CLEAN SOLUTIONS FOR POWER GENERATION

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Strategies for implementation of low-carbon technologies must be creative to achieve energy security and a stable climate by 2050. This planetary energy transformation must include a mix of clean technologies such as decarbonized coal, carbon sequestration, fuel cells, bioenergy, and ultra-efficient gas powered plants.

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Unprecedented, massive innovation must take place to develop, commercialize, and bring to market and to large-scale deployment low-carbon technologies that will revolutionize the world.

Clean energy markets have grown tremendously in recent years, but represent only a fraction of a solution to global warming, which depends on a radical transition to a low-carbon future.

Clean energy has usually included the conventional renewable technologies: energy production from solar, wind, small hydro, biomass, ocean thermal, tidal and wave, geothermal, fuel cells, and related energy storage and conversion technologies.

But comprehensive, low-carbon-technology innovation is needed. We must massively increase use of these renewable technologies and significantly advance low-carbon options such as decarbonized coal, carbon sequestration, ultra-high-efficiency fossil energy production, fuel cells, bioenergy, and derivatives of genomics, nanotechnology, and related fields.

Moreover, today's energy and climate policies alone cannot drive clean energy markets at the scale or pace necessary to solidify energy security and stabilize the climate by 2050. We must be more creative in deploying new, innovative strategies for all these low-carbon options. Also, current structures for financing and commercializing innovative technologies are failing to deliver these much-needed low-carbon technologies to market.

Only by simultaneously tackling the twin challenges of accelerating the pace of low-carbon technology innovation and creating broad-scale financing and commercialization can we achieve a planetary energy transformation.

Low-Carbon Technology Solutions

In addition to renewables—such as solar photovoltaics, wind, ocean energy—and efficiency technologies, promising low-carbon technology solutions include the following:

Decarbonized coal: Integrated Gasification Combined Cycle (IGCC) represents a new generation of coal plants that are technologically superior and environmentally preferable to conventional plants. This is due to their ability to gasify coal, thereby reducing the levels of oxides of sulfur, oxides of nitrogen, particulates, and mercury emissions before combustion. IGCC plants also significantly reduce carbon dioxide emissions and can be further configured to capture carbon, eliminating the final cleanup.

Coal can be decarbonized three ways—through end-of-pipe scrubbers, sequestration, and IGCC (or IGCC plus sequestration). The three methods of decarbonization are already available commercially, but they need to be produced and deployed in large quantities to compete with and put a stop to new construction of conventional coal plants. This is especially true in developing countries, where the projected growth in conventional coal plants is very high. In a future carbon-constrained world, IGCC could become the coal plant of choice.

Ultra-efficient gas power plants: Natural gas plants that utilize advanced combined-cycle turbines have higher efficiency and produce less greenhouse gas emissions than conventional coal plants. At various times in 2005, natural gas was a more expensive and volatile fuel than coal, making cost/economics a critical factor. How future supplies of natural gas develop may affect any cost differential. Incen-

AP/Wide World Photo

A 250-kilowatt fuel cell, part of the system that generates electricity and heats water for a Sheraton hotel in New York.

tives to increase cost competitiveness may be needed to encourage widespread use of ultra-efficient gas technology.

Fuel cells: Fuel cells convert hydrogen and oxygen into electricity, with only water and heat (no greenhouse gases) as by-products. They are a promising technology for multiple applications, especially for producing clean, distributed power on site at locations with sensitive power loads, such as airports, banks, data centers, first responder stations, hospitals, and telephone switching stations.

On-site fuel cells offer energy security with sustained, high-quality power. They can operate on natural gas as well as renewable fuels. Barriers to fuel cell technology include relatively high upfront capital cost, maintenance and operation requirements, the cost of producing hydrogen fuel, and fuel storage and delivery issues. In order to achieve widespread adoption, fuel cells should be considered for critical sites such as hospitals and other places where power disruption can have severe consequences. For those types of facilities, the cost differential may be less of a barrier. Other barriers to greater penetration of fuel cells at the utility level, such as exorbitant rates charged to tap into the power grid when a fuel cell is shut down for maintenance, must also be overcome.

Cellulosic biomass and biofuels: As interest in the production and use of biofuels rises, there is more use of biomass technologies, such as anaerobic digesters and gasifiers, to make power from crops, crop waste, and manure. However, the bioenergy market is relatively nascent and has a way to go to reach the point that signals the rapid and widespread adoption of biomass and biofuels technologies. Further, from a low-carbon perspective, it is widely recognized that using cellulosic (plant-based) biomass is preferable to growing dedicated crops, such as maize, to produce biofuels because harvesting and transporting the dedicated crops increases carbon dioxide emissions. Genomics research may be critical to advance this technology, but it has yet to be harnessed to develop and commercialize high-energy-producing biofuels and energy systems.

Sequestration: Sequestration—capturing and locking away excess carbon emissions rather than releasing them to the atmosphere—falls into two categories: (1) biological, in which the carbon is captured in plants known to absorb a lot of carbon and planted in specific areas; and (2) geological, in which carbon is injected into rock formations. A host of technologies is being explored for both types of sequestration, but none is yet available on a widespread basis. All actors, public and private, should take more aggressive action to address quickly the various scientific and technical questions regarding how best to store and capture carbon for long periods of time.

There are probably many other low-carbon technologies yet to be invented that could disrupt the status quo of more traditional energy technologies. The challenge lies not only in the invention, but also in establishing and rapidly expanding the markets for future low-carbon technologies.

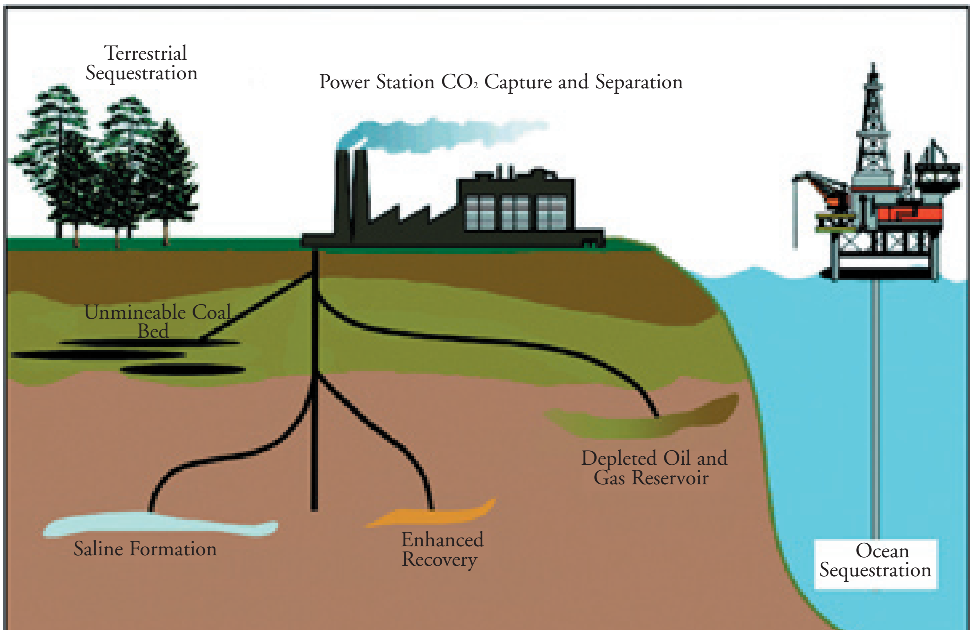
Accelerating Innovation

There are multiple low-carbon technology challenges and opportunities on the horizon. Experts agree that successful development of clean energy will require attention, not just to advances in basic and applied sciences, but also to the commercial dynamics that surround emerging technologies.

The Group of Eight (G8) countries recognized this pressing need for technology innovation and its commercialization when it launched the G8 Dialogue on Climate Change, Clean Energy, and Sustainable Development at Gleneagles, Scotland, in July 2005. The World Bank developed an "investment framework" to serve as a cornerstone for this dialogue, acknowledging the critical need for technology innovation to support a massive scale-up in investment, research and development, and commercialization of low-carbon technologies.

The World Bank's investment-framework report concludes that the current policies and funding from public

Carbon Sequestration Options



Courtesy Energy Information Administration, Washington, D.C.

Carbon dioxide (CO_2) captured from emissions or removed from the air can be stored long term in vegetation, soil, and underground reservoirs; injected deep into oceans; or converted to rock-like solid materials. Compressed CO_2 can be used to enhance recovery of oil from oilfields and methane from unmineable coal beds. Once used for this purpose, CO_2 remains safely and permanently stored beneath the Earth's surface.

and private sources are not enough to promote technologies that will reduce carbon to stabilize emissions.

Challenges of Energy Transformation

Transforming the world's energy system will be tremendously difficult. It is the most capital-intensive industry in the world, a complex and interdependent financial, regulatory, and institutional network with over a century of incumbent protection and support. However, an energy revolution can be swift: The car replaced the horse as a mode of transportation in about 30 years, while central electrification diffused throughout the United States in fewer than 40 years.

The transformation at hand will need to be equivalent in scale to the energy-fueled technological transformation in the industrialized nations over the last 100 years. This was a period that saw a transition from waterwheels for industry, wood and kerosene for domestic use, and horse-drawn transportation to near-universal electrification, the dominance of coal for electric production, millions of gas- and diesel-fueled vehicles, jet travel, and, eventually, the microchip and the digital economy it spawned.

To achieve a transformation on a similar scale, several changes must take place:

- Of the utmost importance, the government, academia and the private sector should coordinate research and development (R&D) *with* deployment and technology commercialization, rather than treat R&D as a sole area of focus.
- Debate on low-carbon technologies should take place at various levels (international, subnational) and within many frameworks for subnational stakeholders, as well as the United Nations Framework Convention on Climate Change and the G8 Dialogue on Climate Change, Clean Energy, and Sustainable Development.
- The task of reducing carbon emissions on a global scale should be distributed to all levels of the public and private sectors. This would open the door to the kind of creative problem solving that would address market shortcomings, promote low-carbon technology transfer and information sharing, foster linkages among disciplines, and produce real results.
- Energy finance must shift aggressively toward new forms of capital accumulation to build the low-carbon energy infrastructure of the future.
- The G8 investment framework and other forms of international collaboration must answer broader questions on technology innovation and commercialization. Gaps in the innovation chain must be filled in order to shift to low-carbon technologies in both industrialized and developing countries. To produce results, this must be coupled with a significant expansion of resources and distinct budgets. Public-private partnerships need to make it a top priority to accelerate the pace of low-carbon technology innovation and adoption.

Comprehensively addressing these issues is the energy security challenge of the 21st century. ■

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COGENERATION
More Energy, Less Pollution From Fossil Fuels

Cogeneration has been known since inventor Thomas Edison applied the idea in 1882 in the first U.S. power plant. The process uses a by-product of electricity to also provide heating and cooling. It was only quite recently that the U.S. government and environmental groups embraced this and other integrated energy systems as one of the best ways of improving energy efficiency and reducing air pollution. Cogeneration and trigeneration, which includes also cooling, reduce energy costs and improve power reliability and quality.

Currently used to power some commercial buildings and industrial facilities, these systems convert 80 to 85 percent of fuel's energy content into usable energy, compared to 50 percent at conventional thermoelectric stations and only 33 percent for power generation in general, according to the Midwest Cogeneration Application Center. Increased efficiency of energy utilization reduces the amount of fossil fuels consumed per unit of energy used, cutting by 45 percent air emissions that would come from conventional power plants.

Yet the concepts of combined cooling, heating, and power (CCHP) generation, as trigeneration is known, and combined heat and power (CHP) generation, as cogeneration is known, have failed to create the same excitement and interest as, say, hybrid cars. The share of power generation from integrated systems and renewables in the global market has increased only slightly, going from 7 percent in 2002 to 7.2 percent in 2005, according to a survey by the World Alliance for Decentralized Energy (WADE).

WADE blames this slow growth on "persistent" regulatory barriers and the high prices of natural gas, the second most used fuel in the integrated systems after coal. Some experts, however, argue that the lack of one-stop shopping for the integrated systems and the incompatibility among parts from different manufacturers have hampered the expansion.

Electric generator/microturbine provides different energy functions within a building.

Courtesy Midwest Combined Heat and Power Application Center

A cogeneration system consists of an engine, turbine, or fuel cell that generates on-site electricity, and a heat recovery unit that captures waste heat from the generation process. In commercial buildings, cogeneration systems are usually connected to an absorption chiller that provides heating and cooling for the central heating, ventilation, and air conditioning systems.

Experts predict a more positive outlook for cogeneration in coming years, thanks to standardized parts and preassembled modular systems. According to David Engle, a writer specializing in construction topics, the new generation of cogeneration systems will transform the integrated energy industry and broaden the potential customer base to hospitals, nursing homes, data centers, food-processing plants, supermarkets, warehouses, hotels, and educational facilities. Facility operating costs will dive as equipment prices drop and energy efficiency rises, he says in a 2005 article published by the journal *Distributed Energy.*

WADE believes that growth potential in emerging markets is greater than prospects in the developed world. In India alone, integrated systems have the potential to cogenerate enough electricity from by-products of sugar-cane processing to become a major player in satisfying that country's growing demand for electricity, according to Winrock International, a nongovernmental organization that works on natural resource and environmental issues. And in Brazil, new gas discoveries off the southeast coast, coupled with relatively new regulatory incentives, provide opportunities for cogeneration investment in São Paulo and Rio de Janeiro, according to WADE.

WADE says that future market prospects for cogeneration everywhere depend on removing regulatory barriers in the electricity market and creating a level playing field for all forms of electricity generation. ■