# POWER-UP Project

## Demonstration of an industrial scale alkaline fuel cell system with heat capture

Fuel Cells and Hydrogen Joint Undertaking
Programme Review Days 2017

Panel 3
Technology validation in stationary applications: CHP, back-up power

N. Ploumis, Head of Projects
AFC Energy plc, Project Coordinator

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# Overview

I. Consortium and Project
II. Project Site
III. Fuel Cell System Design
IV. Manufacture
V. Construction, Installation & Commissioning
VI. Operation & Maintenance
VII. Validation, QA/ QC, Certification
VIII. Benefits of FCH JU Funding
IX. Next Steps

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# I. Consortium and Project

Scope: Demonstration of an industrial scale alkaline fuel cell system with heat capture

Duration: April 2013 – June 2017

Total Budget: €11.5 Million

EU FCH JU FP7 Funding: €6.1 Million

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# I. Consortium and Project

| PARTNER NO | PARTNER NAME | CONTRIBUTION | LOGO | COUNTRY |
|---|---|---|---|---|
| PROJECT COORDINATOR | AFC Energy plc | Technology and plant owner | AFC Energy | UK |
| 2 | Air Products plc | Site provision & infrastructure support, hydrogen supply | AIR PRODUCTS | UK |
| 3 | Zentrum für Brennstoffzellentechnik ZBT Gmbh | CE Marking, Independent data validation | ZBT | Germany |
| 4 | GB Innomech Limited | Manufacturing automation | innomech Automation Solutions | UK |
| 5 | Paul Scherrer Institute | Life-cycle and cost analysis | PAUL SCHERRER INSTITUT PSI | Switzerland |
| 6 | FAST in cooperation with European Hydrogen Association | Project dissemination | FAST EHA | Italy |

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# I. Consortium and Project

**Stated Objectives for Project POWER-UP:**

1. Delivery of an AFC system that converts hydrogen into electricity and heat at competitive prices
2. Successful scaled-up manufacture of fuel cell components that meet relevant ISO standards
3. Demonstration of a functioning automated process that assembles components into fuel cell stacks ready for incorporation within the system
4. Reduced installation and commissioning times (and costs) of the system through the development of a modular, containerised Balance of Plant
5. Effective recycling/reconditioning of substrate plates, catalyst materials and stack components
6. Understanding and quantifying the direct and indirect environmental burdens of the fuel cell system (including its hydrogen supply and component recycling) and the relevant socio-economic factors
7. Meeting end-user reliability requirements and compatibility with end-user's plant maintenance schedules

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# I. Consortium and Project

| WORK PACKAGE NO. | WORK PACKAGE TITLE | TYPE OF ACTIVITY |
|---|---|---|
| WP1 | Initiation | DEM |
| WP2 | Cell manufacture | DEM |
| WP3 | Automated cell assembly | RTD |
| WP4 | Manufacture of Balance of Plant | DEM |
| WP5 | Phased installation of AFC systems | DEM |
| WP6 | Automated cell disassembly | RTD |
| WP7 | Operation and maintenance of fuel cell system | DEM |
| WP8 | Data-gathering, analyses | RTD |
| WP9 | Testing, validation, QA/QC, certification & regulatory compliance | DEM |
| WP10 | Dissemination | RTD |
| WP11 | Project management | MGT |

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# II. Project Site



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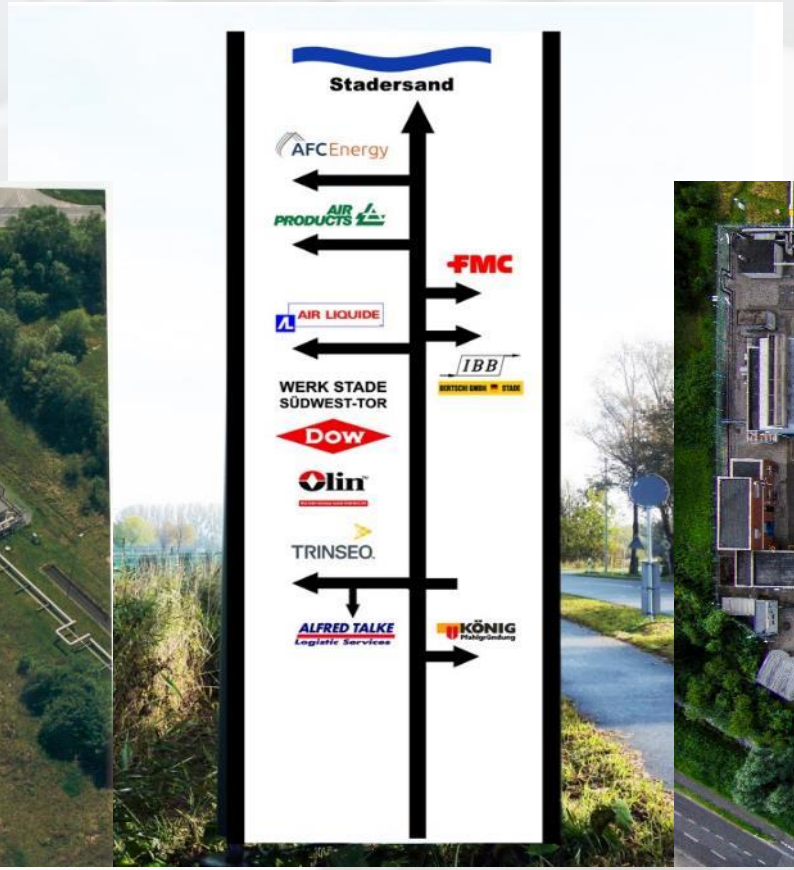
# II. Project Site




**Stade Site Before**

**Stade Site Today**

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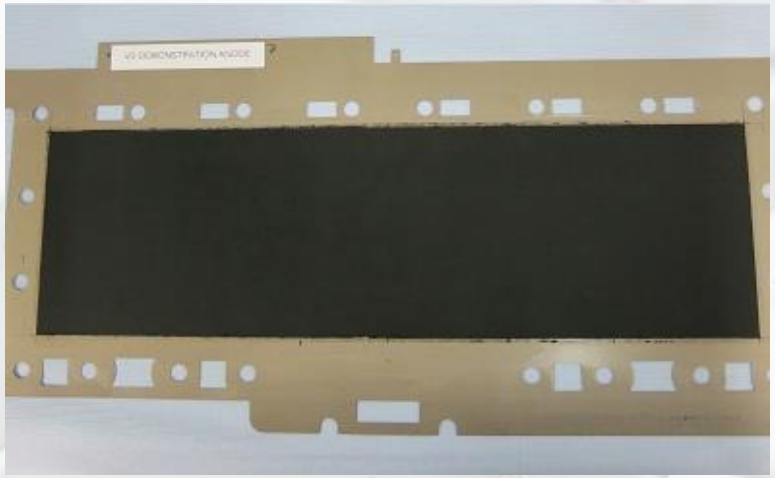
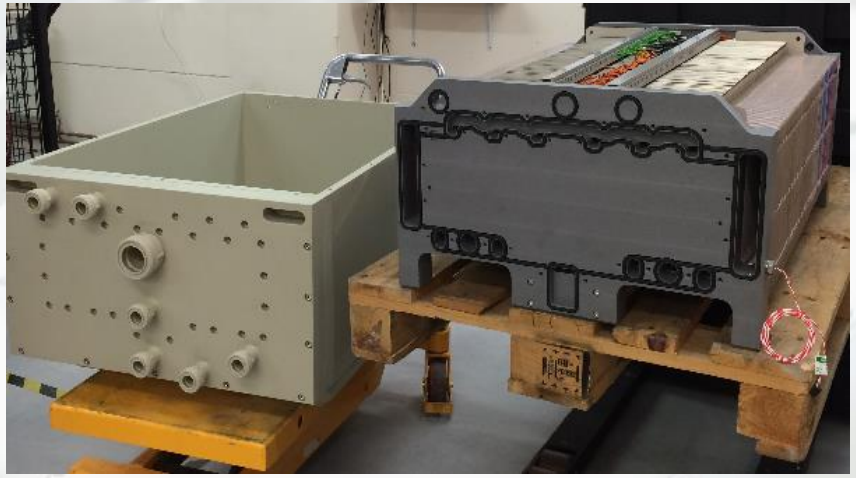
# III. Fuel Cell System Design



Electrodes (x4848)



Cartridges (x24)

Balance of Plant (x1)

Pilot Plant (x1)

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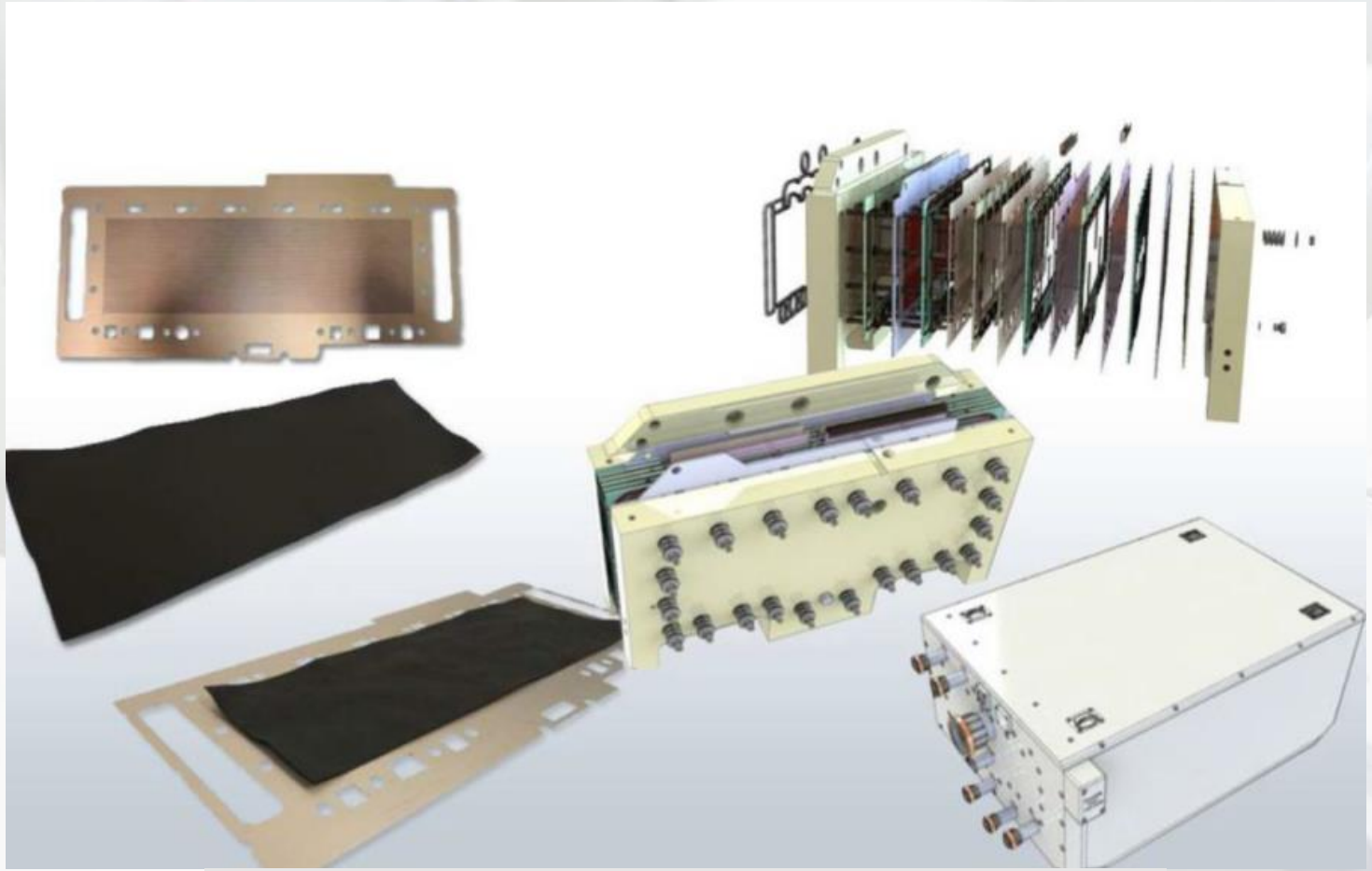
# III. Fuel Cell System Design



From electrode to cartridge assembly

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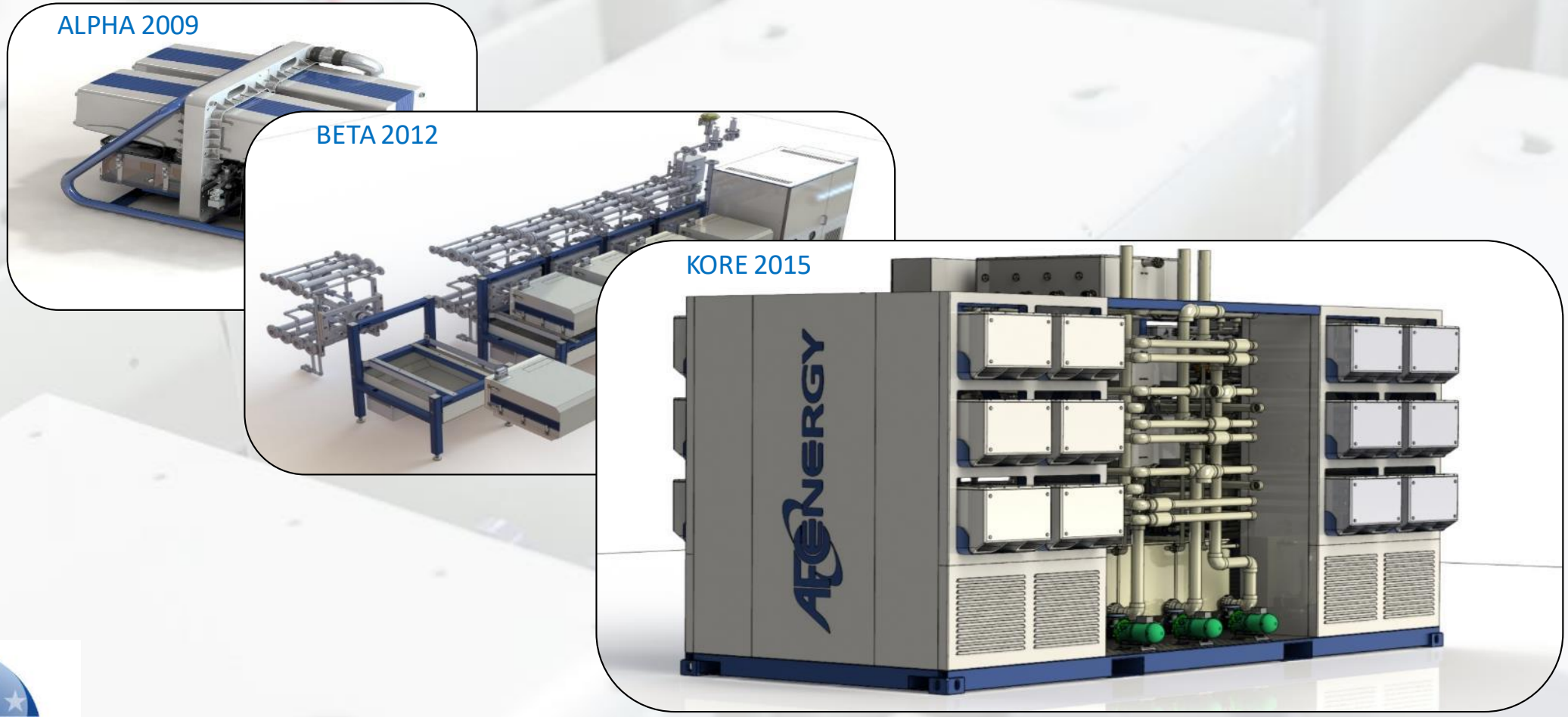
# III. Fuel Cell System Design




**Balance of Plant design history**

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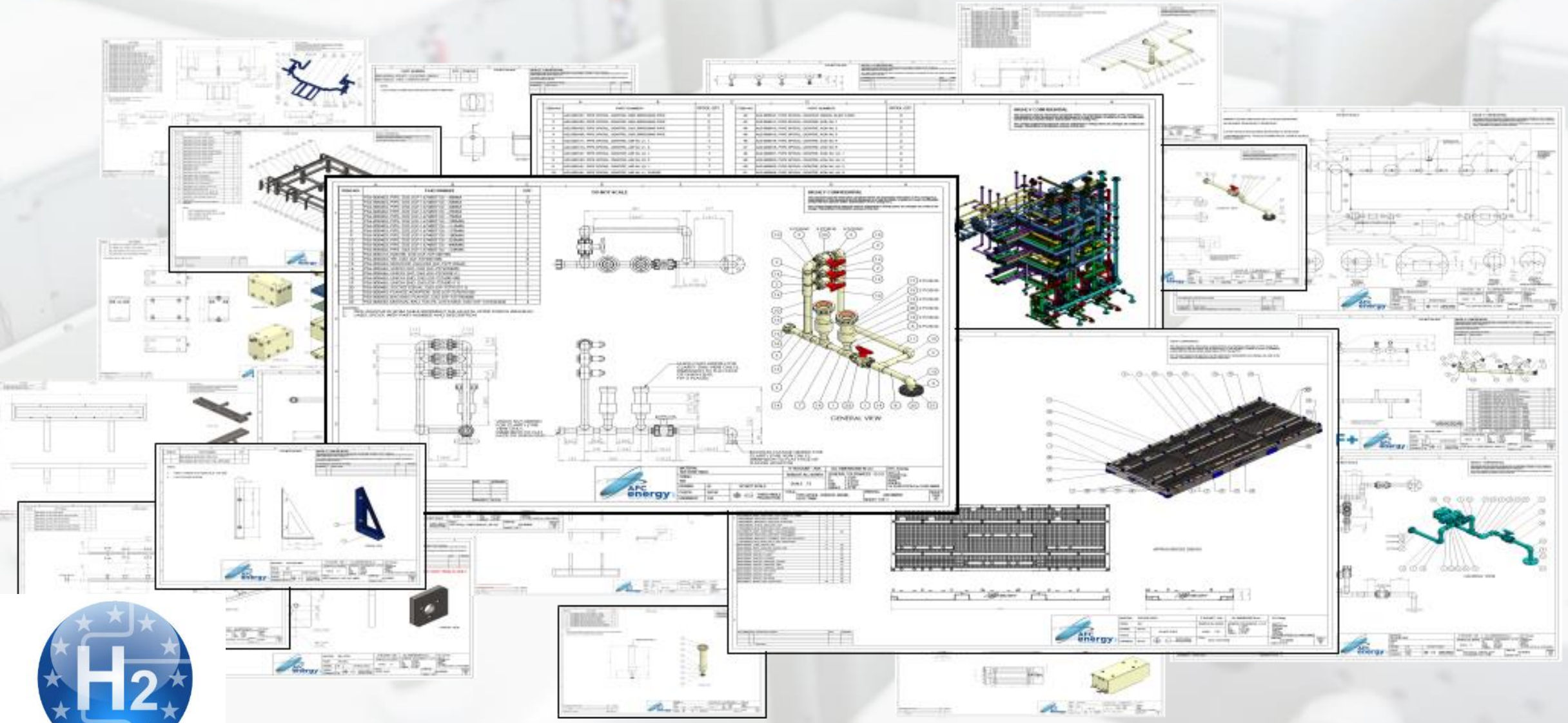
# III. Fuel Cell System Design



**KORE BoP / Design**

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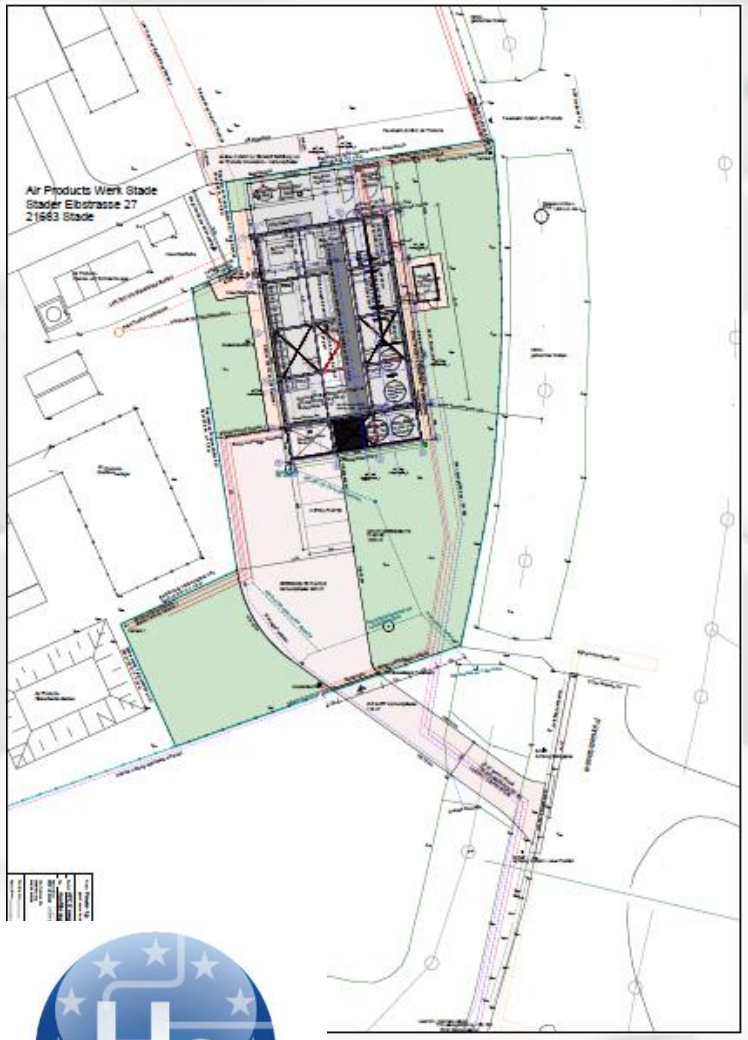
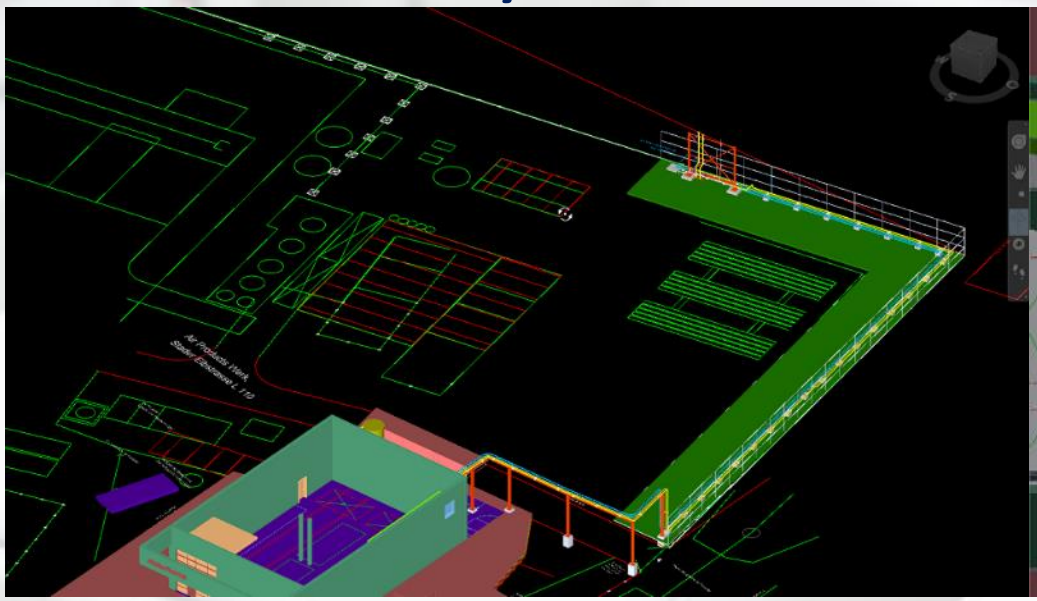
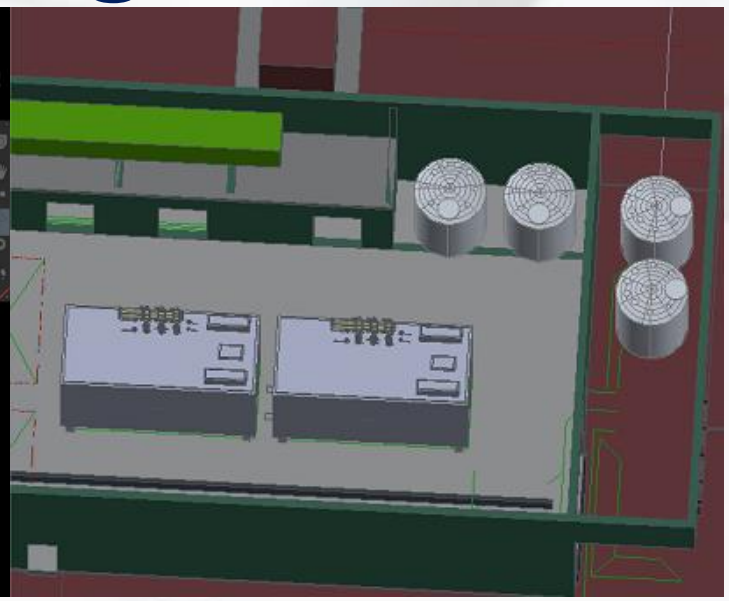
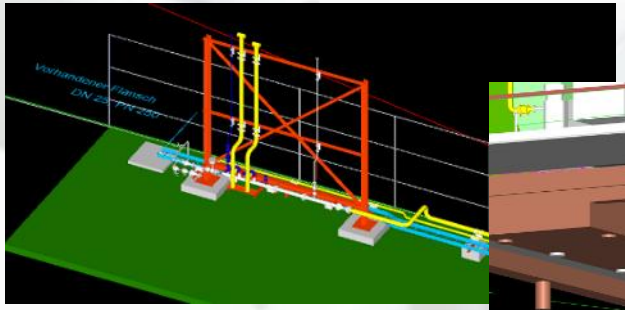
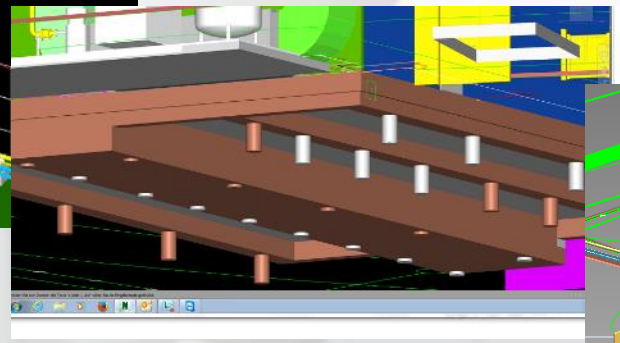
# III. Fuel Cell System Design

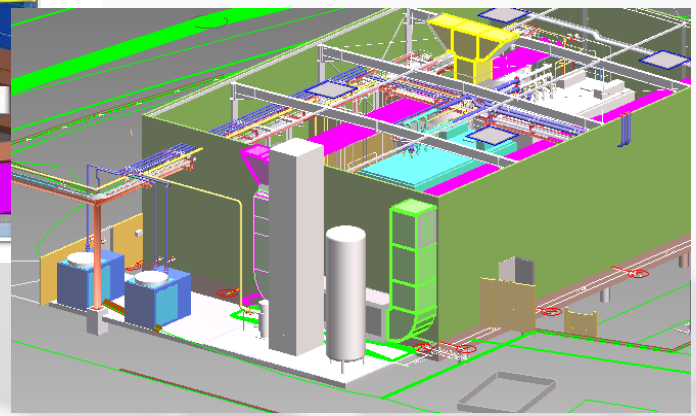










**Pilot Plant/ Aspects of Design**

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# III. Fuel Cell System Design

In order for the POWER-UP project to comply with both German codes, standards and regulations, as well as host Air Products' technical and safety requirements, the Coordinator:

- Performed a Hazard and Operability review (HAZOP) for
  - the KORE BoP,
  - The H2 let-down station and supply pipeline to the plant and
  - The pilot plant in its' entirety
- An explosive atmosphere potential (ATEX) study was also undertaken.

These safety reviews were performed by German engineers and consultants, compliant with all applicable German regulation and permitting requirements, including AFC Energy staff and Air Products process safety engineers.

- In addition, elements of the pilot plant, such as the PCU, were reviewed for German Medium Voltage Grid Code compliance, in conjunction with Siemens and Stadtwerke Stade, the local power take-off company.
- TÜV also certified the pilot plant pipework and tanks for compliance.

These actions allowed AFCEN to secure the necessary building permit and operating license for the plant design, allowing a construction timeline of just over 4 months.

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# IV. Manufacture

Automated Extrusion of Electrode Layers

Automated Electrode Stacking

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# IV. Manufacture

Stack Assembly Robot in Action

Fuel Cell Cartridges Ready to Ship

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# IV. Manufacture






KORE BoP Manufacture in Coventry, England

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# V. Construction, Installation & Commissioning



KORE BoP / 3D CAD Model to Manufacture

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# V. Construction, Installation & Commissioning





## KORE BoP / Arrival and Final Assembly at Stade

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# V. Construction, Installation & Commissioning


KORE BoP in situ

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# V. Construction, Installation & Commissioning


- Control System
- Cell Voltage Monitoring
- Software
- Site Integration
- Power Electronics

## Control, Electronics and Power

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# V. Construction, Installation & Commissioning

| Company | Role |
|---|---|
| Foster Wheeler Energy Ltd | Scoping study |
| Artelia GmbH | Civil & structural design, permitting. EPCM until April 2015 |
| PlantIng GmbH | Plant design, engineering & construction, EPCM from May 2015, O&M support |
| Stadtwerke Stade ( SWS) | Power off taker & MV Grid Connection |
| Siemens AG | Design, supply, commissioning and BDEW certification of power inverters |
| Georg Fischer (GF Piping Systems) | Fabrication of piping assemblies for the KORE module |
| Richard Ditting GmbH & Co. KG | Civil works sub-contractor |
| Rudolstaedter Systembau (RSB) | Building shell sub-contractor |
| Zwingmann GmbH | Piping sub-contractor |
| Hanseatische MessTechnik (HMT) GmbH & Co. KG | Electrical, C&I sub-contractor |

## Stade Facility / Other key participants

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# VI. Operation & Maintenance

O&M activities include:

a. On-site monitoring of fuel cell stack runs at start of operation
b. Remote monitoring of fuel cell stack runs throughout operation
c. Logistics of f.c. cartridges transportation from Dunsfold to Stade and return for recycling/ reclamation
d. Equipment regular inspection and servicing (e.g. IA compressors, plant ventilation, water management system, KOH management system, general C&I upkeep, PCU, etc.)
e. Troubleshooting


The Coordinator and its local partners ensure plant operation is in compliance with German codes, standards and permitting requirements (HAZOP, ATEX, etc.).

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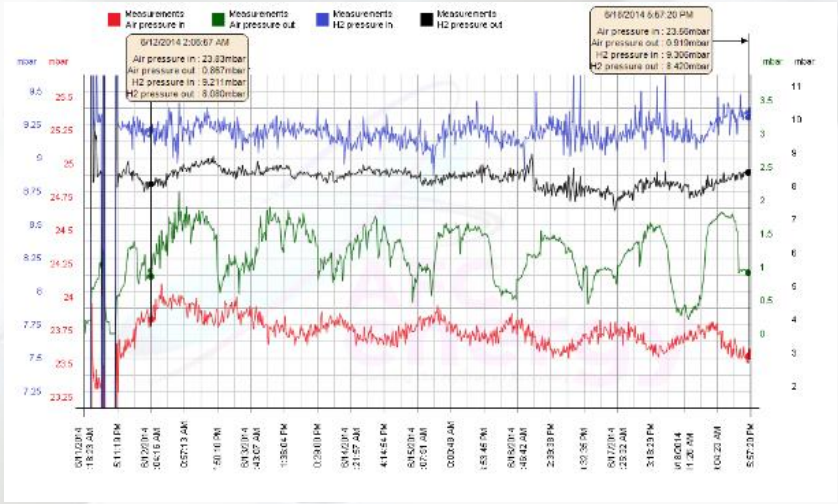
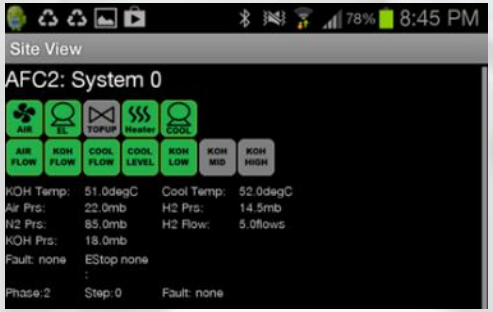
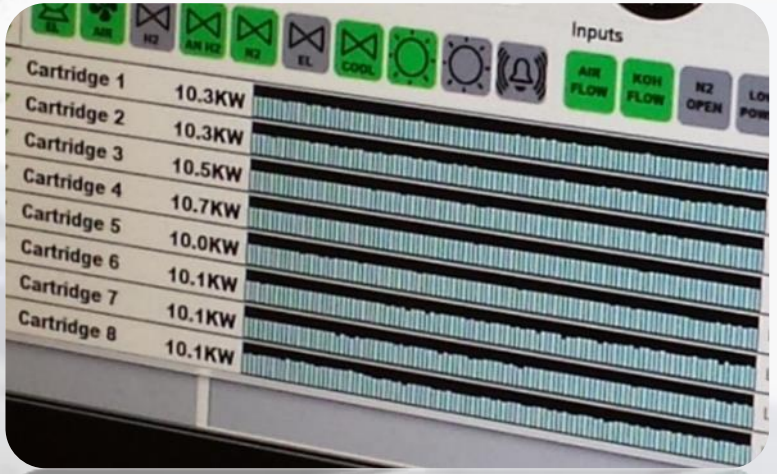
# VI. Operation & Maintenance

- Application for acquiring and managing data from AFC Systems
- Tool for accessing and viewing data from AFC Systems
- Notification of Alarm conditions via email
- Versatile data plotting and exporting routines
- Mobile Phone App




## Remote Monitoring – SiteView

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# VII. Validation, QA/ QC, Certification

Due to the ambitious nature of this project, several validation, QA/QC and certification actions were taken to ensure compliance, both with the FCH JU targets and German regulations, codes and standards.

- ZBT Project Milestones Validation
- Regulatory Compliance, via ZBT and also German consultancies Artelia and plantIng
- CE Certification, again with ZBT support, to ensure the design and documentation controls comply with CE marking requirements
- Stadtwerke Stade and Siemens supported the Coordinator to address grid code compliance for the Power Conditioning Unit
- TÜV Rheinland, for Stade infrastructure pipeline and storage tanks certification
- New, more rigorous QA/ QC criteria introduced into stack mabufacturing
- PSI contributed with the LCA, SEA and cost analysis spreadsheet tool

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# VII. Validation, QA/ QC, Certification

Dedicated work package for data gathering and analysis, led by the Paul Scherrer Institut (PSI). Indicative example of the Life Cycle Assessment of our alkaline fuel cell systems:

**GEN1**: 'as-built' scenario,

**GEN2**: 'near future' scenario using similar components to GEN1, but with some marginal improvements,

**SOAK**: 'Second Of A Kind' scenario that represents near-future technology with significant improvements in cell design and system efficiency,

**NOAK**: 'Nth Of A Kind', which represents a future scenario where the POWER-UP system has been built many times and has been well optimised.

Criteria examples: kg CO2/kWh, Total Energy Use MJ/kWh, Human Health Impact DALY/kWh, etc.

The scenarios selected are specific for the POWER-UP project and the concurrent status of AFC technology. The report was accompanied by a detailed cost calculation spreadsheet. Results were consistent with commercial pricing for power generation plants in the industry.

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# VIII. Benefits of FCH JU Funding

The project accomplished several of its key milestones and success criteria, which would not have been possible within this project timeline without the FCH JU FP7 contribution.

- ✓ The Coordinator's Alkaline Fuel Cell (AFC) systems developed from small-scale testing and partly populated fuel cell stacks all the way to a fully populated BoP, with the requisite > 4,800 electrodes, being tested in 'real world' conditions, at a dedicated pilot plant sited in a major German chemical park.
- ✓ Both ZBT and PSI have increased their in-depth knowledge of, and expertise in, FCs and AFCs, with some results circulated to the wider scientific and engineering community.
- ✓ Air Products' experience with fuel cell installations, on the way to a 'Green Hydrogen' driven economy, has also increased.
- ✓ GB INMC and FAST-EHA have new opportunities for product deployment, services and support.

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# VIII. Benefits of FCH JU Funding

- ✓ The project helped install, commission and is now operating the **world's first industrially sited large-scale alkaline fuel cell power plant**, the biggest of its' kind in the world.
- ✓ Local employment, both short-term and long-term, increase. Main benefits reaped in the UK and Germany.
- ✓ A predominantly European based supply chain for alkaline fuel cell systems has now been established.
- ✓ Several potential customers have now approached AFC Energy because of this project, opening up new markets for large-scale alkaline fuel cell systems both in the EU and other regions.


Plant signage at Stade

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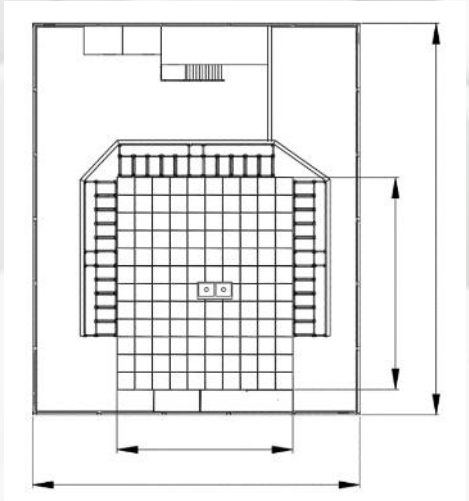
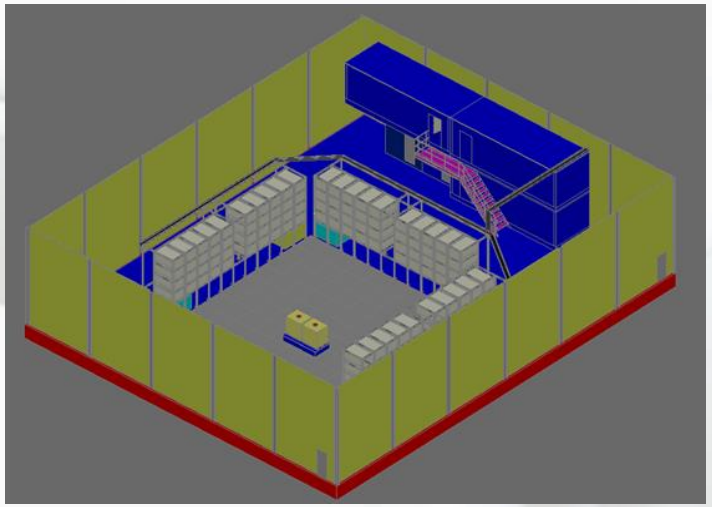
# IX. Next Steps

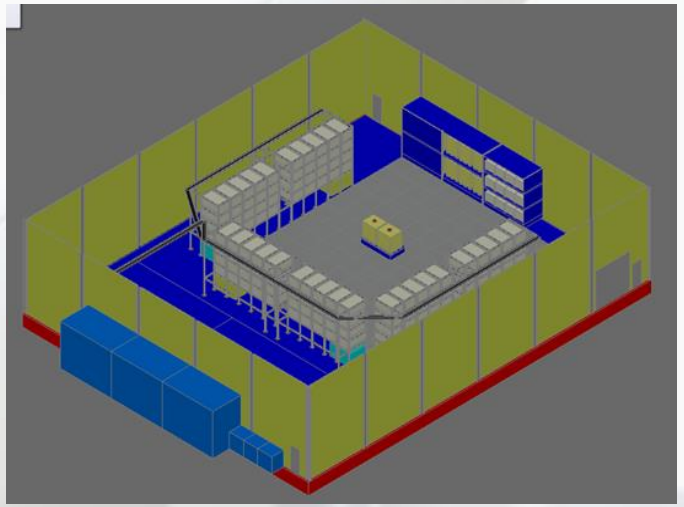
AFC Energy has been the main beneficiary, technology wise, of the POWER-UP project.

The opportunities that have now become available by establishing a diverse supply chain, expert engineering and project personnel and expertise, a large-scale automated fuel cell manufacturing base and a pool of specialised contractors include:

- Large scale fuel cell power plant projects, ≥1MWe, with basic engineering design completed.







Indicative layout and 3D preliminary models for 1MWe installations, fully scalable

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# IX. Next Steps

- Integration potential of H2 generation, storage and on-site power generation, focusing on the 'Green Hydrogen' economy potential and curtailed energy opportunities.
- Establishing long-term partnerships and joint collaboration relationships with companies such as Industrie De Nora, allowing us to improve key performance indicators of our alkaline fuel cell stacks and systems (P.L.A.C.E.).

  **P**ower – Output delivered by our fuel cells in terms of $kW_e$

  **L**ongevity – Period the fuel cells last before requiring replacement

  **A**vailability – Proportion of time operational (excluding maintenance)

  **C**ost – Cost to install and operate in terms of €/$kW_h$

  **E**fficiency – Energy delivered relative to hydrogen input

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# POWER-UP Project

Thank you for your attention.
Questions please?

N. Ploumis, Head of Projects
AFC Energy plc, Project Coordinator
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