Fuel cells and hydrogen
Joint undertaking

SOFCOM

SOFC CCHP with poly-fuel: operation and management

Massimo Santarelli

New Energy World JU
fuel cells & hydrogen for sustainability

Programme Review Day 2012
Brussels, 28 & 29 November 2012

http://www.fch-ju.eu/

SOFCOM (278798)

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FCH-JU project

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General Overview

- SOFC CCHP with poly-fuel: operation and management
- 3 yrs
- Total Budget: 6,219,613 € - FCH contribution: 2,937,753 €
- Partnership: 10 Partners
  - **Companies**: Topsoe Fuel Cells A/S (DK), Società Metropolitana Acque Torino spa (IT), Matgas 2000 A.I.E. (SP)
  - **Research Centers**: Teknologian Tutkimuskeskus VTT (FL), Consiglio Nazionale delle Ricerche (IT), Instytut Energetyki (PL)
  - **Universities**: Politecnico di Torino (IT), Ecole Polytechnique Fédérale de Lausanne (CH), Technische Universitaet Muenchen (DE), Università di Torino (IT)

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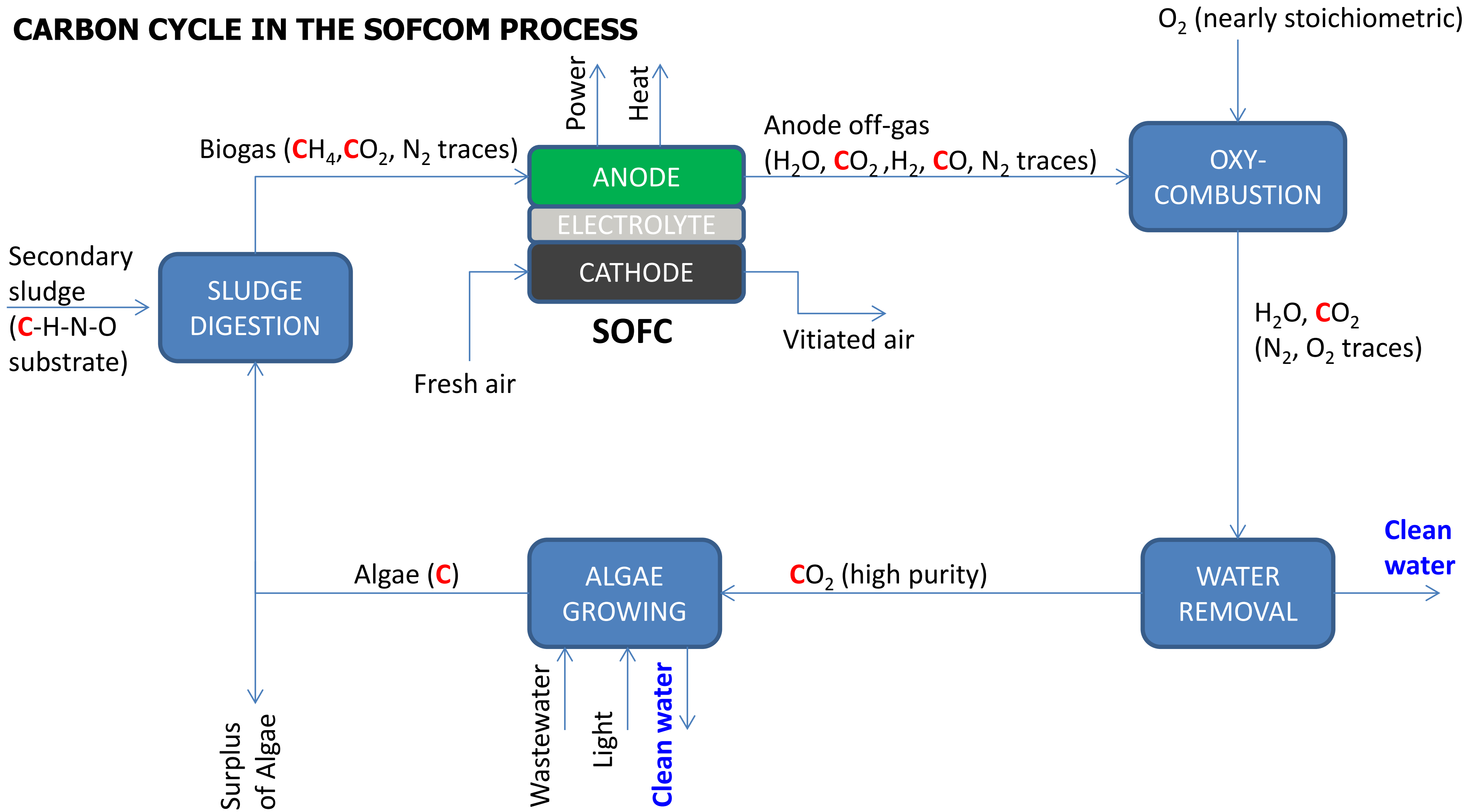
Goal DEMO example: plant in Torino (IT)

CARBON CYCLE IN THE SOFCOM PROCESS



Goals LAB:

LAB tests developed on every section of the whole system at laboratory-scale: fuel section; fuel cleaning section; fuel processing section; SOFC CCHP section, for the production of electrical and thermal (cooling and heating) power; carbon capturing module (in Demonstration 1).

This level of analysis is preparatory to the Demonstration Axis.

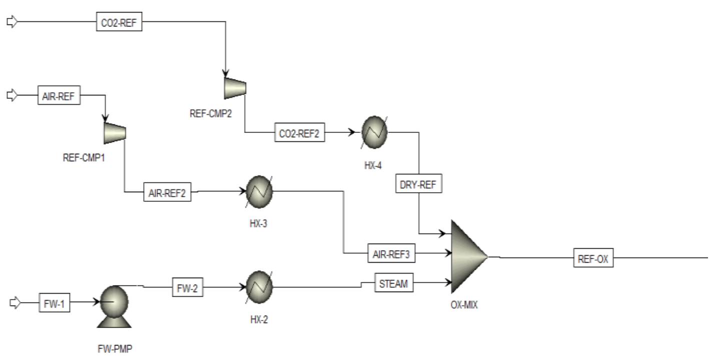
GOALS of Lab-scale Experimental Analysis Axis	Month
Lab-scale results on influence of pollutants on SOFC anodes and fuel processing reactions, and gas cleaning (both WWTU biogas and gasification gas): Guidelines for implementation of proofs-of-concepts.	M12
Lab-scale results on influence of pollutants on SOFC anodes and fuel processing reactions, and gas cleaning (both WWTU biogas and gasification gas): Scientific advances in poisoning mechanisms	M18
Lab-scale: carbon sequestration technologies: Guidelines for implementation of proofs-of-concept 1	M21

Project achievements

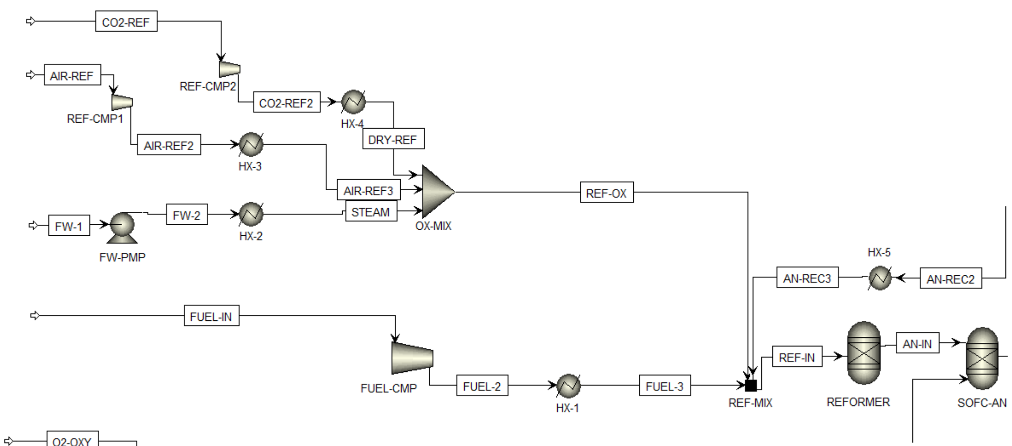
Goal System Analysis:
DEMO Design; Scenario Analysis

SCHEMATIC MODELS (ASPEN+) FOR SOFC-BASED PLANTS

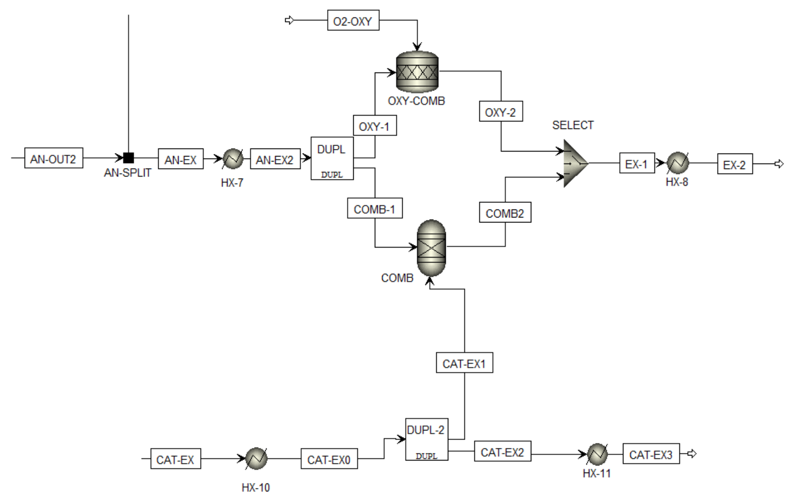
Biogas processing unit



SOFC anode section



SOFC exhaust gases combustion



Project achievements

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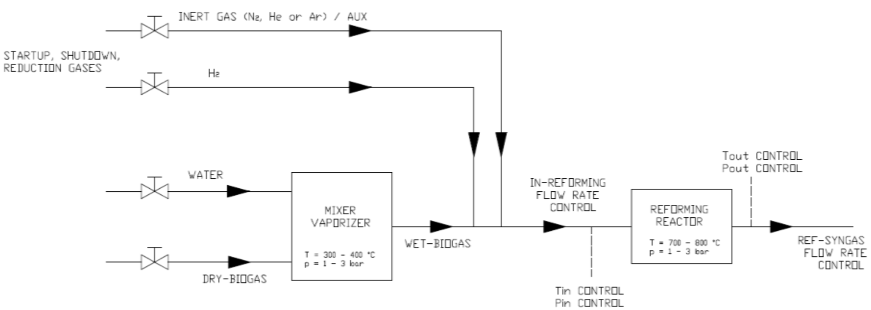
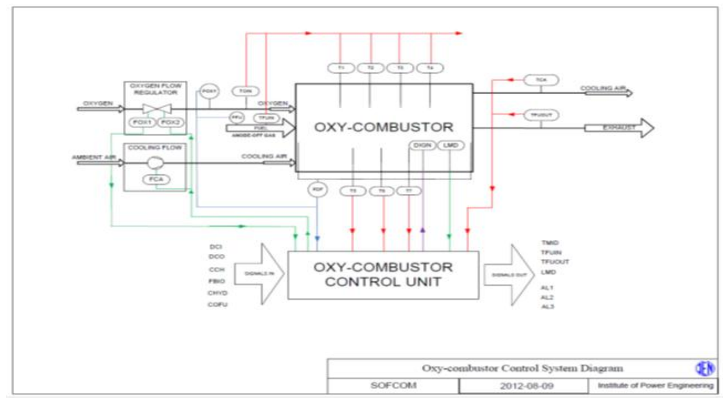
Advanc. DEMO example: plant in Torino (IT)

Biogas procressing unit



Anode exhaust oxy-combustor unit



CO2/H2O separation unit

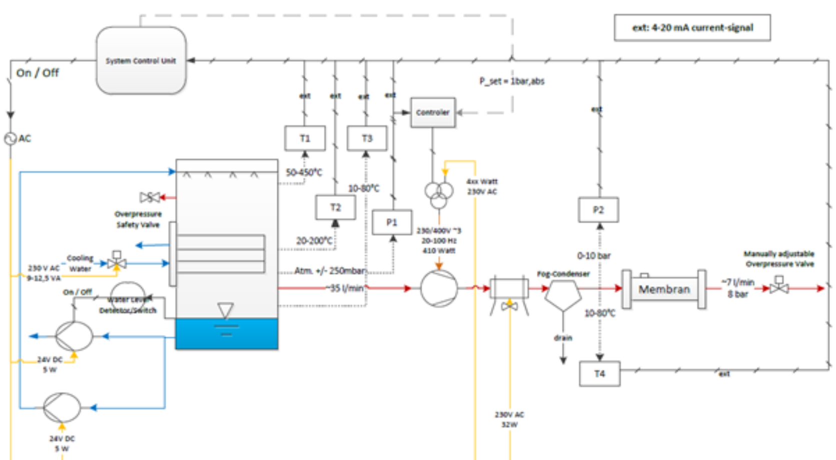
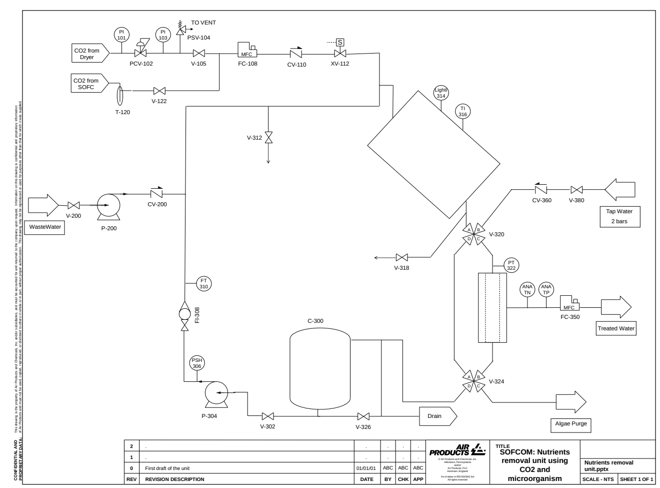


Photo-bio-reactor unit



Project achievements

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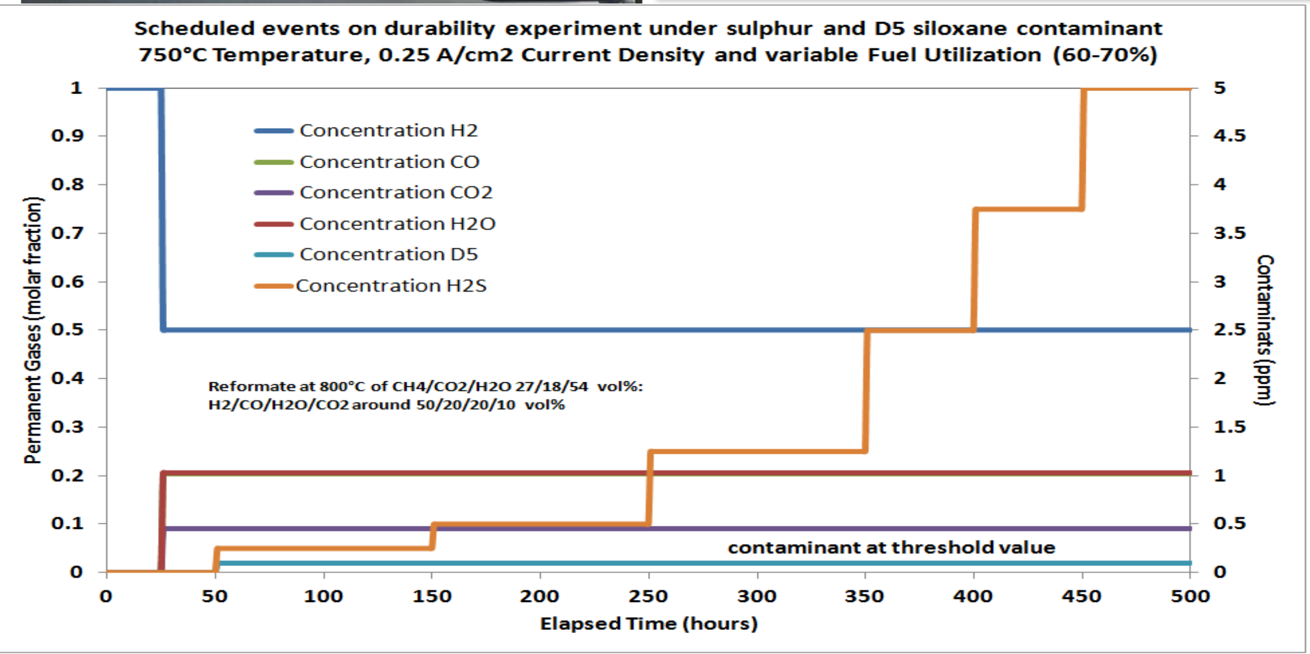
Advanc. LAB example: biogas contaminant tests

Contaminant	Model Compound	Low Value	High Value
Hydrocarbons	C_2H_4	0	100 ppm
Halocarbons	C_2Cl_4	0	1 ppm
Siloxanes	D5	0	1 ppm



Other contaminants:

- HCl
- L4
- acetylene

Criteria and performance/research Indicators (to be achieved):

Claim 1.
Fuel issues considering detailed poisoning mechanisms, advancing in cleaning and processing technologies (just started)

Claim 2.
Define and operate *new proof-of-concept fuel cell systems* fully integrated with *biomass processing units* and *carbon sequestration and handling* technologies (good advancement)

Claim 3.
Maintenance, *safety*, *repair* and *de-commissioning* of fuel cell systems on a *demonstration scale* (not yet started)

Alignment to MAIP/AIP

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Correlation of the project with the corresponding Application Area

Overall Objective	How SOFCOM addresses the Overall Objective
The programme aims to achieve the principal technical and economic requirements that will be needed if fuel cells are to compete with existing energy conversion technologies. These include high electrical efficiencies of 45%+ for power systems and of 80%+ for CHP systems, with lower emissions and use of non-fossil fuels. Focused efforts will be required to address lifetime requirements of 40,000 hours for fuel cell systems, and to meet commercial cost targets, which will vary according to the type of application.	SOFCOM foresees the final demonstration of complete biofuel-fed SOFC systems in CCHP configuration, which will achieve electrical efficiencies 50%+, overall efficiencies of 80%+, and eventually a complete use of the H and C atoms in the primary fuel, as the excess fuel will be stored in form of algae: therefore, a potential exergy efficiency of 90%+.
Demonstration activities target proof-of-concept, technology validation or field demonstrations, depending upon technological maturity. Proof-of-concept activities will take place within in-house test facilities at a representative scale, validation activities either in-house or in the field in a representative environment, whilst field demonstrations will be required to be undertaken in a real operating environment with end-users.	SOFCOM foresees two final demonstration of complete biofuel-fed SOFC systems: DEMO 1 Torino (IT): field demonstration of WWTU biogas-fed SOFC with CO2 recovery and reuse; real operating environment. DEMO 2 Helsinki (FI): technology validation within in-house test facility of bio-syngas-fed SOFC; in-house validation.
Field demonstration activities are split into small (residential and commercial applications) and large (distributed generation or other industrial or commercial applications) scale. Any validation proposal must show that proof-of-concept has been successfully undertaken, and any field demonstration proposal should show that both proof-of-concept and validation activities have been successfully completed.	The DEMO 1 in Torino is a small demonstration activity but performed in a real industrial application scale. The DEMO 2 in Helsinki is a small demonstration activity but with emphasis on future scale-up (biomass gasification fuel).

Alignment to MAIP/AIP

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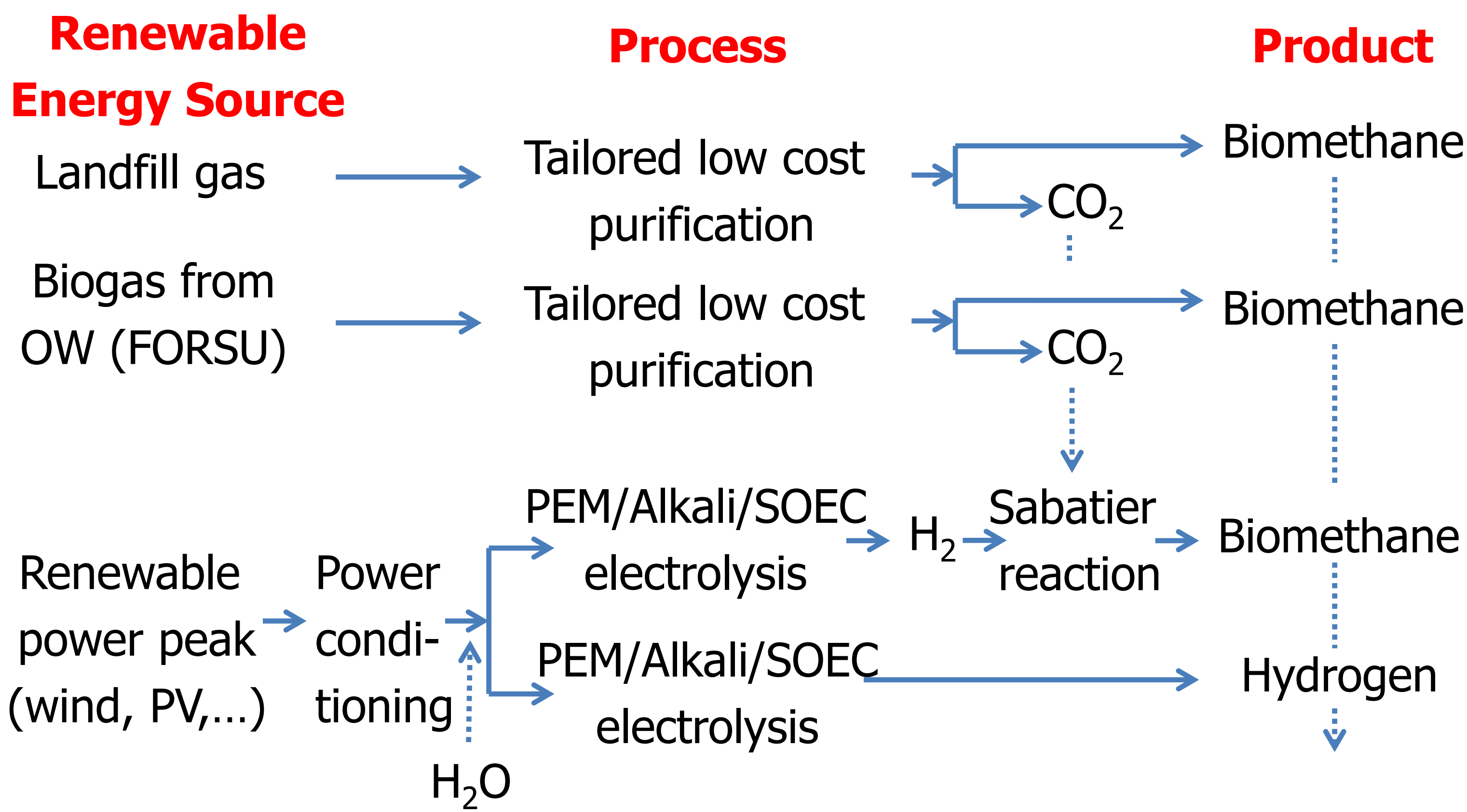
Project activities & results/achievements versus MAIP/AIP document targets

MAIP target	How SOFCOM addresses the MAIL target
Development of proof of concept prototypes that combine fuel cell units into complete systems	The present project foresees the development of two proof-of-concept demonstration plants, which integrates SOFCs into complete systems: WWTU-SOFC in CCHP (Torino); bio-syngas-SOFC (Helsinki)
Maintenance and repair issues to reduce downtimes from known failure mechanisms	The repair and maintenance activities are the core of the Work Packages dedicated to Demonstration 1 and Demonstration 2; also, the formulation of repair strategies, the monitoring analysis on the long run, and the development of pre-normative results leading to recommended practices for those plants will be part of the final results of the project.
Identification of technical and economic requirements in order to be competitive in the marketplace	This part is analysed in the last period, following the real experience performed in the Demonstration Activity, with a scale-up analysis of the integrated SOFC systems studied.
Validation activities, performed in a real system environment or with real equipment in a simulated system environment	The proof-of-concept validation of the tested systems on the demonstration sites will be one of the main results of the project; this will be followed by a close examination of the lessons learned, which will eventually enable us to identify the reliability of the SOFC integrated systems, weaknesses, and eventually to establish the market maturity.
Fulfilment of the diverse application needs	The demonstration completely fulfils all the application needs listed in the Topic: combine fuel cell units into complete systems, integration and testing with fuel delivery and processing subsystems; interface with devices featuring delivery of customer requirements (power, heat, cooling and CO2 capture).
Validation of the whole system built, supply chain, costs targets, including life-cycle considerations and integration into power plants and networks	This validation will be achieved through the scale-up analysis of the integrated SOFC systems, following the real experience performed in the Demonstration Activity; life-cycle and economic assessments will be also performed within the WPs dedicated to the concept design of the energy systems and their techno-economic analysis
Establishment of quality control procedures and techniques to ensure quality of systems	Fully-automated test procedures and advanced control systems will be employed on tested units to produce a reliable and reproducible monitoring of the performance, and safe control of the overall systems and its components.
Addressing relevant manufacturing solutions linked to the validation of fuel cell systems	The most relevant manufacturing solutions are defined in the concept design of the systems (WP4 and WP5), will be applied in the demonstrations (WP6 and WP7) and will be analysed and validated in the final analysis of the lessons learned (WP8).

Alignment to MAIP/AIP

Priorities and topics possibly under/over-estimated in the AIPs

POWER-TO-GAS PROCESSES (strictly related to FCH JU topics)



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Cross-Cutting Issues

Cross-Cutting Issues	How SOFCOM addresses the Cross-Cutting Issues
Training and Education	*Erasmus Mundus II PhD (SELECT+) and MSc (SELECT) in Environomical Pathways for Sustainable Energy Systems* SELECT (www.exploreselect.eu) considers the conversion chain, from primary energy source to final energy service delivered to mankind. The Program is a joint consortium formed by KTH (Royal Institute of Technology, SW), POLITO (Politecnico di Torino, IT), Aalto University (Eespo, FL), TU/e (Eindhoven University of Technology, NL), UPC (Barcelona Tech, SP), IST (Lisbon, PT) and AGH (Warsaw, PL). Many Companies are partners for different activities (Internships, Final Thesis, etc.). The specialization on Fuel Cells is offered by POLITO, with the coordination of Prof. Santarelli. Thus, the SOFCOM project will be strictly related to the activities of the PhD and MSc.
Safety, Regulations, Codes and Standards	One of the principal outcome of SOFCOM is to impact the standardisation activities in the areas related to the operation, management and maintenance of SOFC CCHP systems fed by biogenous fuels. The collaboration with RC&S Institutes is done at the level of the international RC&S institutes: Prof. Santarelli is member of the ISO/TC 197 "Hydrogen Technologies", IEC/TC 105 Fuel Cells, of the RC&SWG of IPHE.
Dissemination & public awareness	The Dissemination is performed by a web site (www.sofcom.eu, active since M1),a Newsletter (First Issue August 2012), several participation to conferences
Information on publications	Journal Papers: 12 Participation to Conferences (10, of which 3 invited speaker) Patents: 3 patents deposited

Technology Transfer / Collaborations

Project	SOFCOM interaction
ENEFIELD "European-wide field trials for residential fuel cell micro-CHP" (FCH JU 2011)	Data on SOFC performances and reliability, installation requirements Collaboration in the RC&S topics
BIOALMA "Biofuels from Algae" (National 2011)	Algae and photo-bio-reactors (DEMO 1 Torino)
PRIN 2009 "Experimental and energy-strategy analysis of the use of syngas from coal and biomass to feed SOFC systems integrated with CO2 separation processes" (National 2011)	Syngas-fed SOFC: cleaning, procesing, degradation issues Technologies and processes for CO2 separation from anode exhausts
OZ-BOX "Design of Balance of Plant of a integrated SOFC stack" (National 2011)	All issues connected to exigencies of real installation of a SOFC system in a indutrial environment.
RES-COGEN "Economic analysis of FC-based CHP systems" (National 2011)	Data concerning the design and the operation costs of a real SOFC CHP installation

Project Future Perspectives

Strict integration and enhancement of future power-to-gas (P2G) processes at EU level