ENERGY PLANNING METHODOLOGIES AND TOOLS

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Summary

As with any tool, it is useful to look ahead before choosing an energy planning tool. Also, there will usually be choice between different tools that all might, at least in principle, serve the energy planning task to be addressed with the tool. To facilitate efficient selection of a tool, it is important to specify not only the overall purpose of using the tool, but also to formulate specific questions. Here it is argued that one criterion for the selection of a tool should be the simplest and gives relevant answers to the questions raised.

In many situations of energy planning, uncertainty is an important aspect. Although stochastic models address uncertainty by design, it should be remembered that for this type of models to be really useful, the probability distributions built into the model should be known, at least within reasonable limits. If they are not, the uncertainty is just shifted from the model parameters to the parameters of a class of probability distributions. Care must also be taken when assessing model validity. The so-called "back-casting" (running the model for the past to check whether it correctly produces actually observed values) fails to produce much evidence if it is possible to specify model parameters with the benefit of hindsight. One strategy to stay clear of the pitfalls of modeling would be to attempt to learn from a model in a way that the lessons learned would be explainable without explaining the model.

1. Introduction

Rapid progress made in the field of electronic data processing has led to a boom of computerized tools in the field of energy planning as much as in any other areas of systematic analysis. Not only the quantity but also the quality of energy planning tools has increased markedly in the course of past years. This progress has already come to the point where the capabilities of modern computers have pushed the limits of data handling capacities and computability into domains that challenge the intellectual capacities of the interpreting human mind. Moreover, the ease and speed with which today's hardware and software solve complex problems make it easy for users to forget that the original purpose of modeling was the analysis of simplified abstract images of the real world.

It seems worth remembering then that the thrust of computer modeling ought to point towards simplification, and the model choice ought to be the simplest to serve the given purpose. But which is the given purpose? This is the question that ought to be answered as precisely as possible before any energy planning tool is applied. Ideally, the purpose of modeling should be defined in terms of a set of concrete questions that are to be answered by model results. This normative statement alludes to the common-sense observation that a well-formulated question is already half of its answer, which means that modeling is an art in addition to being a science, at least to the extent that the better the questions the better the expected model results. Trivial as this may sound, the analyses of actual modeling suggest that it seems to have been notoriously difficult for energy analyses to follow such simple advice.

This chapter will therefore take the description of energy planning issues and tasks in *Some Issues in Energy Policy and Planning* of this encyclopedia as a point of departure and attempt to describe tools that appear adequate for their systematic treatment.

2. The Framework

These introductory strategic remarks apply to a wide range of computer models. The models and tools described in this section refer only to energy planning models, however. These models form a subset of all computer models, and it is characterized by very specific features. One of the most important of them is uncertainty surrounding the subject matter, which enters through many doors. Given the premise of *Some Issues in Energy Policy and Planning* – that energy planning is primarily concerned with externalities, most of which belong to the group of environmental impacts – the uncertainty surrounding the size of any given impact can be substantial. As one of the most prominent examples, the size of the impact of climate change is highly uncertain – and is the subject of continued discussion and even controversy. The problem of uncertainty is compounded by the incommensurability of many environmental impacts with other economic variables, most notably costs. Many attempts have been made to quantify the value of human health and an intact environment, but there are no universally accepted values. The problem cannot be ignored, however, because doing so runs the risk of implicitly attaching extreme values to damages in these areas. A zero value would obviously be wrong, but also the other extreme of implicitly attaching an infinite value to such damages is risky because it readily leads to contradictions between normative and actually observed behavior.

An important stratagem devised to deal with uncertain risks is the so-called precautionary principle, according to which decision making should not rely on an "infinitely forgiving mother nature", but rather proceed cautiously, trying to keep the environmental impact of policy measures within limits so as to cater for some outcomes to turn out on the unfavorable side. Elegant and reasonable as this principle may sound, the problem with it is that it is not readily quantifiable, and we are back to the basic requirements of energy planning tools, i. e., that they must account for uncertainty. And if it is not the tools themselves, then the way of their application must come to rescue. The common way to address uncertainty with deterministic models is via the use of scenarios. A scenario is a possible development of the system modeled. The main feature of a scenario is that it is a complete and consistent description of a given system. In a scenario, a subsystem cannot be changed in isolation without proper regard of the repercussions of such a change in the entire system.

Important functions of scenarios are that they are suited to study the consequences of given decisions in a predefined and reproducible way. A collection of different scenarios allows for the analysis of the robustness of decisions. If scenarios reflect different "states of the world", i. e., different uncontrollable developments, a decision is robust if its consequences are acceptable under a wide range of assumed developments, i. e., in a large fraction, if not all, of the scenarios considered.

In cases where scenario projections take the place of forecasts (in most cases of applying energy planning models, the term "forecast" has been eliminated as being potentially misleading by implying a truth value that is not actually warranted), scenarios are often required to be plausible. Such scenarios are also referred to as descriptive. This term is intended to distinguish them from normative – or prescriptive – scenarios.

There are several possible reasons for wanting to construct normative scenarios that are not necessarily plausible. One example is to describe limiting cases of developments to define a range of possible outcomes. A given policy would then attempt to address all eventualities of this range including the extremes. Another possible purpose of a normative scenario is to describe an example of a sufficient condition for the achievement of a given goal, for example a stabilized global climate or sustainable development.

To the extent that scenarios address uncertainties, the question arises whether stochastic models, i. e., models that work with parameters and variables that are distributed according to probability functions, can serve the same purpose more efficiently. One answer to this complex question is that stochastic modeling is particularly useful in those cases where the probability distributions are known well enough. If they are not, a full analysis of a stochastic model would have to include a sensitivity analysis testing the consequences of using different probability density functions for one and the same model variable. In the face of the infinitely dimensional space of such functions, this seems like a rather arduous – not to say infeasible – task.

3. Classification of Energy Planning Tools

Energy planning tools can be classified according to many criteria, one of which – descriptive vs. prescriptive we have just presented in Section 0. In particular in the area of models setting out to calculate the costs of climate mitigation strategies, the distinction between "bottom-up" and "top-down" models has become a subject of intense debate of the question whether there is such a thing as an emission reduction potential at zero costs. Before summarizing this discussion, let us briefly characterize these two model types.

Bottom-up models, sometimes also referred to as "engineering-type" models, typically include the description of given energy-related tasks (rather than energy demands), which are to be accomplished at minimum costs by a given menu of technologies. In contrast, typical top-down models do not consider energy-related tasks but energy demand in the form of functions that typically depend, among others, on total or sectoral economic product and on energy prices.

The question about the costs of climate mitigation arises because bottom-up models very often find a portion of emission reduction that can be achieved at negative "costs" (the so-called "free lunch" situation). This kind of result arises whenever it can be shown that a better (i. e., less emitting) way than the one actually chosen for performing a given energy-consuming task existed. In contrast to such bottom-up models, the results of typical top-down models suggest that even the slightest amount of mitigation costs something ("There ain't no free lunch."). To make the discrepancy even more pronounced, top-down models usually project demand to increase in response to innovative energy supply options that make energy conversion cheaper. Although this discrepancy between model results of these different kinds puzzled many, it can be largely resolved by two observations.

The first observation concerns the definition of a "free lunch". In top-down models, any emission reduction that comes at negative "costs" is not an emission reduction because it is simply included in the "base line". By the same definition, genuine emission reduction is a measure that incurs extra costs. The second observation has roots in the introductory remarks made on energy planning tools, in particular those that concern the issue of a question to be answered by energy models. In our illustrative example, top-down models ask: *By how much does a given energy price movement change energy demand or energy-related carbon emissions?* In contrast, bottom-up models ask: *How can a given emission reduction task be accomplished at minimum costs?* There seems to be nothing in these questions that justifies the expectation of identical outcomes of the two approaches.

The complex real world does not follow either of these two paradigms literally, however, and both approaches tell some important part of the full story, and the discrepancies between the model types have led those interested in a resolution of seeming contradictions to learn from the logic and from the lessons taught by the two approaches.

Another methodological classification distinguishes between optimization and simulation models. This is not quite the same as the distinction between normative and descriptive models – the normative being similar to the optimization and the descriptive being similar to the simulation models – but it comes close. An important ingredient of optimization models is the *objective function*, i. e., a mathematical formula describing, the minimand or maximand depending on the definition..

One class of optimization models that has been very popular since its invention in the 1940s is the class of Linear Programming models. Besides their obvious limitation relative to the fact that the world is not always linear, this type of models has other specific problems, particularly with the stability of the optimal solution. Ways around these problems have been introduced over the years, but the most important progress has been made in the wake of drastically increasing computer power, which is responsible for the enormous development of the state of the art of modeling methods. Models of ever increasing size can now be solved within reasonable time with the help of more flexible tools such as non-linear and discrete-optimization methods.

A similar caveat as the one described above for stochastic models applies to optimization models. Optimization is most effective in cases where the functioning of a system and its objective function are known with sufficient precision. The notion of being able to have all energy planning tools calculate optimal decisions (and thereby rendering human decision makers redundant) is – largely as a consequence of the uncertainties involved – false.

4. Energy Planning Techniques

Following the rather general methodological classification of energy planning tools as above, this section describes energy planning techniques at increasing levels of comprehensiveness. These techniques may or may not fall completely into one of the above classes. Since in many cases the membership of a technique in one of the model classes from above depends on the specific kind of application, no cross-classification is attempted in the sequel.The following gives an introductory overview. Readers interested in further information are referred to the literature in the field.

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Biographical Sketch

Leo Schrattenholzer has been affiliated with IIASA (International Institute for Applied Systems Analysis) since 1973, after graduating from the Technical University of Vienna. Presently he is Leader of ECS (Environmentally Compatible Energy Strategies) Project at IIASA.

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Dr. Schrattenholzer received his master's degree in mathematics in 1973 and his Ph.D. in energy economics in 1979, both from the Technical University of Vienna. His Ph.D. thesis was on modeling long-term energy supply strategies for Austria. From 1972 to 1974, he was a research and teaching assistant with the Institute of Mathematics I of the Technical University of Vienna. He has worked as a consultant to the Energy Sector Management Assistance Program sponsored by the World Bank and UNDP, for which he conducted a major project assessing personal computer models for energy planning in developing countries. He has also been a consultant to governmental institutions on national strategies to reduce greenhouse gas emissions. Other consultancy work has included the design and implementation of a computerized information system about space heating demand in the city of Vienna. He has represented IIASA-ECS in international teams working for three major projects co-sponsored by the European Commission and has lectured at universities and other educational centers. He is a Lead Author of the IPCC's (Intergovernmental Panel on Climate Change) Second Assessment Report. He is also the member of editorial board of the Pacific and Asian Journal of Energy (PAJE) and the International Journal of Global Energy Issues (IJGEI).

His scientific interests include the development, implementation and application of energy-economy-environment models, energy forecasting, and scenario analysis.