

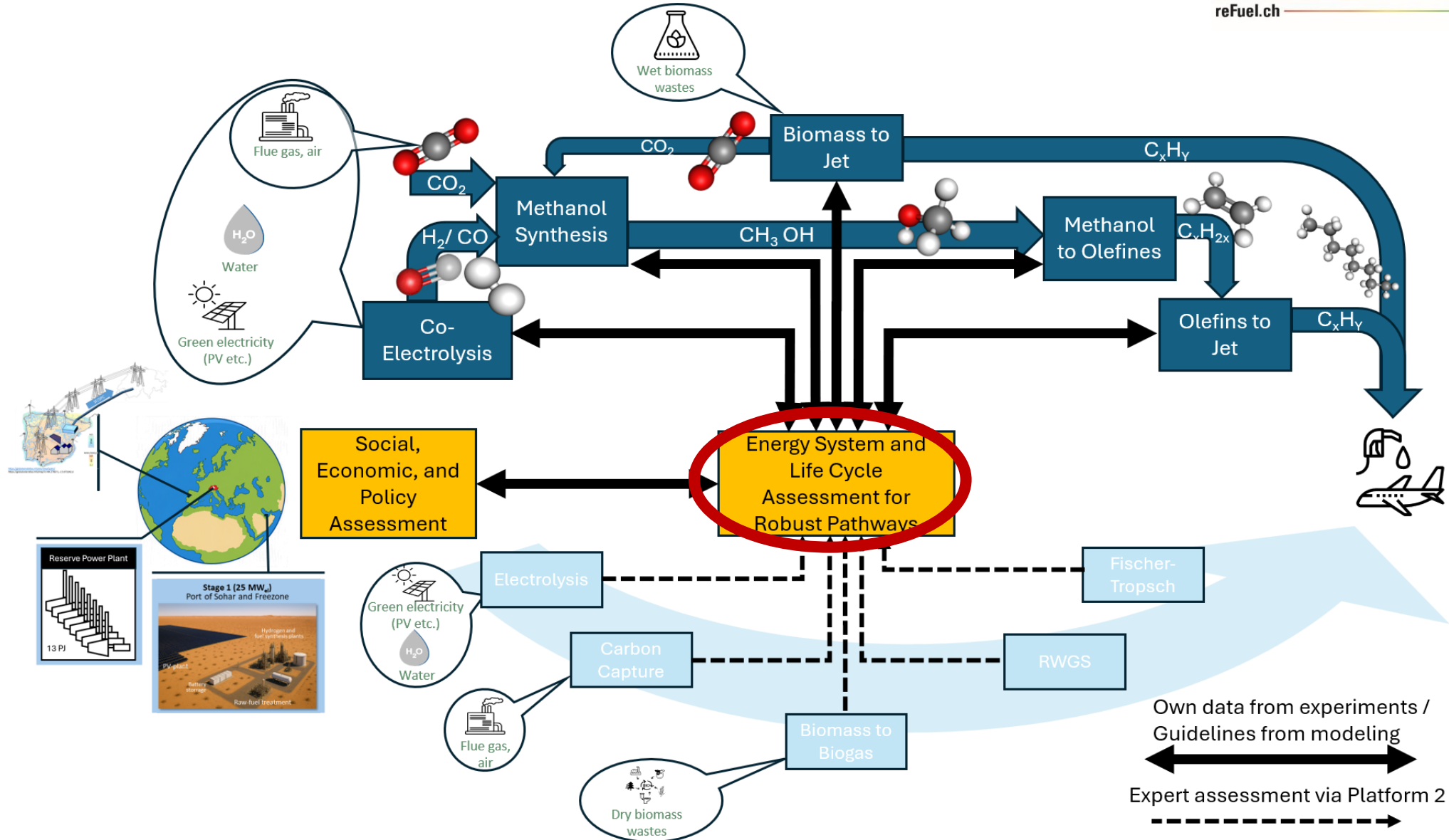
Renewable **Fuels** and **Chemicals** for Switzerland*

Facility location allocation and logistics optimisation for domestic SAF production in Switzerland

Presenter: Viola Rühlin

*reFuel.ch is a consortium sponsored by the Swiss Federal Office of Energy's SWEET programme and coordinated by Empa.

High-level introduction & link to consortium

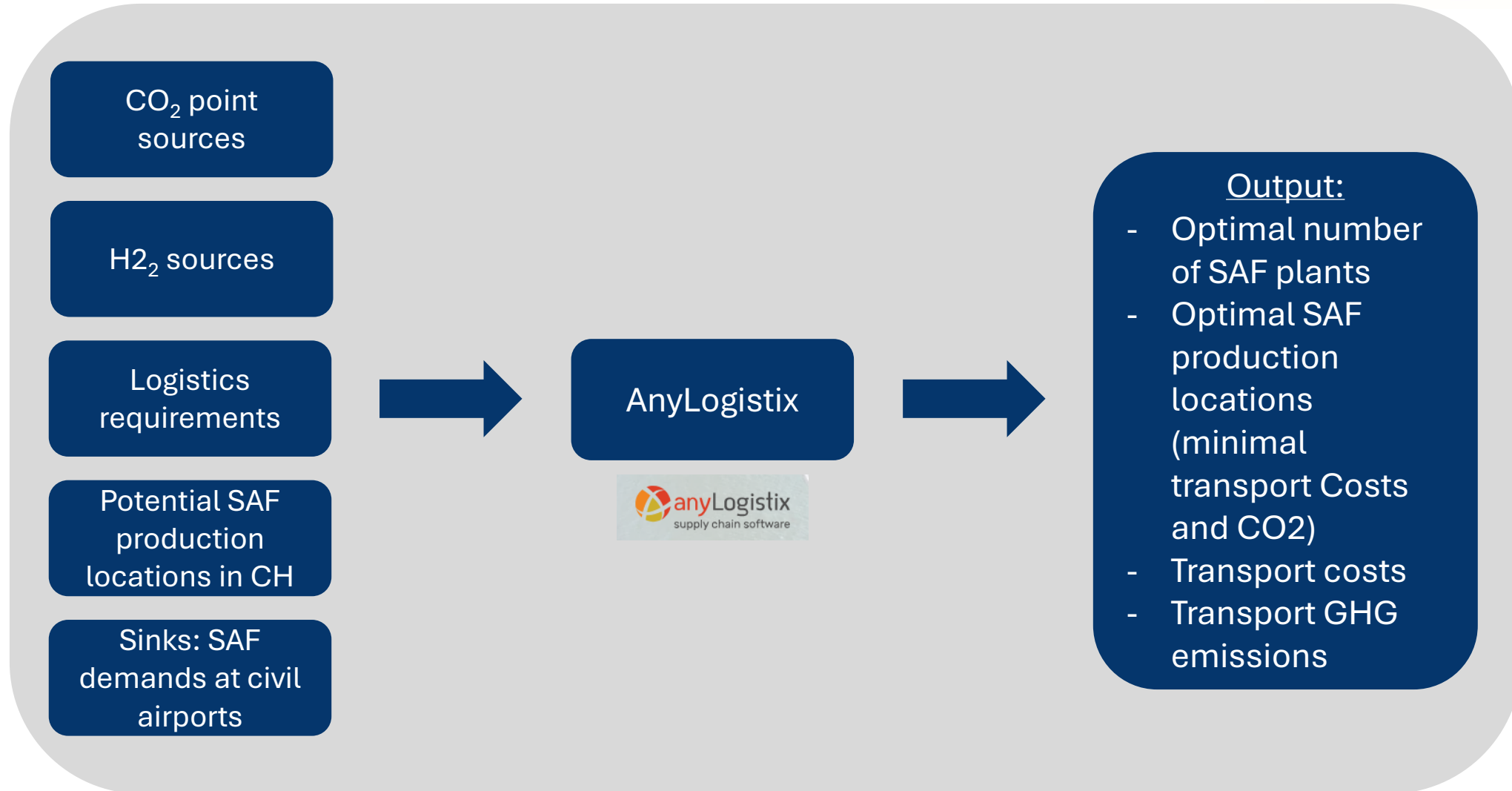


Background & Goals

- What is the feedstock availability for PtL SAF production now and in the future in Switzerland?
- What are the technical requirements for transporting, handling and storing the different compounds involved in the SAF logistics from source of feedstock to the SAF production site and from the production site to the SAF destination?
- What effects do these transport requirements have on the optimal production location selection as well as logistics costs and GHG emissions?
- What trade-offs in terms of costs and GHG emissions arise when deciding whether to import SAF and its feedstock, or to source them domestically?

Model description

Overview Logistics Optimization Model



AnyLogistix Model

Discrete incapacitated plant location problem
(mixed-linear programming using
predetermined potential locations of the
facilities)

- Objective function: $\min Z = \sum_{i \in I} F_i y_i + \sum_{i \in I} \sum_{j \in J} c_{ij} x_{ij}$
 - Z – total costs
 - F_i – opening costs for facility
 - y_i – opening decision facility (binary)
 - c_{ij} – per unit cost of transport from i to j
 - x_{ij} – quantity shipped from point i to j
- Sources of raw materials (including capacity restrictions)
- Transport distances (automatically calculated using a routing API)
- Transport costs (using values from internal database)
- Transport emissions
- Alternative factory locations



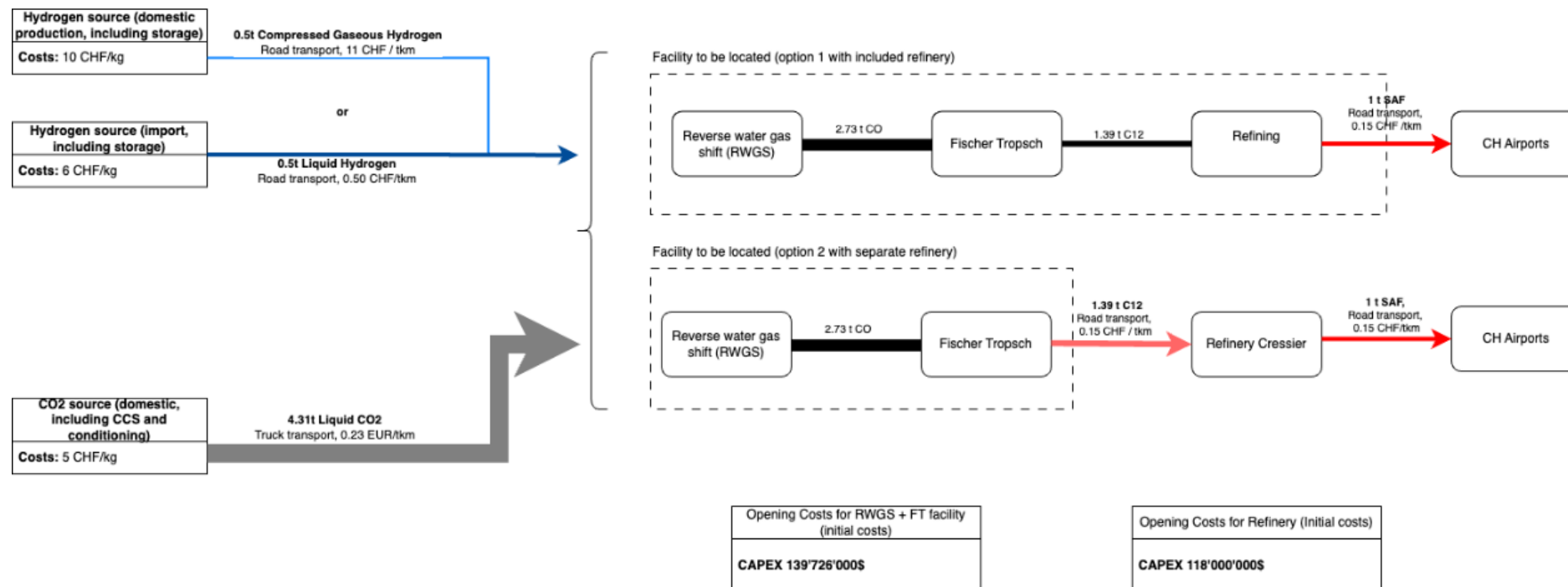
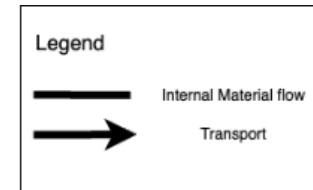
Outputs:

- Optimal location to source materials (including quantities)
- Optimal number of facilities to open
- Production quantity per facility
- Transport costs
- Transport emissions

Model Visualization

Modelling Framework Facility Location for SAF plant (AnyLogistix)

As-is case (2025, 2% blending quota)

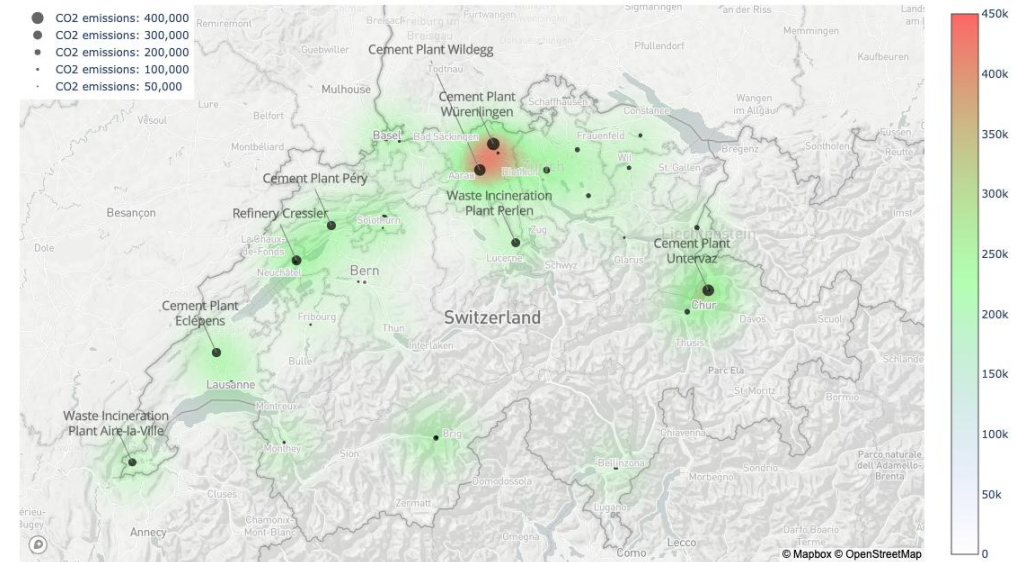


Model Inputs

The CO₂ emitted by the top ten facilities could be used to produce around 240'000 t of SAF annually

Top 10 CO₂ point sources today

- Source: Swiss PRTR register (only contains point sources above a certain threshold)
- Model contains top 10 point sources: 5 cement plants, 4 major waste incineration plants, 1 refinery
- Out of scope: smaller waste incineration plants, other smaller plants according to Swiss PRTR pollutant register
- Location and type of major point sources can change in the future (e.g. certain industries may shut down, new waste incinerations plants may be built), major changes regarding CO₂ point sources out of scope of our work



Type	Operator	Canton	City	Emissions [t CO2 / a]
Cement plant	Holcim (Schweiz) AG	AG	Würenlingen	446'000
Cement plant	Holcim (Schweiz) AG	GR	Untervaz	418'000
Cement plant	Jura Cement Fabriken	AG	Wildeg	413'000
Refinery	Varo Refining Cressier SA	NE	Cressier	359'000
Cement plant	Holcim (Suisse) SA	VD	Ecléps	339'000
Cement plant	Vigier Cement AG	BE	Péry	334'000
Waste incineration plant	Renergia Zentralschweiz AG	LU	Perlen	328'000
Waste incineration plant	Les Cheneviars	GE	Aire-la-Ville	299'000
Waste incineration plant	KEBAG AG	SO	Zuchwil	272'000
Waste incineration plant	ERZ KHKW Hagenholz	ZH	Zürich	264'000

Logistics requirements for H₂ and CO₂

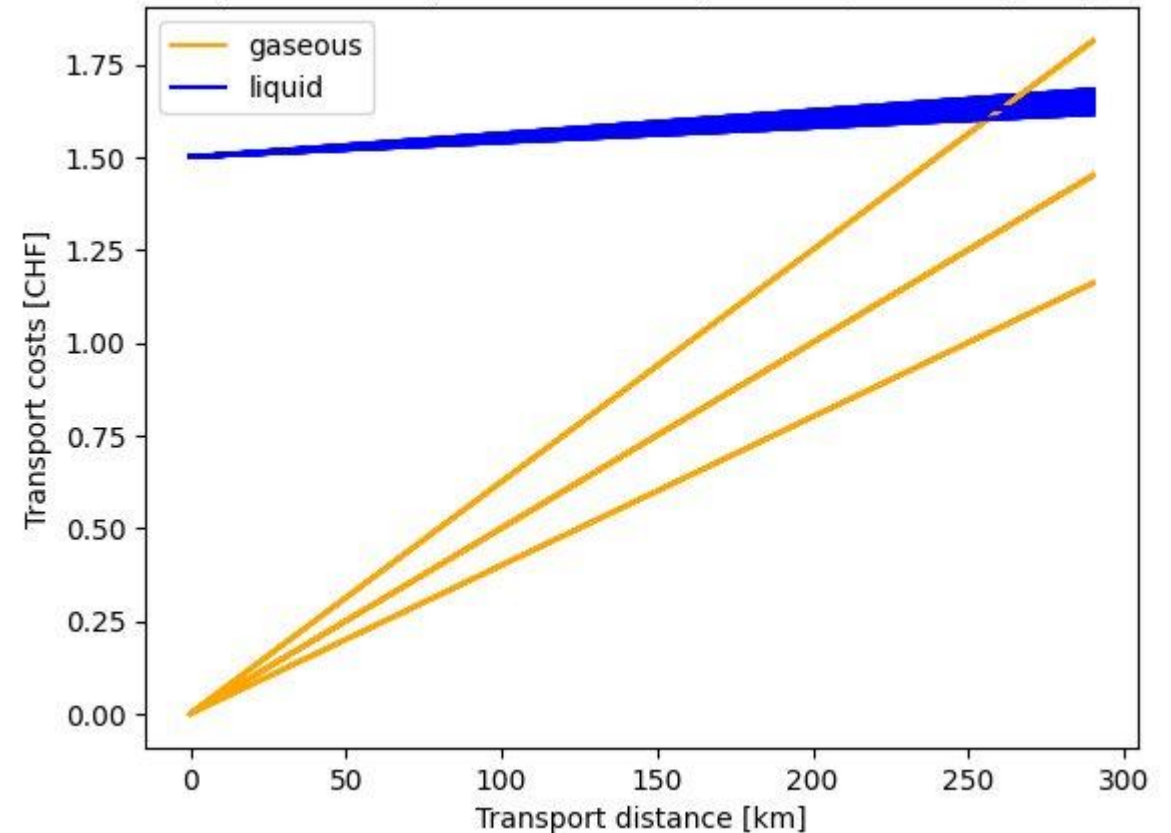
H₂ transport and storage

- Modes of transport: Repurposed NG pipelines (low cost but danger of embrittlement of steel alloys), hydrogen pipeline (high cost, but higher capacity), compressed gas road transport, liquid H₂ road transport, liquid H₂ and compressed gas rail transport, ship (early trial phase)
- Hydrogen logistics requires storage near its production, consumption point or both
- Storage options: line packing for pipeline transport (storage duration <1d), above-ground pressurised tank (storage duration 1-2 days), above-ground liquid tank (storage duration 1-2 weeks)
- Conditioning into gaseous or liquid state required:
 - Lower cost for compression but lower capacity (400kg H₂ per truck)
 - Higher density, which leads to a higher capacity of liquid H₂ but at a higher cost (4000-5250 kg H₂ per truck)
- Liquefaction is energy-intensive and only makes sense for transport distances > 200km (not for domestic transport)

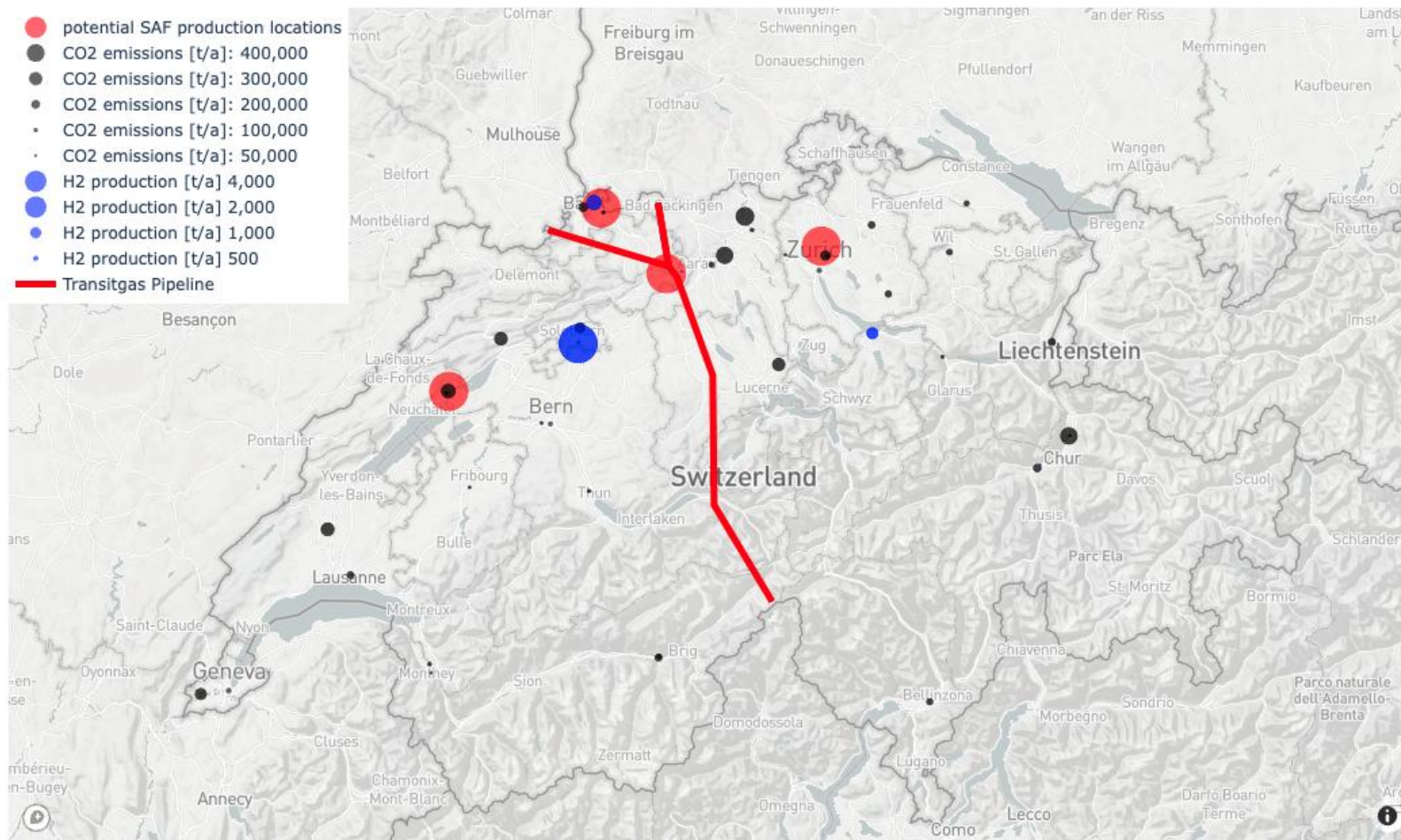
CO₂ transport and storage

- Modes of transport: liquid and compressed gas CO₂ truck transport (20 t liquid CO₂ per ISO-tank container), liquid and compressed gas CO₂ rail transport (ISO-tank container), barge, pipeline (solid and gaseous)
- CO₂ storage near its capture facility or consumption point is required
- Conditioning into gaseous, liquid and solid states required

Comparison transport costs for liquid and gaseous hydrogen



Potential SAF production locations in Switzerland



SAF Sinks: Civil aviation airports (ZRH, GVA, BSL)

- No official numbers have been published on the kerosene demand of individual airports
- To estimate the total kerosene demand at major civil airports, the number of flight movements before and after the Covid-19 pandemic was analysed and used as a proxy
- Future kerosene demand was extrapolated using data from BAZL
 - Projections for kerosene demand until 2050 range from a low scenario of -0.3% to a high scenario of 2.6%
- Estimates of future Sustainable Aviation Fuel (SAF) demand were made using EU blending quotas
- The numbers were validated using SWEET-Cross projections
- Military aviation makes up 1.6% of total kerosene demand

Airport	Annual flights (average 2017-2019)	Estimated annual fuel demand [t]	Blending Quota	Estimated annual SAF Demand [t]	Order Interval
Zürich (ZRH)	274'747	914'695	2%	18'294	7 days
Geneva (GVA)	187'994	625'875	2%	12'517	7 days
Basel (BSL)	97'398	324'260	2%	6'485	7 days

Scenario Definition

SAF Sinks: Civil aviation airports (ZRH, GVA, BSL)

- To account for uncertainties arising from domestic production quotas, the minimum domestic H₂ sourcing requirement, the availability of the H₂ pipelines for imports, the model was built to cover different scenarios:

ID	Year	Domestic production Quota	Blending Quota	Fuel demand	Refinery included in SAF plant	CO2 point availability	sourceH2 min. domestic sourcing	H2 production price [CHF/kg]	domestic H2 available (import) pipeline
2025-A	2025	100%	2%	Base	Yes	Base	6%	base	No
2025-B	2025	100%	2%	Base	No	Base	6%	base	No
2035-A	2035	10%	20%	107%	Yes	107%	6%	base	Yes
2035-B	2035	10%	20%	107%	No	107%	6%	base	Yes
2035-C	2035	50%	20%	107%	Yes	107%	6%	base	Yes
2035-D	2035	50%	20%	107%	No	107%	6%	base	Yes
2035-E	2035	100%	20%	107%	Yes	107%	6%	base	Yes
2035-F	2035	100%	20%	107%	No	107%	6%	base	Yes
2035-G	2035	100%	20%	107%	Yes	107%	20%	base	Yes
2035-H	2035	100%	20%	107%	No	107%	20%	base	Yes
2035-I	2035	50%	20%	107%	Yes	107%	20%	base	No
2035-J	2035	50%	20%	107%	No	107%	20%	base	No
2050-A	2050	10%	70%	113%	Yes	113%	6%	-25%	Yes
2050-B	2050	10%	70%	113%	No	113%	6%	-25%	Yes
2050-C	2050	50%	70%	113%	Yes	113%	6%	-25%	Yes
2050-D	2050	50%	70%	113%	No	113%	6%	-25%	Yes
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2050-F	2050	100%	70%	113%	No	113%	6%	-25%	Yes
2050-G	2050	100%	70%	113%	Yes	113%	20%	-25%	Yes
2050-H	2050	100%	70%	113%	No	113%	20%	-25%	Yes

Results and conclusions

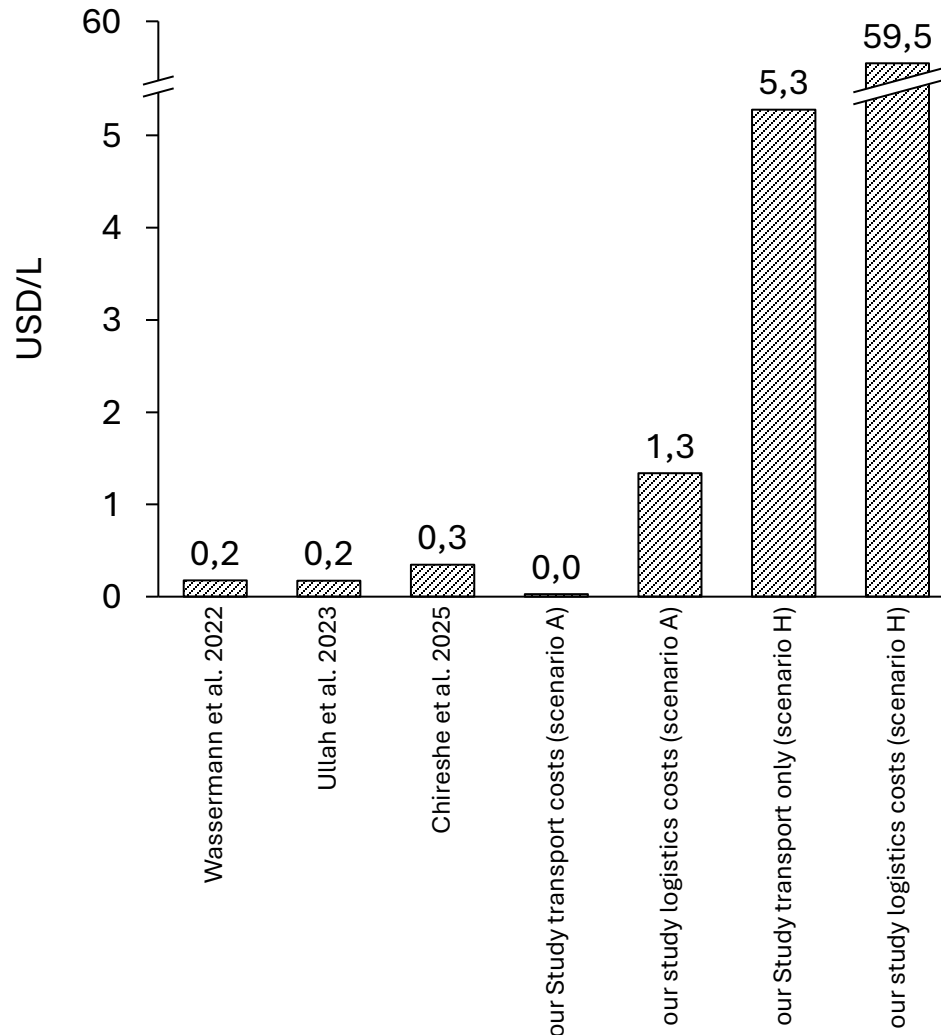
Results and conclusions

- One SAF production facility is economically optimal in almost all scenarios
 - **Olten** is the preferred location in most scenarios, followed by **Basel Auhafen**
- Increasing domestic production → substantially higher logistics flows and costs
- Cost driver: Storage (242–293 CHF/t SAF)
- GHG driver: Feedstock conditioning/handling (22.68–36.17 kg CO₂-eq./t SAF)



Cost and emission hotspots are not the same

Results and conclusions



Transport costs

- ~1 order of magnitude below previous studies
- Plausible due to Switzerland's smaller size and shorter transport distances

Total logistics costs

- Substantially higher than transport-only estimates
- Handling, conditioning & storage are usually neglected in previous models



Transport-only models may substantially underestimate total SAF logistics costs

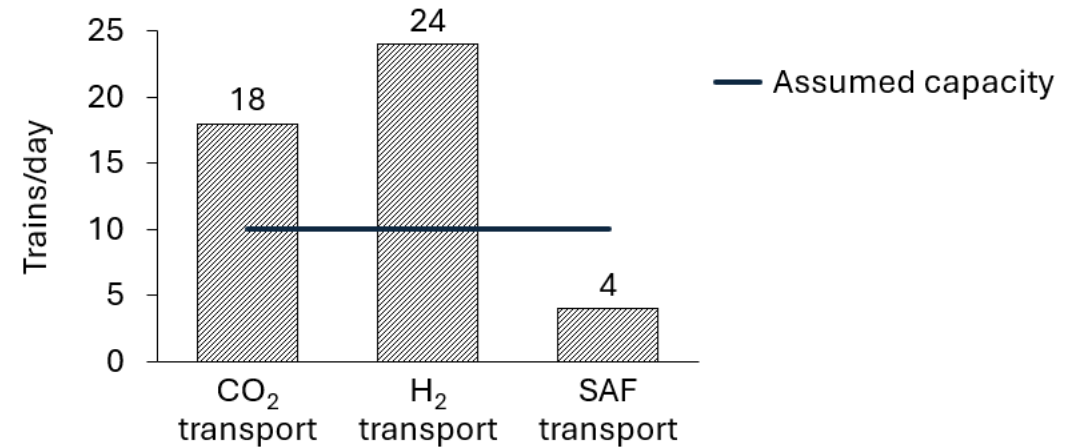
Results and conclusions

Domestic SAF production creates increasing logistics requirements

- ~2% reasonable considering total logistics costs
- ~20% transport costs remain comparable with literature
- >20% increasingly cost-intensive
- High quotas → increasing pressure on transport infrastructure



If domestic SAF production primarily serves strategic supply security, a quota between ~2% and 20% appears to be a reasonable range.



At high domestic production quotas (100% domestic production at 70% blending quota), the optimal logistics network may exceed available rail capacity

Limitations

Data uncertainty

- Limited empirical data on handling, conditioning & storage
 - Cost and energy assumptions therefore uncertain
- H₂ source availability strongly influences facility location, while the future expansion of domestic H₂ production remains uncertain
- Future H₂ pipeline connection to Switzerland is uncertain

Next steps

- Alignment of the scenario with the latest WP3 scenarios
- Validation of the data on handling, conditioning and storage
- Extension of the model with methanol pathway

Thank you for your attention!

Questions and discussion

Acknowledgement

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The authors bear sole responsibility for the conclusions and the results presented.