

# Quantification of the CROSS Scenarios with the Swiss TIMES Energy systems Model (STEM)

## STEM model description

The STEM model description is structured as follows:

- Resources:** Coal, Oil, Gas, Nuclear fuel, Wind, Solar, Hydro, Solid biomass, Wet biomass, Wastes, Geothermal.
- Technologies:** Energy conversion (Electricity & Heat generation, Hydrogen production, Biomass processing and biofuels, Synthetic fuels production, (Bio-) Refineries, Power-to-X, Other conversion); Fuel distribution and storage (Electricity storage and grids, Gas storage and pipelines, LNG ports, Hydrogen storage and distribution, Oil storage and distribution, Other fuels storage distribution, CO2 storage and distribution); End-use sectors (Residential: Heating, cooking, appliances, etc.; Services sectors: Heating, cooking, appliances, etc.; Industry: Iron&steel, cement, aluminum, etc. incl. non-energy; Agriculture; Passenger Transport: road, rail, aviation; Freight Transport: road, rail, aviation).
- Policies:** CO2 certificates trade, CO2 sinks and storages, CO2 emissions.
- Constraints:** Imports and exports, Trade matrices of energy carriers and certificates, Domestic resource extraction.
- Climate change impacts:** Energy demand drivers (Building stock, Appliances stock, Gross value added, Industry production, Vehicle stock, Vehicle-km, Passenger-km, Ton-km).
- Outputs:** Energy flows, Investments, Emissions, Energy system costs.

- Based on the open-source TIMES framework of IEA-ETSAP
- Long term horizon (2050+), in steps of 10 years
- Energy system transformation pathway analysis
- 288 hourly time steps within a year
- Technology-rich with detailed age structure of the assets
- Full energy system representation of Switzerland
- Endogenous infrastructure deployment
- Full unit commitment implementation for power plant dispatching
- Ancillary markets (operational reserve capacity markets)
- Endogenous variability of renewable energy sources
- Consumer segmentation in households and transport
- Endogenous hourly profiles for electricity, heat and mobility demands
- Demand response and several storage and flexibility options

## CROSS Scenarios

Harmonized scenario definition

Climate policy: Net-zero with compensation abroad

Energy market integration:

- Moderate integration → abroad-together
- Low integration → abroad-alone
- Minimum import dependency in 2050 → abroad-alone-strict

- Baseline (BAU): extrapolation of current trends, by considering the COVID-19 effects and the 2022 energy crisis and energy savings measures
- Abroad-together: implementation of the relevant CROSS scenario, by assuming that 5.7 Mt CO<sub>2</sub>-eq are compensated abroad in 2050.
- Abroad-alone: implementation of the corresponding CROSS scenario, which focuses on mitigation of electricity imports but allows other imports
- Abroad-alone-strict: own variant of abroad-alone aiming at reducing overall net import dependency on annual basis to almost 0 in 2050

## SURE-CROSS-Results

### Efficiency and electrification in end-uses

Final energy consumption by fuel (excl. international aviation)

### Electricity supply becomes weather dependent

Electricity supply by major fuel and technology

### Power-to-X and synfuels contribute to autarky

In 2050, hydrogen based synfuels substitute in abroad-alone-strict scenario more than 90% of the gas imports in abroad-together scenario

### Transport & buildings with biggest efficiency gains

Final energy consumption by sector (excl. international aviation)

### Coordinated flexibility (abroad-together scenario)

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 (524 MW)
Electricity shifts (DSM) in industry, services, residential	10% of demand (5.5 TWh)

### Milestones to net-zero CO<sub>2</sub> emissions

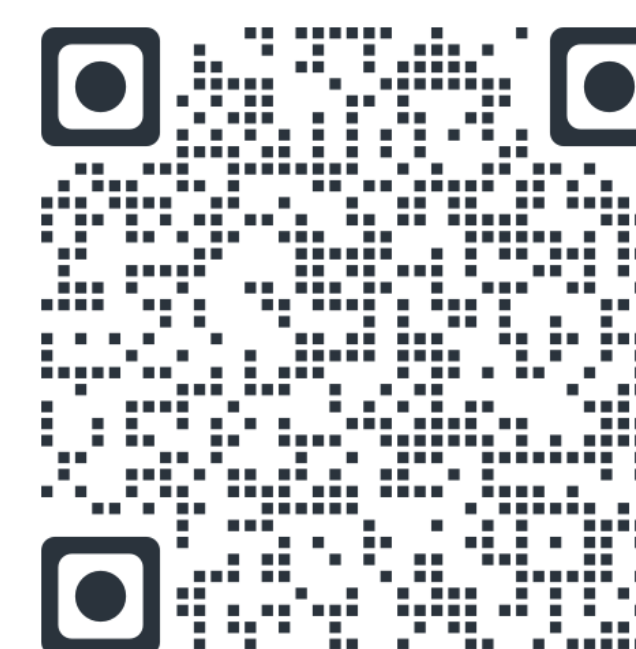
Year	Heat Pumps	EVs in car sales	Solar PV	TPES
2020	12%	15%	3 GW	33300 kWh/cap
2030	55%	39%	8 GW	26100 kWh/cap
2050	75%	87%	26 GW	17350 kWh/cap

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The research published in this poster was carried out with the support of the Swiss Federal Office of Energy SFOE as part of the SWEET project SURE. The authors bear sole responsibility for the conclusions and the results presented in this publication.