Chapter 4
Energy and Environmental Insecurity

Energy security is now a commanding priority. The emerging energy system is far more complex and global than the industrial era system that it is slowly replacing. Today when security planners talk about energy security, they are as likely to be referring to carbon emissions and diminishing water supplies as energy self-reliance and affordable oil. Moreover, emerging energy and environmental security problems are increasingly beyond the ability of any single country to control. This chapter examines critical issues surrounding energy in the evolving security environment and proposes potential pathways for pursuing solutions.

The Emerging International Energy Security System

Energy has become one of the most pressing problems in national and global security. Significant increases in the price of oil have weakened the global economy, contributed to a sharp rise in global food prices, and transferred trillions of dollars to autocratic oil-exporting regimes. At the same time, rapid fluctuations in the price of oil—from around $25 per barrel in 2001 to as much as $150 in 2008 and back to below $50 in 2009—have increased risk and discouraged investment in energy technology and infrastructure ensuring that global markets will not be prepared for the next cycle of high prices. Internationally, energy diplomacy has become increasingly confrontational as states jockey for control of gas and oil markets and pipelines. Meanwhile, concerns about pollution and greenhouse gases have strained diplomatic relations with other nations and are forcing fundamental changes in energy policy.

The emerging crises are symptoms of a gradual transformation in the underlying geopolitical and economic system that has supplied the world with

DOD (Dick Moreno)

Drivers in Kuwait use headlights to see through smoke from oil wells set afire by retreating Iraqi forces, Operation *Desert Storm*, 1991

cheap energy for over a century. Since the 1800s, cheap fossil fuels have powered the rise of industrialization and globalization. During this period, free-market mechanisms ensured that world markets had access to petroleum and other sources of energy. This system relied on market competition to drive the price of energy commodities toward the price of extraction and depended on a liberal trading order in which governments generally left energy transportation, supply, and demand to the market.

Over the life of the energy market, the fundamental threat to cheap and reliable energy commodities has been that government intervention in the supply, transport, and demand for energy would transform the global distribution system from one adjudicated mainly by markets to one based on politics and force. Threats to the market-based system have always been possible. States with diplomatic or military influence on the global lines of communication by which energy is transported have frequently been tempted to further their interests by charging rents for access. Supplying states have regularly attempted to band together to increase market prices. At least since the 1970s, environmental groups have put pressure on governments in rich states to look beyond the market and consider externalities when setting energy policy.

Despite these pressures, until recently, the world has generally maintained a global free-market energy economy in which the prices of energy commodities have hovered around the cost of extraction and supply has been dependable. Historically, this system has rested on three pillars: a reliance on freedom of the seas for most international energy trade; a multiplicity of energy-exporting nations and multinational corporations that made collusion and nationalization difficult; and the preference given by oil-importing nations to energy supply and price, over other considerations such as the environment. Each of these pillars, and hence the basic energy system, is increasingly uncertain.

Insecure Energy Lines of Communication

Unimpeded transportation of energy has never been assured. Throughout the history of the modern energy market, states attempted to influence transit routes for parochial reasons. During the World Wars, the Cold War, and the Iran-Iraq war, belligerents used diplomatic and military power to interdict opponents' energy supplies. However, because most global energy commodities traveled by sea, and because Great Britain and the United States were dominant sea powers, their opponents' efforts were generally frustrated in war and free-market distribution mechanics persisted in times of peace.

In recent years, however, a number of events have begun to undermine freedom of energy transportation. Over the last two decades, natural gas has become an increasingly important part of Europe's energy economy, and Russia and Central Asian states have begun to supply a large portion of that resource. Unlike petroleum exports, which mainly travel across oceans to final buyers, natural gas must generally travel by pipelines through sovereign territory. The main geopolitical implications of overland transport are that the United States cannot use its maritime power to secure energy sea lines of communication and that Russia can use its geographic proximity and influence on Central Asian and Eastern European states to seek economic and diplomatic rents from natural gas exports.

Russia has routinely made use of its influence over energy supply routes. In January 2006, Russia flexed its muscles by cutting off natural gas exports to Ukraine and did the same in 2007 to Georgia and Belarus. After Russia's intervention into Georgia in 2008, Russian leaders made it clear that opposition to Moscow could affect natural gas supplies. Russia's energy *realpolitik* has been effective. Major European states have regularly recoiled in the face of threats to their energy lifeline. Meanwhile, U.S. support for the free transport of gas in Central Asia and Eastern Europe has put it at odds with Russia.

Supply lines have also become less secure in the Persian Gulf's narrow Strait of Hormuz through which 40 percent of global oil exports flow. As Iran amasses modern antiair and antiship missiles and enhances its capacity for harassing tanker shipping, America's role as guarantor of the freedom of the seas assumes a riskier and costlier burden. In the longer term, China's growing dependence on Middle Eastern oil may heighten Beijing's concern about U.S. control of the sea lines of communication. These concerns have led China to expand its influence along the routes connecting the Arabian Gulf, Indian Ocean, Strait of Malacca, and South China Sea through a network of treaties, access to ports and airfields, and modernized military capabilities. If global petroleum demand continues to outpace supplies, the temptation for regional powers to seek diplomatic and financial rents by controlling sea lines and chokepoints is likely to increase.

From Free Market to Oligopoly

For more than a century, global energy supply has been dominated by international corporations competing to find and extract energy resources for profit. The result has been that known reserves have often expanded faster than demand and prices have usually remained low. Petroleum, in particular, has averaged around $20 per barrel in inflation-adjusted dollars for nearly a century. While energy-exporting nations have attempted to coordinate their export policies to reduce supplies and increase prices, the large number of exporting states and the critical role international corporations have played in providing technology and expertise have usually frustrated cartels.

The longstanding dynamics of the global energy market are changing. Known oil and gas reserves have become increasingly consolidated in the hands of a small clique of often politically unstable states. In four of the top eight reserve-holding nations—Iran, Iraq, Nigeria, and Venezuela—a combination of international sanctions, war, civil disorder, and corruption has reduced energy exploration and extraction below market expectations, diminishing supply and increasing prices. Over the same period, as extraction technology has spread from private companies to states, exporting countries have regularly nationalized their reserves and seized multinational oil and gas companies doing business within their territory. Whereas most reserves and nearly all major energy companies were once private, more than 80 percent of all reserves are now under state control and a progressively larger number of oil and gas companies are partly or wholly owned by exporting governments.

As this has happened, major importing powers have become keen to influence supplying nations through diplomatic and military instruments of state power. The system that allocates energy internationally has become more mercantilist. China has vigorously attempted to use its newfound financial muscle to bring autocratic African and Central Asian oil-exporting regimes within its sphere of influence to bypass market mechanisms. Russian attempts to control the flow of energy in Central Asia and Eastern Europe have regularly escalated to energy blackmail and threat of force. Similarly, at least since the early 1990s, the United States has used various diplomatic tools, including military-to-military contacts, with regimes in Central Asia and the Middle East to increase their connections with the West.

The net effect of these changes has been to reduce the amount of gas and oil on the international market and to move the market toward oligopoly. The emerging system is less stable and less predictable than the older market-driven system. In the old system, the large number of competing energy-supplying states and companies dampened the effects of actions by particular suppliers and inhibited the ability of suppliers to coordinate policy. In the new system, market supply is increasingly dependent on the nuances and preferences of individual states. Recently, even apparently trivial political events in exporting nations have been enough to cause dramatic fluctuations in prices, and the United States has, on occasion, been reduced to cajoling Saudi Arabia and other major exporters to increase energy supplies to reduce market prices. From the viewpoint of the emerging autocratic oil-exporting oligarchy, the system works. It is funneling trillions of dollars into their economies and increasing their political power at home and diplomatic power abroad. Even short term dips in prices help them in the long term by suppressing investment in conservation and alternative fuels. There is little reason to expect the current trend toward oligopoly to reverse itself or anticipate a return to the more stable energy environment of the 20th century.

Environment and the Diminishing Importance of Price

The third dynamic altering the current global energy market is the increasing importance of environmental concerns in determining importing states' energy policies. Whereas energy policies in rich states were once determined mainly with an eye to reducing price, price today is becoming decreasingly important vis-à-vis fears of pollution and particularly of global warming.

For several decades, the governments of rich countries have been under mounting pressure to modify energy policies to account for environmental factors. The success at influencing governments over the environment has varied across countries and time. But the contemporary era is particularly green, and the influence of environmental groups is growing rapidly. While clashes once mainly pitted naturalists against economic interests, as concerns about global climate change grow, the number and political influence of groups committed to environmental policies will expand. Today, many governments and non-governmental organizations are lobbying the United States for more eco-friendly policies, and U.S. energy policy has become a major point of diplomatic, as well as domestic, friction.

It is difficult to predict the effect of environmental concerns on energy markets. In general, environmentalists argue for higher prices on carbon-based fuels to reduce demand. However, environmental science is too young and lobbying too disparate to make prediction easy. In the United States, conflicting interests sometimes pit one environmental interest against another. For instance, lobbies aimed at reducing radioactive waste and preserving natural ecosystems currently restrict the construction of U.S. nuclear and hydroelectric plants. In the process, however, they have caused the country to increase the number of dirty, carbon-producing coal plants. Also, some policies are self-defeating. To reduce greenhouse gases, the United States funds research on electric cars. However, since 50 percent of U.S. electricity is derived from coal, electric cars can produce more carbon and other pollutants per mile than cars running on regular gasoline. In addition, some policies have unintended consequences. Recent legislation that discourages the use of new fuels that emit more carbon across their lifecycle than petroleum appeared relatively benign when low oil prices made North America's vast reserves of unconventional fossil fuels unprofitable to extract and refine. However, should high prices make these reserves profitable—as they briefly did in 2008—the legislation will effectively limit access to most of America's oil reserves. In the meantime, environmentalists and energy suppliers both hold out hope that new technology will eventually solve current problems.

Environmental concerns, and particularly global climate change, may prove to be this century's greatest security challenge. Whatever the eventual outcome, however, they are fundamentally changing the way the global system extracts, transports, and uses energy and injecting uncertainty into global markets. As concerns over climate change increase with time and governments search among myriad proposed solutions, the price and volatility of energy are likely to increase and incentives for privately funded research and infrastructure development are likely to be adversely affected.

As the global energy economy transitions toward a more statist and mercantilist system, policymakers are likely to find themselves operating in *terra incognita*. In the old system, private companies absorbed most of the risk; in the emerging system, states will bear a larger portion of the risk as they pioneer new policies. Many of the policies that will set the tenor for the next century will be developed and implemented in the next decade. Global leadership is needed, and difficult national choices will have to be made. The world is changing and the dynamics that facilitated a world powered by cheap fossil fuels are

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AP Images (Misha Japaridze)

Russian workers weld connection for new pipeline operated by state-run natural gas company Gazprom

European Energy: Security in Coordination

The states of the European Union (EU) face significant challenges to their energy security because of dependence on a limited number of oil and gas suppliers and serious concerns about Europe's contributions to global carbon emissions and climate change. Because EU members are mostly net energy importers, and because most energy-related policies are left to individual member states to negotiate, suppliers in the Organization of the Petroleum Exporting Countries (OPEC), and especially Russia with its nationalized oil and gas industries, hold a significant advantage in negotiations with European states. Europeans are well aware that energy security requires diversified suppliers and transit routes. However, this awareness has not yet resulted in the creation of a common energy policy enabling coordination of EU relations with international energy suppliers.

In 2007, the Council of the European Union proposed an energy policy for Europe to address the security of energy supply, climate change, and the creation of a single EU market for energy. The EU has done a better job of addressing climate change and its internal energy market than it has of solving the problem of supply diversity. As a cornerstone of a climate change policy, the EU introduced a "cap-and-trade system" for carbon dioxide (a concept also under consideration by the U.S. Congress). The EU is currently in a second round of cap-and-trade programs based on lessons learned from the initial round, which resulted in low emissions prices and little mitigation. The EU also introduced energy competition for electricity and natural gas by requiring member states to allow all residential, commercial, and industrial customers the right to choose energy suppliers. This competition policy came under pressure as consumers continued to see energy prices rise in spite of this liberalization.

The EU is aware of the growing problem of its energy security. A 2006 *Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy*, for example, recommended the following trio of priorities: establish a functioning internal energy market; move energy conversion to low-carbon technologies, with renewable energy producing 20 percent of supply by 2020; and achieve end-use energy efficiency improvements, achieving a 20 percent reduction in energy consumption by 2020. These actions continue the EU's aggressive moves toward diversification in energy as a mechanism for creating competitive economies and mitigating climate change through programs fostering environmental sustainability.

The current European energy supply portfolio reflects a desultory track record of independent decisions made by the organization's 27 individual member states. These past decisions, involving the role of nuclear power, coal, and imported natural gas, have led to divergent energy portfolios. For instance, nuclear power accounts for 40 percent of France's energy needs, but it provides only 9 percent of the United Kingdom's power supply and none of Austria's. Similarly, coal has no role in electricity generation in France, but coal represents 92 percent of Poland's supply, 65 percent of the Czech Republic's supply, 62 percent of Greece's supply, and 50 percent of Germany's supply. The EU is moving ahead in some areas with EU-wide policies on energy supply using the issue of climate change as the policy driver. Thus, a January 2008 proposed directive on renewable energy requires that 20 percent of member state energy come from renewable sources by 2020, as recommended in the earlier Green Paper.

The EU is most vulnerable in the oil and gas sectors, with oil providing between 40 and 50 percent of primary energy needs for most EU members and natural gas sales dominated by Russia's Gazprom. More worrisome, forecasts suggest that the trend is toward greater EU foreign dependence, with the EU projected to import 90 percent of its oil and 80 percent of its natural gas by the year 2030. At present, 45 percent of EU oil imports are from the Middle East and 40 percent from OPEC members. Increased dependence on a small number of suppliers and supply routes will make the EU more susceptible to energy disruption.

Given the reluctance of individual EU member states to cede greater authority to the Union, members must rely on the hope that individual states will display solidarity in the event of a supply crisis. The EU is promoting the diversification of supply, analyzing stockpiling, and improving transparency through the establishment of an EU Energy Observatory to collect and verify energy data. The EU also plans to use its partnership mechanisms to enhance ties with energy suppliers in the Caspian Sea, Black Sea, and North Africa regions.

If the states of Europe were to relinquish more sovereignty to permit the European Union to make critical decisions on energy policy, the result might well provide greater energy security for the EU. In the near term, however, it appears that individual member states will continue to pursue their own national energy policies.

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diminishing. Leaders face the question of whether they can overcome inertia and adapt and change with it.

Recent Trends in the Changing Energy Landscape

Recent trends in current energy markets suggest that the world is on an unsustainable and undesirable trajectory with regard to energy. These trends include tight supplies and the elimination of excess capacity, persistent and growing demand, infrastructure and capabilities limitations, heightened geopolitical and investment risk, higher prices, and growing concern over climate change. At the same time, absent a major strategic shift in policy, U.S. influence in global energy markets will continue to erode because of the emergence of new global players and trends that will play an increasingly larger role in shaping tomorrow's energy system.

The urgent need to address climate change presents both a challenge and a clear opportunity for the United States and other major states to shift energy priorities in favor of greater efficiency and low emission fuels. This shift will fundamentally alter the geopolitical, economic, and environmental dynamics. In so doing, however, caution must be taken to develop strategies that balance government policies and market practices, to deploy new technologies while maintaining existing infrastructure, and to facilitate the transition to a new and sustainable energy future without undermining the present system's relative stability.

Over the next 25 years, the world's population is projected to grow from some 6.7 billion to well over 8 billion people. With population, economic growth, and standards of living expected to increase in already densely populated areas, society will require greater resources (from water and food, to land, energy, and other basic materials) to fuel and sustain this expansion. As the world struggles to meet these energy needs, new trends and dynamics will shape our collective energy future.

Shifting Supply and Demand Dynamics

The first major trend shaping the energy future concerns the shift in who supplies energy and who demands it. Global energy demand is projected to increase approximately 55 percent by 2030, with nearly 74 percent of growth coming from developing economies, 45 percent from China and India alone. In fact, energy demand from developing economies (non–Organisation for Economic Co-operation and Development [OECD] countries) is expected to overtake energy consumption in the developed world within the next 2 years. Over the same time period, energy supplies are projected to come from approximately the same fuel mix, mainly fossil fuels, and many of the same resource holders that exist today.

While there is always a chance that energy demand will not achieve these projected levels of growth, either because of an economic slowdown or better than historic rates of energy productivity, the overall outlook nonetheless remains daunting. Slower economic growth, while temporarily forestalling the need for increased energy supplies, does nothing to alter the basic trend lines and carries with it adverse consequences. In addition, while higher energy prices have already slowed consumption growth in some areas of the world, notably in the United States and Europe, in other areas (such as the Middle East and Asia) demand growth has proven remarkably resilient. The emergence of the non-OECD world as a major energy consumer further accentuates the global economic shift already under way. In 1997, the Group of Eight (G–8) countries accounted for 65 percent of global gross domestic product (GDP). A decade later, that figure had dropped to 58 percent and projections indicate that by 2015, those nations will account for less than half of global economic activity. Non-OECD nations will then comprise both the majority of conventional resource holders as well as represent the bulk of new economic growth areas. Furthermore, as internal energy demand grows within producer nations, absent massive new investment in production capacities, export volumes will inevitably decline.

In addition, as oil demand continues to grow internationally, the inability of non–Organization of Petroleum Exporting Countries (OPEC) producers to keep pace has dramatically enhanced OPEC leverage. With Russian oil output reaching a plateau and production decreasing in the North Sea, the United States, and Mexico, the world is becoming more reliant on supplies from a handful of producer nations—many of which have different agendas, production policies, and internal political needs. The International Energy Agency (IEA) has projected that by the middle of the next decade, the "gap" between presumed oil demand and available global supply (after accounting for reservoir decline rates) could exceed 10 million barrels per day. While glob-

al inventories could help offset part of that deficit, at least temporarily, ultimately the allocator of scarce resources will be markedly higher prices.

The Changing Resource Base and Delivery Requirements

A second trend shaping the energy future is the changing resource base and the requirements for delivering it. The world is not running out of energy, but it is becoming more difficult to gain access to, produce, and convert the world's energy resources and deliver them to the people who want them. Energy resources are geographically, geologically, technologically, and financially more difficult to reach. Large supplies of conventional oil and natural gas remain located in the Middle East and Eurasia, while the Western Hemisphere is rich in unconventional fuels such as oil sands, oil shale, and extra-heavy oil deposits. Geographically, the presence of these nonconventional reserves should buttress security, but they also present sizeable environmental challenges, particularly in an age of carbon constraints.

Maintaining a robust, secure delivery infrastructure for long-distance transport of vast volumes of oil and gas through congested transit points is a salient concern. In the coming years, energy trade flows will be affected by a concentration of supply and demand centers not geographically collocated. Coal, natural gas, biomass, and other resources are being transported longer distances to reach demand centers. While alternative energy forms provide a welcome supplement to conventional energy resources, they are unable to serve as replacements at scale and require significant new infrastructure and investments of their own.

In a dramatic shift from previous decades, national ministries and national oil companies control more than 80 percent of conventional oil reserves and account for more than half of current crude oil and natural gas production. In contrast, international oil companies, which have been indispensable to the development of oil and natural gas resources throughout the world, are now in danger of marginalization. The new class of national oil companies is well funded, has access to advanced technology, is becoming involved in exploration and production activities in foreign markets, and is gaining experience and honing project management skills with each passing day. In places where foreign investment and international oil company involvement are politically unpalatable, bilateral energy agreements with other national companies are perceived to have a competitive advantage over many international companies. Many of those companies are adjusting to this new operating environment, but the potential long-term implications are worrisome.

High Price Environment and Investment Challenges

A third trend shaping the energy future centers on the high price of energy and the risky nature of energy investments. Notwithstanding the drop in gas prices in late 2008, persistent demand and tight supplies, as well as escalating equipment and materials costs, have generally caused energy prices to rise across the board. While most analysts foresee some relief within the near term, the continued growth in demand will eventually lead to higher prices. Much of the world's economy was built on cheap energy. In the United States, homes, vehicles, transportation habits, and heating and cooling preferences are all geared toward

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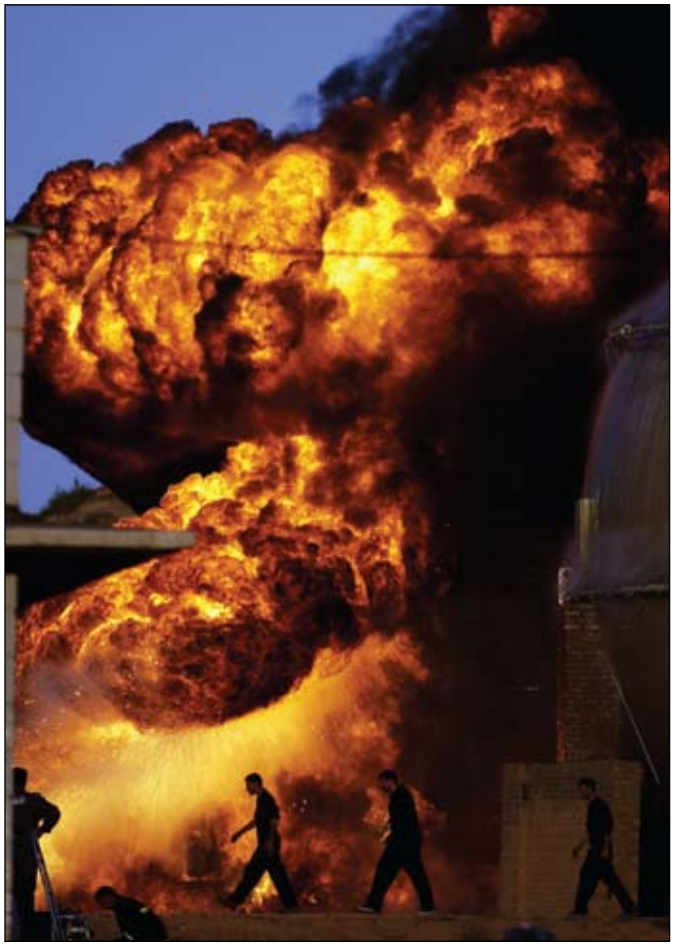


U.S. Air Force (Samuel Bendet)

Iraqi firefighters battle pipeline fire after rocket attack at Northern Oil Company in Kirkuk, November 2006

Major Contentious Oil and Natural Gas Pipelines

1 Cano Límon-Coveñas Frequent target of sabotage by guerrillas of the ELN and FARC; U.S. military advisers have worked with Colombian government forces to enhance security along the pipeline route.

2 East Siberia-Pacific Ocean (ESPO) Originally, Moscow agreed to terminate the ESPO pipeline at Kozmino Bay and deliver most of its oil to Japan, but persistent lobbying by Beijing has led to a plans for a spur from Skovorodino to Daqing in China, questioning the viability of completing phase two to the Pacific (though some oil will be delivered by rail cars). Major environmental hurdles also have to be overcome in completing the project.

3 Caspian Pipeline Consortium (CPC) The Russian state holds the largest share in CPC, but Chevron and other Western firms also hold significant portions. Kazakhstan seeks to expand capacity to 1.3 mb/d, but Moscow is balking over transit fees.

4 Kazakhstan-China Represents a calculated effort by China to reduce its dependence on Middle Eastern oil and enhance its energy security, in particular by reducing its vulnerability to a future trade blockade enforced by the U.S. Navy.

5 Baku-Tbilisi-Ceyhan (BTC) Built with strong U.S. backing to avoid reliance on pipelines transiting Russia or Iran. Russian hostility to the pipeline (and resulting U.S. support for the pro-Western government in Georgia) was a major factor in Moscow's August 2008 invasion of Georgia and its continuing support for the breakaway enclaves of Abkhazia and South Ossetia.

6 South Caucasus Pipeline (SCP) Like the BTC, viewed in Moscow as a challenge to its control over the flow of Caspian Sea energy to European markets and so a factor in its August 2008 invasion of Georgia.

7 Nabucco Designed to reduce heavy European reliance on Russian natural gas and so enjoys strong backing from the EU and the U.S. The Russian invasion of Georgia in August 2008 may have been intended to blunt enthusiasm for Nabucco as most of its gas would be obtained from Azerbaijan via the SCP.

8 Caspian Gas Pipeline Intended to transport Turkmen gas to Russia, Ukraine, and Europe via Gazprom's extensive pipeline network. The new conduit will connect to the existing Central Asia-Center gas pipeline network on the Kazakh-Russian border. Designed to frustrate EU and U.S. efforts to secure Turkmen gas for Nabucco via a proposed Trans-Caspian link to the SCP.

9 Chad-Cameroon Partly financed with a World Bank loan in the hope that increased international oversight would lead to a greater allocation of oil revenues to grassroots social and economic development in Chad. However, persistent intransigence by the Chadian government led the Bank to suspend loans to Chad in 2006; although a compromise was later reached, the government repaid the original pipeline loan in 2008 without satisfying the Bank's initial development objectives.

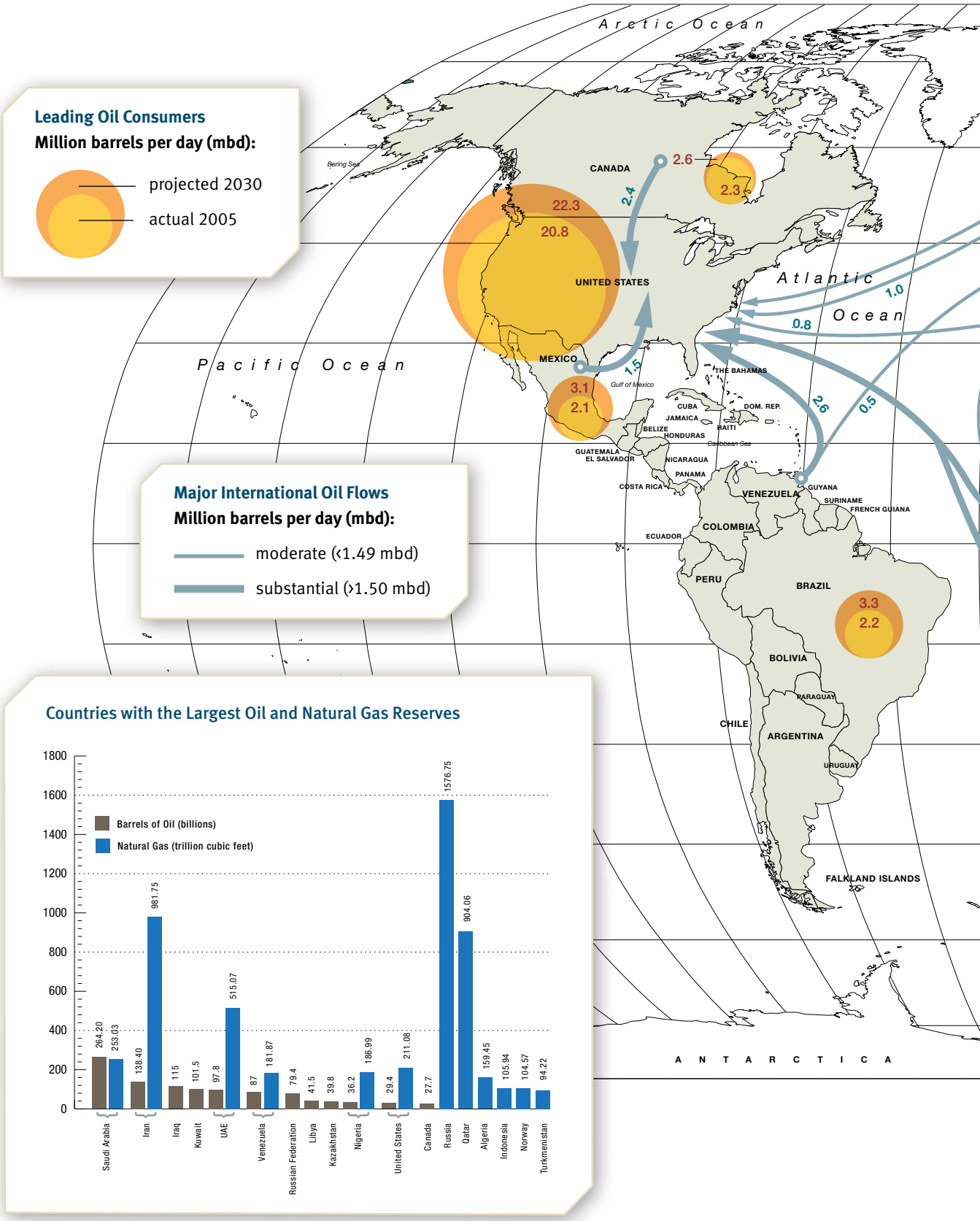
10 Trans-Saharan Gas Pipeline Intended to transport Nigerian gas to Europe. Could cost $21 billion or more and pass through extremely harsh and often embattled areas. Strongly backed by the EU as a way of reducing reliance on Russian natural gas.

Source: Country analysis briefs posted at Web site of U.S. Department of Energy's Energy Information Administration.
bcfd = billion cubic feet per day
bd = barrels per day
mbd = million barrels per day

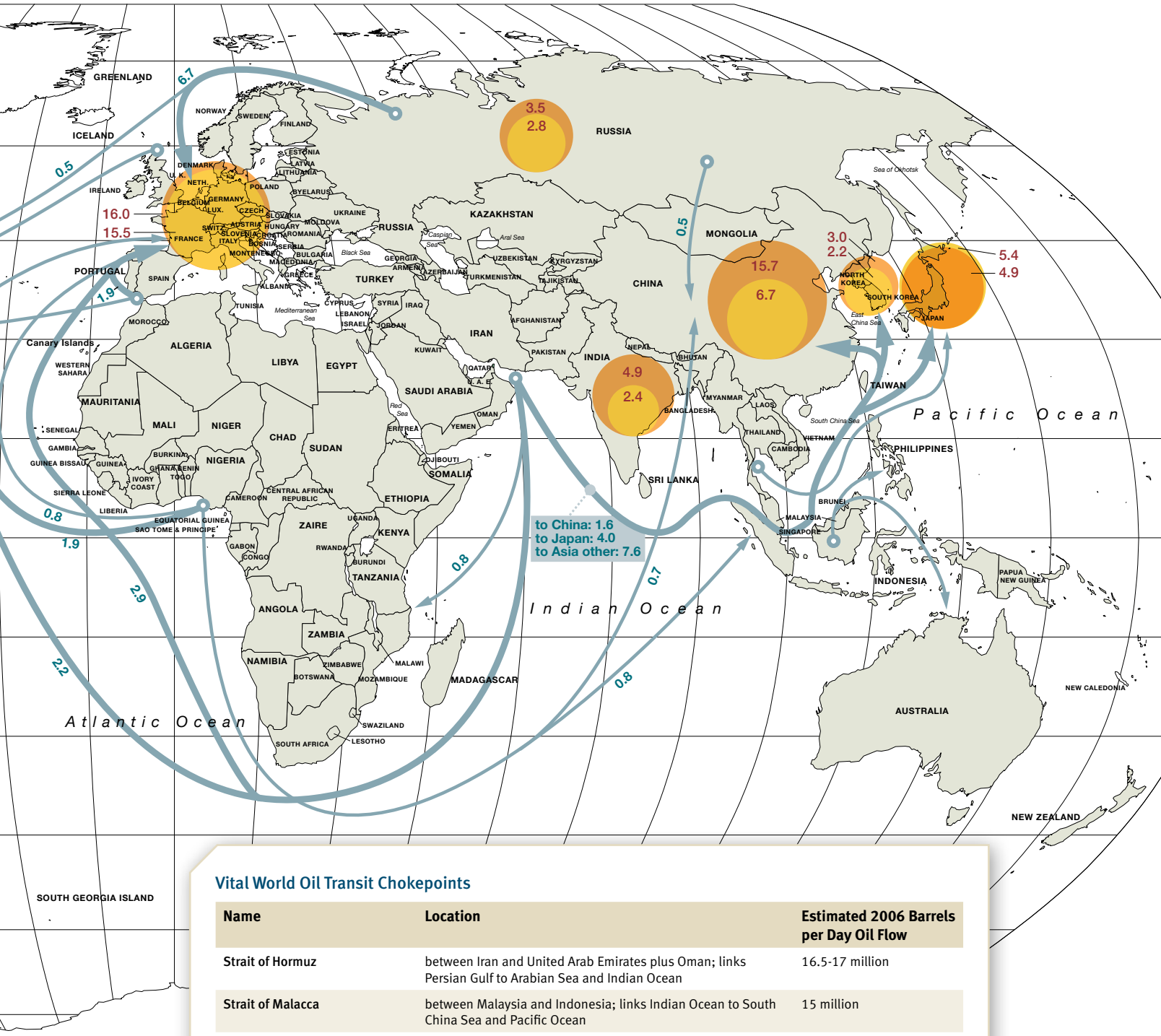
Energy Use by Country

Energy consumption per capita in kilograms of oil equivalent per year (2005):

- low (‹1,000)
- medium (1,000–3,499)
- high (›3,500)



Source: BP, *Statistical Review of World Energy June 2008*.
Does not include unconventional products such as Canadian tar sands.



Vital World Oil Transit Chokepoints

Name	Location	Estimated 2006 Barrels per Day Oil Flow
Strait of Hormuz	between Iran and United Arab Emirates plus Oman; links Persian Gulf to Arabian Sea and Indian Ocean	16.5-17 million
Strait of Malacca	between Malaysia and Indonesia; links Indian Ocean to South China Sea and Pacific Ocean	15 million
Suez Canal and Suez-Mediterranean (SUMED) Pipeline	connects Red Sea and Gulf of Suez to Mediterranean Sea; approximately 3,000 tankers transit the canal annually; because of canal's narrow width oil is also transported via pipeline	4.5 million (3 million via SUMED)
Bab el-Mendab	between Yemen and Djbouti; links Gulf of Aden to Red Sea	3.3 million
Turkish Straits (Bosporus and Dardanelles)	between European and Asian Turkey; links Black Sea with Aegean and Mediterranean Seas	2.4 million
Panama Canal	connects Caribbean Sea with Pacific Ocean	.5 million

Source: U.S. Department of Energy, Energy Information Administration, "World of Oil Transit Chokepoints," January 2008

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a world in which energy is relatively inexpensive. In places where energy prices are already unaffordable, governments often bear the burden of subsidizing the price of fuels and electricity. These subsidies dampen the demand response to price increases and place economic pressure on government budgets.

The IEA estimates that industry and governments will need to invest $22 trillion between now and 2030 to meet the forecast energy demand. That high figure does not take into consideration the investment necessary to shift the global energy system from its current state to a lower carbon alternative. The inability to access lowest cost reserves combined with new demands for materials and labor has substantially increased project development costs. New capacity, whether from conventional oil and natural gas, coal, nuclear power, pipeline and transmission facilities, or a new generation of renewable energy forms with its infrastructure, will require heavy and sustained investment over a long period.

Shifting Geopolitical Dynamics and Outmoded Institutions

Geopolitics constitutes a fourth trend shaping the energy future. Higher prices have caused a resurgence of resource nationalism and the tendency to exert greater state control over the resource base. The severity of restrictions on access to oil and natural gas resources ranges from a complete prohibition on foreign investment, to mandatory partnerships with national energy companies, to demands for a greater share of equity, control, and production-related revenues (sometimes retroactively) for the host government. While sovereign nations have always controlled their resources, the revision of legal and regulatory structures has created an atmosphere of investment uncertainty. Other factors—such as the changing role of geopolitical alliances in forming energy deals; poor governance and political stability issues; threats to facilities, infrastructure, and transit areas; and a greater focus on human rights, environmental degradation, poverty alleviation, and energy equity issues—have emerged as elements of the changing geopolitical landscape affecting energy production, delivery, and use. As a result of these factors and high prices, governments are increasingly concerned about their immediate and long-term energy security.

Global receptivity to U.S. alliances and Western-based institutions has declined in recent years—as a function of both the eroding legitimacy of the United States and the emergence of new global players with different cultures, business practices, foreign policy agendas, and clout. The rules of the road in today's more multipolar world have yet to be written; when they are, the writers will include a new group of global and regional powers.

These changing dynamics call into question the utility, relevance, and effectiveness of existing institutions, many of which are the result of a post–World War II order conceived in a decidedly different environment from the global dynamics we are currently experiencing. The existence and size of today's sovereign wealth funds are allowing strategic resource holders and burgeoning economic powers to self-finance new investments both at home and abroad without the involvement or structures of traditional lending institutions such as the World Bank, International Monetary Fund, and regional development banks; the emergence and desires of growing economic powers such as China, India, and Brazil are challenging traditional notions of free trade and globalization.

The capacities and leverage of existing institutions are also being challenged. Examples include IEA efforts to include major new consumers such as China and India that are not OECD members (a prerequisite for IEA membership), and United Nations (UN) attempts to fashion an equitable and effective climate change plan that incorporates the varied concerns of diverse nations. Similar challenges extend to regional and global treaty organizations now pressed to expand their traditional mandates to increasingly complex and expensive endeavors. The emergence of single focus, voluntary "coalitions of the willing" and nonstate actors, beyond traditional nongovernmental organizations, will further muddy the geopolitical and diplomatic landscape.

Urgent Environmental Concerns

Of all the trends listed so far, growing concern over climate change has the greatest potential to alter fundamentally the future of energy production and use. Fossil fuels have been identified as a major contributor of anthropogenic (human-generated) greenhouse gas emissions into the atmosphere—a key factor in global warming. Scientists state with increasing levels of certainty that atmospheric concentrations of greenhouse gases must be stabilized to avoid the most dangerous impacts of climate change. A key component of policies aimed at mitigating climate change is to slow, stop, and ultimately reverse the growth in greenhouse gas emissions from human activity. A prime target for action is the carbon dioxide emitted by the burning of fossil fuels.

The world relies on fossil fuels for nearly 85 percent of its energy needs. Reducing that dependence will require significant new investment, technology improvements, and massive-scale deployment. A recent IEA study confirmed that even halving global fossil fuel consumption (the goal being discussed among the G–8 leaders for whom the study was written) will require a titanic shift in public policy, changes in consumption behavior, and massive new investment, and will take decades to complete. Transitioning to a low-carbon energy future will require a complete transformation of the energy delivery system upon which the world has relied for a century and movement toward a new, more resilient and sustainable system, but one that is largely theoretical, untested at scale, and expensive. Given the unsustainability of the current system, however, such a transition must inevitably occur, and in many ways, the transformation is already under way.

These trends and challenges are not entirely new. Growing import reliance, increasing energy prices (albeit at lower levels), vulnerable infrastructure, diminishing access to resources, geopolitical tensions, and the environmental impact of energy production and use are phenomena the world has endured for years. Yet until recently, no one issue or combination of issues posed a serious enough concern to warrant sustained policy attention. In the future, this may no longer be the case. The fragility of the current system is akin to a house of cards. A significant shift in one or more of these trends or a precipitous action taken by one or more of the major or emerging players now threatens the overall stability of the entire energy system, making the potential for serious consequences more likely on multiple fronts.

It is against this backdrop that future U.S. and global energy policy—and all of its various facets related to sustainable economic, environmental, and foreign/security policy—must be fashioned.

Energy and Central Asia

Central Asia and its energy are becoming increasingly important in international security. First, Central Asia contains large untapped reserves of oil and gas, located in countries that are not members of the OPEC cartel. Second, new oil and gas will be coming onto the market from these countries in the coming decade, and the routes of delivery are still in negotiation. These delivery routes are the focus of a competition for control over future resources that involves China, Russia, and Europe. Third, several Central Asian states are awash in oil revenues but still face serious governance challenges.

Kazakhstan has the largest share of Caspian oil and is home to Kashagan, the fifth largest oil field in the world—and the largest field outside the Middle East. Kazakhstan's current export output averages 1.2 million barrels per day (bbls/day) and is expected to more than double within the next 10 years. Export levels above 3 million bbls/day, which Kazakhstan envisions, would put it among the top five exporters in the world. In natural gas, Turkmenistan represents a similar opportunity. Under its previous leadership, full information about Turkmen natural gas riches was carefully

Table 1. Natural Gas Production and Proven Reserves, 2007

	Production (billion cubic feet)	Production Rank	Reserves (trillion cubic feet)	Reserves Rank
Central Asia				
Turkmenistan	2.432	11th	94.216	13th
Uzbekistan	2.302	12th	61.603	20th
Kazakhstan	0.985	23d	67.203	17th
Azerbaijan	0.345	<25th	45.132	23d
Rest of the World				
Russia	23.064	1st	1,576.753	1st
United States	19.278	2d	211.085	6th
Canada	6.604	3d	57.550	21st
Iran	3.952	4th	981.748	2d
Norway	3.270	5th	104.567	12th

protected, but Turkmenistan may rank among the top 10 in world natural gas reserves. Kazakhstan, Uzbekistan, and Azerbaijan also have significant natural gas, with reserves ranking 17th, 20th, and 23d, respectively, in the world. Development of all these reserves depends on clear markets and delivery routes—and the latter pose particular challenges for these land-locked states.

Routes of Delivery

The challenge for Central Asia is to export its oil and gas through new routes, moving away from exclusive reliance on Russia. At present, only one gas and three oil pipelines offer export routes that do not cross Russian territory. Only one line has the added advantage of requiring no transit states: the small-capacity, relatively new Kazakhstan-China oil pipeline. The Baku-Supsa oil pipeline also has relatively small capacity, but has operated successfully for the longest period of time. The Baku-Tbilisi-Ceyhan (BTC) pipeline is longer and has a larger capacity (1 million bbls/day). To date, the oil is from Azerbaijan, but the pipeline may in the future include oil from Kazakhstan. The Baku-Tbilisi-Erzerum natural gas pipeline currently has a capacity of 8.8 billion cubic meters per year (bcm/year), expandable to 20 bcm/year. Continued successful operation of these lines is critical to confidence of investors in oil and gas in the region, and Kazakhstan and Turkmenistan are seeking investors.

Kazakhstan's oil routes. Kazakhstan's President Nursultan Nazarbayev maintains that it is in his country's national interest to export energy resources in all four directions of the compass. Actual export patterns, however, demonstrate that Russia is a transit country for more than 80 percent of Kazakhstan's oil exports. In 2007, Kazakhstan exported 34 percent using Russian rail and pipelines, and another 52 percent using the Caspian Pipeline Consortium (CPC), a privately owned pipeline that runs across Russian territory (the Russian government is one of several owners). The likely doubling of Kazakhstan's exports within 10 years has caused great competition for future export routes. Kazakhstan is developing a system that will commit it to the BTC pipeline for the future. This project, the Kazakhstan Caspian Transportation System (KCTS), would connect onshore oil fields via pipeline to an Aktau port, from which 500,000 bbls/day would be barged to the BTC pipeline. KCTS would serve U.S. interests in keeping the BTC full even as Azerbaijan's oil declines, in strengthening Kazakhstan's economic ties to the West, and in giving Kazakhstan more independence from Moscow in transit.

U.S. Coast Guard (Michael Anderson)

Canadian ship *Louis S. St-Laurent* maneuvers to moor up with USCG *Healy* during cooperative science mission in Arctic Ocean

But the KCTS—which would rely on the security of Azerbaijan, Georgia, and Turkey as transit states—is not Kazakhstan's only option. For many years, Iran has accepted Kazakh oil shipments, used that oil in its northern cities, and then exported an equivalent amount of its own oil under the Kazakh flag into the Gulf. This is called an *oil swap* and helps Iran meet its domestic needs and circumvent embargoes of its oil. Approximately 6 percent of Kazakhstan's exports traveled through Iran in 2007. Iran's swap capacity was expanded in 2004 to 150,000 bbls/day. Iran could expand capacity to accommodate 500,000 bbls/day, but demand for that route—except during periods of regional conflict—has not been sufficient to justify expansion. A southern pipeline route through Iran would be direct and relatively inexpensive, but the United States maintains pressure on Kazakhstan and the oil companies working there to reject that possibility. China may be a more attractive recipient since demand in the Asian markets is expected to grow some 8 million bbls/day in the next 15 years. In 2007, only 7 percent of Kazakhstan's exports went to China. Plans to double the capacity of the Kazakhstan-China pipeline have been put on hold. For reasons both technical and political, the pipeline's current 200,000 bbls/day capacity is not yet fully used, even though Russian companies add almost one-quarter of the daily input.

The one route that seems to be well on its way toward expansion is the one planned by the CPC. Plans are under way to expand from its current 800,000 bbls/day to 1.34 million. Russia has not been an entirely satisfactory transit state—members of the CPC, though it is a private pipeline built for Kazakhstan oil exports, have often been subjected to pressure to include more Russian oil in the pipeline than specified in agreements. Russia has strongly favored expansion of the CPC. Kazakhstan's leadership assumes that it will continue a close energy relationship with Russia, but it remains unclear if Kazakhstan can expand its options without damaging that positive relationship.

Turkmenistan's natural gas routes. Turkmenistan is also being courted by the East and West to the possible detriment of the North. The Central Asia Center pipeline, which carries Turkmen gas to Russia and has been Turkmenistan's longstanding export route, is undergoing expansion to increase its capacity from 60 to 80 bcm by 2012. Two significant new routes that would not cross Russian territory are under consideration. The 1,100-mile Turkmenistan-China natural gas pipeline with a capacity of 30 bcm would originate on the Turkmen-Uzbek border. Crossing 325 miles of Uzbekistan and Kazakhstan, the pipeline would end in northwestern Xinjiang. China is eagerly pursuing this route, and agreements necessary for construction have been signed. The reported timeline, however (coming on line by 2012), is probably unrealistically ambitious. Since actual amounts of natural gas available in Turkmenistan remain unclear, this pipeline is seen as competing with the European-favored Nabucco line. Europe and Azerbaijan have encouraged Turkmenistan to take part in this proposed pipeline, which would transport Azerbaijani and Central Asian gas to Europe. The proposed initial capacity is 13 bcm, expandable to 31 bcm. Success of this pipeline depends on Turkmenistan's participation and the construction of an undersea line across the southern Caspian. Russia has been working to keep Turkmenistan from committing to the Nabucco line.

Governance Challenges to the Region

Central Asian states face two key challenges: their current supply of oil and gas to outside markets can be interrupted by transit states, and the windfall profits in revenues from oil and gas make their weak states vulnerable to corruption, inflation, and increasingly authoritarian rule.

Security of supply. Typically, the United States frames security of supply in terms of the interests of importers. In this region, however, the ability to export freely is a key security concern. The United States throughout the 1990s promoted the idea among these states that *happiness is multiple pipelines*, but the August 2008 military incursions into Georgia have reminded the region that Russia's so-called near abroad remains significantly under Russian influence. The states must balance their economic desire for diversity with their political desire for harmony with Russia. This poses a challenge not only for western-bound supply, but also for eastern-bound supply. Although the Shanghai Cooperation Organization (SCO) has established energy as one of its platforms of cooperation, energy exports are more likely to drive a wedge into the organization than to strengthen it. Russia may attempt to use the SCO to manage China's efforts in Central Asia, but the Central Asian states' interests will be best served by using SCO as an additional access point to China, and an opportunity to involve China in moderating Russia's control over energy exports. In pursuing western routes, the Central Asian states must rely on market-motivated investors rather than states. Political events in the Caucasus have considerably increased the perceived political risk, which is likely to dampen

investor enthusiasm for security-enhancing routes such as Nabucco. Such routes will require high-level political assistance in order to succeed, on a level with the political support received in years past by the BTC pipeline.

Petrostate governance. There is a tendency for governance in petrostates to become worse as revenues rise. In the Caspian area, governance has worsened in recent years. These already weak states are facing hyperinflation, increasing levels of corruption, and persistent lack of transparency in state affairs. States that depend on oil revenues often function as if it is safe to ignore the wishes of the population, since revenues come not from the people but from an industry to which the government has direct access. Central Asian states are energy rich and sparsely populated. Because these states have high reserves per capita, they have more of a cushion than densely populated petrostates. Even so, they are not immune to popular demands. However, the challenge of providing advice and assistance in improving governance will persist and will likely worsen in these states. States awash in revenues can easily resist offers from outside states to extend governance assistance. This makes the energy-rich states of Central Asia particularly vulnerable in the longer term.

Countries external to this region may define their key interest as securing access to the region's resources. More conservatively, they may define their key interest as ensuring that these states themselves are supported in their pursuit of open markets and the free flow of resources. Diversification in any direction helps Central Asia and reduces Russian influence there. However, routes toward China may have the unintended effect of making European countries even more reliant on Russia's energy resources.

Climate Change

Both greenhouse gases (GHGs) and climate change are important elements in global energy security. GHGs include a group that occurs naturally—carbon dioxide (CO_2), methane, nitrous oxide, and ozone—as well as compounds such as chlorofluorocarbons that do not occur in nature. All of these gases have become much more prevalent because of human activity.[1] Buildup of these gases has altered the composition of the Earth's atmosphere, with consequences for the Earth's climate. They are termed *greenhouse gases* because they trap heat in the atmosphere, reflecting that heat back to Earth.

The Threat and Its Estimations

The debate on climate change—whether it is happening, the extent to which it is anthropogenic (human-generated), and the extent to which it is a threat—has persisted in the United States much longer than in other developed nations. In spite of early U.S. leadership in climate science and climate policy negotiations, the United States now lags behind many other developed states in its policies and analysis. The Intergovernmental Panel on Climate Change (IPCC), a UN community of climate scientists who shared the Nobel Prize with Al Gore in 2007, has been united in explaining the risks for many years.

Why do the data—and the predictions—keep changing? Scientific uncertainty about the rate of warming persists because it is difficult to create predictive models about open environmental systems. As the atmosphere warms and nature responds, unanticipated effects continually appear. Early predictive models, for example, did not incorporate the impact of thawing permafrost tundra's release of methane into the atmosphere—a process that is accelerating GHG accumulation dramatically because methane is an especially potent GHG. Nor did the early models properly incorporate the increased growth rates of key tree populations that pull CO_2 out of the air—a process that is slowing upper atmosphere accumulation of greenhouse gases.

Evidence is compelling that nearly 1 degree Celsius warming has already occurred relative to pre-industrial times.[2] Continued acceleration of the rate of warming in recent years is the key source of concern. Many analysts identify 2 degrees as a critical threshold level—an environmental tipping point.[3] Two Washington area think tanks in 2007 collaborated on a careful comparison of available models of likely future climate change patterns and the potential security impacts.[4] Their analysis assumes a best-case scenario of a temperature increase of 1.3 degrees centigrade by 2040. Under such a scenario, they assert that key likely security impacts are increases in global prevalence of insect-borne diseases, coastal inundation (which will affect urban centers and agriculture), and migration caused by crop failure and loss of land. According to their analysis, changes above 2.6 degrees (their medium case scenario) would lead to devastating nonlinear events that may render areas ungovernable—events such as large-scale loss of potable water, spread of overwhelming pandemic disease, up to 15 million additional people being affected by inundation of coastal communities, and substantial changes in marine and ecosystems

due to changes in undersea currents. Troublingly, the IPCC predicts that a warming of more than 4.5 degrees by midcentury is possible.

What we know with a high level of certainty is that the accelerated density of GHGs in the upper atmosphere is causing weather to behave less predictably. But the rate of temperature change and the security risks posed by such change remain uncertain. Even improved models cannot provide policymakers with certainty about the emerging interactive effects. The chances of catastrophic slowing of the thermohaline conveyor belt that warms the northern Atlantic remain unclear; increased threat of hurricanes is believed to be associated with global warming, but this cannot be definitively proven in the near term; and the number of degrees that ocean temperature is likely to rise in the 10-, 50-, and 100-year future is still intensely debated.

In a climate of uncertainty, when action is believed to be expensive and politically unattractive, it is tempting to do nothing. However, climate change belongs to a category of phenomena known as long-wave events: events in which, while the threat remains distant and not entirely understood, political will to act to reduce the threat is absent. Once the risk is evident enough to galvanize political will, the moment in which the risk could have been reduced is past and the task of nations becomes mitigation of consequences. (The unfolding of the HIV/AIDS epidemic in Africa is one example of such a long-wave event.)

The U.S. Role

The problem of climate change poses key security threats for the international political environment as well as for the natural environment. In spite of a lack of U.S. domestic consensus on the proximity of the threat, a clear fact remains. The United States is now and has historically been a lead contributor to the problem. The United States was the world's lead emitter of GHGs every year until 2007, when Chinese emissions surpassed U.S. emissions. Americans still produce more than four times as much carbon per capita as the Chinese, and have been producing high levels of carbon since the Industrial Revolution. Climate change is a key security concern for U.S. allies, so the United States fails to exercise leadership at its own peril. Strategists must consider not only the environmental risks of climate change, but also the international diplomatic risks of not doing enough about it.

The United States must move away from its recent role—internationally perceived as obstructionist—and seek to occupy a meaningful leadership role in international efforts to address the problem. The Kyoto Protocol, which entered force without U.S. signature, will expire in 2012. By that time, a new set of international mechanisms will be put into place for the future. It behooves the United States to be part of that process, preferably in a leadership role. As the United States contemplates its options, three issues should be foremost in the minds of policymakers: the key actors that must be involved in a meaningful solution, the key sectors that must be transformed as a matter of priority, and the key policies that could enable the United States to have the greatest impact on CO_2 abatement at the least cost.

Key State Actors

The key actors in treaty negotiation are states. States make policies and can bind their citizens to international commitments. Since high-altitude pollutants such as CO_2 have an impact globally, UN efforts have focused on involving as many nations as possible. The UN Framework Convention on Climate Change, which contained no binding limits on emissions, was ratified by 192 nations, including the United States, in 1992. It is on the basis of that treaty that all signatory nations use standardized measures of GHG emission and capture, and provide regular reports of energy consumption, emissions, and threats posed by climate change. This regime should be continued, regardless of the future of associated treaties, as it provides common language, a forum, and a useful information base.

However, since fewer than 20 countries are responsible for 80 percent of the world's emissions, it is often contended that including the other 150-plus countries as partners makes effective solutions more difficult to achieve. It is often argued that the number of nations truly needed to solve the problem of climate change is small. Since the current Kyoto Protocol is not signed by the United States and imposes no emissions targets on Brazil, India, and China, it does not touch key historical contributors or crucial rising emissions powers.

The earliest effort to create a new coalition was through the Gleneagles Dialogue on Climate Change, Clean Energy, and Sustainable Development initiated in 2005 under British leadership. The Gleneagles Dialogue has continued since then, and includes the G–8 countries plus China, India, Brazil, Australia, and a handful of other lead emitting states. It also includes international organizations such as the European Union, IEA, and World Bank. The United States

has supported this forum, but it has also promoted a competing White House initiative called the Asia-Pacific Partnership on Clean Development, which includes Australia, China, India, Japan, and South Korea, focusing on voluntary measures to introduce more clean technologies relevant to greenhouse gas reduction. These projects to date have been partial fixes, ones that neither satisfy allies who believe the threat to be imminent, nor offer targets for reduction. There has also been substantial competition for who will be included, and how leadership and monitoring of progress will be achieved.

Key Actors within the States

Effective climate policy, domestic and international, will rely on the successful interaction of several communities. Domestic laws must lead: governments must be involved in setting policies and laws that regulate emissions and punish offenders within their territories. Since GHG emissions have historically been regarded as environmental externalities, their cost has not been incorporated into production of goods and services. Governments must create the incentives necessary to internalize these externalities. Industry must be closely involved to ensure that efforts to reduce emissions are undertaken in ways that encourage least-cost approaches and maximize innovation, the better to meet ambitious abatement goals. States, such as California, exercising leadership in state-based legislation on emissions should be encouraged, since their efforts provide laboratories to test potential future policies. However, at the present moment, the Federal Government is challenging the right of states to set such standards. Finally, the nongovernmental sector, including think tanks and foundations, must be involved to provide ongoing critique of the efforts and visions of the future in this area. Climate change is a highly complex phenomenon, not only in terms of open environmental systems, but also in terms of the economic, scientific, and policy interests and equities involved.

Key Sectors

In the same way that there are key nations, there are also key sectors that must be engaged if emissions reductions are to be meaningful. Analysis consistently suggests that these sectors are power, the building sector (often combined with power in analysis), industry (especially cement and steel), transport, and land use and agriculture. According to World Resources Institute, electricity and heat account for 24.6 percent of world GHG emissions, transportation constitutes 13.5 percent, industry 13.8 percent, deforestation 18.2 percent, and agricultural processes 13.5 percent. Complete GHG abatement policies will set clear guidelines and priorities for each of these sectors, which should be engaged in the development of least-cost policies. But the sectors must receive clear signals that regulation of carbon emissions is imminent and a serious policy priority.

Key Policies

The most widely recognized approach to reducing carbon emissions remains establishing a cap on them, combined with ensuring a functioning and regulated market for emissions permits. In 2008, both Presidential candidates endorsed such systems for the United States. Since these programs are mandated under the Kyoto Protocol, a number of signatory states have years of experience in creating and regulating such markets. The United States should learn from their best practices, complementing its own experience in other air quality cap-and-trade systems such as the United States Sulfur Dioxide program. The United States should also seek to retain its historic role as a leader in technological innovation, which can only occur if legislation presses for improved efficiency.

The Kyoto Protocol may represent a flawed international approach, but it has established important experience and precedents. The United States should not abandon the negotiations of a follow-on treaty. It may be effective to engage a smaller number of states in a separate agreement, but any "coalition of the willing" approach will be rightly criticized if it does not impose limits and does not offer resources for adaptation and mitigation for poorer nations. Such a separate agreement would ideally incorporate the group of countries responsible for 80 percent of emissions, rather than defaulting to countries with whom it is easiest to reach agreements.

Water Security

Water scarcity is the principal indicator of water security, and it includes both physical and economic water scarcity. *Physical water scarcity* is a situation in which water use for agriculture, industry, and domestic purposes is approaching or exceeding sustainable limits. *Economic water scarcity* is a situation where institutional, infrastructural, or financial limitations prevent populations from gaining access to water, even though there is enough available to meet human demands. Overall, the drivers of physical and economic water scarcity complicate sustainable management of water and create critical observable trends.

Table 2. Global Water Use by Sector (percent)

Region	Agriculture	Industry	Domestic and Residential	Ecosystems
Developing Countries	81	11	8	?
Developed Countries	46	41	13	?
World	70	20	10	?

Source: World Resources Institute, Earth Trends Environmental Database, 2007.

Quantity

Global. Researchers have calculated that, by the year 2025, water scarcity will affect more than 75 percent of the world's population. Currently, 2.8 billion people face some level of water scarcity.[5]

Globally, the United Nations Environment Programme (UNEP) points out that *excessive withdrawals from surface waters and aquifers, industrial pollution, inefficient use, climate change and variability, and natural disasters are major causes of water stress, threatening human well-being and ecological health.*[6]

The anthropogenic competition between agriculture, industry, and households for water is increasing (see table 2). Additionally, water required to sustain essential natural ecosystems is seldom included in global formulas for water usage. Moreover, the complex ecosystem services provided by functioning ecosystems, to include flood regulation, climate moderation, and water purification, are often underappreciated and unprotected.[7] In particular, global climate change is expected to create enormous stress on natural ecosystems and overall water quality and quantity.

Africa. Water security in Africa is tenuous. On the continent, more than 300 million people out of a total population of more than 800 million live with physical and economic water scarcity challenges. These water-scarce conditions exist even though Africa contains one-third of the world's major international river basins and its population uses less than 6 percent of its renewable water resources. The uneven spatial and temporal distribution of Africa's water resources exacerbates many complex regional water issues. On average, African governments spend less than 0.5 percent of their GDP on water resource development. The majority of African farmers depend on rainfall to supply water for crops. Water supplies in cities are comparatively better than in rural areas. In general, Africa needs more integrated approaches to water resource management.

Asia and Oceania. The water security situation in Asia and Oceania is also fragile. Similar to Africa,

AP Images (Jerome Delay)

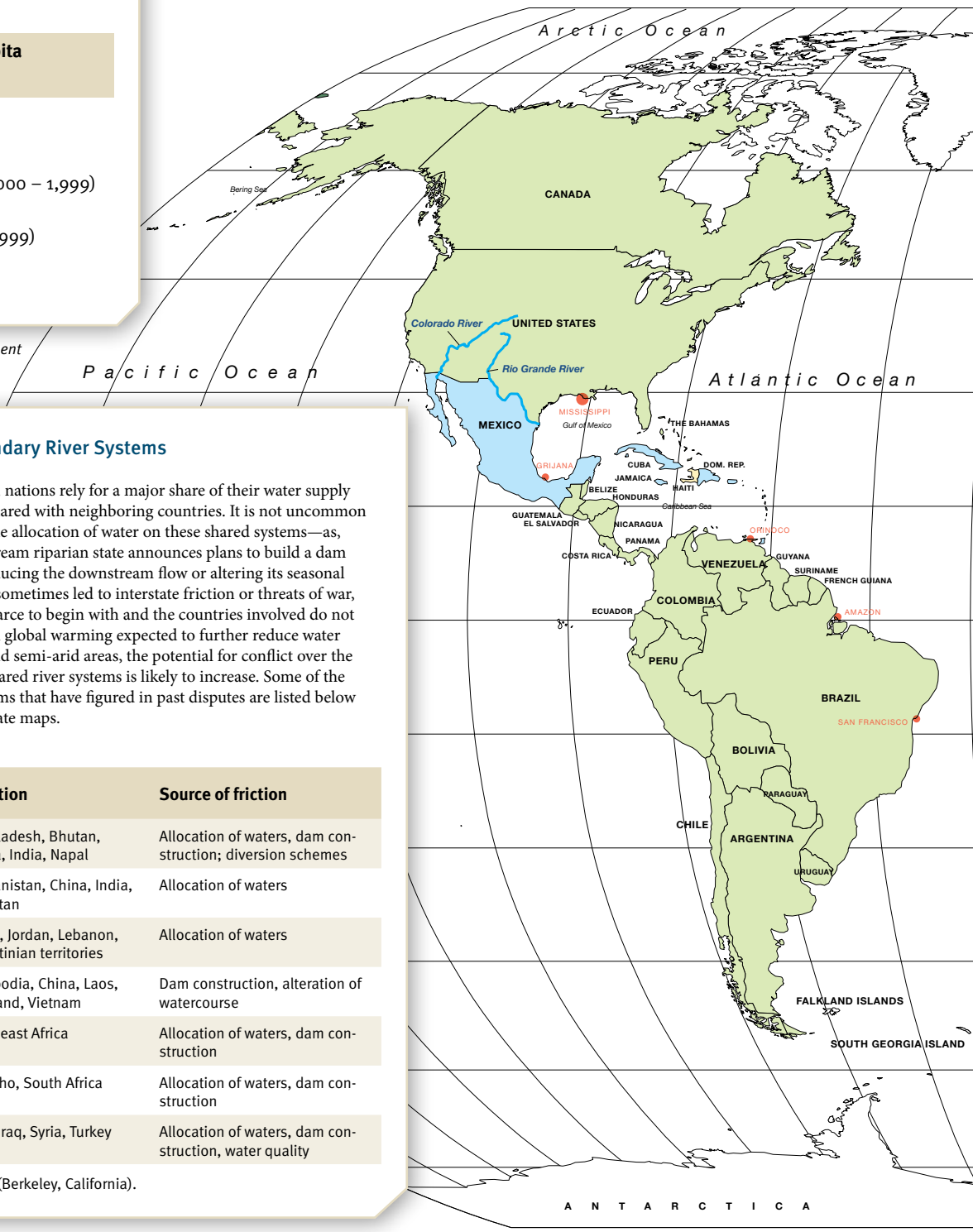
Chinese contractor supervises Liberian workers building sewer system in Monrovia

Water stress by country

Water availability per capita per year (cubic meter):

- severe (<1,000)
- potentially severe (1,000 – 1,999)
- moderate (2,000 – 3,999)
- low (>4,000)

Source: World Bank, *World Development Indicators 2008*.



Contested Trans-boundary River Systems

In many areas of the world, nations rely for a major share of their water supply on river systems that are shared with neighboring countries. It is not uncommon for disputes to arise over the allocation of water on these shared systems—as, for example, when an upstream riparian state announces plans to build a dam on the river, potentially reducing the downstream flow or altering its seasonal cycle. These disputes have sometimes led to interstate friction or threats of war, especially when water is scarce to begin with and the countries involved do not enjoy warm relations. With global warming expected to further reduce water availability in many arid and semi-arid areas, the potential for conflict over the allocation of water from shared river systems is likely to increase. Some of the trans-boundary river systems that have figured in past disputes are listed below and are illustrated in separate maps.

River	Location	Source of friction
Ganges-Bhramaputra	Bangladesh, Bhutan, China, India, Napal	Allocation of waters, dam construction; diversion schemes
Indus	Afghanistan, China, India, Pakistan	Allocation of waters
Jordan	Israel, Jordan, Lebanon, Palestinian territories	Allocation of waters
Mekong	Cambodia, China, Laos, Thailand, Vietnam	Dam construction, alteration of watercourse
Nile	Northeast Africa	Allocation of waters, dam construction
Orange	Lesotho, South Africa	Allocation of waters, dam construction
Tigris-Euphrates	Iran, Iraq, Syria, Turkey	Allocation of waters, dam construction, water quality

Source: International Rivers (Berkeley, California).

River Deltas and Megadeltas: Potential for Inundation and Social Disorder

Many scientists fear that some of the world's most highly populated river deltas are at risk of inundations due to sea-level rise as temperatures increase around the world, heating the oceans and causing them to expand. Global warming is also expected to increase the rate of glacier melt in Greenland and Antarctica, further adding to the rise in global sea levels. Many deltas are at risk due to natural subsidence and a loss of sediment buildup as a result of upstream dam construction. Added together, these risks pose a significant threat to the future habitability of various large deltas around the world. According to one study published in 2006, as many as 1 million people could face severe risk in the Nile, Mekong, and Ganges-Bhramaputra Deltas by 2050, and lesser numbers at some 21 other deltas. In many cases, these people will be forced to abandon homes and move to safer areas inland, often facing hostility of those already occupying these areas.

Degree of Risk Extreme ● High • Medium •

Source: J.P. Ericson et al., "Effective Sea-Level rise and Deltas," *Global Planet Change*, 50 (February 2006), 63–82.

GREENLAND
ICELAND
NORWAY
SWEDEN
FINLAND
RUSSIA
ESTONIA
LATVIA
LITHUANIA
DENMARK
U.K.
RHINE
NETH.
IRELAND
POLAND
BYELARUS
BELGIUM
GERMANY
LUX.
CZECH
SLOVAKIA
UKRAINE
SWITZ.
AUSTRIA
HUNGARY
MOLDOVA
FRANCE
SLOVENIA
CROATIA
ROMANIA
ITALY
BOSNIA
SERBIA
MONTENEGRO
BULGARIA
MACEDONIA
GREECE
ALBANIA
PORTUGAL
SPAIN
SEBOU
MOULOUYA
MOROCCO
Canary Islands
WESTERN SAHARA
ALGERIA
TUNISIA
Mediterranean Sea
Black Sea
Caspian Sea
Aral Sea
KAZAKHSTAN
MONGOLIA
Sea of Okhotsk
NORTH KOREA
SOUTH KOREA
JAPAN
East China Sea
CHINA
TURKEY
GEORGIA
ARMENIA
AZERBAIJAN
UZBEKISTAN
KYRGYZSTAN
TURKMENISTAN
TAJIKISTAN
Indus River
Salween River
Bhramaputra River
Mekong River
Tigris River
Euphrates River
SYRIA
IRAQ
CYPRUS
LEBANON
ISRAEL
JORDAN
NILE
IRAN
AFGHANISTAN
PAKISTAN
Jordan River
KUWAIT
QATAR
U.A.E.
SAUDI ARABIA
OMAN
YEMEN
Red Sea
ERITREA
LIBYA
EGYPT
Nile River
MAURITANIA
SENEGAL
Senegal River
MALI
NIGER
CHAD
SUDAN
GAMBIA
GUINEA BISSAU
GUINEA
BURKINA
GHANA
BENIN
TOGO
NIGERIA
IVORY COAST
SIERRA LEONE
LIBERIA
VOLTA
NIGER
EQUATORIAL GUINEA
SAO TOME & PRINCIPE
CAMEROON
CENTRAL AFRICAN REPUBLIC
ETHIOPIA
DJIBOUTI
SOMALIA
UGANDA
KENYA
ZAIRE
GABON
CONGO
RWANDA
BURUNDI
TANZANIA
ANGOLA
ZAMBIA
NAMIBIA
ZIMBABWE
BOTSWANA
MALAWI
MOZAMBIQUE
MADAGASCAR
Orange River
SWAZILAND
SOUTH AFRICA
LESOTHO
Atlantic Ocean
Indian Ocean
Pacific Ocean
INDUS
SHATT AL ARAB
INDIA
Ganges River
NEPAL
BHUTAN
BANGLADESH
MYANMAR
LAOS
THAILAND
VIETNAM
CAMBODIA
MAHANADI
GODAVARI
KHRISHNA
GANGES-BHRAMAPUTRA
MEKONG
SRI LANKA
TAIWAN
South China Sea
PHILIPPINES
BRUNEI
MALAYSIA
SINGAPORE
INDONESIA
PAPUA NEW GUINEA
NEW CALEDONIA
AUSTRALIA
NEW ZEALAND
Turkey
Euphrates River
Murat River
Lake Van
ATATURK DAM
ILLEGIBLE HIGHLANDS
Khabur River
MOSUL DAM
Great Zab River
Balikh River
Little Zab River
Mosul
Lake Assad
TABQA DAM
Tigris River
Iran
Syria
SAMARRA BARRAGE
Diyala River
Baghdad
Iraq
Hammar Marshes
Basra
Kuwait
Saudi Arabia
Persian Gulf
Tigris-Euphrates River Basin
Alexandria
Cairo
Israel
Egypt
Saudi Arabia
Libya
ASWAN DAM
Lake Nasser
Nile River
Red Sea
Chad
Sudan
Atbara River
Khartoum
KHASHIM AL-GIRBA DAM
JABAL AULIYA DAM
Eritrea
SENNAR DAM
Dinder River
ROSEIRES DAM
Lake Tana
Sudd Swamplands
Blue Nile
Djibouti
Central African Republic
JONGLEI CANAL (PROJECTED)
Ethiopia
Sobat River
White Nile
KABALEGA (MURCHINSON) FALLS
Lake Kyoga
Lake Turkana
Lake Mobutu (Albert)
Somalia
OWEN FALLS
Uganda
Congo
Kenya
Lake Edward
Lake Victoria
Rwanda
Tanzania
Nile River Basin
Sidon
Lebanon
Hasbani River
Damascus
Litani River
Tyre
Baniyas River
Syria
Mediterranean Sea
GOLAN HEIGHTS
NATIONAL WATER CARRIER
Lake Tiberias (Sea of Galilee)
Haifa
Yarmuk River
Israel
PROPOSED SITE OFAL-WAHDA (UNITY DAM)
KING ABDULLAH CANAL
Jordan River
Jordan
Tel Aviv
WEST BANK
Amman
Jerusalem
Gaza
Dead Sea
International borders
Cease-fire / disputed borders
Jordan River Basin
Kabul River
Indus River
China
Kabul
L.O.C.
Peshawar
KASHMIR
Srinigar
Afghanistan
Jhelum River
Ravi River
Amritsar
Lahore
Indus River
Chenab River
Sutlej River
New Delhi
Pakistan
Panjnad River
India
Jaipur
Indus River
Hyderabad
Karachi
Arabian Sea
L.O.C. = Line of Control (cease-fire line between India and Pakistan in Kashmir)
Indus River Basin
Mekong River
China
Myanmar
Hanoi
Laos
Vietnam
Rangoon
Thailand
Bangkok
Cambodia
Phnom Penh
Ho Chi Minh City
Mekong River Basin

the irregular spatial and seasonal distribution of resources in Asia and Oceania complicates regional water security problems. China alone has over 22 percent of the world's population and only 8 percent of the world's fresh water. This fact has contributed to a shortage of drinking water for more than 12 million Chinese. Water shortages are causing rising food prices and forcing migrations in some areas of China. The UNEP points out that in India, *urban water demand is expected to double and industrial demand to triple by 2025*. In the Middle East, *between 1985 and 2005, overall per capita freshwater availability fell from 1,700 to 907 cubic meters/year and based on projected population increases, it is expected to decline to 420 cubic meters/year by the year 2050*.[8] Overall, population and economic growth will increase demands for water supply and irrigation services, and the fact that approximately 60 percent of the region's water flows across international borders further complicates demand challenges.

Europe. Europe's water quantity challenges are not as acute as Africa or Asia/Oceania but do exhibit state-centered problems. Cyprus, Bulgaria, Belgium, Spain, Malta, Republic of Macedonia, Italy, the United Kingdom, and Germany are showing signs of economic water scarcity, and Ukraine and Belarus are exhibiting indications of physical water scarcity. Salt-water intrusion into underground aquifers is beginning to affect water resources in Italy, Spain, Malta, Cyprus, and Turkey. Overall, 14 percent of Europe's population is affected by water scarcity. However, many Europeans are moving to cities and the growing urban populations should have access to adequate water supplies for the near future. In addition, Russian and the Nordic countries have vast supplies of relatively untapped water and could supply fresh water to Europe, China, and Central Asia. In 2000, the European Union made water protection a priority with the implementation of the European Union Water Framework Directive.

North America. Americans and Canadians overall have ample water supplies. The United States and Canada possess approximately 13 percent of the world's renewable fresh water, but water users are not always close to water sources, and some consumers experience periodic shortages. In addition, over the last 20 years, North Americans have lowered their per capita water consumption yet remain the highest per capita water users in the world. However, sections of the western United States are beginning to experience physical water scarcity, and water rationing affects approximately 16 million Americans.[9] Global climate change is expected to exacerbate these and other water deficits. Agricultural irrigation, the major use for water, continues to increase and is competing with cities for limited supplies. In reaction,

UN (Martine Perret)

National park in Timor-Leste protects coral reefs and monsoon rainforest

water restrictions and conservation strategies have become common.[10] The greatest challenge North Americans face in the future regarding water will be the equitable allocation of water resources.

Quality

Global. Human activities often degrade water quality, degraded water quality harms human and ecosystem health, and degraded ecosystems cannot perform indispensable ecosystem services. A circular, deleterious causal relationship begins when water quality declines. Globally, each year in developing states, 3 million people die from water-borne diseases, and the majority are children under the age of 5. The single greatest cause of human illness and death internationally is contaminated water, and agricultural and urban runoffs are major sources of pollution.[11]

Africa. The biggest threat to water quality in Africa is land degradation, which causes economic stress, destroys biodiversity, reduces water availability, and alters river flows, all leading to inferior water quality. In addition, land degradation weakens essential ecosystem services such as flood control and water purification. Soil salinization as a result of inefficient irrigation methods is also degrading water supplies. In Africa, approximately 647,000 square kilometers, or 2.7 percent of its total land area, is impacted by salinization, representing over 26 percent of the world's salinized land area. Poverty also contributes to poor water quality in Africa. Over 72 percent of sub-Saharan Africa's urban population lives in slums where they do not have adequate housing, clean drinking water, or access to sanitation facilities. Overall, about 313 million Africans do not have access to satisfactory sanitation services.

Asia and Oceania. In Asia and Oceania, over the last decade, remarkable progress has been made to increase access to clean drinking water, but some 655 million people in the region (17.6 percent) still do not have access to unpolluted water. Five of the 10 most polluted rivers in the world are found in Asia: the Yangtze, Mekong, Salween, Ganges, and Indus. In India, diarrhea diseases cause over 450,000 deaths annually. In China, 75 percent of drinking water is heavily polluted, and most lakes have nitrogen and phosphorus levels from agricultural chemicals that exceed national water quality standards. Chinese officials have also stated that almost 90 percent of the groundwater in China is contaminated with organic and inorganic pollutants. However, Chinese officials have recently made efforts to reverse these negative trends. Chinese leaders recently invested more than $2.5 billion in small-scale projects intended to increase the number of people with access to clean water by 60 million.

UN (Tim McKulka)

Sudanese refugees wait to draw water from hand pump

Europe. Most Europeans have access to good quality drinking water. In addition, in most parts of Europe water quality is improving due to reductions in contaminant loads from wastewater treatment and industries, as well as declines in industrial and agricultural activities. However, many Europeans still do not have access to clean water and sanitation facilities. The main source of water pollution in Western Europe is agriculture, and over 120 million people in Europe have water access and sanitation problems. Unique challenges in individual countries are still present. Russia has approximately 200,000 tons of materials from chemical weapons buried in over 350 sites. Nevertheless, European governments have responded to these challenges. The 1999 Protocol on Water and Health was designed to protect human health and well-being by better water management.[12] It is the first international agreement specifically designed to create sufficient supplies of clean water and adequate sanitation for all Europeans.

Latin America. Almost 28,000 cubic meters of fresh water are available per capita to Latin Americans each year, a level much higher than the world average. Conversely, freshwater resources are unevenly distributed. As of 2005, almost 50 million Latin Americans still lacked access to clean drinking water and over half (34 million) lived in rural areas. In addition, only 14 percent of sewage was adequately treated, and approximately 127 million people lacked access to sanitation facilities.[13] In the region, for the first time in three decades, water availability has begun to limit the socioeconomic development of some Latin American and Caribbean areas, particularly in the Caribbean.[14] Nevertheless, some improvements to water quality have been made. The percentage of people with access to clean drinking water increased from 82.5 percent in 1990 to 91 percent in 2004. In the same period, urban access to clean water increased from 93 percent to 96 percent, and rural access increased from 60 percent to 73 percent. Also, in 1990 approximately 68 percent of the region's population had access to sanitation services; this percentage improved to over 77 percent in 2004 (85.7 percent urban and 32.3 percent rural).

North America. Although drinking water in North America is the cleanest in the world, some locations in the region have water of lower quality.[15] Agricultural runoff, sewage treatment plant discharges, and hydrologic modifications are the primary sources of water pollution. In the United States, from 1985 to 2000, Americans experienced over 250 disease outbreaks and almost 500,000 cases of waterborne illness from polluted drinking water. Every year more than 3.5 million U.S. citizens get sick from exposure to pollution from sewer spills and overflows. In particular, 42 percent of U.S. shallow streams are in poor environmental condition, and 40 percent of major U.S. estuaries are highly eutrophic as a result of excessive nitrogen enrichment. The excessive nitrogen comes from Mississippi River Basin farms, and the nitrogen flowing into the Gulf of Mexico helps create the world's second largest hypoxic *dead zone* (the largest is in the Baltic Sea).[16] Canadian lakes, rivers, streams, and aquifers are also experiencing similar threats to water quality from increased fertilizer use by farmers, more livestock per acre, and overapplication of manure to farm land.

Some researchers contend that conflicts over freshwater resources may increase the prospects for lower-level armed conflict,[17] and others assert that conflicts over freshwater resources will replace oil as the major cause of international wars.[18] It is not inevitable, however, that these conflicts will lead to violence or remain unresolved.[19] Specifically, new water use technology, more inclusive decision-making, and better alignment of economic signals and incentives could reduce conflict and enhance cooperation globally, regionally, and locally.[20]

Currently, new technology is changing how water is used and reused to meet human economic and environmental needs.[21] Technological advances have also been accompanied by water management reforms such as Integrated Water Resource Management, an eco-based system for addressing water quantity and quality issues. These innovations must also be an adjunct to improvements in water economics, and "getting the price of water right"—that is, pricing water in a way that encourages productive use and conservation without excluding the poor from access to this irreplaceable resource—is crucial. In sum, broad application of new technological, administrative, and economic water resource management tools is urgently needed to avoid violent conflict over scarce water resources while ensuring future populations have high-quality, sustainable water supplies now and tomorrow.

The Department of Defense: Trailblazing New Energy Infrastructure and Fuels

The United States currently faces a number of interconnected energy security problems, including a growing dependence on foreign oil, the effects of rapidly fluctuating oil prices on the economy, and

the effects of U.S. greenhouse gas emissions on the global climate and on U.S. relations with other states. Since the mid-1980s, the Department of Defense (DOD) has played an increasingly important role in helping to solve these problems by reducing its own energy use and carbon emissions, by pioneering new conservation techniques and alternative fuels, and by instituting policies that help those technologies and techniques diffuse to larger audiences.

Using government organizations, and particularly security institutions, to blaze trails for industry is not a new idea. Since the construction of the empire-securing Roman roads two millennia ago, security has been one of the greatest impetuses for new technology and infrastructure projects, and defense establishments have regularly proven able to take on projects too large, risky, or unprofitable for private industry. Over the last century, DOD and affiliated defense organizations have accomplished a number of such goals. The Manhattan Project, which opened the way for nuclear energy, is the best-known project of this type, but the Atlas Missile Project, which paved the way for commercial space, and ARPANET (Advanced Research Projects Agency Network), which provided the foundation for the Internet, are additional examples.

In the current era, DOD's role in trailblazing solutions to energy-related problems is taking two paths: complying with—and exceeding—Federal mandates, and working with other governmental organizations to use its defense laboratories, massive base structures, and networks of contractors to address energy-related problems in ways that other Federal agencies cannot.

Mandated Change

Although energy has been a critical component of the U.S. defense infrastructure for more than a century, DOD's current move toward conservation, low emissions, and alternative fuels began more recently through a series of regulations that seek to reduce Federal energy use and to create markets for new energy conservation techniques and technologies. Since the mid-1980s, DOD has independently pursued more efficient and sustainable use of energy. In 1992, these efforts were reinforced when Congress passed the Energy Policy Act providing guidelines for energy conservation and use of renewable fuels by Federal agencies. In 1999, Executive Order 12123 set a 2005 deadline for Federal organizations to reduce their infrastructure energy consumption by 20 percent from 1985 levels. The Energy Policy Act of 2005 further increased requirements for renewable energy, and in 2007, Executive Order 13423 called for, among other things, a further 30 percent increase in energy efficiency by 2015.

Like many other Federal agencies, DOD has been

U.S. Air Force (Nadine Y. Barclay)

Solar panels covering 140 acres of Nellis Air Force Base provide power to base

successful at meeting mandated requirements. As of 2008, through conservation and technological initiatives, DOD reduced the energy its facilities consumed by 28.5 percent and increased the amount of electricity its installations received from renewable sources to around 10 percent. Because DOD is the single largest energy-using organization in the world, these improvements are significant. However, DOD has gone beyond mandates and taken steps to use its unique assets to exceed congressional requirements. While most Federal institutions can only meet green renewable fuels requirements by buying green energy from the grid, DOD has exceeded requirements by using its laboratories and base facilities to generate their own renewable energy. Moving beyond Federal requirements, on its own initiative, the department set standards that require its installations to obtain 25 percent of their electricity from renewable sources by 2025.

4th Combat Camera Squadron (Rick Sforza)

KC–135 refuels F–22 with new synthetic fuel

DOD research labs and commanders approached their green energy and energy independence requirements with enthusiasm. Currently, the Navy's innovative China Lake base is powered entirely by geothermal energy. The Navy also maintains major solar and wind turbine facilities. Similarly, the Army maintains the world's largest geothermal installation at Fort Polk and is taking significant steps to increase its use of solar power both in the field and at installations such as Schofield Barracks in Hawaii. The Air Force has gone further yet, enforcing a Service-wide energy policy that requires leaders to consider energy as a factor in every decision. So far, the Service has developed renewable energy facilities that remove 3 of its bases from the grid entirely, and 10 more bases have large renewable energy projects under way.

Beyond Mandates: The Alternative Fuels Program

One weakness in congressional energy regulation as applied to DOD is that—albeit for important reasons—fuel used for tactical purposes is excluded from mandates. While absolutely necessary, this exception is unfortunate because the majority of DOD energy purchases go toward aviation fuel used for tactical applications. Thus, by excluding tactical fuel from conservation and alternative fuel mandates, Congress removed around 62 percent of all DOD energy consumption from its program.

In 2006, under the direction of then–Air Force Secretary Michael Wynne, a handful of Air Force leaders took on this problem. At the time, the Air Force was experiencing considerable problems due to the volatility and increasing price of JP–8 (the price of petroleum had fluctuated from below $25 in 2001 to above $60 in 2005). By one estimate, a $10 rise in the price of fuel increases the Service's annual costs by over $600 million. The cost and price swings had serious implications for the Service's ability to carry out its mission.

In an effort to control its vulnerability to the shifting market, the Air Force launched its own alternative aviation fuel initiative. The goal of the program is to gradually insulate the Air Force from swings in the petroleum market by pioneering a domestic market in alternative fuels. Specifically, the program calls for the Air Force, by 2016, to be prepared to acquire 50 percent of its domestic aviation fuel from domestic sources produced in a manner that is greener than fuels produced from conventional petroleum, and to do so at a competitive cost.

The tack the Air Force is taking to meet its ambitious goal is innovative. The plan calls for the Service to quickly certify its fleet to fly on alternative fuels and allow private industry to provide various blends for the Air Force to test. When a firm provides a fuel that meets tactical, green, and economic requirements, it can obtain a long-term contract to supply its product to the Air Force. The plan rests on the idea that a market for alternative fuel does not currently exist—despite estimates that these fuels can be produced at prices below rates charged for petroleum-based fuels—largely because industry is unable to accept the risk of developing fuels that have no existing market.

There is, of course, no way to know in advance precisely what types of fuels the market will provide. The genius of the plan is to set broad requirements and allow the market to meet them. Whether or not the fuels developed will be cheaper than conventional fuels will largely depend on the vicissitudes of the petroleum market and the innovation of private laboratories and industry. Whatever the case, however, any fuels purchased by the Air Force will be greener, domestically produced, and less subject to the price swings of foreign markets than conventional fuels.

The Air Force's alternative fuels initiative has implications that stretch beyond the Services or even the Nation. The department's efforts to create a market for alternative fuels have provoked interest among airlines around the world. Airlines have significant incentives to move to alternative fuels. Like the Air Force, their budgets are sensitive to changes in fuel prices. More than that, however, as concerns about greenhouse gases grow, airlines find themselves pressed by regulatory agencies. Numerous airline leaders have noted that they would like to move to alternative fuels but cannot overcome the financial obstacles to fostering a new market. Thus, by using its power as a government entity to overcome a market failing, DOD is taking a major step toward addressing a global problem.

The Department of Defense is first and foremost concerned with providing for the security of the United States. Where energy is concerned, its first charge will always be to defend the Nation and protect global lines of energy transportation. Yet the energy security problems that the Nation is currently experiencing do not easily lend themselves to direct solutions. Overcoming these problems will require an indirect approach that utilizes U.S. resources in innovative ways. It will require harnessing the imagination and initiative of civilian leaders, military commanders, and defense scientists, inspiring them with the need to overcome what is often described as a collection of the most pressing security concerns the Nation faces today.

Today, the Department of Defense is the largest nonstate economic entity in the world. Its bases and personnel span the globe. DOD contracts provide numerous industries with their major means of support, and, when spread throughout the global economy, its regulations and requirements channel trillions of dollars each year. DOD energy policies have enormous impact on audiences that extend to every corner of the globe. The department's energy initiatives go a long way toward solving many of the world's most serious energy-related problems. **gsa**

NOTES

[1] See Intergovernmental Panel on Climate Change (IPCC) reports. For example, from 1800 to 1992, concentrations of carbon dioxide in the atmosphere increased by more than 25 percent, while methane more than doubled, and nitrous oxide concentrations rose 8 percent. See IPCC, *Climate Change 1992—The Supplementary Report to the IPCC Scientific Assessment* (Cambridge: Cambridge University Press, 1992). Carbon dioxide is the most prevalent of the gases, and in accordance with U.S. policy, all greenhouse gases are measured in million metric tons of carbon-equivalent.

[2] See the Stern Review on the Economics of Climate Change, United Kingdom Treasury, 2006.

[3] See, for example, California Environmental Associates, "Design to Win: Philanthropy's Role in the Fight against Global Warming," August 2007.

[4] Kurt M. Campbell and Richard Weitz, ed., *The Age of Consequences: The Foreign Policy and National Security Implications of Global Climate Change* (Washington, DC: Center for Strategic and International Studies and Center for a New American Security, November 2007).

[5] Ger Bergkamp and Claudia W. Sadoff, "Water in a Sustainable Economy," in *State of the World 2008: Innovations for a Sustainable Economy* (Washington, DC: Worldwatch Institute, 2008), 108.

[6] United Nations Environment Programme (UNEP), *Global Environment Outlook: GEO–4 Environment for Development* (Malta: Progress Press Ltd., 2007), 197.

[7] *Millennium Ecosystem Assessment, Ecosystems and Human Well-Being: Synthesis* (Washington, DC: Island Press, 2005), 6.

[8] UNEP, GEO–4, 264–265.

[9] Jerome C. Glenn and Theodore J. Gordon, *2007 State of the Future* (Washington, DC: American Council of the United Nations University, 2007), 2–45.

[10] UNEP, GEO–4, 198.

[11] Ibid., 116–117.

[12] Glenn and Gordon, 2–45.

[13] UNEP, GEO–4, 244.

[14] Ibid., 242.

[15] Ibid., 262.

[16] UNEP, GEO–4, 262; Marc Ribaudo and Rob Johansson, "Water quality: impacts of agriculture," in *Agricultural Resources and Environmental Indicators*, ed. Keith Wiebe and Noel Gollehon (Washington, DC: Department of Agriculture, Economic Research Service, 2006); Janet Larsen, *Dead Zones Increasing in World's Coastal Waters* (Washington, DC: Earth Policy Institute, 2004), available at <www.earth-policy.org/Updates/Update41.htm>.

[17] Nils P. Gleditsch et al., "Conflicts Over Shared Rivers: Resource Scarcity or Fuzzy Boundaries?" *Political Geography* 25, no. 4 (2006), 361–382; Hans P.W. Toset, Nils P. Gleditsch, and Havard Hegre, "Shared Rivers and Interstate Conflict," *Political Geography* 19 (2000), 971–996; Paul R. Hensel, Sara McLaughlin Mitchell, and Thomas E. Sowers II, "Conflict Management of Riparian Disputes," *Political Geography* 25, no. 4 (2006), 383–411; Kathryn Furlong, Nils P. Gleditsch, and Havard Hegre, "Geographic Opportunity and Neomalthusian Willingness: Boundaries, Shared Rivers, and Conflict," *International Interactions* 32 (2006), 79–108.

[18] Malin Falkenmark, "Freshwaters as a Factor in Strategic Policy and Action," in *Global Resources and International Conflict: Environmental Factors in Strategic Policy and Action*, ed. Arthur H. Westing (New York: Oxford University Press, 1986), 85–113; Peter H. Gleick, "Water and Conflict: Fresh Water Resources and International Security," *International Security* 18, no. 1 (Summer 1993), 79–112; Steve C. Lonergan, "Water Resources and Conflict: Examples from the Middle East," in *Conflict and the Environment*, ed. Nils P. Gleditsch (Dordrecht, Germany: Kluwer, 1997); Michael T. Klare, *Resource Wars: The New Landscape of Global Conflict* (New York: Metropolitan Press, 2001).

[19] Jaroslav Tir and John T. Ackerman, "Politics of Formalized River Cooperation," *Journal of Peace Research*, forthcoming.

[20] Bergkamp and Sadoff, 109, 115–121.

[21] Ibid., 116.

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