# SCIENCE AND TECHNOLOGY TO MEET OUR ENERGY NEEDS

## EXECUTIVE SUMMARY


The American Chemical Society and the American Institute of Chemical Engineers (ACS and AIChE) believe it is critical that government, industry, and academia come together to develop a comprehensive energy policy that addresses the following issues:

- Energy availability and efficient utilization are critical to meeting economic, environmental, social, and security goals in the United States. Current resources and usage patterns are not sustainable.
- Scientific research and technology development are essential for providing the foundation to change current energy production and usage patterns and to reduce vulnerability to interruptions and price volatility. While some progress has been made over the last 25 years, pace will not meet demand before a critical imbalance develops between the availability of affordable energy and the country's need. We should pursue both current science and technology (S&T) and cutting-edge ideas to advance new solutions to this problem.
- The underfunding of energy research and development (R&D) cannot be allowed to continue. A cut by half of U.S. support (in constant dollars) over the last 25 years and the small fraction of R&D funds dedicated to meeting energy needs (compared to other developed countries) will not provide enough new ideas and technologies to keep our nation prosperous and secure.
- A combination of policies—ranging from support of basic science and education to favorable tax and regulatory policies—is needed to encourage industrial and business commitment and is required to face energy challenges.
- A mix of energy sources is required to provide sufficient power for the future, and each of these energy sources requires new S&T. A comprehensive energy policy must enable the development of economically and environmentally sustainable resources—both fossil and renewable.

Government leadership must raise the energy issue to a level of importance that demands national attention and comprehensively and effectively addresses critical, future needs.


Plentiful, accessible, inexpensive energy is the underpinning of modern society. It is the basis for meeting numerous national and global needs such as increased demands for electricity and transportation, affordable food and water, and adequate resources for manufacturing. In the U.S., reliable, affordable energy is crucial to the economic well-being and security of our nation. The time has come for us to confront future energy options. The ACS and AIChE believe a comprehensive national energy strategy must address S&T opportunities thoroughly to make the best near-term decisions and develop new options for a more sustainable future.

The most important reason to address this issue now is the growing, global dependence on oil and natural gas, which experts agree are available in limited and rapidly declining quantities. Demand for oil will

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*ACS, founded in 1876, is a nonprofit scientific and educational organization, chartered by Congress, with more than 159,000 chemical scientists and engineers as members. The world's largest scientific society, ACS advances the chemical enterprise, increases public understanding of chemistry, and brings its expertise to bear on state and national matters.*

*AIChE, founded in 1908, is a professional association of more than 40,000 chemical engineers. AIChE fosters and disseminates chemical engineering knowledge, supports the professional and personal growth of its members, and applies the expertise of its members to address societal needs and improve the quality of life.*

*Chemical scientists and engineers are creative problem-solvers who perform research and development on products and processes using the principles of chemistry, engineering, physics, biology, mathematics, and other disciplines. Our 200,000 members bring immense experience in energy technologies to such diverse industries as energy, chemicals, pharmaceuticals, and electronics. They are also leaders in environmental health, safety, and sustainability. Their work improves the quality of life for people the world over.*

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continue to grow as countries raise standards of living—especially populous, developing nations like China and India. As we move beyond the world's maximum oil production point and demands continue to rise, prices and instability will certainly increase. Estimates vary on total oil resources, but it would be a mistake to assume that fossil fuel would remain at current prices, given the inherently unstable nature of commodity markets, geopolitics, and policy changes. We believe a targeted allocation of funds and timely change in energy policy would postpone the inevitable date that oil production would begin to decline. Thus, investment in increasing energy options is paramount.

Market forces will play an important, but not sufficient, role in meeting future energy needs. A sudden increase in energy prices or long periods of energy-price instability would result in energy shortfalls, which in turn would significantly impact global economic growth. Sufficient investment in energy innovations to increase availability and allow profound infrastructure changes (e.g., converting gasoline vehicles to hydrogen or increasing the use of public transportation) would require an ongoing, commitment over several decades. Given the investment of time and the technology needed, it is imperative to take immediate steps toward solving this problem.

According to the Energy Information Agency, U.S. domestic energy utilization in 2003 was roughly 85 percent fossil fuel, 8 percent nuclear power, and 6 percent renewable energy—including hydroelectricity. Clearly, America is overly dependent on fossil fuel, much of which comes from unstable regions of the world. Energy-use patterns—22 percent residential, 52 percent industrial, and 27 percent transportation—must also be considered in developing a comprehensive U.S. energy policy. Energy efficiency and conservation must be encouraged across the board.

At present, the S&T required to move beyond fossil-energy dependence and provide safely produced, sustainable power to meet growing, global needs, is simply not available. The ACS and AIChE recommend developing a dual-track, comprehensive R&D strategy that would simultaneously implement a near-term advancement of energy technologies (including fossil, solar, wind, nuclear, and efficient utilization) and a comprehensive S&T policy for developing sustainable sources to replace dwindling fossil supplies in the long term.

Finding solutions to meet advancing world needs for sustainable energy is one of the biggest challenges mankind will ever face. Burning fossil fuels places humanity at risk environmentally, and the potential consequences are dramatic. We must call upon universities, the private sector, and national laboratories to provide the best minds and teams to develop creative solutions through energy R&D.

A multidisciplinary-team approach to energy solutions is necessary. Advisory teams—including scientists, engineers, economists, business specialists, environmental scientists, and policymakers—should be selected to guide important energy R&D investment decisions, especially at involved agencies like the Department of Energy and National Science Foundation. In addition, industry should be encouraged through tax incentives and other policies to help design and execute a comprehensive energy plan.

Educating the next generation of world-class scientists and engineers is vital to bringing sustainable energy to fruition, but government cutbacks over the last 25 years have resulted in fewer top students pursuing energy-related careers. To meet energy and security needs in the new century, government must increase support for energy S&T in academic programs, as well as in public and private laboratories, and reinvigorate the robust, scientific and engineering cadre that made so many technological breakthroughs during the second half of the twentieth century.

In summary, the ACS and AIChE urge the U.S. government to develop a comprehensive energy policy to address growing demands for accessible, plentiful, inexpensive and sustainable energy sources. They also recommend taking advantage of all current energy options for short-term policies, while funding a robust medium- and long-term R&D initiative to take advantage of opportunities provided by the S&T community.

## POLICY RECOMMENDATIONS

**University, Private Sector, and Federal Laboratory Research**
The U.S. government has lowered its constant-dollar commitment to energy R&D by nearly 50 percent since 1980 and expends a smaller fraction of R&D investment in energy than almost any other nation in the developed world. Given the enormous public benefits and reduced private investment, government must increase investment in fundamental basic research.

A balanced program of federal investment in research must be a top priority. This balance involves significant investment in peer-reviewed, individual investigator basic research and related investments on a national and international level. A portion of federal research investment also should focus on applied research, technology development, and enabling technologies such as non-energy source-specific electricity storage and transportation. An integrated systems approach to the government's energy R&D portfolio at the various agencies must be established to choose the best available S&T and minimize investments driven by factors other than technical potential. Emphasis should be placed on investing in cutting-edge research, which is often overlooked as high-risk, thus depriving us of potentially significant areas of exploration.

The expertise and facilities of our national laboratories also are essential to an energy plan by encouraging multidisciplinary, multi-sector R&D and providing unique instruments. Government should facilitate U.S. leadership in international research and technology collaborations to address domestic and global energy problems.

**Energy Efficiency and Conservation**
Energy efficiency reduces energy needs, preserves limited resources for critical uses, and often leads to economic savings. For example, current marine anti-foulant coatings reduce the energy used in shipping by 40 percent, which saves nearly $1 billion annually. Research into materials, processes, and practices to boost efficiency gives us added time to develop new energy sources and improve long-term energy sustainability. We should promote efficiency for electric power, transportation, buildings, and industrial uses through tax incentives, corporate automobile fuel economy (CAFE) standards, and other policy mechanisms.

Raising the public's knowledge of science through education would boost awareness of the S&T underlying energy supply and demand and would increase student interest in energy-related S&T. This would positively impact the energy problem. Individuals and businesses must recognize the long-term adverse consequences of choosing low-fuel-efficiency vehicles, excessive lighting/heat/AC, lack of public transportation, and other choices, even when those choices provide short-term benefits.

**Industrial Innovation**
A comprehensive national energy policy should encourage private sector investment to develop new energy options and sustainable economic strength. The chemical and allied products industries have already made considerable strides in saving energy through technology improvement such as combined heat and power (CHP) or co-generation strategies. Natural gas efficiency has more than doubled in certain industrial processes. While technology already is available in several areas, capital investment requirements and increasing natural gas prices result in problematic economics. Moving forward, policies to encourage CHP with other fuel sources could improve industrial energy efficiency in many settings.

Government should make targeted investments in demonstration projects bridging development and commercialization—particularly those involving high-potential, yet high-risk, technologies. The market place could not support these projects without such a demonstration. Government should explore and support new R&D consortia and public/private partnership models (with appropriate cost sharing, tax benefits, and intellectual property protections) to foster R&D on targeted and market-relevant energy technologies.

**Tax Incentives**
Tax incentives are a useful tool for promoting necessary R&D in the business community. The R&D tax credit should be modified to foster long-term energy R&D and research collaborations with universities, national laboratories, and nonprofits. Emphasis should be placed on tax incentives that encourage industry-government partnerships in the demonstration of new, efficient, and renewable energy sources. These technologies may provide important advances in the transportation (e.g., hybrid and fuel cell vehicles), building, and electric power sectors (e.g., distributed electricity generators such as solar panels and stationary fuel cells). Taxes may also prove a viable policy option to encourage individual choices in areas like energy conservation and automobile energy efficiency.

**Regulatory Changes**
Regulations place an uneven burden on different energy sources, often by not reflecting full life-cycle costs. For example, plant-permit regulations have created barriers to the introduction of new domestic energy facilities. Consequently, there has been a lack of new U.S. coal-fired power plants over the last 20 years—plants that potentially could have incorporated cleaner technologies. Regulations restrict energy production by forbidding alternative energy sources to connect to the energy grid. Regulatory incentives and deterrents should be reviewed and streamlined to ensure that the private sector is driven to invest in the most sustainable energy technologies, while continuing to protect the environment.

## SPECIFIC ENERGY SOURCES AND USES

A recent report, *Energy and Transportation,* from the National Research Council series *Challenges for the Chemical Science in the 21st Century,* contains a wide-range of recommendations to direct research for improving both sources and uses of energy. These are highlighted in the bulleted items under the following subsections:

***Fossil fuels***
To meet projected demands for electricity using fossil fuels over the next 20 years, emphasis should be placed on improvements at gas- and coal-fired plants—specifically on the technological challenges of capturing carbon dioxide and increasing efficiency. These advances have significant potential because the U.S. has large coal reserves and relatively developed, cleaner-use technologies. Continued use of coal requires a high priority be put on carbon-sequestration research to minimize negative impacts on air quality and climate. In addition, technologies allowing more efficient use of petroleum products in transportation should be a priority.

Fossil fuel research needs include the following:

- Technologies and catalysts for cleaner use of coal as fuel and for its conversion to other fuels.
- Technologies for improved use of conventional fossil fuels and unconventional sources such as oil shale, tar sands, and deep-sea methane hydrates.
- Practical and environmentally responsible methods to capture and sequester carbon dioxide.

***Renewables***
Resources should be allocated to ensure the development of breakthrough technologies necessary to make solar power and other renewables competitive with fossil and nuclear energy. Photovoltaic (solar), wind, tidal, and geothermal energy require a wide range of new and improved technologies to increase their small share in the energy market, including materials, batteries, membranes, and catalysts. Since these resources are economically unproven, and fossil fuels are available and affordable, it is difficult to encourage industry investment. Therefore, government must take the lead in developing next-generation energy-mix technologies as they become more critical over the next century.

Biomass represents a unique, renewable resource because it can be used for energy production as well as alternative feedstock for chemical production. Thus, the development of biomass for energy must be considered in light of its potential dual use, and the resulting uncertain competition and pricing for the most valuable resources.

Research needs on renewables include the following:

- More stable, less expensive materials and methods to capture solar energy and convert it to electricity or other useful products.
- Opportunities to use biomass as a renewable fuel source as well as feedstock for industrial applications.
- New technologies for the economical conversion of cellulosic wastes (such as corn stover or wheat straw) and energy crops (such as switchgrass or energy cane).

***Hydrogen***
Current technologies for generating hydrogen as an energy resource are problematic in the absence of significant breakthroughs. Hydrogen and related-liquid fuels, such as methane, are potentially critical elements of a long-term energy strategy. These can be used to produce, store, and transport energy for use in fuel cells and other localized energy-generation applications. Increasing transportation and residential use of these fuels will require materials and technologies for storage and utilization beyond those currently being developed. In the short term, nuclear energy can provide a non-fossil source of energy to produce hydrogen; however, efforts should be made to improve the technologies and economics of long-term hydrogen generation from solar power and other renewable resources.

Hydrogen research needs include the following:

- Materials and processes for hydrogen generation from renewable sources.
- New materials for hydrogen storage with capacity for achieving economically viable hydrogen density.
- Development of an infrastructure for distribution and delivery of hydrogen.

***Nuclear***
Focus should be placed on the U.S. generation of inherently safe, environmentally acceptable, and economically available nuclear energy in order to reduce reliance on limited fossil-fuel resources. To overcome public concerns and facilitate nuclear energy as a major element in our energy mix (as it is in Europe), the government must assure reliable disposal and storage of nuclear waste. In addition, it must increase S&T on the nuclear-fuel cycle and continue investment in up-to-date plant designs. Steps to provide nuclear non-proliferation guarantees must accompany U.S. nuclear-power expansion. American expertise in nuclear sciences and engineering, which is dangerously atrophied, must be bolstered. Specific actions should be taken to encourage students to study in these fields and assure the viability of the academic departments where they can study.

Nuclear research is needed to do the following:

- Securely concentrate, treat, and dispose of radioactive waste products from nuclear-energy plants.
- Design inherently safe and proliferation-resistant reactors that minimize waste.
- Develop fusion energy sources.

***Energy efficiency***
A wide assortment of new technologies is needed to use energy more efficiently. We must optimize the generation and transmission of electric power used in residential, industrial, and mobile applications. Because half of all U.S. energy is used by industry, methods to improve energy efficiency in industrial settings are critical to a comprehensive energy strategy. Many technologies developed to save energy in one setting can be applied more broadly and enable more extensive energy savings.

Energy-efficiency research needs include the following:

- Inexpensive, high-energy-density, and quickly rechargeable energy storage devices that make electric vehicles truly practical.
- Less expensive, more stable fuel cells with improved membranes, catalysts, electrodes, and electrolytes.
- Photocatalytic systems with efficiencies great enough to use for chemical processing on a significant scale.
- Superconducting materials for energy distribution over long distances.
- Lower cost, lighter weight, more durable, more resilient, and recyclable materials for the construction of safer light-weight vehicles.