# Hydrogen for clean transport

## Green Hydrogen technologies for transport

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# Today’s presenter

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# About us

Public

# Facts and Figures

AVL

## Global Footprint

Represented in 26 countries

45 Affiliates divided over 93 locations

45 Global Tech and Engineering Centers (including Resident Offices)

**1948**
Founded

**11,500**
Employees Worldwide

**10%**
Of Turnover Invested in Inhouse R&D

**70+**
Years of Experience

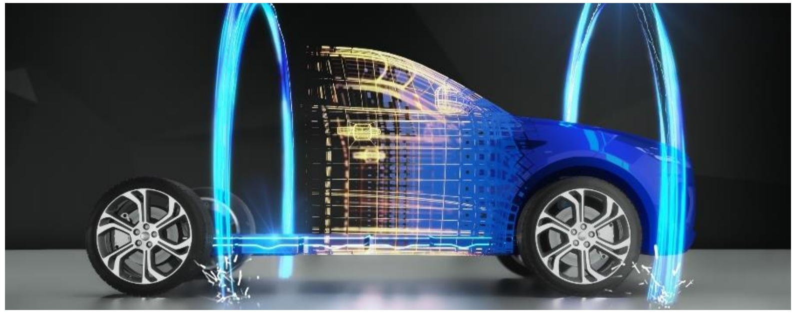
**65%**
Engineers and Scientists

**1,500**
Granted Patents in Force

**96%**
Export Quota

# Looking Beyond the Limits of Technology

ELECTRIFICATION



ADAS AND AUTONOMOUS DRIVING

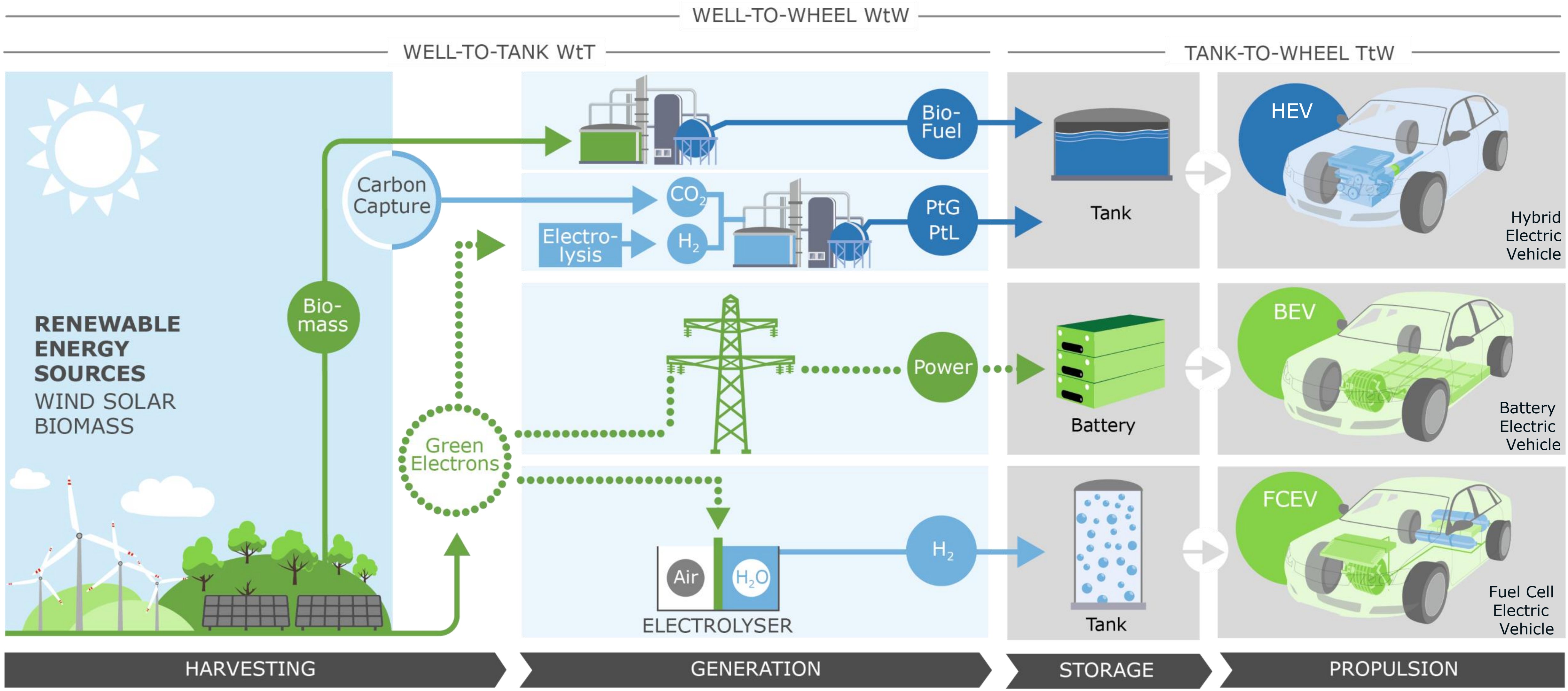
ZERO-IMPACT EMISSION

VEHICLE ENGINEERING

DATA INTELLIGENCE

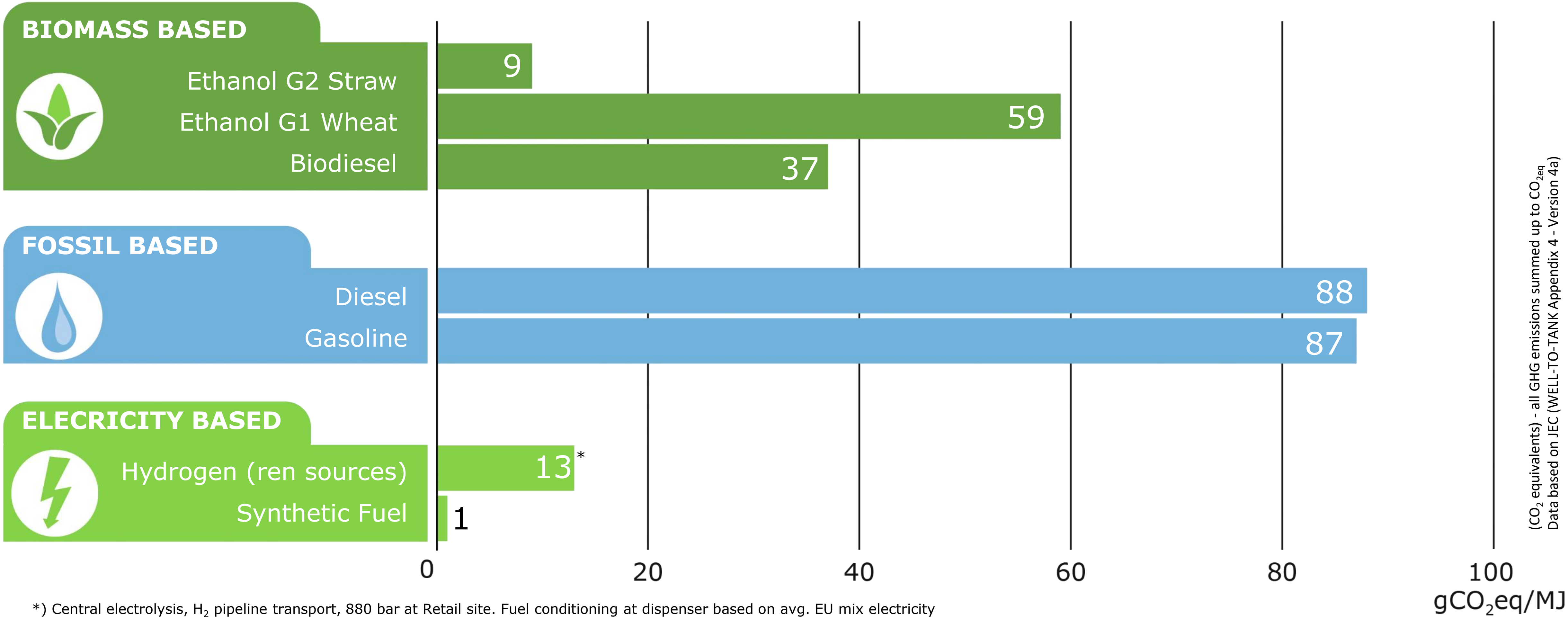
# Energy production

# Clean and Sustainable Energy Systems are important for Future Developments



# Greenhouse Gas Emissions

## ($CO_2$ equivalents) for fuels well-to-wheel

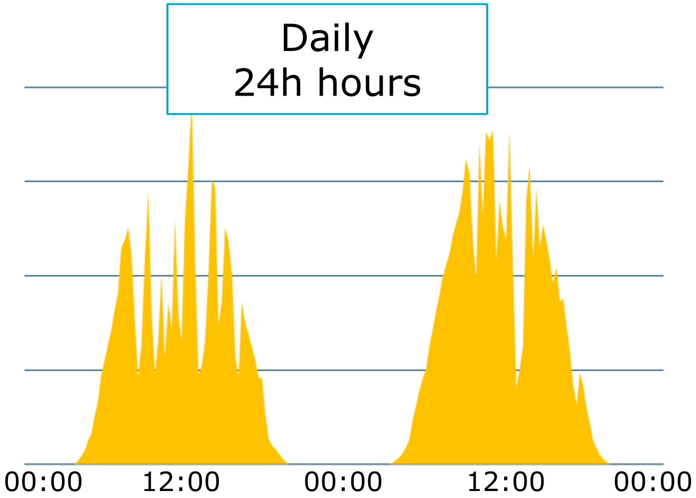



*) Central electrolysis, $H_2$ pipeline transport, 880 bar at Retail site. Fuel conditioning at dispenser based on avg. EU mix electricity

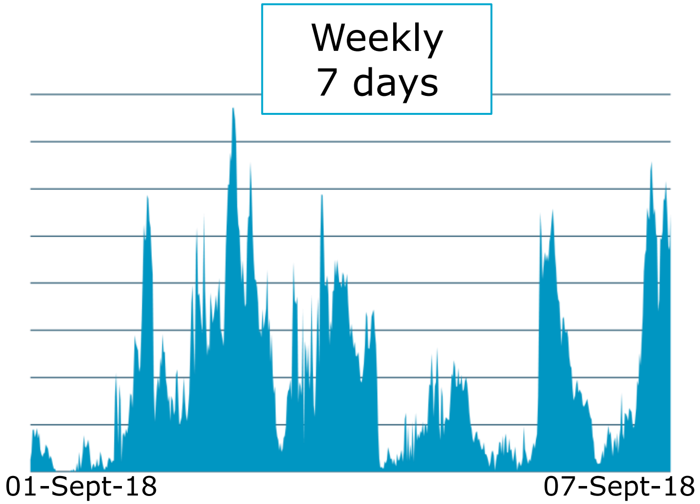
Electricity-based fuels are expected to outperform second generation biofuels in green house gas emissions.

# Intermittency

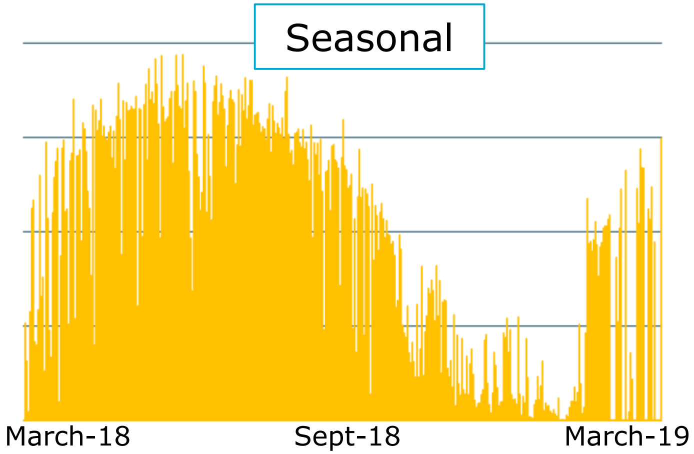
## Variability of renewable energy



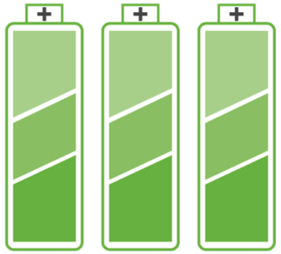

Source: PV park Germany, 99.6kW



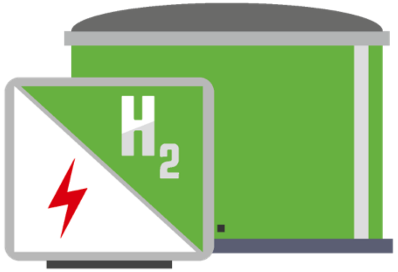

Source: wind park Germany, 2000kW




Source: PV park Germany, 99.6kW



Decentral
(e.g. Electrochemical Storage)




Central
(e.g. mechanical or chemical storage)

**Different types of intermittency require energy storage methods adapted to the use case**

# Overview of Hydrogen Production

## "Grey Hydrogen" - Steam Reforming natural Gas

13kgCO$_2$/kgH$_2$
Efficiency **η <60%**

Natural Gas

Oil

Coal

## "Blue Hydrogen" Biogas Reforming and C-neutral Processes

1.7 kgCO$_2$/kgH$_2$
Efficiency **η <50%**

Slurry

Sludge

Plants

## "Green Hydrogen" - Electrolysis of $H_2O$ with renewable electricity

0.5 kgCO$_2$/kgH$_2$
Efficiency **η 60-80%**

Alkaline Electrolysis
η 60-80%

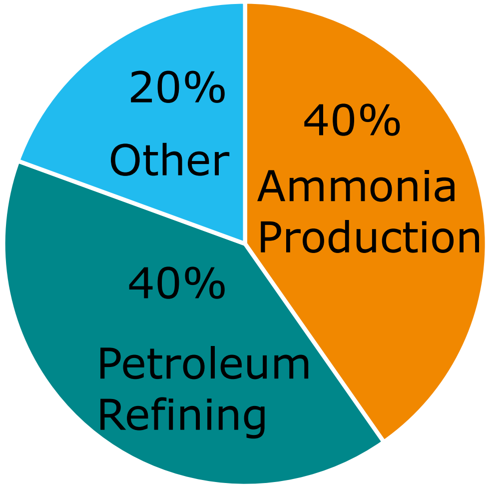
Polymer-electrolyte membrane electrolysis
η 60-80%

Solid oxide electrolysis
η >80%
utilization of $CO_2$

Sources: JRC, WELL-TO-TANK Report, Version 4a, April 2014; BMBF

# Hydrogen economy trends

## $H_2$ production today




**4270 k t**

Western Europe Hydrogen Production (2018)

95% of hydrogen production via steam methane reforming (fossil)

*Source: IHS Markit 2018*

## Chemical energy carrier from renewables

- Transport: energy import possible (MENA)
- Storage: for managing intermittent renewables
- Universal usage: Transport and power-fuel, heavy and chemical industry

## Political push for hydrogen

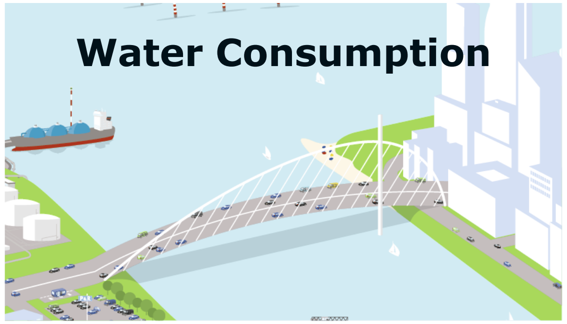
EU strategy with over 100 bn. € funding:
- Greening of $H_2$ production
- Incentivize hydrogen usage

- Political will
- National $H_2$ roadmaps
- Cross industry cooperation
- Funding

Source: EU hydrogen strategy, published 8.7.2020; Link

# What do we need to produce hydrogen at scale?




**56 Mio. t**
Annual demand Germany

equals to*

**15 Mio.t**
Annual Hydrogen demand
(1/5 of global
$H_2$ production today)

require**

**684 TWh**
Annual electricity demand
(Germany 527 TWh)

+

**137 Mio. t**
4% of annual consumption
Germany

Domestic generation impossible
Energy needs to be imported in any scenario

*) Fuel energy content & PT efficiency normalized **) 72% electrolyzer efficiency

Significant resources required to build up hydrogen production at relevant capacity

# Can Hydrogen replace Diesel fuel?

# Hydrogen use case:
# Geofenced fleet Bernegger quarry (stone pit)



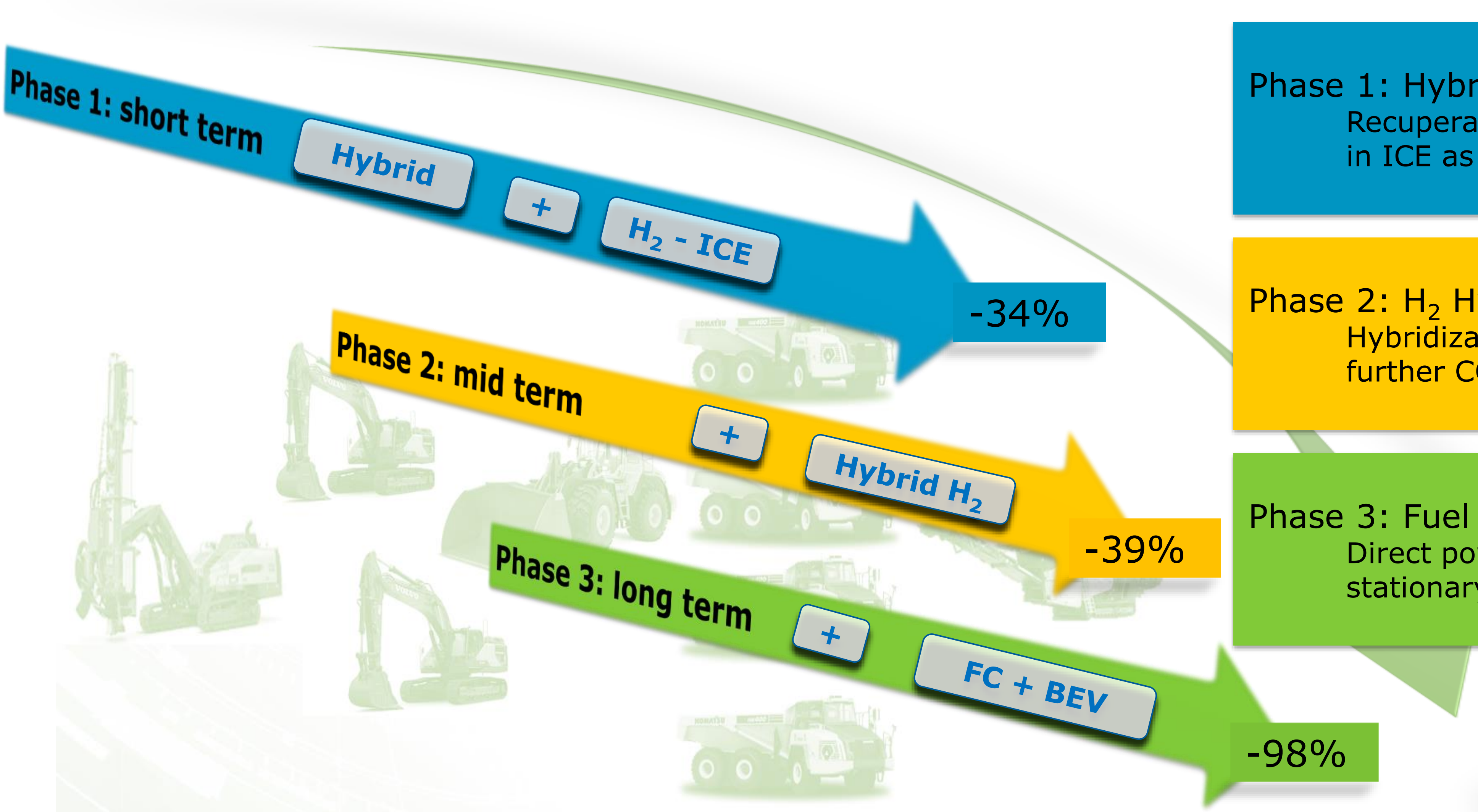
| Average total Diesel fuel consumption in liter | |
|---|---|
| per day | 2,355 |
| per week | 11,775 |
| per year | 591,105 |

Diesel fleet of 9 vehicles → $H_2$ in ICE or fuel cell → Hydrogen production via electrolysis

How to reduce $CO_2$ for a small off-road fleet by using hydrogen?

# Geofenced Fleet Bernegger

## Technology / Timeline / $CO_2$ Potential




**Phase 1: Hybridization Diesel + $H_2$ ICE**
Recuperation energy and hydrogen in ICE as short term solution

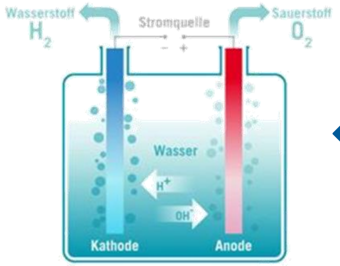
**Phase 2: $H_2$ Hybridization**
Hybridization of $H_2$ in ICE to utilize further $CO_2$ potential

**Phase 3: Fuel cell + Cable electric**
Direct power supply via Cable for stationary applications

# Geofenced fleet Bernegger quarry (stone pit)

## Electric power demand for Fleet / Quarry

| | **Electric Power** $H_2$ **Production per year** | **Electric Power Cable operation** | **Solar park** |
|---|---|---|---|
| Phase I | 16.5t $H_2$<br>750 MWh | - | 0.6 ha<br>0.8 football fields |
| Phase II | 28t $H_2$<br>1,260 MWh | - | 1 ha<br>1.4 football fields |
| Phase III | 24t $H_2$<br>1,100 MWh | 345,000l Diesel replaced<br>2,000 MWh | 2.5 ha<br>3.5 football fields |
| | 3,100 MWh | | |


Excavator
Jaw crusher
Drill rig

Onsite production of green power for hydrogen production and cable electric operation

# Hydrogen, what else?

# All energy pathways need to contribute

For a more sustainable mobility all technology pathways are challenged to contribute in their optimum use case.

zero-impact

50% efficiency

hydrogen mobility

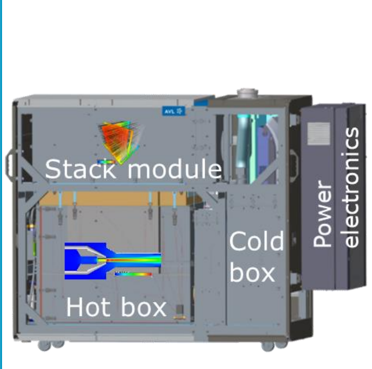
green $H_2$ production

smart charging

fleet electrification

Hybrid

Fuel Cell




Battery Electric

# City Bus Fleet Electrification

***A Battery Bus does not replace a Diesel Bus 1:1***

Risk: Investment in wrong Equipment

**Differences Electric ←→ Diesel**

- 2-3x more expensive
- Charging Time > Refueling Time
- Recharging Infrastructure required
- Lower Range and significant weather impact
- Battery Lifetime dependent on Usage Profile


## *AVL Approach*

Current Fleet
- Analysis of Fleet Operation
- Real-World Data

Digital Model
- Simulation of E-Bus
- Simulation of Charging

Optimi-zation
- E-Bus Verification
- TCO Optimization

**Better Planning**
- Optimized Fleet & Infrastructure
- Lower Risk
- Lower Cost

AVL supports a proper planning of vehicle fleet transformation and operating equipment

# Conclusion

For a more sustainable mobility all technology pathways are challenged to contribute in their optimum use case.

## Cross industries approach

For sustainable transportation a cross industries approach including fuel industry as well as OEMs is required.

The $CO_2$ challenge requires to make use of renewable energy production.

## All technologies

Green electricity shall be used directly, or converted and stored chemically

All propulsion pathways need to contribute to a net-zero-$CO_2$ world.

## Start now

Upscaling of today's $H_2$ production and distribution systems are required

Hydrogen at large scale is required, but the conversion towards renewable energy carriers must be started in small fleets – NOW.

# Let’s stay in touch

| LOCATION | PHONE | EMAIL | WEBSITE |
| --- | --- | --- | --- |
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# Thank you

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