

Infrastructure Analysis as Part of the European Hydrogen Energy Roadmap (HyWays)

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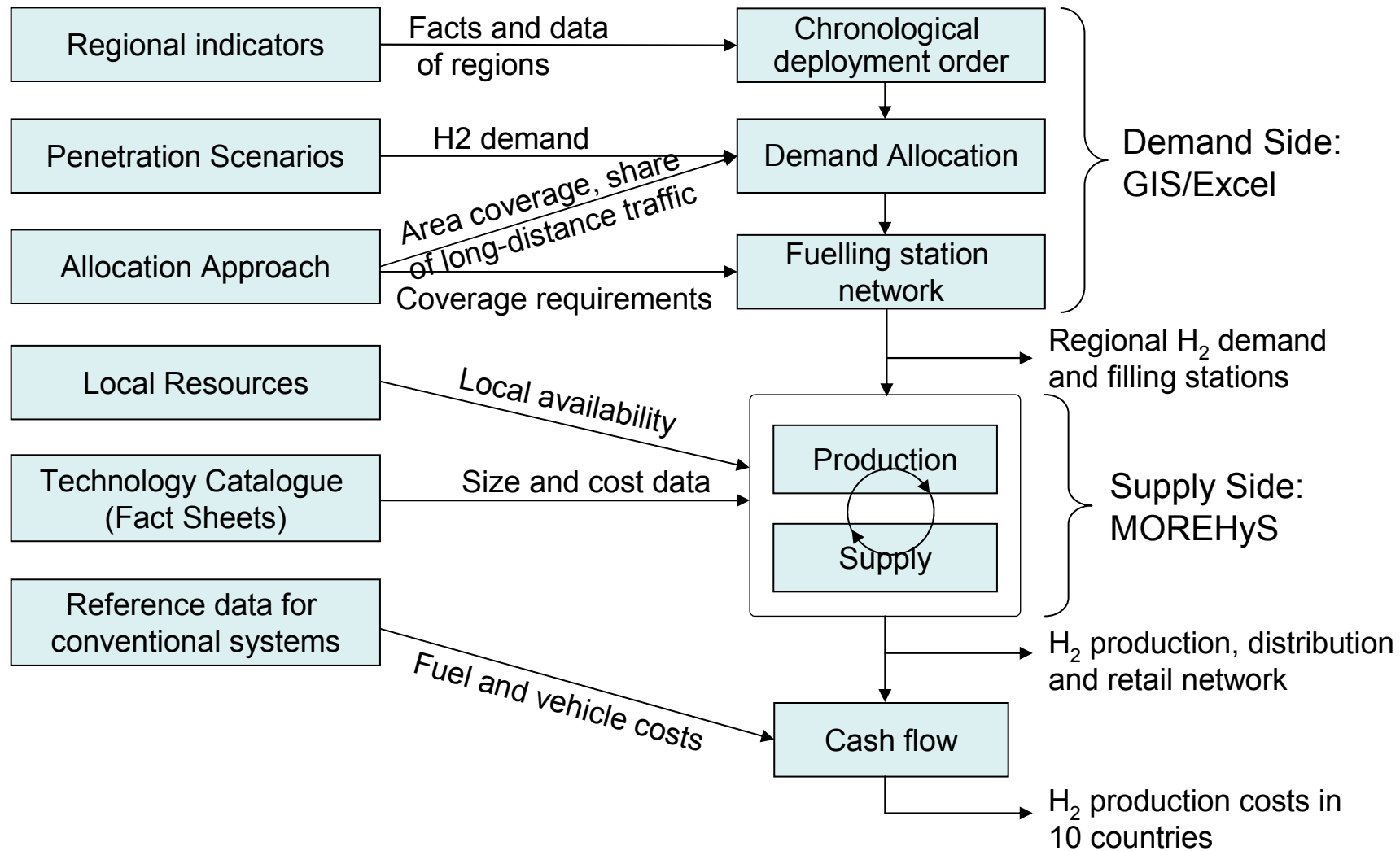
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- **Introduction and motivation**
- **Infrastructure analysis methodology**
- **European hydrogen map**
- **Feedstocks and production**
- **Role of transport options**
- **Costs of infrastructure build-up**
- **Conclusions**

- **HyWays: Hydrogen roadmap for Europe on the basis of in-depth investigation of 10 countries**
- **How can the visions be implemented?**
- **Which role do the technology options play?**
- **What are the costs of an integrated supply infrastructure?**

=> Input for development of policies

Infrastructure analysis methodology



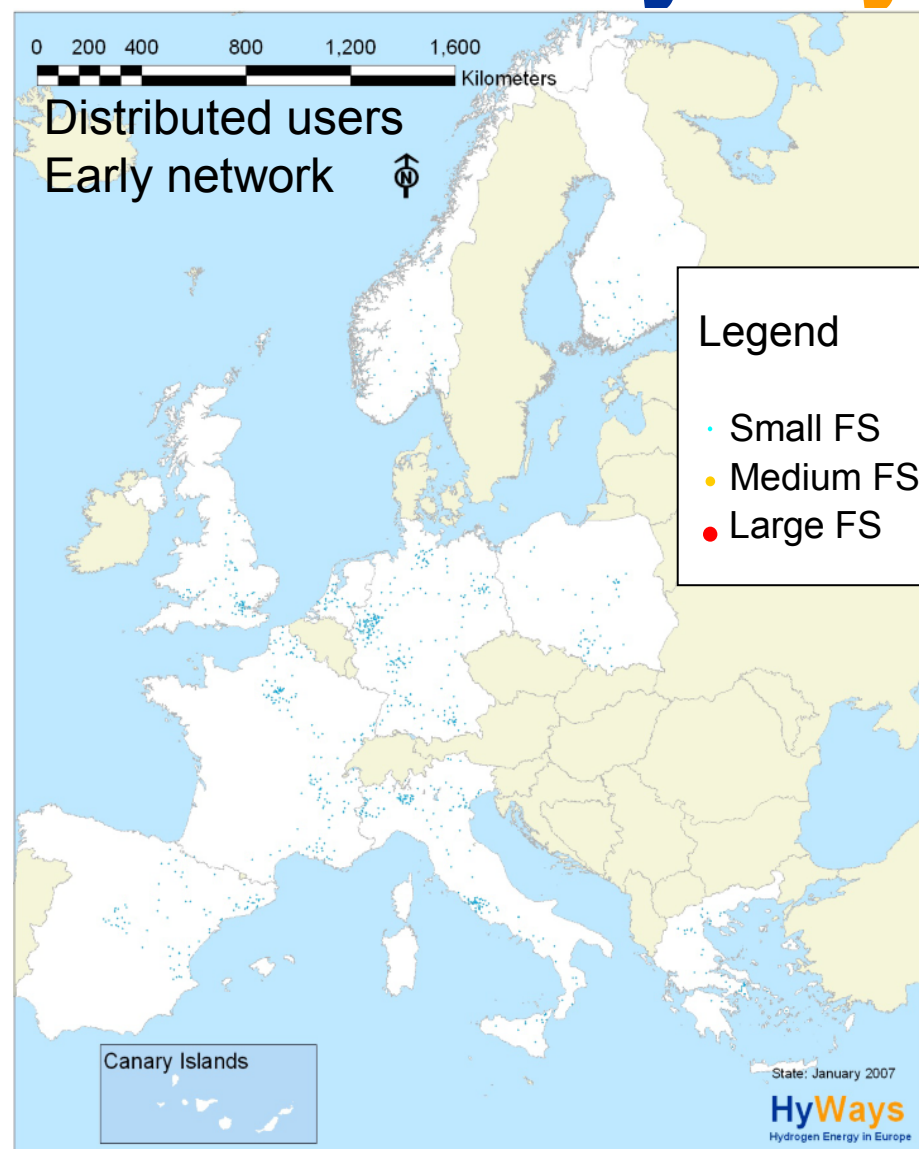
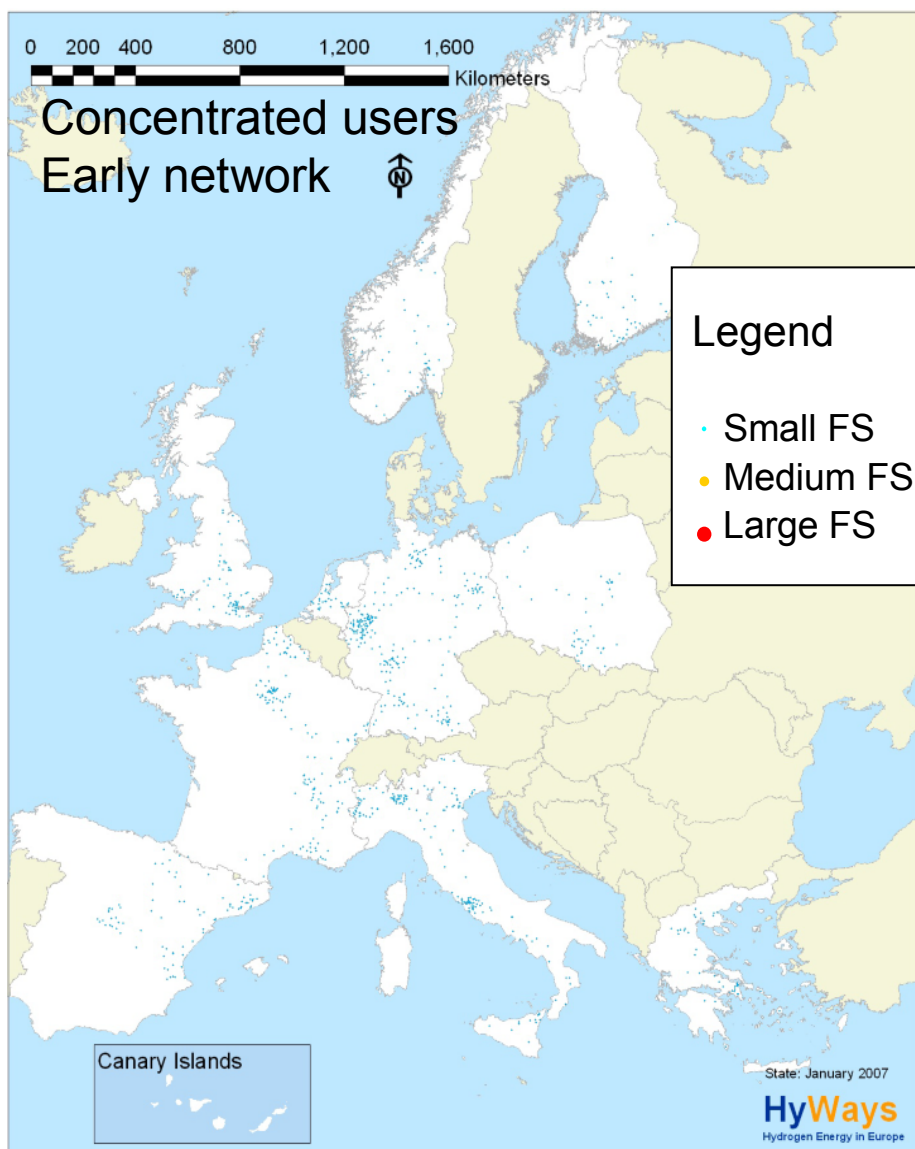
- **Concentrated / distributed users**
- **Early / late transit road network**
- **Feedstock bounds / no bounds**
- **High / medium / low penetration rate**
- **20% LH₂ demand / no LH₂ demand**

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European hydrogen map – Fuelling stations 2014 (medium penetration scenario)

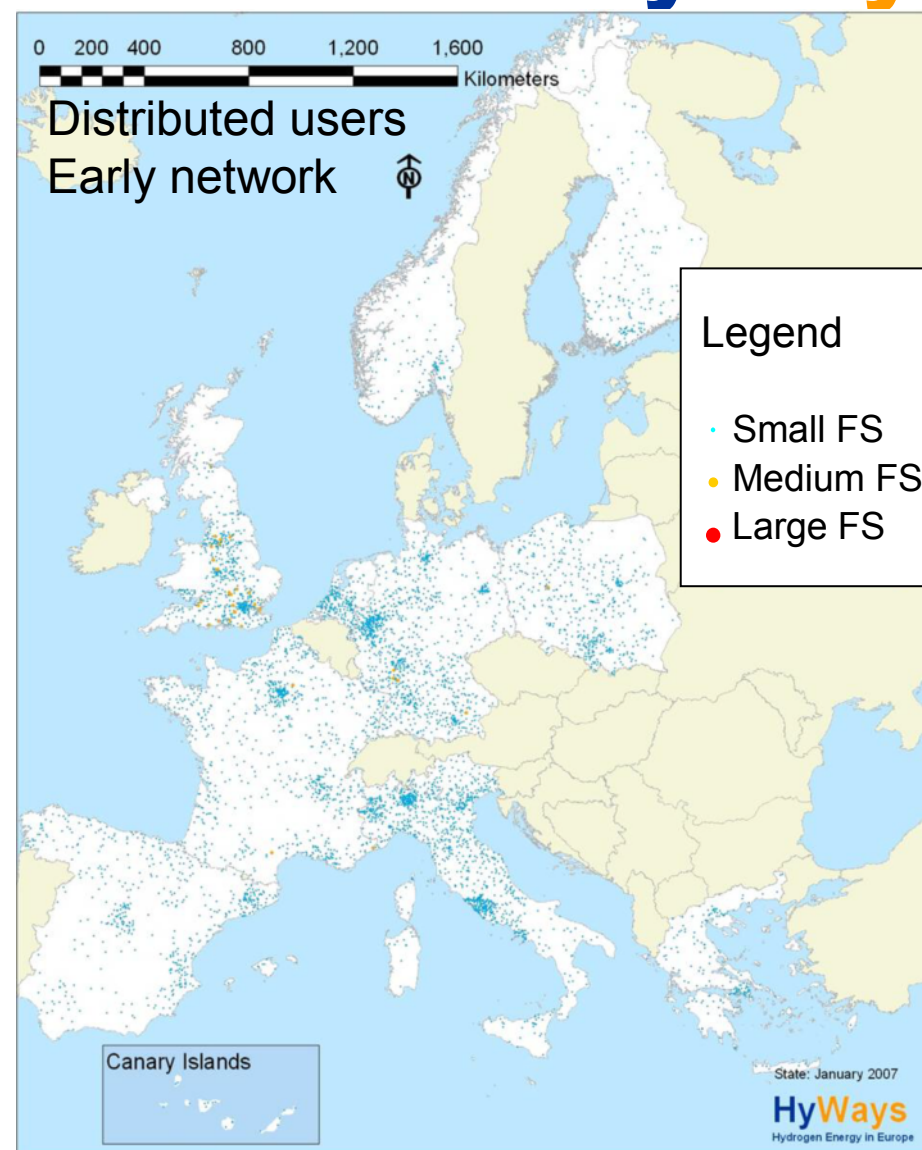
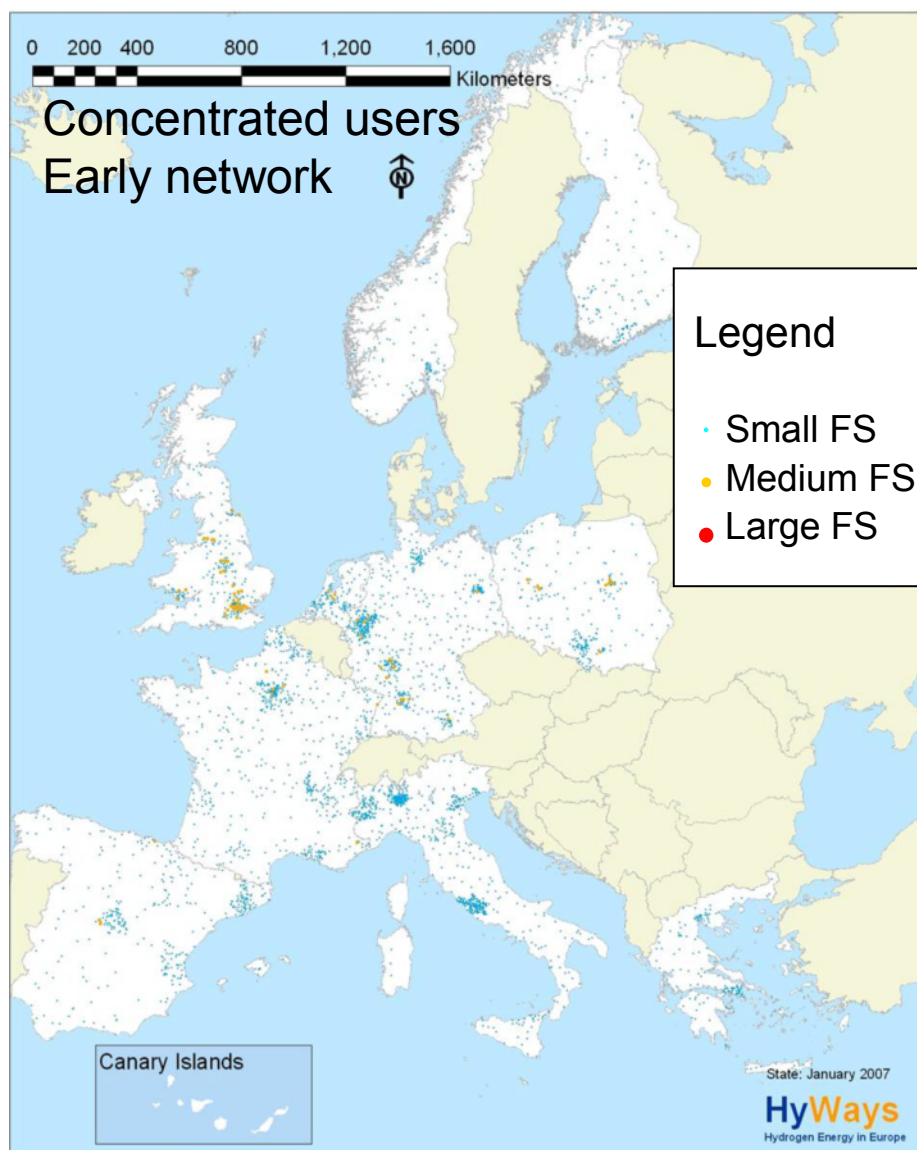
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European hydrogen map – Fuelling stations 2017 (medium penetration scenario)

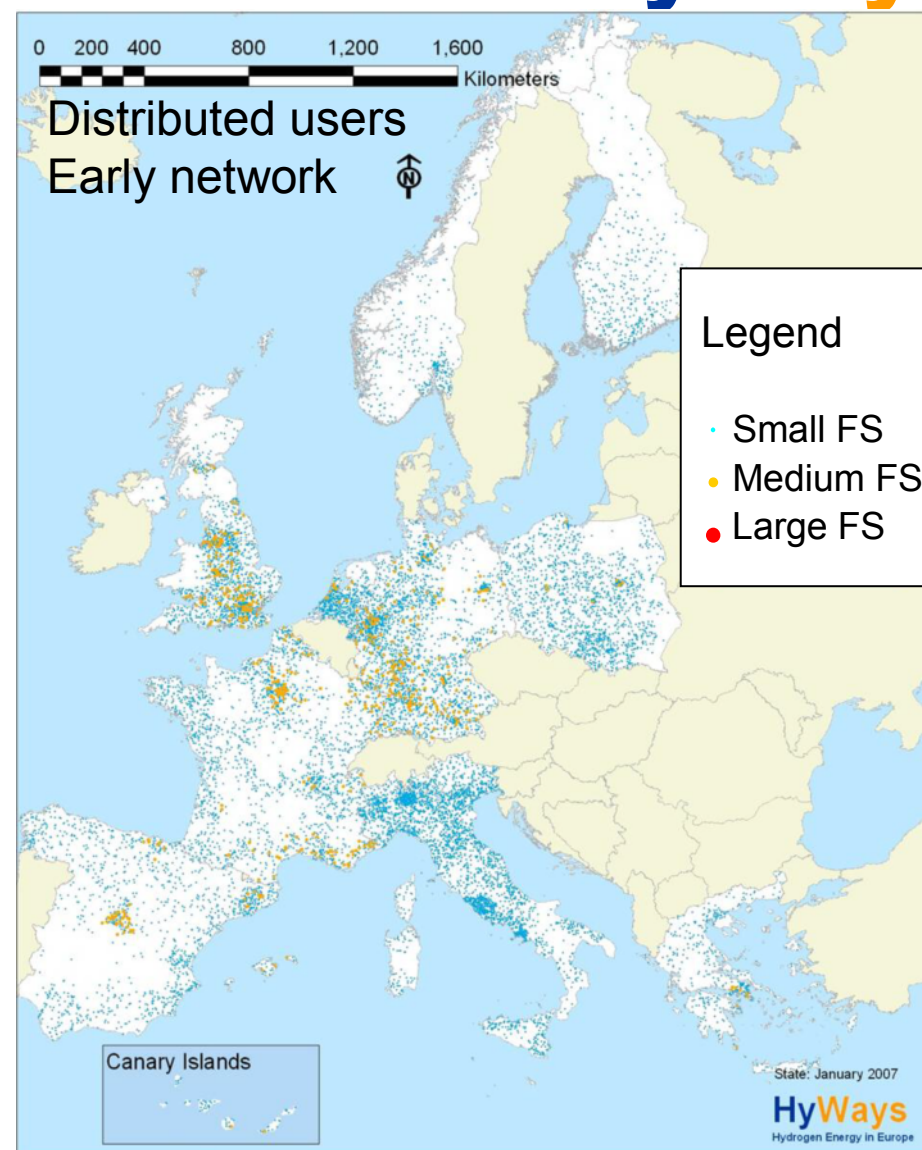
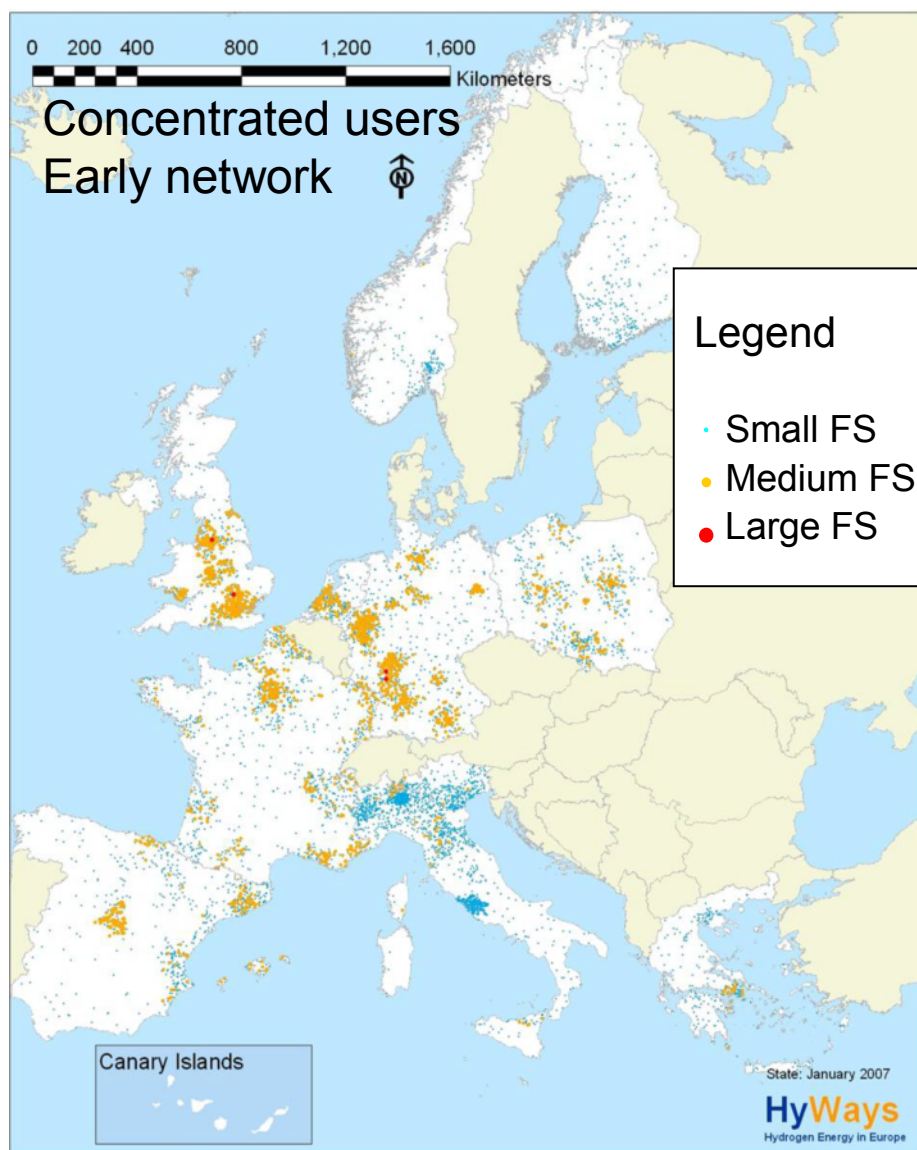
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European hydrogen map – Fuelling stations 2021 (medium penetration scenario)

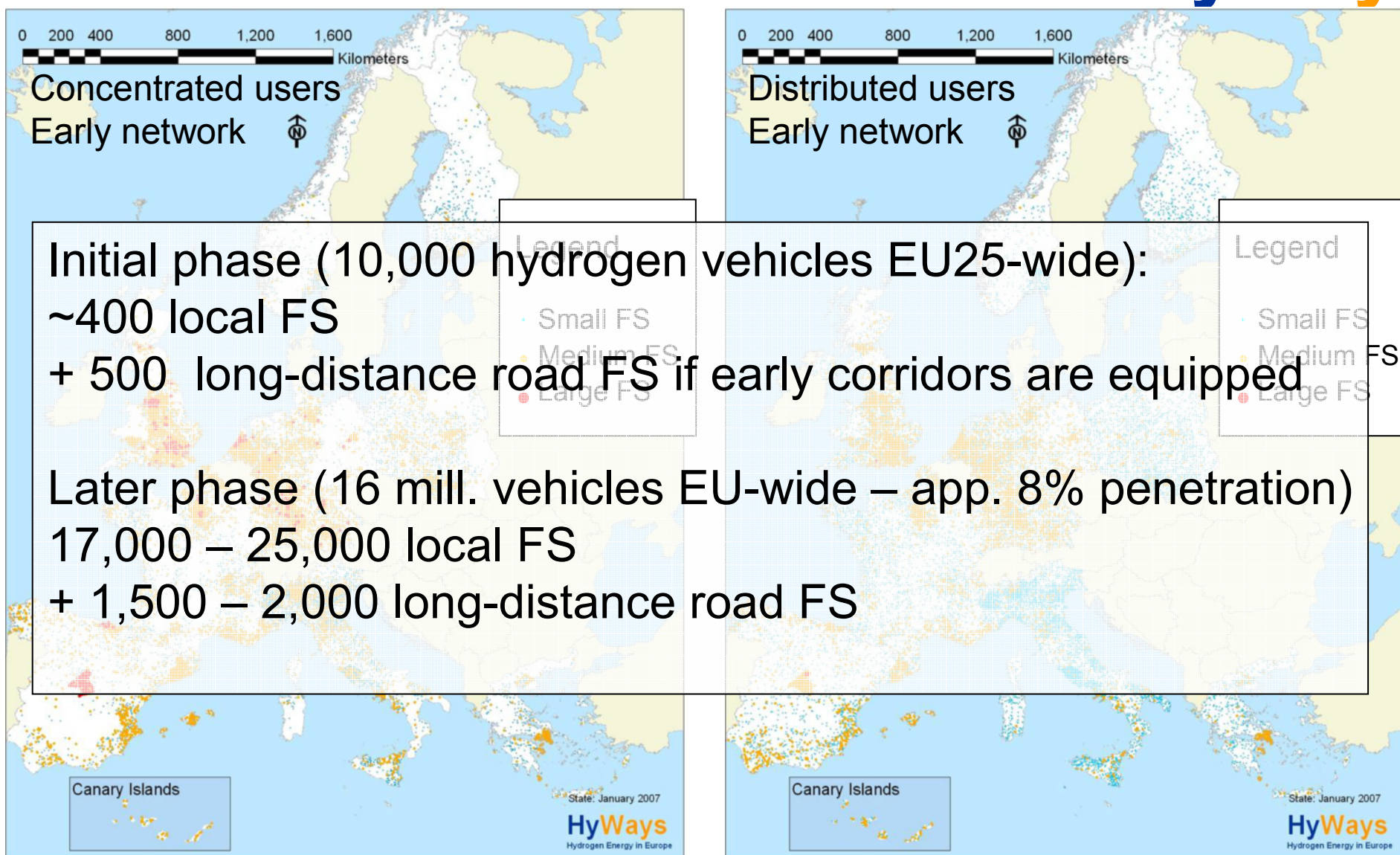
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European hydrogen map – Fuelling stations 2027 (medium penetration scenario)

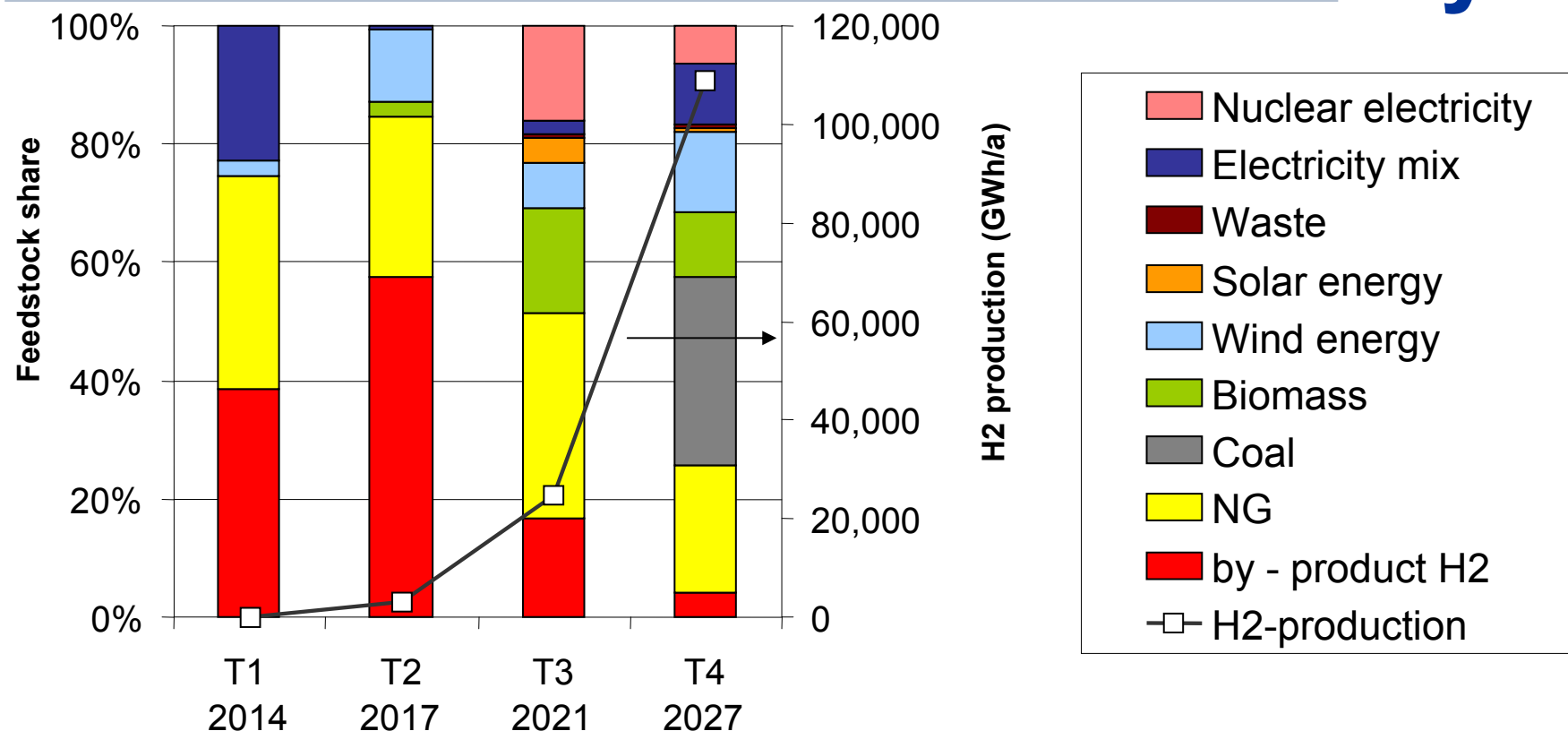
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Feedstocks and production

Applied feedstocks (aggregated)



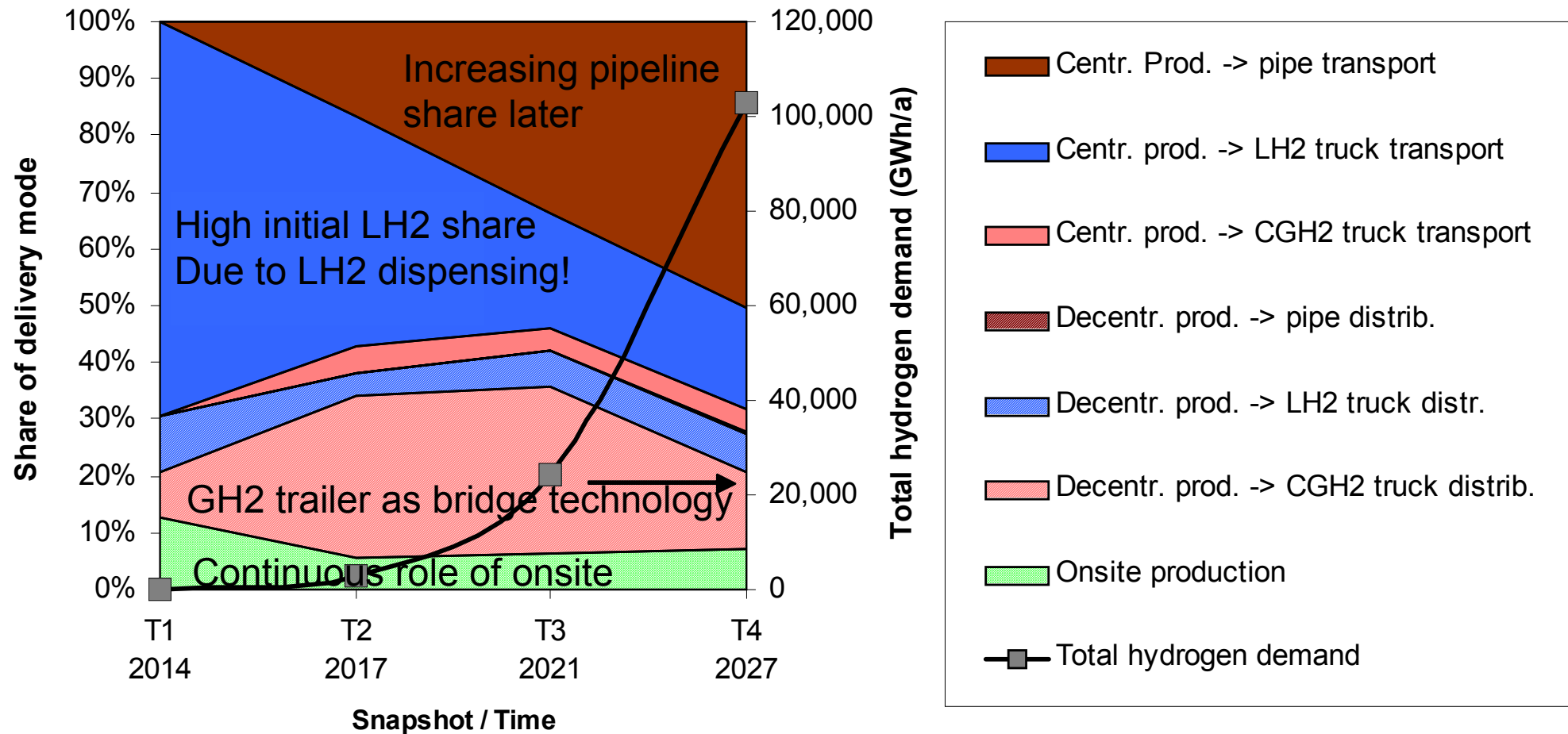
- Based on stakeholder input
- In 2027: >50% fossil fuels w/CCS
- ~ 25% renewables (wind, biomass, solar)
- Balance: Grid electricity*, nuclear, by-product

- **Strong use of renewables for H₂ production: Norway, Greece, Spain (huge resources, low population density)**
- **Nuclear energy for H₂ production expected in France, Finland, Poland**
- **High share of coal and NG in Germany, Netherlands, Poland, Italy**
- **Excess grid electricity envisaged in Norway, France, Finland, Germany**

Role of transport options

Shares resulting from infrastructure model

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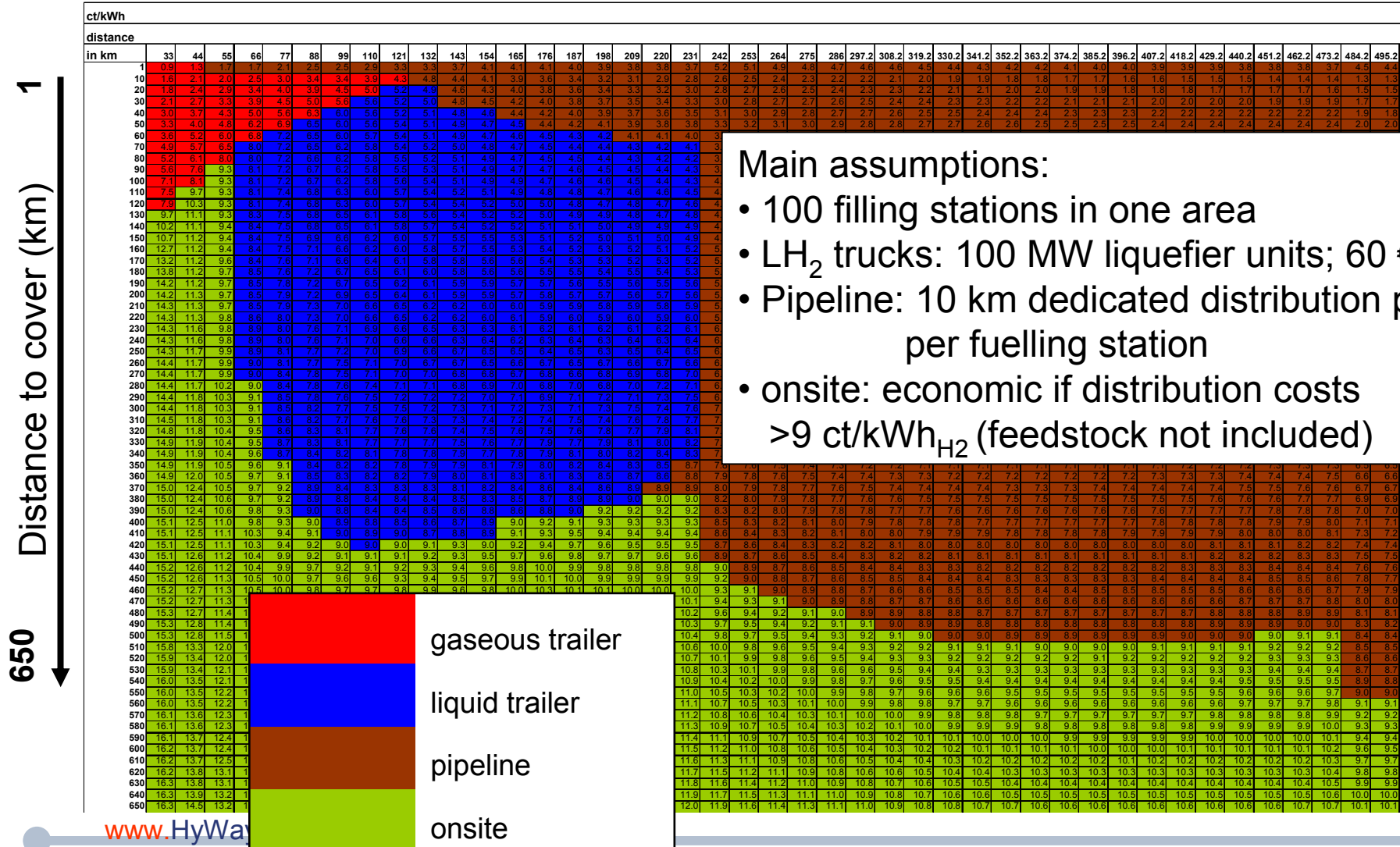
Sensitivities: Transport distances, fuelling station turnover, demand for LH₂, energy prices, density of fuelling stations

Role of transport options Decision matrix (Sensitivity Analysis)

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33 Demand per fuelling station in t/year

500



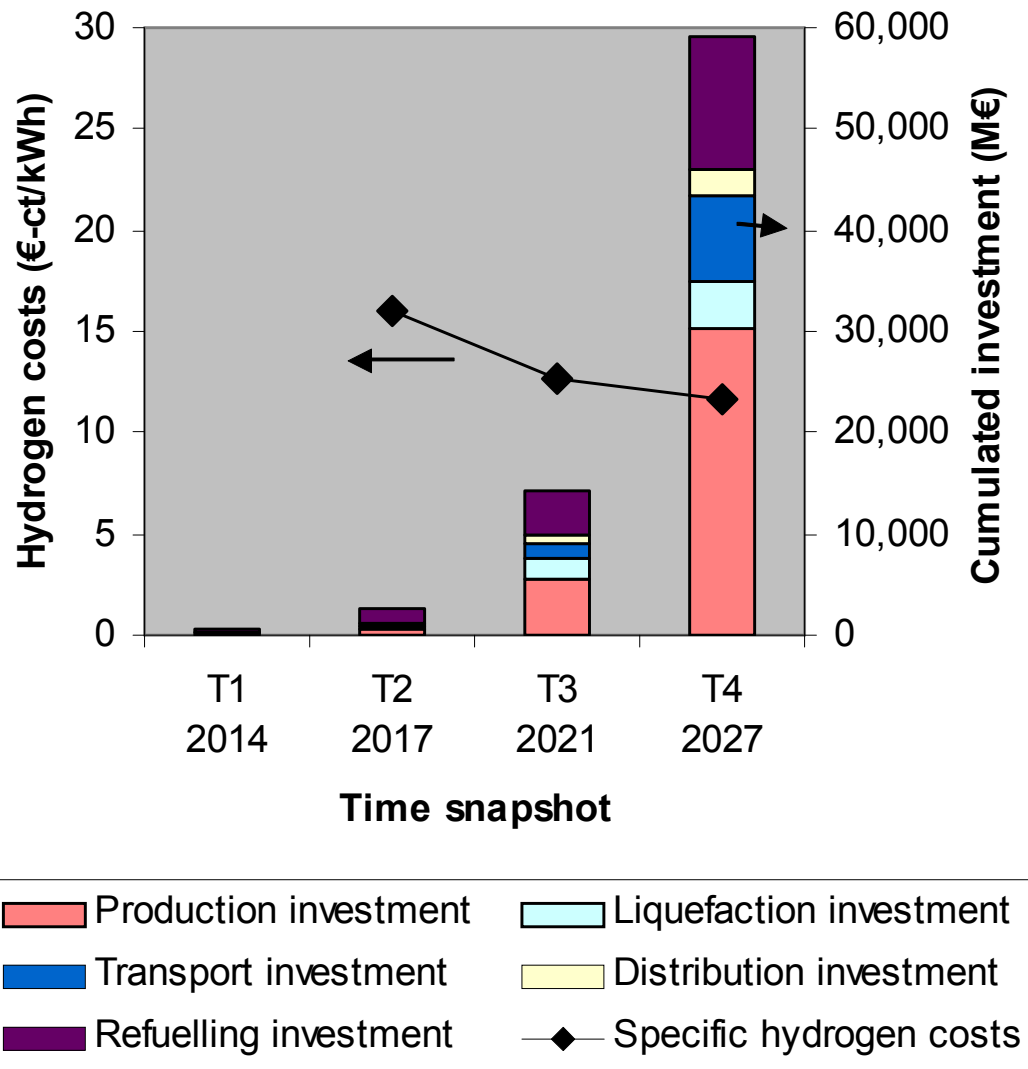
- Onsite: initial phase, permanently in sparsely populated, remote areas. But: initially low FS utilisation, later high energy prices
- LH₂ trucks: Strongly in the initial phase (NB: 20% LH₂ demand assumed – without LH₂ demand, the picture changes!). Later mainly for remote locations, competing with onsite

- **Pipelines:** Solution for central hydrogen production and transport to demand areas. Distribution pipelines in densely populated areas and for larger fuelling stations
- **CGH₂ trucks:** Mainly during transition phase from LH₂ to pipeline, but also an option for local distribution of produced hydrogen for less densely populated areas

Costs of infrastructure build-up

Cumulated investment and spec. H2 costs

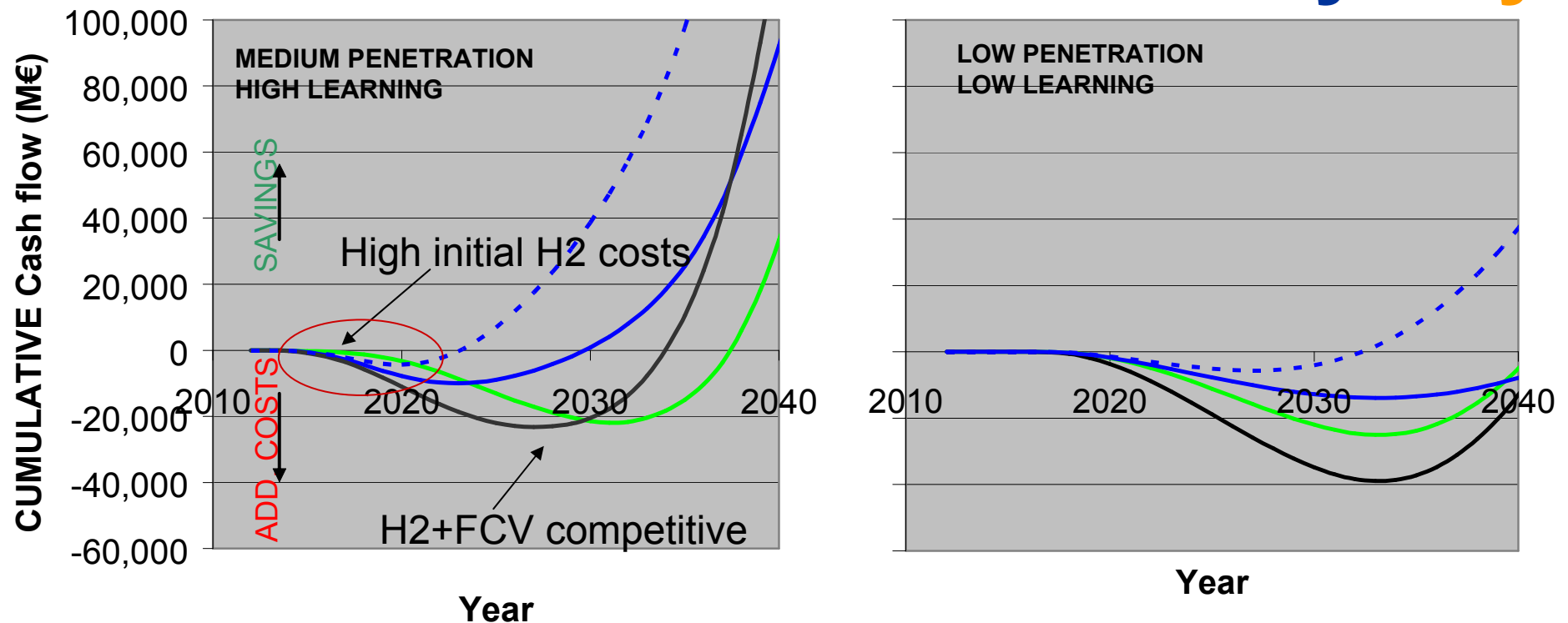
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- Low total investment in the initial phase
- Specific costs of 11-16 €ct/kWh (3.7-5.4 €/GGE) from second phase
- Transport, distribution and refueling contribute significantly to investment

Costs of infrastructure build-up

Cash flow analysis



Assumptions:

Fuel: WETO-H2 oil prices (\$66 by 2030)
 Fleet: 12 years vehicle life time;
 1000-2000 € extra / vehicle tolerable

Fuel Cash Flow:

"Conventional fuel costs
 MINUS H2 fuel costs"

Fleet Cash Flow:

"Conventional vehicle costs
 MINUS H2 vehicle costs"

— Fuel Cash Flow — Fleet Cash Flow (+1000€) — Overall Cash Flow - - - Fleet Cash Flow (+2000€)

- Initiation of hydrogen use mostly in populated areas (but also some remote areas)
- Initially, LH₂ trucks (due to LH₂ end-demand) and onsite are predominant supply options
- Later, pipelines gain ground in densely populated areas
- In the transition to pipelines, CGH₂ trucks for distribution fill a gap
- Outlook: Pipeline for dense areas, CGH₂ trucks for less dense areas, LH₂/onsite for remote areas

⇒ All supply options play a role under specific conditions

- High initial specific hydrogen costs, but low economic impact of that.
- Hydrogen costs below 6 €/GGE from second phase (i.e. 500,000 cars EU25-wide)
- H2+FCV can become economically competitive with other fuels by 2025-2030 (supposed 1000 € extra costs per vehicle are tolerable)
- Or even ~5 years earlier, assuming higher oil prices, taxation measures considering externalities or the customer's willingness to pay more for an environmentally friendly car.
- The faster the market penetration, the earlier the break-even and the higher the savings!

HyWays is an integrated project, co-funded by the participating research institutes, companies and national agencies and by the European Commission (EC) under the 6th Framework Programme [contract N° 502596].

Thanks for your attention!