5. The case for immediate action

Scientific evidence is overwhelming that current energy trends are unsustainable. Immediate action is required to effect change in the timeframe needed to address significant ecological, human health and development, and energy security needs. Aggressive changes in policy are thus needed to accelerate the deployment of superior technologies. With a combination of such policies at the local, national, and international level, it should be possible—both technically and economically—to elevate the living conditions of most of humanity, while simultaneously addressing the risks posed by climate change and other forms of energy-related environmental degradation and reducing the geopolitical tensions and economic vulnerabilities generated by existing patterns of dependence on predominantly fossil-fuel resources.

This chapter presents nine major conclusions reached by the Study Panel, along with actionable recommendations. These conclusions and recommendations have been formulated within a holistic approach to the transition toward a sustainable energy future. This implies that not a single one of them can be successfully pursued without proper attention to the others. Prioritization of the recommendations is thus intrinsically difficult. Nonetheless, the Study Panel believes that, given the dire prospect of climate change, the following three recommendations should be acted upon *without delay and simultaneously*:

- Concerted efforts should be mounted to improve energy efficiency and reduce the carbon intensity of the world economy, including the worldwide introduction of price signals for carbon emissions, with consideration of different economic and energy systems in individual countries.
- Technologies should be developed and deployed for capturing and sequestering carbon from fossil fuels, particularly coal.
- Development and deployment of renewable energy technologies should be accelerated in an environmentally responsible way.

Taking into account the three urgent recommendations above, another recommendation stands out by itself as a moral and social imperative and should be pursued with all means available:

- The poorest people on this planet should be supplied with basic, modern energy services.

Achieving a sustainable energy future requires the participation of all. But there is a division of labor in implementing the various recommendations of this report. The Study Panel has identified the following principal 'actors' that must take responsibility for achieving results:

- Multi-national organizations (e.g., United Nations, World Bank, Regional Development Banks, etc.)
- Governments (national, regional, and local)
- Science and technology (S&T) community (academia)
- Private sector (businesses, industry, foundations)
- Nongovernmental organizations (NGOs)
- Media
- General public

Conclusions, recommendations, actions

Based on the key points developed in this report, the Study Panel offers these conclusions with recommendations and respective actions by the principal actors.

Conclusion 1

Meeting the basic energy needs of the poorest people on this planet is a moral and social imperative that can and must be pursued in concert with sustainability objectives.

Today an estimated 2.4 billion people use coal, charcoal, firewood, agricultural residues, or dung as their primary cooking fuel. Roughly 1.6 billion people worldwide live without electricity. Vast numbers of people, especially women and girls, are deprived of economic and educational opportunities without access to affordable, basic labor-saving devices or adequate lighting, added to the time each day spent gathering fuel and water. The indoor air pollution caused by traditional cooking fuels exposes millions of families to substantial health risks. Providing modern forms of energy to the world's poor could generate multiple benefits, easing the day-to-day struggle to secure basic means of survival; reducing substantial pollution-related health risks; freeing up scarce capital and human resources; facilitating the delivery of essential services, including basic medical care; and mitigating local environmental degradation. Receiving increased international attention, these linkages were a major focus of the 2002 World

Summit for Sustainable Development in Johannesburg, which recognized the importance of expanded access to reliable and affordable energy services as a prerequisite for achieving the United Nation's Millennium Development Goals.

Recommendations

- Place priority on rapidly achieving much greater access of the world's poor to clean, affordable, high-quality fuels and electricity. The challenge of expanding access to modern forms of energy revolves primarily around issues of social equity and distribution—the fundamental problem is not one of inadequate global resources, unacceptable environmental damage, or unavailable technologies. Addressing the basic energy needs of the world's poor is clearly central to the larger goal of sustainable development and must be a top priority for the international community if some dent is to be made in reducing current inequities.
- Formulate policy at all levels, from global to village scale, with greater awareness of the substantial inequalities in access to energy services that now exist, not only between countries but between populations within the same country and even between households within the same town or village. In many developing countries, a small elite uses energy in much the same way as in the industrialized world, while most of the rest of the population relies on traditional, often poor-quality and highly polluting forms of energy. In other developing countries, energy consumption by a growing middle class is contributing significantly to global energy demand growth and is substantially raising national per capita consumption rates, despite little change in the consumption patterns of the very poor. The reality that billions of people suffer from limited access to electricity and clean cooking fuels must not be lost in per capita statistics.

Needed actions

- Given the international dimension of the problem, multinational organizations like the United Nations and the World Bank should take the initiative to draw up a plan for eliminating the energy poverty of the world's poor. As a first step, governments and NGOs can assist by supplying data on the extent of the problem in their countries.
- The private sector and the S&T community can help promote the transfer of appropriate technologies. The private sector can, in addition, help by making appropriate investments.
- The media should make the general public aware of the enormity of the problem.

Conclusion 2

Concerted efforts must be made to improve energy efficiency and reduce the carbon intensity of the world economy.

Economic competitiveness, energy security, and environmental considerations all argue for pursuing cost-effective end-use efficiency opportunities. Such opportunities may be found throughout industry, transportation, and the built environment. To maximize efficiency gains and minimize costs, improvements should be incorporated in a holistic manner and from the ground up wherever possible, especially where long-lived infrastructure is involved. At the same time it will be important to avoid underestimating the difficulty of achieving nominal energy efficiency gains, as frequently happens when analyses assume that reduced energy use is an end in itself rather than an objective regularly traded against other desired attributes.

Recommendations

- Promote the enhanced dissemination of technology improvement and innovation between industrialized and developing countries. It will be especially important for all nations to work together to ensure that developing countries adopt cleaner and more efficient technologies as they industrialize.
- Align economic incentives—especially for durable capital investments—with long-run sustainability objectives and cost considerations. Incentives for regulated energy service providers should be structured to encourage co-investment in cost-effective efficiency improvements and profits should be de-linked from energy sales.
- Adopt policies aimed at accelerating the worldwide rate of decline in the carbon intensity of the global economy, where carbon intensity is measured as carbon dioxide equivalent emissions divided by gross world product, a crude measure of global well-being. Specifically, the Study Panel recommends immediate policy action to introduce meaningful price signals for avoided greenhouse gas emissions. Less important than the initial prices is that clear expectations be established concerning a predictable escalation of those prices over time. Merely holding carbon dioxide emissions constant over the next several decades implies that the carbon intensity of the world economy needs to decline at roughly the

same rate as gross world product grows. Achieving the absolute *reductions* in global emissions needed to stabilize atmospheric concentrations of greenhouse gases will require the worldwide rate of decline in carbon intensity to begin outpacing worldwide economic growth.
- Enlist cities as a major driving force for the rapid implementation of practical steps to improve energy efficiency.
- Inform consumers about the energy-use characteristics of products through labeling and implement mandatory minimum efficiency standards for appliances and equipment. Standards should be regularly updated and must be effectively enforced.

Needed actions

- Governments, in a dialogue with the private sector and the S&T community, should develop and implement (further) policies and regulations aimed at achieving greater energy efficiency and lower energy intensity for a great variety of processes, services, and products.
- The general public must be made aware, by governments, the media, and NGOs, of the meaning and necessity of such policies and regulations.
- The S&T community should step up its efforts to research and develop new, low-energy technologies.
- Governments, united in intergovernmental organizations, should agree on realistic price signals for carbon emissions, recognizing that the economies and energy systems of different countries will result in different individual strategies and trajectories, and make these price signals key components of further actions on reducing the carbon emissions.
- The private sector and the general public should insist that governments issue clear carbon price signals.

Conclusion 3

Technologies for capturing and sequestering carbon from fossil fuels, particularly coal, can play a major role in the cost-effective management of global carbon dioxide emissions.

As the world's most abundant fossil fuel resource, coal will continue to play a large role in the world's energy mix. It is also the most carbon-intensive conventional fuel in use today, generating almost twice as much carbon dioxide per unit of energy supplied than natural gas. Today, new coal-fired power plants—most of which can be expected to last more than half a century—are being constructed at an unprecedented rate. Moreover, the carbon contribution from coal could expand further if nations with large coal reserves like the United States, China, and India turn to coal to address energy security concerns and develop alternatives to petroleum.

Recommendations

- Accelerate the development and deployment of advanced coal technologies. Without policy interventions the vast majority of the coal-fired power plants constructed in the next two decades will be 'conventional' pulverized coal plants. Present technologies for capturing carbon dioxide emissions from pulverized coal plants on a retrofit basis are expensive and energy-intensive. Where new coal plants without capture must be constructed, the most efficient technologies should be used. In addition, priority should be given to minimize the costs of future retrofits for carbon capture by developing at least some elements of carbon capture technology at every new plant. Active efforts to develop such technologies for different types of base plants are currently underway and should be encouraged by promoting the construction of full-scale plants that utilize the latest technology advances.
- Aggressively pursue efforts to commercialize carbon capture and storage. Moving forward with full-scale demonstration projects is critical, as is continued study and experimentation to reduce costs, improve reliability, and address concerns about leakage, public safety, and other issues. For capture and sequestration to be widely implemented it will be necessary to develop regulations and to introduce price signals for carbon emissions. Based on current cost estimates, the Study Panel

believes price signals on the order of US$100–150 per avoided metric ton of carbon equivalent (US$27–41 per ton of carbon dioxide equivalent) will be required to induce the widespread adoption of carbon capture and storage. Price signals at this level would also give impetus to the accelerated deployment of biomass and other renewable energy technologies.

- Explore potential retrofit technologies for post-combustion carbon capture suitable for the large and rapidly growing population of existing pulverized coal plants. In the near-term, efficiency improvements and advanced pollution control technologies should be applied to existing coal plants as a means of mitigating their immediate climate change and public health impacts.
- Pursue carbon capture and storage with systems that co-fire coal and biomass. This technology combination provides an opportunity to achieve net negative greenhouse gas emissions—effectively removing carbon dioxide from the atmosphere.

Needed actions

- The private sector and the S&T community should join forces to further investigate the possibilities for carbon capture and sequestration and develop adequate technologies for demonstration.
- Governments should facilitate the development of these technologies by making available funds and opportunities (such as test sites).
- The general public needs to be thoroughly informed about the advantages of carbon sequestration and about the relative manageability of associated risks. The media can assist with this.

Conclusion 4

Competition for oil and natural gas supplies has the potential to become a source of growing geopolitical tension and economic vulnerability for many nations in the decades ahead.

In many developing countries, expenditures for energy imports also divert scarce resources from other urgent public health, education, and infrastructure development needs. The transport sector accounts for just 25 percent of primary energy consumption worldwide, but the lack of fuel diversity in this sector makes transport fuels especially valuable.

Recommendations

- Introduce policies and regulations that promote reduced energy consumption in the transport sector by (a) improving the energy efficiency of automobiles and other modes of transport and (b) improving the efficiency of transport systems (e.g., through investments in mass transit, better land-use and city planning, etc.).
- Develop alternatives to petroleum to meet the energy needs of the transport sector, including biomass fuels, plug-in hybrids, and compressed natural gas, as well as—in the longer run—advanced alternatives such as hydrogen fuel cells.
- Implement policies to ensure that the development of petroleum alternatives is pursued in a manner that is compatible with other sustainability objectives. Current methods for liquefying coal and extracting oil from unconventional sources like tar sands and shale oil generate substantially higher levels of carbon dioxide and other pollutant emissions compared to conventional petroleum consumption. Even with carbon capture and sequestration, a liquid fuel derived from coal will at best produce emissions of carbon dioxide roughly equivalent to those of conventional petroleum at the point of combustion. If carbon emissions from the conversion process are not captured and stored, total fuel-cycle emissions for this energy pathway as much as double. The conversion of natural gas to liquids is less carbon-intensive than coal to liquids, but biomass remains the only near-term feedstock that has the potential to be truly carbon-neutral and sustainable on a long-term basis. In all cases, full fuel-cycle impacts depend critically on the feedstock being used and on the specific extraction or conversion methods being employed.

Needed actions

- Governments should introduce (further) policies and regulations aimed at reducing energy consumption and developing petroleum alternatives for use in the transport sector.
- The private sector and the S&T community should continue developing technologies adequate to that end.
- The general public's awareness of sustainability issues related to transportation energy use should be significantly increased. Again, the media can play an important role in this effort.

Conclusion 5

As a low-carbon resource, nuclear power can continue to make a significant contribution to the world's energy portfolio in the future, but only if major concerns related to capital cost, safety, and weapons proliferation are addressed.

Nuclear power plants generate no carbon dioxide or conventional air pollutant emissions during operation, use a relatively abundant fuel feedstock, and involve orders-of-magnitude smaller mass flows, relative to fossil fuels. Nuclear's potential, however, is currently limited by concerns related to cost, waste management, proliferation risks, and plant safety (including concerns about vulnerability to acts of terrorism and concerns about the impact of neutron damage on plant materials in the case of life extensions). A sustained role for nuclear power will require addressing these hurdles.

Recommendations

- Replace the current fleet of aging reactors with plants that incorporate improved intrinsic (passive) safety features.
- Address cost issues by pursuing the development of standardized reactor designs.
- Understand the impact of long-term aging on nuclear reactor systems (e.g., neutron damage to materials) and provide for the safe and economic decommissioning of existing plants.
- Develop safe, retrievable waste management solutions based on dry cask storage as longer term disposal options are explored. While long-term disposal in stable geological repositories is technically feasible, finding socially acceptable pathways to implementing this solution remains a significant challenge.
- Address the risk that civilian nuclear materials and knowledge will be diverted to weapons applications through continued research on proliferation-resistant uranium enrichment and fuel-recycling capability and on safe, fast neutron reactors that can burn down waste generated from thermal neutron reactors and through efforts to remedy shortcomings in existing international frameworks and governance mechanisms.
- Undertake a transparent and objective re-examination of the issues surrounding nuclear power and their potential solutions. The results of such a re-examination should be used to educate the public and policymakers.

Needed actions

- Given the controversy over the future of nuclear power worldwide, the United Nations should commission—as soon as possible—a transparent and objective re-examination of the issues that surround nuclear power and their potential solutions. It is essential that the general public be informed about the outcome of this re-examination.
- The private sector and the S&T community should continue research and development efforts targeted at improving reactor safety and developing safe waste management solutions.
- Governments should facilitate the replacement of the current fleet of aging reactors with modern, safer plants. Governments and intergovernmental organizations should enhance their efforts to remedy shortcomings in existing international frameworks and governance mechanisms.

Conclusion 6

Renewable energy in its many forms offers immense opportunities for technological progress and innovation.

Over the next 30–60 years sustained efforts must be directed toward realizing these opportunities as part of a comprehensive strategy that supports a diversity of resource options over the next century. The fundamental challenge for most renewable options involves cost-effectively tapping inherently diffuse and in some cases intermittent resources. Sustained, long-term support—in various forms—is needed to overcome these hurdles. Renewable energy development can provide important benefits in underdeveloped and developing countries because oil, gas, and other fuels are hard cash commodities.

Recommendations

- Implement policies—including policies that generate price signals for avoided carbon emissions—to ensure that the environmental benefits of renewable resources relative to non-renewable resources will be systematically recognized in the marketplace.
- Provide subsidies and other forms of public support for the early deployment of new renewable technologies. Subsidies should be targeted to promising but not-yet-commercial technologies and decline gradually over time.
- Explore alternate policy mechanisms to nurture renewable energy technologies, such as renewable portfolio standards (which set specific goals for renewable energy deployment) and 'reverse auctions' (in which renewable energy developers bid for a share of limited public funds on the basis of the minimum subsidy they require on a per kilowatt-hour basis).
- Invest in research and development on more transformational technologies, such as new classes of solar cells that can be made with thin-film, continuous fabrication processes. (See also biofuels recommendations under conclusion 7.)
- Conduct sustained research to assess and mitigate any negative environmental impacts associated with the large-scale deployment of renewable energy technologies. Although these technologies offer many environmental benefits, they may also pose new environmental risks as a result of their low power density and the consequently large land area required for large-scale deployment.

Needed actions

- Governments should substantially facilitate the use—in an environmentally sustainable way—of renewable energy resources through adequate policies and subsidies. A major policy step in this direction would include implementing clear price signals for avoided greenhouse gas emissions.
- Governments should also promote research and development in renewable energy technologies by supplying significantly more public funding.
- The private sector, aided by government subsidies, should seek entrepreneurial opportunities in the growing renewable energy market.
- The science and technology community should devote more attention to overcoming the cost and technology barriers that currently limit the contribution of renewable energy sources.
- NGOs can assist in promoting the use of renewable energy sources in developing countries.
- The media can play an essential role in heightening the general public's awareness of issues related to renewable energy.

Conclusion 7

Biofuels hold great promise for simultaneously addressing climate-change and energy-security concerns.

Improvements in agriculture will allow for food production adequate to support a predicted peak world population on the order of 9 billion people with excess capacity for growing energy crops. Maximizing the potential contribution of biofuels requires commercializing methods for producing fuels from lignocellulosic feedstocks (including agricultural residues and wastes), which have the potential to generate five to ten times more fuel than processes that use starches from feedstocks like sugar cane and corn. Recent advances in molecular and systems biology show great promise in developing improved feedstocks and much less energy-intensive means of converting plant material into liquid fuel. In addition, intrinsically more efficient conversion of sunlight, water, and nutrients into chemical energy may be possible with microbes.

Recommendations

- Conduct intensive research into the production of biofuels based on lignocellulose conversion.
- Invest in research and development on direct microbial production of butanol or other forms of biofuels that may be superior to ethanol.
- Implement strict regulations to insure that the cultivation of biofuels feedstocks accords with sustainable agricultural practices and promotes biodiversity, habitat protection, and other land management objectives.
- Develop advanced bio-refineries that use biomass feedstocks to self-generate power and extract higher-value co-products. Such refineries have the potential to maximize economic and environmental gains from the use of biomass resources.
- Develop improved biofuels feedstocks through genetic selection and/or molecular engineering, including drought resistant and self-fertilizing plants that require minimal tillage and fertilizer or chemical inputs.
- Mount a concerted effort to collect and analyze data on current uses of biomass by type and technology (both direct and for conversion to other fuels), including traditional uses of biomass.
- Conduct sustained research to assess and mitigate any adverse environmental or ecosystem impacts associated with the large-scale cultivation

of biomass energy feedstocks, including impacts related to competition with other land uses (including uses for habitat preservation and food production), water needs, etc.

Needed actions

- The S&T community and the private sector should greatly augment their research and development (and deployment) efforts toward more efficient, environmentally sustainable technologies and processes for the production of modern biofuels.
- Governments can help by stepping up public research and development funding and by adapting existing subsidy and fiscal policies so as to favor the use of biofuels over that of fossil fuels, especially in the transport sector.
- Governments should pay appropriate attention to promoting sustainable means of biofuels production and to avoiding conflicts between biofuel production and food production.

Conclusion 8

The development of cost-effective energy storage technologies, new energy carriers, and improved transmission infrastructure could substantially reduce costs and expand the contribution from a variety of energy supply options.

Such technology improvements and infrastructure investments are particularly important to tap the full potential of intermittent renewable resources, especially in cases where some of the most abundant and cost-effective resource opportunities exist far from load centers. Improved storage technologies, new energy carriers, and enhanced transmission and distribution infrastructure will also facilitate the delivery of modern energy services to the world's poor—especially in rural areas.

Recommendations

- Continue long-term research and development into potential new energy carriers for the future, such as hydrogen. Hydrogen can be directly combusted or used to power a fuel cell and has a variety of potential applications—including as an energy source for generating electricity or in other stationary applications and as an alternative to petroleum fuels for aviation and road transport. Cost and infrastructure constraints, however, are likely to delay widespread commercial viability until mid-century or later.
- Develop improved energy storage technologies, either physical (e.g. compressed air or elevated water storage) or chemical (e.g. batteries, hydrogen, or hydrocarbon fuel produced from the reduction of carbon dioxide), that could significantly improve the market prospects of intermittent renewable resources such as wind and solar power.
- Pursue continued improvements and cost reductions in technologies for transmitting electricity over long distances. High voltage, direct-current transmission lines, in particular, could be decisive in making remote areas accessible for renewable energy development, improving grid reliability, and maximizing the contribution from a variety of low-carbon electricity sources. In addition, it will be important to improve overall grid management and performance through the development and application of advanced or 'smart' grid technologies that could greatly enhance the responsiveness and reliability of electricity transmission and distribution networks.

Needed actions

- The S&T community, together with the private sector, should have focus on research and development in this area
- Governments can assist by increasing public funding for research and development and by facilitating needed infrastructure investments.

Conclusion 9

The science and technology community—together with the general public—has a critical role to play in advancing sustainable energy solutions and must be effectively engaged.

As noted repeatedly in the foregoing recommendations, the energy challenges of this century and beyond demand sustained progress in developing, demonstrating, and deploying new and improved energy technologies. These advances will need to come from the S&T community, motivated and supported by appropriate policies, incentives, and market drivers.

Recommendations

- Provide increased funding for public investments in sustainable energy research and development, along with incentives and market signals to promote increased private-sector investments.
- Effect greater coordination of technology efforts internationally, along with efforts to focus universities and research institutions on the sustainability challenge.
- Conduct rigorous analysis and scenario development to identify possible combinations of energy resources and end-use and supply technologies that have the potential to simultaneously address the multiple sustainability challenges linked to energy.
- Stimulate efforts to identify and assess specific changes in institutions, regulations, market incentives, and policy that would most effectively advance sustainable energy solutions.
- Create an increased focus on specifically energy-relevant awareness, education, and training across all professional fields with a role to play in the sustainable energy transition.
- Initiate concerted efforts to inform and educate the public about important aspects of the sustainable energy challenge, such as the connection between current patterns of energy production and use and critical environmental and security risks.
- Begin enhanced data collection efforts to support better decisionmaking in important policy areas that are currently characterized by a lack of reliable information (large cities in many developing countries, for example, lack the basic data needed to plan effectively for transportation needs).

Needed actions

- The S&T community must strive for better international coordination of energy research and development efforts, partly in collaboration with the private sector. It should seek to articulate a focused, collaborative agenda aimed at addressing key obstacles to a sustainable energy future.
- Governments (and inter-governmental organizations) must make more public funding available to not only boost the existing contribution from the S&T community but also to attract more scientists and engineers to working on sustainable energy problems.
- The why and how of energy research and development should be made transparent to the general public to build support for the significant and sustained investments that will be needed to address long-term sustainability needs.
- The S&T community itself, inter-governmental organizations, governments, NGOs, the media and—to a lesser extent—the private sector, should be actively engaged in educating the public about the need for these investments.

Lighting the way

While the current energy outlook is very sobering, the Study Panel believes that there are sustainable solutions to the energy problem. Aggressive support of energy science and technology must be coupled with incentives that accelerate the concurrent development and deployment of innovative solutions that can transform the entire landscape of energy demand and supply. Opportunities to substitute superior supply-side and end-use technologies exist throughout the world's energy systems, but current investment flows generally do not reflect these opportunities.

Science and engineering provide guiding principles for the sustainability agenda. Science provides the basis for a rational discourse about trade-offs and risks, for selecting research and development priorities, and for identifying new opportunities—openness is one of its dominant values. Engineering, through the relentless optimization of the most promising technologies, can deliver solutions—learning by doing is among its dominant values. Better results will be achieved if many avenues are explored in parallel, if outcomes are evaluated with actual performance measures, if results are reported widely and fully, and if strategies are open to revision and adaptation.

Long-term energy research and development is thus an essential component of the pursuit of sustainability. Significant progress can be achieved with existing technology but the scale of the long-term challenge will demand new solutions. The research community must have the means to pursue promising technology pathways that are already in view and some that may still be over the horizon.

The transition to sustainable energy systems also requires that market incentives be aligned with sustainability objectives. In particular, robust price signals for avoided carbon emissions are critical to spur the development and deployment of low-carbon energy technologies. Such price signals can be phased in gradually, but expectations about how they will change over time must be established in advance and communicated clearly so that businesses can plan with confidence and optimize their long-term capital investments.

Critical to the success of all the tasks ahead are the abilities of individuals and institutions to effect changes in energy resources and usage. Capacity building, both in terms of investments in individual expertise and institutional effectiveness, must become an urgent priority of all principal actors: multi-national organizations, governments, corporations, educational institutions, non-profit organizations, and the media. Above all, the general public must be provided with sound information about the choices ahead and the actions required for achieving a sustainable energy future.