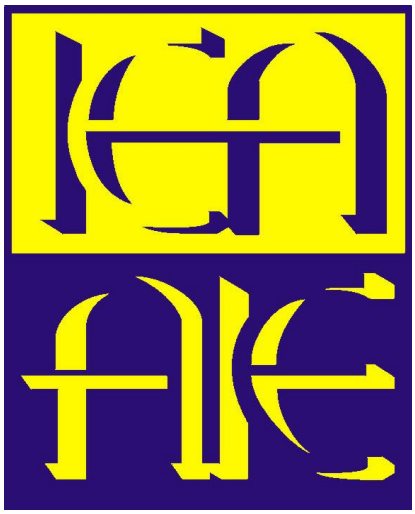

International Energy Agency

Agreement on the Production and Utilization of Hydrogen

5-Year Plan: 2004 – 2009

As approved by the Executive Committee on 1st of April 2004

and

Submitted for approval to the IEA – CERT

5-Year Plan: 2004 – 2009

1. FOCAL POINTS

The IEA HIA looks back to a 26-year history of collaborative international RD&D programs in regards to hydrogen production, conversion, storage, transport, end-use, safety and market economics.

Over the next five years (2004 – 2009), the Second Generation HIA strives to expand its leadership role in the advancement and communication of hydrogen science and technology. As illustrated in Figure-2, the five focal points for the HIA will be:

- Designing and conducting **collaborative RD&D** programs that address pre-commercial basic research needs;
- Undertaking **independent analyses** of hydrogen science, technology, systems and economics that support its RD&D and outreach programs;
- Increasing **membership participation**;
- Involving a broad range of **industry partners**; and
- Raising the level of hydrogen **awareness, understanding, knowledge and support** throughout all sectors of the economy.

Figure-2: Five focal points of 5-year HIA program during term 2004 – 2009.

2. 5-YEAR MISSION

In support of the HIA vision for a hydrogen-based sustainable energy supply future of global proportions, the 5-year mission of the HIA (2004 – 2009) is to **advance the adoption of a Hydrogen Economy** through strategic implementation of collaborative RD&D and outreach programs that address key issues and barriers.

3. STAKEHOLDERS, GOVERNANCE & MANAGEMENT

HIA's main stakeholders are its member governments, the IEA-CERT, the research experts of all current tasks, and the society at large. It is expected that industry will play a greater role as a stakeholder in the near future. The HIA is governed by its Executive Committee and complies with the IEA/CERT management requirements. The Executive Committee is comprised of a representative of each member country and meets twice per annum. The HIA Secretariat has professional management on a part-time basis. The manager supports the Chairman and Executive Committee. Management responsibilities include operations, coordination and supervision, communication and outreach, and representation. Due to increasing demands and expansion opportunities, the Second Generation HIA plans to pursue a multi-phase growth strategy during the 2004 – 2009 period. It will in a first phase support the establishment of full-time management for the Secretariat by 2005. In a second phase, a further expansion of the Secretariat role will be pursued with the support for, and/or establishment of, a permanent Hydrogen Office (HO), singularly or in association with another hydrogen organisation or body. Located either in Europe or northern America, the HO is planned to start operation in 2006 – 2007 and have multiple staff and an Executive Director by the end of this 5-year term (2009). The HO, most likely majority-funded by the HIA, is intended to operate as an independent center of excellence.

4. 5-YEAR GOALS

The generic objectives and actions outlined in the HIA Strategic Framework remain valid. The HIA has developed a 5-year Plan for the period 2004 – 2009. Along with its five focal points for 2004-2009 (as introduced above), being

- Collaborative RD&D,
- Independent analyses,
- Membership participation,
- Industry partners, and
- Confidence with hydrogen,

there are three principal hydrogen goals for the Second Generation HIA (refer also to Figure-3 on the following page). These goals are:

- **Advancement of science and technology** via pre-commercial collaborative RD&D programs;
- **Assessment of market environment**, including the non-energy sector; and
- **Implementation of outreach program**, aiming at community acceptance and support.

A program of cross-cutting, rigorous analyses tasks will support these goals on an on-going

basis to facilitate success.
Given its strategic framework, focal points and goals, the Second Generation HIA aims to enhance its position as a unique leader in pre-commercial hydrogen RD&D and the premier global resource for expertise in hydrogen technology. The HIA expects to be the first choice for authoritative impartial advice by policy makers, the research community, industry, the IEA and other interested parties on the implications and practicalities of the use of hydrogen as chemical commodity, energy carrier and alternative clean fuel.

5. SCOPE & PROGRAM OF WORK

5.1. Collaborative RD&D

Having invested and coordinated close to 1000 man-years of collaborative RD&D over the past 26 years, the Second Generation HIA will continue to focus its efforts on the strategic advancement of hydrogen science and technology, primarily addressing pre-commercial RD&D needs in its second generation of operations. HIA's three core RD&D tasks over the next 5 years will address (refer to Figure-3):
• Hydrogen **production** from renewable energy sources (photoproduction processes) and from advanced approaches to carbon-containing materials;
• Hydrogen **storage** (metal hydrides and carbon materials); and
• Integrated hydrogen **systems** (design, performance validation and optimisation),
including a component focus on advanced water electrolysis.

Overall, RD&D and analyses efforts of the HIA will be designed and structured for the main benefit of systems integration, subsequent validation and optimization. This is mandatory to facilitate the phased implementation of a robust hydrogen infrastructure and, ultimately, to support comprehensive market penetration of hydrogen technologies.

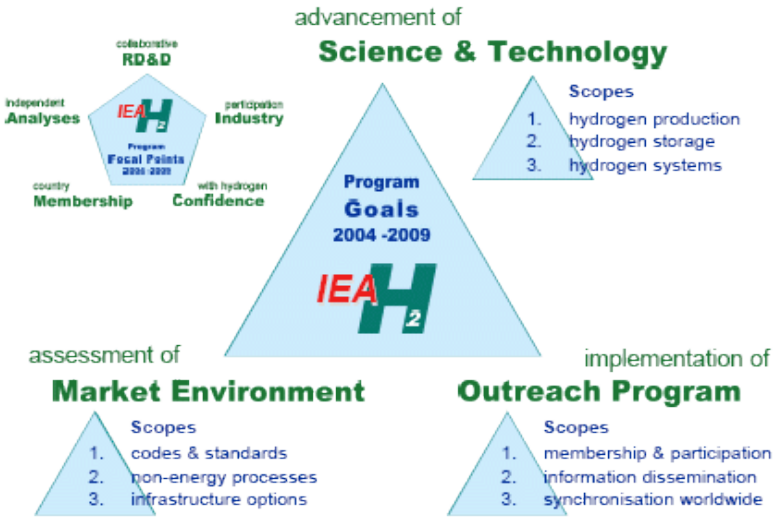

Figure-3: Principal goals and scopes of 5-year HIA program during term 2004 – 2009.

5.1.1. Production

Though significant science and engineering progress has been made over the past 5 years in the hydrogen photoproduction areas of photoelectrolysis (16% conversion efficiency) and of photobiology (sustained production), the research efforts are still at a relatively early but very promising development stage. Material science and systems engineering are the keys to success for novel photoelectrolytic solar hydrogen production cell developments. Genetic mutation and engineering of organisms (mainly bacteria and algae) are forming the nucleus of future solar-driven biohydrogen production options. These two areas of fundamental and pre-commercial hydrogen production research will remain a priority for collaborative task shared RD&D efforts at HIA over the next 5 years.

The solar hydrogen production tasks will be complemented with further R&D on production options based on carbon-containing materials. Conducted with strong industry collaboration,R&D will focus on (a) near-commercial techno-economic challenges related to small-scale hydrogen supply options using natural gas or biomass, and (b) technology advancements toward emission-free, large-scale hydrogen production from natural gas and from coal.

The **main objectives** of the production subtask are to develop **photoelectrolytic and photobiological hydrogen production** systems that are capable of s**plitting water reliably** (1000-hour test) with a net solar-to-hydrogen conversion efficiency of **10%**, and to assist industry with the techno-economic **advancement** of small- and large-scale **hydrogen** production options **from carbon-containing materials**.

5.1.2. Storage

Over the years, the HIA has committed considerable collaborative resources to develop solutions for hydrogen storage, focusing on metal hydrides and carbon structures for “solidstate” hydrogen storage. The HIA continues its leadership in initiating, planning, consolidating and coordinating leading research in the field and to systematically prioritise research initiatives. Hydrogen storage tasks are principally geared toward the development of practical storage media for onboard vehicle storage, although stationary storage is also of interest. Thanks to the leading efforts of the HIA over the past 5 years, experts can now access concise and reliable information on the state-of-the-art research in this field from a centrally-located and managed database. The next 5 years strives to advance these fundamental hydrogen storage RD&D efforts.

The **main objective** of the storage subtask remains to develop **“solid-state” storage** systems that operate on a fully **reversible** basis with a hydrogen storage density of at least **5-wt%**, recoverable at less than **80°C** and **1 atm** absolute pressure.

5.1.3. Systems

Hydrogen energy system demonstrations continue to be undertaken throughout the world. The experiences gained from these projects need to be compiled, analyzed, compared and made available to future demonstrators. Public response must be captured and considered when planning any hydrogen demonstration. System efficiency and cost optimization will also remain paramount issues for developing competitive hydrogen-based systems. This is understood to be particularly relevant with regards to advanced water electrolysis technology options, warranting the conduct of further dedicated RD&D sub-programs as planned by the HIA for the period 2004 – 2009. Thus, the HIA sees that utilising all available information and international expertise and that continually refining and expanding modeling tools (engineering and Life Cycle Assessment – LCA) will be imperative for the advancement of hydrogen energy systems. The 5-year program aims to further HIA's database as well as expertise on integrated hydrogen systems, and will include an detailed analysis of the pertinent question: "where does the hydrogen come from?"

The **main objective** of the systems subtask is to assist in the **identification** an **optimum combination** of existing, advanced and evolving **technologies** that meet the three fundamental criteria for integrated hydrogen systems within the next 5 – 10 years. These are increased efficiency, minimal environmental impacts and, most critically, cost competitiveness.

5.2. Market Environment

In parallel with the planned science and technology research efforts on hydrogen energy production, storage and utilization technologies, a set of in-depth analyses of the market environment is needed to advance the use of hydrogen and to eventually implement a viable transition to the Hydrogen Economy. Such analyses must explore the wider context of the market conditions and environmental forces within which hydrogen as an energy carrier exists. The complex network of environmental forces includes political-legal, economic,socio-cultural and technological forces. HIA's three main market environment scanning tasks over the next 5 years will address:

- Hydrogen safety and technology transition in the context of **codes & standards** for local mainstream approval and global synchronisation;
- Market analysis and improvement of **non-energy** hydrogen **processes**; and
- Techno-economic evaluation of **infrastructure options** (primarily supply chain analyses addressing centralized versus decentralized infrastructure options).

5.2.1. Codes & Standards

Worldwide, the status of hydrogen codes and standards is seen as a significant barrier to the successful establishment of a market-receptive environment for

commercializing hydrogen based technologies, products and systems. In this context, safety considerations and smooth technology transition are main concerns underlying codes and standards. Given the importance and multi-year requirements of such development efforts, the HIA plans to collaborate over the next 5 years with key government and industry bodies worldwide to prepare, review and promulgate hydrogen codes and standards needed to expedite hydrogen infrastructure developments and technology as well as product adoption.

The **main objective** of the codes & standards subtask is to establish the groundwork for the HIA to become an authoritative, independent **advisory group** for **hydrogen safety**, technology transition and technical market adoption.

5.2.2. Non-energy Processes

Hydrogen use in non-energy processes such as the chemical, metallurgical, ceramics and food industries has been identified by the HIA as an area where a concentrated analysis and research effort could facilitate the increased utilization of hydrogen. Annually, these industries account for nearly 50 percent of the world's total hydrogen consumption of 540 billion Nm3. Process improvements and novel synthesis approaches are expected to lead to overall efficiency improvements and reduced environmental impacts. Likewise, increased market share for hydrogen in these areas should lead to more competition and an expedited infrastructure development, two requirements for facilitating the advancement of the hydrogen as energy carrier and of renewable-energy-based hydrogen applications. The HIA plans to embark on an extensive market analysis program of the non-energy hydrogen sectors during the proposed 5-year HIA extension program.

The **main objective** of the non-energy processes subtask concerns a comprehensive **market analysis** of non-energy hydrogen processes, applications and operation, presented as a web-interactive **non-energy hydrogen information database**.

5.2.3. Hydrogen Infrastructure

The question about the choice of the most suitable and cost-effective hydrogen technology supply infrastructure as well as logistic implementation path remains unanswered. During the 5-year program, the HIA aims to collaboratively undertake Live Cycle Assessment (LCA) and to model the solutions of the “chicken-and-egg” challenge of supply and demand that will ultimately dictate the adoption of centralized versus decentralized hydrogen supply options. The work focus will be on stationary applications, building on and complementing international efforts regarding “well-to-wheel” LCAs. At the next level of analysis during the second part of the 5-year HIA program, the logistic implementation path requires scrutiny. These efforts on hydrogen infrastructure will also make good use of technology intelligence that is being assembled by a “hydrogen technology watch team” of the HIA on an ongoing basis.

The **main objective** of the hydrogen infrastructure subtask is the conduct and presentation of a detailed **LCA analysis** for **stationary hydrogen application options**.

5.3. Outreach Program

In spite of up to 170 years of safe large-scale hydrogen production (electrolysis, coal gas, natural gas reformation), distribution (pipeline, tanker), storage (cryogenic, pressure vessel) and utilization (town gas, petro-chemical industries, etc.), the benefits of hydrogen are still largely unknown to the majority of our society in general and to the political and industrial leaders in particular. HIA's three core outreach tasks over the next 5 years will address:

- Expansion of **HIA membership** and promotion of **industrial participation**;
- Implementation of multi-phase **information dissemination program**; and
- Collaboration with leading **international hydrogen working groups**.

5.3.1. Membership Drive

The adoption and implementation of a Hydrogen Economy requires a whole-of-society approach for it to be successful. The HIA strives over the next 5 years to continue its ongoing membership expansion, particularly in regards to IEA member countries and to emerging economies in transition such as China, India, Mexico and Brazil. The HIA will also seek widespread international participation from hydrogen industries, to act as know how carriers, sponsors and advisory committee members. The expansion into the non-energy hydrogen sector is paramount due to the significant size of the industry sectors, their profound experience as well as local knowledge, and their worldwide presence.

The **main objectives** of the membership drive subtask are to **double its country membership** (to 26 members) and to **secure** championing **industry participation** with **every new Task** program (above all Subtask Leadership).

5.3.2. Dissemination Program:

The scope of the 5-year dissemination program is based on key activities managed by the Secretariat, including communication, liaison, website expansion, branding, publishing, presentation, networking, stakeholder-group participation and media engagement. The program has multiple phases that are in line with the planned growth of the Second Generation HIA.

The **main objective** of the dissemination **program** subtask is to provide everyone, predominantly via the internet, with **knowledge and trust** about **hydrogen** as prime fuel energy carrier.

5.3.3. International Team Efforts

The HIA will place increased emphasis on coordinating its efforts with international peak hydrogen organizations (ie. IPHE, IEA-HCG, EU-HLG, EHA, AHA, ISO-TC197, etc.) in order to jointly prioritize activities and establish collaborations of mutual interest. Such coordination is becoming increasingly

important as there are a multitude of conflicting and/or competing views on how the different energy technology solutions will develop, when the Hydrogen Economy will be realized, which technologies are important, what the appropriate paths are to follow, what areas to emphasize on, etc. These views are all strongly influenced by political and commercial goals, which vary throughout the world. The HIA will seek over the next 5 years to serve as a neutral organization, with focused activities that address common areas of concern and that require a longer-term, pre-competitive effort.

The **main objective** of the international team effort subtask is to contribute to **hydrogen activity coordination** on a **worldwide** basis.

5.4. Program of Work

The HIA has been developing a 5-year extension program of work that builds on the success of the current 5-year term (1999 – 2004) and takes advantage of the significantly increasing world interest in hydrogen as a energy carrier and of the resulting HIA membership growth. The Second Generation HIA program of work was developed with the full participation of the HIA Executive Committee. Portfolio enhancements are expected to occur over the five-year term of its implementation.

Figure-4 illustrates the key elements of the program of work proposed by the HIA for the new 5-year term 2004 – 2009. The main elements of the program of work are divided into two collaborative Task program parts managed by dedicated Operating Agents, and two administrative parts managed primarily by the Secretariat. All program parts are operated under the direction of the Executive Committee of the HIA.

The high degree of past intra-member-country and inter-IA collaboration will be expanded during the proposed 5-year program of RD&D work (2004 – 2009), particularly toward the IEA SolarPACES, Bioenergy, PVPS, Greenhouse Gas R&D, Advanced Fuel Cells and Advanced Motor Fuels programs.

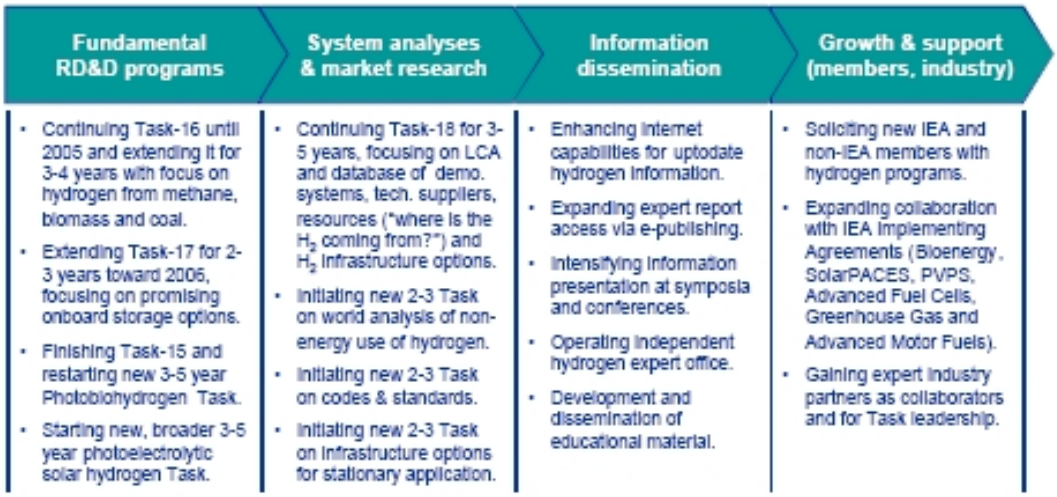

Figure-4: Key elements of the proposed 5-year program of work by HIA (2004 – 2009), divided into two collaborative Task program parts and two administration Task parts.

The eight main, collaborative RD&D Task activities presented above are illustrated in Figure-5 on a tentative timeline for the 5-year program of work (2004 – 2009) proposed by the HIA.

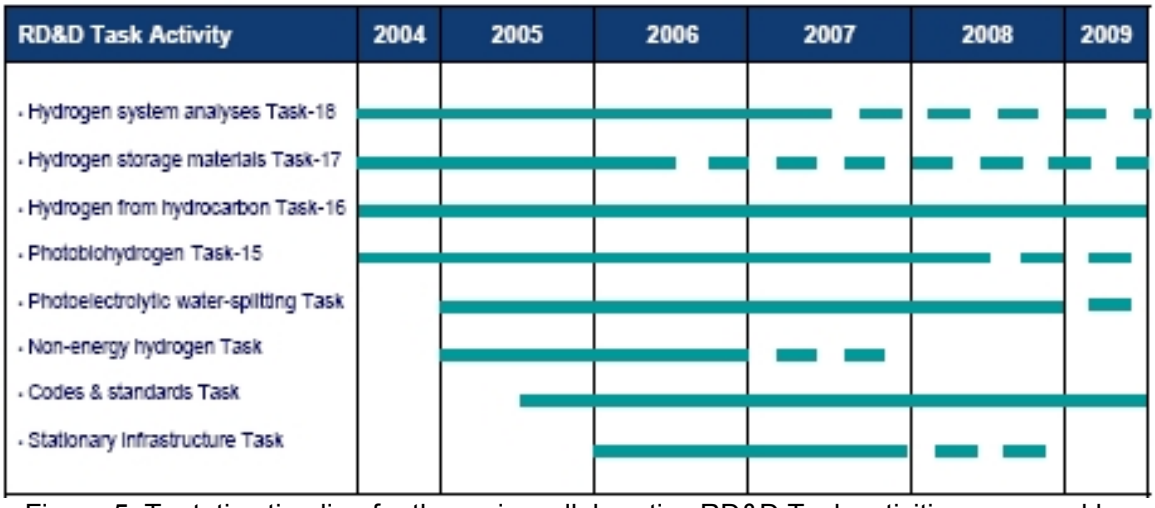

Figure-5: Tentative timeline for the main, collaborative RD&D Task activities proposed by HIA (2004 – 2009).

6. OUTCOMES & CONTROLS

The HIA has been planning for significant growth to result during the 5-year extension term 2004 – 2009. Table-4 presents a comparison of the major achievements of the current 5-year term 1999 – 2004 with the targeted outcomes from proposed 5-year HIA plan.

Table-4: Comparison of the major achievements of the current 5-year HIA term with thetargeted outcomes of the proposed 5-year HIA term.

Criterion	Achievements / Targets	1999 – 2004	2004 – 2009
Membership	Number of members at end of term	14	~ 28
Partnership	Number of industry cooperation and sponsorship	53	~ 100
RD&D Tasks	Number of RD&D Tasks active during term	7	~ 8
Level of effort	Number of man-years invested on RD&D Tasks	~ 300	~ 500
Workshops	Number of expert Task workshops conducted	36	~ 50
Publications	Number of HIA summary publications produced	11	~ 20
	Number of scientific papers produced by experts	> 200	> 200
Presentations	Number of conference presentations held by HIA	~ 10	~ 25
Support	Direct member supports for Operating Agents [1]	~ US$ 1 mil	~ US$ 1 mil
	Indirect support through industry participation [2]	~ US$ 2 mil	~ US$ 3 mil
HIA Budget	Cumulative operating budget of HIA during term	US$ 0.4 mil	~ US$ 1 mil

[1] Cash and in-kind support provided by government members, excluding in-kind support through Executive Member participation. It must be noted that the HIA program activities generate a range of leverage factors across world hydrogen RD&D programs in general and the IEA member country programs in particular.

[2] In-kind support provided by industries and government research institutes through Task participation and Task part-leadership (best estimates only).

The Executive Committee of the HIA plans to conduct its business during the proposed 5-year extension term 2004 – 2009 with a full-time Secretariat function that is expected to grow into a full-service Hydrogen Office. The Executive Committee itself will continue to operate as a Governing Board, accepting and performing its duties and responsibilities toward CERT and the IEA at large.

7. ACTIONS FOR IMPROVEMENTS

Considering the five basic aims of the IEA, the HIA focuses particularly on the one regarding *improvement of the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use*.

The HIA prides itself for its long-standing leadership in conducting pre-commercial hydrogen RD&D across the prime areas of need and in a world-unique collaborative approach. Given the ongoing growth of hydrogen interest and activities around the world, and in keeping with the overarching goals of the IEA, the CERT and the REWP, the HIA is preparing for a major expansion of its activities. In pursuit of its goals, focal points and objectives over the next 5-year term (2004 – 2009) as outlined in this paper, the HIA seeks the support from the **IEA** to begin its second-generation hydrogen RD&D program. The specific **support actions** desired from the IEA headquarters include:

- **Administrative assistance** in support of HIA's **membership recruitment** initiatives (i.e. facilitating joining the IEA in a fast-tracked manner to participate in the HIA and its RD&D programs; providing information such as market research and member survey results that aid HIA's recruitment initiatives; etc.);
- **IA collaboration facilitation** and **streamlining** (i.e. promotion of internal liaison events and collaboration opportunities among other IAs as HIA leads charge on hydrogen RD&D; facilitation of work coordination strategy meetings to reduce work duplication; etc.); and
- **Public relations support** (i.e. assisting with editing and publishing; stepping-up publicity through greater IEA web presence and media recognition; promotion of HIA's "Second- Generation Hydrogen RD&D Program"; etc.);

Overall, the Second Generation HIA aims to be recognised as the premier global resource for expertise in hydrogen technology. It strives to become the first choice for authoritative impartial advice by policy makers, the research community, industry, the IEA and other interested parties on the implications and practicalities of the use of hydrogen as chemical commodity, energy carrier and alternative clean fuel.

8. PUBLICATIONS

HIA's main publications from the outgoing term 1999 – 2004 can be accessed through our internet on http://www.eere.energy.gov/hydrogenandfuelcells/hydrogen/iea/publications.html. A list of the over 200 papers published by the respective RD&D Task experts during this 5-year term can be requested from the HIA Secretariat.