

Chapter 10

Stochastic Programming Models in Energy

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Abstract

We give the reader a tour of good energy optimization models that explicitly deal with uncertainty. The uncertainty usually stems from unpredictability of demand and/or prices of energy, or from resource availability and prices. Since most energy investments or operations involve irreversible decisions, a stochastic programming approach is meaningful. Many of the models deal with electricity investments and operations, but some oil and gas applications are also presented. We consider both traditional cost minimization models and newer models that reflect industry deregulation processes. The oldest research precedes the development of linear programming, and most models within the market paradigm have not yet found their final form.

Key words: Stochastic programming, energy, regulated markets, deregulation, uncertainty, electricity, natural gas, oil.

1 Introduction

The purpose of this chapter is to discuss the use of stochastic programming in energy models. This is not a well defined topic. Let us therefore start by outlining what this chapter is and what it is not. First, this is not an annotated bibliography. Its purpose is to help the reader see where stochastic programming can be used, and to point to relevant existing literature. We do not attempt to be complete in our references, only to help the reader find good starting points. We shall discuss both existing models and the potential for new arenas.

Then, what shall we understand by the reference to energy models in *stochastic programming*? Generally, stochastic programming refers to a problem class, and not to the choice of solution procedures. Many of the models in this class can be solved both with tools from mathematical programming and as stochastic dynamic programs (SDPs). This book is about stochastic programs solved with tools from mathematical programming. However, the view we have taken in this chapter is that we cannot include or exclude interesting models solely on the basis of what solution method the authors have chosen. Hence, if an existing model represents a stochastic dynamic decision problem which can be formulated as a stochastic program, we include it irrespective of whether it is solved with methodology from mathematical programming or set and solved as an SDP.

Furthermore, to have made the point, this chapter is not about operations research and energy. This ought not to affect our models too much, as we are of the opinion that most real decisions are made under uncertainty, but it will affect our referencing to the literature.

As part of the preparation for this chapter we had the privilege of reading a text, which for our field, is very old. Massé (1946) authored two volumes on hydro scheduling. The books are based on work performed before and during World War II. Of course, he does not discuss stochastic programming as such—the term was not invented at the time—but he discusses models and methodology that would fit the premises of this chapter. It is very interesting to see how he walks his readers through some very deep arguments about why deterministic models are not good enough. He points to the fact that looking at a deterministic future is far too optimistic, and that flexibility will be disregarded.

His major point is that hydro scheduling is about releasing water such that the immediate financial gain equals the expected future value of water. The expected future value of water is presented as a function of reservoir level, present inflow (to the extent that there is memory in that process), and time (to represent seasonality). He gives optimality conditions for this case. In fact, he has a long discussion to the effect that all uses of natural resources is a tradeoff between use now and use in a stochastic future. To illustrate the use of statistics about the future, he makes the reference that if you wish to check the probability that you are alive tomorrow, you look at your present health, if you wish to know if you are alive in thirty years, you resort to statistics.

Another fact, dear to all stochastic programmers, is his pointing out that while deterministic multiperiod optimization yields decisions for all periods, a stochastic approach only yields policies or strategies.

A further major issue in the books is the objective function of the optimization. Should we maximize expected profit or expected utility (which he denotes psychological expectation in contrast to mathematical expectation)? He is concerned about some of the well known paradoxes when using expected profit, and he always refers to Borel for these examples. He is also very much concerned about risk, and strongly believes that risk will always be with us.