THE INTERNATIONAL ENERGY AGENCY HYDROGEN IMPLEMENTING AGREEMENT (IEA HIA): A GLOBAL PERSPECTIVE ON PROGRESS AND POLITICS IN R,D&D COOPERATION FOR WHTC2011 CONFERENCE

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ABSTRACT

The International Energy Agency Hydrogen Implementing Agreement (IEA HIA) is the world's largest and longest-lived collaborative organization in hydrogen research. It includes 21 countries, the European Commission (EU), and the UN Industrial Development Organization (UNIDO). The IEA HIA's core business is hydrogen R,D&D. It offers researchers an established, global network and acts as a catalyst and framework for collaboration. The IEA HIA Strategic Plan for the period 2009-2015 has three themes: Collaborative R,D&D; Analysis that Positions Hydrogen; and Hydrogen Awareness, Understanding and Acceptance. Each theme has multiple portfolios. Together, the portfolios comprise 11 IEA HIA tasks that encompass the full range of hydrogen R,D&D topics. The IEA HIA believes that if the question concerns sustainability, the answer involves hydrogen. Our vision is one of a hydrogen future based on a clean sustainable energy supply of global proportions that plays a key role in all sectors of the economy. Our mission is to accelerate hydrogen implementation and widespread utilization to optimize environmental protection, improve energy security and promote economic development internationally while establishing the IEA HIA as a premier global resource for expertise in hydrogen. This paper will provide an overview of the IEA HIA collaboration and our tasks with highlights of major recent results, underscoring the conference theme of "renewables to hydrogen."

INTRODUCTION

During its 30+-year history of international cooperation, the International Energy Agency Hydrogen Implementing Agreement (IEA HIA) (www.ieahia.org) tasks and activities have achieved much technical progress in hydrogen (H_2) production, storage, conversion, safety, integrated systems and infrastructure. With a new *Strategic Plan for 2009-2015*, the IEA HIA expanded its commitment to analysis and outreach to advance introduction and commercialization of H_2 energy technology. [1] This paper examines the purpose, approach and significant recent progress of the 11 current tasks, using the 2009-2015 strategic framework of themes and portfolios, as well as task milestones and the newest Annual Reports. [2]

THE IEA HIA FRAMEWORK

The 2009-2015 IEA HIA strategic framework has three themes that stem from its vision and mission. Each theme has several associated portfolios.

- **Collaborative R,D&D** that advances hydrogen science and technology

  The four Collaborative R,D&D portfolios are:
  - Hydrogen Production
  - Hydrogen Storage
  - Integrated Hydrogen Systems
  - Hydrogen Integration in Existing Infrastructure
- **Analysis that Positions Hydrogen** for technical progress and optimization for market preparation and deployment for support in political decision-making

  The three Analysis portfolios are:
  - Technical
  - Market
  - Support for Political Decision-Making
- **Hydrogen Awareness, Understanding and Acceptance** that fosters technology diffusion and commercialization

  The three Hydrogen Awareness, Understanding, and Acceptance portfolios are:
  - Information Dissemination
  - Safety
  - Outreach – inform and engage critical subset of HIA stakeholders and decision makers

While long-term, precompetitive IEA HIA efforts in fundamental R,D&D are ongoing, there is an increasing emphasis on applied R,D&D.

IEA HIA MEMBERS

The IEA now has 23 members, consisting of 21 countries, the Commission of the European Union, and the UN Industrial Development Organization (UNIDO). The member countries are Australia, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Italy, Japan, Korea, Lithuania, The Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the U.S. In the near future, the IEA HIA hopes to inaugurate a "sponsor" membership category that will include industry.

FUNDING AND MANAGEMENT

IEA HIA members contribute to a Common Fund for management and promotion. All members are eligible to participate in any/every task at no additional cost on a "task-shared" basis, compensating their experts directly on a person years/year basis. A typical task-shared labor commitment ranges from 0.25–0.5-person years/year. This system is lean and efficient: no money changes hands for labor at the secretariat level. The IEA HIA Secretariat is managed by Mary-Rose de Valladares of M.R.S. Enterprises.

THE IEA HIA TASKS [3]

All IEA HIA tasks are initiated and developed on a democratic "bottom-up" basis by members. Each task is managed by an Operating Agent (OA); subtasks typically have Leaders (STL). Of the 31 tasks created by the IEA HIA, 20 have been completed. Eleven (11) tasks are currently in place. Four-fifths of these current tasks have a strong "renewable to hydrogen" component, denoted by an (RE) in the task list below:

- Task 21 - BioHydrogen (RE)
- Task 22 - Fundamental and Applied Hydrogen (H_2) Storage Materials Development
- Task 23 - Small-Scale Reformers for Hydrogen (H_2) Production (RE)
- Task 24 - Wind Energy & Hydrogen Integration (H_2) (RE)
- Task 25 - High Temperature Production from Wind and Solar (RE)
- Task 26 - Advanced Materials for Hydrogen (H_2) WaterPhotolysis (RE)
- Task 27 - Near-Term Market Routes to Hydrogen (H_2) by Co-Utilization of Biomass with Fossil Fuel (RE)
- Task 28 - Large-Scale Hydrogen (H_2) Delivery Infrastructure
- Task 29 - Distributed and Community Hydrogen (DISCO H_2) (RE)
- Task 30 - Global Hydrogen System Analysis (RE)
- Task 31 - Hydrogen (H_2) Safety

To carry out their work programs, all but one task meet for 2-3 days on a semi-annual basis at rotating locations determined by task members. Sometimes the task meetings are held in conjunction with related conferences. The lone exception to the semi-annual interval, Task 22, now meets at nine-month intervals because its Gordon conference style meetings are 4-5 days long.

COLLABORATIVE R,D&D

The IEA HIA's core competence, and the main focus of the majority of our tasks, is R&D. IEA HIA R&D is typically long-term, pre-competitive research. However, there is an increasing amount of applied R&D. There are four R,D&D portfolios.

R,D&D PRODUCTION Portfolio

Of the 20 completed IEA HIA tasks, over half were production related. Today, six (6) of the 11 current tasks are production related. All six (6) deal with renewable H_2, exclusively or in part.

Production: Task 21 – BioHydrogen (2010-2013) (OA Dr. Michael Seibert) is concerned with the production of H_2 by microorganisms. This is the "grow your own" approach to renewable H_2 production. Its activities include bacterial dark fermentation (which uses biomass materials and other organic wastewaters), photosynthetic microbes, and in vitro and bio-inspired systems. The task is also interested in BioHydrogen from economic and sociological perspectives. BioHydrogen is a relatively new but ambitious research topic with great potential. An earlier phase of Task 21 began in 2005 and ended in 2010. The current task was also conceived with a five-year framework: a three-year period followed by an optional two years if deemed necessary by members. Twelve (12) members comprise Task 21: Canada, Finland, France, Germany, Italy, Japan, Korea, The Netherlands, Norway, Sweden, Turkey, and the U.S. In 2011, Task 21 experts reported 96 peer-reviewed publications and five patents either filed or issued. The five subtasks are:

Subtask A – Bio-inspired Systems (STL P. Lindblad) looks to increase H_2 production from substrates above currently achievable yields (i.e., 3 to 4 moles H_2/mole glucose). In an important milestone, four U.S. groups have synthesized functional water-oxidizing catalysts and three other groups have synthesized water-reducing (H_2 production) catalysts that do not contain noble metals. The U.S. also identified a molybdenum-oxo complex that can generate gaseous H_2 either from water at neutral pH or from seawater.

Subtask B – Dark BioHydrogen Fermentation Systems (STL P. Hallenbeck) seeks to demonstrate potentially practical processes for the conversion of water or organic substrates to H_2 using solar energy. An important milestone was met by the EU/Task 21 Hyvolution Program which developed an integrated system incorporating a sequential dark anaerobic fermentation and photo-fermentation process to enhance H_2 production efficiency from biomass waste. Japan met another milestone of scaling up an H_2 producing fermentation technology with industrial support for

the Sapporo Brewery pilot plant in Sao Paulo, Brazil.
Subtask C – Basic Studies of Light-Driven BioHydrogen Production (STL M. Rousset) identifies promising applications of enzymes and biologically inspired processes for H_2 production and fuel cells. The U.S. discovered a new H_2 producing marine cyanobacterium capable of producing large amounts of H_2 (up to 900 ml/l in 2.5 days) under aerobic conditions, another important milestone.
Subtask D – Biological Electrochemical Systems (STL A. Guwy) identifies and develops promising applications of microbial/enzymatic electrochemical cells for H_2 production processes. The demonstration of an industrial-scale microbial electrolysis cell (MEC) for H_2 production at the Napa wine Company in California met the task milestone to demonstrate a pilot-scale MEC.
Subtask E – Overall Analysis (STL J. Miyake) This subtask investigates how to introduce and integrate Bio-inspired H_2 and BioHydrogen processes in society. With the feasibility study for the Sapporo Brewing Company, Japan has met the milestone to develop cost information for the industrial scale-up of a two-state BioHydrogen/ biomethane plant. In another important development, Sweden published a major work on analysis tools for cyanobacterial systems biology.

Production: Task 24 – Wind Energy and Hydrogen (H_2) Integration (2006-2011)
(OAs Dr. Luis Correas and Mr. Ismael Aso) aims: (1) to explore in detail all possible uses (technical, economic, social, environmental, market and legal) related to H_2 production via electrolysis with wind energy; and (2) to explore all possible applications for H_2 produced by electrolysis using wind energy. This is an applied R&D task, as wind energy and electrolysis technologies are commercially available today. The integrated wind/H_2 system is considered an attractive storage option for both grid-connected and stand-alone because it addresses the issue of intermittent availability of wind power. It also provides load balancing for grid-connected applications. Task 24 members are Canada, Denmark, Germany, Greece, Japan, Norway, Spain, Switzerland, the United Kingdom and the USA. Task 24 has four subtasks, which are described below. The final reports for all subtasks are slated for completion in late 2011.

Subtask A – State of the Art (STL A. Hoskins) is conducting an in-depth review of the current state of the art in wind turbines, electrolyzers and the power electronics that allow for system integration.
Subtask B – Necessary Improvements & System Integration; Technology Development on Equipment and System Integration Concepts (STL K. Harrison) focuses on two main components for H_2 production–the wind turbine and the electrolyzers. One very interesting lesson learned involves system efficiency and hardware for system controls. Maximum Powerpoint Tracking (MPT) Testing indicates a relationship between incidence of solar radiation and energy transfer from photovoltaic array (PV) to electrolyzer stack. At or below 500 watts/m^2, direct coupling of the PV array to the electrolyzer stack is more efficient; over 500 watts/m^2 performance is improved through use of the power converter.
Subtask C – Business Concept Development (STL K. Stolzenburg) categorizes wind-H_2 systems relative to their main purpose (e.g., electricity or fuel production), and addresses regulations on electricity and fuels. One of the conclusions of this research, in view of growing market penetration by wind energy and concerns for grid stability, is that the support mechanisms for renewable energy are beginning to be subject to adjustment based on the implications of renewable resource fluctuation. For Task 24 member countries, this finding could contribute to the medium-long term appeal of energy storage in the form of H_2.
Subtask D – Applications Emphasis on Wind Energy Management (STL R. Garde) addresses near term applications for wind produced H_2 with a special emphasis on fully integrated wind and H_2 systems, and use of H_2 for energy storage.

The Task 24 ITHER, or "Green Hydrogen from Wind and Solar Mobile Applications" Project, won the 2010 IEA HIA Project Prize in the demonstration category. ITHER showcases H_2 and renewable energies in an integrated wind energy and H_2 demonstration at the Foundation for the Development of New Hydrogen Technologies in Aragon, Spain.

Production: Task 25 – High Temperature Hydrogen Production Processes (2007-2011)
Task 25 (OA Dr. François Le Naour) investigates production of massive amounts of H_2 via nuclear and/or solar high temperature (>500° C) processes (HTP) with no CO_2 emission. A "white paper" is being prepared as the final Task 25 report.
Subtask A – Scientific, Technological Review and Analysis of Temperature Processes and the State of the Art (STL C. Sattler) performed a technical review of different processes utilizing the results of different processes to create a database of Innovative High Temperature Routes for H_2 Production (INNOHYP) projects that maps HTP process studies and development worldwide. The review employed a multi-criteria analysis method. France and the U.S. advocate use of solar and nuclear High Temperature Steam Electrolysis (HTSE). This subtask demonstrated that H_2 produced by HTSE could be cheaper than H_2

produced by alkaline electrolysis if the life cycle of the electrolyzer is long enough.

Subtask B – Benchmarking of Calculation and Methodology (STL A. Giaconia) defined the main criteria for integration of HTP into the H_2 chain. It benchmarked the investment level for four simple scenarios and developed a multi-criteria Analysis methodology called Electre.

Subtask C – Establishment of Benchmarks, Recommendations for HTP R&D and Future Industry Deployment is an ongoing process that will be completed by September 2011 in time to prepare the final subtask report.

Subtask D – Communication Actions: Coordination and Links with Other International Organizations plus Information Dissemination (F. Le Naour) developed 12 process description and two general brochures, which may be found at http://ieahia.org/page.php?s=d&p=documents&t=task&id=25. For more information on Task 25, see the June 2011 IEA HIA NEWS at http://ieahia.org/pdfs/HIANewsJune2011.pdf.

Production: Task 26 – Advanced Materials for Waterphotolysis (2008-2011)

Task 26 (OA Dr. Eric L. Miller) seeks to develop new semiconductor materials for stable and efficient photoelectrochemical (PEC) hydrogen-production system. The objective is a low-temperature, low-tech, direct water-splitting process powered by sunlight, the renewable source. In addition to administration, Task 26 has six subtasks built around Theory, Synthesis, and Analysis techniques to develop the most promising materials classes to meet the PEC challenges in efficiency, stability and cost. Task 26 is seeking a one-year extension to complete its final report and prepare a proposal for a possible follow-up task.

In the recent past Task 26 has made significant strides towards its goals and objectives. A new benchmark (>16%) was reported in the U.S. on III-V Tandem device performance with progress in surface validation. The U.S. also reported a new benchmark of 4.3% in multi-junction PEC device based on cathodically stable CGSe/CIGSe thin film materials by MVsystems and University of Hawaii. Another new benchmark >1% was established in an all-silicon triple-junction PEC device. The European NanoPEC program led by 2010 Millennium Prize winner Dr. Michael Graetzel also established a new benchmark level in the performance of low-cost nanostructured iron oxide materials, the so-called "Holy Grail" materials of PEC water-splitting. There have been advances in bilayer oxides in South Korea and photocatalyst progress in Japan.

Production: Task 27 – Near Term Market Routes to Hydrogen (H_2) Via Co-Gasification Using Biomass as a Renewable Resource (2008-2011) (Co-OAs Dr. Jan Erik Hanssen and Ms. Berrin Bay Engin) looks to advance the development of H_2 production based on renewable sources–primarily biomass–and their co-utilization with fossil fuels for industrial applications. Task 27 has eight (8) members: Finland, Italy, The Netherlands, New Zealand, Norway, Spain, Turkey, and the United States. Final reports for Subtasks A, B, and C are being finalized and reviewed. Subtask D is still on-going.

Subtask A – Co-Gasification of Biomass with Fossil Fuels (STL A. Bardi) investigates flexible co-processing. It contemplates: key parameters for all biomass classes; ash fusion issues (critical for EF gasification); quantification of large-scale co-gasification of in existing industrial plant; methodologies for techno-economic process analysis; pre-engineering of 10 MW scale demo plant (5t/h co-gasification); co-gasification tests at Puertollano 30 MW full scale IGCC; and economic and social barriers. The Subtask A final report highlights the need for feedstock consistency to guarantee reliable economics of scale. The main technical challenges continue to be feedstock prehandling and gas reforming. H_2 can be usefully produced by co-gasification with coal at 20-30 wt% biomass in conventional gasifiers. The most promising technological option is to use entrained flow gasifiers able to produce H_2 rich, low tar content syngas. Milling biomass to 0.3 mm particle size can cost up to 1/10 of energy input, while torrefication reduces milling power need by ~80% and prevents potential problems in co-feeding.

Subtask B – Hydrogen Market Facilitation Based on Distributed Processing of Biomass (STL B. Beld) examines the value of bio-energy carriers in securing the consistency of feedstock across time and time This subtask compares processes for H_2 production from biomass-derived intermediates (liquids, slurries, pellets, torrefied materials; reviews and analyzes all gasification processes for H2 production (entrained flow). It maps industrial gasifiers; reviews the experience on entrained flow gasification of intermediates, mostly for liquids; and estimates transport costs for intermediates (BTG pyrolysis liquids) by land and sea from Malaysia to Europe. Worldwide, there are nine H_2 producing plants whose collective production capacity is 15.6 million Nm^3/day. Industrial gas facilities are found in major markets across Europe and in high demand growth zones where there is an excellent match with availability of agricultural residues. BTG/BTL is constructing a 10 MW_{th} plant in the eastern Netherlands to process fast pyrolysis liquids at 5 tons/hour. This plant represents a potential market-enabling breakthrough for industrial use of pyro liquids.

Subtask C – Near-term Stand-alone Biomass (STL C. Kurkela) has reviewed all technologies and

pilot plants/projects for dedicated biomass conversion. Its final report categorizes and analyzes techno-economic issues.
Subtask D – Roadmap Development and Verification (STL J.E. Hanssen) is developing a scenario for mainstreaming renewable H_2 using tradable bio-energy carries and co-gasification.

R,D&D STORAGE Portfolio
Storage is considered one of the great H_2 research challenges, as well as one of the most promising near term applications for renewable energy.

Task 22: Fundamental and Applied H2 Storage Materials Development (2006-2012) (OA Bjorn Hauback) has three targets: reversible or regenerative H_2 storage; fundamental and engineering understanding of qualified H_2 storage media; mobile, stationary, and other applications. Task 22 counts 53 experts from 17 countries: Australia, Canada, Denmark, the European Commission, France, Germany, Greece, Iceland, Italy, Japan, Korea, the Netherlands, Norway, Switzerland, Sweden, UK, and USA. Its 47 projects encompass experimental, engineering, theoretical and modelling research, as well as safety aspects of H_2 storage materials. The following classes of materials are included: reversible metal hydrides (31 projects); regenerative H_2 storage materials; nanoporous materials (13 projects); and rechargeable organic liquids and solids. There are three applied R&D storage projects.

There have been significant achievements in Task 22. Highlights in the nanoporous area include the development of new compounds and improved understanding of phenomena such as spillover. Many new metal hydride compounds were developed based on Task 22 collaboration as well. There have also been important substitution, nanoconfinement, and catalyst activities related to modification of known compounds. International collaboration has been vital to Task 22 progress. Although the collaboration has not yet found “the” H-storage material for vehicles, it has made advances for other applications.

Dr. Hauback participated in the February 2011 IEA workshop on *Energy Storage Issues and Opportunities.* A proposal for a new storage task that combines basic and applied research, with an enhanced emphasis on applied R&D, will be presented at the 65th Executive Committee meeting in October 2011.

R,D&D: INTEGRATED H2 SYSTEMS Portfolio and/or H_2 INTEGRATION IN EXISTING INFRASTRUCTURE Portfolio
The Integrated H_2 Systems theme is system specific, while H_2 Integration in the Existing Infrastructure refers to incorporation of H_2 systems in the broader environment.

Integrated H_2 Systems and H_2 Integration in Existing Infrastructure: Task 23 – Small-Scale Reformers for On-site H_2 Supply (SSR for H_2) (2007-2011) (OA Dr. Ingrid Schjølberg) seeks to provide a basis for harmonization of reformer technology for on-site production of H_2 from hydrocarbons – fossil and renewable. Task 23 has ten member countries: Denmark, France, Germany, Italy, Japan, The Netherlands, Norway, Sweden, Turkey and the U.S. This task brings together suppliers, gas companies and research institutes. The strong industry participation is evidence of commercial potential: industry can supply H_2 from small scale reformers at a reasonable price now. Moreover, on-site H_2 production is an important stepping stone in early development of the refueling infrastructure. The final task report, and subtasks reports, will be completed in 2011.
Subtask 1 – Harmonized Industrialization (STL E. Ochoa) is harmonizing the approach to reformer capacities to facilitate industrialization and reduce costs. Its report will provide up-to-date lists of suppliers for reformer technology, together with set of standards of each system component.
Subtask 2 – Sustainability and Renewable Sources (STL C. Nelsson) has analyzed fuel paths and conducted a sensitivity analysis, and a survey of carbon capture and sequestration technology.
Subtask 3 – Market Studies (STL I. Yasuda) performs an average cost comparison of reformer units in three sizes (50 Nm^3/hr, 100Nm^3/hr, and 500Nm^3/hr) for three market segments (Japan, California, Germany). Results include cost curves.

Hydrogen Integration in Existing Infrastructure: Task 28 – Large-scale Hydrogen (H_2) Delivery Infrastructure (2010 -2013) Task 28 (OA Dr. Marcel Weeda) is investigating transport and distribution aspects of large-scale H_2 delivery infrastructure through modelling and analysis. This task has significant industry participation. There are seven members (Australia, Denmark, France, Germany, Japan, the Netherlands and U.S.) and four subtasks, the first of which is management. The others are:
Subtask 2 – Scenarios (STL A. Pigneri) aims to determine the number and size distribution of H_2 refueling station (HRS) using a market analysis approach.
Subtask 3 – H_2 HRS (STL M. Weeda) compares central and on-site production based systems to identify general requirements and key parameters.
Subtask 4 – Analysis of H_2 Delivery Routes (STL A. Elgowainy) aims to develop performance and cost databases.

Integrated Hydrogen Systems: Distributed and Community Hydrogen (DISCO H_2) (2013-2013) (OA Dr. Federico Villatico) aims to progress the optimization and replication of "green" hydrogen produced at the local level within distributed and community systems. With five subtasks (including management and outreach) the scope of DISCO H_2 encompasses: 1) urban communities; 2) rural and island; and 3) industrial distributed H_2 applications.
Subtask 2 – Analysis and Selection (STL CRES) has assembled a list of projects for assessment. The report for this subject has been completed and the results will be presented at WHTC.
Subtask 3 – Models Concept Development will select six projects, two per category, for analysis and use as the basis for model concept development
Subtask 4 – Replicability (STL IRL) will develop replicable distributed and community models.

ANALYSIS THAT POSITIONS H2

This theme bespeaks an "analytic imperative" to provide balanced H_2 analysis for technical, market, and policy-related purposes.

Task 30 – Global Hydrogen Systems Analysis (2010-2013) Task 30 **(**OAs Mr. Jochen Linssen and Dr. Susan Schoenung) is performing comprehensive technical and market analysis of H_2 technologies and resources, supply and demand related to the projected use of H_2 in a low-carbon world with sustainable (including intermittent) energy sources. Task members are Canada, France, Germany, Greece, Italy, Japan, Norway, Spain, Sweden, and the United States. Of the three Subtasks, A and B are described below and aim to produce reports and databases. Subtask C (STL K. Espegren) was designed as a liaison function with IEA headquarters analytics to optimise value added for both the Agreement and IEA headquarters hydrogen related efforts.
Subtask A – Detailed Analysis: Global H_2 Resources (STL S. Schoenung**)** is assessing H_2 resources worldwide based on projections/potential of primary energy sources for different regions from 2010 to 2050 subdivided by sector, including trading and projected costs of H_2. Report expected in mid-2012.
Subtask B – Building a Harmonized H_2 Technology Database (STL J. Linssen) is developing a database structure for all hydrogen technologies that is unique for production, distribution and use, and for performing data checks for IEA headquarter analytic models.

H2 AWARENESS, UNDERSTANDING & ACCEPTANCE

Task 31 – Hydrogen Safety falls into this theme under the safety portfolio. **Information Dissemination and Outreach,** the other two portfolios under this theme, are the domain of the IEA HIA Executive Committee and Secretariat. While information dissemination is an important activity for every task, it is a vital function for the Secretariat, which produces an Annual Report, newsletters, and brochures while maintaining the website and coordinating conference participation and other outreach activities. Podcasts will be initiated soon. Beyond simply informing, the Outreach portfolio looks to engage and influence stakeholders and decision makers, expand membership and foster mission appropriate growth.

Awareness, Understanding and Acceptance: Task 31 - Hydrogen Safety (OA William Hoagland) seeks to provide a technically sound and credible basis for risk informed codes and standards for stationary and transportation systems. The four subtasks and their scope of activity appear below:
Subtask A – Physical Phenomena (S.T. Leader P. Bernard) covers gaseous and liquid phase properties of outflow and dispersion, consequences and ignition, and quantitative tools.
Subtask B – Storage Systems and Materials Safety Issues (ST Leader J. Khalil) addresses solid storage issues; liquid and cryo-compression materials issues related to pressurized and low temperature storage; and sensors/leak detection.
Subtask C – Early Markets (STL A. Tchouvelev) focuses on hazard analysis and risk characterization for early markets.
Subtask D – Knowledge Analysis, Dissemination and Global Relevance: Safety Knowledge Tools (STL Steven Weiner) is enhancing Task 19 databases and websites, helping to shape Task 31 products, and developing collaborations and tools.

Two hydrogen safety workshops will be held in 2012 to disseminate the findings and lessons learned from the predecessor task, Task 19.

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