ENERGIE PARK MAINZ

Power-to-Gas Project “Energiepark Mainz”

Operational and economical analysis of the worldwide largest Power-to-Gas plant with PEM electrolysis

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ENERGIEPARK MAINZ

1. Background

2. Energiepark Mainz – Project status and operational experiences
    - Project scope and key facts
    - Operational experiences

3. Economic feasibility of Power-to-Gas projects
    - Challenge: Economic feasibility
    - Optimization of the power supply

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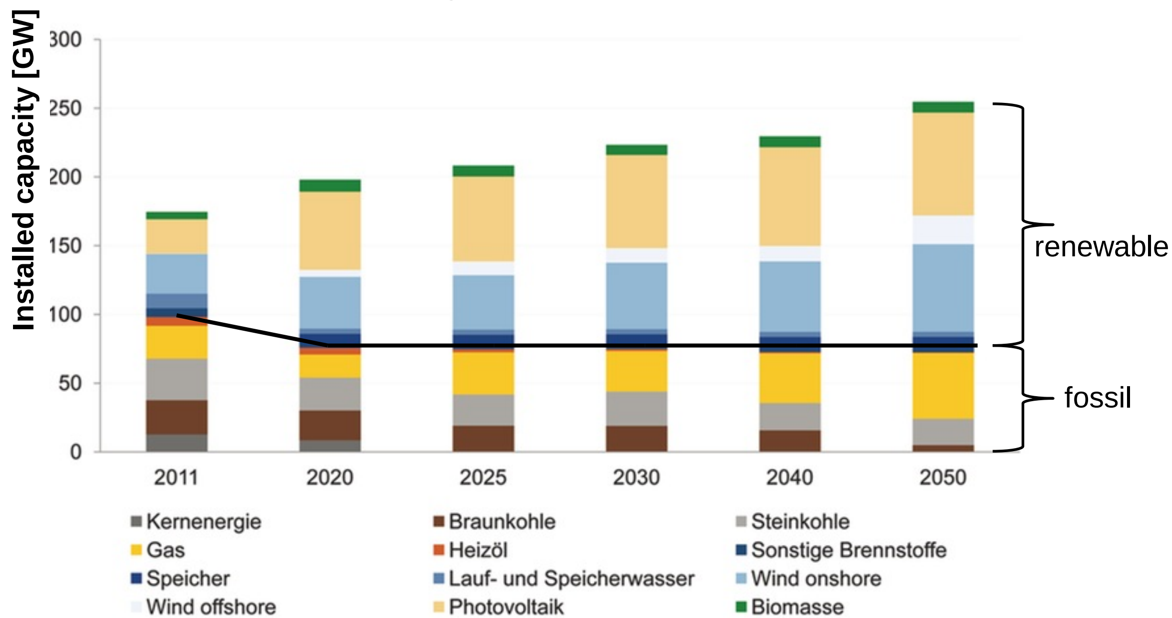
Background

Development of renewable energy in Germany

- Increasing amount of volatile energy feeding into the power grid
- Power-generation exceeds demand
  - in local grids
  - in transmission systems
- Conventional power-plants are still necessary as safeguards but low operating hours affect operating results

Development of power generation in Germany



Source: Prognos/EWI/GWS 2014

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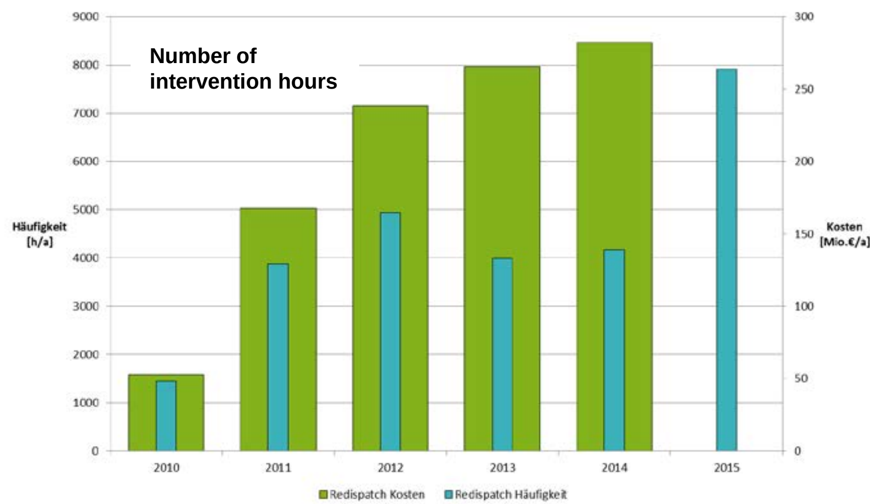
Background

Increase of critical network events

- Today: Temporally disconnection of renewable energy sources despite priority feed due to lack of transportation capacity of the power grid
  → higher frequency in future

- §13 para.1 EnWG: Should the safety / reliability of the system be at risk, network / market related measures will be taken.

Measures acc. to §13 para. 1



Reference: BNetzA 2011/2012/2013, Bundesregierung 2014, ENTSOe

Flexibility-options:

Flexible power plants | Network extension | Energy storage | Demand Side Management

Centralized ← → *Decentralized*

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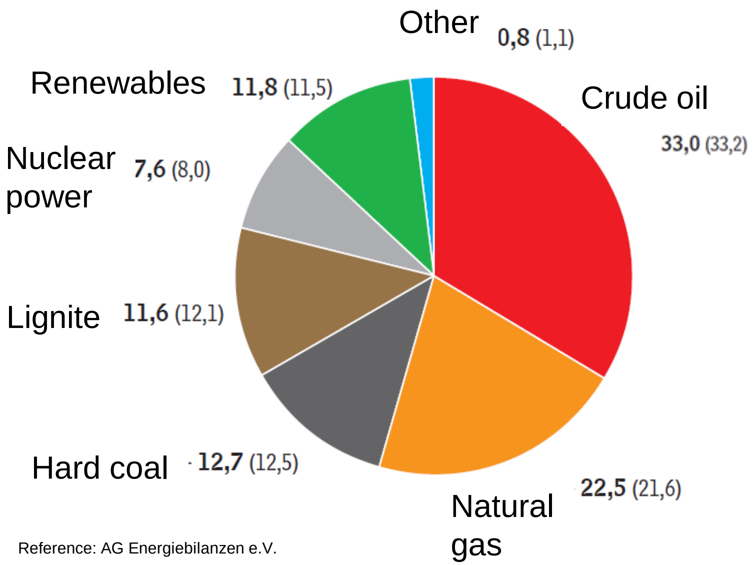
Electrolysis hydrogen for energy storage and transport

Hydrogen - Interconnector between the energy-systems

- Hydrogen can be produced and stored at large scale.
- Hydrogen transport is well known via pipeline and gas trailer.
- Hydrogen is used as a raw material for many kinds of industries as well as for mobility applications such as fuel cell vehicles.
- More than 75% of the German energy-consumption in 2013 was used for heating, cooling and mobility sectors.
- Hydrogen from electrolyzers can function as interconnector and make renewable energy available to other sectors (energy vector).
- Power, heat, cooling and mobility must be considered and optimized as an integrated system.

Structure of the German primary energy consumption for 2013, shares in percent (2012)



Reference: AG Energiebilanzen e.V.

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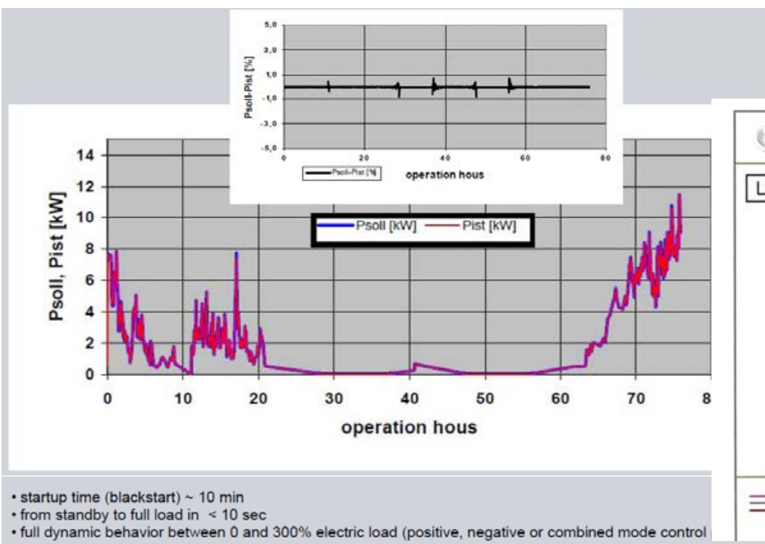
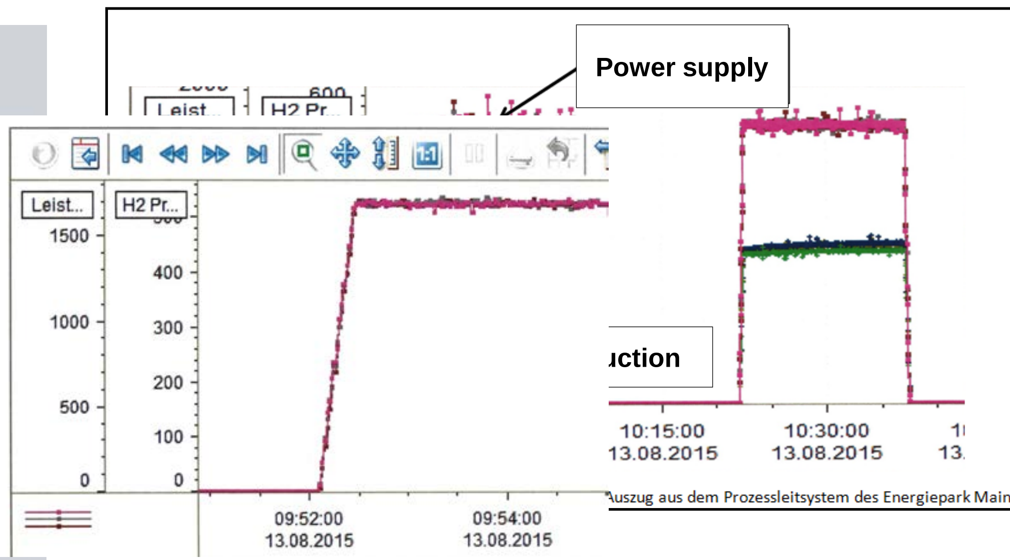
Electrolysis hydrogen as energy storage and vector

Electrolyzer for grid optimization

- Fast-responding, modern PEM-Electrolyzers can be used to transform excess power to hydrogen
→ System can manage local grid bottlenecks and provide balancing power

- Mandatory pre-qualification test for the participation at the secondary control reserve market is successfully passed





Reference: Siemens AG

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Energiepark Mainz – Project status and outlook

Project scope and key facts

Development of an decentralized hydrogen energy storage plant

- Location: Mainz
- Partners Stadtwerke Mainz, Linde, Siemens, Hochschule RheinMain
- Connected to a wind-farm (8 MW)
- 6.3 MW peak electrolyzer (3 stacks, each 2.1 MW)
- 1000 kg storage (33 MWh)
- 200 tons target annual output
  - Injection in local gas grid
  - Multi-use trailer-filling
- Budget: total 17 m€
- Funding: ~50% (BMWi)
- Timeline: 4 years (10/2012 – 12/2016)

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Energiepark Mainz – Project status and outlook

Planning of infrastructure and civil engineering

- Planning started in 10/2012

- Plant layout and buildings.
- Infrastructure for components:
  - Grid connection (20 kV)
  - Water supply
  - Gas grid injection
  - Drain
  - Traffic
- On site transport issues.
- Safety measures:
  - Fire protection
  - Explosion prevention
  - Noise protection
  - Access control

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Energiepark Mainz – Project status and outlook

Hydrogen storage and handling facility

Power grid connection 20kV

↓

Transformer-Rectifier Unit

↓

Electrolysis 2-3.5 MPa

↑

Water purification

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Energiepark Mainz – Project status and outlook

First operational experiences

- Regular operation in September and October 2015
  - Electricity purchase (efficiency optimized) at EPEX Spot market (on working days 8:00-18:00)
  - 700 MWh power procured
  - 40 trailers filled

→ Expectations considering system dynamic and power consumption are met

→ No critical breakdown

Month	Power consumption [MWh]	Trailer filling H_2 [tons]	Difference H_2-storage [kg]	H_2 [Nm^3]	$H_{2\,(HHV)}$ [MWh]	Utilization factor$_{(HS)}$	Operating hours
September	432.5	6.51	+ 10.1	72,526	256.9	59.4%	146 h

- The power consumption of the whole plant is considered (electricity meter of the grid operator)
- The data of the produced hydrogen is derived from the weighing documents of the truck trailers

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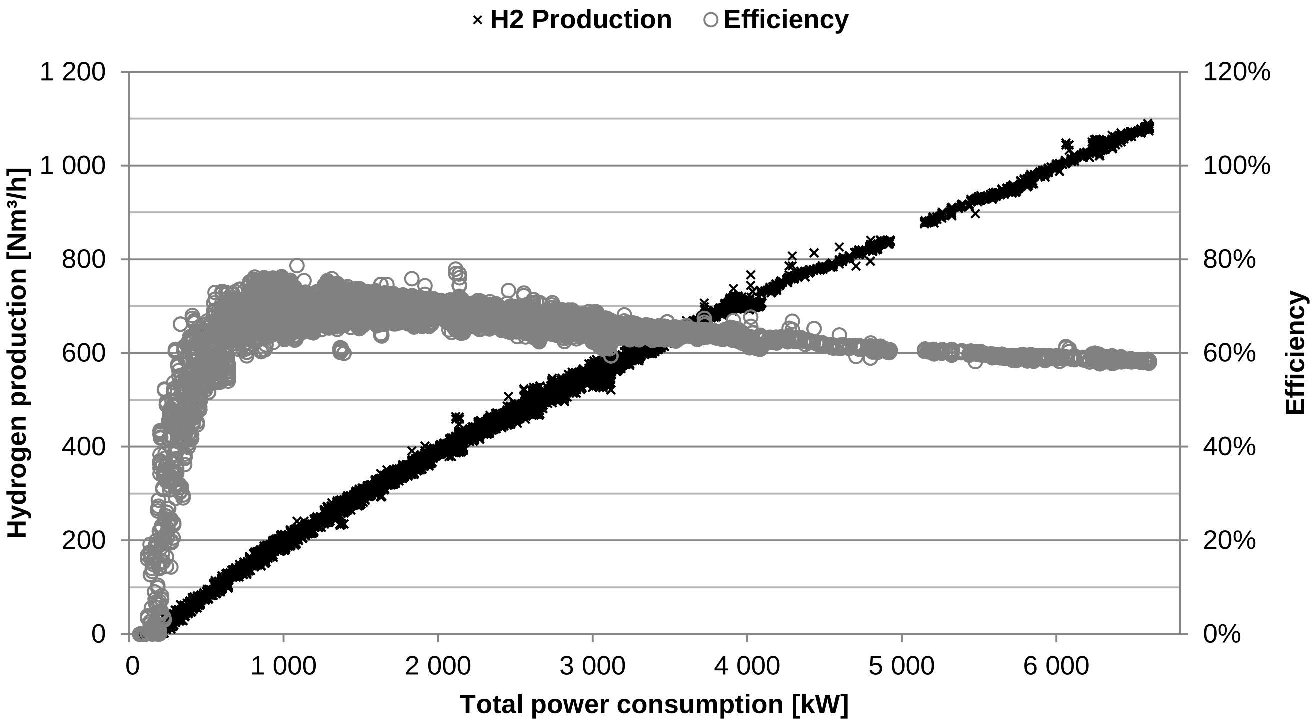
Energiepark Mainz – Project status and outlook

Evaluation of measurements

- Considering the **total** power consumption of the plant and the produced hydrogen
- Efficiency is referred to the caloric value of the hydrogen (3.54 kWh/Nm³)
- Raw data set of October 2015



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Energiepark Mainz – Challenge: Economic feasibility

Aktuell keine Wirtschaftlichkeit

Diverse Studien belegen, dass eine Wirtschaftlichkeit von P... gen heute... und i... unter den gegebene... im deutschen Strom... nicht zu erreichen ist.

Currently no economic feasib...

Source: Sieling et al (2... Gas – Eine wirtschaftlic...

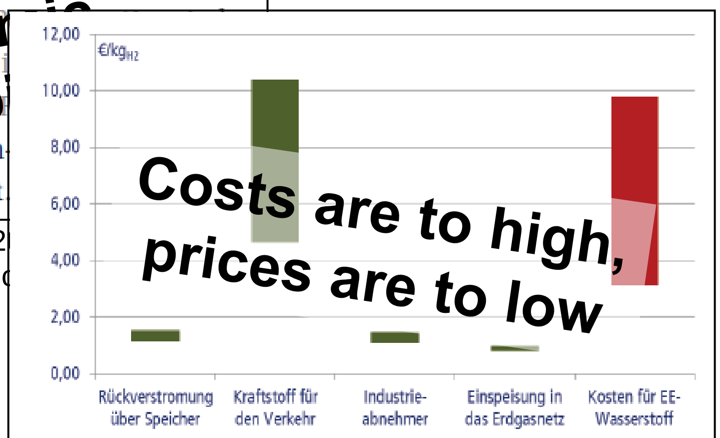
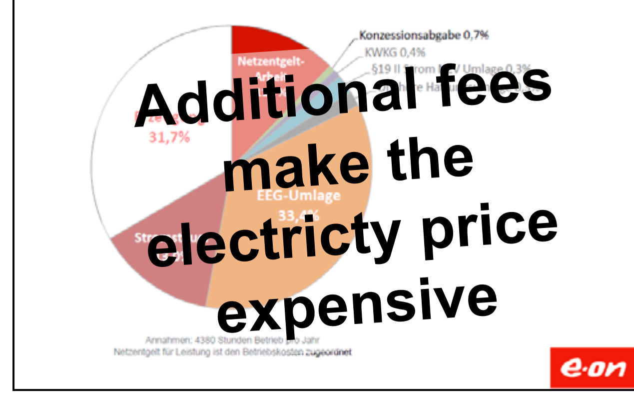


Abbildung 17: Erzielbare Preise und Kosten für EE-Wasserstoff in €/kg$_{H2}$ (auf Basis historischer Werte)

Source: Albrecht et al (2013) – Analyse der Kosten Erneuerbarer Gase

"WindGas Falkenhagen": Strombezugskosten in der Diskussion



Source: Schoof (2014) - Innovative Energiespeicherung- Fokus Power-to-Gas

Energieinstitut an der ... Hierbei ist insbesondere anzumerken, dass zur Überführung der Power-to-Gas-Technologie in den Markt kurz- und mittelfristig ... notwendig sein wird, um in der Implementierungsphase die Kosten zu reduzieren, sodass auch mittel- bis langfristig ... sowie eine Wettbewerbskompatibilität ohne Förderungen erreicht werden können.

A combination of different business cases is recommended

Source: Tichler et al (2014) – Wirtschaftlichkeit und Systemanalyse von Power-to-Gas Konzepten

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Question:

How to run the PtG-plant at it’s optimum?

Technical and economical

Optimization tasks

Power Supply

- Power generation from wind turbines
- Participation at the secondary reserve market
- Purchasing on the SPOT market

Minimization of purchase prices

Conditions of the plant

- Technical restrictions (minimum / nominal / peak load)
- Efficiency curve
- Stand-By – losses
- Other operating parameters

Maximizing

- Feeding into natural gas network
- Trailers filling

Hydrogen selling

Source pictures: http://www.cleanthinking.de/wp-content/uploads/dena-Power-to-Gas.jpg

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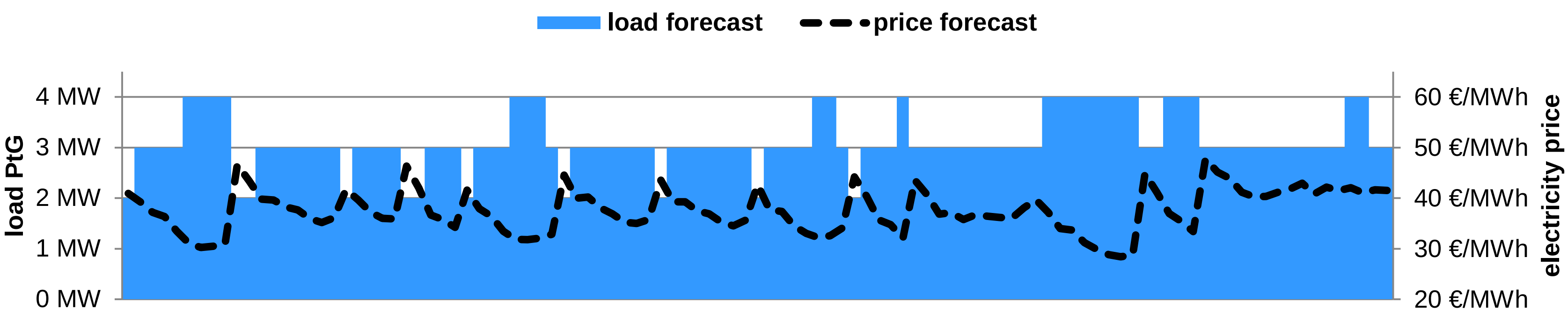
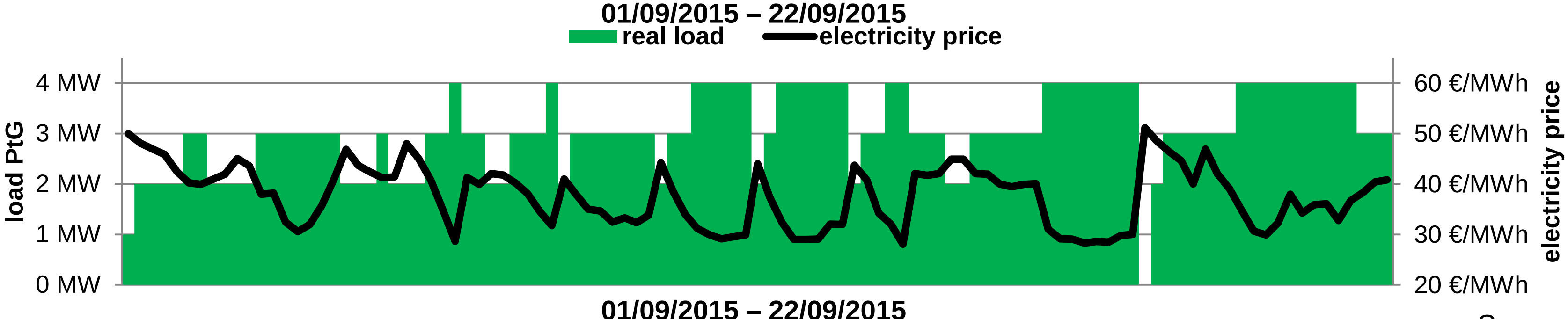
Energiepark Mainz

Considered options of power purchase

Power purchase on the SPOT market – 09/2015 + 10/2015





Source: own research

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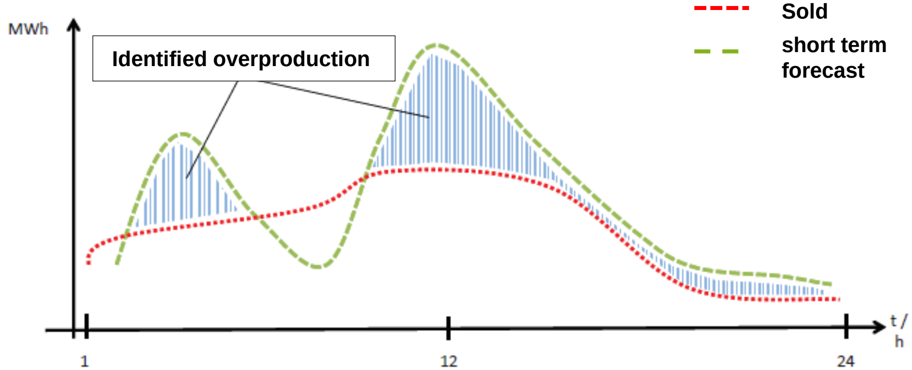
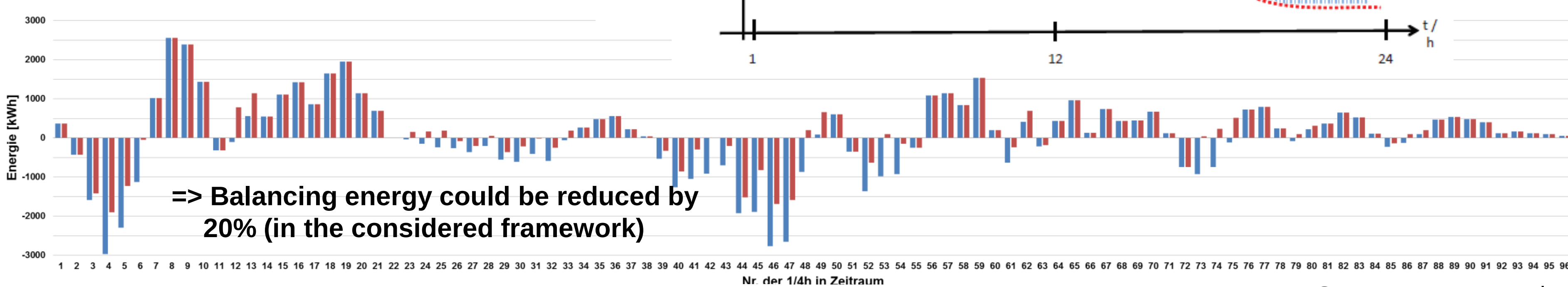
Energiepark Mainz

Considered options of power purchase

Power-to-Gas as flexible load for wind farm operator – Q1 / 2016

- The adjustment of forecast errors of the wind farm production leads to a reduction of balancing energy
- The wind farm operator avoids additional costs / penalties





Source: own research

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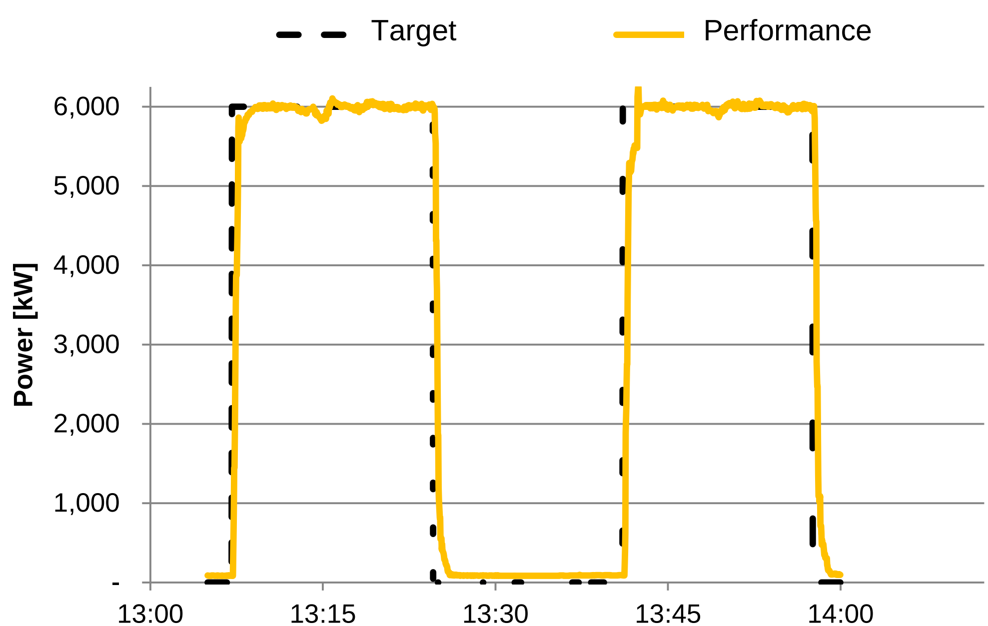
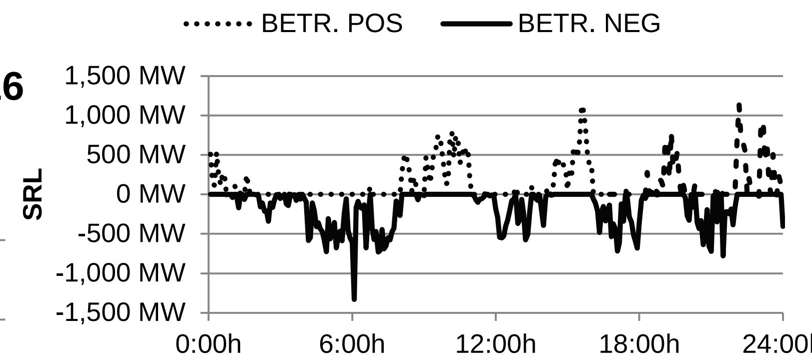
Considered options of power purchase

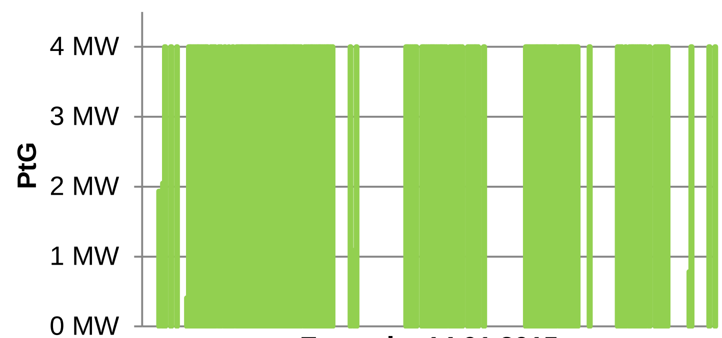
Participiation at the control reserve market – Q2-Q4 2016



Source: own diagram, measurements from the Energiepark Mainz

Appropriate value of secondary control reserve and the possible running of PtG





Example: 14.01.2015

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Thank you for your attention

Further information:

www.energiepark-mainz.de/en/
www.forschung-energiespeicher.info/en/

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APPENDIX

Energiepark Mainz – Project status and outlook

Project partners

The Linde Group

- World-leading gases and engineering company with 62,000 employees in more than 100 countries.
- Linde "Clean Technology" offers a wide range of technologies to render renewable energy sources; ranges from CO_2 separation to alternative energy carriers such as LNG and hydrogen.

Stadtwerke Mainz AG

- Municipal energy supplier on the German market (shareholder is the city of Mainz).
- Supply of energy (electricity, gas, heat), water and mobility to the city of Mainz and the region.
- Pursuing a sustainable change in energy policy for a number of years.

Siemens AG

- Global powerhouse in electrical engineering and electronics; world's largest environmental tech provider
- In its Drive Technologies Division, Siemens is developing a PEM hydrogen electrolysis system.

The RheinMain University of Applied Sciences

- Regional stronghold for research on hydrogen and fuel cell technology.
- Involved in several related projects and networks of excellence.

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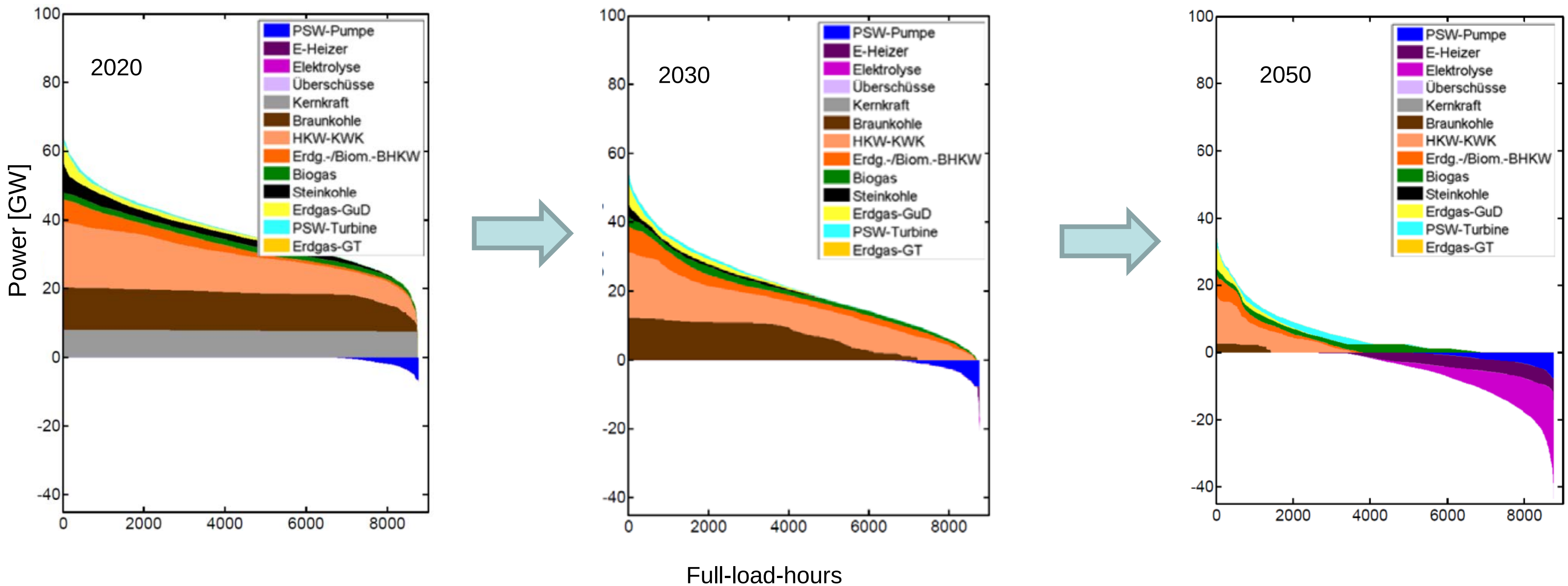
Background

Future demand for energy-storage in Germany

Simulation of the future power-plant operation in Germany *(DLR, Fraunhofer IWES, IfnE, 2012)*



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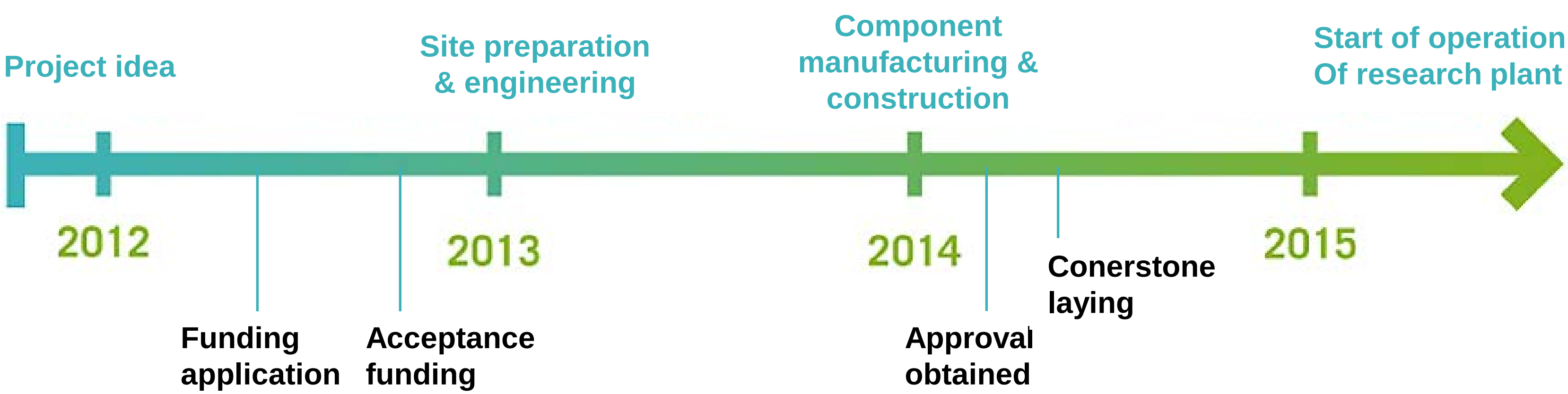
Energiepark Mainz – Project status and outlook

Objectives and timeline of the research project

1. Local grid integration by storing fluctuating renewable power
2. Provision of ancillary services in the electricity grid (including negative control reserve)
3. Testing and further development of megawatt class PEM electrolysis
4. Intelligent and efficient hydrogen conditioning, storage and handling, smart management structure
5. Research of effects of the increased hydrogen concentrations in the gas grid and end devices
6. Public relations and public acceptance



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Energiepark Mainz – Project status and outlook

Further planing until the end of the project

- Q1/2016: plant planning and scheduling through wind farm operator
  - Adjustment of prognostic errors
  - Avoidance of balancing energy (costs)
- Q2-4/2016: Participation at the control reserve market
  - Minutes reserve
  - Secondary control reserve (pos/neg)
- 12/2016: project end
- After 12/2016: further operation, if economic feasibility is proven

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Energiepark Mainz – Project status and outlook

Electrolysis

- Three electrolysis units (SILYZER 200)
- Electrical power consumption:
  - 1.3 MW continuos
  - 2.1 MW time limited peak load
- H_2 output pressure level of up to 3.5 MPa
- Highly dynamic operation over a broad load range (ramp speed 10% per sec.)
- Widely adjustable DC power supply

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Energiepark Mainz – Project status and outlook

H_2-injection into a natural gas (distribution) grid

- municipal gas pipelines to the city district Mainz-Ebersheim:
  - Owner: Stadtwerke Mainz AG
  - Operating pressure: 0.7 – 0.9 MPa
  - Volume flow: max. 1,000 m³/h
  - In summer minimal flow rate → limited feed-in possibility.

H_2-trailer filling stations

- 2 positions + 1 parking lot
- Fully-automatic operation
- H_2 pressure in the trailers is up to 22.5 Mpa
- Loading time is ~3 – 4 hours

Energiepark Mainz – Project status and outlook

Degree of energy utilization

- The power consumption of the **whole** plant is considered (electricity meter of the grid operator)
- The data of the produced hydrogen is derived from the weighing documents of the truck trailers

Month	Power consumption [MWh]	Trailer filling H_2 [tons]	Difference H_2-storage [kg]	H_2 [Nm^3]	$H_{2\ (HHV)}$ [MWh]	Utilization $factor_{(HS)}$	Operating hours
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