CH2P

Cogeneration of Hydrogen and Power using solid oxide based system fed by methane rich gas

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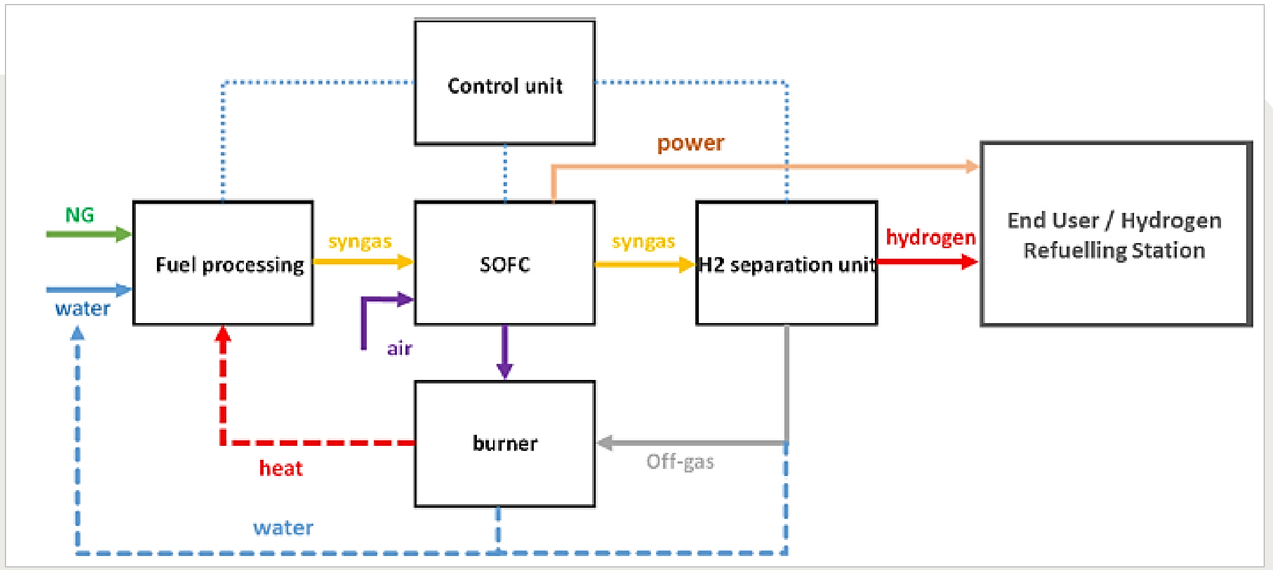
PROJECT OVERVIEW

- **Call year:** 2016
- **Call topic:** FCH-02.4-2016: Co-generation of Hydrogen and Electricity with High-Temperature Fuel Cells (>50kW)
- **Project dates:** 01.02.17 – 31.07.20
- **% stage of implementation 01/11/2018:** 43%
- **Total project budget:** 6.8 mil €
- **FCH JU max. contribution:** 3.9 mil €
- **Other in-kind financial contribution: 1.0 mil €**
- **Partners:** Fondazione Bruno Kessler (I, Coordinator), SOLIDpower Spa (I), SOLIDpower SA (CH), Ecole Polytechnique Fédérale de Lausanne (CH), Deutsches Zentrum Fuer Luft und Raumfahrt Ev (D), Hygear Technology and Services Bv (NL), Shell Global Solutions International Bv (NL), Vertech Group (F)

PROJECT SUMMARY - INTRODUCTION

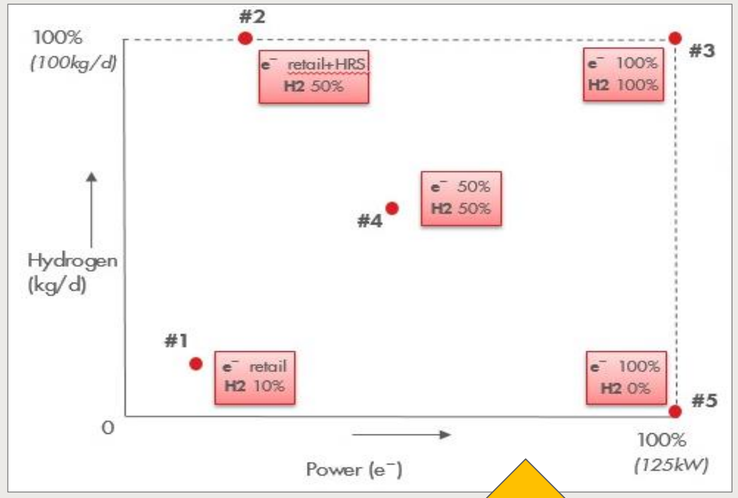
CH2P project
(Cogeneration of Hydrogen, Heat and Power)
has the objective to realize a **new technology** **at high efficiency and limited impact** on carbon emissions,
for use **in refueling stations of the next future**
impacting the sustainability of the transport sector

The CH2P project has as **primary objective** to cogenerate hydrogen, heat and power using Solid Oxide Fuel Cell technology fuelled by methane-rich gases



PROJECT SUMMARY - OBJECTIVES

- Production of hydrogen and electricity more efficiently than conventional technologies
- Optimization of decentralized H_2 production from the point of view of an HRS, especially during the ramp-up phase, by flexible hydrogen production capability
- Purity level of hydrogen for use in the automotive sector
- Economic hydrogen generation
- Modularity, to enable a staged deployment of such infrastructure
- Dynamic hydrogen production capacity adapted to 5 operation modes and a hot stand-by state
- In future developments, grid stabilization services through flexible power generation and electric energy storage service in the form of H_2



Test bench for stack testing in FBK

Operation modes for CH2P technology

GLOBAL POSITIONING VS **INTERNATIONAL STATE-OF THE ART**

CH2P is introducing several innovative aspects **beyond the actual state of the art** in **SOFC** technology:

1) **HYDROGEN AND POWER** can be generated through SOFC using methane-rich gases. The SOFC technology is based on novel stack to be integrated with a pre-reformer, modulated in fuel utilization and output generation
2) **Extended operability of the SOFC stack**, with high dynamic from **full capacity** on hydrogen power generation (**100 kg/d + 125 kW**) to retail power supply to HRS and limited H2 production (15 kg/d + 40 kW)

2) The design of the CH2P system with **fully embedded hot and cold subsystems**, modulated through **heat exchanger network and burner**;

3) **Upstream natural gas management** to allow for wide acceptance on NG composition, full management for **downstream H2 quality** allowed for transport applications

100 kgH_2/d

PILOT TESTING

Size for the Pilot site testing at Shell Technology Center in Amsterdam

75%

OVERALL EFFICIENCY

Overall efficiency between output H2 and power capacity and input gas calorific value

99,999 %

PURITY LEVEL 5N

In compliance with requirements of **ISO 14687-2:2012**

4,5€/kg

H_2 PRODUCTION COST

Based on innovative cost model at refueling station

APPLICATION AND MARKET AREA

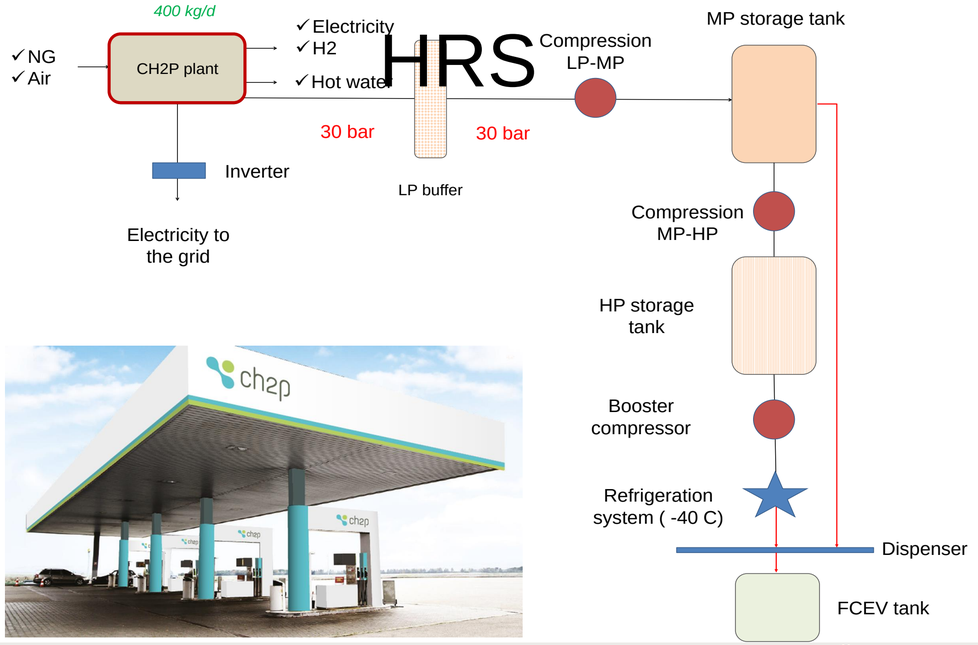
The CH2P project aims at building a bridge across this valley of death of early infrastructure deployment. CH2P project targets the market of HRS

Specific impacts of CH2P are:

1. **Hydrogen cost and associated carbon emissions**: a business case for a 400 kg/day system with hydrogen cost below €4.50/kg, competitive with centrally produced hydrogen with delivery
2. **Potential for market introduction**: under hypothesis to reach 10% of the potential market in Europe and 5% at world level, there is a potential of 300 HRS for CH2P by 2025. This is equivalent to 50 MW stack manufactured in 5 years.
3. **Impact on job creation**: CH2P can account for an additional job creation of more than 100 people at the level of the overall Consortium, for the period 2020 – 25.
4. **Other societal impacts**: the high overall efficiency of the system has a positive impact on carbon emissions.
5. **Environmental profile**: life cycle analyses will be performed on the design at a scale of 400 kg/day. The environmental assessment will be comparing CH2P with competitive technologies.
6. **Security**: the innovative method of “total system design” will grant the system a high security level for the developed technology

LCA and LCC analyses

CH2P: a novel tech for HRS



PROJECT PROGRESS/ACTIONS – SYSTEM SIZE

Achievement to-date

0 kg_{H2}/day

20kg_{H2}/day

100 kg_{H2}/day

25% 50% 75%

- Call topic demands for a prototype of 20kg_{H2}/day size. **CH2P aims at realizing a 100kg_{H2}/day and 125 kW power capacity at full load**
- At the present, the **20kg_{H2}/day module** is under realization. Engineering design is frozen with steady state modelling and system optimization
- In a second step, five modules will be integrated to have 100kg_{H2}/day and 125 kW of electrical power production
- Final step will include the engineering of a **400kg_{H2}/day system**

PROJECT PROGRESS/ACTIONS – SYSTEM PRODUCTION

Achievement to-date

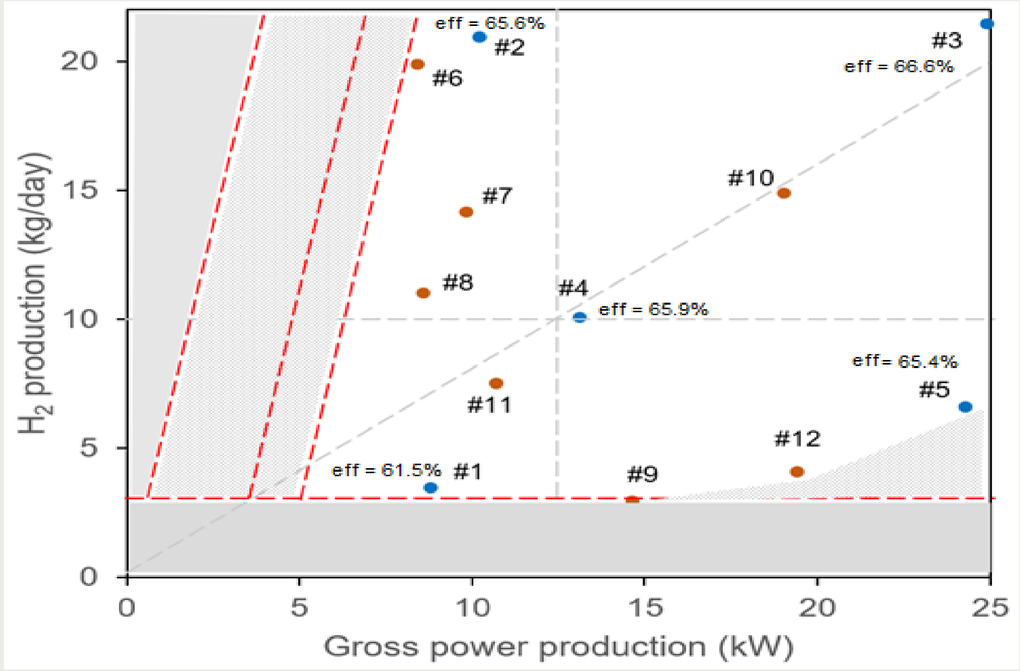
0-100% H_2 **OR** 0-100% power

System designed for 5 OPERATION MODES

25% 50% 75%

15-100% H_2 **AND** 33-100% power

- Call topic demands for a SOFC system with **power modulation** between only electricity produced and 50% electricity and 50% hydrogen produced
- CH2P system is designed to work in **5 operation modes**, adapting to the specific request at the HRS
- CH2P allows for a **wide dynamic range**: from 33% electricity and 15% hydrogen up to full load with 100% electricity and 100% hydrogen produced.



PROJECT PROGRESS/ACTIONS – SYSTEM EFFICIENCY

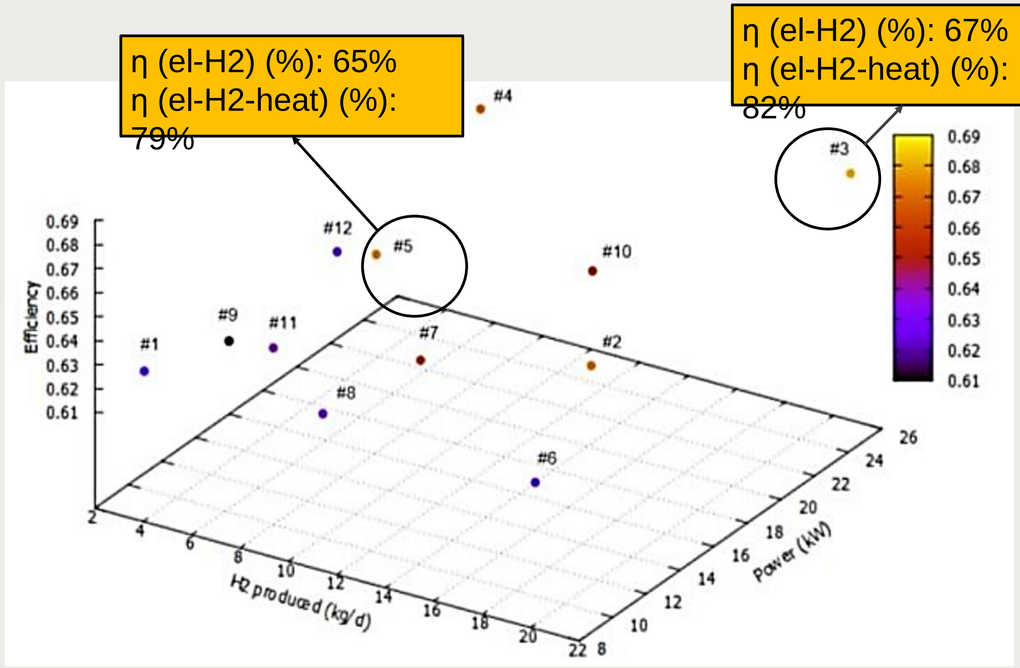
Achievement to-date

75 %, theoretically demonstrated

50 % → **75%**

25% 50% 75%

- Call topic demands for a SOFC system with **overall efficiency** of 65%
- Actual technologies have lower efficiency (SMR:50-50 %, PEM – ALK Electrolysers: 50-74 %) **limited** to only H2 generation
- CH2P demo was designed to achieve max 79% of efficiency in **full power and H2 production** (mode 3). Efficiency includes tri-generation mode (power + hydrogen + heat)
- Multi-objective optimization (MOO) was used to **maximize the average energy efficiency** by adjusting the operating plant variables and proposing a common heat exchanger network to all the operation modes



RISKS AND CHALLENGES

CH2P is a new technology in the landscape of SOFC solutions:

- 5 use cases are moving the CH2P technology to work on largely **different working modes**
- Working modes are demanding to the SOFC a very **high dynamic behavior** and special fuel and air ratios
- Most of the CH2P technology parts must integrate a **component out of standard** and customized: e.g. burner, reformer, heat exchangers

The CH2P-technology is a new solution for polygeneration using SOC technology. It extends the current application scenario. It can be relevant for sector coupling and for long term contracts and services

RISKs

RISK CATEGORY	MAIN RISKs	MITIGATION MEASURE
MANAGEMENT, PERSONNEL, EXPERTISE and COMPETENCES	**KEY TEAM LEADERS LEAVE THE CONSORTIUM**. This happened at least in three occasions by FBK, HTc and SP	The team leaders have been substituted promptly with minor effects on the project schedule and on the guidance on the specific activities
COMPONENTS, MANUFACTURING	**CH2P MANUFACTURING CAPACITY**. The Project is delivering a major effort on manufacturing with considerable use of in-kind contribution	Manufacturing of stacks prompted up in HTc, in a dedicated line. Additional hiring of personnel to guarantee the production capacity required
TESTING, VALIDATION	**BAD RESULTS FROM TESTING and VALIDATION**, affecting the overall project results	Revision of the control strategy. Preliminary validation of single components in laboratory. In the worst case, recovery action with probable project extension

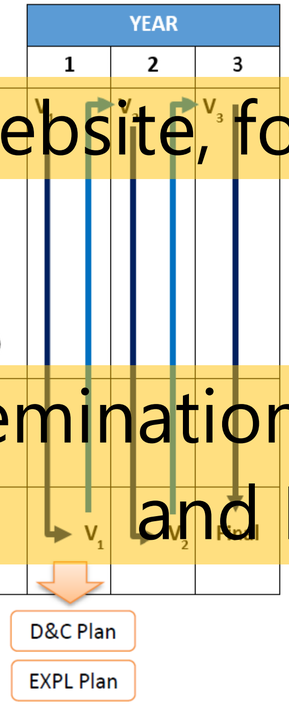
DISSEMINATION AND COMMUNICATION ACTIVITIES

Full brand with LOGO and CH2P project identity

Website, focused on the market sector of CH2P

Overall strategy for the Dissemination, Communication and Exploitation plans

Dissemination plan	• Dissemination strategy: objectives and targets • Dissemination activities and channels • Dissemination KPIs to measure effectiveness and efficiency • Management of the three dissemination activities: - packaging knowledge for an effective take up - reaching the selected early adopters - preparing the effective exploitation of the project results • Dissemination administration (approval, reporting, deliverable)
Communication plan	• Project website • General communication material & Social media • Scientific publications
Exploitation plan	• IPR strategy • Exploitation plan for the project results • Business plans for key project results



DISSEMINATION AND COMMUNICATION ACTIVITIES

- CH2P is at an early stage for the Communication and Dissemination actions, most of the concrete deliverables of the project will materialize in the second project period
- CH2P partners started to do campaign on press releases, dissemination of the results in Conferences and Fairs (planned in Hannover Messe 2019)
- A **plan for Dissemination and Communication** has been developed for the whole CH2P duration, targeting the specific objectives

COMMUNICATION OF CH2P	#
Flyer	1
Website	1
Communication Campaign (e.g. Radio, TV)	2
Participation to a Conference	4
Participation to a Workshop	1
Participation to an Event other than a Conference or a Works	1
Trade Fair	1

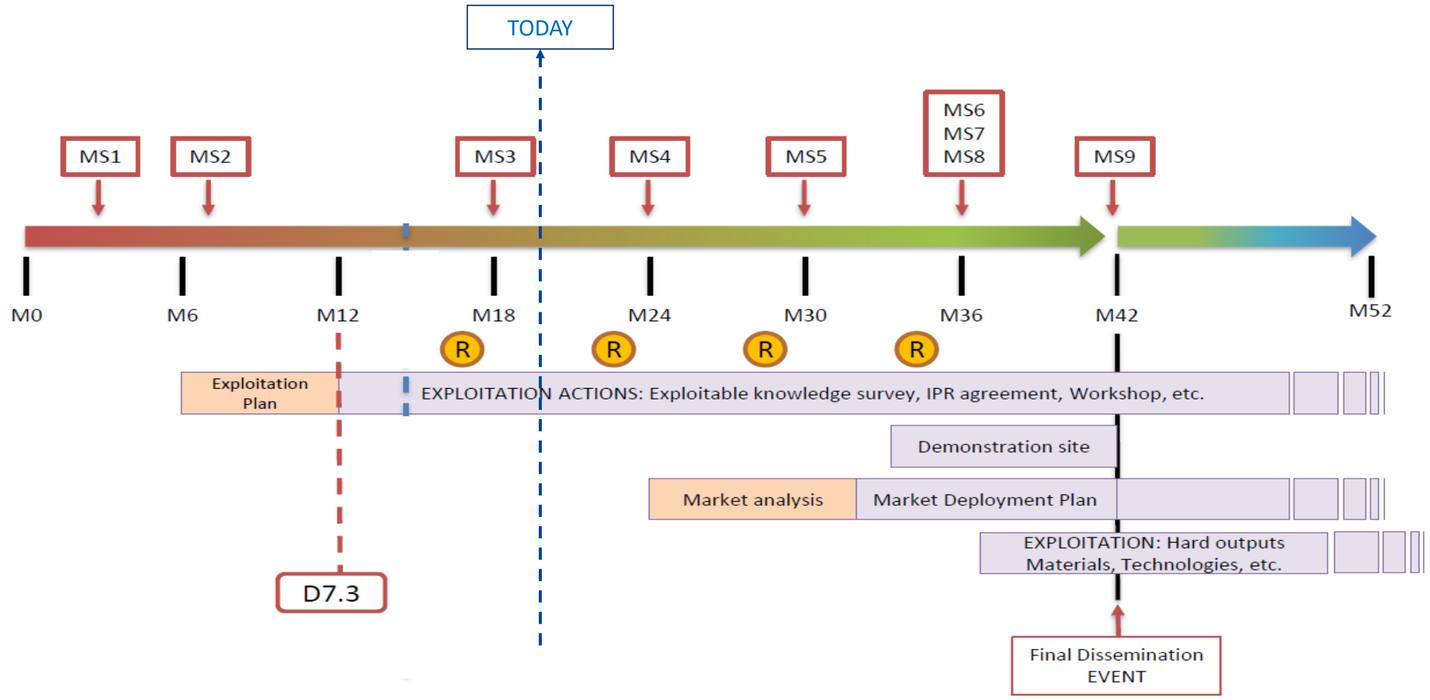
No.	Type	Title	Authors	Title of the Journal/Proc./Book
1	Publication in Conference proceedings/Workshop	Process optimization of a SOFC system for the combined production of hydrogen and electricity	M. Pérez-Fortes, A. Mian, S. Diethelm, L. Wang, F. Maréchal, J. Van herle, S. Santhanam, M.P. Heddrich, S.F. Au, E. Varkaraki, Z. Wuillemin, R. Makkus, I. Mirabelli, R. Schoon, M. Grippa, M. Testi, L. Crema	Proceedings of 13th European SOFC & SOE Forum 2018 (Chapter 06, Session A13)
2	Publication in Conference proceedings/Workshop	Thermo-mechanical reliability of SOFC stacks: impact of component tolerances and operating conditions	F. Greco, A. Nakajo, Z. Wuillemin, J. Van herle	Proceedings fo 13th European SOFC & SOE Forum 2018 (A1403)
3	Publication in Conference proceedings/Workshop	Characterization of the local morphology at triple-phase boundaries after SOFC/SOEC operation	G. Rinaldi, A. Nakajo, M. Cantoni, W.K.S. Chiu, J. Van herle	Proceedings of 13th European SOFC & SOE Forum 2018 (B0304)

EXPLOITATION PLAN

Exploitation

A full plan for CH2P exploitation has been developed with targeted actions on:

- Survey on Exploitable knowledge
- Definition of IPR agreements
- Exploitation workshop
- Market analysis
- Definition of Market Deployment Plan
- Exploitation agreements



R EXPL plan - revision

Task description	Lead Partner	Contribution by Partner	Delivery date
Exploitable Knowledge survey (Technology Know-how, experience improvements, hard outputs, etc.)	FBK	ALL PARTNERS	M12 ÷ M36
Exploitation Workshops	FBK	ALL PARTNERS	M24, M36
Demo site measurement campaign and results	SHELL	DEMO SITE INVOLVED PARTNERS	M38 ÷ M42
Market analysis	FBK /SHELL	ALL PARTNERS	M31
IPR Agreement	FBK	ALL PARTNERS	M36
Market Deployment Plan	SHELL	ALL PARTNERS	M42
Final Exploitation Agreement	FBK	ALL PARTNERS	M42

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

ch2p

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