Hydrogen Trains and Infrastructure in Germany

Case Study

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„FCH-JU and Shift2Rail Hydrogen Train Workshop"

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Renewable wind hydrogen energy seems promising, but are there business plans ready to be implemented?

Project goal

- To assess expansion and development opportunities of a hydrogen storage economy

Project scope

- Detailed (current) market analysis & sensitivity analysis
- Analysis of economic efficiency of hydrogen
- Analysis of framework conditions of hydrogen marketability
- Identification of favourable regulatory frameworks

Project deliverables

- Assess economic viability at current stage and derive operating models (plans)
- Analyze relevant (pipeline) path
- Development a suitable future roadmap for implementation

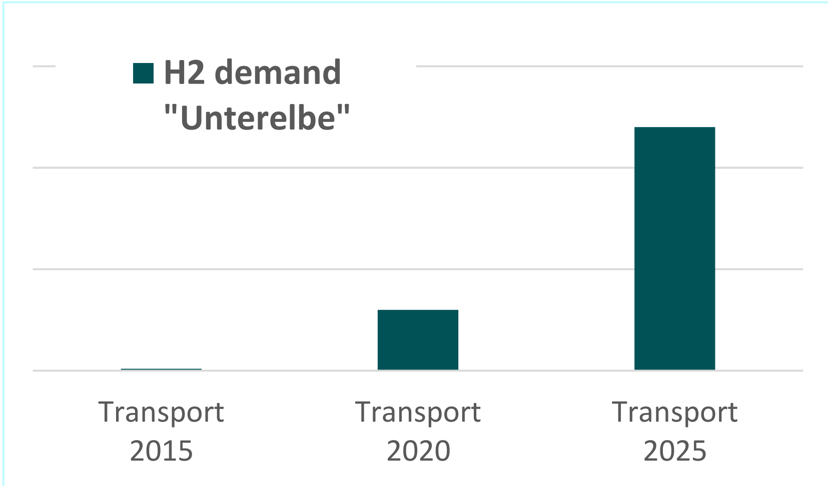
1. Objectives

Case Study:

Realisation of a Wind Hydrogen Economy

(ChemCoast)

http://www.chemcoast.de/



Currently hydrogen is primarily generated and consumed as industrial gas at place of use, only 5% is transported and traded

Major insights

- Increasing demand for green hydrogen, but for implementation following conditions are essential:
  a) Exemption of grid fees and similar cost allocations
  b) Exemption from EEG apportionment (H2 as transport fuel)
  c) Exemption from the prohibition of multiple sales

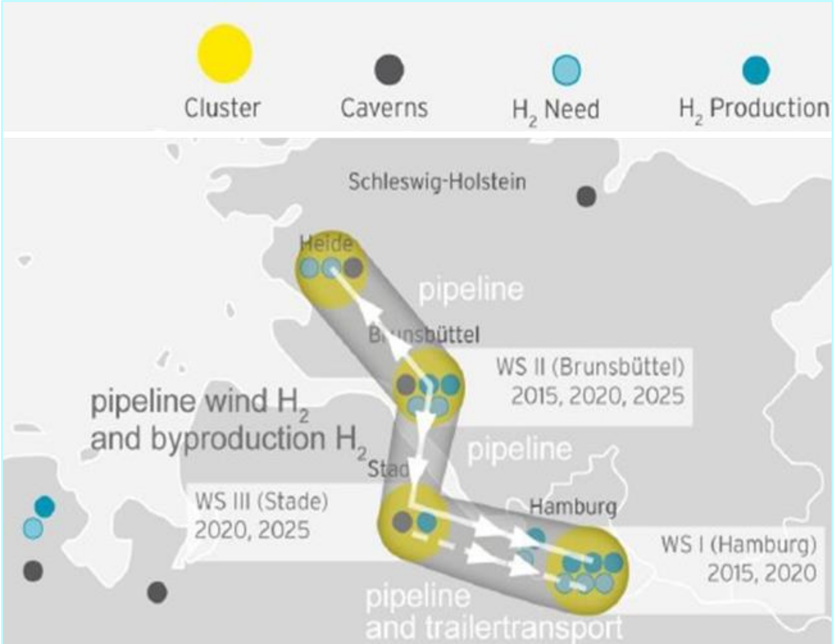
Roadmap for implementation

- Phase 1 (2015): laying foundation for renewable wind hydrogen use by industry
- Phase 2 (2015 – 2020): market growth through maturing transport sector
- Phase 3 (2020 – 2025): shift towards supplier market through decreasing production costs

Principle challenge for green hydrogen: “market price”

- Substitution of brown by green hydrogen is unlikely (price difference approx. 5 EUR/kg)
- But, commitment for sustainability in public transport and targets for reduction of CO2 emissions is a great chance

2. Main insights



Today, **key hydrogen demand** comes from industry (chemical, petrochemical and steel industry + transport sector)

While technology is available, key challenges are hydrogen production, transport, storage and finding the right business case

Project goal

- To study necessary technical, legal and economic conditions for sustainable supply of hydrogen (H2) to existing rail infrastructure in Germany

Key project deliverables

- Detailed technical analysis (feasibility)
- Economic viability check and definition of operator models that facilitate H2 supply
- Campaign to increase market acceptance

Project framework

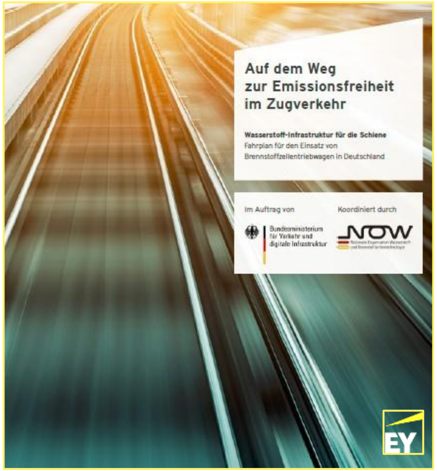
- About 50% of German rail network is not electrified
- Overhead wire construction is cost intensive, not profitable on little-used sections and not wanted in scenic areas
- To reduce emissions, electric trains with hydrogen-operated fuel cells are a promising alternative
- However, required H2 supply infrastructure is not yet present

1. Objectives

Case Study:

Towards zero emissions in rail transport

(BMVI, NOW)



bmvi-wasserstoff-infrastruktur-fuer-die-schiene.pdf

To ensure feasibility, not only hydrogen production, supply and filling must be considered, but also the implementation of suitable routes

Sources of hydrogen for railways

Potential H2 sources

- By-product of industrial processes
- H2 generation in natural gas steam reformer
- H2 generation by electrolysis

Hydrogen logistics and supply paths

- On-site electrolysis, Pipeline, Tank container by truck, Rail tank

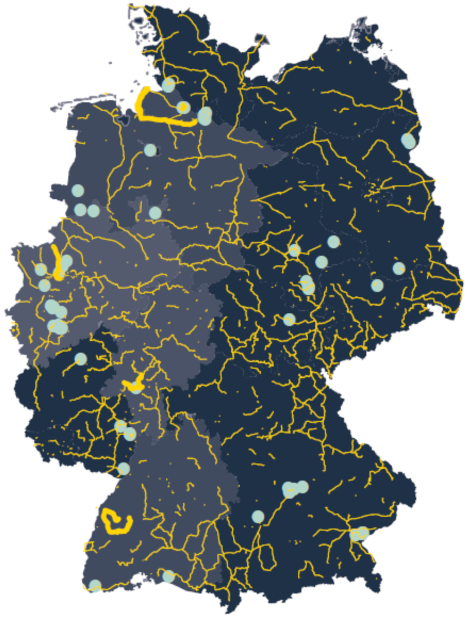
Filling stations

- Technology already existent
- Daily demand about 1.5 – 2 tons (150kg per train)

Best-fit routes

a) Speed 120 – 160 km/h
b) Roundtrip about 650km
c) Filling time about 45 minutes/train
d) High number of stations/uneven territory

2. Technical feasibility



Pilot regions, DE

- Lower Saxony
- North Rhine Westfalia
- Hesse
- Baden-Wuerttemberg

Reference route *(example)*:

Buxtehude-Bremerhaven-Bremervörde-Cuxhaven-Buxtehude

240km & 44 stations

Fuel energy required compared to diesel: **-29%**

Economic viability can be achieved but only with the right legal framework and while competing with established diesel technology

Under the right circumstances and the right operator model, hydrogen outperforms diesel for railways

- Economic efficiency advantage **4.8% / train**
- Potential of further cost reduction effects: **15%**
- Removal of diesel fuel subsidies: **3.2%**
- Total possible economic efficiency advantage: **23%**

Operator Model 1 – Separate contracting of H2 provision

Operator Model 2 – Provision with integrated awarding of H2 supply

In order to increase market acceptance for hydrogen

- Set-up Project Office for aligning communication activities
- Continuous analysis of awareness of all actors
- Involve local population, local politicians, associations, NGOs
- Celebratory event of inauguration
- Share experience through specialist articles and events

3. Economic viability

	Einheit	Wasserstoff-Infrastruktur	Diesel-Infrastruktur
		Brennstoffzellenantrieb	Dieselantrieb
Einmalige Investitionskosten			
Angenommene Investitionskosten pro Zug	MEUR	ca. 5,3	rd. 4,3
Jahreslaufleistung	km/Jahr	200.000	200.000
Laufende Betriebskosten			
Betriebskosten			
Instandhaltung ohne Nebenkosten	EUR/km	0,72	0,80
Treibstoffkosten			
Treibstoffverbrauch	kg H2/km bzw. l Diesel/km	0,23	1,20
Betankung frei Zapfpistole	EUR/kg H2 bzw. EUR/l Diesel	5,05	1,10
Gebühren			
Trassenpreise	EUR/km	2,25	2,25
Preise je Stationshalt	EUR/Station	2,47	2,47
Infrastrukturbereitstellungs-kosten (laufende Kosten)	MEUR/Jahr	0,92	0,96
Korrekturfaktor für Reifegrad der Technologie	Faktor	0,85	–
Subventionen	EUR/l Diesel	–	0,18
Bereinigte Infrastrukturbereitstel-lungskosten (laufende Kosten)	MEUR/Jahr	0,78	ca. 1,0

Vergleich Kostenpositionen Dieselantrieb und Brennstoffzellenantrieb pro Zug und Jahr

Thank you very much for your attention!

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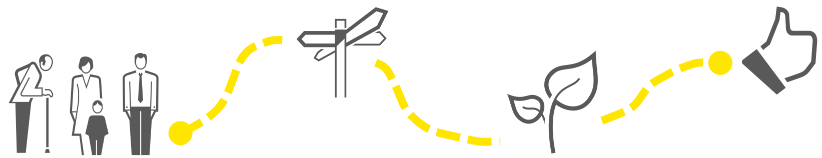


Backup

Better questions lead to better answers

Backup

Case Study: Realisation of a Wind Hydrogen Economy (ChemCoast)

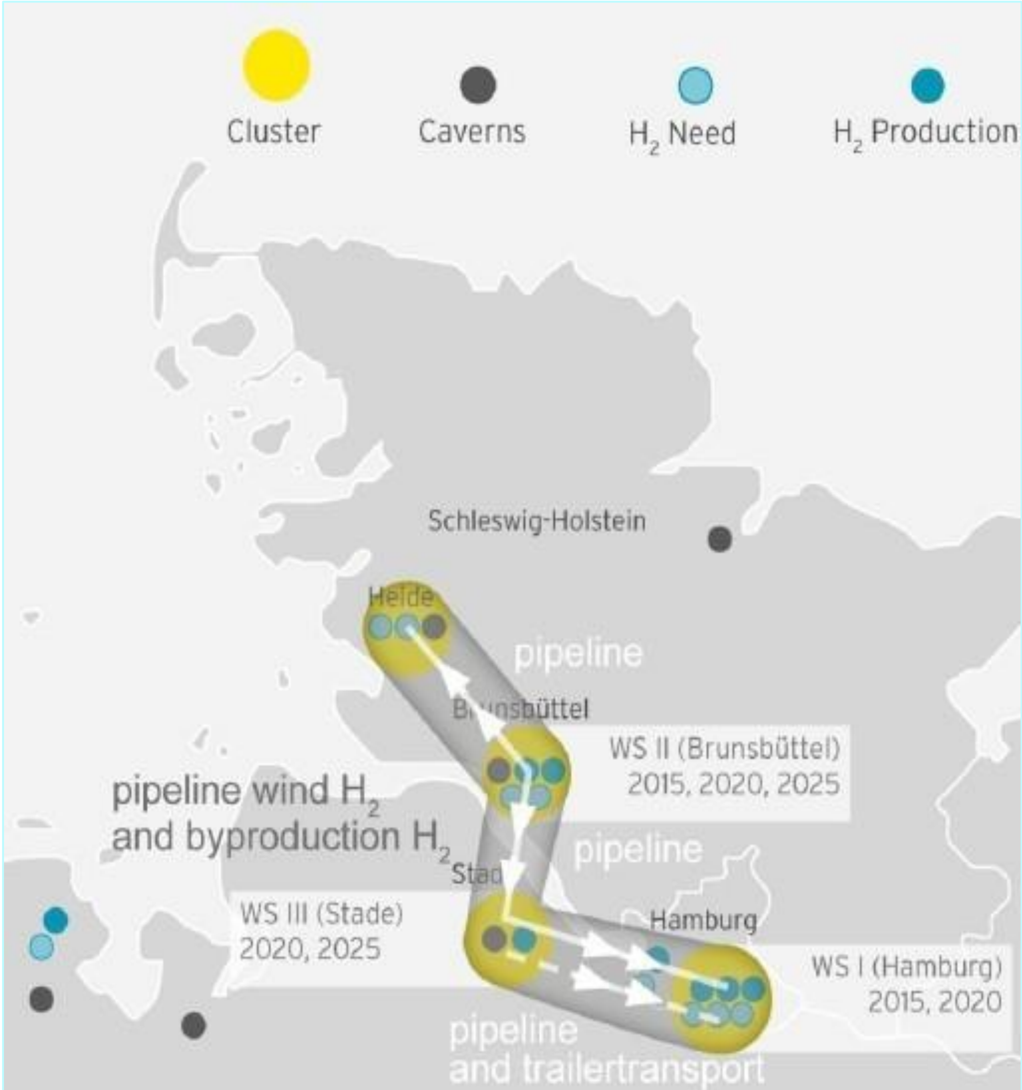
Options for operator models

Three value added paths

- Path I: Hamburg
- Path II: Brunsbüttel – Heide
- Path III: Stade region

Three development phases

- By 2015: laying foundation for renewable wind hydrogen use by industry
- 2015 – 2020: market growth through maturing transport sector
- 2020 to 2025: shift towards supplier market through decreasing production costs



„Roadmap 2025“ - **Example - Path 1: Hamburg**

Phase 1: Laying of foundation by 2015

- Construction of an industrial electrolysis plant with 20 MW electric input power
- Investments of 16.3 MEUR
- In first step only yellow hydrogen to meet industry demand

Phase 2: Market growth 2015 - 2020

- Total demand of 2.2k t of yellow hydrogen
- Construction of 3km pipeline
- Increase capacity through expansion of electrolysis plants (to 34 MW)

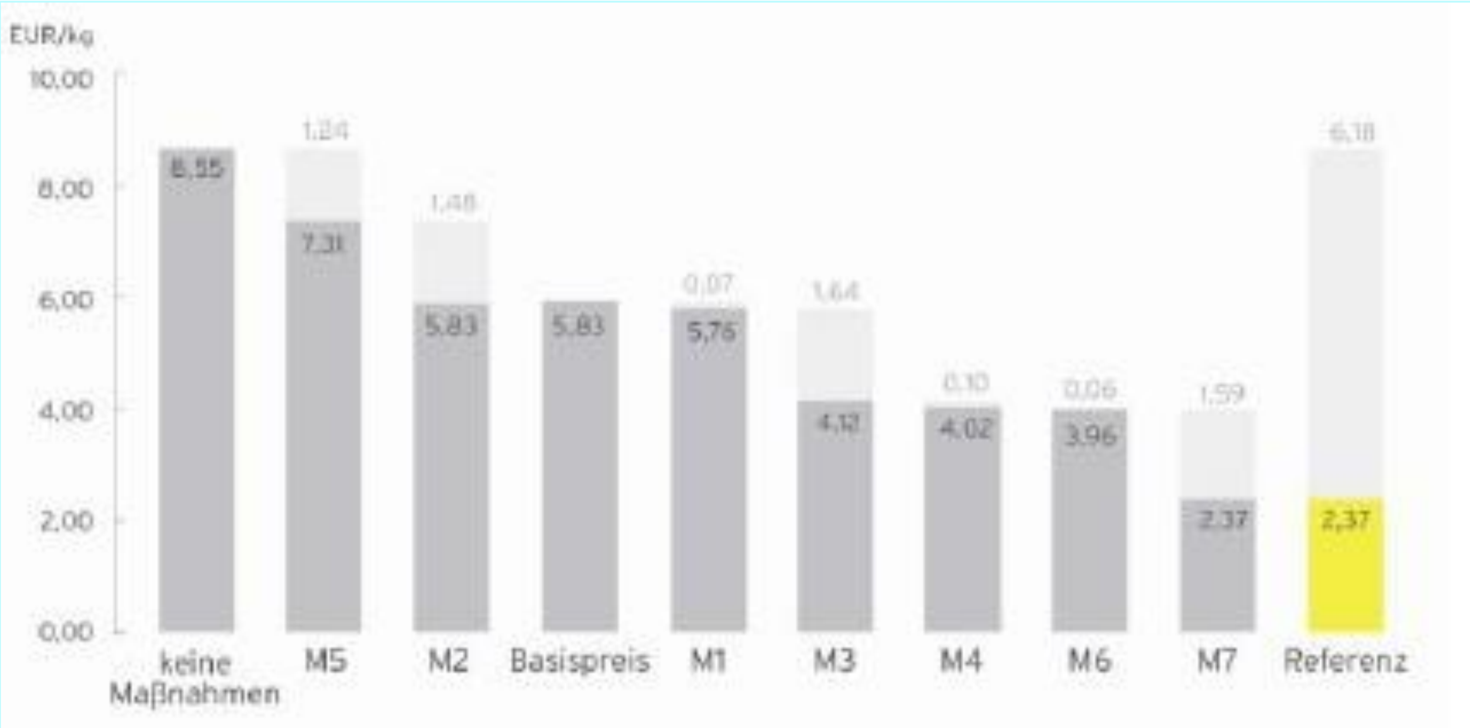
Phase 3: Shift towards supplier market 2020-2025

- Transport sector main consumer of green hydrogen with demand of 7k t p.a.
- Stade region will have electrolysis capacity of 156 MW electric input power to meet industry and transport sector demand

Markt launch of green hydrogen

Market launch plan

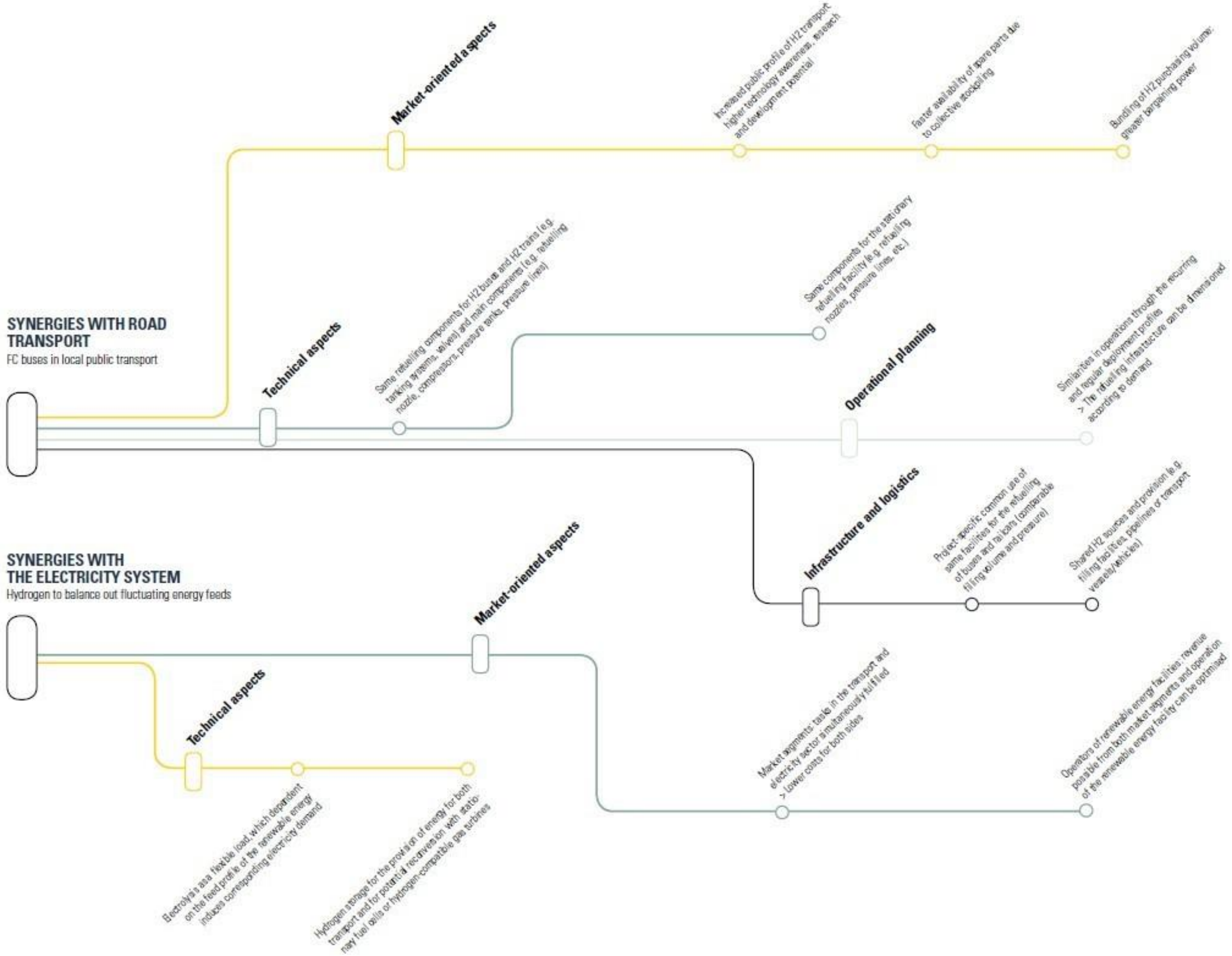
- Infrastructure build up by Public-Private-Partnership Projects
- Market incentive programme
- Price mechanism (EEGasG with direct marketing)



Backup

Case Study: Towards zero emissions in rail transport (BMVI, NOW)

Synergies with road transport and electric system



Options for operator models

- Option 1 – Provision with separate contracting of hydrogen provision
  - Conventional procurement of vehicles
  - Commissioning authority vehicle pool

- Option 2 – Provision with integrated awarding of the hydrogen supply
  - H2 Service Model
  - LNVG H2 Model
    - All advantages of commissioning authority vehicle pool
    - Provision of vehicles and (hydrogen) infrastructure under one roof
    - Assumption of risks (esp. technical) by private partners
    - Reduction of the competitive landscape (disadvantage)