A Software Tool to Help Building Operators Respond to Real Time Electricity Rates

Leslie. K. Norford, Tabors Caramanis & Associates and Massachusetts Institute of Technology
Scott L. Englander, and Benjamin. J. Wiseley, Tabors Caramanis & Associates

Building operators are increasingly faced with complex pricing information from electric utilities. Operators of commercial and industrial facilities have the opportunity to respond to price signals in whatever ways are feasible. In principle, operators can evaluate in a rational manner the costs and benefits of operating equipment in a manner that reduces electricity bills. This evaluation can include equipment that uses a fuel other than electricity, such as on-site generators, or thermal—storage systems that can provide a service when needed but use electricity at times when it is inexpensive. The evaluation also involves the trade-offs between costs and possible reduction or shifts in end-use services fueled by electricity, such as lighting and regulation of space temperature.

The flexibility associated with real-time rates come at the expense of a demand for increased vigilance, knowledge, and computational skills on the part of the building operator. This paper describes software developed to aid building operators in minimizing energy costs under real-time pricing electricity rates by assessing possible control strategies and performing the necessary numerical computations.

INTRODUCTION

Real-time prices (RTP), described in detail by Schweppe et al. (1988), are designed to accurately convey to the customer the electricity provider's time-varying marginal costs, so as to encourage electricity use at times when it costs less to provide. The value-added service of innovative pricing structures such as RTP does little good, however, if customers do not have the knowledge, information, or tools to respond.

Price is not enough. Three functions—planning and evaluation, operation, and control—are required to make RTP valuable to customer and provider. First, customers need to be able to develop appropriate control responses and evaluate their energy and cost impact. Second, while operating in an RTP environment, customers need to know how to respond specifically to the next day's hourly prices. And third, they must have the control hardware and software in place to implement the response.

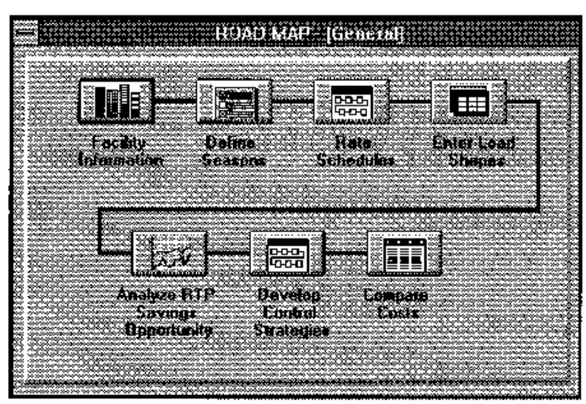
The software described in this paper demonstrates those features required for the planning and evaluation function. While some software has been available that compares costs under conventional and RTP rates, these packages require the user to provide load shapes that embody the response. No help is offered to the user in developing a set of system-specific responses and evaluating the trade-off between the service provided by electricity-consuming equipment and the cost of operating this equipment.

Figure 1 shows the functional organization of KBS/RTP, an RTP-response software package developed by the authors under contract to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (Norford, 1996a and 1996b). This software, which enables the user to compare electricity use and cost under several load and rate scenarios, was designed to perform the activities listed above.

EQUIPMENT CONTROL STRATEGIES

In addition to whole facility base case load shapes and rate information, the user enters information about systems that can be controlled in response to real time prices, including an

Figure 1. The basic functional organization of KBS/RTP.



auxiliary generator, thermal storage (TES), lighting systems, space temperature control, and other miscellaneous loads (Figure 2).

The control of equipment in response to real-time prices typically falls into one of three categories:

- Making use of an alternative supply option when (marginal) electricity prices are higher than the operating cost of that option, or shifting use at the point of supply from periods when prices are high to periods when prices are low.

- Curtailing use when prices exceed some threshold and service is less than critical.

- Shifting use at the point of service from periods when prices exceed some threshold to periods when prices are lower.

These types of control differ as to whether service is compromised, and how annual energy use is impacted. Table 1 characterizes control for a variety of systems according to these attributes, and according to whether RTP control involves a shift in the time when equipment is operated.

USING THE KNOWLEDGE BASE TO DEVELOP CONTROL STRATEGIES

When RTP-based control of a system does not involve a potential compromise of service, the control strategy incorporated in KBS/RTP is based primarily on a price evaluation. For example, an on-site generator should be used when it is less expensive to operate than to purchase electricity. Thermal storage should be scheduled to both displace mechanical cooling at hours when electricity prices are high and recharge the storage when prices are low, subject to

Figure 2. *On this form, the user enters operating data for the cooling system, for use in calculating the response of the thermal storage system. Pressing the ''show graph'' button will display cooling load curves.*

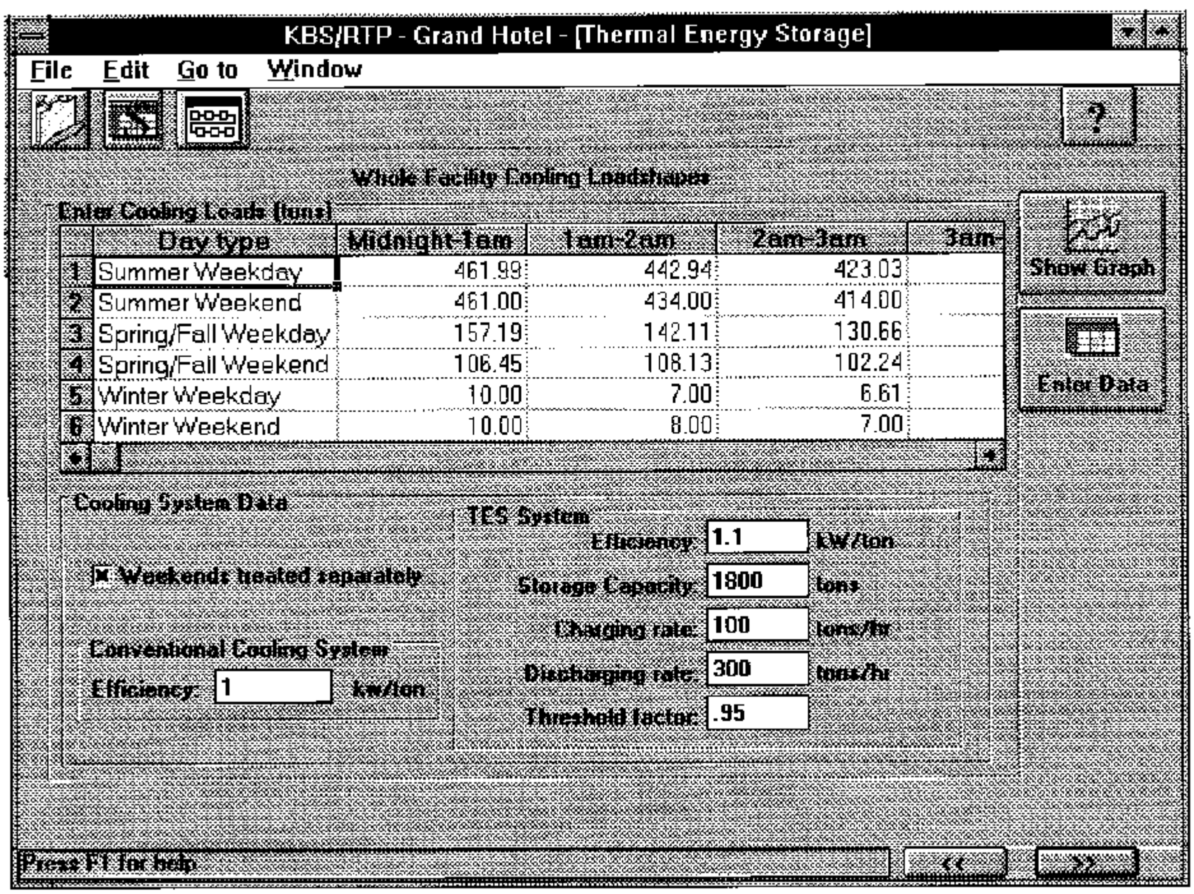


Table 1. *Key Features of RTP-Based Control for Various Systems*

System	Service Compromised?	Annual Energy Use	Time-Shift in Use
Generator	no	same	no
Misc. Shiftable	no	same	yes
TES	no	increase	yes
Refrigeration	no	increase	yes
Water Heating	no	increase	yes
Lighting	maybe	decrease	no
Space Temperature	maybe	increase	yes
Misc. Curtailable	yes	decrease	no

constraints due to storage size, and charge and discharge rates. In both cases, KBS/RTP allows the user to ‘‘tilt the playing field’’ to account for externalities. With the generator, external factors could include the noise of generator operation that would influence a facility to operate the generator only when the price of electricity exceeds generator costs by a specified factor.

Service is potentially compromised for lights and space temperature control as well as control of miscellaneous curtailable loads. In these situations there is a trade-off between the value of the provided service and the cost of providing that service. A facilities manager may want to take steps to curtail service (dim lights, let temperatures drift from set points) if that service is not essential and if the savings are substantial. For example, corridor lights in a hotel could be dimmed or some lights turned off if electricity prices are high, but lights in an occupied conference room would probably stay on because the service is important.

The knowledge-based components come into play when the importance of service must be evaluated. The knowledge base incorporates the kind of decision making process that facilities managers and energy analysts have made in setting up RTP-based control which may compromise service provided by a system. For these systems, rules contained in the knowledge base are fired as needed to determine the constraints on control and the price threshold above which the control will be implemented in the simulation (Figure 3). The price-based control strategies recommended and evaluated by KBS/RTP often are in the form of a control action being taken when the hourly price exceeds some threshold, e.g., ‘‘the lights in a given zone will be turned off weekday evenings when the price is very high (>$0.12/kWh) or higher.’’

COST COMPARISON

Once data entry is complete, the software will compute the hourly control response and compare annual energy use and cost for several rate and load scenarios, and display their results in tabular and graphical form (Figures 4 and 5).

CONCLUSION

The software package briefly described here is designed for use by electric utility personnel and managers of large commercial facilities. It enables the user to compare electricity use and cost under several load scenarios (base case and controlled) and rate scenarios (time of use and real time prices). The program demonstrates how knowledge based decision-making can be used to devise equipment control strategies that balance the user’s requirements for service and comfort with the objective of reducing electricity costs. It shows how such knowledge-based analysis can be combined with thermal and quantitative economic analysis to generate system-specific control heuristics. The software has been enhanced by the developer and a major controls manufacturer and is now available as a commercial product.

Figure 3. *Knowledge trees for the general case of equipment control. Each box represents a premise or a conclusion. The inference process begins by seeking the conclusions (at the top) and chains backward (down, in this case) as it seeks the premises referred to by each rule as it is fired.*

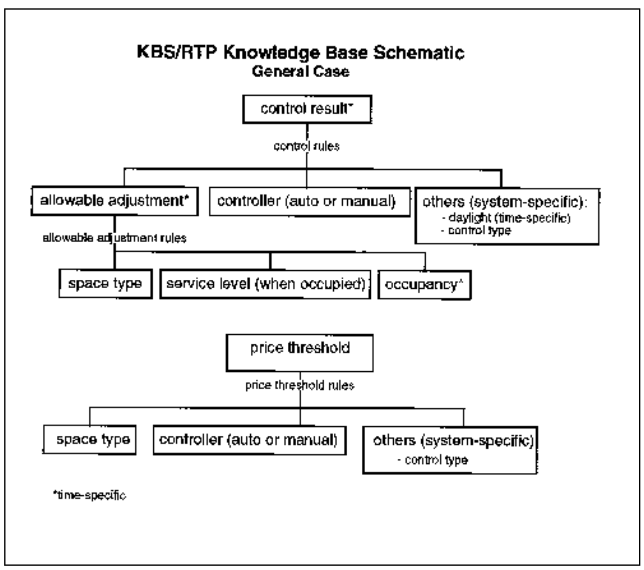
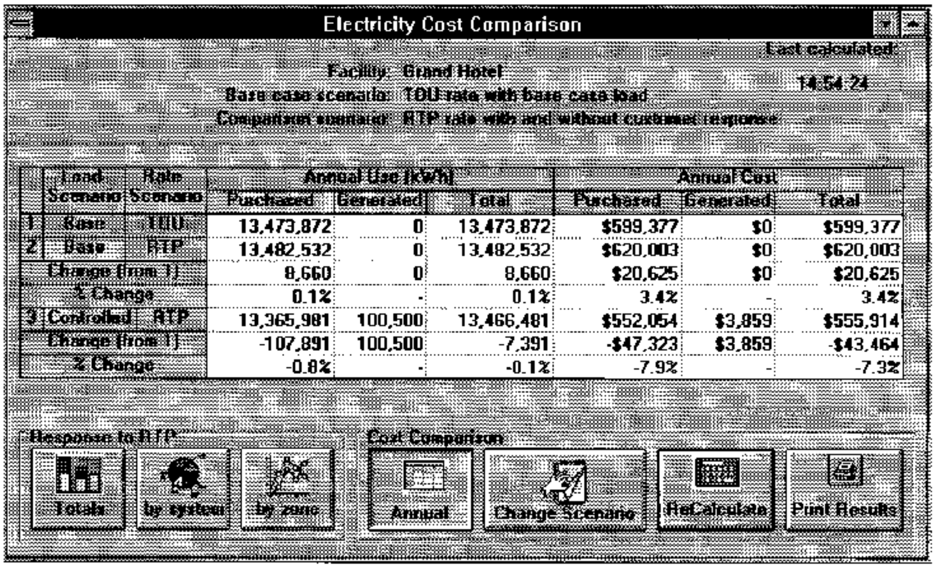


Figure 4. *Summary of annual energy and cost impacts calculated by the software for different rate and load scenarios. The user can view the hourly or total control response for individual systems or zones by pressing the buttons at the bottom of the form.*



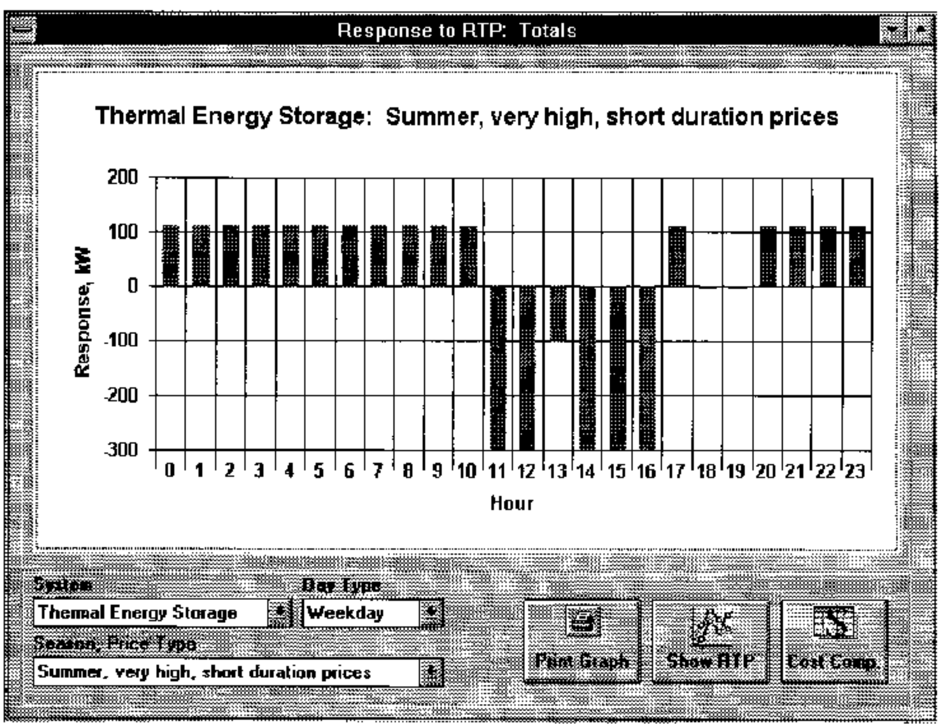
Electricity Cost Comparison

Last calculated: 14:54:24

Facility: Grand Hotel
Base case scenario: TOU rate with base case load
Comparison scenario: RTP rate with and without customer response

	Load Scenario	Rate Scenario	Annual Use (kWh) Purchased	Annual Use (kWh) Generated	Annual Use (kWh) Total	Annual Cost Purchased	Annual Cost Generated	Annual Cost Total
1	Base	TOU	13,473,872	0	13,473,872	$599,377	$0	$599,377
2	Base	RTP	13,482,532	0	13,482,532	$620,003	$0	$620,003
	Change (from 1)		8,660	0	8,660	$20,625	$0	$20,625
	% Change		0.1%	-	0.1%	3.4%	-	3.4%
3	Controlled	RTP	13,365,981	100,500	13,466,481	$552,054	$3,859	$555,914
	Change (from 1)		-107,891	100,500	-7,391	-$47,323	$3,859	-$43,464
	% Change		-0.8%	-	-0.1%	-7.9%	-	-7.3%

Figure 5. *This graph shows the response of the thermal storage system.*



ACKNOWLEDGMENT

Tabors Caramanis & Associates acknowledges the financial and technical support of ASHRAE.

REFERENCES

Norford, L.K., S.L. Englander, and B.J. Wiseley. 1996a. *Demonstration Knowledge Base to Aid Building Operators in Responding to Real-Time-Pricing Electricity Rates*. Final Report of Research Project 833-RP. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

Norford, L.K., S.L. Englander, and B.J. Wiseley. 1996b. ''Demonstration Knowledge Base to Aid Building Operators in Responding to Real-Time-Pricing Electricity Rates (833-RP).'' Draft technical paper submitted for publication in *ASHRAE Transactions*. Atlanta: American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE).

Schweppe, F.C., M.C. Caramanis, R.D. Tabors, and R.E. Bohn. 1988. *Spot Pricing of Electricity*. Boston: Kluwer Academic Publishers.