Energy Security Concepts for Sustainable Development in Northeast Asia

Recommended Citation

David F. von Hippel, "Energy Security Concepts for Sustainable Development in Northeast Asia", NAPSNet Special Reports, September 01, 2014, https://nautilus.org/napsnet/napsnet-specia--reports/energy-security-concepts-for-sustainable-development-in-northeast-asia-2/

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18 March 2014

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This paper was prepared with support from the Hanyang University Energy Security and Governance (EGS) Center as EGS Working Paper Number 2014-06, available as http://www.egskorea.org/common/download.asp?downfile=Working_Paper_2014_60.pdf&path=board

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1 Introduction

"Energy Security" has typically, to those involved in making energy policy, meant mostly securing access to oil and other fossil fuels. With increasingly global, diverse energy markets, however, and increasingly transnational problems resulting from energy transformation and use, old energy security rationales are less salient, and other issues, including climate change and other environmental, economic, and international considerations, are becoming increasingly important. This ongoing evolution in the implicit and explicit meaning of energy security was accelerated markedly by the tragic Fukushima accident in March of 2011, when the Sendai earthquake triggered a tsunami that, in turn, triggered a series of events that ultimately lead to the effective destruction of the Fukushima Dai-ichi nuclear power plant units number 1 through 4, accompanied by radiation releases in amounts not seen from a reactor accident since the Chernobyl accident in the Ukraine in 1987.

Another recent set of considerations regarding energy security in many areas of the world, including Northeast Asia, is the burgeoning interest in unconventional forms of oil and particularly gas extraction, specifically, the use of hydraulic fracturing ("fracking") and advanced drilling technologies to release gas held in rock formations. Fracking is widely practiced in North America, and has led to a revolution in oil and gas production there, with a precipitous drop in gas prices. This situation in turn has led to great interest in the prospects of vastly expanded gas use in Asia, whether from sources in the region, such as gas-bearing shales in China, or whether from imports into Asia from new liquefied natural gas (LNG) plants in North America[1], and projections that North America will play an increasing role in global energy markets.[2]

That the Fukushima accident happened in Japan is particularly significant, as a key rationale for Japan's acquisition and development of an advanced nuclear power program had been to improve the nation's "energy security", based on a complex set of energy security–related policy decisions dating back decades. That these decisions put Japan on the path toward Fukushima offers a salient example of why a broader view of energy security is in order. In reaction to the oil price shocks of the 1970s, Japan made a choice to focus on nuclear energy as a key to reducing its dependence on foreign petroleum and other fuels, as well as its exposure to the volatility of the oil market. This energy security policy, together with its subsequent nuclear energy technology and siting choices and the close relationship between regulators and regulated companies in the nuclear industry, all helped to set the stage for the unfortunate combination of natural disaster and technological/institutional failure. With the March 2011 accident as a riveting cautionary example, policymakers around Northeast Asia and beyond—including in China—are realizing that there are multiple facets to energy security that must be considered. The impacts of the Fukushima accident on the operation of the energy sector and energy planning in Japan have been pervasive, leading not only to the (at least temporary) cessation of generation at all of the nation's nuclear power plants, but to a national re-thinking of Japan's energy future. The impacts of Fukushima on energy policy have not, however, been limited to Japan. Nations as far away as Germany significantly changed their plans for future energy development in part due to consideration of the lessons of Fukushima, and in reaction to civil society reactions galvanized by the Fukushima accident.[3] In Northeast Asia, the ROK and China were spurred by Fukushima to take a second look at safety measures at their nuclear power plants, resulting in at least some delay in what has been a rapidly accelerating deployment of nuclear power plants in China. One can argue that, at least implicitly, the meaning of energy security in Northeast Asia is shifting even more post-Fukushima.

In a similar way, the large-scale production of shale gas in Northeast Asia or large-scale, presumably low-cost imports of shale gas from outside the region or from further away in the Pacific (for example, Australia) will have their own energy security impacts beyond traditional energy security definitions. For example, scientific opinion remains divided as to whether production of shale gas releases sufficient methane to render greenhouse gas emissions benefits of gas over competitor fuels, such as coal, much less substantial. What happens if Northeast Asia pins its hopes on LNG from America, but political forces in America conspire to limit gas exports? Would the constructions of large LNG import and export facilities effectively "lock in" gas use for decades, thereby slowing advances in deployment of renewable energy sources? Will consumption of gas in America expand sufficiently to take up the increasing supplies of gas from shale sources?[4]

Finally, there is a significant link between the Fukushima accident and developments in Northeast Asia's natural gas markets. With all of Japan's reactors, as of this writing, shut down for safety reviews and retrofits, Japan's imports of natural gas for electricity generation have grown enormously, affecting supplies and prices of LNG in the region.[5]

A broader meaning of energy security is needed to address the range of issues that affect, and are affected by, energy policy decisions and emerging issues such as those above, along with a workable framework for analysis of which future energy choices are likely to yield greater energy security in a broader, more comprehensive sense.

Work done in the late 1990s as a part of the Nautilus Institute's "Pacific Asia Regional Energy Security" (PARES) project developed a broader definition of energy security, and described an initial analytical framework designed to help to compare the energy security characteristics—both positive and negative—of different quantitative energy paths as developed using quantitative energy planning software, as well as qualitative analytical tools. This framework has been elaborated and adapted over the years for use in a variety of countries and contexts, many of them in East Asia[6]. The remainder of this paper provides background on the definition of energy security, along with the broader definition proposed and used by the authors, a review of the concept of "sustainability" as it applies to energy planning, and a presentation of a framework for analysis of the relative energy security costs and benefits of different energy sector decisions[7].

2 Energy Security

Many of the existing definitions of energy security begin, and usually end, with a focus on maintaining energy supplies—and particularly supplies of oil[8]. This supply-based focus has as its cornerstones reducing vulnerability to foreign threats or pressure on oil supplies, preventing a supply crisis from occurring, and minimizing the economic and military impact of a supply crisis once it has occurred. Current national and international energy policies, however, have been facing many new challenges, and have at their disposal new tools that need to be considered as key components of new energy security concepts.

Why has oil been the primary focus of energy security policy? There are good reasons behind this particular focus. First, oil is still the dominant fuel (~37%) in global primary energy supply (as of 2011[9]), provides the vast majority of transport fuel for the industrialized world, and is also the primary energy source for the world's militaries. Second, the Middle East, where the largest oil reserves exist, is still one of the most unstable areas in the world; though the universe of oil suppliers has broadened significantly in recent decades, the market has also tightened, meaning that any significant disruption in supplies from a major oil supplier has the potential to roil oil markets. Third, and related to the second reason, oil supply and prices are often influenced by political decisions of oil suppliers and buyers. Fourth, world economic conditions, as aptly demonstrated in the years leading up to the recent global recession, are still vulnerable to oil price volatility, since there are certain key sectors that are heavily dependent on oil (such as transportation, petrochemicals, agriculture, and others) with limited short-term alternatives for substitution. Fifth, the key words here are "volatility" and "instability". Although globalization has improved the transparency of the oil market, oil prices remain to some extent at the mercy of speculators, as well as being affected by fluctuations in currency values, subject to manipulation by oil suppliers and, of course, sensitive to the forces of market supply and demand[10]. This has been dramatically shown in the last five years, with oil prices roughly doubling between mid-2007 and mid-2008 to well over

100 US dollars per barrel by, followed by a 75 percent decline in price by early 2009, followed by a return to mid-2007 price levels by mid-2009, and a further rise to the $85 to $100/bbl level by mid-2011, remaining in that range through the time of this writing[11].

Few works have made a serious attempt to clarify the concept of energy security. One attempt at a clear definition of energy security was that of the Working Group on Asian Energy and Security at the Massachusetts Institute of Technology (MIT)'s Center for International Studies. The MIT Working Group defined three distinct goals of energy security[12]:

1. reducing vulnerability to foreign threats or pressure,
2. preventing a supply crisis from occurring, and
3. minimizing the economic and military impact of a supply crisis once it has occurred.

These goals implicitly assume that an "oil supply crisis" is the central focus of energy security policy. In essence, the central tenets of conventional energy security policy are: 1) reduction of threats to oil supply, and 2) operating in a mode of crisis management. These tenets constitute a shared view among key energy policy-makers in both the East and West.

Analyzing the conventional (oil supply-focused) view of the energy security concept in terms of the three key components of security policy enumerated above yields the following:

What Elements of the Economy and Society Should Energy Security Enhancements Protect?

As has already been stated, oil supply has been the dominant "what" to be protected in conventional energy security thinking. In developed countries and most developing countries, oil remains the dominant fuel in the total primary energy supply picture, at least with regards to imports. Oil is also the most strategic fuel, in particular for the transport and military sectors. Therefore, securing oil is an essential condition for a nation's security and economic welfare. In addition to physical supply, stable oil prices are also a paramount condition and concern for security and economic welfare, as has been demonstrated by the social and political response, particularly in nations where oil is not taxed heavily, each time oil prices rise significantly[13].

What Risks Should Energy Policies Protect a Society from?

Sudden oil supply disruption (which can be caused by a variety of circumstances such as a supplier's embargo, accidents, bad weather or other natural disasters) is the foremost risk that a nation or an economy is to be protected from in the conventional view of energy security. Long-term oil resource depletion periodically—and with increasing frequency—receives serious consideration, but is currently not at the center of the supply debate, as constraints in oil supply capacity are the chief worry in the near-term (for example, the next 2 to 5 years).

Similar to sudden oil supply disruption, sudden price shock is a critical risk to be protected from. In fact, during the two "energy crises" in the l970s, physical shortage of oil supply was less important than the price shock. Thus, keeping oil prices stable is a principal component of conventional energy security policy. Price shocks and sudden supply disruptions are heavily, but not 100 percent, correlated. Price shocks could happen at any time with merely the *expectation* of a supply shortage, which in turn could be brought on by various events or perceived risks, including the risk of international political conflict or disruption. A 2008 short-term rise in oil prices, for example, was blamed in part on concerns about possible supply disruptions of conflict after Iran's test-firing of missiles.[14]

How to Protect Society from Energy Security Risks?

Prevention is the best way to minimize the risk. Fostering friendly diplomatic relations with oil supplier countries (such as U.S. relations with Saudi Arabia over most of the 1980s through 2001, and Chinese relations with Sudan[15]), while at the same time shifting away from heavy dependence on oil are the major policy measures of large oil consuming countries. For example, promotion of nuclear power generation and increased utilization of non-oil fossil fuels (coal and natural gas) have been primary vehicles for reducing oil dependency in countries such as Japan and the Republic of Korea. Many countries have invested large sums of money in research and development (R&D) to move away from oil, including investments in alternative energy technologies such as coal liquefaction, coal gasification, and solar thermal power generation, as well as advanced nuclear fuel cycles. Such R&D programs have met with both success and failure. Some of the alternative energy sources, such as wind and geothermal, have had commercial success. Success in deploying alternative energy technologies, however, at least at a level sufficient to have a significant impact on fossil energy use, to date seems to have depended largely on local and national political and economic support, and of course on favorable availability of renewable resources.

Despite the best efforts to prevent a supply crisis, one can still occur. In this instance, energy security thinking dictates the application of policies designed to minimize the impact of the crisis on national security and economic welfare. Strategic stockpiles, often owned and managed, at least in part, by the government, are one of the most effective ways to deal with a supply disruption crisis and/or price shock[16]. Although stockpiles have rarely been used in the case of shortages, they are considered essential to minimize price impact during a crisis situation. U.S. Strategic Petroleum Reserves were tapped to reassure oil markets in 1990/1991, prior to and during the first Gulf War, in 2005, when Hurricane Katrina resulted in the shutting down of considerable Gulf of Mexico oil and gas production, and in 2011 when unrest in Libya affected international oil supplies[17]. Other crisis management measures include both diplomatic and military actions. Although military actions are typically carried out only as a last resort, the first Gulf War is an example of a joint military venture designed (in large part) to protect oil supply.

2.1 Emerging Paradigm: Toward Comprehensive Energy Security

National energy policies in the new century are facing challenges on multiple fronts. The substance of these challenges needs to be incorporated into a new concept of energy security. It is important to note here that energy security policies in various countries are now showing trends of "convergence" rather than "divergence", despite the basic differences in national situations and approaches to energy security as discussed above. This convergence does not eliminate regional and national differences, of course, but it is an encouraging sign with regard to minimizing the potential conflict that may come from differences in energy security approaches, as reflected in the different energy security policies that countries adopt.

The following is a quick review of the major challenges that will help to bring about a new energy security concept.

Environment

Perhaps the most serious challenge to traditional (supply-security-oriented) energy policy thinking is the need to protect the environment. If environmental problems are to be solved, energy policies will have to be reformulated. International environmental problems present the greatest impetus for change. Two international environmental problems inherently linked with energy consumption, and in particular, fossil fuel consumption, are acid rain—still a problem although the advent of scrubbers on many new power plants have helped[18]— and global climate change.[19] Trans-boundary air pollution (acid rain) has been an international issue in Europe, and North America, and continues to develop as an issue in East Asia. Trans-boundary air pollution even has trans-Pacific elements that have only in the last 15 or so years started to be fully appreciated.[20]

Global climate change poses an even broader and more complex challenge to energy policy than trans-boundary air pollution. Although there are relatively straightforward (though often not cheap) technical solutions—including flue gas desulfurization devices—to significantly reduce the emissions of acid rain precursors, greenhouse gas emissions cannot so easily be abated by “end-of-pipe” methods, despite the touted promise of “carbon capture and sequestration”. A comprehensive approach toward greenhouse gas (GHG) emissions reduction is necessary. The climate change issue also brings in a much longer time perspective than business and governments are used to dealing with. Moreover, particularly with the consideration of much broader and different technologies for fossil fuels extraction and trade, climate-related issues are becoming more complex in a political sense. For example, as Mongolia vastly expands its coal exports to China, which country bears responsibility for the additional carbon dioxide emissions involved? Similarly, if LNG is exported to Asia from North America, and displaces coal use in Asia, Asian GHG emissions might be somewhat reduced, but methane leaks and the fuels required to compress and transport LNG may substantially offset those savings, albeit in other locations. How should those tradeoffs be taken into account, particularly to the extent that energy security analysis and planning is typically national, rather than regional or global? Other environmental issues, such as radioactive waste management, also require long-term perspectives. In sum, environmental issues must be incorporated into the energy security concept[21].

Technology

Risks associated with development and deployment of advanced technologies challenge current energy policy thinking. Conventional thinking understates such risks and tends to see them as short-term, not long-term. Risks include nuclear accidents such as those at Three Mile Island in the United States, Chernobyl in the former Soviet Union, and, of course, Fukushima, natural disasters with impacts on energy infrastructure (such as Hurricane Katrina’s impacts on oil and gas production, or the impact of the July, 2007 earthquake near Niigata, Japan on the seven-unit Kashiwazaki-Kariwa nuclear plant), or the failure of R&D efforts—such as the synthetic fuel, fast breeder reactor, and solar thermal programs in the U.S. during the 1970s and 1980s—to perform as expected. Technological risks can be transnational; the accident at Chernobyl is a good example of an incident with decidedly transnational implications. Also, markets for advanced technologies are becoming global, and as a result, technological risks can be exported. Nuclear technology, for example, is being exported to a number of countries, most notably China and India, but also including Vietnam and the United Arab Emirates, and potentially including Indonesia, Thailand, Pakistan, and Malaysia.[22] Similarly, if unconventional natural gas rapidly becomes the fuel of choice, then health and related concerns hamper gas development, nations banking on natural gas imports may from such sources find themselves in a technological bind.[23] As the world moves rapidly moving toward a “technology intensive” energy society, a new energy security concept must address the various domestic and international risks associated with advanced technologies.

Demand-Side Management

Another challenge to energy policy thinking is the need to address energy demand itself. Conventional energy policy seeks to assure supply while assuming that demand is given. This notion has been changing since the mid-1980s, when the concept of demand side management (DSM) was first incorporated into energy planning. Now, management of energy demand is almost on an equal footing with management of supply, in many nations, and is recognized as a key tool in the achievement of climate change mitigation and other environmental goals.

There are risks associated with policies designed to affect energy demand, just as with policies designed to address energy supply. Conventional energy policy thinking has tended to underestimate demand-side risks. Risks stem from, for example, demand surges (periods of peak demand in response to extreme conditions). These are a serious concern for utility management, but managing peak demand is not easy, particularly given uncertainties in consumer behavior. Long recessions are another major concern for energy industry managers, since recession means large supply capacity surpluses. Uncertainty (risk) in the demand side of the total energy picture is therefore a key component of a new concept of energy security.

Social-Cultural Factors

Not in my backyard (NIMBY) and environmental justice concerns are becoming global phenomena, making it increasingly difficult, time-consuming, and costly to site "nuisance facilities" such as large power plants, waste treatment and disposal facilities. Although people may recognize the need for such facilities, many communities prefer not to have the actual plants in their neighborhood. Opposition to plant siting has elevated the importance of local politics in energy policy planning. Who has the right to decide to locate such facilities? Who has the right to refuse? Can any rational policymaking process satisfy all stakeholders? These questions pose not only a challenge to energy security policy, but also to democratic institutions themselves. NIMBY epitomizes the "social and cultural" risks that need to be recognized in policymaking agendas. Various social-cultural factors present a challenge to current energy policy thinking. With the advent of more international energy trade, for example, in natural gas, these social-cultural factors have the potential to be of concern both within nations and across the globe, and everywhere in between. If US states refuse or delay permits to build LNG export facilities, for example, nations in Asia looking to import less expensive American gas may find themselves waiting much longer than anticipated for new supplies to materialize, and simultaneously suffering the economic and other consequences of relying on conventional coal and LNG.

There are "enviro-economic" concerns inherent in some energy policies as well. It is often the case that the party who bears the risk should get economic compensation. Salient recent examples include discussions of compensation for communities hosting (or potentially hosting) facilities for nuclear spent fuel management. How much compensation is reasonable, and who should be qualified to receive such compensation? These issues are often difficult to decide.

Public confidence is also a social factor influencing energy policy. Once lost, public confidence is hard to recover. "Public confidence", however, should be distinguished from "public acceptance", which is commonly used in traditional energy policy thinking. Promoting public acceptance is often the object of public relations campaigns. Promoting public confidence involves more than public relations. Examples of efforts to increase public confidence in energy decisions include, for example, efforts by the U.S. Department of Energy (DOE) to increase information disclosure, as well as effort by the Japanese governments to make the nuclear policymaking process more transparent (for instance by holding roundtable discussions), though a Commission tasked with reviewing the Fukushima accident found continuing problems with transparency in decisionmaking by the nuclear utilities and nuclear establishment in Japan[24]. Accounting for social-cultural factors and increasing public confidence in energy choices are therefore central components of a new concept of energy security.

International Relations--Military

New dimensions in international relations and new military risks are challenging traditional energy policy-making. The end of the Cold War has brought in its wake a new level of uncertainty in international politics. Although the risk of a world war has been drastically reduced, the threat of regional conflicts has increased, as demonstrated by, just to name just a few, ongoing conflicts in the Middle East, the Balkans, the former Soviet states of the Caucasus and the Ukraine, and, more recently, heated rhetoric in long-simmering territorial disputes in East Asia, including between China and Japan[25], China and India,[26] and other Asian nations. New LNG shipments from unconventional gas will need to move through trade routes secured by the militaries of the United States and others. The international politics of plutonium fuel cycle development, with its associated risks of nuclear terrorism and proliferation remains an area where energy security and military security issues meet. One of the issues under discussion between the United States and the Republic of Korea as the two parties seek to renegotiate their nuclear energy cooperation agreement is the ROK's desire to pursue the plutonium fuel cycle through a variant of reprocessing known as "pyroprocessing", which has ramifications for, among other issues, reaching international agreement with the Democratic People's Republic of Korea over the latter's nuclear weapons program[27]. The brave new world of post-Cold War international relations must be accounted for in a new, comprehensive concept of energy security.

2.2 Comprehensive Concept of Energy Security

The above five key components—environment, technology, demand side management, social and cultural factors, and post-Cold War international relations—are central additions to the traditional supply-side point of view in a Comprehensive Energy Security Concept.

A nation-state is energy secure to the degree that fuel and energy services are available to ensure: a) survival of the nation, b) protection of national welfare, and c) minimization of risks associated with supply and use of fuel and energy services. The six dimensions of energy security include energy supply, economic, technological, environmental, social and cultural, and military/security dimensions. Energy policies must address the domestic and international (regional and global) implications of each of these dimensions.

What distinguishes this energy security definition is its emphasis on the imperative to consider extra-territorial implications of the provision of energy and energy services while recognizing the complexity of implementing national energy security policies and measuring national energy security. The definition is also designed to include emerging concepts of environmental security, which include the effects of the state of the environment on human security and military security, and the effects of security institutions on the environment and on prospects for international environmental cooperation[28].

2.3 Sustainability and Energy Planning

As environmental and other considerations, apart from energy supply, play increasing roles in the development of energy policies both in industrialized and developing nations, the concepts of sustainability and sustainable development are becoming intimately entwined with the goals of energy policy. An understanding of what these concepts mean, and what they may mean for energy security, is therefore helpful.

Sustainability

A strict definition of sustainability is as follows[29]: "A sustainable process or condition is one that can be maintained indefinitely without progressive diminution of valued qualities inside or outside the system in which the process operates or the condition prevails." Further, from a biophysical perspective, sustainability means "maintaining or improving the life support systems of earth." Due to recent "intense and pervasive" human activity, "biophysical sustainability must, therefore, mean the sustainability of the biosphere minus humanity. Humanity's role has to be considered separately as economic or social sustainability. Likewise, sustainable development should mean both sustainability of the biophysical medium or environment and sustainability of human development, with the latter sustaining the former."

Sustainable Development

As defined in the report of the 1987 World Commission on Environment and Development, sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Other recent definitions of this concept have spanned the range from "Corporate Sustainability", meaning "responsible environmental and labor management practices" in business, to a definition of sustainable development that includes "a vast, diverse set of goals, such as poverty elimination and fair and transparent governance"[30].

As with ensuring energy security, pursuing sustainable development includes addressing numerous, often conflicting issues, including[31] human poverty, impoverishment of the environment, the possibility of wars on all different spatial scales, oppression of human rights, and wastage of human potential. The forces driving these issues—which are also forces affecting energy security—include excessive population growth, poor distribution of consumption and investment, misuse of technology, corruption and mismanagement, and lack of knowledge/power on the part of victims.

Though sustainable development will arguably never have a single, clear definition, as "sustainability" depends on what is being sustained, and "development" depends on the desired outcomes, it is clear that achieving sustainable development, like enhancing energy security, depends on addressing a variety of economic, social, and environmental goals—and these goals are often in conflict.

Achieving sustainable development, as with improving energy security, is hampered by uncertainty, often unavoidable, in a host of areas, including lack of knowledge about the state of the world, including the environment, both today and in the past, the need to incorporate consideration of the very different time scales for economic, social, biological, and geological processes (for example), uncertainty as to how human actions or interventions do or will affect the biosphere, including the linearity or non-linearity of response of different environmental elements to different stresses and remedies, and uncertainties as to human (social and economic) responses to the intended "sustainable development" measures undertaken.

In addition to these impediments, there are sustainable development/energy security challenges related to actually accomplishing the goals of sustainable development policies. For example, Smil[32] underlines some of the formidable challenges involved in replacing fossil fuels with renewable fuels as a part of a move toward sustainable development, including the scale of the shift in fuel use required, the relative energy and power densities of fossil versus renewable fuels and power systems, the intermittency of many renewable fuels, and the geographical distribution of renewable resources relative to where fossil fuels are currently used. These challenges may ultimately mean that a truly sustainable economy must actually produce less in the way of goods and services than our global economy does today, rather than using alternative resources to sustain or expand the existing level of output.

The International Atomic Energy Agency (IAEA), in cooperation with other agencies, has assembled a list of indicators for sustainable energy development[33]. The IAEA list starts with a consideration of the economic, environmental, social, and institutional dimensions of sustainable development, and develops 30 different indicators, most with several sub-components. Many of these indicators touch upon the issues and perspectives noted above, and many are reflected in the discussion of methods and parameters for evaluating energy security that are presented later in this Working Paper.

The World Energy Council has outlined three dimensions of "energy sustainability", energy security, social equity, and environmental impact mitigation, which it defines as follows:[34]

- *"Energy security*: For both net energy importers and exporters, this refers to the effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of participating energy companies to meet current and future demand. For countries that are net energy exporters, this also relates to an ability to maintain revenues from external sales markets.
- *"Social equity*: This concerns the accessibility and affordability of energy supply across the population.
- *"Environmental impact mitigation*: This encompasses the achievement of supply and demand-side energy efficiencies and the development of energy supply from renewable and other low-carbon sources."

No matter how it is defined and measured, sustainable development in general, and sustainable energy development in particular, will require increasing understanding of the interlinked nature of environmental, social, and economic problems—as addressing single problems without consideration of linkages to other problems may be risky. Sustainable development—and addressing energy security—will also require increasing transparency in planning and decision-making of all types, particularly for large projects, and building human capacity (and societal support for such education) to ensure that the capabilities exist in all "stakeholder" groups (those affected by decisions) to address multifaceted problems and participate in planning processes.

3 Evaluating and Measuring Energy Security

Given the multiple dimensions of energy security identified above, and the linkages and overlaps between energy security dimensions and the dimensions of sustainability and sustainable development, a framework for evaluating and measuring—or at least comparing—the relative attributes of different approaches to energy sector development is needed. Such a framework should be designed to help identify the relative costs and benefits of different possible energy futures—essentially, future scenarios driven by suites of energy and other social policies. Further, given the increasingly interconnected energy systems in the world as a whole, and Northeast Asia in particular, an energy security framework needs to take into account the reactions in other places from actions nearby, and the impacts on national energy systems from actions taken or not taken across the world. The discussion below identifies some of the policy issues associated with the dimensions of energy policy noted above, and presents a framework for evaluating energy security, as broadly defined.

3.1 Conceptual Framework

The dimensions of energy security as broadly defined above are provided in Table 1, along with a sampling of policy issues with which each dimension of energy security is associated, plus examples that might be used to address the types of both routine and radical risk and uncertainty that are faced in the planning, construction, and operation of energy systems. It should be noted that although Table 1 provides what is intended to be an extensive, but by no means complete, list of policy issues, even the categories shown are not necessarily independent. Certain energy technologies will be affected by climate change (for example, hydroelectric power and inland nuclear power plants may be affected by changes in water availability), and there are many other examples of interdependence that need to be carefully thought through in a full consideration of the energy security impacts of candidate energy policies.

Table 1: Energy Security Conceptual Framework

Dimension of Risk or Uncertainty	Policy Issues to be Addressed	Examples of Management Strategies	
		For Routine Risk	**For Radical Uncertainty**
Energy Supply	Domestic vs. imported Absolute scarcity Technology/energy intensity Incremental, market-friendly, fast, cheap, sustainable?	Substitute technology for energy use Put efficiency first Diversify of import sources (national and region) and types of fuel, including fuels produced from different types of resources	Detect potential and analyze technological breakthroughs Explore to develop new reserves Consider impacts of developments and decisions abroad
Economic	Price volatility Cost-benefit ratio Risk-benefit ratio Social cost of supply disruption Local manufacturing of equipment Labor Financing aspects Benefits of "no regrets" strategies Pricing of international energy commodities in markets where prices vary significantly from nation to nation	Compare costs/benefits of insurance strategies to reduce loss-of-supply disruption Invest to create supplier-consumer interdependence via shared infrastructure Insure by fuel stockpiling (uranium reactor fuel, oil, gas, coal), global (IEA) or regional quotas (energy charters)	Export energy-intensive industries Focus on information-intensive industries Export energy or energy technologies
Technological	R&D failure Technological monoculture vs. diversification New-materials dependency in technological substitution strategies Catastrophic failure Adoption/diffusion or commercialization failure	Invest in renewables Improve resilience and optimize scope of energy supply, demand, and distribution systems Consider nuclear fuel cycle (recycling vs. once-through, alternative uranium resources)	Develop permanent nuclear waste storage/disposal strategies Diversify use of and reliance on new and risky technologies
Environmental	Local externalities Regional externalities both atmospheric and maritime Global externalities Pursue precautionary principle	Risk-benefit analysis and local pollution control Pursue treaties Emissions mitigation Technology transfer	Work to understand thresholds for radical shifts of state such as sea level rise and polar ice melt rate Understand how environmental risks abroad affect energy security locally

Dimension of Risk or Uncertainty	Policy Issues to be Addressed	Examples of Management Strategies	
		For Routine Risk	**For Radical Uncertainty**
Social-Cultural	Managing consensus and conflict in domestic or foreign policy making among different actors Institutional capacities to address problems Siting and downwind distributional impacts Populist resistance to or rejection of technocratic strategies Existing perceptions and lessons from history with regard to different energy systems	Transparency Participation Accountability Side payments and compensation Education Training	Consider the potential social/cultural impacts that technologies deployed abroad might have on energy imports
International Military/Security	International management of plutonium Proliferation potential of nuclear fuel cycle Security of sea lanes and energy shipping amid rising powers Geopolitics of oil and gas supplies	Non-proliferation Treaty/security guarantees regime Security and physical protection of energy facilities against terrorism Creation of security alliances Naval power projection Transparency and confidence building	Disposition and disposal of excess nuclear warhead fissile materials Military options for resolving energy-related conflicts, securing infrastructure Combatting terrorism

Table 2 presents a set of examples of potential measures and attributes of energy security—some quantitative, but many qualitative—that might be applied to the analysis of the comprehensive energy security impacts of proposed energy policies.

Table 2: Examples of Dimensions and Measures/Attributes of Energy Security

Dimension of Energy Security	Measures/Attributes	Interpretation
Energy Supply	Total Primary Energy	Higher = indicator of other impacts
	Fraction of Primary Energy as Imports	Lower = preferred
	Diversification Index (by fuel type, primary energy)	Lower index value (indicating greater diversity) preferred based on index formula as derived by Neff (1998)
	Diversification Index (by supplier, key fuel types, key fuel sources)	Lower index value preferred (see above)
	Stocks as a fraction of imports (key fuels)	Higher = greater resilience to supply interruption

Economic	Total Energy System Internal Costs	Lower = preferred
	Total Fuel Costs	Lower = preferred
	Import Fuel Costs	Lower = preferred
	Economic Impact of Fuel Price Increase (as fraction of GNP)	Lower = preferred
Technological	Diversification Indices for key industries (such as power generation) by technology type	Lower = preferred
	Diversity of R&D Spending	Qualitative—Higher preferred
	Reliance on Proven Technologies	Qualitative—Higher preferred
	Technological Adaptability	Qualitative—Higher preferred

Table 2 (continued): Dimensions and Measures/Attributes of Energy Security

Dimension of Energy Security	Measures/Attributes	Interpretation
Environmental	GHG emissions (tonnes CO_2, CH_4), including full energy cycle impacts	Lower = preferred; consider on both national, global scale
	Acid gas emissions (tonnes SOx, NOx)	Lower = preferred
	Local Air Pollutants (tonnes particulates, hydrocarbons, others)	Lower = preferred
	Other air and water pollutants (including marine oil pollution)	Lower = preferred
	Solid Wastes (tonnes bottom ash, fly ash, scrubber sludge)	Lower = preferred (or at worst neutral, with safe re-use)
	Nuclear waste (tonnes or Curies, by type)	Lower = preferred, but qualitative component for waste isolation scheme
	Ecosystem and Aesthetic Impacts	Largely Qualitative—Lower preferred
	Exposure to Environmental Risk	Qualitative—Lower preferred
Social and Cultural	Exposure to Risk of Social or Cultural Conflict over energy systems, both local and international	Qualitative—Lower preferred
International Military/Security	Exposure to Military/Security Risks, including those related to fuel access and transport	Qualitative—Lower preferred
	Relative level of spending on energy-related security arrangements	Lower = preferred

3.2 Testing Different Energy Scenarios

Evaluation of energy security impacts of different policy approaches will include such tasks as deciding on manageable but useful level of detail, incorporation of uncertainty, consideration of risks, evaluating tangible and intangible costs and benefits, comparing impacts across different spatial levels and time scales, and balancing analytical comprehensiveness and transparency. With these factors in mind, a framework based on a variety of tools, including diversity indices and multiple-attribute (trade-off) analyses, is as described below. The framework requires the use ofa tool for evaluation of alternative energy and environmental paths or scenarios for a nation or a region[35]. Central to the application of the framework is its application to the search for robust solutions—sets of policies that meet multiple energy security and other objectives at the same time, in a way that is transparent and inclusive of a wide range of criteria and perspectives.

The framework for the analysis of energy security (broadly defined) includes the following steps:

1. Define objective and subjective measures of energy (and environmental) security to be evaluated. (Within the overall categories presented in Table 1, these measures could include some of the metrics presented in Table 2, but can vary significantly between different analyses, depending on the goal of the analysis pursued.)
2. Collect data and develop candidate energy paths/scenarios that yield roughly consistent energy services but use assumptions different enough to illuminate the policy approaches being explored.
3. Test the relative performance of paths/scenarios for each energy security measure included in the analysis.
4. Incorporate elements of risk.
5. Compare path and scenario results.
6. Eliminate paths that lead to clearly suboptimal or unacceptable results and iterate the analysis as necessary to reach clear conclusions.

The possible dimensions of energy security, and potential measures and attributes of those dimensions, range from the routinely quantified—such as total direct costs, capital costs, greenhouse gas emissions, or fraction of fuels sourced from abroad—to essentially unquantifiable—such as risk of social or cultural conflict. It should be noted that many of these dimensions and measures can and do interact, and a solution to one problem may exacerbate another. It is therefore incumbent on the analyst evaluating energy security policy choices and on policymakers reviewing analytical results to take a comprehensive approach to reviewing the options available, making sure to consider different points of view. In addition, those reviewing the results of comprehensive energy security analyses need to avoid falling into (at least) two traps. The first is to implicitly weight more heavily the results of comparison of quantitative metrics, simply because they are quantifiable, and thus, in some senses, more easily comprehended. This has been referred to as “confusing the countable with the things that count. The second potential trap to avoid is not examining results, either for quantitative or qualitative measures, in their proper context. As one example from a previous EGS Working Paper by the authors[36], a difference between the costs of East Asian regional scenarios for nuclear spent fuel management was computed at several billion dollars per year by 2050. Taken in a context, however, of electricity generation systems with costs on the order of trillions of dollars per year, and economies with GDPs totaling tens of trillions of dollars per year, it is clear that the difference between nuclear spent fuel management cases is miniscule—well within the range of error of measurement of economic quantities. As such, though apparently a big number and a major consideration, the billions of dollars separating the scenarios is in fact neither, and other considerations, as a consequence, need to be seen as playing a more important role in the nuclear policy discussion.

There is often a temptation, in step 5 of the procedure above, to attempt to put the attributes of energy security into a common metric, for example, an index of relative energy security calculated through a ranking and weighting system.   A number of authors have suggested such systems, and ranking and weighing systems do have the advantage that the results, at least nominally, are more straightforward for policymakers and other "consumers" of energy security analyses to review. Such systems almost invariably, however, involve procedures that amplify small differences between paths/scenarios, play down large differences, hide necessarily subjective analytical choices, and give an illusion of objectivity to weighting choices that are by their nature quite subjective. More reliable is the laying out of each of the energy security attributes of each path/scenario side by side, which allows reviewers, stakeholders, and decision makers to see the differences and similarities between different energy futures for themselves and to apply their own perspectives and knowledge, in consultation with each other, to determine what is most important in making energy policy choices. Also not explicitly included in steps 5 or 6 are mathematical tools for optimizing energy security results over a set of paths or scenarios. Optimization can be attractive, as it appears to identify one "best" path for moving forward. Optimization models can in some cases offer useful insights, provided that the underlying assumptions and algorithms in the analysis are well understood by the users of the results. Optimization, however, like weighting and ranking, involves subjective choices that may appear objective, especially when applied across a range of different energy security attributes, and as such should be employed only with caution and with a thorough understanding of its limitations in a given application.

4 Testing the Energy Security Attributes of Shale Gas Trade: Key Questions

The framework for energy security analysis above can be applied to a wide variety of different energy security questions and future scenarios. Although a thorough application of the framework is beyond the scope of this Working Paper, we can hint at some of the issues that might be considered in an application of the framework to one of the key issues being considered today, that of the prospects of trade of shale gas to the major gas consumers of Asia from North America. We explore these issues through a series of **some** (hardly all) of the questions that would need to be answered to weigh the overall energy security costs and benefits of gas trade relative to other possible scenarios of the evolution of the energy systems in the region. Below we organize these questions with respect to the six dimensions of comprehensive energy security outlined above.

4.1 Energy Supply

- What are the net impacts on primary energy use of expanding shale gas exports to Asia, when transport and LNG liquefaction losses are factored in?
- To what extent can North American gas contribute to energy supply diversity in Asian nations, by source of gas (conventional/unconventional), by supplier, and for forms of energy overall?
- What is the likely timing of significant gas imports from North America?
- What are the risks related to the timing of gas imports?
- What are the risks of future interruptions in supply once North American gas exports have started? How can those risks be mitigated?

4.2 Economic

- How is the pricing of North American gas exports to Asia to be accomplished?

- What are the price risks associated with delays in and/or cost escalation of LNG export terminals and related facilities (such as pipelines) in North America?
- What are the potential price volatility risks inherent in imports from North America under different pricing regimes and different types of contracts? What happens, for example, if Henry Hub (the index price for U.S. gas) prices rise to a point where LNG imports from North America exceed the price of imports from other regions?
- How might falling prices of natural gas in Asia as a result of increased shale gas supplies affect the regional and global consumption of gas overall?
- How will spending on LNG import infrastructure affect spending on renewable energy and energy efficiency infrastructure, both at the outset and in the future (for example, through required continued recovery of sunk costs)?
- What is are the relative economic benefits, including jobs and economic competitiveness, of an economy with higher imports of lower-cost LNG versus an economy that depends on other fuels (and/or other energy paths, such as paths with a greater emphasis on energy efficiency and/or renewable energy)? How are those benefits likely to be distributed across societal groups?
- Could a potential oversupply of LNG lead to more volatile markets for energy infrastructure, and thus markets for LNG itself? What would be the impacts of market volatility on the overall economies of importing and exporting nations?[37]

4.3 Technology

- What are the technological risks associated with the environmental performance of shale gas extraction?
- How might falling prices of natural gas in Asia as a result of increased shale gas supplies affect the development and deployment of renewable energy and energy efficiency technologies?
- What affect will increasing use of LNG have on future technological diversity in the energy sector?
- What types of infrastructural changes will be needed in Asia to accommodate expanded gas imports?
- Relative to other future energy scenarios, does expanded LNG imports allow for greater or less future technological flexibility (for example, in the face of the sudden appearance of “disruptive” technologies)?

4.4 Environment

- How might the effect of falling prices of natural gas in Asia (as a result of increased shale gas trade) on consumption of gas overall affect prospects for climate change mitigation and achievement of mitigation goals at the national, regional, and global levels?
- What are the environmental risks associated with methane leaks from expanded gas production and transport facilities?
- What are the local (for example, risks to water supplies and local air pollution) environmental risks associated with shale gas production, both in America and in Asia?
- Which fuels will be used less if LNG consumption in Asia expands, and what will be the net air pollutant emission consequences of those changes?
- Relative to other future energy scenarios, does expanded LNG imports allow for greater or less

future technological flexibility (for example, in the face of the sudden appearance of “disruptive” technologies)?

4.5 Social and Cultural

- What are the economic and related risks to Asia if social and cultural forces in North America cause a delay, decrease, or cessation in LNG exports?
- Which groups in North America are likely to be affected, positively and negatively, but LNG exports to Asia?
- What are the relative social benefits of expanded LNG imports relative to other possible paths of energy system development?
- Which societal groups in Asia nations will be differentially affected by expanded LNG imports versus other energy system development alternatives, and how will those groups be affected? For example, are there particular income, occupation, social or ethnic groups upon whom the changes required to accommodate increased gas imports would fall they hardest? Are there groups that will benefit more than others?

4.6 International Military/Security

- What types of additional international military/security arrangements will be required by expanded LNG trade, relative to other energy sector scenarios? Which nations will be involved in providing those arrangements?
- Will the security requirements of expanded LNG trade exacerbate tensions between powers in the area?
- What will be required to secure on-shore facilities associated with LNG exports and imports, relative to other energy scenarios?
- In what ways could an energy scenario with expanded LNG imports help or detract from the potential for reducing tensions in the region related to North Korea?

Addressing these and other questions is a key part of a thorough analysis of the overall impacts on energy security, broadly construed, of expanded LNG imports into Asia from unconventional gas sources.

5 Conclusion

Energy security, whether defined narrowly or broadly, will remain a key driver of energy and economic policies throughout the world. Defining energy security more broadly, to include not only energy supply and economic elements, but also issues such as the environment, technological risk, social/cultural consideration, and international military/security aspects, and with an eye toward how energy security policy decisions and their related impacts in one part of the world may affect energy security in other places, and vice versa, is a better fit with sustainability definitions and goals, as more nations pursue “sustainable development”, and offers a framework for reaching policy decisions that will be more robust, and lead to better outcomes, in the long-term. The analytical framework presented here is simple in concept to apply, and transparent by design, but depends, as most analysis does, on careful and thoughtful interpretation by analysts, and by the consumers of the analysis, to interpret and translate analytical results into conclusions that can helpfully shape future national and international energy policies.

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