 2050 from 1990
Carbon neutrality after 2050

JASM scenario structure

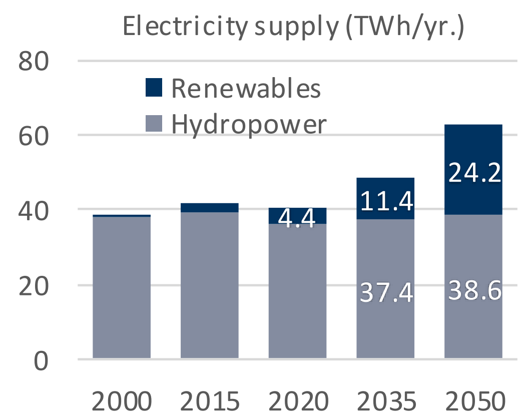


Overview of the core scenarios

	E-POL	CLI	BAU
	Towards well-below 2000 W/capita	*Towards carbon neutrality*	
Objective	**Efficiency, renewables, grid & storage**	**Strategic objective to reduce emissions**	**Benchmark scenario, current policies**
Main feature	New energy act implemented & extrapolated	Proposed CO2 act implemented & extrapolated	Current energy and CO2 law implemented & extrapolated
Nuclear power	No new nuclear power, 60yrs lifetime	No new nuclear power, 60yrs lifetime	No new nuclear power, 60yrs lifetime
Renewables	Targets for electricity supply & final energy	Targets for electricity supply & final energy	No specific targets
Efficiency	Per capita consumption targets and buildings standards	No specific targets	No specific targets
GHG emissions	No specific targets, but vehicle standards included	GHG emissions targets, incl. taxes & standards	Current policies and practices

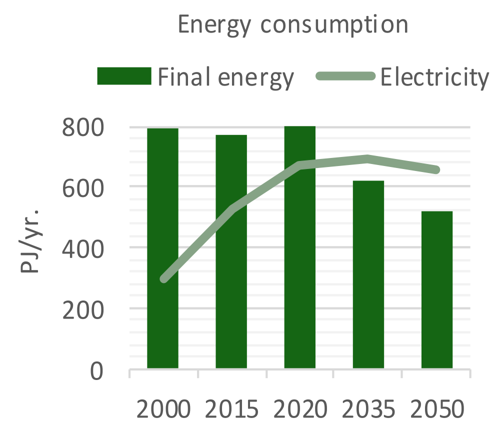
Main inputs to E-POL scenario

Renewables



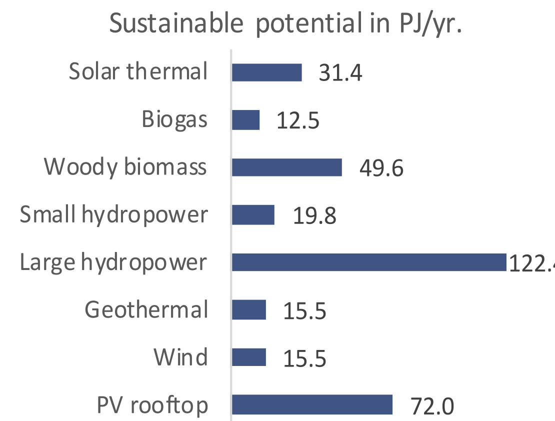
Source: SES 2050

Efficiency



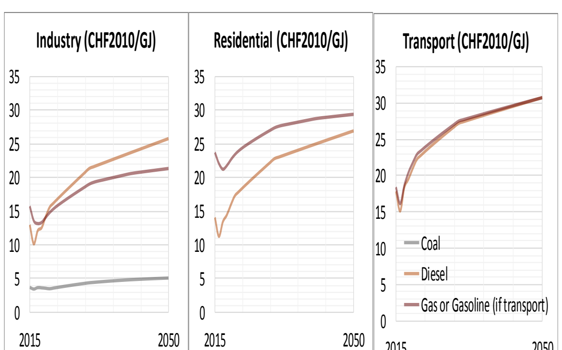
Source: SES 2050

Potentials



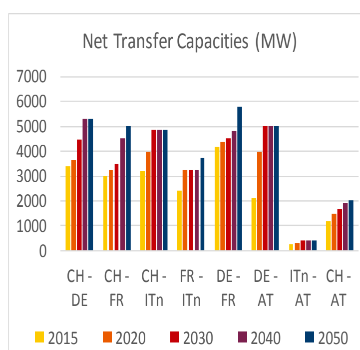
Source: Bauer et al, 2017

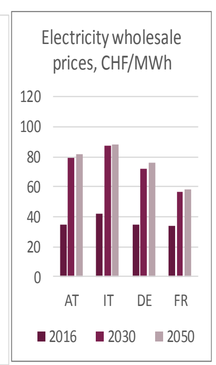
Energy prices



Source: IEA, 2018 NPS scenario

Electricity grids





Source: ENTSO-E, TYNDP 2018

Other

Swiss ETS linear factor 2.2% p.a.

Support for renewables phase out by 2030

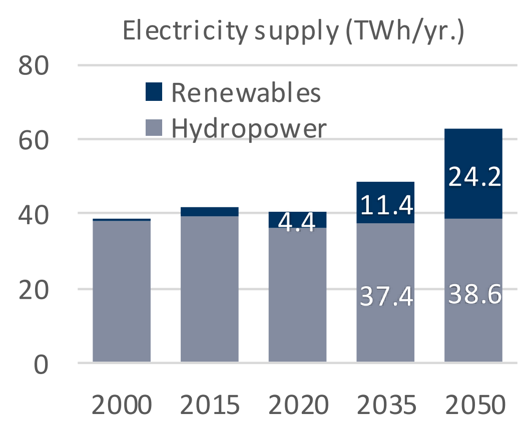
Efficiency standards in buildings

CO_2 emissions standards for vehicles inline with the EU

Climate change impacts on demand and hydro

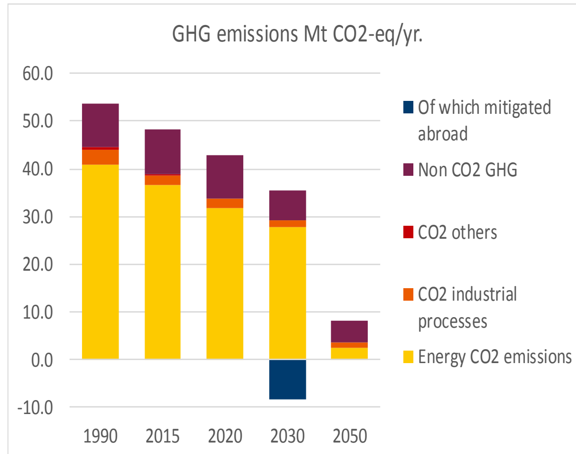
Main inputs to CLI scenario

Renewables



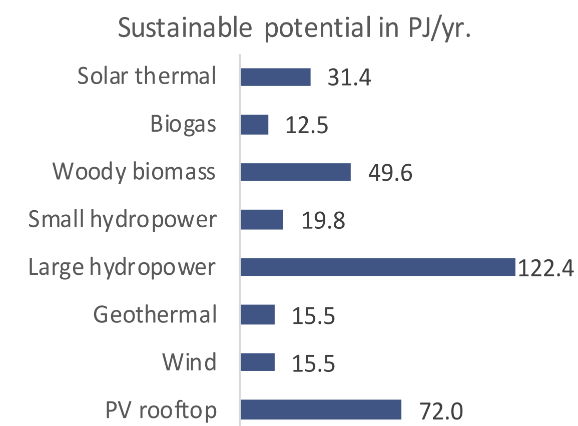
Source: SES 2050

GHG emission targets



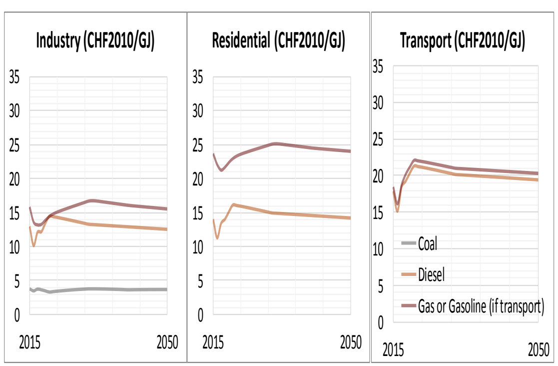
Source: CO2 Act & own calculations

Potentials



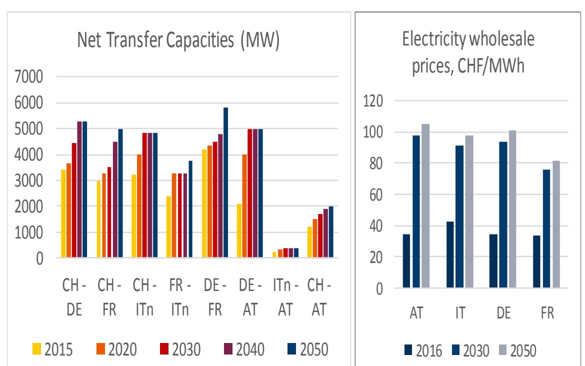
Source: Bauer et al, 2017

Energy prices



Source: IEA, 2108: BDS scenario

Electricity grids

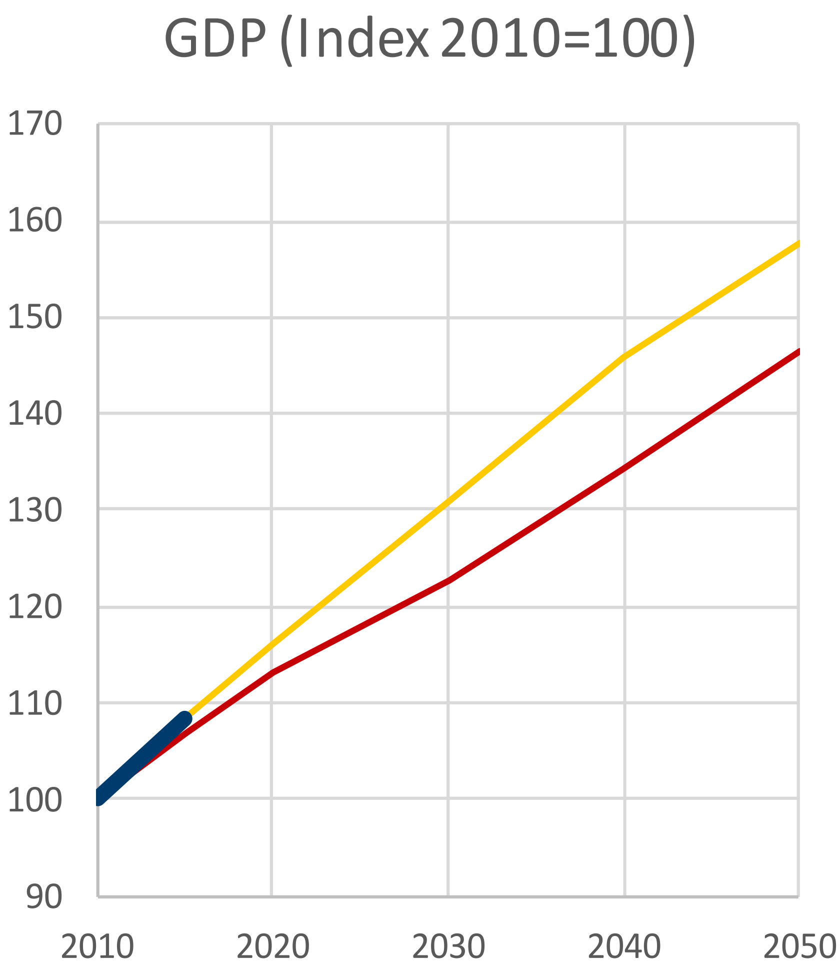


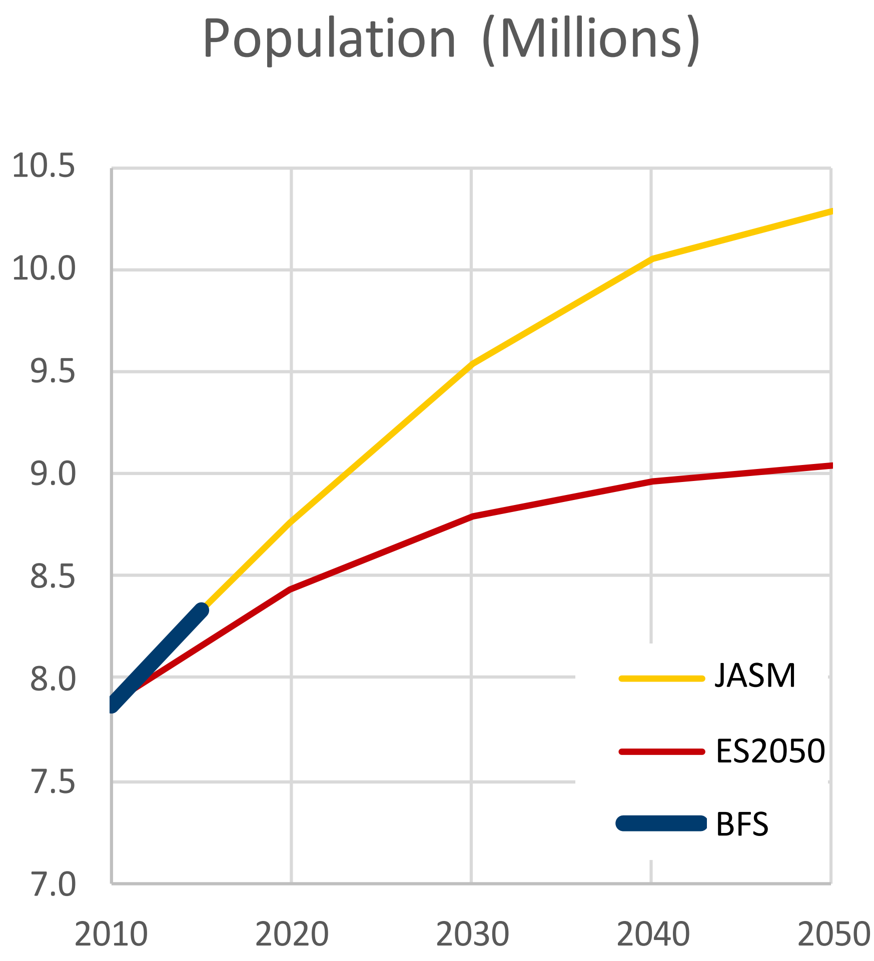
Source: ENTSO-E, TYNDP 2018

Other

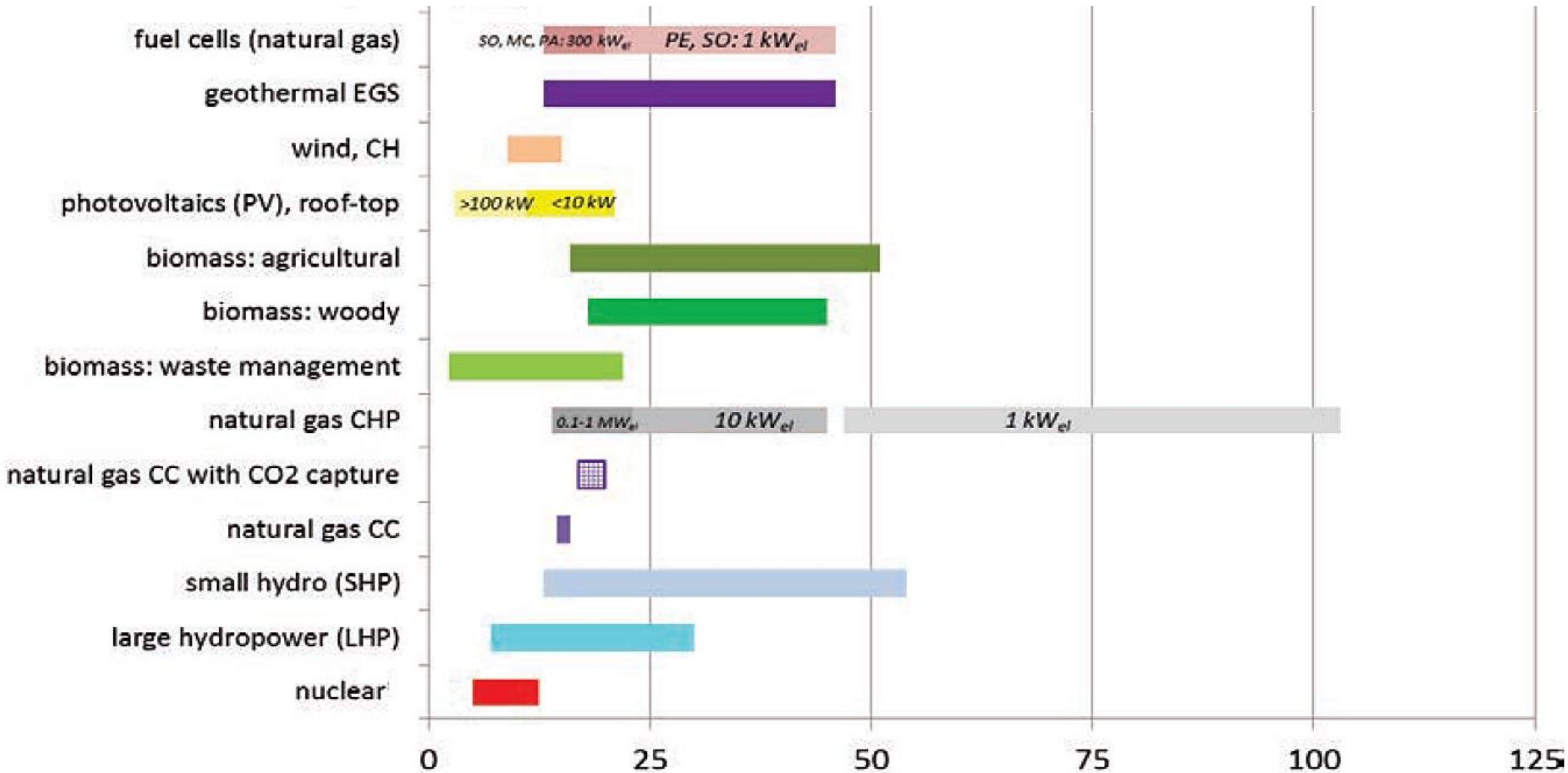
- Swiss ETS linear factor 2.6% p.a.
- Support for renewables phase out by 2030
- Emission standards in buildings
- CO2 emissions standards for vehicles inline with the EU
- Climate change impacts on demand and hydro

Population and GDP





Characteristics of future power technology

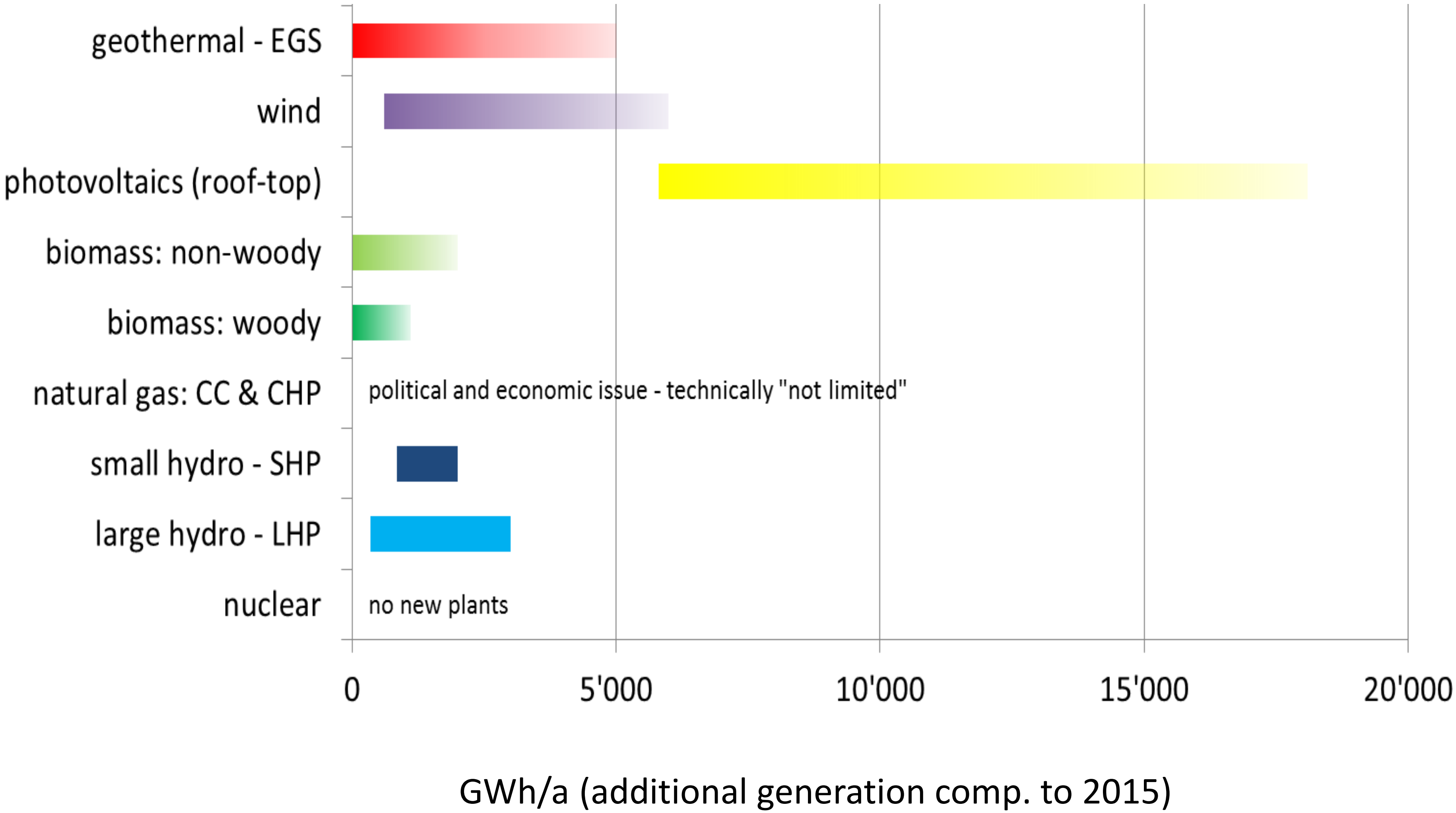


Levelised cost of electricity generation in 2050 (Rp./kWh)

Ranges reflect variability of site conditions, feedstock costs & future technology cost development

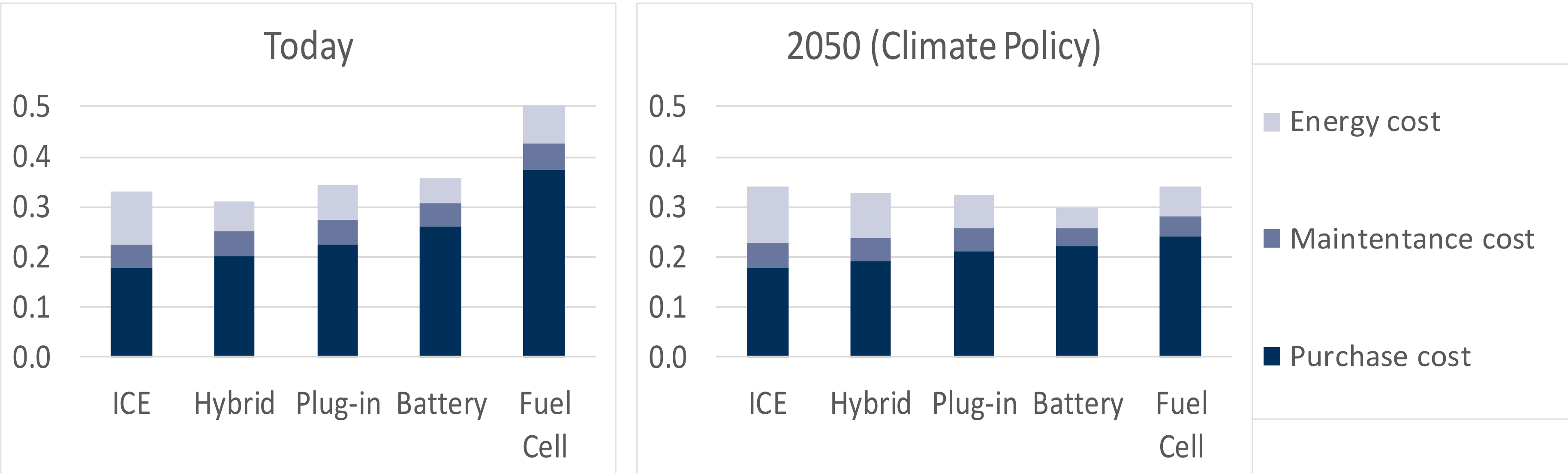
Source: Bauer, C. *et al.* 2017. *Potentials, costs and environmental assessment of electricity generation technologies*. (PSI, WSL, ETHZ, EPFL, 2017).

Resource potential for electricity generation



Source: Bauer, C. *et al.* 2017. *Potentials, costs and environmental assessment of electricity generation technologies*. (PSI, WSL, ETHZ, EPFL, 2017).

Private cars costs



Car ownership cost in CHF/km
(best estimate, medium size car, 12000 km/yr.)

Source: Cox, B. et al, 2019. Life cycle environmental and cost comparison of current and future passenger cars under different energy scenarios (under review)

Definition of the variants

Techs

Advanced consumer responsibility & higher acceptance of new technologies

- Increased technology deployment by consumers & access to domestic renewable resources
- Increased R&D worldwide to Power-to-Gas, H2 supply & consumption technologies

Markets

Better market integration of distributed generation, increased digitalization and smart grids

- Community-level trading markets, smart prosumers, increased demand flexibility (e.g. DSM, V2G)
- Higher integration with the European energy and electricity markets

Users

Skepticism stemming from fragmented international energy & climate policies

- Reduced learning rates of renewable technologies, NIMBY consumers
- Integration with the European energy and electricity markets partly achieved (or failed)

Preliminary results at national scale

STEM

Swiss Times Energy System Model; detailed representation of all relevant sectors

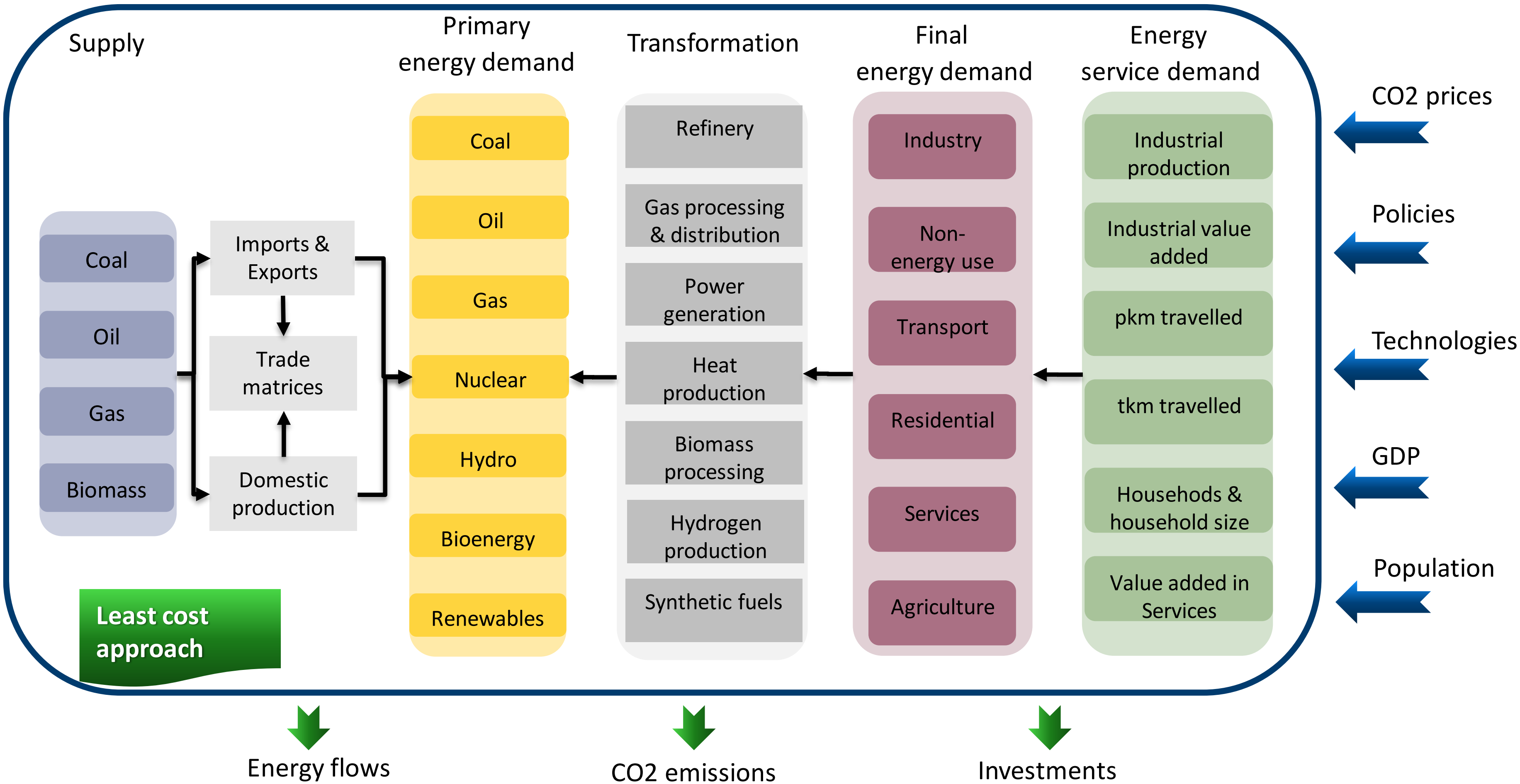
SES-TD

Swiss EnergScope-Typical days; simple but complete model of the energy sector

Swissmod

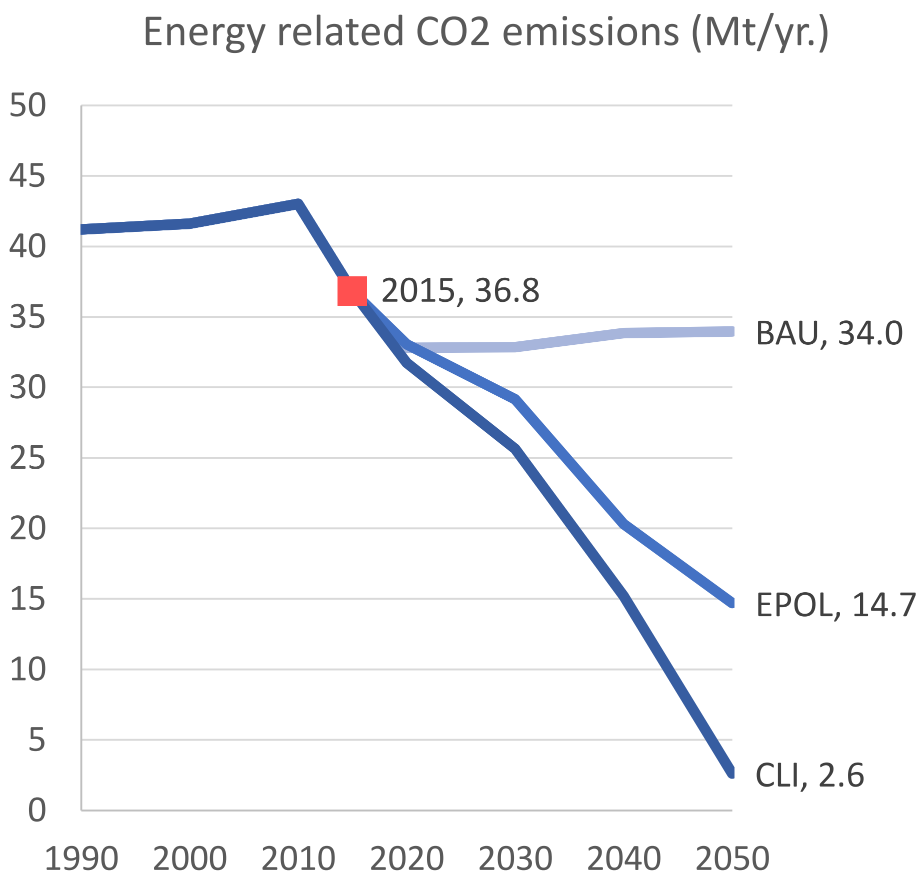
Transmission grid model including connections to neighboring countries

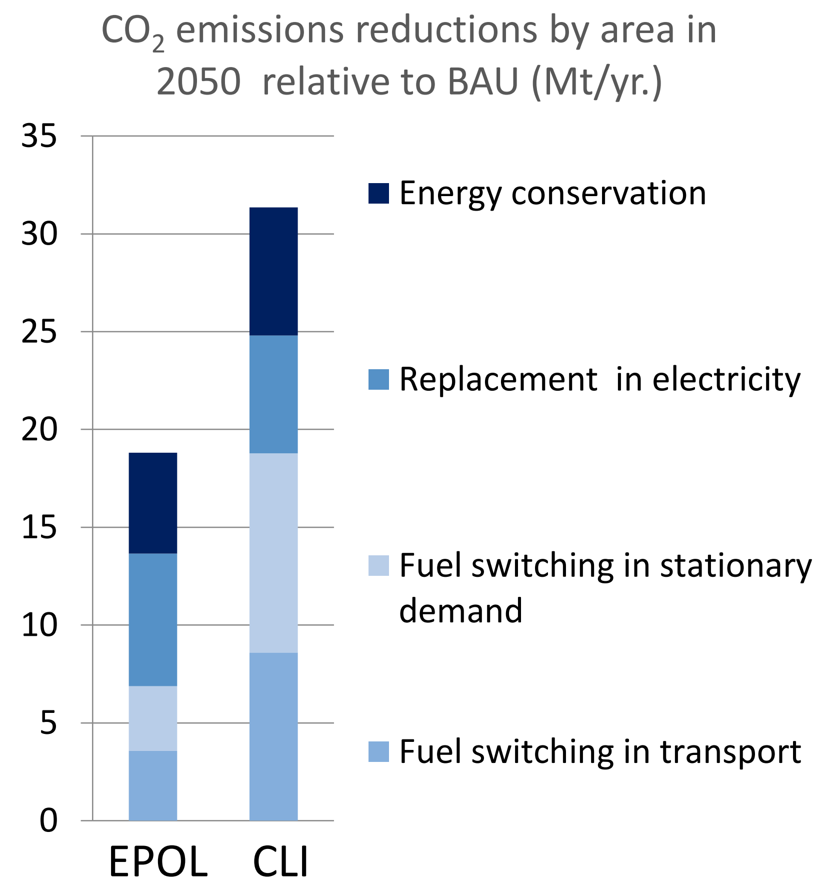
The Swiss TIMES Energy Systems Model



- Representation of the whole Swiss energy system
- Long term horizon with high intra-annual resolution

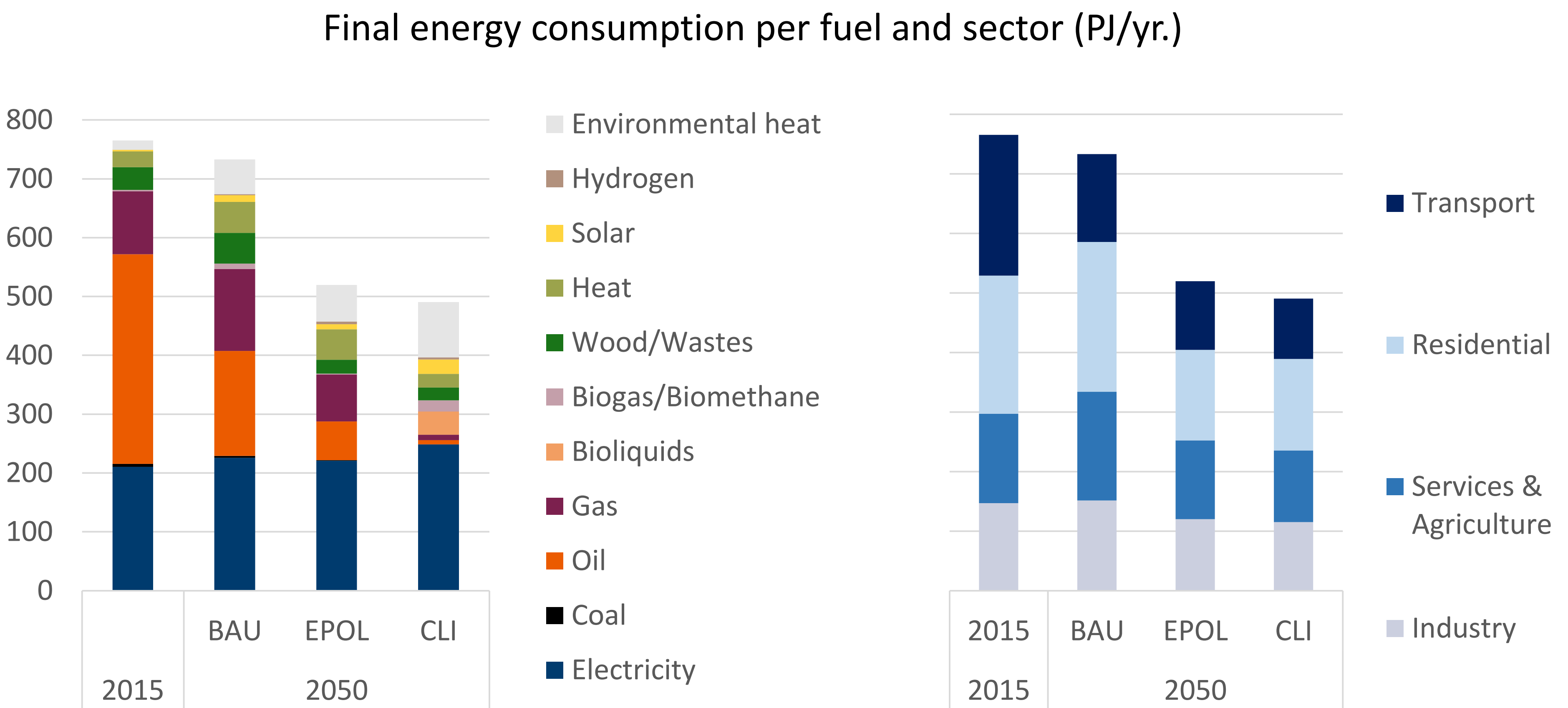
Energy related CO2 emissions (excluding international aviation)





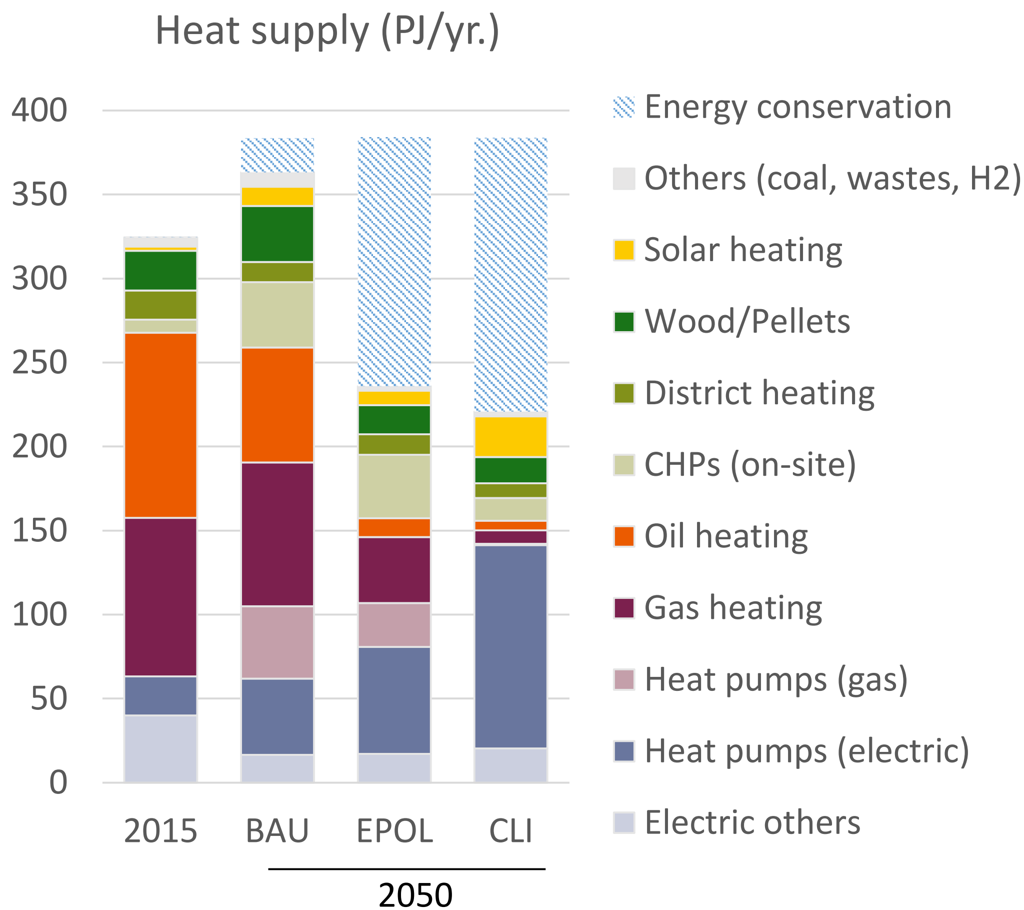
- Efficiency and electrification key pillars for a low carbon Swiss energy system

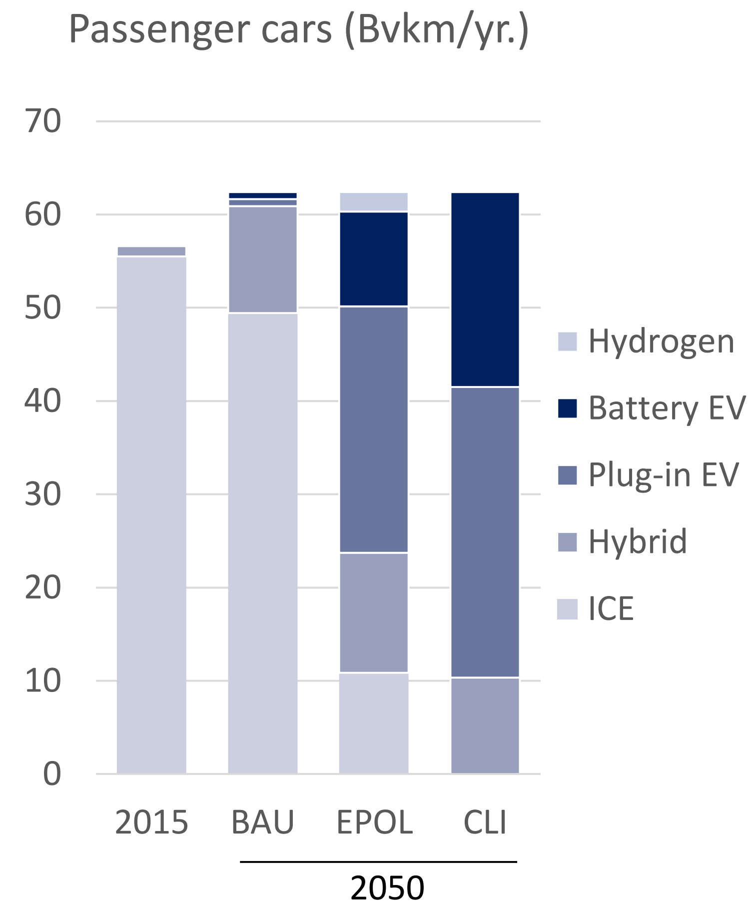
Final energy consumption (excluding international aviation)



- Reduction of per-capita energy consumption in CLI beyond SES targets in 2035 (-46% compared to -43% in SES)
- Electricity hardly increases over time in E-POL as efficiency absorbs new uses in mobility & heat
- Electrification and renewables essential in CLI to decarbonise end-use sectors

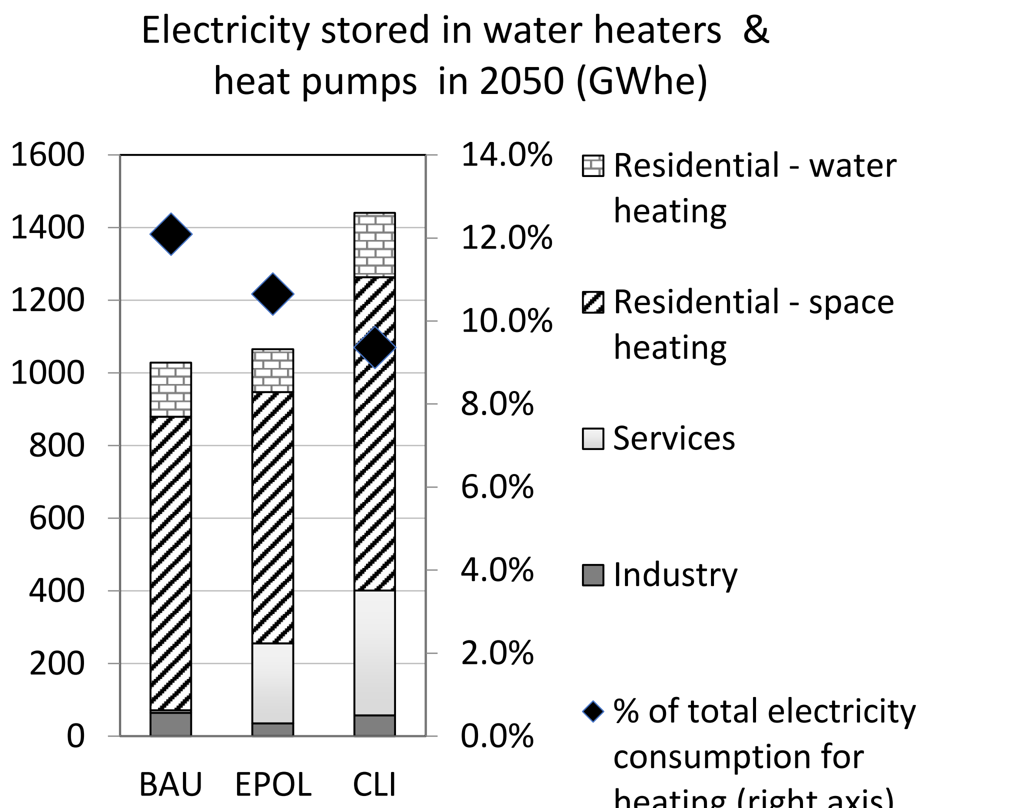
Heat supply and mobility

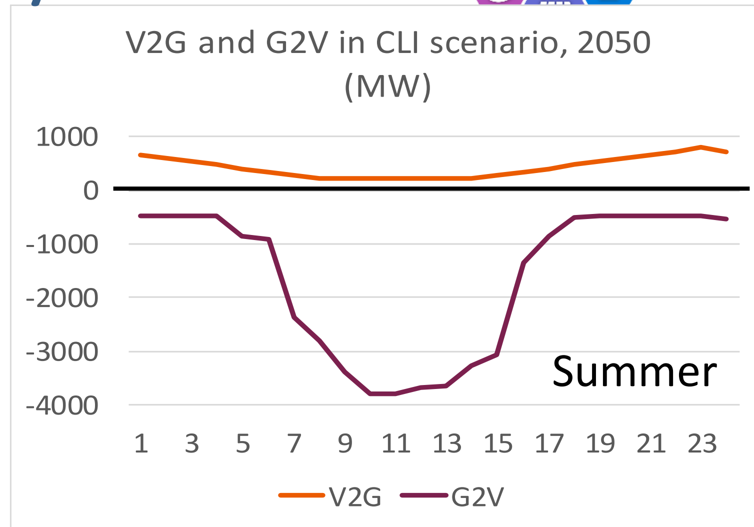


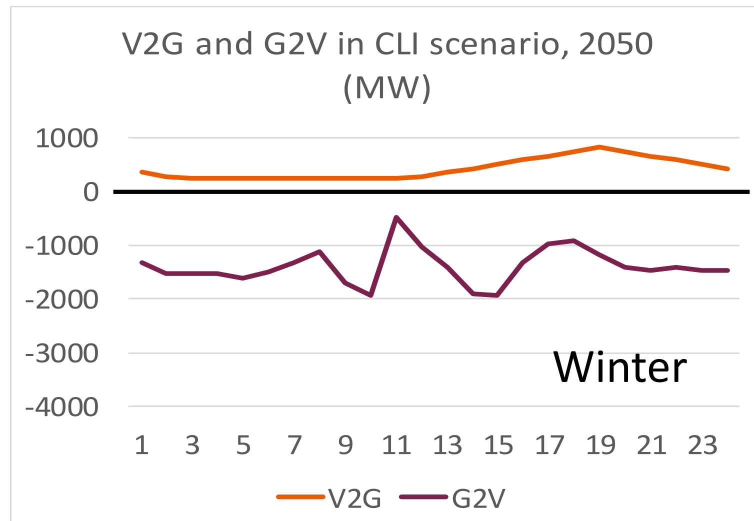


- Heat pumps share 55% in CLI; conservation measures up to 50% of current stock
- Electrification of private transport in CLI requests about 10 TWh_e /yr. in 2050

Flexibility in heating and mobility

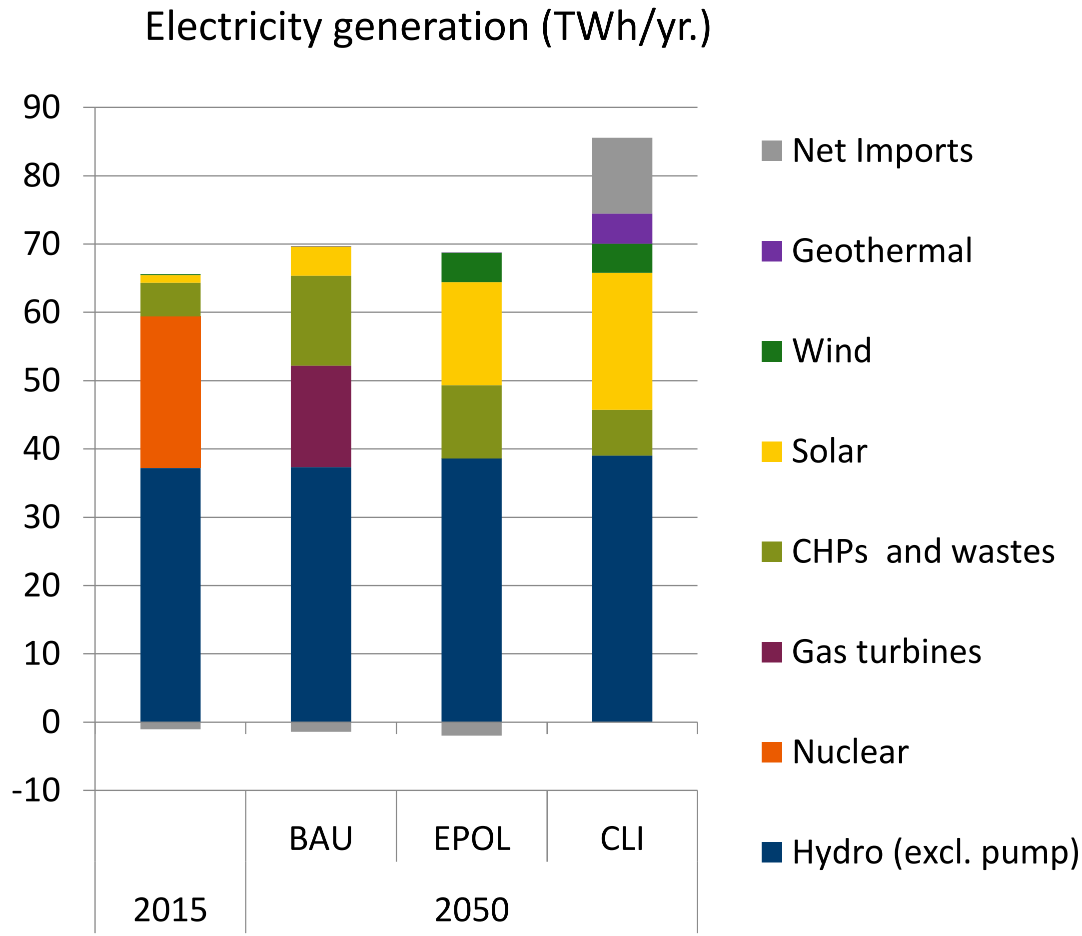


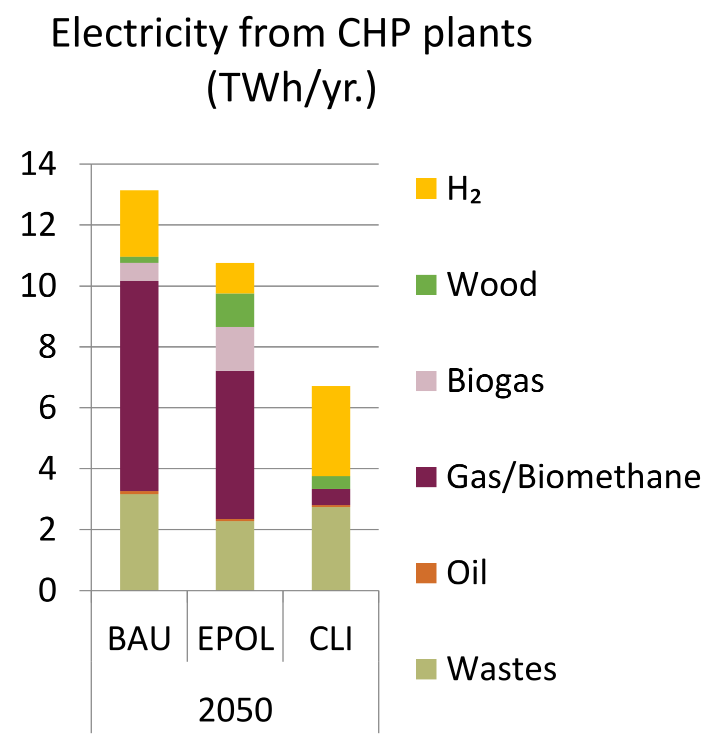




- Linkage to Storage (Swiss Competence Center for Energy Research) and sccer mobility
- Decoupling of electricity consumption in electric-based heating and heat supply
- V2G provides about 3.8 TWh to the grid, mainly during the evening peak hours; G2V important in summer absorbing excess solar electricity

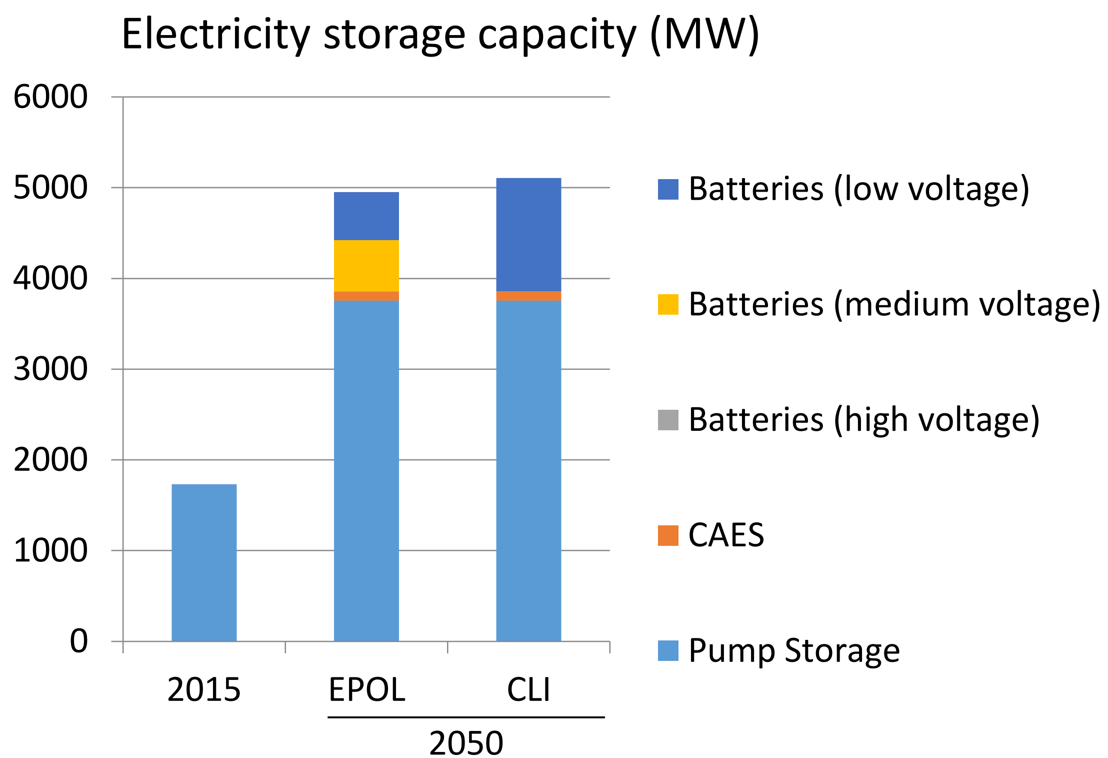
Electricity supply mix





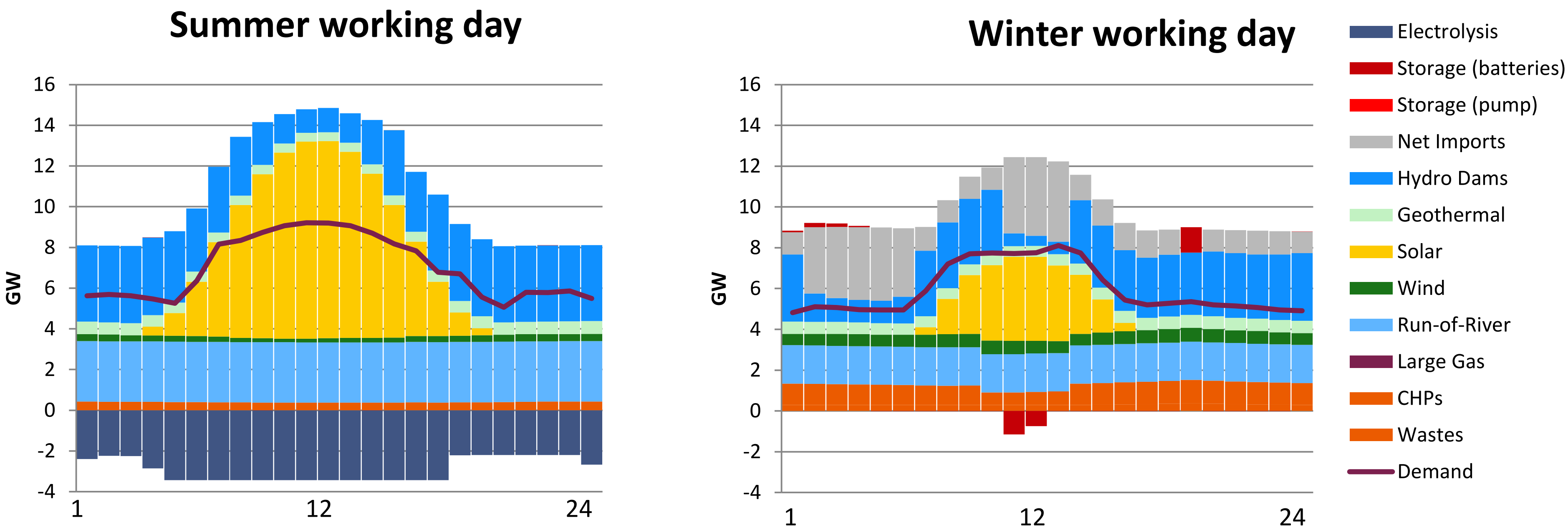
- Variable RES account for 33% of the domestic supply in CLI in 2050
- Balancing of the supply and demand is also provided by CHP + heat storage systems

Electricity stationary storage



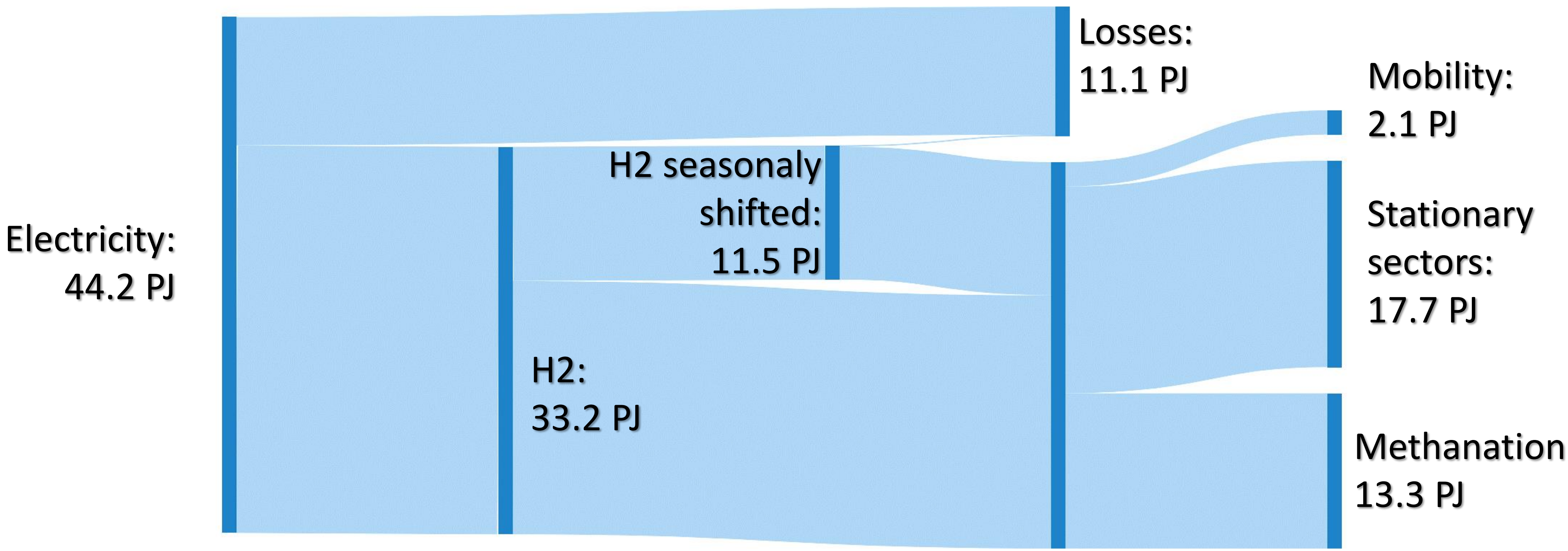
- In CLI, V2G and P2G reduce deployment of batteries as these options contribute both to decarbonisation and balancing
- In EPOL, batteries are important for balancing the increased supply from variable RES and achieve peak shavings
- Pump hydro correlates with international trade

Operating profiles in CLI scenario in 2050



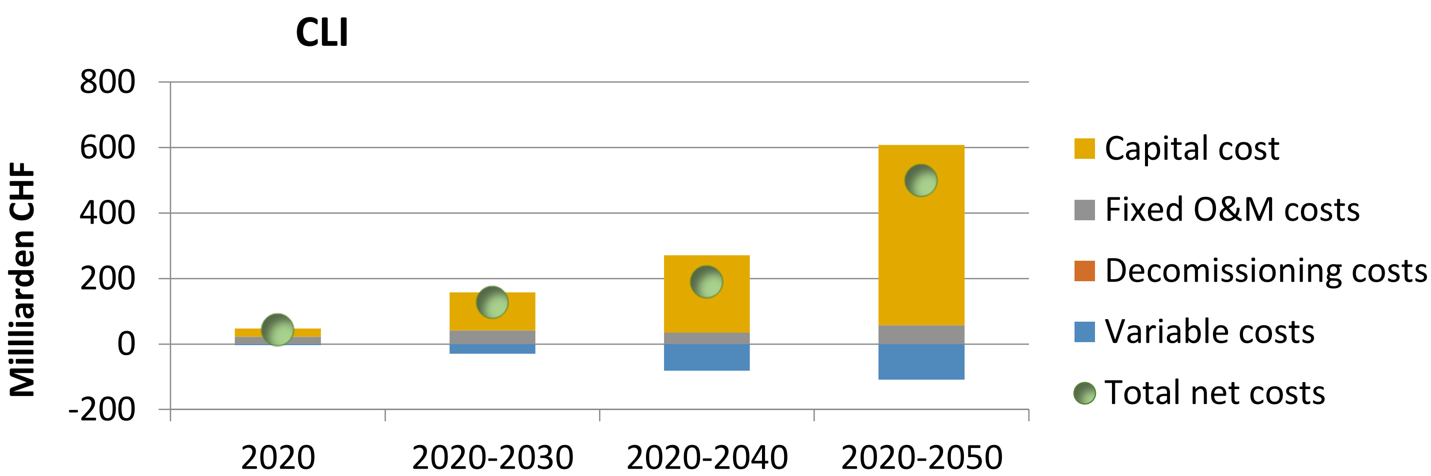
- In summer, electrolyzers work almost base load to convert excess electricity into H2 and «clean» gas
- The shape of the demand curve is different from today due to shifts incurred by DSM flexibility and storages

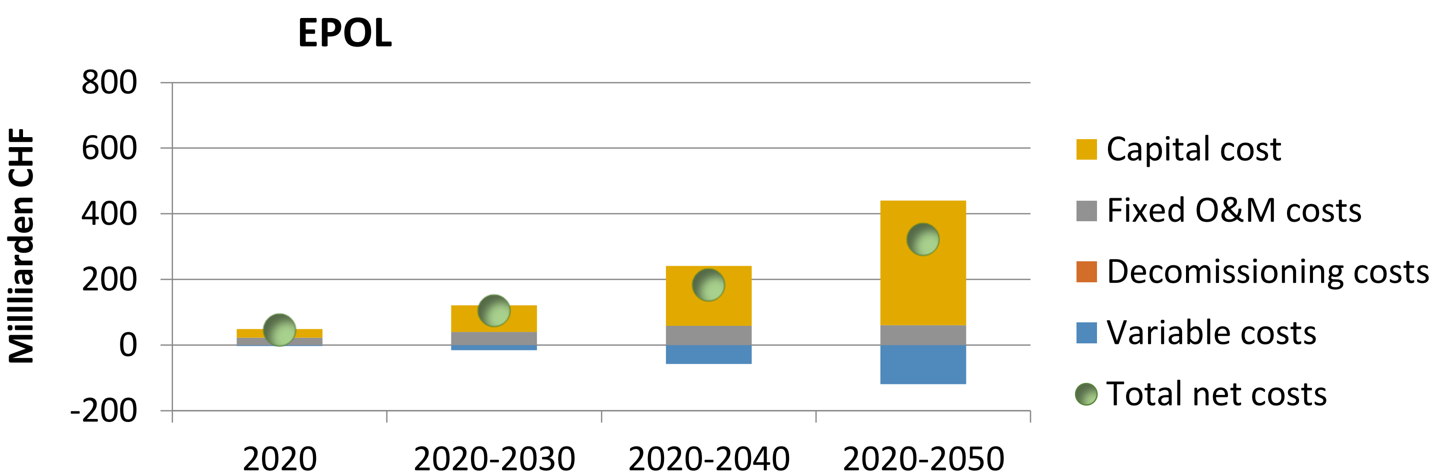
Power to gas (P2G) pathways in CLI in 2050



- A hydrogen economy starts to emerge in CLI scenario in 2050
- About 12 TWh of electricity enter into P2G pathways to produce clean fuels
- About 1/3 of the produced hydrogen is seasonally shifted via storage
- P2G important for decarbonisation of demand and for providing balancing service

System cost (cumulative, undiscounted relative to BAU)





Conclusions

- If potentials on energy demand <u>and</u> supply side can be unlocked, the ambitious targets of the SES 2050 can be achieved at lowest possible costs.

- To achieve a 1.5C compatible energy system increased ambitions beyond the SES 2050 required.

- Collaboration across multiple SCCERS beneficial to advance the analytical framework for the Swiss energy system.

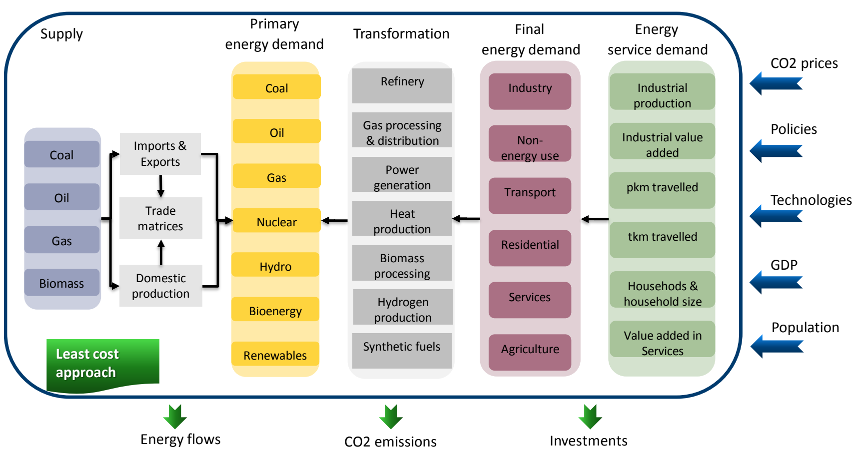
STEM – Swissmod link

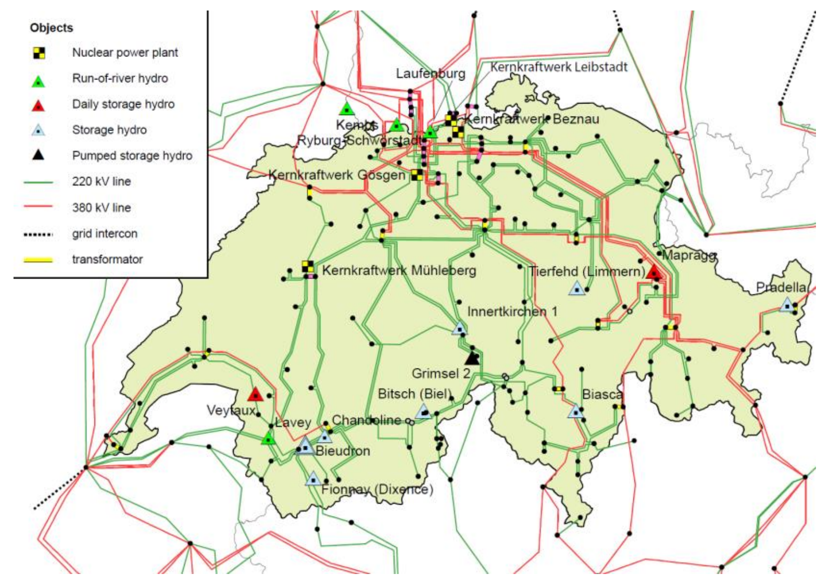
STEM

- Swiss TIMES Energy System Model
- Detailed representation of all energy sectors
- Only coarse representation of electrical grids

Swissmod

- DC load flow, dispatch, cost-minimization model
- Transmission System
  - Ca. 230 nodes (150 in CH), 400 lines
- Particular detail on hydropower
- Hourly resolution
- Neighboring countries included in simplified representation

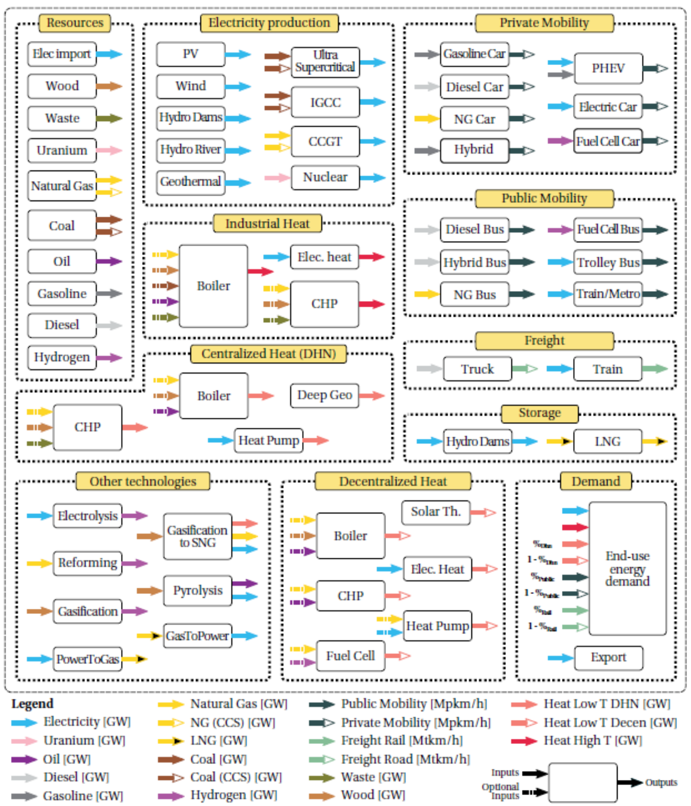


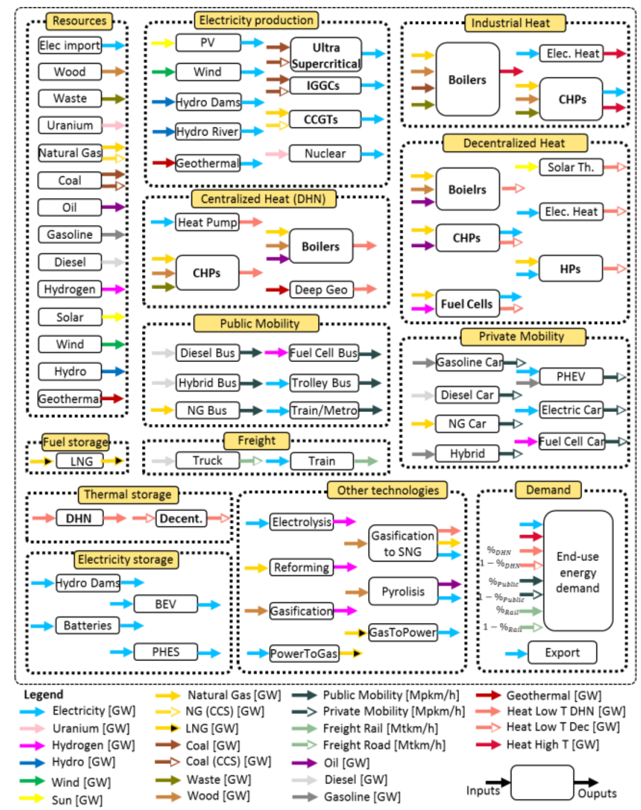


Verification of transmission grid feasibility

- STEM results are "energy-feasible"
- Swissmod
  - Are they also "transmission grid feasible"?
  - Do they work out with different hourly patterns of PV, wind and load?
  - Is the hydro-system flexible enough?
- Resulting indicators
  - Binary indicator whether scenarios are grid-feasible
  - If not, loss of load-hours
  - Curtailment of renewables: How much energy cannot be used, stored or transported?
  - Congestion evaluation: line usage, price differences, critical connections

Swiss EnergyScope Typical days (SES TD)

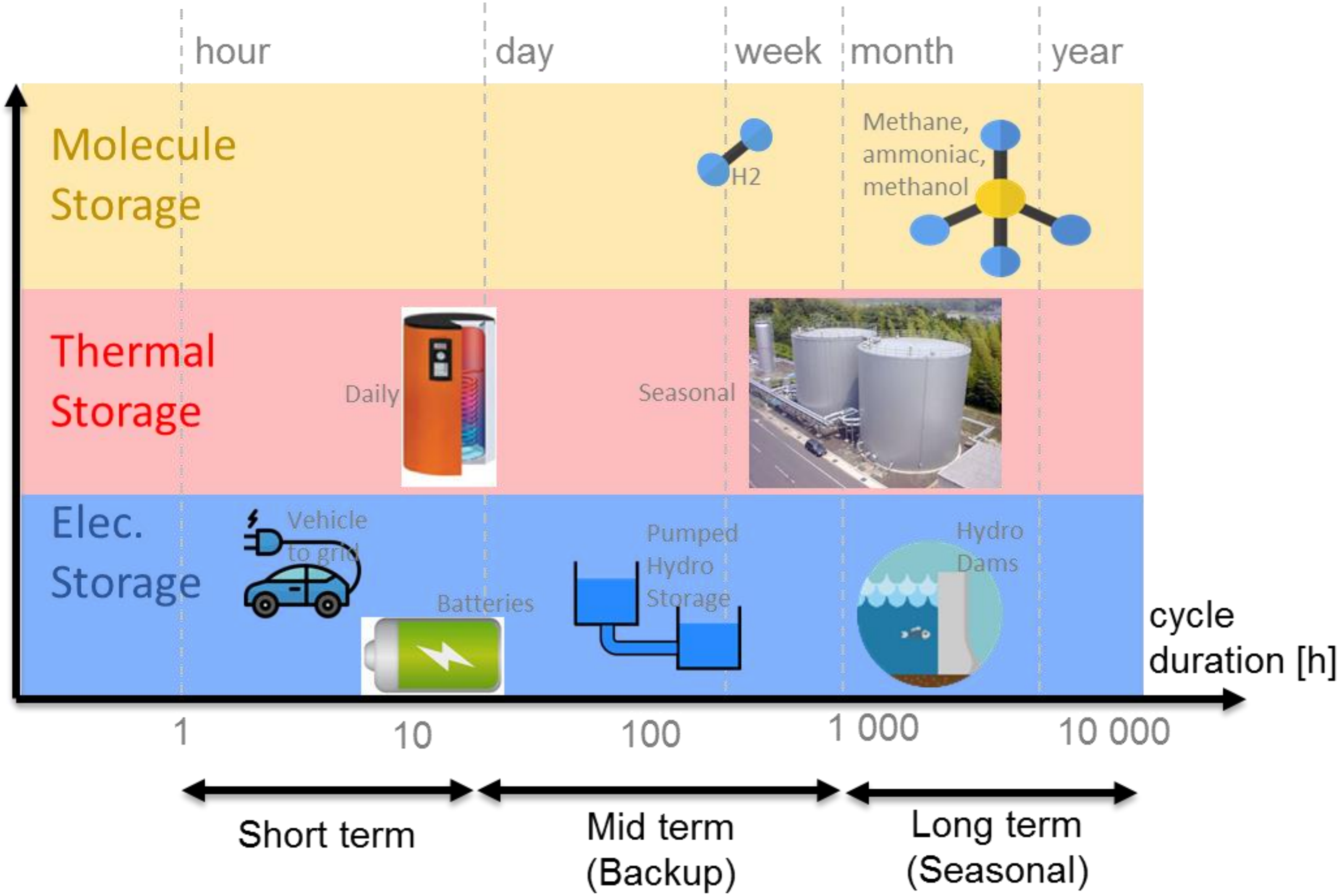




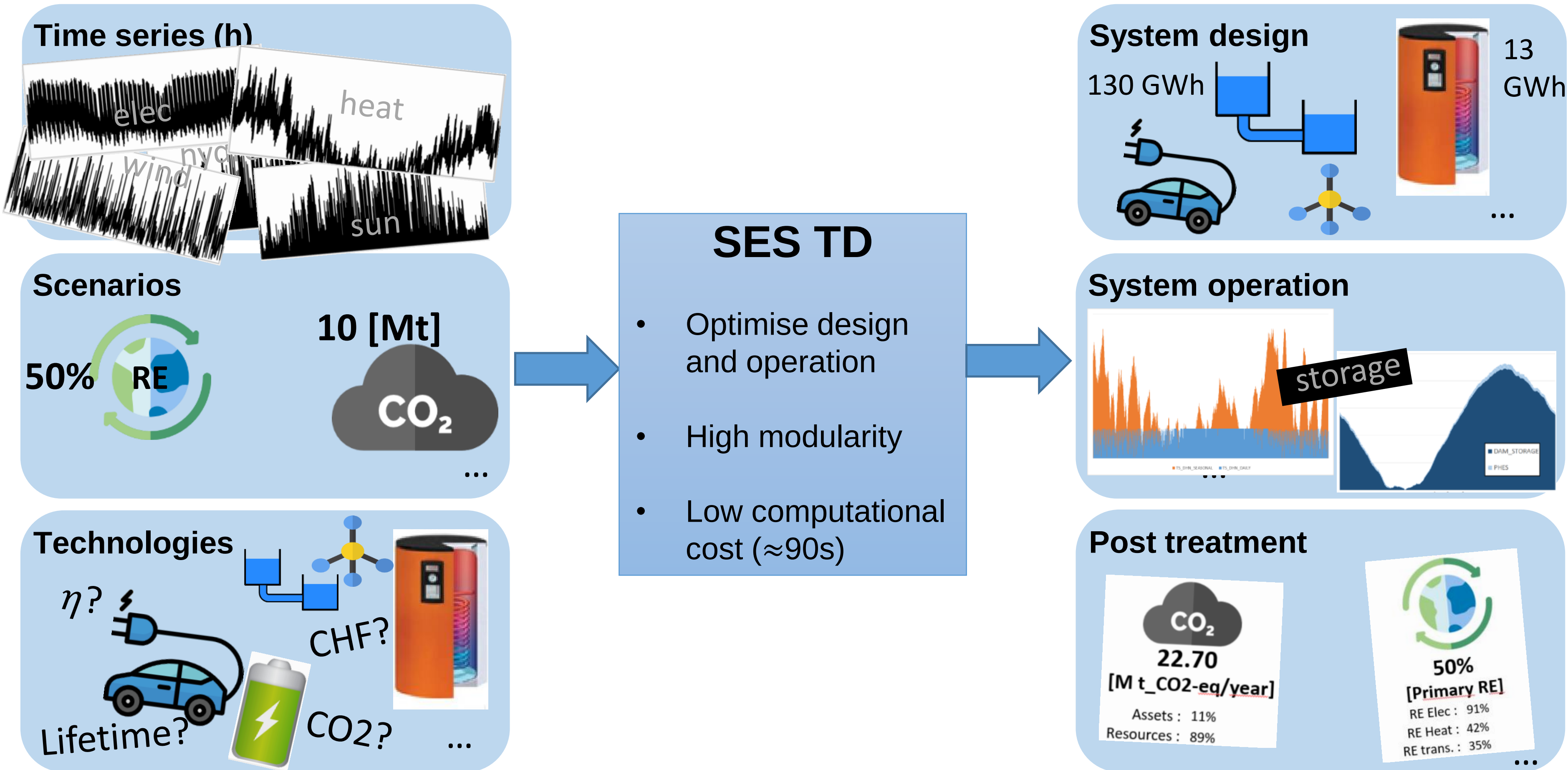
Stefano Moret's original model at monthly resolution

My new version at hourly resolution with typical days to better capture storage technologies at all time scales

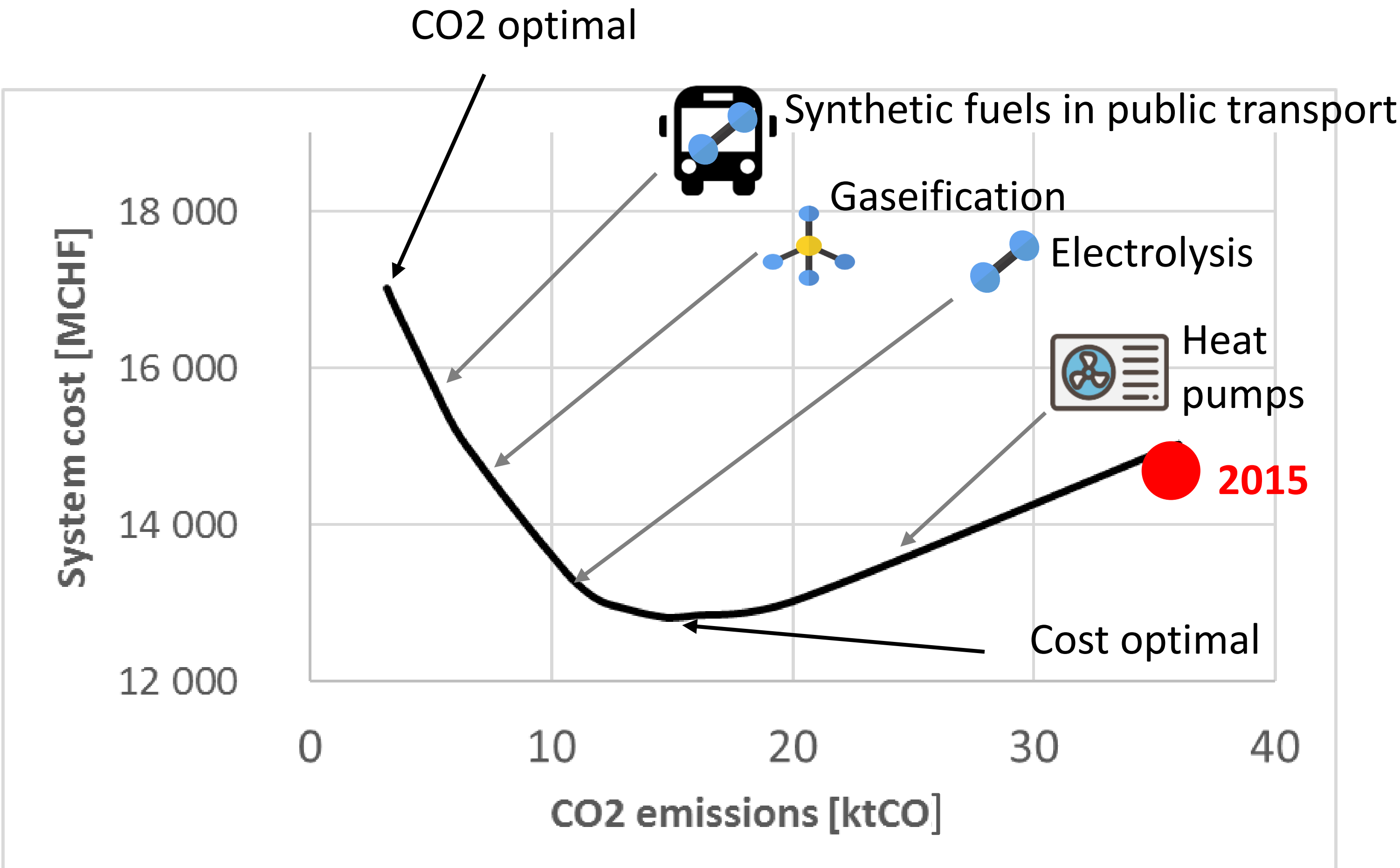
Storage technologies



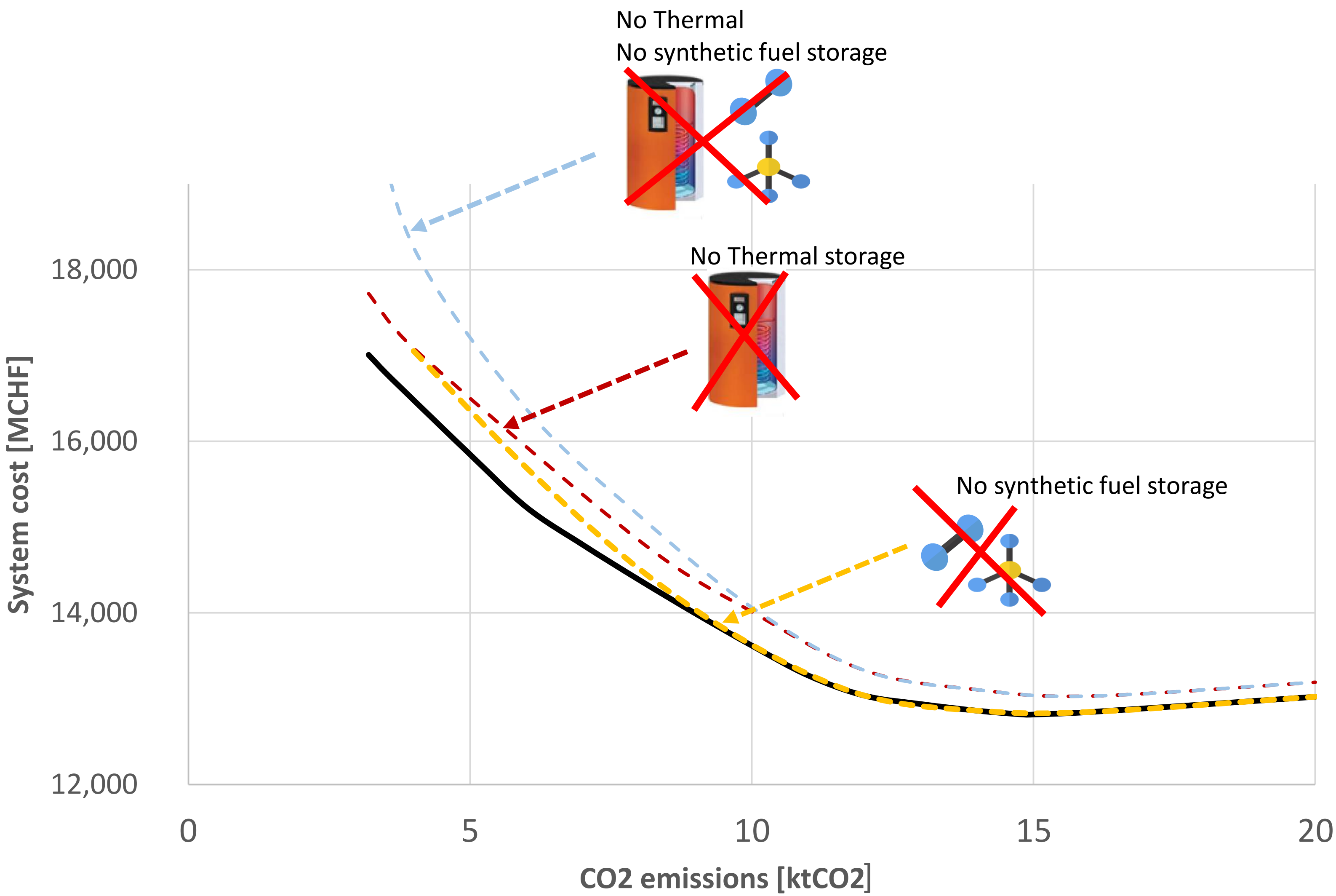
Inputs & outputs



Results for CLI scenario / TECH variant

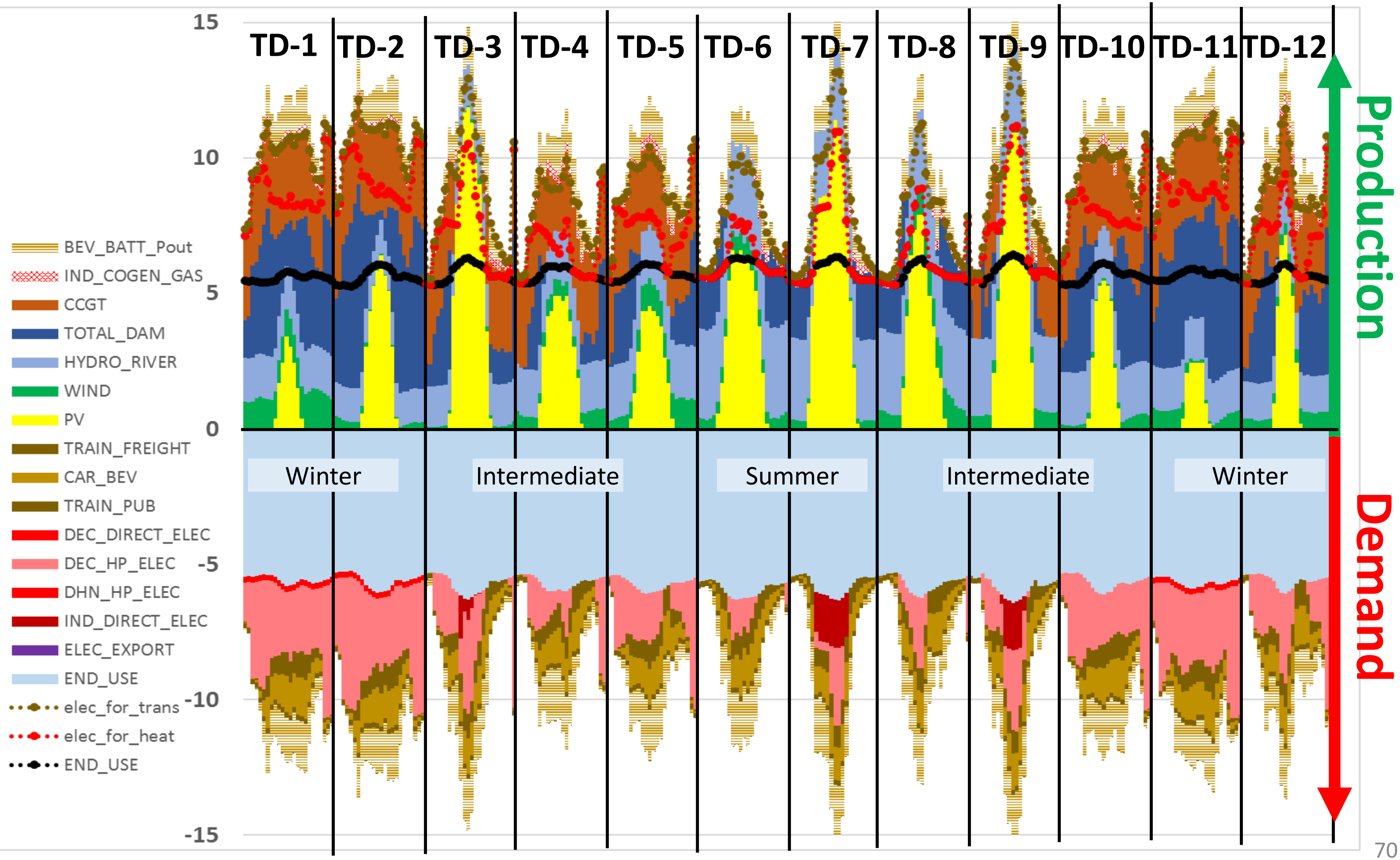


Results for CLI scenario / TECH variant

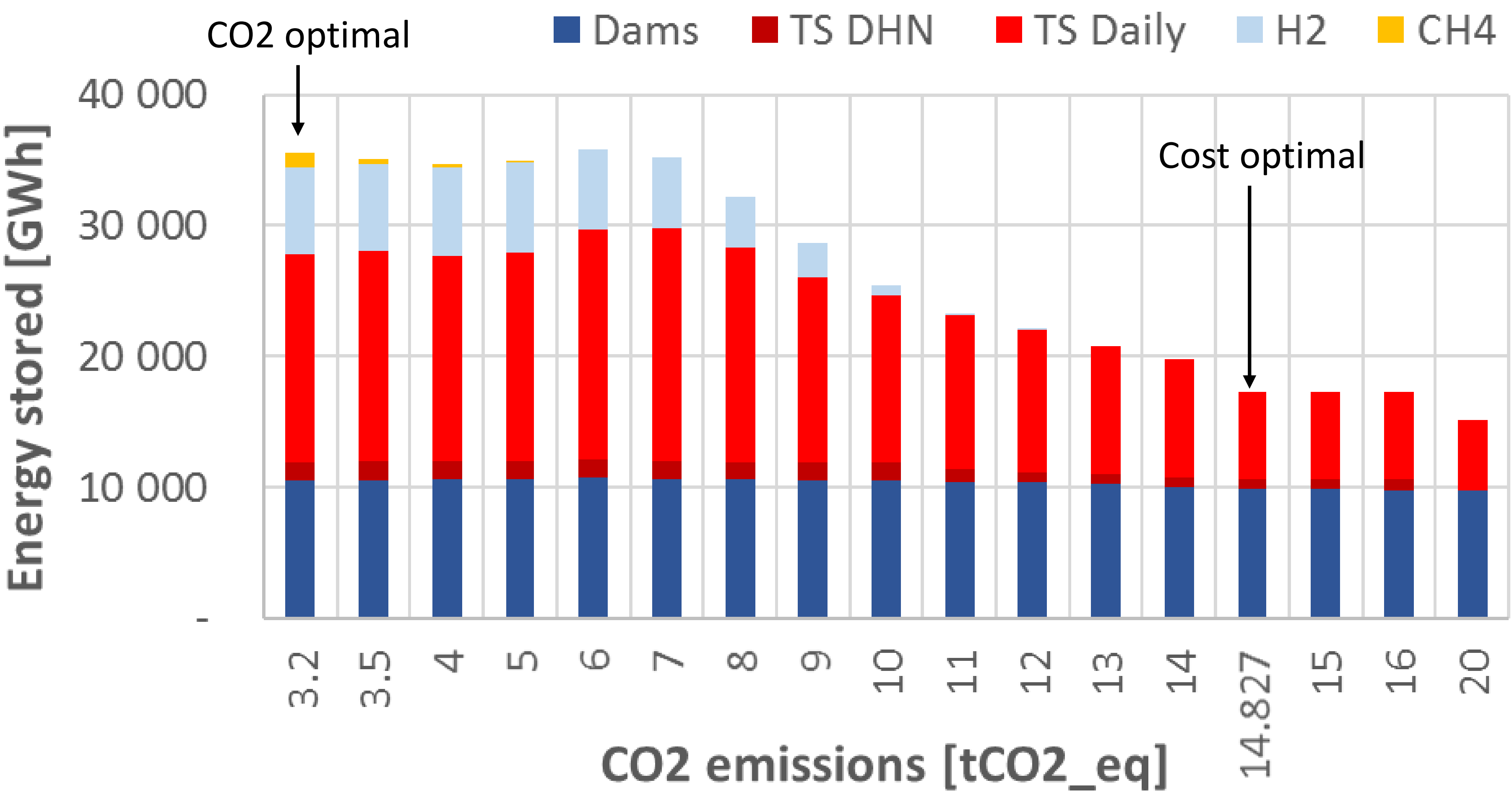


Electricity production and demand (GW)

Cost optimal point @ 14.6 Mt_{CO2}

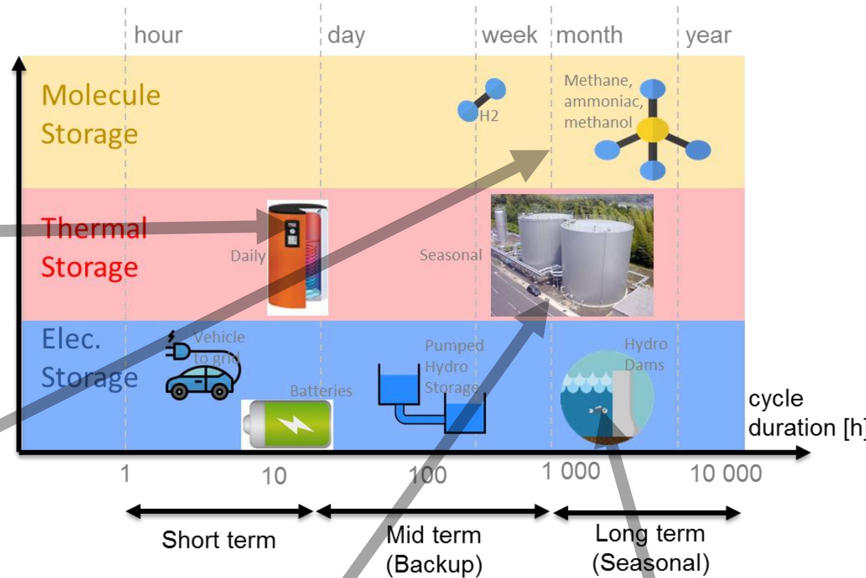


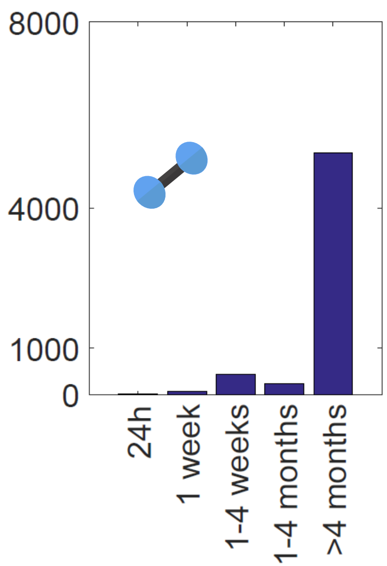
Energy passing through a storage device
Yearly aggregate

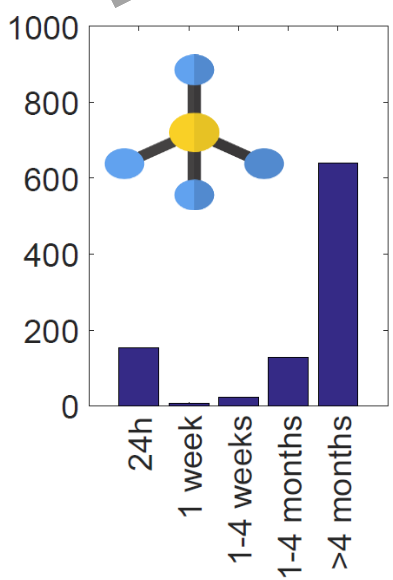


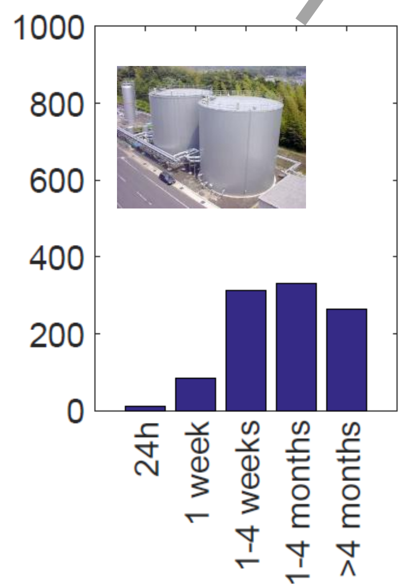
Energy passing through a storage device
Breakdown into time scales, CO_2 optimal point @ 3.2 Mt_{CO2}

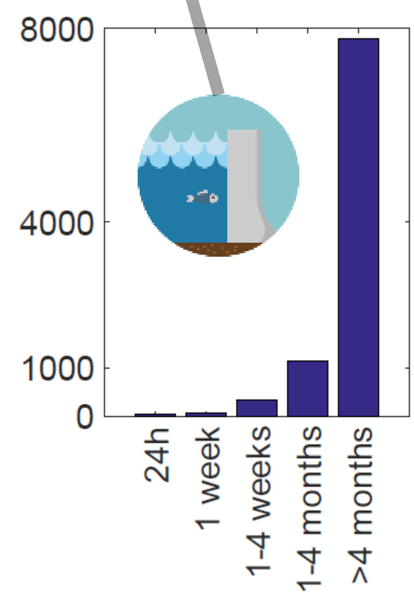
Capacity : 53 GWh
Energy stored :
15 854 GWh



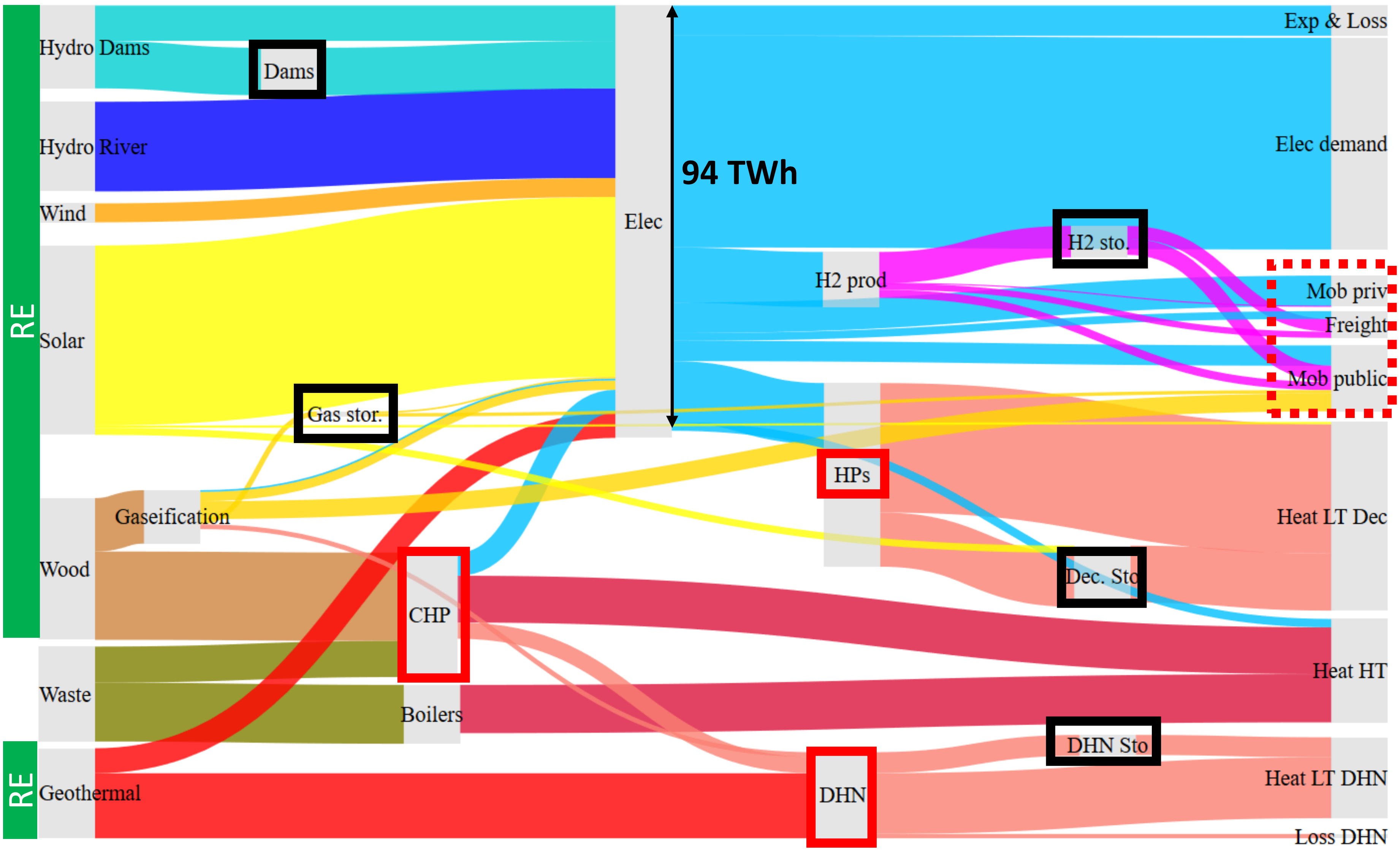








Energy flows in a year
CO_2 optimal point @ 3.2 Mt_{CO2}



Think global, act local!

Case study

Future heat supply for Baden-Nord

LV/MV-grids

How can we maximize the PV generation?

Case study Baden Nord

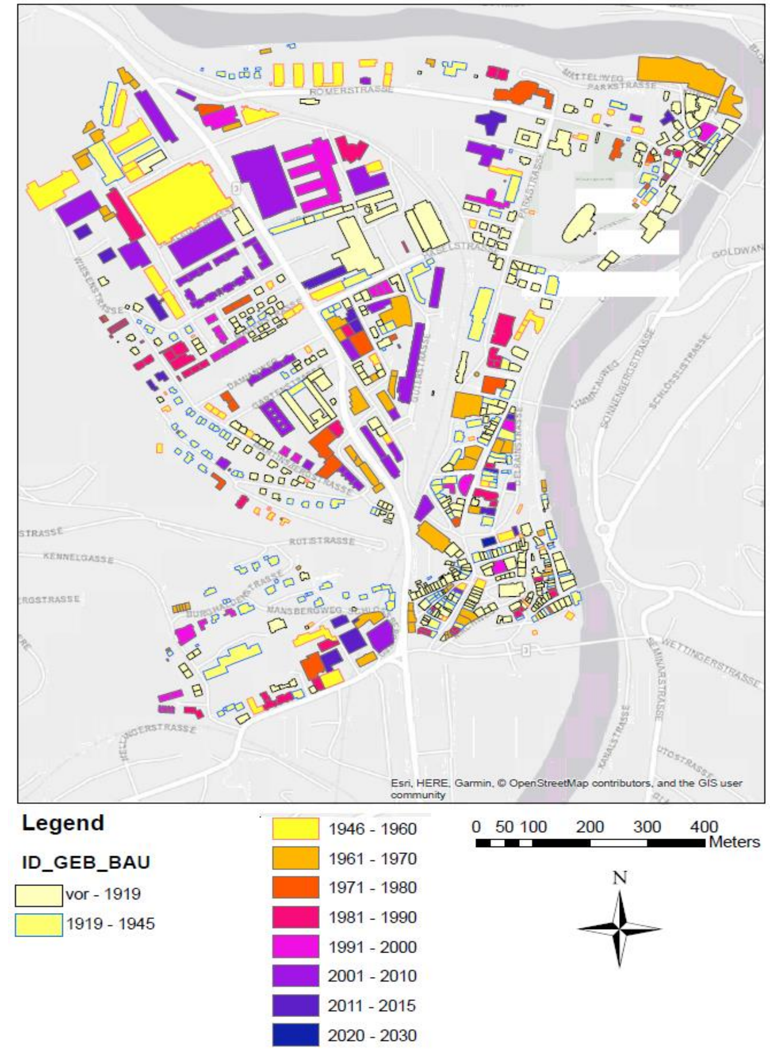
JASM

Empa
Materials Science and Technology

Regionalwerke
Baden

Case study Baden Nord

- Analysis objectives:
  - Increasing the share of renewable energy
  - Trade-offs between centralised systems or distributed systems per district
  - Trade-offs between costs and carbon emissions emitted for operating the systems
  - Need for deployment of heating or cooling networks?
    - At district level or between districts?
  - Connection heat supply to waste treatment plant from Refuna?



Baden North – map building ages

Case study Baden Nord – Ehub tool approach

1. Energy demand simulation

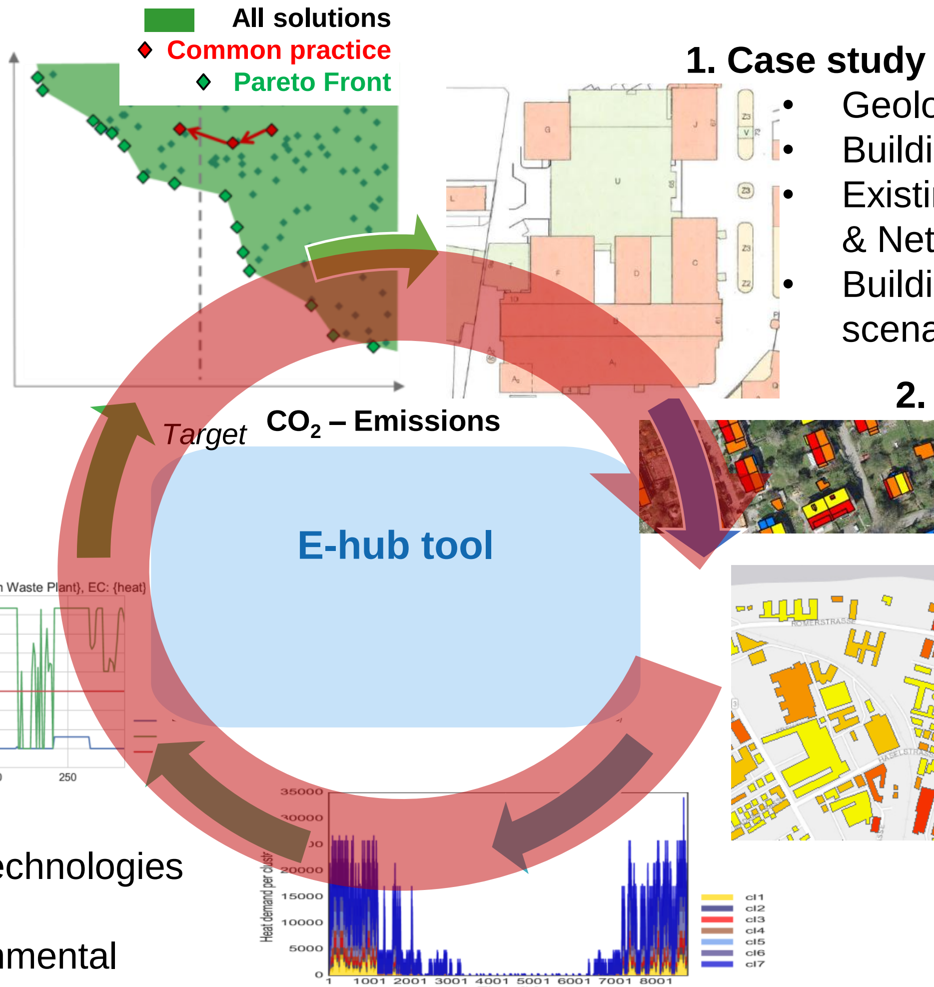
1. Case study implementation
- Geolocation
- Buildings information
- Existing energy systems & Networks
- Buildings layout different scenarios

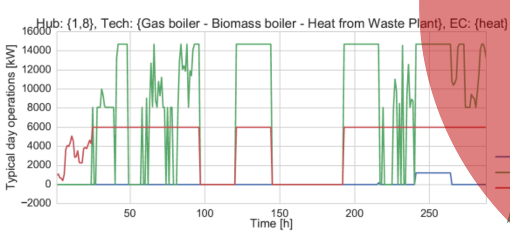
2. Simulation
- Renewable potentials (solar & weather file
- Energy demand profiles correlated to annual demand

2. Optimisation of the energy supply system

5. Optimisation
- Trade-off costs for design and operations of energy systems VS. Environmental impact

- Trade-off retrofitting measures VS. supply measures

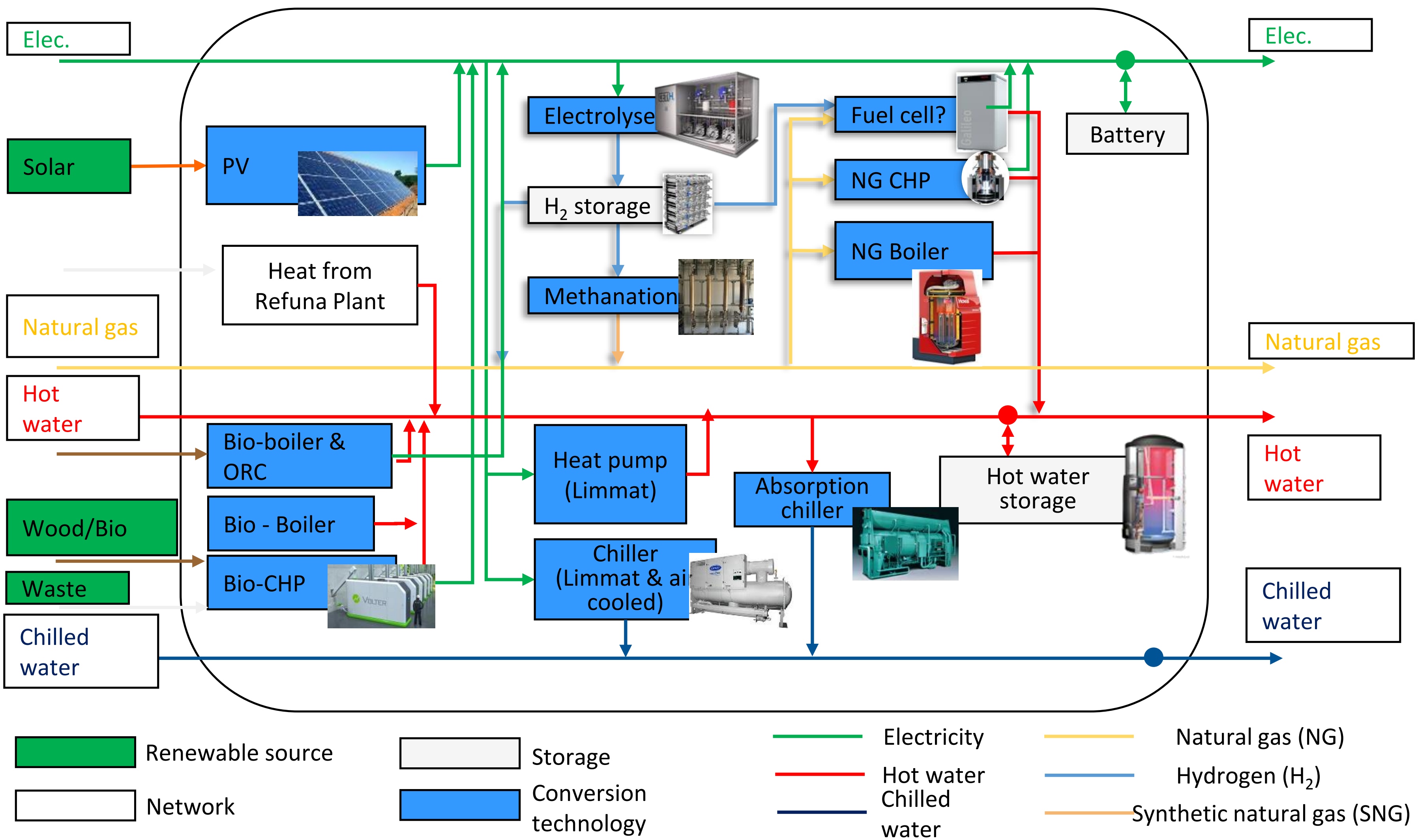




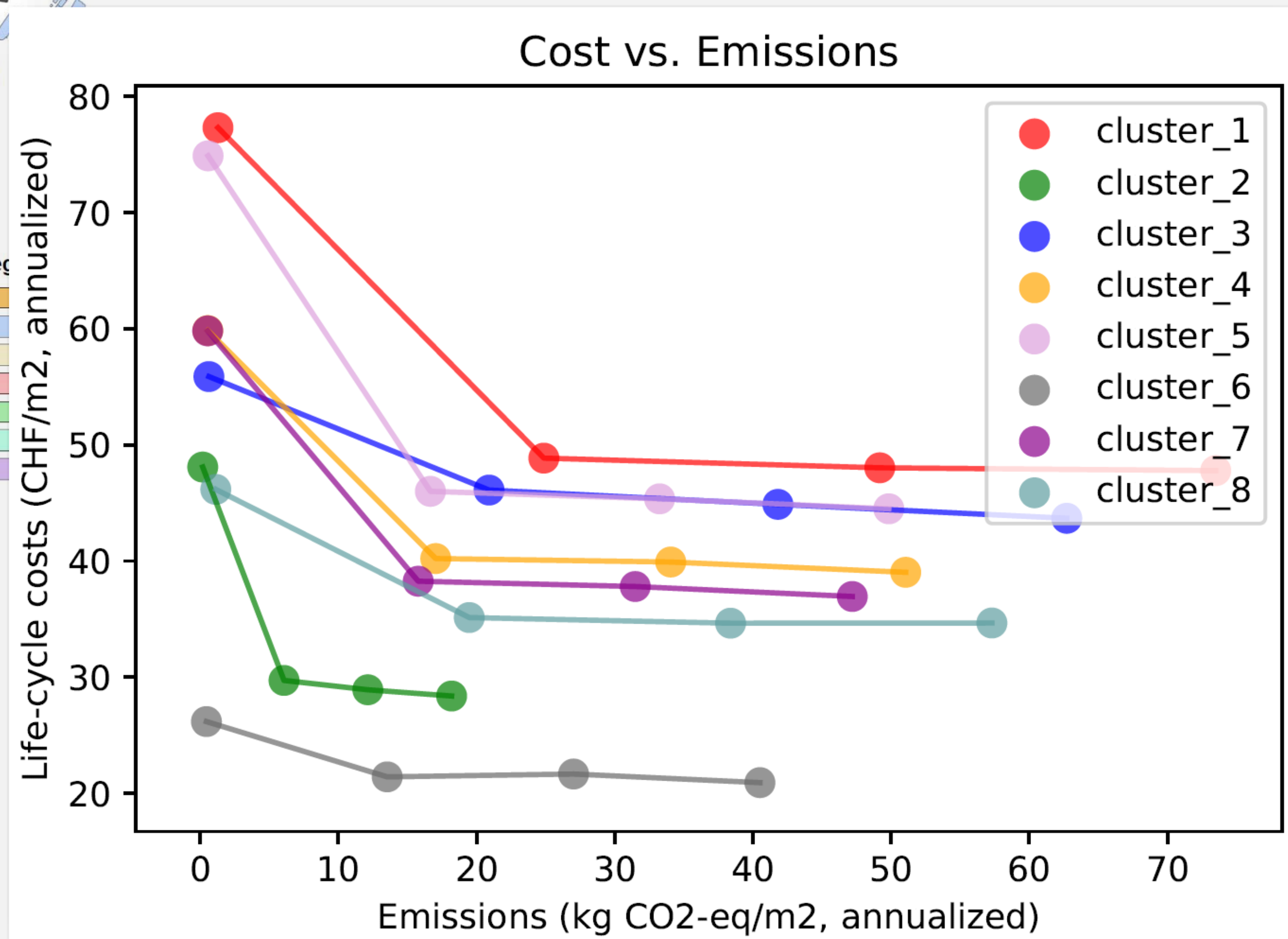
4. Modeling
- Energy candidate technologies
- Specific constraints
- Economic & environmental parameters

3. Clustering – data mining energy systems positioning

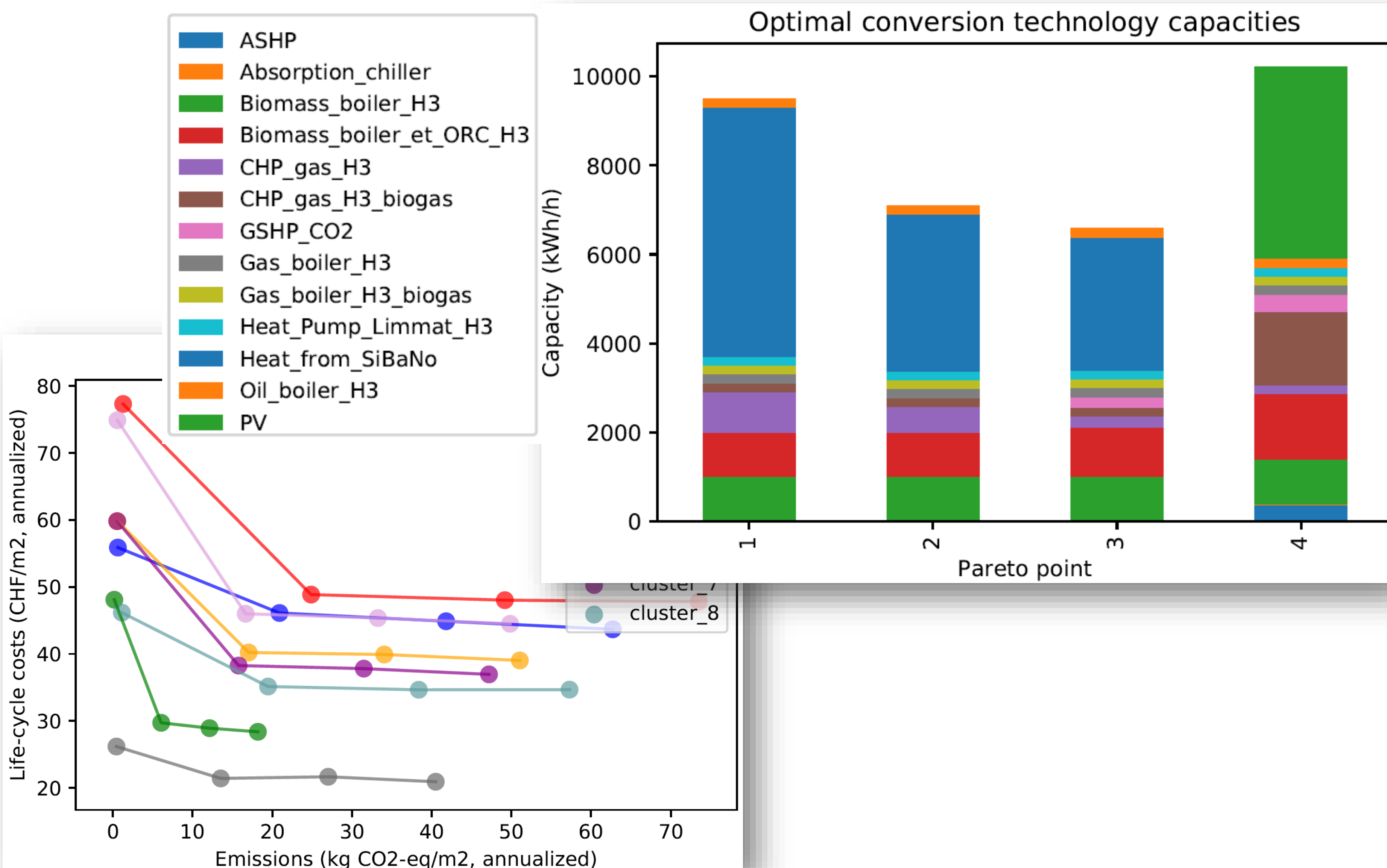
Case study Baden Nord – Energy systems optimisation



Pareto front results

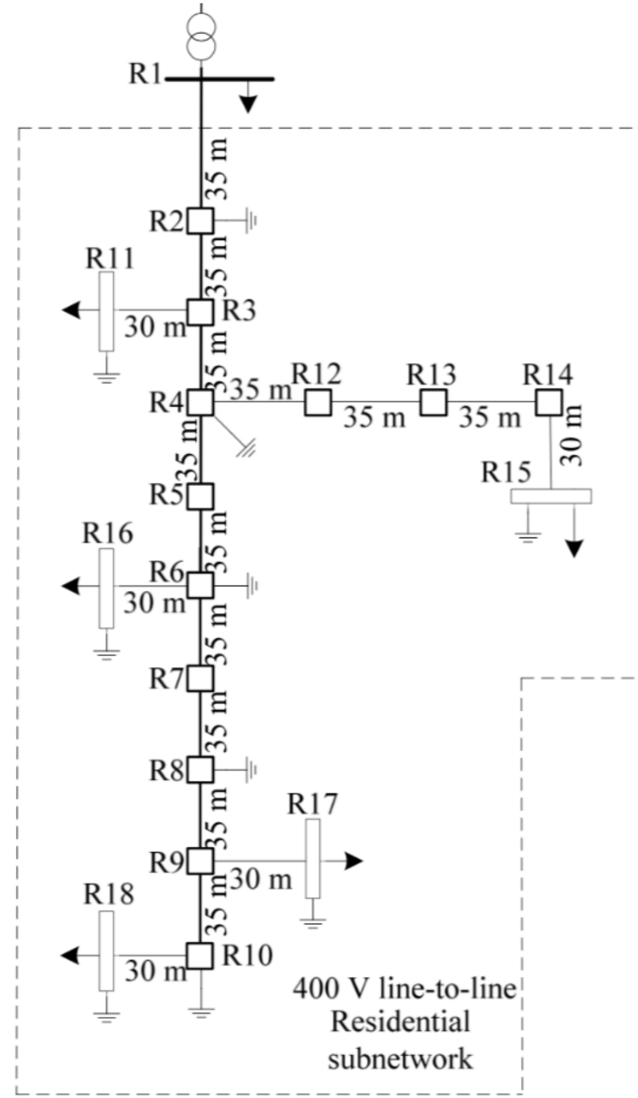


Pareto front: Baden North – Cluster 1



How to put more PV in distribution grids?

- Lines' **ampacity ratings** and **stationary voltage levels limit the capacity of** existing distribution networks to **host** distributed **PV** generation.
- **Energy storage systems** may **increase PV hosting capacity** while providing **other ancillary services simultaneously** — *as opposed to grid reinforcements (powerline replacement, new substations)*
- **Size** and **site** of **storage** can be determined by adapting **optimal power flow** problems with **tractable** formulations based on linearized or convexified load flow models [Sossan2018].



[Sossan2018] "Increasing the PV hosting Capacity of Distribution Grids with Distributed Storage: Siting, Sizing and Costs", F. Sossan, R. Gupta, E. Scolari, M. Paolone, Technical Report, available online, 2018.

Problem Formulation

Minimize

{ Capital investment to deploy energy storage systems }

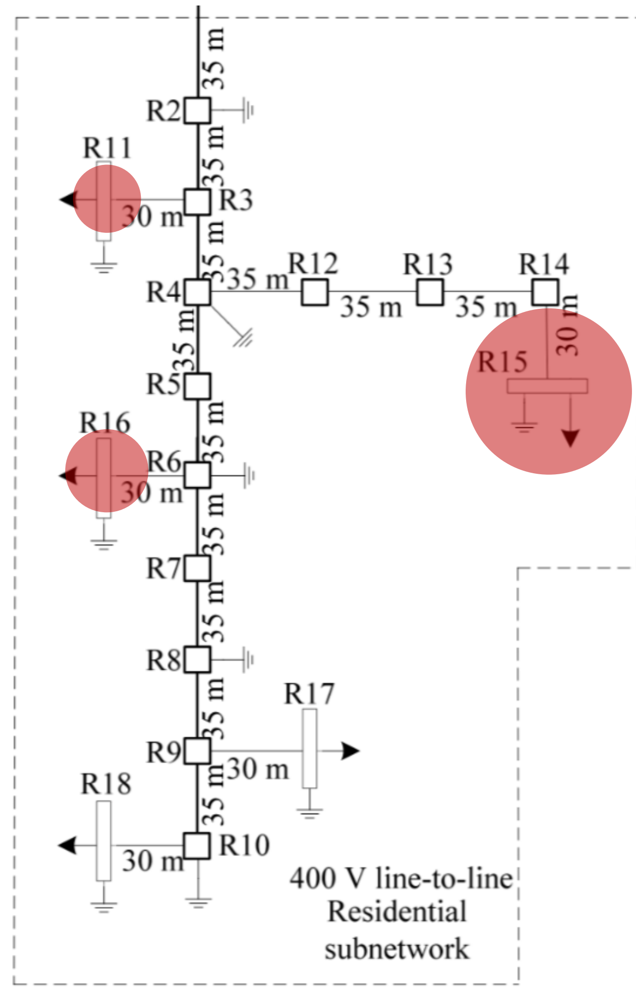
(installation costs, cost per kWh, cost per kVA)

subject to

Grid model (admittance matrix)

Voltage statutory limits,	*for all nodes*
Current ampacity limits,	*for all the lines*
Storage state-of-energy model,	*for all nodes*
Land use constraints,	*for all location*
Highly spatiotemporal resolved time series of demand and PV generation,	*for all nodes*

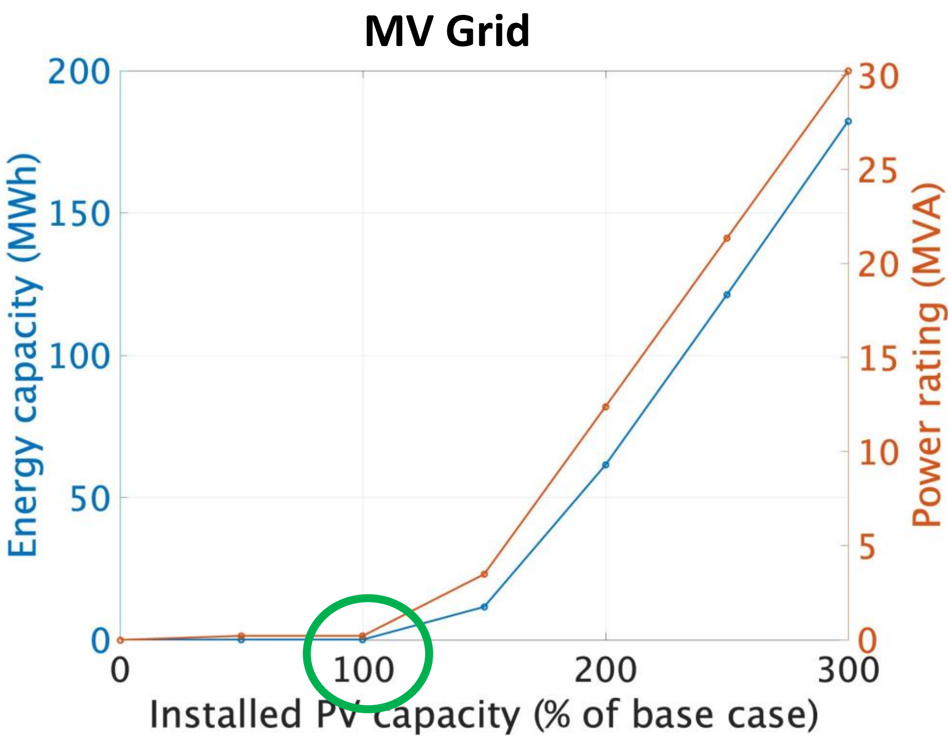
Output of the problem

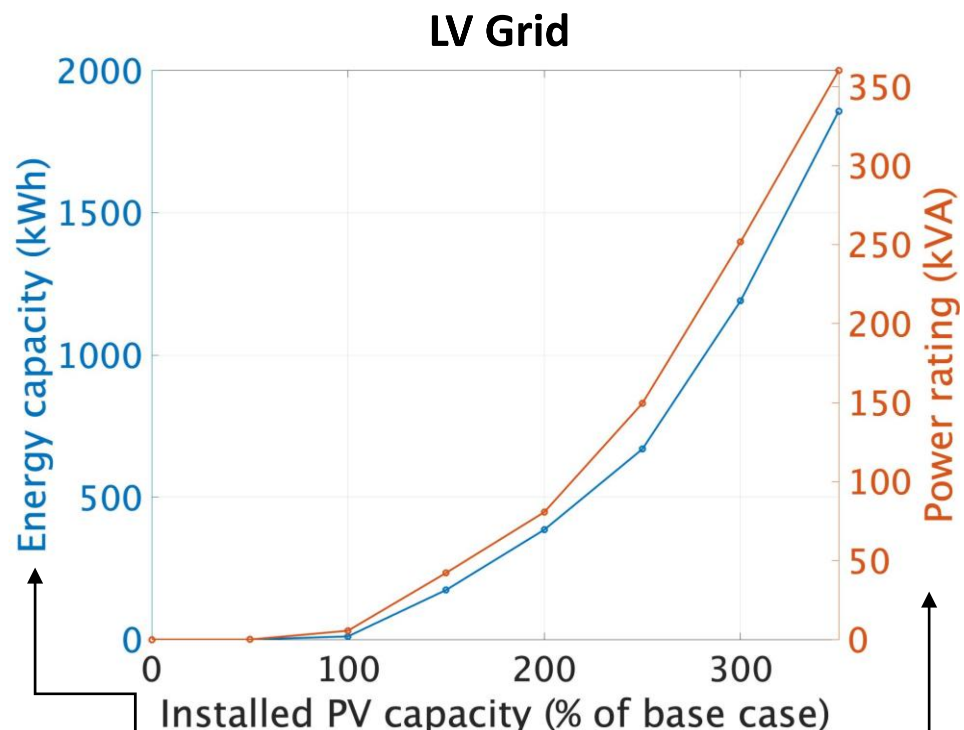


Storage site and capacity

Results for CIGRE' grids

Energy capacity and power rating to deploy for the CIGRE benchmark systems





Grid's PV hosting capacity

Above the hosting capacity, power and storage capacity is required to add PV

Energy intensive application -> low C-rate (**<0.2**), it couples well with power intensive applications, like primary frequency control

Final objectives

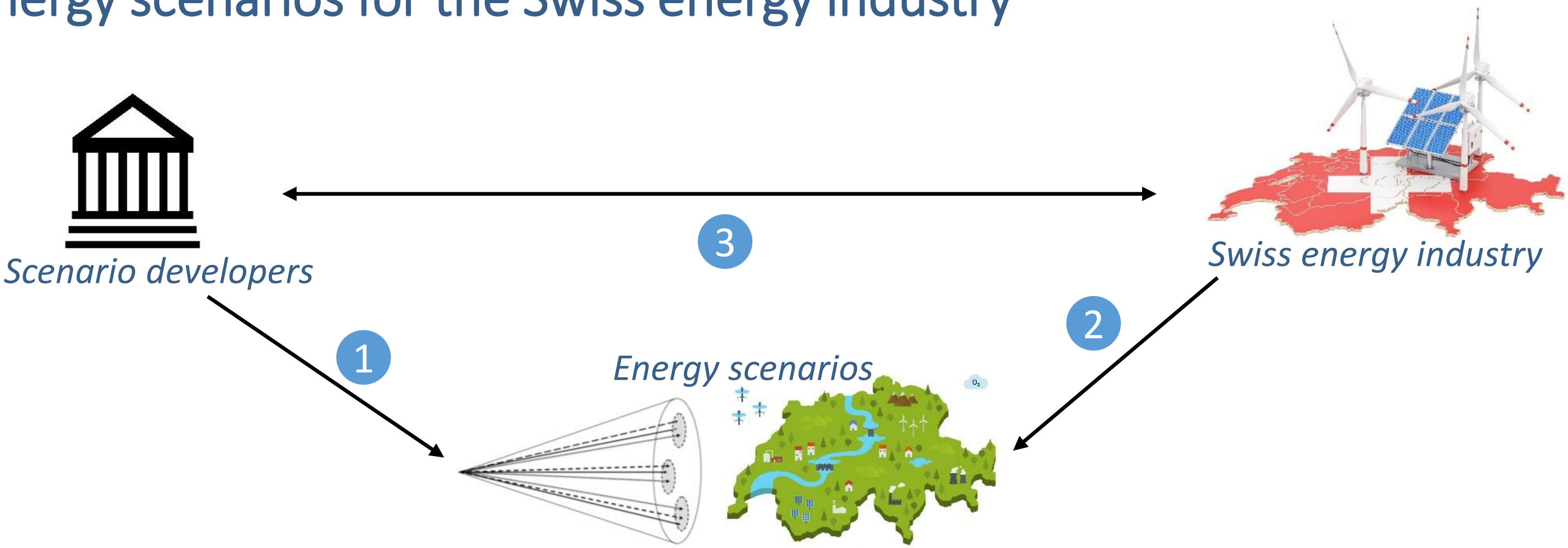
By relying on a method capable to assess the PV hosting capacity in distribution grids accounting for: (i) the stochastic behavior of the connected resources as well as (ii) potential asset reinforcement via distributed storage, the research provides quantitative answers to the following main questions:

- Can existing distribution networks of Switzerland accommodate the PV installed capacity levels designed in the scenarios?
- How much energy storage capacity is required to adequate existing distribution networks?
- How does the cost of installing energy storage systems compare to traditional network reinforcement solutions?
- What is the contribute of energy storage systems to others critical power systems' ancillary services (e.g., primary frequency control, synchronization services to support inertia-less power systems)?

Impact on stakeholders

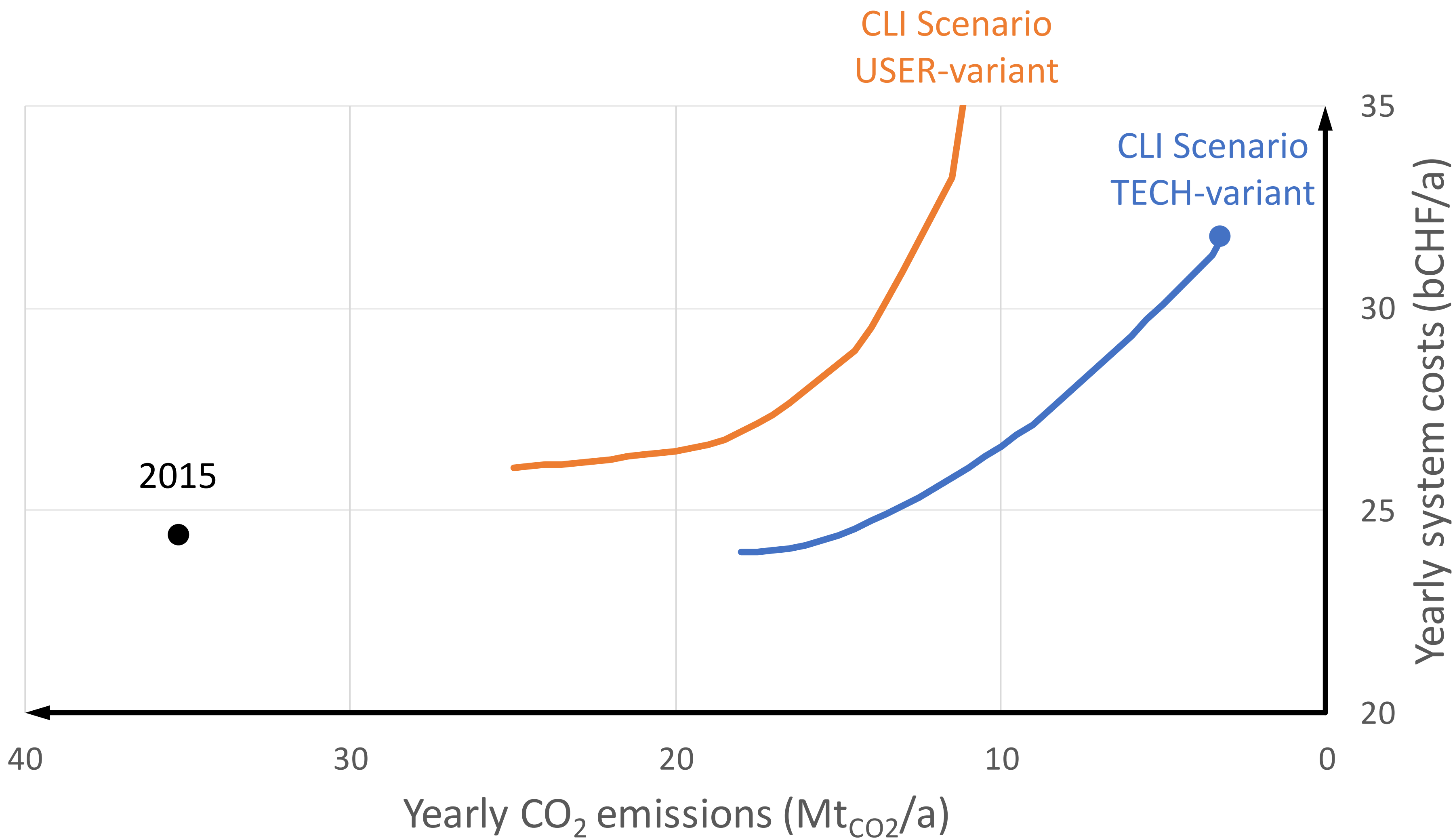
Making sense of the energy future

Increasing the relevance and usability of model-based energy scenarios for the Swiss energy industry

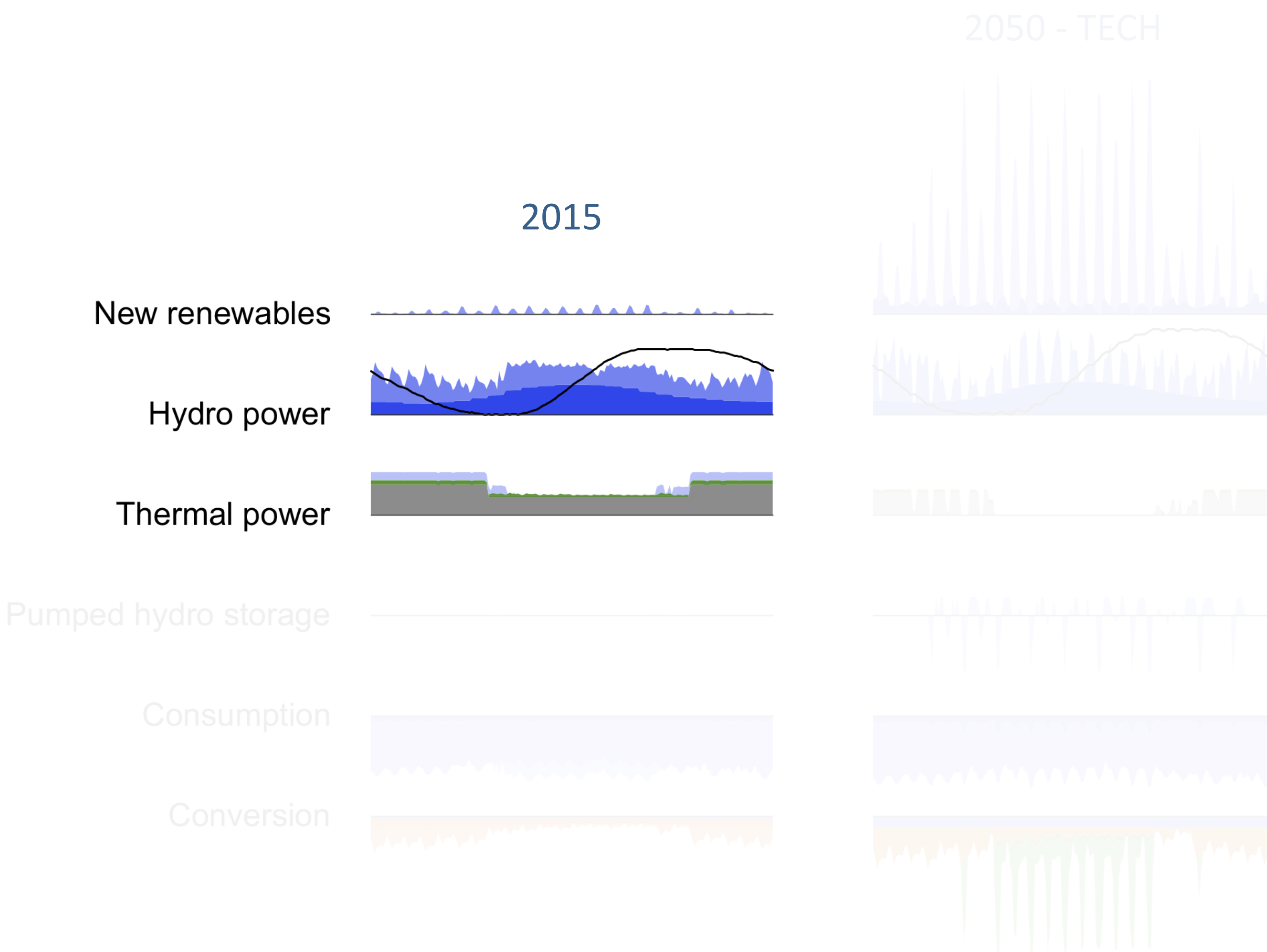


1. According to academic scenario developers, in what ways can scientifically derived energy scenarios function as decision-support tools for the Swiss energy industry?
2. What are the interests, competencies and requirements of the energy industry towards energy scenarios?
3. Linking the perspectives: How can the credibility, legitimacy and salience of energy scenarios be improved for a key actor group of the Swiss energy transition?

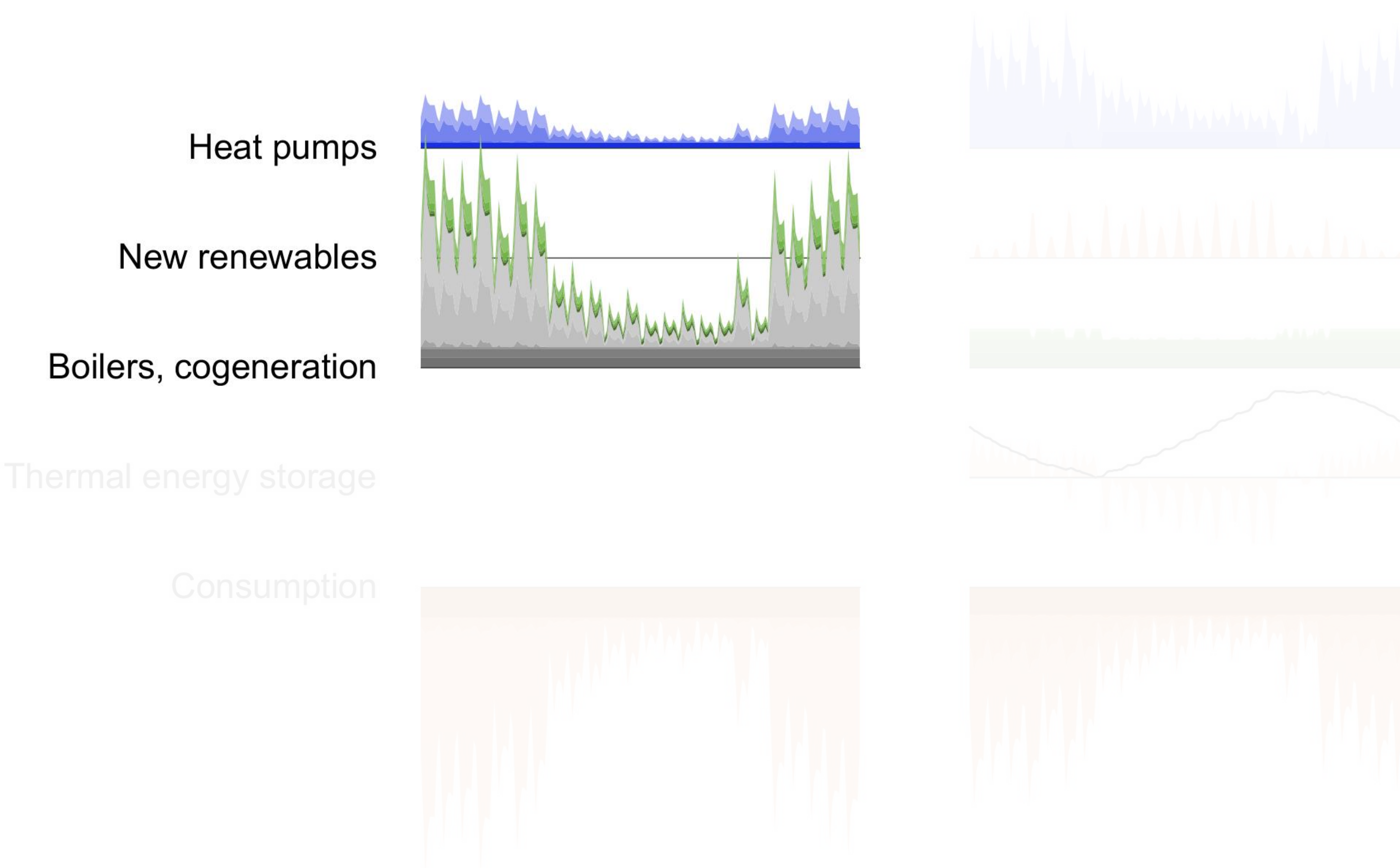
Cost/emission optimal Pareto front



Electricity



Heat


Heat pumps
New renewables
Boilers, cogeneration
Thermal energy storage
Consumption

Natural gas and hydrogen

Natural gas import

Synthesis

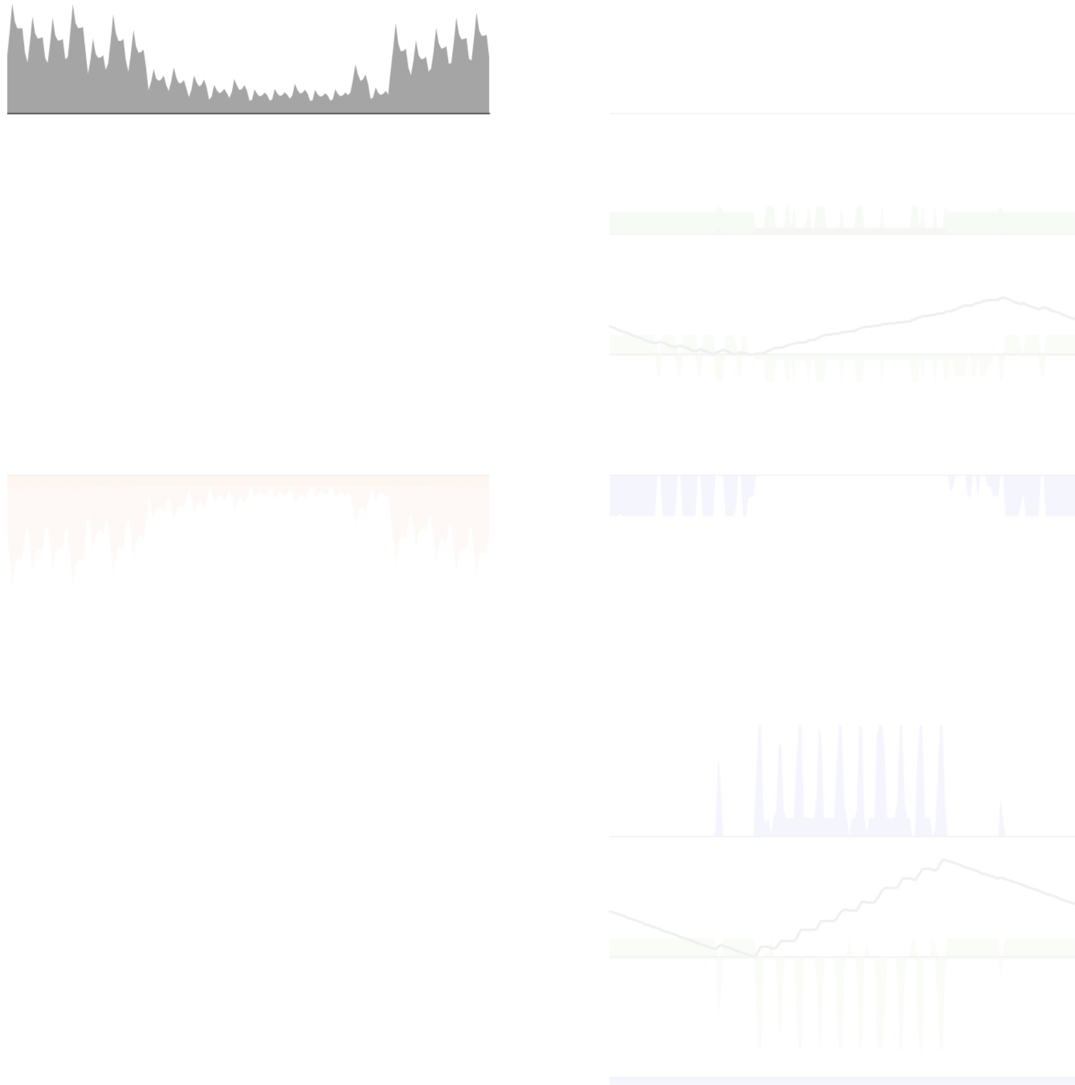
SNG storage

Consumption

Synthesis

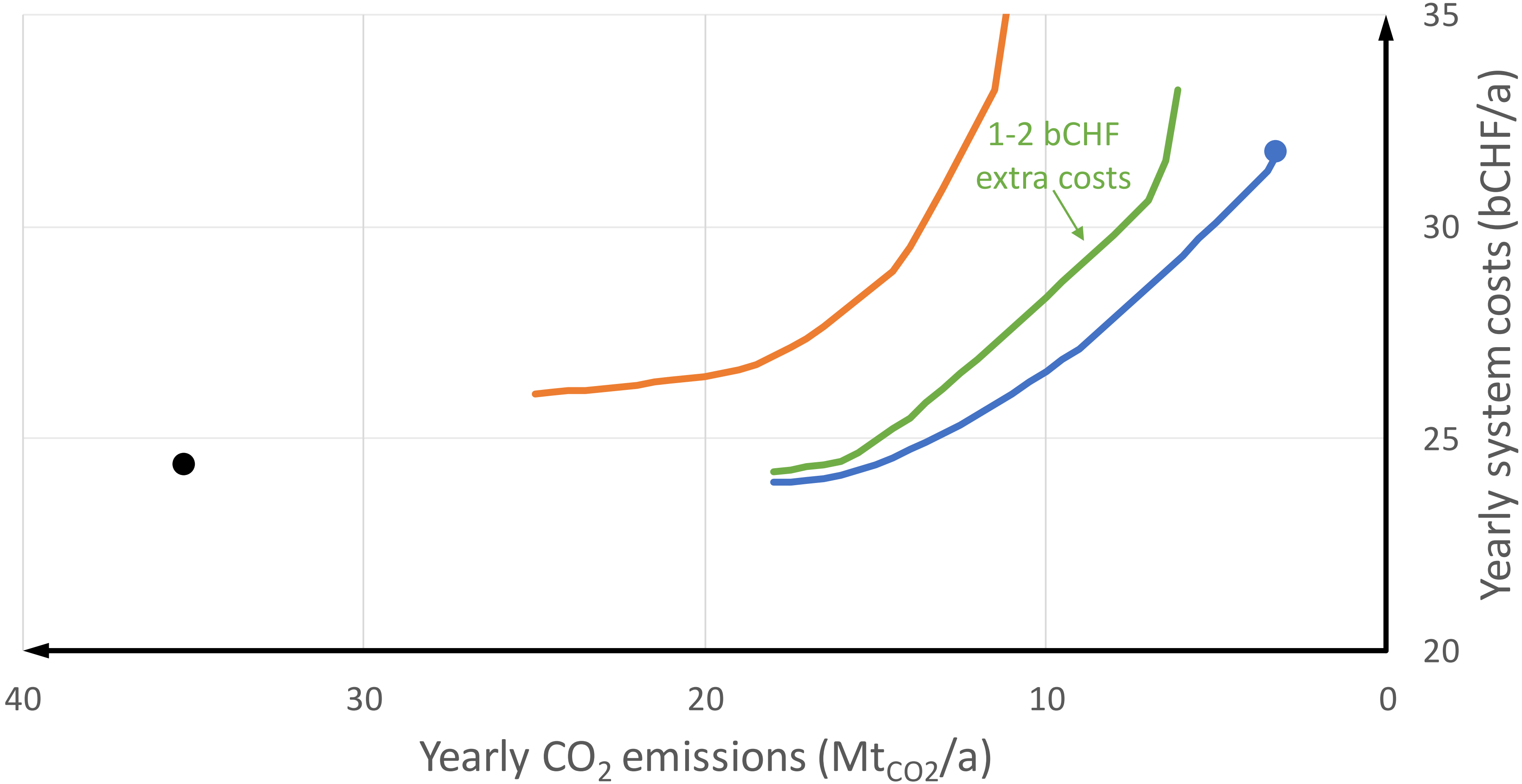
Hydrogen storage

Consumption

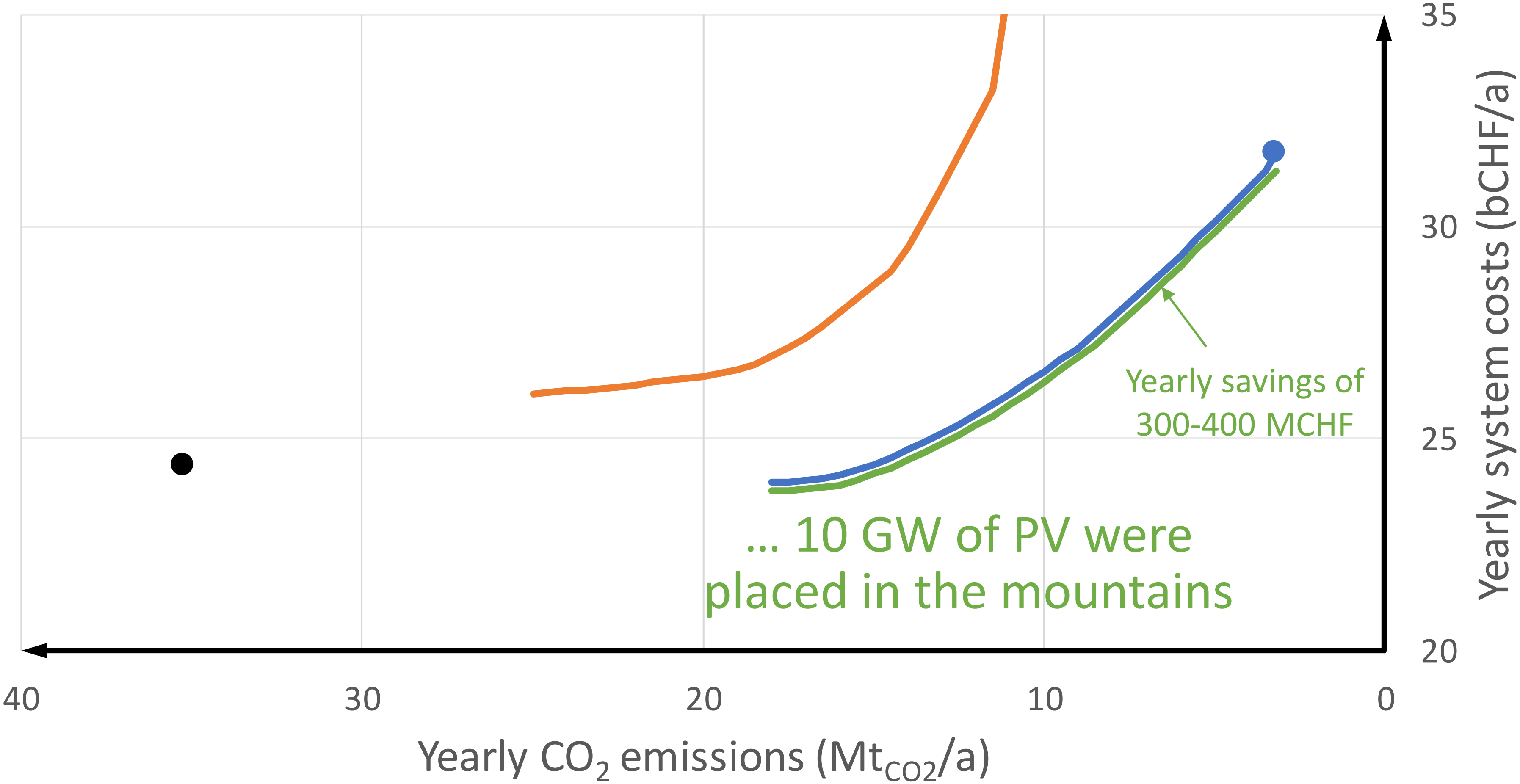


What if…

There was no seasonal storage available

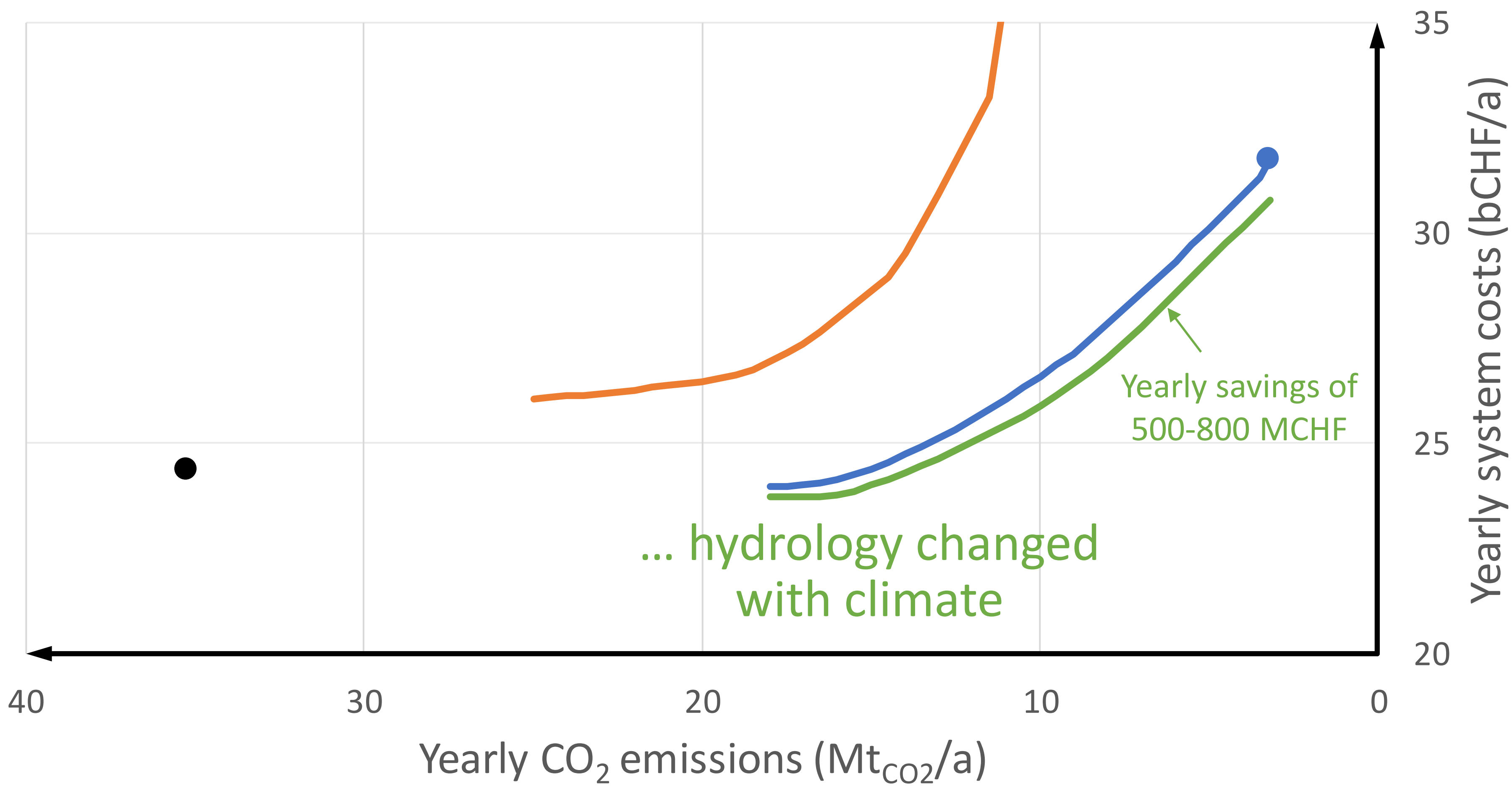


What if…



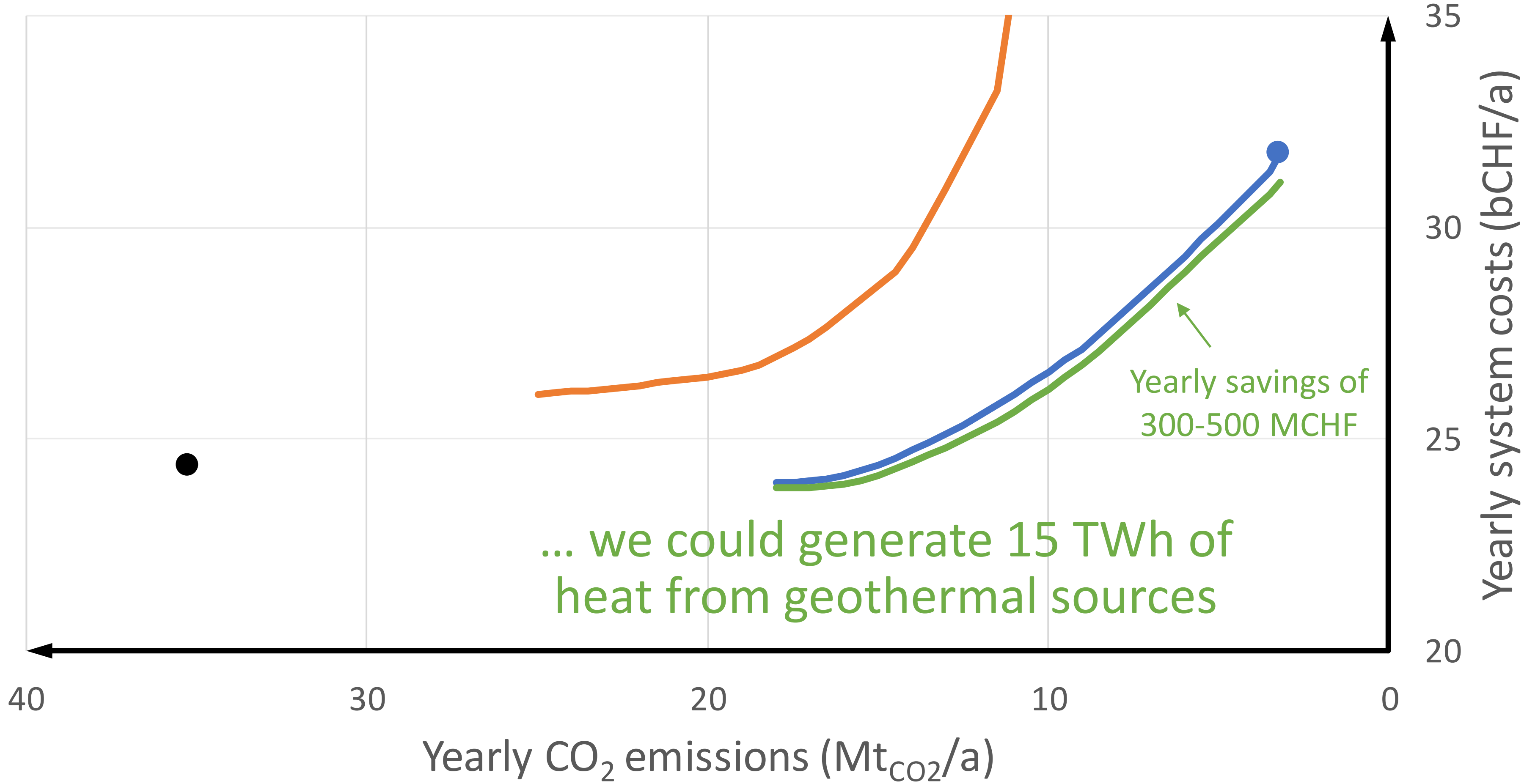
35
30
25
20
40
30
20
10
0
Yearly system costs (bCHF/a)
Yearly CO$_2$ emissions (Mt$_{CO2}$/a)
Yearly savings of
300-400 MCHF
… 10 GW of PV were
placed in the mountains

What if…



35
30
25
20
40
30
20
10
0
Yearly system costs (bCHF/a)
Yearly CO2 emissions (MtCO2/a)
Yearly savings of
500-800 MCHF
… hydrology changed
with climate

What if…


35
30
25
20
Yearly system costs (bCHF/a)
40
30
20
10
0
Yearly CO_2 emissions (Mt_{CO2}/a)
Yearly savings of
300-500 MCHF
… we could generate 15 TWh of
heat from geothermal sources

Summary

Connection to the eight SCCER

SCCER	Inputs to JASM	Benefits for SCCER
SoE	Hydrological forecasts based on CH2018 Potential/cost data for hydro, PV, wind	Value of flexibility measures that compete with other flexibility providers
FEEB&D	Impact of renovation measures and climate change on heating demand	Cost-optimal mix of heat technologies, role of local storage
BIOSWEET	Biomass potential, options for biomass conversion routes (costs, performance)	Value of conversion routes in cost-optimal energy system, highlight role as a feedstock of climate-neutral carbon
HaE	Characteristics of storage technologies (batteries, thermal storage, etc)	Value of storage technologies for various time scales (hours to seasons), understand competition with other flexibility providers
EIP	Realistic values for future savings in energy consumption	Value of energy savings for the energy system as a whole
Mobility	Up-to-date characteristics (costs and performance) of future technologies Driving patterns for private cars	Cost-optimal mix of technologies for low-CO2 scenarios, highlight the role of sector coupling in providing flexibility (G2V/V2G)
FURIES	Reality check on future distributed PV generation, role of battery storage	Future electricity demand, input for T&D grid assessment
CREST	Coupling of energy system results with economic models (e.g. CGE)	Realistic technical vision of the future Swiss energy system

Wrap-up

- All energy system models conclude that very low CO_2 emissions ($\leq 3\ Mt_{CO2}/a$) can in principle be reached (excluding international aviation)
- There are differences in technology composition and costs which will be further analyzed
- The analysis of grid adequacy will follow

Summary

- JASM will deliver scenarios for a future Swiss energy system at very low CO_2 emissions
- We need to know from the research community what can be done better
- We need to know from the stakeholders of the energy system how we can help you

- Follow us on www.sccer-jasm.ch

JASM
Joint Activity Scenarios & Modelling

Thank you for your attention!

Visit us on www.sccer-jasm.ch

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