European Hydrogen & Fuel Cell Technology Platform

"IMPLEMENTATION PLAN – Status 2006"

IMPLEMENTATION PANEL

March 2007

A message from the Implementation Panel Chairs

On January 10, 2007, the European Commission put forward key elements for a new Energy Policy, a common European response to the need for sustainable, secure and competitive energy. New technologies are a key ingredient of this Policy. It includes a Strategic Energy Technology Plan and calls for an increase of 50% in energy research spending to accelerate the shift towards a low-carbon, high efficiency energy system.

Hydrogen and Fuel Cell technologies can play a significant role in Europe's new energy system. They can allow renewable energy to be applied to transport, facilitate distributed power generation, and help us cope with the intermittent character of renewables such as wind power. But if they are to make a significant market penetration in transport and power generation, there will need to be research, development and deployment strategies in which all the stakeholders are committed to common objectives. This was the ambition of the European Union when it created the Hydrogen and Fuel Cell Technology Platform.

The first aim for this Platform was to define the technological and market developments needed by 2020 to create a hydrogen-oriented energy system by 2050. These strategies led us to define a concrete Implementation Plan for a European Hydrogen and Fuel Cell Programme from 2007 to 2015. This document sets out that plan.

The Implementation Panel believes that this Programme represents a practical approach to meeting the needs for developing and deploying Hydrogen and Fuel Cell technologies in Europe. It focuses on four main innovation and development actions:

- Hydrogen vehicles and refuelling stations, for sustainable mobility
- Fuel Cells for heat and power generation, for efficient, distributed and diversified energy production
- Sustainable hydrogen supply, to prepare for the transition to clean energy carriers
- Fuel Cells for early markets, to foster commercial use of both hydrogen and fuel cells

This Programme will deliver secure and sustainable energy and create a new, high value industry in Europe.

The required investment is high, at €7.4 billion between 2007 and 2015. But it is also consistent with current spending commitments from the public and private sectors. The unique feature of this Programme is that it represents the first broadly agreed, pan-European effort to develop a strong position in hydrogen and fuel cell technologies.

This far-reaching Programme needs the right structure at the European level. The Joint Technology Initiative, an industry-led public-private partnership, appears to be the best candidate among the options.

More than 100 European stakeholders from across Europe and from all parts of society were involved in developing this Programme, as was the European Commission itself. Our work also benefited from extensive public consultation. We want to thank all stakeholders for their efforts so far. Now it is up to you to keep up the momentum and to make sure that this Programme succceeds.

François JACKOW
Air Liquide

John LOUGHHEAD
UK Energy Research Centre

Executive Summary

The European Union and the world need affordable, secure and sustainable flows of increasing amounts of energy. They are a key element for the achievement of the Lisbon goals for European competitivness and prosperity. The link between energy security, sustainability and competitiveness highlights the challenges that the EU faces and points out to the need for an integrated energy policy. Boosting the development and deployment of cleaner and more efficient energy technologies is a vital part of this policy. Hydrogen and fuel cell (FC) technologies have the potential to contribute significantly to it.

Within the European Hydrogen and Fuel Cell Technology Platform (HFP) an Implementation Panel (IP) was established in 2006 to take the HFP strategy for RTD and demonstration of hydrogen and fuel cells technologies, elaborated in its Strategic Research Agenda and Deployment Strategy, to the implementation stage.

More than 100 European stakeholders were involved in the working groups of the Implementation Panel. They came from research institutes, industry, associations, governmental agencies, NGOs and the European Commission. Through their contributions and extensive public consultation, a European programme in this area has been defined.

This programme is designed to facilitate and accelerate the development and deployment of cost-competitive, world class European hydrogen and fuel cell technologies. They would find use in transport, stationary and portable power in the next ten years. It is tailored to build upon Europe's strengths.

Drawing on current and previous initiatives and successes at EU, national, regional and local levels, it presents a comprehensive and coherent work programme to mobilise research and industry in integrated and joint activities.

The programme comprises four Innovation and Development Actions (IDAs). They spell out the priorities for Europe and point to the technology which must be developed and acquired to foster hydrogen and fuel cell use in transport, stationary and portable applications by 2010-2015, and to achieve the *"Snapshot 2020"* targets of the HFP.

For each IDA, a comprehensive set of actions that covers both technology development and market-enabling activities is proposed. These actions are necessary as a whole to fulfil the objectives for the proposed Programme in response to the EU's policy drivers. They are further analysed by priority to ensure meeting the development goals assigned to the IDAs, and by the contribution needed from research and industry. High priority levels are assigned to critical elements for the realisation of *"Snapshot 2020"* and the onward *"2050 vision"*, especially those that help build up sustainable hydrogen infrastructure and competitive fuel cell supply chains across the EU and strengthen the European industry. It is therefore recommended that an integrated approach to these activities be adopted and that a critical mass be reached at the EU level.

The four Innovation and Development Actions (IDA) of the Programme

Hydrogen Vehicles and Refuelling stations

IDA 1 addresses transport applications, emphasising road transport but also other transport applications, to meet EU goals on competitiveness and sustainable mobility. The top priority is the development of competitive hydrogen-fuel cell vehicles with an emphasis on component performance and reliability, aligned with the establishment of a hydrogen refuelling infrastructure and the supporting elements for market deployment and industry capacity build-up.

Sustainable Hydrogen Production and Supply

IDA 2 is key to enabling the programme's contribution to the EU's environmental and security of energy supply goals. A high priority is low-temperature electrolysis, a modular technology that allows for the integration of renewable energy sources. With rising demand for hydrogen, biomass-to-hydrogen (BTH) and fossil-based technologies with carbon capture and storage (CCS) will take up a growing share of the hydrogen supply chain. They are allocated a medium or lower priority. The development of advanced hydrogen production pathways and of alternative hydrogen storage technologies are prioritised in the longer term, as key elements for implementing a sustainable supply infrastructure.

The development of decision-making support tools that can assist an integrated analysis across the whole spectrum of the hydrogen value chain is of prime importance. Large investments will be necessary to implement a fully-fledged hydrogen economy and such analyses are considered as a high priority for the early days of the programme.

Fuel Cells for CHP and Power Generation

Reaching the planned distributed power generation capacity of 1 GW from fuel cells by 2015 requires all three technologies, PEMFC, SOFC and MCFC, to be deployed. Although these three technologies are in different stages of maturity with MCFC being closer to commercialisation while SOFC is in its early stage of development, none of them have been fully qualified to be successfully deployed in competitive markets. This IDA suggests an integrated approach for the three FC technologies that includes basic, applied research and industrial capacity-oriented actions. The efforts dedicated to each technology are tailored to their respective states of maturity and their expected evolution during this programme. A strong focus is given to SOFC in line with its ability to be exploited in both residential and industrial markets and the perceived strength of the EU industrial base.

Fuel Cells for Early markets

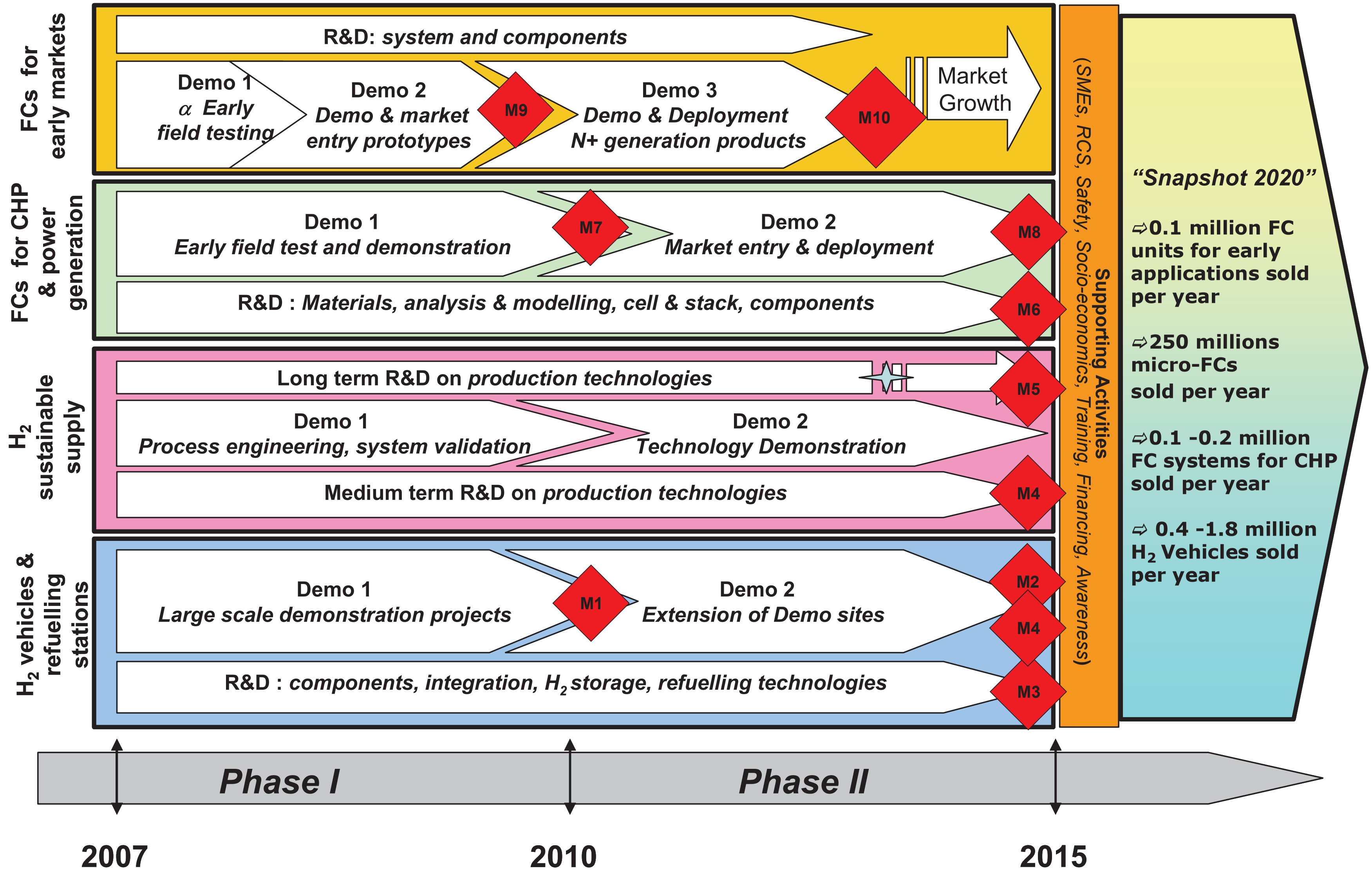
Given the key importance of early markets in preparing for the "hydrogen economy" the programme focuses on several short term demonstrations, the development of fuel cell power modules and the creation of industrial capability. The sectors addressed are portable generators, specialty vehicles, by-product hydrogen power generation and micro fuel cells.

This IDA calls for an integrated and iterative process of development and demonstration to gain operating experience which can feed back into technical development and manufacturing processes, and to demonstrate the technology to potential users.

The main components and timelines of the programme are shown in the Figure below. Specific milestones have been included which show gradual and appropriately-timed increases in performance and capacities towards tangible market penetration by 2020.

The programme's emphasis on technology deployment includes efforts to foster SME development, provide relevant education and training, stimulate early demand through the identification and structuring of buyers' pools and joint procurement schemes, and to ensure that local partnerships and regulatory measures are in place to sustain the deployment of early market products.

European Roadmap for development and deployment of H2 & FC Technologies



M1	13 demo sites for road vehicles including captive fleet, 200 vehicles, 9 refuelling stations
M2	30 demo sites, 3000 vehicles, Cost of delivered H_2 at pump <2.5 €/kg (1)
M3	Cost 100 €/kW, durability 5000h(2)
M4	10 -20 % of Hydrogen energy demand, carbon free/lean
M5	Cost of hydrogen production 2 to 5 €/kg(3)
M6	6 000 €/kW (Micro CHP FC), 1 000 to 1 500 (industrial CHP)
M7	100 MW installed
M8	1 GW installed
M9	3 000 units in the market
M10	17 000 new units in the market

Advanced hydrogen production pathways and mass supply technologies will require longer time horizons for their development. To allow for these longer term prospects, efforts beyond 2015 up to 2025 (corresponding to a third Phase) have been included. They are illustrated by the break in the arrow in the figure above.

(1) Cost of hydrogen delivery at the pump (centralized and decentralised) (excl. taxes)
(2) Road propulsion FC systems
(3) Cost of production through a longer-term sustainable H2 supply

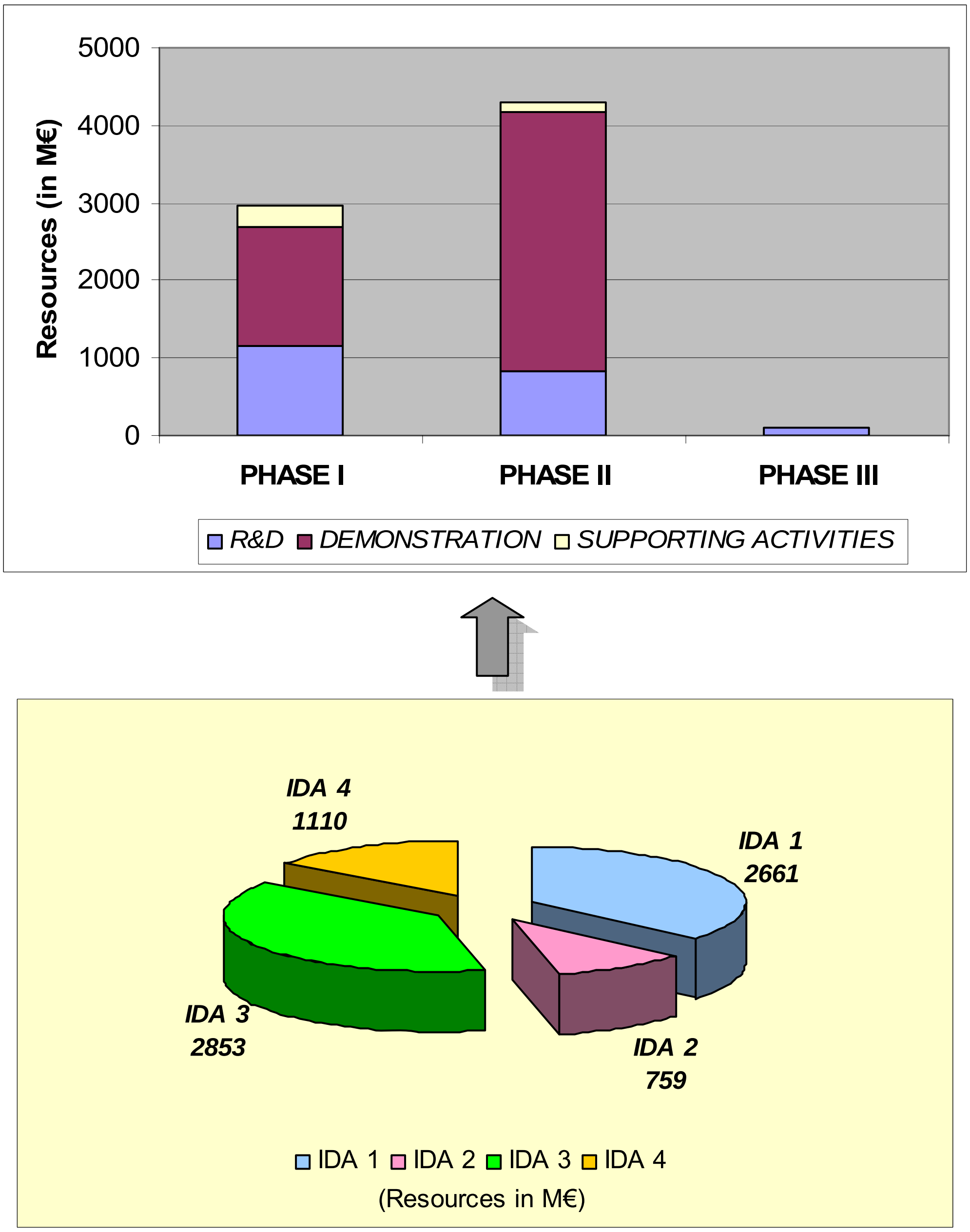
The total public and private resource requirements for the proposed programme are €7.4 billion for 2007 – 2015. This is consistent with existing public and private investments in hydrogen and fuel cell technologies and involves only an achievable increase over current or planned spending from public and from private sources. European funding has an especially important role to play but aligning the various sources of public funding is needed to achieve the Plan's goals. Without major contributions from member states and regions it will not be possible to achieve the common goals of this Implementation Plan.

However, this Plan is strongly market-driven. It envisages two-thirds of its resources being spent on demonstration activities. It also recognises the importance of research and development in achieving the widespread use of hydrogen and fuel cells by 2050. A third of the planned resources are for research and development and cross-cutting activities.

To meet the technological challenges that exist for hydrogen and fuel cells during the course of the programme, this plan suggests devoting more resources to R&D in the early stages. The focus shifts increasingly to demonstration and pre-commercial deployment later on, to prepare for and kick-start market entry. This calls for a two-phase programme, with the first phase running until 2010. Sustained, albeit relatively smaller, efforts and resources are foreseen to be allocated to long-term technology development activities for sustainable H2 supply just before the end of the 2nd Phase of the programme; this is noted as Phase III taking place beyond 2015 in the planning.

The suggested distribution of the resources of the programme is shown in the figures below. The proposed plan for resource allocation is by no means prescriptive, but does show how effort could be directed over the duration of the programme.

Planning and Distribution of the proposed Programme's Resources



Finally, this report contains proposals for the full implementation of this programme. This will call for a strong, long-term, public-private partnership on hydrogen and fuel cell technologies with several aims:

- to accelerate the transition towards a sustainable energy economy and ensure Europe takes a leading role in global technology development
- to leverage efforts in a more efficient way and with better focus, to make sure the technology will progress rapidly
- to set the frame for coherent research and deployment activities with clear commercialisation targets, and to avoid fragmentation of this large investment

The Joint Technology Initiative is expected to play a critical catalysing role. The activities carried out through the JTI will be generally market-driven and will focus on the 2015 – 2020 period market enetry targets. They will encompass applied R&D and demonstration, accompanied by market preparatory activities. It is recommended to concentrate on high and medium priority activities in the four IDAs described in the plan. The JTI should be the interface to national programmes on hydrogen and fuel cell technologies in the Member States or European Regions, and to other international programmes. The goal should be to identify possibilities for mutual beneficial global cooperation.

On behalf of the Implementation Panel, its Coordination Group:

Chairs	**J. Loughhead** **F. Jackow**	
Vice-Chairs	**D. Stolten** **K. Scheuerer**	
WG	**Lead**	**Deputy**
Transport	**K. Bonhoff**	**G. Rovera**
Stationary	**R. Rosenberg**	**J. Lewis**
H2 Production	**P. Mulard**	**J. Reijerkerk**
Portable, Early Markets	**(A. Delfrate)** **E. Middelman**	**M. Diehl**
Cross-cutting	**H. Wancura**	**B. Mayo**

For more information on the Implementation Plan contact could be made with the HFP Secretariat:

Estathios D. Peteves
E-mail: estathios.peteves@ec.europa.eu
Phone: +31 – 224 - 565245

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1 Introduction – Background

The European Union and the world need affordable, secure and sustainable flows of increasing amounts of energy. For the EU, energy is vital for the achievement of the Lisbon goals for Europe's future economic prosperity and competitiveness.

The link between energy security, sustainability and competitiveness highlights the challenges that the EU faces. It also points to the need for an integrated energy policy. This will involve a range of strategic options ranging from improving energy efficiency and reducing energy demand, shifting to low-carbon energy and implementing abatement technologies such as carbon capture and storage. Boosting the development and deployment of cleaner and more efficient energy technologies is a crucial part of this policy.

Within Europe's future energy mix, hydrogen and fuel cell (FC) technologies have the potential to become a complementary energy carrier to electricity and the main energy conversion device of a sustainable energy system, whilst supporting and benefiting from other alternatives. The Implementation Panel is clear that the greatest benefits and results will only be delivered if a range of new technology pathways is implemented in a coordinated and synergetic way over time.

In 2005 the European Hydrogen and Fuel Cell Technology Platform (HFP) defined future Research and Deployment Strategies[1] for this sector. These detail how technology leadership can be achieved through an integrated 10-year programme of research, technological development and demonstration as well as market preparation. This would position Europe to achieve the market penetration levels foreseen in *"Snapshot 2020"* and lead towards the *"2050 Vision"*[2] of a hydrogen-oriented economy by the middle of the century.

An Implementation Panel (IP) was established in 2006, under the direction of the Advisory Council (AC), and in consultation with the Member States Mirror Group (MG). Its aim was to take the strategy for research and demonstration of hydrogen and fuel cells technologies to the implementation stage. To do this, it is developing a programme of research and demonstration which is consistent with the strategic documents of the HFP, including the Action Plans of the Initiative Groups. It is designed to foster the use of hydrogen and fuel cells for transport, stationary and portable use by 2010-2015. It could form part of the 7th Research Framework Programme (FP7). It is also intended to provide recommendations for the core contents of a possible Joint Technology Initiative (JTI) in this field.

The Implementation Plan described in the following sections summarises the findings of the IP Working Groups (IP-WG) and the ensuing discussions in the Coordination Group and the Plenary of the IP[3]. It also addresses the comments of the two public

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[1] HFP Strategic Research Agenda; July 2005; HFP Deployment Strategy; August 2005, & HFP Deployment Strategy Report 2005, October 2005, available at https://www.hfpeurope.org/hfp/keydocs

[2] EUR 20719 EN – Hydrogen Energy and Fuel Cells – A vision of our future, available at https://www.hfpeurope.org/hfp/keydocs

[3] The IP Working Group reports are available at https://www.hfpeurope.org/hfp/keydocs

consulations on its interim and draft reports[4], the views and recommendations of the Advisory Council and the Mirror Group of the Member States on its 'work in progress,' supplemented by its own internal quality assurance process.

1.1 The need for a Hydrogen and Fuel Cell Research, Technology Development and Demonstration Programme

The strategic importance of hydrogen and fuel cells in the EU's search for a long-term, sustainable and secure energy supply is confirmed in FP7. It is seen as a key technological priority requiring a European approach and a long-term public-private partnership in the form of a JTI. European Framework Programmes have already contributed to the development of these technologies since the 1980s. EU support for research and demonstration in this area has totalled more than €500 million, with €300 million in FP6 alone between 2002 and 2006.

It is apparent that the next stage should be a European-level programme backed by the commitment of all stakeholders, including the Member States. The risks involved mean that market forces alone are not sufficient to ensure success in this field. But at the same time, public intervention may not be able to meet the required volume of effort and coordination to overcome the technical and other challenges. The volume of coordinated effort needed for *"Snapshot 2020"* cannot be achieved by a short-term initiative which is fragmented by technology or end use. A long-term programme is needed which aligns resources along the complete value chain from research to the final user. This approach will allow Europe to match the global competition and ensure that its sustainability goals are met. Such a programme will facilitate Member State coordination while strengthening the EU's interests in the international arena of hydrogen and fuel cells. It will point to opportunities for mutually beneficial global cooperation and make the EU the partner of choice for developing and deploying these technologies.

[4] The results of the two public consultations on the IP drafts are available at: https://www.hfpeurope.org/hfp/ip_consultation

2 The basis for a European Programme

2.1 *Programme Underpinning – "Snapshot 2020"*

The *"Snapshot 2020"* as depicted in the Deployment Strategy, Figure 1, has been accepted by the IP as a reference market scenario for the Implementation Plan.

Figure 1: ***"Snapshot 2020"*: Key assumptions on Hydrogen & Fuel Cell Applications for a 2020 Scenario**

	Portable FCs for handheld electronic devices	**Portable Generators & Early Markets**	**Stationary FCs** Combined Heat and Power (CHP)	**Road Transport**
EU H_2/ FC units sold per year projection 2020	~ 250 million	~ 100,000 per year (~ 1 GW_e)	100,000 to 200,000 per year (2-4 GW_e)	0.4 million to 1.8 million
EU cumulative sales projections until 2020	n.a.	~ 600,000 (~ 6 GW_e)	400,000 to 800,000 (8-16 GW_e)	1-5 million
EU Expected 2020 Market Status	**Established**	**Established**	**Growth**	**Mass market roll-out**
Average power FC system	15 W	10 kW	<100 kW (Micro HP) >100 kW (industrial CHP)	80 kW
FC system cost target	1-2 €/ W	500 €/kW	2000 €/kW (Micro) 1.000-1.500 €/kW (industrial CHP)	< 100 €/kW (for 150.000 units per year)

From this scenario, it is possible, with a number of assumptions, to roughly evaluate hydrogen demand in Europe by 2020. A preliminary estimate[5] for a high and a low scenario has been undertaken by the IP for the Road Transport, Portable Generators and Portable micro-Fuel Cells and is shown in Table 2-1 below. The high scenario allows for higher market penetration in the transport sector by hydrogen and fuel cell technologies, for higher power for each micro fuel cell unit, and for longer operational times in applications using portable generators. It is anticipated that stationary fuel cells installed by 2020 will mostly rely on other sources of energy than hydrogen.

[5] An in-depth analysis is required to give more elaborate demand profiles such as these developed in the EU project HYWAYS (www.hyways.de)

Table 2-1: Projected hydrogen demand as per Snapshot 2020 to meet the "*Snapshot 2020*" targets

Application	**Hydrogen demand** (ton)[6]	
	Low Scenario	***High Scenario***
Road transport	58,500	750,000
Portable Generators	720,000	1,150,000
Portable micro-Fuel Cells	82,000	620,000
Total	**860,500**	**2,520,000**

The challenging performance and cost targets detailed in the HFP Strategic documents, notably the Strategic Research Agenda, can be addressed and met by 2015, enabling the EU to realise *"Snapshot 2020"*, provided that strong public and private partnerships are established and adequate investments are made to support a highly focused, long-term RTD, demonstration and deployment programme.

2.2 Programme Outline

In order to mobilise research and industry communities towards implementable joint objectives, the programme is structured according to four main Innovation and Development Actions (IDAs). They target hydrogen vehicles and refuelling stations for transport applications, fuel cells for combined heat and power and power generation, sustainable hydrogen production and supply, and fuel cells for early markets, especially portable applications. These development pathways for hydrogen and fuel cell technologies are intended to achieve the *"Snapshot 2020"* reference scenario and pave the way for the realisation of the High Level Group (HLG) vision for Europe in 2050, as depicted in Figure 2. Important interfaces are expected between these programme clusters. They are considered synergistically in this programme, drawing mutual benefits from each other's results.

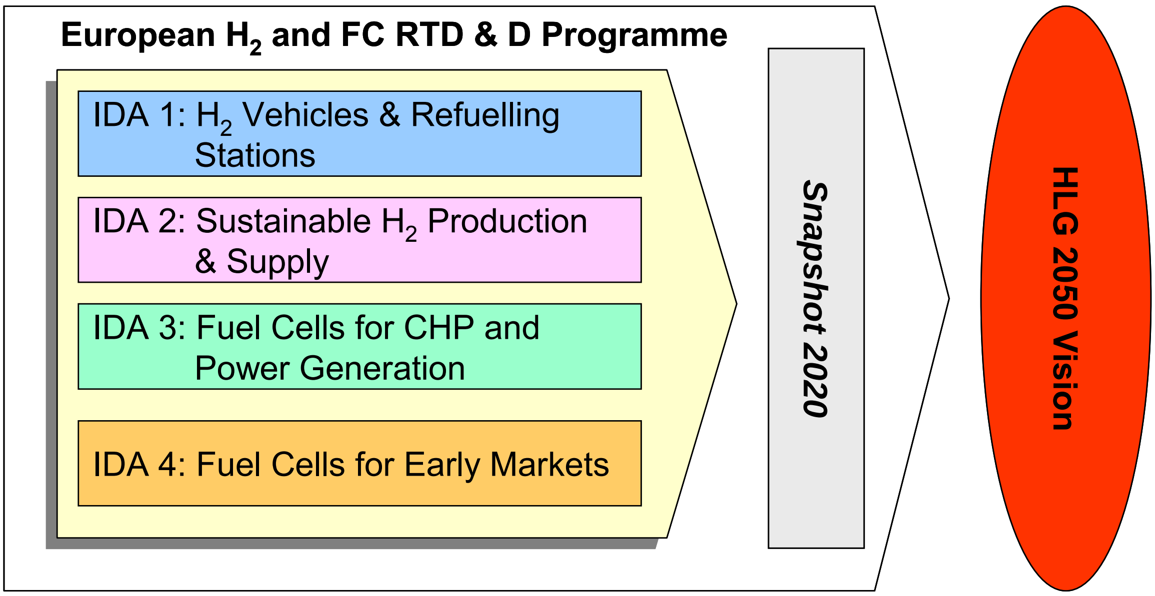


Figure 2. The European Hydrogen and Fuel Cell RTD & D programme

[6] 1 kg of hydrogen = 120 MJ = 33.33 kWh = 2.75 kg of gasoline

The following chapters present a comprehensive set of actions for each IDA. They cover technology developments and market enabling activities. The technology-related activities may be supported by long-term research, technology validation, small or large-scale demonstration, and deployment. These are all essential to fulfil the objectives set for the proposed Programme. The actions are further analysed in terms of their priority and of the contributions needed from the research and industrial communities if the development goals assigned to the IDAs are to be met.

The required level of contributions is based on the stage of development of the targeted technologies, market enablers and the amount of action required such as R&D and technology demonstration. This is linked to the stakeholder's know-how, capabilities and potential interest in carrying out these activities. Note that this analysis only provides an indication that the Panel considers consistent with the contents of the JTI on hydrogen and fuel cells. It is clear that implementating the proposed plan will involve all stakeholders, from large companies, SMEs and the research community.

High priority levels are granted to actions that are critical for the realisation of the *“Snapshot 2020”* and the onward *“2050 vision”* and are important to building up a sustainable hydrogen infrastructure and a competitive fuel cell supply chain across the EU, and for strengthening the EU's industry capacities. An integrated approach is needed to ensure a critical mass of activity at the EU level.

Medium priority levels are allocated to actions that are needed to achieve and consolidate the transition and build-up of Europe’s hydrogen and fuel cell infrastructure and industry. This requires coordination of current and future activities taking place across Europe.

Low priority levels are assigned to actions focused on components of the hydrogen and fuel cell value chain that already have a comparatively well established infrastructure, or are of limited scope for the long-term development of a sustainable hydrogen economy. These are activities which should continue but do not require additional effort.

These priority levels have been designed to provide some preliminary recommendations on the implementation of the programme in chapter 4 at European, national and regional levels.

A short summary of the content of each IDA, including resource distributions, preliminary timelines, and key technical and non-technical targets is also provided in Annex I at the action level.

3 Programme description

3.1 IDA 1 : Hydrogen Vehicles and Refuelling Stations

Goal: Improve and validate hydrogen vehicle and refuelling technologies to the level required for commercialisation decisions by 2015 and a mass market-rollout by 2020

3.1.1 IDA 1 Contents

Energy efficient, very low polluting and greenhouse gas-neutral transport is one of the key objectives of European transport and energy policies. This IDA concentrates on preparing for the commercialisation of hydrogen powered vehicles[7] in all transport modes (air, maritime, rail and road) with the goal of exceeding an annual production of 400 000 hydrogen vehicles, with Fuel Cell and Internal Combustion Engine (ICE) drive trains, by 2020.

An integrated approach across the whole hydrogen value chain, encompassing hydrogen delivery, refuelling and transport vehicle technologies and market enabling activities, is a prerequisite to meeting this mass-market objective.

Hydrogen refuelling and transport technologies are the basis for this IDA. Technological actions within it aim at developing and improving hydrogen-fuelled vehicles and refuelling technologies. The objective is to kick-start the mass production of hydrogen vehicles by 2015 and permit their ensuing market deployment. This includes validating their performance, including safety and cost issues, under real and competitive market conditions.

For this to happen on the hydrogen supply side, the objective is to develop and install distribution chains for hydrogen vehicles. This involves planning and developing the main components of hydrogen refuelling stations. It is essential to provide enough hydrogen fuel and storage capacity, and for it to meet requirements for quality, cost, ease of handling, and safety for refuelling road vehicles.

Actions on hydrogen vehicles target developing and integrating the critical components of ICE and fuel cell-based propulsion technologies. The aim is to meet customer requirements by 2015. Efficient fuel cell-based auxiliary power units are also considered for a broad range of applications. APUs for uses such as power or emergency units for airplanes, power supply for ships of different sizes or for primary heavy road transport are also taken into account. Hydrogen-fuelled ICE vehicles is seen as instrumental for accelerating the build-up of the hydrogen infrastructure.

The development of critical components will target a lead application, whose market requirements are the most technically and economically challenging and for which there is a European industry with the critical size to support and eventually benefit from the

[7] The term “vehicle” applies loosely here to all modes of transport

marketing of these components. These lead applications will spin off benefits to other applications by reducing the effort of further development for the components in question. System integration activities and clearly defined industrial targets[8] are needed to make sure every application fulfils its market needs.

The development of PEMFC technology for the road vehicle drive chain, and perhaps for rail use, will be the first priority. This technology can probably also be utilised in other transport applications later. Captive fleets (such as busses) can play an important role in demonstration. Their intensive use provides maximum experience in minimum time as well as high public exposure.

In other transport modes, on-board fuel processing developments including desulphurisation will be led by aviation. SOFC and MCFC technologies which fall within the scope of maritime applications will be developed in synergy with the third IDA. For some short distance or intermittent operation applications, PEMFC technology has also potential for maritime use and there are ongoing European projects in this field.

Hydrogen and fuel cell technologies can still be considered to be in their early stage of development for mass market requirements such as transport. Although steady progress has been made over the last decade to close the gap towards commercial standards for automotive applications, there is still a strong need to improve the performance, cost, and reliability of hydrogen production, storage, and use. Hydrogen storage materials and systems and high-temperature PEM fuel cells are critical fields where significant scientific and technical advances are both needed and anticipated. Long-term research leading to new ideas and concepts is key to overcoming these challenges. It is, therefore, an integral part of this programme. It is intended to address critical barriers that can hinder lead applications in the medium term, and to open up new pathways for technology and manufacturing in the long run.

A sound long-term market framework is essential to fostering industry developments and investments. Actions are proposed to strengthen and expand the EU's hydrogen and fuel cell supplier base, with a special focus on SMEs acting both as integral part of the supply chain of OEMs and as OEMs themselves for smaller production volumes and early markets. Human capital development is also targeted as a key element of industry capacity build-up. Regulations, codes and standards, as well as safety, recycling and public awareness, will be addressed within this IDA as critical factors for the marketability of new products.

Synergies exist at different levels within and between IDAs, for example on materials, manufacturing and testing. Close synergies between IDA 1 and IDA 2 on sustainable hydrogen production and supply will be continously fostered in this plan to promote the uptake of sustainable hydrogen production technologies for validation and deployment. Strong links with the third IDA will be pursued to allow for the uptake of all fuel cell technology developments for transport APUs and propulsion systems. The fourth IDA will be instrumental in sharing the latest advances in fuel cell technology and manufacturing. Equally important are the benefits sought from the synergies between the air-rail-maritime and road transport APU applications. For example, air transport

[8] Component and system targets for different markets and applications (drive train and APU) have been outlined by the WG-Transport

applications pose the most stringent weight requirements for fuel cells, whereas these for rail are less demanding and could be considered as standing halfway between stationary and road transport applications. The demonstration of some key technologies in rail may be easier than in other transport modes.

The portfolio of actions considered within this first IDA is presented in Table 3-1 below. In this Table, actions are grouped by thematic clusters. Reference numbers provide a link to action details outlined in Annex I. X symbols indicate the lead application for a given action as described above.

Table 3-1: Action clusters for IDA 1

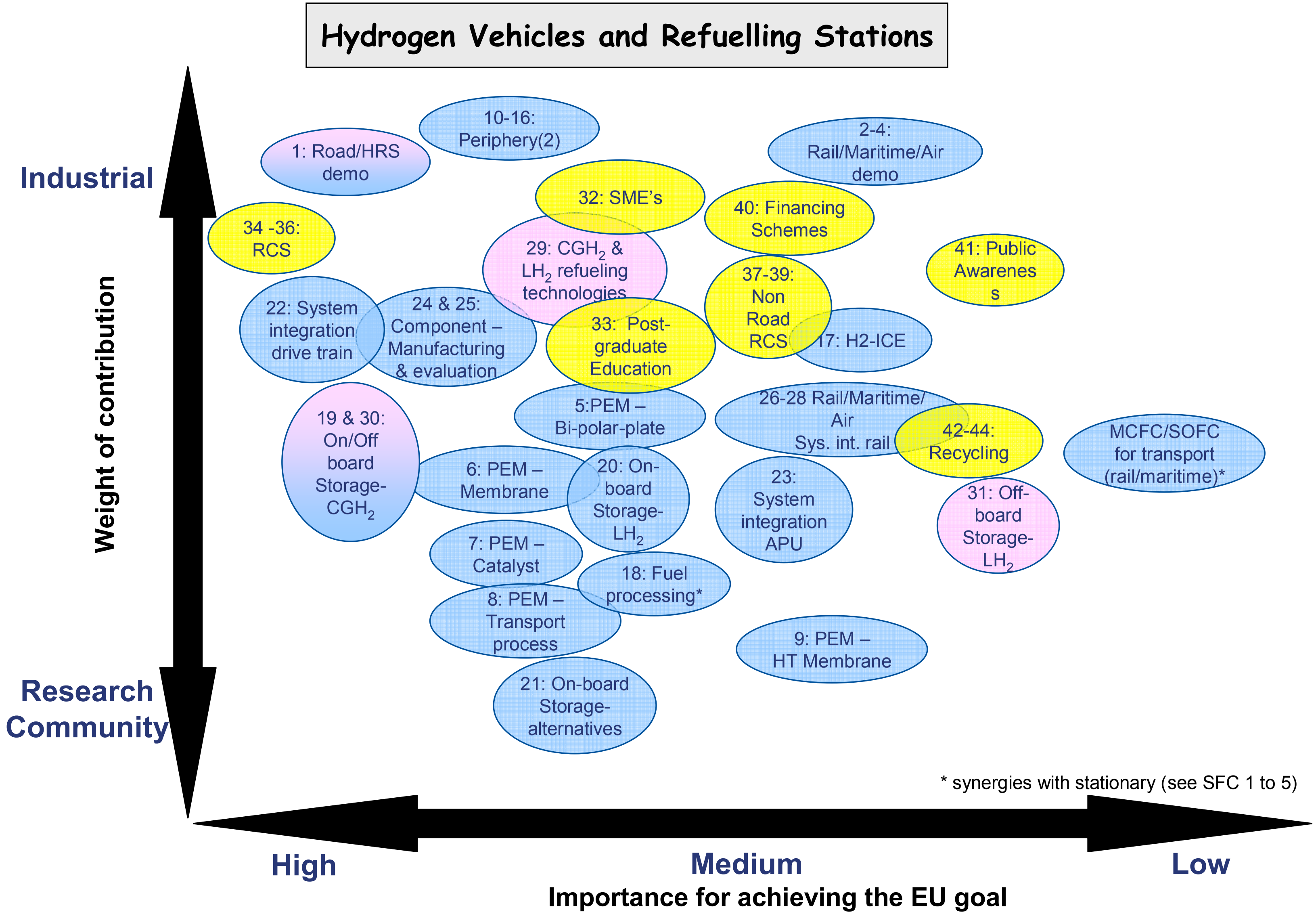
Action type	Action number	Action focus	H_2 refuelling Technologies	Road	Air	Maritime	Rail	Supporting Activities
		Demonstration transport and H_2 refuelling technologies						
DE	1	Road vehicles- supply infrastructure: Passenger cars (ICE/FC - APUs) ; Captive fleets e.g. buses (ICE/FC - APUs)		X				
		Refuelling stations	X					
	2	Air: Emergency unit (H2/O2 with PEM), FC Power Unit (PEM/SOFC) with reformer			X			
	3	Maritime: MCFC/SOFC system APU, Propulsion - Phase II, (PEMFC optional for short range operation)				X		
	4	Rail: PEMFC-based propulsion					X	
		R&D Transport						
BR+AR	5 to 9	PEMFC (bi-polar plate, membrane, catalyst, transport process, HT membrane)		X				
AR	10 to 16	Periphery (air supply, valves/ piping, e-drive, HV battery, H_2 loop, power electronics, cooling)		X				
AR	17	H_2 ICE		X				
BR+AR	18	Fuel processing		X	X	X		
BR+AR	19 to 21	Storage (CGH_2, LH_2, Alternatives)		X				
AR	22 to 28	System integration (drive train, APU, component manufacturing, component evaluation, Air, Rail, Maritime)		X	X	X	X	
		R&D H_2 Refuelling technologies						
AR+DE	29	HRS&Components (CGH_2 & LH_2 refueling technologies)	X					
BR+AR	30 to 31	Off- board H_2 Storage (CGH_2, LH_2)	X					
		Supporting activities						
	32	From research to market - Developing a healthy European scene for H_2 and Fuel Cells (supporting and fostering SME's involvement)						X
	33	Engineering the excitement - solving the people capacity bottleneck for growth (post graduate and professional development training needs)						X
	34 to 39	RCS (Coordinated European Strategy towards RCS, Supporting relevant directive initiatives, road vehicle logistics, maritime, rail, aerospace)						X
	40 to 41	Building the Market - Stimulating and Meeting Early Demand (financing schemes for building the production volumes, public awareness)						X
	42 to 44	Recycling (technologies, regulatory framework)						X

(BR: basic research, AR: applied research, DE: demonstration)

3.1.2 Key priorities

The prioritised portfolio of actions is presented in Figure 3 below. In this graph, blue circles relate to transport applications, pink colour circles to hydrogen supply and yellow colour to supporting activities. Gradients of colours show joint activities between the different sectors. Reference numbers provide a link to action details outlined in Annex I. The area allocated to high, medium and low prioritites in the graph (and those later in this report) may not be equal, purely for layout reasons.

Figure 3: IDA 1 - Portfolio of Actions



3.1.3 Resource requirements

The overall resource requirement for IDA 1 has been estimated at €2661 million. This includes €2195 million for transport activities, €290 million for hydrogen supply activities and €176 million to support technology deployment. A breakdown of these proposed activities is shown in Table 3-2 below.

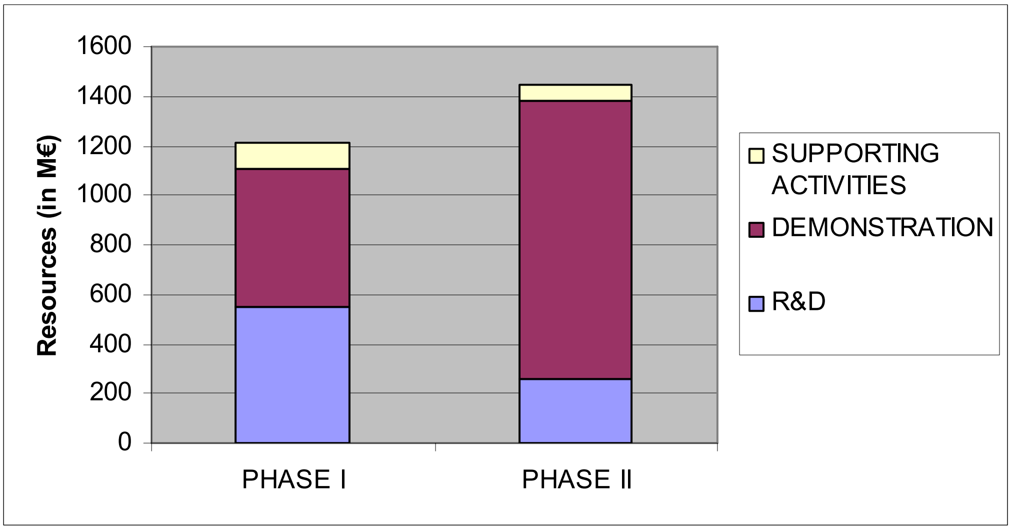
Table 3-2: Resource distribution for IDA 1

		H_2 refuelling technologies	Road	Air	Maritime	Rail	Supporting activities	Total
	Resource in M€ (% within IDA 1)	290 (11%)	1500 (56%)	150 (6%)	300 (11%)	245 (9%)	176 (7%)	2661 (100%)
Of which	*% R&D*	*44*	*33*	*33*	*33*	*14*		
	% Demonstration	*56*	*67*	*67*	*67*	*86*		

Within this IDA ,it is planned to spend roughly 30% of the resources on research and development and 60% on demonstration activities. This planning is based on the assumption that the technological challenges which still exist will be met during the course of the programme.

The distribution of the resources within the two proposed phases of the programme is shown in Figure 4 below.

Figure 4: Scenario for the distribution of resources in IDA 1



It is anticipated that more resources will be spent on R&D and Supporting Activities in the first phase of the programme, which is assumed to end by 2010. The aim is to reduce the cost of the technology, improve system reliability and endurance and set the framework for deployment by tackling regulation and safety issues. Demonstration activities will focus on technology validation under real life conditions. For instance, a few demonstration sites integrating road transport fleets and refuelling stations are foreseen, as decribed in Annex 1. More resources will be dedicated to demonstrating the results of the R&D work in the second phase of the programme (from 2010 to 2015)

in conjunction with an expansion campaign of demonstration sites, paving the way for a broad infrastructure build-up. Existing sites will be expanded according to the best options, determined from Phase 1, which satisfy criteria of sustainability and commercial viability. New facilities will be built up to link “hydrogen clusters” in preparation for growing market coverage.

3.2 IDA 2: Sustainable Hydrogen Production and Supply

Goal: 10-20% of the Hydrogen supplied for energy applications to be CO_2 lean or free by 2015

3.2.1 IDA 2 Contents

The overall objective of this IDA is to develop a portfolio of sustainable hydrogen production, storage and distribution processes. Sustainability here encompasses cost-competitiveness, low well-to-tank carbon content, high energy efficiency and minimum dependence on fossil energy.

A medium-term quantitative target for this programme is to supply 10-20% of the hydrogen energy demand with CO_2 lean or CO_2 free hydrogen by 2015. On this time horizon, the major hydrogen energy demand is expected to come from transport applications as well as early markets such as portable generators. Small-scale decentralised hydrogen production processes are expected to play a critical role early on, with bigger and more centralised hydrogen production facilities being developed alongside mass-market deployment of hydrogen-fuelled technologies.

Several processes and feedstocks can be used to produce hydrogen. They have different degrees of maturity, production capacity and sustainability. By 2020, leading technologies for hydrogen production may include low-temperature electrolysis, biomass to hydrogen (BTH) conversion, and hydrocarbon reforming, including the reforming and partial oxidation of biofuels as well as technology for producing hydrogen by coal gasification. This process can be adapted to include carbon capture. Industrial by-product hydrogen can come from existing sources such as chlorine production plant. Some of this hydrogen is wasted today and is in effect a free energy source. These can be opportunistic sources of hydrogen for local stationary applications and possibly transport applications. PEMFCs running on by-product hydrogen are an early market for fuel cells and therefore, addressed in IDA4. Consideration is also given to the home refuelling concept within the scope of reforming technologies.

Technological actions proposed in this IDA aim to bring these production processes to the level of performance and sustainability needed to supply 10-20% of the anticipated demand, with the rest to be supplied from the merchant market and from already mature production technologies. Specific attention should be paid to hydrogen purity and quality standards, where there is a trade-off between fuel cell vehicle longevity and the economics and availability of processing technologies on the supply side.

Close synergies with the other IDAs will be promoted within this plan. The aim is to test sustainable hydrogen production under real market conditions as soon as possible. Essential for the fossil fuel-based hydrogen production pathways is the development and implementation of carbon capture and storage (CCS) technology. CCS is a

prerequisite if fossil fuels are to be used for producing hydrogen in the medium and long term. CCS is primarily addressed under the Zero Emission Fossil Power Generation Technology Platform (ZEP)[9]. The HFP should liaise with ZEP to make sure that appropriate actions are taken to promote CCS in connection with hydrogen production or its co-production with electricity and possibly other fuels. Links with other European technology platforms that address elements of hydrogen production pathways is also recommended. This includes coordination with the Biofuels Technology Platform (BIOFRAC)[10] at the interface between biomass-to-hydrogen processes and Biofuels.

Strategic planning, in-depth assessments of infrastructure build-up and comprehensive market analysis are of paramount importance in anticipating and assigning industrial and R&D investments. This calls for integrated socio-economic models and tools to support decision makers in industry and policy-making bodies.

A fully-fledged hydrogen economy ranging from stationary applications to transport use is envisaged beyond 2020. So a second objective of this integrated priority is to develop the components of a sustainable hydrogen infrastructure beyond 2020-2030. A new generation of hydrogen production processes and delivery infrastructure will be necessary if the full benefits of hydrogen as the alternative energy carrier to electricity are to be realised as the foundation documents of the HFP anticipate. Technological actions for this long term objective target the development of advanced production pathways based on the thermal-electrical-chemical decomposition of water at high temperature, and the biological decomposition of water or biological feedstocks at low temperature. Pipeline transmission and distribution as well as solid-state hydrogen storage technologies are also an integral part of these longer term activities, as key elements of a mass delivery infrastructure.

Action clusters considered within this second IDA are presented in Table 3-3 below. More specific details at the action level are given in Annex 1.

[9] For more information about the Zero Emissions Plant Technology Platform please consult with: http://ec.europa.eu/research/energy/nn/nn_rt/nn_rt_co/article_2268_en.htm ; http://www.zero-emissionplatform.eu/website/index.html
[10] For more information about the European Biofuels technology platform please consult with: http://ec.europa.eu/research/energy/nn/nn_rt/nn_rt_bm/article_4012_en.htm ; http://www.biofuelstp.eu/overview.html

Table 3-3: Action clusters for IDA 2

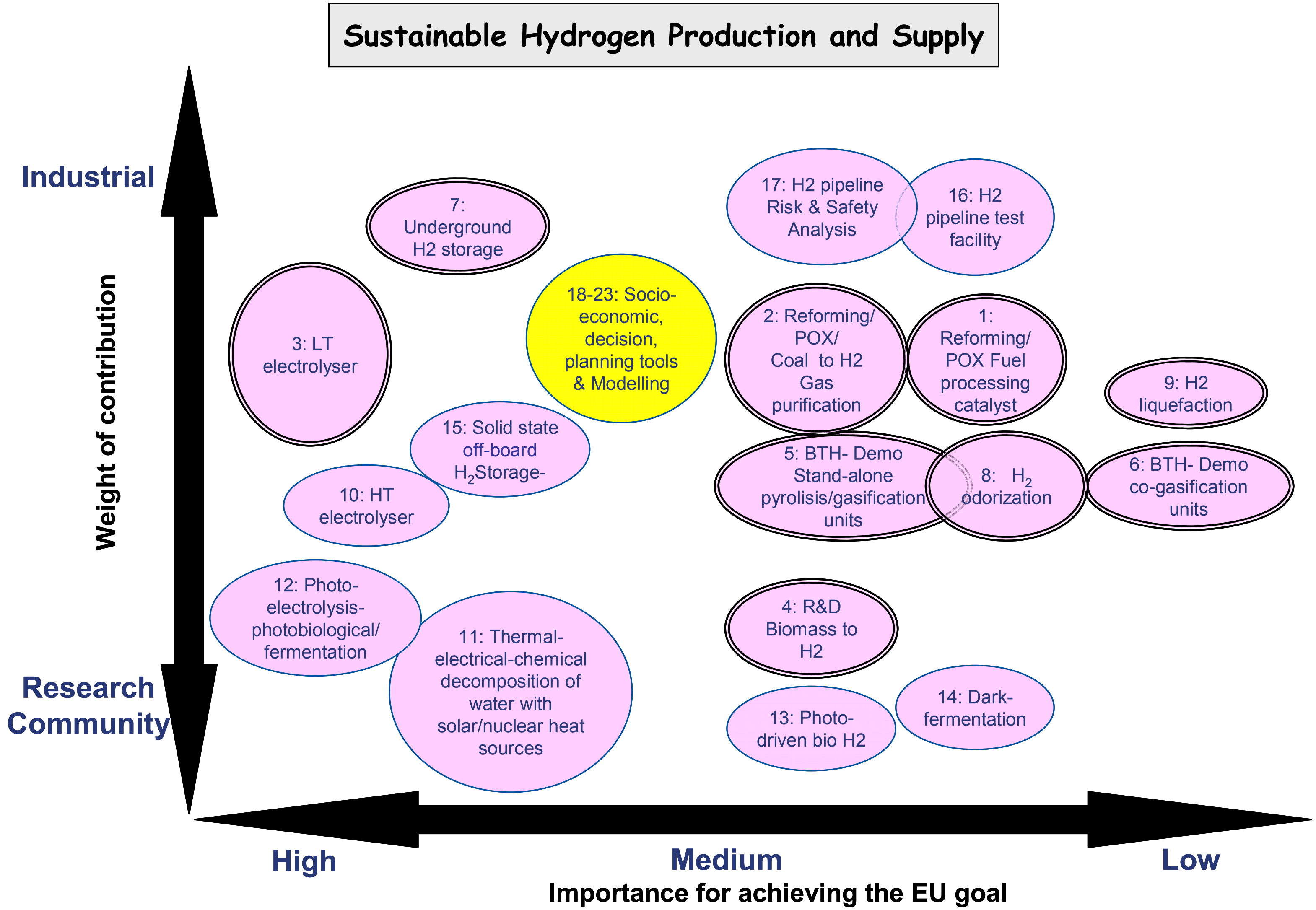
Action type	Action number	Action focus	Medium Term Technologies	Long term Technologies	Supporting Activities
		Sustainable H_2 supply			
AR + BR	1 to 2	Reforming/POx/CTH (Fuel Processing Catalyst, Gas Purification)	X		
BR+AR+DE	3	Low temperature electrolysis (Development of low cost/efficient low temperature electrolyser)	X		
BR+AR	4 to 6	Biomass to Hydrogen (R&D on advanced technologies for BTH, Demo Standalone pyrolisis/gasification units, Demo co-gasifications)	X		
AR+DE	7 to 8	HRS&Components (Underground H_2 storage and/or production, H_2 odorization)	X		
AR+DE	9	H_2 Liquefaction	X		
BR+AR	10	High temperature electrolysis (Development of a new generation of High temperature electrolyser)		X	
BR+AR+DE	11 to 14	Advanced Technologies (Decomposition of water through thermo-electrical-chemical processes with solar/nuclear heat sources, low temperature processes: photoelectrolysis and photobiological / fermentation, Photodriven bio-hydrogen, Hydrogen by dark fermentation)		X	
BR+AR	15	Solid-state Off-board H_2 Storage		X	
AR+DE	16 to 17	Pipelines (Field Test Facility, Risk & Safety Analysis)		X	
		Supporting activities			
	18 to 23	Getting the numbers right - socio-economics modelling and tools (Integrated database, market analysis, planning tools, regulation analysis, role of hydrogen in sustainable energy system)			X

(BR: basic research, AR: applied research, DE: demonstration)

3.2.2 Key priorities

The portfolio of actions is shown in Figure 5 below. Double line circles relate to medium-term targets, single line circles to longer-term activities, and yellow to supporting activities. Reference numbers provide a link to action details in Annex I.

Figure 5: IDA 2 – Portfolio of Actions



3.2.3 Resource requirements

The overall resource requirement for this IDA has been estimated at €759 million, of which €380 million is assigned to the mid-term portfolio of actions, €331 million to the long-term one and €48 million to supporting activities. A breakdown of the proposed resources between these categories is presented in Table 3-4 below.

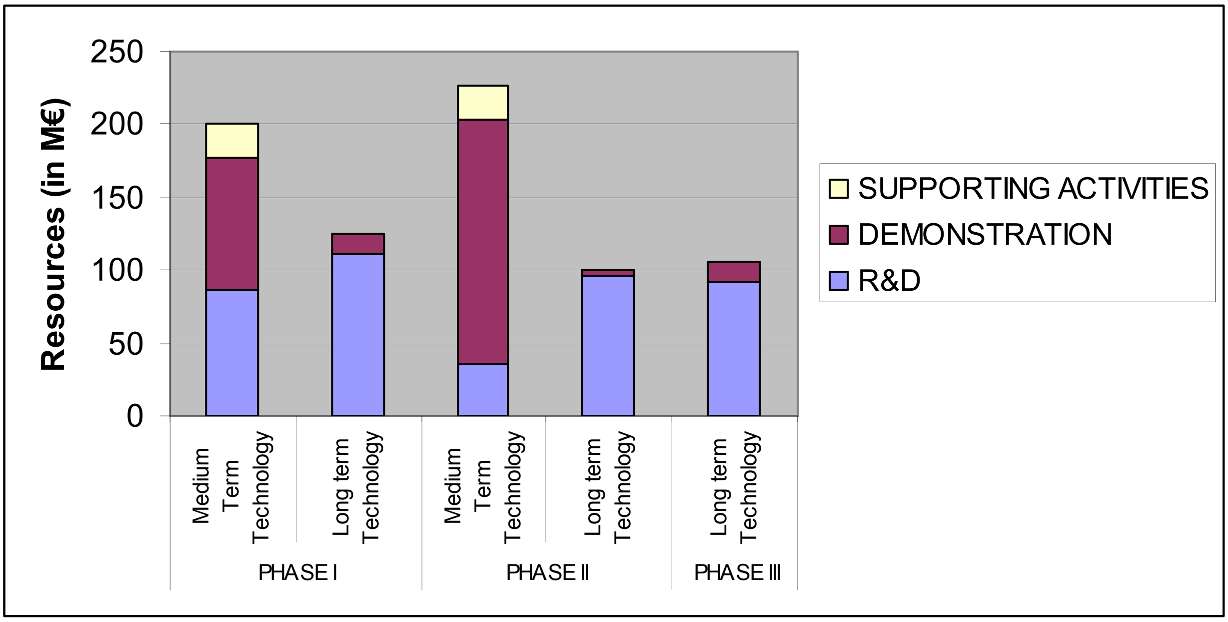
Table 3-4: Resource distribution for IDA 2

		Medium term technologies	Long term technologies	Supporting Activities	Total
	Resource in M€ (% within IDA 2)	380 (50%)	331 (44%)	48 (6%)	759 (100%)
Of which	*%R&D*	*32*	*91*		
	%Demonstration	*68*	*9*		

Within this IDA it is planned to spend roughly 56% of the resources on R&D and 38% on demonstration activities. Significant research and development work is proposed on critical technological barriers whose removal will allow the sustainability of the hydrogen production to be enhanced in the medium term, and to exploring new production avenues for large scale hydrogen supply and distribution in the longer term.

The planned distribution of the resources for medium and long-term technology development in IDA 2 is shown in Figure 6, on the same basis as for IDA 1 above.

Figure 6: Scenario for the distribution of resources for the medium term technology portfolio in IDA 2



During the first phase of the programme (ending around 2010) a resource distribution balanced between R&D on materials, key components etc. and process developments is proposed. The latter would involve pilot production for all the hydrogen production processes in the medium term technology portfolio. In the second phase (ending around

2015), technology assessment and process integration will be pursued in medium size demonstration prototypes. This work would be carried out in parallel with R&D to address the remaining challenges.

The long term technology portfolio is designed to focus R&D effort onto the fundamental scientific and technical challenges for the next generation of hydrogen production, storage and delivery. It is crucial to sustain a continuous research and development effort during these two phases to support the long term technology portfolio whilst building up experimental facilities and early prototype units to be explored during the next phase, phase III. Because of the need for long-term research on these technologies, a third phase of research is proposed, running from 2015 to approximately 2025.

3.3 IDA 3: Fuel Cells for CHP and Power Generation

Goal: Commercially competitive Fuel Cells for CHP and Power Generation; > 1 GW capacity in operation by 2015

3.3.1 IDA 3 Contents

The power sector is leaning towards more and more decentralised modes of power generation, which fuel cells are well suited to support. Combined heat and power or power generation systems using fuel cells offer high electrical efficiency with either natural gas or renewable fuels. This means that they can play an important role in achieving early CO_2 savings, while providing mass market opportunities for fuel cell technologies.

This third integrated priority area pursues the overall objective of bringing stationary fuel cells to a commercial stage by 2010. As a medium-term quantitative target - on the way to the “Snapshot 2020” targets - this IDA involves installing more than 1 GW of capacity by 2015. This total would be reached by the deployment of MCFC, SOFC and PEMFC technologies. It is made up of 80,000 1-10kW units in residential use, 2,600 10kw-1MW units in industrial use and a further 50 units of 1MW or more also in industrial use. These units would make use of existing forms of fuel supply to begin with, mainly natural gas. Biogas, biodiesel, and syngas would have a growing role. However, hydrogen is anticipated to play a crucial role in applications such as peak-shaving for electricity from renewable energy sources and in industrial power generation using by-product hydrogen, a joint area of development with the second and fourth IDAs.

The residential units will use PEMFC[11] and SOFC technologies, perhaps in roughly equal proportions depending on future improvements in the two technologies. For larger units of 10 kW to 1 MW, MCFC and SOFC technologies are likely to be preferred and the more advanced status of MCFC technology means that it will account for most of the installed units in the early years of this programme. However, the expected development of SOFC technology will ensure that a greater proportion of the total units will be based on SOFC technology in the latter half of this programme. Similarly, units of more than 1 MW will primarily use MCFC, but SOFC units could play a greater part

[11] In this document, both PEFC - low temperature polymer electrolyte fuel cell (80°C) - and PEMFC (high temperature polymer electrolyte fuel cell (120-200°C) - are accounted for in the wording PEMFC.

closer to 2015. The message is that all three technologies require development if the cumulative deployement goal of 1 GW is to be reached. However, the three approaches are in different stages of maturity, and require differing amounts of research and development, as illustrated in Figure 7 in the next section.

The proposed portfolio of technological actions is aimed at improving cell and stack technology to the level required by the stationary market and bridging the gap between lab prototypes and pre-commercial systems. This includes developing fuel cell products at an industrial scale, comprising “balance of plant" components as well as the scale up of manufacturing capacities. At the same time there would be test campaigns for product validation under real market conditions, and preparations for the start-up of fuel cell installation, operation and maintenance services.

Regulations, codes and standards for indoor use and grid interconnection are a pre-requisite for deploying fuel cell systems in the stationary energy markets. Financing schemes will also be necessary to support and stimulate the use of these emerging technologies in well established markets. All these critical elements are an integral part of this third IDA.

Close synergies with the first and fourth IDAs will also be promoted within this plan, to share advances in fuel cell technology. It is expected that developments in MCFC and SOFC from this area will contribute to the work on transport APUs and on non-transport systems, while stationary systems will take advantage of the developments on PEM technology from the first IDA. IDA 4 is also closely linked, as an early testbed for stationary fuel cell products and manufacturing capacities. Action clusters within this third IDA are presented in Table 3-5 below.

Table 3-5: Action clusters for IDA 3

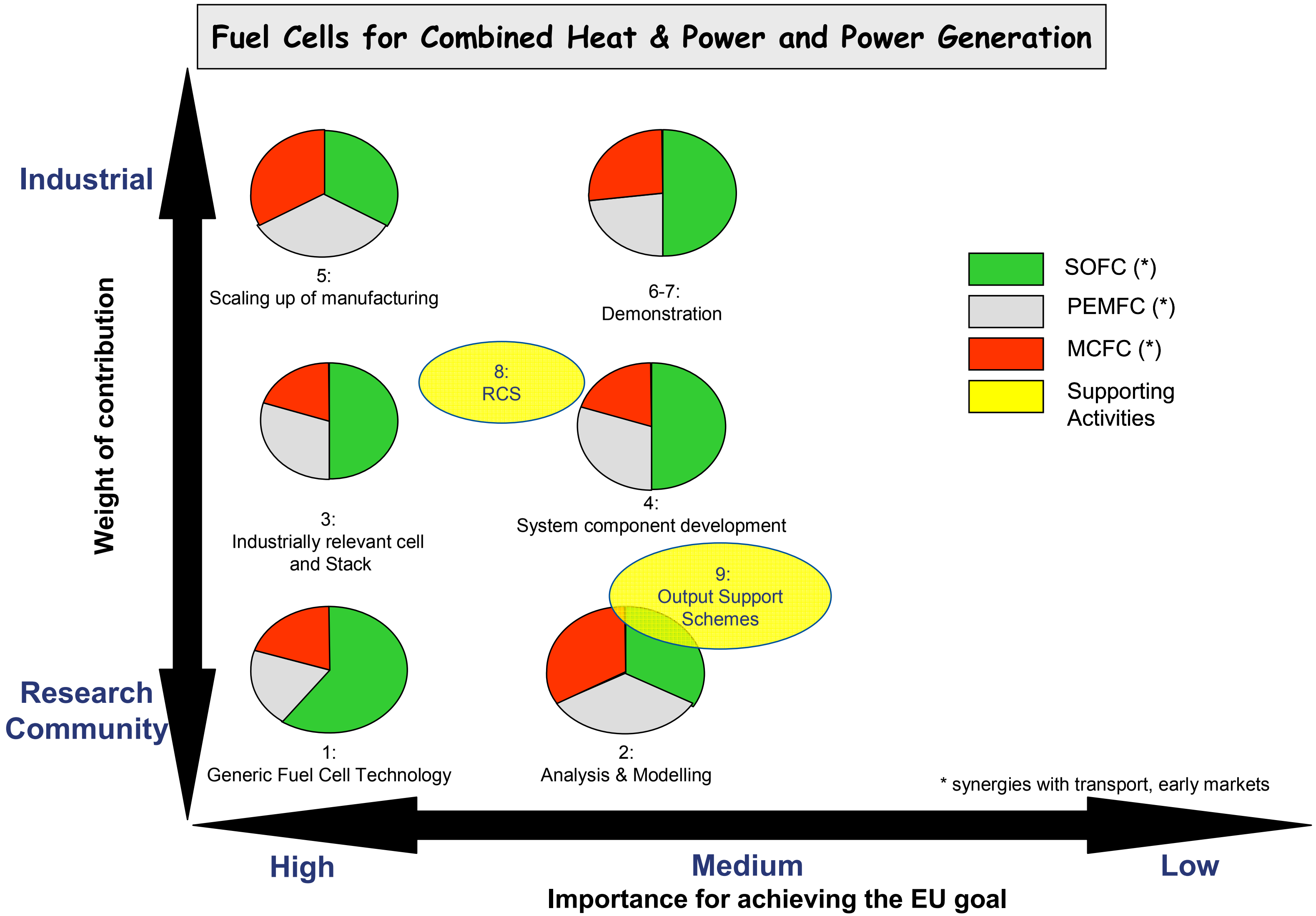
Action type	Action number	Action focus	SOFC	PEMFC	MCFC
R&D					
BR	1	Generic Fuel Cell Technology	X	X	X
BR	2	Analysis and Modelling	X	X	X
AR	3	Industrially relevant cell and stack	X	X	X
AR	4	System component development	X	X	X
Demonstration					
DE	5	Scaling-up of Manufacturing	X	X	X
DE	6	Technology validation -Residential applications	X	X	
		Technology validation - Industrial applications	X		X
DE	7	Market entry - Residential applications	X	X	
		Market entry - Industrial applications	X		X
Supporting activities					
	8	Creating Peace of Mind - Developing and Implementaing Harmonised RCS (Grid-Interconnect RCS)	X	X	X
	9	Building the Market - Stimulating and Meeting Early Demand (Develop schemes for public procurement and degressive incentivised product price for the output)	X	X	X

(BR: basic research, AR: applied research, DE: demonstration)

3.3.2 Key priorities

The prioritised portfolio of actions is presented in Figure 7 below. Three-colour pie charts show the resource distributions for the SOFC (green), PEMFC (grey) and MCFC (red) actions; yellow indicates supporting activities.

Figure 7: **IDA 3 – Portfolio of Actions**



3.3.3 Resource requirements

The overall resource requirement for IDA 3 has been estimated at €2853 million, of which €1394 million is for SOFC, €706 million for PEMFC, €728 million for MCFC and €25 million for supporting activities. A breakdown of the proposed spending on each type of fuel cell is presented in Table 3-6 below.

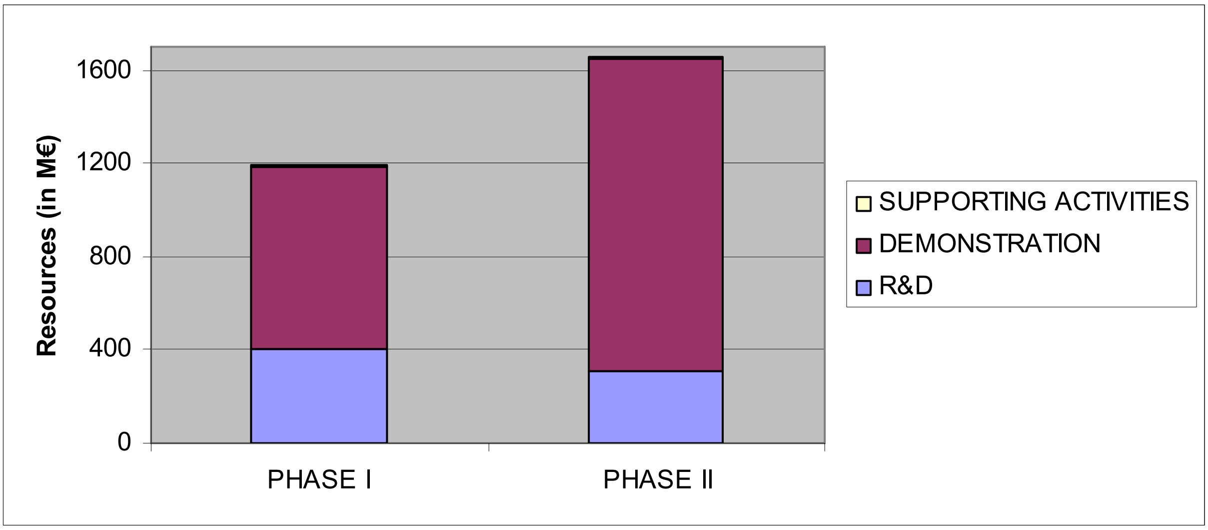
Table 3-6: Resource distribution for IDA 3

		SOFC	PEMFC	MCFC	Supporting Activities	Total
	Resource in M€ (% within IDA 3)	1394 (49%)	706 (25%)	728 (25%)	25 (1%)	2853 (100%)
Of which	*%R&D*	*25*	*30*	*21*		
	%Demonstration	*75*	*70*	*79*		

Within this IDA it is planned to spend roughly 25% of the resources on research and development and 74% on demonstration activities.

Following the same approach as for the previous IDAs, a scenario for the distribution of these resources is presented in Figure 8.

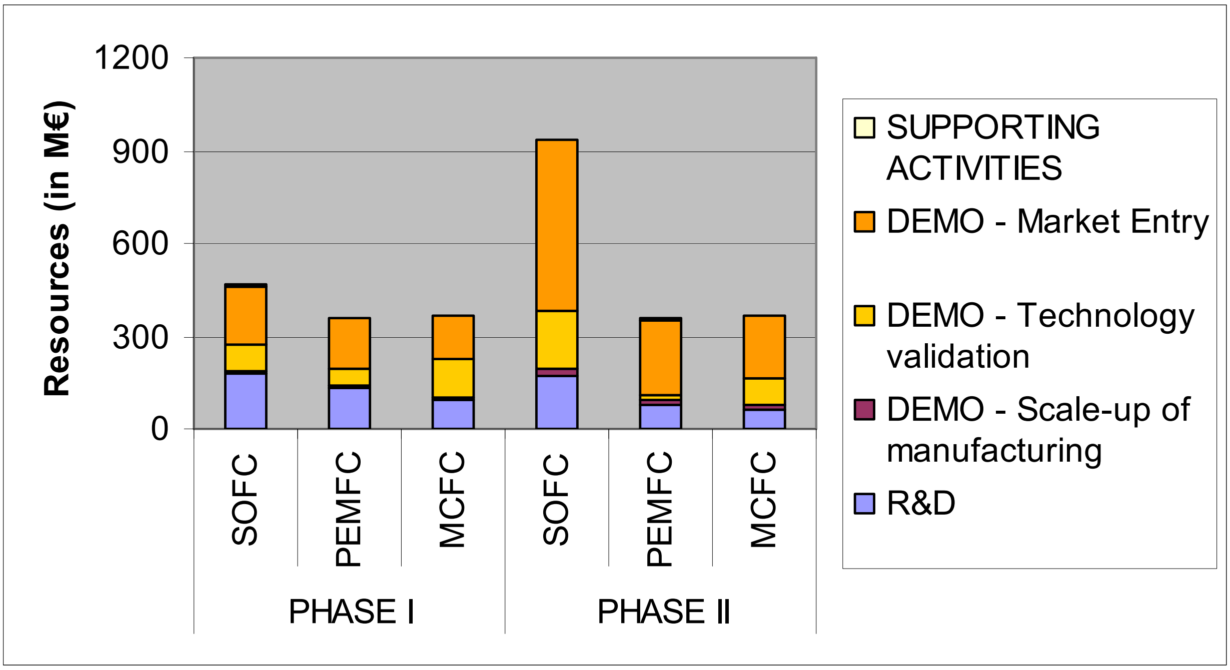
Figure 8: Scenario for the distribution of resources in IDA 3



Reaching 1 GW capacity in operation by 2015 requires all three technologies, PEMFC, SOFC and MCFC, to be deployed, which in turn calls for an integrated approach for all these technologies. Its elements include basic, applied research on materials, cells and stacks, balance of plant, components and stack manufacturing, and demonstration activities targeting technology validation, the scale-up of manufacturing facilities and market entry. The latter will be more predominant in the second phase, which encompasses technology improvement, investment in volume production, infrastructure build-up and commercial readiness.

The proposed resources for R&D and demonstration projects for each of the three techologies are shown in Figure 9. They are tailored to the maturity of each technology and its expected development during the timeframe of this programme. Both research and development and process engineering are needed for all three technologies if we are to achieve the EU's ambitious goal for this programme. There is a strong focus on SOFC in line with its potential in both residential and industrial markets and the perceived strength of the EU industrial base for this technology.

Figure 9: Scenario for the distribution of resources per fuel cell technology in IDA 3



3.4 IDA 4: Fuel Cells for Early Markets

Goal: X000 commercial early market FC products in the market by 2010

3.4.1 IDA 4 Contents

The goals of this fourth IDA are:

- to develop a range of products and services that can be cost-competitively released in the market within the next 3 to 4 years
- to initiate and sustain the build-up of a manufacturing and supply base for fuel cell systems (including balance-of-plant), components and materials, enabling industry to invest in technical development, people and production facilities
- to ensure that all necessary structural conditions are in place for the deployment of fuel cell technologies

The target for this IDA, on the way to reaching the “Snapshot 2020” milestone, is to achieve cumulative production of 200MW (circa 20,000 units) not later than 2012.

To achieve this target the programme calls for an integrated and iterative process of development and demonstration to gain 'real-world' operating experience, providing feedback into technical development and manufacturing processes, and to demonstrate the technology to potential users. This process comprises the following steps:

- Pilot, test and characterise the existing state of the art; define RTD needs and set product targets
- System development including applied RTD, system modelling, reduction of system complexity, and improvement of performance
- Demonstrate prototypes to confirm targets through extensive field testing, and identify RTD requirements for pre commercial units
- Large-scale demonstration of second-generation pre-commercial products. This should confirm system specifications, lifecycle costs and training needs for product installation and use, and show public acceptance once they are in place

In addition, transfer from research to the market should be accelerated and consolidated by supporting Start-ups and SMEs, which are expected to make a significant contribution in this area. The current partial subsidies system fails to help the smaller companies that are now developing innovative components but lack the funds to match the grants and loans they receive. It is vital to supply equity and grants to small firms which need them, and to develop a culture of seed-financing and early-stage financing with appropriate instruments to deliver them. A specific involvement and qualification programme for SMEs is suggested, to make the benefits of engagement in the hydrogen and fuel cell industry apparent to SME owners and managers.

Early market successes will be of paramount importance, as they will act as role models to encourage others to invest. They are likely to be seen in a series of specific niches where this technology has a natural advantage. It is critical that such niches not be seen in isolation, but can be bundled together, perhaps via buyer pools or coordinated public procurement, to make the total size of the market apparent. Regions, industrial clusters and public/private partnerships can all help to create the necessary structural conditions for early investment in this technology.

Due to their modularity and high efficiency, fuel cell-based systems can provide benefits over existing energy technologies in many niche and premium applications. Building on the existing development of power modules with common components and architecture, it is possible to develop a variety of mobile, stationary and backup applications. Today component standardisation for these applications is developing rapidly. For example, the power module used in backup system can be used in specialty vehicles with only minor modifications. This supports component standardisation and leads to lower costs.

In this IDA, four main classes of applications will be investigated. They are portable generators, UPS and Back-up power systems; specialist vehicles; industrial power generation using by-product hydrogen fuel cells (of a few MWs capacity); and micro fuel cells for specialist products such as power tools. They are considered to be financially attractive in the short term for an emerging European hydrogen and fuel cell industry. They are also technically representative of the power ranges and applications that are anticipated for other early uses of fuel cells. The programme will be flexible enough to ensure that the requirements of possible early markets can be addressed, and can benefit from the development of the four reference applications.

No major technical breakthroughs are necessary for these markets to be opened up. There are real commercial customers for portable and premium systems in the period 2007-2013. But the area still needs RTD support because customers' requirements cannot yet be fulfilled at all or in full. As with any relatively immature commercial product in a competitive environment, continuous and rapid improvement in performance is needed to gain and consolidate market share. The main development effort for early market products will concentrate on improving stack performance, system integration and simplification, and on field testing different generations of products, from prototypes to pre-commercial systems.

Strong links and synergies with the other IDAs will be promoted throughout the programme. The basic R&D on key components, directed primarily at stationary and transport applications, should be integrated into the programmes directed at premium applications. Because of the early field introduction of these applications, high quality technology feedback is expected to contribute positively to the development of the other applications.

It must also be recognised that the cost of producing these fuel cell systems will be higher than the market clearing price until high-volume production is achieved. Public support will be required to help close the gap. Subsidies or capital grants to the user of between €500 - 1000 per kW were recommended in the Deployment Strategy. This is consistent with the direct financial support currently provided to purchasers of renewable technologies and, in the past, of condensing boilers.

Table 3-7: Action clusters for IDA 4

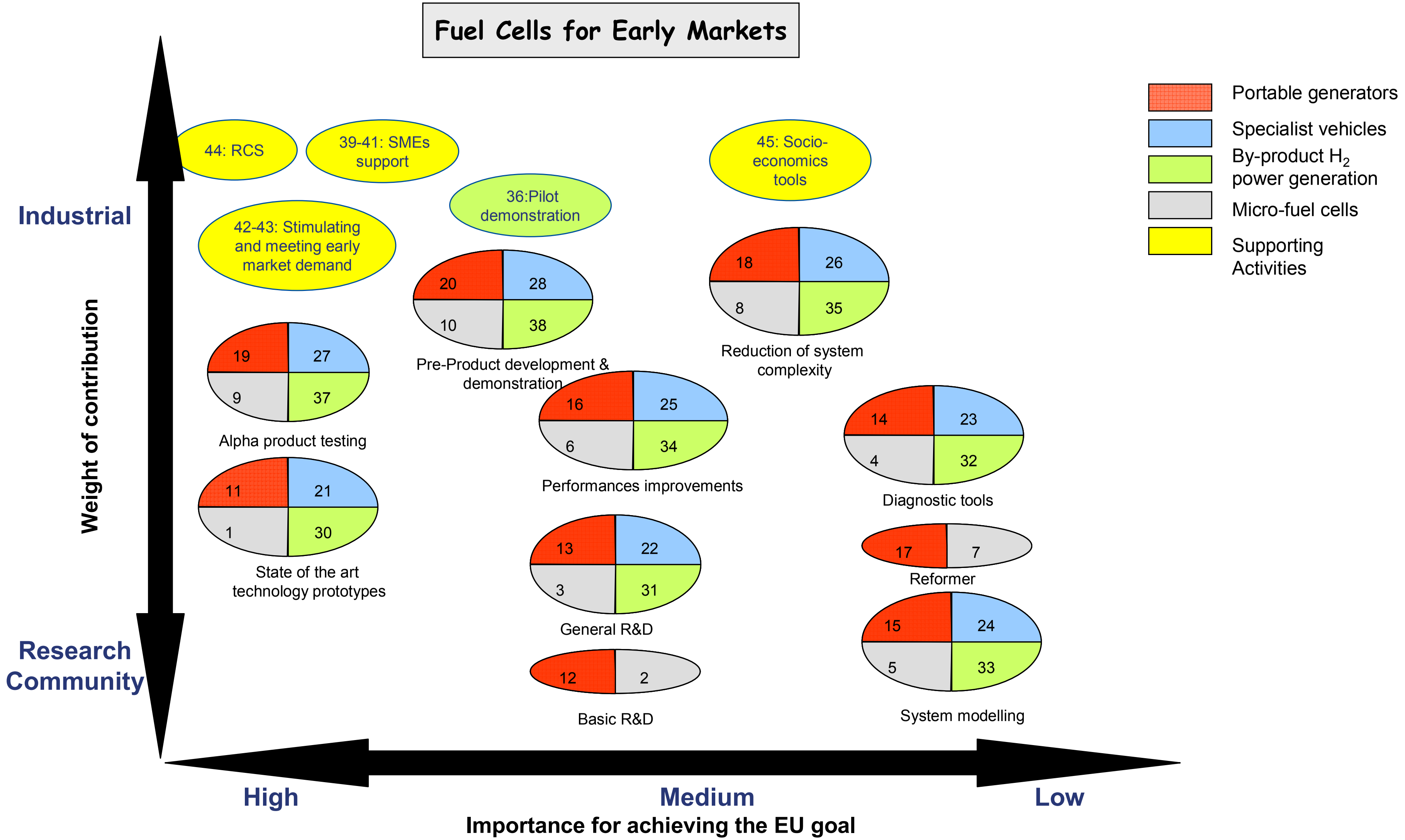
Action type	Action number	Action focus	Micro FCs	Portable generators	Specialist Vehicles	By-product H_2	Supporting activities
		Portable Micro-FCs					
AR+DE	1	State of the art technology	X				
BR + AR	2 to 8	System developments (Basic & applied R&D stack systems, diagnostic tools, system modelling, reduction of system complexity, reformer, improvement of performances)	X				
DE	9 to 10	Demonstration (Alpha testing, pre-commercial product development & demosntration)	X				
		Portable generators, Back-up power, UPS					
AR+DE	11	State of the art technology		X			
BR + AR	12 to 18	System developments (Basic & applied R&D stack systems, diagnostic tools, system modelling, reduction of system complexity, reformer, improvement of performances)		X			
DE	19 to 20	Demonstration (Alpha testing, pre-commercial product development &		X			
		Specialist vehicles					
AR + DE	21	State of the art technology			X		
AR	22 to 26	System developments (Applied R&D stack systems, diagnostic tools, system modelling, reduction of system complexity, improvement of performances)			X		
DE	27 to 28	Demonstration (Alpha testing, pre-commercial product development & demonstration)			X		
		By-product H_2 Power Generation					
AR + DE	30	State of the art technology				X	
AR	31 to 35	System development (Applied R&D stack systems, diagnostic tools, system modelling, reduction of system complexity, improvement of performances)				X	
DE	36 to 38	Demonstration (Pilot, Alpha testing, pre-commercial product development & demonstration)				X	
		Supporting Activities					
	39 to 41	From research to market - Developing a healthy European scene for H_2 and Fuel Cells (financing options for start-up & SMEs, SMEs'promotion activities, Research & Academia spin-off)					X
	42 to 43	Building the Market - Stimulating and Meeting Early Demand (Support Buyers' Pools, create the necessary structural conditions - regions, industrial clusters and public-private partnerships)					X
	44	Creating Peace of Mind - Developing and Implementaing Harmonised Regulations, Codes and Standards (in-door use of H2 and Fuel Cell Devices)					X
	45	Getting the numbers right - socio-economics modelling and tools (initiating the EU H_2 & FC Business Observatory ("EHFO"))					X

(BR: basic research, AR: applied research, DE: demonstration)

3.4.2 Key priorities

The portfolio of actions is shown in Figure 10. The areas are colour-coded. Red circles relate to portable generators, UPS and back-up power, blue to specialist vehicles, yellow to supporting activities, green to by-product hydrogen power generation and grey to micro-fuel cells.

Figure 10: IDA 4 - Portfolio of Actions



3.4.3 Resource requirements

The overall resource requirement for this IDA has been estimated at €1110 million. This consists of €234 million for each application - portable fuel cell, micro-fuel cell and specialist vehicle - €244 million for by-product hydrogen power generation and €163 million for supporting activities. A breakdown is presented in Table 3-8.

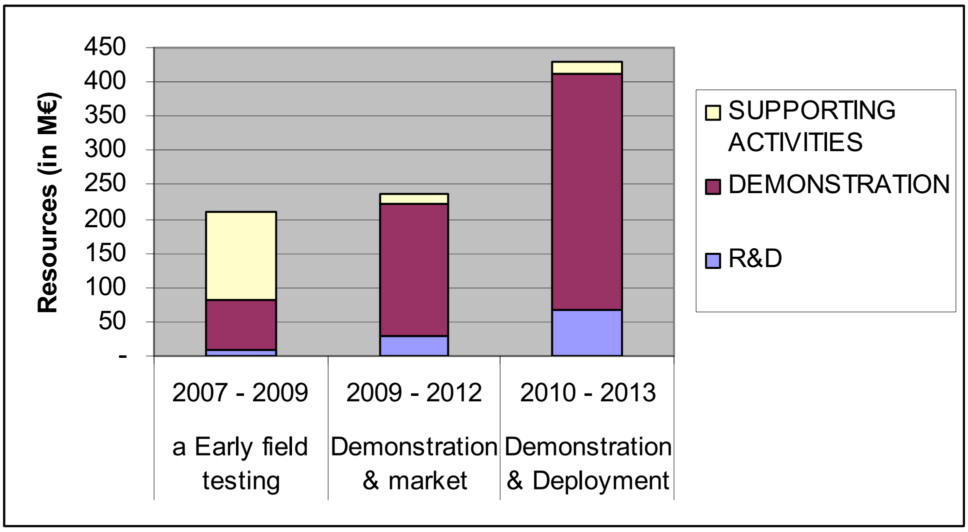
Table 3-8: Resource distribution for IDA 4

		Total for specific applications (Portable FCs, Micro FCs, Specialist vehicles, By-product hydrogen power generation)	Supporting activities	Total
	Resource in M€ (% within IDA 4)	947 (85%)	163 (15%)	1110
Of which	*%R&D*	*15*		
	%Demonstration	*85*		

Within this IDA it is planned to spend roughly 13% of the resources on R&D and 87% on demonstration and supporting activities.

Following the approach for IDA 1, a scenario for the distribution of these resources is given in Figure 11. Note that the breakdown of resource distribution for R&D and Demonstration activities only applies to portable generators, UPS and Back-up power systems, specialist vehicles, and industrial power generation using fuel cells fed by by-product hydrogen.

Figure 11: Scenario for the distribution of resources in IDA 4[12]



The integrated and iterative process of development and demonstration described in the introduction to this IDA is embedded in the proposed resource distribution between R&D

[12] Please note that the amount of resources – € 234 M - allocated to micro fuel cells is not included in this breakdown. This is because the European industry has not decided yet on its preferred business model for micro – FCs, i.e. whether to concentrate on suppliers to global OEMs or OEMs themselves.

and demonstration activities, with resources growing over time as market deployment is approached. Recognising the importance of these early markets in strengthening and developing the EU industry base, it is proposed from the beginning of this programme to launch a set of actions to support and foster the involvement of SMEs in this field, and to develop innovative financial options with a special focus on their equity dilemma.

3.5 Programme highlights

3.5.1 Priority highlights

Hydrogen vehicles and refuelling stations

IDA 1 addresses transport applications, emphasising road transport, as well as other transport applications, to meet EU goals on competitiveness and sustainable mobility. The top priority is the development of competitive hydrogen-fuel cell vehicles with an emphasis on vehicle component performance and reliability, plus the establishment and testing of a hydrogen refuelling infrastructure, and the full range of supporting elements for market deployment and increasing industry capacity.

A second priority level is given to efficient fuel cell-based APUs. Critical actions are also foreseen – on regulations, codes and standards, manufacturing and supply chain development – to support the industrialisation phase and mass market roll-out.

Sustainable hydrogen production and supply

IDA 2 is vital for meeting the programme’s contribution to the EU's environmental and security of energy supply goals. A high priority is given in this plan to low temperature electrolysis, a modular technology that allows for the integration of renewable energy sources. At a later stage, with rising demand in hydrogen, biomass-to-hydrogen and fossil-based technologies with capture and carbon sequestration will take up a growing share in the hydrogen supply chain. These are therefore allocated a medium or lower priority level. The development of advanced hydrogen production pathways and of alternative hydrogen storage technologies is prioritised in the longer term, as key elements for implementing a sustainable supply infrastructure.

The development of techno-socio-economic tools that can provide integrated analysis of the whole hydrogen value chain is of prime importance. Large investments in infrastructure will be necessary to implement a fully-fledged hydrogen economy. Such analyses are considered as a high priority within the early days of the programme.

Fuel cells for CHP and power generation

As indicated, the target of 1 GW capacity of fuel cells in operation by 2015 requires all three technologies, PEMFC, SOFC and MCFC, to be deployed. Although these three technologies are in different stages of maturity with MCFC being closer to commercialisation while SOFC is in its early stage of development, none has been fully qualified to be successfully deployed in competitive markets. It is therefore an aim of this IDA to follow an integrated approach for all these technologies that includes basic, applied research-oriented and industry-related actions. The amount of effort dedicated to each technology for research and development and demonstration projects will be matched to their developing maturity as they evolve during the timeframe of this programme. As a result, a strong focus is given on SOFC in line with its ability to be

exploited in both residential and industrial markets and the strength of the EU industrial base.

Fuel cells for Early markets

Given the key importance of early markets in preparing for the hydrogen economy, the programme focuses on several short term demonstrations, the development of fuel cell power modules and the creation of industrial capability.

Top priorities are to foster SME development, to stimulate early demand through buyers' pools and joint procurement schemes, and to ensure that local partnerships and regulatory measures are in place to sustain the deployment of early market fuel cell products.

On the technology front, a high priority is given to applied research on fuel cell stacks and components, to improve their performances and lower their costs through materials and manufacturing R&D while achieving overall simplification of these systems. A high priority is also given to volume manufacturing processes, system compactness, power electronics and control, and the use of alternative fuels.

Strategic Support Services

The implementation of this programme will require coordination with other initiatives on hydrogen and fuel cell technologies, with other technology platforms, and with regulations, codes and standards bodies at the national, regional, European and international levels. Support for regulatory activities (for example via ISO, IEC and UN/ECE) will be required to achieve EU-wide and global harmonisation of this emerging technology.

Such strategic activities span all four IDAs and may require close coordination at EU level. Because of their generic nature, they have not been allocated to specific IDAs. They could come under the responsibility of the JTI Programme Office or be managed through an inter-IDA organisation. This may also apply to safety and risk management, to harmonising procedures across the EU and globally, and to facilitating the design and consent for demonstration activities under this programme. Research in support of these activities, for example demonstrating that hydrogen bears no more risks than conventional fuels, will be addressed by the respective IDAs, with activities at both component and system levels.

A long-term investment in education and training in this area will be made at the EU level and activities on this front have been recommended [13]. Other strategic activities include public awareness and establishing and maintaining harmonised databases of techno-socio-economic data.

3.5.2 Overall resource requirements

The overall resources, presented in Table 3-9, required to achieve the goals specified in the Innovation and Development Actions of this programme amount to €7383 million for the next seven years.

[13] Preliminary estimate of the resources identified by the IP for education related actions is € 18M.

This total includes public and private contributions to activities that are carried out under joint public-private funding schemes at EU, national, regional and local levels such as the European 7th Framework Programme and a possible future JTI. It does not include activities carried out by private stakeholders without any public contribution. Funding of research organisations carrying out basic research is only included where it complements public funding.

During the 6th Framework Programme, the European Commission spent €300 million on hydrogen and fuel cell RTD & D activities, an average of €75 million per year. The overall budget for the 7th Framework Programme is substantially larger than for FP6. For example the indicative breakdown amount for Energy in the Cooperation theme is €2350 milllion, 40% more than in FP6. This increase is expected to translate into higher budgets for hydrogen and fuel cells as part of FP7 over the duration of the programme.

National budgets for this technology across Europe have been estimated by the HY-CO ERA-Net to amount to around €200 million per year, plus additional funds through recently announced Member States programmes such as that of Germany, which amounts to some €50 million per year for the coming 10 years. Regional funding in some Member states is significant, but is difficult to quantify because of differences in reporting from country to country.

It is estimated that public funding in this area may amount to €320-350 million per year across Europe. If this were to continue for the coming years, it would provide about €2.2 - 2.5 billion over the duration of the proposed programme. Complemented by the higher share of private budgets required for demonstrations and outlined below, this would imply that the proposed programme is a realisable proposition. But this "business as usual" scenario will not be able to meet the resources required to fully implement the proposed Programme.

It is often noted that the global automotive industry alone spends a large proportion of this figure (about €5 billion) per year on hydrogen and fuel cell technologies, whereas the International Partnership for the Hydrogen Economy (IPHE) cites global public funded RTD at $1 billion per year, about €770 million at February 2007 exchange rates. In addition, major European industries said in their joint declaration during the 3rd General Assembly of the HFP in October 2006 that industry is set to invest over €5 billion in the next 10 years in hydrogen and fuel cell technologies, including publicly funded projects[14]. The signatories to that declaration anticipate the level of industry investment to continue and probably increase well beyond 2016.

Two conclusions can be drawn from these estimates:

- The resources necessary to undertake the proposed programme for achieving the consensus goals of *"Snapshot 2020"* for Europe represent an achievable increase over current or already planned spending, from both public and private sources
- Funding at the European level has an important role to play in focusing the various sources of public funding on the joint acheivement of common goals. Without major contributions from Member states and regions it will not be possible to achieve the common goals set by this Implementation Plan

In terms of the resource distribution between the different applications targeted within this programme, a roughly equal share for transport and stationary applications is

[14] The declaration of the industrial stakeholders can be found at: https://www.hfpeurope.org/hfp/ga06-press-releases

proposed, with 36% and 39% of the resources respectively. These recommendations draw upon the recommendations of the DS Report 2005. These were: for road transport €1.5 billion, for industrial stationary fuel cells €1.56 billion and for residential fuel cells €740 million. Recognising the role of early and premium markets for deployment of hydrogen and fuel cell technologies and for building up industrial capacity, is recommended to allocate 15% of the resources to foster SME development and boost technological development in four main promising early and premium markets.

The second IDA accounts for 10% of the overall programme resources. Significant resources are dedicated to upstream and downstream research and development work to solving critical technological challenges. Their removal would raise the sustainability of hydrogen production pathways in the medium term and open up new production avenues for long term production and hydrogen transport. It should be noted that hydrogen refuelling infrastructure is an integral part of the first IDA. The outcomes of this second IDA are designed to be taken up within the large-scale demonstration activities proposed in other IDAs.

Table 3-9: Breakdown of the programme resources at the IDA level

		IDA 1	IDA 2	IDA 3	IDA 4	Total
	Programme resources in M€ (% within the programme)	2661 (36%)	759 (10%)	2853 (39%)	1110 (15%)	7383
Of which	*% R&D*	*30%*	*56%*	*25%*	*13%*	*28%*
	% Demonstration	*63%*	*38%*	*74%*	*72%*	*66%*
	% Supporting Activities	*7%*	*6%*	*1%*	*15%*	*6%*

This market-driven programme, with a focus on delivering *"Snapshot 2020,"* proposes that 66% of its resources support demonstration activities with two main goals - validating technologies under real market conditions and preparing for mass market deployment. Such a high share of funding for demonstration activities may be a novel use of Community budgets but it could be met through increased investments from other public sources and the private sector. Technology validation activities will be more predominant in the first half of this programme, while commercialisation preparation activities will grow in importance in the later phase of this programme. In line with these deployment efforts, support activities have a high profile with roughly 6% of the total resources. The importance of the remaining challenges facing fuel cell and hydrogen technologies is recognised by their 28% share for research and development activities.

3.6 Synergies

This programme addresses the development of hydrogen and fuel cell technologies for different markets and time horizons. An integrated and comprehensive approach has been adopted in the design of the programme to fulfill the needs of each IDA while capitalizing on the work performed on similar areas in other IDAs. These synergies are crucial to

- speeding up the learning process in different sectors, and ensure the interoperability

of industrial and energy infrastructure across the applications
- ensuring the development of a regulatory framework, support schemes and human capacity across all sectors
- fostering the exchange of industrial best practice and know-how, while creating opportunities and bolstering cooperation between stakeholders from all sectors
- streamlining the use of finite resources

A number of synergies have already been highlighted in the description of the different IDAs. These are summarised in this section and are categorised as technical and non-technical, or market enablers.

Synergies between market enablers are of particular importance in establishing a framework for the deployment of the technologies and for the development of the EU industry. This plan therefore suggests actions on cross-cutting issues such as strengthening and expanding the supplier base, with a special focus on SMEs, human capital build-up, the development of socio-economic strategic analyses modelling and decision-making tools, regulations codes and standards, public awareness, safety and recycling issues. These are included into the IDAs and referred to as supporting activities. Some elements of these though may be best organised and executed centrally, perhaps via the JTI programme office.

Topics have been assigned to a specific IDA by a lead application analogue approach. Thus the IDA that either had the highest level of existing know-how in the area (IDA 1 for recycling due to the End of Live Directive for Automobiles, for example) or the most pressing need (e.g IDA 4 for public procurement and buyer pools or SME financing) became the owner of the relevant action and its planned expenditure. But these actions are important for all IDAs. Safety is of key importance not only for transport but also for stationary applications and hydrogen refuelling. Table 3-10 summarises the main cross-cutting issues dealt with in this plan.

Table 3-10: Summary of cross-cutting issues

Action focus	Details	Action number
Solving the people capacity bottleneck for growth	post-graduate and professional development training, development of an EU network of graduate courses, EU wide national curriculum integration programme for H_2 & FC	IDA1: 33, Strategic Support Services
Developing and Implementing Harmonised RCS	development of a coordinated EU Strategy towards RCS, sectoral RCS developments	IDA1: 34-39, IDA3 - 8, IDA4 – 44
Socio-economic modelling and tools	harmonised and integrated database, market analysis, Planning tools, initiating the European H_2 & FC Business Observatory	IDA2: 18-23, IDA4 – 45
Stimulating and Meeting Early Demand	financial schemes for building production volumes, public awareness, support buyers' pools, role of regions and public private partnerships, public procurement and incitivised product price	IDA1: 40-41, IDA4: 42-43, IDA3 - 9
Developing a healthy European scene for Hydrogen and Fuel Cells	financial options for start-ups, SMEs, SMEs promotion, research and Academia primed for spin-off, outreach and involvement programme for SMEs	IDA4: 39-41. IDA1 - 32
Recycling	develop recycling technologies, regulatory framework, demonstration recycling plant	IDA1: 42-44

Advancing hydrogen and fuel cell technologies to the market will require important developments in materials, manufacturing techniques, components, energy and industrial infrastructures. Although the requirements can differ from one technology to another or one application to another, integrated research, development and demonstration can be of great value and effectiveness.

Synergies between IDA 3 as the lead application for SOFC and MCFC developments and IDA 1 and 4 show how outcomes from actions on stationary fuel cells will feed into system integration on APU for all transport modes, and support early-market portable generators, UPS and backup power application developments. Actions on PEM and fuel cell component development in IDA 1, such as those targeting road applications, and cross-technology research and development actions in IDA 3, are another example of this approach.

Table 3-11 summarises the potential synergies between different IDAs.

Table 3-11: Fields of potential technological synergies between IDAs

	IDA 1	IDA 2	IDA 3	IDA 4
IDA 1		•Off/on board hydrogen storage •Fuel processing •Refuelling stations/ fleet vehicles	• SOFC • PEMFC • MCFC • Manufacturing • Fuel processing • System and components developments	• SOFC, • PEMFC, • MCFC • Manufacturing • Fuel processing • System and components developments
IDA 2			• SOFC, HT Electrolysers	• H_2 by product
IDA 3				• SOFC, • PEMFC, • MCFC • Manufacturing • Fuel processing • System and components developments
IDA 4				

In recent years, a number of European technology platforms (ETPs) have been established in various industrial fields. Several have a direct link or influence on the hydrogen and fuel cell programmes. It is chosen to draw on the work of these platforms, rather than competing for scarce investment resources. For instance, Carbon Capture and Storage is expected to be addressed within other programmes to be proposed by the Zero Emission Fossil Fuels Power Plants Technology Platform (ZEP). ZEP and HF are obvious potential partners on developing and deploying CCS technologies for hydrogen production. Possible engagements with other technology platforms include work with BIOFRAC for synergies between BTH and Biofuels pathways, SUSCHEM (sustainable chemistry) for material developments and MANUFUTURE on manufacturing and process engineering issues[15].

[15] http://cordis.europa.eu/technology-platforms/home_en.html

Following the same approach, a number of “transition technologies” towards hydrogen and fuel cells have been identified, such as hybrid electric cars and combustion engines for stationary applications. They can help support early market introduction of hydrogen and fuel cell technologies. There are no specific actions related to these in the programme but due to their importance it is recommended that they be addressed by other RD&D programmes.

Finally, this technology could have both civil and defense applications. There are possibilities for cooperation and joint development activities including developments led by defence applications. Procurement opportunities should be explored and encouraged with other European entities, such as the European Defense Agency.

3.7 Managerial aspects

It is recommended that the planning of this programme should be flexible enough to allow for technological breakthroughs and other changes in the overall environment as they arise along the 7-10 years of the programme’s lifespan. As noted before this programme is structured around two phases, the earlier dedicated primarily to R&D and early markets, and the later focused mainly on validating and demonstrating the results of the R&D work. The outcomes of the technology validation and demonstration will feed into a new phase of R&D that will address the remaining critical challenges for commercialisation and pursue new pathways for breakthroughs. Therefore, after the first phase of the programme, the approach to overcoming the technological obstacles has to be critically reviewed for each IDA.

In particular, a review of the outcomes from the research, demonstration and development carried out during the first phase of the programme is recommended. It may lead to adjustments to the balance of effort currently proposed for the second phase, affecting whether more R&D or more demonstration is needed to ensure the commercialisation of these technologies.

It should be noted that the distinction between RTD and demonstration is neither strict nor clear-cut. The more applied a research activity is, the more it can be regarded as a demonstration. Indeed, one goal of demonstration projects is to show the viability of a technology at an appropriate scale. This might begin with first generation prototypes or single pilot validation testing and move on to light-house projects, to satisfy independent evaluation and potential end-users prior to commercialisation.

Given that the programme is driven by the market principle, it is unavoidable that its details may change as circumstances change. To ensure this, the portfolio of RTD and demonstration activities within each action should be managed in the context of the market targets. There should be continuous feedback between RTD and demonstration, as depicted in Figure 12 below. R&D milestones will measure progress towards the demonstration phase, which in turn may lead to decisions on commercialisation. A variety of approaches will be developed by the stakeholders to overcome technological challenges, and a diverse range of products will be designed in line with different companies’ corporate strategies. Detailed interim milestones at the project level should be defined as part of the management of the programme. This level of management will also allow the synergies described in section 3.6 to be best dealt with. Table 3-11 may serve as a management tool in this respect.

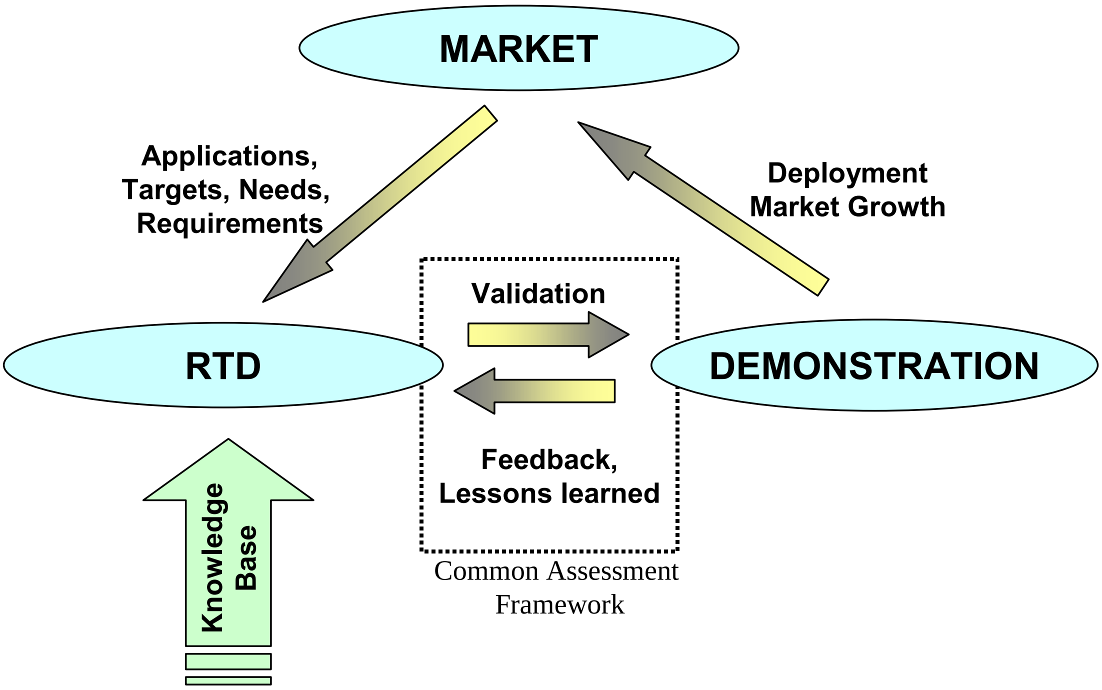


Figure 12. Schematic of programme interactions between RTD, Demonstration and Market.

Finally, special attention should be paid to SMEs as critical players in the EU fuel cell supply chain. It is crucial to ensure their participation in demonstration activities as well as to support them in finding access to national, regional and EU funding. Specific schemes should be devised to account for these issues, such as simplified procedures backed up by training initiatives, and collaborative mechanisms for participation.

Innovative financial instruments, such as the European Investment Bank's Risk Sharing Finance Facility (RSFF), and similar product developments currently under way, are also expected to play a role in building up the European hydrogen and fuel cell industry.

4 Joint Technology Initiative

A strongly rooted and long-term public private partnership on hydrogen and fuel cell technologies is needed:

- to accelerate the transition towards a sustainable energy economy and ensure Europe will take a leading role in global energy technology development
- to leverage efforts to make sure technology will progress rapidly
- to set the framework for coherent research and deployment activities with clear commercialisation targets, and avoid fragmentation of investment

A Joint Technology Initiative (JTI) is foreseen as an industrially led RTD & Demonstration programme carried out by a public-private partnership to address these needs. Its scope is to deliver robust hydrogen and fuel cell technologies to the point of commercial takeoff in 2010 for early market applications, in 2015 for stationary applications, and mass market roll-out by 2020 for transport applications. This will significantly enhance Europe's competitiveness and in the longer term address Europe’s energy policy drivers. Priorities within the JTI activities should reflect these collective public benefits. The formal aspects of a JTI such as its legal structure and governance are under consideration among the stakeholders of the HFP.

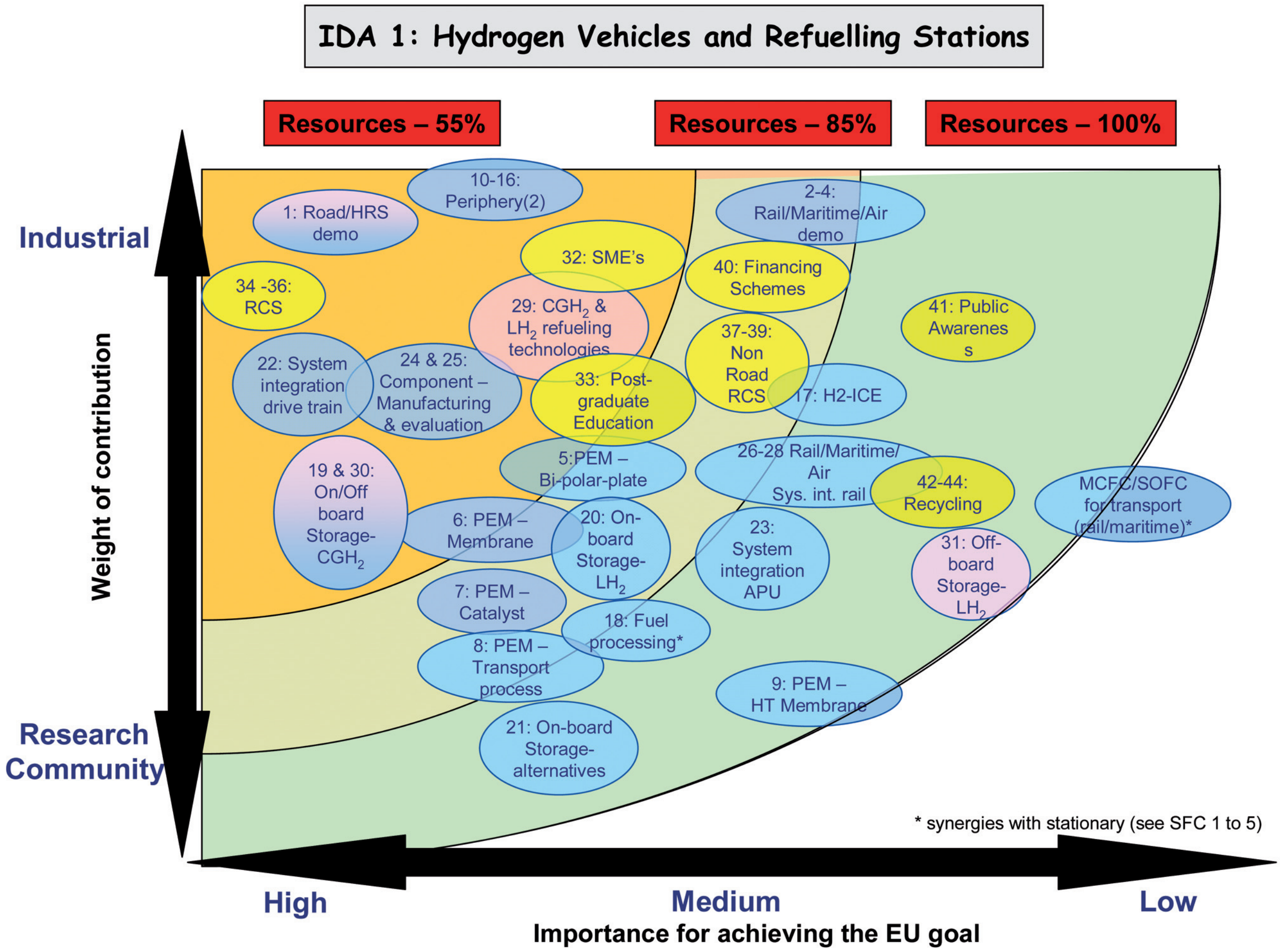
The task of this Implementation Plan is to recommend the portfolio of integrated RTD & D actions and market enabling activities that are needed at European level to realise “*Snapshot 2020.*” This includes the core contents of the proposed JTI as well as upstream research needs as appropriate.

It is broadly understood that the overall programme described in this Implementation Plan should be structured into JTI activities focused on market and product-specific needs, and on research which can provide new ideas and concepts to improve hydrogen and fuel cell technology in parallel to its deployment and commercialisation.

In general, the activities carried out through the JTI will be market-driven with a time focus on 2015 - 2020, encompassing applied R&D and demonstration, accompanied by market preparatory activities. They should be focused on the basis of the four IDAs described in the document. It will be crucial to build upon synergies between these areas and to implement appropriate processes to realise them.

Figure 13 will be utilised to elaborate a possible scenario for including actions from IDA 1 in the JTI. It is based on meeting the EU’s goals, on possible contributions by the different stakeholder groups as discussed in section 2.2, on the availability of resources, and on the public and or private interest in pursuing specific goals.

Figure 13: Available resources on the JTI programme against the IDA 1 prioritised actions



As noted in section 2.2, there is a crucial need to implement the high-priority actions by an integrated activity at the EU level. These actions are prime candidates for JTI activities. A strong alignment of national and regional programmes with the JTI portfolio is also important in resource allocation for this activity. The required integration can take several forms. It is proposed to concentrate the core content of the JTI on these actions if 55% of the necessary resources for undertaking IDA 1 become available. As the availability of resources increases, say to 85%, upstream research activities of medium priority could be considered for the JTI, as noted in Figure 13. Then the JTI could act as a vehicle for enhancing cooperation at the EU level, linking to projects under the Framework programme and other initiatives. This would ensure an interface between hydrogen and fuel cell programmes within and beyond the remit of the JTI in the Member States and European Regions.

The resources available to the JTI will depend on the partnership between industry and the research community and their respective will and commitment to carry forward the proposed actions and to pursue specific applications. Hence, the JTI's portfolio of actions, delimited by the available resources waves, is very likely to deviate from the symmetrical shape depicted for illustrative purposes in Figure 13.

GLOSSARY

Definitions and nomenclature used in the Implementation Plan

Basic research	*Research activities addressing basic scientific fundamentals related to critical barriers that can hinder technology commercialisation and deployment in the medium term, and open up new pathways for technology and manufacturing improvements in the long run.*
Applied R&D	*Research activities that directly support the development, operation and commercialisation of products within the duration of the programme.*
Demonstration	*Development activity for a given technology and/or infrastructure comprising:* *1) a validation/field testing phase of prototype/pilot systems including feedback for RTD, proof of safety, endurance testing under real-life conditions.* *2) a market preparation phase aiming at infrastructure development and expansion, customer acceptance and regulations development, economic assessment – capital investment, O&M costs for commercial deployment.*
Pilot/Prototype systems	*Systems in an early stage of integration and optimisation, built for field testing and pre-commercialisation qualification and which include all the basic technical characteristics and performances of the planned commercial product.*
Market introduction	*First step for introducing a new system on the market. This step follows the demonstration development phase and lies ahead of a potential deployment.*
Deployment	*Development phase for a given technology and/or infrastructure from its market introduction to its widespread use.*
Roll-out	*Market penetration and volume growth with time.*
Niche markets	*A small area of trade within the economy, often involving specialised products. Markets of limited sizes concerned with specific applications for a given product.*
Early Markets	*Short-term markets encompassing a group of applications for which products can be commercially deployed within the 2007-2013 timeframe.*
Innovation and Deployment Action	*A programmatic cluster targeting a specific objective of the programme and encompassing a set of relevant technologies and market enablers along with the actions to achieve it.*
Implementable Action	*A set of activities (R&D and or Demonstration etc.) within an Innovation and Deployment Action targeting specific technologies and market enablers with the goal of developing and/or implementing these systems to the level required to meet the objective assigned to the relevant action cluster.*
Lead application concept	*An integrated programmatic approach developed in this programme to capitalise on technological and/or market enabling related synergies between different applications.* *Under this concept at the technology level, technology developments on specific components which can be used by several applications target applications whose market requirements are the most technically and economically challenging and/or are representative of a set of applications. Additional developments to tailor these technologies to other applications' requirements are accounted for within this programme in activities related to system integration. For supporting activities, actions are led by applications that either have the highest level of already existing know-how in the area or the most pressing need.*
Cost	*Total cost of a product covering labour, overheads, materials, manufacture, marketing, transport and installation, setting to work and warranty.*
Price	*The purchase cost of a product to the customer (it usually but not always covers costs as defined above and incorporates a profit margin).*

Acronyms and Abbreviations:

APU	Auxiliary power unit
AC	Advisory Council of the HFP
BTL	Biomass to Hydrogen (Fischer-Tropsch fuel from biomass)
CGH2	Compressed gaseous hydrogen
CHP	Combined heat and power (generation)
CTH	Coal-to-Hydrogen (Fischer-tropsch fuel from coal)
CCS	CO_2 capture and storage
DoE	US Department of Energy
DS	Deployment Strategy
FP6	6^{th} Research and Development Framework Program of the European Union (2002-2006)
FP7	7^{th} Research and Development Framework Program of the European Union (2007-2013)
GHG	Greenhouse gas (emissions)
HFP	European Hydrogen and Fuel Cell Technology Platform
HLG	High Level Group
HY-CO ERA-NET	ERA-NET project aiming at the coordination of European national and regional R&D programmes in the field of hydrogen and fuel cells
ICE	Internal Combustion engine
IDA	Innovation and Deployment Action
IEC	International Electrotechnical Commission
IP	Implementation Panel
IPHE	International partnership on the hydrogen economy
ISO	International organisation for standardisation
JTI	Joint Technology Initiative, a public private partnership within the FP7
MCFC	Molten carbonate fuel cells
MS MG	Member States' Mirror Group
OEM	Original Equipment Manufacturer. OEM refers to a company that acquires a product or component and reuses or incorporates it into its own range of products
PEMFC	Proton exchange membrane fuel cells
Pox	Partial oxidation
RCS	Regulations, codes and standards
SME	Small and medium enterprises
SMR	Steam methane reforming
SOFC	Solid Oxide fuel cells
SRA	Strategic Research Agenda
UN/ECE	United Nations Economic Commission for Europe
UPS	Uninterruptable power supply

5 FIGURES

6 TABLES

7 Annex 1: Innovation and Development Actions at a glance

7.1 IDA 1: Hydrogen Vehicles and Refuelling Stations

7.1.1 Targets

Main targets: Road propulsion FC system		
Characteristics	***Units***	***2015 Target***
Efficiency (NEDC)	(%)	> 40
Specific cost	(€/kW)	100
Lifetime	(hr)	
Passenger Car		5 000
Bus		10 000

Main targets: Road APU FC system		
Characteristics	***Units***	***2015 Target***
Efficiency (P_{max})	(%)	35
Specific cost	(€/kW)	<500
Lifetime	(hr)	
Passenger Car		5 000
Heavy Good Vehicles		40 000

Main targets: ICE propulsion		
Characteristics	***Units***	***2015 Target***
Efficiency (best value)	(%)	40
Passenger car		>> 26
Bus		42
Specific cost	(€/kW)	18
Passenger car		
Bus		1.5 more than Diesel
Lifetime		
Bus		25 000 – 30 000

Main targets: Air fuel cell power unit with reformer		
Characteristics	***Units***	***2015 Target***
Efficiency (full load incl. head and power)	(% LHV)	> 60
Specific cost	(€/kW)	500
Lifetime	(hrs)	~ 30 000

Main targets: Maritime fuel cell power unit		
Characteristics	***Units***	***2013 Target***
Efficiency (full load)	(%)	> 55
Specific cost	(€/kW)	< 1 000
Lifetime	(hrs)	50 000

Main targets: Rail fuel cell propulsion and power unit (PEM)		
Characteristics	***Units***	***2015 Target***
Efficiency (full load)	(%)	> 45
Specific cost	(€/kW)	500
Lifetime	(hr)	50 000

Main targets: Hydrogen refuelling technologies			
Characteristics	***Units***	***2020 Target***	
		2015	2020
Hydrogen production and distribution cost	Reduction factor on current cost		3
Cost of hydrogen delivery at the pump (centralized and decentralised) (excl. taxes)	(€/kg)		< 2.5

Market Enablers targets		
Characteristics	***Indicator***	***2020 Target***
Trained staff	* 1000 people	X
Regulations, Codes & Standards and Safety issues		In place
Industrial capacity		
Production capacity	Vehicles/year	400 000
Industry involvement issue		SMEs' involvement

7.1.2 Portfolio of actions

Action type	Action number		Action focus	Details: Phase I (2006-2010)	Details: Phase II (2010-2015)	Refuelling technologies	Road	Air	Maritime	Rail	Supporting Activities
						Resources in M€					
Large scale DE	1	Road vehicles-supply infrastructure	Passenger cars (ICE/FC - APUs) Captive fleets e.g. buses (ICE/FC - APUs) Refuelling stations	3 main sites (eg. 50 vehicles/site) 10 mains sites - 5 vehicles per site 3 main sites (eg. 9 refuelling stations)	5-10 main sites (300 vehicles/site) 20 sites larger fleets Expansion	150	1005				
	2	Air	Emergency unit (H2/O2 with PEM), FC Power Unit (PEM/SOFC) with reformer	Ground demonstration	Flying test bed			101			
	3	Maritime	MCFC/SOFC system APU, Propulsion - Phase II, (PEMFC optional for short range operation)	2-4 demo. projects@ 250+ kW power - 1 ship per proj.	5-15 demo projects @500 + kW power - 1 or more ship per proj.				201		
	4	Rail	PEMFC-based propulsion	3 sites (1 vehicle/site)	- Phase II (2010-2015): 7-10 sites 1-2 vehicles/site					210	
R&D Transport											
BR+AR	5	PEMFC	Bi-polar plate	bi-polar-plate: low cost materials, higher conductivity and durability			203	13	35	15	
	6		Membrane	longer lifetime, water management and lower costs							
	7		Catalyst	noble metal, activity, sensitivity (-> reformate gas) and costs							
	8		Transport process	water transport processes in porous media							
	9		HT membrane	proton conductivity, temperature range, water uptake							
AR	10	Periphery	Air supply	air supply, high speed electric motor, compressor design			64	6	9	5	
	11		Valves/ piping	valves and pipes: material, design, safety							
	12		E-drive	reduced friction and improved durability, compact specific drive train							
	13		HV battery	HV battery: electrode and electrolyte, production process							
	14		H_2 loop	humidification and hydrogen feeding/ recirculation							
	15		Power electronic	power electric: thermal management, material, efficiency							
	16		Cooling	cooling system: design, material, costs							
AR	17	ICE	H2 ICE	injection, lubrication, exhaust after-treatment, combustion process			30	1	1		
BR+AR	18	Fuel processing	Fuel processing	catalyst, temperature, stability, costs, membrane, purification			40	12	15		
BR+AR	19	Storage	CGH_2	fibres, coating, manufacturing, safety			69	7	25	6	
	20		LH_2	out-gasing, safety, insulation materials							
	21		Alternatives	solid, hybrid							
AR	22	System integration	Drive train	operating strategy (e.g. hybridisation), packaging			89	9	15	8	
	23		APU								
	24		Component manufacturing	improved manufacturing process, automated assembly							
	25		Component evaluation	test procedures							
	26		Air	flight envelope							
	27		Rail	shock & vibration							
	28		Maritime	shock/slamming loads, atmosphere contamination, salinity							

Portofolio of actions (continued)

Action type	Action number		Action focus	Details	Refuelling technologies	Road	Air	Maritime	Rail	Supporting Activities
				R&D H2 Supply						
AR+DE	29	HRS&Components	Improved performance of CGH_2 & LH_2 refueling technologies	refuelling procedures, nozzles, LH_2 & CH_2 flow metering	20					
BR+AR	30	H2 Storage	Improved high pressure gaseous H_2 storage for transport applications	liners, fibres, coating, safety, Standardise 700 bar H2 dispensers and nozzles for rapid refuelling, sensors, flow meter	60					
BR+AR	31		Improved Liquid H_2 storage	H_2 liquefaction and active cooling (Magnetic refrigeration ect.) , insulation materials, gas boil-off, sensors, filling procedure, safety, LH_2 station scaling down	60					
				Supporting activities						
	32	SME's support schemes	From research to market - Developing a healthy European scene for H2 and Fuel Cells	outreach and involvement programme for SME's (Supporting and fostering SME's involvement)						38
	33	Human capital	Engineering the excitement - solving the people capacity bottleneck for growth	Assessment of post graduate and professional development training needs						3
	34	RCS	Creating Peace of Mind - Developing and Implementaing Harmonised Regulations, Codes and Standards	development of a coordinated European Strategy towards RCS						9
	35			supporting the relevant directive initiatives						9
	36			road vehicle logistics						9
	37			aerospace RCS Development						9
	38			maritime Transport RCS Development						9
	39			rail transport RCS development						9
	40	Early demand support	Building the Market - Stimulating and Meeting Early Demand	develop financing schemes for building the production volumes to meet demonstration, lighthouse project and early market deployment						17
	41			develop a comprehensive Public Awareness Plan						21
	42	Recycling		develop recycling technologies (optimum recycling methods/processes						10
	43			develop recycling regulatory framework (e.g. toxicity issues, legal						6
	44			Demonstration recycling plant						30

7.1.3 Timelines

Action number	Action focus		T0 (2007) – T0 + 3 (2010)	T0 + 4 (2011) – T0 + 7 (2015)
			PHASE I	PHASE II
1	Road vehicles			
	supply infrastructure			
2	Air			
3	Maritime			
4	Rail			
			PHASE I	PHASE II
5	PEMFC	Bi-polar plate		
6		Membrane		
7		Catalyst		
8		Transport process		
9		HT membrane		
10	Periphery	Air supply		
11		Valves/ piping		
12		E-drive		
13		HV battery		
14		H_2 loop		
15		Power electronic		
16		Cooling		
17	ICE	H_2 ICE		
18	Fuel processing	Fuel processing		
19	Storage	CH_2		
20		LH_2		
21		Alternatives		
22	System integration	Drive train		
23		APU		
24		Component manufacturing		
25		Component evaluation		
26		Air		
27		Rail		
28		Maritime		
			PHASE I	PHASE II
29	HRS&Components	Improved performance of CGH_2 & LH_2 refueling technologies		
30	H_2 Storage	Improved high pressure gaseous H_2 storage for transport applications		
31		Improved Liquid H_2 storage		
			PHASE I	PHASE II
32	SME's support schemes	From research to market - Developing a healthy European scene for H2 and Fuel Cells		
33	Human capital	Engineering the excitement - solving the people capacity bottleneck for growth		
34-39	RCS	Creating Peace of Mind - Developing and Implementaing Harmonised Regulations, Codes and Standards		
40-41	Early demand support	Building the Market - Stimulating and Meeting Early Demand		
42-44	Recycling			

7.2 IDA 2: Sustainable Hydrogen Production and Supply

7.2.1 Targets

7.2.1.1 Hydrogen production technologies

Medium term portfolio

Main targets for LT electrolysers		
Characteristics	***Units***	***2015 Target***
Energy efficiency (LHV basis)	(%)	> 70
Current density	(A/cm^2)	1
Cost of modular system	(€/Nm^3)	1 000
System availability	(%)	> 99
New design efficient/high pressure module		**2012 target**
Production flow rate	(Nm^3/hr)	Several hundreds
Operating pressure	(MPa)	3 to 5
PEM electrolyser		
Production flowrate	(Nm^3/hr)	100
Lifetime	(hr)	40 000

Main targets for BTH standalone pyrolisis/gasification units		
Characteristics	***Units***	***2015 Target***
Hydrogen production cost	(€/kg)	< 3

Main targets for BTH co-gasification (large scale IGCC)		
Characteristics	***Units***	***2015 Target***
Hydrogen production cost	(€/kg)	1.2
Biomass feedstock cost	(€/GJ)	3

Long term technology portfolio

Main targets for HT thermo-electrical-chemical processes with solar/nuclear heat sources		
Characteristics	***Units***	***2015 Target***
Hydrogen production cost	(€/kg)	< 2
Reduction of CO_2 emissions for fossil reforming	(%)	> 25
Hydrogen from biomass – mass efficiency	(%)	> 40

Main targets for LT temperature processes: photo-electrolysis and photobiological / fermentation		
Characteristics	***Units***	***2015 Target***
Photoelectrolysis		
Proved efficiency vs PV + electrolysis system	(%)	> 25
Lifetime	(hr)	> 5 000
Hydrogen production cost	(€/kg)	< 5
Photobiological		
Conversion efficiency	(%)	10

Main targets for hydrogen by dark fermentation		
Characteristics	Units	2015 Target
Molar efficiency of sugar to H_2 conversion (under stable conversion processes)	(Mol H_2/mol sugar)	> 3 to 4

7.2.1.2 Delivery technologies

Main targets for refuelling station (CGH_2 & LH_2)		
Characteristics	***Units***	***2015 Target***
Multiple consecutive refuellings	(Nbr per hr per dispenser)	10
Pressure (CGH_2)	(Bar)	700
Filling time	(min)	3
On-site production and trucked-in hydrogen	(kg/H_2 per station per day)	150
		2020 target
On-site production and trucked-in hydrogen	(kg/H_2 per station per day)	300

Main targets for off-board hydrogen storage			
Type of H_2 storage	H_2 tank system density by volume (kWh/l) *present*	H_2 tank system density by weight (%) *present*	H_2 tank system density by weight (%) *2015*
Liquid H_2	1.2	6	12
Compressed gaseous 700 bar	1.3	4	9
Metal hydrides (AB_2, AB_5)	1.8	1.5	2
Complex Metal hydrides (alanates)	0.7	1.8	4.5
Chemical hydrides (boro-amino hydrides, and organic liquids)*	1.4	6	9
Activated carbons, nanoporous materials	0.2	1	2

7.2.2 Portfolio of actions

Action type	Action number		Action focus	Details	Medium Term Technologies	Long term Technologies	Supporting Activities
					Resources in M€		
Sustainable H_2 production and supply							
BR+AR+DE	1	Reforming/POx/CTH	Develop Fuel Processing Catalyst with reduced cost, improved durability, flexible fuel capability	multi-metal catalysts, catalyst supports, porosity or channel scale	80		
ARDE	2		Gas Purification	HT membrane for WGShift, Reversible adsorption materials for PSA/TSA, Hybrid membrane/PSA	21		
BR+AR+DE	3	Electrolysis	Development of low cost/efficient low temperature electrolyser	Efficency and stability of electrodes, diaphragm materials, Increase operating pressure, durability and Lifetime, component reliability, Manufacturing technologies, System integration with RES	100		
BR+AR	4	Biomass to Hydrogen	R&D of advanced technologies for BTH thermal conversion process	Heat transfer technologies, pyrolisis heat carriers, ash removal, Syngas clean up, membrane catalytic reformer/shift reactor, non cryogenic air separation	10		
DE	5		Demonstration of BTH conversion based on stand alone pyrolisis/gasification units	Stand-alone demo systems from 1 to 10 MW_{th} biomass input by 2015, biomass supply chain	32		
DE	6		Demonstration of BTH conversion based on co-gasification with coal & fossil fuels	Prototype stream application of 10 MWth biomass input in large scale coal fed oxygen blown gasifier, Biomass supply chain	32		
AR+DE	7	HRS&Components	Underground H_2 storage and/or production	Underground storage, production on-site installation (codes & standards), Compactness	10		
AR	8		H_2 Odorization	Safety, odorization	5		
AR + DE	9	H_2 Liquefaction	Development of large scale H_2 Liquefaction units & processes	large scale plant design, usage planning (location, Construction logistics), Component/subsystem level development	90		
BR+AR	10	Electrolysis	Development of a new generation of High temperature electrolyser	New electrode materials, high current density cell design . ageing, protonic conducting material, architecture prototype and system, manufacturing cost decrease, Demo sytems coupling with elect. and heat(solar/nuclear) sources up to 1 MW		110	
BR+AR+DE	11	Advanced Technologies	R&D programme & experimental platform on decomposition of water through thermo-electrical-chemical processes with solar/nuclear heat sources	Multi-disciplinary research coordination, R&D infrastructure at 1MW level (Heat exchanger, HT solar thermal sources, material component testing), Component system development (Heat exchangers, chemical loop, heat media), Demo HT electrolysis (1MW) + coupling heat/electricity source		60	
BR+AR	12		Basic research programme on low temperature processes: photoelectrolysis and photobiological / fermentation	High efficiency/long life photoelectrode (PEC), photo/dark fermention processes, PEC & Bioreactor protoype design and building		25	
BR	13		Photodriven bio-hydrogen	H_2 yield, Efficiency of light conversion, New efficient (small footprint) photobioreactors		6	
BR+AR	14		Hydrogen by dark fermentation	Sugar into H_2 conversion efficiency, bio-electric systems, biomass pre-treatment, raw material flexibility processes		5	
BR+AR	15	H_2 Storage	Improved solid H_2 storage for portable, stationary & potentially transport applications	materials, cyclability, safety, recycling, solid storage tank design, hybrid tank concepts,		100	
AR+DE	16	Pipelines	H_2 Pipeline Field Test Facility	Pressurised H_2 pipelines: materials, components (valves, compressors…), diagnostic tools		20	
AR+DE	17		H_2 Pipeline Risk & Safety Analysis	modeling, demonstration		5	
Supporting activities							
	18	Getting the numbers right	Socio-economics modelling and Tools	Create Harmonised and Integrated Databases			8
	19			Analyse portable, light vehicles and stationary applications			8
	20			identify regulatory driven market demand: Functional synergies and planning of integration of renewable energy systems together with hydrogen and fuel cell infrastructures.			8
	21			Create and regularly update robust pathway planning tools			8
	22			Develop a European Masterplan			8
	23			Role of hydrogen in sustainable energy systems			10

7.2.3 Timelines

Action number		Action focus	T0 (2007)	T0 + 3 (2010)	T0 + 4 (2011)	T0 + 7 (2015)	T0 + 13 (2020)	T0 + 18 (2025)
			PHASE I		PHASE II			
1	Reforming/POx/CTH	Develop Fuel Processing Catalyst with reduced cost, improved durability, flexible fuel capability						
2		Gas Purification						
3	Electrolysis	Development of low cost/efficient low temperature electrolyser						
4	Biomass to Hydrogen	R&D of advanced technologies for BTH thermal conversion process						
5		Demonstration of BTH conversion based on standalone pyrolisis/gasification units						
6		Demonstration of BTH conversion based on co-gasification with coal & fossil fuels						
7	HRS&Components	Underground H_2 storage and/or production						
8		H_2 Odorization						
9	H_2 Liquefaction	Development of large scale H_2 Liquefaction units & processes						
			PHASE I		PHASE II	PHASE III		
10	Electrolysis	Development of a new generation of High temperature electrolyser						
11	Advanced Technologies	R&D programme & experimental platform on decomposition of water through thermo-electrical-chemical processes with solar/nuclear heat sources						
12		Basic research programme on low temperature processes: photoelectrolysis and photobiological / fermentation						
13		Photodriven bio-hydrogen						
14		Hydrogen by dark fermentation						
15	H_2 Storage	Improved solid H_2 storage for portable, stationary & potentially transport applications						
16	Pipelines	H_2 Pipeline Field Test Facility						
17		H_2 Pipeline Risk & Safety Analysis						
			PHASE I		PHASE II			
18-23	Getting the numbers right	Socio-economics modelling and Tools						

7.3 IDA 3: Fuel Cells for CHP and Power Generation

7.3.1 Targets

	Early field tests	Demonstration	Lighthouse and deployment
Stationary applications 1 –10 kW (residential			
Timeframe	2006 – 2008	2007 – 2010	2009 – 2012
Electrical efficiency @ BOL, including DC/AC conversion [--]	30-40%	32-40%	34-40%
Total fuel efficiency BOL; @ best point [--]	> 70%	75%	80%
System cost [€/kW]	20,000	10,000	6,000
Stack durability (90 % BOL performance) [h]	5000	8000	>12 000
Number of low-temperature start-ups from 15 °C [1/a]	20	35	50
Stationary applications ≥100 kW (community/industrial)			
Timeframe	2006 – 2008	2007 – 2010	2009 – 2012
Electrical efficiency @ BOL, including DC/AC conversion [--]	45%	50%	50%
Total fuel efficiency BOL; @ best point [--]	80%	85%	90%
System cost [€/kW]	8-12,000	3,000-8000	1,500-5,000
(90% BOL performance h)	10-20,000	15-30,000	>30,000

7.3.2 Portfolio of actions

Action type	Action number	Action focus	Details	SOFC	PEMFC	MCFC	Deployment residential	Deployment Industry	Supporting activities
				Resources in M€					
			R&D						
BR	1	Generic Fuel Cell Technology	Materials, layers & components for cells and stacks based on industrially relevant raw materials; Industrially relevant manufacturing and testing methods and testing standards	30	10	10			
BR	2	Analysis and Modelling	Characterisation methods for cells and stack analysis; industrially relevant online testing methods and testing standards; microstructural-, materials engineering-, electrochemical-, degradation- and loss-of-performance models	20	20	20			
AR	3	Industrially relevant cell and stack	Cell and stack robustness, large size cells and stacks, cost effective raw materials, industrially viable manufacturing methods, standardisation of cells and stacks	100	60	40			
AR	4	System component development	System components (valves, sensors, blowers, heat exchangers, power electronics etc.), system models, subsystems (gas cleaning, reformer, humidifier, control units, etc.), system integration and validation	200	120	80			
			Demonstration						
DE	5	Scaling-up of Manufacturing	Low cost, automated manufacturing with on-line quality assurance procedures, standardisation of quality, safety, performance measurements; development of critical systems components	30	30	30			
DE	6	Technology validation	System components, FC systems, Prototype manufacturing				132	415	
DE	7	Market entry	Definition and selection of field test sites and conditions, field test infrastructure, Operation & service,				800	680	
			Supporting activities						
	8	Creating Peace of Mind - Developing and Implementaing Harmonised Regulations, Codes and Standards	Grid-Interconnect RCS						9
	9	Building the Market - Stimulating and Meeting Early Demand	Develop schemes for public procurement and degressive incentivised product price for the output						17

7.3.3 Timelines

Action number	Action focus			T0 (2007) – T0 + 3 (2010)	T0 + 4 (2011) – T0 + 7 (2015)
				PHASE I	PHASE II
1	Generic Fuel Cell Technology		SOFC		
			PEMFC		
			MCFC		
2	Analysis and Modelling		SOFC		
			PEMFC		
			MCFC		
3	Industrially relevant cell and stack		SOFC		
			PEMFC		
			MCFC		
4	System component development		SOFC		
			PEMFC		
			MCFC		
				PHASE I	PHASE II
5	Scaling-up of Manufacturing		SOFC		
			PEMFC		
			MCFC		
6	Technology validation	Residential	SOFC		
			PEMFC		
		Industrial	SOFC		
			MCFC		
7	Market entry	Residential	SOFC		
			PEMFC		
		Industrial	SOFC		
			MCFC		
				PHASE I	PHASE II
8	Creating Peace of Mind - Developing and Implementaing Harmonised Regulations, Codes and Standards				
9	Building the Market - Stimulating and Meeting Early Demand				

7.4 IDA 4: Fuel Cells for Early Markets

7.4.1 Targets

Main targets: Micro-Fuel Cells: Low-power system consumer electronic device		
Characteristics	***Units***	***2015 Target***
Energy density	(Wh/l)	500–1,000
Specific energy (preliminary, tbc)	(Wh/kg)	150–200
Volumetric power density	(W/l)	80–150
Gravimetric power density	(W/kg)	80–200
Lifetime	(hr)	1 000 to 5 000
Cost	(€/W)	3 – 5
Operating temperature range (preliminary, tbc)	(oC)	-20 to 60
Start-up time (hybridised)		Instant
Additional target		
Establish distribution channels for fuel containers, inc. regulatory approval Military standards, ruggedised, no signature, light weight		

Main targets: By-product Hydrogen Power Generation		
Characteristics	***Units***	***2015 Target***
Electrical efficiency	(%)	45 - 55
Cost (at production volume)	(€/kWe)	< 1 500
Stack Lifetime	hrs	> 40 000

7.4.2 Portfolio of actions

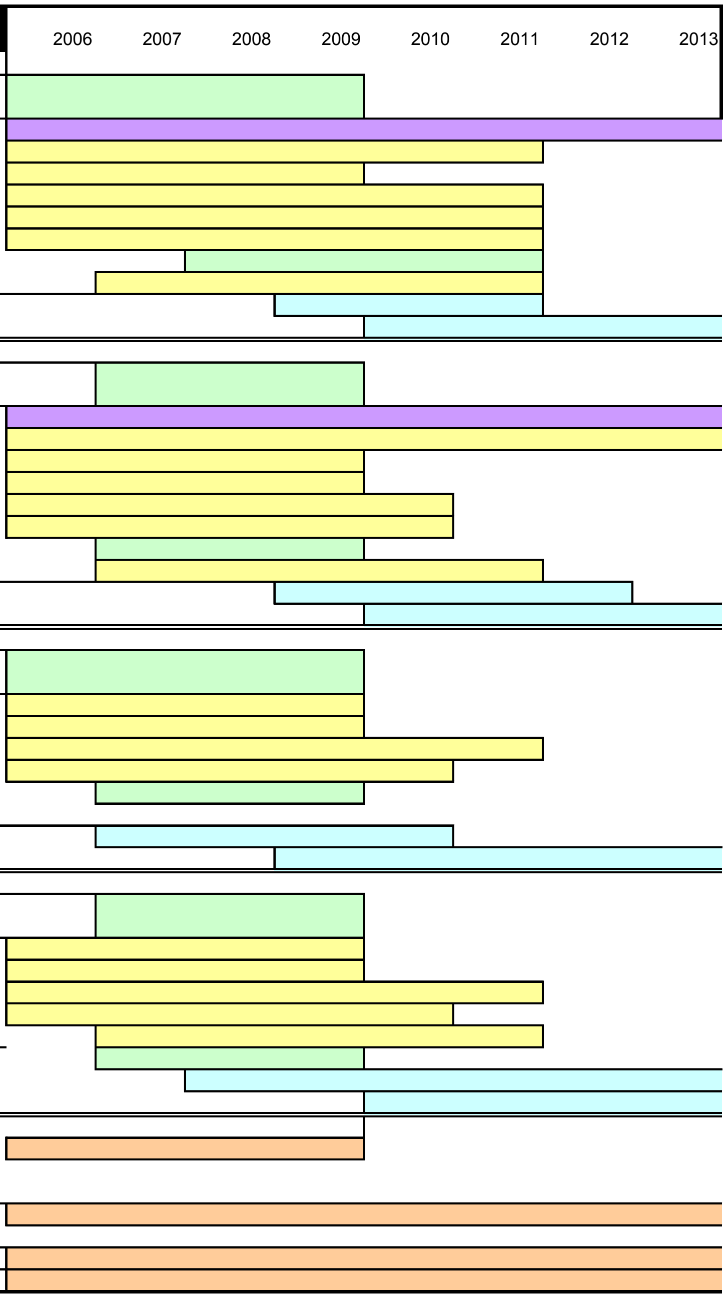
Action type	Action number	Action focus		Details	Micro FCs	Portable generators	Specialist Vehicles	By-product H_2	Supporting activities
							Resource in M€		
				Portable Micro-FCs					
AR+DE	1	State of the art technology		XX units pilot monitoring, performance assessments					
BR	2	System development	Basic R&D	volume manufacturing processes for FCs and planar modules, high-efficiency & miniaturised BoP components					
AR	3		General	improved/new membrane material, alternative fuels, Passive operation, no or few moving parts/low power & compact system components, micro system technology, Fuel distribution, storage and safety					
AR	4		Diagnostic tools	development (failure modes, system architectures, sizing, data analysis) & verification in real operating conditions					
AR	5		System modelling	system model development (sub-component characterization, reduce control requirements, field data verification)					
AR	6		Reduction of complexity	BoP simplification, component optimisation, integration with fuel storage, "passive" control strategies, miniaturized system architecture					
AR+DE	7		Reformer	highly integrated and low cost fuel processor, Miniaturisation and Integration with FC systems					
	8		Improvement of performances	improved reliability in real operating conditions					
DE	9	Demonstration	Alpha testing	field demonstration (system verification & certification, accelerated life test)					
	10		Product development & demo	demo of business proposition					
				Portable generators, Back-up power, UPS					
AR+DE	11	State of the art technology		XX units pilot monitoring, performance assessments					
BR	12	System development	Basic R&D	lower cost, improved stack components, HT-PEMFC, Internal reforming SOFC, Direct utilisation of liquid fuels					
AR	13		General	lower cost, improved stack components, HT-PEMFC, Internal reforming SOFC, Direct utilisation of liquid fuels, Fuel distribution, storage & safety					
AR	14		Diagnostic tools	development (failure modes, system architectures, sizing, data analysis) & verification in real operating conditions					
AR	15		System modelling	sub-component characterization, strategies for increasing system efficiency, integration with renewable H2					
AR	16		Reduction of complexity	BoP simplification, component optimisation, integration with fuel storage, reduced number of sensors, design for modular installation					
AR + DE	17		Reformer	highly integrated and low cost fuel processor					
AR	18		Improvement of performances	efficiency, cyclings, packaging & modularization					
DE	19	Demonstration	Alpha testing	field demonstration (system verification & certification, accelerated life test)					
	20		Product development & demo	demo of business proposition					

Portofolio of actions (continued)

Action type	Action number	Action focus		Details
				Specialist vehicles
AR + DE	21	State of the art technology		4 Pilot monitored fleet, refuelling strategies assessment (fuel logistic issues)
AR	22	System development	General	lower cost, improved performance stack components
AR	23		Diagnostic tools	development (failure modes, system architectures, sizing, data analysis) & verification in real operating conditions
AR	24		System modelling	system model development (sub-component characterization, hybridization strategies, field data verification)
AR + DE	25		Reduction of complexity	BoP simplification, system integration, component optimisation, integration with fuel storage, hybrid configuration, compact & reliable fuel processing technologies, reduced number of sensors, simplified dispensing & filling procedures)
AR	26		Improvement of performances	shock & vibrations (component & system)
DE	27	Demonstration	Alpha testing	fleets demonstration of alpha systems
	28		Product development & demo	demonstration of business proposition
				By-product H_2 Power Generation
AR + DE	30	State of the art technology		test of 2 systems (500kW - 1MW size)
AR	31	System development	General	lower cost, improved performance stack components, stack durability, models development for accelarated life test, failure prediction
	32		Diagnostic tools	development (failure modes, preventive maintenance, sizing of system hybrisation, data analysis) & verification in real operating conditions
	33		System modelling	system simulation, sub-component characterization, strategies for increasing system efficiency
	34		Reduction of complexity	BoP simplification, system integration, component optimisation, reduced number of sensors
	35		Improvement of performances	efficiency, cyclings, system modularization
DE	36	Demonstration	Pilot	demonstration in representative locations, performance evaluation
	37		Alpha testing	increase size of demonstrators to industry requirements (> 5 MW)
	38		Product development & demo	demonstration in representative locations, bdemonstration of business proposition
				Supporting activities
	39	From research to market - Developing a healthy European scene for H2 and Fuel Cells		develop financing options for start-ups, Micros and SME's (equity gap, risk assessment assistance for local financial intermediaries)
	40			specific SME Promotion Activities (Financing of technically qualified projects from SME's via new financing pathways and partners)
	41			getting Research and Academia primed for Spin-off
	42	Building the Market - Stimulating and Meeting Early Demand		initiate and support Buyers' Pools
	43			fostering the role of regions, industrial clusters and public-private partnerships to create the necessary structural conditions
	44	Creating Peace of Mind - Developing and Implementaing Harmonised		in-door use of H2 and Fuel Cell Devices
	45	Getting the numbers right - socio-economics modelling and tools		initiating the European Hydrogen & Fuel Cell Business Observatory ("EHFO"):

7.4.3 Timelines

Action number	Action focus	
	Portable Micro-FCs	
1	State of the art technology	
2	System development	Basic R&D
3		General
4		Diagnostic tools
5		System modelling
6		Reduction of complexity
7		Reformer
		Reformer
8		Improvement of performances
9	Demonstration	Alpha testing
10		Product development & demo
	Portable generators, Back-up power, UPS	
11	State of the art technology	
12	System development	Basic R&D
13		General
14		Diagnostic tools
15		System modelling
16		Reduction of complexity
17		Reformer
18		Improvement of performances
19	Demonstration	Alpha testing
20		Product development & demo
	Specialist vehicles	
21	State of the art technology	
22	System development	General
23		Diagnostic tools
24		System modelling
25		Reduction of complexity
26		Improvement of performances
27	Demonstration	Alpha testing
28		Product development & demo
	By-product H_2 Power Generation	
30	State of the art technology	
31	System development	General
32		Diagnostic tools
33		System modelling
34		Reduction of complexity
35		Improvement of performances
36	Demonstration	Pilot
37		Alpha testing
38		Product development & demo
	Supporting Activities	
39	From research to market - Developing a healthy	
40		
41		
42	Building the Market - Stimulating and Meeting Early	
43		
44	Creating Peace of Mind - Developing and	
45	Getting the numbers right - socio-economics modelling	



8 Annex 2: List of the members of the IP

IP Chairs		
Name	*Last Name*	*Affiliation*
JACKOW	Francois	Air Liquide
LOUGHHEAD	John	UK Energy Research Centre

IP Vice-Chairs		
Name	*Last Name*	*Affiliation*
SCHEUERER	Klaus	BMW
STOLTEN	Detlef	FZJ Forschungszentrum Jülich

WG Transport		
Name	*Last Name*	*Affiliation*
ANDRITSAKIS	Eleftherios	Athens Urban Transport Organization (OASA)
BARDI	Nicolas	Commissariat a l'Energie Atomique - CEA
BONHOFF	Klaus	DaimlerChrysler
BRAESS	Holger	BMW
BÜNGER	Ulrich	Ludwig-Bölkow-Systemtechnik (LBST)
CALLOW	Geoffrey David	TEC Ltd
CARILLO DE ALBORNOZ	Eduardo	Boeing Research and Technology
COSTES	Bruno	PSA Peugeot Citroën
EKDUNGE	Per	Volvo Technology Corporation
GIANOLIO	Giuseppe	Environment Park - HYSYLAB
GODULA-JOPEK	Agata	EADS - European Aeronautic Defence and Space Company (CRC-G)
HIEBEL	Volker	EADS Airbus Engineering
KLINGENBERG	Heinrich	hySOLUTIONS GmbH
KRAINZ	Guenter	MAGNA STEYR Fahrzeugtechnik AG & Co KG
KRÜGER	Roland	Ford Forschungszentrum Aachen GmbH
LAGANA	Antonio	Ferrovie dello Stato S.p.A.
LEPPERHOFF	Gerhard	FEV Motorentechnik GmbH
MATTIELLO	Giorgio	Hydrogen Park
MÖLLER	Emil	hydrogenmaastricht.org
MOLLER-HOLST	Steffen	SINTEF
NAILIS	Mark Robert	Centre for Process Innovation (Fuel Cell Application Facility)
NAVAS	Carlos	NTDA
NYHUS	Eirik	Det Norske Veritas AS - DNV
PRENNINGER	Peter	AVL List GmbH
QUASTHOFF	Marcus	MAN Nutzfahrzeuge AG, Central Division Advanced Development
ROVERA	Giuseppe	CRF - Fiat Research Centre
SCHULZ	Philippe	Renault
THIESEN	Lars Peter	GM/Opel Fuel Cell Activities
VOLKMAR	Dr. Henning	Volkswagen AG
Observers		
PERUJO MATEOS DEL PARQUE	Adolfo	EC, DG-JRC, Institute for Environment and Sustainability

WG Stationary		
Name	*Last name*	*Affiliation*
BALLHAUSEN	Andreas	EWE Aktiengesellschaft
BERG	Joachim	Vaillant GmbH
BISCHOFF	Manfred	MTU CFC Solutions GmbH
FLINT	Bob	Ceres Power Limited
CASTRO	África	Hynergreen Technologies, S.A. (Hynergreen)
FONTELL	Erkko	Wärtsilä Corporation
GLASER	Steven	London Hydrogen Partnership / Energy Centre for Sustainable Communities
HOLM-LARSEN	Helge	Topsoe Fuel Cell A/S
HOPFER	Martin	E.ON
LEWIS	Jonathan	RollsRoyce Fuel Cell Systems
MARCENARO	Bartolomeo	ANSALDO FUEL CELLS
MORENO	Angelo	ENEA
PAULMIER	Philippe	Axane Fuel Cell Systems
RIETVELD	Bert	Energy research Centre of the Netherlands (ECN)
ROSENBERG	Rolf	VTT/Research Institute
STEINBERGER-WILCKENS	Robert	Forschungszentrum Jülich (FZJ)
STEVENS	Philippe	Electricité de France

WG Portables and Early Market Applications		
Name	*Last name*	*Affiliation*
AGERT	Carsten	Fraunhofer Institute for Solar Energy Systems ISE
ANTONUCCI	Vincenzo	CNR
BROWNING	Darren	Defence Science and Technology Laboratory (Dstl)
DE BLAS POMBO	JUAN	BESEL SA
DE SANCTIS	Sergio	SAPIO Produzione Idrogeno Ossigeno S.r.l.
DELFRATE	Alessandro	Nuvera
DIEHL	Manfred	Umicore
HEINZEL	Angelika	ZBT - Center for Fuel Cell Technology
IRVINE	John	1. University of St Andrews 2. St Andrews Fuel Cells Ltd 3. Scottish Hydrogen and Fuel Cell Association
LUNDSGAARD	Joergen S.	IRD Fuel Cells A/S
MIDDELMAN	Erik	NedStack Fuel Cell Technology BV
MIGUEL CRESPO	Oscar	CIDETEC, Centre for Electrochemical Technologies
PRIESTNALL	Michael	CMR Fuel Cells plc
SCHULTE	Stefan	Masterflex AG
TREZONA	Patrick	Fuel Cell Europe

WG Hydrogen Supply		
Name	*Last name*	*Affiliation*
CARVANI	Luigi	Venezia Technologies
CLOUMAN	Andres	HYDRO
DI MARIO	Francesco	ENEA
DONATINI	Franco	Enel - Divisione GEM - Ricerca
GUTHRIE	EMMA	Air Products
GRUBEL	Holger	Vattenfall Europe
HOEHLEIN	Bernd	LZE-NRW
ITOIZ	Carlos	ACCIONA ENERGIA
JEENINGA	Harm	Energy research Centre of the Netherlands (ECN) - Unit Policy Studies
LUCCHESE	PAUL	Commissariat a l'Energie Atomique - CEA
LYMBEROPOULOS	Nicolas	Centre for Renewable Energy Sources (CRES)
MULARD	Phillippe	TOTAL
MULLER	Thomas	Gaz de France
PERRIN	Jérôme	Air Liquide
RAINE	Diana	Air Products (Replacement E.Guthrie)
REIJERKERK	Jaco	Linde AG - Linde Gas Division
REMOND	Isabelle	SHELL HYDROGEN
TAMAYO MADURGA	Fernando	GAMESA ENERGIA
TSATSAMI	Vasso	BP
VON HELMOLT	Rittmar	GM/Opel Fuel Cell Activities
WEINMANN	Oliver	Vattenfall Europe (Observer)

WG Cross-cutting Issues		
Name	*Last name*	*Affiliation*
ADAMSON	Kerry-Ann	Fuel Cell Today
AHRER	Werner	Profactor Produktionsforschungs GmbH
AZKARATE	Iñaki	INASMET
BARON	Frédéric	EDF
BARTEN	Henk	Ecofys bv
CLAASSEN	Pieternel	Agrotechnology and Food Sciences Group
CORDINER	Stefano	University of Rome "Tor Vergata", Dep. of Mechanical Engineering
CORREAS	Luis	FUNDACION HIDROGENO ARAGON
FERNANDES	Tomas Rei	Instituto Superior Técnico, Lisbon
FISCHER	Albert	Planet Capital Management
FJERMESTAD HAGEN	Elisabeth	Norsk Hydro
GARCIA PENA	Francisco	ELCOGAS S.A.
HAUGOM	Gerd Petra	Det Norske Veritas AS (DNV)
HEINZE	Erna	Initiative of Hydrogen and Fuel Cell Technology Hamburg
JUNKER	Michel	ALPHEA HYDROGENE
LAKEMAN	Barry	Defence Science and Technology Laboratory (Dstl)
LAZAR	Roxana Elena	National R&D Institute for Cryogenics and Isotopic Technologies
MAIO	Patrick	Hinicio
MAYO	Ben	THE CENTRE FOR PROCESS INNOVATION
MCLOUGHLIN	Sean	Fuel Cell Markets
MEISSNER	Dieter	University of Applied Sciences Wels, Eco-energy Studies
MERTENS	Jean-Jacques	European Investment Bank
NAGEL	Rolf	Munich Venture Capital Partners

PELLISCHEK	Gloria	CLEPA RTD
RAMESOHL	Stephan	Wuppertal Institute for Climate Environment Energy
READ	Tom	Scottish Hydrogen & Fuel Cell Association (SHFCA)
REIJALT	Marieke	Italian Hydrogen and Fuel Cell Association H2IT
ROSA IGLESIAS	Manuel Felipe	INTA
SIGFUSSON	Thorsteinn	University of Iceland
STEIN	Alfred	Hydrogen and Fuel Cell Initiative Hessen (Germany)
TILLMETZ	Werner	Zentrum für Sonnenenergie und Wasserstoffforschung (ZSW)
URBANIEC	Krzysztof	Warsaw University of Technology
VAN DEN HOED	Robert	Ecofys bv
WANCURA	Herbert	ALPPS Fuel Cell Systems GmbH
ZAKOSTELSKY	Andreas	Raiffeisen KAG
Corresponding Members		
Conte	Mario	ENEA - Ente Nazionale per le Nuove Tecnologie, l'Energia e l'Ambiente
Selmer-Olsen	Staale	Det Norske Veritas AS (DNV)

OBSERVERS		
Name	*Last name*	*Affiliation*
Mirror Group-observer to the IP-Coordination Group		
NEEF	Hanns-Joachim	FZJ, Jülich

European Technology Platform for
Hydrogen and Fuel Cells (HFP)

For more information, please contact the HFP Secretariat:
Telephone: +32 27 749652
E-mail: Secretariat@HFPeurope.org
Website: www.HFPeurope.org