



# wind2hydrogen – first results

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## Transforming renewable energy into Hydrogen for the storage and transportation in the natural gas infrastructure



**EVN**



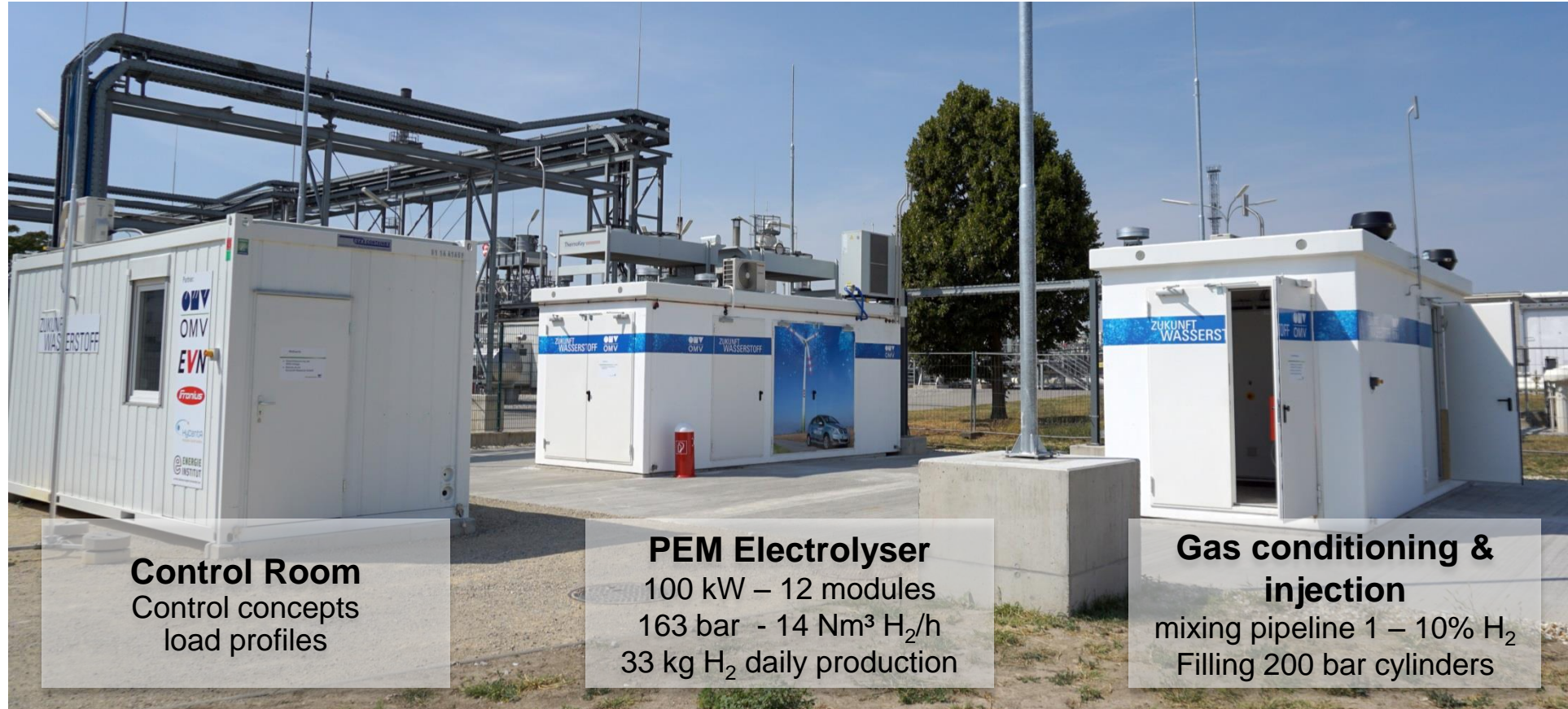
- ▶ Funded under e!MISSION.at – Energy Mission Austria
- ▶ Project duration 2014-2017
- ▶ EUR 2,8 Mio. total budget

# wind2hydrogen Research Focus



- ▶ Development of a **modular, highly flexible high pressure Proton Exchange Membrane PEM-Electrolyser** for the production of high quality hydrogen
- ▶ **H<sub>2</sub> production at 163 bar** (pilot plant w2h) and **350 bar** (R&D development) **without compressor**
- ▶ Injection into the high pressure gas grid
- ▶ Filling into gas cylinders for H<sub>2</sub> Mobility
- ▶ Experience from two years of experimental operation at different loads and market conditions to evaluate business models
- ▶ Ecological, economic and legal analysis in preparation for a roll out

# wind2hydrogen Pilot Plant at OMV Gas Station Auersthal, Austria

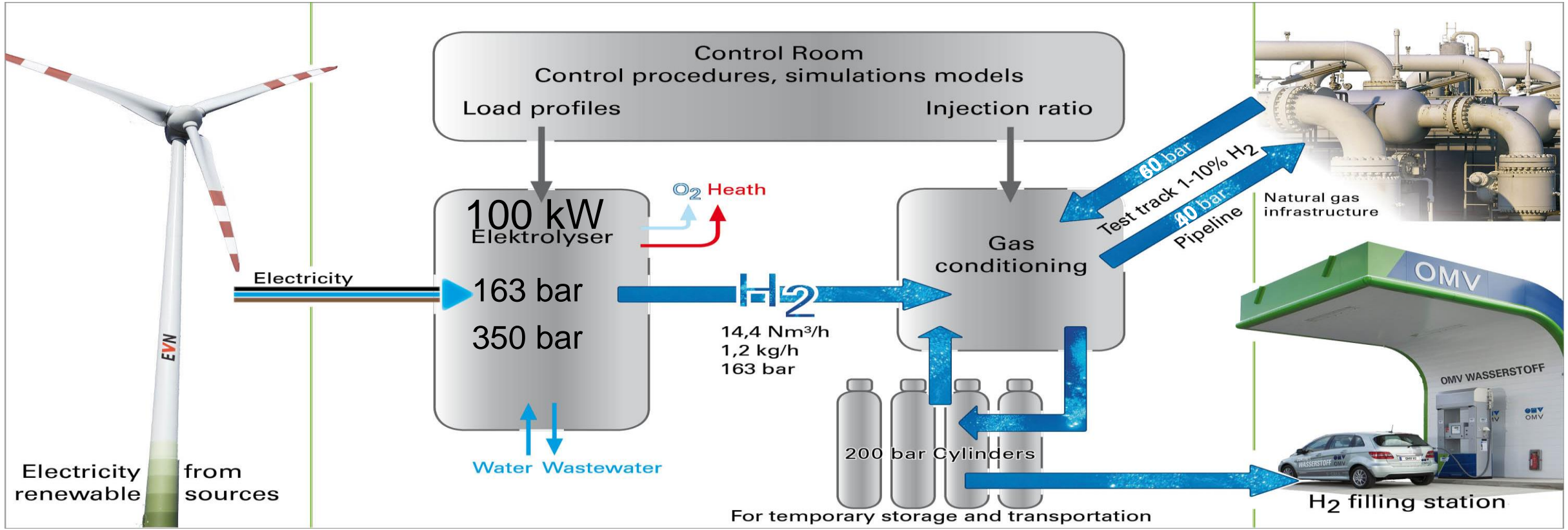


**Control Room**  
Control concepts  
load profiles

**PEM Electrolyser**  
100 kW – 12 modules  
163 bar - 14 Nm<sup>3</sup> H<sub>2</sub>/h  
33 kg H<sub>2</sub> daily production

**Gas conditioning & injection**  
mixing pipeline 1 – 10% H<sub>2</sub>  
Filling 200 bar cylinders

# wind2hydrogen Technical Project Setup



# High Pressure Electrolyser based on Fronius Energycell 10.0E

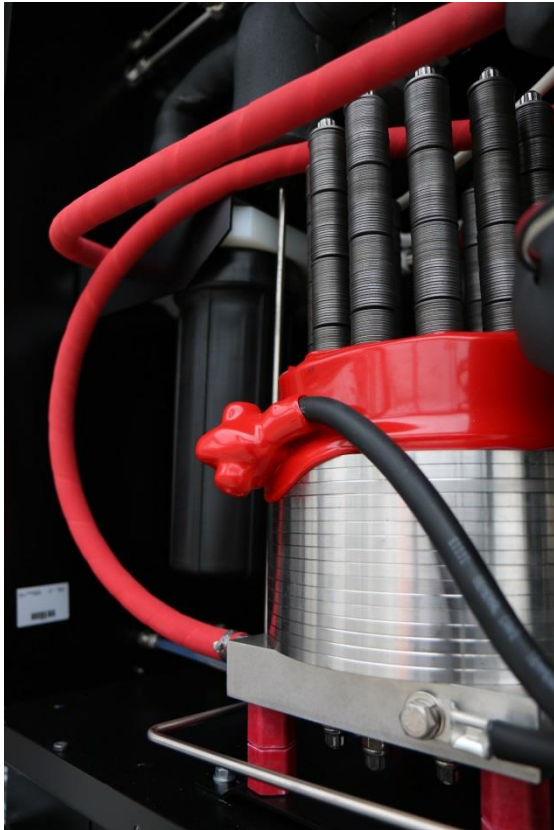
- ▶ 163 bar H<sub>2</sub> product gas pressure without mechanical compression
- ▶ >60% (HHV) hydrogen generation efficiency
- ▶ Best H<sub>2</sub> quality for PEM fuel cells
- ▶ Modular system concept for high availability, dynamic load following and part load operations
- ▶ 80°C operation temperature for by-product heat utilization
- ▶ Integrated safety concept at European standards



**Energycell 10.0E**  
8kW/400VAC  
1,2Nm<sup>3</sup>/h, 160bar, 80°C  
L/W/H 1000/380/990 mm  
ISO 22734-1:2008, EMC

# Electrolyser

## Modular 100 kW high pressure PEM Electrolyser



163 bar PEM Elektrolyser-Stack  
Proton Onsite

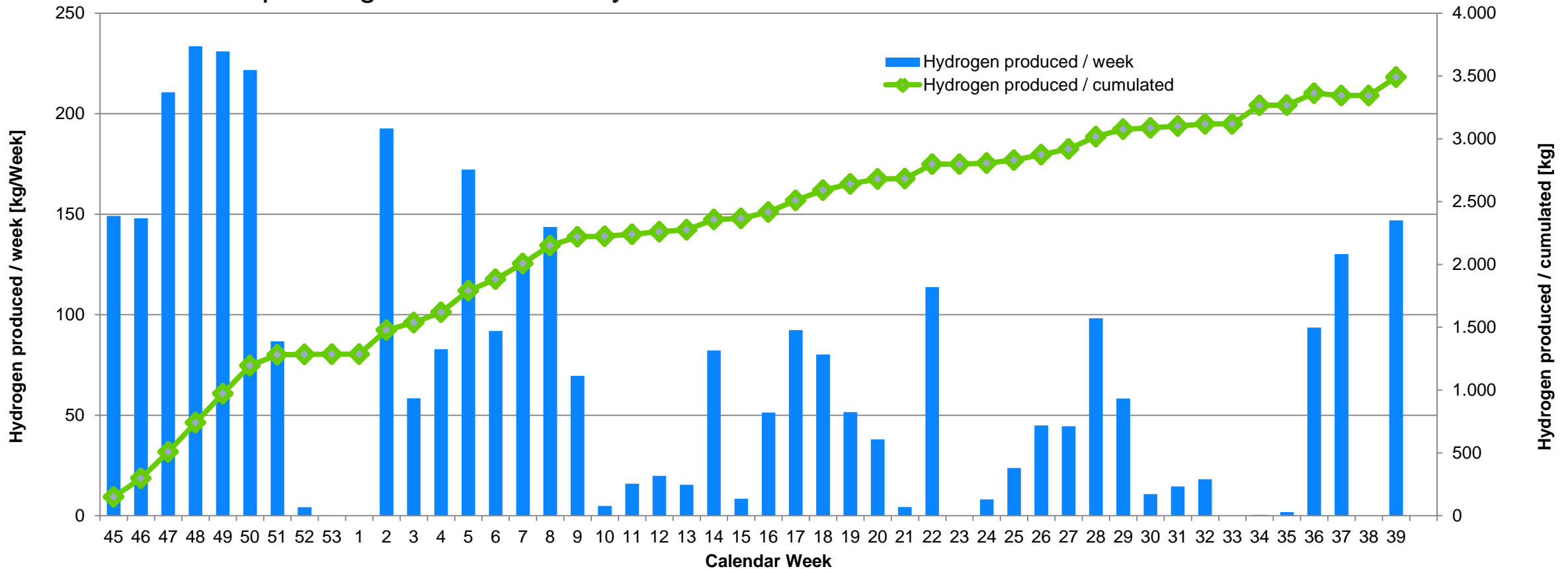


- ▶ Modular design makes the electrolyser suited for ultra-dynamic operation
- ▶ 12 individual PEM modules provide maximum flexibility towards electricity load
- ▶ H<sub>2</sub> production at a pressure of 163 bar without compressor - proven technology
- ▶ Under development:  
Fronius Energycell 32.0E” 350bar H<sub>2</sub> by electrochemical principle and without using a mechanical compressor

# wind2hydrogen Pilot Plant

## Hydrogen production during pilot operation

- ▶ Hydrogen produced : **3 491 kg** (2015 11 03 – 2016 09 30)
- ▶ Cumulated operating hours of electrolyser modules: 30 477 hrs



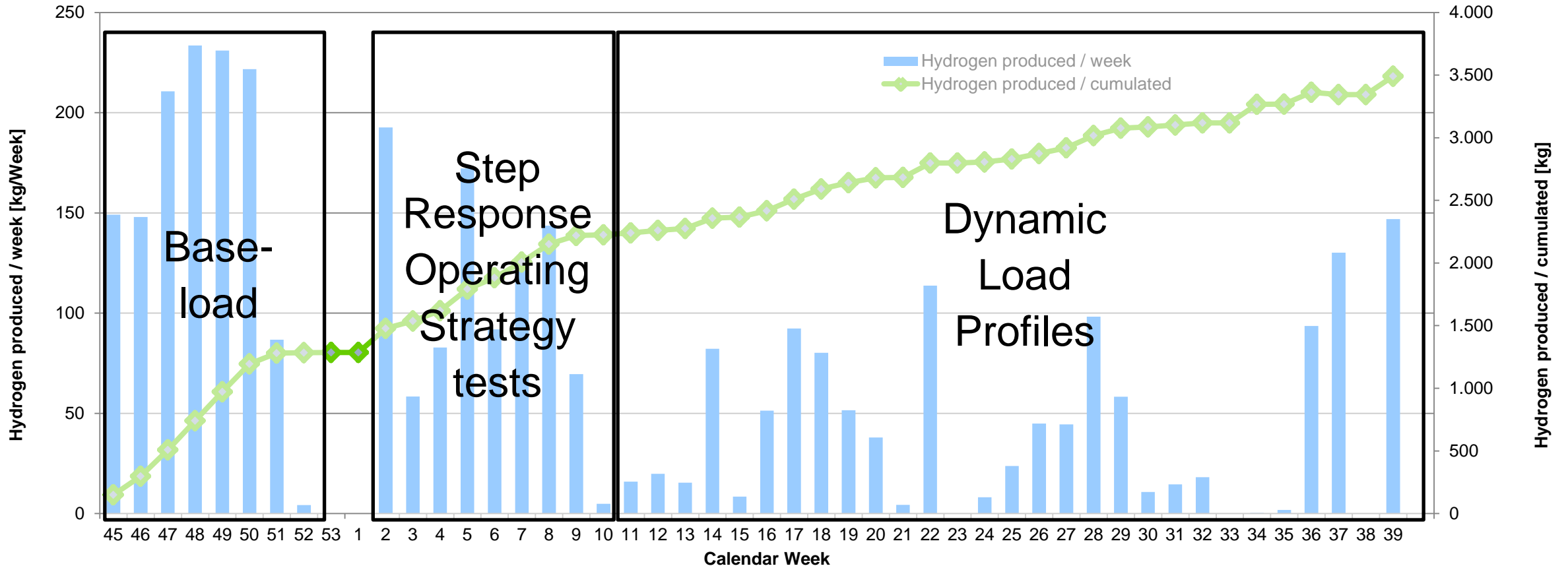


# wind2hydrogen Pilot Plant

## Hydrogen production during pilot operation

▶ Hydrogen produced : **3 491 kg**

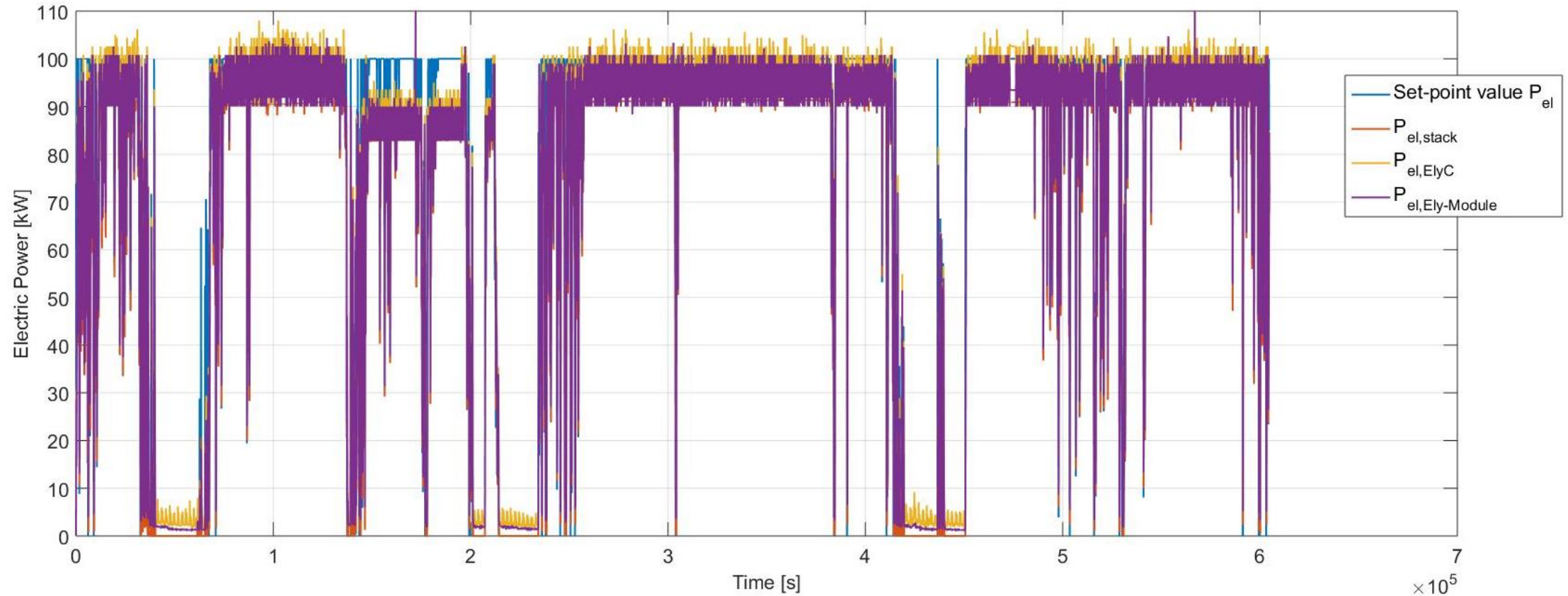
(2015 11 03 – 2016 09 30)



# wind2hydrogen

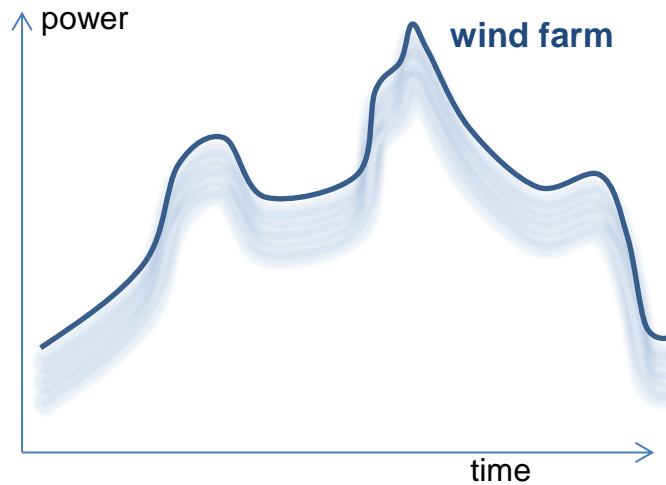
## Dynamic Operation

- ▶ Electrolyzer feeded by electricity from windpark
- ▶ 10-11 of 12 Modules in Operation; Power variation: 2 min; 1-week profile



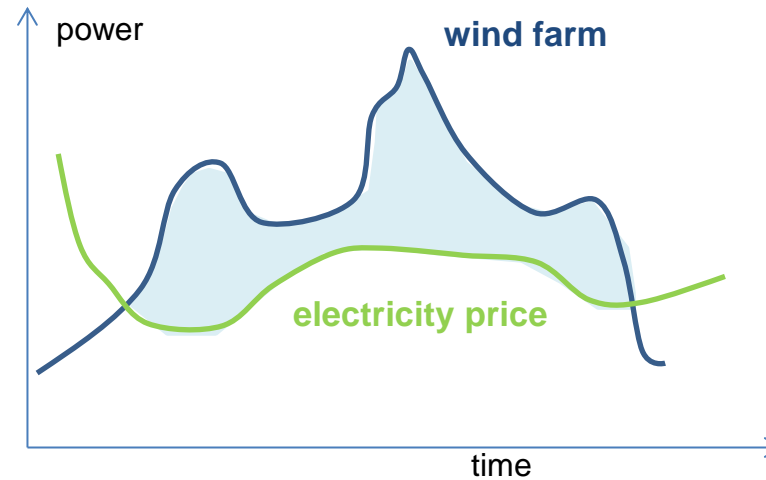
# Evaluation of several business cases

## Maximum H<sub>2</sub>-Production



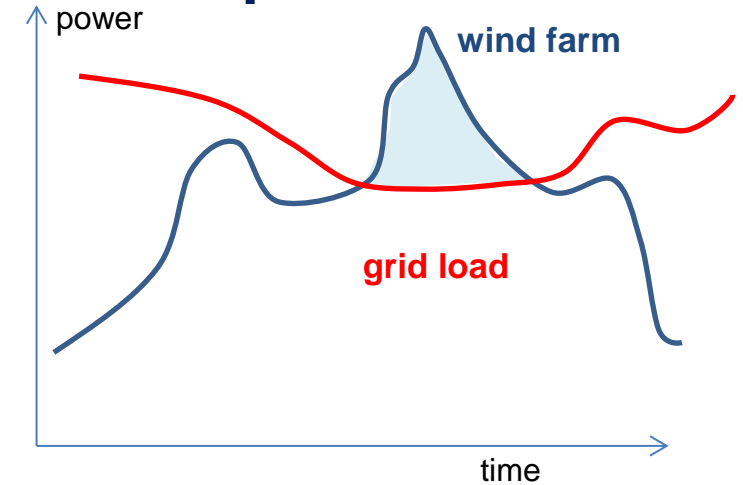
- ▶ Base load H<sub>2</sub>-Production from renewable energy
- ▶ Direct power supply from wind farm (cold start-up and stand-by)

## Electricity market driven production



- ▶ Specific cost reductions of H<sub>2</sub>
- ▶ Surplus electricity in power grid (price driven)

## Power grid service provider

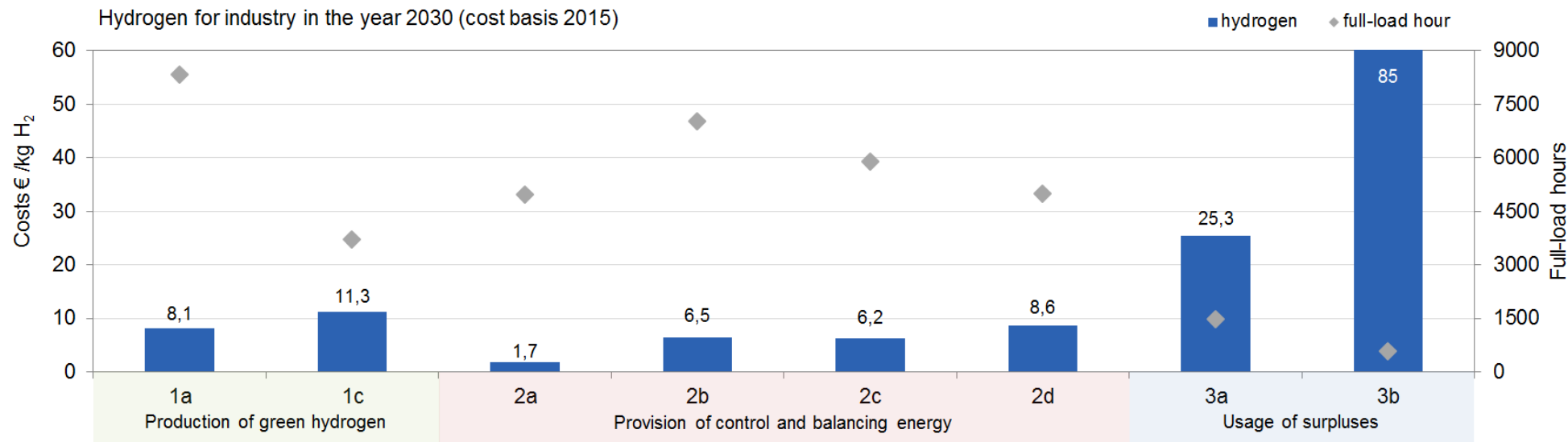


- ▶ Provision of frequency control energy
- ▶ Provision of balancing energy
- ▶ Storage of surplus fluctuating renewable energy

# Evaluation of several business cases

## First economic evaluations (in progress)

- Economic results highly depend on the business case and the full-load hours of the plant
- The sole use of surpluses (3a, 3b) is not an asset, as the plants should run on high full load hours → a combination with other business cases is useful

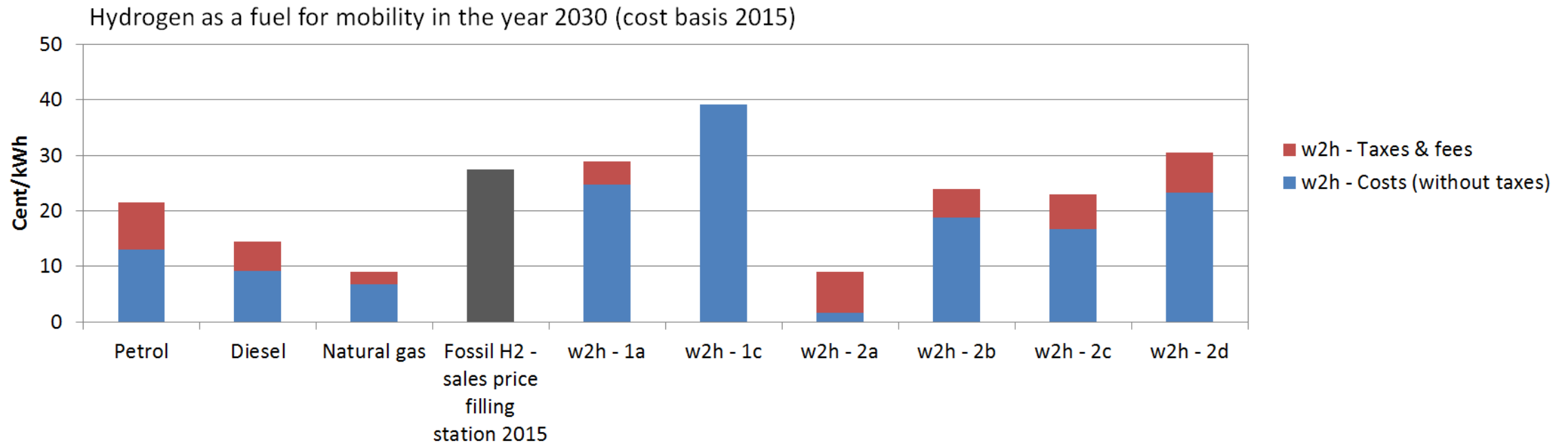


Business cases:  
 1a ... Maximum hydrogen production  
 1c ... Using electricity directly from a wind power plant  
 2a ... Negative secondary control energy  
 2b ... Positive secondary control energy  
 2c ... Negative and positive secondary control energy  
 2d ... Negative and positive primary control energy  
 3a ... Surpluses renewable power - quantity controlled  
 3b ... Surpluses public power grid - price controlled

Source: Energieinstitut an der JKU

# Profitability depends on CAPEX, electricity price, full load hours and revenues from services to the electricity market

- Competitive Green H2 production is feasible, if part of the plant capacity operates as service provider for the electricity market (frequency control energy)



Business cases:

1a ... Maximum hydrogen production

1c ... Using electricity directly from a wind power plant

2a ... Negative secondary control energy

2c ... Negative and positive secondary control energy

2d ... Negative and positive primary control energy

2b ... Positive secondary control energy

Source: Energieinstitut an der JKU

### ▶ High Pressure PEM-Elektrolyser

The FRONIUS Electrolyser meets all functionalities required for decentralized H<sub>2</sub> Production based on fluctuating renewable electricity

- ▶ High availability through modularity
- ▶ High part load and dynamic load cycle capability
- ▶ 163 bar H<sub>2</sub> production without mechanical compressor (less investment, less service & maintenance)
- ▶ unique micro-reactor and mechatronic approach on module level reduces PED maintenance and inspection requirements to a minimum
- ▶ Perfect product gas quality for PEM fuel cells
- ▶ > 3.500 production hours and high numbers of start-stop cycles show no impact
- ▶ 60 -80°C byproduct heat
- ▶ Modularity allows for appropriate H<sub>2</sub> production @ site and easy adaption to growth or customer needs

# wind2hydrogen

## what we already know ....

### ▶ Economic terms

- ▶ Economic H<sub>2</sub> production highly depends on the business case and the full-load hours of the plant
- ▶ Additional benefits from participation in the balancing and control energy market
- ▶ Significant price reduction for investment is expected with the number of modules sold
- ▶ Depending on the full-load hours the main part of the production costs are related to CAPEX and OPEX; the other big part are the electricity costs and taxes
- ▶ A rollout wind2hydrogen-plant has the potential to produce H<sub>2</sub> to a competitive price

### ▶ Some issues to solve

- ▶ Legal requirements not in place
- ▶ Reduction in Capex
- ▶ Electricity market and prices in balancing market
- ▶ Speed of development of fleets and/or passenger cars

# Thank You!

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OMV

EVN

FRONIUS

HyCentA

Energieinstitut Linz

OMV Resourcefulness

