competitive, the concept of energy security needs wide-ranging and intense scrutiny. Security concerns distinct from physical supplies of fuel are receiving more attention as potential determinants of energy policies. A new, broader definition of "energy security" is therefore in order.

Our major goal in the first phase of the PARES Project was to establish a framework for analyzing energy security that incorporates at its core a comprehensive concept of energy security. A second, and equally important, goal was to apply the new PARES framework to an investigation of a single nation's energy security. Japan was selected as the subject for the initial country case study. Japan was selected because it presents an instructive contrast to the United States. Japan is an island nation with relatively few fossil fuel resources. The United States is a continental nation with relatively abundant fuel resources. The United States and Japan also have sharply differing cultures. Japan was also selected because, as one of the world's major industrial powers, its energy policy decisions have global ramifications, and Japan is an economic and technological model for other Asian countries. Its vision of energy security has and will continue to have considerable influence on the policies of other governments in the region.

The overall analytical approach taken by the PARES Project was to: 1) prepare a consensus working definition of energy security, 2) develop a multidimensional analytical framework for evaluating energy security, 3) prepare quantitative and qualitative descriptions of two different short-to-medium range energy "paths" for Japan (1995 to 2020), 4) evaluate the energy paths against a suite of energy security criteria using the analytical framework, and 5) review the results for applicability to other countries of the region.

Chapter 2 (The Historical Background and Significance of Energy Security in Japan) provides background on energy use and energy security policy in Japan. This background information includes a review of the history of energy use, a summary of the status of energy supply and demand as of the mid-1990s, a description of current energy policies, discussions of the national and international implications of Japan's energy security policies, and a look at the implications of changing domestic and global market trends on energy security and related policies in Japan.

Major events and periods in the history of energy use in Japan that have shaped the development of its energy security strategies include:

- the period of post-war reconstruction of coal mining and hydroelectric infrastructure,
- the period of rapid economic growth during the 1960s and early 1970s, with a corresponding rapid increase in energy use fueled largely with imported oil,
- the "energy crises" of the 1970s, which prompted Japan to pursue energy security policies such as securing oil supplies, establishing oil reserves, developing nuclear power, and pursing energy efficiency improvements, and
- the period of diversification of fuel supplies in the 1980s and 1990s, particularly the import of natural gas as liquefied natural gas (LNG).

As of mid-1995, oil supplied 56 percent of Japan's primary energy needs, with most of the

remainder supplied by coal, nuclear energy, and gas. Virtually all of Japan's oil supplies, and supplies of most other fuels as well, were imported, and the bulk of oil imports were from the Middle East. The industry and transport sectors were the two major consumers of fuel in Japan as of 1995.

Japan's current stated energy policy emphasizes working toward energy security, economic growth, and environmental protection simultaneously. This overall policy promotes measures such as fuel diversification, fuel stockpiling, nuclear and alternative energy technology development, and securing of fuel supplies. These policy measures are funded primarily through taxes on fuels. The national implications of Japan's policies include higher fuel prices for the consumer, which act as a drag on the Japanese economy but which have helped spur higher energy efficiency. The international implications of Japan's policies include the impacts of Japan's investments and technologies on international markets for energy-related goods and services, and their influence on the thinking of leaders in other nations. Recent and ongoing domestic and global trends and events, for instance enhanced competition and privatization in many energy industries, the stagnant domestic economy, nuclear accidents, and changes in the regulation of and government support for many energy industries, will likely help to radically reshape Japan's approach to energy security in the coming years.

Chapter 3 (The Concept of "Energy Security") zeroes in on the concept of energy security. Chapter 3 considers the components and principles of security in general, discusses the "conventional" view of energy security, probes the differences in energy security policies between countries, summarizes alternative definitions of energy security, and presents the "PARES paradigm" for comprehensive energy security. The history of energy security policy in Japan is discussed, along with a review of the attributes of each type of fuel now used and potentially usable in Japan. In addition, a suite of potential policy measures for increasing energy security in Japan is laid out. The concept of energy security in Japan is typically ill-defined, and usually focuses on securing supplies of oil.

The components, or central questions, of energy security can be stated as follows:

1) What is the object of protection?
2) What risks are to be protected from?
3) How is the object of protection to be protected?
4) Who is protecting whom (or what)?

The five principles of security policy that help ensure risk minimization are also discussed. These five "insurance" principles of security are cost sharing, cost minimization, multi-dimensionality or multi-purposeness, flexibility or switchability, and expectation of non-return. There are three main differences that help to distinguish the way that policy-makers in different countries think about energy security: 1) the degree to which a country is rich or poor in energy resources, 2) the degree to which market forces are allowed to operate as compared to the use of government intervention to set prices, and 3) the degree to which long-term versus short-term planning is employed.

In addition to the usual focus on security of energy supply, a new, comprehensive energy

security concept must address the disparate challenges of environmental protection, the risks associated with advanced technologies, the management of energy demand, social and cultural risks and concerns, and international relations/military risks. In Japan, as it true elsewhere, it is important to evaluate how the attributes of each of the fuels that could or do help to supply energy services can help to meet these comprehensive energy security challenges. Energy security thinking in Japan has evolved from an emphasis, in the wake of the oil supply crisis of 1973, on securing oil supplies and investing in alternative fuels, to a more recent official emphasis on "energy, environment, and economy." This shift is consistent with the more comprehensive energy security concept defined by the PARES research team. The measures that can be used to enhance Japanese energy security, in the comprehensive sense, include:

- improvement of the fuel supply portfolio,
- enhancement of crisis management measures,
- strengthening of the role of natural gas,
- continuation of energy efficiency improvement, particularly in the transportation, commercial and household sectors,
- incorporation of a regional and global approach to environmental protection, including facilitation of scientific research and technology transfer in the region on environmental issues,
- reorganization of the tax system to enhance environmental protection,
- continuation of the process of opening up energy-related decision-making processes,
- networking of experts inside Japan and beyond in various technical fields,
- diversification of research and development efforts and budgets,
- provision of enhanced government incentives to private investment in energy and environmental technology development,
- provision of better information to policy-makers in the area of the security and military implications of energy policy, and
- pursuit of confidence-building measures on both the domestic and international levels, including improving transparency in energy planning.

Chapter 3 concludes by offering a working definition of comprehensive energy security. 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 dimensions of energy security within each of these three objectives that national energy policies must address, include energy supply, economic, technological, environmental, social and cultural, and military/security dimensions. *And*, energy policies must address the domestic and international (regional and global) implications of each of these dimensions. Thus, national energy policies should be evaluated against each of the three basic objectives as manifested in the domestic and international implications of each dimension. What distinguishes the PARES 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 actualizing (and measuring) national energy

security.

Chapter 4 (Environmental Security) focuses on the new field of "environmental security." The chapter begins with a brief history of the concept of environmental security, and an overview of the various definitions of the term in current use. We then set forth the definition of environmental security used in the PARES study, and discuss how this concept is incorporated into our work on comprehensive energy security.

The concept of environmental security was first coined in 1977, but did not receive significant attention until the early 1990s with the end of the Cold War when policy-makers turned their attention to non-traditional (non-military) threats to security. Environmental degradation and resource scarcity is seen in some security circles as a significant threat to national security. Environmental security has been defined in quite different ways, however. The principal questions posed by analysis of environmental security include:

- How does the state of the environment affect the survival of humanity (human security)?
- How does the state of the environment affect the survival of a nation (military security)?
- How do security institutions affect (positively and negatively) the environment?
- How do environmental security ideas themselves affect the prospects for international environmental cooperation?

In the PARES project, environmental security as it applies to a nation-state is defined to include: a) protection of the health and welfare of the nation's citizens from the deleterious impacts of environmental change, b) protection of the economic interests of the nation from the negative consequences of environmental change, and c) securing unstable regions against environmental change which may directly or indirectly adversely affect the nation. Thus defined, environmental security, as with energy security, implies that the international dimensions of environmental issues as they relate to national security must be taken into account. Both the PARES energy and environmental security definitions argue that nations are compelled to consider larger regional and global issues in their struggle to ensure domestic security. The methodological approach adopted in the PARES Project is to incorporate environmental security concerns into a comprehensive concept of energy security.

Chapter 5 (Analytical Approaches to the Assessment of Comprehensive Energy Security) outlines the many methodological problems encountered in measuring energy security. In this chapter we describe some of the key existing approaches for evaluating the costs and benefits of energy security measures. We propose a draft framework for the evaluation of the energy security impacts of different energy paths, and discuss necessary future research in the field of energy security analysis.

Problems or challenges that must be overcome in evaluating the energy security impacts of different policy approaches in a given country include: a) deciding upon a manageable but useful level of detail for the description of energy policies and applicable measures of energy security, b) incorporating the elements of uncertainty and risk (both routine risk and risk arising from radical uncertainty), c) comparing and weighing tangible and intangible costs and benefits, d) addressing

and comparing impacts that occur on many different spatial levels and on many different time-scales, and d) balancing comprehensiveness with the need for transparency and other practical considerations.

Two specific tools used to evaluate energy security impacts in the PARES Project are *diversity indices* and *multiple-attribute analysis*. Diversity indices can be used to quantitatively evaluate the impacts of measures that affect the mixture of fuels used. Multiple-attribute or tradeoff approaches provide a systematic means of tracking and weighing the diverse quantifiable and non-quantifiable costs and benefits of energy security measures. Both diversity indices and multiple attribute analysis are employed in the framework we propose in Chapter 5. The basic steps in applying the framework are:

1. Define objective and subjective measures of energy security;
2. Develop candidate energy paths (and/or longer-term scenarios);
3. Test the relative performance of paths/scenarios by evaluating measures of energy security;
4. Incorporate elements of risk from unforeseen events (including accidents, natural disasters, war, etc.);
5. Compare path and/or scenario results—including quantitative and qualitative comparisons; and
6. Eliminate energy paths that lead to clearly sub-optimal or unacceptable results.

Table 5-1 in Chapter 5 provides a listing, for the draft framework proposed, of the energy security attributes measured under each of the different dimensions of energy security, and a guide to the interpretation of attribute values. Central to the PARES draft framework is its application to search for a "robust" solution—a set of policies that meet multiple energy security objectives.

Chapter 6 (Energy Demand/Supply Model and Paths for Japan) describes the two illustrative 1995 to 2020 energy "paths," or energy demand and supply models, assembled to test the draft framework for energy security analysis. The Business-As-Usual or "BAU" path largely follows and extrapolates recent Japanese trends in energy demand, energy supply investment, and environmental emissions control, with continued emphasis on fossil fuel use and only modest increases in energy efficiency and in the use of renewable energy. The BAU path includes increasing use of oil in the transport sector, and some continuing substitution of natural gas for other fuels in end-use sectors. The "Alternative" path includes increased emphasis on substitution of natural gas for coal and oil in both end-use demand sectors and in electric power generation, plus aggressive application of end-use efficiency improvement and renewable fuels in all sectors. The fraction of overall electricity generating capacity supplied by nuclear power over time is similar in the two paths.

Base year data for 1990 and 1995 from a number of different Japanese and international sources were used in compiling the energy paths. The two paths are designed to produce roughly the same energy services. Consequently, consistent assumptions for economic growth and demographic changes were used in each case. An end-use model was used to evaluate each path, which required that the paths be elaborated in some detail. The detailed quantitative and

qualitative assumptions that underlie the paths are presented in Chapter 6 and in Attachments to the PARES Synthesis Report. These assumptions include descriptions of policy measures designed to address the types of risk included in the concept of comprehensive energy security.

Chapter 7 (Results of Analysis) describes the results of applying the analytical framework from Chapter 5 to the energy paths elaborated in Chapter 6. Between 1995 and 2020, energy use in Japan in the BAU path grows at an average rate of 1.2 percent per year. In the Alternative path, on the other hand, overall energy use actually declines, as a result of energy efficiency and other "demand-side" measures, from 14.9 billion gigajoules (GJ) in 1995 to 14.5 billion GJ in 2020, an average rate of decline of about 0.1 percent per year. Overall primary fuel use in 2020 is nearly 25 percent lower in the Alternative path than in the BAU path, and is only modestly higher than in 1995. Crude oil imports to Japan under the Alternative path are about 15 percent less, by 2020, than in the BAU path. The amount of nuclear fuel used in the Alternative path in 2020 is approximately 17 percent less than the nuclear fuel used in the BAU path, but because less primary fuel is used overall, nuclear fuel constitutes a slightly greater share of the 2020 energy mix (10.6 versus 11.2 percent) in the Alternative path. Fuel gases—mostly natural gas/LNG—constitute a larger share of the energy mix by 2020 in the Alternative path than in the BAU path, but the absolute amount of fuel gases used in the Alternative path is slightly lower than in the BAU path. Fossil fuel use in the BAU path in 2020 is about 24.9 billion GJ, versus 16.3 billion GJ (about 65 percent of the BAU level) in the Alternative path.

In addition to lower total primary energy use relative to the BAU path in 2020, the fraction of fuels imported is lower under the Alternative path, the diversity of fuel supply is higher, fuel stocks are sufficient for a longer period, total energy system costs are lower, technological diversity is arguably higher (though the use of currently proven technologies is less), environmental emissions are generally lower (carbon dioxide emissions in 2020 are 63 percent of those in the BAU path), the production of nuclear wastes is somewhat lower, exposure to environmental risk appears lower, risks of social or cultural conflict over energy systems or resources are probably lower, and military-related security risks are likely lower as well. Table 7-7 provides an overview of the comparison between the two paths. A qualitative look at how variations in the two paths might affect the results of the analysis, and a description of a "scenario" method of analysis used during the PARES Project to consider alternative energy futures, are also provided.

Chapter 8 (Conclusion and Areas for Further Work), the final chapter of the PARES Synthesis Report, summarizes the project achievements, describes the work yet to be done on Japanese energy path analysis, evaluates the ramifications of the results for Japanese and Pacific Asia energy policies and energy futures, assesses the applicability of analytical methods and of the Japan case study results to other nations, and suggests areas for future work on elaborating and applying the analytical framework for energy security analysis in Northeast Asia.

Work to be done in elaborating the Japanese energy paths analysis includes assembling more Japan-specific data on energy-efficiency and other technologies, getting better fuel cost data, obtaining more information and expert advice on how Japanese energy industries would adapt to different policies, elaborating end-use data, getting better estimates of the extent of energy resources—both within Japan and in the Northeast Asia region, and considering additional

and different energy paths.

Although the results of the Japan energy path evaluation summarized above are based on paths that are meant primarily to be illustrative, it is clear that many of the differences are large in energy security attributes between the two paths. Given that the paths cover both a relatively limited time span and, at least as when applied to Japan, result in relatively modest growth in the need for energy services, it seems reasonable to conclude that the differences between similar energy paths for a country like China—or even North Korea—would be truly monumental. The structure proposed for analysis of energy security attributes of different energy paths is applicable to any national or regional situation. The structure can easily be modified to add or delete attributes to suit the nation or region under study, and can accommodate that results of a host of local information resources so long as transparency is maintained.

Application of an energy security evaluation framework on both national and regional levels could provide revealing insights. It is possible that regional-level analyses will suggest a set of robust policy directions similar to those suggested by country-level studies. Conversely, strategies for enhancing energy security on the country level could, when considered in their regional context, be sub-optimal with respect to regional energy security. In both cases the major importance of the evaluation framework is to provide a structured, documented, relatively easy-to-understand approach to thinking about the broader impacts of energy system issues. At a minimum, national and regional application of an analytical framework such as the one proposed here should increase understanding between the countries of a region and serve as a confidence-building exercise. The results of the analyses, taken in aggregate, may well suggest robust policy directions that will clearly enhance energy security in the region. Timely and well-designed dissemination of analytical results to regional policy-makers and the public would be the next step in moving the identified energy security policies toward implementation.