COMPARATIVE ANALYSIS OF INFRASTRUCTURES // Hydrogen Fuelling and Electric Charging of Vehicles

Study for H2 MOBILITY by Forschungszentrum Jülich
(preliminary results, final study to be released end of October)

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presented first at EVS Stuttgart

All graphs and numbers are from the study "Comparative analysis of infrastructures: …" if not quoted otherwise.

Nikolas Iwan | H2 MOBILITY | 10 October 2017

WHAT IS THE INVESTMENT REQUIRED TO FUEL OR CHARGE 20 MILLION EV'S?

H2 MOBILITY WASSERSTOFF TANKEN

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We want to provide a solid foundation on which to discuss the cost of infrastructure!

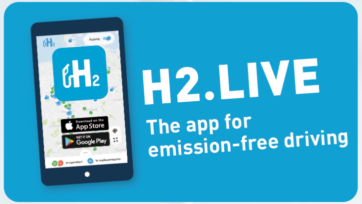
- Is the infrastructure for FCEVs expensive?
- What about BEVs?

Available literature does not give us the answers we need!

- Comprehensive analysis of 79 existing studies with focus on Germany
- Assumptions behind the studies are mostly not provided or transparent
- General tendency: H2 infrastructure is seen to be expensive, no results for higher numbers of BEV so far

THE STUDY WAS CONDUCTED BY FZ JÜLICH ON BEHALF OF H2 MOBILITY

H_2 MOBILITY
WASSERSTOFF TANKEN



- Our mission:
  the customer friendly hydrogen infrastructure in Germany
- We plan, build and operate H_2 refuelling stations
- Currently 25 people

JÜLICH
FORSCHUNGSZENTRUM

- Institute of Energy and Climate Research / Electrochemical Process Engineering (IEK-3)
- Team: Martin Robinius, Thomas Grube, Patrick Kuckertz, Jochen Linßen, Markus Reuß, Peter Stenzel and Detlef Stolten

THE FUTURE OF OUR ENERGY SYSTEM WILL BE SUNNY AND WINDY!

Working assumptions about the energy of the future

- The electrification of the energy system in Germany and the growth in renewable energy is an irreversible trend for decades to come.
- It will lead to at least 80% “green” electricity.
- The renewable electricity generation will be dominated by wind and solar.

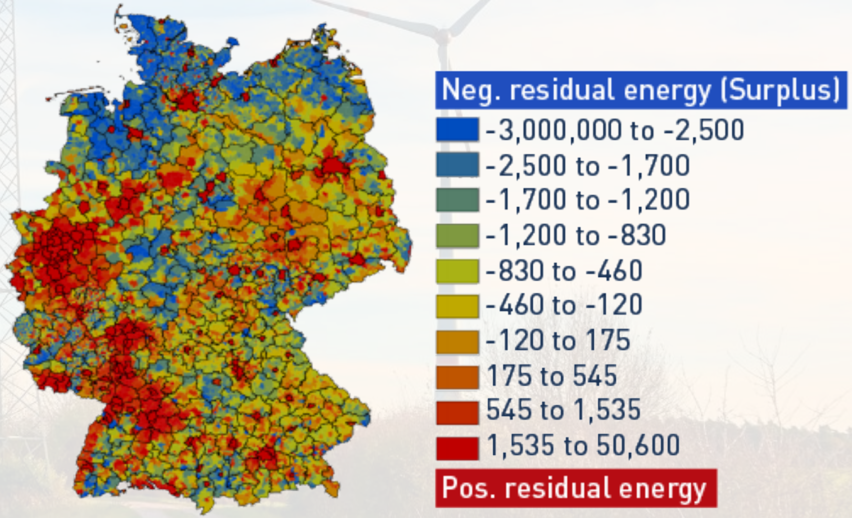
The electricity supply will become increasingly volatile!

AT 80% RENEWABLE ELECTRICITY THERE WILL BE A SIGNIFICANT RESIDUAL ENERGY OF AROUND 270 TWH …

Electricity surplus set to increase

- High residual energy generation thanks mainly to onshore (N-E) and offshore (N-W) wind
- At 80% green electricity, annual surplus can reach 270 TWh
- Note: 90 TWh will be enough to power half of the fleet in Germany with H2 (or 20 million FCEV)

Residual energy MWh/km2



Source: Robinius, 2015

... AND EVEN THE PERFECT GRID WON'T HELP

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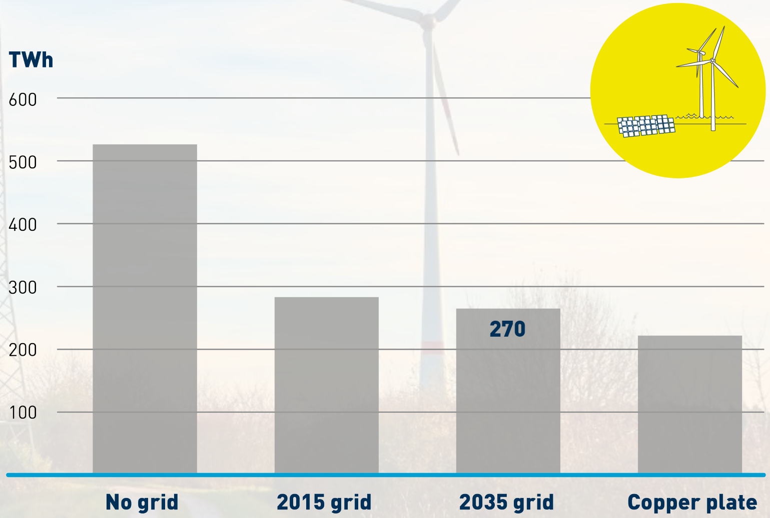
The grid will not solve the problem!

- Even a perfect grid will reduce surplus by only 50 TWh – from 270 to 220 TWh
- The wind doesn't (always) blow and the sun doesn't (always) shine when demand requires it

Curtailment of renewable energy



THE COMPONENTS OF INFRASTRUCTURE FOR EV'S USED IN THE MODEL

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Transmission grid

Distribution grid
(cables, transformers, etc.)

Home or (slow) street charger, 3.7 – 22 kW depending on scenario

Fast charger, 150 – 350 kW

H_2 production via electrolysis with storage in underground caverns

Transport by trailer with tubes storing GH_2

Transport via pipeline GH_2 grid

Sale of hydrogen at HRS (hydrogen refuelling stations)

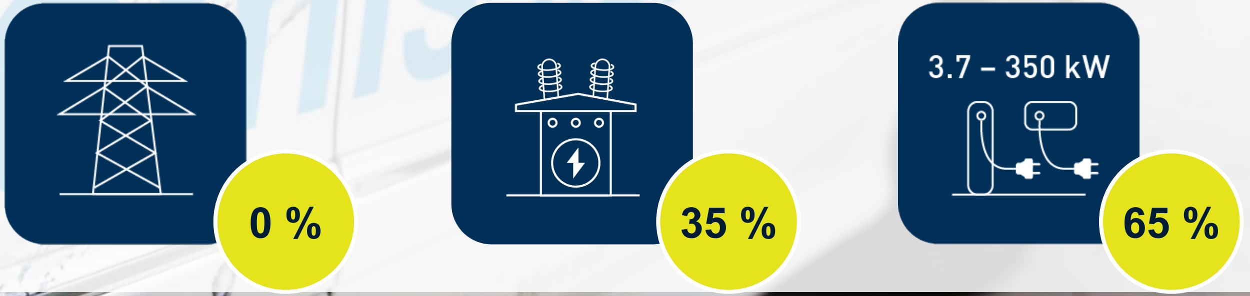
ONE THIRD OF THE TOTAL INVESTMENT FOR 20 MILLION BEV'S GOES TO DISTRIBUTION GRID EXPANSION

- No additional investment in transmission grid assumed
- Grid in 2035 (as per NEP)

- 35% of total investment for upgrading cables and transformers

- 65% of investment in chargers (slow and fast)

Prod./storage → Transmission → Distribution → Sale



THE INVESTMENT IN ASSETS TO USE SURPLUS ELECTRICITY FOR GREEN HYDROGEN PRODUCTION DRIVES THE INVESTMENT OVERALL

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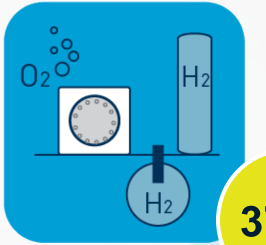
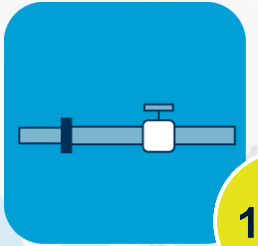


37 %



15 %

9 %

39 %

Prod./storage	Transmission	Distribution	Sale
• 100% green hydrogen from electrolysis • Underground storage for 60 days	• Transmission to central hubs by pipeline	• Transport by trailer from hub to hydrogen refuelling station	• Sale at existing (upgraded) fuel stations

FIRST DOMINATED BY HOME CHARGING, WITH INCREASING NUMBERS OF CARS MOST INVESTMENT GOES TO GRID EXPANSION AND FAST CHARGERS

	100,000	3 mill.	10 mill.	20 mill.
Transformer		1,800 km x6,100*	28,000 km x55,000	183,000 km x187,000
3.7 kW / 22 kW	x100,000	x2.8 mill	x6,5 mill	x11 mill
150 kW / 350 kW	x6,000	x81,000	x175,000	x245,000

Ramp-up → Mass market

*Transformer; the number in km is the necessary length of cable for expanding the distribution grid

FIRST DOMINATED BY REFUELLING INFRASTRUCTURE, AT 3 MIO FCEV'S AND BEYOND THE INVESTMENT IS DRIVEN BY PRODUCTION AND STORAGE

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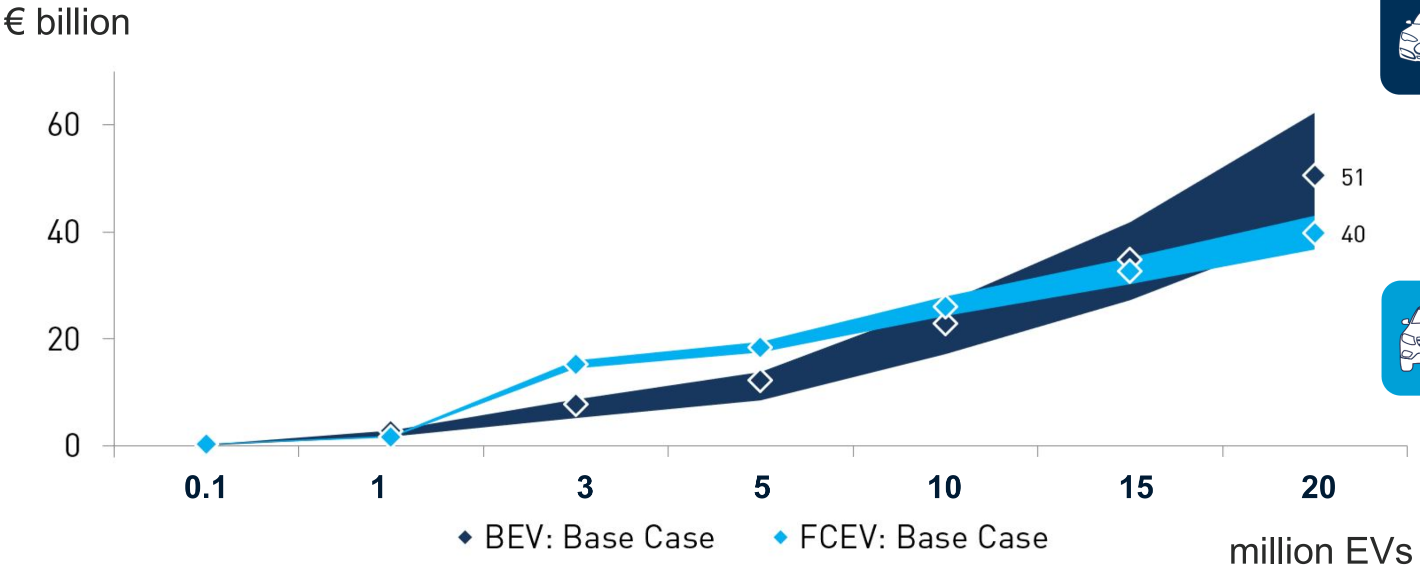
100,000	3 mill.	10 mill.	20 mill.
	2 TWh* 3 GW	5 TWh 10 GW	10 TWh 19 GW
x42	x730	x1,500	x3,000
	12,000 km	12,000 km	12,000 km
x400	x1,500	x3,800	x7,000

Ramp-up → Mass market

*in TWh: the required storage capacity in GW: the required size of electrolyzers

IN THE LONG RUN THE INVESTMENT IN CHARGING INFRASTRUCTURE WILL BE 11 BILLION € HIGHER

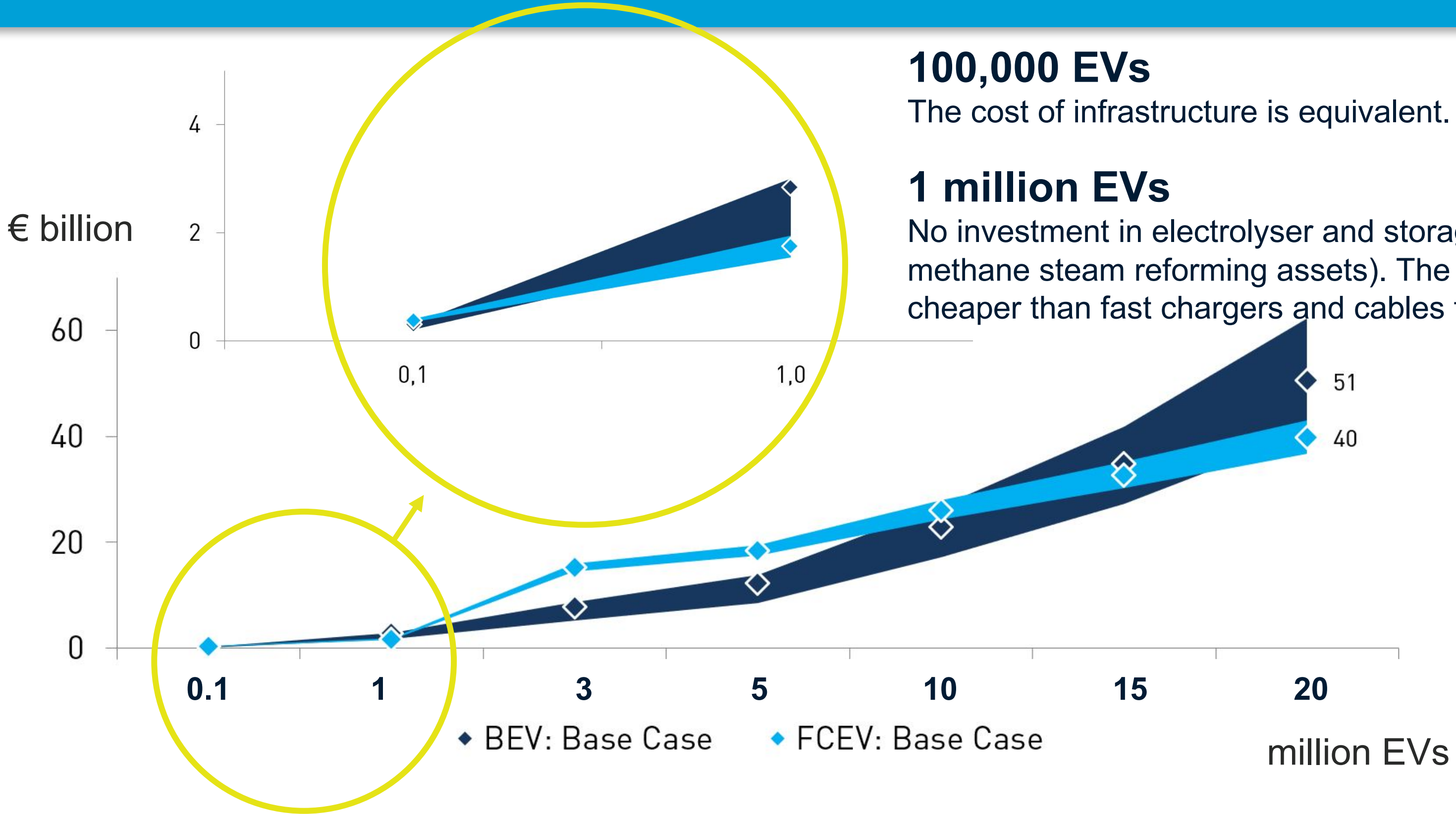


Sensitivity:

Top // larger batteries with 100 kWh dominate in the long run (base case +100 kWh)
Bottom // no fast charging at 350 kW in cities

Top // base case +20% investment in stations
Bottom // base case -20% investment in stations

THE COST FOR REFUELLING STATIONS IS LOWER THAN FOR CHARGERS – ALREADY ABOVE 100.000 VEHICLES



100,000 EVs

The cost of infrastructure is equivalent.

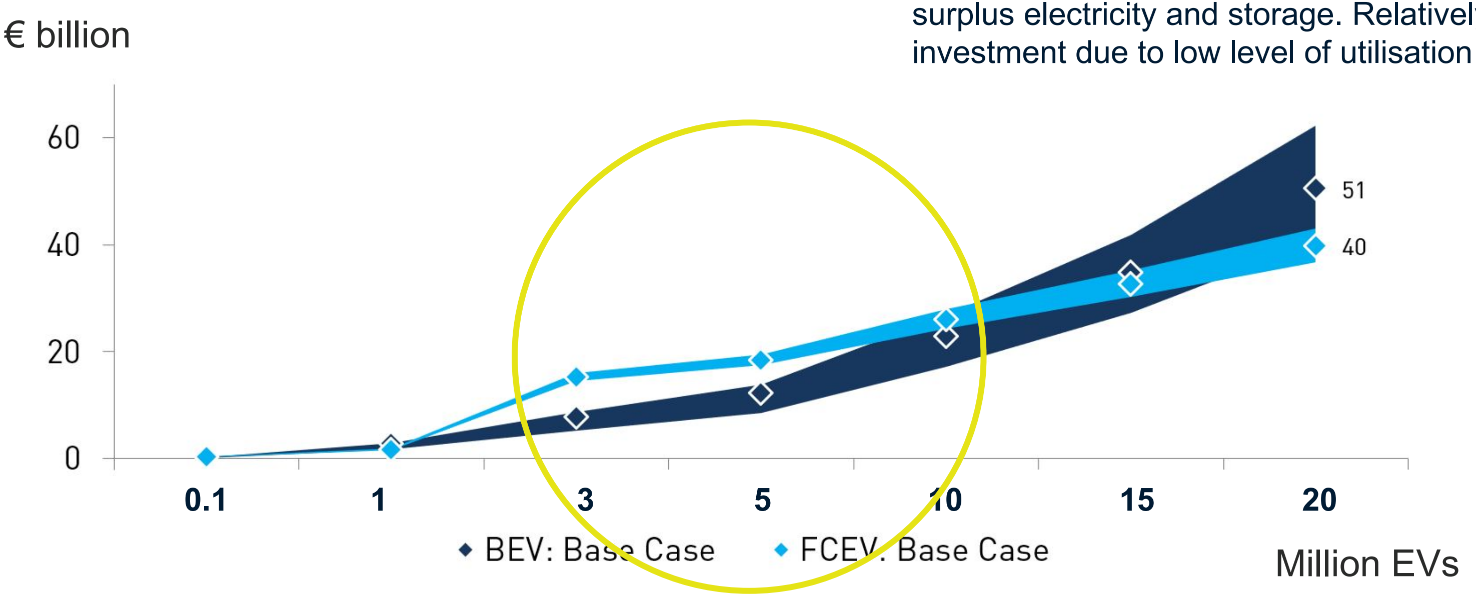
1 million EVs

No investment in electrolyser and storage yet (using existing methane steam reforming assets). The refuelling stations are cheaper than fast chargers and cables for 1 mill BEVs.

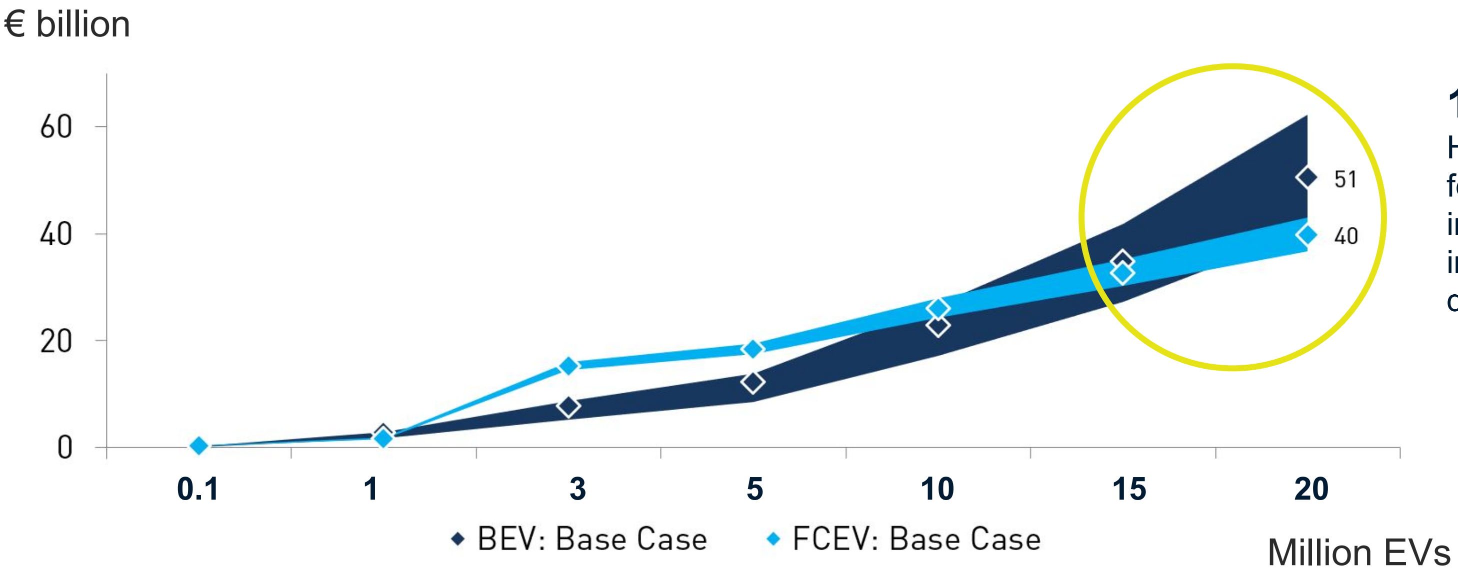
THE INVESTMENT IN PRODUCTION AND STORAGE OF 100% GREEN HYDROGEN DRIVES THE INVESTMENT IN THE H2 INFRASTRCUTRE AT 3 MIO VEHICLES

3 - 10 million EVs

Investment in 100% green hydrogen production from surplus electricity and storage. Relatively high investment due to low level of utilisation of assets.



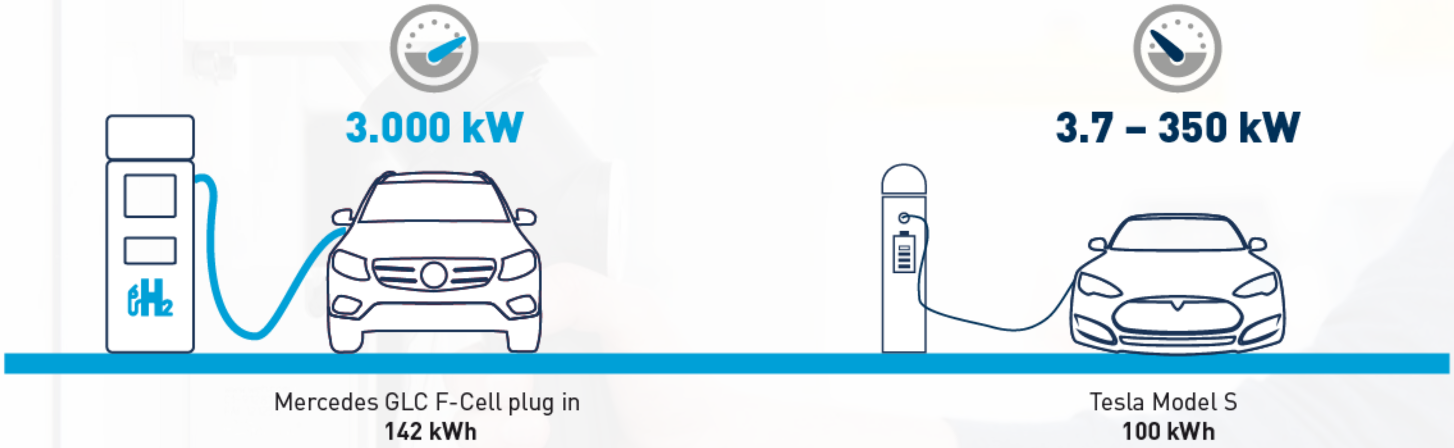
… FOR HIGHER NUMBERS OF VEHICLES THE COST FOR THE H2 INFRASTRUCTURE IS LOWER DUE TO ECONOMIES OF SCALE



15+ million EVs

Higher scale is beneficial for the H2 assets. BEV infrastructure requires increasing investment in distribution grid.

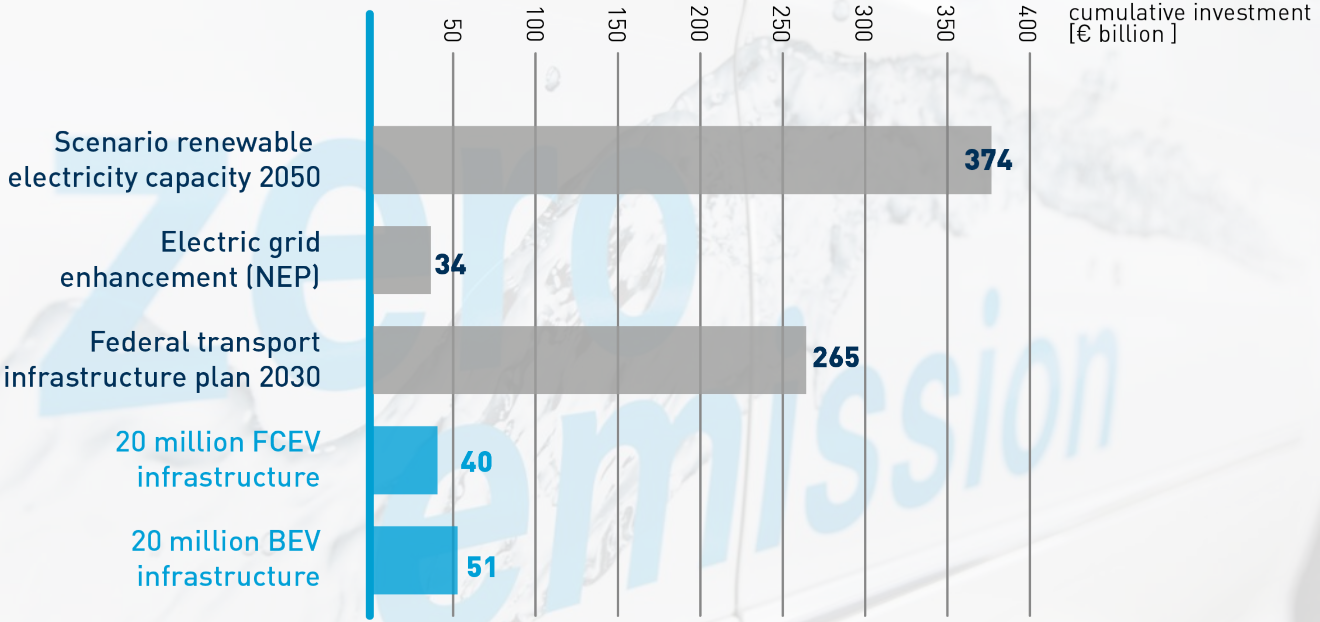
THE SPEED OF THE REFUELLING PROCESS DRIVES THE ECONOMIES OF SCALE FOR HYDROGEN



The ultra-fast refuelling process drives the efficient use of the asset:

- ✓ **Time efficiency: more efficient use of production and refuelling assets**
- ✓ **Economics: greater turnover per time unit**

COMPARED WITH OTHER INFRASTRUCTURE PROJECTS, THE INVEST IN BOTH THE FCEV- AND THE BEV INFRASTRUCTURE SEEMS NOT EXTRAORDINARY



Invest calculation ren. electricity generation:
wind onshore: 171 GW / 1,000 €/kW // wind offshore: 59 GW / 2,500 €/kW // PV: 55 GW / 1,000 €/kW

CONCLUSIONS

- With a major share of RE from wind and solar, even the perfect grid doesn’t help to avoid surplus. H_2 will be required to store energy to balance volatile electricity production and demand. At 80% RE one third of the surplus electricity allows powering 50% of the German fleet with H_2.
- The refuelling infrastructure for FCEVs is very (time) efficient. The more vehicles, the better the economies of scale work in favour of the hydrogen infrastructure.
- At 100.000 vehicles the cost for both infrastructures is about the same. At 1 mill. EVs the investment for hydrogen refuelling stations is lower than that for the charging points.
- Investment in green H_2 production and storage drives the cost for the H_2 infrastructure temporarily above the investment for BEVs. For higher numbers of vehicles the increase of additional investments in infrastructure is steeper for BEVs than for FCEVs.
- The investment in an infrastructure for producing and storing 100% green H_2 to refuel 20 mill. FCEVs is around 11 bn € lower than the investment required for charging 20 mill. BEVs.

THERE ARE SOME OPEN QUESTIONS WHICH NEED FURTHER INVESTIGATION

Open questions on the FCEV side

- How much of the existing natural gas pipeline grid can be used for H2? What is the cost of the upgrade?
- Legal action is required to make electrolysis economically feasible.

Open questions on the BEV side

- The NEP (grid expansion plan) assumes 6 mill. BEVs. We have assumed the transmission grid will cope with 20 mill.
- Investment in the distribution grid is the main factor pushing up costs – our cost assumptions need to be verified.

MY PERSONAL BELIEF

The Energy transition challenge (= to organise emission-free transport) is huge.

For real emission-free driving there are only two solutions:

BEV, FCEV

We certainly need both technologies. They will be complementary.

Thank you.

Nikolas Iwan
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In preparation

Link	Name	Topic	Publications
Stolten	Stolten et al.	Comparative analysis of infrastrctures: Hydrogen Fuelling and Electric Charging of Vehicles	
Syrandis	Kostantinos Syrandis	Pan-European electrical power flow simulations investigating the potential for Power-to-X applications	Control Techniques and the Modeling of Electrical Power Flow across Transmission Networks. Renewable & Sustainable Energy Reviews, under review
Tietze	Vanessa Tietze	*Techno-ökonomischer Entwurf eines Wasserstoffversorgungssystems für den deutschen Straßenverkehr*	Tietze, V. & Stolten, D. 2015. Comparison of hydrogen and methane storage by means of a thermodynamic analysis. International Journal of Hydrogen Energy 40(35), 11530 - 11537
Reuß	Markus Reuß	Techno-ökonomische Analyse alternativer Wasserstoffinfrastruktur	Reuß, M., et al. (2017). " Seasonal storage and alternative carriers: A flexible hydrogen supply chain model." Applied Energy 200 (2017) 290–302

Published

Robinius, 2015		**Strom- und Gasmarktdesign zur Versorgung des deutschen Straßenverkehrs mit Wasserstoff**	