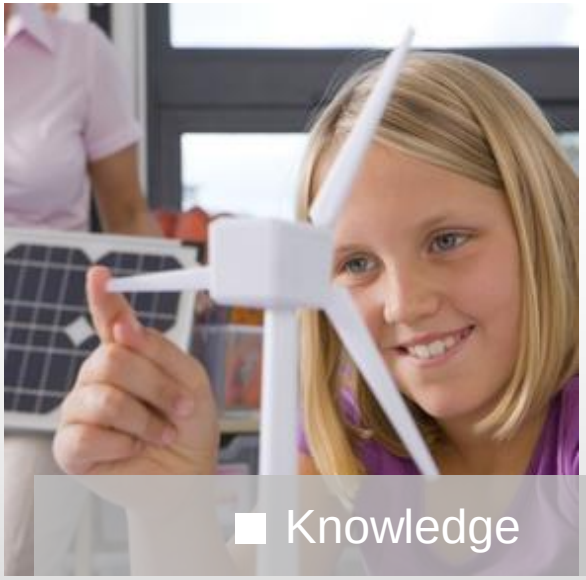
Heliocentris

Power for the 21st Century



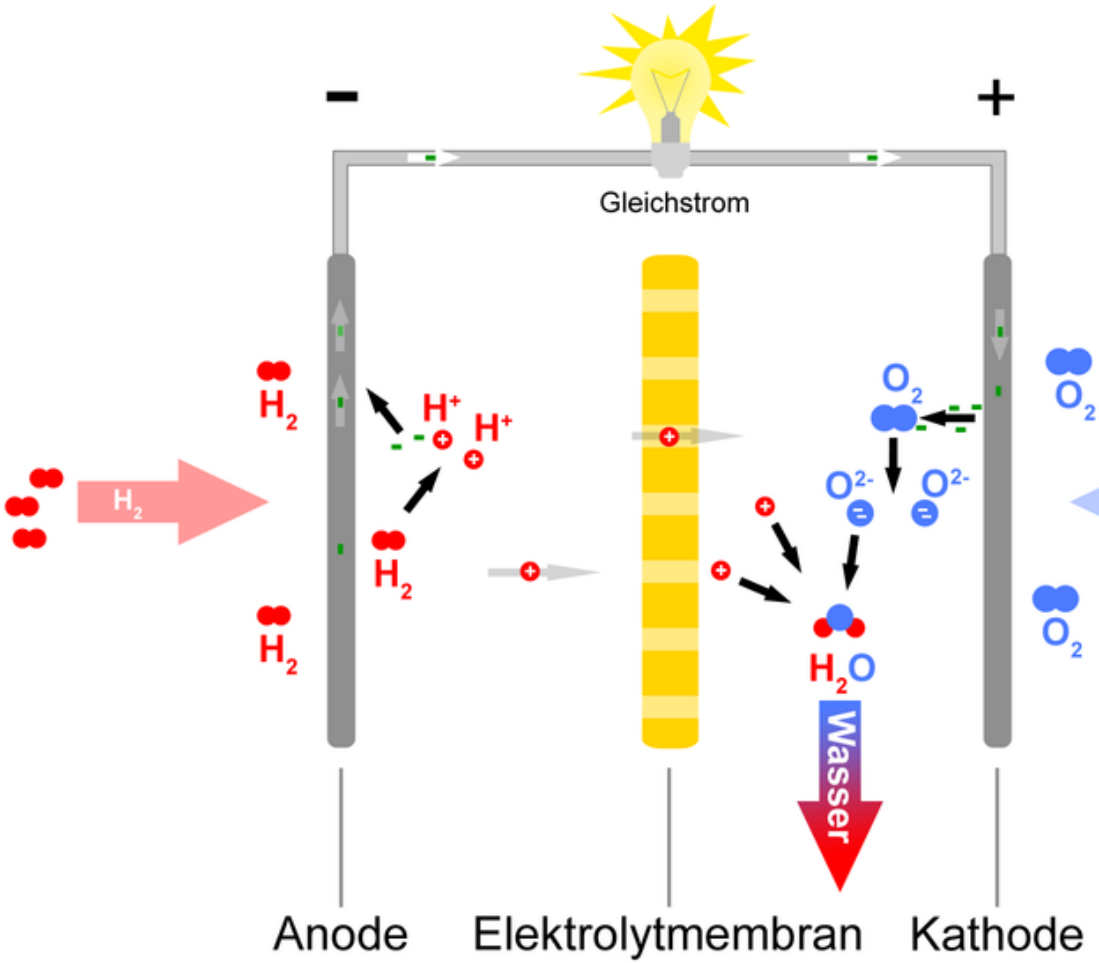
Heliocentris Fuel Cell Systems for critical infrastructures

CeBIT Security Forum, March 15th, 2016

Mark-Uwe Osswald (VP Fuel Cell & Electrolyzer Systems)

Principal - Fuel Cell functionality

PEM-Brennstoffzelle (Proton Exchange Membran)



Reaktionsgleichung:
$2\ H_2 + O_2 \Rightarrow 2\ H_2O$

Anode:
$2\ H_2 \Rightarrow 4\ H^+ + 4e^-$

Kathode:
$O_2 + 4\ H^+ + 4e^- = 2\ H_2O$

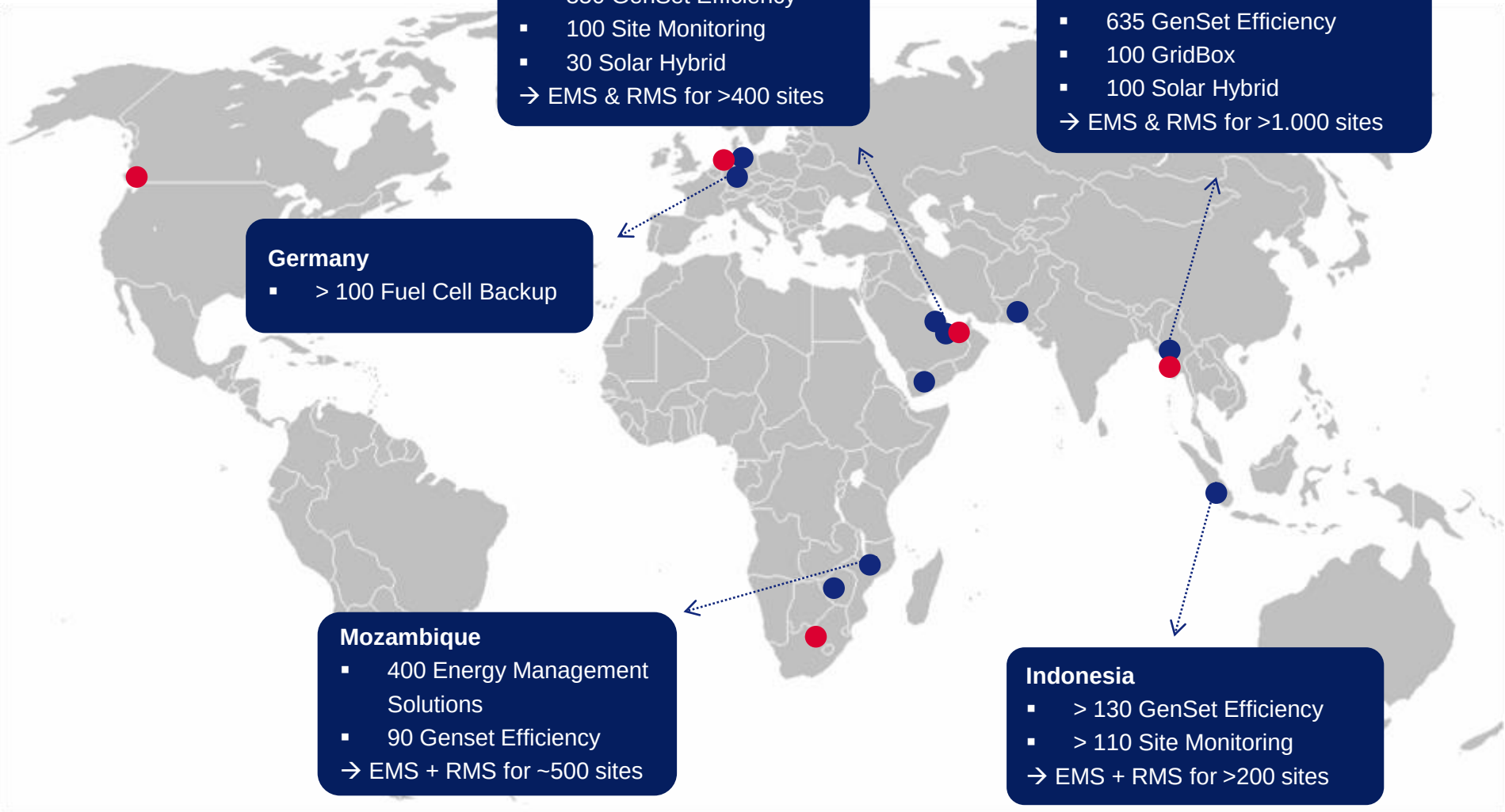
Theoretische Leerlauf-Spannung pro Zelle: 1,23V

Company Overview

History	1995: Company Foundation
Products	Energy Management Systems Turnkey Power Solutions Network Management Software Power Operations Services Fuel Cell & Electrolyzer Systems
Markets	> 50 countries
Locations	Berlin (HQ), Munich, Stuttgart, Dubai, Vancouver, Johannesburg, Yangon

Over 3,000 Managed Power & Monitoring Solutions

Selected Projects



United Arab Emirates
- 350 GenSet Efficiency
- 100 Site Monitoring
- 30 Solar Hybrid

→ EMS & RMS for >400 sites

Myanmar
- 635 GenSet Efficiency
- 100 GridBox
- 100 Solar Hybrid

→ EMS & RMS for >1.000 sites

Germany
- > 100 Fuel Cell Backup

Mozambique
- 400 Energy Management Solutions
- 90 Genset Efficiency

→ EMS + RMS for ~500 sites

Indonesia
- > 130 GenSet Efficiency
- > 110 Site Monitoring

→ EMS + RMS for >200 sites

Fuel Cell products ready for all use cases of reliable power

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Good Grid

- Critical Infrastructure
- Extended Backup requirements

Unreliable Grid

- Varying & unpredictable load pattern
- Noise restrictions due to proximity to communities

Remote Off-Grid

- Extremely remote sites
- Difficult site access

Emergency Power

Complementary Power

Autonomous Power

Jupiter - H_2 Fuel Cell Backup Power System

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10kWp Indoor Configuration

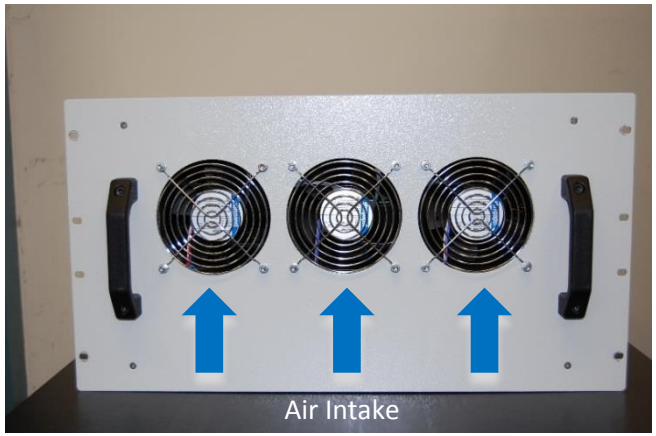
Designed for

- ✓ **high reliability**
- ✓ **high flexibility**
- ✓ **very low standby costs**

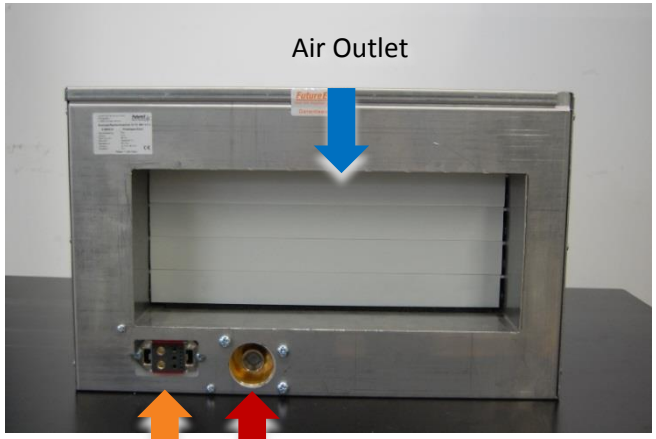
System key features

MODULAR	Rated power scalable in 2.5 kWp steps; Redundant layout of certain system components
FLEXIBLE	Configuration as online or offline UPS; Load modulation from 30 … 120 %
EFFICIENT	> 50 %
RELIABLE	Very simple system design, no consumables, no fuel degradation
QUIET	63 dBA (@ 1 m)
ROBUST	Operating range from -40 … +50 °C
LOW MAINTENANCE	1 site visit per year

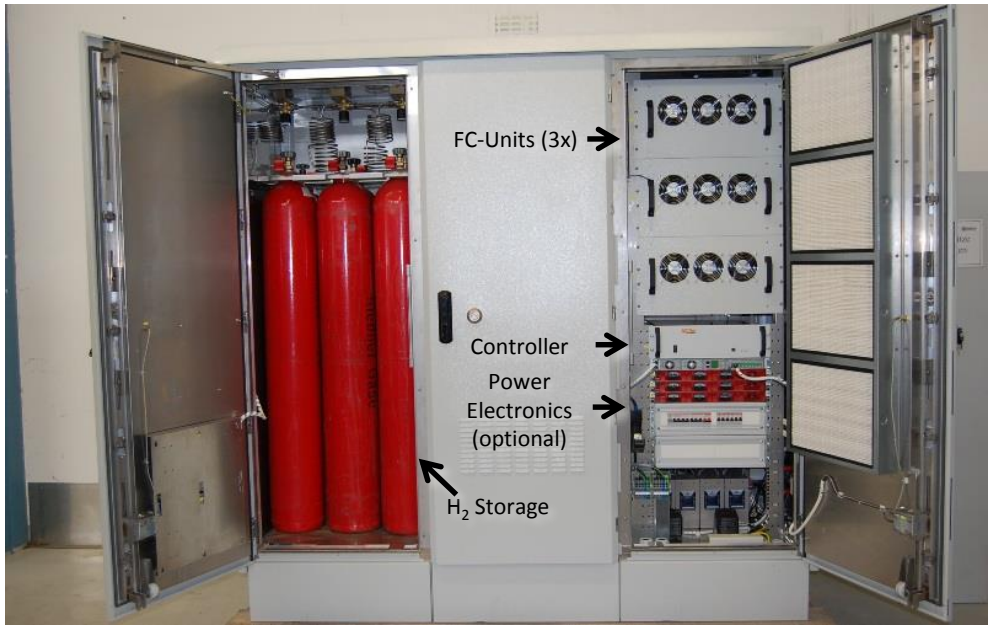
Fuel Cell Module (FC) - Front side



Fuel Cell Module (FC) - Back side



Fuel Cell System (FCS) – Front side



e.g. 6kW @ 400 VAC Outdoor FCS incl. H_2 compartment

- Easy installation, commissioning and service:
  - Space saving (19 and 23" units available)
  - Low unit weight (all units < 30 kg)
  - Front handling
- Standardized interfaces
- Remote Monitoring and Control

Principle - H_2-storage in High-Pressure Tanks

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For Hydrogen the ideal gas equation with compression factor z(p) applies:

P*V=(m/M)*R*T*z(p)

P [bar]	1	20	200	300
z(p)	1	1,02	1,132	1,201

Calculated with 33 kWh/kg for H_2: ([p]=bar; [V]=liter; [z]=1)

Energy content W = (p*V/T*z(p))*0,8 kWh

50 liter storage volume	bottle @ 200 bar	bundle @ 200 bar	bottle @ 300 bar	bundle @ 300 bar
Energy content gross	25,8 kWh	309,6 kWh	36,5 kWh	438 kWh
Energy content net (~ 50 η)	**~ 12 kWh**	**~ 150 kWh**	**~ 18 kWh**	**~ 200 kWh**
H_2-standard volume	8,6 Nm^3	103,2 Nm^3	12,17 Nm^3	146,04 Nm^3
H_2-weight	0,77 kg	9,24 kg	1,1 kg	13,2 kg
Example for 4 kW: range of stored Hydrogen	3 h	37,5 h	4.7 h	50 h

Jupiter - Why H_2 Fuel Cell Backup [1]

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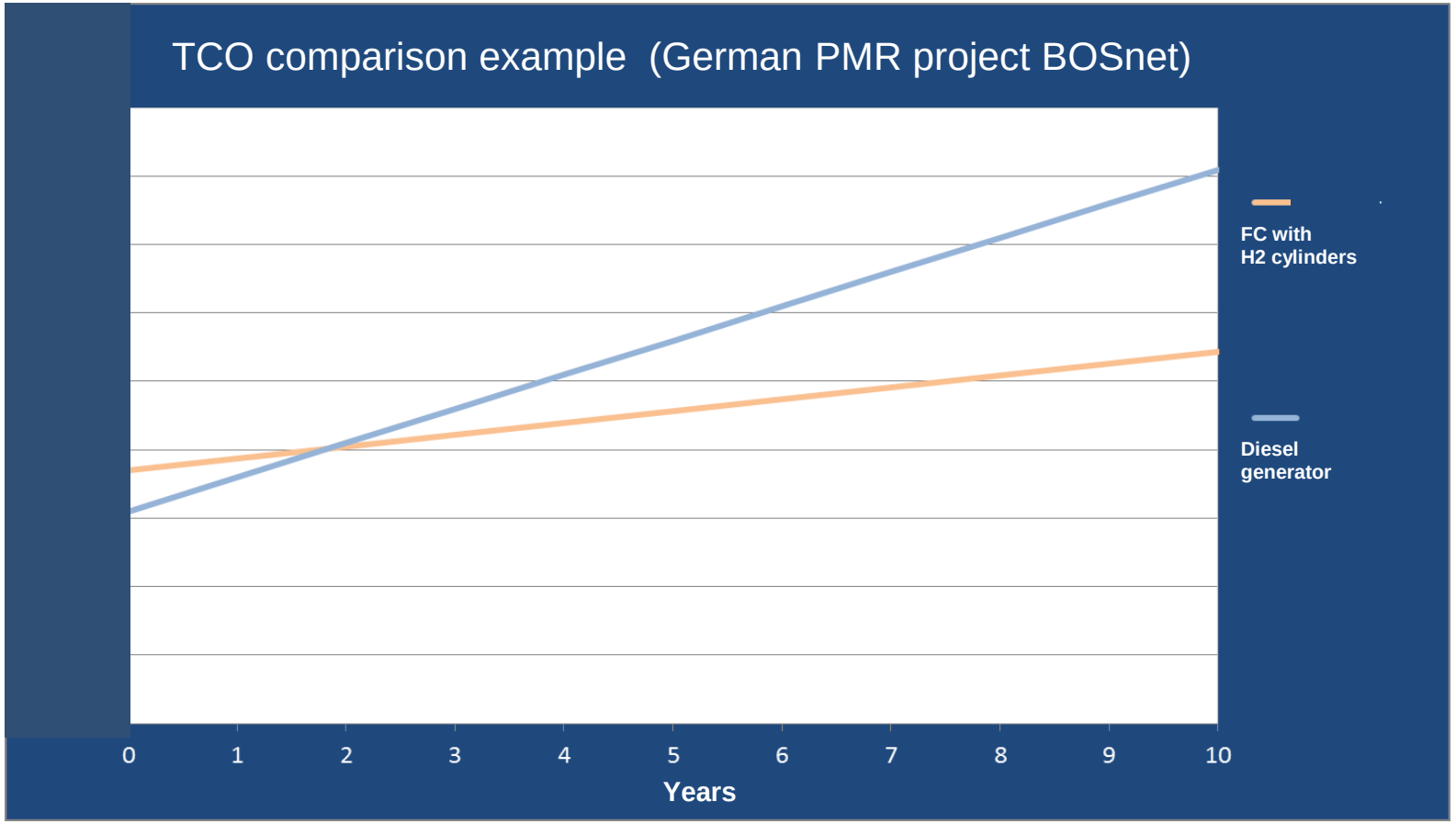
Requirement	Jupiter Fuel Cell Backup Power		Diesel Backup Power	
Required autonomous runtime	✓	can be ensured by an appropriate number of hydrogen bottles	✓	can be ensured by the appropriate tank size
Uninterrupted refueling	✓	Exchange or refilling of the pressurized H2 storage while operating is possible	✓	Refilling of the diesel tank while operating is possible
Additional supply of maintenance resource	✓	For disaster situations appropriate precautionary provisions are necessary and possible	✓	For disaster situations appropriate precautionary provisions are necessary and possible
Scalability of power	✓	Well matched to the power required by modular cascading. High efficiency at partial and full load (> 50%).	✗	Due to the torque characteristics they are usually oversized in power. Consequence: operating at partial load with low efficiency (<15%)
230 / 400 V AC	✓	Via integrated DC/AC converter	✓	Via integrated synchronous generator
Material safety	✓	Outdoor-cabinet up to RC4 available	✗	RC only possible with container assembly
High availability	✓	Intrinsic: in standby mode a FC hardly ages and H2 ages not at all. The system design is simple and therefore robust and low-maintenance	✗	Diesel engine and fuel wear out on standby. High availability is only ensured by increased maintenance costs and monthly test run @ load.
Customizability to special site circumstances	✓	Due to the modular system concept several design versions are possible and the transport is easy.	✗	The diesel generator is a large heavy block, therefore not easy to transport and inflexible.

Why H_2 Fuel Cell Backup [2]

After already 2 years the total costs (TCO) of a Jupiter backup power supply is more attractive than a diesel-system!



Assumptions: Fuel Cell: 5 kW_P, 230 V AC, 13x 300 bar H_2 cylinder rented, outdoor cabinet, foundation, installation
Diesel Genset: 12 kVA, 150 liter tank, foundation, installation, monthly test runs
Prices as of 2014

References

Jupiter - Professional Mobile Radio (PMR)

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Already more than 100 systems successfully in operation

APPLICATION

Backup for PMR “BOS Digitalfunktechnik”

SYSTEMS

“Jupiter” FC-Systems: 2-6 kW @ 230 VAC

HOUSING

Outdoor Cabinet (RC4)
Outdoor Cabinet (RC2)
Outdoor Cabinet (RC0)
Container (RC3)
Indoor:

LOCATIONS

Germany (BOS)

INSTALLATION

2011 – 2015

Jupiter – Telecom network nodes

Deutsche Telekom

APPLICATION

Backup power supply with
peak-power shaving and minute reserve

SYSTEM

„Jupiter“ FC-System: 14 / 28 kW @ -60 VDC

HOUSINGS

Indoor, Outdoor and Container

LOCATIONS

Germany / Czech Republic

INSTALLATION

2009 - 2011

Jupiter - Base Stations Off-Grid

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e·plus

APPLICATION

Grid Independent Power supply
(100% zero emissions)

SYSTEMS

Jupiter FC-System: 2/4 kW @ -48 VDC

ENCLOSURE

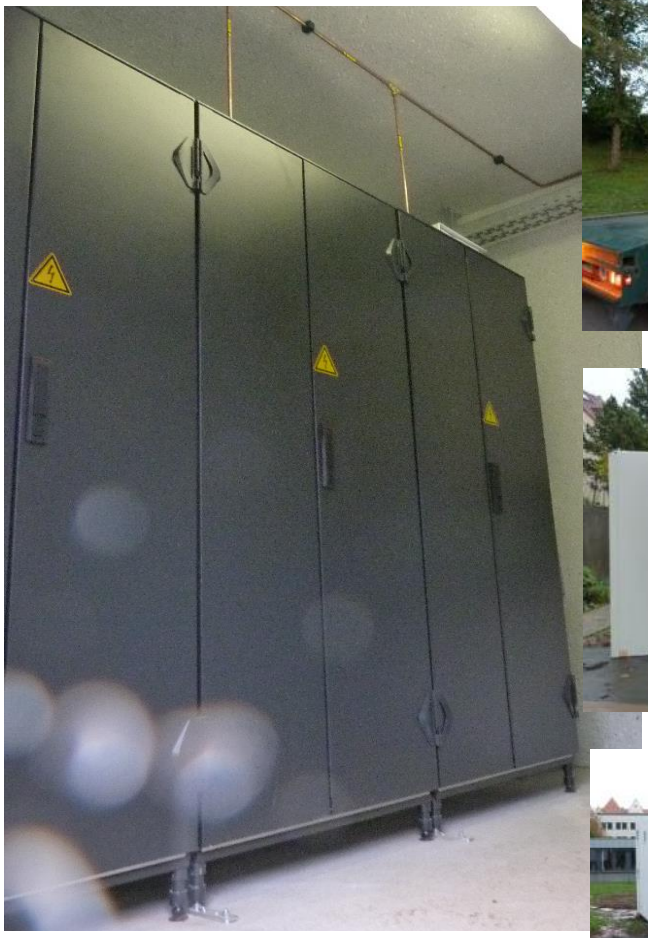
Container

LOCATION

Versmold and Büren, Germany

INSTALLATION

2011 and 2012



Landkreis Göppingen
Herzlich willkommen im Stauferkreis

APPLICATION

Backup power supply for IT Center

SYSTEM

“Jupiter” FC-System: 20 kW @ 380 VAC

HOUSING

Container solution

LOCATION

Göppingen, Germany

INSTALLATION

2012

DB BAHN

APPLICATION

Range extender for electrical energy storage for signal box

SYSTEM

“Jupiter” FC-System: 6 kW @ 60 VDC

HOUSING

RC2 outdoor cabinet

LOCATION

Germany

INSTALLATION

2013

Jupiter – Radar

Hamburg Port Authority

APPLICATION

Backup power supply

SYSTEMS

“Jupiter” FC-System: 6 kW @ 380 VAC

HOUSING

Outdoor cabinet

LOCATION

Germany

INSTALLATION

2013 and 2015

Jupiter – Power Distribution / Switching Stations

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Stromnetz Hamburg

APPLICATION

Backup power supply

SYSTEMS

“Jupiter” FC-System: 6 kW @ 220 VDC

HOUSING

Indoor FC cabinet with outdoor H2 cabinet

LOCATION

Germany

INSTALLATION

2015

Thank You / Vielen Dank

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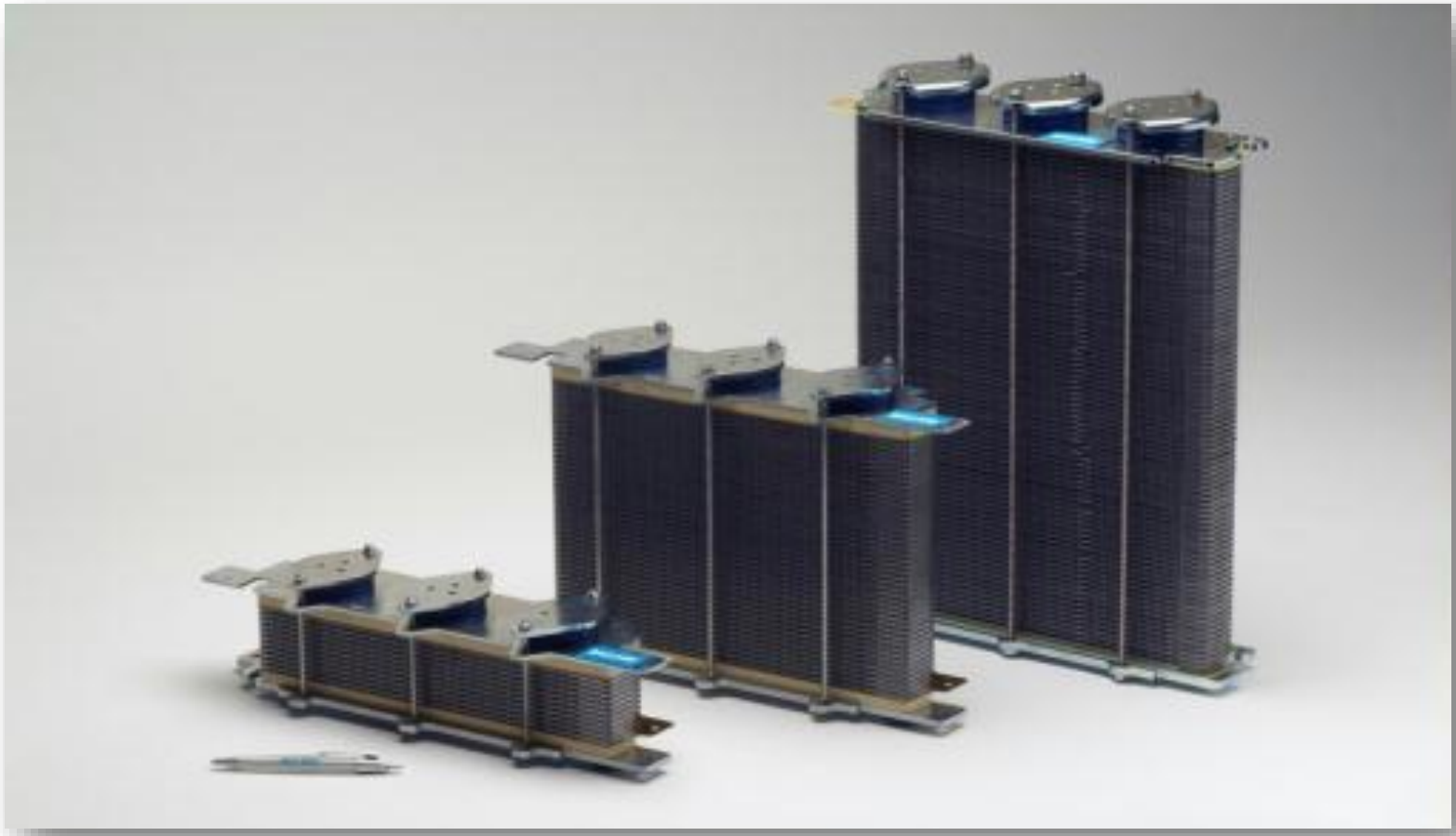
Example - Fuel Cell Stack



Source: Ballard Power Systems Inc.

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Motivation for deploying fuel cell backup power systems

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Issues with battery bank and Diesel genset backup-systems

- Battery bank needs to be cooled with air con
- Battery has short life span (2-5 years)
- Disposal of lead acid battery is hazardous to the environment.
- Diesel gen-set needs regular maintenance to keep its availability (2-6 site visits/year)
- Diesel genset is noisy during operation
- Diesel genset has toxic emissions (particles, SOx, NOx)
- Weight and vibrations prevent many rooftop installations
- Genset and diesel fuel are often subjected to thefts

Potential achievements through fuel cell technology

- Replacement of backup diesel gensets
- Reduction of OPEX due to less site visits
- Reduction of CO2 emission
- Reduction of noise emission
- Installation at sites where genset is not possible/allowed
- Improve network availability
- Reduction of lead acid batteries banks
- Reduction of air-conditioning usage (due to smaller battery banks)

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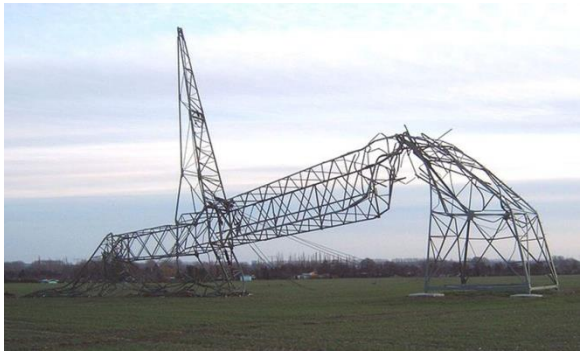
LAND BRANDENBURG

BOS DIGITALFUNK

Why do we need a reliable backup power supply (3/5)?

Hurricane „Kyrill“

(on January 18th and 19th, 2007)



Kyrill in numbers:

- 47 persons died, 11 of them in Germany
- Damages amounting to approx. 3,5 billion Euro
- Wind velocities of up to 225 km/h (Europe-wide max. wind gust at 2850 m)
- Extensive power outages lasting more than 24 hours in all of Germany
- In the southern part of Brandenburg power outages lasted up to 48 hours