IPESE
Industrial Process and Energy Systems Engineering

EPFL

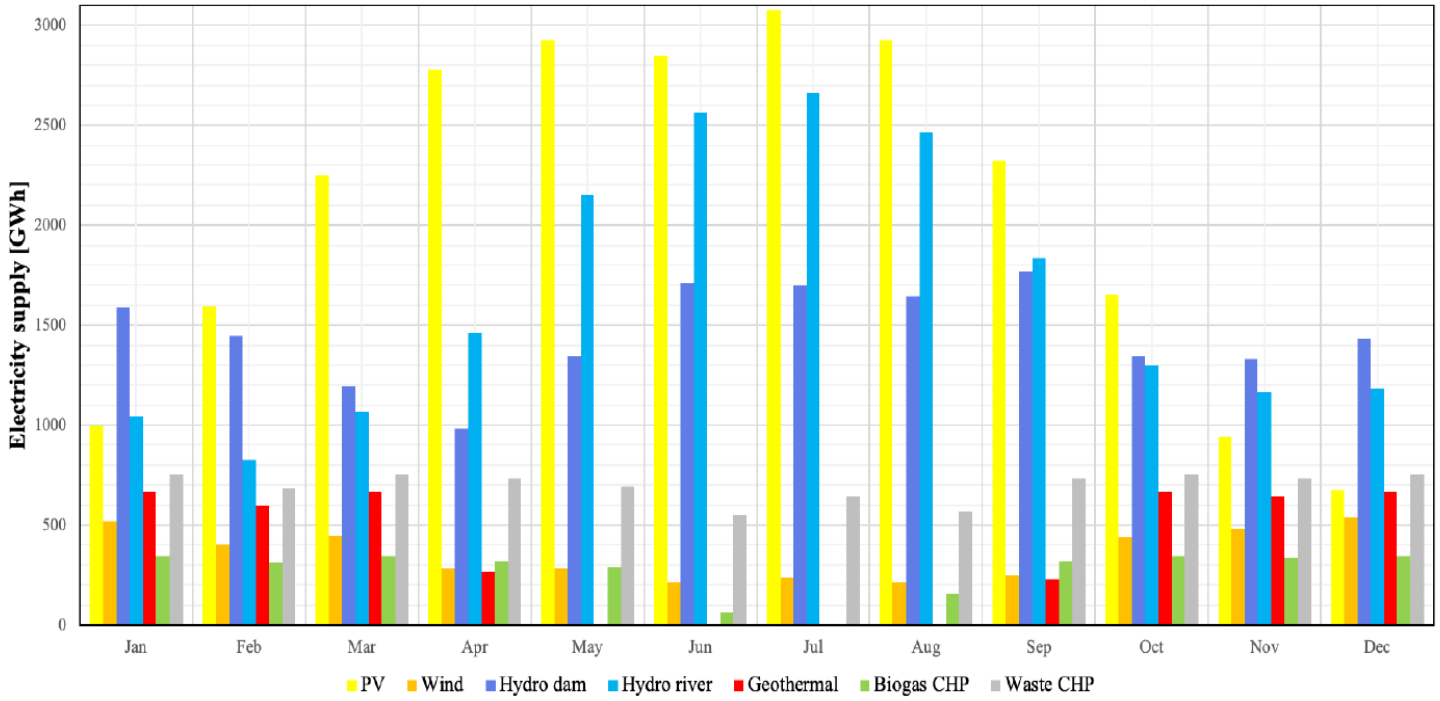
The Role of Biomass in the Swiss Energy Transition

Dr. Theodoros Damartzis

Doctoral School, 12 November 2020

Example – Net Zero Emissions Scenario

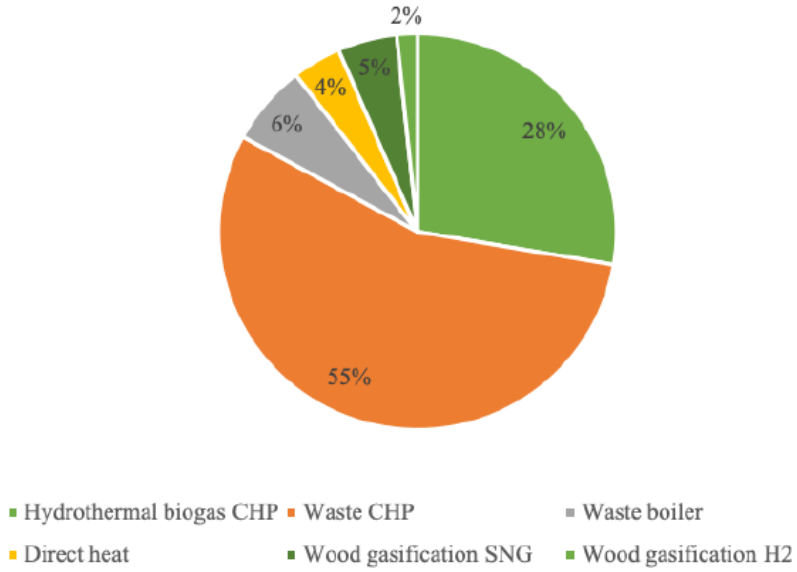
Monthly electricity supply by technology



However, depending on the input values and assumptions (subject to uncertainty), multiple "optimal" solutions can be identified!

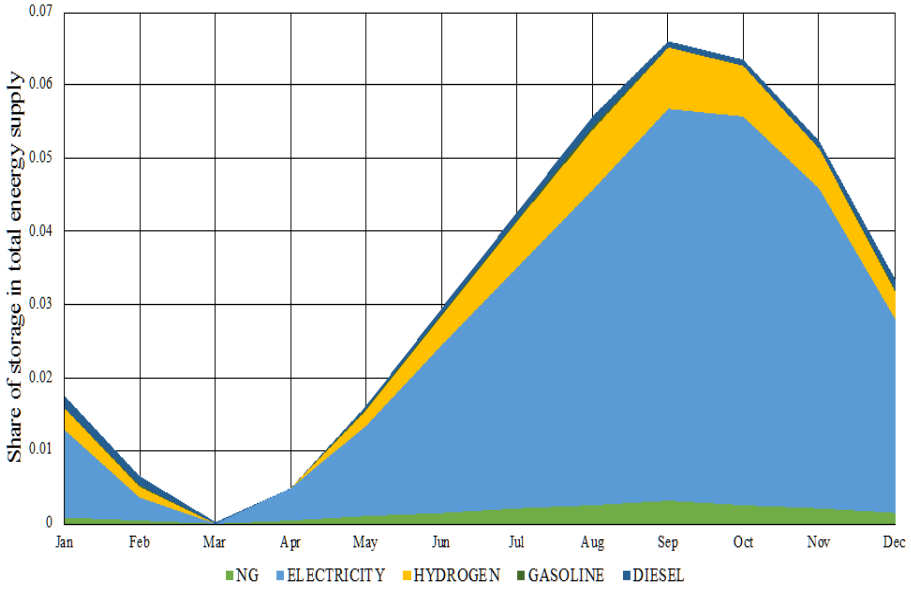
The model is run using all available data to minimize the total system cost, under the constraint of ***net zero CO_2 emissions.***

Process heat supply



Energy storage and monthly carbon flows

Share of energy storage in total energy supply

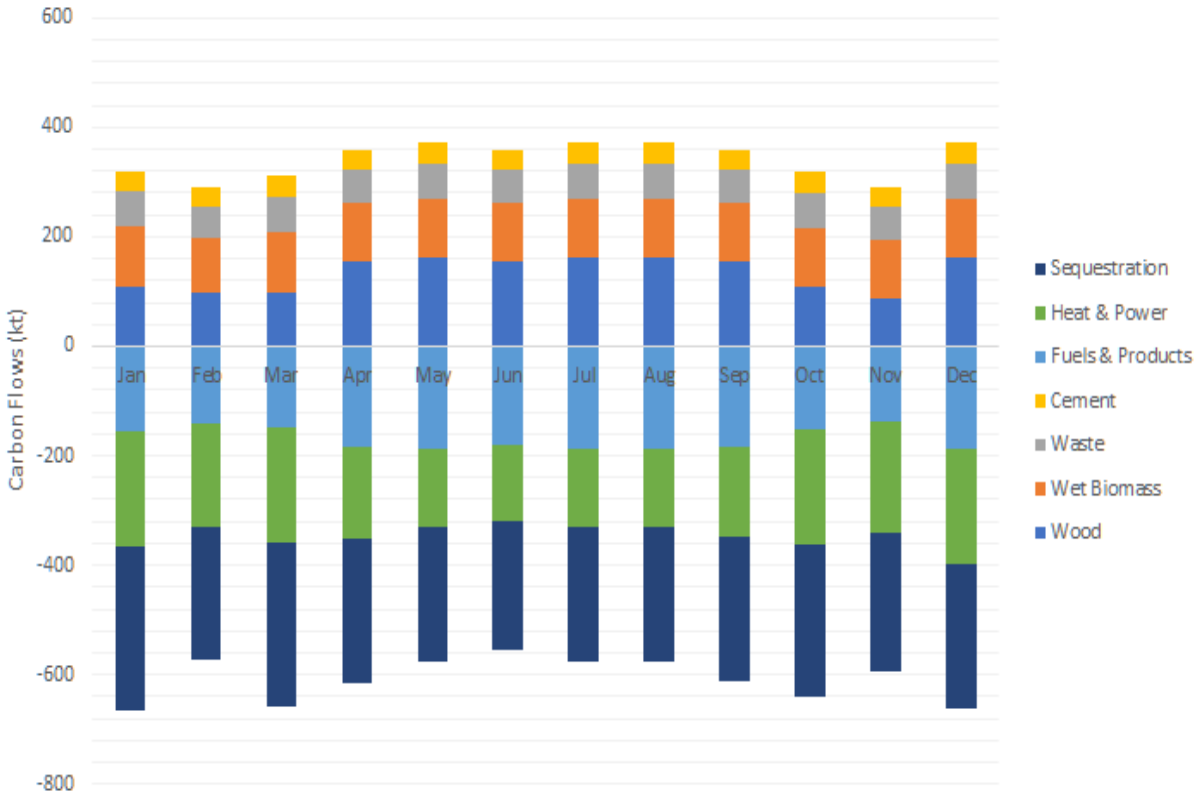


Competition of Power to X (PtX) with:

- hydro power dams (electricity storage)
- CO_2 sequestration (decarbonization)
- hydrogen (seasonal storage)

X. Li, Th. Damartzis, F. Maréchal, "Decarbonization of the Swiss energy system in 2050: Integrated scenario analysis", *SCCER JAS&M Report, 2020.*

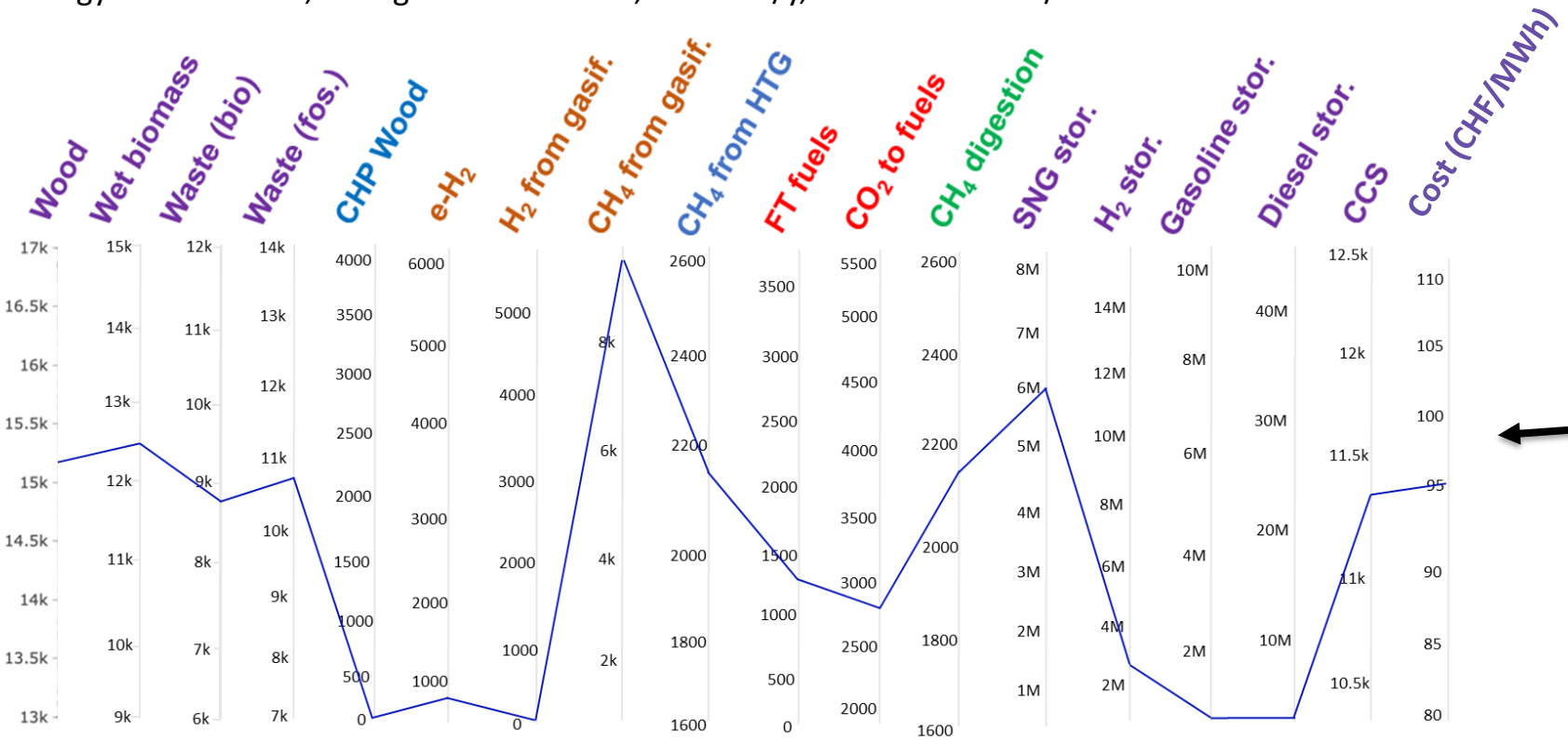
Monthly input and output carbon flows



CO_2 sequestration holds a large share in the system's carbon flows

Solution Representation – Parallel Coordinates

Energy flows in GWh, storage volumes in m^3, CCS in kt/y, total cost in CHF/MWh.



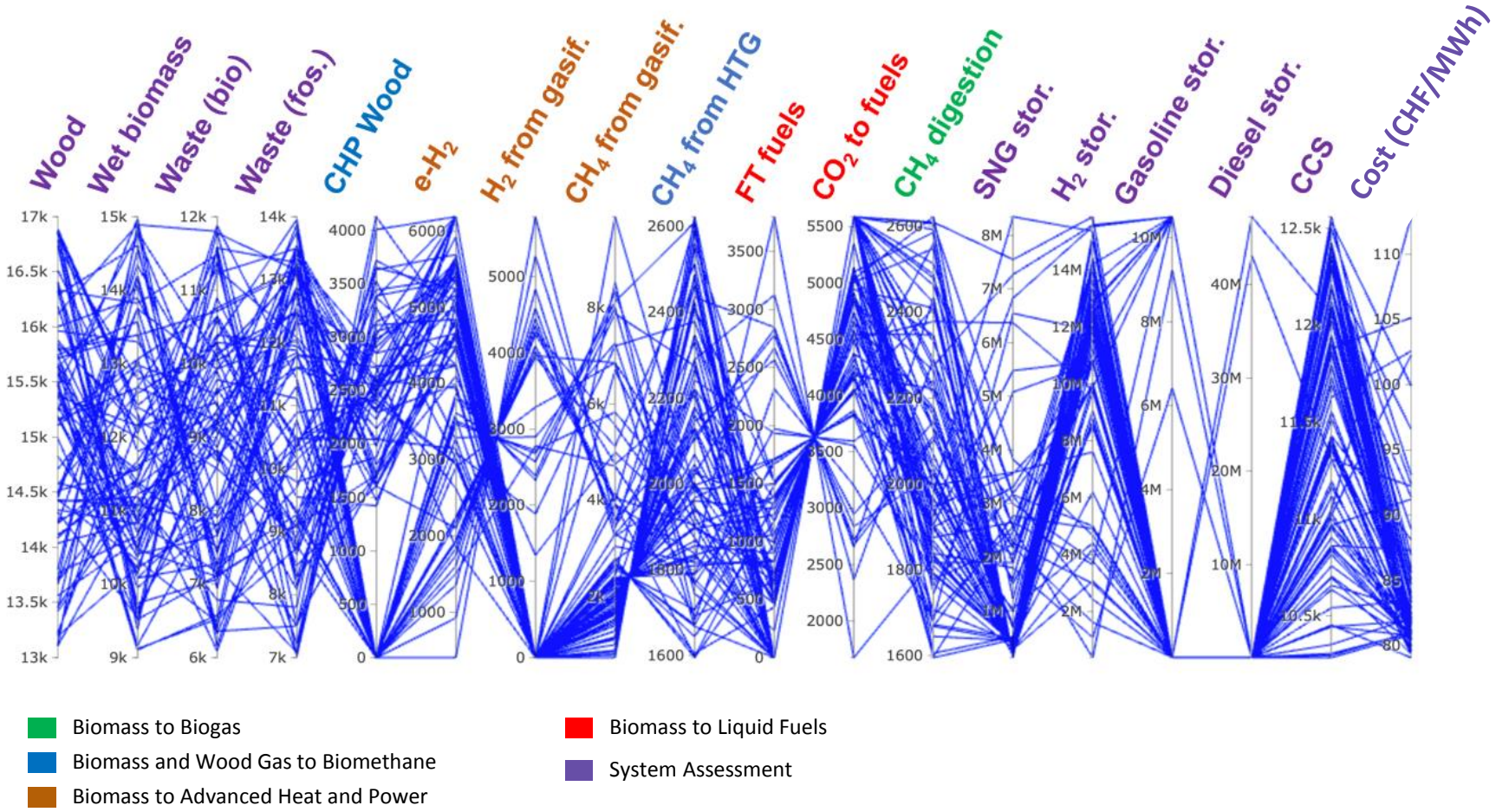
Biomass to Biogas
Biomass and Wood Gas to Biomethane
Biomass to Advanced Heat and Power
Biomass to Liquid Fuels
System Assessment

Identification of uncertainty parameters and range (e.g. biomass potentials, process costs etc.)

Use of Sobol sequences to explore the entire solution space

Solution Representation – Parallel Coordinates

Energy flows in GWh, storage volumes in m^3, CCS in kt/y, total cost in CHF/MWh.



- Biomass to Biogas
- Biomass and Wood Gas to Biomethane
- Biomass to Advanced Heat and Power
- Biomass to Liquid Fuels
- System Assessment

Total System Costs

79 - 112

CHF/MWh

~

1570 - 2250

CHF/y/cap

~

82 - 117 %

of today's energy system

CO_2 Sequestrated

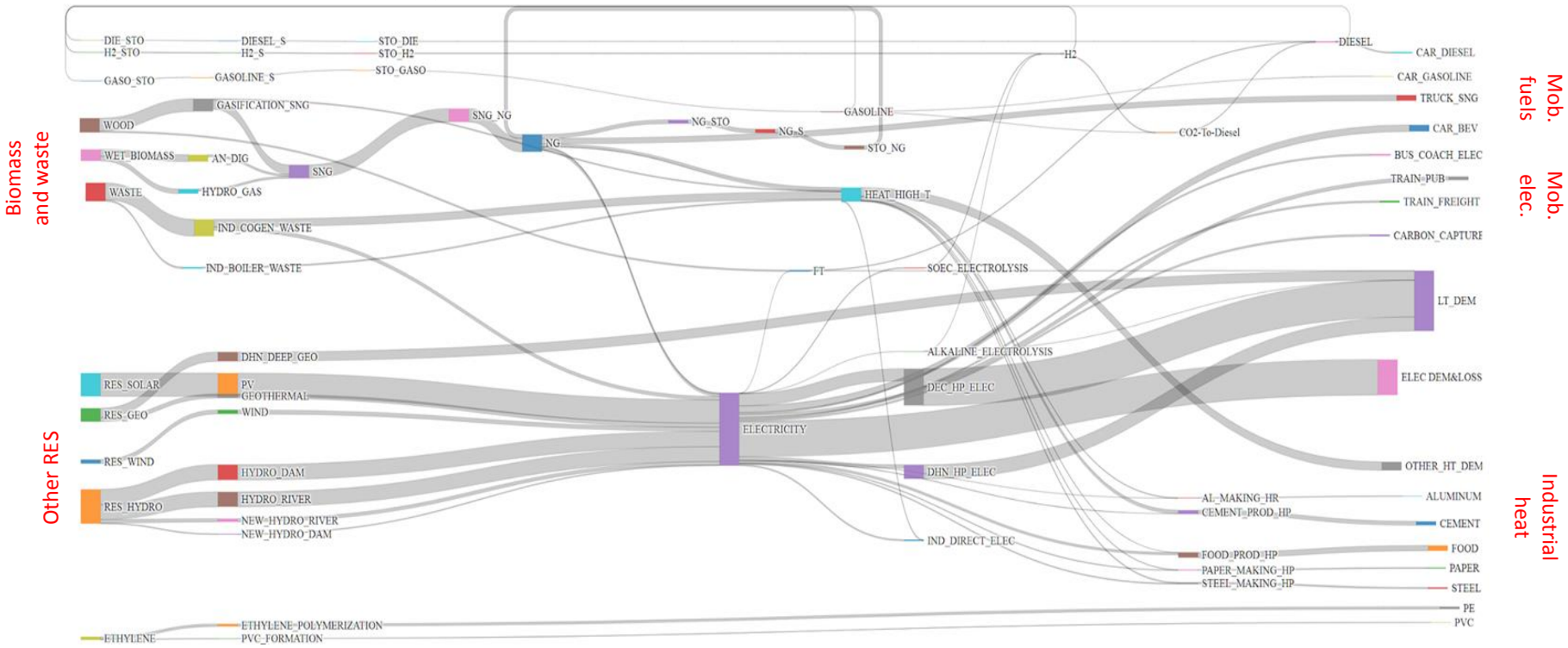
1.05 – 1.26

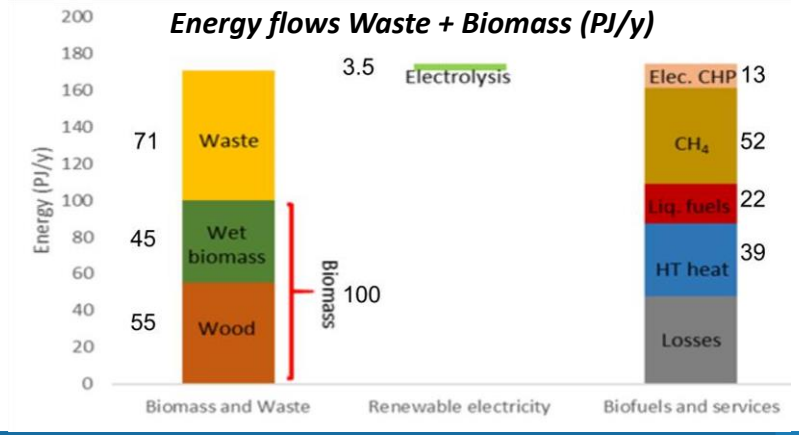
t/y/cap

Li, X., Damartzis, T., Stadler, Z., Moret, S., Meier, B., Friedl, M., & Maréchal, F. (2020). Decarbonization in complex energy systems: a study on the feasibility of carbon neutrality for Switzerland in 2050. *Frontiers in Energy Research*, *8*, 274.

Net Zero Emissions Scenario – Energy Flows

Example: Net zero emissions system without bio jet fuels





Other Renewables

Hydro : 133 PJ/y

Wind : 16 PJ/y

Geothermal : 16 PJ/y

PV : 90 PJ/y

Total : 255 PJ/y

Total system cost **: 16.10 bCHF/y**

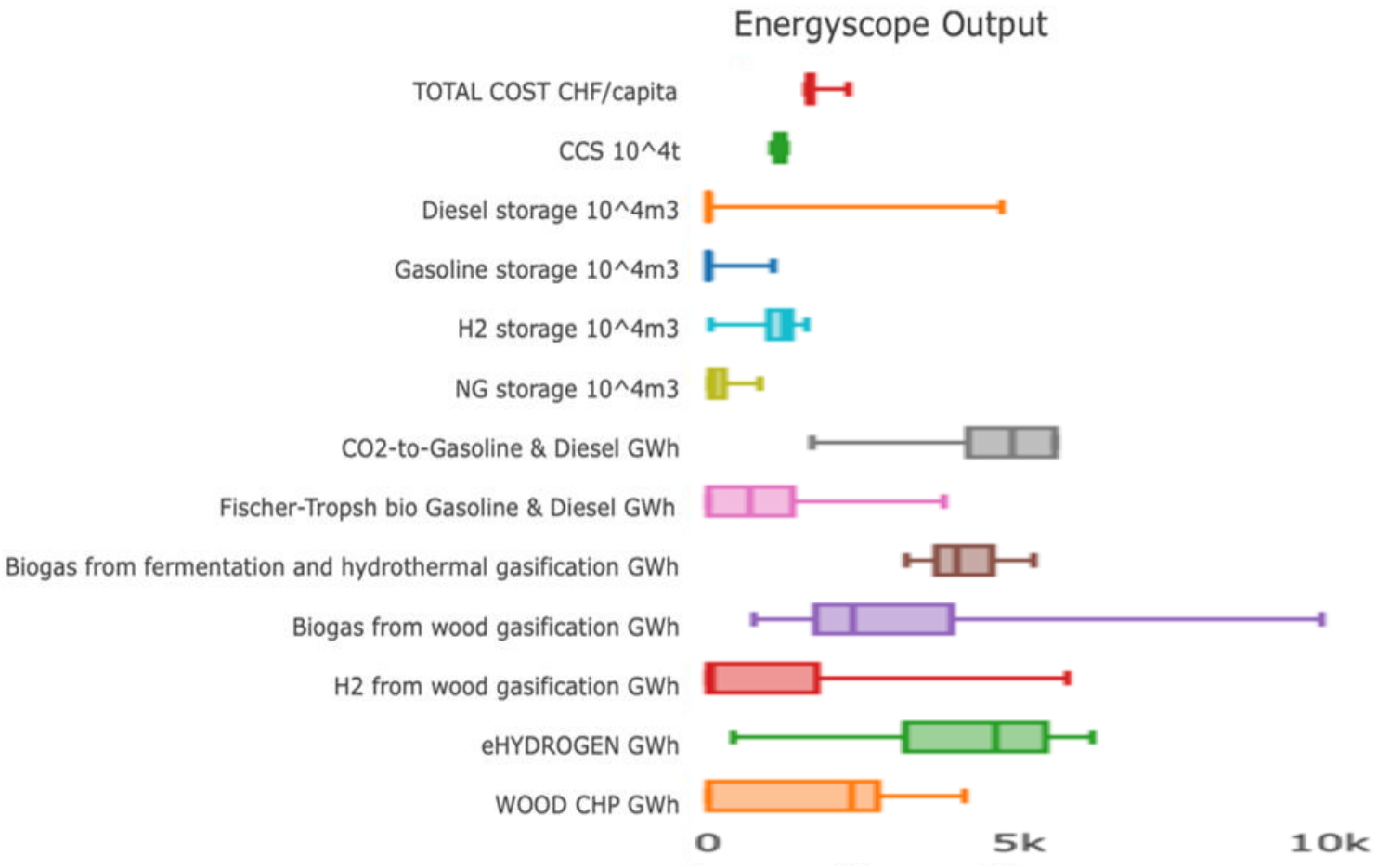
~ 1610 CHF/y/cap

CO_2 sequestrated **: 11.3 Mt/y**

~ 1.1 t/y/cap

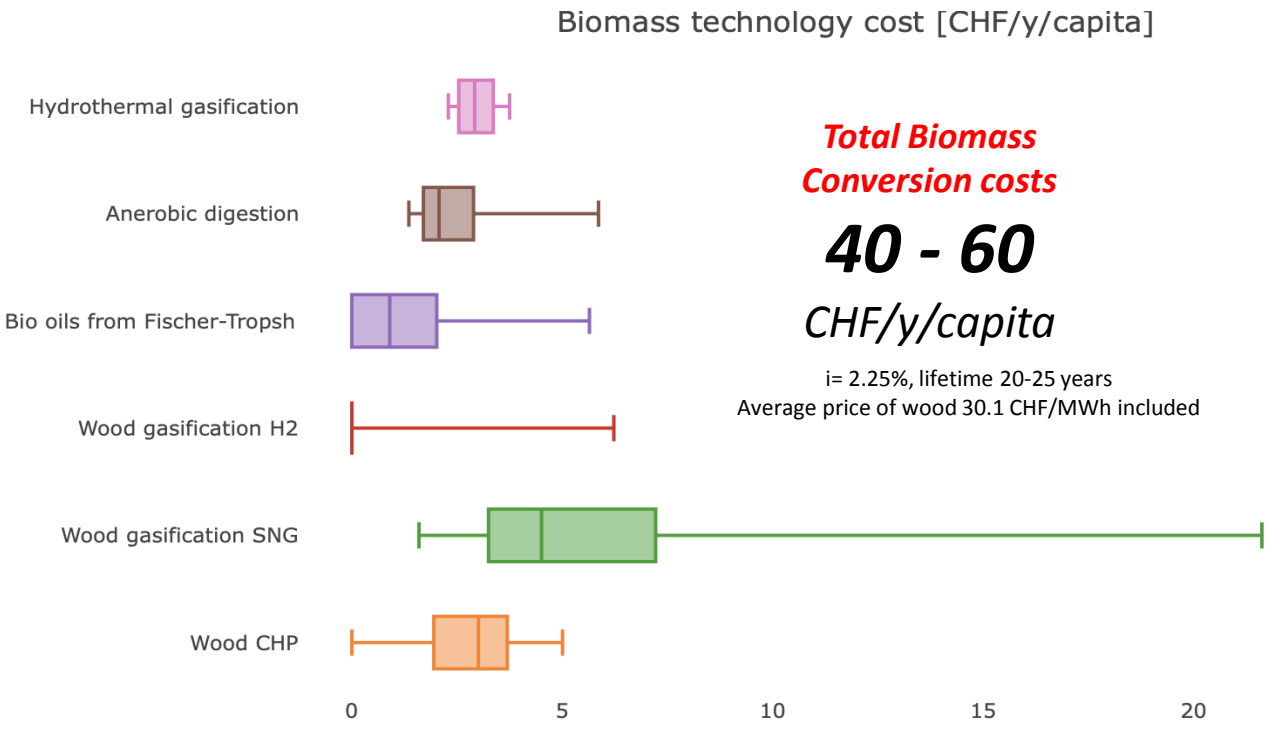
Utilization of Biomass Conversion Technologies

Utilization Range of Biomass Technologies



Cost of Biomass Conversion Technologies

Cost Range of Biomass Technologies (resource conversion to fuels)



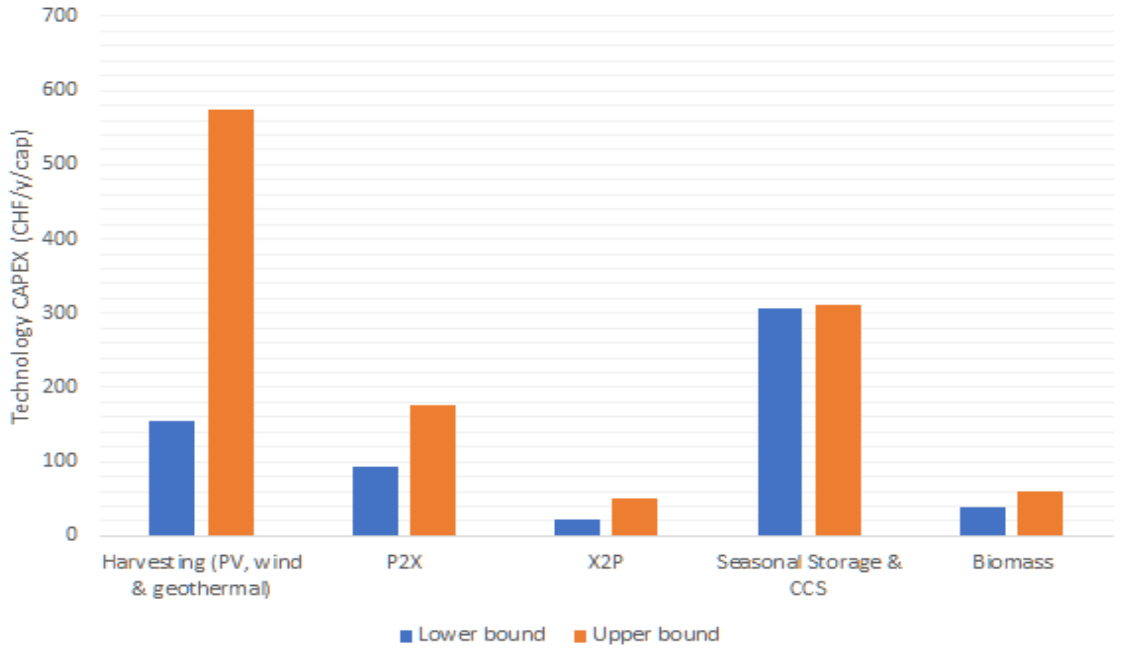
Total Biomass Conversion costs

40 - 60

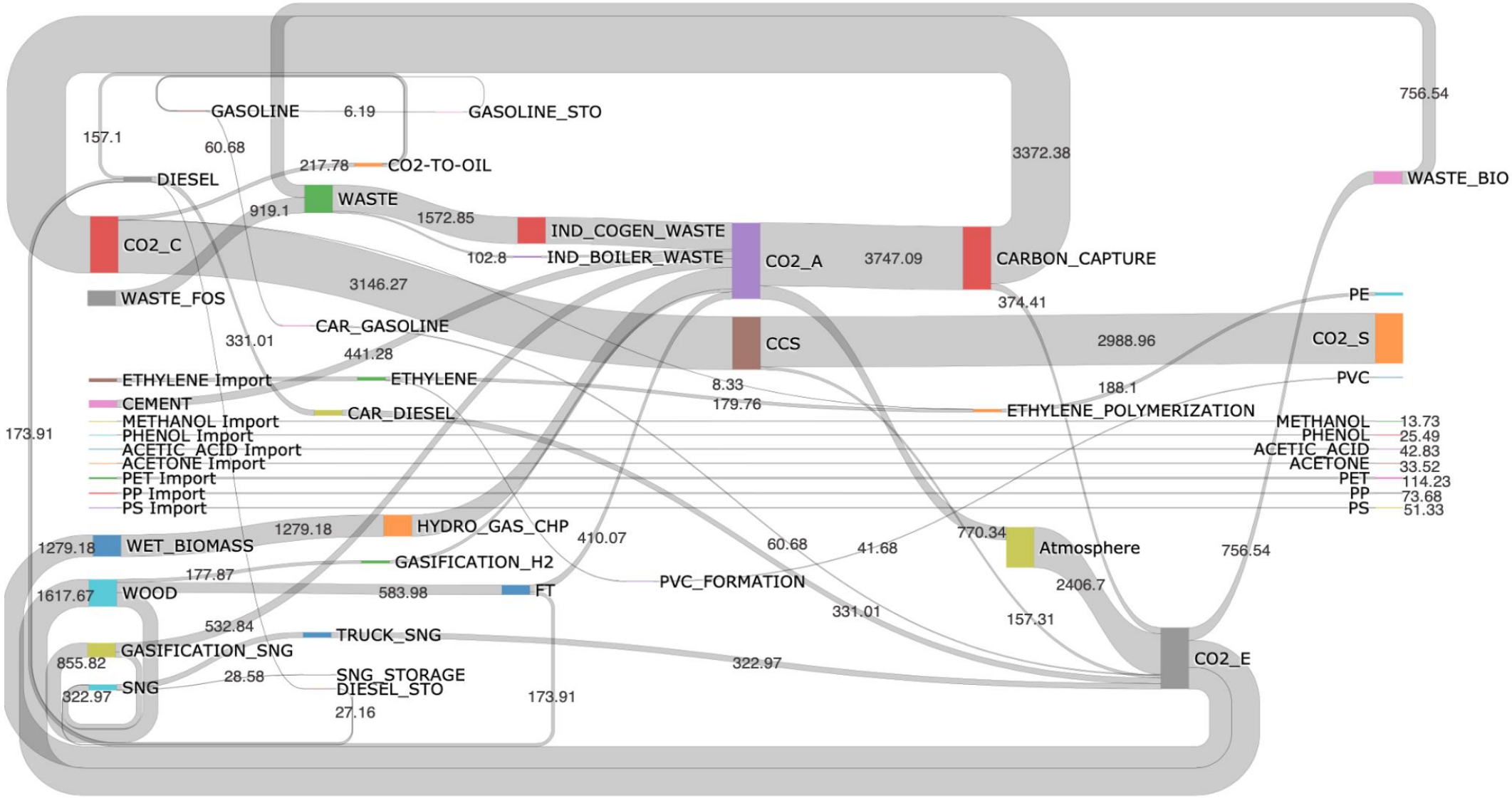
CHF/y/capita

i= 2.25%, lifetime 20-25 years
Average price of wood 30.1 CHF/MWh included

CAPEX ranges (CHF/y/cap) for different technology groups



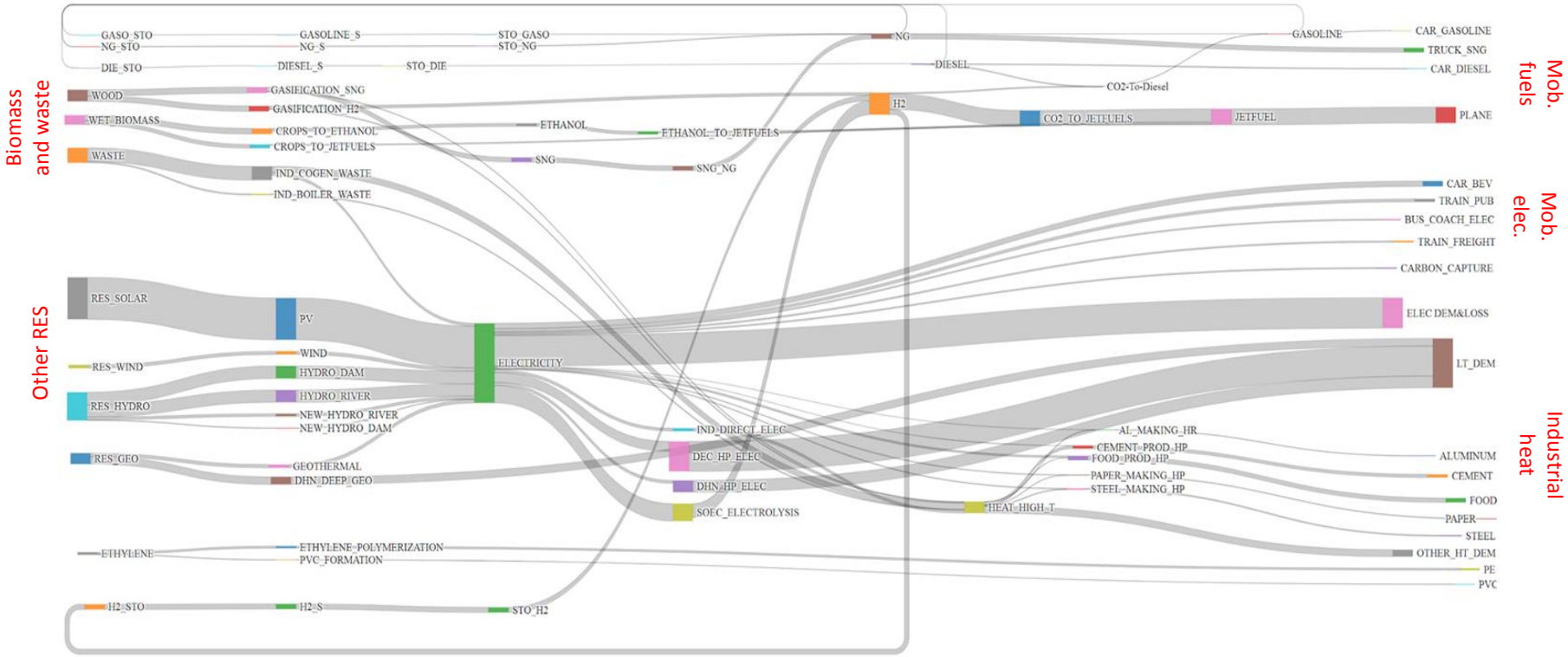
Net Zero Emissions Scenario – Carbon Flows



CO_2 captured: 12.36 Mt/y ***CO_2 sequestrated: 10.96 Mt/y***

The Role of Bio – Jet Fuels

Example: Net zero emissions system with bio jet fuels



Total system cost **: + 3.13 bCHF/y**

~ 1920 CHF/y/cap

CO_2 sequestrated **: + 0.9 Mt/y**

~ 1.2 t/y/cap

Energy flows (PJ/y)

<u>Other Renewables</u>: + 144 (+56%)

Hydro: + 0

Wind: + 0

PV: + 144 (+160%)

Geothermal: + 0

<u>Biofuels:</u>

bio-SNG: - 30.6 (-58%)

bio-H_2: + 13.3

bio-gasoline: + 0.72 (+100%)

bio-diesel: - 0.72 (-17%)

bio-jet fuels: + 76

<u>HT Heat</u>: +15.1 (+38.5%)

biomass conversion: + 1.8 (+3.2%)

<u>Electricity</u>: + 107 (+40%)

<u>Electrolysis</u>: H_2: + 63.4 (+2400%)

Take Home Messages

- Biomass can be used for energy management.
- Biomass is transformed to easily storable fuel (e.g. CH_4, liquid fuels).
- Synergy with hydro.
- HT heat can be derived from:
  - Waste combustion.
  - Bioprocesses (waste heat recovery).
  - Fuel (e.g. CH_4) via CHP use.
- CO_2 capture is important in order to:
  - provide the system with carbon to be re-used (increase the degree of fossil substitution).
  - reduce environmental emissions.
- CO_2 sequestration is essential to reach net zero emissions.