PLANNING CONSERVATION PROGRAMS
DECISION SUPPORT WITH THE CONSERVATION POLICY ANALYSIS MODEL

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ABSTRACT

System Dynamics has proven to be a useful paradigm for the construction of a policy analysis model in support of energy conservation decisions in the United States Pacific Northwest. This paper outlines the most important complexities faced by the Bonneville Power Administration planners, how system dynamics has provided a framework for analysis and how the integrated model currently used by staff members (the Conservation Policy Analysis Model) has been applied successfully to a wide range of problems.

0. Introduction

The purpose of this paper is to present modeling professionals with an overview of the context and application of two large system dynamics models developed at the Bonneville Power Administration, a federal utility responsible for sales and distribution of electricity in the United States Pacific Northwest. These models, collectively known as the Conservation Policy Analysis Models, give analytical staff a tool for evaluating the effects of proposed electric utility energy conservation program packages. The models are currently used on a continuous basis for conducting ad hoc analysis and annually as part of a regional resource planning process.

The paper is presented in five parts. The first section presents a brief discussion of the electric energy conservation history of the United States Pacific Northwest. The second discusses the usefulness of system dynamics in framing the analysis of conservation. The third section examines the features of the models which are made possible by the system dynamics approach. The fourth section provides some specific results along with their application in the planning arena. Finally, the fifth provides a conclusion.

1. Complexities of the Pacific Northwest planning environment

The Pacific Northwest region of the United States presents a complex challenge to regional energy analysts. Large amounts of precipitation, great rivers and mountainous terrain combine to provide ample hydro-electric potential. (1) Development of this potential, beginning in 1933, provided the region with one of the world's largest hydro-electric systems and, historically, some of the lowest electric power rates. (2)

The extremely low electric rates enjoyed by the region suffered a blow in the 1970's when events combined to increase spending on capacity expansion. Like many utilities, those in the Pacific Northwest looked to nuclear energy to meet anticipated growth in demand. Armed with forecasts derived primarily from "sum of the utilities" techniques, which added up the independently projected demands of all the regional utilities, planners advocated the development of five large nuclear power stations. These projects fell on hard times as double digit inflation escalated capital costs while technology changes and unanticipated overruns increased construction costs. Conditions worsened as high energy costs sparked significant reductions in demand growth and decreased the need for these plants. In the decade 1970-1980, these conditions caused electricity costs to soar region-wide and rates to increase substantially. These troubles precipitated the passage of the Pacific Northwest Electric Planning and Conservation Act of 1980 (3) and, indirectly, the modeling effort which is the focus of this paper.

The Pacific Northwest Electric Planning and Conservation Act (the Regional Power Act) delivered a mandate to the Bonneville Power Administration (Bonneville) to take a central role in regional energy planning. Several provisions of the Act are critical to the strategic analysis performed by the

Office of Conservation. First, Bonneville became obligated to provide for any future need for electric power in the region. Second, the Act gave Bonneville the authority and responsiblity to acquire resources to meet load placed on it. Bonneville was directed to include both the costs and power associated with the new plants with those of the existing hydro-electric system. Last, and perhaps most important, the Act mandated Bonneville to consider conservation (along with renewables and cogeneration) preferentially when determining what resources to acquire to meet future load growth.

Prior to the passage of the Act, Bonneville had done little large scale research or development of the conservation resource. Hence, planners had little experience in fulfilling their new responsibilities. Many questions arose from early discussions. Many of these proved difficult to answer because of large differences between the traditional generating resources such as coal plants and newly-available conservation options such as residential weatherization programs (4). Some of the most challenging included these:

1. How much conservation is available to the system?

2. How quickly is it available?

3. How much would it cost?

4. Should it come from commercial buildings, industrial facilities or from residences?

5. Should programs concentrate on existing or yet-to-be-built stock?

6. On what criteria should the various options be judged?

7. How will exogenous phenomena affect the outcome of the decision?

Prior to 1983, Bonneville had access to traditional utility planning tools to examine these questions. These tools included econometric analyses which could predict future levels of price induced conservation, linear programming routines which could chose mathematically optimal mixes of conservation packages, load forecasting programs which could treat conservation as a load reduction for sensitivity testing, etc.

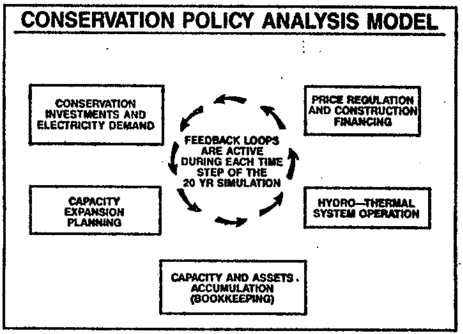
2. System Dynamics has proven useful in framing the problems faced in the analysis of conservation as a resource.

After the passage of the Regional Power Act, some of the various traditional analytical tools were used to examine conservation. These tools proved inadequate to answer the important questions outlined above. As a result, in 1983 Bonneville's Office of Conservation began the evaluation of a system dynamics approach to modeling conservation issues. The eventual decision to move forward along this path was critical to the development of a used and useful tool for policy analysis (5).

This decision was important for two primary reasons. First, choosing this methodology implied construction of a fully integrated model. Second, the model would be driven by causal mechanisms subject to endogenously controlled feedback structures. Although these features are common to all system dynamics models, they were lacking in the previously available corporate models at Bonneville. The reason they are important relates back to the nature of the conservation resource.

3. Due to the system dynamics framework, CPAM has many desirable features.

The fact that the Conservation Policy Analysis Model (CPAM) is integrated gives it particular strength when it is used for conservation policy questions. Conservation is a multi-faceted resource. It affects utility costs since the utility may provide financial assistance, research, program evaluation, advertising, etc. It also affects rates, depending on the amount of utility contribution to the total costs indicated by the specific program. It impacts the demand in incremental steps as each structure "comes on line". Without inclusion of all the elements of a utility system, models have difficulty characterizing the different impacts of different programs. Figure 1 illustrates the components of CPAM (6).



The fact that CPAM is controlled by endogenous causal loop and feedback structures enables planners to get a realistic look at how continuously changing conditions will affect proposed policies. Perhaps the most important difference the modeling approach made is the ability to separate price induced (market) responses from program induced (policy) responses. Planners at Bonneville continually deal with questions related to how cost effective various proposed conservation strategies will be.

A quick examination of some of the key questions posed earlier reveals the utility of an approach which utilizes feedback. How much conservation is available to a program and how quick? It depends on when the program is initiated and the effectiveness of the market in inducing private investment prior to program initiation. How much will it cost? It depends on how many of the least expensive measures were purchased as a result of the market inducements. What sector should Bonneville begin with, and should it be new or existing structures? It depends, again, on how sensitive each of the sectors has been to prices (a function of their discount rates, propensity to change fuels, behavior changes, and how price changes have differentially affected their rates over time) and the proposed timing of the policy. The Conservation Policy Analysis Model, through its use of feedback and causal mechanisms, allows Bonneville analysts to make meaningful policy studies which would otherwise be impossible. Some recent policy studies are outlined in the next section.

4. CPAM is proving to be used and useful.

In 1985 Bonneville used CPAM to analyze a variety of conservation strategies in order to select a diverse set of strategies for use in its annual resource planning process (7). When used in this way, the CPAM becomes a screening tool to select the most promising conservation strategies for analysis in the larger corporate models. In 1985 CPAM was used to generate savings targets by sector, given different combinations of conservation policies for different time periods through the 20 year planning period.

In considering alternative strategies for resource acquisition planning Bonneville uses multiple criteria to judge which is best (8, 9). The first criterion, Minimizing Energy Service Cost, evaluates whether the region is investing its money in those resources that will provide energy services, e.g., heat, light, and machine operation, for the least economic cost. The second goal, Minimizing Cost to the Utility, examines the financial burden on the utility given different programs. Finally, the goal of Minimizing Bonneville Rates addresses the concern of assuring Bonneville customers the best value for their energy dollar and providing equitable treatment for those not participating in conservation programs.

Sometimes desirable goals come into conflict. For example, we found that when conservation is acquired, progress is made toward the goal of minimizing utility costs. However, conservation may work simultaneously against the goal of rate minimization in the short term. At current rates a decrease in utility revenues may result in a rate increase to cover expenses. The magnitude of the rate increase will be a function of the value of displaced generating resources or increased sales. Because the Pacific Northwest is currently in surplus, conservation programs tend to raise rates modestly in the near term. These goals also can come into conflict on ratepayer equity issues. For instance, many programs prove beneficial to the region as a whole since relatively expensive generation is displaced. However, some individual ratepayers can be worse off if they cannot or do not participate in utility programs.

Table 1 shows representative model results from the CPAM screening process. Results are based on Bonneville's medium load forecast. The strategies included span the range of activity from minimum (strategy (G)) and conservation in new structures only (strategy (F)) to cost sharing incentive levels of 90% in all sectors (strategy (A)). Strategy (A) has the worst one-year rate penalty, but it provides the largest benefits to the region and to the utility over the forecast period. Strategy (F) generates a higher rate impact than either of strategies (C) or (E) while providing less benefits. This phenomena occurs because conservation resources are available at lower unit cost than generating resources. Higher strategies tap relatively more of this potential during the planning period.

Table I. Impacts of Alternative Conservation Strategies

Strategies	(A)	(B)	(C)	(D)	(E)	(F)	(G)
<u>Utility Incentives</u>							
Residential							
New	90%	75%	75%	75%	75%	75%	-
Existing	90%	75%	75%	75%	50%	-	-
Commercial							
New	90%	75%	75%	75%	75%	75%	-
Existing	90%	75%	50%	-	50%	-	-
Industrial							
New	90%	75%	50%	-	50%	-	-
Existing	90%	75%	50%	-	50%	-	-
<u>Results</u>							
Utility Conservation Spending over 20 Years (85 \$, 10^9)	\$4.2	\$2.7	\$2.0	\$1.8	\$1.6	\$1.3	\$0.8
Utility Spending per Net Ave. KW Saved (85 \$, 10^3)	\$3.3	\$2.7	\$2.5	\$3.1	\$2.3	\$3.6	-
Average Rate Penalty (mills/kwh, 85\$)	0.2	0.0	0.0	0.1	0.0	0.0	-
Worst Year Rate Penalty (mills/kwh, 85\$)	0.9	0.5	0.3	0.2	0.2	0.1	-
Regional Benefit (NPV) (85 \$, 10^9)	\$1.2	\$0.8	\$0.6	\$0.3	\$0.4	\$0.1	-

One of the issues raised for the analysis is whether to do conservation in a surplus. Our analysis indicated that Bonneville may do well to begin programs in a surplus. Conservation in a surplus period makes sense because it allows the region to accumulate enough savings to defer construction of the more expensive generating plants (required when the system goes deficit), and reduce current operating costs or increase power exports in the near term. Some benefits accrue from starting any of the strategies immediately. Other model runs indicate that if program implementation were delayed for 5 years, followed by the most aggressive strategy, additional benefits would be minimal and utility cost would be high. Further, the prospect of shutting off programs and then turning them back on aggressively

5 years later was deemed unrealistic from a program delivery standpoint. The ultimate policy decision was to proceed to implement conservation programs at the Medium to Medium-High levels, trading off the regional benefits against the rate penalties.

CPAM can also be used to examine program design issues as they relate to broad impacts on the system. Late in 1985 a question came up about how much of a program financial incentive Bonneville should pay in utility service territories who do not place load requirements on Bonneville. Due to the unique ratemaking structure for Bonneville wholesale power, we needed to determine the financial benefit received by current Bonneville customers from conservation resources acquired by potential Bonneville customers. During 1985, CPAM was disaggregated to portray the three major customer groups individually, i.e., the public utilities, the private, investor-owned utilities (IOUs) and the direct service customers (mainly aluminum smelters) which purchase their power directly from Bonneville.

Bonneville has a different relationship with each of these customer groups, both historically and due to changes embodied in the Regional Power Act. Three factors are important: (1) all Northwest utilities can rely on Bonneville for their load growth requirements by giving seven years notice before placing a load on the system; (2) all the residential and rural customers of every Northwest utility have rights to the cheapest firm power pool rate through the residential and rural exchange provisions of the Regional Power Act (Bonneville exchanges power at the utility's average system cost); and (3) IOU's must pay a melded new resources rate for nonresidential loads put on Bonneville. The situation is further complicated by the fact that Bonneville does not know how much load will be placed on the system beyond seven years, or whether or not utilities will exchange loads. This complex ratemaking situation makes it difficult to assess the relative benefit to the Bonneville system of conservation on IOU loads.

Therefore, a disaggregated system-level model was needed. An analysis conducted in the Spring of 1986 using the Subregional Model considered the financial impacts on Bonneville relative to those on the investor owned utilities of early conservation savings on IOU loads. We used CPAM to simulate the financial impacts of an advancement of new home efficiency improvements to 1986 rather than 1989. The 1985 Bonneville medium load forecast was used as the basis for the analysis. The period of study was set to 1986-2005. The savings achieved were modeled as a 100% effective code within the IOU service territory. No utility cost was associated with the savings since the goal was to calculate only the relative financial benefit to Bonneville and the IOUs. The IOUs were represented as a single entity, and no geographical or climate area breakdowns are represented. Sensitivity analysis was performed on the assumption of IOU load placement on Bonneville in the long term: (1) no load placement (0%); (2) Bonneville provides 50% of the new resources to serve IOU deficits; and (3) 100% reliance on Bonneville to meet IOU new resource requirements.

The model was run twice for each load placement assumption. The base case run assumed the code for the IOU service territory began in 1989. The test case then assumed the code began in 1986. The difference in IOU loads and the net present value of future Bonneville and IOU revenue requirements were used as the primary indicators of impacts. Table II presents the results.

Table II. Benefits of Conservation on IOU Exchange Loads

IOU Deficits Placement	0%	50%	100%
Reduction of PV of Bonneville Rev. Req.	$43 M	$83 M	$135 M
Reduction of PV of IOU Rev. Req.	$154 M	$136 M	$121 M
Bonneville % of Total	22%	38%	53%

As the IOUs place load on Bonneville, Bonneville benefits from the early conservation in two ways. First, less residential load is exchanged, so Bonneville saves the difference between the average system cost of the IOUs and its priority firm power rate on each kilowatt-hour saved. Second, since the IOUs are not building their own new, expensive resources, their average system cost and the cost of each unit exchanged is lower over the long term. The IOUs benefit because they build less capacity and avoid the costs and risks of large, capital-intensive construction ventures.

The magnitude of the benefits of advancing construction standards varies with the extent to which IOUs place load on BPA. The shift in relative benefits toward Bonneville from higher IOU load placement is due to (1) the reduced cost of the exchange due to lower average system costs for the IOUs, and (2) higher avoided costs for Bonneville from the additional generating resources needed to serve the larger system load. The opposite is true for the IOU customer group. The ultimate policy decision was to make the conservative judgment that 25% of the benefits would accrue to the Bonneville system, and a program cost sharing offer was extended to the IOUs on that basis.

5. Conclusion.

System dynamics has proven useful in studying conservation policy questions at the Bonneville Power Administration. Because the technique necessarily entails the use of complete system representation, causal relationships among the components and feedback mechanisms, it is particularly well suited to problems related to conservation planning.

Conservation policy analysis, particularly in the Pacific Northwest, takes place within an enormously complex, and ever-changing environment. The endogenous representation of system changes over time, a feature not found with traditionally available planning tools, is a key to the success of the Conservation Policy Analysis Models. The utility of the technique is exemplified by the models' ability to track the effect of prices on the impact of conservation programs, as well as the impact of timing on their relative costs and benefits.

The models are used by staff analysts on both an ad hoc basis and as part of the annual corporate resource planning cycle. Recent uses of the model include the testing of significantly different conservation policy strategies to determine their impact on the total system costs over the twenty year planning horizon and determining the impact of timing of a particular program on different customer groups in the region.

END NOTES

1. The Columbia River, the fourth largest in North America, drains approximately 259,000 square miles with an annual discharge rate of 180 million acre-feet. The Columbia's drop is approximately 2 feet per mile, four times as steep as the Mississippi. A detailed description of the resources in the region is found in Bonneville (1980) pg. 6-7.

2. The Grand Coulee and Bonneville Dams were initiated in 1933. For a more thorough treatment, please see Bonneville (1980) pg. 29.

3. For an annotated description and text of the Regional Power Act, please see Bonneville (1981).

4. For a more complete discussion of the ways in which conservation differs from generating resources and the reasons that these questions are critical see Bull and Barton (1986).

5. Ford and Naill (1985) Chapter 4 provides a description of the Regional Conservation Policy Analysis Model and an overview of electricity supply and demand in the region.

6. Bull, et. al (1985).

7. Bonneville (1986).

8. Bonneville (1985).

9. Ford and Geinzer (1986).

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