Ceramic Fuel Cells Residential Generator BlueGen™

Ultra-efficient distributed power generation in Smart Grid Environment

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International Gas Union Research Conference

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www.cfcl.com.au

Who we are

- **Formed in 1992, from the Australian Government research organisation (CSIRO)**
- **130 staff**
  - **Melbourne Head Office, R&D, product development and prototyping**
  - **German manufacturing plant**
  - **UK ceramic powder plant**
- **High efficiency electricity generation products for home and small business (solid oxide fuel cell technology)**
- **About 300 million USD invested in technology & product development**
- **Listed on ASX and London AIM market (CFU)**

Ceramic Fuel Cells' Technology

Why Fuel Cells and SOFC?

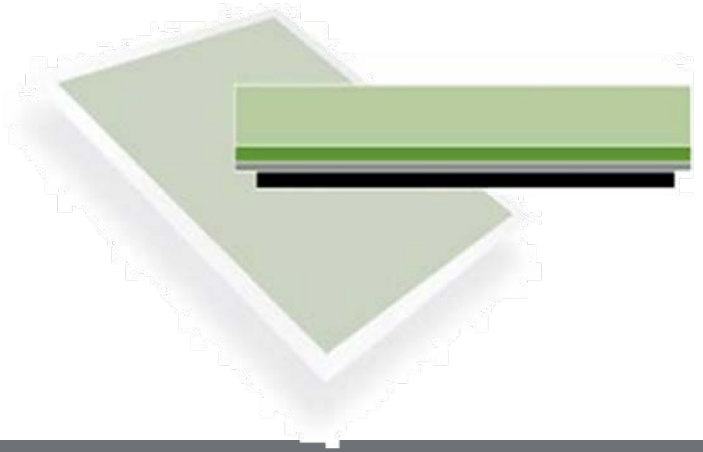
SOFC generators offer significant advantages

Prime Competitive edge

Potential for very high electrical efficiency
Power modulation over wide window at high efficiency

Additional Advantages

- Operate on conventional fuels (fuel flexible)
- Wide range of sizes (W to MW) and design options (tubular, planar…)
- Low heat output – long operating hours
- Environmental benefits
  - Low CO_2 emissions
  - Very low noise and vibrations
  - Virtually no NOx or SOx emissions



Current drawbacks

- Costs, familiarity,
- Long start-up time, compactness, proven robustness

How to Harness High Electrical Efficiency

Stack Theoretical Efficiency

$$\varepsilon_{(th)} = \Delta G_T / \Delta H^0 \times U_F$$

The Methane Fuel Cell

"the chemical combined cycle system"

$$CH_4 + 2\,H_2O + \text{Heat} \rightarrow 4\,H_2 + CO_2$$

$$4H_2 + 4O^{2-} \rightarrow H_2O + 8e$$

ΔH^0 (CH_4) = -802 kJ/mol
ΔH^0 $(4H_2)$ = -968 kJ/mol } +20%
ΔG_{750C} (CH_4) = -798 kJ/mol
ΔG_{750C} $(4H_2)$ = -786 kJ/mol

$$\varepsilon_{(th)} = [-786/-802 \times 0.85] \times 100 = 83\%$$

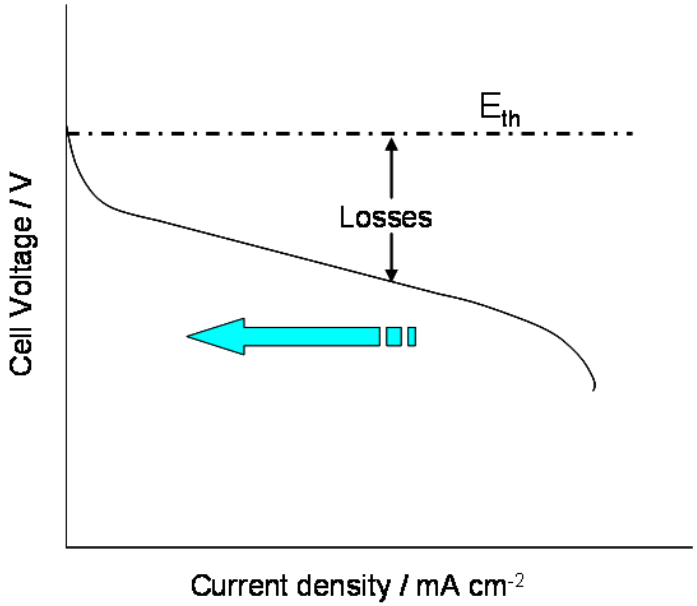
$\varepsilon_{(th)}$ (Hydrogen Fuel Cell)= 68%

How to Harness High Electrical Efficiency

Stack DC Efficiency

$$\varepsilon_{(FC)} = [\varepsilon_{(th)} \times \varepsilon_{(V)}]\,100$$

$$\varepsilon_{(V)} = E/E_{th} = (E - IR - \eta)/E_{th}$$



Fuel Cell System Efficiency

$$\eta_{System} = \eta_{Stack} - BoP\ Losses$$

- Stack Efficiency (>65%) — Maximise
- Parasitic losses
  - Fuel and **air blower** (ΔP in system)
  - Power Electronics
- Thermal losses
  - Stack and system insulation
  - Gas manifolds
  - Tight Integration (reformer-burner-stack)

Minimise

Fuel Cell stack needs to be designed as system component

Maximising Efficiency - Summary

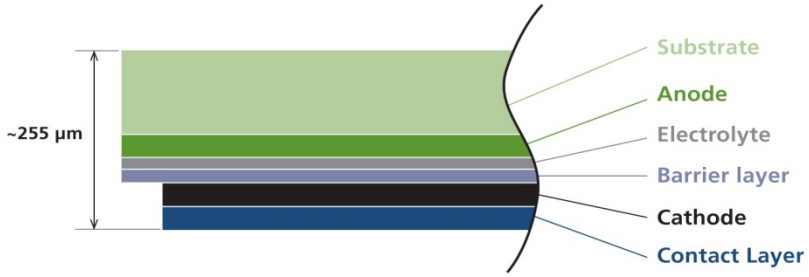
- Internal Steam Reforming:
  - The “chemical combined cycle”
  - Low air ratios – endothermic cooling
- Operation at high Cell Voltage (>800mV/layer)
  - Low overpotential and ohmic losses
  - High performance cells (acceptable power densities)
- High Fuel Utilisation
- Effective Thermal and Flow Management
  - Minimise thermal losses
  - Minimise temperature gradients
  - Uniform fuel distribution
  - Low ΔP (parasitic losses)

High Performance Cells

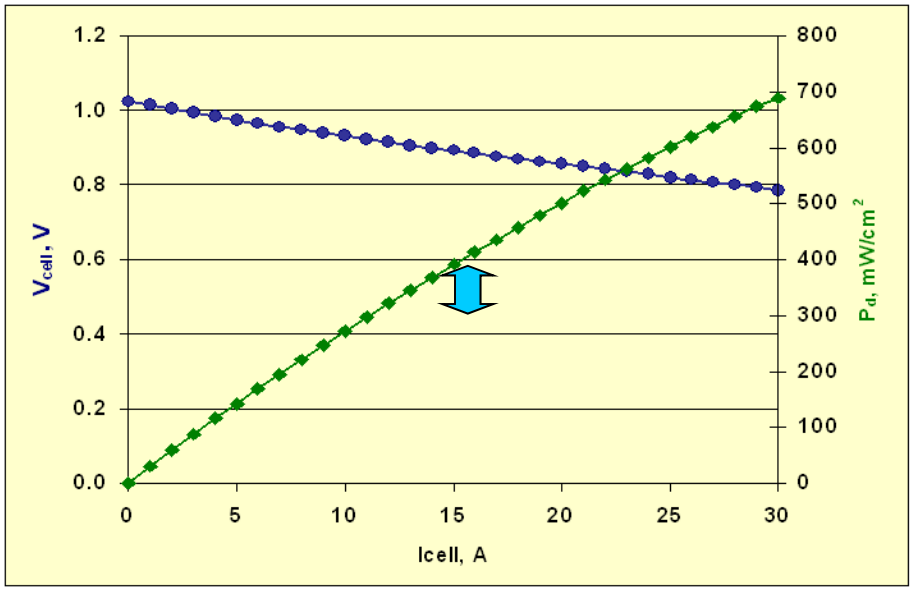
Structure and Performance

- Anode supported cell (350 microns)

- Fuel: NG, 10% pre-reformed and de-sulfurized
- Temperature: 750°C
- 100% Direct Internal Reforming of CH_4
- Fuel Utilization: up to 90% in single pass
- Gross η_e: >70% in single pass



6-layer ASC (70x70mm)

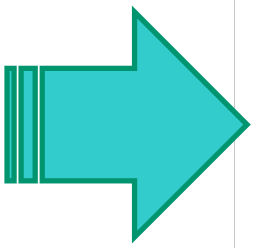


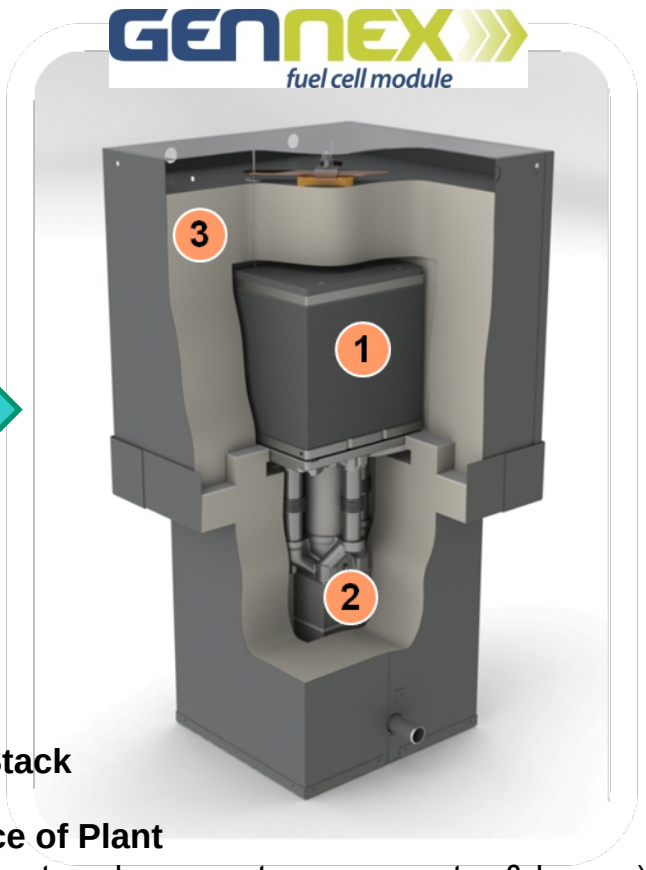
CFCL's SOFC Technology

4x4 Array Stack

Performance

- Operating temperature 750 °C (average)
- Direct internal reforming
- Fuel utilisation - approx 85%
- Gross electrical output up to 2.3 kWe
- Gross stack electrical efficiency >68 %



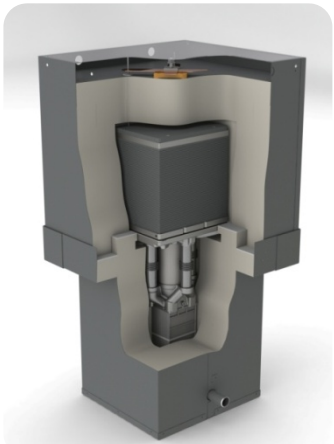


1. **Fuel Cell Stack**
2. **Hot Balance of Plant**
   (air & fuel heat exchanger, steam generator & burner)
3. **High Temperature Insulation**

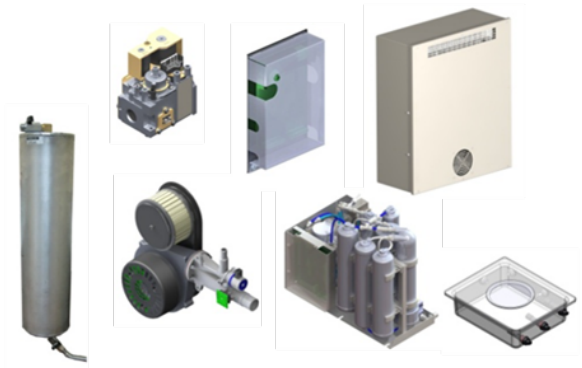
Ceramic Fuel Cells' Products

Products using Gennex Module

Common technology platform



GENNEX fuel cell module



Fully integrated mCHP

- *Power + space heating and hot water*
- *For customers needing a complete heating solution*

With Partners:
Bruns
EWE
e·on UK
BDR
GDF SUEZ

Modular Co-Gen

- *Power + hot water*
- *For markets with lower heating demand (Australia, Japan, US)*
- *And customers with existing heating systems (EU retrofit)*

CFCL

BlueGEN

BlueGEN Unit

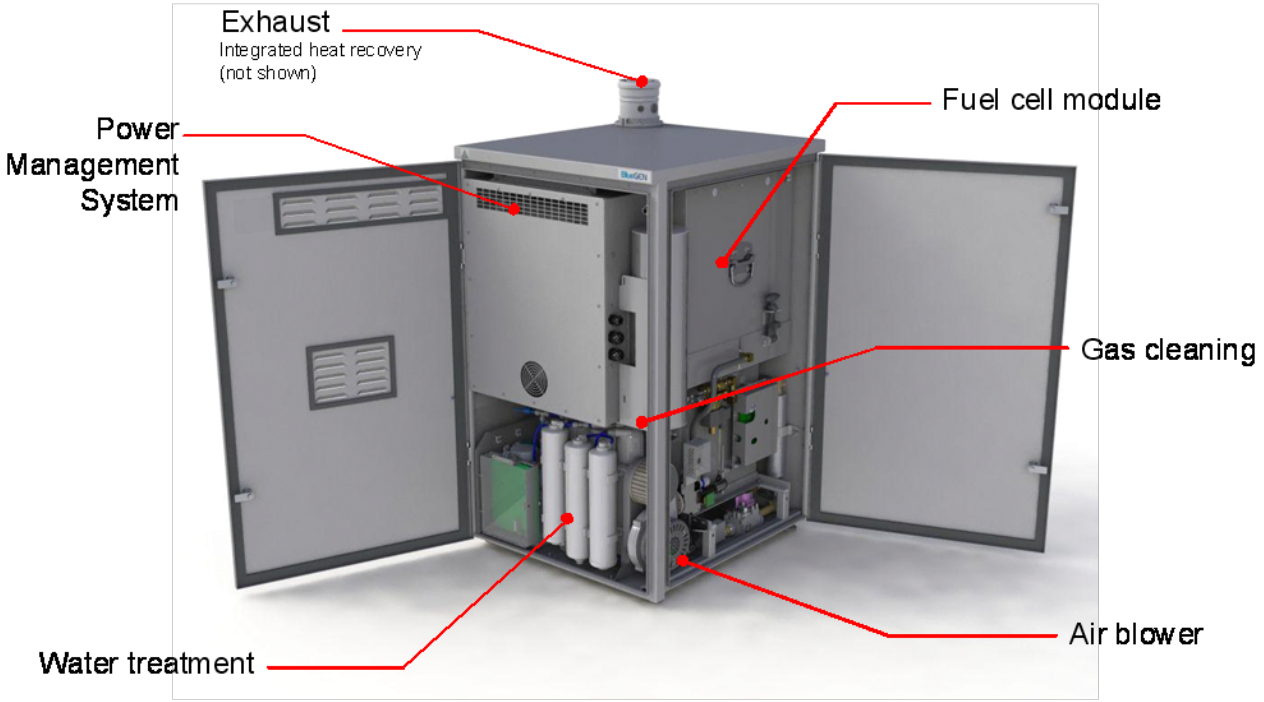
Mono-generation or co-generation

- Highly flexible mini-power station

Electrical Output:
Up to 2kW

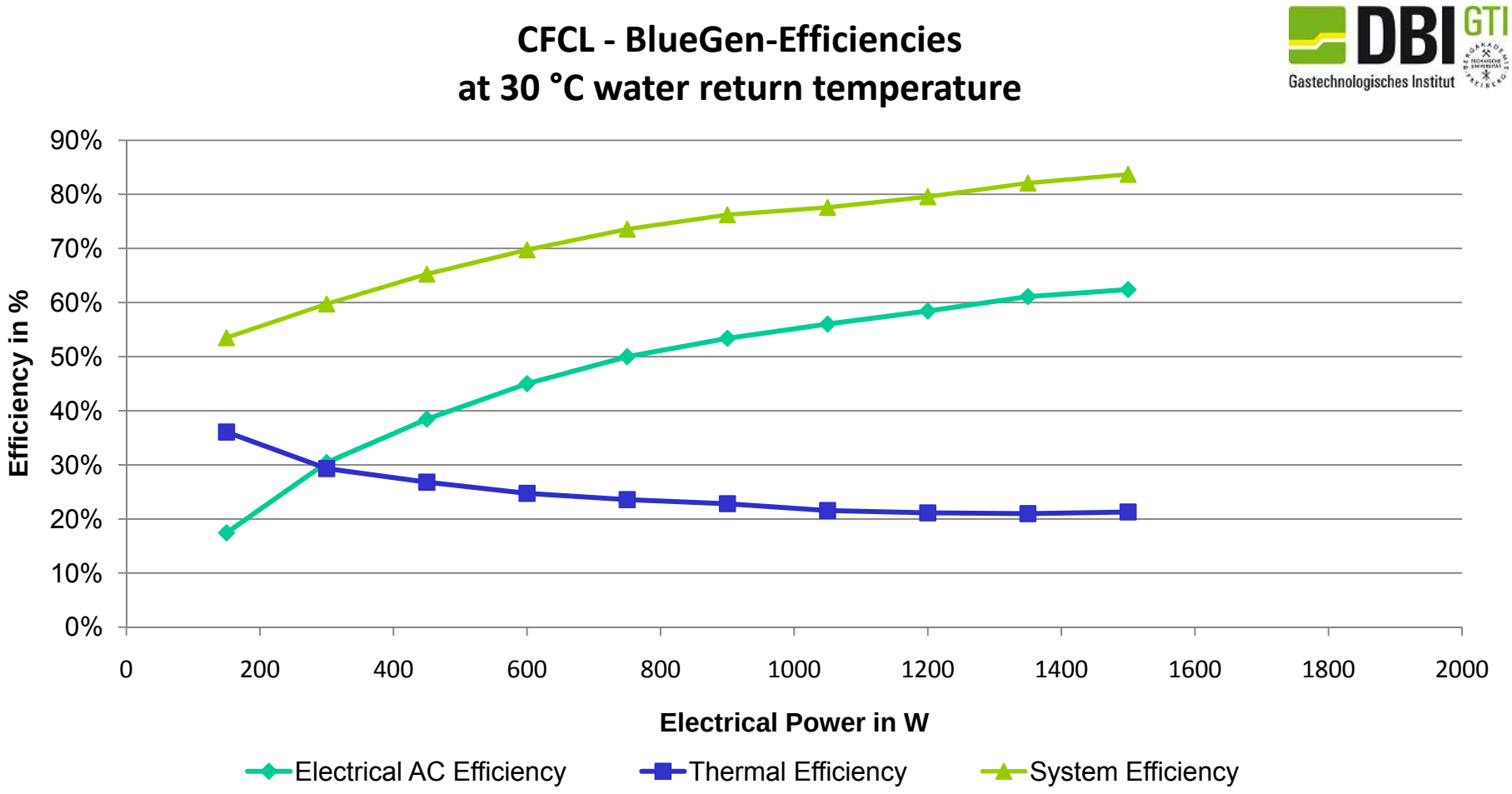
Peak electrical efficiency:
60% NET AC at 1.5 kW

Size of a home dishwasher:
660 mm (D)
600 mm (W)
1010 mm (H)



Customer Data – German Gas Association

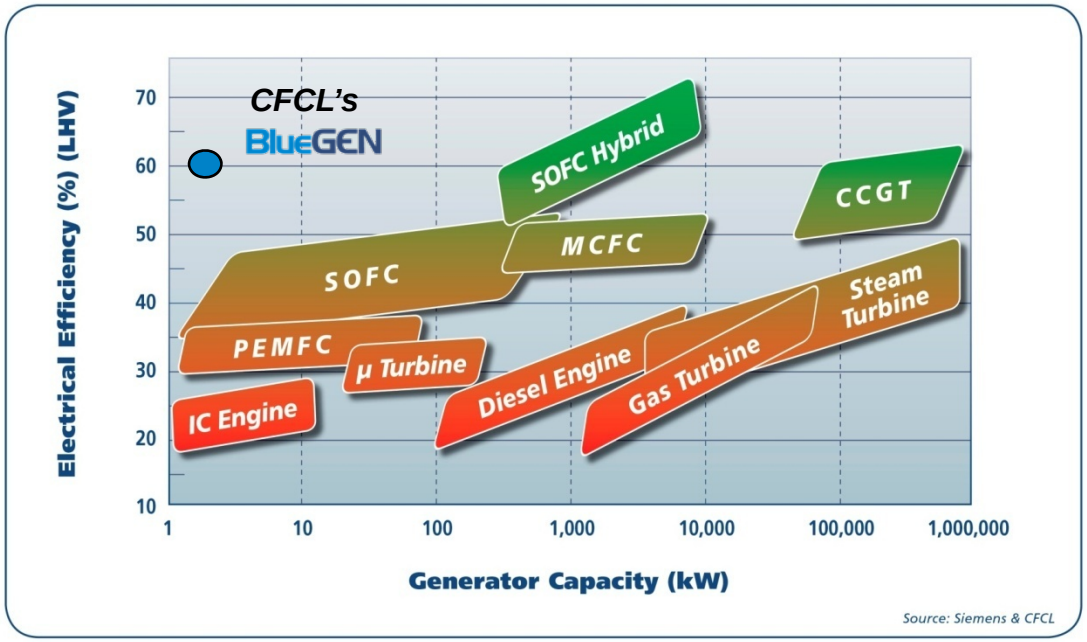
DBI GTI Gastechnologisches Institut

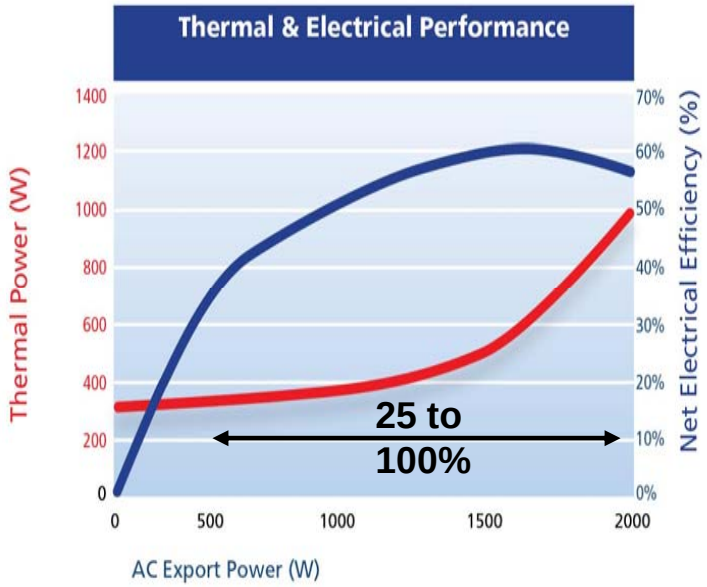


Capability of SOFC Technology

Trend towards highly efficient distributed generation

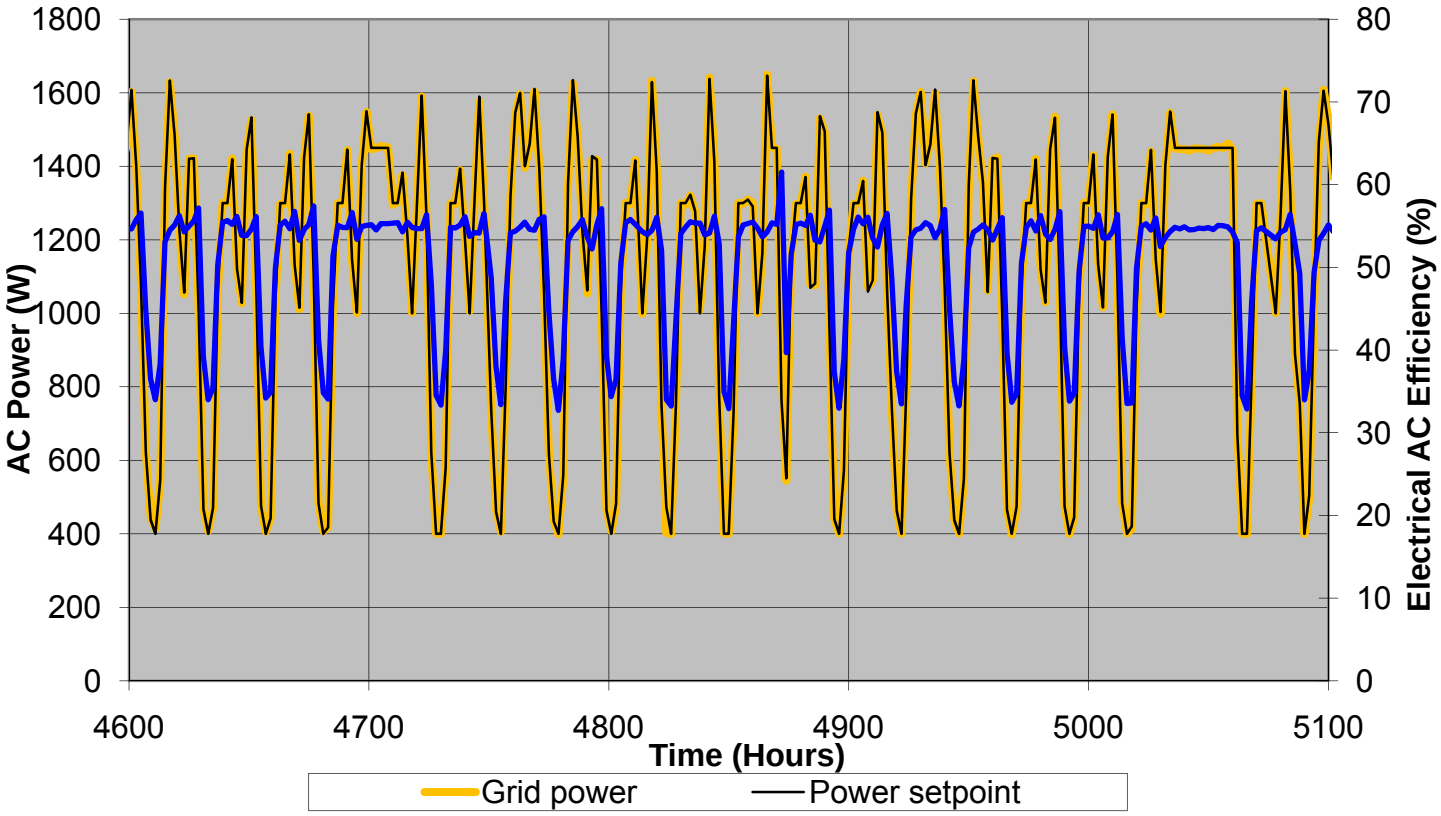
- **Large Power stations no longer efficiency advantage**





Flexible power generation is required in "electricity internet"

Power Modulation

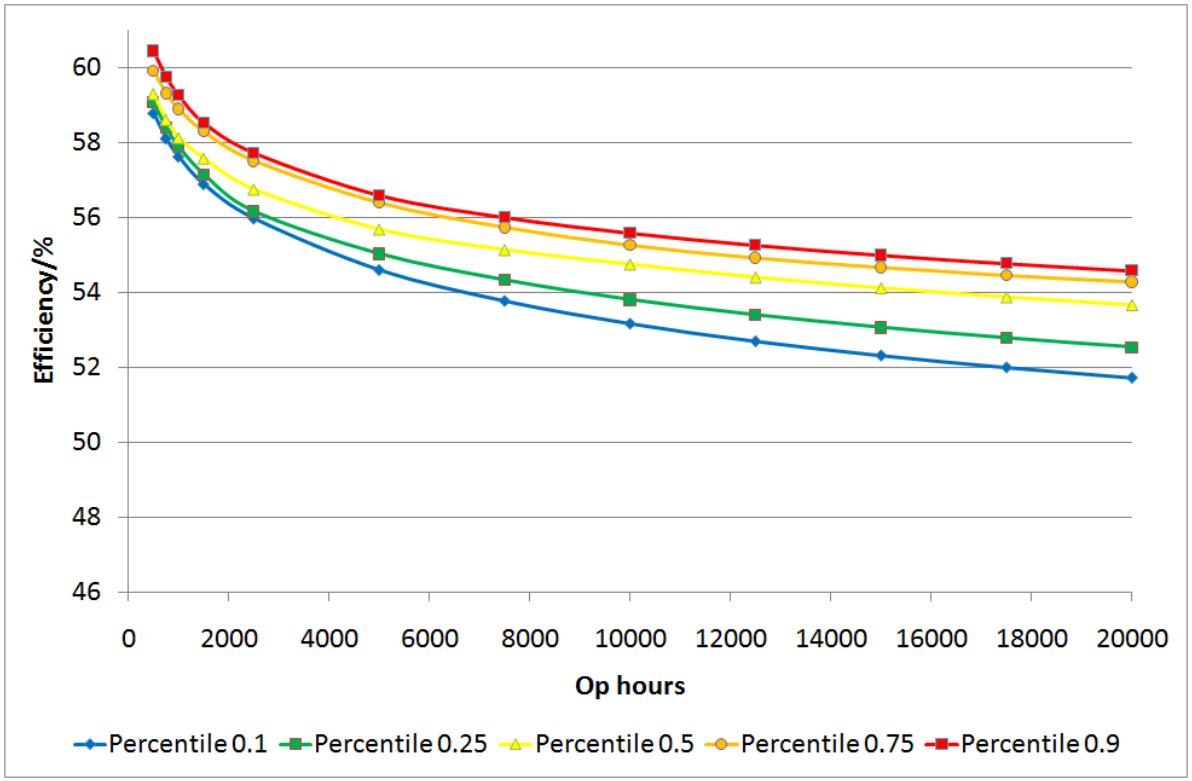


Complex power modulation demonstrated with multiple customers:

- Remotely configurable to match customer demands
- 400W to 1.6 kW at efficiencies of 35% to 55%

Efficiency Life Data

Statistical Analysis of Current Production Systems



- Still performance differences between current production systems, but significant reduction in spread of efficiency degradation compared to early systems
- Further gains through improvement in technology and manufacturing processes

Remote Monitoring and Control

www.bluegen.net

Currently

- Display performance data for Customers
- Remote monitoring & control for CFCL
- Maintenance Monitoring

In future

Extensive internet based Monitoring and Control tools for customers, CFCL and maintenance contractors.

BlueGen Performance Summary

At End August, 90 BlueGen and mCHP units are installed at sites in Europe, Japan, USA and Australia

- Aggregate operation of more than 300,000 hours
  (= more than 30 years' collective operation)

Earliest installed units operating for more than 10,000 hours or 14 months

Continuing to improve fuel cell stack lifetime towards commercial target of 4-5 years and robustness, including 'cycling' on and off, to deliver commercial product performance

All BlueGen units have achieved starting electrical efficiency of 60% or more, demonstrating robust and repeatable performance in many different real world conditions

Applications

Many installation possibilities…

Indoors
Residential
Gasterra
Netherlands

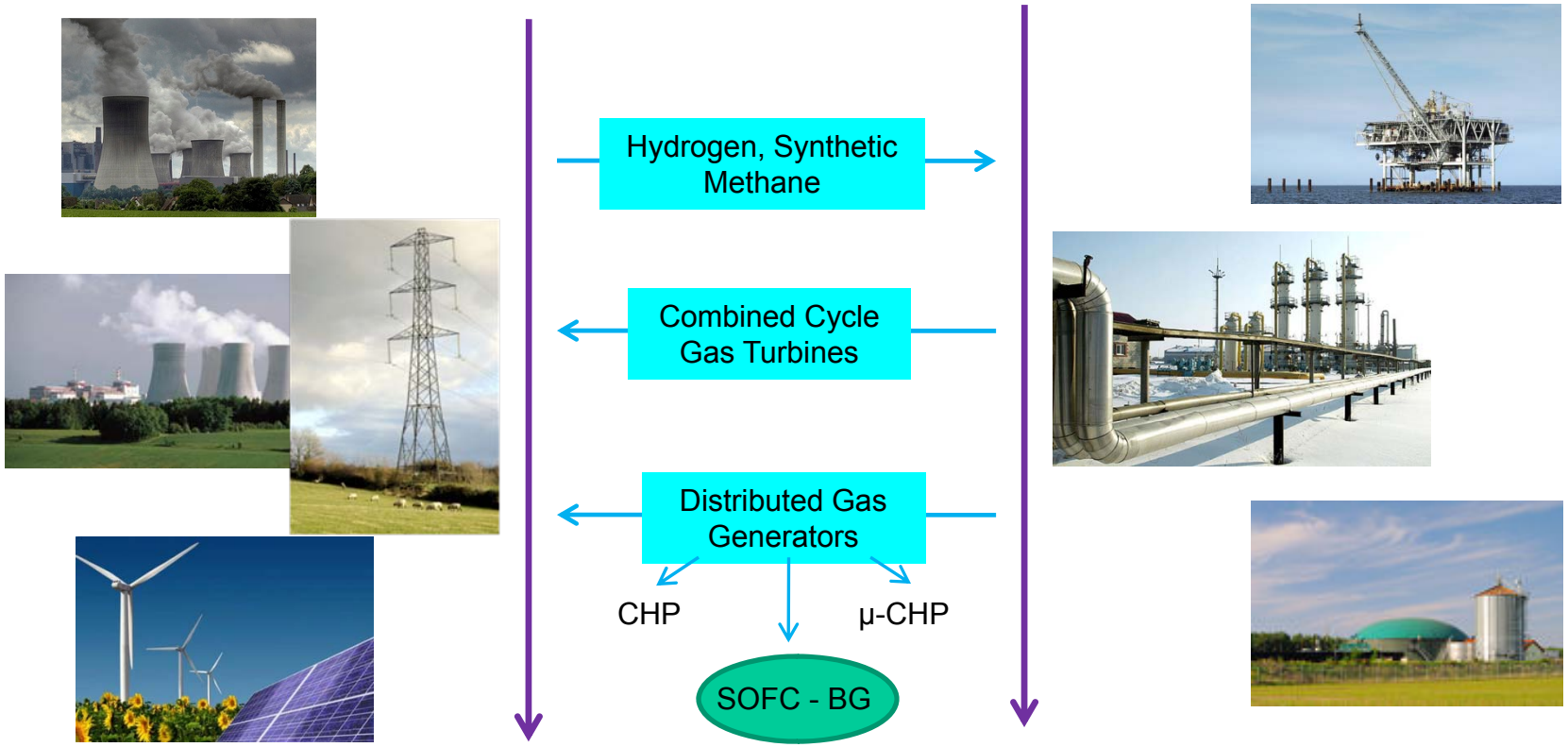
Outdoors
Residential or Commercial
Vic Urban
Melbourne

Indoors
Commercial
Sanevo
Germany

Inside a car park!
Electric Vehicle charging station
Adelaide Council

Future Smart Energy System

Gas and Electricity Grids merge



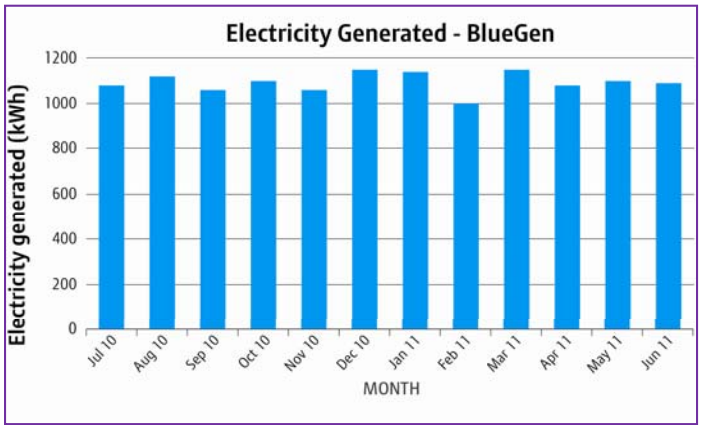
Smart "Home" - Smart Grid Installations

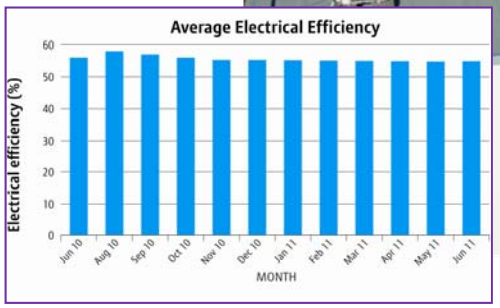
Alliander Netz Ag – Heinsberg

Smart Energy system for Administration Building

BlueGen is complimentary to Renewables:

Solar PV
Solar Thermal
Micro-Wind

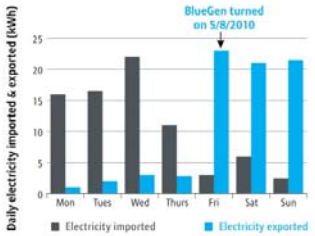


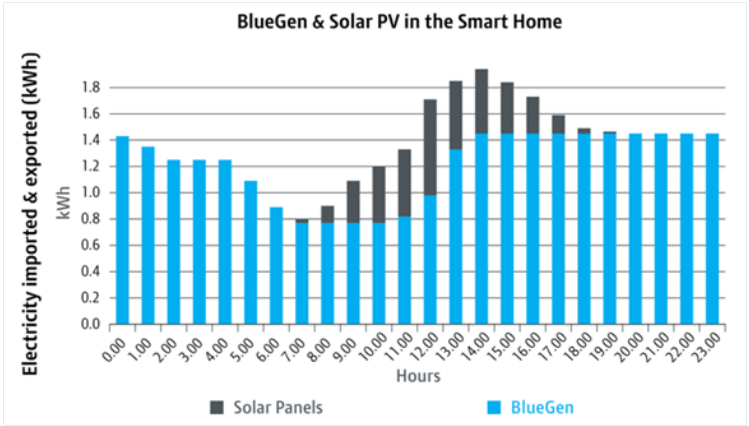


Smart Home/ Smart Grid Installations

Ausgrid 'Smart Home'

- Renovated home in Sydney – showcase existing energy technologies
  - solar PV, energy storage, energy efficient appliances & BlueGen
- The smart home is real – being 'road tested' by a family of three
  - Living a normal life, and… blogging about their experiences online
  - www.smarthomefamily.com.au
- BlueGen installed August 2010





BlueGen + NG + Renewables

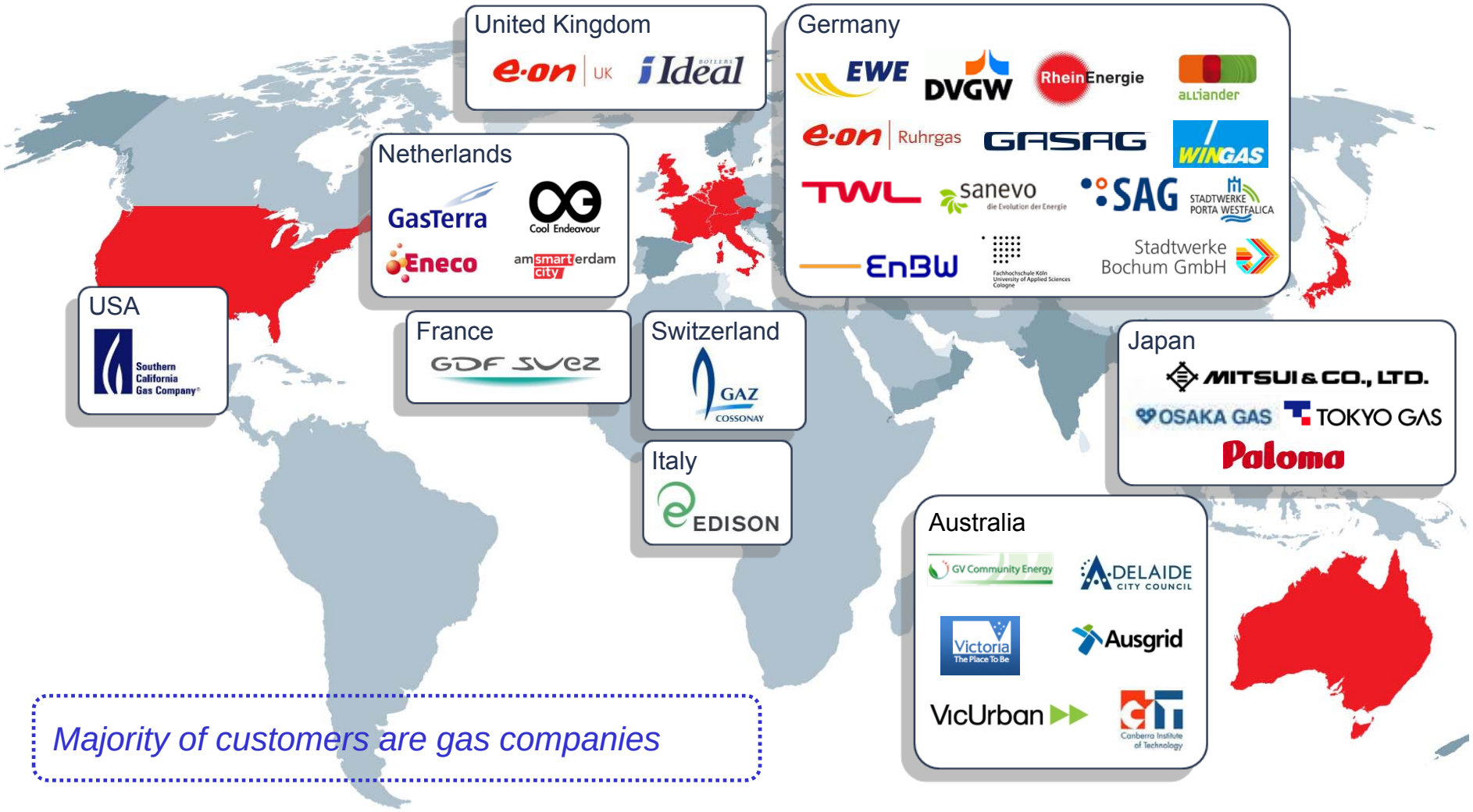
Synth. NG

Solar PV on the roof and BlueGen + NG in the basement for production of *baseload, peak* and *control power*

Highly efficient SOFC like BG + Natural Gas not only interim solution but critical component of sustainable energy future

Commercialisation

Global Customers



Majority of customers are gas companies

Volume Manufacturing in Germany

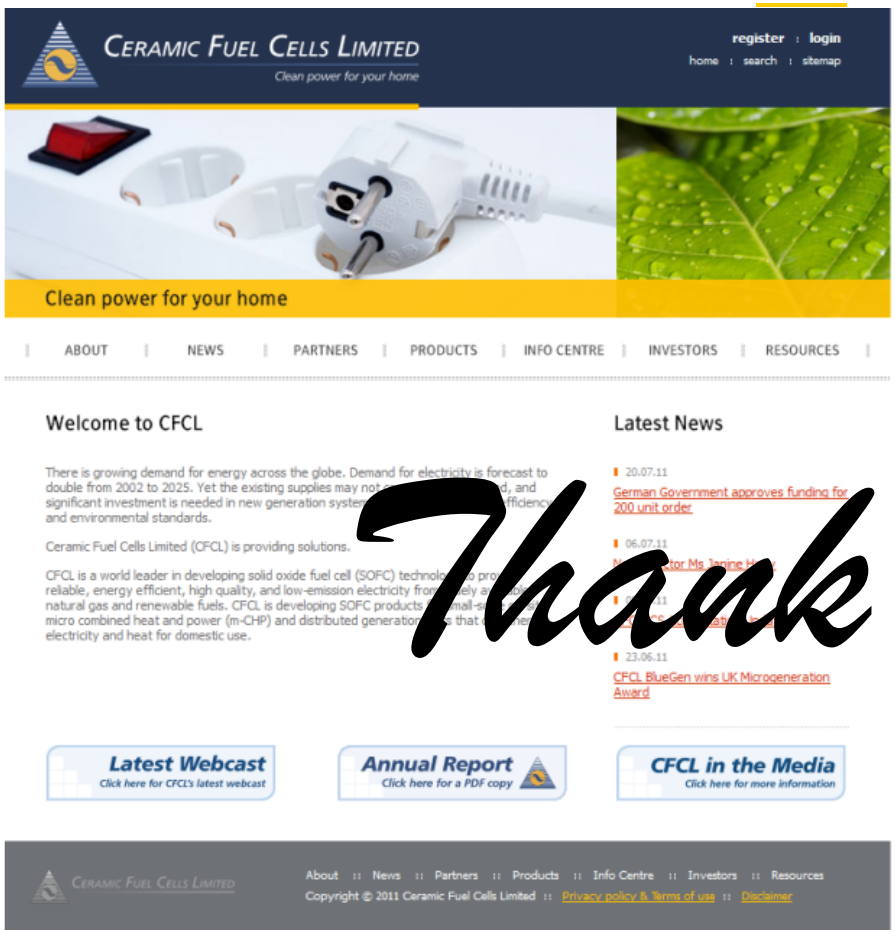
Industriepark Oberbruch, Heinsberg

Robotic stack assembly

•Capacity 10000 stacks pa

Assembly of BlueGen units

- Current capacity 1000 system per year
- Plant has been certified as part of CE approval



Product website in German, English, Dutch

Thank You

www.cfcl.com.au www.bluegen.info www.bluegen.net

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