Vision of the Excess Electricity and Power-to-Gas in Energyscope

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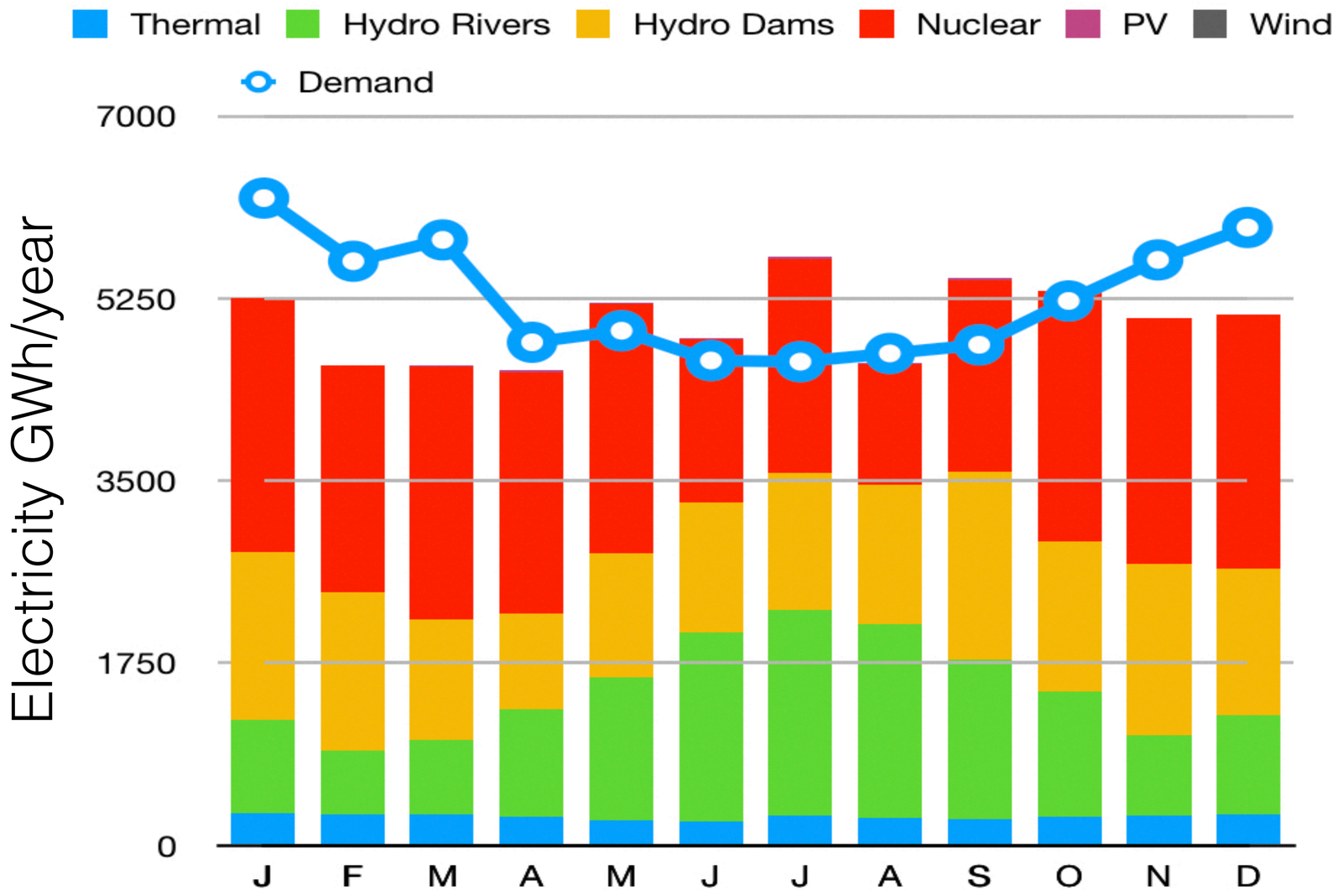
EPFL Valais Wallis
CH-1950 Sion

What is energyscope ?

The energyscope.ch project

Sources:

[1] Swiss Federal Council. *Perspectives Énergétiques 2050 - Analyse Des Variantes d'offre d'électricité Du Conseil Fédéral*. May 2011.
[2] Swiss Federal Office of Energy (SFOE). *Swiss electricity statistics 2011*. DE/FR. Tech. rep. Bern, Switzerland, 2012.



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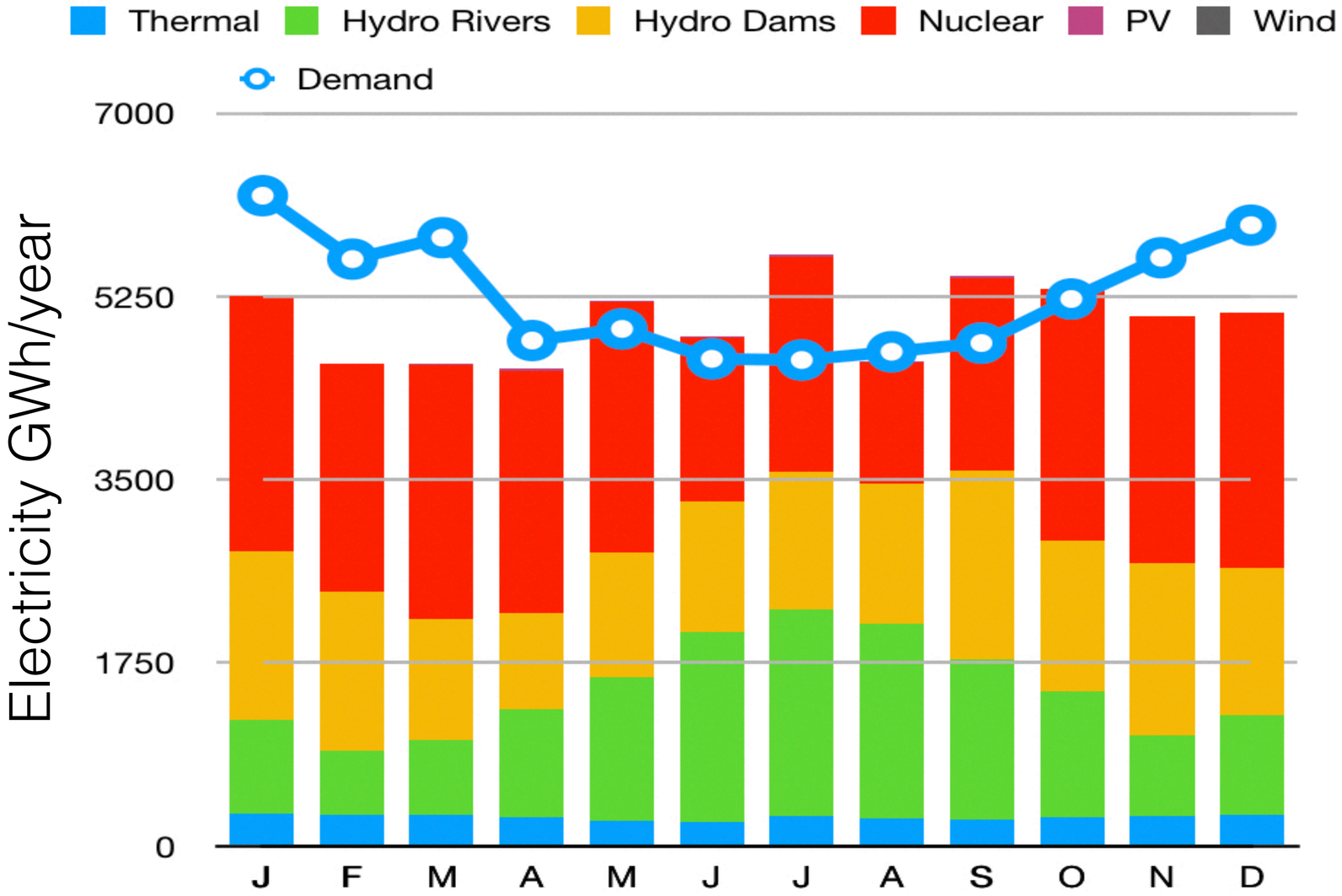
Fukushima, March 25th, 2011



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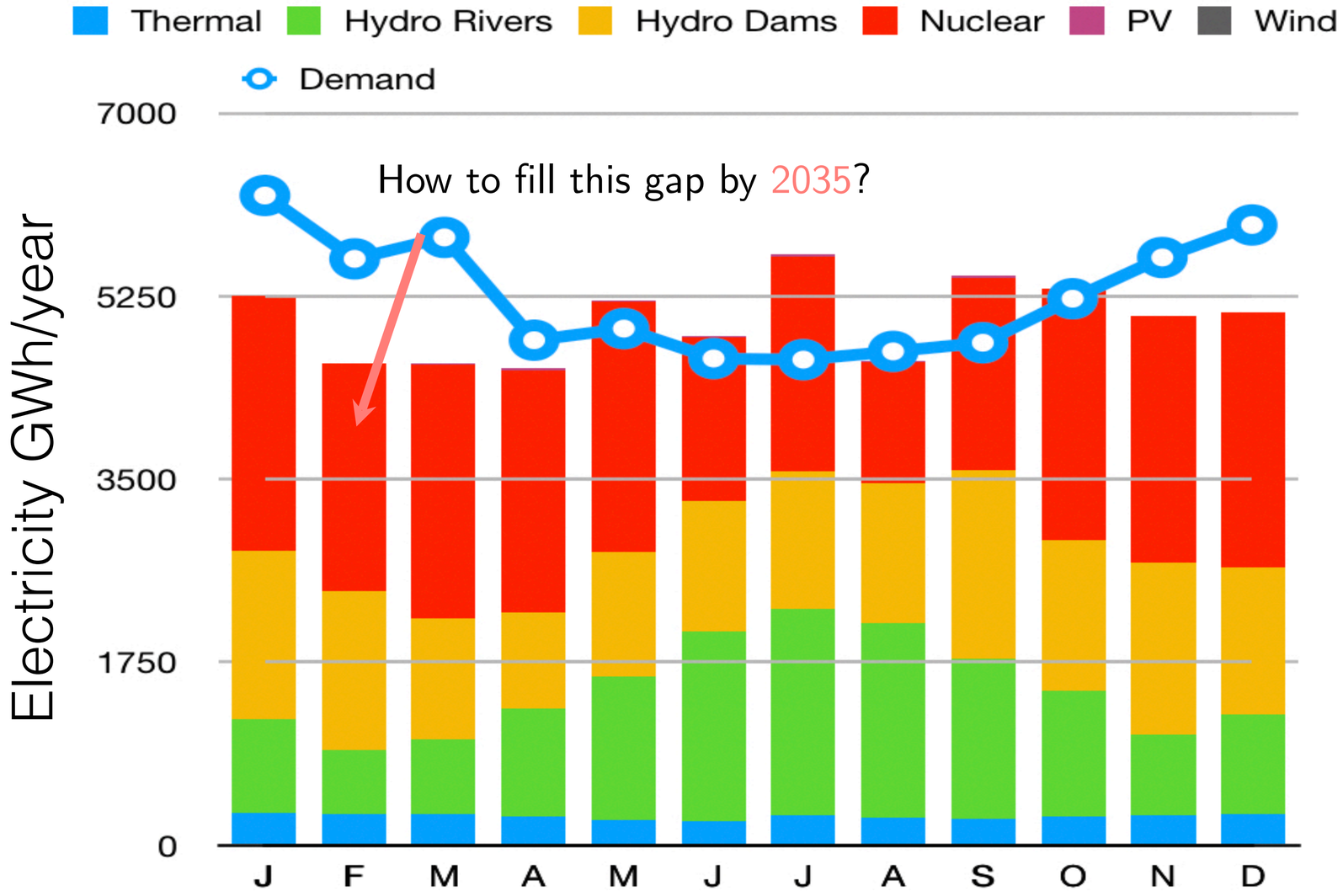


Energyscope

[1] S. Moret et al. "Swiss-EnergyScope.Ch: A Platform to Widely Spread Energy Literacy and Aid Decision-Making". In: *Chemical Engineering Transactions* 39 (2014), pp. 877–882
[2] V. Codina Gironès et al. "Strategic Energy Planning for Large-Scale Energy Systems: A Modelling Framework to Aid Decision-Making". In: *Energy* 90, Part 1 (Oct. 2015), pp. 173–186.

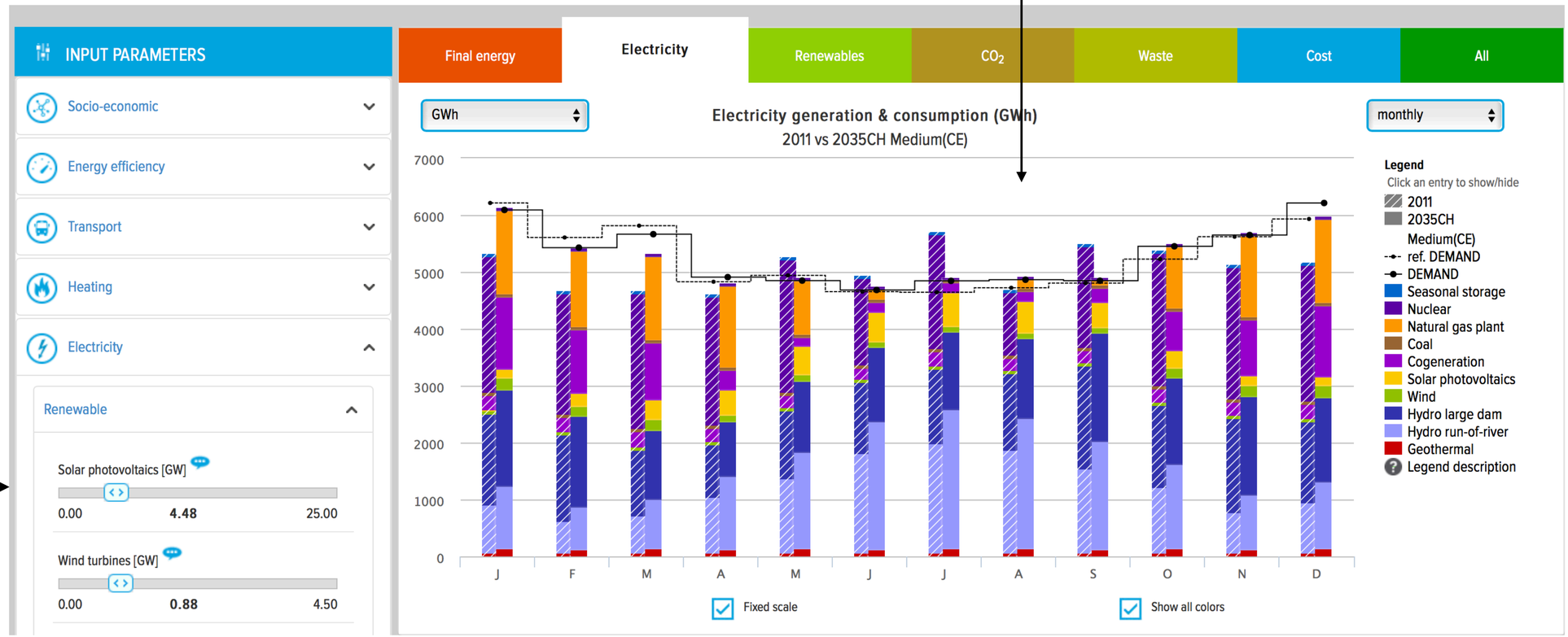
The energyscope.ch project

- Online platform energyscope.ch[1]
- Excel version of the model[2]

PLATFORM SWISS-ENERGYSCOPE DEVELOPPED BY THE ENERGY CENTER OF EPFL
EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
WITH THE SUPPORT OF
swiss energy
canton de vaud
fee

Compare results

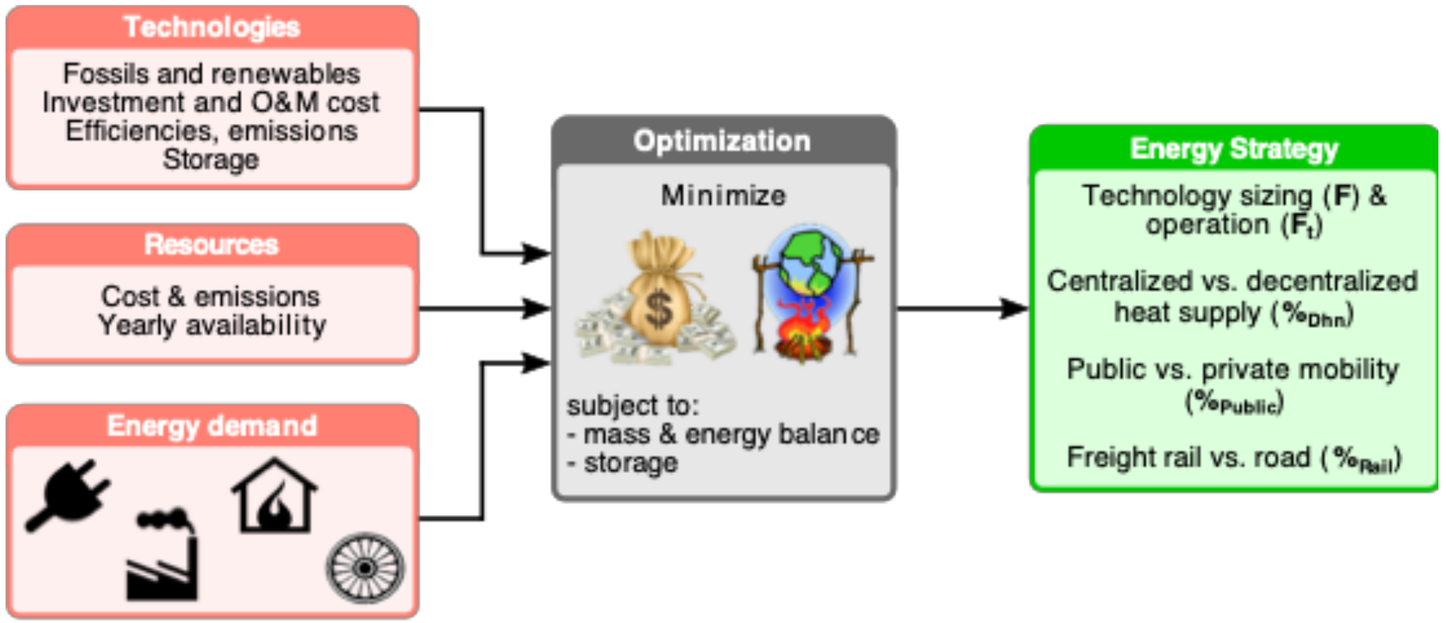
Choose options



Energyscope

Sources:
[1] S. Moret, F. Babonneau, M. Bierlaire, and F. Maréchal. "Decision support for strategic energy planning: a complete robust optimization framework ", 2018 (Under review)

A new mixed integer linear programming version



- Energy-based model
- "Snapshot" modeling approach: optimization of the system in a target future year
- Simplified yet complete energy system: inclusion of heating and mobility → could complement more complex models
- Multiperiod formulation: seasonality of demand and energy storage
- Concise structure and low computational time → uncertainty applications

Energyscope

Sources:
[1] S. Moret, F. Babonneau, M. Bierlaire, and F. Maréchal. "Decision support for strategic energy planning: a complete robust optimization framework ", 2018 (Under review)

Mixed Integer Linear Programming model : https://www.github.com/stefanomoret/SES_MILP

Why yet another energy model?[1]

Model	Open Source	Investment & Operation	All sectors	Timestep[a]	Run time	Stochastic[b]
EnergyPlan[c]	✓	Operation only	✓	h	Seconds	✗
MARKAL/TIMES[d]	✗	Investment only	✓	h/d/m	5-35 min	✓
MESSAGE[e]	✓	✓	✓	5y	-	✓
NEMS[f]	✓	✗	✓	y	1-12 h	✗
SMART[g]	✓	✓	✓	h	1-20 h	✓
Oemof[h]	✓	✓	✓	h	Mins.	✗
PyPSA[i]	✓	✓	✓	h	Mins.	✓
OSeMOSYS[j]	✓	Investment only	✓	d	Mins.	✗
ETEM[k]	✓	✓	✓	h/d/m	1-30 min	✓
energyscope (this paper)[l]	✓	✓	✓	m	Seconds	✓

- Most models are not open-source or are – at least partly – commercial
- Most model tend to focus only (or mostly) on the electricity sector
- Need of optimizing both investment & operation strategy in the system
- Complex formulation and high computational time → difficult to consider uncertainty

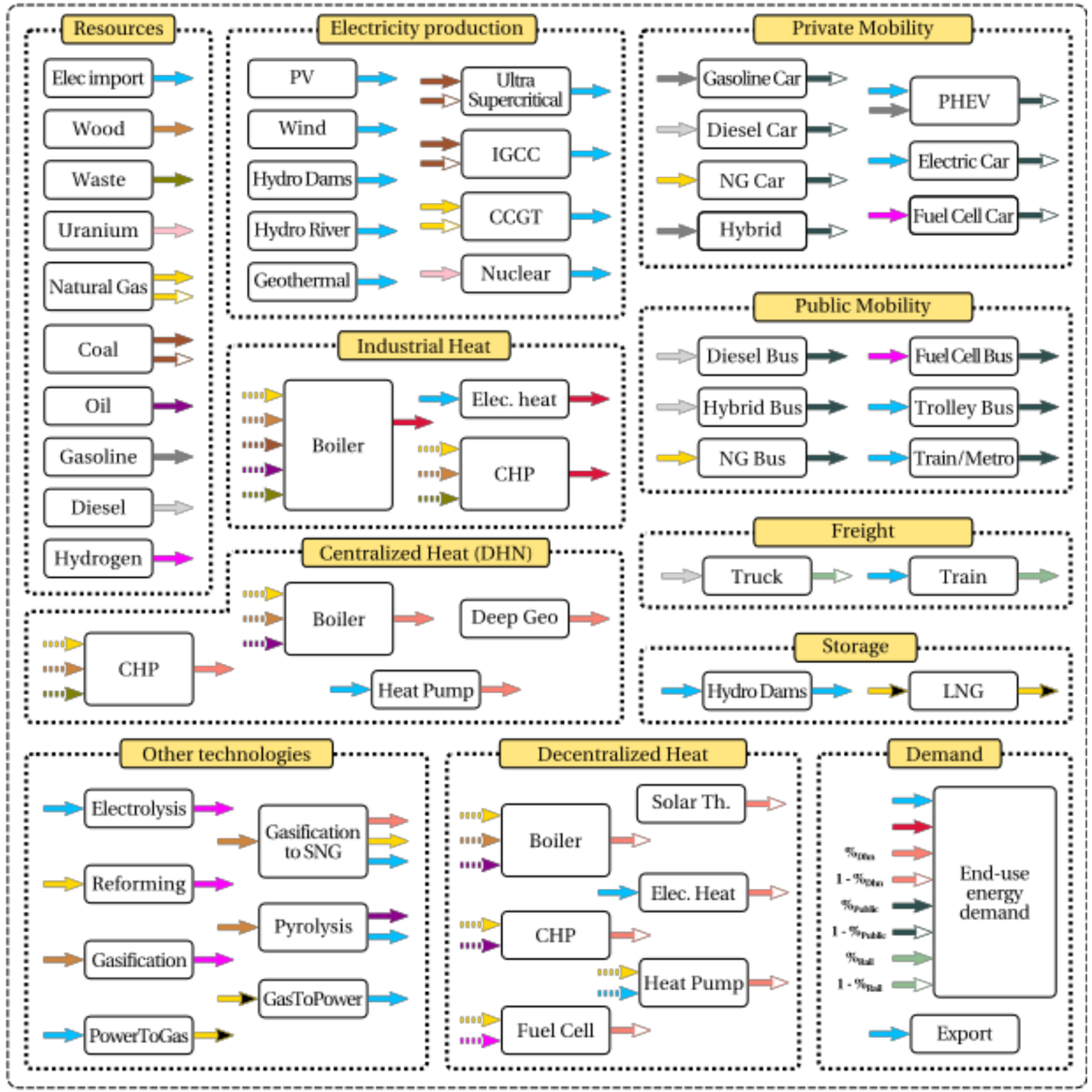
What is not energyscope

- Not Times-Markal
  - Transition is not modelled
  - Not economic equilibrium
  - Economic drivers are too uncertain
- Not energyplan
  - Seasonality is considered
  - Optimisation instead of rule based
  - Solution generator instead of simulation
- Fast Scenario generator

Energyscope

Sources:
[1] S. Moret, "Strategic energy planning under uncertainty", 2017

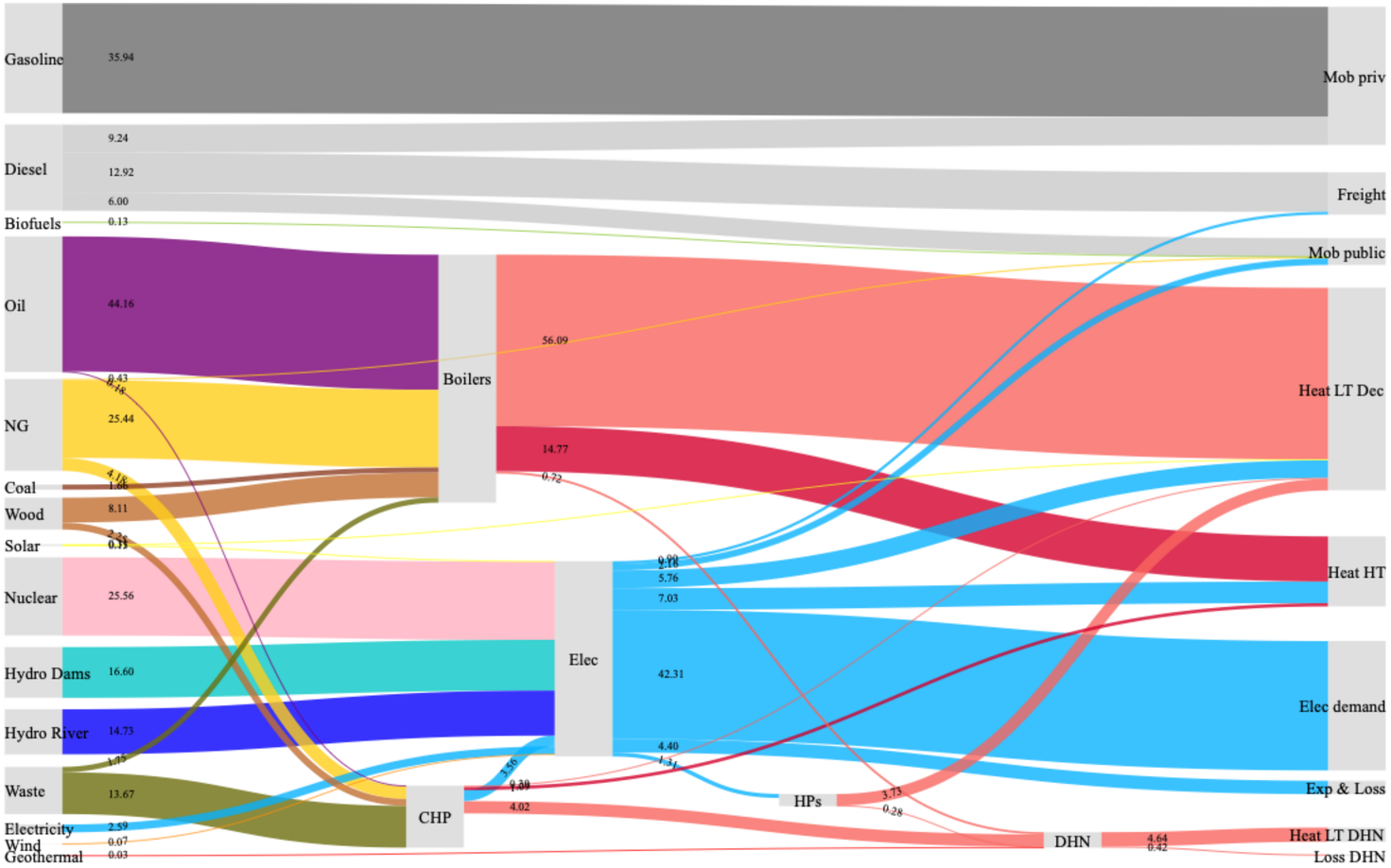
Application to Switzerland



- 20-year time horizon → 2050 as target year
- Additional constraints for CH
- Model complexity:
  - 1633 decision variables
  - 118 binaries
  - 56 integers
  - Solved in seconds

Sources:
[1] S. Moret, "Strategic energy planning under uncertainty", 2017

Model validation fitted with the SFOE data as reference



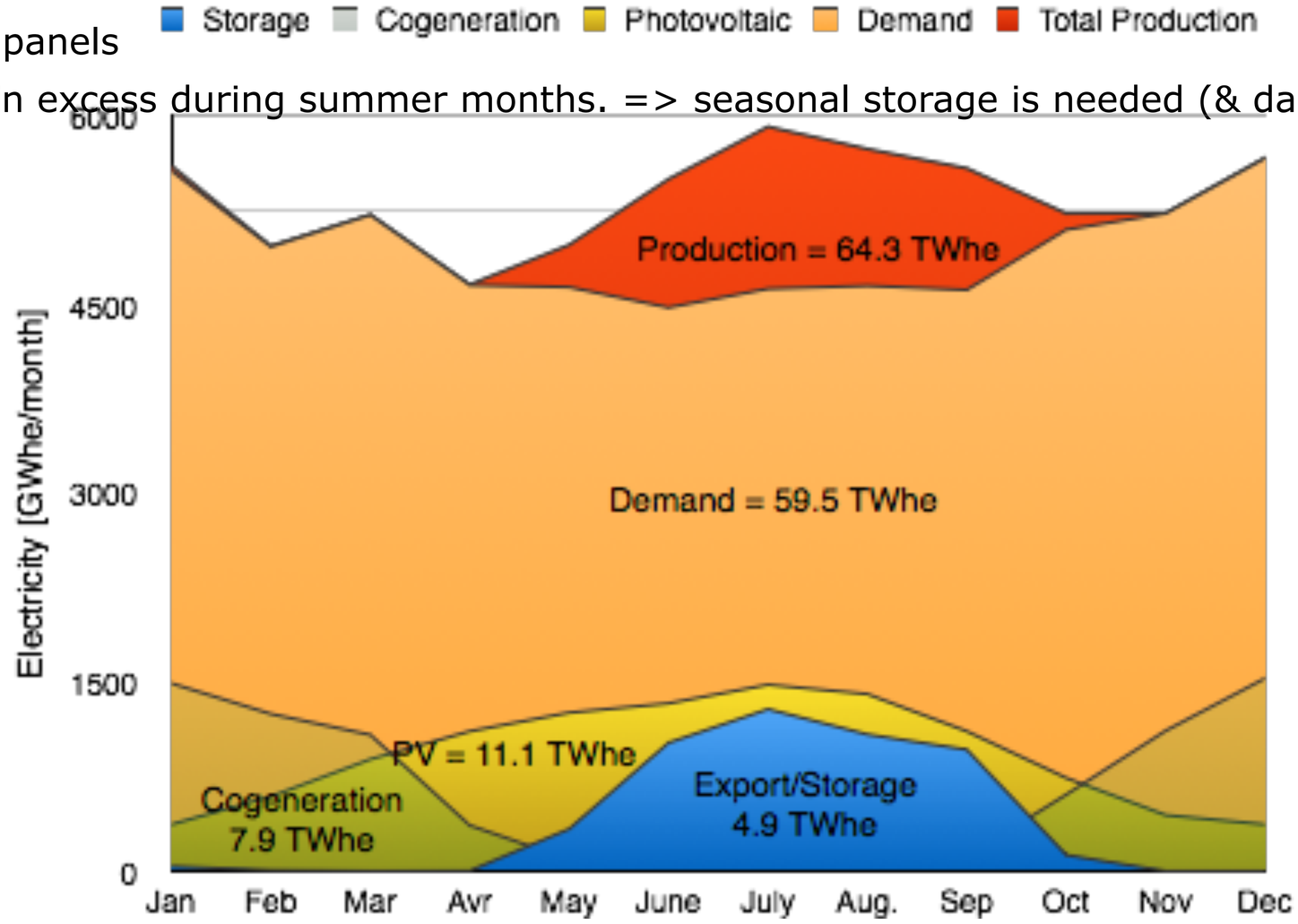
Model validation: Switzerland, year 2011

			Actual 2011	MILP	Δ	Units
Primary Energy Consumption		**Gasoline**	35.94	37.36	1.42	TWh
		Diesel	28.16	26.16	-2.00	TWh
		NG	30.05	28.40	-1.65	TWh
		Elec. imports	2.59	2.76	0.17	TWh
		Coal	1.66	1.43	-0.23	TWh
		Solar	0.46	0.48	0.02	TWh
		Geothermal	0.03	0.02	-0.01	TWh
		Waste	15.41	10.65	-4.76	TWh
		Oil	44.34	46.20	1.86	TWh
		Wood	10.36	9.32	-1.04	TWh
		Total	169.0	162.8	-6.21	TWh
Technologies Output		**Boilers**	71.59	72.53	0.94	TWh
		CHP	9.06	8.58	-0.48	TWh
		HPs	4.02	4.23	0.21	TWh
GHG emissions (fuels)			47.51[a]	46.92	-0.59	$MtCO_2$-eq.
Installed Technologies	**HPs**	**Installed units**	191.8	160.6	-31.2	kUnits
		Total	2.87	1.66	-1.21	GW_{th}
	CHP[b]	**Installed units**	41	51	10	Units
		Total	0.96	1.02	0.06	GW_{th}

[a] Total GHG emissions following the Kyoto protocol [84], removing the direct non-energy related emissions from industrial processes.
[b] Large CHP installation (> 1 MW). 2011 Data for HPs and CHP in [78]

Integrating in the energy system

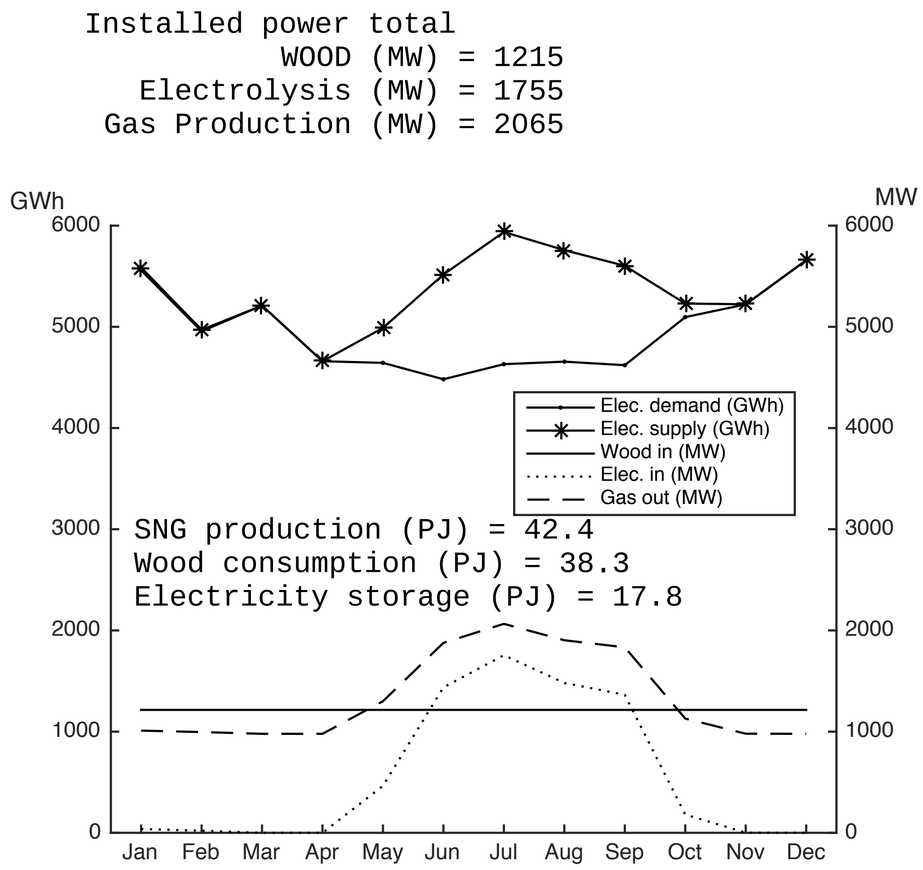
- Use of biomass to further decrease the CO2 emissions
- Deployment of PV panels
- 50% electricity is in excess during summer months. => seasonal storage is needed (& dams are not sufficient)



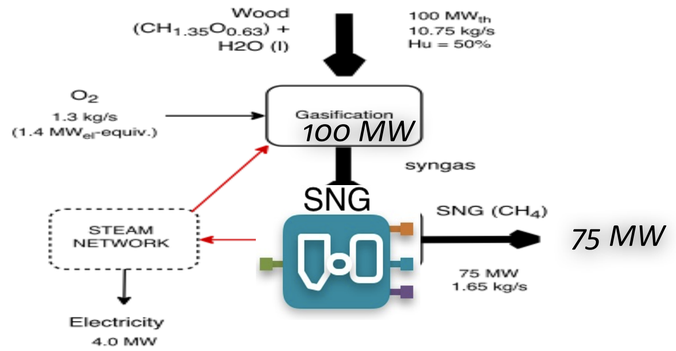
NEP scenario

Wood Biomass for Renewable Electricity Storage

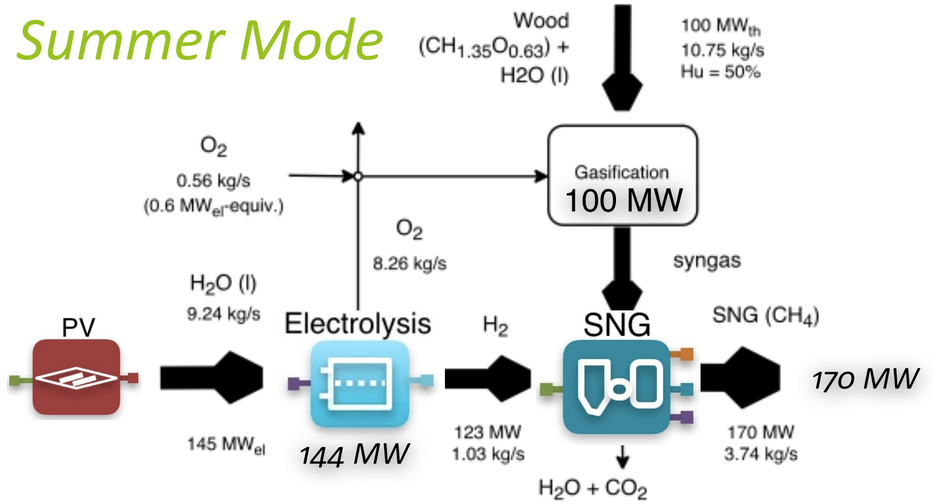
- BIO-SNG = operating 100%
- Power 2 gas takes the excess => new flexible system design



Winter Mode



Summer Mode

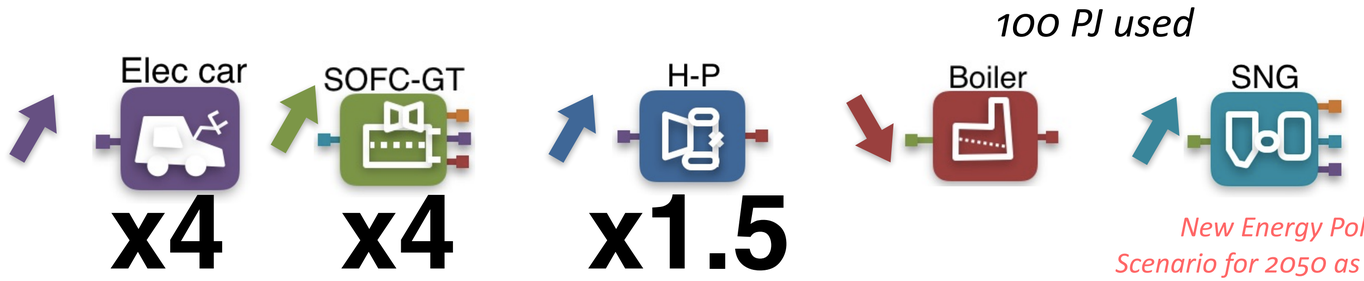


Codina Gironès, Víctor, et al. "On the assessment of the CO2 mitigation potential of woody biomass." *Frontiers in Energy Research* 5 (2018): 37.

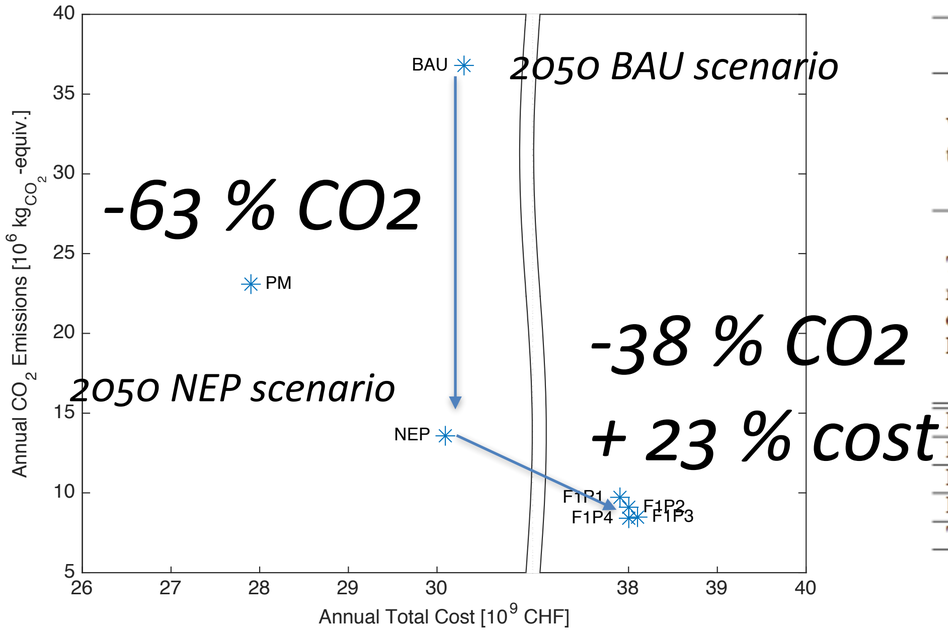
Wood Biomass for the energy transition

- Design of new energy scenarios.

  Minimizing energy dependency of Switzerland : i.e. minimise the CO2 emissions



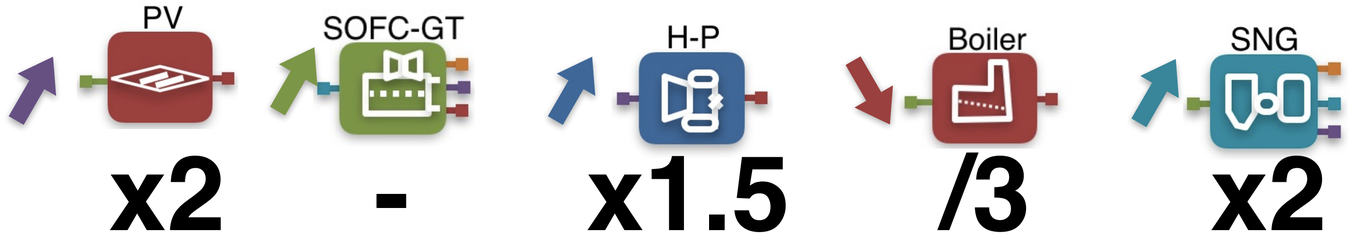
New Energy Policies
Scenario for 2050 as reference



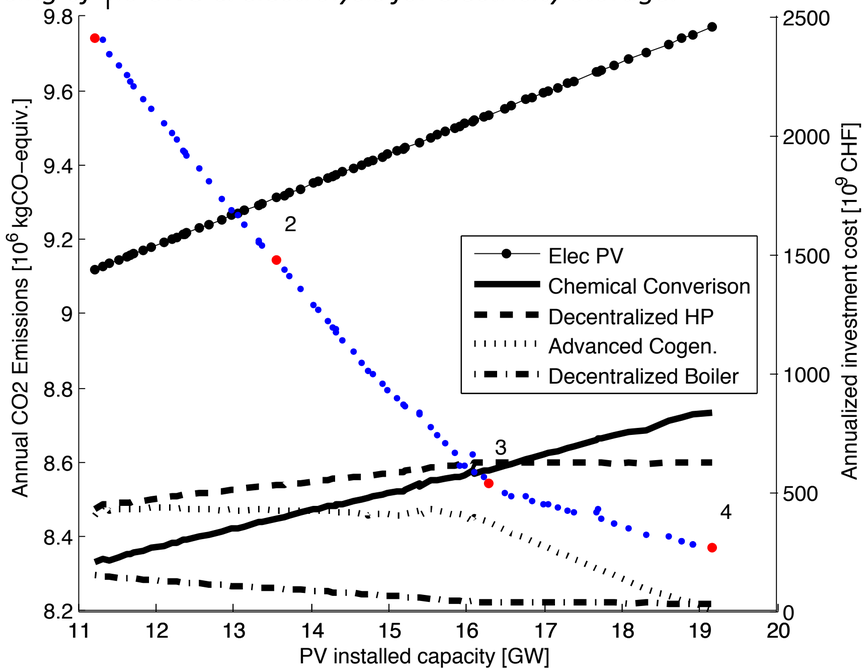
Input / Output data		NEP	F1P1	F1P2	F1P3	F1P4
Vehicle types	Battery electric vehicles	21.9	85.0	84.8	84.1	85.0
	Hybrid vehicles	15.3	15.0	15.0	15.3	12.2
	Natural gas vehicles	2.1	0.0	0.0	0.2	1.6
	Hydrogen vehicles	4.4	0.0	0.1	0.3	0.7
	Gasoline/Diesel vehicles	56.3	0.0	0.1	0.1	0.5
Technology mix for distributed heating [%]	Electric heat pump	18.7	27.6	33.2	39.4	39.3
	Thermal heat pump	0.0	0.0	0.0	0.0	0.0
	Cogeneration	7.7	7.7	7.7	7.7	7.7
	Advanced cogeneration	0.3	1.2	1.1	1.0	0.0
	Boiler	25.6	15.7	10.2	4.1	5.2
	Solar	46.1	46.1	46.1	46.1	46.1
	Electric heater	1.6	1.6	1.6	1.6	1.6
Installed capacity PV [GW]		11.21	11.21	13.55	16.28	19.16
Installed capacity SNG [GW_{WoodIn}]		0.00	0.37	0.70	1.07	1.50
Natural gas import [GWh]		16257	9671	5200	0	0
Equivalent CO_2 emissions [10^6 tonnes]		13.6	9.7	9.1	8.5	8.4
Total cost [10^9 CHF]		30.1	37.9	38.0	38.1	38.0

Wood Biomass for Renewable Electricity Storage

- Design of new energy scenarios. Goal:
  Minimizing energy dependency of Switzerland + Not allowing import and export of electricity.



- *Increasing PV installed capacity.*
- *Using of bio-SNG & electrolysis for electricity storage.*



100 PJ biomass used

Input / Output data		NEP	F1P1	F1P2	F1P3	F1P4
Vehicle types	Battery electric vehicles	21.9	85.0	84.8	84.1	85.0
	Hybrid vehicles	15.3	15.0	15.0	15.3	12.2
	Natural gas vehicles	2.1	0.0	0.0	0.2	1.6
	Hydrogen vehicles	4.4	0.0	0.1	0.3	0.7
	Gasoline/Diesel vehicles	56.3	0.0	0.1	0.1	0.5
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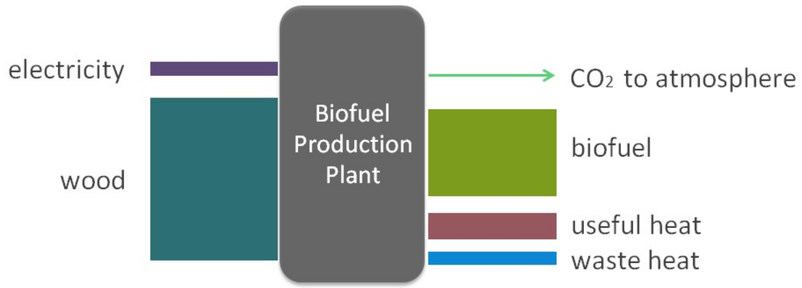
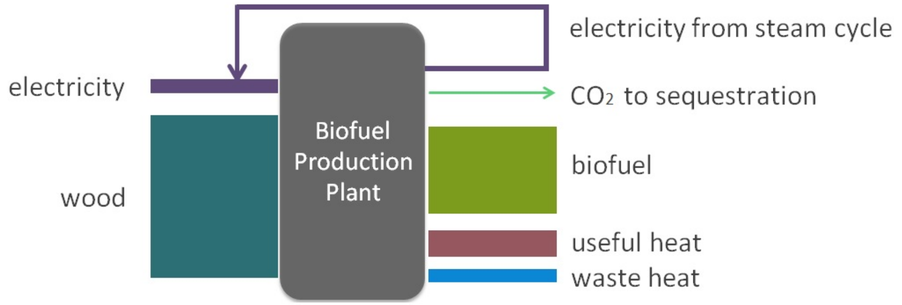
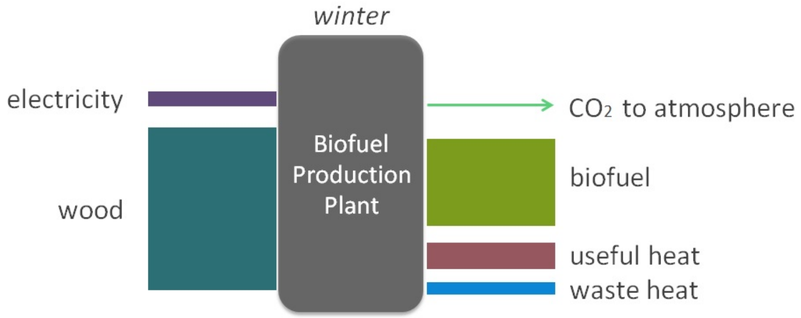
Power2gas perpsectives

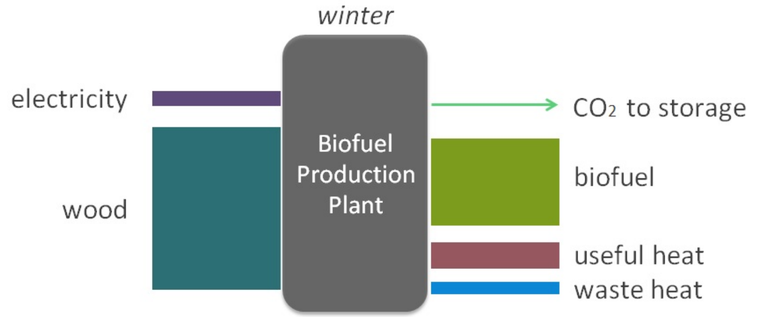


(a) I

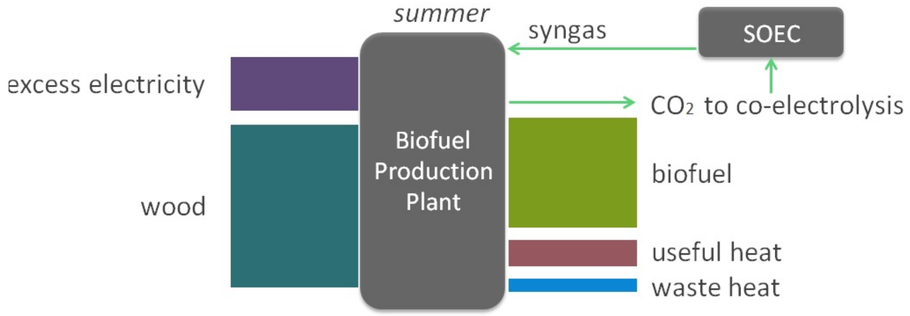


(b) II

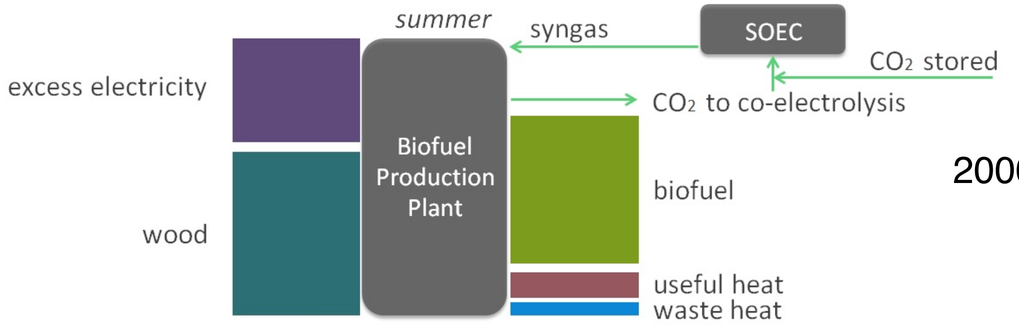




6700 h/year



(c) III



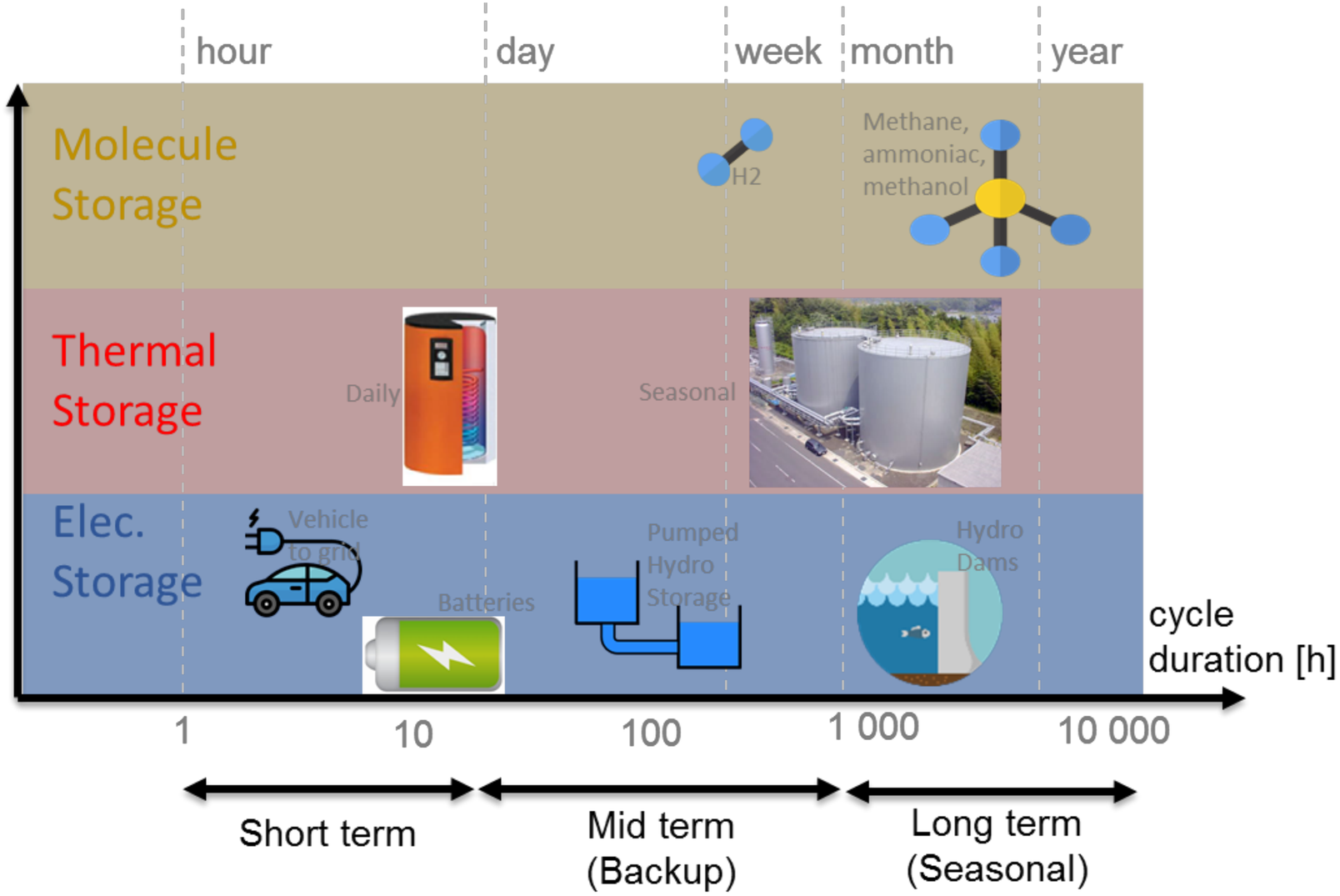
2000 h/year

(d) IV

Storing renewable electricity : Power to X

Energyscope & Energy storage : competing options

Application to Switzerland: JASM project

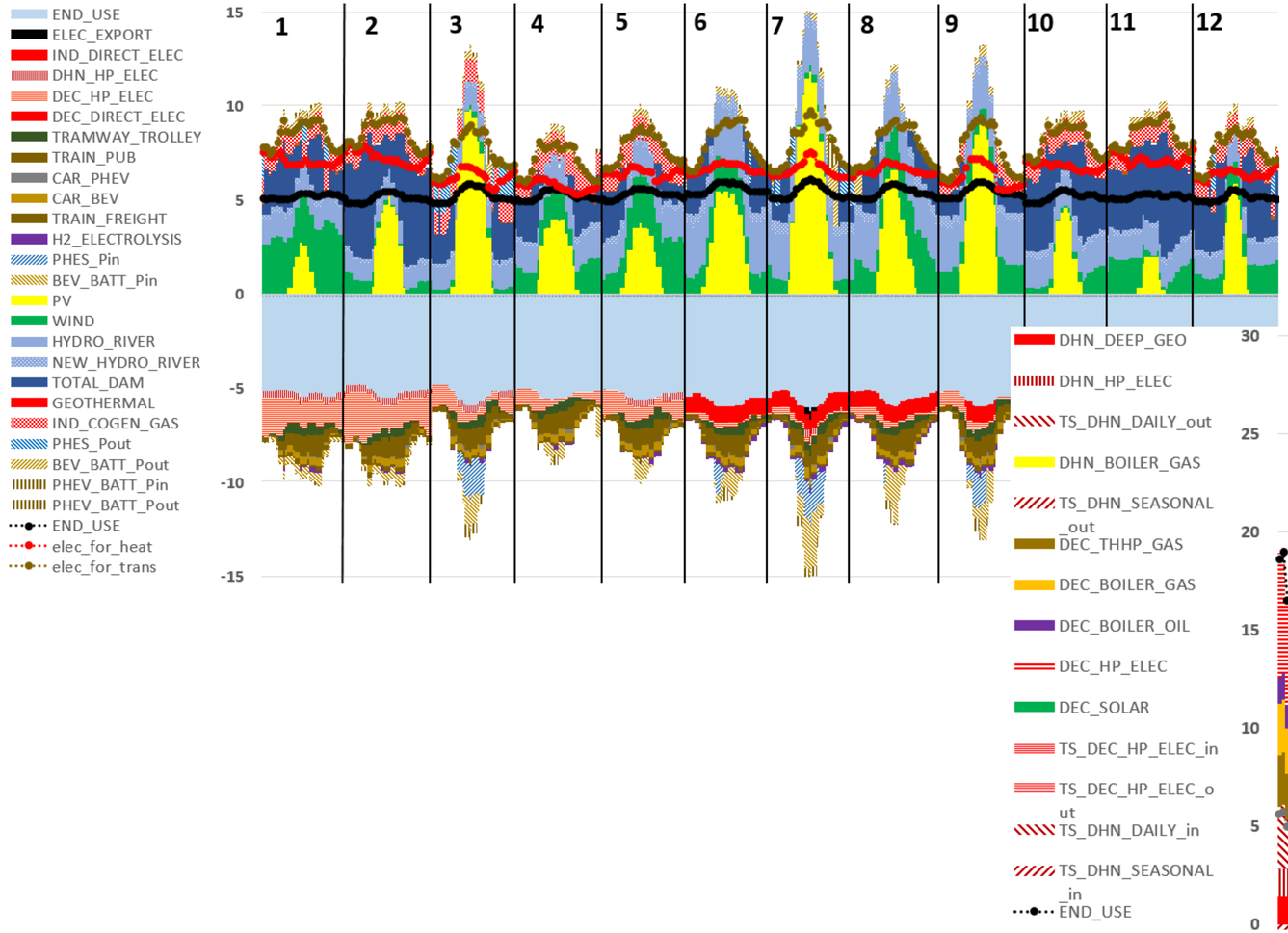


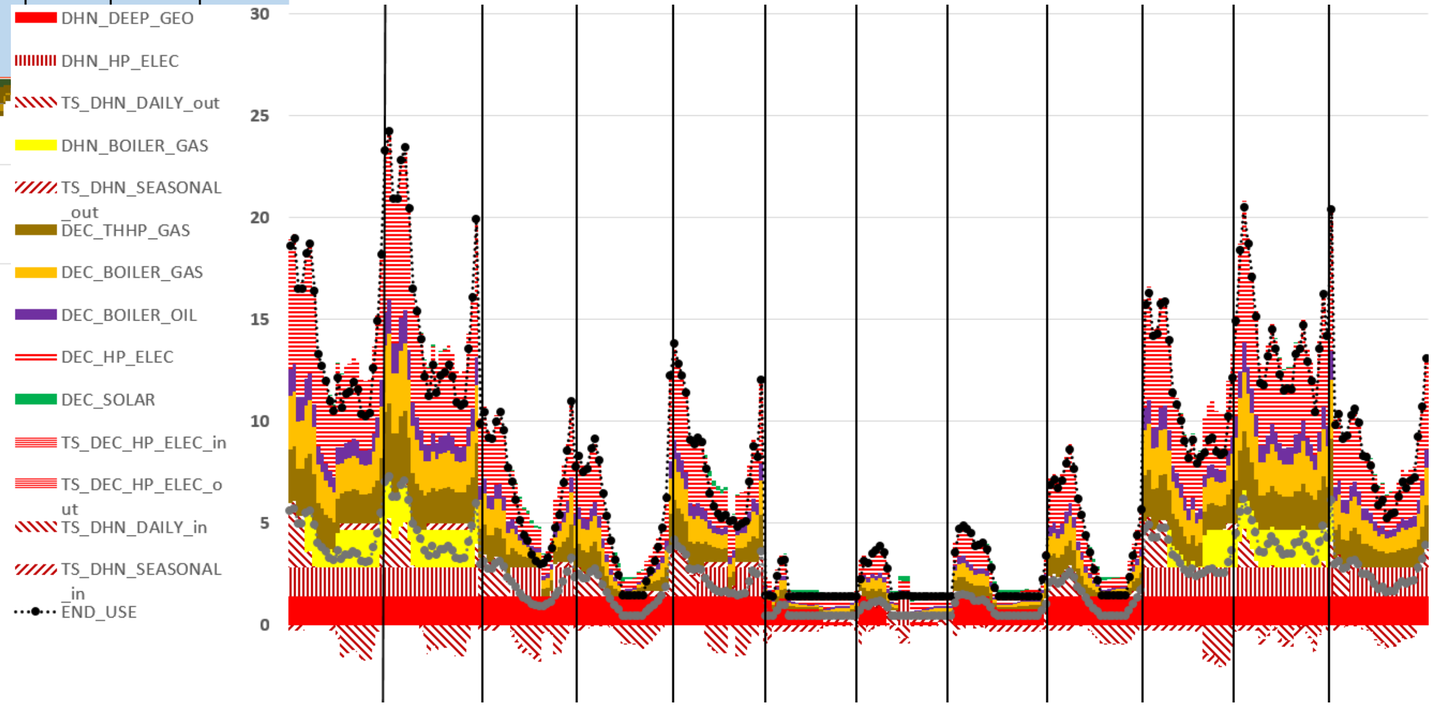
Energyscope

Sources:
[1] G. Limpens et al, in preparation

Typical days version when hourly resolution needed

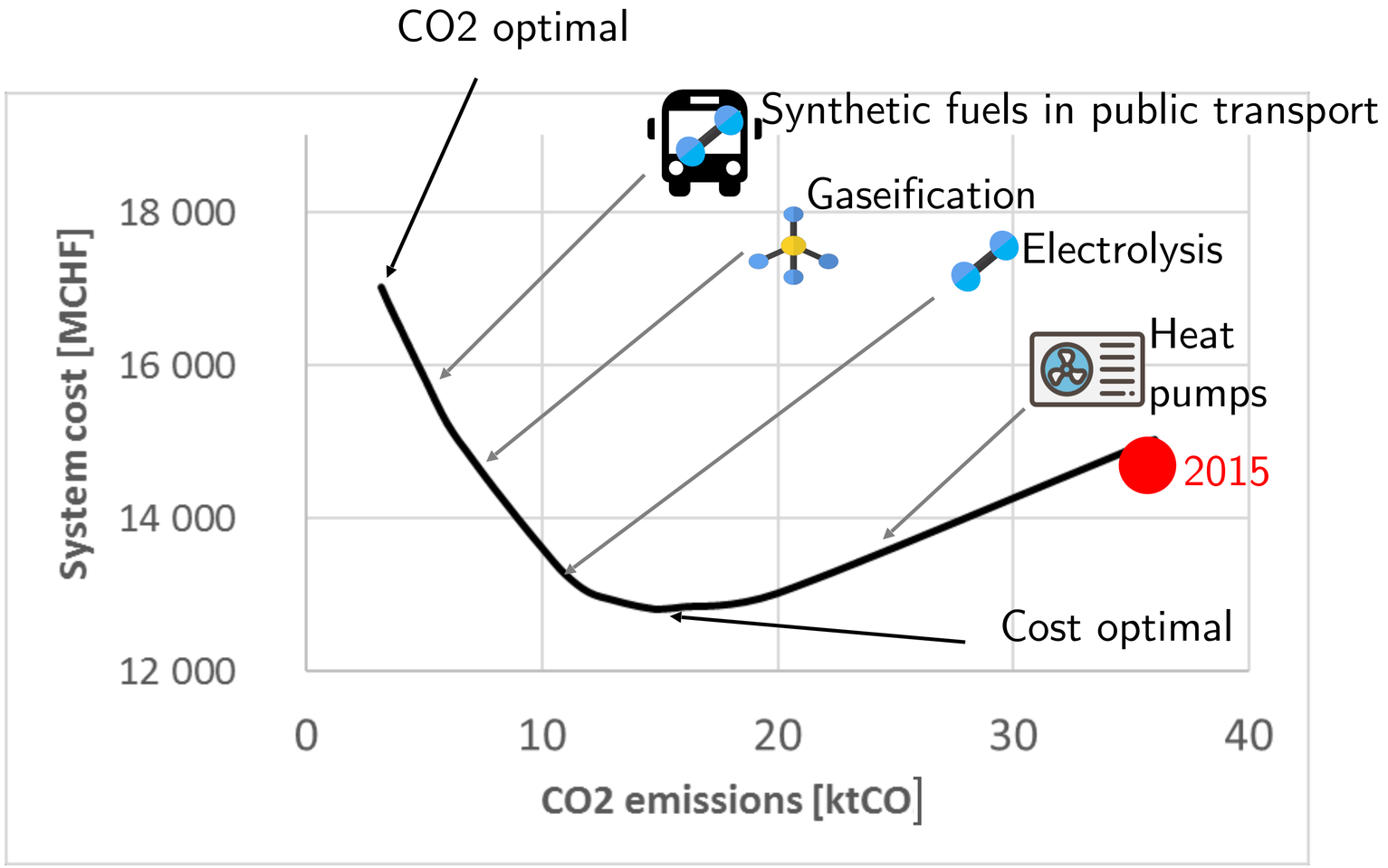
Latest developments: hourly resolution, storage (daily & seasonal, thermal & electrical), electric mobility (V2G)





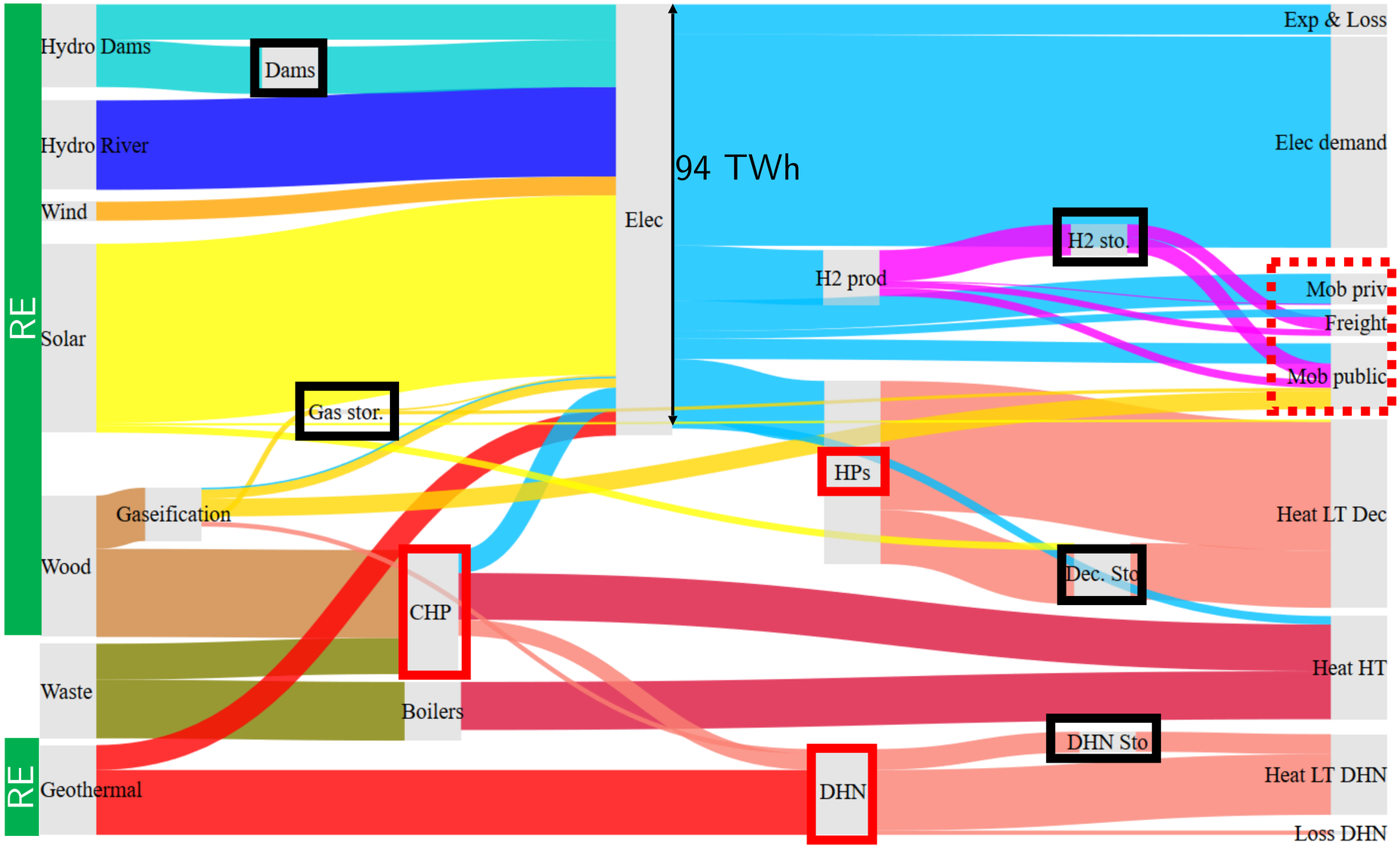
Energyscope

Application to Switzerland: JASM project



Energyscope

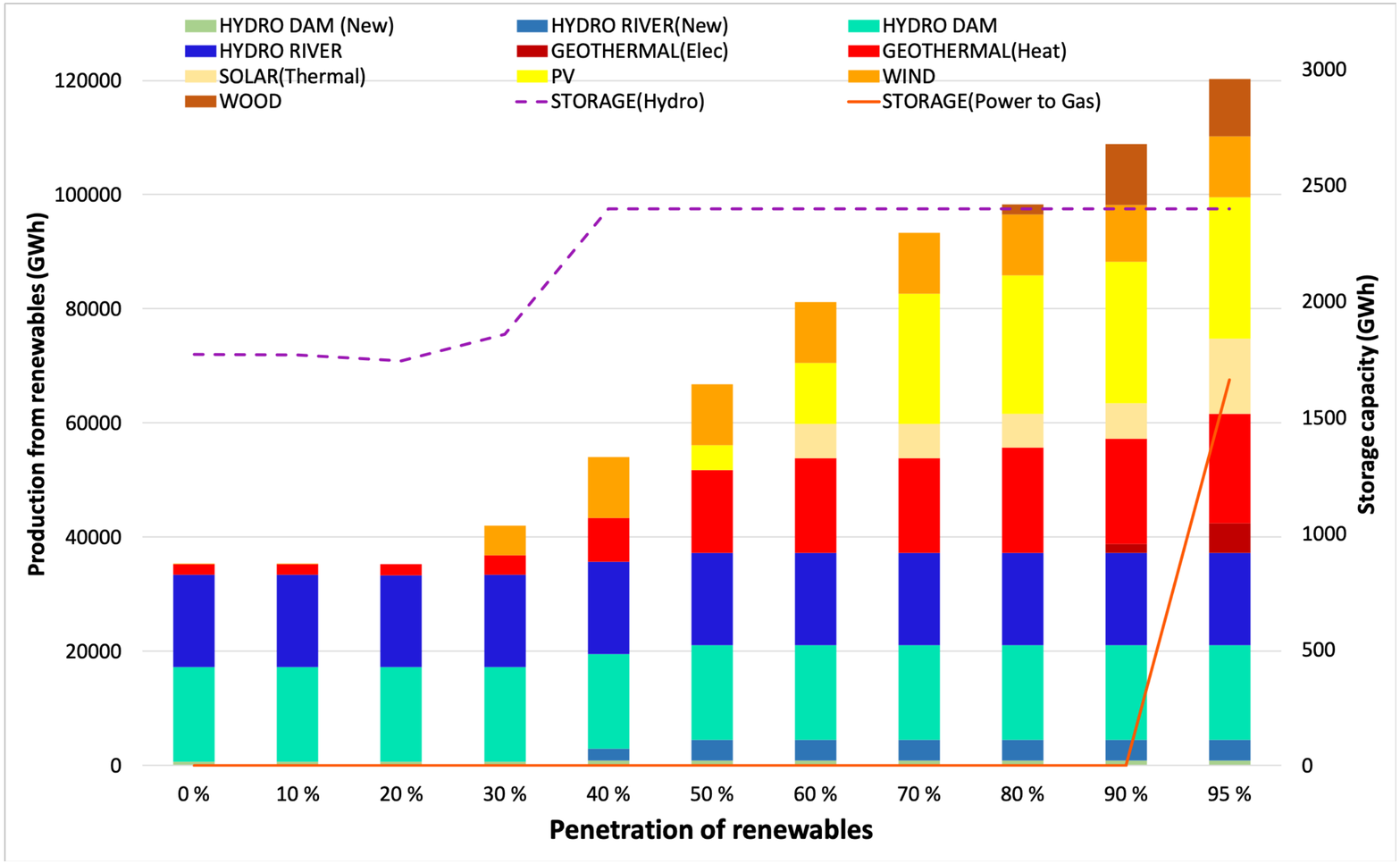
Application to Switzerland: JASM project towards low CO2 emissions Switzerland



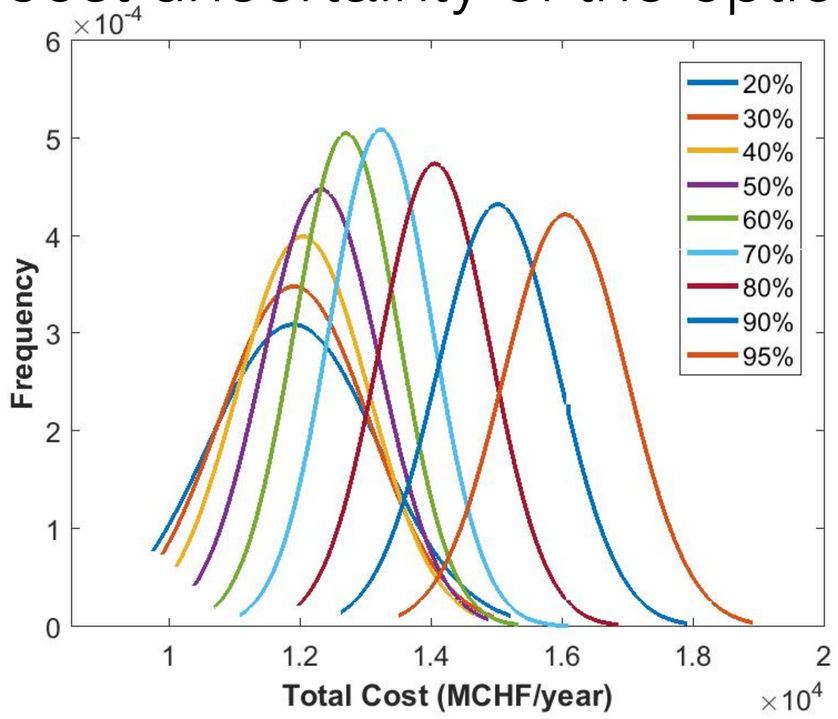
Energyscope

Sources:
[1] Xiang Li et al, in preparation

CO2 emissions reduction

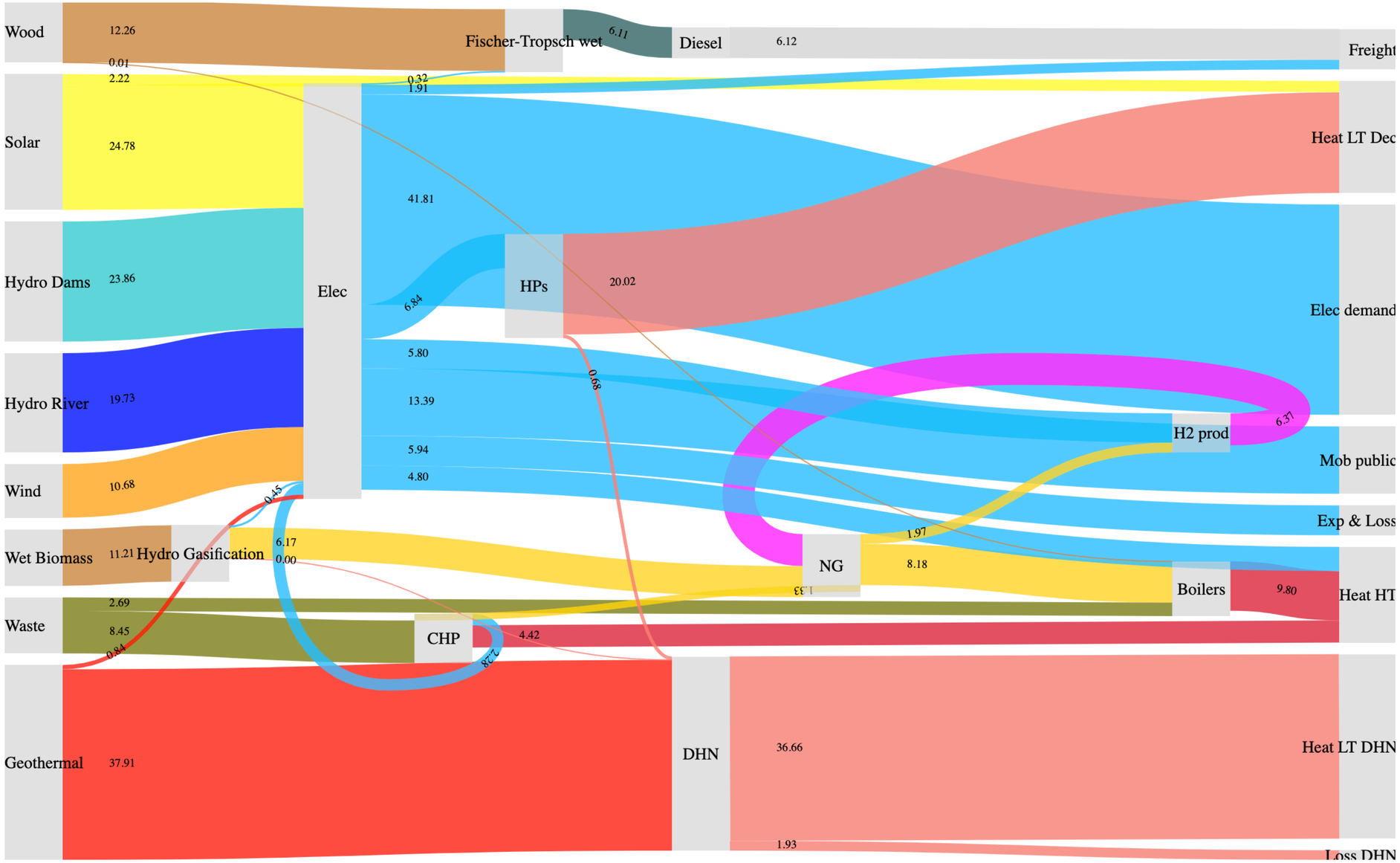


cost uncertainty of the options



Generating different options

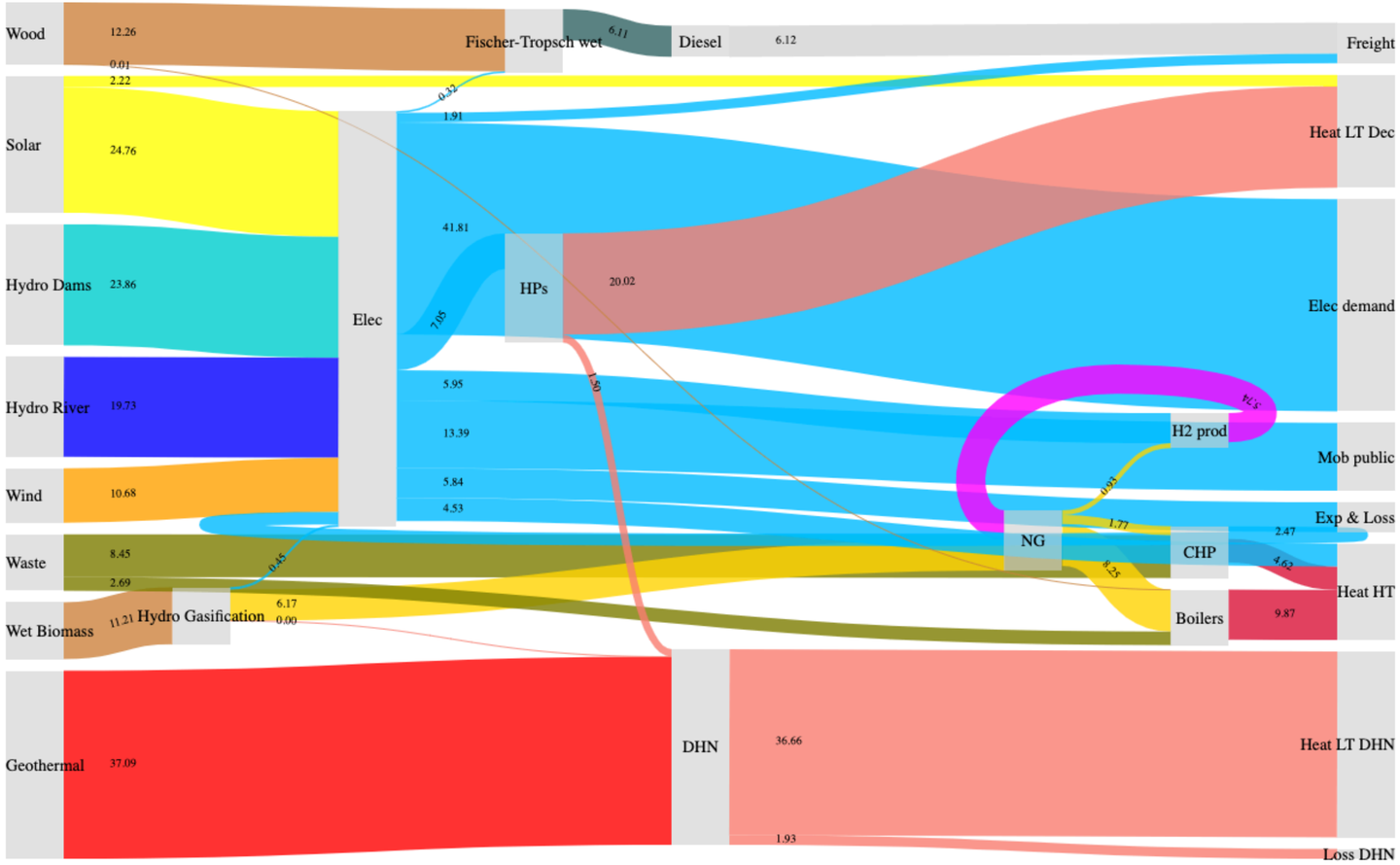
Different assumptions leads to different solutions



Electrical mobility

6000 GWh Hydro storage storage
4 kt CO2/year

Power2gas energyscope vision



Conclusions

- EnergySCOPE is a solution generator
  - allows to show competing/synergetic/enabling options
  - allows to test assumptions

Swiss Energyscope

Developped by IPESE, EPFL, Switzerland

Author: François Maréchal, Michel Lopez and Xiang Li

Input Parameters

Wood

10,000 — 15,000

10,000 10,500 11,000 11,500 12,000 12,500 13,000 13,500 14,000 14,500 15,000

Wet_Biomass

10,000 — 13,000

10,000 10,300 10,600 10,900 11,200 11,500 11,800 12,100 12,400 12,700 13,000

Dry_Wood

0 — 1,000

0 100 200 300 400 500 600 700 800 900 1,000

Gasoline

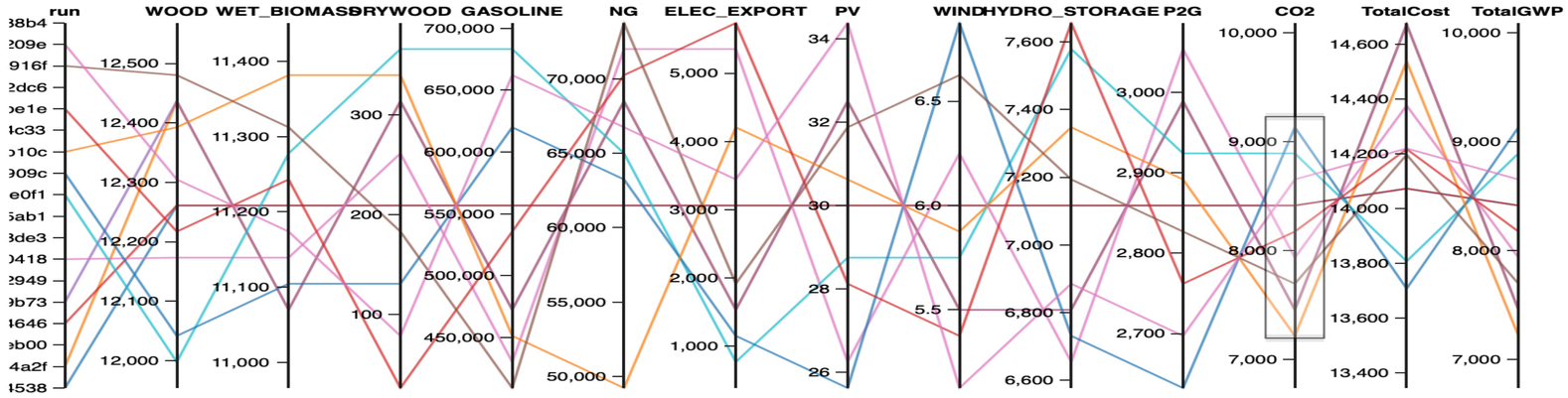
0 — 1,000,000

0 100,000 200,000 400,000 600,000 800,000 1,000,000

NG

0 — 100,000

Optimization Results



Select Run Result

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