ENERGY PLANNING

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Summary

Energy is a crucial resource for economic development; its rate of utilization is seen as a measure of the level of development achieved by a country. Serious and widespread interest in energy planning can be directly attributed to the oil price increases of the early 1970s. Integrated Energy Planning (IEP) means the analysis of all energy issues within a unified policy framework in order to arrive at a set of nationally optimal energy solutions over the long term (say, fifteen to twenty years). One of the most crucial outcomes of IEP has been the energy master plan (EMP).

The scope of IEP may be clarified by examining the complex relationships between the energy sector and the rest of the economy. At the highest and most aggregate level, it should be clearly recognized that the energy sector is a part of the whole economy. The second level of IEP treats the energy sector as a separate entity composed of subsectors such as electricity, petroleum products and so on. The third and most disaggregate level relates to planning within each of the energy subsectors.

A planning process should be dynamic and continuous, with all data; assumptions and analyses being constantly revised using the most recent information, and state of the art analytical tools.

The IEP procedure itself may be broken down into the following steps: socioeconomic background and national objectives; energy demand analysis; energy supply analysis; energy balance; policy formulation and impact analysis. It should be noted that these divisions are conceptual, and in practice there will be considerable overlap among them.

In general two modeling approaches have been used in IEP. The top-down modeling approach uses generalized macroeconomic models and focus on the economy at large. A key assumption underlying many top-down analyses is that the economy is in equilibrium. The bottom-up approaches focus on the energy sector alone. They are based on detailed engineering–economic studies of energy supply and end-use technologies, and on micro-economic studies of end-use markets.

1. Energy and Economic Development

Energy is a crucial resource for economic development; the level of energy demand is seen as a measure of the level of development achieved by a country. The emphasis always is on commercial energy that plays a decisive role in development. The notions of energy intensity—i.e. final energy demand per unit of GDP—and the per capita consumption of energy are reflective of the level of development and, possibly, the kind of economic structure (notably the role of the industrial sector) in a country.

From the viewpoint if integrated energy planning, the most directly important component of the planning process is the input-output table, which has to be constructed to include most of the sectors of the economy as data availability permits. These sectors could be further aggregated in the input-output used in economic planning which might obscure the importance of many energy sub-sectors. For instance, electricity, gas, and oil may be aggregated into one sector named the energy sector. This includes generation, transmission and distribution of electricity, exploration, production and distribution of oil and gas and so on.

An important issue in integrating energy planning with economic planning is the extent to which the energy sector should be disaggregated to ensure proper representation and a balanced evaluation of the sector's relationships with the rest of the economy. Undoubtedly, there is considerable scope for developing separate modules for some energy-related activities (as there is for any other activity in the economy) but it is important to ensure that any module that is developed is consistent with the structure of the rest of the economic planning model. At a minimum, the energy sector should require specific estimation of flows to all the other sectors of the economy.

These linkages between the energy sector and each of the consuming sectors would depend on the level of activity in each sector, various technological parameters, as well as price and income variables.

1.1 Energy and the Environment

Energy systems could be a major cause of environmental degradation. They could be a major source of air pollution. This is likely to occur during production, transportation, distribution, and use. Main pollutants are sulphur dioxide, particulates, hydrocarbons, carbon monoxide, and nitrogen oxides. Air quality in many of the large urban centers is bad because of the use of older cars and leaded fuel, and sometimes because of the burning of wood and charcoal using inefficient technologies for domestic needs in developing countries (principally cooking and space-heating). Energy systems can also pollute the soil and water through mining, burning, accidental oil-spills, and acid precipitation. The serious indirect environmental effects of traditional energy systems include depletion of wood resources, which contribute in some cases to deforestation and desertification, and which may endanger biodiversity. Burning fossil fuels without adequate environmental controls is the main cause of acid precipitation, with regional (and transnational) consequences on agricultural productivity, the preservation of ecosystems, the quality of inland water bodies, and the conservation of buildings and structures.

Oil spills are the most notorious energy-related source of water pollution due to their devastating after effects. Similarly, water is an important component in thermal electricity generation. Large electric power plants require large amounts of water for cooling, if waste heat is discharged directly into water bodies severe harm to the aquatic and marine life would occur.

Energy systems account for the largest share of anthropogenic emissions of greenhouse gases (GHG), which threaten the stability of the global climate. Traditional agricultural practices may no longer be appropriate or viable, as patterns of rainfall and drought change due to altering regional climatic conditions. Global warming could further reduce the agricultural productivity of the arid countries in Africa, while the ensuing sea-level rise, as well as the possible increasing number and intensity of typhoons during climate transition periods, will threaten small island states.

It is particularly unfair that the developing countries, which contribute an almost negligible share of greenhouse gas emissions, are among the countries most likely to be affected by climate change. While until today developing countries have contributed little to the build-up of greenhouse gases in the atmosphere, its contribution will grow as the pursuit of progress demands increasing use of energy services. As parts of developing countries become more prosperous, people will use more energy to mprove their standard of living, with global environmental consequences. Implementation of the Kyoto Protocol, which assigns legally, binding emission reduction targets, will greatly influence the energy policies of many parts of the world. Furthermore, the Clean Development Mechanism, under the Kyoto Protocol, through which parties can meet part of their emission reduction targets by financing initiatives to reduce greenhouse gas emissions in developing countries, will help to lever financial support and technology transfer for sustainable energy development by providing additional benefits to investors.

1.2 Energy and Sustainable Development

It is now clear that development, in order to be sustained over a long period of time, must not destroy the resources on which it depends. The objective of sustainable development is therefore not only economic growth: it is also social development, the eradication of poverty, improvement of health, conservation of natural resources, environmental protection, and a better quality of life. In the field of energy, sustainability, rather than physical scarcity of resources, has become the main driver for change. Although it is possible in principle to give a precise definition of "sustainable energy" (Daly, 1991), it is apparent that a transition to a fully sustainable system cannot be achieved in the short or medium term; moreover each individual country should respect the conditions of sustainability globally, and not necessarily. This is especially true for the poorest developing countries; which contribute very little to global environmental problems and climate change but desperately need energy services for survival and sustainable development. Sustainable development is made up of three equally important factors: economic development, social development, and protection of the environment. Therefore, the guidelines to creating sustainable energy systems are quite clear: improve efficiency of energy production and use; and propmte renewable sources of energy.

1.2.1 Energy Efficiency Technologies

Technological improvements have been achieved since the early 1970s both in the energy supply and demand sides. The progress in power generation has been outstanding, not only in increasing efficiency, but also in improving the economics and flexibility, and in reducing the unit size of plants. To single out a few notable results, gas-fuelled dual cycle power stations have reached efficiencies of 60%, a result that was unheard of ten years ago. The introduction of aeroderivative gas turbines for stationary applications, as well as development of heat resistant materials and improved cooling of blades, have helped in reaching this target. Combined heat and power generation (CHP) is progressing, high-efficiency small-scale CHP systems are also now available. The next step toward microgeneration will probably be the introduction of the fuel cell for power generation. The substantial cost reduction expected from technological improvements as well as from mass production (especially if use penetrates the transport sector) could make the fuel cell the preferred solution for small-scale power generation and CHP. The modular nature of the fuel cell makes its cost per unit of power almost independent of the size of the plant.

Progress has been made in techniques to explore and exploit oil and gas fields, both inland and off-shore, including advanced prospecting methods, horizontal drilling, and field stimulation technologies. Progress has also occurred in refinery technology (including the gasification of tars); in the transportation of gas and oil (such as underwater pipelines); and in techniques to deal with oil spills. Progress has been slower in the gasification of coal, an important technology for the cleaner and more effective use of coal through dual cycle power production. The technology exists and is tested, but its appeal is limited in the market because of its high cost compared with conventional methods. Technologies leading to improved energy efficiency in the demand side are progressing. Very often the rate of efficiency achieved is still far from the theoretical limits.

To name just a few fields in which substantial progress has been made, as concerns industry, emerging technologies include separation by means of semi-permeable membranes, drying by means of heat pumps, and selective heating by microwaves. Digitally controlled electric motors deliver higher efficiency in variable speed operations. In the field of agriculture, direct energy utilizaation has been reduced not only in the field (including greenhouses) and in post-harvest operations, but also, and perhaps more importantly, indirect energy use through fertilizers and pesticides. Their consumption has been reduced through plant breeding or better information for farmers, and this has had positive effects on the environment as well. New building materials are now on the market in the construction sector, including transparent insulators, glasses with variable transparency, and materials that store heat. Improved designs reduce the energy required for heating, cooling, ventilation, and lighting by using the properties inherent in natural materials.

Household appliances are also benefiting from continuous improvements and some basic innovations. In the transport sector, vehicles of all types could run more efficiently. New types of vehicles, such as electric and hybrid vehicles (including electric bicycles and scooters), are already being used for special applications, and may become more widely diffused in the future. Great progress has been made in the last few years in increasing the specific power and reducing the cost of the polymer membrane in fuel cells, which may soon power vehicles of all kinds, as they have twice the efficiency of existing engines and virtually no emissions. They may be expensive now, but with mass production there is no reason why the cost of a fuel cell vehicle should not come down in a few years to the level of conventional vehicles. Research and development will continue to improve traffic systems, especially through the use of information and communication technologies. A modal shift (from private road transport to public and rail) must happen to reduce fuel consumption and pollution, but there are many obstacles in the way.

1.2.2 Renewable Energy Technologies

1.2.2.1 Solar Thermal Applications

Several solar technology application options were available. They employ both low and high temperature technologies. Solar systems for less than 80ºC were extensively demonstrated and utilized all over the world for domestic water heating, industrial processes heat applications, and agricultural drying. The technology of solar thermal electricity generation utilizes solar energy to superheat molten salt to more than 1000ºF. This high temperature substance is transferred to a hot storage tank to be pumped through a steam generating system. The resulting superheated steam is used to power a turbine generator and produce electricity. Demonstration plants for this technology are operating in Southern California, Spain, Italy, Japan, France, and Russia. It is certain that when solar power becomes commercial, it will be used in the so-called "hybrid" plants, where part of the energy is still produced from fossil fuels. Solar power could then reduce the world's dependency on fossil fuels. One advantage of solar power plants that use molten salt is the ability of energy storage up to 12 hours. There are, of course, limitations to this technology, which is its site dependency. The solar power plants are much suited to locations with high solar energy intensity. Another constraint is its dependence on land availability. They are normally located in areas with enough uninhabited low cost land in desert regions. The most daunting barrier for penetration of this technology is the economics associated with the low prices of its competing fuel sources such as oil and natural gas. However due to international efforts to combat global climate change, this technology would play a significant part in the future world energy picture.

1.2.2.2 Photovoltaics

Certain materials exhibit the property of converting solar radiation into direct electric current. The materials presently in use are silicon (Si) and cadmium sulfide (CdS). To grow and make a single crystal of Si needs a large heat source. Solar cells made out of a single crystal are available but expensive. Amorphous silicon deposition on a substrate of glass or metal has high optical absorption, and can be made into cells of large area. In the process of developing amorphous technology, intermediate methods such as thin film technology by spray deposition have gained importance. The theoretical solar conversion efficiency for single crystal silicon Photovoltaic cells (PV) is 21%. In practice, the maximum solar conversion efficiency is about 18%. PV is already competitive as a stand-alone power source remote from electric utility grids. However, it has not been competitive in bulk grid-connected applications. Cost of PV is expected to improve significantly through R&D as well as with economies of scale. Most of the known Photovoltaics applications were demonstrated and field-tested in the areas of water pumping, desalination, clinical refrigerators and ice making. etc. PV applications for telecommunication systems and high way advertising panels are already commercialized. Several pilot projects for electrification of remote villages using Photovoltaics systems have been implemented in many remote areas of the world.

1.2.2.3 Wind Energy

During the last decade, wind power has established itself as a reliable source of energy for electric utilities. Wind energy systems are now being used for grid-connected power production. Among the faster growing programs are those in Denmark, Germany, India, Spain, the USA, and Egypt. Total installed capacity in the world is estimated at about 6000 MW. Costs could be significantly lower for large wind farms. Wind power systems can also be used with back-up systems for stand-alone operations. Countries with large numbers of operating wind farms sometimes experience public resistance to such factors as the noise of turbines, the visual impact on the landscape and the disturbance of wildlife.

1.2.2.4 Biomass

Biomass is an energy resource derived from organic waste of natural and human activities. Biomass electricity is fueled from many sources, including timber industry byproducts, raw forest material, agricultural crops, household waste and the like. It is one of the most attractive options for addressing concerns over CO_2 because trees and other plants sequester atmospheric carbon dioxide. The growth of plants and their conversion to energy as biomass fuels recycles atmospheric carbon. The result is no net addition of CO_2 into the atmosphere. The use of biomass for power generation has increased over the last decade. In Europe, biomass currently accounts for about 2% of total energy demand. Estimates indicate that it could produce as much as 15% of total electricity demand by the year 2020. Biomass is an important resource in developing countries, particularly in rural areas where it is often the only cheap and affordable source of energy. In addition to cleanliness and low cost, other benefits of biomass energy include local economic development and sustainable agriculture. Costs of biomass energy depend on local conditions, such as land and biomass waste availability and production technology. In addition to ethanol, methanol and hydrogen are promising biofuel options.

1.2.2.5 Geothermal Energy

Geothermal power takes advantage of the Earth's natural heat and steam to drive turbines. No smog-related air pollution is generated since the steam and heat is naturally created. Electricity is generated from geothermal energy in more than 20 countries. Direct use of geothermal water occurs in about 40 countries including the USA and Japan. Various emissions associated with geothermal energy include CO_2, hydrogen sulfide, and mercury

1.2.2.6 Fuel Cell

A fuel cell is an electrochemical engine that produces electricity. A typical combustion generator burns a fuel, such as gas, to turn a turbine that generates electricity. A fuel cell electrochemically combines fuel and air to produce electricity with no moving parts. The reaction, in its simplest form can be stated as in equation 1:

$$H_2 + \text{Air} = \text{Electricity} + H_2O \quad (1)$$

Hydrogen can be produced inside the fuel cell itself from a fuel such as methane (CH_4). Hydrogen can also be produced using solar electrolysis of water. Hydrogen could be used in fuel cells to drive vehicles as an alternative to internal combustion engines. This technology promises to be a good option to reduce carbon dioxide emissions in the transport sector.

Fuel cell technology offers cleaner and more efficient power plants that run on widely available fuels such as natural gas, with an efficiency level that is double that of conventional fossil fuel power plants with almost zero emissions.

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Bibliography

Gelil I. A. (1998). Clean energy technologies, The First World Congress of Health and Urban Environment, Madrid, 6–10 July, pp. 16–440. GRAESAL, S.L.

Codoni R. (1985). *Integrated Energy Planning: A Manual*. Asian and Pacific Development Centre, Kuala Lumpur. [This is a three-volume publication and an executive summary containing a conceptual framework, methods, and tools useful in developing national energy plans.]

Munasinghe M. (1990). *Energy Analysis and Policy*, 315 pp. Butterworth & Co. [A collection of essays on energy economics and policy, which provide an overview of problems, faced in developing energy policies.]

Sathaye J. (1995). *Greenhouse Gas Mitigation Assessment: A Guidebook*. Dordrecht, The Netherlands: Kluwer Academic Publishers. [This describes guidelines for the evaluation of options to mitigate greenhouse gas emissions.]

Ugo F. (1999). *Energy as a Tool for Sustainable Development for African, Caribbean, and Pacific Countries*, 133 pp. EC and UNDP: United Nations Publications.

Biographical Sketch

Dr Ibrahim Abdel Gelil is the Chief Executive Officer of the Egyptian Environmental Affairs Agency (EEAA), the national body responsible for coordination and supervision of environmental affairs in Egypt. It was established in 1982, and since then has undergone various developments aiming at strengthening its role and increasing its effectiveness in environmental management and enforcing environmental regulations. In addition, Dr Gelil is chairing the Egyptian National Committee on Climate Change, and he is a Board member of the New and Renewable Energy Authority (NREA), the Egyptian national agency responsible for development and promotion of the use of renewable energy resources in Egypt. Dr Gelil also is a board member of the Egyptian natural gas association, a member of the national Committee of the World Energy Council, the National Specialized Councils, the National council of natural resources and environment, the Egyptian Academy for Science and Technology, the Egyptian Engineering Syndicate, the Association of Egyptian Engineers, and the Association of Energy Engineers. He is also a member of the national energy efficiency council. Prior to joining EEAA, Dr. Gelil served as the Chairman of the Board of Directors of the Organization For Energy Conservation and Planning (OECP), the Government of Egypt's entity responsible for energy policy analysis and energy efficiency. In that position, Dr Gelil played a key role in building the institutional capacity of OECP, and promoting DSM and energy efficiency, leading national efforts to address the energy–environment issues, particularly the issue of climate change. Dr Gelil received a B.Sc. in Chemical Engineering in 1970 from the Military Technical College, an M.Sc. in 1977, and a Ph.D. in 1984 from Cairo University. In 1993, he was awarded a fellowship to study Natural Resources Management at Cornell University, USA.