Asia-Pacific Economic Cooperation

Asia-Pacific Economic Cooperation

Energy Working Group (EWG)

Interim Framework Document on Hydrogen and Fuel Cells

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1.0 INTRODUCTION

Energy is vital to realizing the opportunities presented by economic growth and development for communities in the APEC region. Sustained economic growth is dependent on adequate, reliable and affordable supplies of energy.

APEC faces a range of energy security challenges, including its dependence on oil for energy production, fully utilizing existing energy resources, expanding these resources through exploration and development, and realizing the potential of alternative energy sources.

At their meeting in 2000, the APEC Economic Leaders identified the risks to the world economy posed by volatility in the oil market and called for appropriate measures to promote stability in the mutual interests of consumers and producers. In response the APEC Energy Working Group developed the Energy Security Initiative (ESI).

The APEC Energy Ministers endorsed a number of recommendations under the Energy Security Initiative at their meeting in 2002 and directed the APEC Energy Working Group (EWG) to promote its implementation. At the 26th EWG in Seoul, members agreed that implementation of other measures under the Energy Security Initiative (Agenda Item 4.4) would include the development of an Interim Framework Document on hydrogen and fuel cell technologies to be reported to Energy Ministers in June 2004. This item is part of the Action Plan to Enhance Energy Security that complements the Energy Security Initiative Implementation Plan, both endorsed by APEC leaders in October 2003.

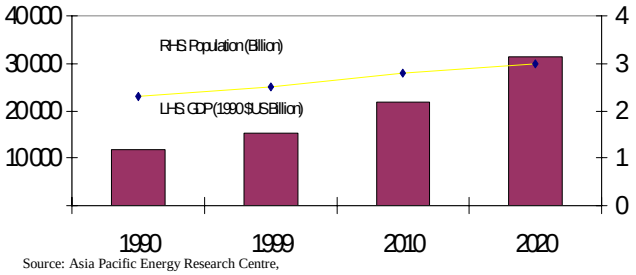
To produce this document, the United States hosted the APEC Energy Working Group "Energy Security Initiative: Hydrogen Interim Framework Document Workshop" on March 29-30, 2004 in Honolulu, Hawaii. The workshop enabled APEC members to discuss the obstacles and opportunities for APEC coordination to advance the "APEC Hydrogen Economy". The issues that are recorded in the Action Plan, which were discussed at the meeting, and are detailed in the subsequent pages of this report, include opportunities to:

- Cooperate with the International Energy Agency (IEA) and the International Partnership for the Hydrogen Economy (IPHE) to advance hydrogen energy;
- Develop a program for capacity building assistance on policy and regulatory issues;
- Work in a long-view toward harmonized codes, standards, and regulations.

1.1 Rationale:

The worldwide growth in transportation will accelerate oil consumption and increase the emission of pollutants responsible for urban air pollution (i.e. nitrogen oxides, sulfur oxides, carbon monoxide, and hydrocarbons) as well as the emission of greenhouse gases, primarily carbon dioxide, resulting in the realization of a critical need to develop alternative energy sources. As an alternative to oil, a growing number of countries around the world have committed to accelerate the development of hydrogen and fuel cell technologies in order to improve their energy, environmental, and economic security. Within APEC, Japan, Australia, Canada, Singapore, China and the United States already have programs or projects focused on developing and demonstrating hydrogen and/or fuel cell technologies. Other economies are working to develop and expand their programs.

Figure 1: APEC GDP & Population



Source: Asia Pacific Energy Research Centre, *APEC Energy Demand and Supply Outlook 2002*

APEC recognizes the economic, environmental, and energy security benefits of the diversification of energy supplies. It furthermore acknowledges the essential contribution of energy to maintaining the Asia Pacific region's economic growth and social development. Growth in the APEC region's energy supply infrastructure will therefore need to keep pace with demand if the region's development goals are to be met. Hydrogen, therefore, presents a viable long-term solution for providing for APEC's energy needs.

A hydrogen economy has the potential to contribute to energy security in a number of ways. Hydrogen can be derived from multiple feedstocks, which fosters versatility. The hydrogen economy would facilitate the transition from limited nonrenewable stocks of fossil fuels to unlimited flows of renewable sources. And the successful development of the technologies and infrastructure to produce, store and distribute hydrogen offers the promise of efficient, pollution-free vehicles as well as residential and business electricity generation. This transition to a hydrogen economy, however, will require considerable investment and significant planning to optimize resource utilization, mitigate costs, and develop the requisite infrastructure.

The APEC region presents a distinctive grouping of economies that can contribute to and benefit from collaboration on key areas of hydrogen and fuel cell development and thereby help to develop a hydrogen economy that will make our energy future more secure.

1.2 Overview of Workshop Process & Outputs:

The APEC Energy Security Initiative, through the APEC Action Plan to Enhance Energy Security, tasked the APEC Energy Working Group to develop an Interim Framework Document on hydrogen and fuel cells to be delivered to the Energy Ministers in June 2004. Specifically, the Energy Working Group was directed to address the following issues:

- Cooperate with the International Energy Agency (IEA) and the International Partnership for the Hydrogen Economy (IPHE) to advance hydrogen energy;
- Develop a program for capacity building assistance on policy and regulatory issues;
- Work together in a long-view towards harmonized codes, standards, and regulations.

To address these issues and to develop the Interim Framework Document, the U.S. hosted the APEC Energy Working Group "Energy Security Initiative: Hydrogen Interim Framework Document Workshop" on March 29-30, 2004.

The Interim Framework was developed with the intent of obtaining a general agreement on how APEC could proceed in supporting hydrogen energy development. This involved the development of a priority list of potential activities that would strengthen APEC's ability to provide products and services to member economies to enhance existing and foster new hydrogen energy development activities. It was not intended as vision, roadmap, or action plan document.

The workshop utilized a four-step process to effectively address requirements. This process involved asking workshop attendees a series of questions that concentrated discussions to provide the Ministers with a generally agreed upon list of potential activities to strengthen APEC's ability to support hydrogen energy development efforts.

STEP 1 – Interim Framework Outline: The first step in this process was to establish an Interim Framework outline from which further discussions would evolve. This outline therefore needed to identify the key areas where an APEC role might be beneficial in advancing hydrogen and fuel cell development efforts. Workshop participants would later be separated into groups to discuss these key areas and develop potential ideas for APEC coordination.

STEP 2 –Unique APEC Opportunities & Competitive Advantages: After identifying the key areas for potential APEC involvement, attendees were asked to articulate the uniqueness of the APEC region in terms of any technical, institutional, financial, special market, or resource differences that could offer APEC certain advantages or opportunities to advance the hydrogen economy. This discussion provided attendees with a platform from which to discuss potential APEC activities within the key areas summarized in the Interim Framework outline.

STEP 3 – Preliminary Findings: In this step, attendees were separated into breakout groups – one for each of the key areas identified in the Interim Framework outline, or:

- Education, Outreach, & Information Dissemination
- Safety, Codes and Standards
- Capacity Building Assistance

These groups were asked to consider what products or services APEC could provide to its member economies to advance hydrogen technology development and commercialization. Attendees were also asked to consider how APEC might work with non-member economies and key international organizations to advance this same objective.

These ideas were then voted upon, tallied, and the top few ideas were presented to the full group in the plenary session. The plenary then, similarly, conducted a vote and identified the top five ideas that received the most support across all three breakout groups.

STEP 4 - Priority Recommendations: During the plenary session, five ideas surfaced as clear leaders and were recognized as the priority ideas that would be presented to the Energy Ministers in June.

These five ideas where then used to split the full group again so that the workshop attendees could discuss, in more detail, the issues facing their successful implementation. The topic areas for these discussions were:

- Challenges/Barriers
- APEC Process Steps (to implementation)
- IPHE and/or IEA Coordination
- Resources (Requirements, Issues, Capabilities, etc...)
- Additional Comments

In this way, attendees were able to fully explore the challenges facing the proposed activities and the potential for coordination with the IPHE or the IEA, while providing an overview of the necessary steps to implementing each of these suggested ideas and a preliminary assessment of the resources, etc. that may or may not be available in each of these efforts.

Priority Recommendations for Potential APEC Activity in Hydrogen and Fuel Cells

- **Web-based "Tool-box" for the Policy Makers within each APEC Economy**: Develop a website "toolbox" to aid in the education and dissemination of information to government leaders and decision makers on the challenges, opportunities, benefits and life-cycle costs of hydrogen and fuel cell technologies. Some felt that this website clearinghouse should also be accessible to the APEC public. Such a website would have:
    - *Downloadable Fact Sheets*. Fact sheets could provide detailed information on a variety of issues, including Benefits, Key Challenges, Production Technologies & Potential Resources, Utilization Technologies, Technology Status, and Safety Issues. These fact sheets could be circulated amongst the appropriate officials and could be disseminated to other select stakeholder groups.
    - *Case Studies*: Case studies that take a snapshot of the successes and failures of existing technology demonstrations. Information might include technical results from demonstration runs.
    - *Online Forum for Information Exchange*: Online discussion forum for officials to exchange information, receive updates, provide opportunities for question and answer session, etc.
    - *Information Sources*: Links to multilateral and bilateral efforts on hydrogen and fuel cell activities and to individual economies.
    - *Frequently Asked Question (FAQs)*: Fact page that provide answers to some of the most commonly heard queries.
    - *Analysis Tools*: Provide a simple, interactive, web-based analysis tool for government officials to investigate the impact that hydrogen might have in terms of energy imports, emissions, and opportunity costs.

- **APEC Policy Forum on the Successes and Failures of Various Mechanisms to Advance Hydrogen Energy Development:** Convene an APEC policy forum where APEC officials can present and discuss the successes and failures of the various policy and regulatory mechanisms employed by each economy to advance hydrogen technology development and integration efforts. This forum will consider the necessary infrastructure - physical, market, and regulatory - for such mechanisms to be effective. It will also provide an opportunity for APEC economies to present their various on-going, priority RD&D efforts, facilitating discussions concerning the direction of current research, development, and demonstration activities. The forum will furthermore involve a technology exposition for APEC officials to gain first-hand knowledge of on-going private sector activities to develop and demonstrate these latest technologies.

- **Comprehensive Codes & Standards Inventory:** Organize an inventory of all on-going codes and standards activities. This activity would assemble all existing codes and standards that are relevant to hydrogen and fuel cell technologies, including items in Fire, Safety, Performance, Vehicles, Buildings, Consumer Products, Environment, and Utility Interconnects. This effort would also provide a summary of all on-going efforts to establish hydrogen and fuel cell codes and standards within nations, regions, and globally. This will enhance awareness of existing C&S efforts, avoiding duplicative efforts, and will provide APEC with a means to discretely assess competing efforts and evaluating the potential impact of these efforts on the APEC region.

- **Workshop to Analyze Hydrogen and Fuel Cell Codes & Standards Gaps:** Hold an international workshop, conducted jointly with the APEC Transportation Working Group (TWG), with the appropriate codes and standards decision makers to identify and discuss the existing gaps in hydrogen and fuel cell codes and standards. Such gap analysis will focus on areas which need additional attention in order to ensure safe, compatible systems, on-going efforts to fill these gaps and the potential discrepancies between these on-going efforts.

- **APEC-IPHE and IEA Information Exchange on Policies and RD&D Status:** Establish an avenue through which APEC and IPHE can exchange information on program direction, policies, and on-going activities in hydrogen and fuel cells. This conduit might eventually lead to cooperative efforts to advance the hydrogen economy. The hydrogen expertise existing within the IPHE organization and the potential market opportunities that exist within the APEC forum provide excellent motivations for transparent information exchange on existing hydrogen policies and technology status.

However it should be noted that actual activities may be subject to change depending on circumstances, including the budgetary situation.

1.3 Structure of the Report

The following sections of the report provide a more detailed overview of the outputs from each of workshop process steps.

2.0 **Interim Framework Outline**: This section presents the general statement of the workshop mission, developed through facilitated discussion, which identifies three key areas for potential APEC involvement in hydrogen and fuel cell activities. This statement served as the guide to structure the remaining workshop activities.

3.0 **Unique APEC Opportunities & Competitive Advantages**: The Asia-Pacific region is a unique area of the world with resources, capabilities, and circumstances that differentiate it from other global communities. It is these distinctions that may offer APEC certain advantages and/or opportunities to advance the hydrogen economy. This section articulates these distinctions.

4.0 **Preliminary Findings**: Workshop participants were divided into groups to develop potential APEC activities that address the three key areas identified in the Interim Framework Outline. This section provides a summary of those discussions.

5.0 **Priority Recommendations:** This section summarizes the ideas that were identified by the APEC economies as the highest priority activities from the breakout group findings. It also provides a bit more detail on the challenges/barriers facing these activities, the steps to implementing them, the potential for IEA or IPHE coordination, and a brief assessment of resource issues.

6.0 **Next Steps**: At the conclusion of the workshop, participants were asked for final comments, reflections, or expectations on the workshop proceedings. This section encapsulates these thoughts and provides a forward look toward future APEC considerations.

Appendix A **Setting the Stage (On-going Activities):** Briefly discusses the international (IEA and IPHE) and individual APEC economies' efforts on hydrogen and fuel cells.

Appendix B **IEA Hydrogen Program, Strategic Plan**

Appendix C **APEC EWG Interim Framework Document Workshop - Attendees**

2.0 INTERIM FRAMEWORK OUTLINE

The APEC Action Plan to Enhance Energy Security tasked the APEC Energy Working Group to address the following issues:

- Cooperate with the International Energy Agency (IEA) and the International Partnership for the Hydrogen Economy (IPHE) to advance hydrogen energy;
- Develop a program for capacity building assistance on policy and regulatory issues;
- Work together to harmonize codes, standards, and regulations.

This direction provided the most important guidance to APEC EWG members at the "Energy Security Initiative: Hydrogen Interim Framework Document Workshop". However, in addition to these tasks, workshop attendees felt that it was important to consider education/information dissemination-type activities. These activities are instrumental in ensuring that the needs of all stakeholders are addressed and that there is transparent and appropriate information exchanged to the groups who will have a significant impact on the success or failure of hydrogen development, demonstration, and adoption.

With this in mind, the following statement was developed as a guide to the Interim Framework Document development effort.

APEC Interim Framework Outline:

To provide support to member economies and work with non-member countries and key international organizations in three key areas:

- **Outreach, Education & Information Dissemination** to policy makers, state and local officials, business decision makers, technical experts, and the general public on the life-cycle costs, benefits, and safety considerations of the hydrogen economy and alternatives.
- **Safety, Codes & Standards** to foster greater harmonization to reduce international barriers to development and testing of hydrogen energy systems.
- **Capacity Building Assistance on Policy & Regulatory Issues** including analysis to direct R&D and target demonstration projects for hydrogen infrastructure development.

3.0 UNIQUE APEC OPPORTUNITIES & COMPETITIVE ADVANTAGES

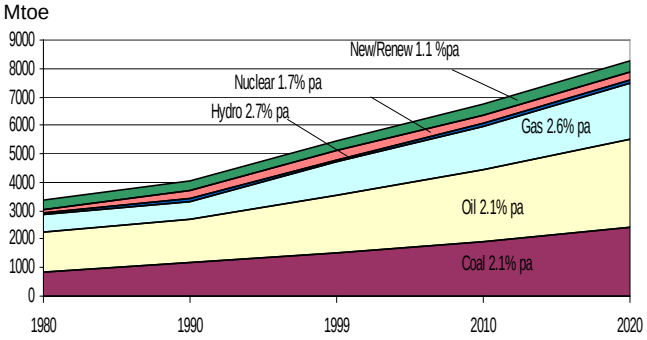
The Asia-Pacific region is a unique area of the world with resources, capabilities, and circumstances that differentiate it from other global communities. (Energy security is a nearly universal driver behind international efforts to develop and demonstrate hydrogen technologies, thus it will not be mentioned among the characteristics listed in the following discussion.) It is these distinctions that may offer APEC certain advantages and/or opportunities to advance the hydrogen economy.

To effectively identify the characteristics that make APEC unique and to provide workshop attendees with a platform from which to discuss the APEC Interim Framework on hydrogen and fuel cells, attendees were asked to articulate the uniqueness of the APEC region relating to hydrogen energy. A variety of topics were discussed ranging from the large natural gas and coal reserves that exist within the APEC arena – a promising source of hydrogen fuel, given efficient, environmentally benign production - to the potential access to the Asian Development Bank (ADB) loans and the perceived longer-term horizon for financial planning decisions in the Asian community. However, a few themes clearly emerged from this conferencing and through a systematic voting process were collectively identified as potentially important factors when considering future APEC activities in hydrogen and fuel cells. These factors are identified below:

3.1 Drivers

- **Expected Growth in Energy Demand**: The Asia-Pacific region is the most rapidly growing area in the world. Heavily dependent on oil, this emerging economic engine is already responsible for 60% of world energy demand as well as 50% of world trade. These numbers are expected to increase in the future. Such economic growth will result in substantial increases to the region's energy demand, and will require similar expansion of the supporting energy supply infrastructure.

Figure 2: APEC Energy Demand



Source: Asia Pacific Energy Research Centre, *APEC Energy Demand and Supply Outlook 2002*

- **Support for Reduction of Emissions**: Pollution from fine particulates is a growing problem within the APEC region. Also, many low-lying Asia-Pacific economies have expressed concern over the threat of rising sea levels, presumably resulting from global warming. Thus, there is a strong interest in the development, demonstration, and implementation of new, alternative energy technologies that are clean, sustainable, and energy-efficient, reducing the emission of greenhouse gases (primarily carbon dioxide) and fine particulates.

3.2 Unique Competitive Advantages:

- **Manufacturing Capabilities**: The APEC region maintains three competitive advantages in manufacturing that could influence its global impact in the development of a hydrogen energy economy:

- **Low-cost, High-Tech Manufacturing**: Many APEC economies are globally recognized for their low-cost, high -technology manufacturing capabilities. As hydrogen technologies begin to enter the marketplace, this capability could be influential in creating market leaders.

- **Automobile Manufacturing**: The APEC region, together, supplies the majority of world vehicle demand. This preeminence in auto manufacturing is significant and could provide an opportunity for collaboration and coordination.

- **Miniaturization**: Considerable expertise in miniaturization also exists within many of the APEC economies. This expertise may become more important as new hydrogen and fuel cell technologies are introduced to consumers.

- **Technical Expertise:** Many APEC member economies are world leaders in hydrogen and fuel cell RD&D. These members provide APEC with access to the latest, most advanced technologies.

- **Existing Communication Infrastructure:** The APEC forum provides a unique and already established communication infrastructure through which to share information. Existing resources, such as the Energy Business Network (EBN) could be valuable in facilitating international dialogue and providing a means through which to cooperate on hydrogen and fuel cell development and demonstration activities. Economies and organizations not included in this forum will not have the same opportunities for technical, economic, and financial discussions and exchanges.

3.3 Unique Opportunities:

- **Receptiveness to New Technology:** Many economies within APEC are globally known for their receptiveness to the latest technologies. Their ability and desire to quickly integrate and adopt these technologies often translates into lower price sensitivity than found in other areas of the world. This may provide an amenable environment for the early market adoption of hydrogen and fuel cell products.

- **Power Demand and Lesser Developed Regions:** The growing demand for power across the APEC region and the significant number of island economies and large underdeveloped areas provide ample market opportunities for the introduction of distributed generation systems. Such areas, whether due to a lack of existing infrastructure or a lack of sustainable energy systems, are ideal candidates for the deployment of new, clean and efficient power generation technologies. With carefully designed and replicable demonstrations, these areas could leapfrog status quo technologies, reducing emissions and enhancing global energy security, while providing a market for hydrogen and fuel cell technology developers.

These points formed the basis for further discussions on how APEC should proceed in supporting hydrogen energy development and in generating ideas for a prioritized list of potential activities which could strengthen APEC's abilities to enhance existing and foster new hydrogen development activities.

4.0 PRELIMINARY FINDINGS

The three key areas identified in the Interim Framework Outline provided a grouping by which to divide attendees to discuss the potential opportunities for APEC to provide products and services to its member countries to advance the development of hydrogen energy. Thus, breakout groups were formed to address each of these areas. The breakout groups were:

- Education, Outreach, & Information Dissemination
- Safety, Codes & Standards
- Capacity Building Assistance (Policy/Regulatory Mechanisms)

Discussions from each of these groups are detailed below:

4.1 Education, Outreach, & Information Dissemination:

This group was tasked with developing ideas that would serve the following purpose, stated in the Interim Framework outline:

> ***"****Outreach, Education & Information Dissemination to policy makers, state and local officials, business decision makers, technical experts, and the general public on the life-cycle costs, benefits, and safety considerations of the hydrogen economy and alternatives."*

Through the course of the discussion, a variety of ideas were generated and were grouped according to the stakeholder group to which they pertained At the conclusion of this breakout session, however, three ideas emerged as clear leaders. The ***ideas targeted policy/decision makers***.

- **Web-based "Tool-box" for the Policy Makers within each APEC Economy**: Develop a website "toolbox" to aid in the education and dissemination of information to government leaders and decision makers on the challenges, opportunities, benefits and life-cycle costs of hydrogen and fuel cell technologies. Some felt that this website tool-box should also be accessible to the APEC public. Such a website would have:
    - *Downloadable Fact Sheets*. Fact sheets could provide detailed information on a variety of issues, including Benefits, Key Challenges, Production Technologies & Potential Resources, Utilization Technologies, Technology Status, and Safety Issues. These fact sheets could be circulated amongst the appropriate officials and could be disseminated to other select stakeholder groups.
    - *Case Studies*: Case studies that take a snapshot of the successes and failures of existing technology demonstrations. Information might include technical results from demo runs.
    - *Online Forum for Information Exchange*: Online discussion forum for officials to exchange information, receive updates, provide opportunities for question and answer session, etc.
    - *Information Sources*: Links to multilateral and bilateral efforts on hydrogen and fuel cell activities and to individual economies.
    - *Frequently Asked Questions (FAQs)*: Fact page that provide answers to some of the most commonly heard queries.
    - *Analysis Tools*: Provide a simple, interactive, web-based analysis tool for government officials to investigate the impact that hydrogen might have in terms of energy imports, emissions, and opportunity costs.

- **APEC Policy Forum on the Successes and Failures of Various Mechanisms to Advance Hydrogen Energy Development:** Convene an APEC policy forum where APEC officials can present and discuss the successes and failures of the various policy and regulatory mechanisms employed by each economy to advance hydrogen technology development and integration efforts. This forum will consider the necessary infrastructure - physical, market, and regulatory - for such mechanisms to be effective. The forum will furthermore involve a technology exposition for APEC officials to gain first-hand knowledge of on-going private sector activities to develop and demonstrate these latest technologies.

- **Training the Trainer Workshops**: Hold a workshop to train the appropriate education officials from each of the APEC economies on the costs and benefits of hydrogen technologies. This information could then be used by the individual economies to disseminate through the proper educational channels to educate and inform teachers and academic staff. By providing information to these groups, future generations may begin to be informed of hydrogen's potential and will be more receptive to the integration and adoption of such new technology.

Additional suggestions voiced on possible education and information dissemination projects targeted a variety of stakeholder groups and are summarized in the table below:

	Policy/ Decision Makers	**Business Decision Makers**	**Technical Experts**	**Public**
IFAT: IFAT Visits to economies interested in developing Hydrogen RD&D Programs	**X**			
APEC Open Solicitations Webpage: Provide a link on the APEC website to a page which clearly identifies APEC funding opportunities (open solicitations). This idea should not be limited to hydrogen initiatives, but could apply to all APEC solicitations, making it easier for the private sector to participate in APEC activities.		**X**		
Public-Private Workshop to Develop Opportunities to Collaborate on Hydrogen RD&D: Through the Energy Business Network, hold a workshop for APEC officials, hydrogen program directors for the individual economies, and high-level representatives of APEC's multi-national companies to discuss potential opportunities to collaborate on hydrogen RD&D and to facilitate network building.		**X**		
Low Interest Loans: Establish a means for economies and private sector companies to obtain low interest loans on hydrogen development projects.		**X**		
Online Chat-room: Develop an online chat-room for technical experts to exchange information on technology status, demonstration efforts, test runs, safety considerations, and codes and standards.			**X**	
Technology Workshops with Technical Experts: Organize targeted technical workshops in interested economies with foreign technology experts to discuss the latest technologies and related issues.			**X**	

Mentoring Relationships: Develop mentoring opportunities where technically advanced economies team with economies that have yet to or have only begun to consider hydrogen energy for assistance and information exchange on policy and technical issues.			**X**	
Coordinated APEC-IPHE Teaming Opportunity: Coordinate with the IPHE to develop opportunities for businesses and technical experts to provide learning opportunities for the least developed economies.		**X**	**X**	
Hydrogen Educational Curricula for School Children: Work within APEC and with other educational organizations to develop curricula for educating children.				**X**
Educational Videos: Develop educational videos on hydrogen energy that can be used to communicate the benefits and safety of hydrogen as an energy source. Such videos could be utilized in schools, museum exhibits, and television programming.				**X**

4.2 Safety, Codes & Standards

This group was tasked with developing ideas that would serve the following purpose, stated in the Interim Framework outline:

> *"Safety, Codes & Standards to foster greater harmonization to reduce international barriers to development and testing of hydrogen energy systems."*

Codes and standards for the design, installation, and operations of hydrogen energy systems will play a significant role in an APEC evolution toward the hydrogen economy. Experts agree – based on extensive experiences with the development and deployment of other advanced energy systems – that achieving greater harmony in hydrogen codes and standards across international boundaries could greatly reduce institutional impediments to hydrogen energy development around the world. Manufacturers, developers, and users of hydrogen energy systems would all benefit from consistent and uniform codes and standards.

In advancing APEC's hydrogen energy interests, effort is needed to contribute to the worldwide effort in hydrogen codes and standards. This will ensure that APEC member economies are able to share in the benefits of global efforts to develop hydrogen codes and standards. There is no need to duplicate efforts that are already underway. *The critical question is: What specific activities can APEC undertake in hydrogen codes and standards that will add value and make a difference?*

- **Comprehensive Codes & Standards Inventory.** First and foremost, awareness and understanding among the APEC member economies needs to be raised about existing hydrogen codes and standards efforts around the world. Towards this end, a key product would be an inventory of international codes and standards activities relevant for hydrogen energy systems, as well as summaries of the on-going international activities to develop such codes and standards for hydrogen fuel cells, vehicles, and power systems.

  This effort would involve assembling all existing codes and standards that are relevant to hydrogen and fuel cell technologies from around the world, including those for the use of

distributed energy systems in buildings and utility applications, and those for vehicles and other transportation systems. This effort should cover codes and standards for fire, safety, product design, and product testing. It is not critical for the inventory to include comprehensive information on environmental regulations, local siting and zoning ordinances, and electric utility interconnection standards.

The inventory would need to provide a summary of all on-going efforts to establish hydrogen and fuel cell codes and standards within nations, regions, and globally. This information will enhance awareness of existing C&S efforts, avoiding duplicative efforts, and provide APEC members with a "baseline" set of information to assess where the gaps might lie and where specific APEC hydrogen codes and standards activities could add the most value. Gathering comprehensive information on existing efforts to develop testing protocols, procedures, and metrics for hydrogen energy systems would be particularly valuable.

In developing the inventory, close coordination with existing APEC activities in this area is paramount. This includes existing efforts by the Energy Working Group to create a Hydrogen Codes and Standards Sourcebook, the codes and standards activities of the Transportation Working Group, and the general codes and standards efforts of the Standards and Conformance Group.

- **Workshop to Analyze Hydrogen and Fuel Cell Codes & Standards Gaps.** To assess the specific codes and standards activities that would need to be undertaken by APEC's Energy Working Group, it would be useful to conduct a comprehensive assessment of the inventory and analyze where gaps in breadth or depth of coverage may lie so that key activities that could add value and make a difference could be identified. Towards this end, APEC could sponsor an international workshop on hydrogen codes and standards and invite experts from around the world to meet and discuss the APEC role in hydrogen codes and standards.

  The Energy Working Group could jointly sponsor the event with the Transportation Working Group to ensure close coordination and leverage resources, capabilities, and expertise. At the workshop, codes and standards experts and decision makers could meet and discuss key developments and issues. Such discussions and gap analysis could focus on areas which need additional attention in order to ensure safe, compatible systems, on-going efforts and identify where value-added activities could be undertaken.

- **Engaging Codes and Standards Expertise.** Once the inventory has been developed, key gaps identified, and areas where APEC could add value and make a difference have been determined, the next phase of activity would involve engaging experts to carry out specific statements of work for specific hydrogen codes and standards products and services. This effort could involve development of specific handbooks and guidebooks that would be made available to APEC member economies, as well as technical assistance in codes and standards development.

4.3 Capacity Building Assistance:

This group was tasked with developing ideas that would serve the following purpose, stated in the Interim Framework outline:

> *"Capacity Building Assistance on Policy & Regulatory Issues including analysis to direct R&D and target demonstration projects for hydrogen infrastructure development."*

A ten-person breakout group including APEC delegates and technical advisors considered the unique role that APEC member economies could provide related to capacity building for hydrogen research, development, and demonstration. The following highest priority concepts emerged as a consensus after extensive deliberations:

- **Actively Coordinate Information Sharing between APEC and the International Partnership for a Hydrogen Economy (IPHE)**
  The International Partnership for a Hydrogen Economy (IPHE) was established in November 2003 and includes both APEC and non-APEC member economies. The APEC delegates endorsed the concept to extensively share information with the IPHE, especially on successful policies and research, development, and demonstration project status.

- **Establish APEC Hydrogen "Test Beds" to Promote Product Development**
  The need to support project demonstrations was recognized as a high priority to gain hands-on experience, gather economic and performance data, and promote product development. It was recognized that integrated hydrogen and fuel cell demonstration projects (power parks, refueling stations, etc.) are an expensive undertaking by individual APEC economies. The idea is to have APEC-supported projects in which all APEC economies are welcome to participate.

- **Endorse an Integrated APEC Hydrogen Strategy that Recognizes the Collective Strengths of Economies**
  The European Union has developed an integrated hydrogen strategy based on the capabilities and interests of individual countries. The concept endorsed was for APEC to develop its own integrated strategy that uses collective strengths and resources of individual economies. Furthermore, regional synergies (Pacific, North America, etc.) should be considered as part of an integrated strategy.

- **Establish an APEC *Virtual University* Center of Excellence**
  The APEC economies have extensive capabilities at their respective universities related to hydrogen research, development, and demonstration. The idea is to link these capabilities via the internet into a "virtual university" in order to offer these capabilities to all APEC economies and leverage their limited resources. Information to be shared could include research and development results, training for hydrogen and fuel cell technologies and opportunities, and sharing of demonstration project performance data.

The group also identified several second-tier ideas related to Capacity Building Assistance which included the following:

- **Establish Consistent APEC Analytical Approaches to Evaluate Performance of Emerging Hydrogen Technologies**
  Evaluating the cost and performance of fuel cells, reformers, electrolyzers and other hydrogen technologies needs to be performed on a consistent and uniform basis in order to be effective. The recommendation is for APEC economies to adopt a uniform set of analytical approaches with which to evaluate hydrogen energy technologies and systems.

- **Educate APEC Economy Policymakers on Priorities Needed to Advance Hydrogen Implementation**
  The transition to a hydrogen economy will undoubtedly require policies to encourage investment on hydrogen infrastructure and technologies. Several APEC economies will be undertaking policy

analysis or implementing progressive hydrogen policies. The idea suggests the need to educate policymakers in each APEC economy on the policy options that will be needed to advance hydrogen implementation.

- **Share Successful Policymaking Mechanisms to Foster Hydrogen Research, Development, and Demonstration (R,D,&D) within APEC Economies**
  APEC economies are studying and/or implementing policymaking mechanisms that could foster hydrogen RD&D. The goal of this concept is to share "lessons learned" on mechanisms that are either working or not working to accelerate hydrogen investment.

5.0 PRIORITY RECOMMENDATIONS

The top ideas generated in the breakout group discussions were brought back to the plenary session and presented to the full group. At the conclusion of these presentations, each economy that was in attendance at the workshop was given five votes and was asked again to select the ideas that they felt were the most valuable to APEC efforts to advance a hydrogen energy economy. It was through this process that the following 5 ideas were identified:

- **Web-based "Tool-box" for the Policy Makers within each APEC Economy**
- **APEC Policy Forum on the Successes and Failures of Various Mechanisms to Advance Hydrogen Energy Development**
- **Comprehensive Codes & Standards Inventory**
- **Workshop to Analyze Hydrogen and Fuel Cell Codes & Standards Gaps**
- **APEC-IPHE and IEA Information Exchange on Policies and RD&D Status**

After the ideas were identified, workshop participants were again divided into groups – this time one group for each priority activity identified in the plenary. Each group was then asked to expand on the following subjects:

- *Barriers/Challenges*
- *APEC Process Steps*
- *IPHE and/or IEA Coordination*
- *Resources(Requirements, Issues, Capabilities)*
- *Comments/Considerations*

The output from these deliberations is as follows:

5.1 Web-based "Tool-box" for the Policy Makers within each APEC Economy

Recommendation 1
Develop a website "toolbox" to aid in the education and dissemination of information to government leaders and decision makers on the challenges, opportunities, benefits and life-cycle costs of hydrogen and fuel cell technologies. Some felt that this website clearinghouse should also be accessible to the APEC public. Such a website would have: o *Downloadable Fact Sheets*. Fact sheets could provide detailed information on a variety of issues, including Benefits, Key Challenges, Production Technologies & Potential Resources, Utilization Technologies, Technology Status, and Safety Issues. These fact sheets could be circulated amongst the appropriate officials and could be disseminated to other select stakeholder groups. o *Case Studies*: Case studies that take a snapshot of the successes and failures of existing technology demonstrations. Information might include technical results from demo runs. o *Online Forum for Information Exchange*: Online discussion forum for officials to exchange

information, receive updates, provide opportunities for question and answer session, etc. o *Information Sources*: Links to multilateral and bilateral efforts on hydrogen and fuel cell activities and to individual economies. o *Frequently Asked Questions (FAQs)*: Fact page that provide answers to some of the most commonly heard queries. o *Analysis Tools*: Provide a simple, interactive, web-based analysis tool for government officials to investigate the impact that hydrogen might have in terms of energy imports, emissions, and opportunity costs.	
Barriers/Challenges:	• *Language differences*: Not all targeted groups speak official APEC language. • *Information Sources*: Sources need to be identified. Consider proprietary issues. • *Data Updates*: Identify party or process to keep data current. • *Internet Access*: Limited access to internet in some APEC economies.
APEC Process Steps:	• *Information Providers:* Identify & establish through APEC processes. • *Web-master:* Identify for data maintenance. • *Information Exchange Facilitator:* Identify for data collection and dissemination. • *Assignment of Password:* Limit access to APEC economies/approved members. • *Equipment acquisition*: Facilitate through APEC, for economies without access.
IPHE/IEA Coordination:	• Link the APEC hydrogen and fuel cell sub-committee with the appropriate sub-committees of the IEA and IPHE.
Comments/ Considerations:	Capabilities: • *Experience*: Wealth of experience in hydrogen and fuel cell RD&D within APEC Issues: • *Limited internet access:* Access limited in less developed economies • *Adequate bandwidth: Necessary* for effective uploading & downloading • *Server location and security* • *Cost:* Determine who pays.

5.2 APEC Policy Forum on the Successes and Failures of Various Mechanisms to Advance Hydrogen Energy Development

Recommendation 2	
Convene an APEC policy forum where APEC officials can present and discuss the successes and failures of the various policy and regulatory mechanisms employed by each economy to advance hydrogen technology development and integration efforts. This forum will consider the necessary infrastructure - physical, market, and regulatory - for such mechanisms to be effective. It will also provide an opportunity for APEC economies to present their various on-going, priority RD&D efforts, facilitating discussions concerning the direction of current research, development, and demonstration activities. The forum will furthermore involve a technology exposition for APEC officials to gain first-hand knowledge of on-going private sector activities to develop and demonstrate these latest technologies.	
Barriers/Challenges:	• *Attendance/Scope*: Targeted groups may have higher priority concerns. • *Cost*: Expensive to hold such a meeting. • *Expert Participation:* Obtaining the "right" experts difficult. • *Diverse Group:* Addressing and developing consensus difficult.

APEC Process Steps:	• *EWG Approval:* Establish EWG approval. • *Obtain funding:* Write proposal for funding. • *Minister's meeting:* Present at June '04 Energy Ministers' meeting.
IPHE/IEA Coordination:	• Invite IEA and IPHE to participate.
Comments/ Considerations:	Issues: • *Cost*: Determine who pays. • *Political Commitment*: Needs work. • *Multi-national Public-Private Institutions*: Linkages create opportunities.

5.3 Comprehensive Codes & Standards Inventory

Recommendation 3
Organize an inventory of all on-going codes and standards activities. This activity would assemble all existing codes and standards that are relevant to hydrogen and fuel cell technologies, including items in Fire, Safety, Performance, Vehicles, Buildings, Consumer Products, Environment, and Utility Interconnects. This effort would also provide a summary of all on-going efforts to establish hydrogen and fuel cell codes and standards within nations, regions, and globally, taking advantage of global codes and standards coordination activities already underway. This will enhance awareness of existing C&S efforts, avoiding duplicative efforts, and will provide APEC with a means to discretely assess competing efforts and evaluating the potential impact of these efforts on the APEC region.

Barriers/Challenges:	• *Language*: Identify and catalogue the variety of C&S efforts. • *International Coordination Process:* Must be established. • *Inventory Maintenance*: Determine responsible party for inventory maintenance.
APEC Process Steps:	• *APEC Economy Contacts:* Identify contacts within each economy. • *Scope of Work:* Define scope of work, timeframe, release RFP. • *Selection Process* • *Issue Report:* Publish report and make available online.
IPHE/IEA Coordination:	• Develop process with IEA & IPHE to remain up-to-date on C&S efforts.
Comments/ Considerations:	• *Funding:* Estimated cost $100,000 to $500,000 USD. • *Information Maintenance:* Establish responsible party. • *Management Staff:* APEC to provide staff. Issue: • *Cost:* Determine who pays.

5.4 Workshop to Analyze Hydrogen and Fuel Cell Codes & Standards Gaps

Recommendation 4
Hold an international workshop, conducted jointly with the APEC Transportation Working Group (TWG), with the appropriate codes and standards decision makers to identify and discuss the existing gaps in hydrogen and fuel cell codes and standards. Such gap analysis will focus on areas which need additional attention in order to ensure safe, compatible systems, on-going efforts to fill these gaps and the potential discrepancies

between these on-going efforts.	
Barriers/Challenges:	• *Language Translation*: Availability of translated C&S efforts. • *Duplication of Efforts:* Avoid duplicative efforts. • *Exclusive Process:* Increase involvement of all stakeholders in C&S development. • *Range of Draft C&S: B*road and narrow C&S development work. • *Coordination with existing APEC Standards Projects:* Ensure transparency within APEC.
APEC Process Steps:	• *Project Proposal:* Form via Expert Group on New & Renewable Technologies. • *Explore Linkages to other APEC Groups:* Work through EWG and APEC Secretariat.
IPHE/IEA Coordination:	• Establish formal coordination process with IEA and IPHE.
Comments/ Considerations:	• *Utilize APEC Expertise*: Capitalize on available APEC human resources. Funding: • *Sources:* Explore self-funding industry sponsorship & international sponsorship in addition to APEC funding. • *Time Lag:* APEC funding limited with 2-year time lag. • *Cost:* Determine who pays.

5.5 APEC-IPHE and IEA Information Exchange on Policies and RD&D Status

Recommendation 5	
Establish an avenue through which APEC and IPHE can exchange information on program direction, policies, and on-going activities in hydrogen and fuel cells. This conduit might eventually lead to cooperative efforts to advance the hydrogen economy. The hydrogen expertise existing within the IPHE organization and the potential market opportunities that exist within the APEC forum provide excellent motivations for transparent information exchange on existing hydrogen policies and technology status.	
Barriers/Challenges:	• *International Protocols:* Understanding multi-national organizations' protocols.
APEC Process Steps:	• *Develop "How":* Through APEC EWG Expert Group & the IPHE Implementation Liaison Committee. • *EWG Endorsement:* Use leaders' direction statement to gain EWG support. • Obtain EWG approval of the process for inter-organizational collaboration.
IPHE/IEA Coordination:	• *IEA Hydrogen Energy Analyses:* Take advantage of available IEA studies. • *IPHE Ministerial Foundation:* Take advantage of existing IPHE institutions.
Comments/ Considerations:	• *Engage Financial Institutions:* Work together to engage financial institutions. • *Obtain consensus:* APEC is a consensus-based organization.

It should be noted that actual activities may be subject to change depending on circumstances, including the budgetary situation.

6.0 NEXT STEPS

The APEC region includes a wide range of economies at various stages of development with a unique grouping of opportunities and competitive advantages. This grouping provides APEC with an excellent opportunity to work together to advance a secure, sustainable future powered by hydrogen energy.

Moving forward, APEC is encouraged to continue value-added efforts and to avoid duplication of on-going or past work. It was also strongly suggested that APEC develop a "Next Steps" document, similar to the IEA's, to clarify what APEC can do in the near-term to address hydrogen.

- Many of the APEC economies are at the critical points in their development where their energy infrastructures are about to be firmly shaped and engrained into society. World leaders in hydrogen and fuel cell technology are encouraged to assist these lesser developed economies learn from their mistakes and avoid the integration and adoption of older, less-efficient power generation systems by leapfrogging to new, clean and efficient power technologies.

- The rapidly expanding Southeast Asian markets present an excellent opportunity for new energy technologies, including hydrogen and fuel cells. However, to significantly affect hydrogen development efforts, APEC must develop a clear case for hydrogen and a reason to change from conventional fuels, which must include a thorough economic analysis to substantiate claims of hydrogen's potential. This analysis should furthermore develop a specific rationale for encouraging the lesser developed APEC economies to look at hydrogen as they build their infrastructure.

- The ideas developed in this Interim Framework Document are very high-level and are excellent starting points for APEC to consider in advancing the hydrogen economy. However, serious preparation for an APEC market in hydrogen and fuel cells will require an escalation in coordination and collaborative efforts, both within APEC and outside of it. Furthermore, next step efforts need to be, to a degree, "tangible". APEC should consider a flagship demonstration of hydrogen and fuel cell technologies both as a learning tool for the APEC economies and as a promotional mechanism that that may serve to catalyze future efforts.

- Finally, APEC, in their efforts to promote and advance hydrogen energy, must consider the circumstances of the various APEC economies. Many of these economies have long-term potential for hydrogen and fuel cell technology adoption and market integration. Their access to various information dissemination conduits, however, may be limited. A concerted effort will be needed to inform these economies on hydrogen's potential benefits and to include them in the RD&D process in the near-term.

The APEC community consists of both the technology leaders with the know-how to develop efficient, reliable hydrogen energy systems and the resources to become a major hydrogen supplier. Furthermore, the Asia Pacific is a rapidly growing region with increasing demand for goods and services. Thus, significant market opportunities exist for hydrogen energy systems to provide solutions for transportation, stationary and portable power needs. These circumstances present an opportunity to coordinate advanced efforts to develop safe and reliable systems; to ensure a compatible international market; and to provide guidance and assistance to economies that have yet to become heavily involved in the push towards hydrogen energy systems through an established and effective international organization.

APPENDIX A: SETTING THE STAGE (ON-GOING EFFORTS)

In a time when increasing demands are being placed on limited supplies, economies around the globe have recognized the potential of hydrogen energy to provide energy security, A secure energy source is essential to nations worldwide for continued social and economic growth. With this in mind, efforts to develop and demonstrate hydrogen and fuel cell technologies have been growing rapidly. Many individual economies have established domestic RD&D programs to advance hydrogen development, while bilateral and multilateral efforts have also increased.

The following section provides a brief summary of some of the on-going efforts, both globally and within the APEC region, to develop and advance hydrogen and fuel cell technology.

Intergovernmental Hydrogen Efforts (IEA and IPHE)

The IEA and the IPHE are two organizations that are coordinating international efforts to develop and demonstrate hydrogen technologies.

IEA

"In April 2003, the IEA Executive Director established the IEA Hydrogen Co-ordination Group (HCG) with the primary objective of adding value to the technology and policy programs of the IEA Member countries by exploiting synergies and benefits of international co-operation. The HCG member list (photo) is annexed to this summary. The HCG will support and enhance co-operation among Member countries to accelerate hydrogen and fuel cell RD&D and infrastructure deployment. It will support harmonisation of national hydrogen and fuel cell policies and seek to expand collaboration with industry, non-Member countries and other international organizations, as appropriate. The HCG's insights on hydrogen technology and policy strategies should benefit national policy makers, programme managers, energy analysts and industry. It will in particular advise IEA bodies on ways to make their programmes more effective. The HCG will report to the IEA Committee on Energy Research and Technology (CERT). The HCG builds on national technology and policy programs in IEA Member countries and on 20-year R&D and policy activities carried out by the IEA Secretariat and relevant IEA Implementing Agreements (IAs) and Working Parties (WPs). In addition to IEA activities focused on hydrogen and fuel cells, carbon capture & storage will also be stressed since it may well be needed to drive the transition from the current fossil-based energy system to a hydrogen-based system."[1]

The Strategic Plan for the IEA's Hydrogen Program consists of seven separate areas designed to address the various issues and concerns behind hydrogen energy initiatives. These areas are: Technology; Energy Security; Environmental; Economic; Market Deployment; and Outreach. Each of these separate Plan sections contains a targeted objective and a list of action items. These objectives and action items can be viewed in Appendix B.

IPHE

Australia, Brazil, Canada, China, France, the European Commission, Germany, Iceland, India, Italy, Japan, Republic of Korea, Norway, Russia, United Kingdom, and the United States have committed to accelerating the development of hydrogen and fuel cell technologies by joining together to create the

[1] Take from the IEA website: http://library.iea.org/dbtw-wpd/textbase/work/workshopdetail.asp?id=138

International Partnership for the Hydrogen Economy (IPHE). The sixteen members, representing 85% of world GDP and over 2/3 of the world's carbon emissions made the Partnership official by signing the IPHE Terms of Reference at a Ministerial Signing event in Washington DC on November 20, 2003.

The IPHE will efficiently organize, evaluate and coordinate multinational research, development and deployment programs that advance the transition to a global hydrogen economy by leveraging limited resources; bringing together world experts; and coordinating international technology standards.

The IPHE is governed by a Steering Committee, currently chaired by the US. The Implementation and Liaison Committee, concerned with more technical and day-to-day aspects of the IPHE, is co-chaired by Germany and Iceland.

APEC Activities

Many economies within APEC have already established hydrogen and/or fuel cell technology programs. APEC recognizes these activities and the potential for a coordinated effort to enhance the region's pursuit of sustainable hydrogen energy. This document is a first step toward developing a coordinated APEC effort on hydrogen and fuel cells.

To assist in this effort, APEC is considering the following projects:

- APEC 21st Century Renewable Energy Development Initiative (Collaborative VI): Development of a Sourcebook of Hydrogen Codes and Standards for APEC Member Economies

  The purpose of this project is to develop an information source, *The Sourcebook for Hydrogen Applications*, which captures the hydrogen and fuel cell experience of APEC members including safety, codes and standards. This document will serve as a baseline from which the future discussions of harmonization of hydrogen related codes and standards for APEC economies can take place.

- APEC 21st Century Renewable Energy Development Initiative (Collaborative VI): Handbook for Developing City/State Hydrogen and Fuel Cell Programs in APEC Member Economies.

  The purpose of this project is to develop a "Handbook for Developing City/State Hydrogen/Fuel Cell Programs in APEC member economies". The handbook will provide a roadmap of what sub-national governments (states/provinces and cities) can do to develop their hydrogen/fuel cell infrastructures and associated projects. This document will be an educational tool and program development guide for local and state officials that shows how their activities can best take advantage of the growing body of information from national hydrogen vision statements and roadmaps as well as the development of critical hydrogen related codes and standards. As a first step in developing the handbook, a workshop will be held which brings together cities and states/provinces which have been at the forefront of hydrogen/fuel cell development. The information gained from the workshop will be combined with lessons from economy wide programs to develop the handbook.

APEC Member Economies

Many APEC Economies have already joined international efforts to develop and expand hydrogen RD&D activities. These members are at various stages of development in their hydrogen programs: some have

well-defined plans that are leading global efforts to develop and commercialize hydrogen and fuel cell technologies; others have more recently honed efforts to develop domestic programs and are actively working to define their R&D priorities; still others have yet to consider hydrogen as a future energy carrier and are focused on more near-term, proven technologies.

Of the many APEC economies actively pursuing new energy technology, the following economies are actively engaged in hydrogen and fuel cell development efforts: **Australia, Canada, China, Chinese Taipei, Korea, Japan, Malaysia, Singapore, Thailand, and the United States.** The following paragraphs provide short overviews of the scope of each of these countries hydrogen programs[2].

Australia:

The national hydrogen study was commissioned by the Australian Government as part of its initiative to investigate the role of hydrogen in Australia's energy future. The study, which was completed in September 2003, built on the results of an international hydrogen conference held in Broome, Western Australia, in May 2003.

The findings and recommendations of the national hydrogen study are direction setting in nature, and are designed to lay the foundations for Australia's participation in a future hydrogen economy. The recommendations include adoption of a national vision for hydrogen; reduction or removal of policies and regulations that represent barriers to hydrogen; participation in international research and industrial collaboration programs; and formation of an Australian hydrogen entity to foster communication with stakeholders. The Australian Government's Energy Task Force is currently considering the study as part of its wide ranging examination of energy policy settings and a response is likely before mid 2004.

Australia's hydrogen study is not an initiative that has been undertaken in isolation. Under its domestic COAL21 strategy, Australia is exploring the zero emission technologies pathway to the hydrogen economy. COAL21 is a partnership between industry, government and researchers which aims to develop a national clean coal strategy. It covers carbon geo sequestration and hydrogen production through coal gasification. In a related move, a new cooperative research centre on greenhouse technologies, called the CRC CO2, has been established to further develop Australia's capabilities in this field.

Throughout Australia, industry, government, universities, and research organizations are undertaking projects in topics ranging from research to commercialization on a variety of technologies. These include electrolyzers; hydrogen storage systems; renewable energy technologies; fuel cells and their applications; hydrogen internal combustion engines; advanced vehicle drive-train technologies; and power management hardware and software.

Canada:

The Government of Canada has invested over CAN$200 million in hydrogen and fuel cell research, development and demonstration activities since the 1980's. Funding for these activities was recently augmented by an additional CAN$215 million over the next five years to help achieve Canada's Kyoto target for greenhouse gas emission reduction. Consequently, Canada's support for hydrogen and fuel cell activities is now over CAN$60 million annually. This amount includes only federal government funding

[2] Some of the information presented in the following summary paragraphs has been taken directly from the International Energy Agency's "Comparative Review of National Programmes on Hydrogen and Fuel Cells R&D" 17-18 December 2003.

and does not include funds spent by provincial and municipal governments, nor does it include private sector investment.

Federal activities in this area are coordinated by the Hydrogen and Fuel Cell Committee which has representation from all the federal departments involved with hydrogen and fuel cells research, development and demonstration. The major players in the area are Natural Resources Canada (NRCan); National Research Council (NRC); Industry Canada (IC) and to a lesser extent, Natural Sciences and Engineering Research Council (NSERC) and Defence R&D Canada.

The research and development activities of NRCan center on hydrogen production and storage, fuel cell technology improvements and codes and standards development. The NRC's Institute for Fuel Cell Innovation focuses on Proton Exchange Membrane (PEM) fuel cells; Solid Oxide Fuel Cells (SOFC); systems integration, testing and evaluation; and materials wear. NSERC supports university research projects in conjunction with industry and is committed to creating five Industrial Research Chairs at Canadian universities, three of which are in place. Defence R&D Canada is developing fuel cell systems for military applications.

The demonstration and evaluation of different systems for the production and delivery of hydrogen to fuel cell vehicles is under the auspices of the Canadian Transportation Fuel Cell Alliance (CTFCA), managed by NRCan. This seven year CAN$33 million program is now beginning its fourth year. In conjunction with industry it will construct and evaluate several different types of hydrogen fuelling stations across Canada, will develop the appropriate codes and standards, and will conduct studies and assessments of the various hydrogen production and delivery systems.

The early market introduction of hydrogen and fuel cell technologies is the objective of the h2 Early Adopters Program of Industry Canada. This CAN$50 million 5 year program, just into its second year, will work with industry to showcase their technologies in working pilot-scale versions of a hydrogen economy.

To assist with commercialization, a Canadian Fuel Cell Commercialization Roadmap was developed in conjunction with industry and published by IC in March 2003. The roadmap calls for four key steps to be undertaken: stimulate market demand, improve product quality while reducing costs; gain increased access to capital for growth; and create a support infrastructure.

Further information and documentation can be found on the following websites.

Canadian Transportation Fuel Cell Alliance: http://www.ctfca.nrcan.gc.ca
Canadian Fuel Cell Commercialization Roadmap: http://strategis.ic.gc.ca/epic/internet/inmse-epe.nsf/vwGeneratedInterE/ep00031e.html
The Canadian Fuel Cell Industry: A Capabilities Guide: http://www.fuelcellscanada.ca/index2.html
H2 Early Adopters Program: http://www.tpc.ic.gc.ca/h2/

China:

- China Ministry of Science & Technology
- Universities are charged with research programs

Shanghai Tongji University
Tsinghua University's
Dalian Institute of Chemical Physics (part of the Chinese Academy of Sciences)
Institute of Metal Research

State Key Lab. of RSA, Institute of Metal Research

Chinese Taipei:

Chinese Taipei began its development and application of hydrogen and fuel cell technology in 1989, focused mainly on Phosphoric Acid Fuel Cell (PAFC) technology. In 2000, however, Chinese Taipei expanded their activities to include a proton exchange membrane (PEM) fuel cell development program. This program is headed by the Energy & Resources Laboratories of the Industrial Technology Research Institute (ERL/ITRI), and in its first phase, ending in 2004, places special emphasis on systems integration.

In 2002, the Taiwanese government and industry jointly launched the Taiwan Fuel Cells Partnership. This partnership was initiated to promote the adoption of fuel cell technologies. The partnership has a secretariat residing within the Taiwan Institute of Economic Research with six working groups: Fuels; Fuel Cell Stacks; Electricity Generators & Other Applications; Standards and Regulations; Transportation (Scooters); and Promotion/Education.

The second phase of this program is envisaged to begin in 2005 and to have a more comprehensive and balanced RD&D scope. While the focus of hydrogen utilization technology will still be on PEMFCs, the program may likely expand to consider hydrogen generation, delivery, and storage, and potentially even technology validation, demonstration, and modeling of hydrogen economy scenarios.

Japan:

Japan has been an early leader in hydrogen and fuel cell technology development. Since the early 1980s, Japan has invested in research and development in various fuel cell technologies, beginning with PAFCs and Molten Carbonate Fuel Cells (MCFCs). Research and development of PEMFCs was escalated in 1992 and, along with MCFCs, will be the focus of Japan's fuel cell research programme.

In 1993, Japan also launched WE-NET, the International Clean Energy Network Using Hydrogen Conversion, which initially focused R&D on core technologies necessary for establishing a hydrogen infrastructure (electrolysis, liquefaction, storage) and then later on the utilization of hydrogen and construction of fueling stations. The ten-year $163 million programme (calculated at $1 = ¥110) yielded several successes and is succeeded by a set of new projects which are now elements of the Ministry of Economy, Trade and Industry's (METI) "New Hydrogen Project" for the commercialization of hydrogen fuel cells.

The New Hydrogen Project (NHP) extends the work initiated in WE-NET and ties together a number of METI's ongoing and new programmes. In particular, it recognizes that in addition to fuel cell technology development, it is necessary to establish technology on the safe use of hydrogen and to promote policy measure such as establishing codes, standards and regulations in order to bring fuel cells to market.

In the area of fuel cell development, a "Policy Study Group for Fuel Cell Commercialization", which consists of various members from industry, academic and public organizations, was established in December 1999. Following several studies and a March 2001 Fuel Cell commercialization Conference, a strategy emerged for the practical application and implementation of fuel cell technologies.

The strategy is based around a three-stage commercialization plan through 2020, which integrates the development of fuel cell, hydrogen production, and hydrogen transportation and storage technologies, concurrently with the implementation of demonstration programs, vehicle sales, construction of refueling

infrastructure, establishment of codes and standards, and a general push to enlarge the consumer market for fuel cells and fuel cell vehicles.

Taken together and building upon the foundations laid by WE-NET, Japan is now undertaking one of the most ambitious and comprehensive hydrogen initiatives in the world. Japan plans to invest $300 million in the fiscal year 2004.

Korea:

Most hydrogen programs in Korea are still at an early, exploratory research stage. Korea's work on hydrogen began in 1988 as part of the larger national R&D program – "10-year Alternative Energy Technology Development Program." Efforts were relatively minor until 2000 when the Ministry of Science and Technology (MOST) initiated the "High-Efficient Hydrogen Production Program," which formed the foundation of Korea's current program: "21st Frontier Hydrogen R&D Center," established in June 2003. Work under this program will be funded by MOST at the level of US $90 million (100 Billion Korean Won) over 10 years from 2003 to 2012. The program is to be the cornerstone for the development of hydrogen technology in Korea.

With respect to fuel cells, fuel cell technology ahs been selected as one of the most important, promising areas requiring the Korean government's full support since 1990. The total R&D budget for fuel cell technology invested during the period of 1990-2003 has been approximately US$70 Million, spread over 42 projects. Work has been conducted primarily on MCFC, PAFC, SOFC, PEMFC, with MCFC as the major focus and accounting for 50% of the funding. However, the emerging technologies (PEMFC< SOFC< DMFC) are gaining more importance and government support. Korea is still in the R&D phase prior to demonstration; work is expected to continue and to receive substantial funding in the future.

The Korean Government is currently in the process of developing a national plan and strategies for the further development of hydrogen and fuel cells.

Malaysia:

According to the Eight Malaysia Plan (EMP) report, it is estimated that energy demand in Malaysia will increase by around 7.8% annually in this decade. Thus, the government has initiated policies to begin diversifying their energy resources. As part of this plan, Malaysia is now considering hydrogen as a potential future fuel and RM30 million has been directed to related institutions for a hydrogen R&D program.

One of the initiatives that has resulted from this funding was the establishment of the National Institute of Fuel Cells in Universiti Kebangsaan Malaysia (UKM). Research projects undertaken at this institution were conducted in collaboration with UKM and Universiti Teknologi Malaysia.

Although Malaysia has yet to launch any hydrogen demonstration projects, there are currently a number of on-going hydrogen R&D activities. Recently a workshop was convened to gather inputs from both government and private sector perspectives on the development of new energy sources, including hydrogen. This workshop was, in part, meant to serve as an opportunity to develop an overview of future hydrogen energy development activities within the country. [3]

[3] http://www.aseanenergy.org/pressea/news/n_malaysia/news_my_11.htm

Singapore:

Singapore's effort in research, development and demonstration of hydrogen energy and fuel cell technologies have been supported and pursued by various government, academic/research, and private sector organizations. Governmental efforts are led by the Economic Development Board and the National Environmental Agency, with funding set aside under the US$29 million SINERGY (Singapore Initiative in New Energy Technology), and the US$12 million IES (Innovation for Environmental Sustainability) Programs. Key projects supported under these programs include the demonstration of six Daimler Chrysler fuel cell vehicles and BP hydrogen refueling stations, up to three fuel cell stationary power generation systems (the first being a 5 kW natural gas fuelled PEM fuel cell system being installed in a carpark). Several companies appear poised to increase their fuel cell activities significantly, with the establishment of linkages to research organizations and international fuel cell companies, in both R&D and demonstration projects.

Nanyang Technological University (NTU) has several groups active in hydrogen and fuel cell R&D, including the Fuel Cell Strategic Research Program at the School of Mechanical & Production Engineering, the Advanced Clean Energy Centre at the Institute of Environmental Science and Engineering (IESE), and the Advanced Materials Research Centre. Research areas include development of new materials, micro and system modeling, and applied research for SOFC, PEMFC; fuel reforming; novel hydrogen production and cool hydrogen technologies. IESE and NTU are organizing the World Hydrogen Technologies Convention, to be held in Singapore in October 2005. At the National University of Singapore, groups in the Dept of Physics and the Dept of Chemical & Environmental Engineering are working on fuel cell materials and catalysts, and hydrogen storage. The Institute of Materials Research & Engineering under the Agency for Science, Technology and Research (A*STAR) is active in the development of PEM fuel cell membranes and materials, and has licensed its membrane technology to a local fuel cell company. Other A*STAR research institutes are also initiating fuel cell and hydrogen energy projects.

An article summarizing Singapore's activities in fuel cell research, development and demonstration will be published in the June 2004 issue of Fuel Cell Bulletin (Elsevier).

Thailand:

Interests in fuel cell research and development in Thailand started in FY 1999, when a government agency, so-called the National Energy Policy Office (NEPO), provided funding (5 millions bahts, which is equivalent to $ 0.12 millions) to the King Mongkut University of Technology Thonburi (KMUTT) to do research on molten carbonate fuel cells (MCFCs). Researchers at the National Metal and Materials Technology Center (MTEC) joined together to develop materials for the electrolyte and the electrodes for MCFCs. In FY 2000, due to their expertise and the in-house facilities for ceramic fabrication using tape casting and screen-printing techniques, MTEC started to focus on solid oxide fuel cells (SOFCs). A feasibility study on SOFCs was conducted and a 3-year project on planar SOFCs was then funded in FY 2001 with a budget of about 11 millions bahts ($0.3 million).

After a year, MTEC decided to promote R&D on tubular SOFCs (FY 2002) through collaboration with Advanced Ceramic Limited (ACL) in the U.K. The project goal is to construct a tubular fuel cell prototype to generate electricity using ethanol.

The SOFC research work is divided into two parts: 1) Cell development and characterization (including performance testing) of solid oxide fuel cells; and 2) Development of an electricity generator prototype from SOFCs. Both parts are run in parallel by Thai researchers from various institutes. The results from this project will contribute to a better understanding of SOFC materials and fabrication technology. The

learning process will lead to the commercialization of an energy source as an alternative to fossil fuels for electricity generation in Thailand in the future.

United States:

The US Department of Energy is the lead US government agency on hydrogen and fuel cell research and development, and cooperates with the Department of Transportation and Environmental Protection Agency on safety, codes and standards, the Department of State on international cooperation, and through the White House Office of Science and Technology Policy Interagency Task Force with other federal agencies, including the military.

The President's Hydrogen Fuel Initiative includes the DOE's Hydrogen Program and the DOE's FreedomCAR and Vehicle Technologies Program, both of which are in the DOE's Office of Energy Efficiency and Renewable Energy. The Hydrogen Program coordinates closely with the Office of Nuclear Energy on nuclear production of hydrogen, the Office of Fossil Energy on solid oxide fuel cells (SOFC) and other stationary fuel cells and hydrogen production from fossil fuels and on carbon sequestration, and with the Office of Science on basic research.

Although the DOE has been exploring hydrogen and fuel cell since the 1970's, the program was reorganized and significantly expanded by President George W. Bush in January 2003, when the President pledged $1.7 billion over 5 years so that "the first car driven by a child born today could be powered by hydrogen. . .and pollution free." The initiative aims to meet technical and economic targets in order to enable a positive commercialization decision by private industry by 2015.

The Office of Hydrogen, Fuel Cells and Infrastructure Technologies has teams working on hydrogen production and delivery, hydrogen storage, and PEM fuel cells, and cross-cutting teams on technology and infrastructure validation and demonstration, codes and standards, and education. The Office of FreedomCAR and Vehicle Technologies coordinates research on advanced vehicle components, including fuel cells and technologies needed for electric drive powertrains.

A more thorough explanation of the US hydrogen program planning and current research activities can be found in the following documents, all of which are available on the DOE website at http://www.eere.energy.gov/hydrogenandfuelcells/

- The US Hydrogen Roadmap
- The US Hydrogen Vision
- The DOE Multiyear Program Plan for Research, Development and Demonstration
- The 2003 Hydrogen, Fuel Cells and Infrastructure Technologies Program Annual Progress Report

APPENDIX B: IEA HYDROGEN PROGRAM, STRATEGIC PLAN

Vision: Our vision for a hydrogen future is based on clean sustainable energy supply of global proportions that plays a key role in all sectors of the economy.

Mission: The mission of the IEA Hydrogen Program is to accelerate hydrogen implementation and widespread utilization.

Technology – *To promote acceptance of hydrogen as an energy carrier*
Actions:
- Conduct R&D to address important barriers to hydrogen's acceptance
- Foster and maintain a balanced portfolio of hydrogen technologies
- Develop safe, efficient, and cost-effective hydrogen storage systems
- Demonstrate integrated hydrogen systems
- Collect, disseminate, and analyze information on hydrogen technologies
- Develop direct-hydrogen production technologies

Energy Security – *Contribute to global energy security*
Actions:
- Facilitate the transition from fossil fuel energy systems to sustainable hydrogen-based energy systems
- Provide resources for converting intermittent and seasonal renewables to base-load, load-following, or peak-load power supplies, and to transportation fuels
- Assist developing countries in evaluating sustainable, indigenous resources for hydrogen production.

Environmental – *Exploit the environmental benefits of hydrogen*
Actions:
- Carry out R&D on renewable hydrogen production techniques
- Promote hydrogen as a "clean" fuel
- Perform life-cycle assessments of hydrogen technologies and energy systems
- Conduct R&D on technologies that lead to the decarbonization of fossil fuels

Economic – *Develop cost-effective hydrogen energy systems that can compete in global markets*
Actions:
- Encourage industry participation to obtain market-oriented input for prioritizing RD&D activities
- Develop and utilize analysis tools to evaluate and optimize hydrogen systems
- Increase involvement of industry in the Hydrogen Implementing Agreement's activities
- Foster clean-system incentive policies
- Identify secondary benefits of hydrogen energy systems, such as a reduction in the use of military force to ensure petroleum supplies.

Market – *Identify and overcome barriers for hydrogen penetration into the energy and fuel markets*
Actions:
- Contribute to the scientific and technical basis for approved codes and standards
- Promote hydrogen infrastructure for supply, maintenance, and operation
- Pursue technologies that will lead to increased market penetration for hydrogen

- Initiate safety-related educational and technology assessment activities.

Deployment – *Promote deployment of hydrogen technologies with important local and global energy benefits*
Actions:

- Provide design support for hydrogen demonstrations
- Conduct cost-shared and task-shared deployment activities for hydrogen energy systems
- Act as an information resource for ongoing and proposed hydrogen demonstration activities, including performance analyses
- Conduct case studies for hydrogen systems in developing countries.

Outreach – *Advertise the benefits of hydrogen*
Actions:

- Increase involvement of private and public organizations in the IEA Hydrogen Program
- Use media tools to promote hydrogen education
- Establish collaborative R&D projects that promote international networks
- Collaborate with other IEA Implementing Agreements to increase the effectiveness of cross-cutting R&D activities
- Increase cooperation to reach “critical mass” in R&D activity.

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