Project no.: *SES6-CT-2003-502612*
Project acronym: *Real-SOFC*
Project title: *Realising Reliable, Durable Energy Efficient and Cost Effective SOFC Systems*

Instrument: *Integrated Project*

Thematic Priority: *6 - Sustainable Energy Systems Research - activities having an impact in the medium and longer term*

Executive Summary

Period covered: from *01.02.2004* to *31.01.2005*

Date of preparation: 15/03/2005

Start date of project: *01.02.2004*

Duration: *48 months*

Project coordinator name: *Dr. Robert Steinberger-Wilckens*
Project coordinator organization name:
Forschungszentrum Jülich GmbH

Table 1.1: List of project partners

Participant Role*	Participant Number	Participant Name	Participant Short Name	Country
CO	1	Forschungszentrum Jülich GmbH	FZJ	D
CR	3	Rolls-Royce plc	R-R plc	UK
CR	4	UGINE-ALZ (Groupe Arcelor)	U&A	F
CR	7	Commissariat à l'Energie Atomique	CEA	F
CR	8	University Court of the University of St Andrew	USTAN	UK
CR	9	Deutsches Zentrum für Luft- und Raumfahrt e.V.	DLR	D
CR	10	EBZ Entwicklungs- und Vertriebsgesellschaft Brennstoffzelle mbH	EBZ	D
CR	11	Energy Research Centre of the Netherlands	ECN	NL
CR	12	Electricité de France	EDF	F
CR	13	Swiss Federal Laboratories for Materials Testing and Research	EMPA	CH
CR	14	ENERGOPROECT AD - Science Research And Technological Institute	ENERGO	BG
CR	16	Gaz de France	GDF	F
CR	18	H.C. Starck GmbH	HCST	D
CR	19	HALDOR TOPØE A/S	HTAS	DK
CR	20	HTceramix SA	HTC	CH
CR	21	The Imperial College of Science, Technology and Medicine	Imperial	UK
CR	22	FOUNDATION FOR RESEARCH & TECHNOLOGY HELLAS-Institute of Chemical Engineering & High Temperature Processes	FORTH-ICEHT	EL
CR	25	Plansee Aktiengesellschaft	Plansee	A
CR	27	Risoe National Laboratory	Risoe	DK
CR	28	SINTEF - Stiftelsen for industriell og teknisk forskning ved Norges Tekniske Høgskole	SINTEF	NO
CR	29	Sulzer Hexis Ltd.	SH	CH
CR	32	University of Birmingham	UBHAM	UK
CR	33	University of Chemical Technology and Metallurgy	UCTM	BG
CR	37	VTT - Technical Research Centre of Finland	VTT	FIN
CR	38	Wärtsilä Corporation	Wärtsilä	FIN
CR	39	University of Genoa	UNGE	IT

*CO = Coordinator CR = Contractor

Executive summary

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Project Approach

The aim of the Integrated Project Real-SOFC is to solve the persisting generic problems of ageing with planar Solid Oxide Fuel Cells (SOFC) in a concerted action of the European fuel cell industry and research institutions. This includes gaining understanding of degradation processes, finding solutions to reduce ageing and producing improved materials that will then be included in components and tested in stacks. In this process consideration will also be given to the design of cost effective materials, low cost components and optimised manufacturing processes.
In close co-operation between industry and research institutions the following steps are to be accomplished (cf. Fig. 1):

- improved understanding of ageing in planar SOFC stacks considering all modes of operation, including long-term testing over 10.000 hrs., thermal cycling up to 100 cycles, and the influences of fuel composition; these results will flow into
- adaptation of materials and protective coatings in order to reduce ageing to well below 0,5%/1000 hrs. as for instance necessary for stationary SOFC applications; the modified materials then are used in
- manufacturing of improved components under commercial conditions and subsequent characterisation in long-term and cycling tests – re-referring to step 1.

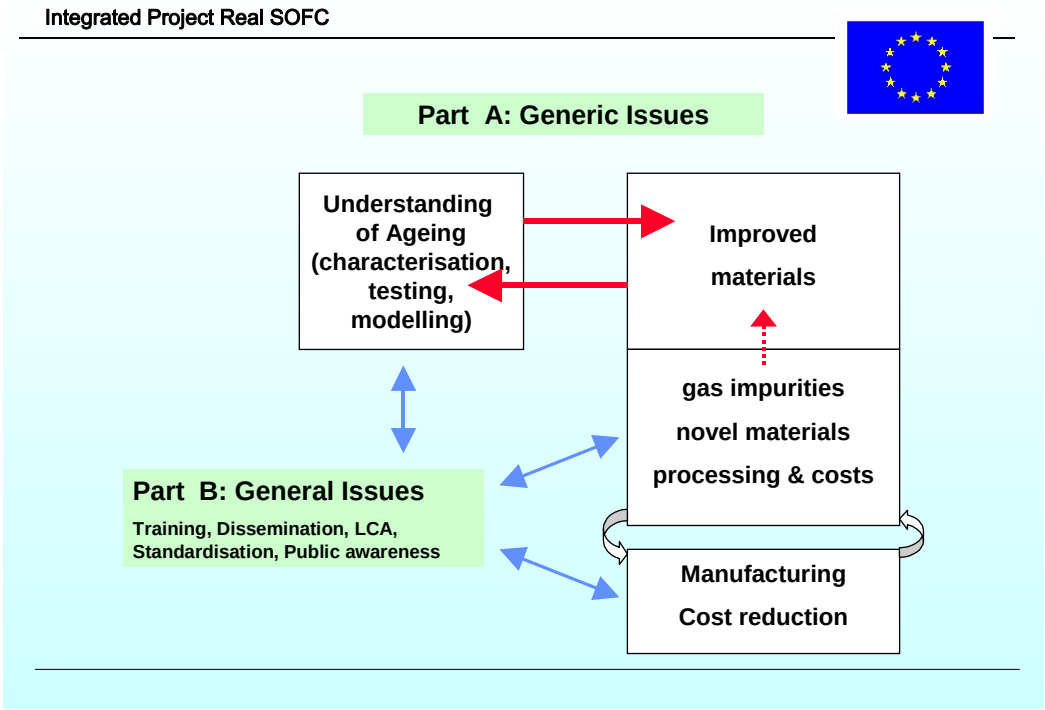


Fig. 1: Basic structure of Real-SOFC.

Following the state-of–the-art first testing campaign at the start of the project two further 'feedback loops' are planned for a second and third generation development of cells and stacks.
Besides the materials development the project addresses the topics of

- Life Cycle Analysis as an essential tool for assessing the environmental impact and recycling of the materials used,
- industrial standardisation as a means of lowering costs and improving industry competitiveness, and
- training and dissemination as a tool of human resource management and a contribution towards gender equality.

Project Objectives

The project addresses the importance of solving the problem in the choice of materials in SOFC stacks under varying operating conditions (e.g. variety of fuels). Whereas the engineering problems of designing and producing SOFC systems for small and medium scale Combined Heat and Power generation (CHP) appear generally not un-solvable (cf. SWPC and SulzerHexis developments) the materials problems at the basis of the degradation mechanisms still constitute a dramatic threat to the feasibility of SOFC technology as a whole. Not meeting the aim of securing 10.000 to 40.000 hrs. of operating time will in the medium term eliminate any chance of market access for SOFC technology in stationary applications.
As a consequence, the project aims at improving the control of durability in SOFC stacks by supplying a broad understanding of degradation processes and from this developing a range of new materials and protective measures for enhanced lifetime. The results are then used by the industrial partners to further develop their cells and stacks (outside of the project) that are then again fed into the project for testing. This 'feedback loop' procedure constitutes the core of the project (Fig. 1).
Topics covered in the project also include further essential properties of SOFC materials:

- increased power density (higher margin for lowering the operating temperature whilst maintaining power output) of SOFC cells
- resistance of anodes against fuel gas impurities and coking (working towards the aim of operation with biogeneous fuels, unprocessed natural gas and reformates)
- low cost standard materials and processing
- new and novel materials and processing routes

The project background activities in standardisation, dissemination and training include:

- agreement on common standards for testing procedures
- Quality Assurance and standardisation as tools for cost reduction in industrial-scale manufacturing
- Life Cycle Analysis of materials, components and SOFC stacks and assessment of environmental hazards; this also includes environmental and hazard legislation with respect to materials processing
- exchange and training programmes for students and scientists
- measures to raise public awareness of the potentials in SOFC technology, support policy measures within the EU and spread information on environmental potential and possible hazards
- measures to promote equal opportunities regardless of sex, origin and race with all contributors to the project

The project aims at generating materials and components of two subsequent waves of improvements, termed 'Generation 2' and '3'. Due to the complex and varied influences on materials development not all materials (ceramics, steels, sealants etc.) and functional layers (anode, electrolyte, cathode, protective etc.) will be developed synchronously in such a way that second (or third) generation cells and stacks could be clearly distinguished in the perpetually evolving development process.

Project Partners

Co-ordinator: FZJ Forschungszentrum Jülich GmbH (D)
Consortium members:

R-R plc Rolls-Royce plc (UK), U&A UGINE-ALZ (Groupe Arcelor) (F), CEA Commissariat à l'Energie Atomique (F), USTAN University Court of the University of St Andrew (UK), DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. (D), EBZ Entwicklungs- und Vertriebsgesellschaft Brennstoffzelle mbH (D), ECN Energy Research Centre of the Netherlands (NL), EdF Electricité de France (F), EMPA Swiss Federal Laboratories for Materials Testing and Research (CH), ENERGOPROECT AD - Science Research And Technological Institute (BG), GdF Gaz de France (F), HCST H.C. Starck GmbH (D), HTAS Haldor Topsøe A/S (DK), HTC HTceramix SA (CH), The Imperial College of Science, Technology and Medicine (UK), FORTH-ICEHT Foundation for Research & Technology Hellas-Institute of Chemical Engineering & High Temperature Processes (EL), Plansee Aktiengesellschaft (A), Risoe National Laboratory (DK), SINTEF - Stiftelsen for industriell og teknisk forskning ved Norges Tekniske Høgskole (NO), SH Sulzer Hexis Ltd (CH), UBHAM University of Birmingham (UK), UCTM University of Chemical Technology and Metallurgy (BG), VTT - Technical Research Centre of Finland (FIN), Wärtsilä Corporation (FIN), and UNGE University of Genoa (IT).

Project Implementation

The project started on February 1st, 2004 and will end January 31st, 2008.
The General Assembly was held in February 2004, followed by the planned work package, Project Coordination Committee and Steering Committee meetings. Initially unplanned, additional meetings were arranged in the form of a 'cluster meeting' of all work packages in Dübendorf in October and a Cell Manufacturer meeting in January 2005 in Leysin. These meetings were focussed on improving the information flow between work tasks and offered a broad platform for discussion of results and approaches.
Since IPR issues are regarded as vitally important in the context of a consortium including both industrial and research groups, special care was given to the implementation of the IPR council. This council consists of three members from three different organisations outside of the project consortium, including high-ranking professionals with academic and juridical backgrounds as well as patent and IPR experts.
A mediatrice for all questions of equal opportunities was appointed to the project.
Contacts have been established with the European FP 5 projects SOFCNET and FCTESTNET and the FP6 project NATURALHY.

First Project Results

Testing equipment has been set up with all project partners and tests have started throughout.

The first 'wave' of materials characterisation (state-of-the-art) and development (precursors for the 2nd Generation) are under way. Definitive results are expected from month 15 onwards.

First, preliminary results include:

- characterisation of two very promising steel interconnect materials, CroFer22APU and Plansee IT11
- extensive characterisation of cathode materials for IP-SOFC modules
- extensive characterisation of LSCF cathode materials, probable 2nd Generation feature
- very promising first results for coking and H_2S tolerant anodes

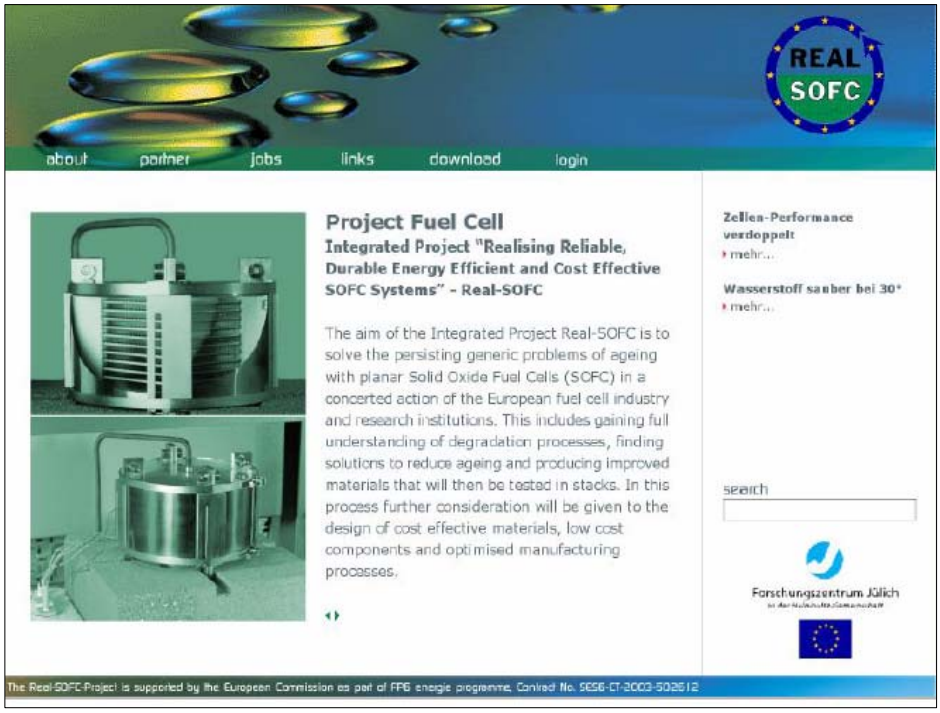
- extensive characterisation of protective layer candidate materials combinations; MnCoFe spinel forming material is candidate for featuring in 2nd Generation stacks

In the area of standardisation and LCA the following was achieved:

- common standard testing procedures for SOFC cells and stacks (to be updated throughout the project)
- draft materials inventory of SOFC stacks

Training and Dissemination Activities

An internal workshop was held on materials' problems and developments in SOFC in November in Cadarache and a Summer School for SOFC rookies in September in Patras.
The web page (cf. figure) will be accessible under the web address www.real-sofc.com and www.real-sofc.info and will be launched on 1 April 2005. General purpose information (info flyer) was developed and distributed at several international conferences and fairs.



Preliminary design of the public Real-SOFC web page

Technology Implementation Activities

The cell manufacturers in the consortium are currently assessing the new trends identified in the project for inclusion in 2nd Generation cells. These would – as they emerge as superior to the state of the art – be continuously integrated into the commercially available catalogue.
The standards set for testing cells and stacks will be introduced into other projects (namely FCTestNet) and will be discussed with international standardisation institutions, as adequate, namely ISO and ASTM.