DRAFT
"IMPLEMENTATION PLAN – Status 2006"

IMPLEMENTATION PANEL

OCT 2006

HFP Secretariat
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A message from the Implementation Panel Chairs

This draft Implementation Plan is being published for discussion during the General Assembly of the Hydrogen and Fuel Cell Technology Platform so that the proposals it contains can be presented and discussed by the HFP community.

The Implementation Panel started its work following the first Plenary Meeting in February 2006 and since then its members - more than one hundred technical experts and stakeholders in the hydrogen and fuel cell field - have devoted great efforts and commitment to creating the contents of this draft Plan. To them, and especially the Leaders of the Working Groups we are very appreciative and grateful for their contributions.

We believe the present Plan represents a practical approach to meeting the needs defined in the SRA and DS, and a bold plan for hydrogen and fuel cell development in Europe for the next decade. The required investment is high, but consistent with current spending commitments from the public and private sectors; the unique feature of this Plan is that it represents the first real mobilisation of efforts at the European scale.

The Panel has maintained a transparent process to enable contributions from all parties with a valid interest in developing Europe's position in these critical technologies. The invitation now to comment on and help further develop the Plan is a key part of this approach. Your views will help refine and develop this approach further, as we move towards finalising the Implementation Plan during the next two months.

Following this consultation the final version of the Plan will be prepared for submission to the HFP Advisory Council in November, and then to the European Commission in December 2006. It may define the European programme for the next decade, so your input is needed.

Finally we take this opportunity to thank sincerely the many people who have generously supported the work of the Implementation Panel; in addition to the external stakeholders we thank especially the HFP Secretariat and staff of the Commission and its JRC without whom this Plan would not have been as complete or timely as it is.

François JACKOW
Air-Liquide

John LOUGHHEAD
UK Energy Research Centre

Foreword to the Implementation Plan

The Implementation Panel, under the direction of the Advisory Council of the HFP, was established early 2006; its mandate - to take forward the HFP strategy, as outlined in the **Strategic Research Agenda** and the **Deployment Strategy,** by defining **implementable actions** that form the basis for a European Programme on Hydrogen and Fuel Cell for the **2007 – 2015 period.**

Through the direct involvement of **more than 100 European stakeholders** in the working groups of the Implementation Panel from research institutes, industry, associations, governmental agencies, Member States and the European Commission, and through extensive consultation a programme has been defined and is presented now for review and comments by the community.

The programme comprises **4 Innovation and Development Actions** (IDAs), which emphasize the priorities for Europe and encompasses all necessary activities to achieve the *"Snapshot 2020"* targets of the HFP:

- **H_2 vehicles and infrastructure :** developing vehicle and infrastructure technologies to kick-start commercialisation by 2015 or earlier
  - ➡ emphasis on cost reductions, vehicle components, including PEM fuel cell and hydrogen storage, and infrastructure build-up
- **Sustainable H_2 supply** : supplying 10-20% of H_2 energy demand with CO_2 free or lean technologies by 2015
  - ➡ focus on low temperature electrolysis in the short term and on CO_2 free or lean centralized mass production technologies in the long term; enable decisions and planning for sustainable hydrogen infrastructure build-up
- **FC for CHP and power generation** : having more than 1 GW capacity in operation by 2015
  - ➡ address developments on all three - PEMFC, MCFC and SOFC - technologies in a balanced way to meet both transition and long term goals
- **FC for Portable and Early Markets** : bringing "thousands" of FC products in the market by 2010
  - ➡ foster and facilitate the introduction of marketable products and industrialisation; select market segments underlying Europe's strengths

The total private - public budget for the proposed programme amounts to **6.7 billion € for the 2007 – 2015 period,** which is consistent with ongoing public funding and private investments on hydrogen and fuel cell technologies. This market-driven programme with a focus on delivering as per *"Snapshot 2020"* proposes that 2/3 of its budget supports demonstration activities. It also recognizes the importance for research and development in meeting the long term challenges to address the *"2050 Vision"* of the High Level Group.

Proposals have been made to identify actions that could be considered in a possible Joint Technology Initiative in this field.

The Third General Assembly is a timely opportunity for the Implementation Plan to be discussed and lively debated. The IP will continue to develop and refine its work, based on the inputs and comments from the HFP community at large. The **final Implementation Plan Repor**t will be submitted for endorsement to the Advisory Council of the Hydrogen and Fuel Cell European Platform in November 2006 and thento the EC, with a goal to publishing it before the end of the year.

On behalf of the Implementation Panel, its Coordination Group:

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

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Table of Contents

1 Introduction – Background

The European Union (and the world) needs affordable, secure and sustainable flows of increasing amounts of energy. This is a key element for the achievement of the Lisbon goals. The link between energy security, sustainability and competitiveness highlights the challenges that EU faces and points to the need for an integrated policy. Boosting the development and deployment of cleaner and more efficient energy technologies is a vital part of this policy – with hydrogen and fuel cell (FC) technologies having the potential to contribute significantly to these policy objectives.

In 2005 the European Hydrogen and Fuel Cell Technology Platform (HFP) defined the Research and Deployment Strategies. These detail how technology leadership can be achieved through an integrated 10 year programme addressing research, technological development and demonstration as well as market preparation leading, with appropriate policies in place, to the market penetration levels of the *"Snapshot 2020"* and then towards the *"2050 Vision"* 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) to take the HFP strategy for RTD and demonstration of hydrogen and fuel cells technologies to the implementation stage. In line with its mission, the IP is developing an integrated and target oriented programme of prioritised, coherent and operational RTD & demonstration actions consistent with the Strategic Overview, the Strategic Research Agenda (SRA) the Deployment Strategy (DS) and the Action Plans of the Initiative Groups of the HFP. This programme, designed for technology development and acquisition to foster market entry of transport, stationary and portable hydrogen and fuel cell applications by 2010-2015 is justifiably required at the European level - it is proposed to be implemented in the course 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 next 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. It also addresses the comments of the public consulation of its interim report and the views and recommendations of the Advisory Council and the Mirror Group of the Member States on its 'work in progress'. It presents a comprehensive and coherent work programme for facilitating and accelerating the development and deployment of cost-competitive, world class European hydrogen and fuel cell technologies for applications in transport, stationary and portable power in the next ten years. It is designed to build upon Europe's strengths. To effectively meet the goals and objectives of this ambitious programme, the setting up of a public-private partnership in the form of Joint Technology Initiative (JTI), as proposed by the Commission in its FP7 Proposal, has been recommended in the HFP Strategy. The JTI could execute the major part of the proposed programme.

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 EU's search for a long-term sustainable and secure energy supply is confirmed in FP7 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, with funding support for RTD and demonstration in this area totalling more than € 500M cumulatively, € 300M in FP6 alone (2002-2006).

Building on the current and previous initiatives and successes at EU, national regional and local levels, the HFP has clearly justified the need for a European level programme that should be backed by the commitment of all stakeholders, including the Member States. Market forces alone are not sufficient to spearhead the development, given the high risks involved, even if the long-term benefits are undeniable. Public intervention alone may simply not be able to meet the required volume of effort and coordination to overcome all challenges, technical and otherwise. The scale effect and continuity needed to reach the *"Snapshot 2020"* are not achievable through a short-term fragmented collaborative work frame. A long-term, programmatic approach, pulling together resources, aligning and complementing efforts through the complete value chain is required to face the technological and market challenges and to match the global competition - whilst ensuring that the sustainability goals are met. Such a programme will facilitate Member State coordination and strengthen the EU's interests in the international arena of hydrogen and fuel cells, identifying opportunities for mutually beneficial global cooperation.

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	2.000 €/kW (Micro) 1.000-1.500 €/kW (industrial CHP)	< 100 €/kW (for 150.000 units per year)

It is considered that the challenging performance and cost targets as extensively detailed in the HFP Strategic documents can be addressed and met by 2015, thus enabling EU to realise the *"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 and joint objectives, the programme is structured according to four main **Innovation and Development Actions (IDAs)** that are targeting hydrogen vehicles and infrastructure for transport applications, sustainable hydrogen supply, stationary fuel cells for combined heat and power and power generation and fuel cells for early markets including, in particular, portable applications. These programmatic lines have been defined as development milestones for hydrogen and fuel cell technologies to achieve the *"Snapshot 2020"* reference scenario and pave the way for the realization of the High Level Group (HLG) vision for Europe in 2050, as depicted in Figure 2 below. Important interfaces are expected between these programme clusters. They are considered synergistically in this programme, drawing mutual benefits from each other's results.

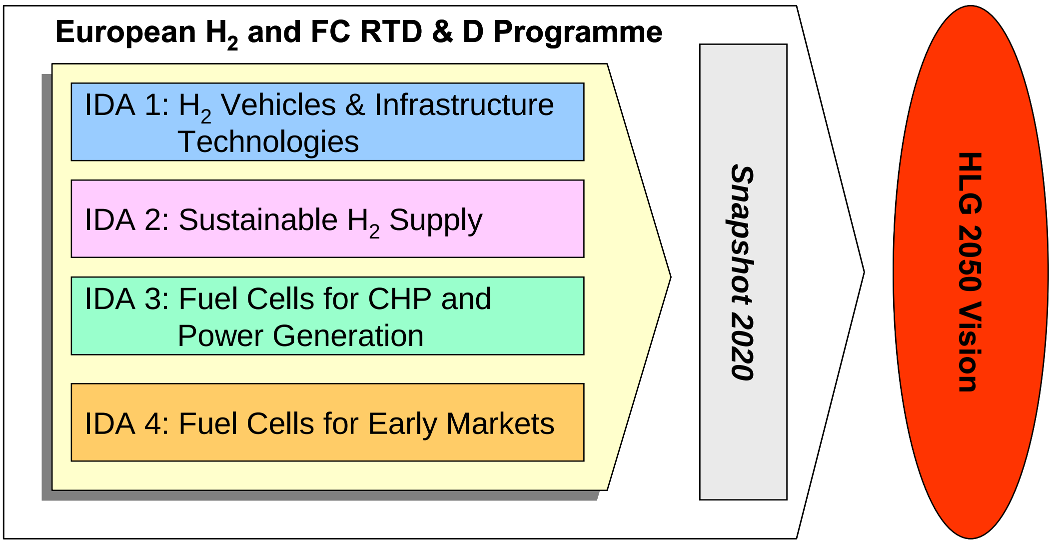

Figure 2. The European Hydrogen and Fuel Cell RTD & D programme

For each IDA, a comprehensive set of actions that covers technology developments, including those that may be supported by long-term research, and market enabling activities is proposed and presented in the next chapters. All actions envisioned are considered to be necessary as a whole to fulfil the development targets assigned to the IDAs. They are further analysed by priority levels to meeting the EU's policy drivers and by contribution needed from research and industry – an analysis that the Panel finds consistent with its considerations for the contents of the JTI on H_2 and FCs. High priority level is considered by the Implementation Panel as of utmost importance to achieve the development goals set for each IDA and of the proposed Programme in its totality within the timeframe of the programme.
A short summary of the content of each IDA including budget distributions, preliminary relevant timelines and key technical and non technical targets that will have to be met to fulfil the objectives of the programme is also provided in Annex I at the action level.

3 Programme description

3.1 Hydrogen vehicles and infrastructure technologies

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

3.1.1 Content

An energy efficient, very low polluting and GHG-neutral transport is one of the key objectives of the European transport and energy policies. This IDA concentrates on preparing the commercialization of hydrogen powered vehicles[1] in all transport modes (road, rail, air, maritime) with the goal to exceed an annual production of 400 000 hydrogen vehicles - Fuel Cell and Internal Combustion Engine (ICE) drive trains - by 2020.

An integrated approach across the whole hydrogen value chain, encompassing H_2 delivery, transport (propulsion, drive-train and auxiliary power) technologies and market enabling activities, is a prerequisite to meet the mass market objective, and therefore it constitutes the framework basis for this IDA. Technological actions within it aim at developing and improving hydrogen-fuelled vehicles and infrastructure technologies to the level required for kick-starting mass production by 2015. This includes validating their performance, encompassing 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. Actions focus on planning and developing the main components of hydrogen refuelling stations, including hydrogen storage and conditioning, with the aim of meeting the requirements in terms of volume, purity/grade, cost, ease of handling, storage capacity and safety for refuelling road vehicles.

Actions on H_2 vehicles target critical components and system integration of ICE and FC based propulsion technologies to fully match customer requirements by 2015. Highly efficient FC-based APUs are also considered for transport applications, with the goal to achieve mass market commercialization prior to FC propulsion based vehicle. The broad range of application opportunities for APUs will generate experience and feedback on the performance and benefits of FC products in competitive environments, facilitating further the penetration of FC powered vehicles and the development of a competitive EU fuel cell industry. The role of H_2-fuelled ICE vehicles is seen as instrumental in accelerating the hydrogen infrastructure build-up.

Developments on critical components will target a lead application, whose market requirements are the most technically and economically challenging. It is considered that lead applications will spin-off benefits to other applications without any major additional developments of the components in question. System integration activities

[1] The term "vehicle" applies loosely here to all modes of transport

and clearly defined industrial targets (system performance targets)[2] are of prime importance to make sure every application fulfils their own needs. Following this lead application concept, most efforts on PEMFC-based drive train critical components will be implemented to meet road transport requirements. Fuel processing developments will be led by air transport applications, whereas SOFC and MCFC technologies which fall within the scope of maritime applications (lead application for transport applications) will be developed in synergy with the third IDA.

Hydrogen and Fuel Cell technologies can still be considered to be in their early stage of development with regards to meeting mass market requirements such as for transport applications. Although steady and constant progress has been made over the last decade to close the gap towards commercial standards for automotive applications, it still remains true that there is a strong need to improve the performance, cost, and reliability of hydrogen production, storage, and use. Advances in hydrogen storage materials, high temperature PEM membrane electrolyte, are just a few examples of critical fields where significant scientific and technical advances are needed to be made. Long-term research providing for new IDAs and concepts is key to overcoming these challenges. It is therefore an integral part of this programme; it aims to address critical barriers that can hinder lead applications in the medium term and open up new pathways for technology and manufacturing improvements on the long run.

Establishing a long-term sound market framework is instrumental in fostering industry developments and investments. Actions are proposed to strengthen and expand the EU H_2 & FC supplier base, with a special focus on SMEs. Human capital development is also targeted as a key element of industry capacity build-up. In parallel to preparing for the deployment of hydrogen and fuel cell technologies, regulations codes and standards (RCS) as well as safety, recycling and public awareness issues will be addressed within this IDA as critical factors for the marketability of new products.

Close synergies with the second IDA on sustainable H_2 supply will be promoted within this plan to foster the uptake of sustainable hydrogen production technologies for field test validation and market deployment. Strong links with the third IDA will be pursued to allow for the uptake of MCFC and SOFC technology developments for transport APUs and propulsion systems. The fourth IDA will be instrumental in sharing the latest advances on FC technologies and manufacturing capacities. Equally important are the benefits sought from the synergies between the air-rail-maritime and road transport applications; for example, air transport applications pose the most stringent fuel cell requirements, whereas these for rail are far less demanding, including infrastructure developments, and stand “halfway’ between stationary and road transport applications.

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.

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

[(2)] Periphery encompasses E-drive, H_2 loop, valve and piping, HV battery, Air supply, Cooling systems and Power electronics

Table 3-1: Action clusters for IDA 1

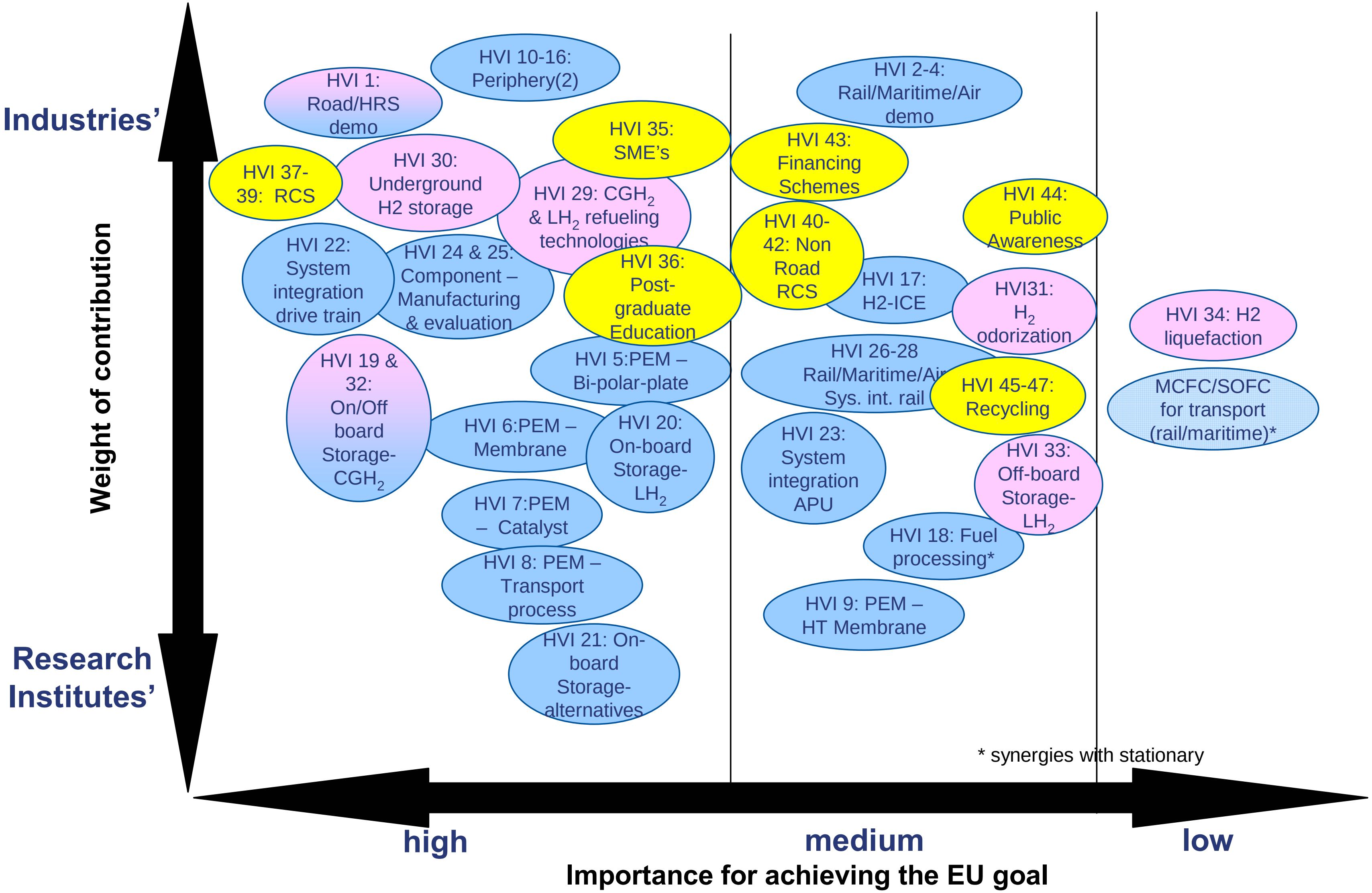
Action type	Action reference	Action number	Action focus		H_2 supply	Road	Air	Maritime	Rail	Supporting Activities
Large scale DE	HVI	1	Road vehicles-supply infrastructure	Passenger cars (ICE/FC - APUs) ; Captive fleets e.g. buses (ICE/FC - APUs)		X				
				Refuelling stations	X					
	HVI	2	Air	Emergency unit for 2008 (H_2/O_2 with PEM), FC Power Unit (PEM/SOFC) with reformer for 2013			X			
	HVI	3	Maritime	MCFC/SOFC system APU (Propulsion - optional)				X		
	HVI	4	Rail	PEMFC-based propulsion					X	
			R&D Transport							
BR+AR	HVI	5 to 9	PEMFC (bi-polar plate, membrane, catalyst, transport process, HT membrane)			X				
AR	HVI	10 to 16	Periphery (air supply, valves/ piping, e-drive, HV battery, H_2 loop, power electronics, cooling)			X				
AR	HVI	17	H_2 ICE			X				
BR+AR	HVI	18	Fuel processing			X	X			
BR+AR	HVI	19 to 21	Storage (CGH_2, LH_2, Alternatives)			X				
AR	HVI	22 to 28	System integration (drive train, APU, component manufacturing, component evaluation, Air, Rail, Maritime)			X	X	X	X	
			R&D H_2 Supply							
AR+DE	HVI	29 to 31	HRS&Components (CGH_2 & LH_2 refueling technologies, Underground H_2 storage and/or production, H_2 Odorization)		X					
BR+AR	HVI	32 to 33	Off- board H_2 Storage (CGH_2, LH_2)		X					
AR + DE	HVI	34	H_2 Liquefaction		X					
			Supporting activities							
	HVI	35	From research to market - Developing a healthy European scene for H_2 and Fuel Cells (supporting and fostering SME's involvement)							X
	HVI	36	Engineering the excitement - solving the people capacity bottleneck for growth (post graduate and professional development training							X
	HVI	37 to 42	RCS (Coordinated European Strategy towards RCS, Supporting relevant directive initiatives, road vehicle logistics, maritime, rail,							X
	HVI	43 to 44	Building the Market - Stimulating and Meeting Early Demand (financing schemes for building the production volumes, public							X
	HVI	45 to 47	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 colour circles relate to transport applications, pink colour circles to hydrogen supply and yellow colour to supporting activities. Gradients of colours entail joint activities between the different sectors. Reference numbers provide a link to action details outlined in Annex I. The dimensional spaces allocated to high, medium and low prioritites in the graph (and those of similar nature presented later in the report) may not be equal, strictly for layout purposes.

Figure 3: Action portfolio of IDA 1 in its analytical framework



3.1.3 Budget requirements

An overall budget for IDA 1 has been estimated at € 2 616M with € 2 195M for transport activities, € 245M for hydrogen supply activities and € 176M for deployment supporting activities. A breakdown of the budget between hydrogen supply, transport applications and supporting activities at the IDA level is presented in Table 3-2 below.

Table 3-2: Budget distribution for IDA 1

		H_2 supply	Road	Air	Maritime	Rail	Supporting activities	Total
	Budget in € M (% within IDA 1)	245 (10%)	1 500 (57%)	150 (6%)	300 (11%)	245 (9%)	176 (7%)	2616 (100%)
Of which	*% Demo*	*43*	*67*	*67*	*67*	*86*		
	% RTD	*57*	*33*	*33*	*33*	*14*		

3.2 Sustainable hydrogen supply

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

3.2.1 Content

The overall objective of this second IDA is to develop a portfolio of sustainable hydrogen production, storage and distribution processes. Sustainability is defined in this area in terms of cost-competitiveness, low in well-to-tank carbon content and high in energy efficiency.

A medium term quantitative target for this programme is to supply 10% to 20 % of the hydrogen energy demand with CO_2 lean and/or free hydrogen production technologies by 2015. At 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 in the beginning of the latter period with an increase in the size and degree of centralisation of hydrogen production facilities as mass market deployment of hydrogen-fuelled technologies is developing.

Several processes and feedstocks can be used to produce hydrogen with different degrees of maturity, production capacities and sustainability. Low temperature electrolysis technologies, biomass to hydrogen (BTH) conversion processes, hydrocarbon, including biofuels reforming and partial oxidation processes as well as coal to hydrogen gasification technologies - with carbon capture and storage - are considered to be the predominant production technologies in the medium term period as per *"Snapshot 2020"*. Industrial by-product hydrogen can also represent opportunistic sources of hydrogen for local stationary applications and possibly transport applications. Technological actions that are proposed in this IDA aim at bringing these production processes to the level of performance and sustainability for supplying 10 to 20 % of the foreseen demand – with the rest to be supplied from the merchant market and from already mature production technologies. Specific attention is recommended to the issue of H_2 purity and quality standards - a trade-off between FC vehicle longevity and the economy and availability of processing technologies on the supply side. Close synergies with the other IDAs will be promoted within this plan to foster the uptake and validation of RTD results on sustainable hydrogen production, under real market conditions.

Strategic planning analyses, in-depth assessment of infrastructure build-up, comprehensive market development prospects, are of paramount importance to anticipate and apportion industrial and R&D investments. Hence, specific actions are proposed to develop integrated socio economic models and tools to support decision makers in both industry and policy making bodies.

The implementation of a fully-fledged hydrogen economy spanning from stationary applications to transport applications is foreseen to occur beyond the market deployment timeframe of this programme. A second objective of this IDA is to develop all constitutive components for a sustainable hydrogen infrastructure beyond 2020-

2030. New generation of hydrogen production processes as well as delivery infrastructure technologies will be necessary to fully realise the potential of hydrogen as the second energy carrier of a sustainable energy system as described in the foundation documents of the HFP. Technological actions for this long term objective target the development of advanced production pathways processes 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 solid-state hydrogen storage technologies are also an integral part of these long 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.

Table 3-3: Action clusters for IDA 2

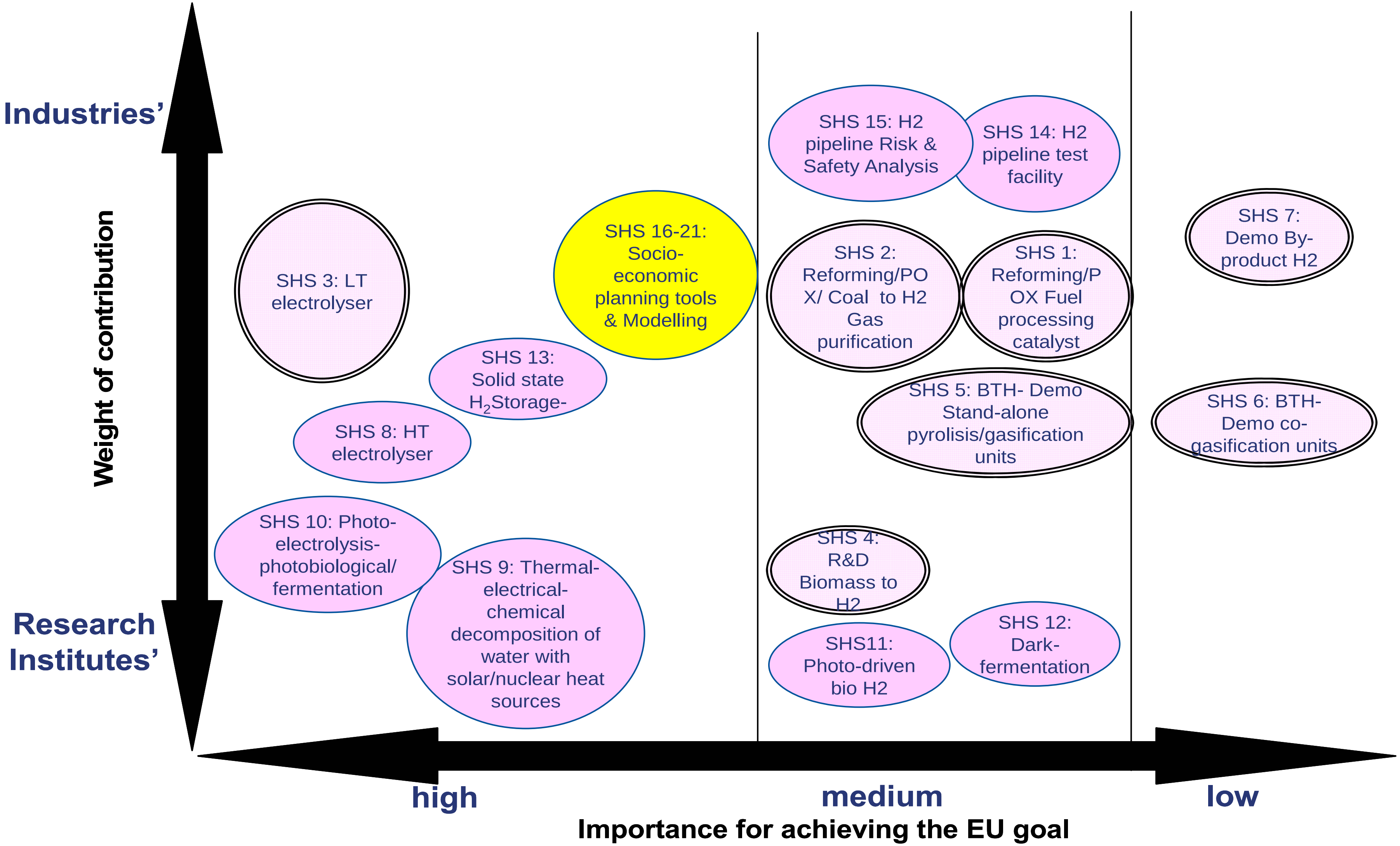
Action type	Action reference	Action number	Action focus	Medium Term Technologies	Long term Technologies	Supporting Activities
			Sustainable H_2 supply			
AR + BR	SHS	1 to 2	Reforming/POx/CTH (Fuel Processing Catalyst, Gas Purification)	X		
BR+AR+DE	SHS	3	Low temperature electrolysis (Development of low cost/efficient low temperature electrolyser)	X		
BR+AR	SHS	4 to 6	Biomass to Hydrogen (R&D on advanced technologies for BTH, Demo Standalone pyrolisis/gasification units, Demo co-gasifications)	X		
DE	SHS	7	Bye-product H_2 & Purification (MW scale, H_2-fed fuel cells for stationary power (and heat) generation)	X		
BR+AR	SHS	8	High temperature electrolysis (Development of a new generation of High temperature electrolyser)		X	
BR+AR+DE	SHS	9 to 12	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	SHS	13	Solid-state H_2 Storage		X	
AR+DE	SHS	14 to 15	Pipelines (Field Test Facility, Risk & Safety Analysis)		X	
			Supporting activities			
	SHS	16 to 21	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 prioritised portfolio of actions is presented in Figure 4 below. In this graph, light pink colour circles relate to the medium term target, pink colour to long term activities and yellow the supporting activities. Reference numbers provide a link to action details in annex I.

Figure 4: Action portfolio of IDA 2 in its analytical framework



3.2.3 Budget requirements

An overall budget for this IDA has been estimated at € 398M, of which € 139M for the mid-term portfolio of actions, € 211M for the long term one and € 48M for supporting activities. A breakdown of the budget between medium term, long term technologies and supporting activities at the IDA level is presented in Table 3-4 below.

Table 3-4: Budget distribution for IDA 2

		Medium term technologies	Long term technologies	Supporting Activities	Total
	Budget in € M (% within IDA 2)	139 (35%)	211 (53%)	48 (12%)	398 (100%)
Of which	*%R&D*	*49*	*79*		
	%Demonstration	*51*	*21*		

3.3 Competitive 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 Content

Fuel Cell CHP or power generation systems offer high electrical efficiency when using natural gas and renewable fuels; hence, they will 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 FC-based CHP and power generation systems to a commercial stage as of 2010. It is proposed as a medium term quantitative target for this programme to have more than 1 GW capacity in operation by 2015. This key target is based on the cumulative deployment of MCFC, SOFC and PEMFC technologies in residential applications (1 to 10 kW) 80,000 units, industrial applications (10 kW-1 MW) 2600 units and industrial applications (> 1 MW) 50 units with the use of existing fuel supply infrastructures. In the short and medium term, natural gas - with increasing share of biogas, biodiesel, and syngas - is expected to be the main fuel used in stationary markets. However, hydrogen is anticipated to play a crucial role in applications such as RES-E peak-shaving and industrial power generation (co-generation) using by-product hydrogen, a joint area of development with the second and fourth IDAs.

The residential units will use PEMFC and SOFC technologies. The distribution could be 50% for each technology, although the exact proportions will depend on the improvements to each technology and their actual performances. For larger units, 10 kW to 1 MW, installed plants will comprise MCFC and SOFC technologies. Given the more advanced status of MCFC technology, the installed units, in the early years of this programme at least, will mostly be MCFC. However, the expected development of SOFC technology will ensure that it will be found in a greater proportion of the total units 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 closer to 2015. These figures clearly show that all three technologies, PEMFC, SOFC and MCFC require development, if the 1 GW goal is to be reached. However, the three technologies are in different stages of maturity, and therefore require differing amounts of research and development as illustrated in Figure 5 in the next section.

The portfolio of technological actions that is proposed aims at improving FC cell and stack technology performances to the level required by stationary market and bridging the gap between generic and applied RTD / first lab prototypes to fuel cells deployment and commercialisation. This includes developing fuel cell products at an industrial scale, comprising “balance of plant" components as well as the scale up of manufacturing capacities in parallel with field testing campaigns for product validation under real market conditions and the preparation for building-up fuel cell operating and installation services.

Setting up regulations, codes and standards for indoor use and grid interconnection, is a pre-requisite for deploying FC systems into the stationary energy markets. Financing schemes will also be necessary to support and stimulate the penetration 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 on fuel cell developments. It is expected that developments on MCFC and SOFC from this area will benefit transport APUs and also non-transport application systems, while stationary systems will take advantage of the developments on PEM technology from the first priority area. IDA 4 is also closely linked as an early testing scene for stationary fuel cell products and manufacturing capacities.

Action clusters considered within this third IDA are presented in Table 3-5 below.

Table 3-5: Action clusters for IDA 3

Action type	Action reference	Action number	Action focus	SOFC	PEFC	MCFC
BR	SFC	1	Generic Fuel Cell Technology	X	X	X
BR	SFC	2	Analysis and Modelling	X	X	X
AR	SFC	3	Industrially relevant cell and stack	X	X	X
AR	SFC	4	System component development	X	X	X
DE	SFC	5	Scaling-up of Manufacturing	X	X	X
DE	SFC	6	Technology validation -Residential applications	X	X	
			Technology validation - Industrial applications	X		X
DE	SFC	7	Market entry - Residential applications	X	X	
			Market entry - Industrial applications	X		X
			Supporting activities			
	SFC	8	Creating Peace of Mind - Developing and Implementaing Harmonised RCS (Grid-Interconnect RCS)	X	X	X
	SFC	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 5 below. In this graph, tri-colour pie charts show the relative budget distributions for the SOFC (green), PEMFC (grey) and MCFC (red) actions, yellow colour indicates supporting activities.

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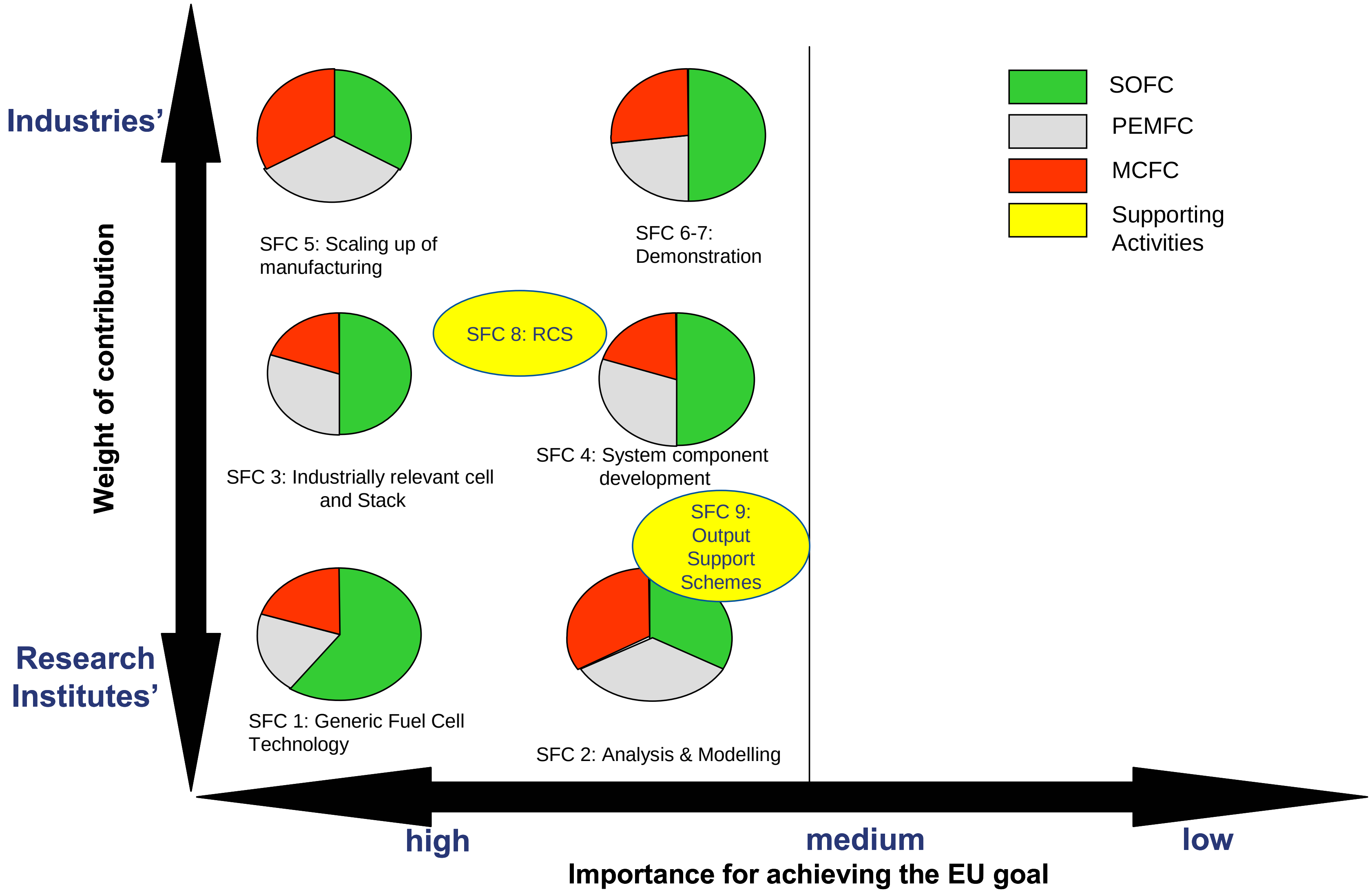
Figure 5: Action portfolio of IDA 3 in its analytical framework



3.3.3 Budget requirements

An overall budget for IDA 3 has been estimated at € 2 853M, of which € 1 394M for SOFC, € 706M for PEMFC, € 728M for MCFC technology and € 25M for supporting activities. A breakdown of the overall budget per type of fuel cells at the IDA level is presented in Table 3-6 below.

Table 3-6: Budget distribution for IDA 3

		SOFC	PEMFC	MCFC	Supporting Activities	Total
	Budget in € M (% within IDA 3)	1 394 (49%)	706 (25%)	728 (25%)	25 (1%)	2 853 (100%)
Of which	*%R&D*	*25*	*30*	*21*		
	%Demonstration	*75*	*70*	*79*		

3.4 Fuel Cells for Early Markets

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

3.4.1 Content

The overall goals for 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 sustain the build-up of the H_2 and FC supplier industry,
- to ensure that all necessary structural conditions are in place for the deployment of fuel cell technologies.

The target for this IDA is to introduce X000 commercial FC products in the market by 2010.

To achieve this target, transfer from research to market should be accelerated and consolidated in supporting Start-ups and SME's, which are expected to take the lead 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. It is therefore paramount to supply equity and grants to small firms in need and to develop a seed and early-stage financing culture and instruments. It is also proposed to develop specific SMEs' involvement and qualification programmes to make the benefits of engagement in the H_2 & FC industry transparent to SME owners and managers.

In addition, early market successes may be of paramount importance, as they will act as "role models" for others to invest. Since early markets are expected in a series of specific premium application niches, it is critical that such niches have the possibility to bundle their volumes, e.g. via buyer pools or coordinated public procurement. The role of regions, industrial cluster and public/private partnerships is also conducive in creating the necessary structural conditions for early investments.

Due to their modularity and high efficiency, FC-based systems can provide additional benefits in numerous and various niche and premium applications with regard to existing energy technologies. Based on the existing development of power modules that use common components and architecture, it is possible to adopt a synergistic approach for a variety of mobile applications as well as for stationary and backup applications. Today, there is a strong convergence in component standardization for those applications (same power module for backup system can be used on specialty vehicles with minor modifications), supporting component standardization and the resulting cost decrease. In this IDA, four main classes of applications will be investigated. These market segments are portable generators, UPS and Back-up power systems, specialist vehicles, industrial power generation using by-product hydrogen fed fuel cell systems (a few MWs total capacity) and portable micro-fuel cells for specialist products such as power tools. They are considered to be financially attractive for an emerging FC & H_2 European industry in the short term while being technically representative of power ranges and application requirements for which fuel cells can be used in other early applications. Nonetheless, the programme will be flexible enough to ensure that the requirements of other market segments that could be potential early markets, can be addressed and benefit from the developments of the four reference classes of applications identified.

Although it is recognized that no major breakthroughs are necessary to enter the above-mentioned markets, the existence of real commercial customers for portable and premium systems in the period 2007-2013 does not lessen the requirement for RTD support. As for any relatively immature commercial product in a competitive environment, continuous and rapid improvements of system performances are mandatory to consolidate and gain market shares. The main development efforts that are proposed for early market products will be concentrated on improving stack performances, system integration and simplification as well as field testing of different generations of products from prototype systems to pre-commercial products.

Strong links with the other IDAs will be promoted throughout the programme to improve the performances of early fuel cell products over time in incorporating the latest developments from longer term transport and stationary applications.

Action clusters considered within this fourth IDA are presented in Table 3-7 below.

Table 3-7: Action clusters for IDA 4

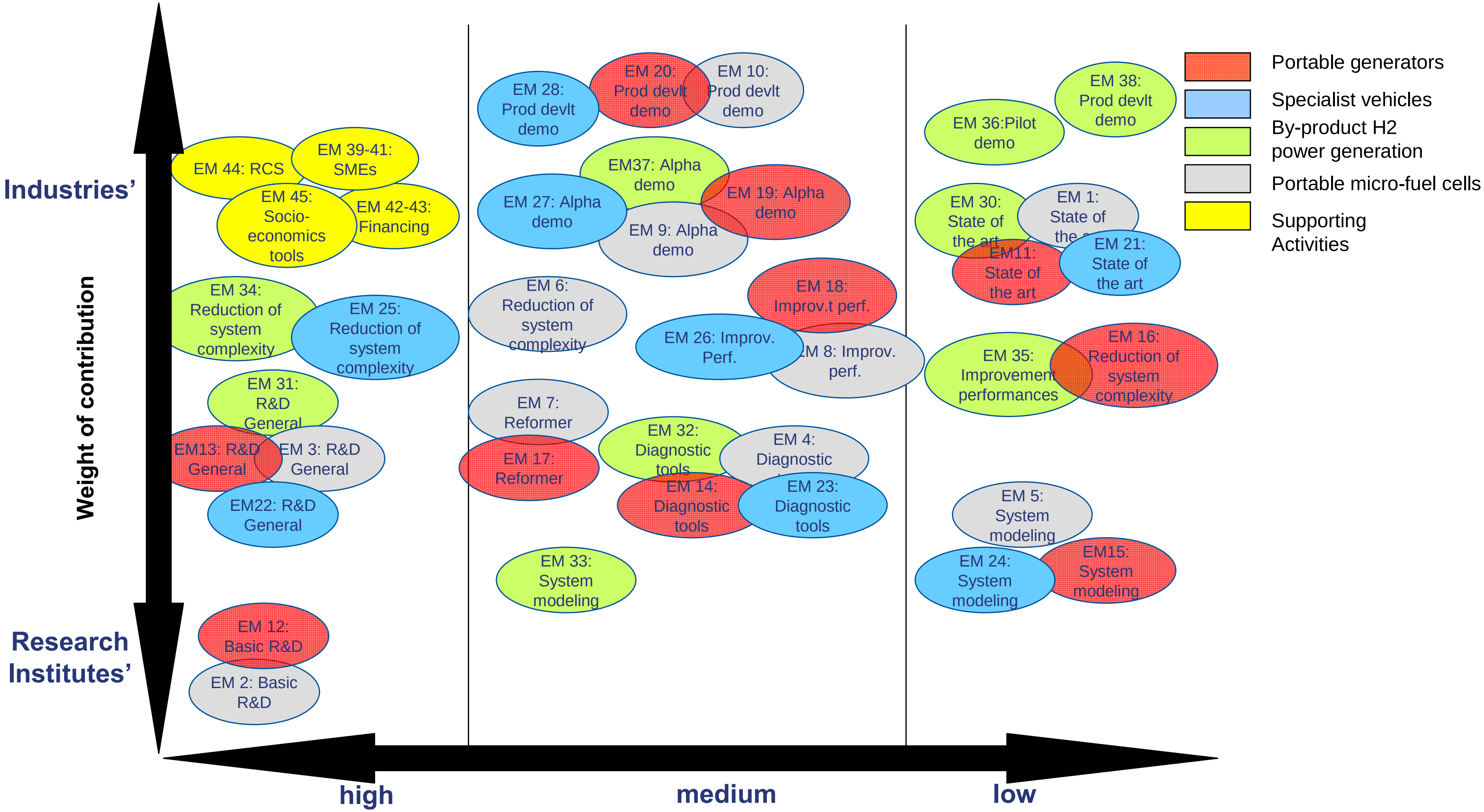
Action type	Action reference	Action number	Action focus	Portable Micro FCs	Portable generators	Specialist Vehicles	By-product H_2	Supporting activities
			Portable Micro-FCs					
AR+DE	EM	1	State of the art technology	X				
BR + AR	EM	2 to 8	System developments (Basic & applied R&D stack systems, diagnostic tools, system modelling, reduction of system complexity, reformer, improvement of performances)	X				
DE	EM	9 to 10	Demonstration (Alpha testing, pre-commercial product development & demonstration)	X				
			Portable generators, Back-up power, UPS					
AR+DE	EM	11	State of the art technology		X			
BR + AR	EM	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	EM	19 to 20	Demonstration (Alpha testing, pre-commercial product development & demonstration)		X			
			Specialist vehicles					
AR + DE	EM	21	State of the art technology			X		
AR	EM	22 to 26	System developments (Applied R&D stack systems, diagnostic tools, system modelling, reduction of system complexity, improvement of performances)			X		
DE	EM	27 to 28	Demonstration (Alpha testing, pre-commercial product development & demonstration)			X		
			By-product H_2 Power Generation					
AR + DE	EM	30	State of the art technology				X	
AR	EM	31 to 35	System development (Applied R&D stack systems, diagnostic tools, system modelling, reduction of system complexity, improvement of performances)				X	
DE	EM	36 to 38	Demonstration (Pilot, Alpha testing, pre-commercial product development & demonstration)				X	
Supporting activities	EM	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
	EM	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
	EM	44	Creating Peace of Mind - Developing and Implementaing Harmonised Regulations, Codes and Standards (in-door use of H_2 and Fuel Cell Devices)					X
	EM	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 prioritised portfolio of actions is presented in Figure 6 below. In this graph, red colour circles relate to Portable generators, UPS and Back-up Power, blue to Specialist vehicles, yellow colour to supporting activities, green colours to by-product hydrogen power generation and grey colour to Portable micro-fuel cells.

Figure 6: Action portfolio of IDA in its analytical framework



3.4.3 Budget requirements

An overall budget for this IDA has been estimated at € 867M, of which € 704M for specific applications and € 163M for supporting activities, Table 3-8 below. A breakdown of the overall budget between the different specific applications has not been worked out yet.

Table 3-8: Budget distribution for IDA 4

		Total for specific applications (Portable FCs, Micro FC portable, Specialist vehicles, By-product hydrogen power generation)	Supporting activities	Total
	Budget in € M (% within IDA 4)	704 (81%)	163 (19%)	867
Of which	*%R&D* *%Demonstration (including field support)*	*15* *85*		

3.5 Programme highlights

3.5.1 Priority highlights

Hydrogen vehicles and infrastructure

IDA 1 addresses trasport applications, emphasising road transport, to meet EU goals on competitiveness and sustainable mobility. A top priority is the development of competitive hydrogen-fuel cell vehicles, aligned with the establishment of a relevant hydrogen supply infrastructure as well as all the supporting elements for market deployment and industry capacity build-up. A second priority level is given to highly efficient FC-based APUs. Critical actions foreseen – on regulations, codes and standards, manufacturing and supply chain development – support the industrialisation phase and the mass market roll-out.

Sustainable hydrogen supply

IDA 2 is key to meeting the programme'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. This is in line with the degree of decentralization of the hydrogen supply infrastructure foreseen by 2015 and the targeted level of sustainability. At a later stage, with the rising demand in hydrogen, BTH and fossil-based technologies with CCS will take a growing share in the hydrogen supply chain and are therefore, allocated a second priority level. In the longer term, high priorities are given to the development of advanced hydrogen production pathways well as to alternative hydrogen storage technologies. These technologies are regarded as key elements to be developed for implementing a sustainable supply infrastructure in the long term.

The development of techno-socio-economic tools that can provide integrated analysis across the whole spectrum of the hydrogen value chain are of prime importance as large investments for building a hydrogen infrastructure will be necessary to implement a fully-fledged hydrogen economy. These activities are considered as a high priority within this programme.

Fuel cells for CHP and power applications

Reaching 1 GW capacity 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 of them have been fully qualified to be successfully deployed in competitive markets. It is therefore recommended in this IDA to follow an integrated approach for all FC technologies that include basic, applied research-oriented and industry-related actions, while tailoring the amounts of efforts dedicated for each technology to research and development and demonstration projects to their states of development as they evolve during the timeframe of this programme. As a result, a strong research focus is given in this programme on SOFC technology, with the most significant anticipated contribution on power generation and its ability to be exploited in both residential and industrial markets.

Early markets fuel cell products

Given the key importance of early markets in preparing for the “hydrogen economy” the programme focus on several short term demonstrations, the development of FC power modules and the creation of industrial capability.

A top priority is given to efforts to foster SME's developments, stimulate early demand through the identification and structuring of buyers’ pools and joint procurement schemes for a variety of early market applications whilst ensuring 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 FC stack and components to improve their performances and lower their costs while achieving an overall simplification of the system. A high priority is also given on volume manufacturing processes, system compactness and the use of alternative fuels.

Strategic Support Services

The implementation of this programme will require that due coordination with similar initiatives on hydrogen and fuel cell technologies, other technology platforms as well regulations, codes and standards bodies at the national/regional European and international levels are ensured. Such strategic supporting activities have not been allocated to the different IDAs by virtue of their cross-cutting and management related aspects. It could be considered that they fall under the responsibility of the JTI Programme Office.

In addition, the IP found of strategic importance that a long term investment in education is made at the EU level and has recommended specific activities on this front. [3]

3.5.2 Overall budget requirements

A consolidated programme budget is presented in Table 3-9 below. The overall effort required to achieve the goals specified in the Innovation and Development Actions of this programme amounts to € 6 734M for the next 7 years.

The overall budget of 6.7 billion € includes public and private contributions to activities that are carried out under joint public-private funding schemes at EU, national and regional/ 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 in cases where this complements the public funding part in the above-mentioned funding programmes.

In the 6th Framework Programme, the European Commission spent € 300M on hydrogen and fuel cells RTD & D activities or an average € 75M per year. The overall budget for the 7th Framework Programme will increase, which is anticipated to translate into increased Community budgets for hydrogen and fuel cells as part of FP7 over the whole duration of the programme.

National budgets throughout Europe have been estimated by the HY-CO ERA-Net to amount to around € 200M per year, plus additional funds per year through recently

[3] A budget estimate for these education related actions is € 18M.

announced new Member States programmes such as, that of Germany (ca. € 50M per year for the coming 10 years). Regional funding in some Member States is significant, but very difficult to estimate due to major differences from country to country.

A total of € 320-350M per year may serve as a conservative estimate of public funding throughout Europe. Assuming this to continue for the coming years this would translate to an about 2.2 - 2.5 billion € investment over the duration of the proposed programme. Complemented by the higher share of private budgets, required for demonstrations, as outlined below, this would imply that the proposed programme is a realisable proposition for an approximate 5-6 billion € required funding. It is often cited that the global automotive industry alone spends a large proportion of this figure per year on H_2 and FC technologies, whereas the International Partnership for the Hydrogen Economy (IPHE) notes a total global public funded RTD at 1 billion USD per year.

Two conclusions can be drawn from these estimates:

1. The budgets 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, both from public and from private sources.
2. Funding on European level has an important role to play in coordinating and aligning the various sources of public funding in order to work jointly on strategic planning for achieving the 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

Concerning the budget distribution between the different applications targeted within this programme, it can be noted that roughly speaking, an equal budget share is proposed for transport and stationary applications, with 39% and 42% of the budget respectively. It should be noted that these budget shares draw upon the recommendations of the DS Report 2005 for example, for road transport 1.5 billion €, for industrial stationary FCs 1.56 billion € and for residential FCs 0.74 billion €. Recognising the role of early and premium markets for deployement of hydrogen and fuel cell technologies and for building up industrial capacity, it is proposed to allocate 13% of the budget to foster SME's development and boost up technological developments in four main promising early and premium markets. The second IDA accounts for 6% of the overall budget. The rationale behind this low percentage figure lies in the core content of this activity. The approach proposed for this specific hydrogen supply activity is to dedicate significant amounts of upstream and downstream research and development work on critical technological barriers to raise the degree of sustainability of the hydrogen production pathways in the medium term as well as opening up new production avenues for long term production and hydrogen transport facilities. It should be noted that hydrogen refuelling infrastructure is an integral part of the first IDA and 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 budget at the IDA level

		IDA 1	IDA 2	IDA 3	IDA 4	Total
	Programme Budget in € M (% within the programme)	2 616 (39%)	398 (6%)	2 853 (42%)	867 (13%)	6 734
Of which	*% R&D*	*30%*	*59%*	*25%*	*12%*	*27%*
	% Demonstration	*63%*	*29%*	*74%*	*69%*	*67%*
	% Supporting Activities	*7%*	*12%*	*1%*	*19%*	*6%*

This market-driven programme with a focus on delivering as per *"Snapshot 2020"* proposes that 67% of its budget supports demonstration activities with two main goals of validating technologies under real market conditions and preparing for mass market deployment. Such a high share of funding for demonstration activities may not be compatible with past practices of expenditure for Community budgets but it could be met through investments from other public sources and the private sector. The former activity will be more predominant in the first half of this programme, whereas commercialisation preparation activities will accrue in importance in the later phase of this programme. In line with these deployment efforts, supporting activities are receiving a high profile with roughly 6% of the total budget. The importance of the remaining challenges facing fuel cells and hydrogen technologies is recognised with a 27% budget share for research and development activities.

3.6 Managerial aspects

It is recommended that the planning of the programme should be flexible enough to allow for the uptake of technological breakthroughs and other changes in the overall environment as they may arise along the programme lifespan.

Given the fact that the programme is driven by the "market principle" it is unavoidable that its details may change in line with the prevailing cisrcumstances. To ensure this, within each IDA of the proposed plan, the portfolio of RTD and demonstration activities should be properly managed without losing sight of the market targets. A continuous feedback process between RTD and demonstration activities and initiatives should therefore be implemented in the projects that will ensue through common assessment frameworks as depicted in Figure 7 below. Hence, targets for R&D milestones will measure progress and implement plans for demonstrations, which, in turn may lead to decisions for commercialisation take-off of the technology.

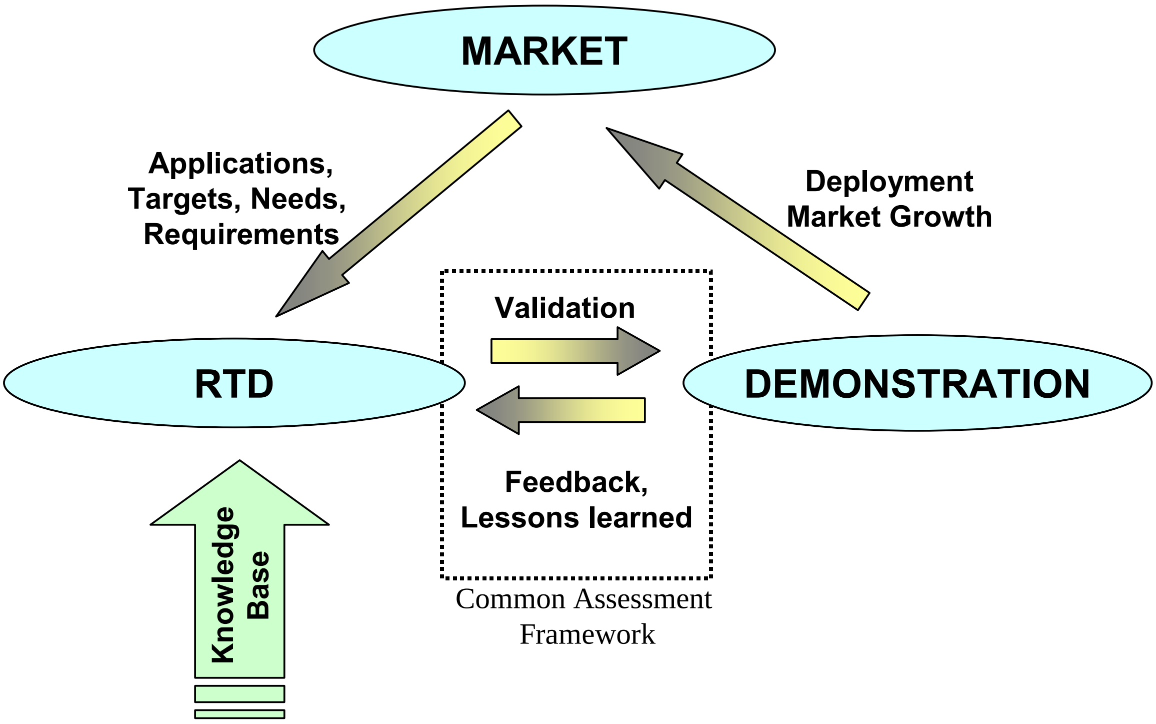


Figure 7. Schematic of programme interactions between RTD, Demonstration and Market.

4 Joint Technology Initiative

A strong 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 technology development
- ✓ to leverage efforts in a more efficient way and with better focus to make sure technology will progress rapidly.
- ✓ to set the frame 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 addressing the above mention needs. The formal aspects of a JTI (e.g. legal structure, governance) are under consideration among the stakeholders within 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*" - including thus,the core contents of the proposed JTI as well as upstream research needs.

It is broadly understood that the overall programme described in this Implementation Plan should be structured into JTI-activities, clearly focussing on market and product specific needs ("market preparation") and long-term research providing new ideas and concept to further improve hydrogen and fuel cell technology performance once commercial activities have started.

The overall scope of the JTI is to accelerate the emergence of a hydrogen-oriented energy system, delivering robust hydrogen and fuel cell technologies to the point of commercial takeoff in 2010 for early markets applications, in 2015 for stationary applications, and mass market roll-out by 2020 for transport applications: This will significantly enhance Europe's competitiveness and on the long term substantially reduce GHG-emissions, significantly increase energy efficiency and provide a diverse portfolio of primary energy feedstocks in Europe. Priorities within the JTI-activities should reflect its respective impact on these collective public benefits.

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. It is recommended to focus the specific activities according to the four IDAs described in the document. It will be crucial to identify synergies between these areas and to implement appropriate processes to realise them.

The JTI would be well-placed to be the key inteface to national programmes on hydrogen and fuel cell technologies of the Member States or European Regions as well as to other international programmes. The principle should be to identify possibilities for mutual beneficial global cooperation.

5 Annex 1: Innovation and Development Actions at a glance

5.1 IDA 1: Hydrogen vehicles and infrastructure (HVI)

5.1.1 Targets

Technical targets: Road propulsion FC system		
Characteristics	***Units***	***2015 Target***
Efficiency (NEDC)	(%)	> 40
Specific cost	(€/kW)	100
Volumetric power density	(l/kW)	1.5
Gravimetric power density	(kg/kW)	1.5
Lifetime	(hr)	
Car		5 000
Bus		10 000
Operating temperature	(°C)	- 25 / + 45

Technical targets: Road APU FC system		
Characteristics	***Units***	***2015 Target***
Efficiency (P_{max})	(%)	35
Specific cost	(€/kW)	-
Volumetric power density	(l/kW)	5
Gravimetric power density	(kg/kW)	5
Lifetime	(hr)	
Car		5 000
Heavy Good Vehicles		40 000
Operating temperature	(°C)	- 25 / + 45

Technical targets: ICE propulsion for passenger car			
Characteristics	***Units***	***Target***	
		2010	***2015***
Torque		equivalent Diesel	
Speed		equivalent gasoline	
Efficiency (NEDC)	(%)	> 26	>> 26
Power density	(kW/l displacement)	> 60	> 80

Technical targets: ICE propulsion for public transport bus		
Characteristics	***Units***	***2015 Target***
Efficiency (best value)	(%)	40
Power density	(kW/l)	18

Technical targets: On-board hydrogen storage		
Characteristics	***Units***	***2015 Target***
Gravimetric storage density	(wt %)	7 - 12
Volumetric storage density	(kWh/l)	1.1
Operating temperature	(°C)	- 40 / +85
Refuelling cycles	(cycles)	> 1 500

Technical targets: Maritime fuel cell power unit (SOFC/MCFC)		
Characteristics	***Units***	***2013 Target***
Investment cost	(€/kW)	< 1 000
Efficiency (full load)	(%)	> 55
Gravimetric power density	(kg/kW)	< 10
Volumetric power density	(l/kW)	< 20
Cycle life	(hr)	10 000
RAMS (Reliability, Availability, Maintainability, Safety)		>= Reciprocating engine

Technical targets: Rail fuel cell propulsion Unit (PEM)		
Characteristics	***Units***	***2013 Target***
Investment cost	(€/kW)	500
Efficiency (NEDC)	(%)	> 45
Gravimetric power density	(kg/kW)	6
Volumetric power density	(l/kW)	6
Lifetime	(hr)	50 000
Operating temperature	(°C)	- 25 / + 45

Technical targets: Hydrogen infrastructure			
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)	(€/kg)	< X	

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

5.1.2 Portfolio of actions

Action type	Action reference	Action number		Action focus	Details Phase I (2006-2010)	Phase II (2010-2015)	Supply	Road	Air	Maritime	Rail	Supporting Activities
							Budget in M€					
Large scale DE	HVI	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	100	1005				
	HVI	2	Air	Emergency unit for 2008 (H2/O2 with PEM), FC Power Unit (PEM/SOFC) with reformer for 2013	Ground demonstration	Flying test bed			101			
	HVI	3	Maritime	MCFC/SOFC system APU (Propulsion - optional)	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		
	HVI	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	HVI	5	PEMFC	Bi-polar plate	bi-polar-plate: low cost materials, higher conductivity and durability			203	13	35	15	
	HVI	6		Membrane	longer lifetime, water management and lower costs							
	HVI	7		Catalyst	noble metal, activity, sensitivity (-> reformate gas) and costs							
	HVI	8		Transport process	water transport processes in porous media							
	HVI	9		HT membrane	proton conductivity, temperature range, water uptake							
AR	HVI	10	Periphery	Air supply	air supply, high speed electric motor, compressor design			64	6	9	5	
	HVI	11		Valves/ piping	valves and pipes: material, design, safety							
	HVI	12		E-drive	reduced friction and improved durability, compact specific drive train							
	HVI	13		HV battery	HV battery: electrode and electrolyte, production process							
	HVI	14		H_2 loop	humidification and hydrogen feeding/ recirculation							
	HVI	15		Power electronic	power electric: thermal management, material, efficiency							
	HVI	16		Cooling	cooling system: design, material, costs							
AR	HVI	17	ICE	H2 ICE	injection, lubrication, exhaust after-treatment, combustion process			30	1	1		
BR+AR	HVI	18	Fuel processing	Fuel processing	catalyst, temperature, stability, costs, membrane, purification			40	12	15		
BR+AR	HVI	19	Storage	CGH_2	fibres, coating, manufacturing, safety			69	7	25	6	
	HVI	20		LH_2	out-gasing, safety, insulation materials							
	HVI	21		Alternatives	solid, hybrid							
AR	HVI	22	System integration	Drive train	operating strategy (e.g. hybridisation), packaging			89	9	15	8	
	HVI	23		APU								
	HVI	24		Component manufacturing	improved manufacturing process, automated assembly							
	HVI	25		Component evaluation	test procedures							
	HVI	26		Air	flight envelope							
	HVI	27		Rail	shock & vibration							
	HVI	28		Maritime	shock/slamming loads, atmosphere contamination, salinity							

Portofolio of actions (continued)

Action type	Action reference	Action number		Action focus	Details	Supply	Road	Air	Maritime	Rail	Supporting Activities
R&D H2 Supply											
AR+DE	HVI	29	HRS&Components	Improved performance of CGH2 & LH2 refueling technologies	refuelling procedures, nozzles, LH2 & CGH2 flow metering	20					
AR+DE	HVI	30		Underground H2 storage and/or production	underground storage, production on-site installation (codes & standards), Compactness	10					
AR	HVI	31		H2 Odorization	safety, odorization	5					
BR+AR	HVI	32	H2 Storage	Improved high pressure gaseous H2 storage for transport applications	liners, fibres, coating, safety, Standardise 700 bar H2 dispensers and nozzles for rapid refuelling, sensors, flow meter	40					
BR+AR	HVI	33		Improved Liquid H2 storage	H2 liquefaction and active cooling (Magnetic refrigeration ect.) , insulation materials, gas boil-off, sensors, filling procedure, safety, LH2 station scaling down	40					
AR + DE	HVI	34	H2 Liquefaction	Development of large scale H2 Liquefaction units & processes	large scale plant design, usage planning (location, Construction logistics), Component/subsystem level development	30					
Supporting activities	HVI	35	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
	HVI	36	Human capital	Engineering the excitement - solving the people capacity bottleneck for growth	Assessment of post graduate and professional development training needs						3
	HVI	37	RCS	Creating Peace of Mind - Developing and Implementaing Harmonised Regulations, Codes and Standards	development of a coordinated European Strategy towards RCS						9
	HVI	38			supporting the relevant directive initiatives						9
	HVI	39			road vehicle logistics						9
	HVI	40			aerospace RCS Development						9
	HVI	41			maritime Transport RCS Development						9
	HVI	42			rail transport RCS development						9
	HVI	43	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
	HVI	44			develop a comprehensive Public Awareness Plan						21
	HVI	45	Recycling		develop recycling technologies (optimum recycling methods/processes						10
	HVI	46			develop recycling regulatory framework (e.g. toxicity issues, legal						6
	HVI	47			Demonstration recycling plant						30

5.1.3 Timelines

Action reference	Action number		Action focus	2007 – 2010	2011 – 2015	2015 – 2020
HVI	1	Road vehicles		PHASE I	PHASE II	
		supply infrastructure		PHASE I		PHASE II
HVI	2	Air		PHASE I	PHASE II	
HVI	3	Maritime		PHASE I	PHASE II	
HVI	4	Rail		PHASE I	PHASE II	
HVI	5	PEMFC	Bi-polar plate			
HVI	6		Membrane			
HVI	7		Catalyst			
HVI	8		Transport process			
HVI	9		HT membrane			
HVI	10	Periphery	Air supply			
HVI	11		Valves/ piping			
HVI	12		E-drive			
HVI	13		HV battery			
HVI	14		H_2 loop			
HVI	15		Power electronic			
HVI	16		Cooling			
HVI	17	ICE	H_2 ICE			
HVI	18	Fuel processing	Fuel processing			
HVI	19	Storage	CGH_2			
HVI	20		LH_2			
HVI	21		Alternatives			
HVI	22	System integration	Drive train			
HVI	23		APU			
HVI	24		Component manufacturing			
HVI	25		Component evaluation			
HVI	26		Air			
HVI	27		Rail			
HVI	28		Maritime			
HVI	29	HRS&Components	Improved performance of CGH_2 & LH_2 refueling technologies			
HVI	30		Underground H_2 storage and/or production			
HVI	31		H_2 Odorization			
HVI	32	H_2 Storage	Improved high pressure gaseous H_2 storage for transport applications			
HVI	33		Improved Liquid H_2 storage			
HVI	34	H_2 Liquefaction	Development of large scale H_2 Liquefaction units & processes			
HVI	35	SME's support schemes	From research to market - Developing a healthy European scene for H2 and Fuel Cells			
HVI	36	Human capital	Engineering the excitement - solving the people capacity bottleneck for growth			
HVI	37-42	RCS	Creating Peace of Mind - Developing and Implementaing Harmonised Regulations, Codes and Standards			
HVI	43-44	Early demand support	Building the Market - Stimulating and Meeting Early Demand			
HVI	45-47	Recycling				

5.2 IDA 2: Sustainable Hydrogen Supply (SHS)

5.2.1 Targets

5.2.1.1 Hydrogen production technologies

Medium term portfolio

Technical 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 electrolyzer		
Production flowrate	(Nm^3/hr)	100
Lifetime	(hr)	40 000

Technical targets for BTH standalone pyrolisis/gasification units		
Characteristics	***Units***	***2015 Target***
Hydrogen production cost	(€/GJ)	< 25

Technical targets for BTH co-gasification (large scale IGCC)		
Characteristics	***Units***	***2015 Target***
Hydrogen production cost	(€/GJ)	10
Biomass feedstock cost	(€/GJ)	3

Long term technology portfolio

Technical 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

Technical 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

Technical 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

5.2.1.2 Delivery technologies

Technical 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

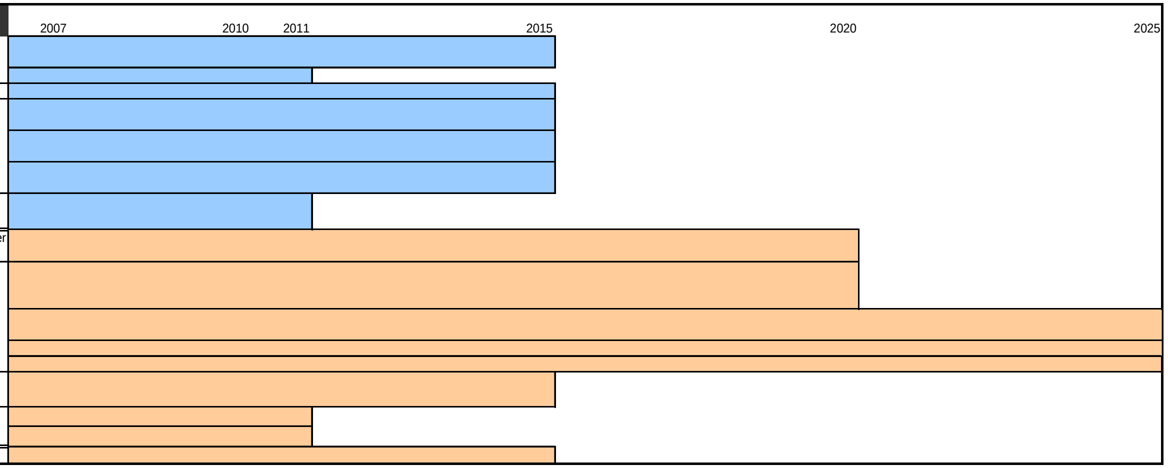
Technical targets for off-board hydrogen storage			
Type of H_2 storage	H_2 tank system density by volume (kWh/l) *present*	H_2 tank system density by weight (%) *present*	H_2 tank system density by weight (%) *2015*
Liquid H_2	1.2	6	12
Compressed gaseous 700 bar	1.3	4	9
Metal hydrides (AB_2, AB_5)	1.8	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

5.2.2 Portfolio of actions

Action type	Action reference	Action number		Action focus	Details	Medium Term Technologies	Long term Technologies	Supporting Activities
							Budget in M€	
				Sustainable H_2 supply				
BR	SHS	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	30		
AR	SHS	2		Gas Purification	HT membrane for WGShift, Reversible adsorption materials for PSA/TSA, Hybrid membrane/PSA	15		
BR+AR+DE	SHS	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	40		
BR+AR	SHS	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	SHS	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	17		
DE	SHS	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	17		
DE	SHS	7	Bye-product H_2 & Purification	Evaluate use of MW scale, H_2-fed fuel cells for stationary power (and heat) generation	Demo by-product H_2 sites as test bed for MW FC scale deployment, market evaluation	10		
BR+AR	SHS	8	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		40	
BR+AR+DE	SHS	9	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		50	
BR+AR	SHS	10		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		15	
BR	SHS	11		Photodriven bio-hydrogen	H_2 yield, Efficiency of light conversion, New efficient (small footprint) photobioreactors		6	
BR+AR	SHS	12		Hydrogen by dark fermentation	Sugar into H_2 conversion efficiency, bio-electric systems, biomass pre-treatment, raw material flexibility processes		5	
BR+AR	SHS	13	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,		80	
AR+DE	SHS	14	Pipelines	H_2 Pipeline Field Test Facility	Pressurised H_2 pipelines: materials, components (valves, compressors…), diagnostic tools		10	
AR+DE	SHS	15		H_2 Pipeline Risk & Safety Analysis	modeling, demonstration		5	
				Supporting activities				
	SHS	16	Getting the numbers right	Socio-economics modelling and Tools	Create Harmonised and Integrated Databases			8
	SHS	17			Analyse portable, light vehicles and stationary applications			8
	SHS	18			identify regulatory driven market demand: Functional synergies and planning of integration of renewable energy systems together with hydrogen and fuel cell infrastructures.			8
	SHS	19			Create and regularly update robust pathway planning tools			8
	SHS	20			Develop a European Masterplan			8
	SHS	21			Role of hydrogen in sustainable energy systems			10

5.2.3 Timelines

Action reference	Action number		Action focus
SHS	1	Reforming/POx/CTH	Develop Fuel Processing Catalyst with reduced cost, improved durability, flexible fuel capability
SHS	2		Gas Purification
SHS	3	Electrolysis	Development of low cost/efficient low temperature electrolyser
SHS	4	Biomass to Hydrogen	R&D of advanced technologies for BTH thermal conversion process
SHS	5		Demonstration of BTH conversion based on stand alone pyrolisis/gasification units
SHS	6		Demonstration of BTH conversion based on co-gasification with coal & fossil fuels
SHS	7	By-product H_2 & Purification	Evaluate use of MW scale, H_2-fed fuel cells for stationary power (and heat) generation
SHS	8	Electrolysis	Development of a new generation of High temperature electrolyser
SHS	9	Advanced Technologies	R&D programme & experimental platform on decomposition of water through thermo-electrical-chemical processes with solar/nuclear heat sources
SHS	10		Basic research programme on low temperature processes: photoelectrolysis and photobiological / fermentation
SHS	11		Photodriven bio-hydrogen
SHS	12		Hydrogen by dark fermentation
SHS	13	H_2 Storage	Improved solid H_2 storage for portable, stationary & potentially transport applications
SHS	14	Pipelines	H_2 Pipeline Field Test Facility
SHS	15		H_2 Pipeline Risk & Safety Analysis
SHS	16-21	Getting the numbers right	Socio-economics modelling and Tools



5.3 IDA 3: FCs for CHP and Power Generation (SFC)

5.3.1 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

5.3.2 Portfolio of actions

Action type	Action reference	Action number	Action focus	Details	SOFC	PEMFC	MCFC	Deployment residential	Deployment Industry	Supporting activities
							Budget in M€			
BR	SFC	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	SFC	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	SFC	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	SFC	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			
DE	SFC	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	SFC	6	Technology validation	System components, FC systems, Prototype manufacturing				132	415	
DE	SFC	7	Market entry	Definition and selection of field test sites and conditions, field test infrastructure, Operation & service,				800	680	
Supporting activities	SFC	8	Creating Peace of Mind - Developing and Implementaing Harmonised Regulations, Codes and Standards	Grid-Interconnect RCS						9
	SFC	9	Building the Market - Stimulating and Meeting Early Demand	Develop schemes for public procurement and degressive incentivised product price for the output						17

5.3.3 Timelines

Action reference	Action number	Action focus	2007	2010	2011	2015
SFC	1	Generic Fuel Cell Technology				
SFC	2	Analysis and Modelling				
SFC	3	Industrially relevant cell and stack				
SFC	4	System component development				
SFC	5	Scaling-up of Manufacturing				
SFC	6	Technology validation				
SFC	7	Market entry				
SFC	8	Creating Peace of Mind - Developing and Implementaing Harmonised Regulations, Codes and Standards				
SFC	9	Building the Market - Stimulating and Meeting Early Demand				

5.4 IDA 4: Fuel Cells for Early Markets (EM)

5.4.1 Targets

Technical targets: Portable 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		

Technical targets: Portable Generators, UPS and Backup Power (250W to 50 kW)		
Characteristics	***Units***	***2015 Target***
System reliability (i.e. Output power availability)	(%)	99.99
System power density		
Lifetime	(hr)	
hours of operation;		
lifetime in stand-by mode		
Start-up time		
Maintenance	(hr/yr)	
Total life-cycle cost / cost-effective fuel supply		
Use of relevant fuels		
Environmental operating temperature	(°C)	

Technical targets: Specialist vehicles (0,25 kW to 100 kW)		
Characteristics	***Units***	***2015 Target***
System reliability		
System power density		
Lifetime (hours of operation)	(hr)	
System ruggedness (shock and vibration, environmental conditions)		
Start-up time		
Maintenance	(hr/yr)	
Total life-cycle cost / cost-effective fuel supply		
Fuel saving with respect to ICE (where applicable)		

Technical 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

5.4.2 Portfolio of actions

Action type	Action reference	Action number	Action focus		Details	Portable Micro FCs	Portable generators	Specialist Vehicles	By-product H2	Supporting activities
								Budget in M€		
			Portable Micro-FCs							
AR+DE	EM	1	State of the art technology		XX units pilot monitoring, performance assessments					
BR	EM	2	System development	Basic R&D	volume manufacturing processes for FCs and planar modules, high-efficiency & miniaturised BoP components					
AR	EM	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	EM	4		Diagnostic tools	development (failure modes, system architectures, sizing, data analysis) & verification in real operating conditions					
AR	EM	5		System modelling	system model development (sub-component characterization, reduce control requirements, field data verification)					
AR	EM	6		Reduction of complexity	BoP simplification, component optimisation, integration with fuel storage, "passive" control strategies, miniaturized system architecture					
AR+DE	EM	7		Reformer	highly integrated and low cost fuel processor, Miniaturisation and Integration with FC systems					
	EM	8		Improvement of performances	improved reliability in real operating conditions					
DE	EM	9	Demonstration	Alpha testing	field demonstration (system verification & certification, accelerated life test)					
	EM	10		Product development & demo	demo of business proposition					
			Portable generators, Back-up power, UPS							
AR+DE	EM	11	State of the art technology		XX units pilot monitoring, performance assessments					
BR	EM	12	System development	Basic R&D	lower cost, improved stack components, HT-PEMFC, Internal reforming SOFC, Direct utilisation of liquid fuels					
AR	EM	13		General	lower cost, improved stack components, HT-PEMFC, Internal reforming SOFC, Direct utilisation of liquid fuels, Fuel distribution, storage & safety					
AR	EM	14		Diagnostic tools	development (failure modes, system architectures, sizing, data analysis) & verification in real operating conditions					
AR	EM	15		System modelling	sub-component characterization, strategies for increasing system efficiency, integration with renewable H2					
AR	EM	16		Reduction of complexity	BoP simplification, component optimisation, integration with fuel storage, reduced number of sensors, design for modular installation					
AR + DE	EM	17		Reformer	highly integrated and low cost fuel processor					
AR	EM	18		Improvement of performances	efficiency, cyclings, packaging & modularization					
DE	EM	19	Demonstration	Alpha testing	field demonstration (system verification & certification, accelerated life test)					
	EM	20		Product development & demo	demo of business proposition					

Budgets for specific applications are not worked out yet

Portofolio of actions (continued)

Budgets for specific applications are not worked out yet

Action type	Action reference	Action number	Action focus		Details	Portable Micro FCs	Portable generators	Specialist Vehicles	By-product H2	Supporting activities
								Budget in M€		
			Specialist vehicles							
AR + DE	EM	21	State of the art technology		4 Pilot monitored fleet, refuelling strategies assessment (fuel logistic issues)					
AR	EM	22	System development	General	lower cost, improved performance stack components					
AR	EM	23		Diagnostic tools	development (failure modes, system architectures, sizing, data analysis) & verification in real operating conditions					
AR	EM	24		System modelling	system model development (sub-component characterization, hybridization strategies, field data verification)					
AR + DE	EM	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	EM	26		Improvement of performances	shock & vibrations (component & system)					
DE	EM	27	Demonstration	Alpha testing	fleets demonstration of alpha systems					
	EM	28		Product development & demo	demonstration of business proposition					
			By-product H2 Power Generation							
AR + DE	EM	30	State of the art technology		test of 2 systems (500kW - 1MW size)					
AR	EM	31	System development	General	lower cost, improved performance stack components, stack durability, models development for accelarated life test, failure prediction					
	EM	32		Diagnostic tools	development (failure modes, preventive maintenance, sizing of system hybrisation, data analysis) & verification in real operating conditions					
	EM	33		System modelling	system simulation, sub-component characterization, strategies for increasing system efficiency					
	EM	34		Reduction of complexity	BoP simplification, system integration, component optimisation, reduced number of sensors					
	EM	35		Improvement of performances	efficiency, cyclings, system modularization					
DE	EM	36	Demonstration	Pilot	demonstration in representative locations, performance evaluation					
	EM	37		Alpha testing	increase size of demonstrators to industry requirements (> 5 MW)					
	EM	38		Product development & demo	demonstration in representative locations, bdemonstration of business proposition					
Supporting activities	EM	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)					38
	EM	40			specific SME Promotion Activities (Financing of technically qualified projects from SME's via new financing pathways and partners)					38
	EM	41			getting Research and Academia primed for Spin-off					38
	EM	42	Building the Market - Stimulating and Meeting Early Demand		initiate and support Buyers' Pools					17
	EM	43			fostering the role of regions, industrial clusters and public-private partnerships to create the necessary structural conditions					17
	EM	44	Creating Peace of Mind - Developing and Implementaing Harmonised		in-door use of H2 and Fuel Cell Devices					9
	EM	45	Getting the numbers right - socio-economics modelling and tools		initiating the European Hydrogen & Fuel Cell Business Observatory ("EHFO"):					8

5.4.3 Timelines

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