MODELING THE RISKS OF GEOTHERMAL DEVELOPMENT

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INTRODUCTION

Geothermal energy has emerged as a promising energy source in recent years and has received serious attention from developers and potential users. Despite the advantages of this resource, such as potential cost competitiveness, reliability, public acceptance, etc., the commercial development and use of geothermal energy has been slow. Impediments to the development of this resource include technical, financial, environmental and regulatory uncertainties. Since geothermal power is unique in that the generation facility is tied to a single fuel at a single site, these uncertainties are of particular concern to utility companies.

The areas of uncertainty and potential risks are well known (see for example EPRI 1978, and Woodward-Clyde Consultants 1980). This paper presents a method for quantifying the relevant uncertainties and a framework for aggregating the risks through the use of submodels. The objective submodels can be combined with subjective probabilities (when sufficient data is not available) to yield a probability distribution over a single criterion (levelized busbar cost) that can be used to compare the desirability of geothermal power development with respect to other alternatives.

THE COMPONENTS OF COST

Figure 1 summarizes the components of busbar cost. The components of capital and operating costs are self-explanatory. The costs associated with plant shutdowns are those which only occur if the plant becomes essentially "inoperable", for whatever reasons, prior to its design life. These consist of the opportunity cost of unavailability of power, the "write-off costs" for the plant, and the cost of any additional losses.

THE RISK MODEL

The uncertainties can be divided into two broad categories. The first category affects capital and O&M costs of an operating plant as well as the project schedule. The second category of uncertainties has a low probability of occurrence but can result in the plant becoming inoperable, thus significantly impacting costs. Among events in the second category are damage from a major earthquake, marked changes in existing regulations, and major plant or reservoir-induced environmental impacts.

Figure 2 illustrates how different kinds of uncertainties can be integrated into an aggregated risk model. The model consists of various submodels that relate the endogenous and exogenous uncertainties to major

major cost components, including the plant shut-down costs. The submodels may be objective (when adequate information and quantitative relationships are available), or subjective (when adequate information is not available, or when the existing information is interpreted differently by different experts). The output of the various submodels is integrated to yield the effect of several sources of uncertainty on a major cost component.

The cost aggregation and accounting model is the focal point of the model. It functions both as a means for integrating the various probabilistic cost components, and to account for financial and economic uncertainties that affect these costs. The last step of the analysis incorporates the uncertainties associated with the contractual arrangement between the utility and the resource company. The submodels are described in more detail in a recent study (Woodward-Clyde 1980).

The advantages of this aggregated approach include the following:

- endogenous and exogenous uncertainties are explicitly addressed,
- the model provides useful intermediate as well as final information for decision making,
- the output is in the form of probability distributions,
- the effect of changes in assumptions on the model output can be easily evaluated, and
- the effects of uncertainty from many diverse sources are aggregated in a unified model.

REFERENCES

Electric Power Research Institute, Proceedings of the Second Geothermal Conference and Workshop, EPRI WS-78-97, October 1978.

Woodward-Clyde Consultants, An Engineering Risk/Benefit Assessment of Geothermal Development in the Imperial Valley, May 1980.

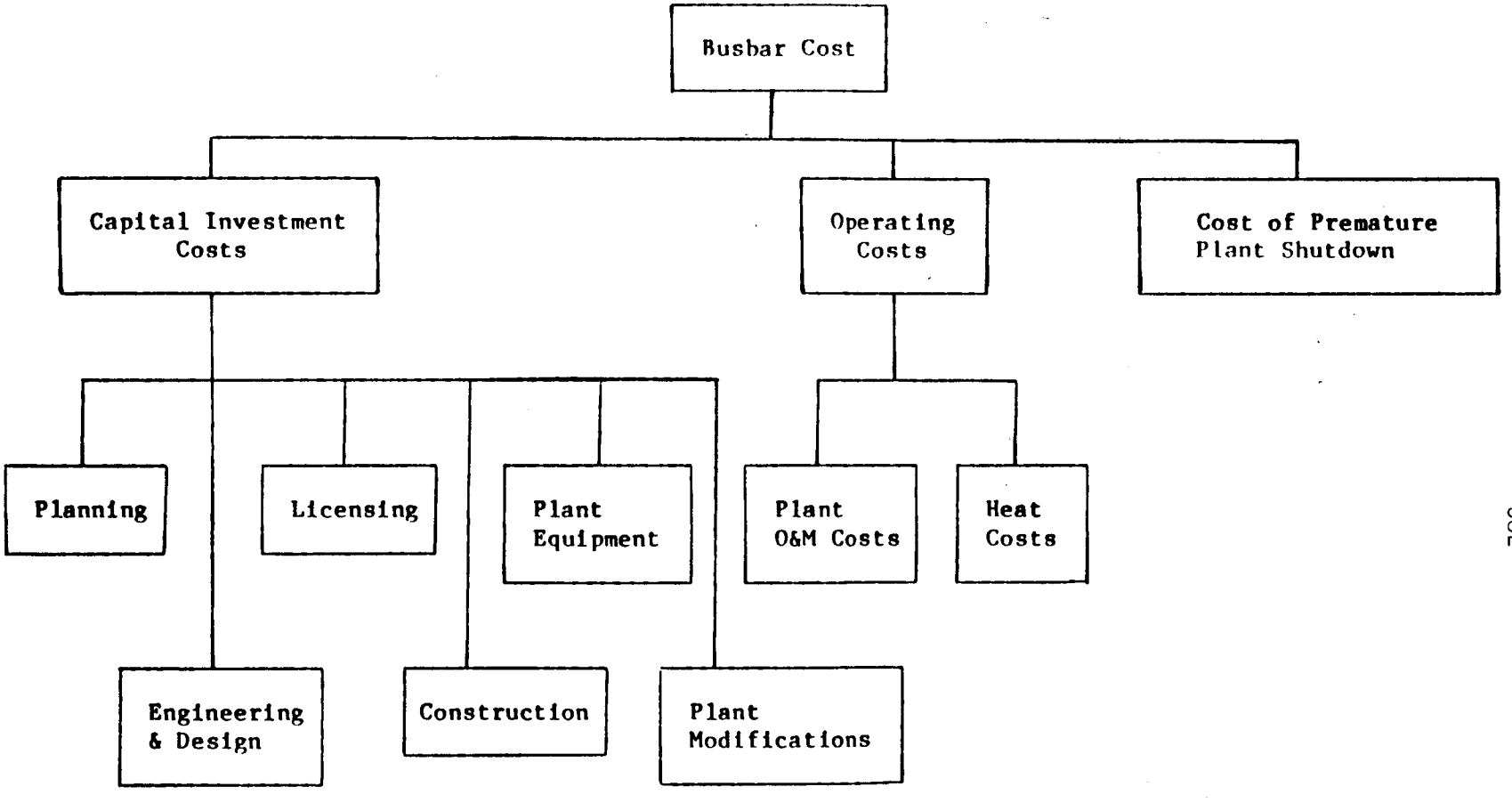

Figure 1. COMPONENTS OF BUSBAR COST

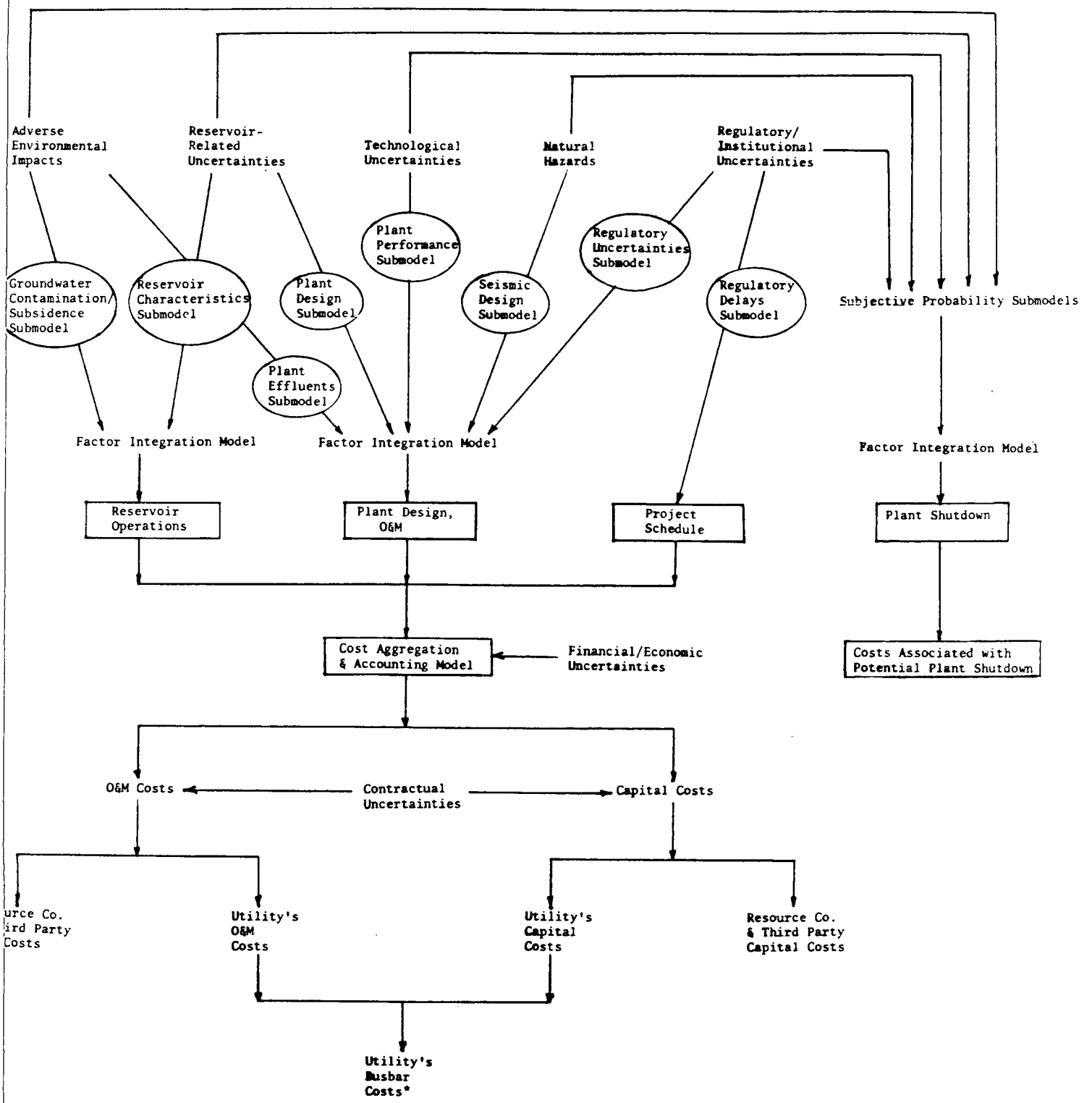

Figure 2. Conceptual Risk Assessment Model

***Does not include costs associated with potential plant shutdown**