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# Alternative Mobility - Drive and Supply Concepts of the Future

Dr. Bodo Groß, IZES gGmbH
Mátrafüred, 28. May 2019

# IZES gGmbH

- Founded in 1999
- Shareholders: Federal State Saarland, several regional utilities, the University of Saarland and the University of Applied Science Saarbrücken
- Interdisciplinary team of professors and researchers with educational background in engineering, law, economics, forestry, energy, social sciences, chemistry and computer sciences
- Approximately 45 employees, including bachelor, master and PhD students

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Picture source: IZES gGmbH

# Organisation Chart IZES gGmbH

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**Administrative Mngt.:** Friedrich Simson

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associated: Prof. Dr. Petra Schweizer-Ries, N.N., N.N.

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| Juri Horst | Bernhard Wern | Mike Speck | Dr. Bodo Groß | Jan Hildebrand |

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# Present Topics in the Department „Technical Innovations“

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- One focus is the planning, development and implementation of electromechanical systems such as an electrostatic precipitator for small biomass boilers.
- Development of specialised hardware and the associated software. This includes the design, layout and production of the electronic components, for example the controller unit for the electrostatic precipitator.

- Construction and operation of innovative infrastructure for alternative mobility concepts, especially for BEV and FCEV.

# Mobility or Powertrain Concepts

## Today's powertrain portfolio

Defined as EV in this report ✓ Primary ✓ Secondary

| ... To a portfolio of powertrains | | | Propulsion | | Energy generation/source | | |
|---|---|---|---|---|---|---|---|
| | | | ICE | E-motor | ICE[1] | Plug-in[2] | Fuel Cell[3] |
| ICE Volkswagen Golf | Internal Combustion Engine | Driving with conventional combustion engine only | ✓ | | ✓ | | |
| HEV Toyota Prius | Hybrid Electric Vehicle | Driving with combustion engine and/or e-motor | ✓ | ✓ | ✓ | | |
| PHEV Mitsubishi Outlander PHEV | Plug-in Hybrid Electric Vehicle | Driving with combustion engine and/ or e-motor, plug-in to recharge battery | ✓[4] | ✓[4] | ✓ | ✓ | |
| REEV BMW i3 with range extender | Range Extended Electric Vehicle | Driving with e-motor only, ICE & plug in (or fuel cell) used to recharge battery | | ✓ | ✓ | ✓ | ✓ Currently in pilots |
| BEV Nissan LEAF | Battery Electric Vehicle | Driving with e-motor only and storing energy in battery | | ✓ | | ✓ | |
| FCEV Hyundai ix35 fuel cell | Fuel Cell Electric Vehicle | Driving with e-motor only and storing energy in hydrogen | | ✓ | | ✓ | ✓ |

From one technology... Internal combustion engine

1 In HEV, PHEV and REEV, energy is also generated through regenerative braking 2 To charge battery
3 Usually generates electricity that directly powers drivetrain; alternative concepts in discussion (e.g. fuel cell as range extender or FCEV with plug-in)
4 Primacy of ICE or E-motor in PHEV varies across models
SOURCE: McKinsey

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Not mentioned here:

- Hydrogen Combustion Engine
- or

Source: http://motografie.magix.net/album/alle-alben/!/oa/7472551/media/123159080, Website visited on May25th 2019

Source: EVolution: Electric vehicles in Europe: Gearing up for a new phase? Amsterdam Roundtable Foundation and McKinsey & Company The Netherlands, April 2014, page 7

# Powertrain Concepts
# Three main Pylons

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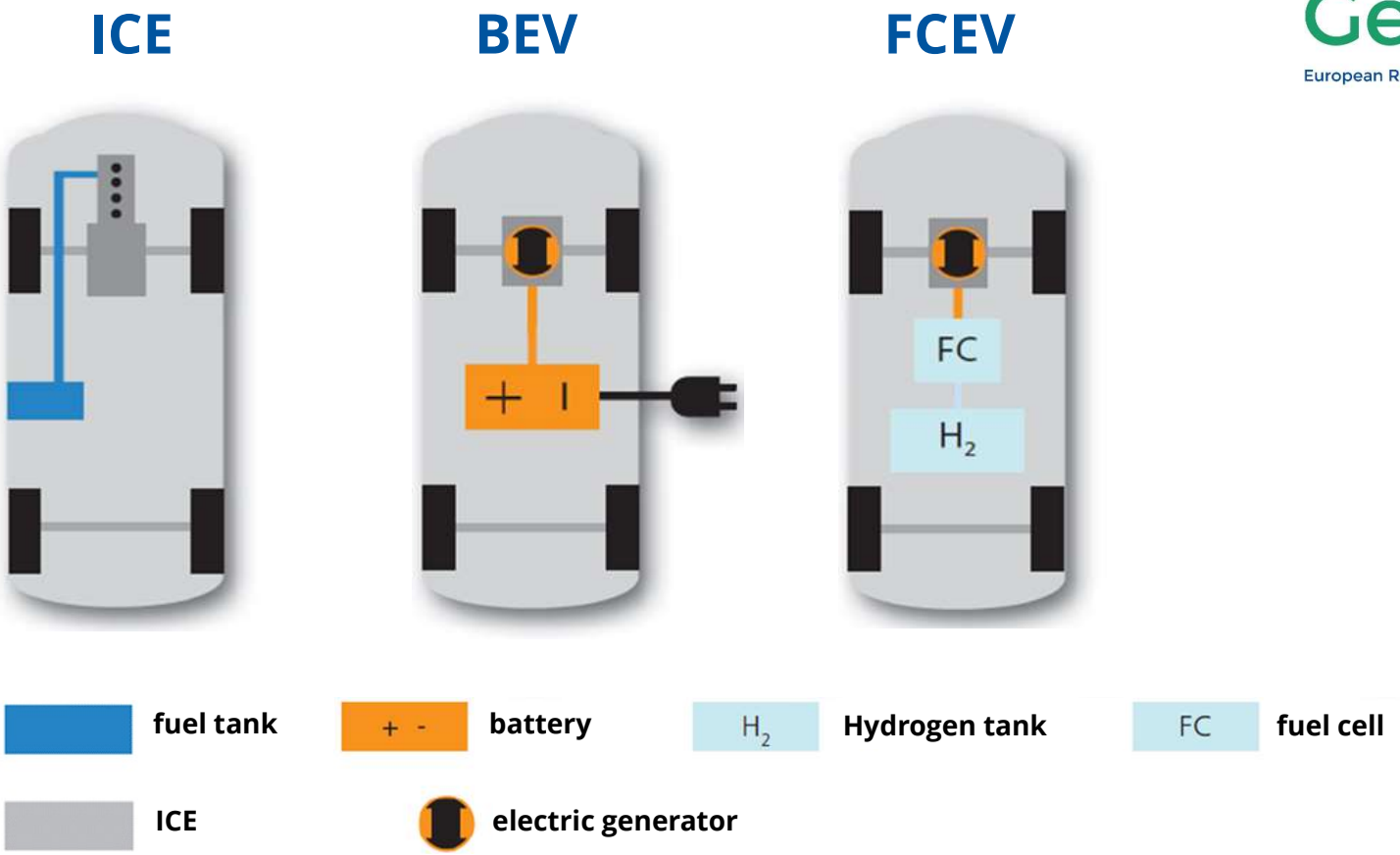


The presentation will be focused on:

- Battery Electric Vehicles (BEV)
- Fuel Cell Electric Vehicles (FCEV)

Graphic source: DLR Studie „Der Pkw-Markt bis 2040: Was das Auto von morgen antreibt“ erstellt im Auftrag des Mineralölwirtschaftsverbands, August 2013, page 16, edited by IZES gGmbH

# Powertrain Concepts
# Advantages, Disadvantages

Graphic source: DLR Studie „Der Pkw-Markt bis 2040: Was das Auto von morgen antreibt“ erstellt im Auftrag des Mineralölwirtschaftsverbands, August 2013, page 16, edited by IZES gGmbH

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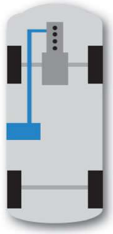
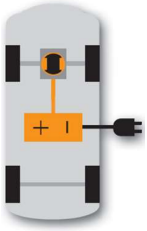


## Advantages

- very well developed technology
- high range/distance up to more than 1.000 km
- infrastructure, especially high number of refuelling stations
- very large selection of models, available in all price, luxury and size segments

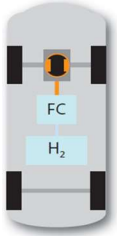
## Disadvantages

- high $CO_2$ emissions, when using fossil fuels
- in Europe very strong dependence of oil-producing countries
- …



- high $CO_2$ saving potential or zero GHG emissions, especially when using renewable electricity
- high efficiency of electric motor & recuperation technology
- very low driving noises
- low maintenance costs

- at present state of development BEV’s are relatively expensive compared to ICE vehicles
- limited range and normally longer charging time, compared to ICE and FCEV
- state of development of the battery technology, especially lifetime and electrolyte




- high $CO_2$ saving potential or zero GHG emissions, especially with renewable produced Hydrogen
- high range/distance, at present up to 600 km
- low driving noises
- …

- state of development of the mobile fuel cell technology, especially system lifetime, loss of performance of the FC
- infrastructure, especially small number of refuelling stations
- at present only two FCEV passenger cars available in EU
- consumer acceptance

# BEV: Worldwide Sales, Production and Battery Production from 2010 to 2017

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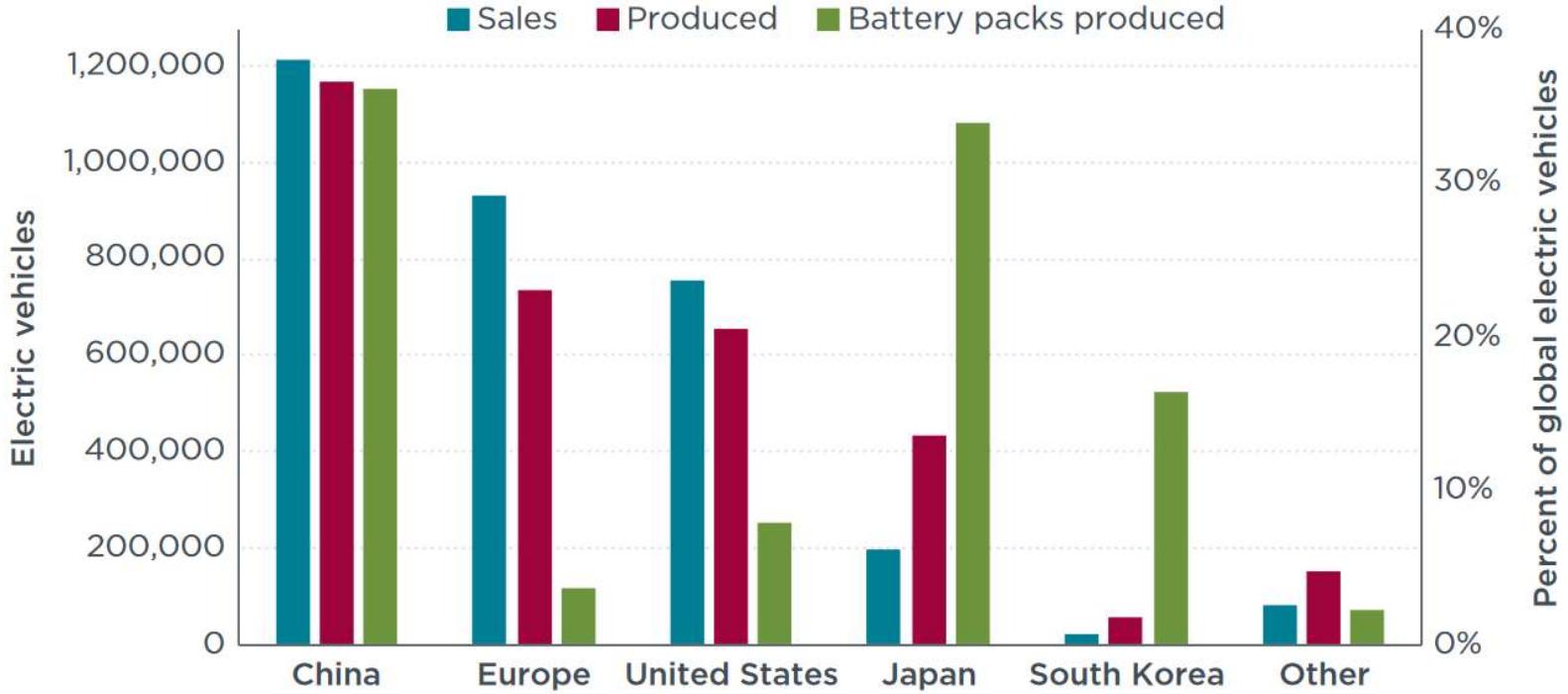


**Figure ES-1.** Electric vehicle sales, electric vehicle production, and electric vehicle battery production by region through 2017.

Source: https://www.theicct.org/sites/default/files/publications/EV_Government_WhitePaper_20180514.pdf, Website visited on May22nd 2019

Diagram shows the cumulative numbers from 2010 to 2017

# Percentage of BEV in Europe
# Top 20 Countries, February 2018

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| | | |
|---|---|---|
| 1 | Norway | 31,2 |
| 2 | Netherlands | 5,4 |
| 3 | Iceland | 4,2 |
| 4 | Austria | 2,0 |
| 5 | Portugal | 2,0 |
| 6 | Sweden | 2,0 |
| 7 | Switzerland | 1,7 |
| 8 | France | 1,4 |
| 9 | Malta | 1,4 |
| 10 | Cyprus | 1,1 |
| 11 | Germany | 1,0 |
| 12 | Ireland | 1,0 |
| 13 | Luxembourg | 0,9 |
| 14 | Hungary | 0,9 |
| 15 | Belgium | 0,7 |
| 16 | Denmark | 0,7 |
| 17 | UK | 0,7 |
| 18 | Latvia | 0,7 |
| 19 | Finland | 0,6 |
| 20 | Slovenia | 0,6 |

EU 28

Average percentage of BEV app. 0,9%

Data source: https://www.elektroauto-news.net/2019/oesterreich-und-niederlande-fuehrend-bei-elektroauto-zulassungen-in-der-eu, Website visited on May22nd 2019

# Total Number of BEV in Europe
# Top 20 Countries, February 2018

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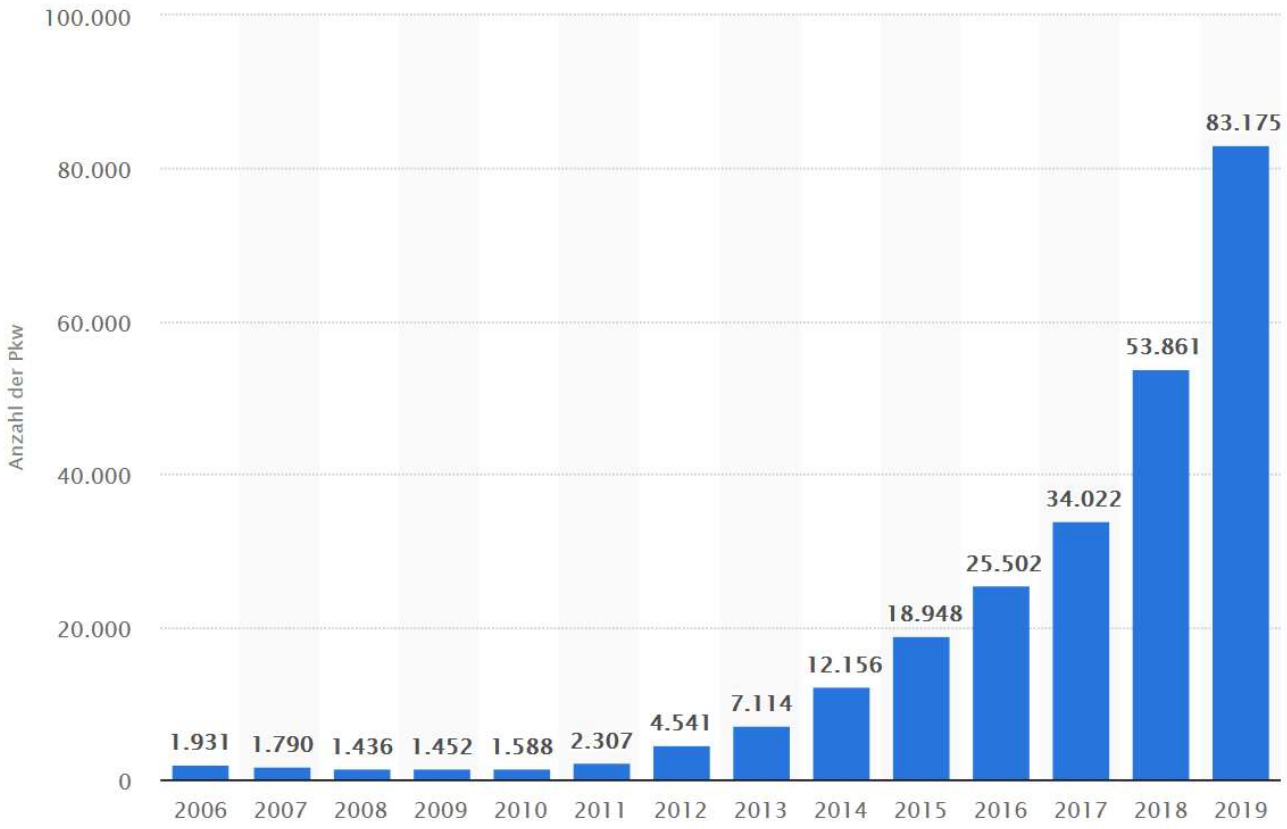
| | | |
|---|---|---|
| 1 | Norway | 46091 |
| 2 | Germany | 35241 |
| 3 | France | 30987 |
| 4 | Netherlands | 23938 |
| 5 | UK | 15532 |
| 6 | Sweden | 7109 |
| 7 | Austria | 6749 |
| 8 | Spain | 6003 |
| 9 | Switzerland | 5090 |
| 10 | Italy | 4978 |
| 11 | Portugal | 4479 |
| 12 | Belgium | 3728 |
| 13 | Denmark | 1460 |
| 14 | Hungary | 1277 |
| 15 | Ireland | 1237 |
| 16 | Finland | 776 |
| 17 | Iceland | 759 |
| 18 | Czech Republic | 699 |
| 19 | Poland | 638 |
| 20 | Romania | 477 |

EU 28

Total number of BEV 147.556

Data source: https://www.elektroauto-news.net/2019/oesterreich-und-niederlande-fuehrend-bei-elektroauto-zulassungen-in-der-eu, Website visited on May22nd 2019

# Total Number of BEV in Germany 2006 – 2019




Ihre Daten visualisiert tableau

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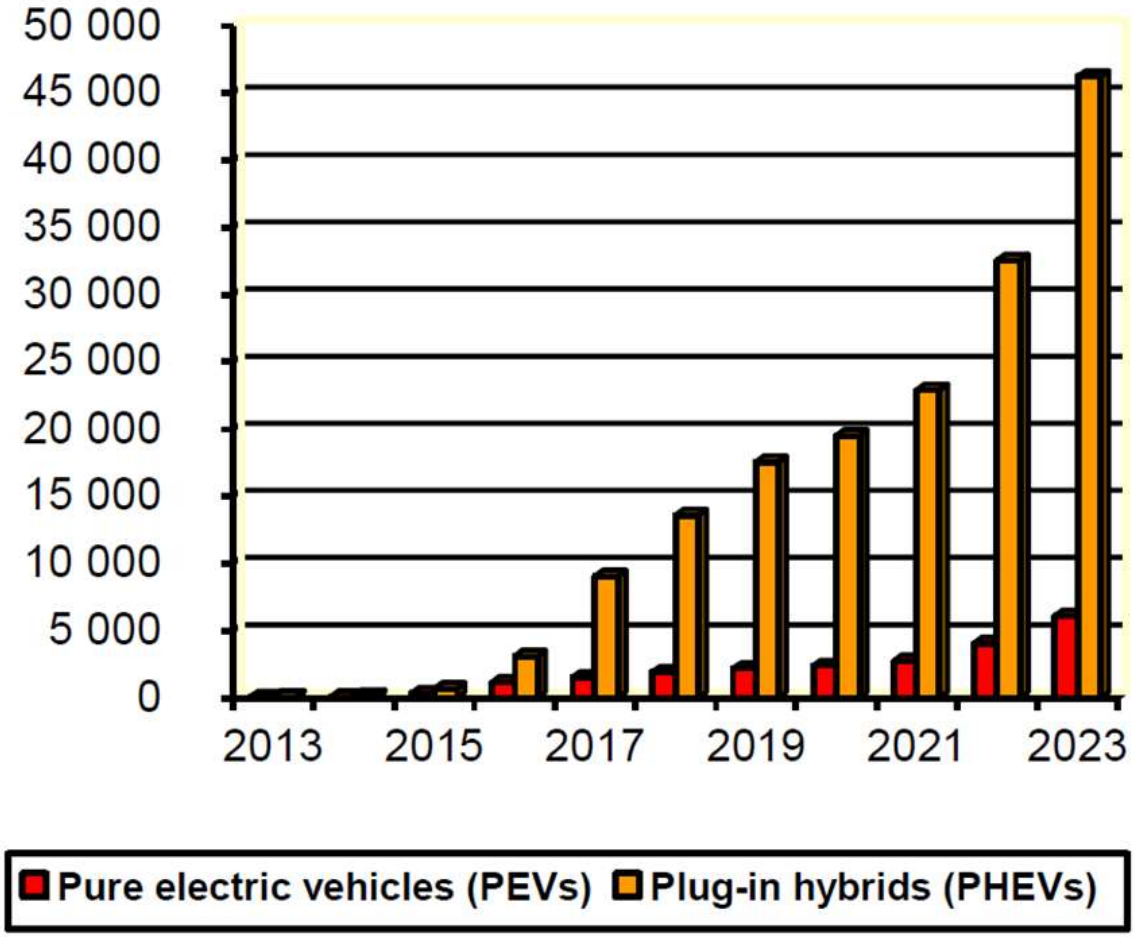
sales figures of BEV's in Germany have 2018 started to rise significantly

Source: https://de.statista.com/statistik/daten/studie/265995/umfrage/anzahl-der-elektroautos-in-deutschland/, Website visited on May 24th 2019

# Number of BEV and PHEV for Hungary Total – REALISTIC scenario




The OPTIMISTIC scenario is more than 2.5 times higher!

The Author of the paper concluded that this would be required incentives from the Government for both, the BEV/PHEV owners and the operators of charging stations

Source: E-mobility Outlook of Hungary, Peter Gyenes: PwC Hungary Ltd. – Energy, Utilities & Mining, H-1055 Budapest, 2015, Trivent Publishing, Engineering and Industry Series; Volume Deregulated Electricity Market Issues in South Eastern Europe, page 191

# Total Number of Charging Locations in Europe Top 20 Countries, May 2019

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| | | |
|---|---|---|
| 1 | Germany | 12004 |
| 2 | Netherlands | 7800 |
| 3 | UK | 7502 |
| 4 | Italy | 4366 |
| 5 | Norway | 2097 |
| 6 | France | 1994 |
| 7 | Sweden | 1479 |
| 8 | Spain | 1446 |
| 9 | Austria | 912 |
| 10 | Belgium | 857 |
| 11 | Switzerland | 709 |
| 12 | Portugal | 661 |
| 13 | Ireland | 650 |
| 14 | Hungary | 474 |
| 15 | Czech Republic | 421 |
| 16 | Finland | 360 |
| 17 | Poland | 189 |
| 18 | Slovakia | 176 |
| 19 | Estonia | 154 |
| 20 | Denmark | 147 |

The total number of charging points is (in some cases) significantly higher.

**Germany: 29.349**

**Hungary: 927**

Data source:
https://openchargemap.org/site/country,
Website visited on May 24th 2019

# Total Number of Charging Locations in Hungary and its neighbouring countries, May 2019

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| | | |
|---|---|---|
| 1 | Austria | 912 |
| 2 | Hungary | 474 |
| 3 | Slovakia | 176 |
| 4 | Croatia | 102 |
| 5 | Slovenia | 96 |
| 6 | Romania | 34 |
| 7 | Ukraine | 16 |
| 8 | Serbia | 16 |

Data source: https://openchargemap.org/site/country, Website visited on May 24th 2019

# Number of Inhabitants per Charging Location in Europe Top 21 Countries, May 2019

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| | | |
|---|---|---|
| 1 | Monaco | 1.027 |
| 2 | San Marino | 1.675 |
| 3 | Netherlands | 2.179 |
| 4 | Norway | 2.527 |
| 5 | Iceland | 2.857 |
| 6 | Andorra | 4.053 |
| 7 | Liechtenstein | 6.333 |
| 8 | Sweden | 6.761 |
| 9 | Germany | 6.831 |
| 10 | Ireland | 7.385 |
| 11 | Luxembourg | 7.945 |
| 12 | Malta | 7.963 |
| 13 | Estonia | 8.442 |
| 14 | UK | 8.798 |
| 15 | Austria | 9.649 |
| 16 | Switzerland | 11.989 |
| 17 | Belgium | 13.419 |
| 18 | Italy | 13.514 |
| 19 | Portugal | 15.129 |
| 20 | Finland | 15.278 |
| 21 | Hungary | 20.464 |

Data source:
https://openchargemap.org/site/country,
Website visited on May 24th 2019

# Total Number of inhabitants per charging location in Hungary and its neighbouring countries, May 2019

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| | | |
|---|---|---|
| 1 | Austria | 9.649 |
| 2 | Hungary | 20.464 |
| 3 | Slovenia | 20.833 |
| 4 | Slovakia | 30.682 |
| 5 | Croatia | 41.176 |
| 6 | Serbia | 437.500 |
| 7 | Romania | 588.235 |
| 8 | Ukraine | 2.750.000 |

Data source: https://openchargemap.org/site/country, Website visited on May 24th 2019

# IZES Projects on Infrastructure Concepts for BEV

- OptiCharge/OptiCharge+
  - Construction of a renewably powered, self-sufficient and energy storage-supported charging location for Battery Electric Vehicles (BEV)
  - The charging location consists of:
    - Vanadium Redox-Flow Battery with 30 kW and 120 kWh
    - four independent charging points, semi public
    - PV-array with 10 kWp
    - EMS as central control system
    - self-developed booking system for the IZES pool cars

# Project OptiCharge
# Project partners and their responsibilities

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izes gGmbH Institut für ZukunftsEnergie- und Stoffstromsysteme

Construction & operation of the entire plant as well as monitoring and scientific follow-up

SCHMID

Construction and further development of the VRF battery

Technische Universität Kaiserslautern

Development of the Energy Management System (EMS)

Universität des Saarlandes

Optimization of active materials (membrane, electrodes) and SOC measurement

# Project OptiCharge
# Images of the Construction Phase

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Picture source: IZES gGmbH

# Project OptiCharge
# Images of the Construction Phase

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Picture source: IZES gGmbH

# Project OptiCharge
# Images of the Construction Phase

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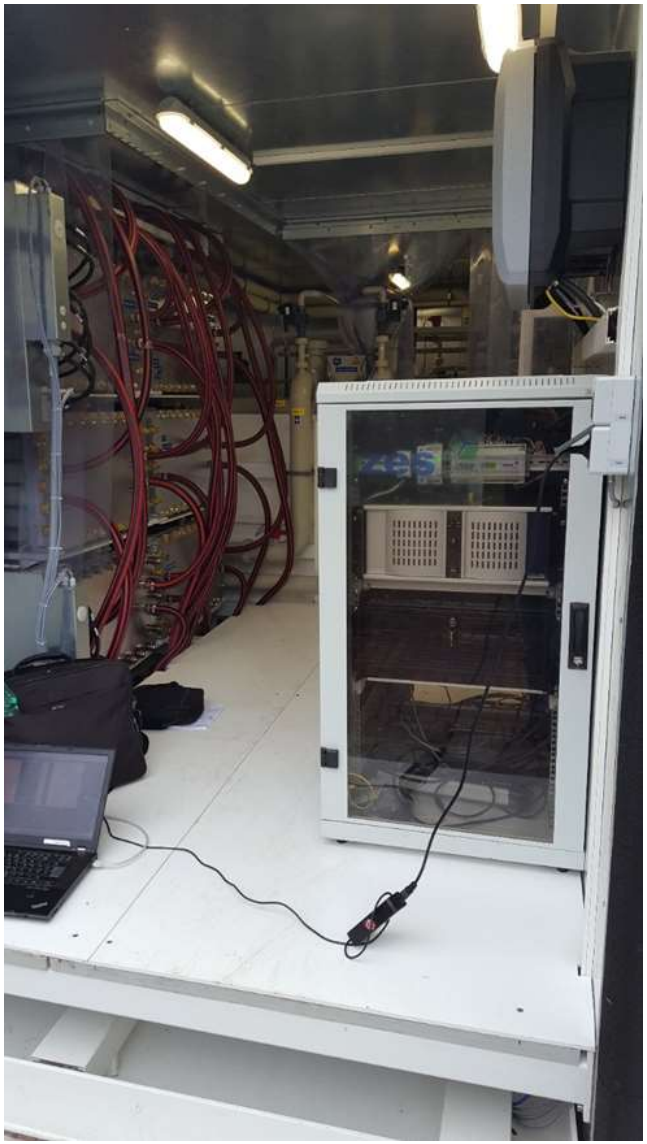
Picture source: IZES gGmbH



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# Project OptiCharge Images of the Construction Phase

Picture source: IZES gGmbH

# Project OptiCharge
# Images of the Construction Phase

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Picture source: IZES gGmbH

# Project OptiCharge
# Images of the Construction Phase

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Picture source: IZES gGmbH

# Project OptiCharge
# Location of the Charging Station

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OptiCharge Charging Station

Vanadium Redox Flow Battery

IZES GmbH office building

# Project OptiCharge
# Results: Loading without EMS

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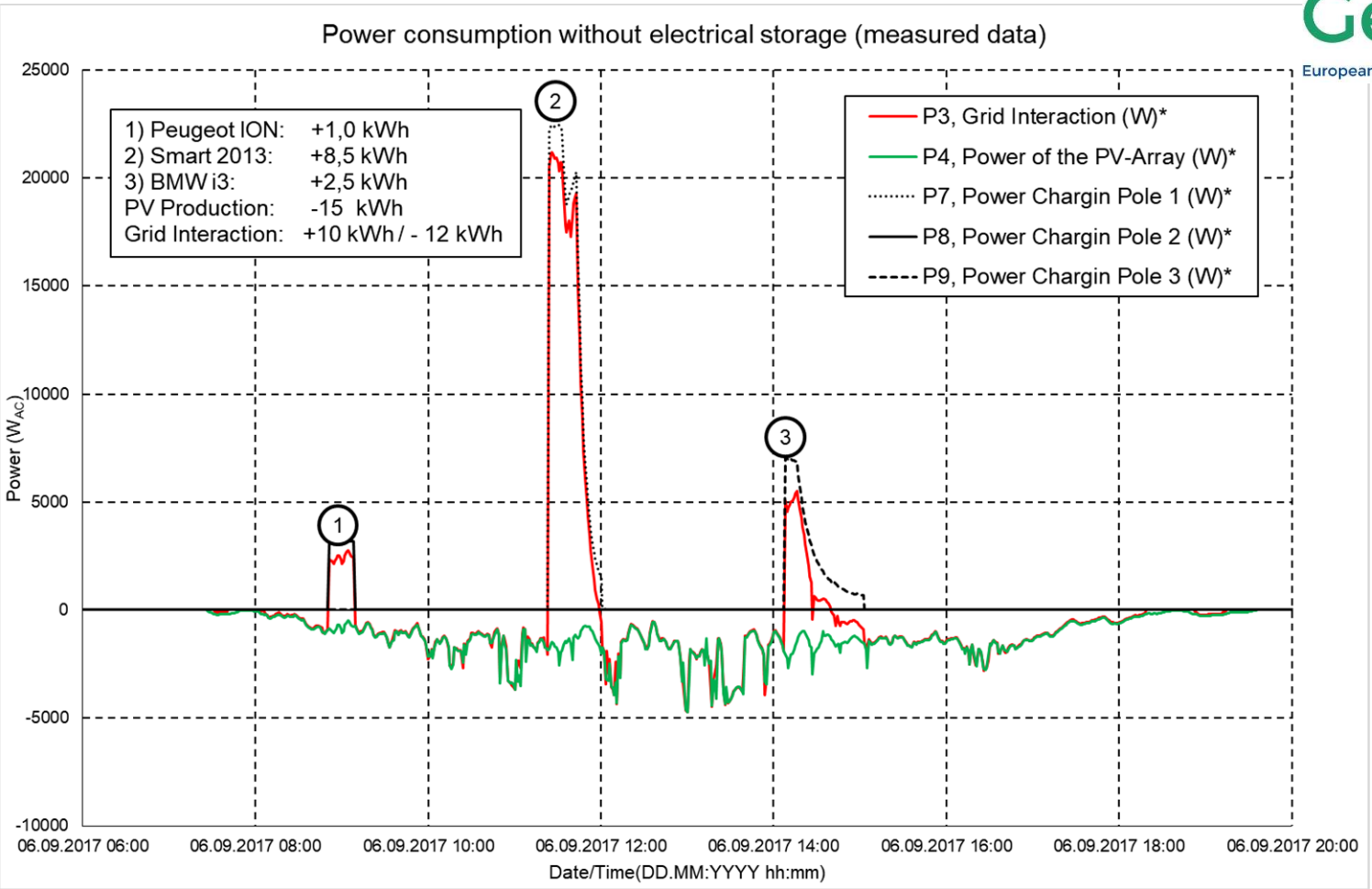
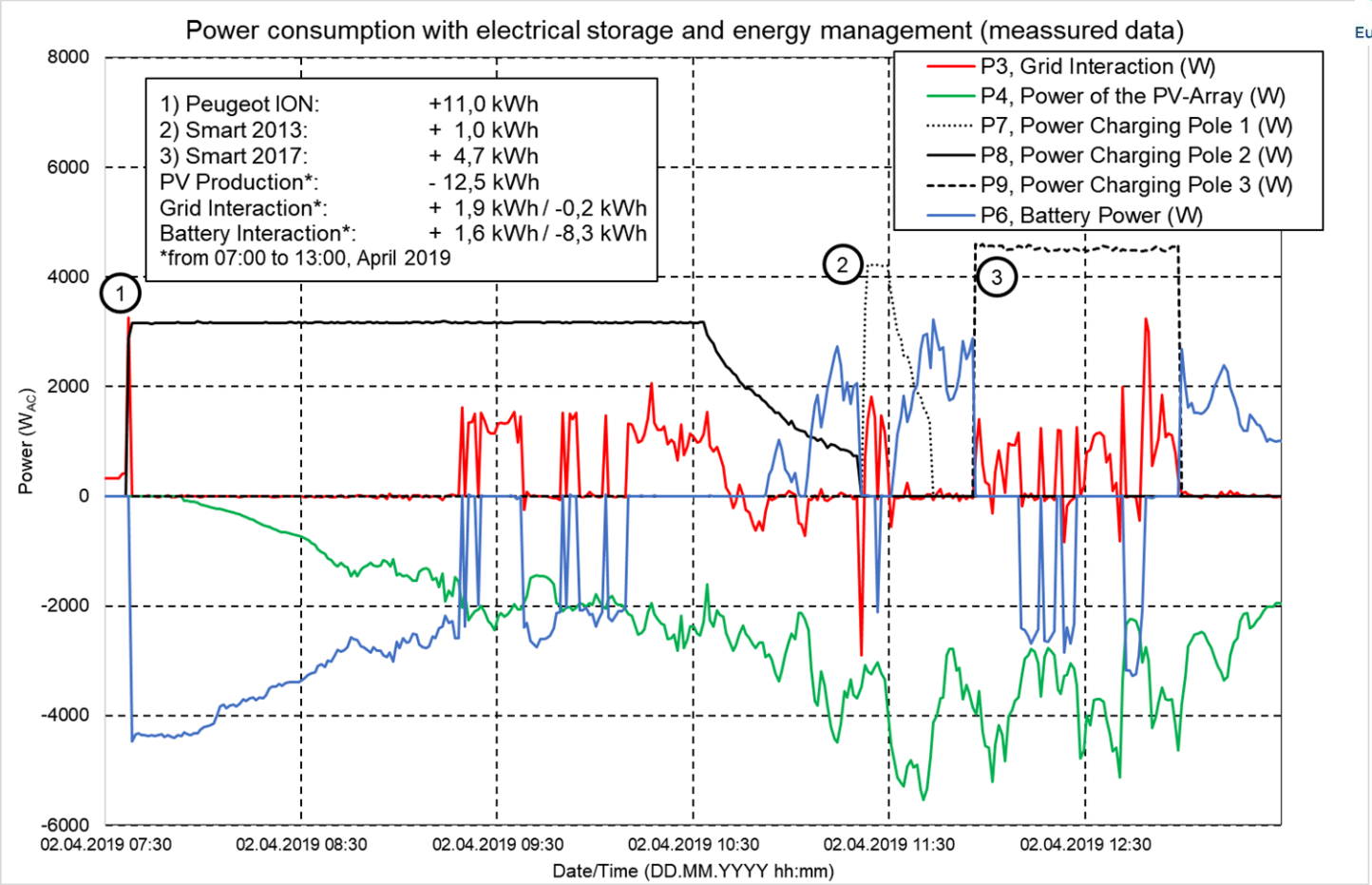



Picture source: IZES gGmbH

# Project OptiCharge
# Results: Loading with EMS

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Picture source: IZES gGmbH

# Comparison BEV vs. FCEV
# November 2018

Source: https://www.wirkaufendeinauto.de/magazin/brennstoffzelle-oder-akku-technologie/, Website visited on May22nd 2019

# Total Number of FCEV in Europe 16 Countries, End of 2018

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| | | |
|---|---|---|
| 1 | Germany | 487 |
| 2 | France | 324 |
| 3 | Norway | 143 |
| 4 | UK | 138 |
| 5 | Denmark | 85 |
| 6 | Switzerland | 56 |
| 7 | Netherlands | 48 |
| 8 | Sweden | 42 |
| 9 | Austria | 24 |
| 10 | Iceland | 23 |
| 11 | Italy | 18 |
| 12 | Belgium | 17 |
| 13 | Slovakia | 9 |
| 14 | Luxembourg | 2 |
| 15 | Finland | 1 |
| 16 | Spain | 1 |

- North America
  - 5.917 / 46%
- Asia
  - 5.617 / 43%
- Europe
  - 1.418 / 11%

Source: IEA Technology Collaboration Programme: AFC TCP 2019 Survey on the Number of Fuel Cell Vehicles, Hydrogen Refueling Stations and Targets

# Total Number of Hyrdogen Refuelling Stations in Europe 16 Countries, End of 2018

Source: IEA Technology Collaboration Programme: AFC TCP 2019 Survey on the Number of Fuel Cell Vehicles, Hydrogen Refueling Stations and Targets

| | | |
|---|---|---|
| 1 | Germany | 69 |
| 2 | France | 23 |
| 3 | UK | 20 |
| 4 | Denmark | 10 |
| 5 | Norway | 9 |
| 6 | Switzerland | 6 |
| 7 | Austria | 6 |
| 8 | Spain | 6 |
| 9 | Sweden | 5 |
| 10 | Netherlands | 4 |
| 11 | Italy | 4 |
| 12 | Belgium | 4 |
| 13 | Finland | 2 |
| 14 | Iceland | 1 |
| 15 | Latvia | 1 |
| 16 | Czech Republic | 1 |
| 17 | Slovakia | 0 |
| 18 | Luxembourg | 0 |

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- North America: 70 HRS
- Asia: 132 HRS
- Europe: 171 HRS
- Rest: 3 HRS
- Total number: 376 HRS

# Operational Hydrogen Refuelling Stations in Europe, April 2019

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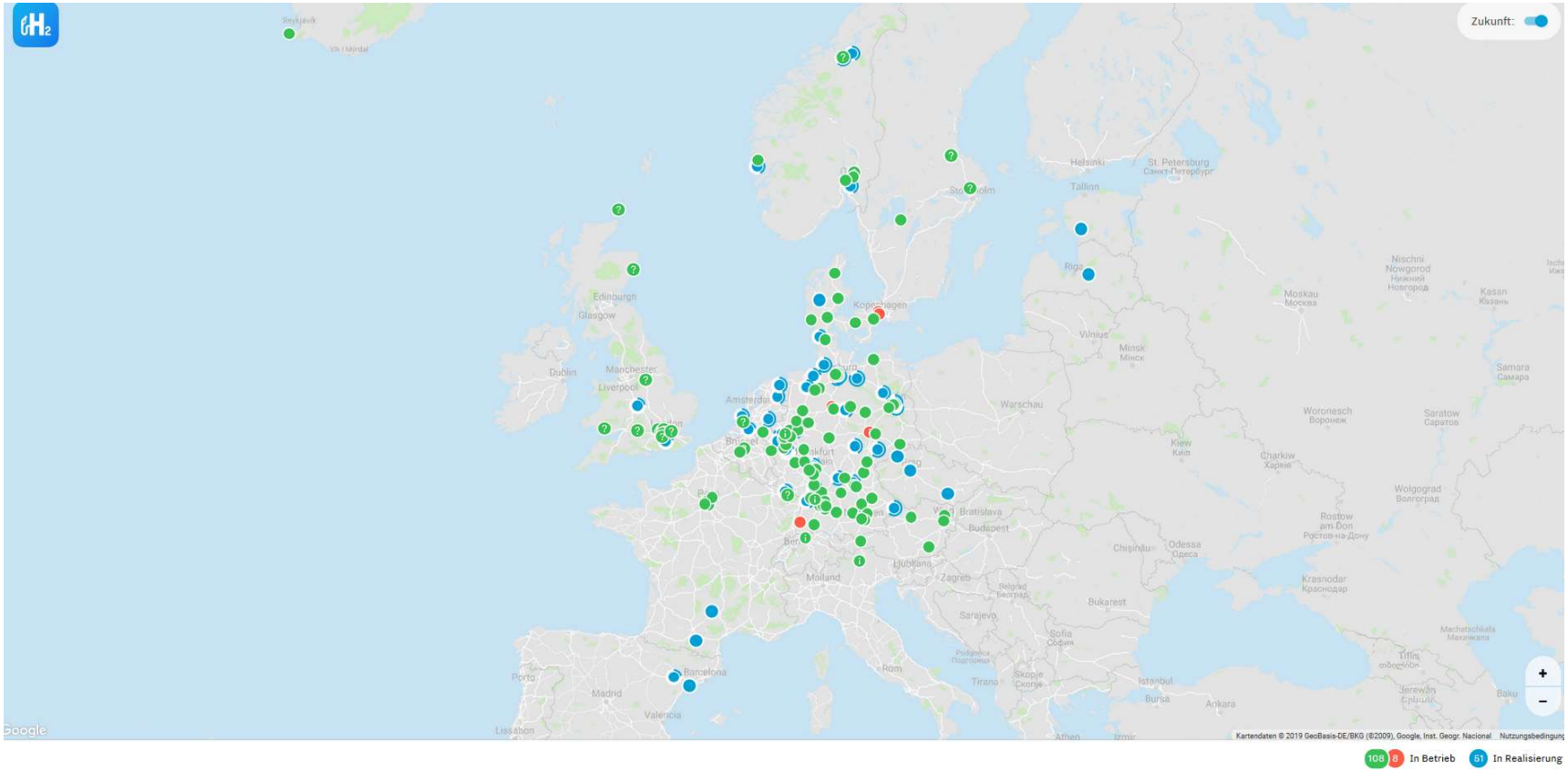
Source: http://h2tankstellen.cleanenergypartnership.de/, Website visited on May22nd 2019

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# Operational Hydrogen Refuelling Stations in Central Europe, April 2019

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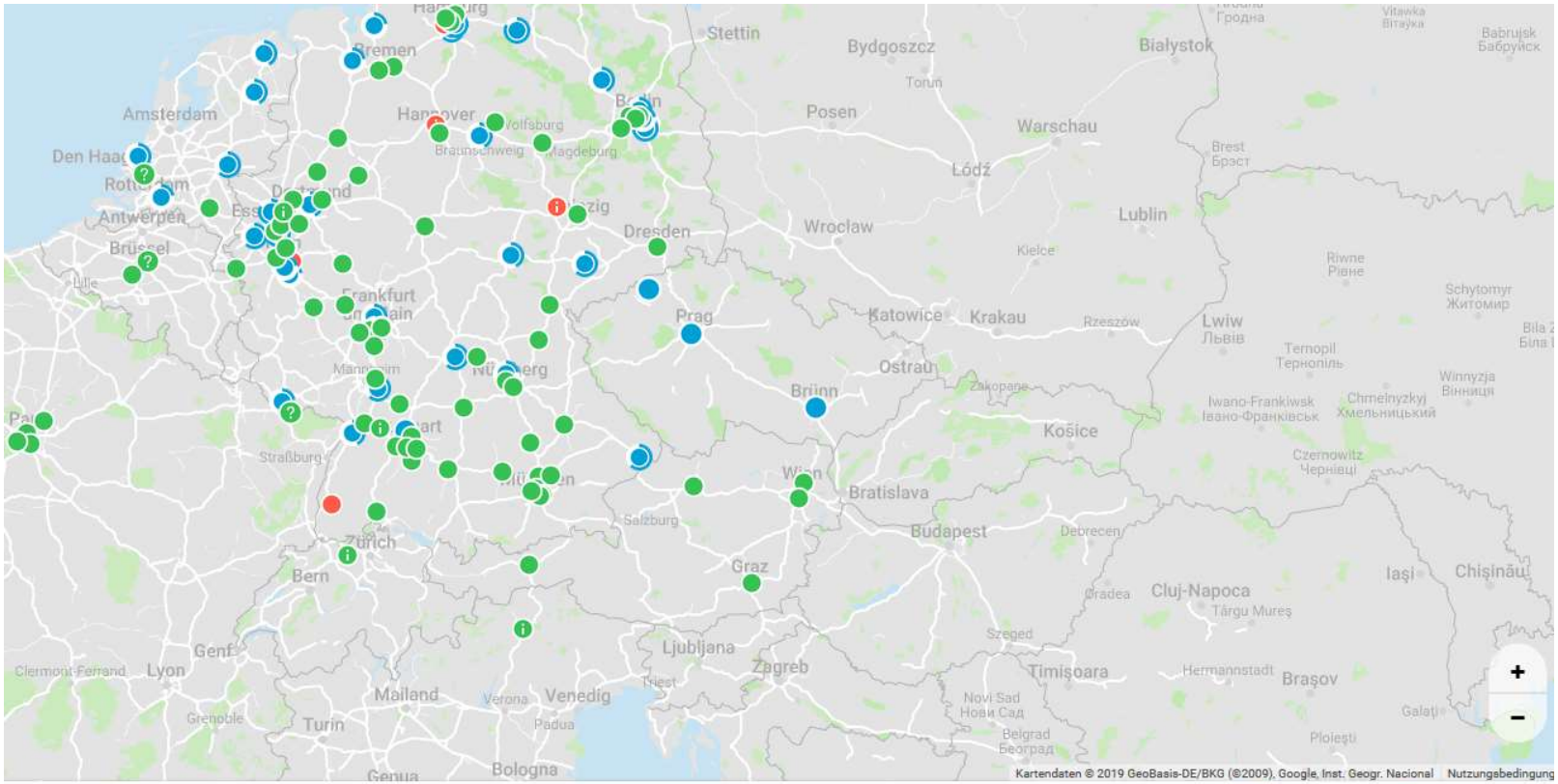
Source: http://h2tankstellen.cleanenergypartnership.de/, Website visited on May22nd 2019

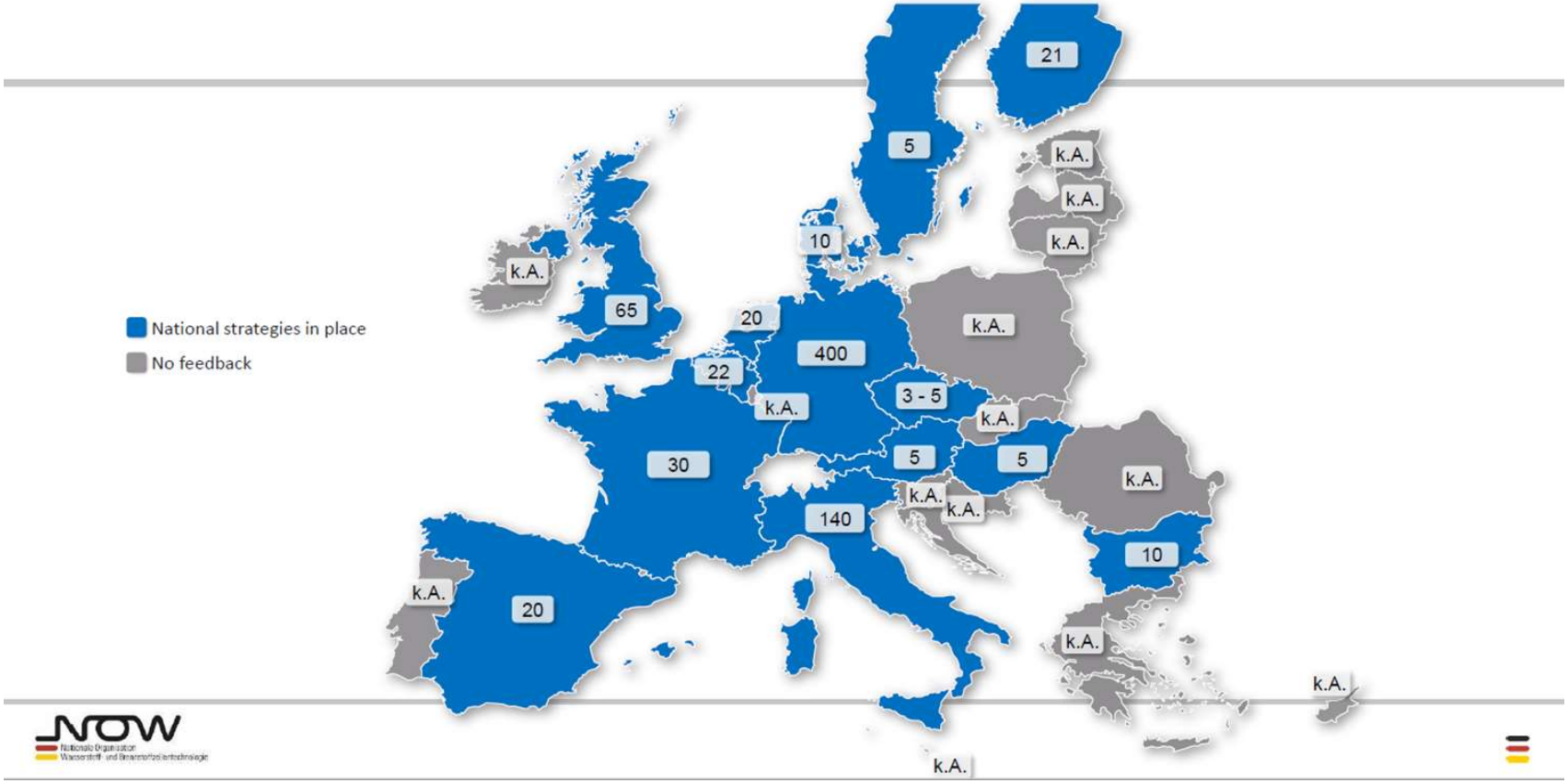



108 8 In Betrieb 51 In Realisierung

# Spotlight on latest Procects and Activities – Infrastructure

Source: Thorsten Herbert, Deployment of Hydrogen and Fuel Cell Tchnology in Europe, EHEC Malaga, March 15th 2018

## NATIONAL STRATEGIC FRAMEWORKS – HYDROGEN



# Operational Hydrogen Refuelling Stations in Germany, April 2019

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**Aktuell: 70 eröffnete H2-Tankstellen**
in Deutschland

Source: https://h2.live/, Website visited on May22nd 2019

# Project GenComm
# Project overview

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- GenComm – GENerating energy secure COMMunities. Smart Hydrogen -Integrated renewable energy, generation & storage to develop a new model for exploiting remotely generated electricity from renewable sources to provide energy security for remote communities.

- GenComm project focuses on increasing the uptake of the local renewable sources by communities, mostly peripheral, in the NWE region, by implementing an energy model that relies on hydrogen as an energy carrier and is utilised to supply the main forms of energy demand: electricity, heating and transportation fuels.

# Project GenComm
# General Overview

Interreg
EUROPEAN UNION
North-West Europe
GenComm
European Regional Development Fund

Ministerium für Wirtschaft, Arbeit, Energie und Verkehr
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- ERDF Funding: 5.63 Million €
- Total Budget: 9.39 Million €
- Lead-Partner: Belfast Metropolitan College
- Ten European Partners from five different Countries

# Project GenComm
# Project Partner List

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- Belfast Metropolitan College, United Kingdom, Northern Ireland
- Viridian Energy Supply Limited, United Kingdom, Northern Ireland
- HyEnergy, United Kingdom, England,
- Pure Energy Centre, United Kingdom, Scotland,
- National University of Ireland Galway, Ireland,
- TK Renewables, United Kingdom, Northern Ireland
- BURN Joint Research Group, Vrije Universiteit Brussels, Belgium
- INSA Rouen Normandie, France
- ENSICAEN, France
- IZES gGmbH, Germany

# Project GenComm
# General Objectives

- Implementation of three pilot plants with different renewable sources
  - Solar Power, Wind Power and Bioenergy
- Usage in the main forms of energetic demand
  - Heat, Power and Transportation
- Validation of the maturity level of hydrogen technologies
- Development of integrated technical and financial decision support tools

# Project GenComm
# Objectives of the IZES part

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- Implementation of the solar powered HRS
- Usage of solar energy for Hydrogen ($H_2$) production
- $H_2$ as transportation fuel for passenger vehicles (FCEV)
- Pilot $H_2$ refuelling station (HRS) using renewable sources
- Validating sustainable transport solutions
- Validation of the maturity level or TRL of $H_2$ technologies
- Technical and financial analysis of the solar powered HRS
- Fighting…

# Project GenComm
# Lighthouse-effect for the Grand Region Saar-Lor-Lux

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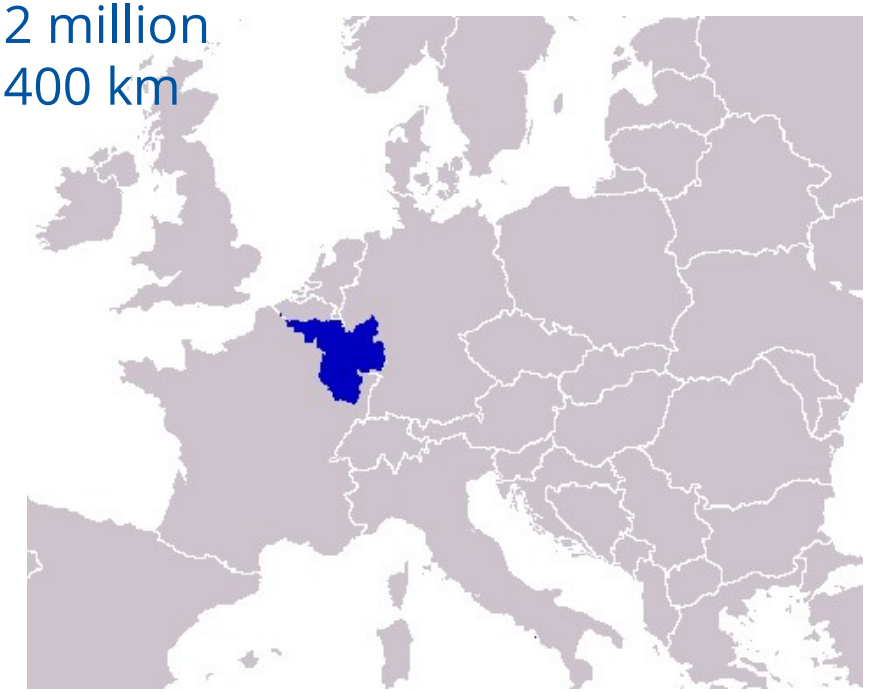
Grand Region Saar-Lor-Lux
Inhabitants: 11.2 million
Area: 65.400 km
Four countries: Belgium, France, Germany and Luxembourg



# Project GenComm
# Hydrogen Refuelling Stations in the Grand Region Saar-Lor-Lux

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## Koblenz: 21.11.2017; 350 / 700 bar

Quelle: http://www.tageblatt.lu/headlines/vorerst-keine-wasserstoff-tankstelle-in-luxemburg/ abgerufen 20181106

## Brüssel: 22.04.2016; 350 bar

Quelle: https://industrie.airliquide.de/sites/industry_de/files/2017/06/22/wasserstoff_macht_mobil_2017.pdf/ abgerufen 20181106

## Sarregumines: 11.04.2017; 350 bar

Quelle: https://mcphy.com/fr/nos-produits-et-solutions/stations-hydrogene/grandes-capacite/ abgerufen 20181106

# Project GenComm
# Design of the Solar Powered IZES Hydrogen Refuelling Station

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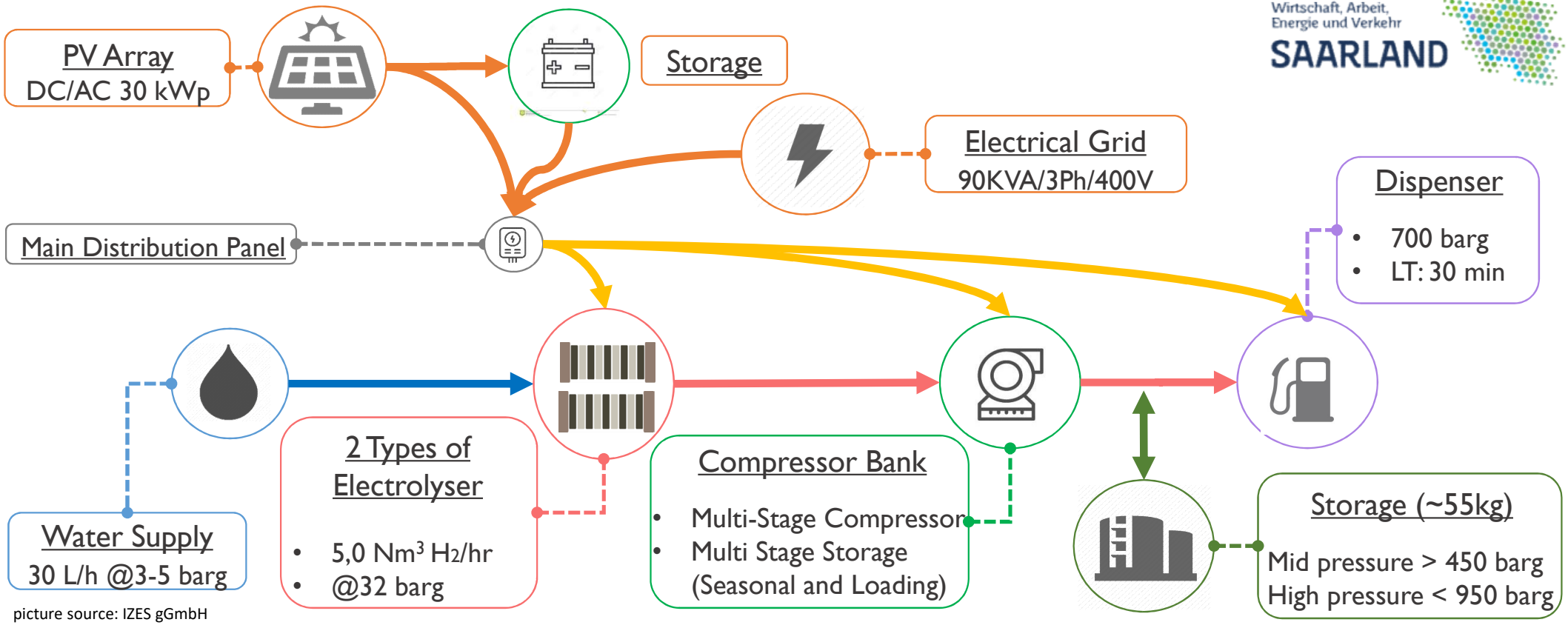


picture source: IZES gGmbH

# Project GenComm
# Description of the IZES Hydrogen Refuelling Station

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- Located in 66115 Saarbrücken, Altenkesseler Straße 17A1, Germany
- Semi-Autonomous Operation (PV-Array; 30 kWp)
- 55 kg storage capacity at two pressure ranges 450/950 barg
- 700 barg loading; maximum loading time 30 min
- Simultaneous use of AEM and PEM electrolyser, maximum $H_2$ production: 5 $Nm^3/h$
- Gas quality: 5.0 or 99,999%
- Water Treatment Unit
- Containerised solution; two 20 feet container
- Operation as a non-public refuelling station
- Monitoring and plant management system

picture source: google maps, edited by IZES gGmbH

# Project GenComm
# Location of the IZES Hydrogen Refuelling Station

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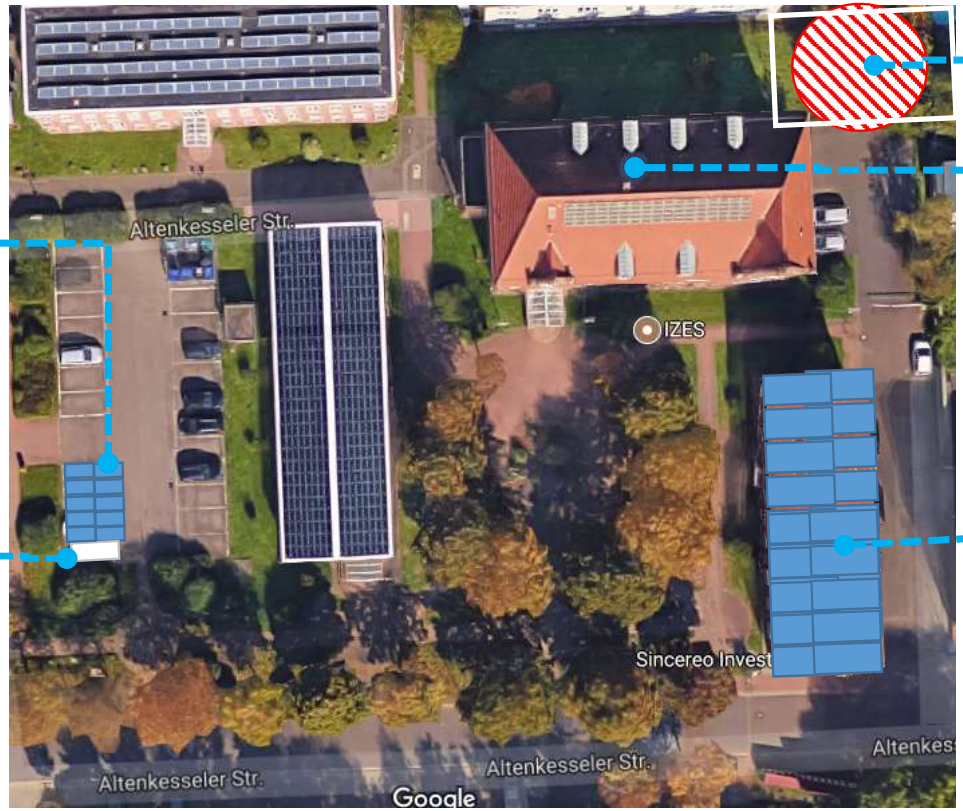


$H_2$ Refuelling Station

IZES GmbH office building

OptiCharge Charging Station

Vanadium Redox Flow Battery

PV Array GenComm

picture source: google maps, edited by IZES gGmbH

# Project GenComm
# Ongoing Work, First Results

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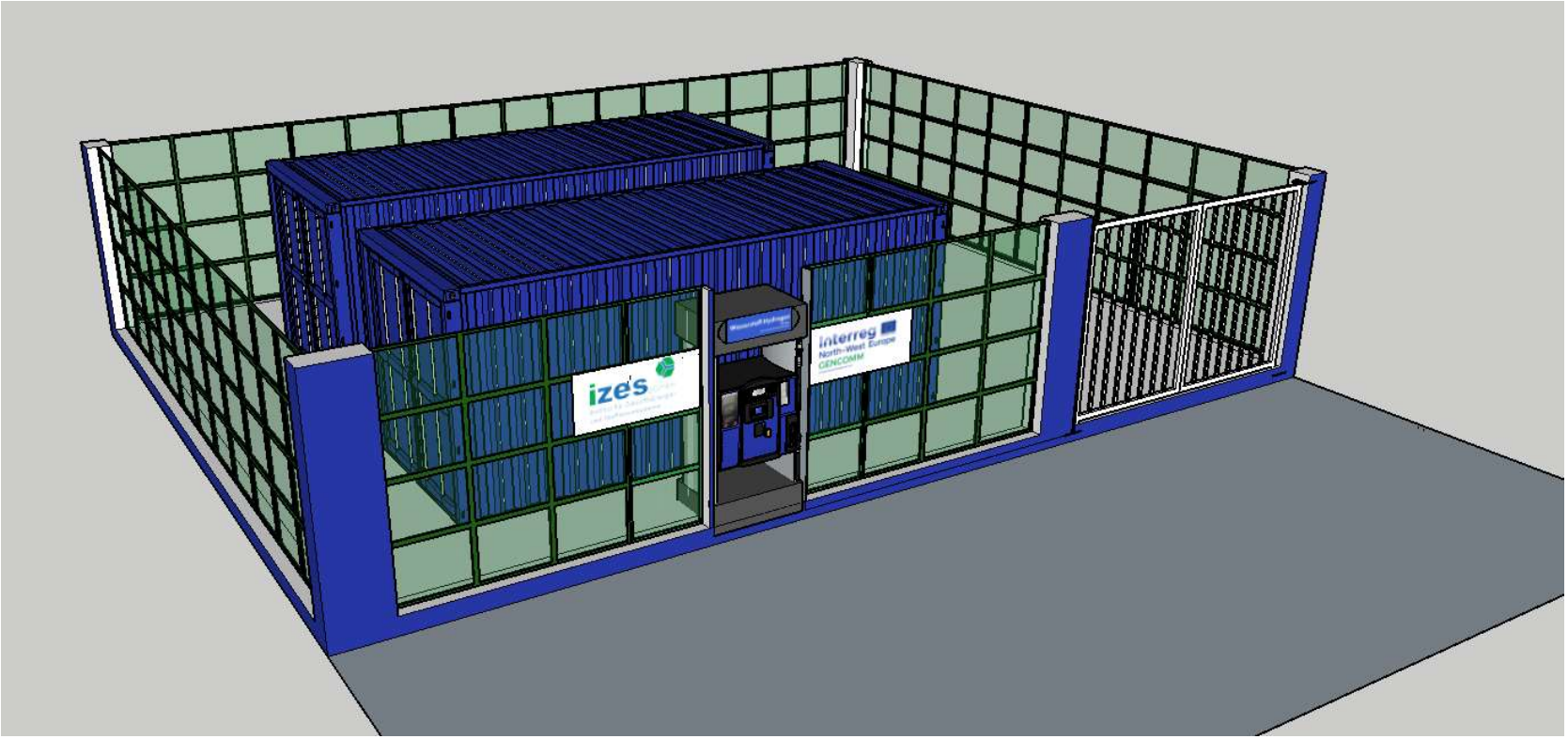
picture source: IZES gGmbH

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# Project GenComm
# Ongoing Work, First Results

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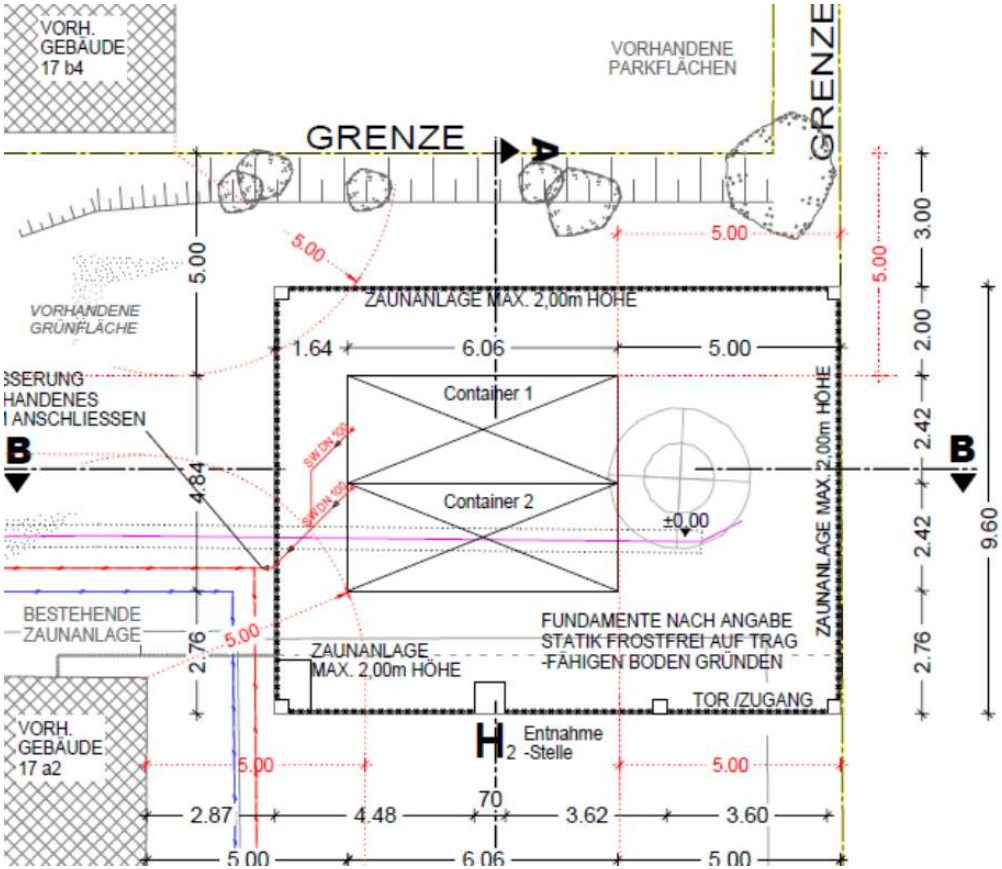
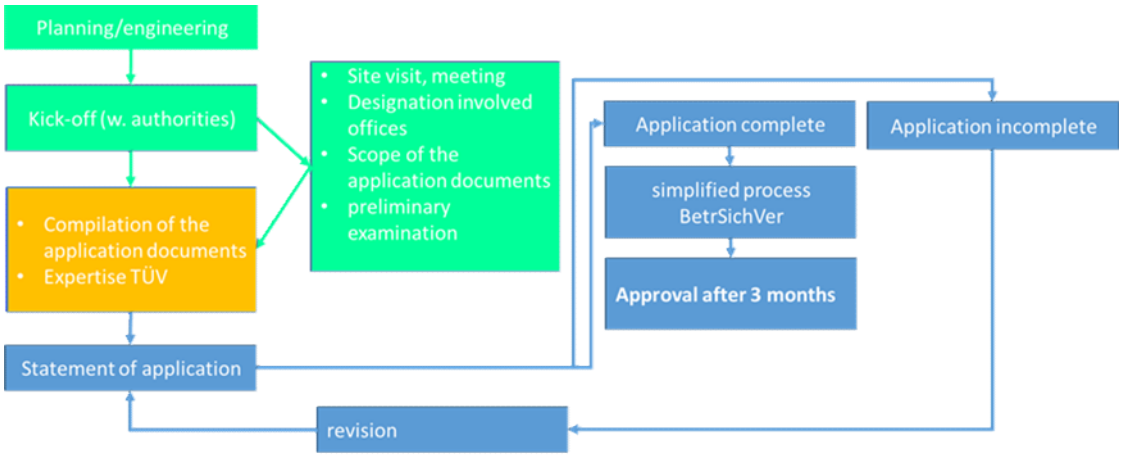
picture source: IZES gGmbH




## Procedure for getting the building and operation permit



# Project GenComm
# Ongoing Work, planned Location of the IZES HRS

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picture source: IZES gGmbH

- Technical approval and building permission takes time, extensive research and „authority engineering“
- At present there are no existing standards for Hydrogen Refuelling Stations
- Mutual learning processes together with
  - Technical Inspection Associations
  - Building Permit Authorities
  - Fire Department
  - Landlords and neighbours
  - Federal Office for the Environment and Work Safety

# Project GenComm
# Ongoing Work, planned Location for the PV-array

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picture source: IZES gGmbH

# Project GenComm
# The first FCEV in the Federal State of Saarland

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# Köszönöm a figyelmet!

**Dr. Bodo Groß**

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