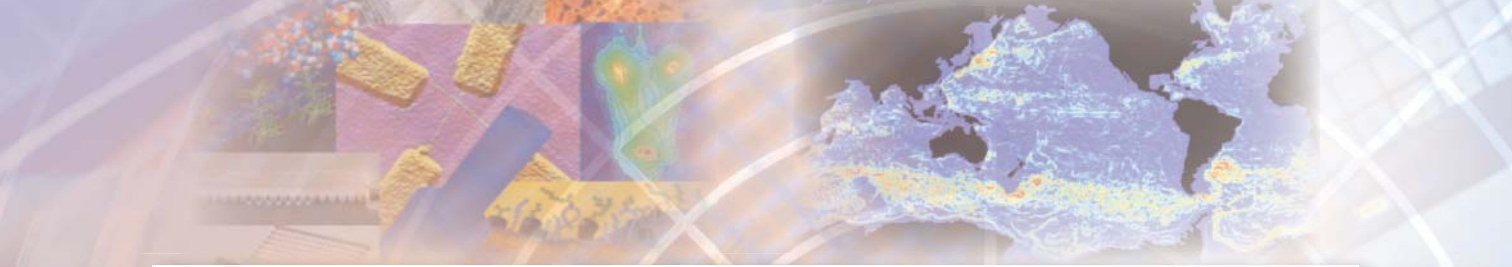
INTERNATIONAL ENERGY AGENCY

Science for Today's Energy Challenges

Accelerating Progress for a Sustainable Energy Future



Foreword

With a growing population and energy demand in the world, there is a pressing need for research to create secure and accessible energy options with greatly reduced emissions of greenhouse gases. While we work to deploy the clean and efficient technologies that we already have – which will be urgent for the coming decades – we must also work to develop the science for the technologies of the future.

This brochure gives examples of some of the most promising developments and it provides "snapshots" of cutting edge work of scientists in the field. The areas of greatest promise include biochemistry, nanotechnology, supraconductivity, electrophysics and computing. There are many others.

The IEA, through its Ad-Hoc Group on Science and Technology (AHGSET), brings together scientists and energy technologists to facilitate breakthroughs in energy technology. The brochure is intended as a tool for this work, which is described in the Annex. I hope that it will also provide an insight, for energy policy makers and other readers, into some highly significant scientific developments.

This brochure is only the start—much more has to be done to call attention to the need to dramatically increase funding for basic science and applied energy research and development. IEA and its member countries ask that you join us in the call for better linkages between critically important basic scientific research and applied energy research and development. I look forward to your interest and support.

Claude Mandil,
Executive Director
International Energy Agency
Paris

Acknowledgements

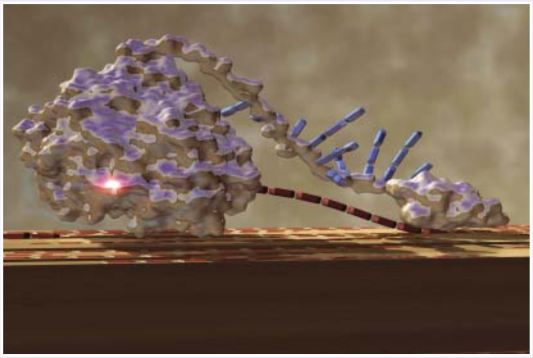
This publication would not have been completed without the insight and input provided by the International Energy Agency's AHGSET Steering Committee and the Committee on Energy Research and Technology. In particular, the author would like to thank David Pumphrey and Robert Vallario of the U.S. Department of Energy, whose leadership helped to start the AHGSET effort. Special mention also goes to Sabine Semke of the German Research Agency Forschungszentrum Jülich, Isabel Cabrita of Portugal's National Institute of Engineering Technology and Innovation, and Jim Skea of the UK Energy Research Centre, all of whom provided critical input on messages and content.

The principal author of this publication is Tom Kerr of the Energy Technology Office. The publication benefited from the input of several IEA colleagues, including Debra Justus and Mary Harries-White, who provided key insights and review comments. Bob Dixon and Neil Hirst provided supervision and encouragement. Rebecca Gaghen, Loretta Ravera, and Bertrand Sadin provided graphics, layout and production support.

The Role of Science in Transforming our Energy System

Secure, reliable and affordable energy resources are fundamental to sustained economic development. The threat of disruptive climate change, the erosion of energy security and the world's growing demand for energy all pose major challenges for energy decision makers. To meet these challenges and transform our energy system, better use of existing technologies will be required along with significant scientific innovation to spur the adoption of new energy technologies.

The recent International Energy Agency publication *Energy Technology Perspectives: Scenarios & Strategies to 2050* describes various pathways to a clean energy future.[1] One of the report's key conclusions is that urgent action is needed to rapidly advance available energy efficiency and low-carbon technologies and practices. The report also urges policy makers, industry and academic institutions to expand research and development budgets to achieve basic science breakthroughs in important areas like hydrogen and fuel cells, advanced renewables, next-generation biofuels and energy storage.



Transformational breakthroughs for biofuels: making new energy feedstocks a reality

At the beginning of the 21st century, there are a number of potential scientific breakthroughs that could provide solutions to our energy challenges. There are opportunities stemming from innovations in technologies and instrumentation, computing, communications, biotechnology, nano-sciences, information technologies, and infrastructure. Together, these opportunities would accelerate scientific progress, and bring new discoveries to the market faster and at lower cost.

However, important barriers prevent full realisation of science's promise to solve our energy challenges. **Basic science and energy research funding has been declining in the public and private sectors for the past several years. Additional funding is critically needed to allow science and applied energy researchers to realize the full potential of these breakthroughs. Additionally, there is a gap between the basic science and applied energy technology communities that prevents scientists and researchers from taking advantage of available opportunities for collaboration, networking and accelerating necessary scientific advances.**

The International Energy Agency's Ad-Hoc Group on Science and Energy Technologies is an international initiative created to address these barriers by improving communication and networking between the basic science and applied energy research communities. AHGSET is reinforcing links between basic science and energy research through international information exchange, networking and outreach. The findings of the most recent AHGSET workshop are summarized in Table 1. This event enabled experts from the basic science and energy communities to identify key challenges and to prioritise opportunities.

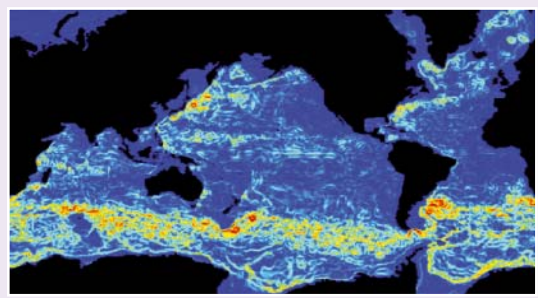
1. International Energy Agency, "*Energy Technology Perspectives: Scenarios & Strategies to 2050*" (2006).

Table 1: Selected findings from AHGSET's Oak Ridge Workshop, Nov. 2005

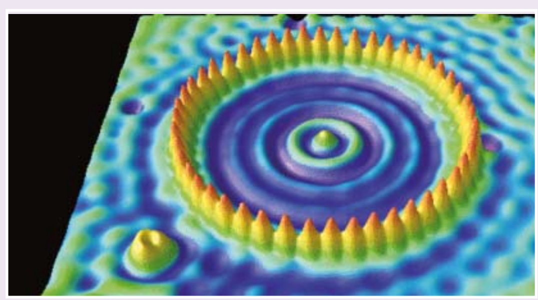
Energy Technology Challenges	*Basic Energy Research Opportunities*
Energy storage	Photon capture Nano-science
Low-cost photovoltaics	Post-genomic/proteomic sciences
Electricity transmission/grid management	Superconductivity/conductivity
Biofuels and other advanced fuels	Electrochemistry/electrophysics
Lighting	Advanced computation
Technology-enabling materials	Catalysis
Advanced fission and fusion	Biophysics/biochemistry
Carbon sequestration, separation and monitoring	Complex, adaptive systems

The good news is that there are a number of examples of successful collaboration between basic science and applied energy research at academic institutions, government, and private sector organisations around the world. This publication gives some examples – by no means exhaustive – of areas where basic science can make a difference, including:

- Lowering solar energy costs through biotechnology and nano-technology
- Improving the efficiency and flexibility of bioenergy through advancements in thermochemical and biochemical processes
- Creating new avenues for carbon-free hydrogen generation, storage and use
- Lowering the costs and risks of carbon capture and storage



Global distribution of phytoplankton



Wave functions of 48 iron atoms

Lowering Solar Energy Costs through Biotechnology and Nano-technology

The key challenge for solar energy is to develop conversion systems that are stable and robust for at least 20 years and that bring a 10-to-50-fold decrease in the cost-to-efficiency ratio for the production of electricity and fuels. To reduce the cost of installed photovoltaic systems to competitive levels will require technologies that do not exist at the present time, including approaches that produce ultra-high conversion efficiency at modest cost, hybrid conversion materials and nano-structured materials; i.e., materials at a size between molecular and microscopic scales that offer substantial efficiency gains in solar energy conversion.

To achieve higher efficiency solar conversion systems, approaches include:

- **Chemical methods** to improve photo-conversion performance of inexpensive materials (such as poly-crystalline, nano-crystalline, and organic materials) to perform at the level of today's single crystals.
- **Materials** which consist of a network with effective charge separation and collection over very short distances, avoiding the requirement that photo-generated charge carriers be able to travel the entire distance of the cell.
- **Thin-film solar cells** that offer low-cost performance through reproducible fabrication techniques that better control film grain boundaries, as well as the development of low-cost panels that remain inert to the thin-film deposition process.

Nano-structured materials also offer new opportunities for solar conversion. Early successes demonstrate significant impact of nano-scale materials on photo-conversion and promise dramatic advances in material design and performance, including:

- **Developing nano-structured silicon-based tandem solar cells.** By creating a lattice of dots made from silicon or similar materials within a set of silicon-based thin films, this research offers the potential for developing highly efficient solar cells with materials that are abundant, non-toxic, durable and low-cost.
- **Using nano-structured metal-organic composite solar cells.** Creating a hybrid cell design that pairs organic photovoltaics with metal nanoscale features would allow for efficient, lower-cost cells.

Nano-science holds promise to overcome many challenges

Snapshot

Innovations in Solar Nano-technology in Australia

The Australian National University's Department of Engineering is using nano-scale patterning to develop next-generation solar cells that absorb greater proportions of light and can be created at lower cost than conventional cells. The Queensland University of Technology is also researching the application of nano-engineered titanium materials which have applications in photovoltaic solar cells for energy production. Additional work involves the creation of a carbon nano-tube composite polymer material for photovoltaic cells.

Source: www.investaustralia.gov.au/media/IS_NA_%20Nano_Energy.pdf

Improving the Efficiency and Flexibility of Bioenergy through Advances in Thermochemical and Biochemical Processes

Biomass is an abundant renewable resource that has the potential to make a substantial difference in liquid fuel supply. However, overall product yields and productivity must be improved. Emerging knowledge in genomics and molecular technologies provides new opportunities for the genetic tailoring of plants and microorganisms to produce novel materials, fuels, and chemicals. An understanding of fundamental mechanisms that govern the physical limitations of plant efficiency will allow the design and control of many useful plant properties.

These include the control and characterisation of plant architecture and composition (lignin, cellulose, and others), improvements in the energy efficiency of plant production (reduced land and nutrient requirements), and an expansion of the range of environments that can be used for cultivation. Further advances in the fractionation of biomass into individual components using physical and chemical treatments offer a major opportunity for cost savings. Metabolic engineering of new microbial bio-catalysts offers the potential to produce novel bio-materials and chemicals that will serve as renewable alternatives to current petrochemicals.

R&D challenges and opportunities in the bioenergy arena include:

- **Improving plant productivity** in adverse environments (saline and degraded soils, arid areas) and **exploiting advances in genetic modification** to increase the efficiency of photosynthesis for key plant species.
- **Advancing post-harvest conversion of plant materials into fuels through bio-technology.** Currently, thermo-chemical or bio-chemical approaches are used; however, biotechnology offers a promising avenue of new and rapidly developing tools to advance our understanding of the ways microbial cells live, multiply and produce needed chemicals and materials.
- **Bio-technology** is being used to develop new substances with preferred properties for fuels or other uses like pulp and paper production. Features unique to certain carbohydrate compounds induce those compounds to self-assemble into nano-structured materials that could be useful as catalysts, reducing resource consumption and increasing energy efficiency.

Snapshot

Genetic Engineering for Better Biofuels at the Massachusetts Institute of Technology

The Massachusetts Institute of Technology (MIT) in the United States is conducting research that aims to turn biomass into fuel using microbes with a simple physical method. With this method, plant matter is broken down into small pieces that are then treated with enzymes to break down complex molecules like cellulose into simple sugars that microbes can digest. Bacteria or yeast are introduced to the sugar solution, which they convert to ethanol. However, the microbes can only convert so much of the sugar, and they have a relatively low ethanol tolerance. As the amount of ethanol in solution goes up, the microbes slow down.

MIT researchers are engineering E. coli and yeast with higher ethanol production and tolerance. They have taken a systems approach to genetic engineering, attempting to take into account networks of reactions in a cell. MIT views the production of ethanol as a property of the whole organism, not the manifestation of a single gene. MIT researchers have succeeded in increasing E. coli and yeasts' ethanol production. They have also introduced a complex yeast trait – tolerance to higher amounts of ethanol – to E. coli cells. MIT scientists believe that this research demonstrates the prospect of engineering organisms to produce low-cost liquid fuels.

Source: www.technologyreview.com/read_article.aspx?ch=specialsections&sc=transportation&id=16765

Snapshot

Japan's NEDO: Creating Highly Efficient Paper Feedstocks through Genetically Modified Plants

Over twenty-five years ago, the Japanese government, in collaboration with industry, established the New Energy and Industrial Technology Development Organisation (NEDO) with the aim of accelerating the development of new energy technologies. Today, NEDO researchers are working on a number of areas with promise to offer energy breakthroughs. One such area involves utilising biotechnology to produce high-growth eucalyptus plants for paper production. In this project, NEDO scientists are working with private sector counterparts to produce transgenic eucalyptus with a fast growth gene, a high pulpability gene, and a cold resistance gene. Scientists have produced trees with 30% more usable biomass that can be planted in areas that are difficult to afforest. To prevent dispersion of the new genes, NEDO has developed technology that inserts the genes only into cells that do not produce pollen. This research will be expanded to plantation-scale areas in the future, with promise to reduce the resource (and energy) inputs utilized by the pulp and paper industry.

Source: www.nedo.go.jp/kankobutsu/pamphlets/kouhou/fy2005/17_18.pdf

Creating New Avenues for Carbon-free Hydrogen Generation, Storage and Use

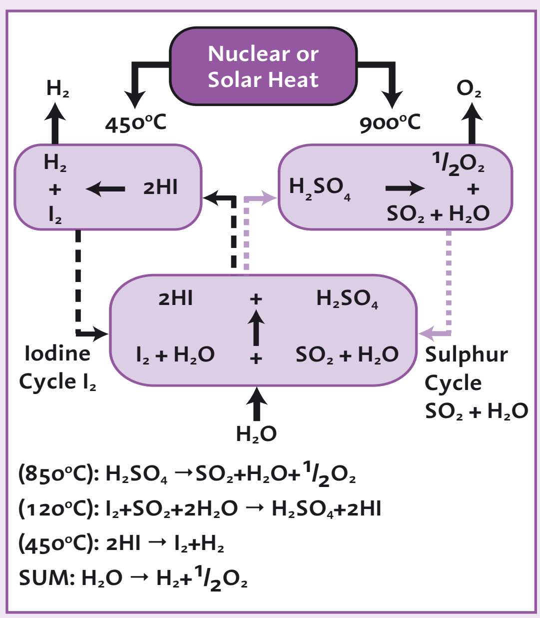
Development of hydrogen as a practical energy carrier illustrates the important role of basic chemical science in providing sustainable energy. One method currently used for hydrogen production is steam reforming of natural gas. In the future, other production technologies that are more efficient and that use more sustainable feedstocks will be required. Processes that hold promise include gasification of biomass or organic wastes, electrolysis of water using electricity from renewable sources and nuclear power.

A lack of practical storage methods has also hindered the widespread use of hydrogen fuels. The most popular storage methods (liquid hydrogen and compressed hydrogen) require that the fuel be kept at extremely low temperatures or high pressures. Fundamental advances in catalysts, membranes and gas separation could enable more efficient, lower-cost fossil hydrogen processes.

The gap between present-day technology and commercial viability cannot be bridged by incremental advances in the present state of the art. Bridging the gap requires not only creative engineering, but also revolutionary breakthroughs in understanding and controlling the physical and chemical processes that govern the interaction of hydrogen with materials.

Recently, there have been important advances in a variety of areas that are seeking to overcome the technical barriers to producing, storing and using hydrogen in a sustainable manner. These advances include:

- **Biohydrogen generation.** Scientists are attempting to convert solar energy directly into molecular hydrogen using genetically modified organisms.
- **Photoelectrochemical water splitting.** Multi-junction cell technology arrangements have the highest theoretical conversion efficiency of any photo-conversion system. Approaches are under way that may allow a material that would otherwise corrode in aqueous solution to be protected by another semi-conducting metal that is stable. This combination provides a higher efficiency than each would offer alone.
- **Hydrogen storage using clathrates.** Researchers are advancing a new class of compounds known as hydrogen clathrates – icy materials made of molecular hydrogen – that allow hydrogen storage under less stringent temperature and pressure conditions.
- **Designing carbon nano-tubes for storing hydrogen.** Carbon nano-tubes have the potential to store hydrogen at a high specific energy density. However, not all carbon nano-tubes act in the same way, leading to inconsistent results. Researchers are addressing this problem by investigating the capacity of carbon nano-tubes for hydrogen storage, and are developing nano-tubes that will allow the easy capture and release of hydrogen.
- **Ionic and mixed-conducting membranes.** Membranes are being designed with high conductivity, stability and selectivity over a broad temperature range. While the quantum effects of nano-technology in optical and electronic processes have been extensively studied, there are also exciting possibilities for better catalysts and for transport of ionic species.



The sulphur-iodine thermo-chemical hydrogen production process

Snapshot

German Ruhr University: Producing Biohydrogen from Micro-organisms

Scientists at the German Ruhr University are collaborating on a project with the aim of producing "biohydrogen" from water and sunlight. This is hoped to be achieved by a two-step mechanism that combines the natural process of photosynthesis, which is the most efficient process for the direct conversion of solar energy, with the reduction of protons as performed by the enzyme Hydrogenase (H_2ase). Both processes occur in nature in cells of cyanobacteria and green algae, but they are never optimally synchronized for efficient hydrogen production. The combination of both processes is being attempted using water as the source of electrons and the sun as a continuous source of energy. This project requires the close collaboration of biochemists, molecular biologists, organic chemists, physical chemists, electrochemists and engineers.

Source: www.ruhr-uni-bochum.de/bioh2/

Biohydrogen grown in an algae culture (Photo courtesy of M. Roegner and T. Happe of Ruhr-Universitaet Bochum)

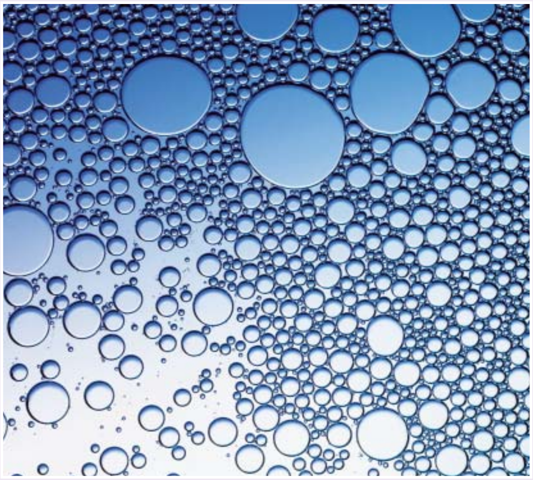
Snapshot

Hydrogen Storage and Renewable Hydrogen Production in the Nordic Region

The Institute for Energy Technology (IFE), Kjeller, Norway is developing new and improved materials for hydrogen storage. IFE has worked on metal hydrides, a promising material for storage, for more than 50 years, using light-weight elements like magnesium, nitrogen and aluminum. Research is also ongoing on hydrogen storage using complex hydrides and nano-structured materials. The use of neutrons from its "JEEP II" reactor gives IFE a unique position, since hydrogen molecules in materials are far more visible to neutrons than other probes; neutrons can also be used to locate hydrogen atoms in bulk materials.

The Nordic region also collaborates via the International Energy Agency's Hydrogen Implementing Agreement to pursue the goal of converting solar energy and water into Hydrogen. In one approach, Nordic scientists have developed photo-biological systems based on green algae and cyanobacteria that are producing renewable hydrogen from solar energy at an efficiency of about 1%. Researchers are aiming toward improved efficiencies in the future. In a second approach, microbes are used to ferment waste or biomass into hydrogen and carbon dioxide. Nordic researchers are evaluating the form and function of needed bioreactor systems and initial life cycle assessments in order to orient fundamental research into a future applied biological system producing renewable hydrogen from solar energy and water.

Sources: www.ife.no
www.egs.uu.se/fysbot/
www.nordicenergy.net



Lowering the Costs and Risks of Carbon Capture and Storage

Fossil-fuel dependent pathways to a low-emissions future are strongly dependent on widespread use of carbon dioxide (CO2) capture and storage technologies. Today, carbon dioxide is already being captured at a handful of electricity generation, manufacturing and fuel processing plants and stored in saline aquifers or injected to enhance recovery of oil and gas. However, a number of important scientific research areas—including advanced membranes to separate and capture CO_2 and more sophisticated methods to predict and monitor CO_2 storage reservoirs—need to be advanced in order to successfully exploit the promise of sustainable CO_2 capture and storage.

Current research in these areas includes:

- **Creating advanced membranes.** Since many CO_2 separation processes involve organic membranes, which have a low melting point, they cannot be used during combustion processes. Therefore, researchers are developing new membrane materials that will operate at higher temperatures, including functionally graded hydrogen membranes, hydrotalcite membranes, and ionic liquid membranes.
- **Developing numerical and simulation methods to predict CO_2 flow.** Before carbon dioxide is injected into geologic formations on a large scale, scientists must predict the movement of the gas and the potential for long-term storage. To that end, researchers are developing new predictive methods with the goal of determining the best locations and safest operation modes for CO_2 injection.
- **Investigating the environmental consequences and effectiveness of various ocean sequestration strategies.** This includes enhancement of the net oceanic uptake from the atmosphere by fertilisation of phytoplankton with nutrients, and the direct injection of a relatively pure CO_2 stream to ocean depths greater than 1000 metres.

Snapshot

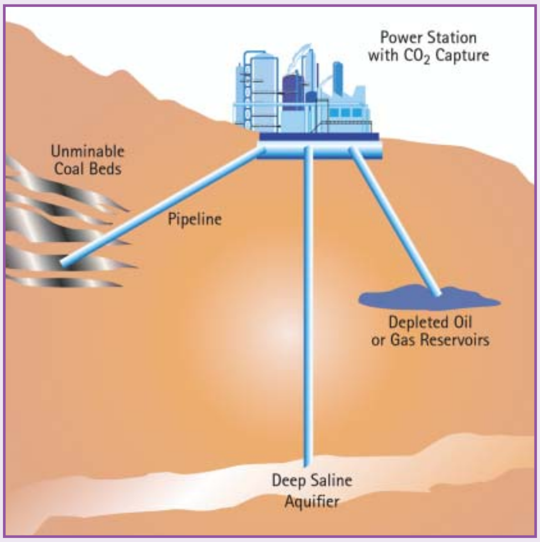
Swiss Federal Institute of Technology Zurich: New Numerical Simulation Frameworks for Carbon Dioxide Sequestration in Subsurface Formations

Swiss Federal Institute of Technology Zurich (SFIT) researchers are developing a new numerical modeling framework to study sequestration via enhanced oil recovery based on CO_2 injection in depleted and operating oil and gas reservoirs.

SFIT researchers are attempting to encode the physics of multi-phase flow in a pore network based on observation and macroscopic equations. To date, conventional particle modeling methods have not been able to describe the correct movement of CO_2 in specific reservoir types and situations. SFIT researchers are developing an approach that is based on estimating flow according to statistical rules consistent with small-scale physics in these geologic settings.

One of the main advantages of this new approach is in providing a consistent link between small and large scales. SFIT researchers expect that their framework can serve to better interpret the effective coefficients and to derive modified macroscopic models for CO_2 injection, advancing the state of the science for this important carbon dioxide mitigation technology.

Source: www.ifd.mavt.ethz.ch/research/groups/group_pj/porous



Geologic carbon storage options

Easing the Transition from Basic Science to Energy Technology Development

Basic research is the enabler for applied energy research and development (R&D). It provides a base of knowledge, skills and techniques for solving problems and can possibly deploy quickly to meet urgent needs. On the other hand, applied R&D is not just a consumer of the results of basic science; it is also a source of questions and challenges to the basic sciences about real-world applications. Moreover, basic science is a platform for much of the professional training that applied scientists receive, while the results of applied science help to strengthen the case, socially and politically, for public investments in basic science. On its face, it would appear that integrating these two activities should offer sufficient value that organisations would pursue this integration on their own. However, there are a number of barriers impeding these linkages, including cultural, organisational, and issues relating to intellectual property rights.

- **Different goals, incentives, and time horizons.** Basic science is concerned with advancing knowledge within disciplines broadly; applied energy R&D is substantially concerned with utility–producing devices, products and services that solve energy challenges.

- **Organisational issues.** Basic research and applied energy R&D functions are often managed and budgeted separately and located in different organisational units, even within corporate and government energy R&D laboratories. These two groups of researchers commonly attend different conferences belong to different professional societies and read different publications. This leads to different contact networks and peer groups, hindering opportunities for linkages.

- **Intellectual property rights.** Basic scientists and applied energy researchers relate to intellectual property rights (IPR) in different ways. Basic science tends to be very open in reporting results to the research community and communicating with peers. In contrast, as it approaches technology production, applied R&D becomes increasingly concerned with proprietary information and data related to the protection of IPR through patents, copyrights, and other mechanisms. These two approaches can sometimes be difficult to reconcile.

Policymakers, private companies and researchers have made progress in creating successful collaborations between the basic science and applied energy R&D communities. Historically, linkages between basic science and applied R&D have been pursued in two ways.

- **Exploiting undirected basic research in key fields for useful findings.** One approach is to have knowledgeable applied R&D experts canvas the research literature, attend professional meetings, and consult basic science experts in a particular field, such as materials or genomics, to seek useful ideas. This approach has been effective in many cases, although it is still common that basic research communities have not addressed a particular applied R&D need.

- **Shaping basic research agendas to address applied technology challenges.** Basic research programmes respond both to the availability of funding and to interesting new scientific questions. Such incentives can convert undirected basic scientific research into what has been termed "mission-oriented fundamental research" which is identical to basic research in practice but more focused and utilitarian in how research questions are selected.

- **Increasing opportunities for interaction.** Basic researchers and energy technology R&D professionals have few opportunities where they can interact, network and create opportunities for greater collaboration. In order for linkages to be made that leverage research activities and funds, government, academia and industry can create more regular, consistent opportunities for interaction.

Snapshot

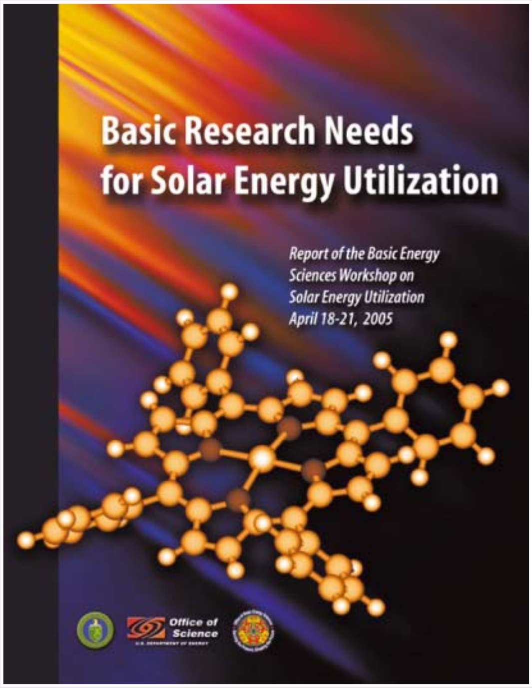
U.S. DOE's 'Basic Research Needs' Workshop Series: Guiding Basic Research Toward Energy Technology Challenges

In 2001, the Office of Basic Energy Sciences (BES) in the U.S. Department of Energy's Office of Science set about identifying basic research investments that could accelerate progress toward the agency's energy technology goals.

A first step was to ask the BES external Advisory Committee (BESAC) to bring together representatives from all the agency's applied energy programs with basic scientists in related areas. This culminated in an October 2002 workshop and report that examined a broad portfolio of energy technology challenges. The event's 37 Proposed Research Directions and crosscutting research topics formed the basis for a continuing series of follow-on workshops. BES then developed its "Basic Research Needs" process. For each of the areas identified in the BESAC report, a workshop would be the first step. Workshop planning, execution and output stages are highly defined and structured. If the workshop identifies areas of research that can address technology R&D challenges, the second step is to issue a solicitation (funded at US$20-30M annually) to enable a robust research community to develop. BES is also developing ideas for the third step, which aims to accelerate the process of going from results of the BRN solicitations to energy technology advances by having representatives from relevant applied programs involved in developing the solicitation and evaluating research proposals.

To date two topics—hydrogen and solar energy—have made it to the second step. The first BRN workshop, "Basic Research Needs for the Hydrogen Economy," was held in May 2003, and the first BRN solicitation was issued in 2005. The second workshop focused on Solar Energy Utilisation in April 2005; the subsequent solicitation was issued in 2006. Additional workshops on Superconductivity, Solid-State Lighting, Advanced Nuclear Energy Systems, Combustion of 21st Century Fuels and Electric Energy Storage have been held or are scheduled. Workshop reports also serve as reference documents that summarize the current state of technology and the associated R&D challenges.

Source: www.sc.doe.gov/bes/reports/list.html

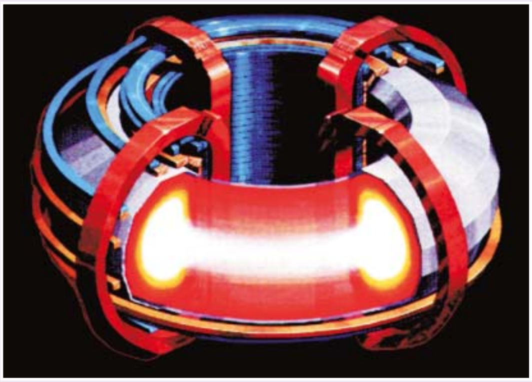


Sample Output from U.S. Department of Energy Basic Research Needs Process

AHGSET: Accelerating Progress

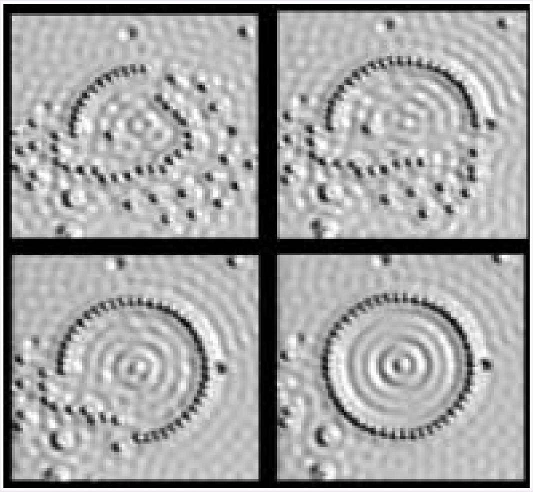
The International Energy Agency's AHGSET effort is designed to transform advances in basic and applied energy research into new energy technologies and systems, expanding the portfolio of options for achieving global energy security and sustainability. Since its creation in 2003, AHGSET has helped increase linkages with IEA's technology networks, shape research agendas, and increase networking between basic science and applied energy researchers.

An important AHGSET activity draws on the convening power of the IEA energy technology network for workshops on key areas of science and technology interest. The strategy of these workshops is to facilitate two-way exchanges. Their purpose is to explore what energy technologists need from basic scientists. This includes identifying the research areas where basic scientists believe they are able to offer applied energy technologists collaborative solutions. To date, AHGSET has organized three workshops that brought together the expertise of a wide range of major stakeholders, including scientists, energy technologists and public policy officials, as well as key stakeholders from IEA nonmember countries.



Tokamak for Fusion Energy Research

The first workshop, "*Tools and Methodologies for Evaluation of Energy Chains and for Technology Perspective*," was sponsored by France and took place near Paris in March 2005. The event addressed the need for more advanced socio-economic decision-aiding tools and methodologies for the prioritisation of energy R&D options. The major challenge that was identified was the need for closer integration of environmental and social sciences. The workshop enabled AHGSET to characterise the scope and limits of existing decision-aiding processes and to study the outlook for development of more advanced tools. The event fostered interdisciplinary co-operation by creating closer links between the stakeholders in the social and environmental sciences and actors in the field of energy socio-economic modelling research.

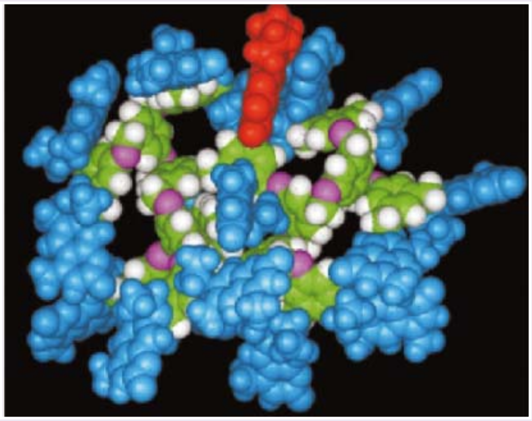


Scanning Tunnelling Micrograph (STM) of Quantum Corral of Iron Atoms

The second workshop, "*The Computational Approach*," dealt with the role of advanced maths and computation in achieving energy innovation. The German-sponsored event took place in Berlin in November 2004. The workshop was planned jointly by the two German Ministries responsible for energy technology and research - the Federal Ministry of Economics and Labour and the Federal Ministry of Education and Research - together with PTJ, the Project Management Organisation. The workshop was designed to explore the technical "pull" from engineers and the scientific "push" from applied mathematicians. Discussions dealt with energy modelling and problems encountered with mismatches between modelling requirements and data availability. Participants studied the differences between micro-scale investigations and macro-scale observations. The workshop highlighted the view that a precondition for strengthening the bridges between science and applied energy technology lies in engineers' ability to formulate the problems that the mathematicians would then try to solve. On the other hand, new results and processes developed by mathematicians must be made available in an understandable form to engineers and physicists. Furthermore, differences in timeframes between curiosity-driven science and applied energy research have to be balanced.

The most recent AHGSET workshop was sponsored by the United States and took place in November 2005 in Oak Ridge, Tennesseee. This workshop explored issues of technology demand pull, science mining and the overall process of research integration, with the aim of creating stronger linkages between science and technology programmes. This event sought to challenge the science community with critical energy technology barriers, and to identify priority opportunities for broad-based crosscutting scientific research areas that could "push" energy technology solutions. It concluded with a list of common priorities for basic research areas that offer the most promise for energy technology advances, summarized in Table 1 above. There are other AHGSET workshops planned. To learn more about AHGSET, consult the attached Annex.

For more information on AHGSET, contact:
Tom Kerr, IEA Secretariat
Email thomas.kerr@iea.org



Molecular photoconversion of light to energy

Annex
IEA's Ad-Hoc Group on Science and Energy Technology

AHGSET's Mission and Strategic Objectives

AHGSET's Mission is to support the development of new energy technologies by strengthening the role of science and the connections between basic science and applied energy programs.

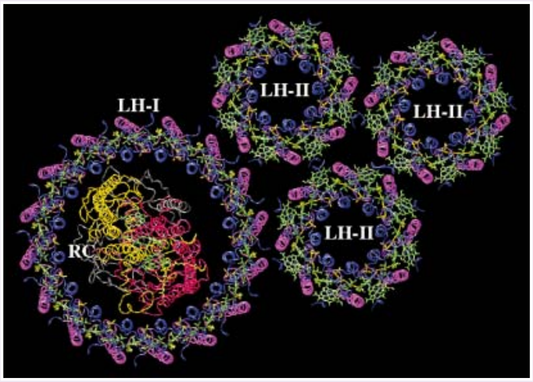
To achieve this mission, AHGSET has identified four strategic objectives.

Objective 1. Advise decision-makers on the opportunities for science to contribute to energy technologies.

It is critical to inform energy and science decision-makers on the opportunities in science for energy. As such, AHGSET collects and publishes information (including case studies) where member countries are actively linking science and energy. AHGSET also provides advice to the IEA technology network on how IEA's activities can best leverage scientific advances.

Objective 2. Improve links between the science and energy technology communities.

Strengthening the role of science in energy technology requires building and strengthening the links between the science, technology and energy policy communities. This involves **sharing information** regarding country capabilities, interests, and stakeholders as a basis for understanding national situations; **facilitating dialogue among stakeholders** in government, academia, and industry on shared priorities; and **engaging non-member countries** such as China, Russia, and India as significant partners in the quest for science-for-energy solutions.

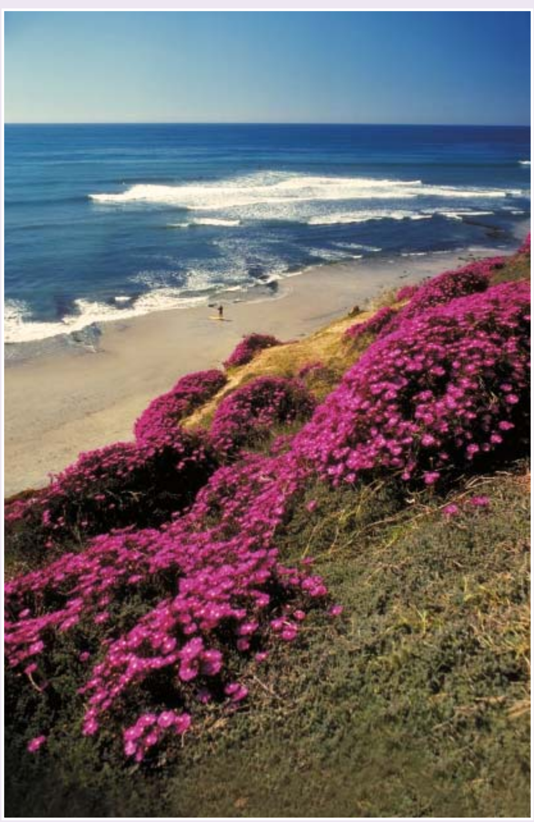


Nano-technology:
Biological self-assembly of complex structures

Objective 3. Develop and share approaches and tools.

The use of innovative research integration approaches and tools within the IEA technology network will be critical to AHGSET's long-term success. Accordingly, AHGSET will undertake areas of strategic emphasis to support the objective of developing and sharing approaches and tools:

- ***Create mechanisms for better exploiting science*** – Identify, develop, and share effective forums for foresighting to mine the results of science and fostering innovation for new energy concepts.
- ***Accelerate science and technology knowledge diffusion*** – Identify, develop, and share improved capabilities for S&T information exchange and knowledge diffusion, including developing workshops and managing a flow of targeted electronic information.
- ***Test a select number of approaches and tools that have application for IEA programmes*** – Explore the use of innovative research integration approaches and tools within the IEA technology network.



Objective 4. Promote strategic international collaboration in science.

There is a long and successful history of international co-operation in science. This stems in part from the increasing dependency on large, expensive facilities that push the frontiers of science. To advance this priority, AHGSET will pursue opportunities for bilateral and multilateral scientific collaboration; and engage and work closely with the IEA Committee on Energy Research and Technology's Working Parties and Implementing Agreements to identify and respond to specific, high-priority technology challenges requiring basic science solutions.

For More Information

International Energy Agency – The International Energy Agency (IEA) is an autonomous body which was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. It carries out a comprehensive programme of energy co-operation among twenty-six of the OECD's thirty member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To assist in the integration of environmental and energy policies.

As such, IEA is uniquely placed to exert leadership in this area, by bringing together nations and disparate communities from the realms of science, policy, and technology to rise to the challenges of accelerating long-term energy innovation.

IEA Committee on Energy Research and Technology (CERT) – The IEA's Energy Technology Collaboration Programme operates under the guidance of the Agency's Committee on Energy Research and Technology. CERT has established 4 expert bodies. In addition, expert groups have been established to advise on R&D priority setting and evaluation and oil & gas issues. Key role of Industry in Basic Energy Research and Energy Technology Development

Through CERT, IEA provides a framework for more than 40 international collaborative energy research, development and demonstration projects known as Implementing Agreements. It enables experts from different countries to work collectively and share results, which are usually published.

For more information, contact:
Tom Kerr, IEA Secretariat
Email thomas.kerr@iea.org

IEA Headquarters
9, rue de la Fédération
75739 Paris Cedex 15
France

www.iea.org

Prepared by the IEA Secretariat for the
Ad-Hoc Group on Science and Energy Technology (AHGSET),
Committee on Energy Research and Technology (CERT)
October 2006

9, rue de la Fédération
75739 Paris Cedex 15, France

Printed in France by the IEA
November 2006