ENERGY REVOLUTION: POLICIES FOR A SUSTAINABLE FUTURE

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Introduction

Business-as-usual forecasts project that global energy use will increase around 2% per year in the coming decades. For example, the U.S. Department of Energy projects that world energy demand will increase by 60% between 2000 and 2025.[11] Oil use would increase by 54%, natural gas use by 99%, and coal use by 49% in this forecast. Fossil fuels would account for nearly 88% of total primary energy supply in 2025, up from their 85% share in 2000.

A high growth, fossil fuel-intensive energy future presents major problems and challenges for humanity. These include air pollution, global warming, security risks, resource depletion, high costs, and inequity.

Air Pollution

Burning fossil fuels releases pollutants that cause acid rain, urban smog, and hazardous soot. These pollutants are harming public health and disrupting ecosystems. It is estimated that 1.4 billion people worldwide are exposed to dangerous levels of outdoor pollution, and that outdoor air pollution is causing on the order of 500,000 deaths annually worldwide.

As bad as outdoor air pollution is in many developing countries, indoor air pollution from burning fuelwood and agricultural residues for cooking and heating is an even greater health hazard. It is estimated that indoor air pollution is causing about 1.8 million premature deaths annually, mainly in women and children.[12] In India, for example, more people die because of indoor air pollution than other major health hazards such as malaria, AIDs, heart disease, or cancer.

Global Warming

Carbon dioxide and other "greenhouse gases" are building up in the atmosphere and causing global warming. The carbon dioxide concentration is higher today than at any point during the past 420,000 years. Consequently, the average temperature of the earth's surface increased about $0.6^{O}C$ over the past century according to the IPCC. Furthermore, the 1990s were the warmest decade on record, 1998 was the single warmest year of the past 1,000 years, and 2001 was the second warmest year.

If current energy supply and demand trends continue, the carbon dioxide concentration could reach 2.5–3.5 times the pre-industrial level by 2100. This would result in a 1.4–$5.8^{O}C$ rise in the earth's average surface temperature by 2100 according to the latest IPCC

Notes
[11] *International Energy Outlook 2003*. DOE/EIA-0484(2003). Washington, DC: U.S. Department of Energy, Energy Information Administration.
[12] Holdren, J.P. and K.R. Smith. 2000. Energy, the Environment, and Health. In *World Energy Assessment: Energy and the Challenge of Sustainability*. New York, NY: United Nations Development Programme.

estimates.[13] A temperature rise even at the lower end of this range could have devastating effects including greatly increasing the frequency and magnitude of severe weather events, spreading infectious diseases, causing sea level rise; reducing crop yields in most inhabited regions, and damaging ecosystems worldwide.

Security Risks

Western nations are highly dependent on imported oil, meaning their economies are vulnerable to price fixing by the OPEC cartel and potential oil price shocks. These countries also face national security risks due to potential oil supply disruptions, military intervention that has been needed at times to maintain vital oil supplies, and the side effects of a strong military presence in the Persian Gulf region. The oil import dependence of the U.S. and other western nations increases in a business-as-usual energy future.

The terrorist attack in the U.S. on 9/11/01 was connected to oil imports. Revenues from oil sales help finance terrorist groups such as the al- Qaida network. Also, the fact that Western nations support undemocratic, repressive governments in the Middle East as long as they keep the oil flowing also contributes to poverty, frustration and terrorism.

Resource Depletion

Oil and other fossil fuels are finite resources. World oil production will peak at some point in the next few decades and then decline. Once conventional oil production starts to decline, oil prices will climb steeply unless alternative fuels become available in large quantity.

There are vast reserves of unconventional oil resources such as oil shale and tar sands in the world. But developing these resources on a large scale would be costly, result in massive environmental damage, and contribute heavily to global warming. Thus, unconventional oil resources are not an attractive alternative fuel option.

High Costs

Building power plants, oil and gas pipelines, and other conventional energy facilities is very capital-intensive. If worldwide energy use continues to rise on the order of 2% per year, energy supply investments of \$35–50 trillion will be needed during 2000–2050 (in 1998 dollars).[14] This level of investment–\$700 billion to \$1 trillion per year–is two to four times the level of investment in energy production and conversion worldwide during the 1990s.

Expanding investment in energy supply and conversion is feasible in some countries, but will be difficult in transition and developing nations. These countries have limited investment capital and also have other investment priorities including improving education, sanitation, health care, and rural development.

Inequity

Energy consumption, like income, is distributed very inequitably around the world. The OECD nations consume about six times more commercial energy per capita than developing nations. Around 2 billion people—one third of the world's population—do not use electricity or modern cooking fuels. In India, for example, less than 30% of rural households use electricity, over 90% use traditional biomass cooking fuels, and more than 55% of farmland is

[13] *Climate Change 2001: The Scientific Basis*. Geneva, Switzerland: Intergovernmental Panel on Climate Change.
[14] Nakicenovic, N., A. Grubler, and A. McDonald. 1998. *Global Energy Perspectives*. Cambridge, UK: Cambridge University Press.

cultivated by animal power.[15] In many African nations, less than 20 percent of the population uses electricity.

Conventional energy policies and trends emphasize increasing energy use among the wealthier citizens of the world both in industrialized and developing nations. Providing modern energy sources and improved energy services to poorer citizens and to rural areas of developing countries is not a high priority.

A business-as-usual, inefficient and fossil fuel-intensive energy future is not desirable. It will worsen air pollution, cause dangerous climate change, rapidly deplete precious oil resources, increase security risks, cost too much, and exacerbate tensions among nations. It is not just for 20 percent of the world's population to increase their already high use of fossil fuels, while one-third of the world's population gathers twigs, stalks, and dried animal manure in order to cook meals and stay warm.

Energy Revolution–Towards a Sustainable Future

A different path is possible, one that emphasizes much higher energy efficiency, much greater reliance on renewable energy sources, and meeting the energy needs of the poor. This energy path would steadily move the world away from fossil fuels and towards renewable energy sources over the coming decades, and it would make greater use of natural gas during the transition.

A host of barriers are limiting the uptake of energy efficiency and renewable energy technologies worldwide, however. These barriers include flaws in the ways markets operate—e.g., subsidized energy prices, energy prices that do not include full social and environmental costs, or poorly informed consumers. These barriers also relate to human behavior—e.g., the low priority given to saving energy by many businesses or the tendency of consumers to purchase products based on least first cost rather than least lifecycle cost. Still other barriers relate to public policies and institutions—e.g., the lack of attractive financing for efficiency and renewable energy measures or regulations that discourage energy efficiency or renewable energy use.

It is possible to remove or overcome these barriers through well-designed and effectively implemented public policies, including:

- Research, development and demonstration
- Financing and financial incentives
- Pricing and market reform
- Voluntary agreements
- Regulations and market obligations
- Information dissemination and training
- Procurement initiatives
- Capacity building, and
- Planning techniques.

[15] Pachauri, R.K. and S. Sharma. 1999. India's Achievements in Energy Efficiency and Reducing CO_2 Emissions. In *Promoting Development While Limiting Greenhouse Gas Emissions*. New York, NY: United Nations Development Programme.

There is no one "silver bullet;" many polices are available and a combination of policies are often needed to overcome the pervasive barriers to greater energy efficiency or renewable energy use in any particular locale.

Fortunately, there are numerous examples from around the world where individual policies have been integrated into successful "market transformation" strategies. Three examples of market transformation are presented below; others are included in *Energy Revolution*.[16]

Brazil – Ethanol Fuel

Brazil initiated a national program to produce ethanol fuel from sugarcane in 1975. The initial goals were to reduce oil imports and also to provide an additional market for Brazil's sugar producers. Ethanol is produced in about 350 privately owned distilleries. Ethanol fuel production was stimulated through: 1) low interest loans for the construction of distilleries, 2) guaranteed purchase of ethanol by the state-owned oil company; 3) sales tax incentives to stimulate the purchase of neat ethanol vehicles, and 4) favorable pricing of neat ethanol relative to the alternative gasoline-ethanol blend.

These policies were very successful. The goal of achieving 20% ethanol in the gasoline blend was reached in the early 1980s. During 1983-89, the large majority of cars sold in Brazil consumed neat ethanol.[17] Ethanol production grew rapidly reaching the level of 13-16 billion liters per year by the late 1990s. At the same time, the cost of producing ethanol steadily declined due to improvements in sugarcane productivity, better ethanol yields, and lower production costs. The government ended subsidies and ethanol price regulation by the late 1990s. Ethanol now provides about one-third of the fuel consumed by cars and light trucks in Brazil on an energy basis.

Brazil's ethanol fuel program provides wide-ranging economic, social, and environmental benefits.[18] Production of ethanol saved Brazil about $33 billion in oil imports during 1976-96. The sugarcane and ethanol industries employ around 700,000 workers in rural areas, and the total investment cost per worker is much less than for other industries in Brazil. In addition, the introduction of ethanol fuel has improved urban air quality and reduced CO_2 emissions.

The Brazilian ethanol fuel program was successful because it featured both financial incentives and market reserves, along with mechanisms to promote technological improvements. Also, it began with a strong industry base (namely the existing sugar industry) and it worked through the private sector. Finally, the federal government maintained its support for the program over the past 28 years, perhaps linked to the large number of jobs that were created.

California – More Efficient Electricity Use

Within the United States, California has been a leading state in implementing more efficient energy use. California adopted appliance efficiency standards starting in the mid-1970s in advance of national standards. California also adopted cutting edge building energy codes and policies to stimulate energy efficiency investments by electric utilities. As of 2002, utilities in the state spent about $280 million or 1.4 percent of their revenues on these efforts. In addition, electricity tariffs were modified to promote electricity conservation; e.g., by adopting time-of-use and inverted block tariffs.[19]

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[16] Geller, H. 2003. *Energy Revolution: Policies for a Sustainable Future*. Washington, DC: Island Press.
[17] Neat ethanol is pure ethanol fuel, not a gasoline-ethanol blend.
[18] Moreira, J.R. and J. Goldemberg. 1999. The Alcohol Progam. *Energy Policy* 27: 229-245.
[19] Inverted block tariffs increase the price of kilowatt-hour as consumption increases.

The combination of utility programs, pricing reforms, appliance standards, and building codes has had a significant impact. As of 2001, California's electricity use per capita was about half that in the other 49 states, and the gap between California and other states has grown over the past 25 years.[20] Part of this gap is due to structural and price differences, but part is due to these policies and programs.

California is realizing both environmental and economic benefits because of its energy efficiency efforts. By reducing its energy intensity, California lowered its pollutant emissions from stationary sources by over 35 percent as of 1995. And by saving energy and shifting expenditures to more productive areas, it is estimated that California increased its economic output by about 3-5% as of 1995.[21]

California scaled up its energy efficiency programs during 2001 when the state was experiencing a power shortage caused by flaws in its utility deregulation policy. During the critical summer months, electricity demand declined nearly 8% relative to demand the previous year, thereby avoiding costly and disruptive power outages.

The California experience demonstrates that dramatic improvements in energy efficiency are possible over the long term through a sustained effort. California employed a complementary and evolving set of pricing reforms, financial incentives, regulations, and education and training programs to increase energy efficiency over the past 28 years. Also, because there was a strong foundation to build on, California was able to respond to a short-term power crisis by relying on energy efficiency improvement and conservation.

Denmark – Wind Power Deployment

Denmark initiated a wind energy development program in the mid-1970s to both cut energy imports and protect the environment. The program began with R&D and capital subsidies to stimulate wind power development. The government also funded wind resource mapping and a wind turbine certification program. By the end of the 1980s, financial support shifted to guaranteed payments for wind power production; i.e., an electricity feed-in law.

These policies stimulated technological innovation and made wind power cost-effective in Denmark. Installed wind power capacity grew from about 300 MW in 1990 to 2,500 MW as of 2001. Denmark obtained about 15 percent of its electricity in 2000-01 from wind power, greatly exceeding the initial goals.[22]

The wind power industry is contributing significantly to Denmark's economy. The wind industry generated about $2.7 billion in revenues and employed about 20,000 people as of 2001.[23] Danish wind turbine companies have large market shares in the United States, Germany, and other European countries as well as successful joint ventures elsewhere. Also about 100,000 Danish families own wind turbines or shares in wind co-operatives.

The Danish wind power program demonstrates that ambitious renewable energy goals can be met if there is adequate and consistent financial incentives along with technological support and market development. Financial incentives for wind power were modified over time as technologies matured. Also, building an industry base and widely dispersing project ownership created strong political backing for the program.

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[20] Bachrach, D., M. Ardema, and A. Leupp. 2003. *Energy Efficiency Leadership in California*. San Francisco, CA: Natural Resources Defense Council and Silicon Valley Manufacturing Group.

[21] Bernstein, M. et al. 2000. *The Public Benefits of California's Investments in Energy Efficiency.* Santa Monica, CA: Rand Corporation.

[22] BTM Consult 2001. A Towering Performance: Latest BTM Report on the Wind Industry. *Renewable Energy World* 4 (4): 68-87.

[23] *Danish Wind Power 2001*. Copenhagen: Danish Wind Industry Association. www.windpower.org/news/stat2001.htm.

Policy Lessons

These case studies, along with other examples of successful (as well as unsuccessful) clean energy initiatives, provide a number of lessons. The first and perhaps most important lesson is that well designed and implemented policies can overcome the barriers to widespread deployment of energy efficiency and renewable energy measures. Other lessons include:

- Make a high-level government commitment in order to sustain policies and programs over the long run. High-level government support will also provide legitimacy for new technologies and encourage investment by the private sector.
- Engage the private sector in production, marketing, and adoption of energy efficiency and renewable energy technologies, creating a market environment where companies innovate, compete, and ultimately profit from these investments.
- Aim to transform markets. Integrate policies into market transformation strategies, addressing the range of barriers that are present in a particular locale.
- Keep policies in place for a decade or more in order to ensure market development, but revise and update policies as appropriate.
- Price energy in ways that stimulate greater efficiency and renewable energy adoption.
- Tax fossil fuels based on their adverse environmental and social impacts. Use some of the tax revenue to support energy efficiency and renewable energy initiatives.
- Provide financial incentives especially for newer energy efficiency and renewable energy technologies. Reward superior performance; e.g., pay for energy savings or renewable energy production. Reduce or phase out incentives as markets develop and costs drop.
- Enact regulations or market obligations to stimulate widespread adoption of energy efficiency and renewable energy measures. Base the standards on analysis of technical and economic feasibility, and update the regulations or obligations periodically.
- Provide education and training to increase awareness and improve know-how with respect to energy management and renewable energy options. But combine such efforts with financial incentives, regulations, and market obligations in order to have a bigger impact.
- Build capacity in the public sector to implement effective policies and programs. Also, train and support the businesses that will manufacture, market, install, and service clean energy technologies.

Global Clean Energy Scenario

What might happen if comprehensive policies along these lines are widely adopted in the coming decades? It is impossible to know for certain. However, scenarios can be created that are consistent with broad-based and strong support for greater energy efficiency and renewable energy use.

The International Institute for Applied Systems Analysis (IIASA) and the World Energy Council (WEC) produced an "ecologically driven" energy scenario assuming greater emphasis is placed on energy efficiency and renewable energy efforts during the 21st century. In this scenario, efficiency improvements limit growth in energy use worldwide to about 0.8% per year on average. Renewable energy sources provide 40% of total global energy supply by

2050 and 80% by 2100. Solar energy and bio-fuels are the two dominant energy sources in the latter part of the century.[24]

The ecologically driven scenario is by no means an upper bound on the rate at which efficiency or renewable energy measures could be deployed. Table 1 and Figure 1 show the author's own "Global Clean Energy Scenario" illustrating how energy supply and demand could unfold during this century if there is a strong and steady commitment to greater energy efficiency and expanded renewable energy use worldwide. The Scenario is based on a self-consistent set of assumptions concerning economic growth, energy intensity reduction, growth in renewable energy supply, and evolution of fossil fuels and nuclear power.[25]

Energy efficiency improvements and structural shifts in the Global Clean Energy Scenario limit growth in energy demand during the century to about 0.6% per year. Renewable energy supply increases about 2.5% per year on average. Renewable sources contribute nearly one-quarter of total global energy supply by 2020, over half by 2050, and all energy supply by 2100. Nuclear energy is phased out within 50 years, coal use in about 60 years and oil use in about 90 years. Natural gas use increases in the near term, but starts to decline around 2060 and is phased out by 2100.

Table 1: Global Clean Energy Scenario

	Primary Energy (billion tons of oil equivalent)							
Region	**1997**	**2002**	**2010**	**2020**	**2040**	**2060**	**2080**	**2100**
OECD	4.88	5.1	4.90	4.66	4.22	3.81	3.45	3.12
EE/FSU	1.03	1.1	1.14	1.20	1.33	1.47	1.62	1.79
LDCs	3.74	3.9	4.29	4.83	6.14	7.79	9.89	12.55
Total	9.65	10.10	10.33	10.70	11.68	13.07	14.96	17.47
Renewables fraction (%)	14	15	18.5	24	40	59	78	100

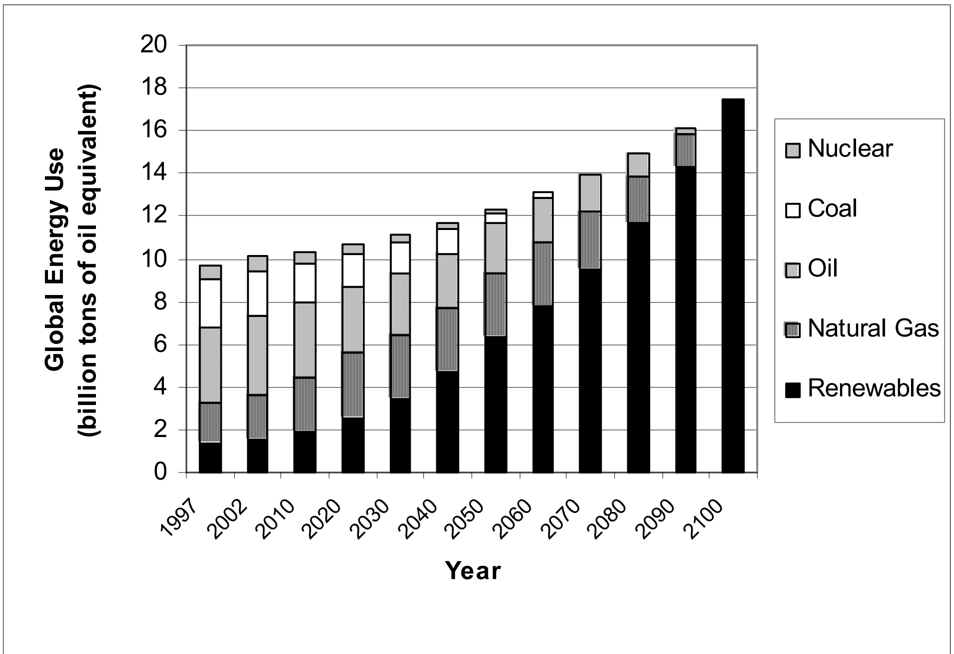

Figure 1: Global Clean Energy Scenario

[24] See Note 4.
[25] See Note 6.

The Global Clean Energy Scenario would address all of the challenges presented by a business-as-usual, fossil fuel-intensive energy future. The Scenario would immediately start to reduce CO_2 emissions from burning of fossil fuels, as shown in Figure 2. If CO_2 emissions decline in this manner, the maximum atmospheric CO_2 concentration would be limited to about 425 parts per million (ppmv), about 52 percent greater than the pre-industrialization level. The maximum concentration would occur around 2065 followed by a gradual decline in the latter part of the century. This in turn would limit the increase in global mean temperature since pre-industrial times to a range of 0.8-2.1°C, with a "best guess" increase of 1.4°C, by 2100.[26] Although there is uncertainty concerning the "safe" level of temperature increase, a number of climate experts have argued for an upper limit of 2°C.[27]

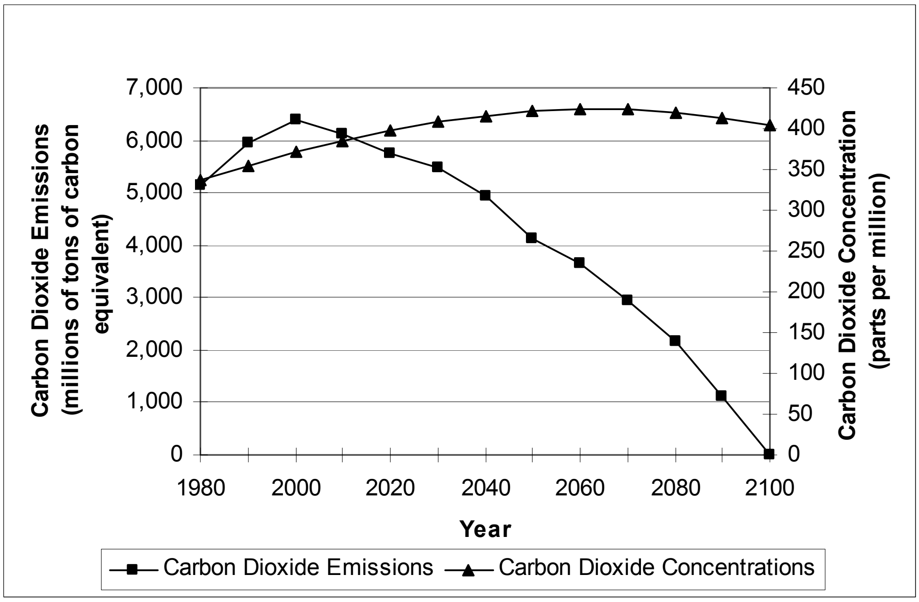

Figure 2: World Carbon Dioxide Emissions and Atmospheric Concentrations in the Global Clean Energy Scenario

In addition to limiting global warming to what is believed to be an acceptable level, the Global Clean Energy would significantly reduce local and regional air pollution throughout the world, thereby improving human health. The Global Clean Energy Scenario would lower the total cost to society associated with energy supply and use, due primarily to the net economic benefits of energy efficiency improvements. And the shift away from oil would reduce national security risks and costs compared to a business-as-usual scenario that maintains growing oil consumption and import dependence among most nations.

The Global Clean Energy Scenario would also help to reduce inequity among nations. Energy consumption declines in OECD nations while increasing in developing countries, although energy efficiency improves everywhere. Per capita energy use in industrialized nations would still be higher than in developing nations throughout the century, but the gap would substantially narrow. And by emphasizing the adoption of modern renewable energy sources, the Global Clean Energy Scenario is compatible with high rates of social and economic development in poorer regions of the world.

[26] This estimate was provided by the Tellus Institute, Boston, MA using the Model for Assessment of Greenhouse-Gas Induced Climate Change.

[27] Schneider, S.H. and C. Azar. 2001. Are Uncertainties in Climate Change and Energy Systems a Justification for Stronger Near-Term Mitigation Policies? Arlington, VA: Pew Center on Global Climate Change. www.pewcenter.org/events/timing_azar_schneider.pdf

A clean energy revolution will take many decades, in part because of the long lives and slow turnover of key devices affecting energy supply and demand. New buildings last 50-100 years or longer; new power plant last 30-50 years. Thus it is critical to hasten rather than delay a clean energy transition so that infrastructure installed in the next few decades is highly efficient and less polluting. Accelerating the transition also should provide technological advances and economic benefits through "learning by doing."

The main obstacles to realizing the Clean Energy Scenario are inertia, opposition from powerful industries, and lack of political will in some countries. The oil, coal, utility, and auto industries often oppose policies to advance energy efficiency and/or renewable energy implementation. These are powerful industries, and they have tremendous influence on national energy policy in the United States in particular. Because of their pressure, neither the Bush Administration nor U.S. Congress is supporting key policies that would boost energy efficiency, expand renewable energy use, or limit CO_2 emissions.

On the positive side, many other industrialized countries and some developing nations are adopting new policies to increase efficiency and renewable energy use. Likewise, California and many other U.S. states are moving forward with significant energy efficiency, renewable energy, and other greenhouse gas mitigation initiatives.[28] These actions provide direct benefits in these jurisdictions. They also help to advance the clean energy technologies and industries, and build coalitions for policy reform. As clean energy coalitions grow in economic and political influence, eventually they should prevail in difficult political battles such as the fight for vehicle efficiency standards, renewable energy obligations, and national CO_2 emissions caps in the United States.

A clean energy revolution cannot be accomplished unilaterally or through action by one block of nations. All countries, rich and poor, must cooperate sooner or later. In a world where armed conflicts, resource conflicts, and social conflicts threaten the security of all citizens, nations uniting behind a common goal and working together to achieve this goal could be an important indirect benefit of a global clean energy revolution.

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[28] Rabe, B.G. 2002. *Greenhouse and Statehouse: The Evolving State Government Role in Climate Change*. Arlington, VA: Pew Center on Global Climate Change.