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Electric mobility in Switzerland: How many Teslas can the system deal with?

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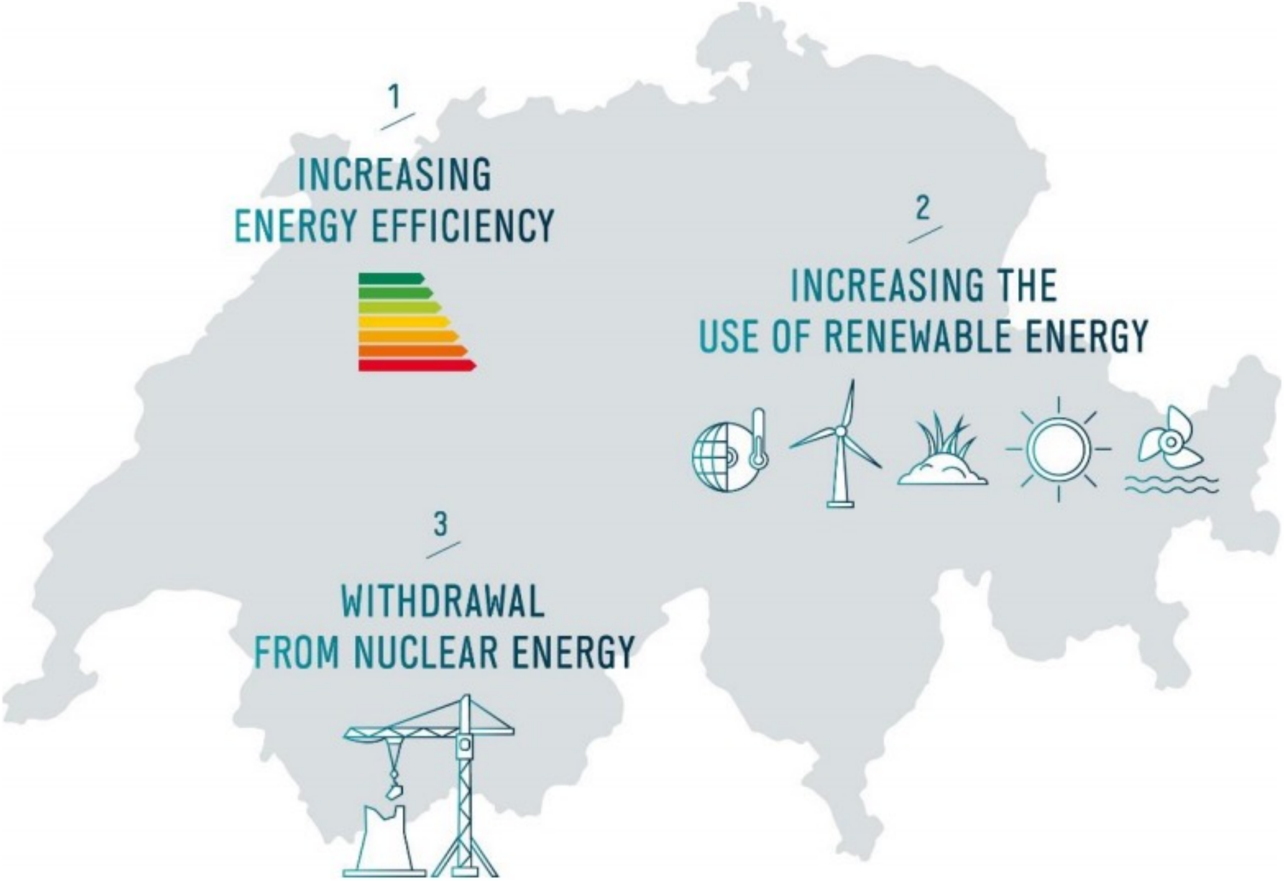
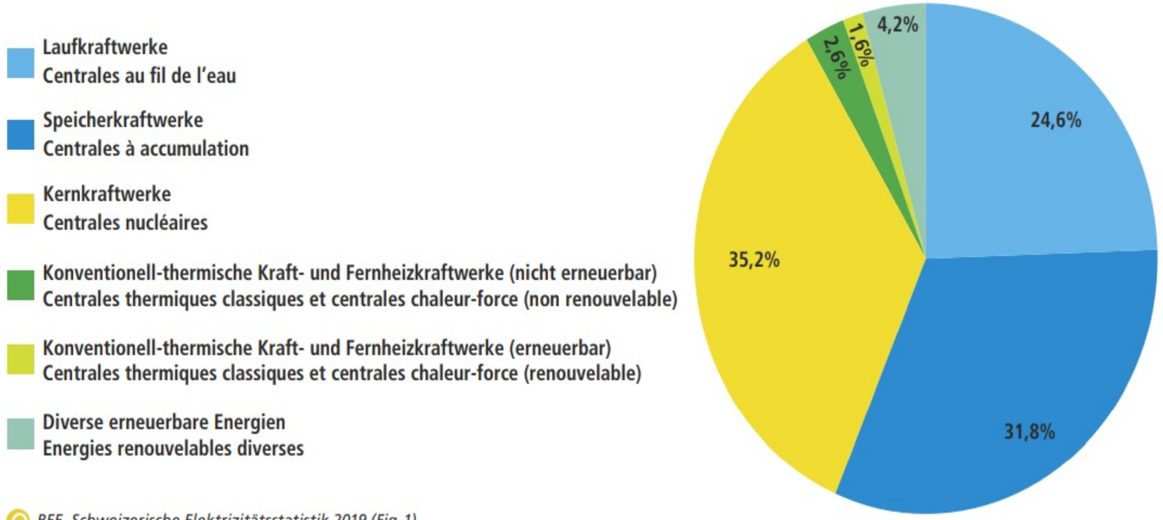
Outline

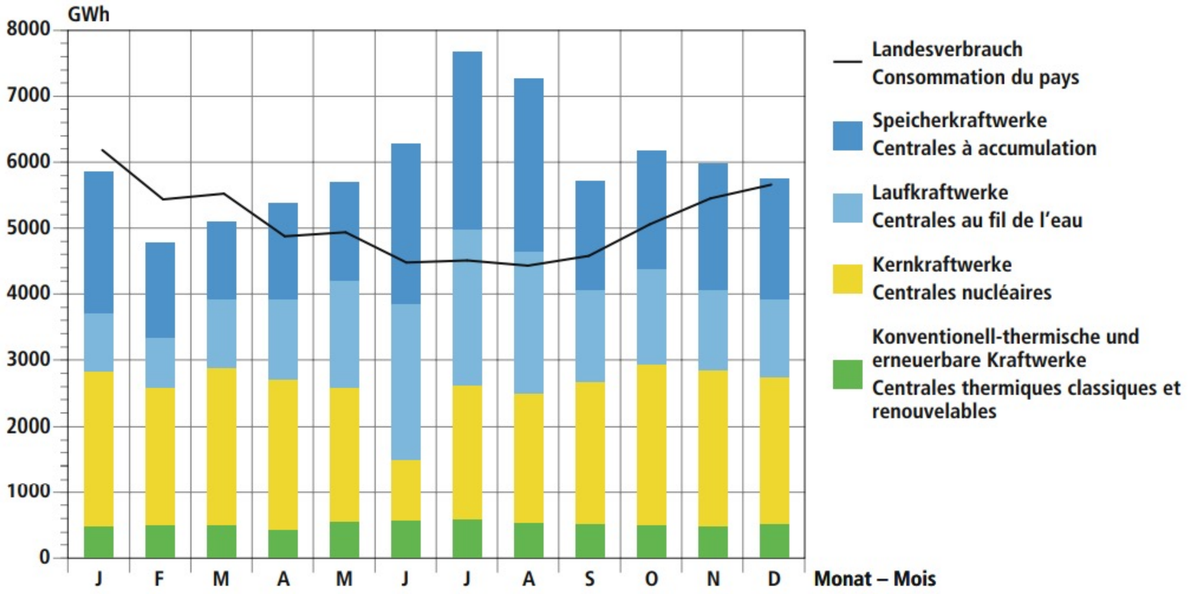
Swiss Energy Strategy 2050



Swiss Energy Portfolio

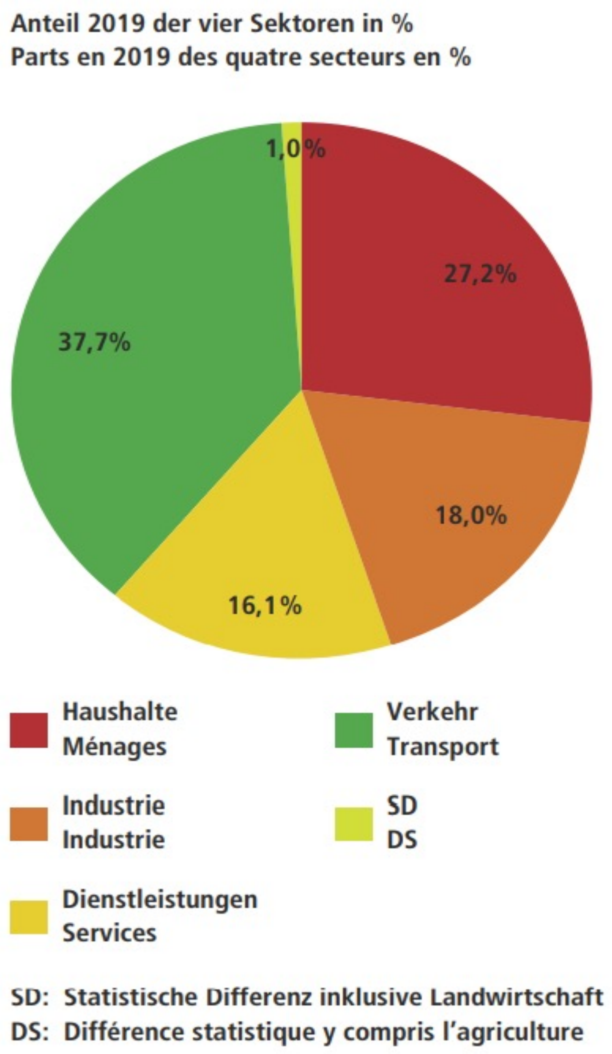


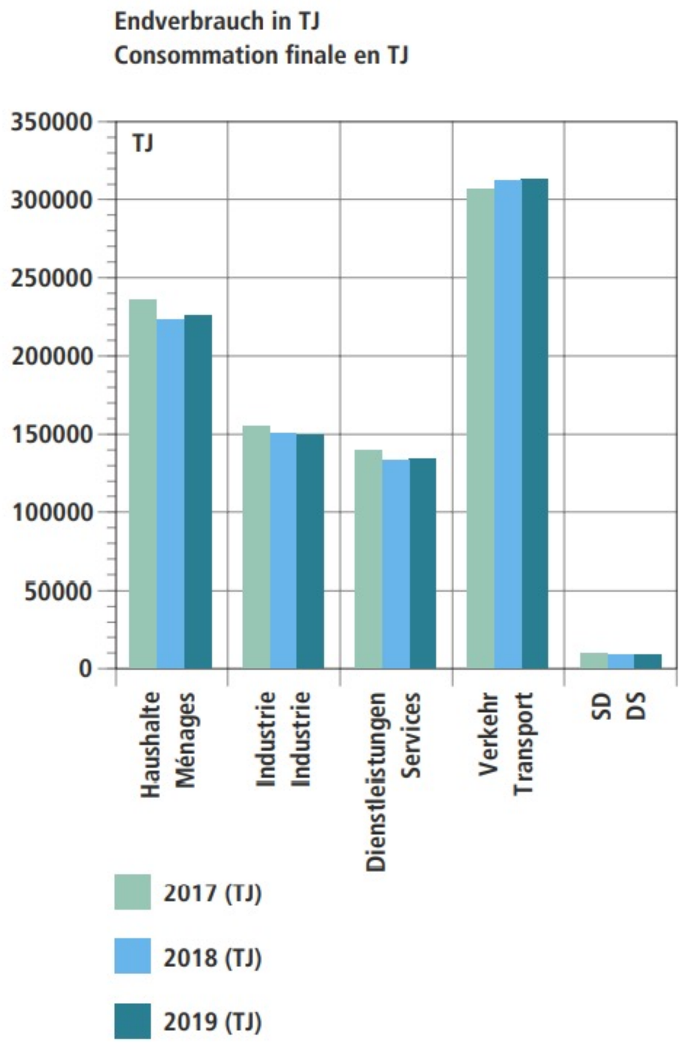
BFE, Schweizerische Elektrizitätsstatistik 2019 (Fig. 1)
OFEN, Statistique suisse de l'électricité 2019 (fig. 1)



BFE, Schweizerische Elektrizitätsstatistik 2019 (Fig. 10)
OFEN, Statistique suisse de l'électricité 2019 (fig. 10)

Swiss Energy Consumption





Source: *Swiss Federal Office of Energy (BFE), 2019.*

Outline

Goals and Contribution

To study possible future interactions of electric vehicle fleets in the Swiss power system in terms of:

– dispatch of power plants

– integration of fluctuating renewable energy

– changes on the power system load

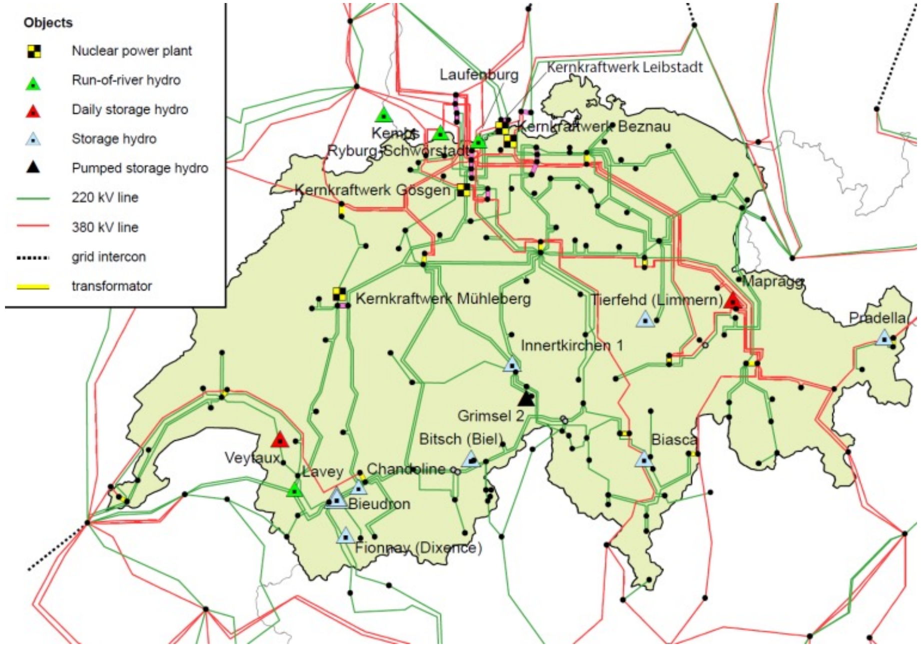
– variable charging costs

– CO_2 emissions

An integrated approach combining technology, economic and environmental aspects is required.

Outline

Swiss Electricity Market Model (Swissmod)



- Cost minimization problem
- Nodal pricing model based on DC load flow approach
- Focus on hydropower elements

$$\min C = \sum_{p,t} (intercept_{p,t} + slope_{p,t}\, Q_{p,t})\, Q_{p,t}$$

- Detail representation of the Swiss power system
  ca. 230 nodes (150 in Switzerland)
  ca. 400 lines

- Aggregated neighboring countries

Demand-Supply balance:

$$\begin{aligned} d_{n,t} = & \sum_c G_{c,t} + res_{n,t} \\ & + \sum_h Turb_{h,t}\, eta_h^{Turb} - Pump_{h,t}\, eta_h^{Pump} \\ & + \sum_{h_{abroad}} Turb_{h_{abroad},t} - Pump_{h_{abroad},t} \\ & - \sum_l inc_{l,n} F_{l,t} \end{aligned}$$

Line Flow

$$E_t^l = b^l \sum_n \mathbf{i}_{l,n} X_t^n$$

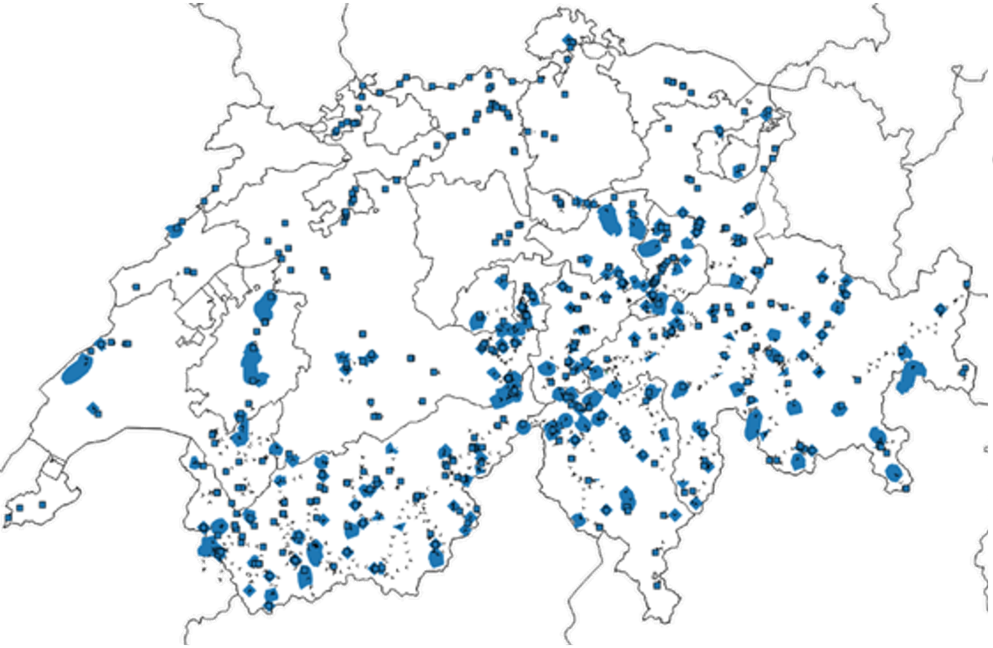
Capacity Restrictions

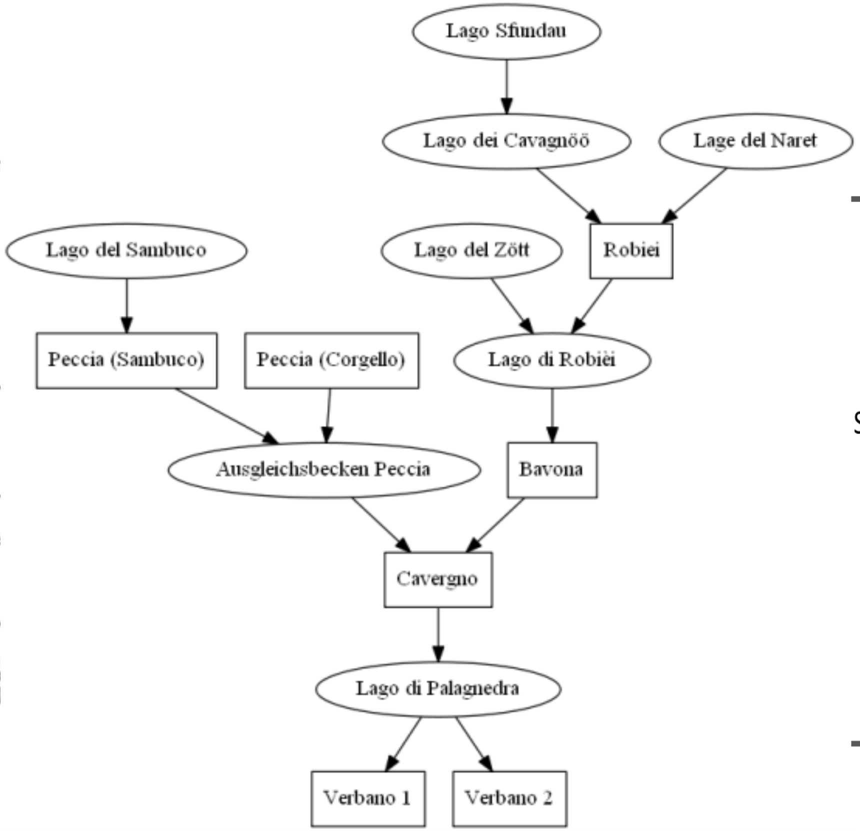
$$E_t^l < \bar{e}^{\,l}$$

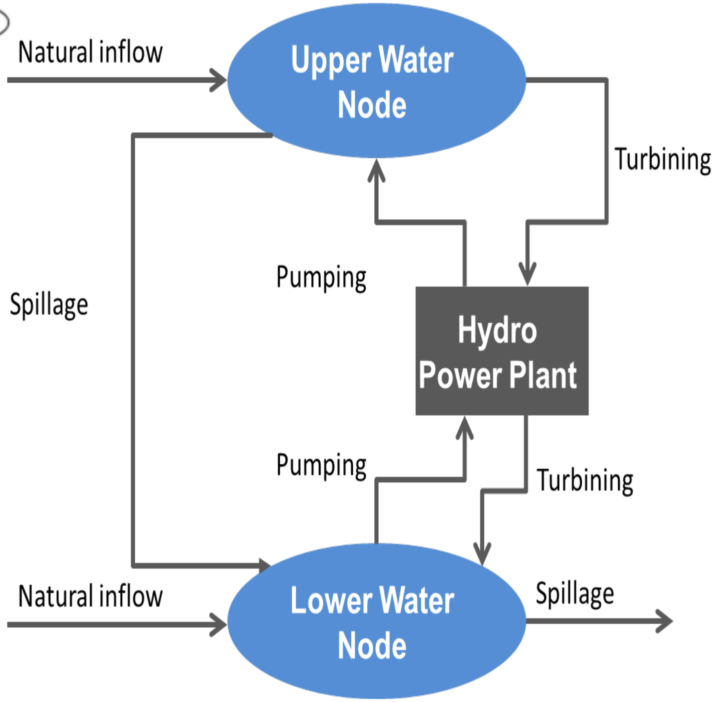
$$E_t^l > -\bar{e}^{\,l}$$

$$E_t^{cpp} < \bar{e}^{cpp}$$

Swiss Electricity Market Model (Swissmod)







Hydro Structure:

- ca. 200 cascades with ca. 400 plants (>95% of production)

Swiss Electricity Market Model (Swissmod)

New demand-supply balance:

$$
\begin{aligned}
d_{n,t} = & \sum_i map^{pl}_{n,i} Q_{i,t} + res_{n,t} \\
& + \sum_h map^{hy}_{n,h} (Turb_{h,t} - Pump_{h,t}) \\
& - \sum_l map^{li}_{n,l} F_{l,t} \\
& + LostLoad_{n,t} - Curtailment_{n,t} \\
& - \sum_c map_{c,n} Charge_{t,c}
\end{aligned}
$$

EVs constraints:

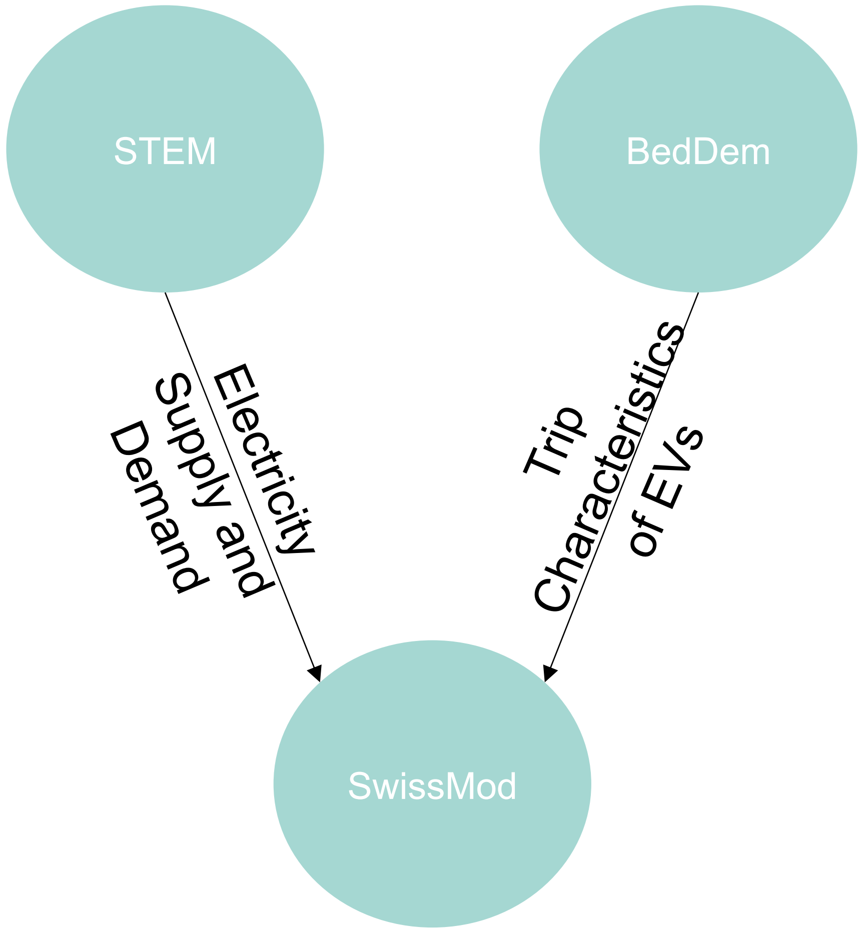
$$
\begin{aligned}
Stor_{t,c} = & \, Stor_{t-1,c} \\
& + Charge_{t,c} \\
& - drivedischarge_{t,c}
\end{aligned}
$$

$$0 \leq Stor_{t,c} \leq battery_c$$

$$0 \leq Charge_{t,c} \leq rate_c \times avail_{t,c}$$

Outline

Scenarios



EPOL: measures of the Swiss Strategy 2050 without a specific CO2 target

CLI: reach net-zero CO2 emissions

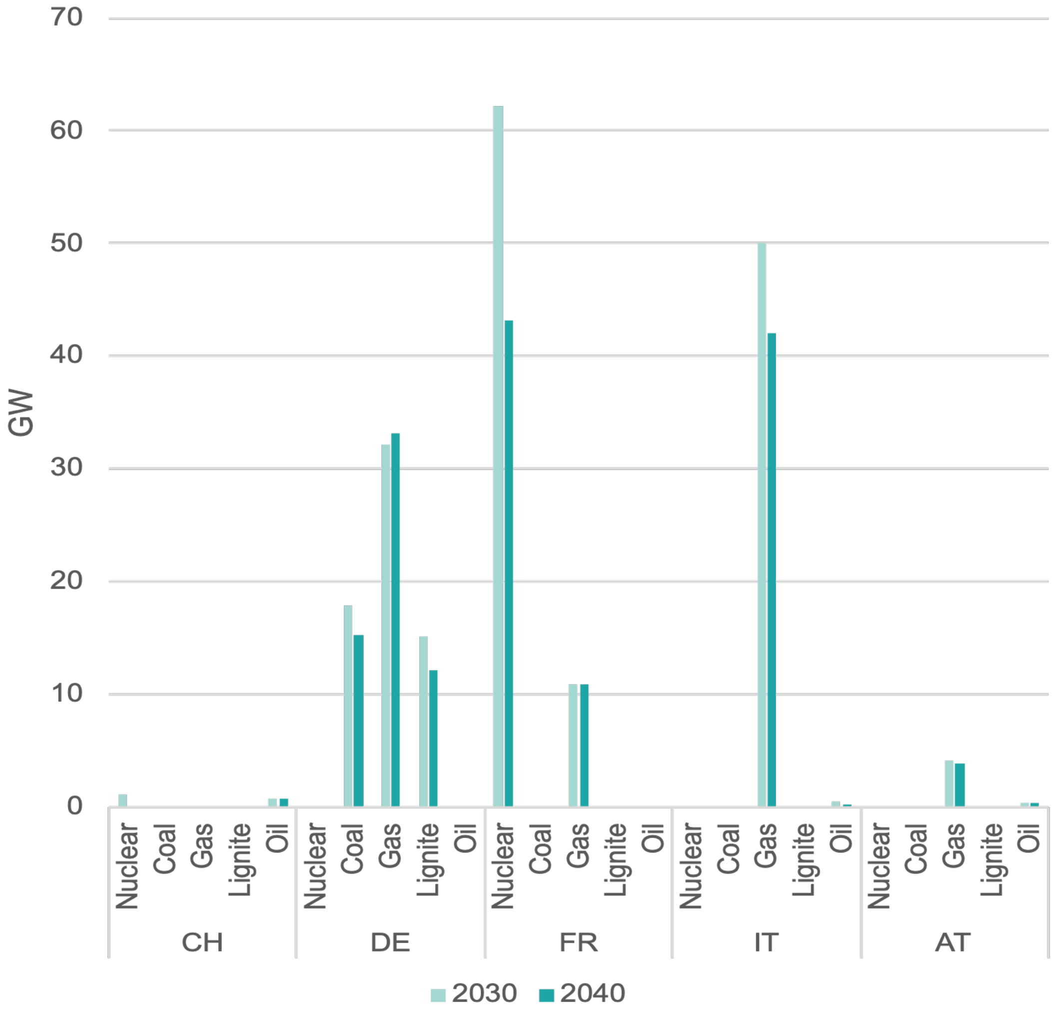
Dimensions:
- technology availability: how many vehicles, types, km per vehicle, max use public transportation

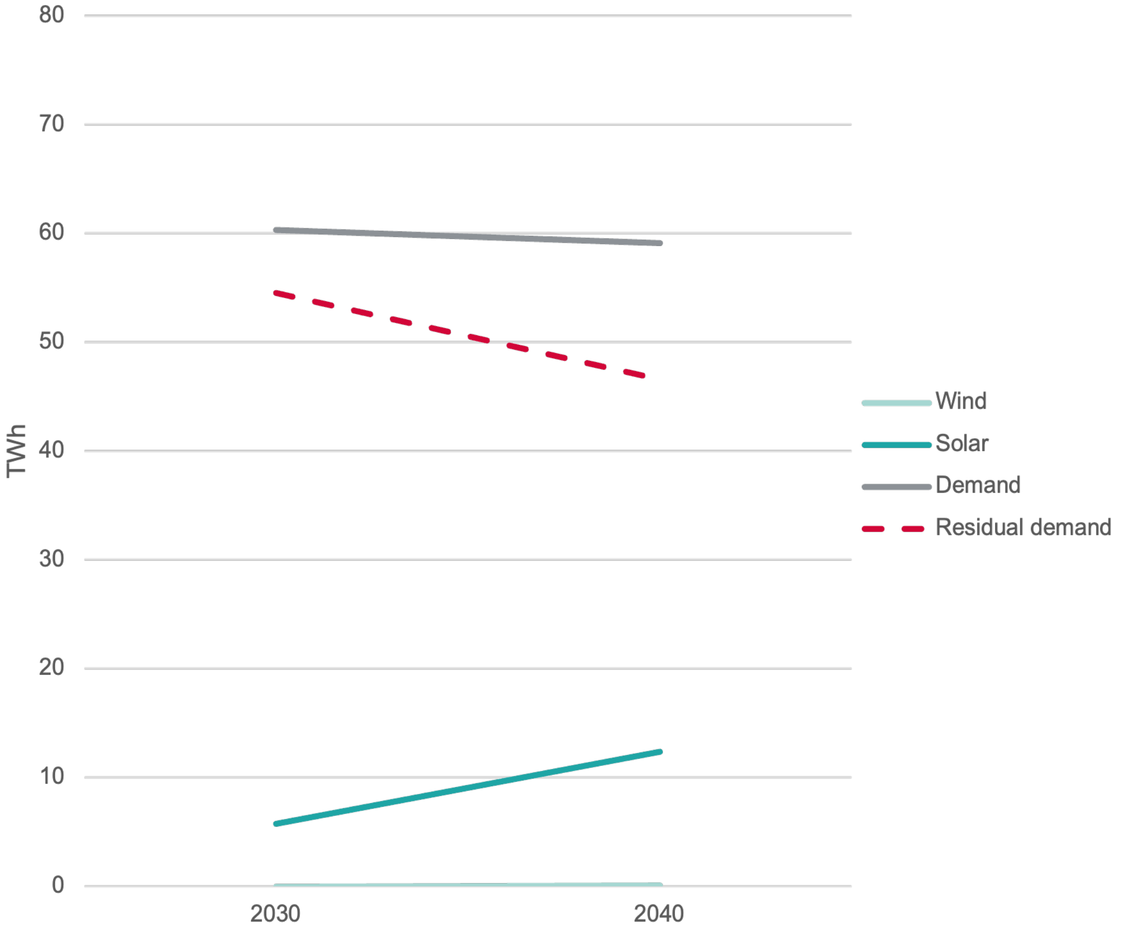
- climate policy: CO2 emissions targets and costs, RES

Scenarios in Swissmod:

- Basecase
- Instant Charging
- Smart Charging
- Restricted Smart
- V2G

Model inputs





Model inputs

		2030	2040
No. Vehicles (million)	EPOL	0.1	1.1
	CLI	0.6	1.8
% Total cars fleet	EPOL	2%	19%
	CLI	12%	33%
EV Consumptions as share of total load (%)	CH	6%	9%
	EU	0.12%	0.17%
Cumulative Battery Capacity (GWh)	EPOL	7	80
	CLI	43	131
Clusters	-	200	200
Charging rate	-	3.7 kW/v	3.7 kW/v

Outline

Prices

Average prices in EUR/MWh

	EU					CH				
	No EVs	Smart Charging	Instant Charging	Restricted Smart	V2G	No EVs	Smart Charging	Instant Charging	Restricted Smart	V2G
2030	81.48	83.16	83.08	83.14	83.11	80.94	129.42	131.91	131.62	126.04
2040	58.65	60.38	63.15	60.81	56.04	60.42	71.42	87.91	75.16	60.44

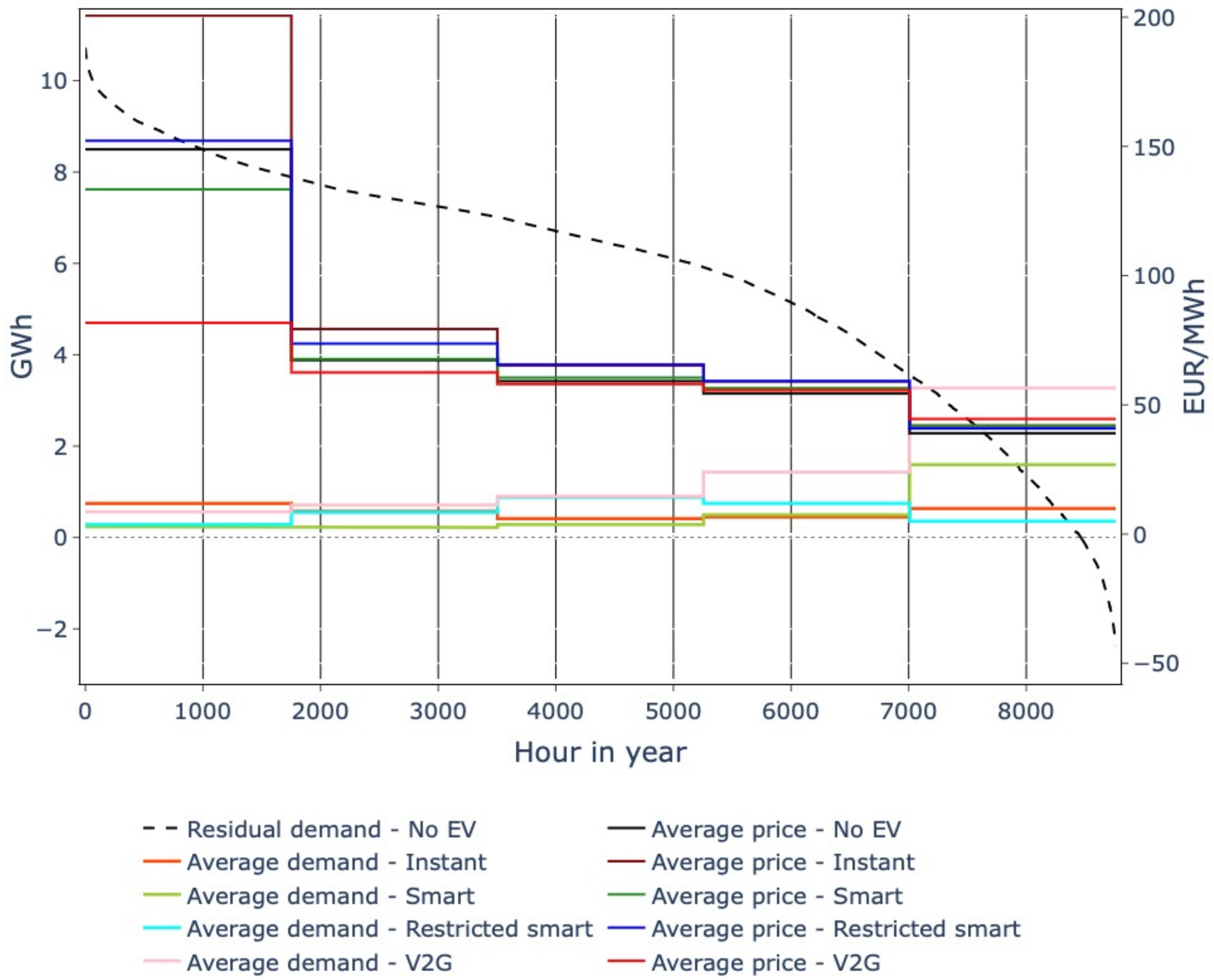
Average charging costs in EUR/MWh

	Smart Charging	Instant Charging	Restricted Smart	V2G
2030	104	136	118	106
2040	51	112	61	46

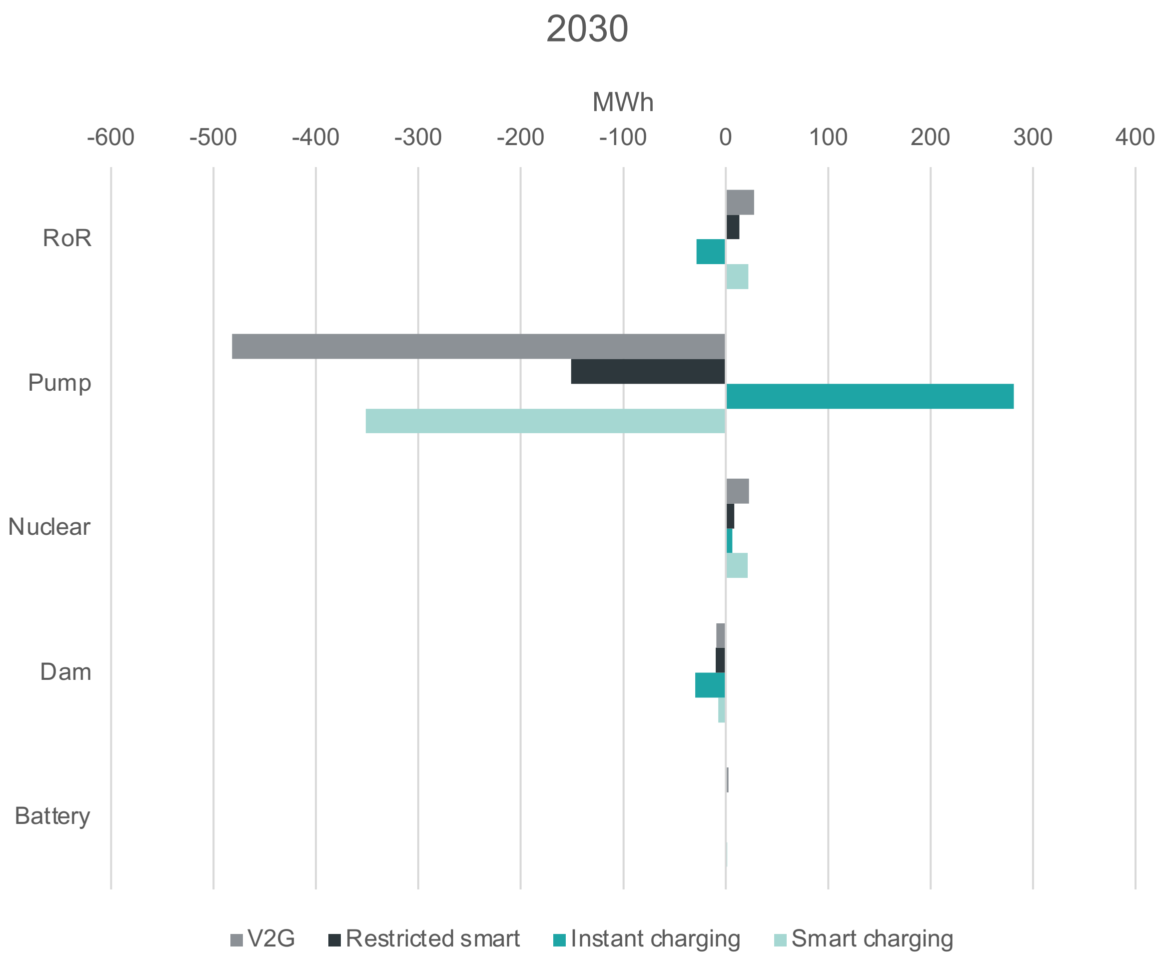
Winter Profiles

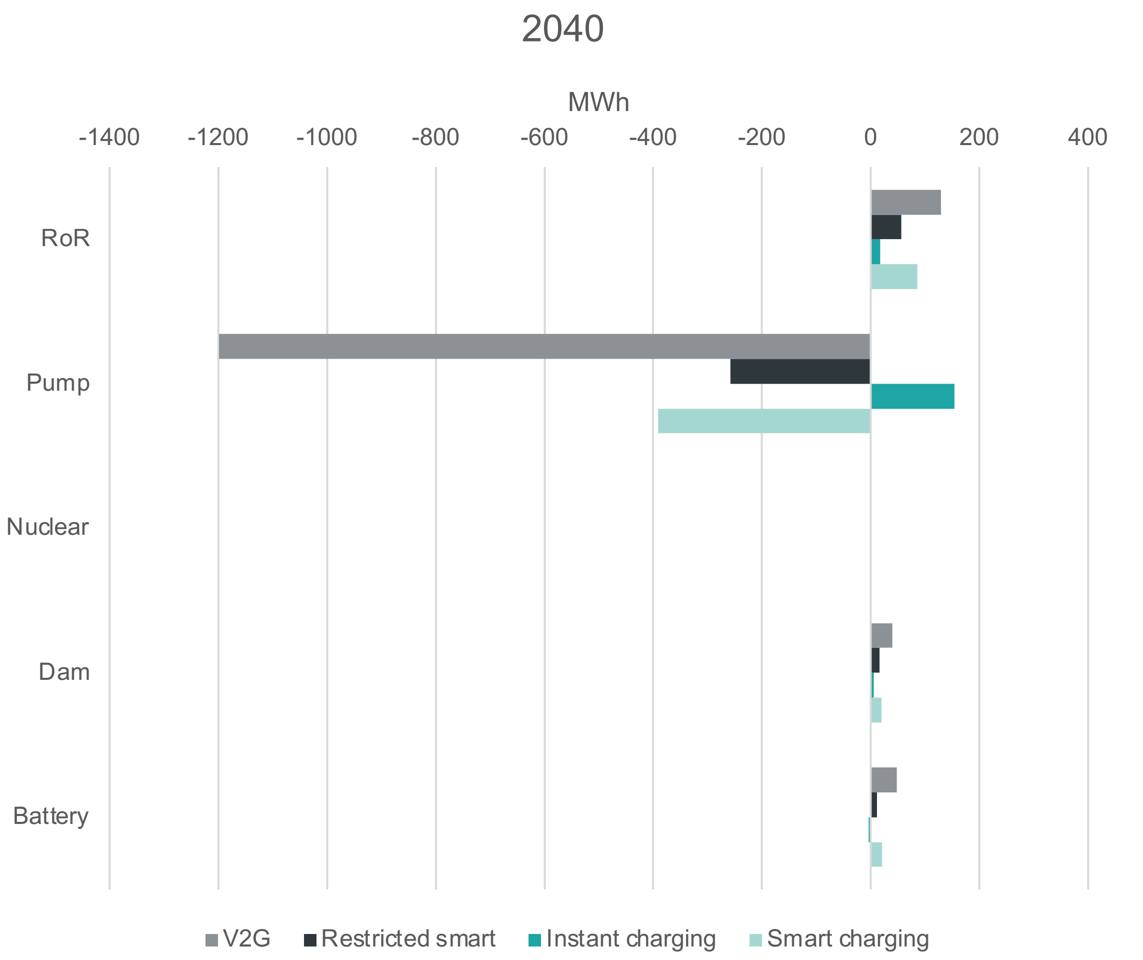
Profiles for a sample winter week in 2040

Residual load duration curve in 2040



Dispatch changes relative to basecase





Hydro revenues

Average revenue in EUR/MWh

	Dam					RoR				
	No EVs	Smart Charging	Instant Charging	Restricted Smart	V2G	No EVs	Smart Charging	Instant Charging	Restricted Smart	V2G
2030	88	133	142	127	120	81	119	125	114	109
2040	87	118	134	108	64	60	77	84	72	53

Average pumping cost and revenue in EUR/MWh

	Pumping Cost					Revenue				
	No EVs	Smart Charging	Instant Charging	Restricted Smart	V2G	No EVs	Smart Charging	Instant Charging	Restricted Smart	V2G
2030	49	77	81	70	69	90	135	143	129	122
2040	37	54	65	47	37	99	135	149	127	71

CO2 emissions

Average CO2 emissions in million tons

	No EVs	Smart Charging	Instant Charging	Restricted Smart	V2G
2030	376	384	385	384	384
2040	398	404	406	405	404

Average CO2 emissions per distance travelled in CO2gr/km

	Smart Charging	Instant Charging	Restricted Smart	V2G
2030	1,31	1,48	1,31	1,31
2040	0,30	0,41	0,35	0,30

Outline

Conclusion

- We use a numerical dispatch model which minimizes overall dispatch costs over a full year
- The overall energy demand of the modeled EV fleets is low compared to the power system
- Swiss EVs have a small effect on EU prices but a considerable one on Swiss prices
- V2G and Smart charging reduce prices while improve Evs owners' profits by decreasing charging costs
- V2G helps to smooth electricity prices while instant charging puts more pressure in the system in cases of peak load
- Pump storage units benefit of arbitrage opportunities between peak and off-peak hours, specially for the instant charging case
- EVs reduce CO_2 emissions

University of Basel

Thank you
for your attention.

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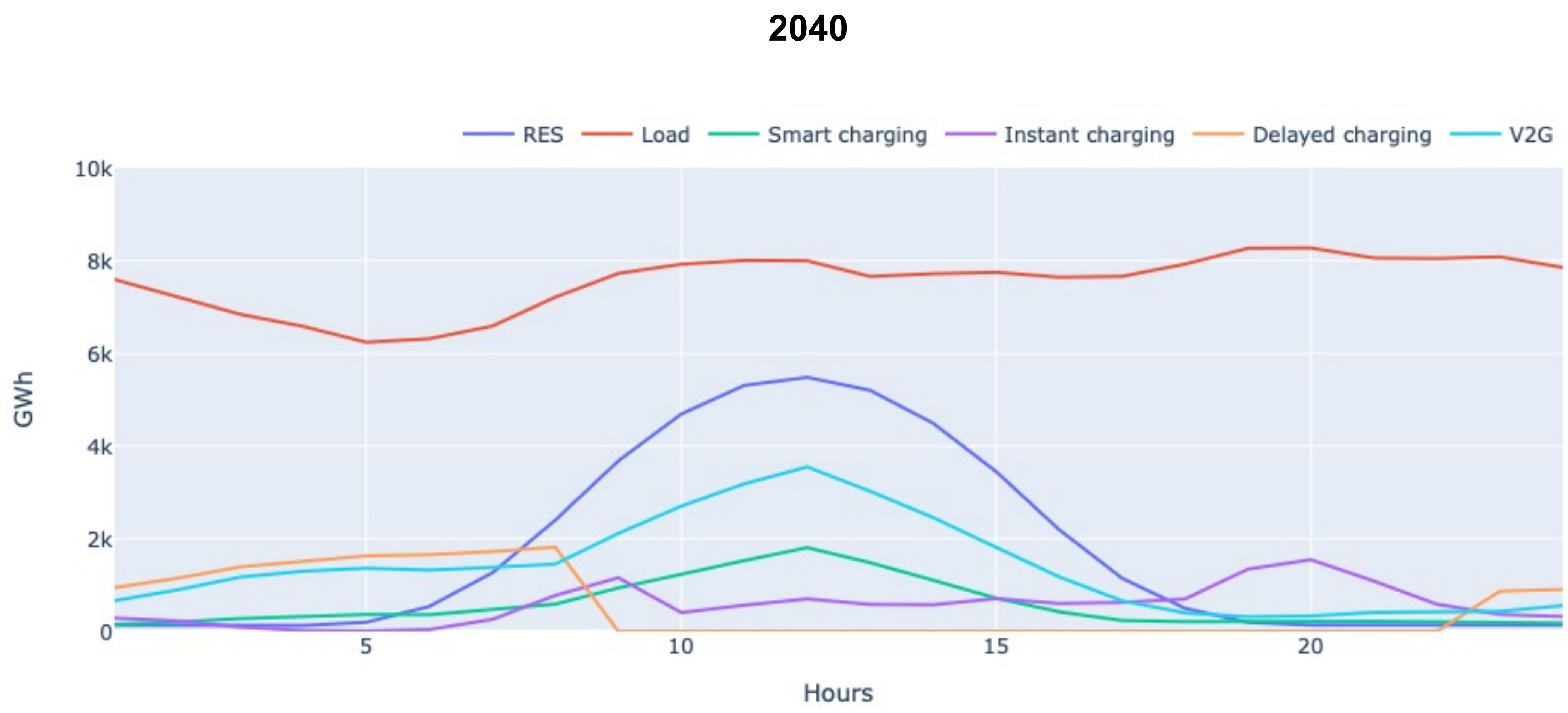
Average EV charging power over 24 hours



Summer Profiles

Profiles for a sample summer week in 2040