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CROSS

CROSS FINAL EVENT

CROSS model result comparison

Snapshot of CROSS scenarios by different models

CROSS scenarios v2022-09

Climate policy → **Energy market integration**

- Net-zero without compensation abroad
  - High integration → **domestic-together**
  - Low integration → **domestic-alone**
- Net-zero with compensation abroad
  - High integration → **abroad-together**
  - Low integration → **abroad-alone**

DeCarbCH	PATHFNDR	EDGE	SURE	
SES-ETH	Nexus-e	Nexus-e	STEM	EMPA
	Calliope			

Questions to modellers
www.menti.com
code: 4508 6633

Swiss Energyscope (ETH)
ETH Zurich
Gianfranco Guidati, Adriana Marcucci

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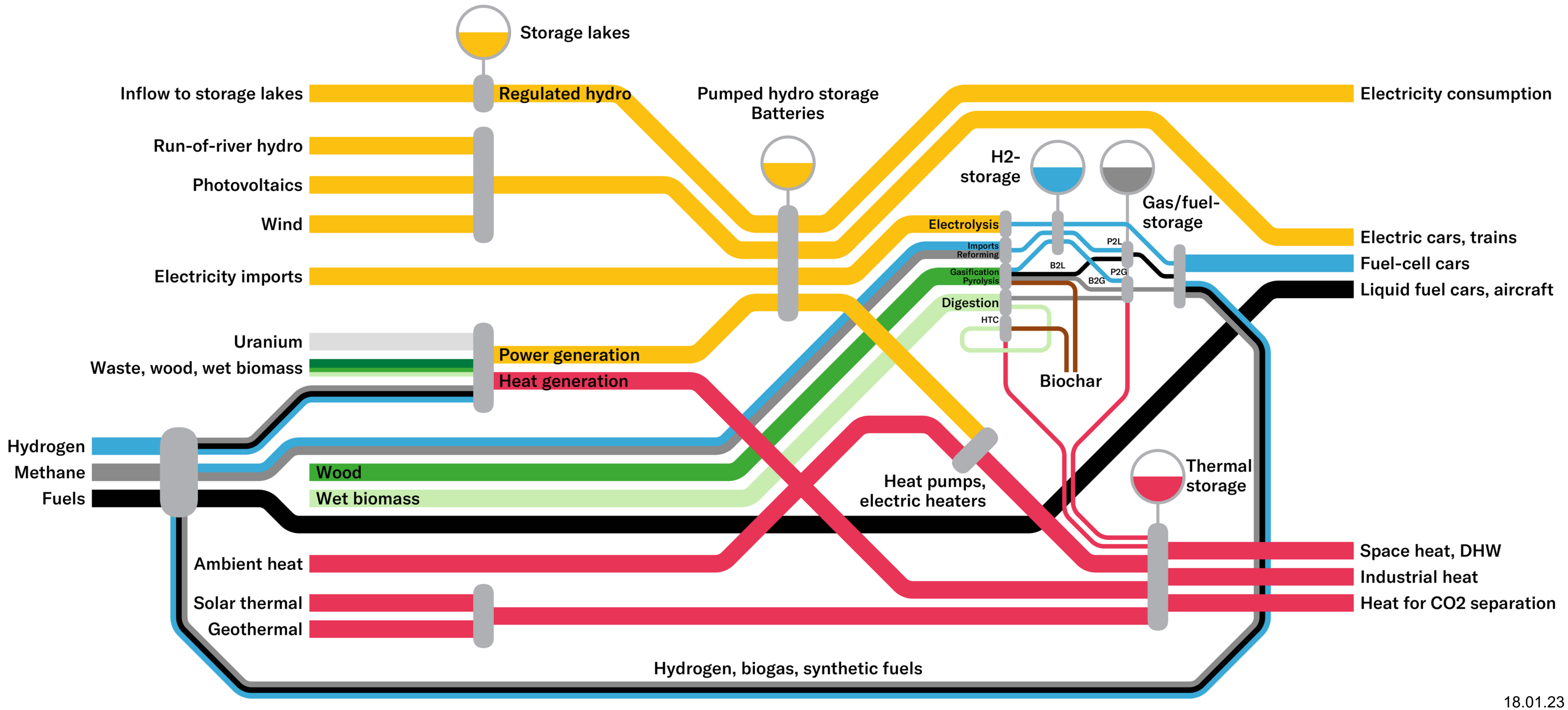
CROSS

Energy Science Center

Model description

- Linear optimization, snapshot model for specific year: here results are for 2050
- Sectors modelled: Heating (space heat, DHW, process heat, heat for CO2 separation), transport (road, rail, aviation), electricity, synthesis of fuels, gases via PtX, BtX processes



Implementation of CROSS scenarios

- Climate policy dimension
  - All scenarios are normative, emission level is prescribed (aviation is neglected)
  - **Domestic:** 0 Mt/a
  - **Abroad:** +6 Mt/a
- Energy market dimension
  - Import of energy is modelled assuming a price and optionally a maximum annual volume and a maximum rate (e.g. limitation of NTC)
  - There is no explicit model of the surrounding countries
  - **Together:** imports of hydrogen, biofuels, biogas as defined in the CROSS scenario documents; no limit on import of electricity
  - **Alone:** only imports of methane, diesel and kerosene
- Two additional dimensions
  - **Technology innovative / conservative:** different levels of hydro power, wind, wood, geothermal, etc
  - **Monte-Carlo variation** of uncertain drivers (technology costs, population count, import prices, etc)

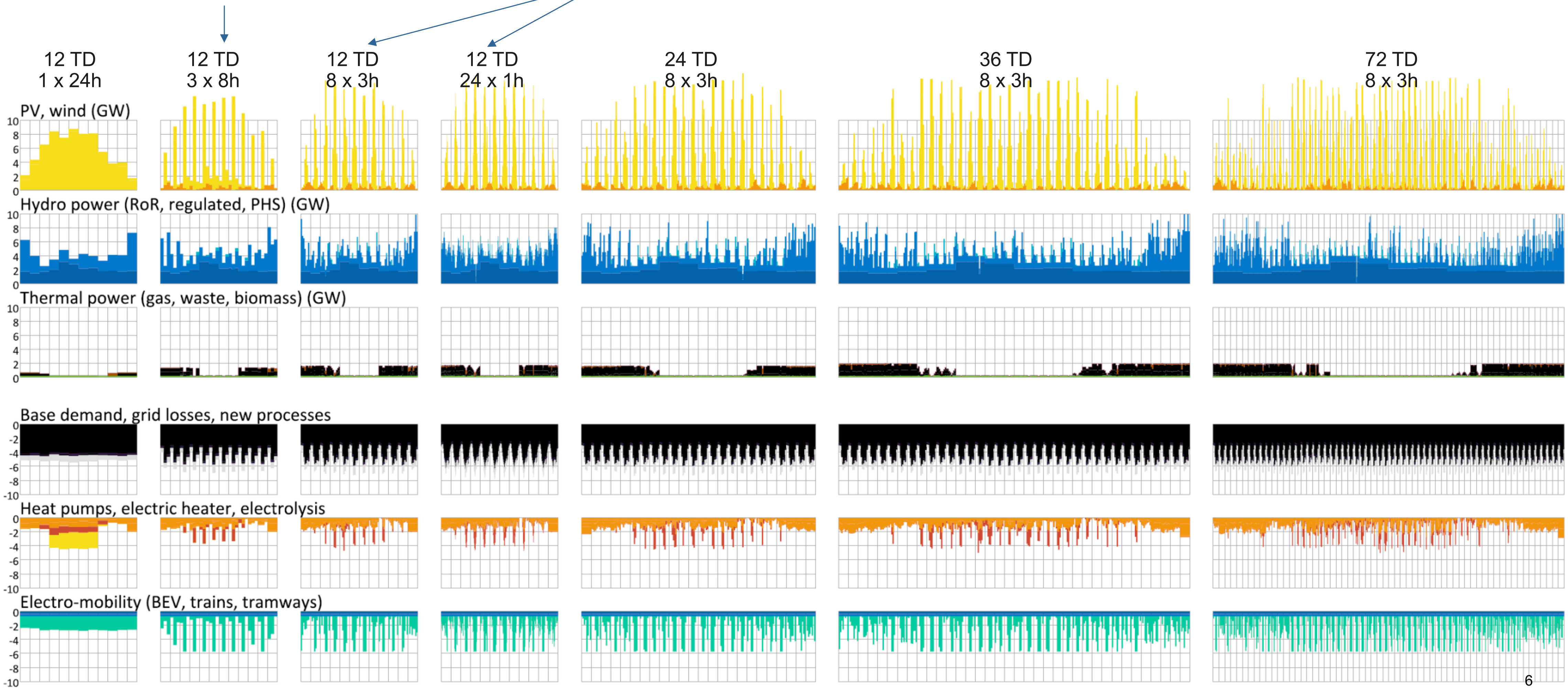
Electricity generation and consumption for 2050

CROSS domestic-alone, technology innovative (variation of typical days and time resolution)

Already the use of 3 x 8h clusters captures the basic effect that PV is available only at daytime

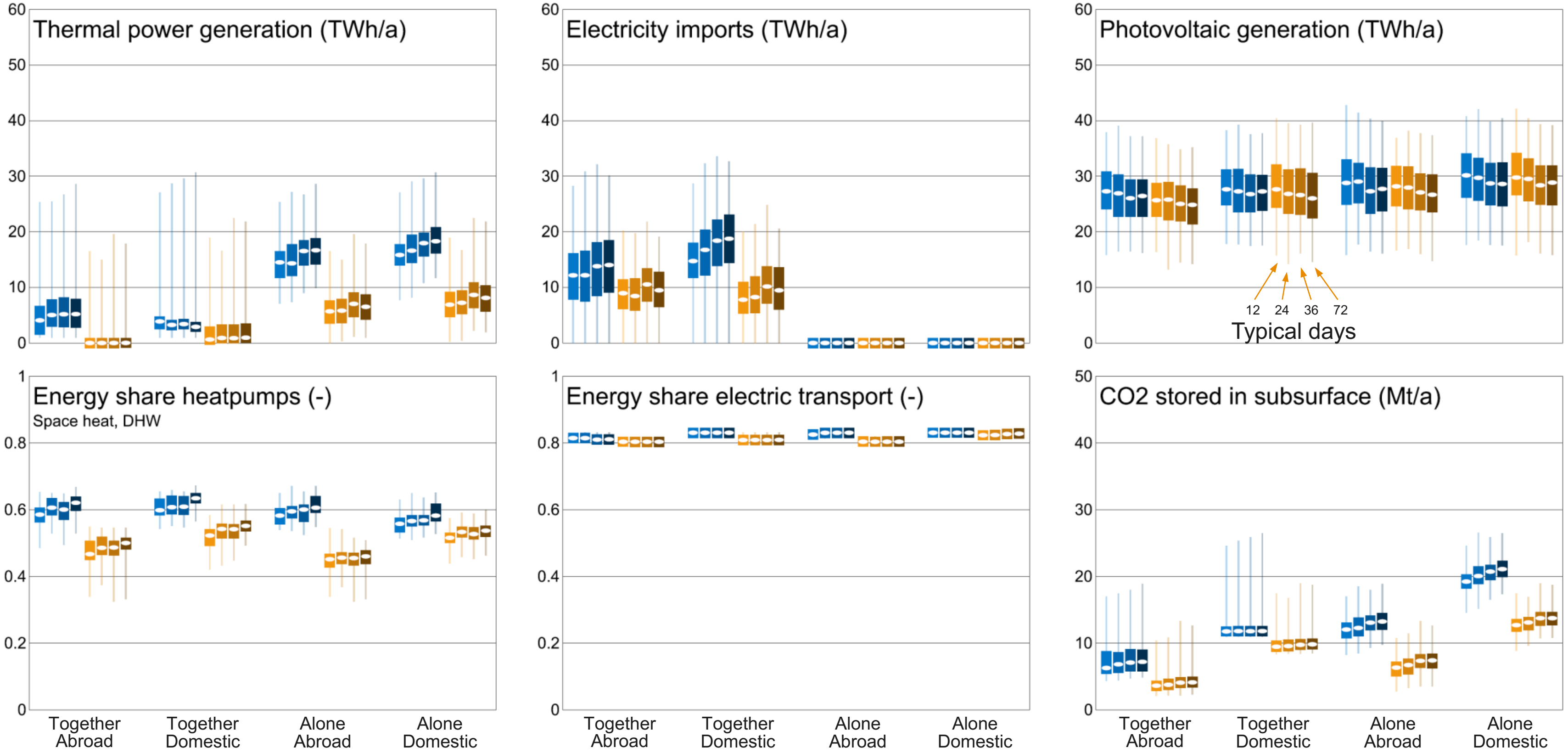
Little detail is added by switching from 8 x 3h to a full resolution of 24 x 1h clusters

The basic insights on the importance of flexible hydro power, heat pumps and BEV charging stations are insensitive to the number of typical days



Selected results for 2050

All CROSS scenarios, technology **conservative**/**innovative**, Monte Carlo variation of drivers



- Winter electricity needs to be supplied by imports or by domestic thermal power generation.
- A robust strategy should aim at a full integration into the European power system (Stromabkommen) while building up a reasonably sized domestic thermal power capacity.
- We need a lot of photovoltaics – on roofs, on free fields and in the alps
- Heat pumps and electric mobility are the key technologies for achieving the Swiss climate targets – and the additional electricity demand can be satisfied
- We need a CO2 pipeline network to connect to a European transport and storage infrastructure

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Euro-Calliope
TU Delft
Francesco Sanvito, Stefan Pfenninger

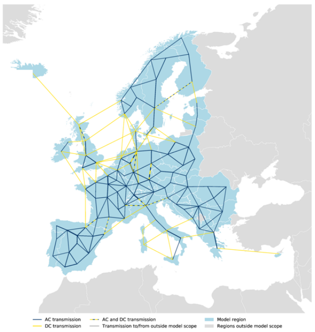
Calliope

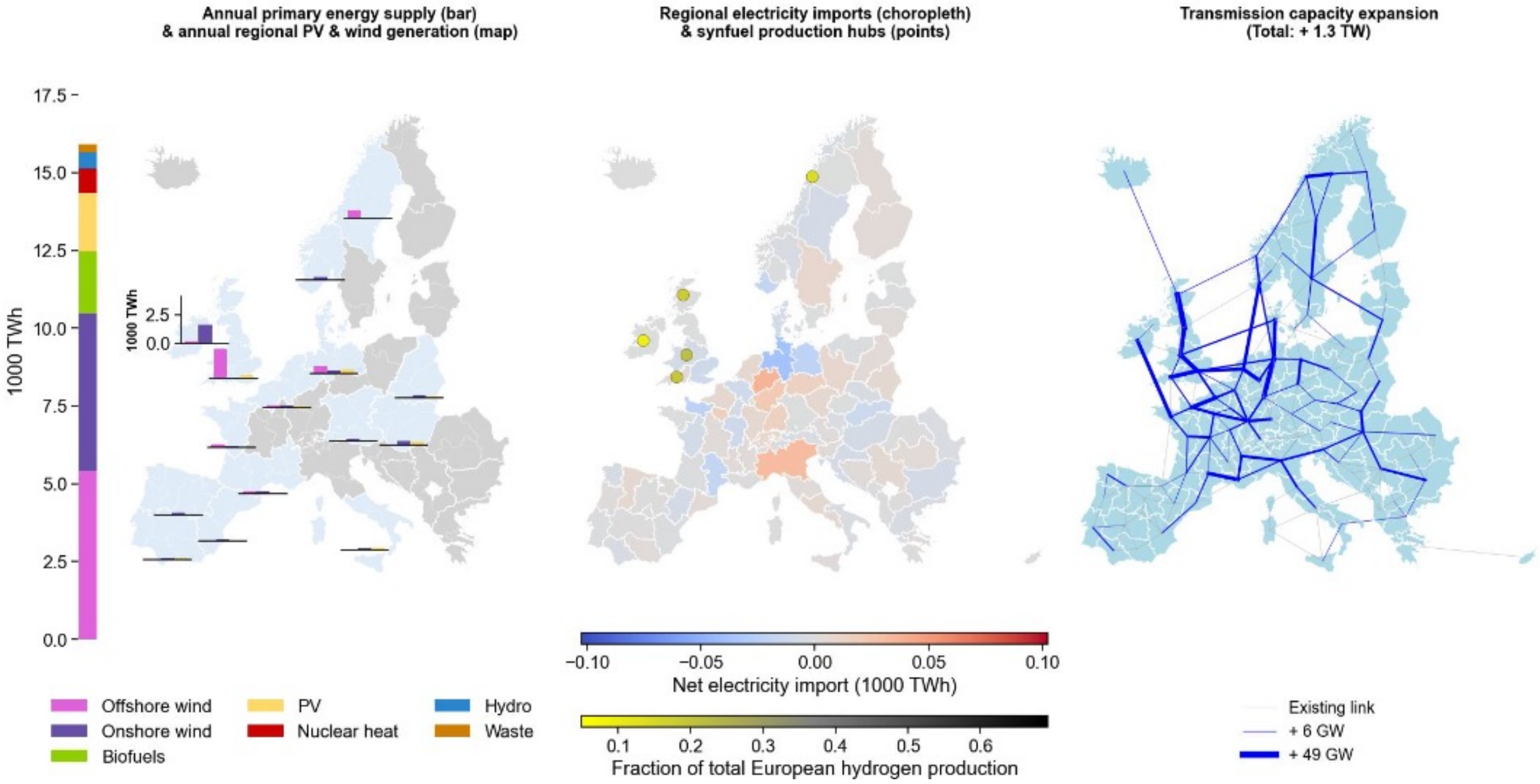
TU Delft

Model description

- Model type: linear optimization, planning mode (+ operation and spores modes)
- Temporal scope: 1 year (Snapshot for a single projection year, e.g. 2030 or 2050)
- Temporal resolution: 1h
- Spatial scope: 98 regions / 35 coutries
- Sectors modelled: Heating, transport (aviation, road, shipping, electricity, industry
- Input param: energy demand, tech capacity limits and characteristics, node interconnections, costs (economic, land use, emissions)

Calliope





Implementation of CROSS scenarios

Calliope

- CROSS scenarios and Euro-Calliope: similarities and differences

  We considered Euro-Calliope model and further detailed/updated demand inputs and technologies.

TECHS

- **Negative emission technologies**: incinerators, chp-biofuels, CCGT (syn-methane) when complemented with CCS.
- **CO_2 storage** (refinements required)
- **Synfuel** import/export
- **Road transport** can be electrified or supplied with synfuels

DEMAND

- **Base demand** includes residential electricity demand, electric hobs, railway demand (100% electrified), industry demand that can be electrified (CO_2 demand with DAC and hydrogen demand via electrolysis). Aggregating the electricity demand helps in keeping the model complexity lower.
- Residential and commercial **heat demand** updated according to CROSS data.
- Demand levels are from multiple sources (JRC, Eurostat, SFOE, DEA). *SENTINEL - D4.2: Model development to match system design models to user needs*

EMISSIONS

- Emission **target**: -5.7 Mton CO_2
- Compensation abroad – Implementation of a European carbon budget
- No compensation abroad – Switzerland-specific carbon budget

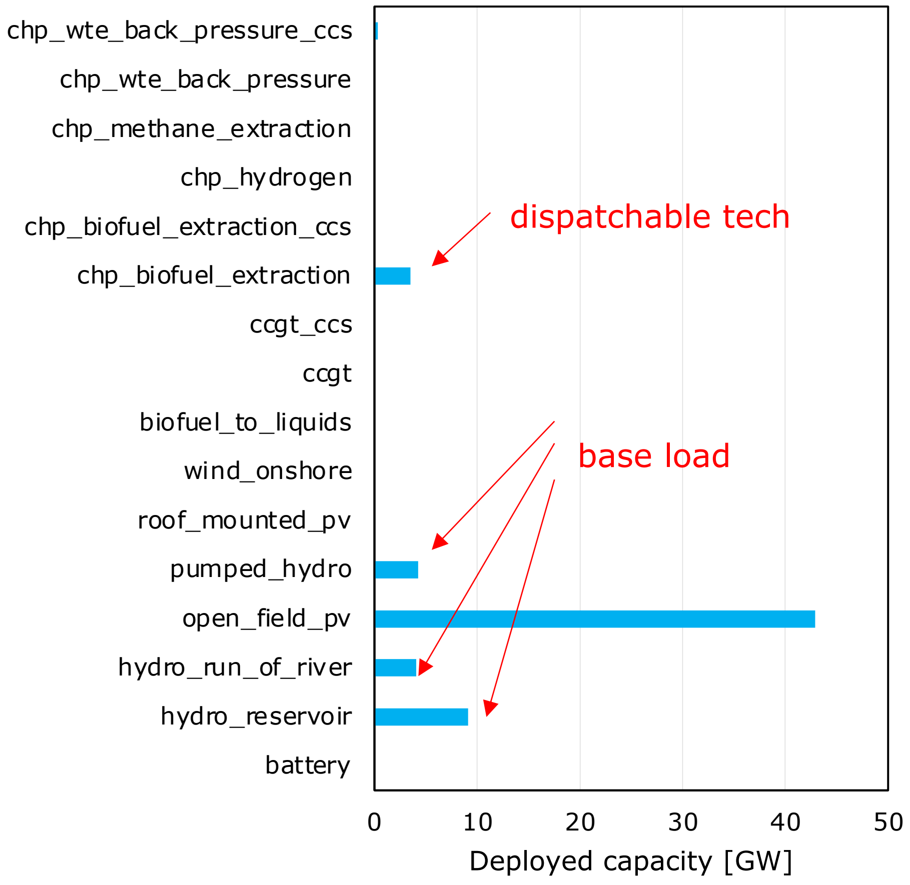
IMP/EXP

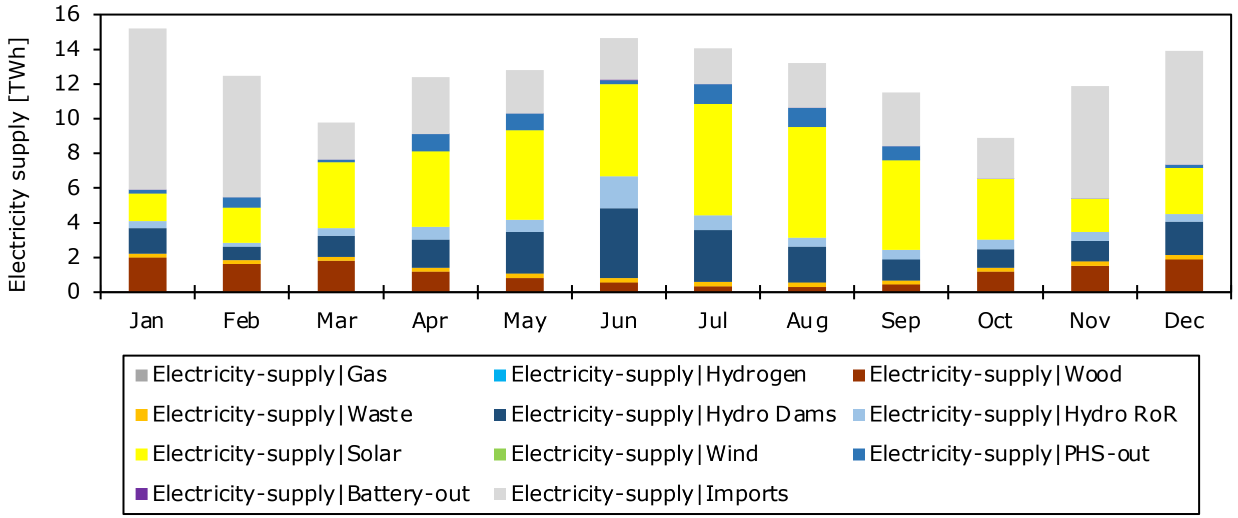
- Imports and Exports of synfuels and electricity are driven by the system-wide cost minimization. No limits applied.

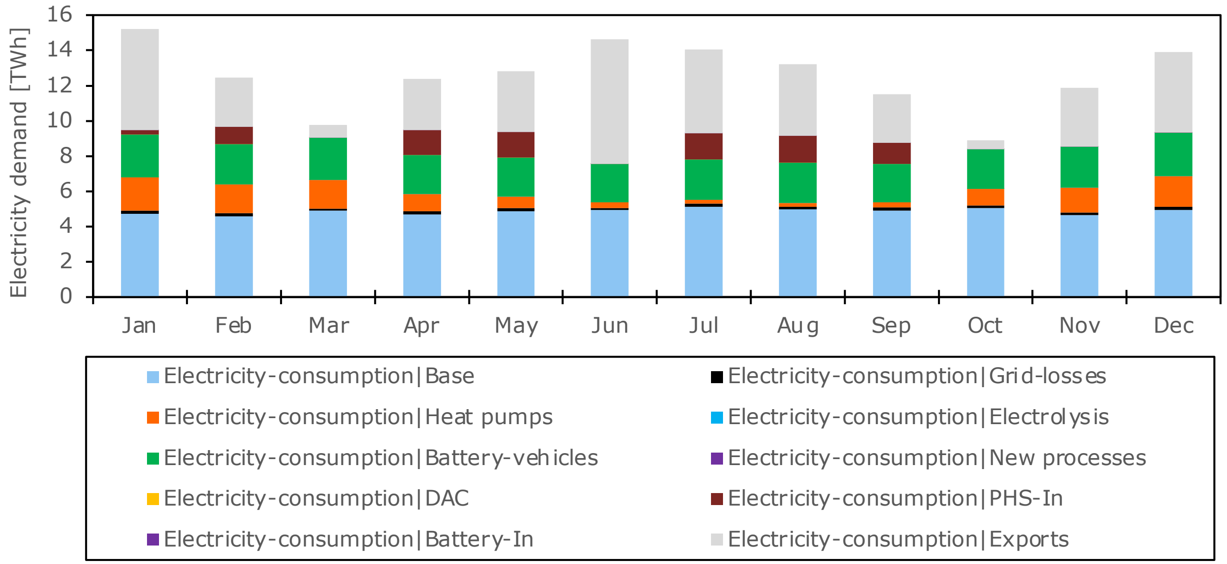
- Reduced NTC limit scenarios are under development considering a limitation on the import and export flows instead of deployed capacities.

Zoom in results

- Installed capacity and monthly electricity supply and consumption in *Compensation abroad* scenario

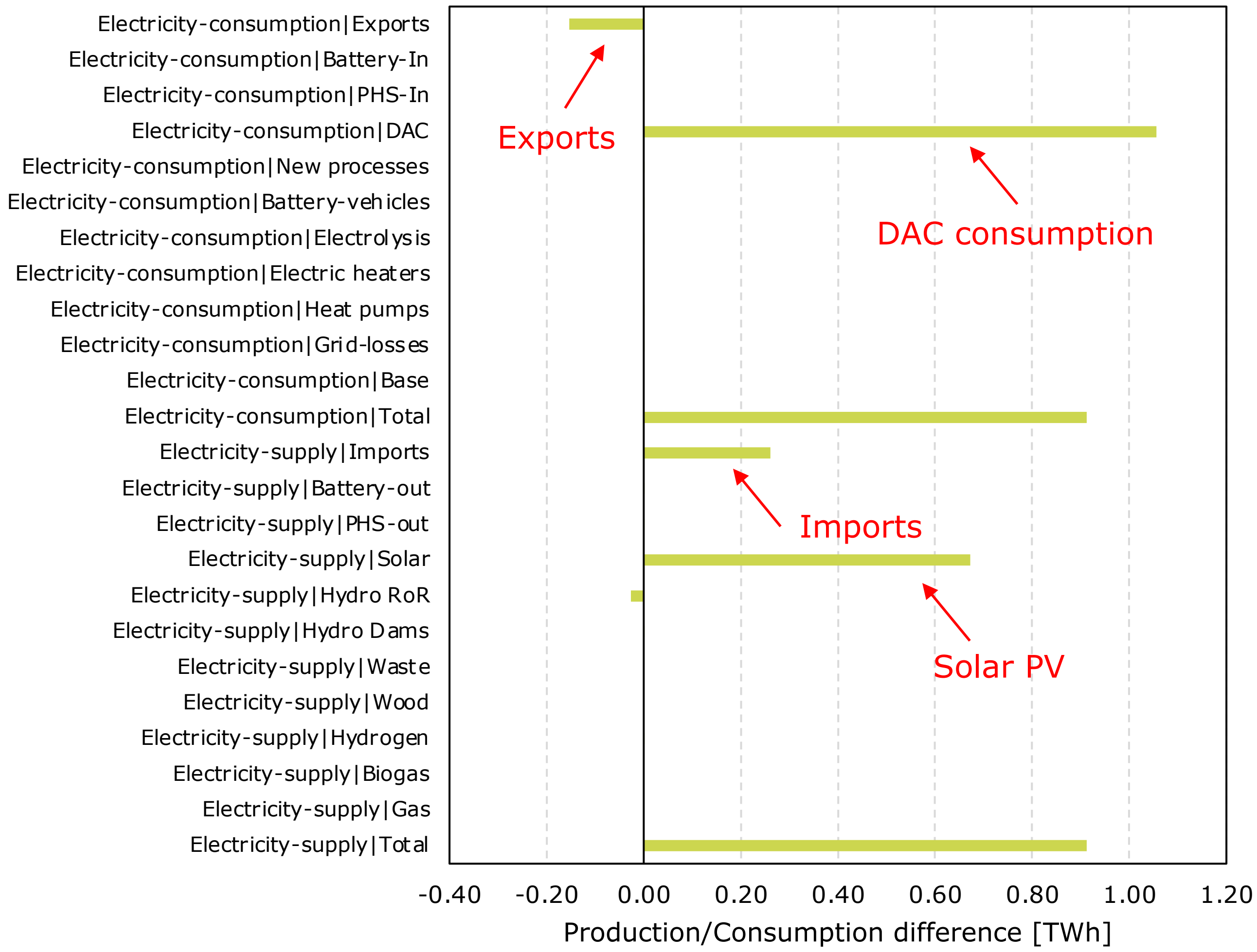






Zoom in results

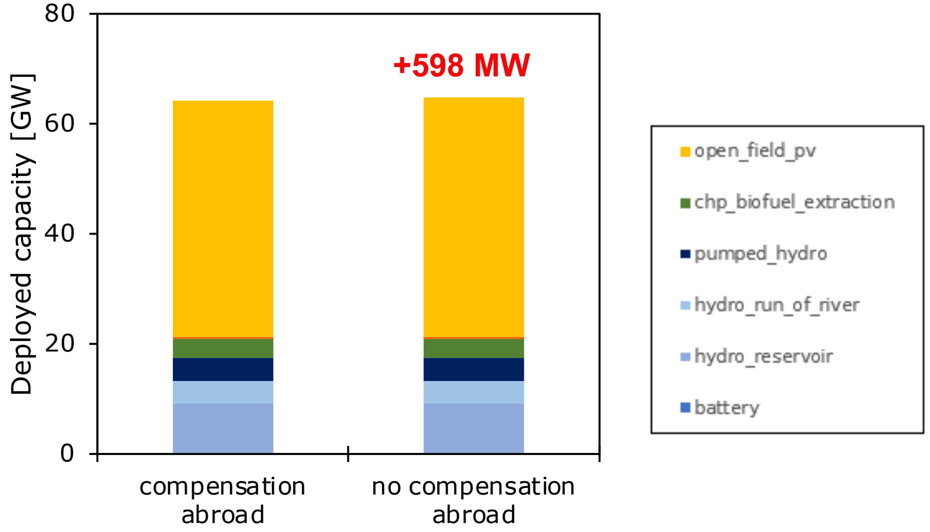
- (No-compensation-abroad) – (Compensation abroad)



DAC requires additional 1.06 TWh of electricity supplied by:

- Additional PV deployment: 0.67 TWh
- Reduction of exports: 0.15 TWh
- Increase of imports: 0.26 TWh

This translates into an additional deployment of 598 MW of open field solar PV capacity.



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CROSS

Nexus-e

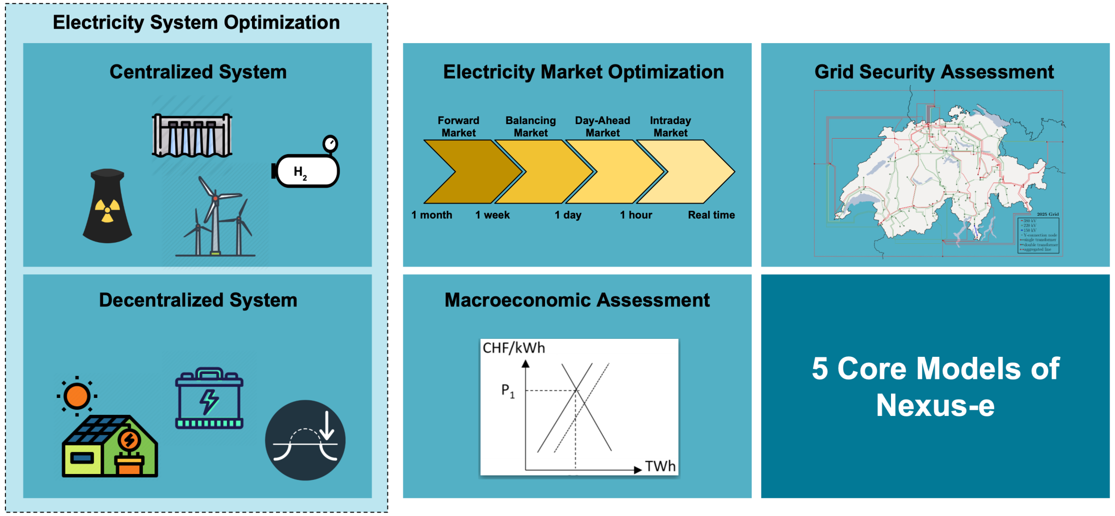
ETH Zurich

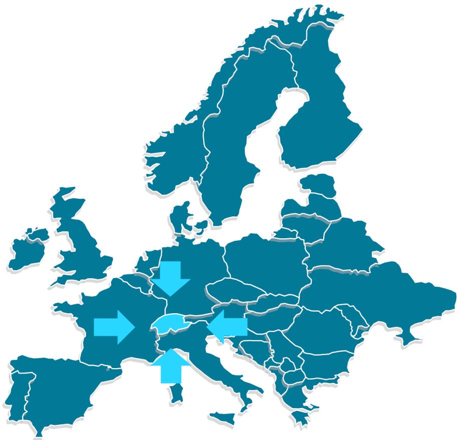
Jared Garrison, Blazhe Gjorgiev, Elena Raycheva, Han Xuejao, et al.

Energy Science Center | PSL Power Systems Laboratory | RRE Reliability & Risk Engineering | Nexus-e | FEN Research Center for Energy Networks Forschungsstelle Energienetze | epse Energy & Process Systems Engineering

Model description

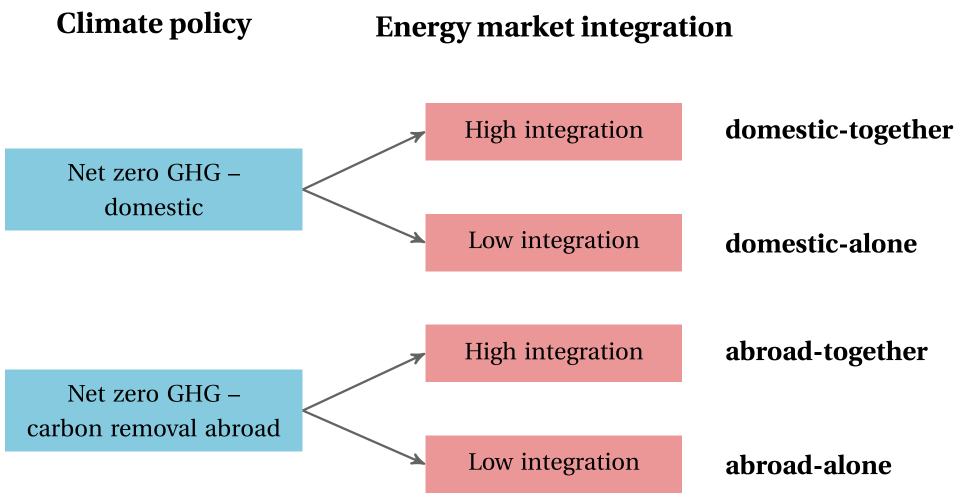
- Model type: LP - economic optimization of investments and operation
- Years: Snapshots for each year 2030-2040-2050 (only 2050 here)
- Sectors modelled: Electricity only
- Connect with Euro-Calliope: Electricity demand profiles (CH+neighbors), gen/storage capacities & RES production profiles (neighbors), power flows to the rest of EU (neighbors)
- Other characteristics: Hourly resolution, Swissgrid transmission network with NTCs to/among Swiss neighbors, represent every individual generator, coordinated centralized and distributed investments, flexibility of e-mobility demand, include existing electricity capacity infrastructure (not a green-field approach), consumer’s perspective rooftop PV investment decision





Nexus-e utilized Euro-Calliope results

Implementation of CROSS scenarios



Climate Policy
(with/without compensation abroad)

- Only reflected in different electricity demands provided by Euro-Calliope (DAC ~ 1 TWh)
- For both cases, we include:
  - Only (near) zero emissions candidates for electricity capacity investments
  - CCS operating costs include disposal to North Sea
  - Phase out of all existing Gas, Oil, Nuclear units in CH
  - Addition of 3 new planned hydro pump units

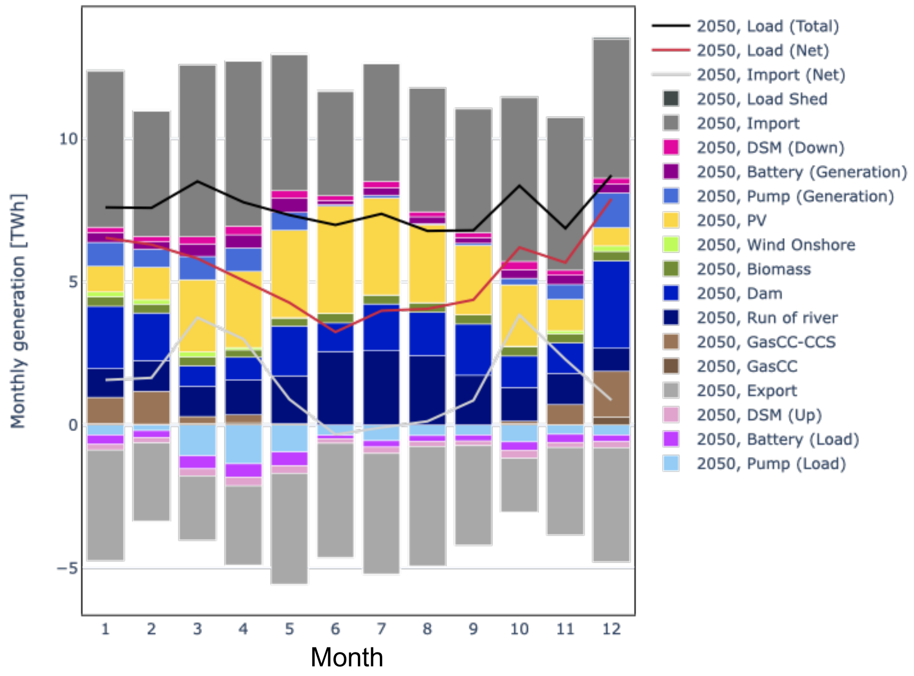
Energy Market Integration
(current/reduced NTCs)

- Reflect the NTC limits on cross border electricity flows
  - Current values as selected by CROSS
  - Reduced values as 30% of Current

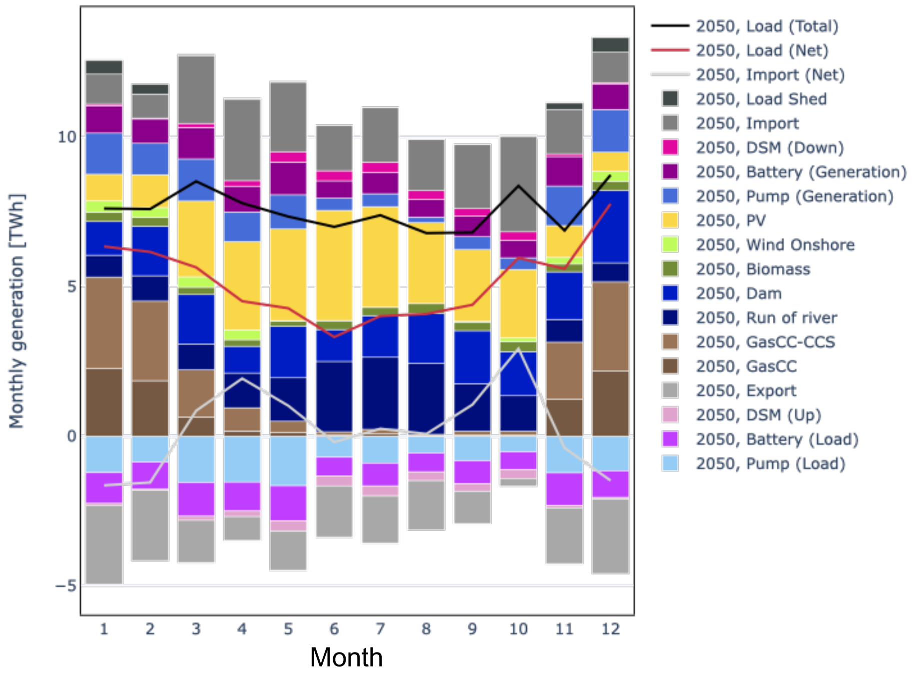
→ All scenarios are feasible but with some load shedding

Restricting transfer capacities:
shift to focus on domestic electricity capacities

Current NTCs



Reduced NTCs

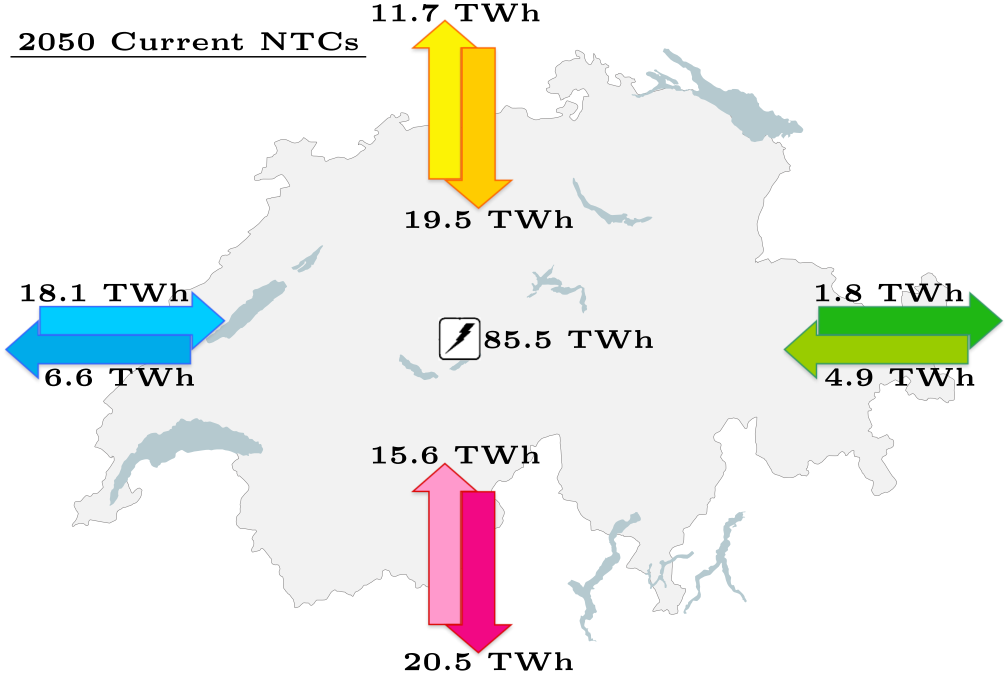


- Imports (59 → 22 TWh) and Exports (40 TWh → 21 TWh)
- Large increase in Gas (5.7 GW / 17 TWh) and BESS (1.7 GW / 6 TWh)
- added Wind, greater use of Pumps

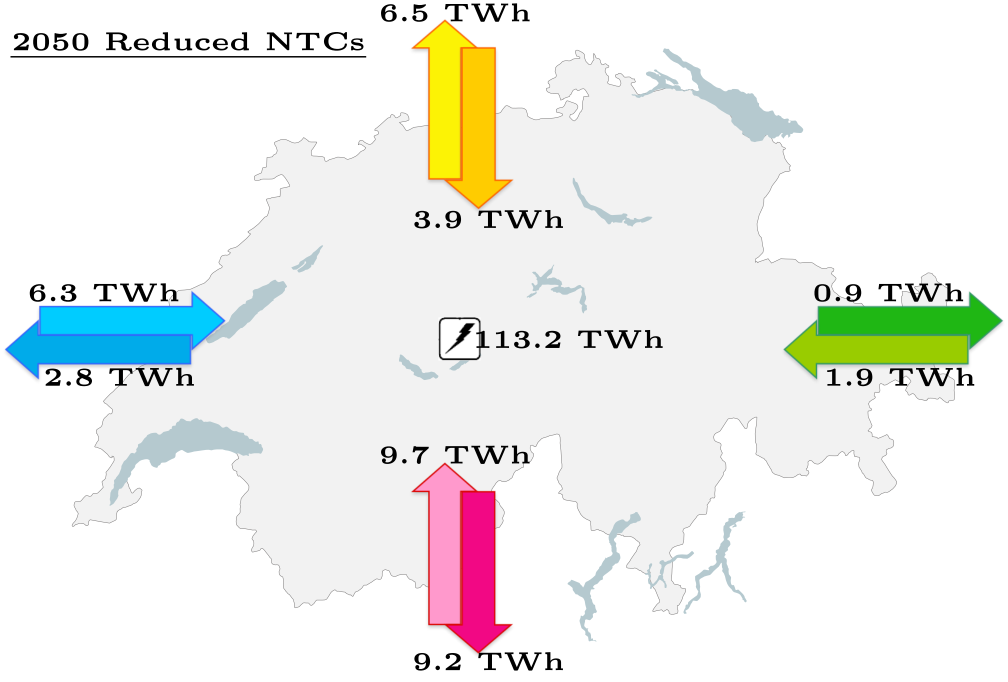
➢ Reduced NTCs: Significant load shedding in winter

Restricting transfer capacities:
imports & exports impacted at all borders

Current NTCs



Reduced NTCs



- 50% or greater reduction across almost all borders
- Still net-importer with FR and IT
- Shift to a balanced trade with IT and net-exporter with DE

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Swiss TIMES Energy Systems Model (STEM)

Laboratory for energy systems analysis, Paul Scherrer Institute
Evangelos Panos

PAUL SCHERRER INSTITUT

Swiss TIMES Energy Systems Model – STEM

Long term horizon (2050+), in steps of 10 years

Energy system transformation pathway analysis

288 hourly time steps within a year

Technology-rich with age structures

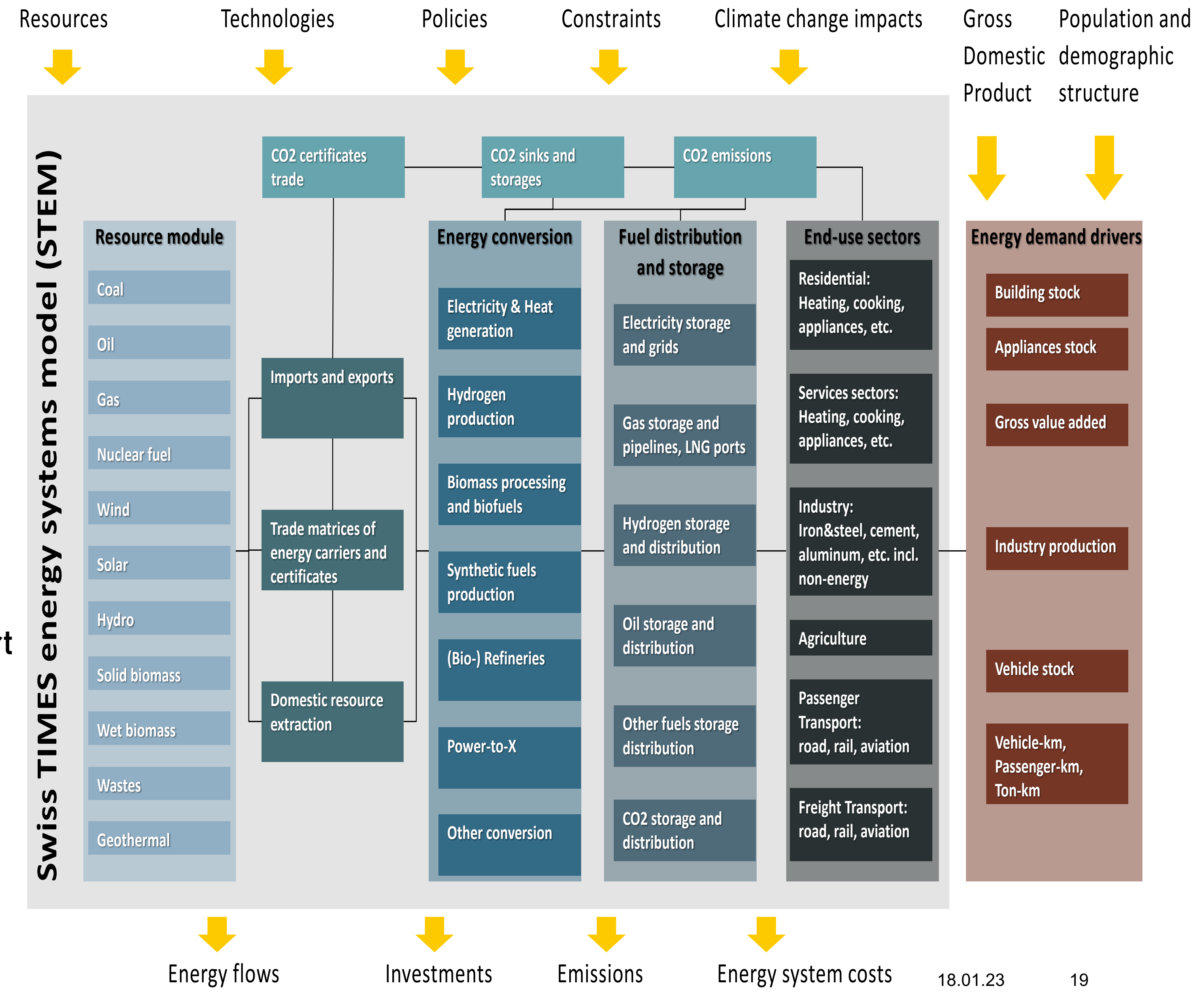
Endogenous infrastructure deployment

Unit commitment and ancillary markets

Consumer segmentation in households and transport

Endogenous hourly profiles for all demands

Demand response and flexibility options



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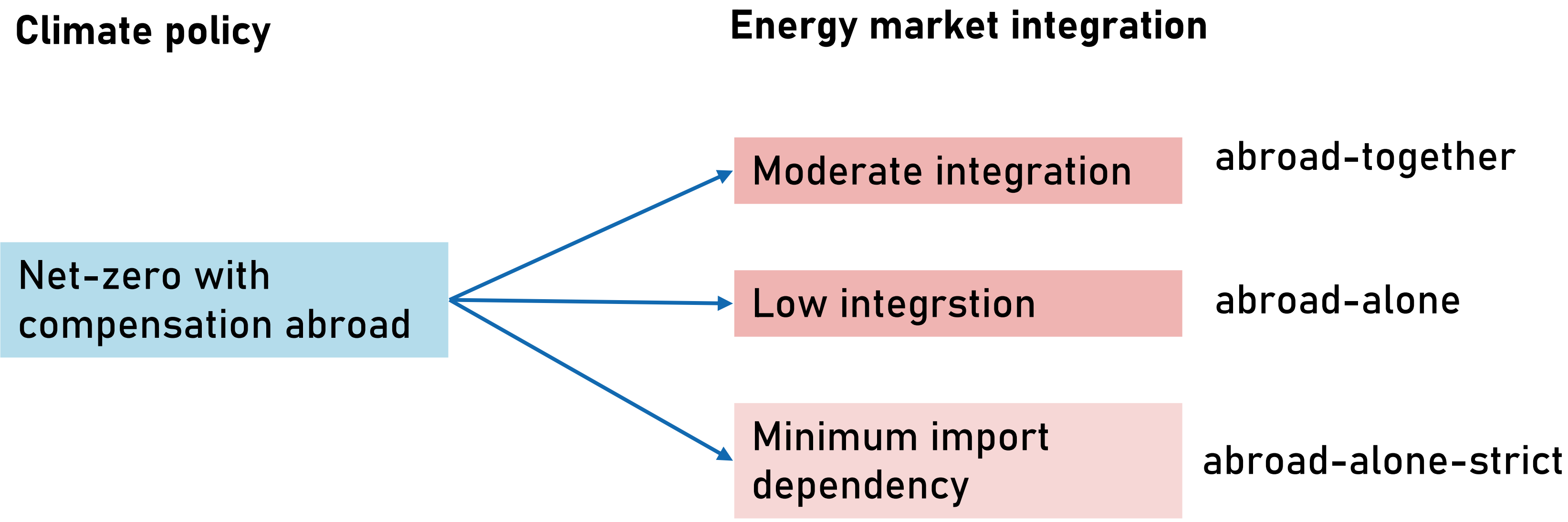
Implementation of CROSS scenarios



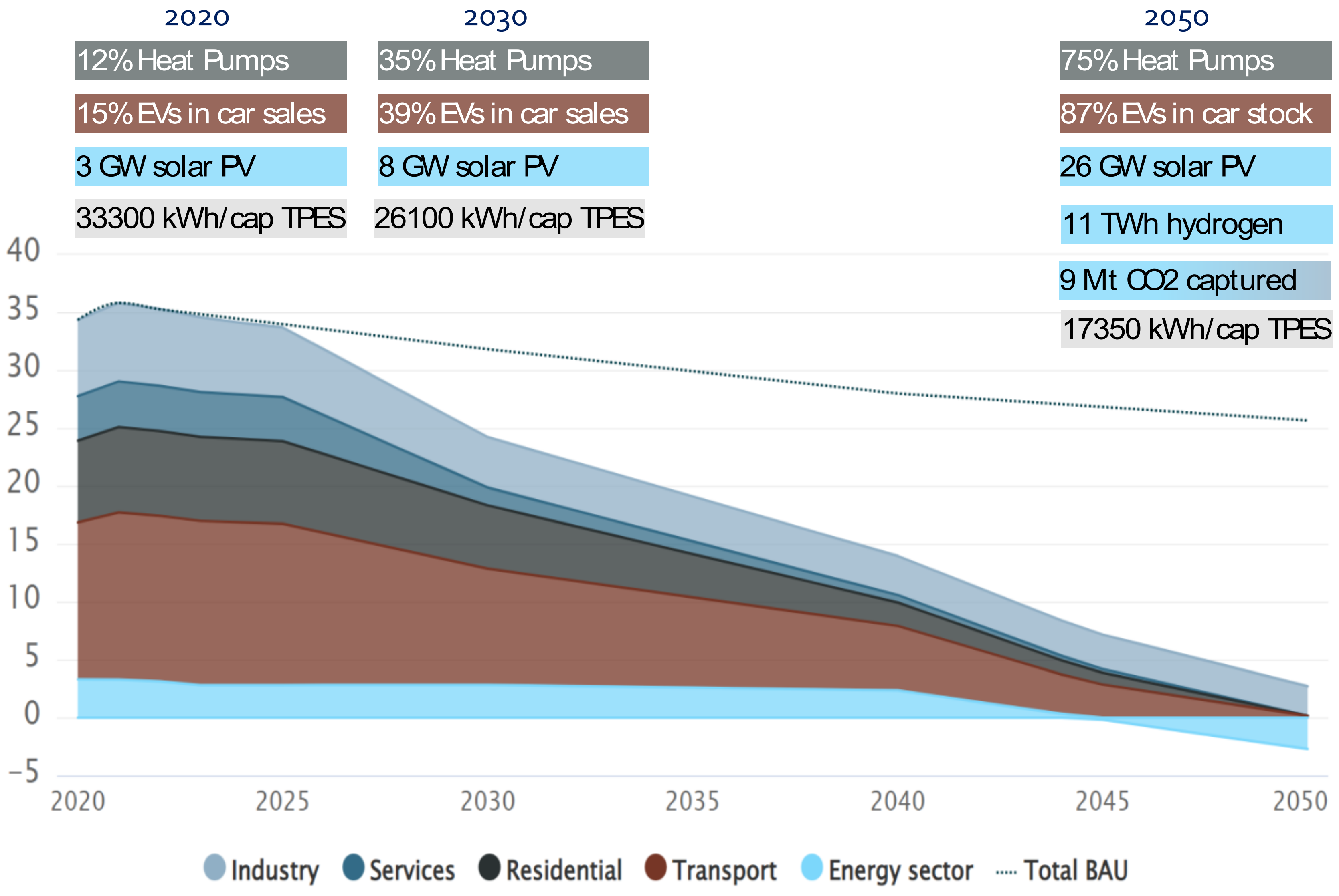
Baseline (BAU): extrapolation of current trends, considering the COVID-19 effects and the 2022 energy crisis and energy savings

Abroad-together: implementation of the relevant CROSS scenario, assuming that 5.7 Mt CO2-eq are compensated abroad in 2050.

Abroad-alone: implementation of the corresponding CROSS scenario, which however allows imports of fossil fuels if needed

Abroad-alone-strict: own variant of abroad-alone reducing overall net import dependency on annual basis to almost 0 in 2050

Milestones to net-zero CO2 emissions in 2050



Consumers increasingly turning to electricity applications

Energy must be used more efficiently in the future

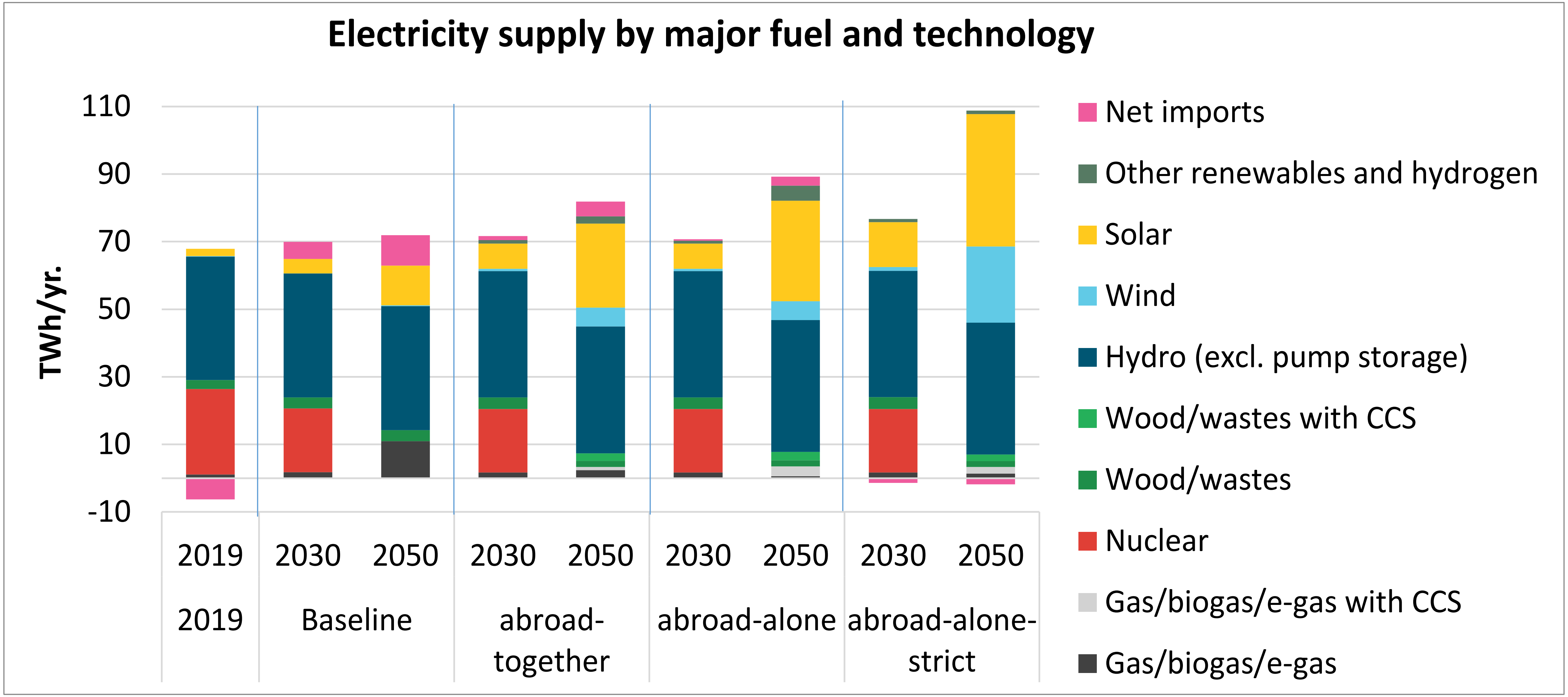
Energy savings help also in reducing import dependency

Expansion of district heating networks in urban areas

Hydrogen substitutes fossil fuels and contributes to the better integration of renewable energies

CO_2 capture, utilization and storage develops around 2040

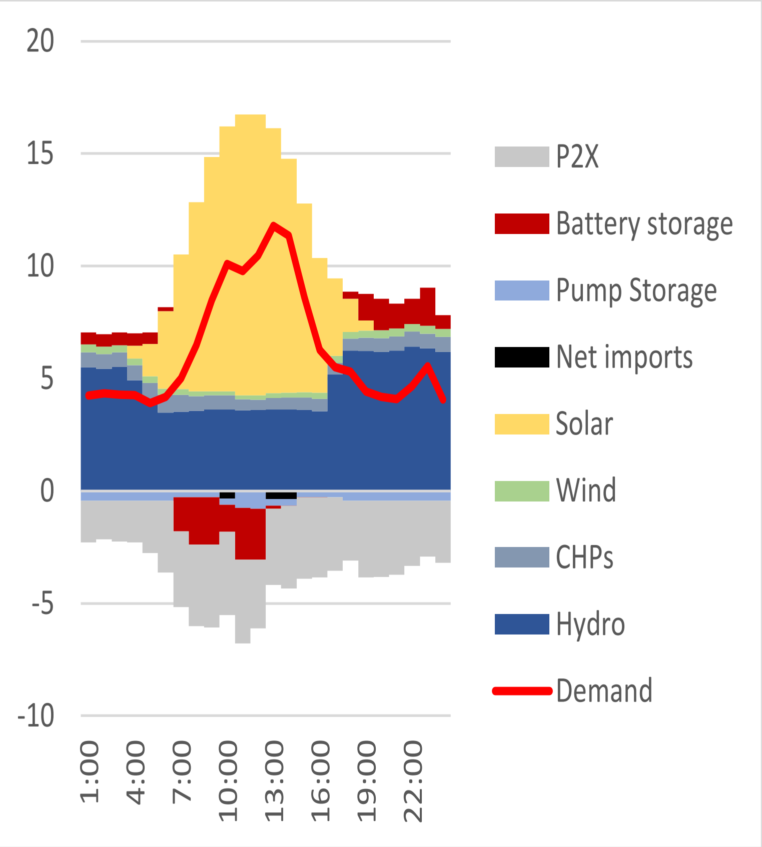
Electricity supply becomes more weather dependent



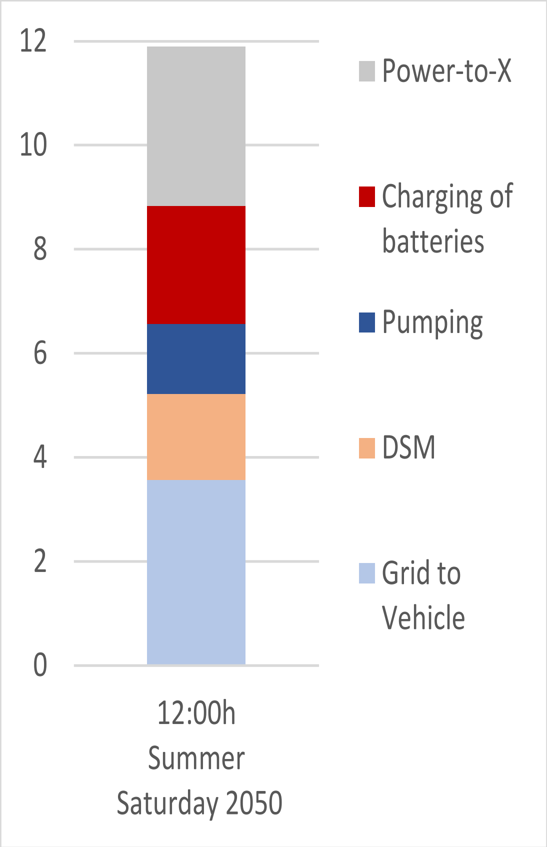
Flexibility to energy system needs to be provided by all actors

ABROAD-TOGETHER

Electricity Supply and demand in Summer Saturday 2050 in GW



Coordinated flexibility deployment at 12:00 in Summer Saturday 2050 GW



Total deployment of flexibility options in 2050

Flexibility option	Deployment (capacity)
Pump storage	4.5 GW , 520 GWh
Stationary batteries	2.1 GW , 11.5 GWh
Thermal storage	5.8 GW , 35 GWh
Thermal storage (seasonal)	1.4 TWh
H2 storage (seasonal)	1.6 TWh
Vehicle-to-Grid (V2G)	output 0.5 TWh (from 13% of the electric cars)
FCR+ reserve demand	+ 45% from 2020 (624 MW)
Electricity shifts (DSM) in industry, services, residential	10% of demand (5.5 TWh)

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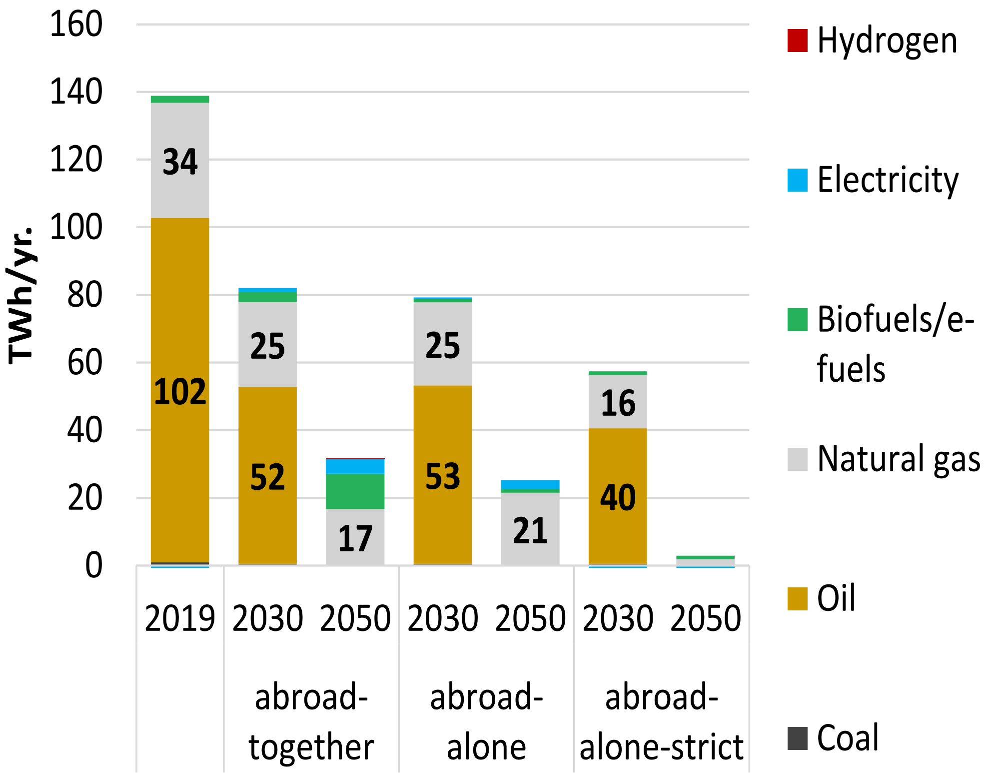
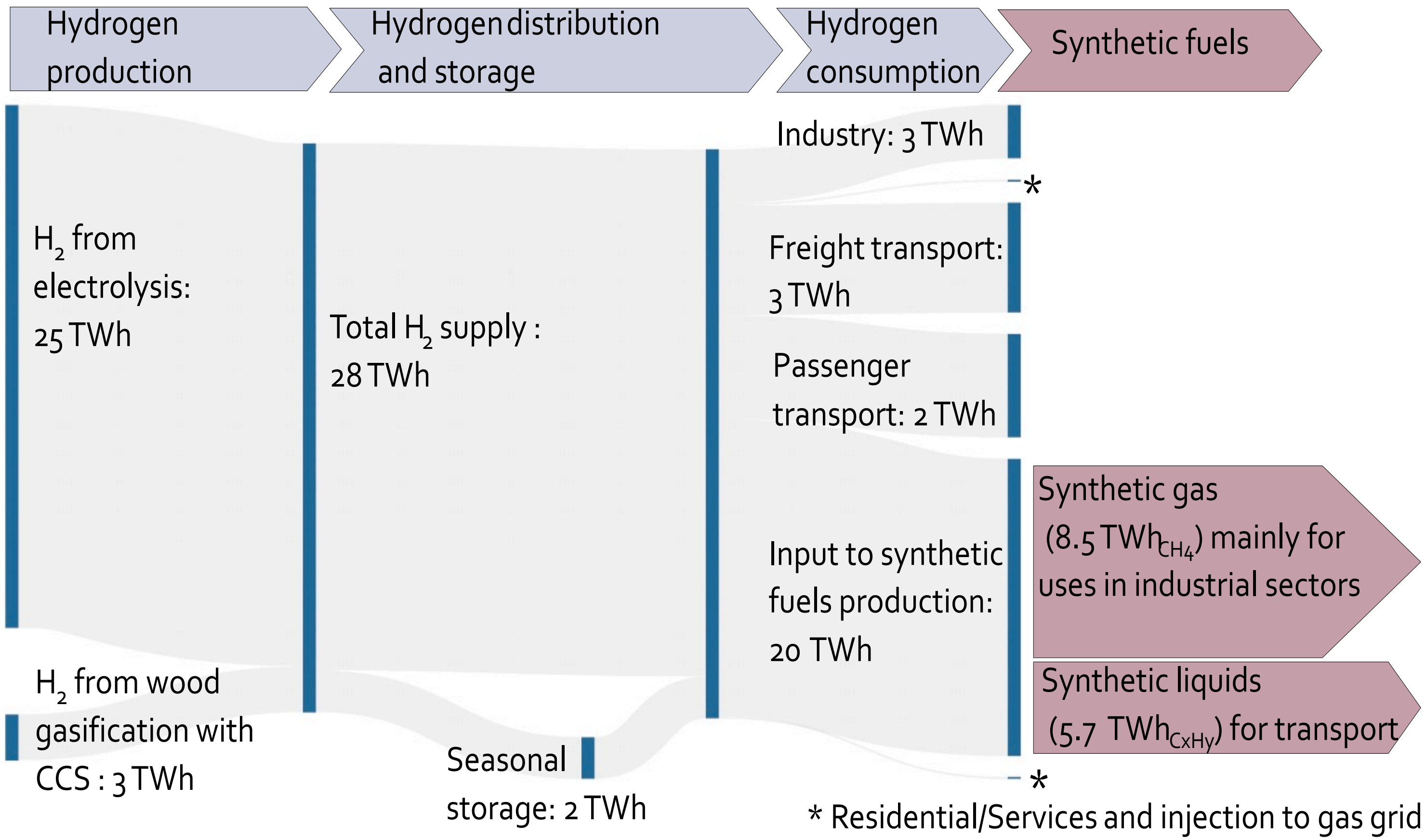
Domestic Power-to-X and Synfuels reduce import dependency

ABROAD-ALONE-STRICT

Net Imports (excl. aviation and nuclear fuels)



In 2050, H2-based synfuels substitute in **abroad-alone-strict** scenario more than half of the natural gas imports in **abroad-together** scenario.



* Residential/Services and injection to gas grid

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Wir schaffen Wissen – heute für morgen

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Energy Economics Group

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CROSS

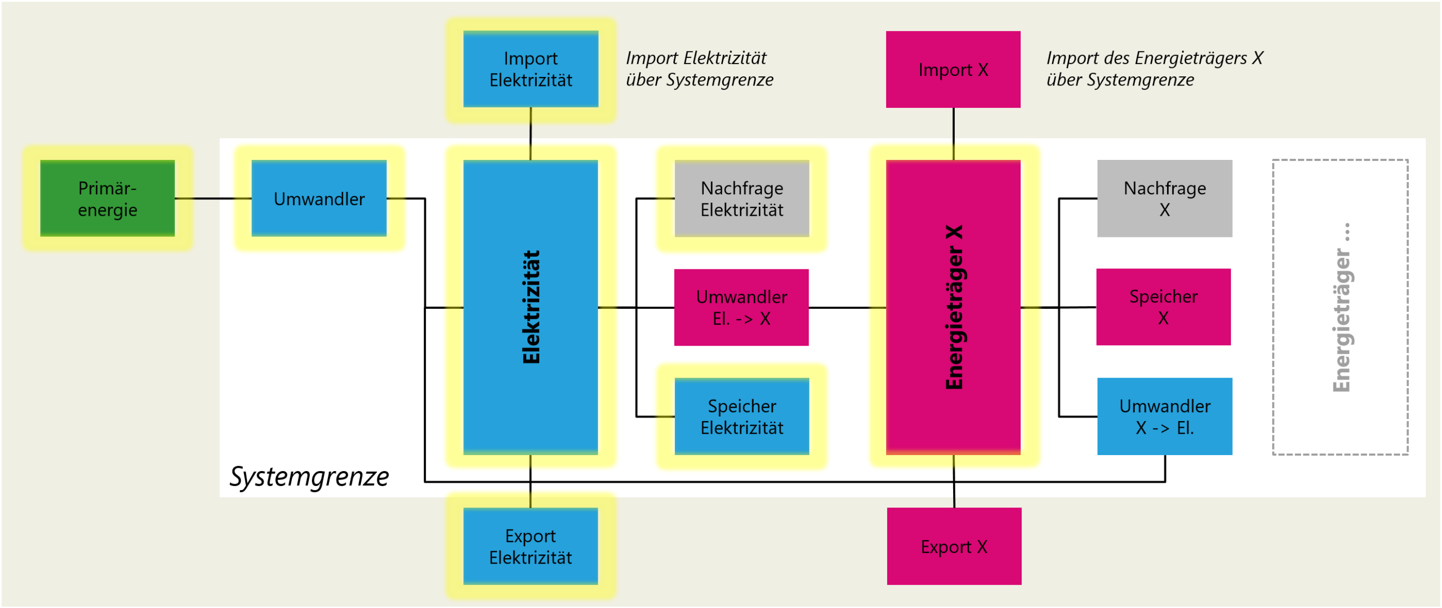
Empa

Martin Rüdisüli, Robin Mutschler, Matthias Sulzer

Empa
Materials Science and Technology

Model description

- Model type: MILP (multi-stage, multi-objective)
- Years: Stages (snapshots) for REF (~2018), 2030, 2040, 2050
- Sectors modelled: Electricity, heating, cooling, transport, industry



Import / Export
Energy flows over System boundaries

Conversion tech
PV, CHP, ...

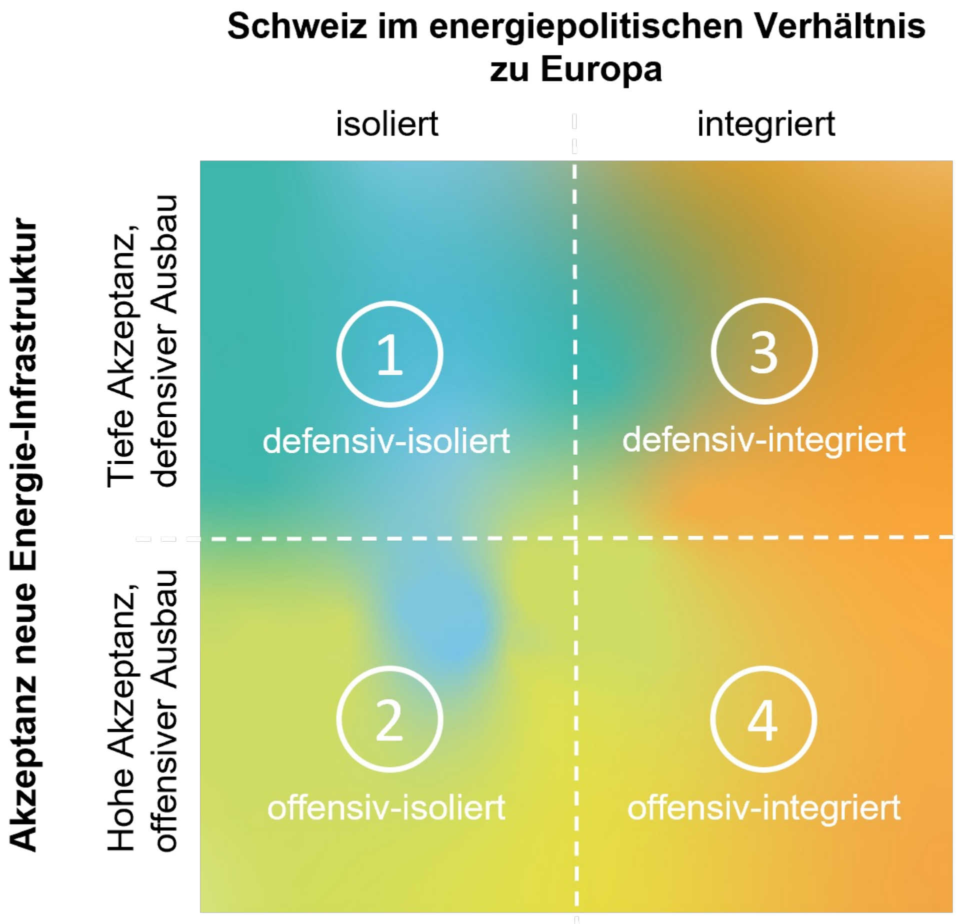
Storage tech
PHS, Battery, Tank, Thermal, ...

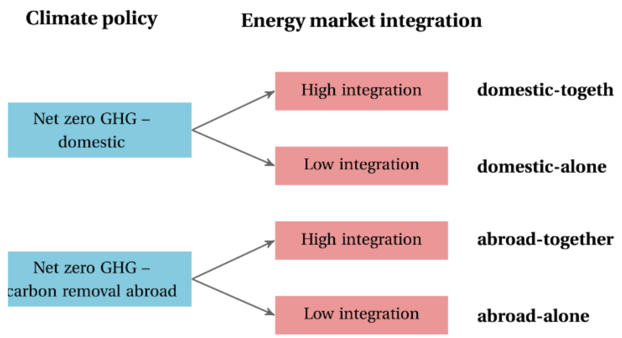
Demand
Useful energy

Energy carrier
Electricty, CH4, Heat, H_2, ...

Implementation of CROSS scenarios

- 2x2 scenario matrix with 2 dimensions:
  - **Acceptance** on new technologies
    - defensive vs. offensive
  - **Integration** in the **EU** energy (electricity and H2) system
    - Isolated vs. integrated
- 1 and 2 are variants of CROSS scenarios domestic-alone (with innovative and conservative technology development)
- 3 and 4 are variants of CROSS scenarios domestic-together (with innovative and conservative technology development)
  - Changes compared to the CROSS scenarios?
    - No “Climate Policy” scenario
      (“net zero” = prerequisite of all scenarios)
  - Are all scenarios feasible?
    - YES

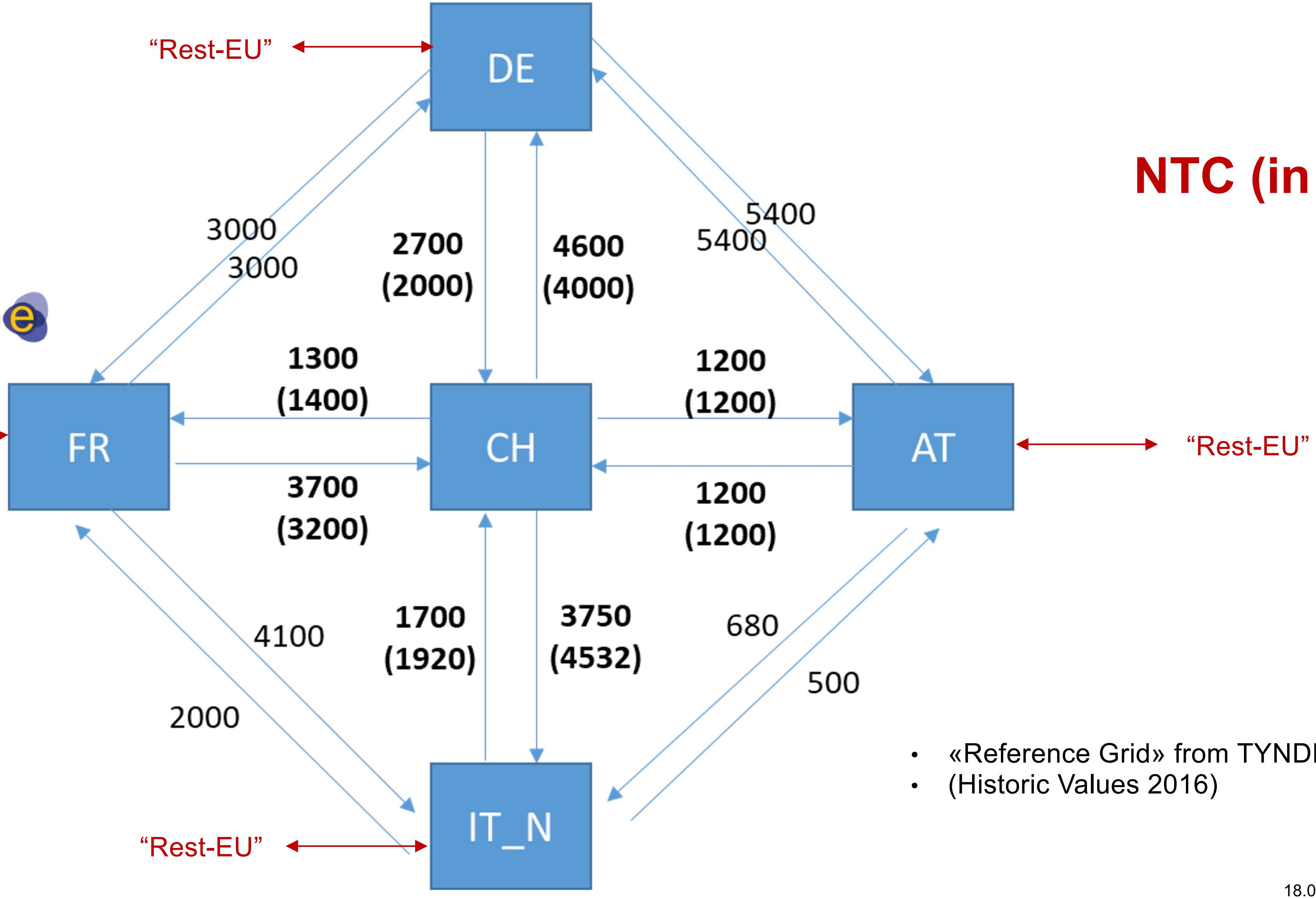




CROSS Scenarios v2022-09 overview

EU Modelling (=Neighbouring Countries)

entsoe



NTC (in MW)

- «Reference Grid» from TYNDP 2020
- (Historic Values 2016)

Some results