Chapter 26

Energy Policy and Climate Change

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Introduction

In some ways, the twentieth century has been all about energy. From 1900 to 2000, engineers and architects built more than 75 000 power plants, at least 3.2 million kilometers of transmission and distribution lines for electricity, 5.1 million kilometers of natural gas pipelines, 300 nuclear waste storage facilities, and more than 600 refineries. The past century saw the world profoundly shaped by the automobile, truck, aircraft, and atomic energy as millions of people shifted from non-mechanized forms of transport and agriculture to reliance on automobiles and industrial food manufacturing. Electricity, once so novel that it was prized for its "healing powers" and served as a spectacle at numerous World's Fairs, moved from its infancy into the primary fuel for heating homes, powering industrial processes, energizing air conditioners (also invented during the century), and enabling the digital-telecommunications-media-computer-information age.

For example, from 1900 to 2000 the population of the earth quadrupled from 1.6 billion to 6.1 billion, but annual average supply of energy per capita grew *even more*, from 14 GJ in 1900 to roughly 60 GJ in 2000. Over this period, energy consumption more than tripled in the USA, quadrupled in Japan, and increased by a factor of 13 in China (Brown and Sovacool 2011). Global use of hydrocarbons as a fuel by humans increased 800-fold from 1750 to 2000 and 12-fold again from 1900 to 2000 (Smil 2000).

If the twentieth century was about energy, then the twenty-first century could very well be about energy governance and climate change. Issues surrounding energy supply and use connect with many of the world's most pressing public policy problems: possible conflagrations over rapid depletion of fossil-fuel reserves, the environmental consequences of climate change, and millions of communities that must

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endure "energy poverty" without access to consistent sources of lighting, heating, water, mobility, or comfort (Florini and Dubash 2011; Yergin 2011; Sovacool *et al.* 2012).

This chapter introduces readers to the energy governance and climate change nexus. It details the processes, sectors, technologies, and countries responsible for greenhouse gas emissions. It then discusses a collection of barriers which explain why progress on reducing emissions has been slow to occur. It lastly elaborates on a common set of policy mechanisms that can overcome these barriers and problems as well as offers a collection of brief case studies.

Two things make the chapter unique. First, it looks at energy supply – things like power plants, pipelines, and oil rigs – alongside energy demand – things like patterns of consumption and energy use. Second, it discusses energy technologies alongside often neglected topics such as consumer behavior, social values and attitudes, politics, and governance concerns.

The Energy–Climate Change Nexus

According to the most recent data available from the Intergovernmental Panel on Climate Change (IPCC 2008), human sources emitted 49 billion tonnes of carbon dioxide equivalent into the atmosphere in 2004. Global greenhouse gas (GHG) emissions grew by 70% from 1970 to 2004, and if trends continue could increase by 130% by 2040. Yet the climate-related impacts of these emissions could last longer than Stonehenge, time capsules, and perhaps even high-level nuclear waste. For each ton of carbon dioxide we leave in the atmosphere today, one quarter of it will still be affecting the atmosphere a thousand years from now (Archer 2009). Put another way, the climate system is like a bathtub with a very large tap and a small drain (Victor *et al.* 2009). As Figure 26.1 shows, four interrelated areas – electricity supply, transport, agriculture and forestry, and waste and water – are responsible for most of these dangerous emissions.

As the following sections demonstrate, sources of emissions come roughly from the following major categories: transportation, buildings, the industrial sector, and electricity supply.

Transportation

On a global scale, the transportation of people and goods accounts for approximately one quarter of the world's energy consumption and 28% of its energy-related CO_2 emissions (IPCC 2008). Over the next few decades the transportation sector is expected to be one of the fastest-growing sources of GHG emissions. Much of the projected increase is attributed to the rapidly growing demand for petroleum-based transportation fuels in non-OECD economies, which are forecast to increase more than 2% per year; as compared with the OECD countries, which are forecast to increase at less than 1% per year (EIA 2006).

Buildings

The built environment – consisting of residential, commercial, and institutional structures – accounts for about one third of primary global energy demand and is the

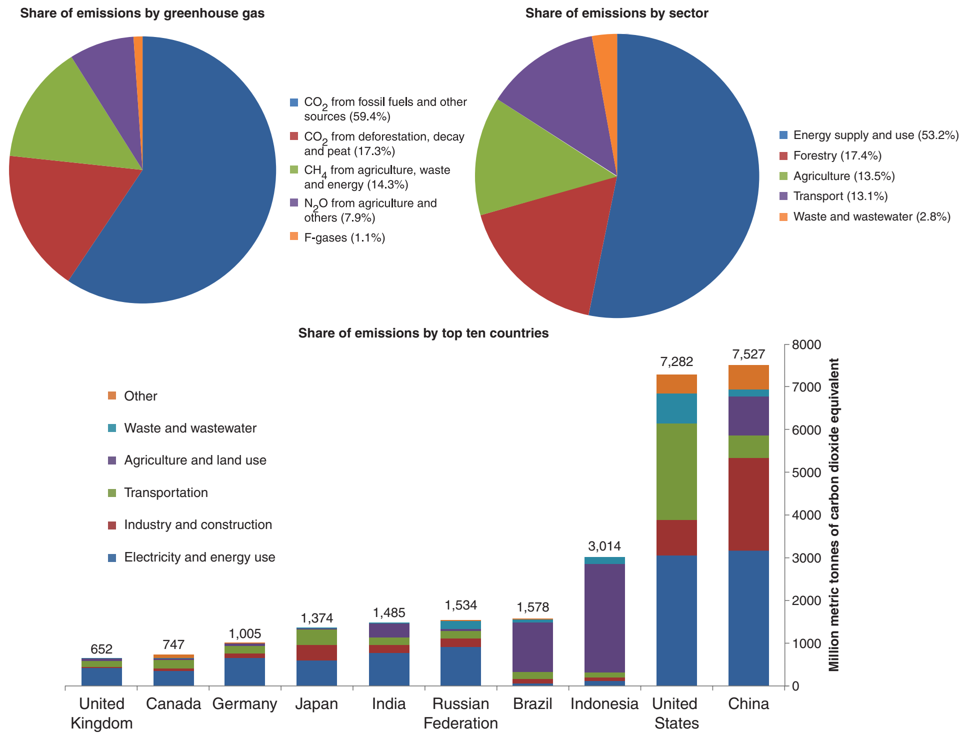

Figure 26.1 Global greenhouse gas emissions by gas, sector, and country.
Source: Brown, Marilyn A. and Benjamin K. Sovacool. 2011. *Climate Change and Global Energy Security: Technology and Policy Options*. Cambridge, MA: MIT Press. © 2011 MIT.

source of 35% of global energy-related CO_2 emissions (International Energy Agency 2010). Over the long term, buildings are expected to continue to be a significant component of energy use and emissions, driven in large part by the continuing trends of urbanization, population, GDP growth, and the longevity of building stocks. A growing body of evidence suggests that improving the energy efficiency of the existing building stock and new construction is a low-cost approach to mitigating GHG emissions (IPCC 2008).

Industry

The industrial sector is the largest consumer of energy worldwide, accounting for an estimated 36% of global primary energy in 2006 and producing a slightly larger share of CO_2 emissions, partly due to the use of fossil fuels as feedstocks in the production of chemicals and other industrial products such as the release of CO_2 in the production of cement (International Energy Agency 2010). Global energy consumption and CO_2 emissions from this sector are projected to increase rapidly through 2030, driven by the expansion of China, India, and other emerging economies such as Brazil and South Africa.

A handful of large industries are highly energy-intensive in most countries of the world where they operate. These include, for instance:

- petroleum refining and the production of chemicals and fertilizers
- the metals industries (including iron, steel, and aluminum)
- pulp and paper
- mineral products (including cement, lime, limestone, and soda ash)
- glass.

Light manufacturing, which includes the manufacture and assembly of automobiles, appliances, electronics, textiles, and food and beverages, generally requires less energy per dollar of shipped product. As a result, these plant managers pay much less attention to their energy requirements, even though light manufacturing remains a large fraction of economic output and contributes significantly to global emissions.

Electricity Supply

Globally, electricity generation is the largest contributor to climate change, producing more than 10 billion t. of carbon dioxide every year, the greatest contribution from any given industry or sector. As world population grows and standards of living rise, the global demand for electricity is projected to continue its rapid expansion in both developing and industrialized economies. Nearly 2 billion people do not have access to the electric grid, but expectations are that this share will continue to shrink, resulting in a rapid expansion of electricity demand. As a result, the electric grid will need an infusion of transmission and distribution (T&D) system investments. Worldwide, the International Energy Agency (2010) forecasts an investment of US$6.8 trillion in T&D upgrades between 2007 and 2030.

Changes in Land Use

Globally, agricultural sources of methane (CH_4) and nitrous oxide (N_2O) account for nearly 60% of non-CO_2 emissions and 48% of US non-CO_2 GHGs primarily from crop and livestock production (Brown and Sovacool 2011). Enteric fermentation is the largest anthropogenic source of methane emissions in the USA, accounting for nearly a quarter of the total. This source of methane continues to increase with the growth of livestock operations. CH_4 emissions from manure management have also been increasing over the past decade, mostly as the result of an increase in the use of liquid systems in swine and dairy cow products.

The livestock sector accounts for 18% of global GHG emissions and 80% of anthropogenic land use. One study projected that deforestation and a small amount of desertification were responsible for 35% of livestock-associated GHG emissions. Put another way, an area the size of Russia and Canada *combined* is currently used exclusively as pasture or cropland to grow animal feed. If this land was converted instead to growing vegetables for human consumption or into forests, it would soak up such large amounts of carbon dioxide that it could cut compliance costs with the Kyoto Protocol in half, rather than being a source of emissions, as it is today (Stehfest *et al*. 2009).

Much of the world's farming, livestock production, and changes in land use have taken place in former forests and tropical forests. Thus forests can be a sink of emissions but also a source, depending on how they are managed. It is helpful to view forests through the lens of stocks and flows. The total stock of carbon in all *tropical* forests equals about 300 billion t., about 1.5 billion t. is converted into 6 billion t. of CO_2 through deforestation that is emitted into the atmosphere (Boucher 2009). In other words, tropical forests alone contribute to about 20% of overall human caused CO_2 emissions per year, making them the largest emitter of carbon in the world after the energy sector. This amount is equivalent to the total emissions of China or the USA, and it is more than the emissions produced by every car, truck, plane, ship, and train on Earth.

High Global Warming Potential Gases

There are numerous highly potent anthropogenic GHGs that are entirely human-made. Three of these also deplete the stratospheric ozone layer: chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and bromofluorocarbons (i.e. halons). These ozone-depleting substances (ODSs) are controlled under the Montreal Protocol of 1987 on Substances that Deplete the Ozone Layer, and as a result their impact on both ozone and the greenhouse effect has been greatly reduced. Other anthropogenic fluorine-containing halogenated substances do not deplete stratospheric ozone but are potent GHGs. The most important of these are collectively called the "F-gases" and include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Numerous other minor trace gases complete the inventory of GHGs. Emissions of high global-warming potential gases are expected to increase significantly worldwide due to growing demand for refrigeration and air conditioning and the industrialization of developing economies.

Barriers to Low-Carbon Technologies

Although we have made progress in terms of understanding the forces behind climate change and available solutions to it, a mesh of obstacles and impediments towards low-carbon technologies and practices exist. The barriers facing these practices and technologies are tenacious, interconnected, and deeply embedded in our social fabric, institutional norms, and modes of production across the world. The most significant of these relate to cost-effectiveness; fiscal, regulatory, and statutory barriers; intellectual property; and "other" cultural, social, and institutional barriers summarized in Table 26.1.

Cost-effectiveness Barriers

Types of cost-effectiveness barriers that impede market introduction and penetration of less carbon-intensive technologies and practices include un-priced externalities, high costs, and technical and market risks. Externalities can make it difficult for clean energy technologies to compete in today's market, where GHG emission

Table 26.1 Typology of barriers to GHG mitigation technologies.

Cost effectiveness	*Fiscal, regulatory, and statutory barriers*	*Intellectual property (IP) barriers*	*Other cultural, social, and institutional barriers*
External benefits and costs	Competing fiscal policies	Anti-competitive patent practices	Incomplete and imperfect information
High costs	Fiscal uncertainty	IP transaction costs	Infrastructure limitations
Technical risks	Competing regulatory policies	Weak international patent protection	Industry structure
Market risks	Regulatory uncertainty	University, industry, government perceptions	Policy uncertainty
Lack of specialized knowledge	Competing statutory policies	Statutory uncertainty	Misplaced incentives

reductions have only limited market value. Clean energy technologies also often have inherently higher up-front costs due to the need for additional features and subsystems required to achieve GHG reductions. These can increase the capital to operating expense ratio. For example, SF_6 is a high GWP gas used in the magnesium industry as a cover gas. SO_2 is being considered as an alternative, but it is more toxic and therefore requires additional monitoring (and cost) to deal with the health and safety issues. There are no simple drop-in substitutes (Brown and Sovacool 2011: 154).

The efficient operation of energy markets is compromised by the existence of external benefits and costs. Externalities occur when important societal benefits and costs are "external" to, or un-priced in, the marketplace. As law professor Noah Sachs notes:

> Think of externalities as a second price tag on every product we consume, representing the real costs of disposing the product and the environmental impacts directly flowing from the existence of that product. The price tag may be less than a cent for some products and several dollars for others, but because this price is never actually "paid" by consumers or producers, the price becomes externalized as a social cost (Sachs 2006: 56).

Indeed, less carbon-intensive technologies may be difficult to deploy (without public intervention) if their principal benefits are entirely societal and external to the marketplace. For low-carbon technologies across most of the USA and many areas around the world, GHG mitigation is not currently governed by explicit regulatory legislation and it is not rewarded in the marketplace. When the developer of a low-carbon technology cannot capture all of the benefits that might accrue to society, the result is underinvestment in its development and a sub-optimal supply of the technology. Because polluters do not pay for their societal damages, the "free rider" makes it difficult for the higher-priced clean energy technologies to compete. In general, goods generating positive externalities are underproduced and goods generating negative externalities are overproduced (Dunn 2008).

Specific examples of externalities in the energy and climate sectors are striking. In the electricity industry, the generation costs from a coal power plant may appear low, but they do not include the costs of coal-mine dust that kills thousands of workers each year; black lung disease that has imposed at least US$35 billion in health-care costs; and coal emissions that cause acid deposition, smog, and global warming and also contribute to asthma, respiratory and cardiovascular disease, and premature mortality. These external costs would easily double the price of coal if they were incorporated into its price (Jacobson and Masters 2001). The negative externalities associated with electricity generation overall amount to about US$13.46 /kWh or more than US$2 trillion in global damages each year (Brown and Sovacool 2011). The global chemical industry would have to spend eight times its profits each year (more than US$20 billion in the 1990s) to pay to incinerate the waste from its top 50 products (Hawken 1998). In the transport sector, vehicle crashes are the leading cause of injury-related deaths in the US for people between the ages of one and 65, causing 40 000 deaths, 2 million injuries, and US$150 billion in economic losses each year that are not reflected in the price of a new vehicle (Brown and Sovacool 2011). Gasoline is cheap because its price does not incorporate the cost of smog, acid rain, and their effects on health and the environment.

Fiscal, Regulatory, and Statutory Barriers

Unfortunately, just as markets can fail, so can public policies designed to correct them. Government action has its own set of problems, too. Public policies can provide broad societal benefits that increase overall economic welfare, for example, but can also inadvertently disfavor certain segments of the economy, including, in some cases, inhibiting the commercialization and deployment of clean energy technologies. When applied to the context of this chapter, these policies are referred to as "competing policies" and considered a barrier to deployment. Many competing priorities result from policies established years ago for a public purpose that could be better addressed in other ways today.

Competing priorities also arise as a result of legal inertia. For example, regulations take a long time to adopt and modify; as a result, they can be slow to adapt to technology advances and therefore inhibit innovation. Similarly, environmental standards that propelled the large-scale reduction of acid rain in the 1980s now enable the continued operation of some of the most polluting power generators in the USA far beyond their normal life and disincentivize investing in plant upgrades. Competing policies caused by outdated fiscal rules include the IRS tax depreciation schedules put into place more than two decades ago as part of the IRS Tax Reform Act of 1986. These rules have not kept up with technology breakthroughs and inhibit the advance of some modern low-carbon technologies. Back-up generators (which provide reliability at the expense of energy efficiency and clean air) are depreciated over 3 years, while a new combined heat and power system (providing both reliability and energy efficiency) is depreciated over 20 years (Brown and Sovacool 2011: 160).

Intellectual Property Barriers

Generally, intellectual property law is intended to stimulate innovation, entrepreneurship, and technology commercialization. However, its application can also impede the innovation process. For example, patent filing and other transaction costs associated with strong patent enforcement and protection, as well as the anti-trust challenges related to technological collaboration and patent manipulation can be serious barriers to technology diffusion. Anti-competitive business practices can also play their part in impeding cleaner energy systems.

Patent warehousing, suppression, and blocking, for instance, are anti-competitive practices undertaken by incumbent firms that impose barriers to technological change. Patent warehousing is a form of patent manipulation that involves owning the patent to a novel technology but never intending to develop the technology (Sabety 2005). Patent suppression involves refusing to file for a patent so that a novel process or product never reaches the market. As one example, in 1977 Tom Ogle developed an automotive system for Ford Motor Company that used a series of hoses to feed a mixture of gas vapors and air directly into the engine. Ford built a small number of prototypes that averaged more than 100 miles per gallon at 55 miles per hour (2.35 liters/100 km), but the technology was ultimately suppressed (Saunders and Levine 2004). Patent blocking occurs when firms use patents to prevent another firm from innovating. While Ford has used Toyota technology (in the Ford Escape), Ford has resisted purchasing Toyota's technology for hybrid vehicles because of hefty licensing fees, and likewise, Honda has not been able to successfully negotiate a license to use nickel metal hydride batteries in their hybrid vehicles. General Electric has also used its patent on variable-speed wind turbines to prevent Mitsubishi (a Japanese firm) and Enercon (a German firm) from entering the US market (Sovacool 2008).

Other Cultural, Social, and Institutional Barriers

Many additional barriers inhibit the deployment of GHG mitigation technologies in ways that are not captured by the categories discussed thus far. These barriers stem in part from the cultural traits that impact the behavior and choices of individuals. The influence of lifestyle and tradition on energy use is most easily seen by cross-country comparisons. For example, cold water is traditionally used for clothes washing in China, whereas hot water washing is common in the USA and Europe. Similarly, there are international differences in how lighting is used at night; the preferred temperatures of food, drink, and homes; and the operating hours of commercial buildings.

The provision of information is subject to a classic public-goods problem. If one person generates useful information, it creates a positive externality because it provides knowledge to others. Those that have information may have strategic reasons to manipulate its value; self-interested sellers have incentives to provide misinformation about their products; and well-distributed misinformation can often overpower the distribution of unbiased and more accurate information.

Technologies that are otherwise expected to be successful may still face difficulties penetrating the market due to infrastructure limitations. These include a wide range of supply-chain shortfalls ranging from inadequate physical systems and facilities; shortage of key complementary technologies that improve the functionality of a new technology; insufficient supply and distribution channels; and inadequate operation and maintenance (O&M) support (Brown and Sovacool 2011).

Solutions and Policy Mechanisms

Thankfully, a slew of public policy mechanisms can overcome these types of barriers. Government interventions have generally fallen into two broad classifications: supply-push mechanisms focus primarily on "pushing" technologies into the market through direct subsidies, and demand-pull mechanisms focus primarily on "pulling" technologies into the market by creating demand for them. Common examples of supply-push strategies include: (a) conducting basic and applied research and development on energy technologies; (b) building large test or prototype facilities; (c) having the government procure large amounts of an experimental technology; and (d) investor tax credits that spur innovation on a given technology. Common examples of demand-pull strategies include: (a) creating markets for technologies through production tax credits; (b) establishing rate-based or purchase-based incentives such as higher rates of return or tariffs; and (c) promoting technologies through training or information and awareness campaigns (Blumstein *et al.* 1980; Loiter and Norneg-Bohm 1999; Espey 2001; Haas *et al.* 2004; Vandenbergh 2004; Lindén *et al.* 2006). Synthesizing from this literature, and updating it to today, the most basic and elementary policy tool is putting a price on carbon; secondary measures include everything from renewable portfolio standards and feed-in tariffs to building codes and appliance standards.

Putting a Price on Carbon

One of the simplest actions countries and international institutions such as the United Nations could take to provide an equity-increasing and welfare-maximizing response to climate change is to create a market price for GHG emissions and charge emitters for the cost of climate mitigation technologies. Putting a price on GHG emissions is accomplished with various policies including energy and carbon taxes and cap-and-trade systems (see also Chapter 27 in this volume). An extensive academic literature suggests that macroeconomic efficiency favors a carbon tax with socially productive revenue recycling over other forms of regulation. The choice of policy instrument, however, is less important than having an effectively designed instrument. In a cap-and-trade program, sources of GHG emissions covered under the program receive allowances that determine the amount of emissions they can produce. Based on that amount, sources of emissions can design their own emission-control strategy using any of several emission-reduction options such as: adopting new technology, purchasing offsets, or trading in the emissions market.

This flexibility provides numerous advantages. Because emissions trading uses markets to determine how to deal with the problem of pollution, cap and trade is often touted as an example of effective free market environmentalism. Markets encourage low-cost solutions rather than mandating specific technologies. While the cap is usually set by a political process, individual companies are free to choose how or if they will reduce their emissions. In theory, firms will choose the least-cost way to comply, creating incentives that reduce the cost of achieving a pollution reduction goal. Putting a price on carbon is a critical "core" policy because it addresses the principal market failure that has prevented individuals and firms from responding effectively to the damages precipitated by GHG emissions. Some have argued that, in fact, putting a price on carbon is all that is needed. Evidence is mounting, however, that complementary policies are required as well.

Energy Supply Options

Complementary energy supply policy options include renewable energy obligations, such as renewable portfolio standards and real-time pricing for electricity, as well as reducing fossil-fuel subsidies and passing feed-in tariffs. Some of these instruments have become quite popular, with 85 countries having some type of policy target for renewable energy in 2009, a jump from only 45 in 2005 (REN21 2010). Europe's target of 20% of final energy by 2020 is predominant among countries belonging to the OECD, Brazil is targeting 75% renewable electricity by 2030, China 15% final energy by 2020, India 20 000 MW of solar by 2022, and Kenya 4000 MW of geothermal by 2030. In early 2010, no fewer than 50 countries and 25 states and provinces had some type of feed-in tariff, and 46 countries were home to renewable portfolio standards for electricity. A number of towns and municipalities around the world – including Güssing (Austria), Dardesheim (Germany), Moura (Portugal), Varese Ligure (Italy), Samsø (Denmark), Thisted (Denmark), Frederikshavn (Denmark), and Rock Port (United States) – have already implemented 100% renewable energy sectors or will implement them by 2015. Table 26.2 provides an overview of these policies at the national level around the world.

As Table 26.2 also demonstrates, planners have adopted a cornucopia of other types of policies to promote renewable energy, many in combination. Direct capital investment subsidies, grants, and rebates are offered in 45 countries; tax credits, import duty reductions, and other tax incentives are offered in more than 30 countries; net metering laws now exist in 10 countries and in 43 states in the USA.

As one example of an innovative program, the city of Ellensburg, Washington, USA, started promoting virtual net metering to incentivize residents to invest in a municipal-scale community solar PV system. The city built a 36 kW solar array in 2006 and asked interested residents to contribute to its capital cost; in return, participants receive a credit on their electricity bill apportioned to their level of investment (Coughlin and Cory 2009).

Transport Options

Transport policies include mandates for biofuel blending along with investments in alternative transport and carbon dioxide standards for cars or airplanes. Biofuel blending mandates exist in 41 states and provinces and 25 countries as of 2010, with most requiring a blending of 10 to 15% ethanol with gasoline or 2 to 5% biodiesel

Table 26.2 Renewable energy promotion policies as of 2010.

Country	*Feed-in tariff*	*Renewable portfolio Standard/ Quota*	*Capital subsidies, grants, rebates*	*Investment or other tax credits*	*Sales tax, energy tax, excise tax, or VAT reduction*	*Tradable RE certificates*	*Energy production payments or tax credits*	*Net metering*	*Public investing, loans, or financing*	*Public competitive bidding*
EU-27										
Austria	X		X	X		X			X	
Belgium		(*)	X	X	X	X		X		
Bulgaria	X		X						X	
Cyprus	X		X							
Czech Republic	X		X	X	X	X		X		
Denmark	X		X	X	X	X		X	X	X
Estonia	X		X		X		X			
Finland	X		X		X	X	X			
France	X		X	X	X	X			X	X
Germany	X		X	X	X			X	X	
Greece	X		X	X				X	X	
Hungary	X		X	X	X				X	X
Ireland	X		X	X		X				X
Italy	X	X	X	X	X	X		X	X	
Latvia	X				X				X	X
Lithuania	X		X	X	X				X	
Luxembourg	X		X	X	X					
Malta			X		X			X		

Netherlands			X	X	X	X	X			
Poland		X	X		X	X			X	X
Portugal	X		X	X	X				X	X
Romania		X			X	X			X	
Slovakia	X			X	X				X	
Slovenia	X		X	X	X	X			X	X
Spain	X		X	X	X	X			X	
Sweden		X	X	X	X	X	X		X	
United Kingdom	X	X	X		X	X			X	
Other developed/transition countries										
Australia	(*)	X	X			X			X	
Belarus									X	
Canada	(*)	(*)	X	X	X			X	X	X
Israel	X				X					X
Japan	X	X	X	X		X		X	X	
Macedonia	X									
New Zealand			X			X			X	
Norway			X		X	X			X	
Russia			X							
Serbia	X									
South Korea	X		X	X	X				X	
Switzerland	X		X		X					
Ukraine	X									
United States	(*)	(*)	X	X	(*)	(*)	X	(*)	(*)	(*)

(*continued*)

Table 26.2 (*Continued*).

Country	*Feed-in tariff*	*Renewable portfolio Standard/ Quota*	*Capital subsidies, grants, rebates*	*Investment or other tax credits*	*Sales tax, energy tax, excise tax, or VAT reduction*	*Tradable RE certificates*	*Energy production payments or tax credits*	*Net metering*	*Public investing, loans, or financing*	*Public competitive bidding*
Developing Countries										
Algeria	X			X	X					
Argentina	X		X	(*)	X		X		X	X
Bolivia					X					
Brazil				X					X	X
Chile		X	X	X	X				X	X
China	X	X	X	X	X		X		X	X
Costa Rica							X			
Dominican Republic	X		X	X	X					
Ecuador	X			X						
Egypt					X					X
El Salvador				X	X				X	
Ethiopia					X					
Ghana			X		X				X	
Guatemala				X	X					
India	(*)	(*)	X	X	X	X	X		X	
Indonesia	X			X	X					
Iran				X			X			
Jordan					X			X	X	
Kenya	X			X						
Malaysia									X	

Mauritius			X							
Mexico				X				X	X	X
Mongolia	X									X
Morocco				X	X				X	
Nicaragua	X			X	X					
Pakistan	X							X		
Palestinian Territories					X					
Panama							X			
Peru				X	X		X			X
Philippines	X	X	X	X	X		X	X	X	X
Rwanda									X	
South Africa	X		X		X				X	X
Sri Lanka	X									
Tanzania	X		X		X					
Thailand	X				X				X	
Tunisia			X		X				X	
Turkey	X		X							
Uganda	X		X		X				X	
Uruguay		X								X
Zambia					X					

Source: Brown, Marilyn A. and Benjamin K. Sovacool. 2011. *Climate Change and Global Energy Security: Technology and Policy Options*. Cambridge, MA: MIT Press.© 2011 MIT.
Note: Entries with an asterisk (∗) mean that some states/provinces within these countries have policies but there is no national-level policy. Only enacted policies are included.

with diesel. Biofuels targets exist in more than 10 countries plus the European Union, and exemptions for fuel taxes and production subsidies are also common.

In Israel, the government has started an ambitious program to promote plug-in hybrid electric vehicles (PHEVs): Project Better Place. The government has teamed up with automobile and battery manufacturers to distribute PHEVs, construct recharging facilities, and create service stations that can quickly replace depleted batteries. Renault and Nissan provide the cars (at a discounted price comparable to gasoline vehicles due to an Israeli subsidy), and Project Better Place provides lithium-ion batteries that are capable of traveling 124 miles per charge. The government provides the infrastructure needed to keep the cars going, such as small plugging stations on city streets, much like parking meters, and at service stations and highways. When batteries no longer perform well, drivers can visit a "car-wash like" station and have them replaced in a few minutes. To get drivers interested, the government offered generous tax incentives and has also invested US$200 million in public funds on electric vehicle infrastructure. Drivers get an electric vehicle at a greatly reduced price and then pay a fixed monthly fee for mileage for the electricity they use (Brown and Sovacool 2011).

Building Options

Building policy options include regulatory approaches such as appliance standards and building codes as well as demand-side management programs operated by electric and gas utilities and incentives for energy service companies (ESCOs). Cities and local governments around the world are becoming especially involved in setting building standards that require the installation of renewable energy. For example, in 2008, Spain became the first county to mandate solar water heating nationwide. And in Jiangsu, one of the most populous provinces in China, all new residential buildings of 12 stories and below must use solar water heating.

As an instance of efforts to promote building energy efficiency at the municipal scale, the city of Minneapolis, Minnesota, USA, and CenterPoint Energy operated a series of innovative neighborhood energy workshops in the early 1990s. Staff working for the city identified and trained volunteers to serve as block captains who then invited their neighbors to energy workshops. These workshops emphasized providing information about energy use habits, the energy efficiency and consumption of domestic appliances, and techniques that could be implemented quickly to save energy such as caulking or adding insulation (Harrigan 1994).

Japan has been especially successful at promoting appliance standards, with minimum energy performance standards beginning in 1983 for refrigerators and air conditioners, and later expanded to virtually all appliances, including the underrated electric toilet-seat warmer. The appliance standards effectively reduced electricity consumption over a short period of time. Average electricity use for refrigerators, for example, declined by 15% from 1979 to 1997, while average refrigerator size increased by 90%. Japanese regulators also applied their performance standards to imported technology ranging from automobiles and televisions to air conditioners and computers, demanding that the efficiency level of new imported products had to meet the best-performing product in the Japanese market, in some cases requiring energy-efficiency improvements of more than 50% (Geller *et al.* 2006).

Industry Options

Industrial policy options include mandatory performance standards or audits for manufacturers along with voluntary agreements and the provision of benchmarking information.

For example, the Netherlands has taken a proactive stance on industrial energy efficiency, beginning with their Long-Term Agreements on Energy Efficiency with industry starting in 1992. These agreements were established through an understanding by the industry that the government is closely observing energy consumption and would not initiate strong regulations so long as industry met the agreed targets. A second phase of this program, launched in 2000, is benchmarking the most energy intensive industries to comparable industries worldwide. The affected industries must be best in class in energy efficiency, and in return, the government will not implement additional stringent climate change policies (Brown and Sovacool 2011).

As is true of most developing countries, India's industrial makeup is dominated by small and medium-sized companies. To achieve the ambitious goal of reducing their energy intensity by 5% each year, India has introduced an energy efficiency trading program. It is expected that this market will be worth US$15 billion and will cover nine sectors by 2015 (Brown and Sovacool 2011). Analogously, from 1980 through 2000, China cut its national energy intensity by 65%, as the result of process and technological changes, as well as structural shifts throughout Chinese industry. Its Energy Conservation Law was revised, its tax policy was modified for export products, tax credits for efficiency investments were granted, and the Top-1000 Energy Consuming Enterprises program was initiated to promote energy efficiency throughout large-scale industry. The end result of these policies has placed China on a path towards reaching its mandates and reducing energy intensity once again (Lin *et al.* 2006).

Agriculture and Forestry Options

Agricultural and forestry options include land-use regulation and harvest quotas for timber alongside financial incentives for improved land management or increased forest area and Payments for Ecosystem Services (PES). One method is to provide financial incentives for organic fertilizer. In the state of Tamil Nadu, India, tea plantation owners have utilized bio-organic fertilization to replenish degraded land, restore soil fertility, and improve productivity. After decades of excessive chemical fertilizer and pesticide application had depleted the soil fertility and crippled the productivity of tea plantations (in some cases instigating crop losses as high as 70% of ordinary yield) plantation managers coordinated with university researchers and a fertilizer company to use natural methods to restore the land. Researchers placed vermicultured earthworms in trenches between tea rows, and relied on tea prunings and high-quality horticultural waste from nearby farms to create organic fertilizer that they then distributed to six large tea estates. The combination of earthworm trenching and organic fertilization increased tea yields from 76 to 239% and saw profits rise significantly (Bennack *et al.* 2003).

Another is Costa Rica's strategy of PES, which distributes payments to the owners of forests and forest plantations in exchange for their preservation and management of the land. The Costa Rican program, passed under their 1996 Forest Law and termed the Private Forest Project, recognizes four services provided by forests – protection of biodiversity, sequestration and fixation of carbon, erosion prevention and water purification, and scenic beauty – and then pays landowners using revenue from activities that threaten those services. A 5% tax on gasoline creates about US$16 million per year used to enhance biodiversity protection, the sale of carbon credits (called Certifiable Tradable Offsets) helps pay for carbon sequestration, and donations from private hydropower companies sponsor hydrologic services. During the first two years of the program more than 1000 landowners signed contracts to receive payments averaging US$120 per hectare per year for plantations, US$60 for forests, and US$45 for forest management and reforestation. The combined taxes and donations now produce about US$16 to US$20 million per year and generate 4 million t. of carbon credits to be brokered on the international market (Brown and Sovacool 2011).

As an example of quotas and forest management in Malaysia, home to less than 0.25% of the world's forests but 10% of its total number of plants and 7% of its species, regulators passed a National Forest Act in the 1980s to classify forests and set limits on harvesting and deforestation. The rules mandated that only trees of a certain length and age could be felled (protecting both young and old trees), prohibited harvesting of timber and wood within an extensive network of reserves, set strict quotas, and relied on surveillance (now performed by satellites) to track compliance. In 2007, the maximum harvest quota was 50 000 cubic meters, and newer standards require that those forests that have been harvested undergo regeneration and restoration efforts. Collectively, such policies have seen the amount of forest area grow from 58.7% of land area in 2000 to 63.6% of land area in 2005 (Brown and Sovacool 2011).

Waste and Water Options

Policy options for waste and water include waste management regulations and volumetric water pricing as well as incentives for waste incineration or anaerobic digestion, cleaner production processes, and extended producer responsibility. One promising approach is to use "cradle to cradle" design that intends to reuse and recycle products back into the manufacturing process at the end of their useful life. Another tool is the promotion of methane capture and biomethanization. In Brazil, for example, the Bandeirantes Landfill Gas to Energy Project captures methane that would otherwise be vented into the atmosphere and converts it to electricity. The city of São Paulo produces nearly 15 000 t. of waste per day and half of it goes to the Bandeirantes landfill. As a result, Bandeirantes is also one of the world's largest landfills, with a current capacity of about 30 million t. (or a size of 175 football fields filled with up to 8 m, or 26 ft., of trash). The Bandeirantes can hold about 20 years' worth of Brazilian rubbish, but it was also responsible for emitting a staggering 808 450 t. of carbon dioxide equivalent per year. Working with the city, Biogás Energia Ambiental SA built a system of degassers, pipes, heat exchangers, and 24 Caterpillar engines to capture the methane and use it to generate about 20 MW of electricity, enough to run the homes of about 400 000 people. From its inception in 2006 the facility has worked with a flare efficiency of 99.997% (meaning it captured almost

100% of the methane) and has reduced the metropolitan region's entire carbon emissions by 11% (Brown and Sovacool 2011).

At a much larger scale, the European Union (EU) has begun to address the pollution coming from discarded products through a principle known as Extended Producer Responsibility (EPR). First enacted in Germany and then expanded into an EU directive in 2001, EPR assigns long-term responsibility for the environmental impacts of products (such as lawnmowers and household paints, computers, batteries, and cellular telephones, to name just a few) from consumers to their manufacturers. It requires that manufacturers take back their products or charge consumers a small fee to pay for collection and recycling (Sachs 2006). While member countries have implemented the EPR directive differently, four types are most prevalent within the EU:

- economic, which requires manufacturers to pay all or a portion of end management and disposal or recycling costs;
- physical, which requires manufacturers to take possession of discarded goods to ensure that materials and components are recycled;
- informative, which requires manufacturers to publish information about where consumers can recycle their product; and
- legal, which makes manufacturers liable for the environmental damage resulting from their products, including costs for remediation, cleanup, and disposal.

The central premise behind EPR is manufacturers should be made responsible for their goods at the source. As a result of EPR legislation in Europe, manufacturers have designed products to be more recyclable and/or with less environmentally damaging raw materials; improved their efforts to collect discarded goods; incorporated recycled components and materials back into their production processes; adopted modular designs that are easier to disassemble; and unified and harmonized standards for various types and grades of materials and plastics.

Global Policy Options

Due to the scale and complexity of energy and climate challenges, a final set of approaches operates at the level above nation-states – at the supranational scale. Intergovernmental organizations (IGOs), for example, are created and funded by national governments, which have secretariats that answer to a governing body, but operate within the global system. Some of these, such as the International Energy Agency or International Atomic Energy Agency, deal with exclusively with energy.

Sometimes, organizations like the United Nations will specifically adopt resolutions aiming to enhance the attention to energy issues, such as the 2012 "International Year for Sustainable Energy for All," which was adopted in December 2010. The initiative seeks to engage governments, companies, and other civil society actors to achieve three goals by 2030: universal access to modern energy services, reducing global energy intensity by 40%, and increasing renewable energy use globally to 30% of total primary energy supply.

Multilateral financial institutions give loans and financial support for infrastructure projects intended to promote economic development, often involving energy systems and technology. The best known of these banks is the World Bank Group, which consists of five Washington, DC-based institutions, the three most important being: the International Bank for Reconstruction and Development, the International Finance Corporation, and the International Development Association. The role that these banks play in shaping national energy programs through financing and technical assistance has come under intensive scrutiny in the past few years, with lending from these banks often exceeding hundreds of millions of dollars per project.

Governments sometimes form treaties dealing with energy. The Energy Charter Treaty, for instance, places an obligation on its 51 current members to facilitate safe transit of energy fuels across territories, with the aim of creating a transparent and efficient energy market. It also offers dispute settlement over energy-transit-related issues, seeks to protect European foreign investments in energy, and promotes free-flowing trade of energy commodities (Sovacool and Florini 2012).

Other supranational institutions focus on setting global technology standards. The International Partnership for the Hydrogen Economy establishes common codes and standards conducive to the global adoption of hydrogen systems through its 17 member countries. Similarly, the Collaborative Labeling and Appliance Standards Program is funded by a variety of organizations including the US government, World Bank Group, and United Nations. It assists with the implementation of various standards and labels relating to energy and energy efficiency technologies and services (Sovacool and Florini 2012).

Lastly, hybrid entities form partnerships, often between public- and private-sector organizations, to accomplish their energy-related goals. One example is the Renewable Energy and Energy Efficiency Partnership (REEEP), which is dedicated to reducing greenhouse gas emissions, improving the access to reliable and clean forms of energy in developing countries, and promoting energy efficiency. The 2008 program year saw REEEP running 145 projects worth a total cumulative investment of €65 million, most of this leveraged from REEEP partners through equity financing, and plans for 37 new projects. These new projects included the promotion of solar water heaters in Uganda, energy-efficient lighting in India, rural biomass development in China, renewable energy financing in Mexico, and assessing the regulatory framework for renewable energy in Argentina (Florini and Sovacool 2009).

Conclusions

Unfortunately, complementary policies such as undertaking R&D, adjusting subsidies, internalizing externalities, promulgating standards, and improving information will not work in isolation. Changing R&D practices without removing subsidies for carbon-intensive technologies, for instance, would have to swim against the current created by existing incentives and momentum. Removing subsidies without promoting public information and education will ensure that consumers remain uninformed about other options and the inefficiency of their current practices. Some energy services fulfill social functions independent of cost, so that people will ignore price changes for as long as possible until it becomes completely prohibitive and a threshold is passed. Consumers want to preserve their lifestyles and often do so until costs become prohibitive, and manufacturers will protect their current practices against any changes that might threaten to disrupt productivity or profitability.

Policy-makers and regulators must design policy mechanisms that match the technical-economic-political-socio-cultural dimensions of current society. Once recognized, they must consistently pursue a variety of policy mechanisms that simultaneously alter R&D practices, fine-tune subsidies, price externalities, and better inform the public if they are to affect consumer demand and promote sustainable energy practices at the speed, scope, and scale required. With this in mind, three conclusions are offered.

First, the energy and climate change issues confronting the world are neither technical nor social, but *socio-technical*. That is, they involve not only technologies including physical devices, objects, infrastructures, systems, and tools, but also people who are motivated by human values, habits and routines, cognitive limitations, and cultural beliefs. This simple conclusion has somewhat profound implications for energy and climate research. Technology research and commercialization efforts must be coupled with attempts to educate and inform consumers, overcome biases and apathy, shift cultural values and behavior, and incentivize people to use new technologies along with old ones that already work. Individuals making relatively simple changes to their lifestyles, such as consuming less energy at home, cycling instead of driving to work, eating less meat, and purchasing second-hand or used items, can in aggregate add up to significant climatic benefits. In short the socio-technical dimension of energy and climate change necessitates holistic and complementary solutions that avoid looking at only one face of the socio-technical coin. Our own individual behavior can be just as important as developing new technology.

Second, the complex socio-technical nature of climate and energy challenges offers a robust justification for government intervention. Numerous market failures and barriers exist on both social and technical planes, including externalities, high costs, infrastructural limitations, and technical risks (technical obstacles) as well as policy failures, utility monopolies, energy price volatility, and lack of knowledge, training, and information (social obstacles).

The good news is that governments can do much to overcome these impediments, from putting a price on carbon to a range of innovative and effective complementary policies, some regulatory and others voluntary. If targeted to overcome behavioral barriers – such as loss aversion, asymmetric information, habits, and heuristics to deal with overwhelming deliberation costs – these policies can transform markets. Options include increasing research expenditures for key technologies, sponsoring neighborhood workshops to personalize information about clean energy choices, reforming subsidies and designing incentives to overcome social impediments, and implementing payments for ecosystem services along with extended producer responsibility.

However, to achieve the levels of market transformation needed to match the challenges faced, a much deeper understanding of policy barriers and drivers is essential. Shifts to individual and institutional behavior are instrumental so that marketable and effective energy and climate technologies and policies become widely adopted.

Third and finally, while intervention by governments is important, it is often much more effective when implemented at a variety of scales in cooperation with a plurality of actors, and with the speed, scope, and scale required to repair the planet. Individuals, cities, corporations, and other groups must act alongside regulators and government officials. Or, as the philosopher Jürgen Habermas once wrote, "in the process of enlightenment there can only be participants." The same holds true for climate change: we must *all* participate.

Individuals, however, can alter many of their daily practices to substantially reduce emissions: they can, for instance, use less energy-intensive goods and services, drive more efficient cars, purchase better electrical appliances, eat less meat, and conserve water. They should not be viewed as passive recipients loosely connected to climate change, but as active participants whose lifestyles play a central role in contributing to energy and climate problems. The situation brings to mind the words of Rachel Carson (1962: ix), who wrote that "the human race is challenged more than ever to demonstrate our mastery – not over nature, but of ourselves."

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