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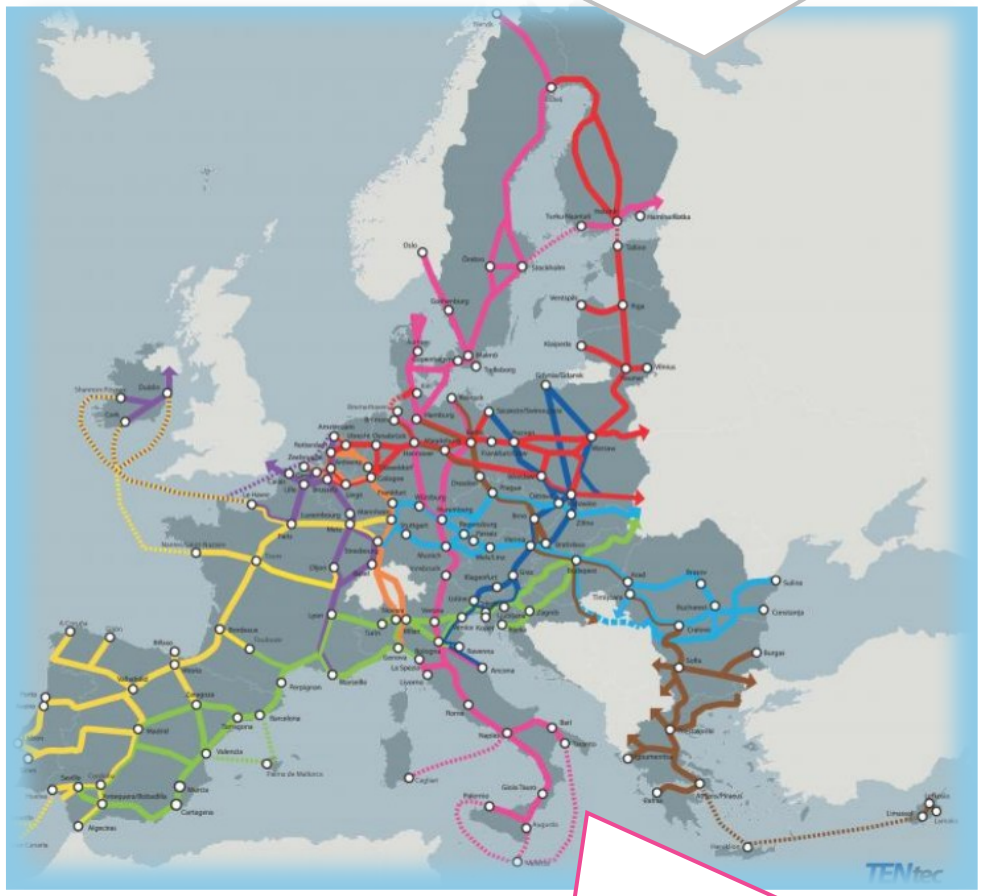
Road freight decarbonization in the TEN-T network in the context of future energy supply infrastructures

Road freight decarbonization in the TEN-T

Corridors of the **Trans-European Transport Network (TEN-T)**



Scandinavian-Mediterranean Corridor

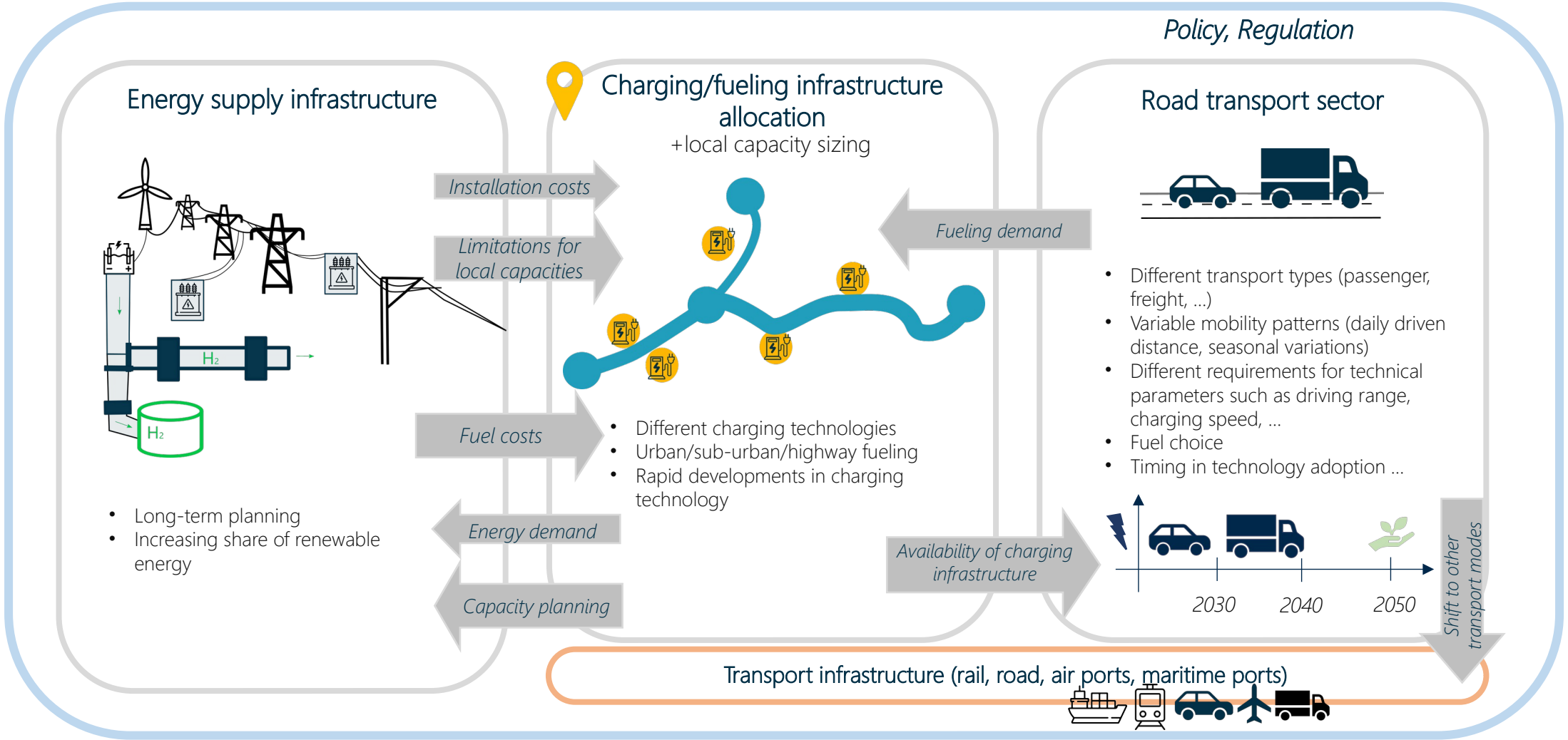
→ European Commission goals:

- „Sustainable & Smart Mobility Strategy“:
  Doubling rail freight until 2050
- Fit For 55:
  - Every 120km truck charging
  - Every 200km hydrogen refueling

→ Diverging expectations on the application of hydrogen fuel cell trucks

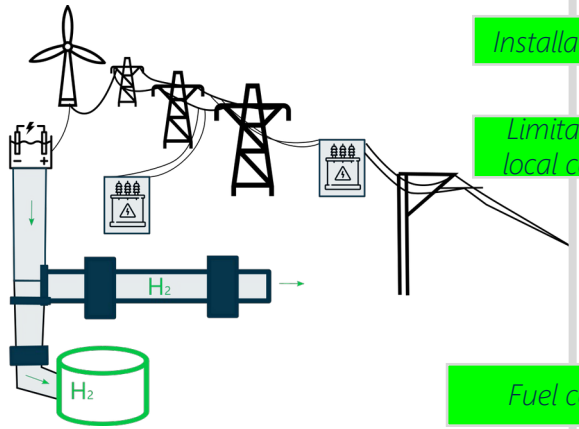
- FCEV for niche applications (f.e. Plötz, 2022)
- European Hydrogen Backbone: Assumption of 55% of road freight fueled with hydrogen by 2050

Overview on the relevant system components



Multi-period planning of charging/fueling infrastructure

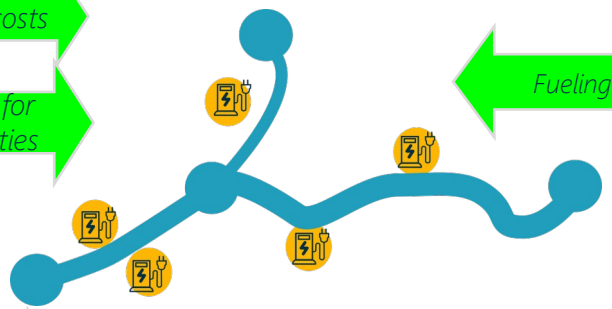
Energy supply infrastructure



- Long-term planning
- Increasing share of renewable energy

Charging/fueling infrastructure allocation

+local capacity sizing



- Different charging technologies
- Urban/sub-urban/highway fueling
- Rapid developments in charging technology

Installation costs

Limitations for local capacities

Fuel costs

Energy demand

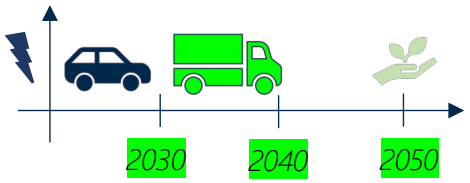
Capacity planning

Fueling demand

Availability of charging infrastructure

Road transport sector

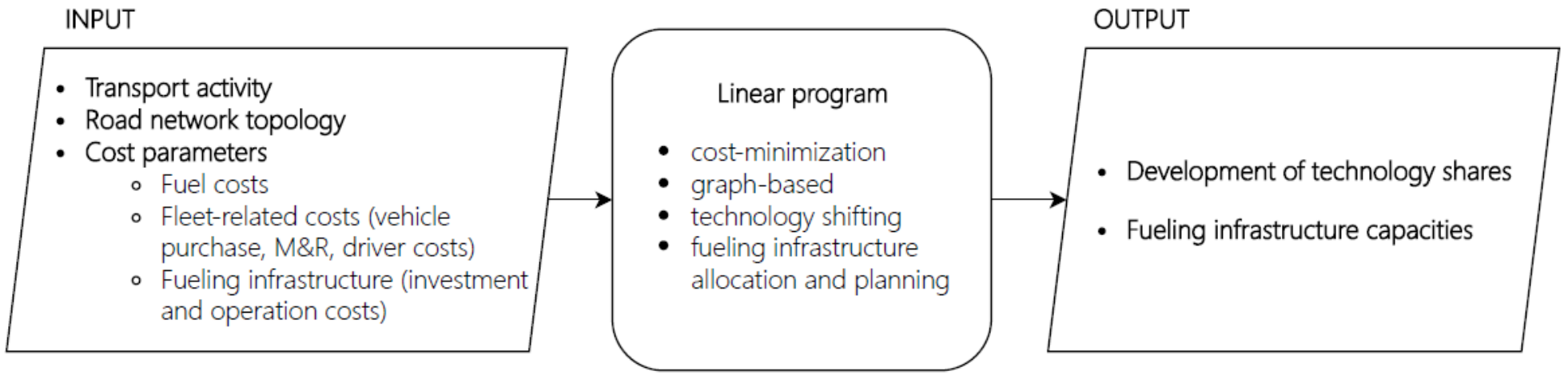
- Different transport types (passenger, freight, …)
- Variable mobility patterns (daily driven distance, seasonal variations)
- Different requirements for technical parameters such as driving range, charging power, …
- Fuel choice
- Timing of technology adoption…



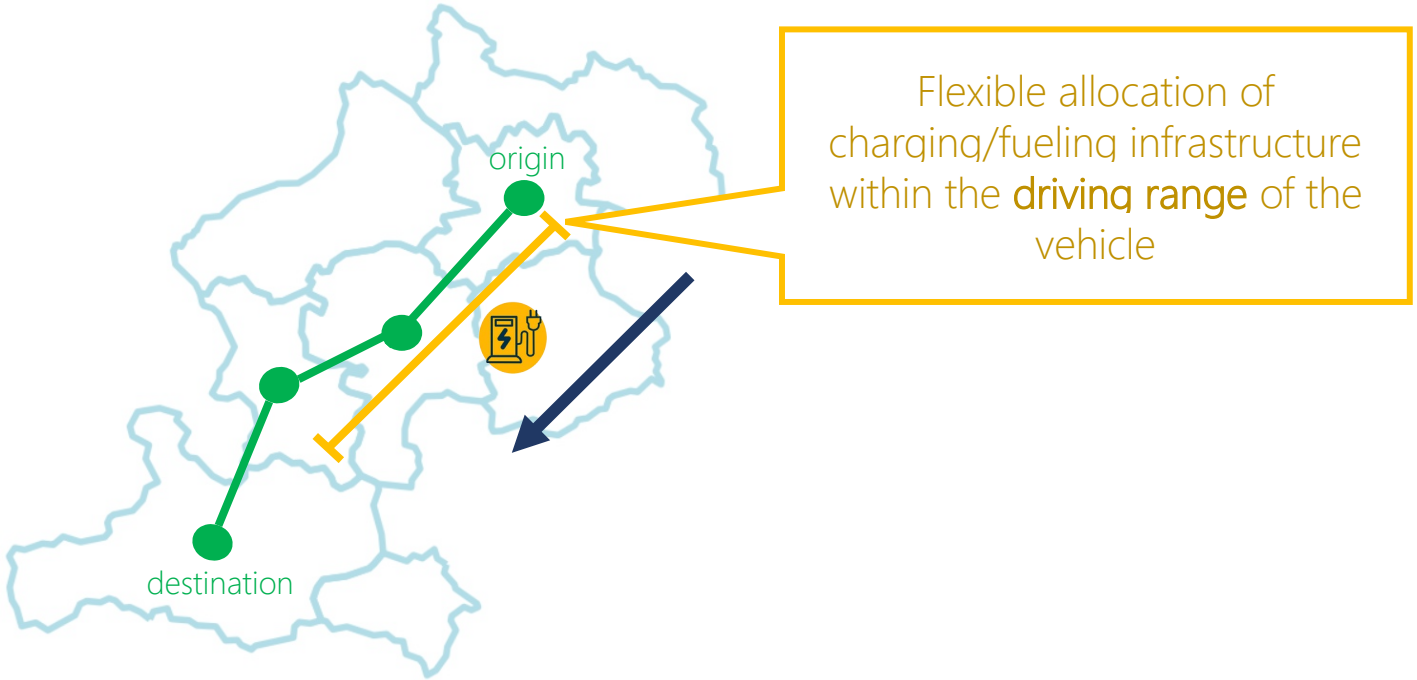
Shift to other transport modes

Transport infrastructure (rail, road, air ports, maritime ports)

Modeling framework



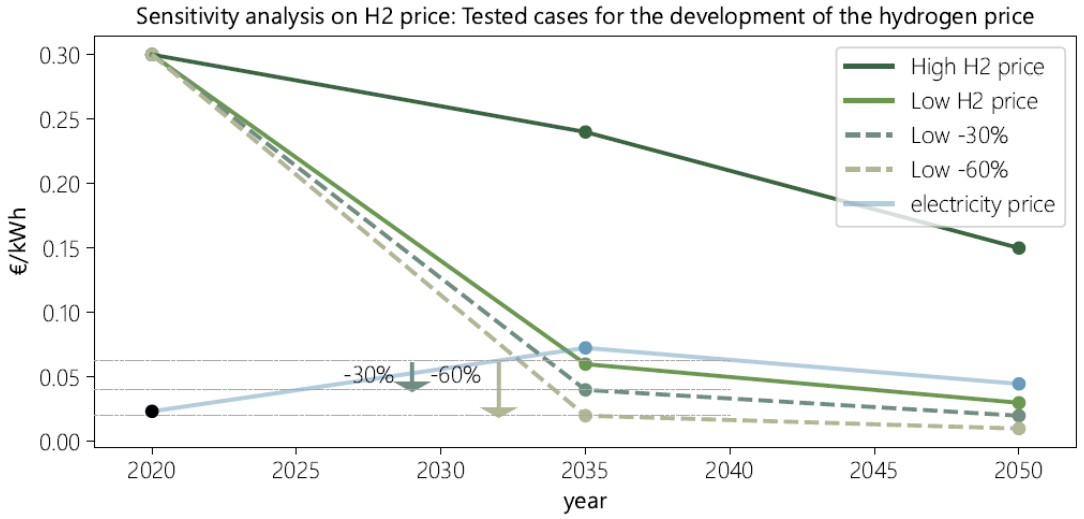
Spatial flexibility

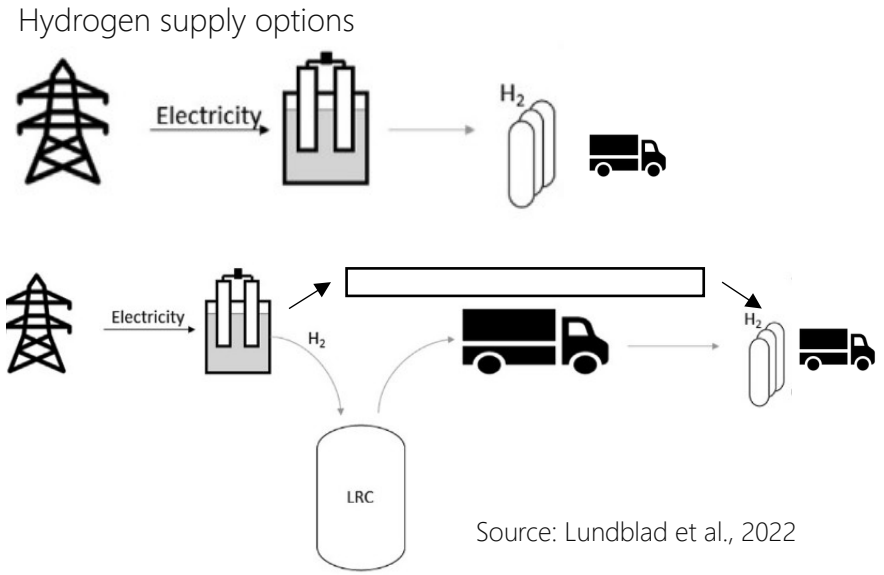


Higher spatial flexibility in charging/fueling infrastructure with a **higher driving range** of drive-train technology

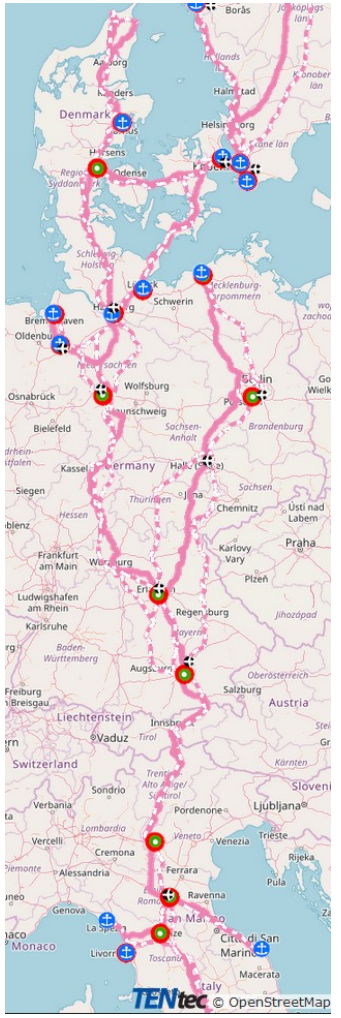
Case study and data

- Scandinavian-Mediterranean (S-M) corridor [Norway, Finnland, Sweden, Denmark, Germany, Austria, Italy]
- Transport demand: Origin-destination data for freight flow projections 2030 (ETISplus)
- Network consideration beyond the infrastructure of S-M corridor
- Spatial dependency in electricity price (source: EMPIRE, NTNU)
- European Hydrogen Backbone plans for spatially varying pipeline connection costs
- Consideration of additional transport costs due to charging time for battery-electric trucks



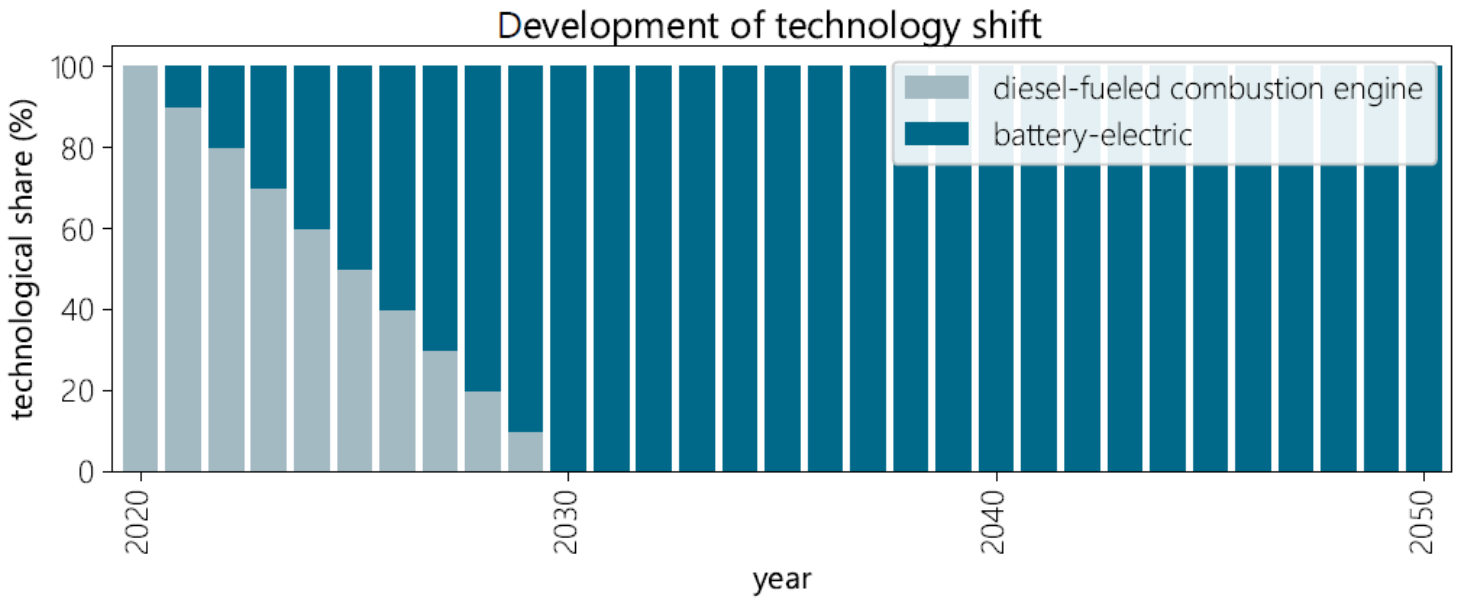


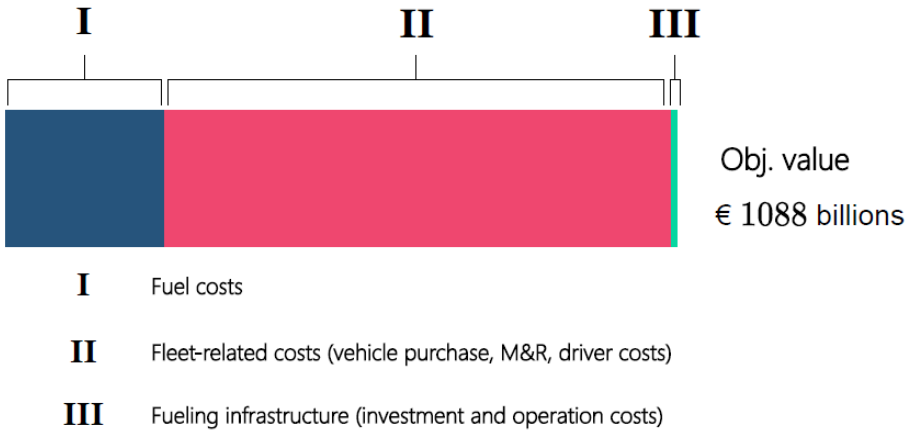
Source: Lundblad et al., 2022



Future technology shift

Scenario	Total cost (Obj. value)	total sum of required fueling infrastructure until 2050	
		charging capacity	H_2 fueling capacity
High H_2 price	€1088 billions	16 GW	-
Low H_2 price	€1088 billions	16 GW	-

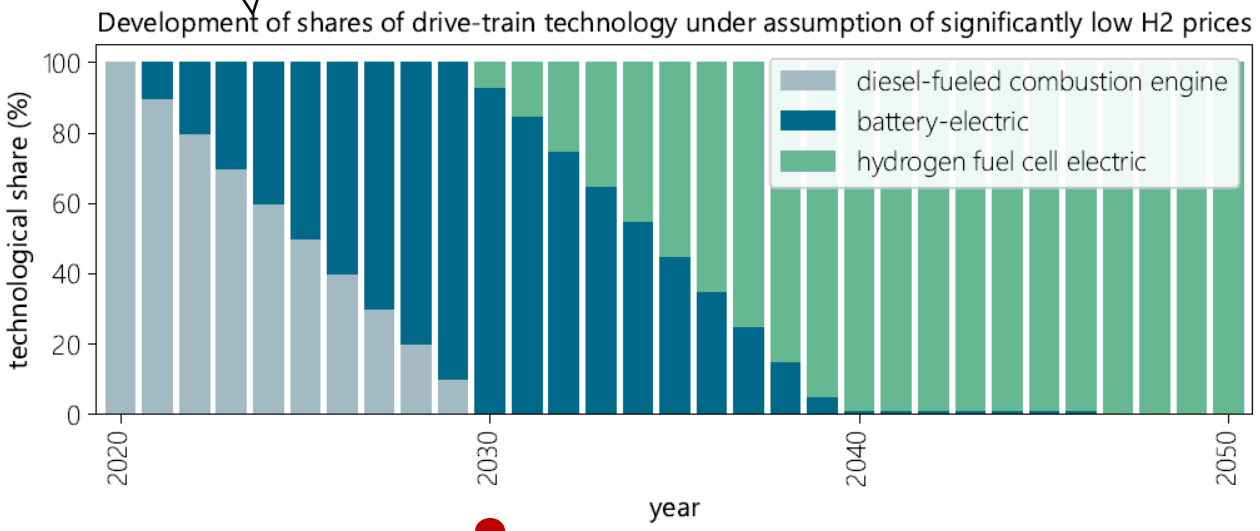


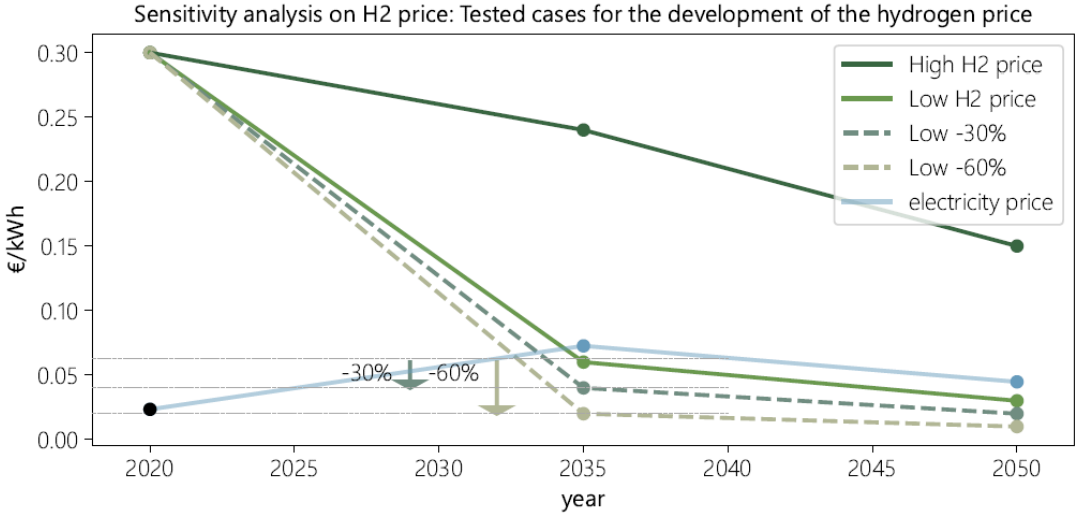


Sensitivity analysis on hydrogen price level

Hydrogen fuel cell electric vehicles in *Low -60% H2 price* scenario (0.02 €/kWh)

		total sum of fueling infrastructure required until 2050	
	Total costs (obj. value)	charging capacity	H_2 fueling capacity
High H_2 price	€1088 billions	16 GW	-
Low H_2 price	€1088 billions	16 GW	-
Low −30%	€1088 billions	16 GW	-
Low −60%	€1067 billions	16 GW	36 GW





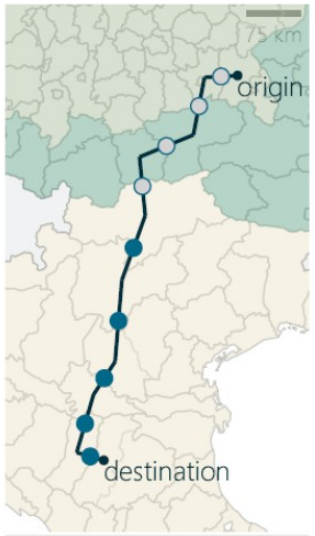
European Hydrogen Backbone (EHB) available and all hydrogen supplied via pipeline

Geographic allocation of fueling activity

Charging at minimal electricity price

Charging activity along selected routes (2035)

Transport demand: 7616 T
Driving distance: 503 km
Energy demand: 315 MWh



Transport demand: 147322 T
Driving distance: 524 km
Energy demand: 6631 MWh

H2 fueling activity along selected routes (2035)

Transport demand: 3714 T
Driving distance: 503 km
Energy demand: 380 MWh

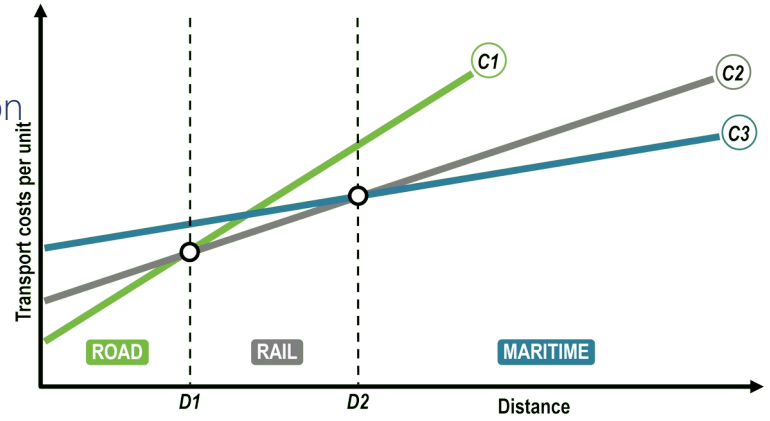
Transport demand: 72043 T
Driving distance: 524 km
Energy demand: 7673 MWh

Hydrogen fueling stations placed near EHB

Conclusions & future work

- Spatial dimension not impactful on technology share
  - Operation costs of vehicles more significant than investments into charging/fueling infrastructure
  - Prices for both technologies are not close enough to become competitive
  - European Hydrogen Backbone sufficiently dense to allow wide-spread application of hydrogen fuel-cell electric vehicles

- Analysis of exogenous barriers and levers for large-scale implementation of zero-emission technologies
  - Availbility of batteries
  - Availbility of charging infrastructure
  - Technological learning
  - Supportive regulatory framework
  - …



- Consideration of different product groups and modal shift to train

- Deeper analysis of savings due to spatial flexibility and quantification of potential impact on electricity demand