ENERGY PLANNING AND MANAGEMENT: METHODOLOGIES AND TOOLS

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Summary

Energy is such a fundamental input to human activity that governments have been reluctant to leave to unfettered, private markets the key decisions about energy resources and technologies. Furthermore, the development and production of various forms of energy usually involve capital-intensive, long-lived investments, which require extensive analysis by corporations in the energy sector, be they private or public. For these reasons, the methodologies and tools of energy planning and management are well developed and sophisticated.

Prior to the 1970s, most significant developments occurred on the supply-side. Technical advances in mineral exploration often originated in the energy sector, where the returns to success could be high. Resources were defined in terms of their potential economic attractiveness, with categories like probable and possible reserves. Optimization techniques were applied to such diverse production and delivery activities as designing and operating petroleum refineries and nuclear plants, or managing

electricity and natural gas networks. On the demand-side, demand estimation techniques could be simple given the steady rate of demand growth in the post-war years.

The rising energy scarcity fears in the mid-1970s caused profound changes. The optimization techniques of supply, formerly restricted to individual energy commodities, were expanded to simulate entire national energy systems, even the global system. On the demand-side, a concern for understanding the dampening effects of energy price increases on demand developed in concert with a growing interest in finding ways of decreasing energy use without sacrificing the level of services in the economy or the economic growth prospects for developing countries. At the same time, many electric utilities also pursued demand reductions as a strategy to reduce supply investment risks. Thus, the techniques of demand forecasting have evolved, from simple links to economic output, to models that include price responses to models that explicitly account for policies that seek to influence the choice of energy-using equipment by firms and households.

Two recent trends, with implications for the future, are the expanded role for markets in allocating resources and the growing concern for the pervasive environmental impacts of energy use. While the first trend suggests a diminished role for planning, the second suggests a need for governments to intervene in energy markets in ways that still require planning and management techniques. The combined effect is to modify the existing planning and management techniques so that they can assist in the setting of objectives and policies at all jurisdictional levels, from urban and regional government to national government and even to international agreements between governments, while relying increasingly on market-based instruments to pursue these objectives.

1. Introduction: the Context and Rationale of Energy Planning and Management

Energy is such a fundamental input to human activity that governments have historically been reluctant to abrogate to the marketplace complete responsibility for its planning and management. This is true both between countries, where energy self-sufficiency or at least supply security is an important concern, and within countries, where government involvement in the energy sector is often significant. This involvement is further justified in that elements of the energy sector cannot easily be left to the marketplace alone.

First, energy-related investments can be a substantial percentage of a given country’s total capital investment, with repercussions for the performance of its entire economy. These investments tend to require long lead-times for planning and construction and to be long-lived once in operation. They can affect the entire character of an economy in terms of technological development, capital concentration, and productivity. Indeed, capital concentration in the energy sector is associated with social and political power at both the national and international levels given the economic importance of major multinational energy corporations.

Second, most key energy forms have at least one characteristic that inhibits the development or desirability of relatively unregulated, private, competitive markets. The electricity and natural gas industries involve monopolistic delivery systems. The nuclear

industry requires high profile policy decisions about safety, plant siting and, more broadly, military interests and military security. Large hydro projects require major public policy decisions about land allocation and water rights. The coal industry requires decisions about domestic versus international supply, sometimes with very large implications for employment and regional economies. The oil industry is influenced by geo-political events and some of its capital-intensive activities, notably refining, is sometimes subject to accusations of less-than-vigorous competition. Finally, the negative environmental impacts of most forms of energy production, transportation, and use, are steadily growing in importance in the eyes of the public and governments.
These attributes suggest the need for substantial government involvement and large-scale private coordination in the development and management of the energy sector. This has been manifested in a number of ways. First, governments have organized themselves to ensure a high profile for the energy sector, often developing large bureaucracies to oversee and guide public policy in energy. Second, large corporate entities have been created, like electric utilities and major oil and gas companies, with considerable resources and a keen interest in a smooth development of both their corporate interests and their sector as a whole. In some cases, these corporate entities are publicly owned, being themselves intended agents of public policy. Even where private, the size of the entities and the need for government involvement blurs the normal distinction between private and public in corporate planning and management activities. Third, independent regulatory and advisory entities have been created by governments (utilities commissions, temporary or permanent advisory bodies, environmental review authorities) to oversee key elements of the energy sector: this includes the economic prudence of its investment and development profile, on the one hand, and the environmental implications of its activities, on the other.

As a consequence of the energy sector's importance, and the large entities involved, the energy sector has a long history of developing and applying relatively sophisticated planning and management tools. Some of these tools are specific to a particular energy industry while others can be applied more generically to all forms of energy. Some of these tools are specific to either government or a private corporation while others can be relevant to any potential user. Some of these tools are designed to inform centrally-controlled decision making while others are intended to guide policies that might influence participants in a fairly deregulated market. Finally, some of these tools are more relevant to either a developed or developing country while others can be applied in virtually any context.

These key planning and management methodologies and tools of the energy sector are presented below. The second section focuses on tools that originated in the field of energy supply. The third section focuses on tools that that are applied in energy demand, and how these are combined for integrated planning and management. The final section assesses how these tools are likely to evolve in future to meet emerging needs.

2. Energy Supply Planning and Management: Methodologies and Tools

2.1 Planning for Energy Mineral Exploration and Development

The fossil fuel sector (oil, natural gas, and coal) operates like other natural resource commodity markets in that prospective producers need to find the resource and then estimate the magnitude of individual deposits they hope to develop. Finding the resource requires the kind of planning techniques that are normally associated with mineral exploration. These include preliminary geological analyses from available secondary data (public and private geological surveys and similar sources) and then in-the-field exploration and further analyses. As the more readily accessible fossil fuel resources have been discovered and exploited, the industry has progressed to exploring in locations which are increasingly remote and challenging for reasons of climate (arctic), terrain (rugged landscape), accessibility (under the sea floor, deeper in the Earth's crust), or resource characteristics (tar sands). Because of these difficulties, exploration and development is costly. Exploratory activities demand a high success rate, which, in turn, creates an incentive for considerable planning effort. This planning effort pertains both to resource exploration and development activity, on the one hand, and to forecasting the demand and likely market price of the resource in order to evaluate investment proposals, on the other.

In terms of resource exploration and development, the oil and gas industry is especially well-known for developing techniques for forecasting the size of the resource. This obviously difficult task is all the more challenging when it is recognized that the size of a resource is not simply a physical measure, but also depends on technological and economic dimensions. The following diagram explains this complexity for the oil and gas sector (Figure 1).

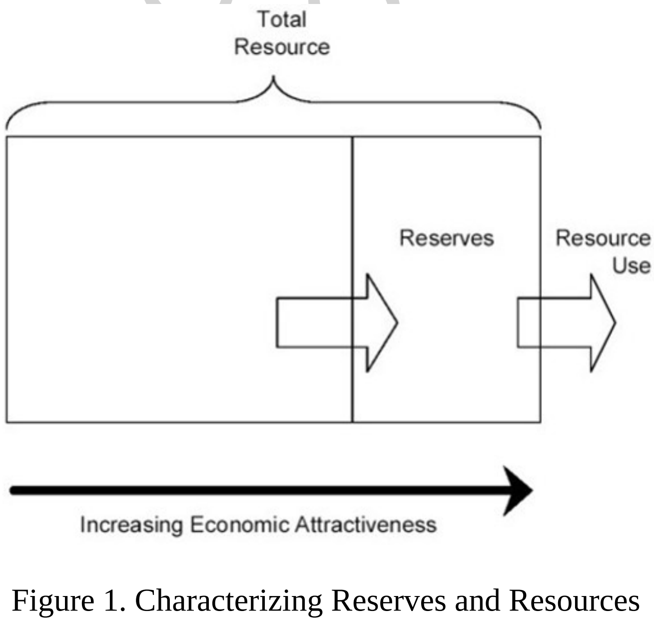

Figure 1. Characterizing Reserves and Resources

While the entire mineral resource (the focus here being fossil fuels), say on a global scale, is unknown, one can estimate its magnitude roughly based on our understanding of geology. However, this quantity is of little interest from an economic perspective because much of a given mineral resource is too expensive to exploit currently. Thus, resource analysts make a distinction between the resource and its reserves. The reserves are that portion of a resource that either is, or is close to being, economically exploitable.

The size of the reserves is not constant. First, the reserves are continually being used up, which pushes the estimate down. Second, changing demand conditions can increase (or decrease) the market price of the resource, increasing (or decreasing) the untapped portion of it that is economic to exploit, and thus in the reserves category. Third, technological advances tend to continuously improve the economics of exploiting some of the known deposits of the resource, moving them into the reserves category. Fourth, major new discoveries will also increase the portion of the resource that is in the reserves category.

The oil and gas industry has further disaggregated the reserves category into proven reserves and probable reserves. While the definitions vary from one organization to another, one can generally say that proven reserves involve a much greater degree of certainty about the reserves' magnitude, usually linked directly to successful exploration activities. As the name suggests, the magnitude of possible reserves is more speculative. However, technical advances in recent years have significantly improved the level of knowledge about a resource in a particular location, even in the absence of focused exploration activity. Geological knowledge of a region is combined with the growing body of data from previous oil and gas exploration (successful and unsuccessful) in order to estimate statistical linkages between specific geological characteristics and the resource. In some cases, estimates of possible reserves have almost the degree of certainty that was formerly associated with proven reserves.

Region- or site-specific reserves estimates are important because the development of fossil fuel resources usually entails a complex array of related major investments, including storage and transportation facilities, the latter sometimes involving pipelines of thousands of kilometers. Therefore, prior to engaging in exploration and development, firms must assess the total picture of resource development. This involves techniques of investment analysis that are among the most sophisticated to be found in any sector of the economy. The risk profile of investment, in particular, is examined with great care.

One statistic that has long been key to fossil fuel investment and management decisions has been the reserves/production (R/P) ratio. This is the ratio of current annual production to the total reserves estimate (proven or a combination of proven and probable). It can be calculated for an individual deposit, the aggregate reserves of a firm, a political entity (state, country) or the entire market. A firm would be interested in how long its current reserves are likely to endure. It would also be interested in the R/P ratio for the entire market because an excess of total reserves suggests that it may take years before exploration and development investments can return production revenue, jeopardizing the economics of such investments. The R/P ratio for a country or region can provide critical information to a political entity concerned with energy supply security or wishing to forecast the effect on public finances of reductions in tax or royalty revenue from declining fossil fuel reserves.

Although the discussion in this section has focused on the fossil fuel industry, the issues apply equally to the uranium used in the production of nuclear power. The size of the resource can be estimated, but it is the exploitable reserves that are of interest, and the estimate of the reserves potential depends on the current state of technological development and market conditions.

2.2 Estimating Energy Resources and Technology Assessment

While energy planning has been focused to a great extent on the exploration and development of fossil fuel resources, the general practice of assessing energy systems and energy options has been more broadly applied. All energy resources, renewable and non-renewable, have a resource potential, and that resource potential is determined by the technologies available to produce, deliver, and use the energy.

Thus, all major energy resources have been evaluated in ways that approximate the resource/reserve distinction applied to non-renewable, energy mineral resources. At the same time, technology assessments allow analysts to estimate the current reserves potential of a resource and even to speculate on its future reserves.

With the rising societal concern over energy since the 1970s, private and public organizations have made estimates of all energy resources. Thus, most countries now have domestic, site-specific estimates of various forms of energy potential, including solar, wind, hydropower, geothermal, and biomass. These estimates may be further differentiated into the most, average, and least, favorable locations from a technological-economic perspective, which approximates the reserves and resources distinction for mineral energy resources. This kind of assessment of renewable energy resources may be especially important in developing countries, where, for economic, social, and environmental reasons, it may be preferable not to follow the same fossil fuel-intense development path of industrialized countries.

The inclusion of technological-economic considerations in assessing renewable resource potential is part of a much broader planning tool called technology assessment. This practice, which is not limited to energy, involves examining technologies for their appropriateness in meeting several potentially conflicting objectives. In general, society is interested in the development of technologies that meet economic, social, and environmental objectives. Analysts, perhaps with public input, can provide assessments of technologies with these objectives in mind.

Few people would agree that the choice between nuclear, coal, and biomass-generated electricity is one that can be reduced to the single dimension of economics. Technology assessment helps the decision maker see how a particular technology fares against several objectives at one time.

The resulting assessment may be very different depending on the values, resources, and level of development of a country or region. A developing country, for example, may assess the same technology very differently than a developed country. Technology assessment can become part of a broader energy planning framework, as will be shown in the section below on integrated resource planning.

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Biographical Sketch

Dr. Jaccard has a Ph.D. in energy economics (1987) from the Institute of Energy Economics and Policy at the University of Grenoble. He has been a professor from 1986 to the present in the School of Resource and Environmental Management at Simon Fraser University in Vancouver, Canada, where he directs the Energy and Materials Research Group. He teaches graduate courses in energy and materials management and policy, energy and materials system modeling, and ecological economics. He has published over 50 refereed articles in leading energy journals from his research in energy system modeling, energy regulation, and energy/environment policy analysis. Dr. Jaccard took a partial leave of absence from the university (1992–1997) to serve as Chair and CEO of the British Columbia Utilities Commission, responsible for regulating all natural gas and electric energy utilities in the province.