National Organisation
Hydrogen and Fuel Cell Technology

Electrolysis - key element for energy and fuel transition

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Workshop ADVANCED ALKALINE ELECTROLYSIS | Dresden | 19th of September 2018 |

NOW GmbH –
Who we are

- **NOW: National Organization Hydrogen and Fuel Cell Technology**
- **GmbH**: Owner is the Federal Republic of Germany (represented by BMVI)
- **Founded 2008** for the implementation of the National Innovation Program Hydrogen and Fuel Cell Technology
- Current task: **Concept development, coordination and implementation of national strategies and public-private programs for future mobility concepts**
- Currently **42 employees**

National Organisation
Hydrogen and Fuel Cell Technology

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NOW GmbH –
Tasks and Projects

National Innovation-Programme Hydrogen and Fuel Cell Technology

- Research and Development
- Market activation

Charging Infrastructure

- Nationwide buildup
- Normal charging
- Fast charging

Battery Electric Mobility

- Research and Development
- Communal mobility concepts
- Vehicle procurement

Mobility and Fuels Strategy

- Alternative fuels (efficient, emission-free)
- LNG as a marine fuel
- Pilot projects

Export Initiative Environmental Technology

- German-Japanese cooperation for P2G
- Development cooperation for H2/FC technologies

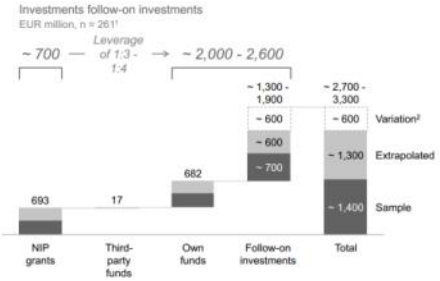
NOW National Organisation Hydrogen and Fuel Cell Technology

Programme coordination and implementation, strategy development, networking and contribution to visibility

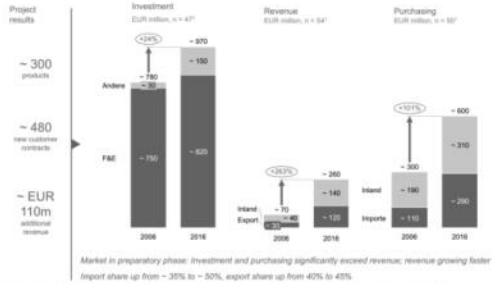
THE NATIONAL INNOVATION PROGRAM HYDROGEN AND FUEL CELL TECHNOLOGY (NIP)

PHASE 1 (2007 – 2016)…

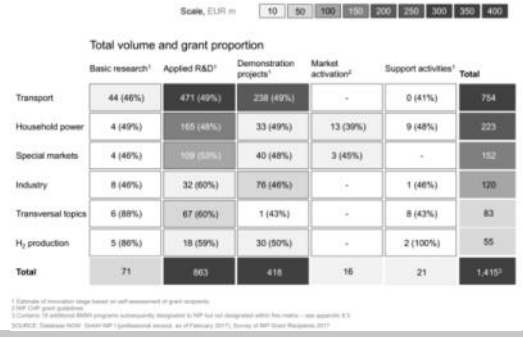
…TRIGGERED FOLLOW-ON-INVESTMENTS



…ACCELERATED MARKET DEVELOPMENT



…710 MILLION EURO PUBLIC R&D FUNDING



	Basic research	Applied R&D	Demonstration projects	Market activation	Support activities	Total
Transport	44 (46%)	471 (49%)	238 (49%)	-	0 (41%)	754
Household power	4 (49%)	165 (48%)	33 (49%)	13 (39%)	9 (48%)	223
Special markets	4 (46%)	109 (52%)	40 (48%)	3 (45%)	-	152
Industry	8 (46%)	32 (60%)	76 (46%)	-	1 (46%)	120
Transversal topics	6 (88%)	67 (60%)	1 (43%)	-	8 (43%)	83
H_2 production	5 (86%)	18 (59%)	30 (50%)	-	2 (100%)	55
Total	71	863	418	16	21	1,415

…SAFEGUARDED GERMANY'S POSITION AS TECHNOLOGY LEADER

GOVERNMENT PROGRAMME 2016 - 2026
CONTINUING THE NATIONAL INNOVATION PROGRAMME HYDROGEN AND FUEL CELL TECHNOLOGIES (NIP)

Research and development			Market activation		
Technical/cost targets			Milestones (quantities/costs)		
Fundamental research	Applied research and development	Demonstration	Hydrogen in transport	Hydrogen from renewable energy sources	Cogeneration (domestic energy supply/industry) secure power supply
Cost reductions			Lead market / lead supplier Germany		
Value creation / competitiveness Germany					

10 years → Federal funding € 1.4 bn → Combining R&D funding with market activation


Government programme for hydrogen and fuel cell technology 2016-2026
– from market preparation to competitive products

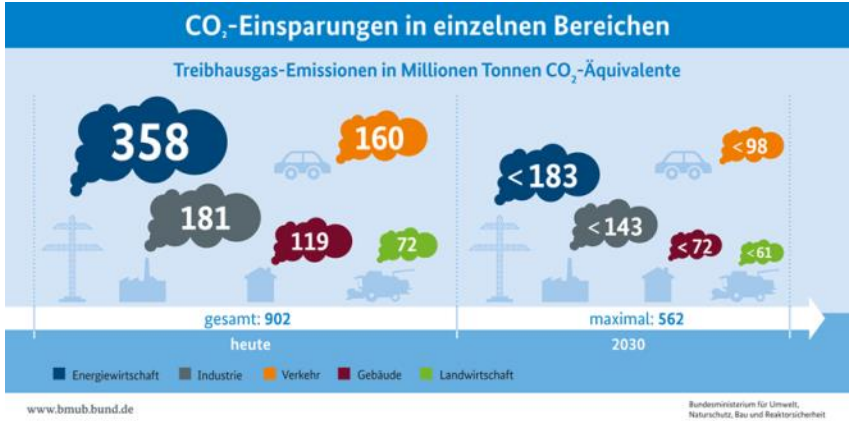
For the continuation of the National Innovation Programme for Hydrogen and Fuel Cell Technology 2006-2016 (NIP)

A joint programme of

Federal Ministry of Transport and Digital Infrastructure (BMVI),
Federal Ministry for Economic Affairs and Energy (BMWi),
Federal Ministry of Education and Research (BMBF) and
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)

The Federal Government

Political framework –
German Climate Action Plan 2050



National implementation of the Parise Climate Agreement

- CO_2 reduction goals for all sectors
- Concept development for the 2030 goals and long-term plan to reach the goals in 2050
- Presentation of the concepts in 2018

GERMAN COALITION AGREEMENT BETWEEN CDU, CSU AND SPD IS STRONGLY REFERRING TO HYDROGEN TECHNOLOGIES

"Investing in electro mobility, amongst others in hydrogen and fuel cells."

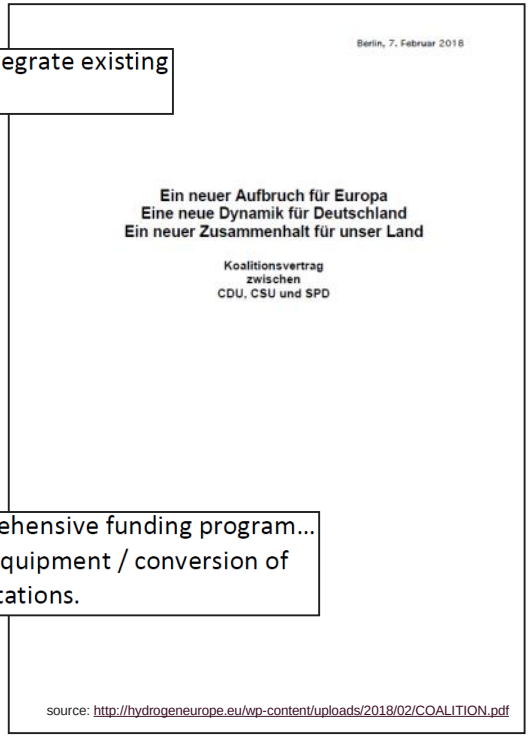
"We want to set up a Fraunhofer Institute for Storage Technology and integrate existing competences. We want to strengthen hydrogen technologies."

We want to push electromobility (battery electric, hydrogen and fuel cell) forward in Germany and enhance and increase the existing subsidies framework beyond the year 2020.
We want to intensify the construction of a nationwide charging and refueling infrastructure.

We want to continue the National Innovation Program on Hydrogen and fuel cell technologies. We want to develop the mobility and fuel strategy (MKS) technology-neutral and increase the means to their implementation. We want to advance "sectorcoupling" and change the regulative framework, so that "green hydrogen" and hydrogen as a product from industrial processes (byproduct) be utilized as a fuel or for the production of conventional fuels (eg natural gas).

Concerning rail passenger transport we want to set up a comprehensive funding program... We want to increase subsidies for fuel cell hybrid railcars incl. Equipment / conversion of depots and construction and operation of hydrogen refueling stations.

At national level, we want to strengthen and stabilize our technology-neutral initiatives in favor of alternative drivetrains and energy sources in shipping and in ports (LNG, Hydrogen / fuel cell, methanol, electromobility).

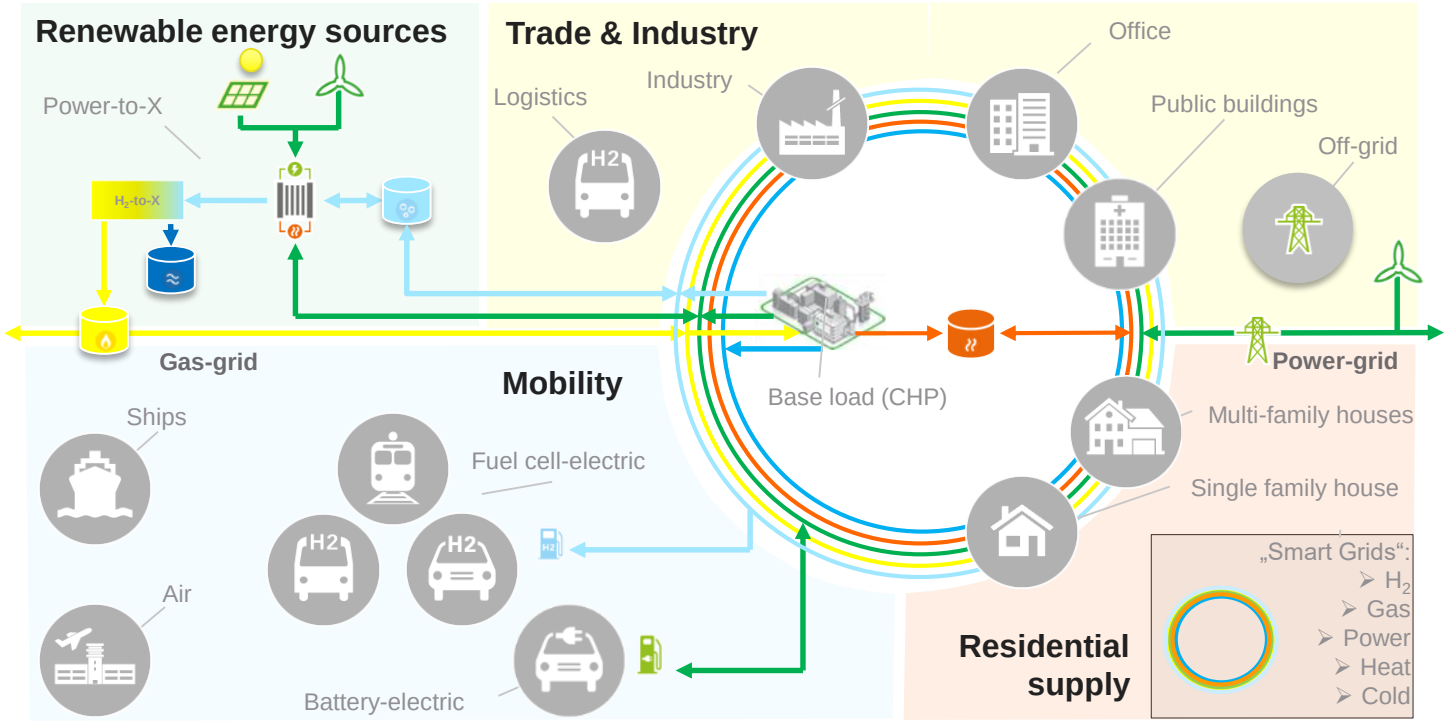

Berlin, 7. Februar 2018

Ein neuer Aufbruch für Europa
Eine neue Dynamik für Deutschland
Ein neuer Zusammenhalt für unser Land

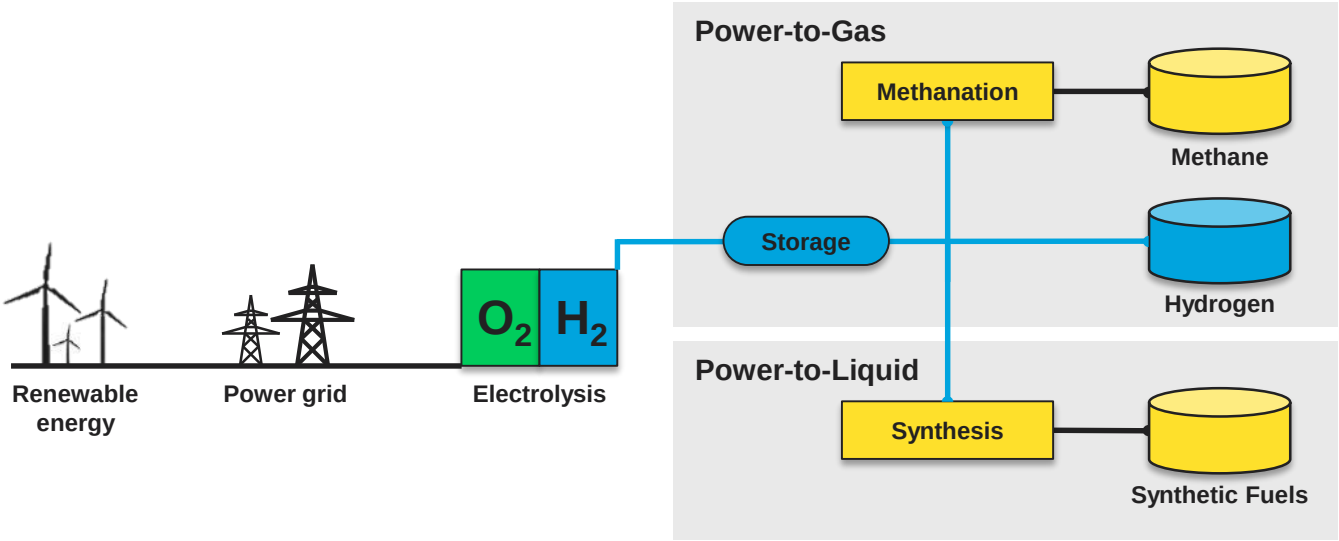
Koalitionsvertrag
zwischen
CDU, CSU und SPD

source: http://hydrogeneurope.eu/wp-content/uploads/2018/02/COALITION.pdf

Integrated energy system –
Renewable, flexible and connected across all sectors



Integrated energy system –
Water electrolysis as key technology



- Emission-free production of hydrogen with water electrolysis technology
- Hydrogen as feed stock for the production of synthetic fuels (i.e. Kerosene, syn. Diesel)

Integrated energy system –
Current study on water electrolysis

Industrialization of water electrolysis in Germany
Towards a GW industry for a successful transition of the energy sector to renewable energies

Fraunhofer ISE

Fraunhofer IPA

E4tech
Strategy | Energy | Sustainability

- ➔ Do we have a powerful WE industry to produce all the required GW?
- ➔ What has to be done now to be ready in the next years
- ➔ Recommendations for the German innovation program NIP 2

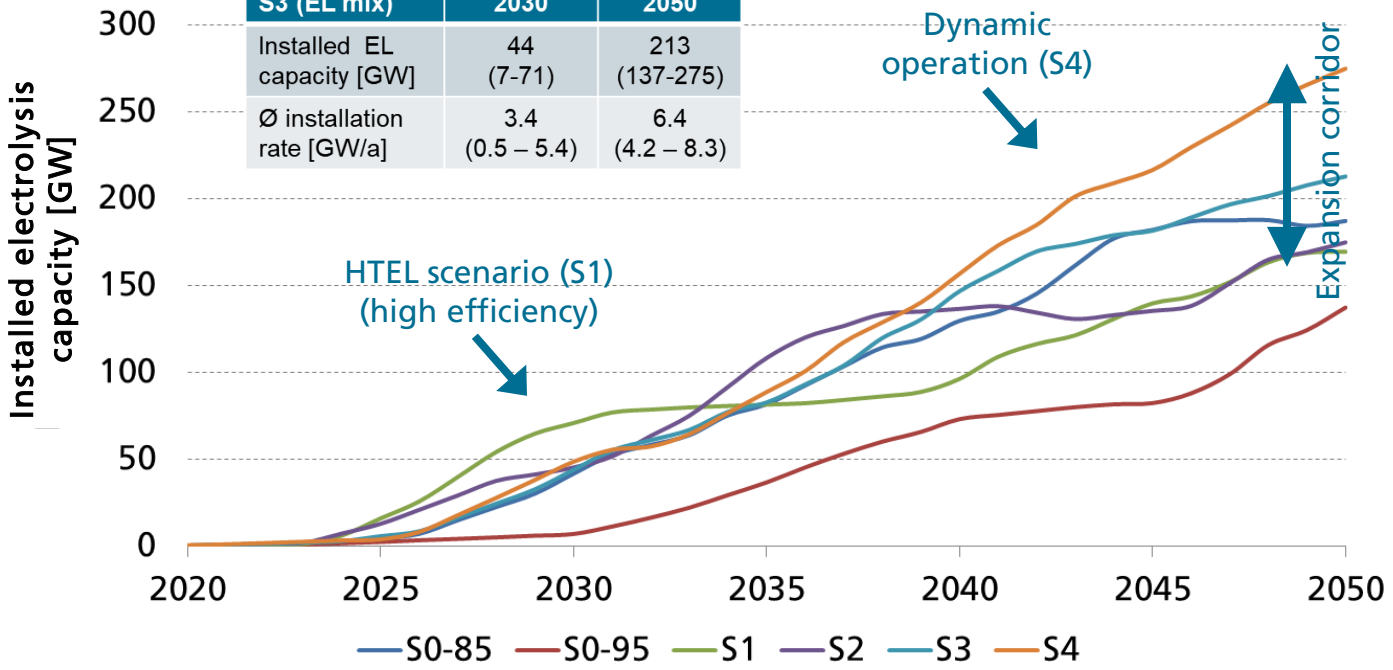
Release of the final report: 17.09.2018

Commissioned by
Bundesministerium für Verkehr und digitale Infrastruktur

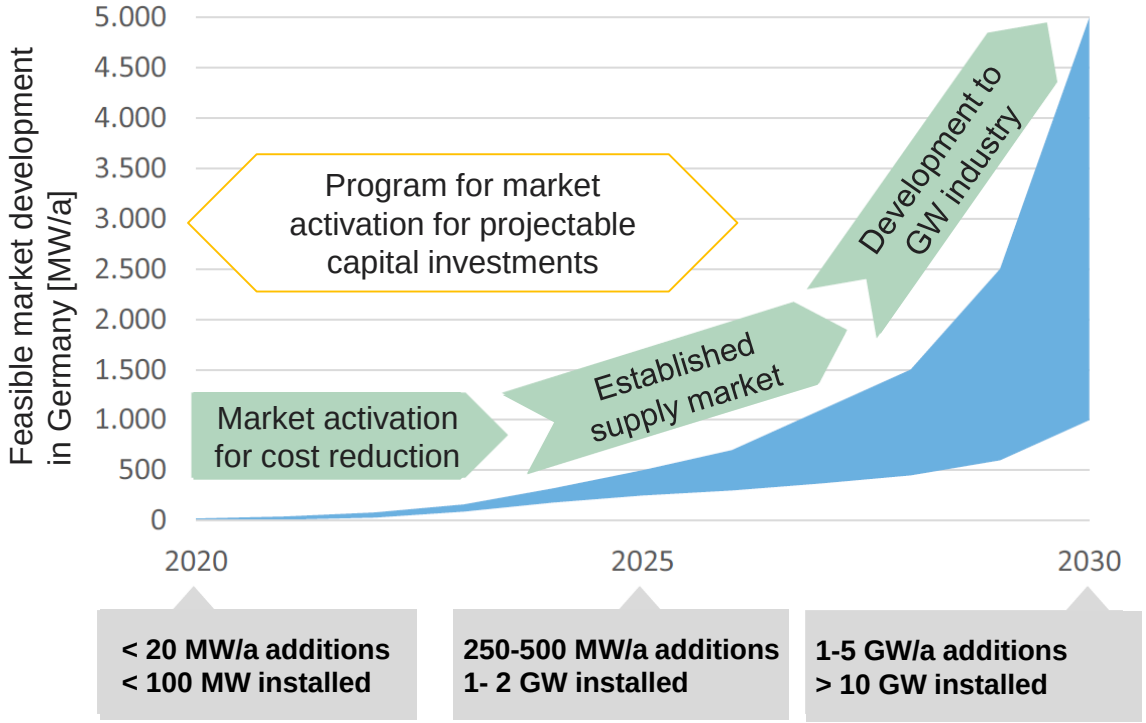
Coordinated by
NOW
Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

Industrialization water electrolysis –
Development of installed water electrolysis capacity

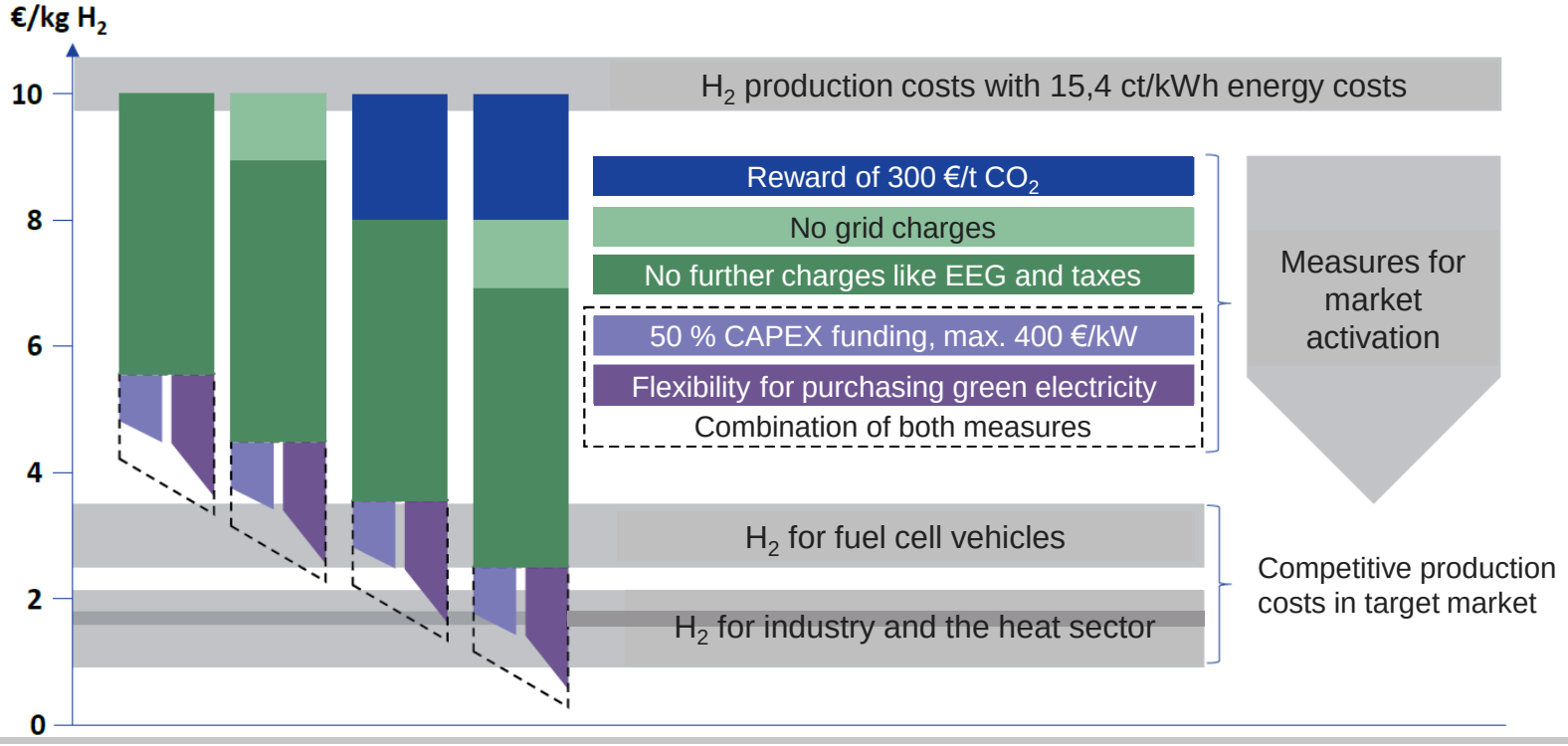
S3 (EL mix)	2030	2050
Installed EL capacity [GW]	44 (7-71)	213 (137-275)
Ø installation rate [GW/a]	3.4 (0.5 – 5.4)	6.4 (4.2 – 8.3)



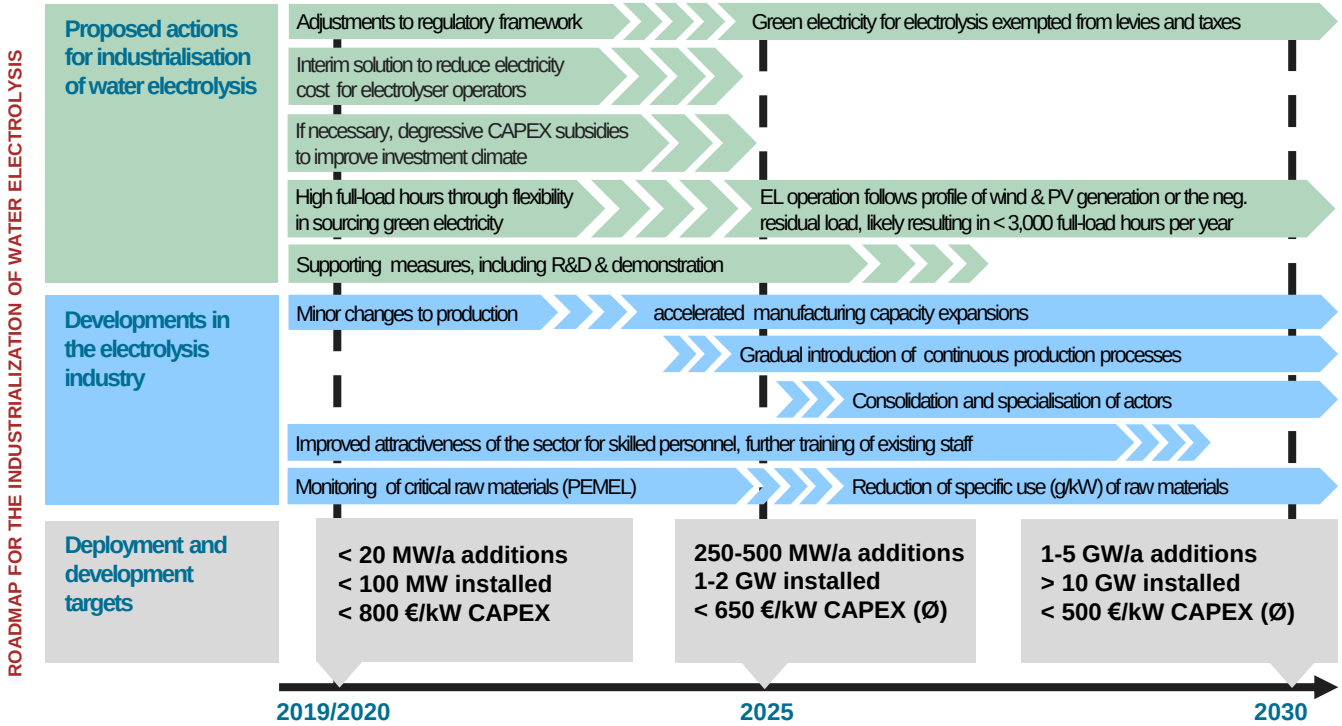
Industrialization water electrolysis –
Development of installed water electrolysis capacity



Industrialization water electrolysis –
Measures to reduce hydrogen costs



Industrialization water electrolysis – Roadmap



CONCLUSIONS

- Electrolysis is a key technology for an integrated energy system based on renewable electricity
- Technology is mature
- Market uptake is needed for economies of scale
- First step to overcome is a production capacity of 1-2 GW installed
- Policy measures for supporting hydrogen are discussed at national as well as EU level

National Organisation
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Thank you!

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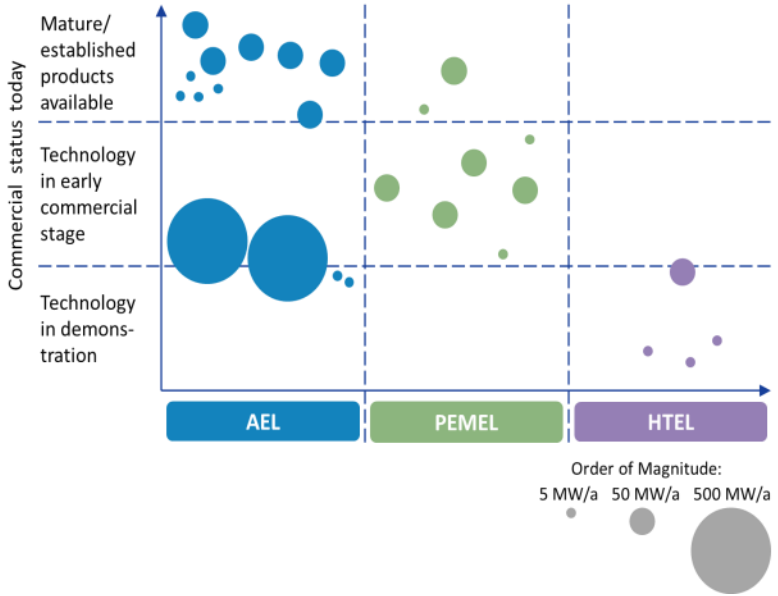
Industrialization water electrolysis –
Comprehensive survey with interviews & questionnaires

Key features:

- Sold EL capacity: ~ 100 MW/a
- Global sales : 100-150 Mio. €/a
- Direct employees: ~ 1.000
- Possible ramp-up in manufacturing capacity by 2020: ~ 2 GW

How do electrolysis system manufacturers work today?

- Standardized stack platforms
- Single order production
- ‘Project-by-project’ business without stock-keeping



Possible production volume in 2020 per manufacturer, provided that corresponding market demand exists

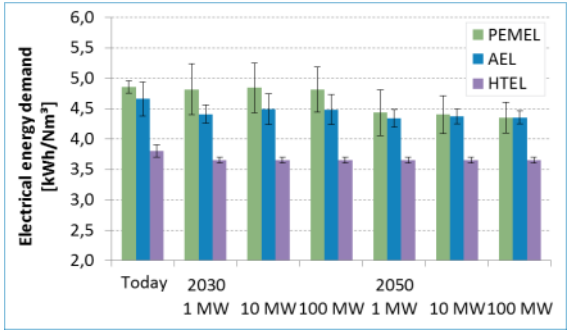
Industrialization water electrolysis –
Electrical energy demand and stack life-time

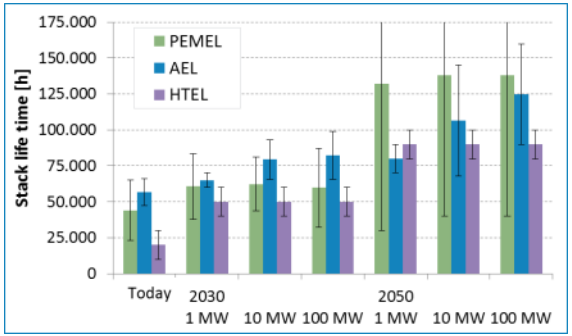
Electr. energy demand

- Feedback partially contradictory (respondents applied different system boundaries)
- PEMEL higher than AEL → adjusted in 2050
- HTEL shows better (electrical) efficiency
  - But steam is required (ca. 200 °C)
- No substantial improvement in 2030/50

Stack life time

- Stack life-time in operating hours
- Uncertainties (see standard deviation)
- Ambitious expectations in this survey
  - 20 – 30 years @ 4.000 h/a (full load)
  - Missing confirmation from literature
- Stack replacement required over total life-time





Black bars indicate the standard deviation.

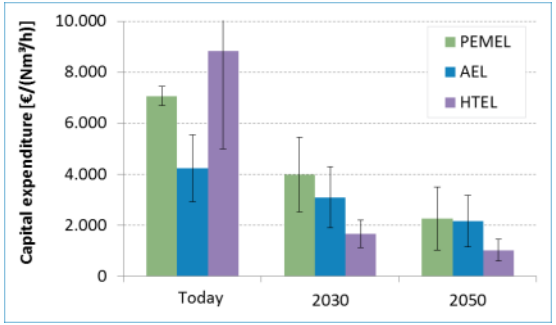
Industrialization water electrolysis –
Capital expenditure and cost break down

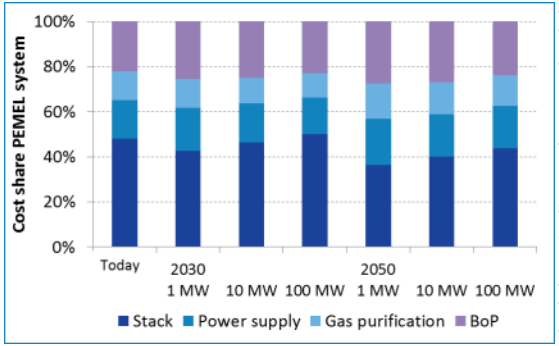
CAPEX

- Low CAPEX still main selling point!
  - Price pressure on the market with tenders for large systems
- Future cost parity between PEMEL and AEL
- Ambitious CAPEX projection for HTEL
  - Potentially low cost, but high uncertainty

Cost breakdown

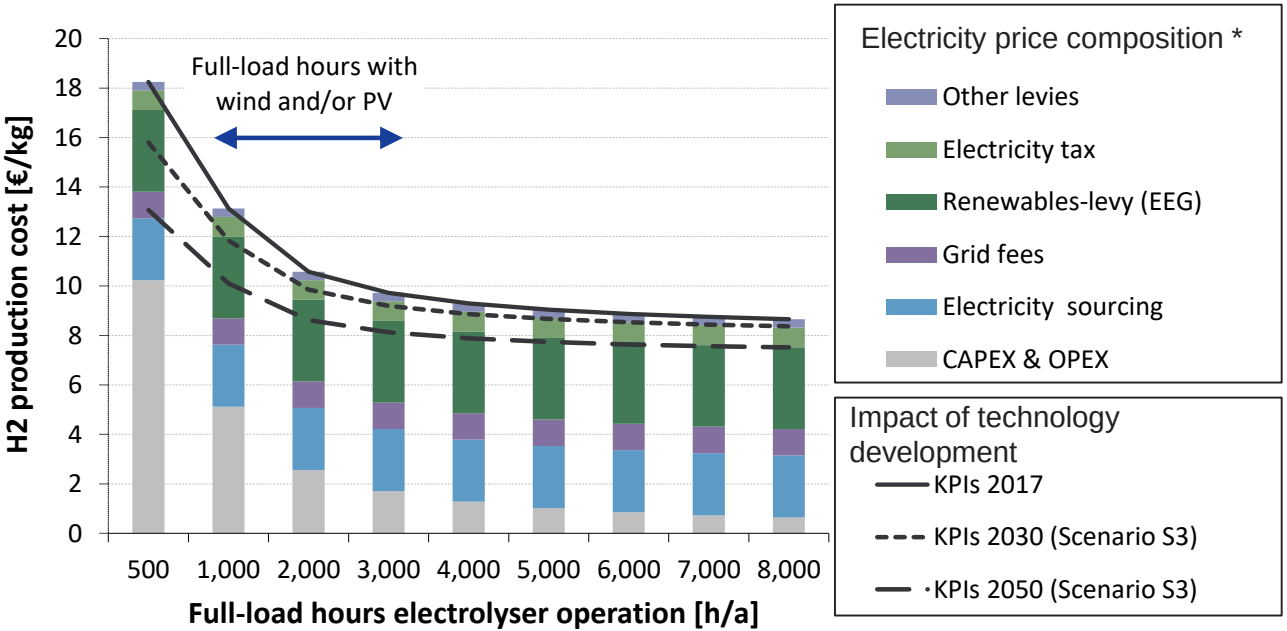
- Feedback in agreement with literature
  - Stack dominant, but less than 50 %
  - Power supply 2nd major cost contributor
  - Stack share increases with system size
- Similar results for AEL systems
- Insufficient responses for HTEL systems





Black bars indicate the standard deviation.

Industrialization water electrolysis –
Cost aspects for hydrogen production



* 15,4ct/kWh average electricity price for industrial users in 2016 for annual consumption of 0.16 to 20 million kWh. Mid-voltage level connection 100kW/1.600h to 4.000kW/5.000h. Source: „BDEW Strompreisanalyse 2018“