Hydrogen in the Transport Sector

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Hydrogen projects since 1997, including:

- **Techno-economic analyses of wind-hydrogen systems and hardware projects**
- **Demonstration of fuel cell road vehicles and hydrogen stations**
  - **Performance assessment, technology validation**
  - **Documentation of lessons learnt und best practices**
- **Project reviews for funding bodies, consulting for “hydrogen-ready” bus depots, …**
- **Study on hydrogen in the maritime sector**

Overview

1. **Why hydrogen as a vehicle fuel?**
2. **Why does it take so long to introduce hydrogen in the transport sector?**
3. **What are the challenges that remain?**
4. **Conclusions**

<u>Aim of the talk</u>:
Highlighting aspects by example, not attempting to be exhaustive

1. Hydrogen in a Nutshell

- **Use of hydrogen (H_2) for more than 100 years in industry**
  - **Non-energetic (e.g. fertiliser synthesis and fat hardening)**
  - **Indirect-energetic (e.g. desulphurisation of petrol/diesel)**
- **Energetic use: H_2 main constituent of town gas**

- **Properties similar to methane (“natural gas”)**
- **Currently: Generated from hydro-carbons mainly, typically natural gas and coal**
- **Future: Importance of water electrolysis expected to grow, with electricity from renewable sources**

1. Hydrogen as an Energy Carrier and Storage Medium

H_2 is universal secondary energy carrier, like electricity

- **Generation**
  - **From a wide range of energy carriers, particularly from fluctuating renewable sources**
- **Storage**
  - **Relatively easy, also in huge amounts (unlike electricity), for balancing supply and demand**
- **Use**
  - **Stationary, mobile and portable**
  - **In internal combustion engines, fuel cells and gas turbines**
  - **Contribution to sector coupling as part of the “Energiewende” (particularly coupling power, heat, mobility and industry)**

1. Why Hydrogen as a Vehicle Fuel?

- **H_2 used in fuel cells (FCs):**
  Generation of power, heat and water vapour only,
  → No local emission of CO_2 or pollutants
- **H_2 generated from renewable power sources**
  → Low emissions also on a “well to wheel” basis

- **Buzz phrase “Power-to-Gas”**
  - **Power-to-Hydrogen: Generation of H_2 via electrolysis**
  - **Power-to-Methane: Subsequent synthesis of methane (CH_4), adding CO_2 / CO**
- **Power-to-Liquids (e.g. methanol), Power-to-Chemicals, …**

1. Energy Densities of Fuels and Batteries

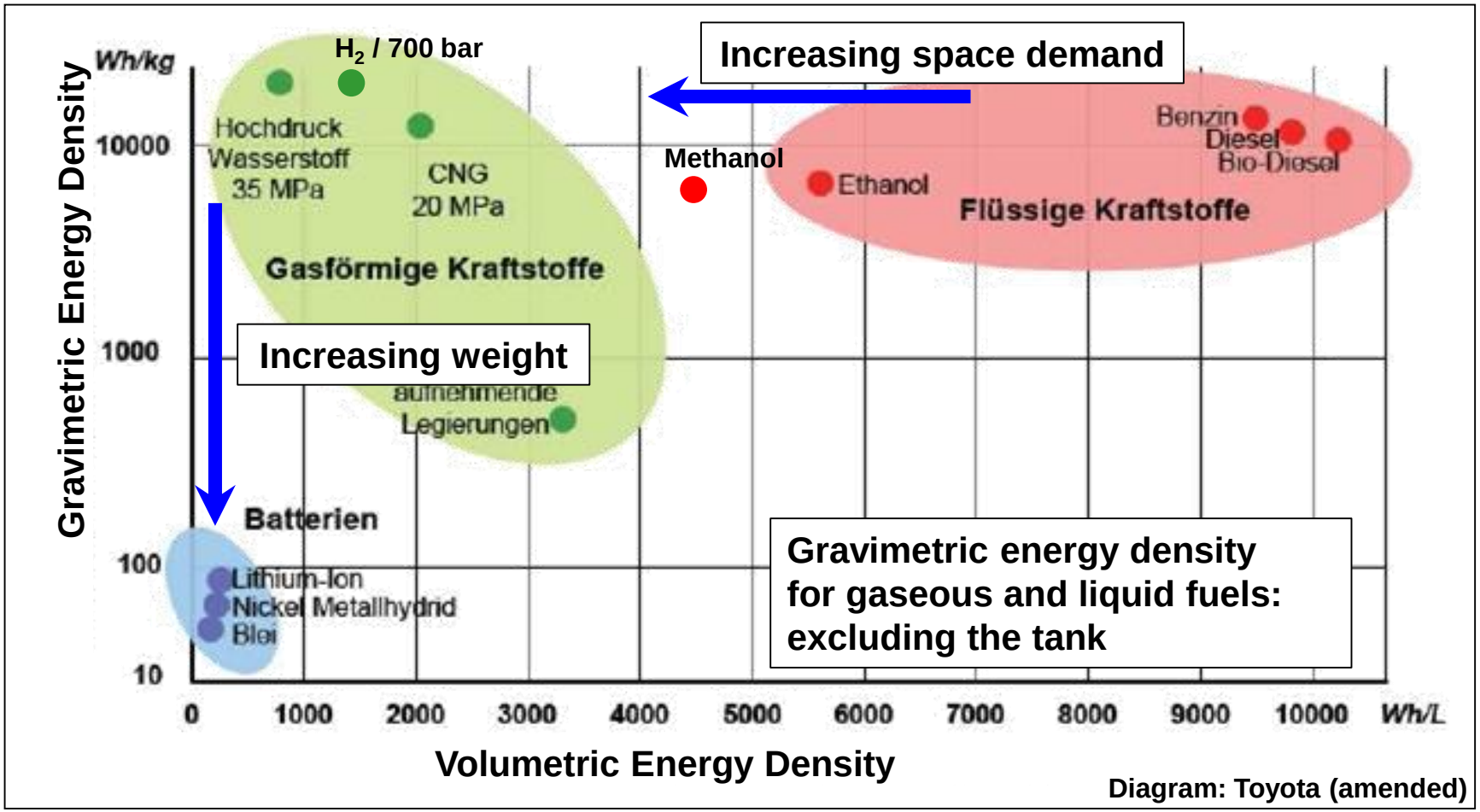
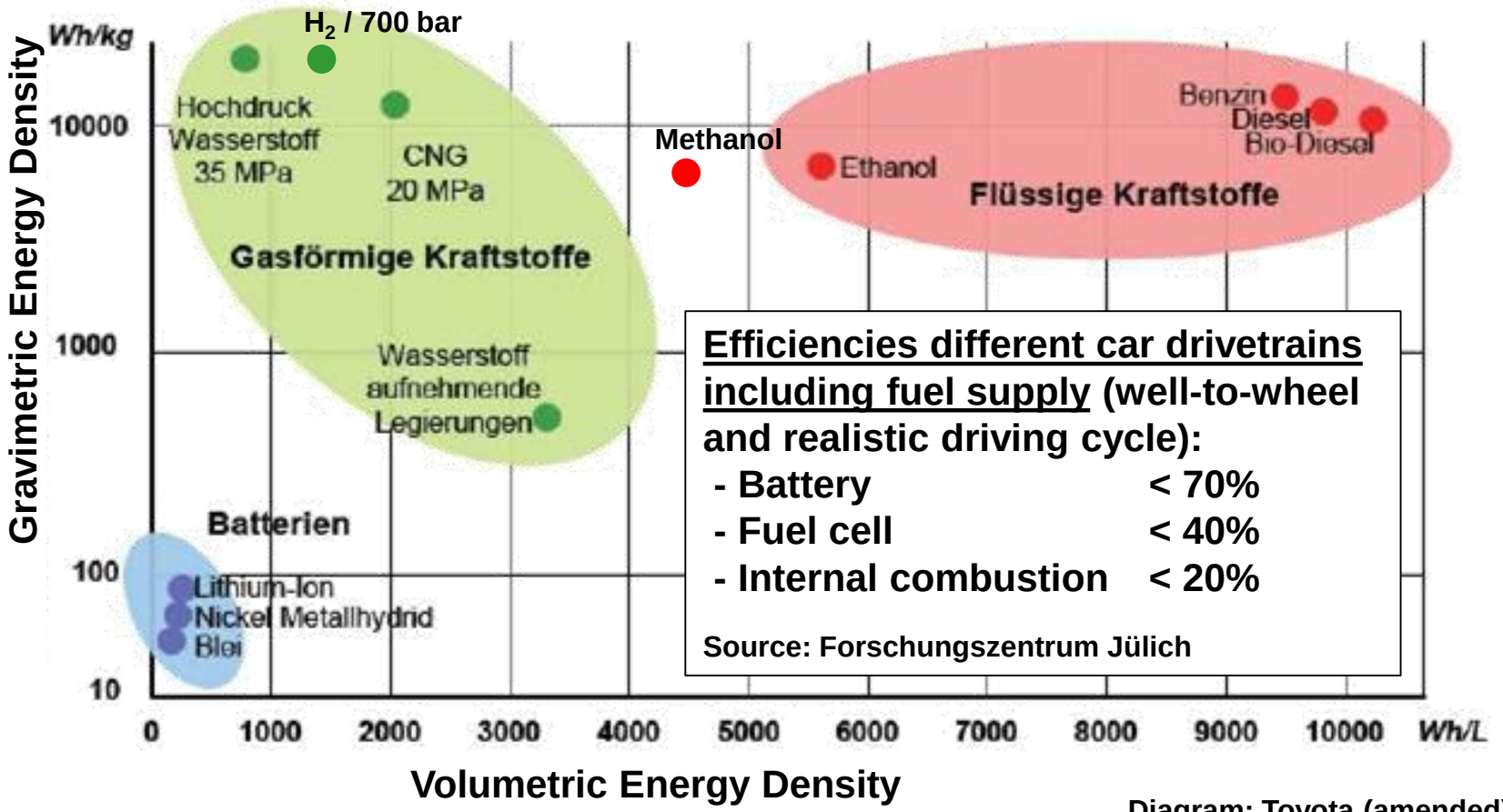


Diagram: Toyota (amended)

1. Energy Densities and Vehicle Efficiencies



Efficiencies different car drivetrains including fuel supply (well-to-wheel and realistic driving cycle):

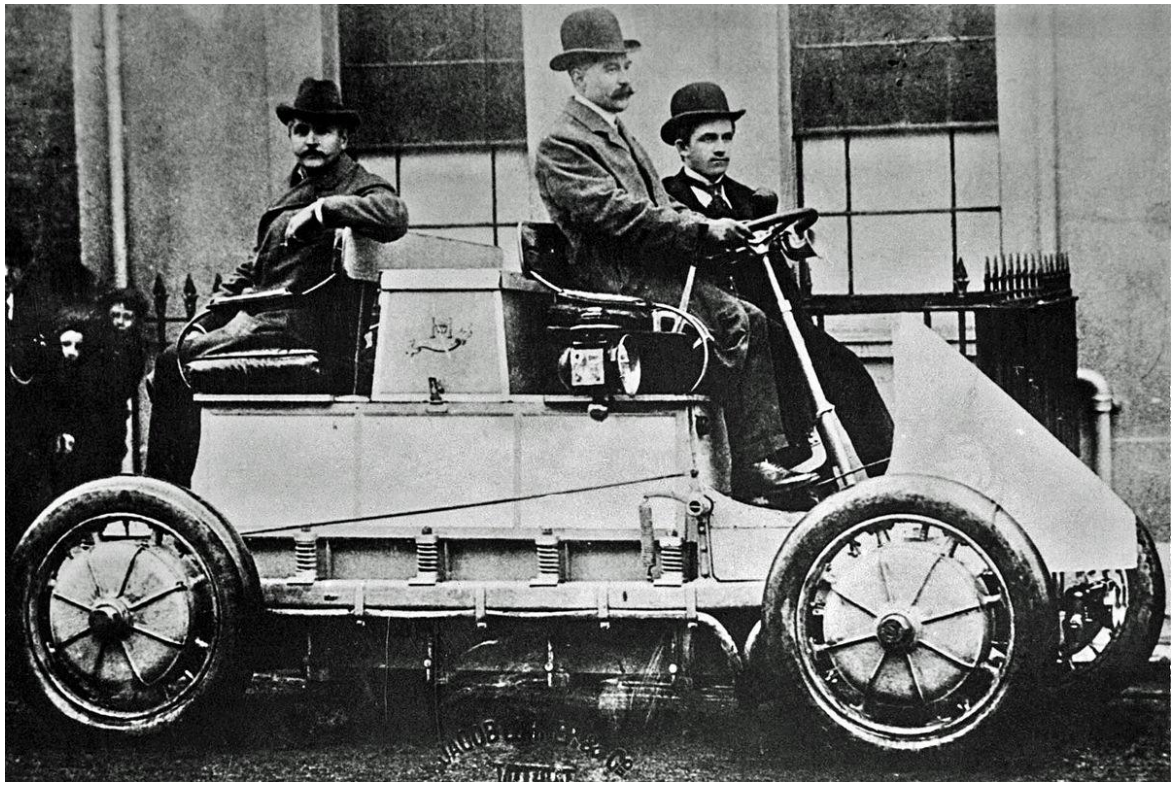
- **Battery < 70%**
- **Fuel cell < 40%**
- **Internal combustion < 20%**

Source: Forschungszentrum Jülich

Diagram: Toyota (amended)

2. Why does it take so long to Introduce Hydrogen in the Transport Sector?

<u>Back answer</u>: Why does it take so long to introduce battery electric vehicles in the transport sector?



Lohner-Porsche, battery-powered, four-wheel drive, built in 1900

Source: de.wikipedia.org/wiki/Lohner-Porsche

2. Why does it take so long to Introduce Hydrogen in the Transport Sector?

- **Powerful competitors: Petrol and diesel**
- **Changes in the energy sector always take a long time**
- **Difficult to talk about “the transport sector” or “mobility” in this context**
  → Look at cars, buses and trains individually

Pictures: PLANET / PLANET / Alstom

2. Fuel Cell Cars / 1

- **Cars are mass market item, unlike ships**
- **Space is scarce, cost pressure high, compactness a cost driver**

Source: DaimlerChrysler

2. Fuel Cell Cars / 2

Toyota Mirai (2014)

Picture: PLANET

Fundamental agreements, early and across the globe:

- **Hydrogen is the fuel, not e.g. methanol (with on-board reforming)**
- **It is 700 bar for cars, not 200 or 350 bar or liquefied hydrogen**

2. Fuel Cell Cars / 3

- **Picture: Hyundai Nexo (2018)**
  - **Range > 700 km, filling time < 5 min**
  - **Price ≈ 70,000 € → no mass market FC cars yet**
- **Ramping up the market for FC cars will take time**
  - **Asian manufacturers ambitious, e.g. target of 30,000 units/year**
  - **German ones are working on it, but seem overly cautious**
- **(At least) two chicken and egg problems to be overcome:**
  - **No refuelling infrastructure ←→ No vehicles on the road**
    → H2 MOBILITY Deutschland to build the first 100 stations by 2020 and another 300 by 2025 depending on vehicle numbers
  - **Small vehicle numbers ←→ Poor supply of spare parts**

2. Buses (Fleet Vehicles)

Picture: PLANET

- **FC buses as a “drop in replacement” for diesel vehicles**
  - **No changes in operation but regarding fuel supply, refuelling and maintenance**
- **Quiet, clean, less vibrations → Drivers and passengers like them**
  - **But: “A bus is a bus” → First of all it must run and be on time. → Reliability is key (chicken-and-egg problem re. spare parts)**
- **Cost of ownership still high, cost pressure on operators**
  - **→ External (political) drivers needed for introducing zero-emission buses**
  - **→ Typically air quality problems or CO_2 reduction targets, for example in Hamburg, London, … and Oldenburg**
- **Strong interest and (again) “cautious” German manufacturers …**

2. Trains (Fleet Vehicles)

Picture: ALSTOM

- **Substitute diesel trains where installing overhead wires is not economical**
- **Two prototypes in operation from summer, line Buxtehude – Bremervörde – Bremerhaven – Cuxhaven**
  - **Contract signed for 14 trains to operate from 2021/22**
  - **Strong interest in other German states and abroad!**
    → German competitor has woken up …
- **Study shows: Competitive operating costs with “non-green” H_2, while still reducing CO_2 emissions**
- **Even longer-term investment than buses**
  → Manufacturer offers a package including fuel supply, refuelling and maintenance

3. What are the Challenges?

<u>Demonstration project have proven</u>:

The remaining challenges are

- **No longer of (fundamental) technical nature**
- **Mainly found in the (techno-) economic and regulatory domains**

3. Techno-Economic Challenges

- **Advancement and optimisation of FC systems, including**
  - **Reduction of material and manufacturing costs**
  - **Improvement of lifetime**
- **Further industrialise the manufacturing of electrolysers and fuel cells, internationally competitive**
  - **Hard cost targets, particularly in car manufacturing**
- **Reliability targets not always met yet**
  - **Fast supply chains also needed for spare parts which are still “exotic” today**

3. Regulatory Challenges

- **Legal frameworks, and regulations, codes and standards were made for the “old world” and have to be adjusted, for example, to**
  - **Account for hydrogen and its specifics**
  - **Enable sector coupling and make it economically feasible**
- **Be ahead of the game in terms of shaping international standards**
- **Regulatory bodies, particularly local ones, need to get acquainted (Golden Rule is to “Educate your regulator”)**

Moreover:

- **Job profiles will change,**
  therefore the requirements for education and training
- **Results from demonstration need to be disseminated better**

4. Conclusions

- **Hydrogen and fuel cells**
  - **Can help to drastically reduce the emissions from mobility**
  - **Have the strong competitors petrol/diesel and the internal combustion engine, in terms of performance and costs**
- **H_2/FC technology has been proven in demonstration projects.**
  - **Yet their market penetration will take time, depending on e.g. policies regarding air quality and decarbonisation**
  - **Medium-term and long-term changes lie ahead with significant challenges**
- **Some German manufacturers seem to need a push**

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OLEC | Arbeitskreis H_2

Energie bewegt den Nordwesten

Batterie und Brennstoffzelle in der Mobilität: Synergien oder Konkurrenz?!

- *Welche Technologie bietet wo welche Vorteile?*
- *Was muss passieren, damit welche Technologie Erfolg hat?*
- *Kann man sich die Verfolgung beider Technologien leisten?*

www.energiecluster.de/wasserstoff

Veranstaltungsort:

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Thank you for your attention!

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