Forum

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Residential Dual Energy Programs: Tariffs and Incentives

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1. Introduction

The problem of efficiently pricing electricity has been of concern to economists and policy makers for some time. A fundamental hurdle in the efficient pricing problem is that electricity is a non-storable commodity with a highly variable demand. Although variations in demand are in fact cyclical, with relatively well known patterns, the effects of peaking demand on required reserve margins and overall system cost and reliability can be significant. Today the problem is compounded by environmental and cost barriers to traditional capacity expansion responses. A natural solution has been to suggest tariffs which in some way smooth demand and thus reduce the need for excessive reserve margins. Time-of-use pricing, marginal cost pricing and peak-load pricing are all variations of this approach, and have been treated extensively in the literature. These principles usually involve some type of differential pricing with the implicit goal of shifting demand away from the peak.[1]

1/ Boiteux (1949) and Vickrey (1971) are among the earliest references offering detailed analysis of spot pricing in this context. Schweppe *et al* (1988) is the most recent comprehensive work on spot pricing and responsive pricing for electricity markets. With regards to peak load pricing see especially Chao (1983) and Crew and Kleindorfer (1976). The issue of interruptibility is treated by, among others, Marchand (1974) and Oren and Doucet (1990).

A recent issue of this *Review* contained two papers (Bergeron and Bernard, 1991; Sollows *et al*, 1991) dealing with an innovative approach to the problem of peak shaving, namely residential dual energy programs (DEP). The general idea of a DEP is that consumers with an electric space heating system are equipped with a second system (usually, though not exclusively oil). This second system is used during periods of peak utility demand. These types of programs are particularly attractive to winter peaking utilities (which is the case for Canada) because of the high correlation between outside temperature and residential heating demand, and the coincidence of the latter with the daily peak demand of electricity. This paper is a comment on the two previous articles intended to highlight the importance and potential of dual energy programs. This serves as an appropriate introduction to an analysis of the tariff structure of Hydro-Québec's dual energy program and a discussion of implementation issues.

2. Analysis of the papers

Comment on earlier ***ESR*** *papers on dual energy programs*

In 'The Residential Dual-Energy Program of Hydro-Québec: An Economic Analysis,' Bergeron and Bernard (hereafter BB) perform a cost-benefit analysis on Hydro-Québec's bi-energy program in order to determine who the winners and losers will be as the program grows along a projected path. Their main conclusion is that the bulk of the gains from this program accrue to participating consumers, while both the utility and the government lose (total social loss is evaluated at $4.5 million per year). Because of this, BB predict that the program has a good chance of either being modified, or dropped completely. It is interesting to juxtapose this conclusion with the analysis of Sollows *et al* (SSV hereafter) in 'A Comparison of Hybrid Heating Systems and New Generation Facilities for Peak Electricity Load Management.' The latter paper discusses the "many advantages" of hybrid systems, and offers an interesting discussion of implementation issues. They conclude that the hybrid system has a lower total cost than the all-electric option. In what follows I hope to reconcile the above studies and at the same time highlight some of the key issues of importance for tariff incentives.

The clear underlying theme of SSV is that the hybrid heating systems are considered to be a load management tool and a way of avoiding construction of new gas turbine generation capacity. As such, it is clearly demonstrated that hybrid heating systems have lower costs, both economic and environmental. From this the case for dual energy systems would seem clear. How then to reconcile SSV with BB's conclusion that the current implementation of Hydro-Québec's bi-energy program (with similar goals) could result in an annual social cost of $4.5 million?

First, it is important to recognize the different methodologies used in the two studies. SSV compute explicit (i.e., out-of-pocket) costs of the hybrid system, considering it as an alternative to central thermal generation. BB on the other hand compute social costs (i.e., consumer and producer surplus) which follow from consumer responses to the particular tariff structure in question. The latter are quite correct to point out that their "analysis of price effects illustrates that out-of-pocket expenses are poor indicators of consumer incentives. ... changes in consumer surplus are greater" (p.155). However, a careful reading of their analysis indicates that the more important cause of the divergence of results with SSV is directly related to effects of the tariff, and not with the method of analysis performed by each. Specifically, Hydro-Québec's tariff, which is temperature (t) dependent, leads to three separate consumer responses:[2]

1) A transfer of electricity demand to oil for t<-12°C;
2) A decrease in non-heating use of electricity for t<-12°C;
3) An increase in all electricity uses for t>-12°C.

Only the first type of consumer response is common to the analysis of BB and SSV. It should be obvious that, of the three, it is the most important target for the type of load management tool under discussion.[3]

Replicating BB's analysis considering only the first effect might be interesting, but goes beyond the scope of this paper. A more germane question is to ask how Hydro-Québec's tariff could be modified qualitatively in order to limit consumers to the first response, a transfer from electric heating to oil during periods of peak demand. Under these conditions we might expect that the results of SSV would be more applicable to the case of Hydro-Québec's bi-energy.

To recap, in spite of their divergent conclusions, the two papers in question are not contradictory. However, in light of SSV, one can see that BB's results beg the question of how to improve Hydro-Québec's program. Part of the answer can be found in SSV's discussion of implementation issues and their notion of

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2/ Very succinctly, in 1990-1991 (the year for which the BB study was performed) bi-energy subscribers paid 2.75¢/kWh for all electricity use when outside temperature was above -12°C. At temperatures below -12°C they paid 10.0¢/kWh for non-heating uses while heating was provided by the backup source. Non bi-energy subscribers on the other hand paid 3.75¢/kWh for their first 30 kWh of daily consumption and 4.46¢/kWh for the balance of their consumption. Both types of consumers paid the same daily demand charge of 31.7¢.

3/ Clearly a decrease in non-heating use of electricity when t<12°C can contribute to reduction of the peak. Likewise, increases in all electricity use when t>12°C can serve the useful purpose of flattening the utility's load curve. I will argue though that the signals provided by Hydro-Québec's bi-energy tariff are at best confusing to consumers, and that they may lead to interconsumer inefficiency due to differential pricing. Because of this, only the first type of consumer response is retained in my modified tariff.

demand management leasing. "Rather than penalizing customers for their peak-coincident demand, it rewards them for their peak-coincident demand reduction" (p.176). This is exactly the idea that could be used for modification of Hydro-Québec's tariff, which is considered in the next section.

3. Hydro-Québec's bi-energy program

3.1 Comments

Qualifying customers (i.e., those with a second source of space heating meeting utility standards) are provided with two direct incentives to adopt Hydro-Québec's bi-energy program. First of all they obtain differential pricing of electricity vis-a-vis regular residential customers (see footnote 2 and Hydro-Québec (1990a)). A second incentive for bi-energy customers comes in the form of an annual grant in the amount of $55 toward the maintenance cost of their backup heating system.[4] In 1989, 90,000 residential customers used bi-energy. Hydro-Québec projected this number to increase to 150,000 by 1992.[5]

Before discussing the proposed modification to the tariff it is worth noting that because the avowed goal of this program is reduction of electric space heating related to peak electricity demand, temperature is an imperfect signal to use. This is because of the imperfect correlation between temperature and peak demand. The daily peak normally occurs in the interval between 16:00 and 20:00, whereas temperature normally falls during this time, reaching a minimum during the night when electricity demand is well below peak.[6] Hence there exists the potential problem of misallocation due to differential pricing.[7] The extent of the resulting distortion depends on several factors, notably price elasticity, but certainly merits further investigation. As pointed out by SSV, this problem cannot be solved completely,

4/ Hydro-Québec estimates that maintenance costs, net of this grant, are $95 annually.

5/ See Hydro-Québec (1990c) for details. As of January 1992 Hydro Québec had only 73,000 residential customers subscribed to its bi-energy tariff. This may explain the introduction of a new program ("bi-énergie nouvelle") designed to encourage an additional 60,000 customers to convert to bi-energy by 1994 (Hydro-Québec (1992)).

6/ The annual point-wise peak occurs randomly, usually within the months of December-February. Many factors, such as temperature, length of the cold period, wind, hours of sunlight, etc. affect the daily peak demand, of which the annual peak is one instance. Note that daily consumption is in fact bi-modal, with a second (usually lower) peak occuring in the morning.

7/ For instance, at 2:00am it is unlikely that the marginal cost of generation is close to 10¢/kWh which is what bi-energy subscribers are charged if the temperature is below -12°C. If so, a potential source of consumer surplus is not being realized.

short of the implementation of time-of-use (TOU) pricing. What can be changed, fairly easily I believe, are some of the incentives provided in the current structure of the tariff.

Not least among the relevant characteristics of electricity is the fact that it is an intermediate consumption good used for heating, cooling, lighting, etc. As such, consumers have at best a nebulous understanding of their direct consumption of electricity.

Current bi-energy tariff in Québec provides an unclear price signal

For the above reason I find the price signal given in the current bi-energy tariff to be unclear, especially if one of the goals of the tariff structure is to encourage potential consumers to adopt bi-energy. Most consumers, because of their lack of understanding of their consumption of electricity, are likely to find it very difficult to evaluate the potential savings of subscribing to the bi-energy program. Even if the utility provides the consumer with reliable data regarding the expected number of hours during which the temperature falls below the critical level, it is not at all clear that the consumer can adequately judge what his or her heating and non-heating electricity consumption is, and what the total effect of differential pricing from bi-energy will be.

To emphasize the point I note that under the current program individual electricity consumption falls in January, February and December.[8] However, electricity and heating oil bills actually rise in January, and have their smallest decrease in February. Likewise, although total annual consumer surplus rises, consumer surplus decreases in January and has by far the smallest increase in February. BB explain the consumer surplus results by noting that "most of the benefit occurs in months when some heating is still taking place while the temperature is above -12°C as in March, April, October and November." Although this might not be considered a major flaw of the tariff, I believe that the fact that the tariff causes a negative impact on consumer surplus in the month in which bi-energy is used the most, and compensates for this in months during which bi-energy is not used, is at best a confusing signal to consumers.

Different prices for different consumers can be inefficient

The second point relating to price signals concerns the efficiency of this type of differential pricing. A basic tenet of economic theory is that, in order to be efficient, the allocation of resources to different activities must be made according to consistent signals. It is therefore inefficient for consumers to face different prices for the same good, as is the case here for non-heating uses of electricity when $t<-12°C$.[9] As has been mentioned, BB note that net changes of electricity consumption per month have

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8/ This is for an average consumer, according to BB. See Table 3 of their paper for details.

9/ For the specific case of electricity markets, Crockett (1976) presents evidence that interconsumer efficiency may in fact decrease due to differential pricing. It is fair to point out though that since the bi-energy tariff might come closer to the true marginal cost of providing electricity, it can be defended on second-best grounds.

three components. Only the first of these components is unambiguously desirable from a load management perspective, since the other two can be criticized on the basis of the inefficiency of differential prices.

A third consideration is risk-sharing. For a consumer to have subscribed to the program it is assumed that some type of individual rationality constraint has been satisfied. The price of heating oil, and its $/kWh equivalent, enter into this calculation. Obviously, a fluctuation in the price of oil will affect expected consumer surplus. The tariff structure makes no allowances for this, and hence consumers bear all the risk of volatility in heating oil prices. This appears to be suboptimal from a policy perspective. It is generally accepted that individual consumers are risk averse, the utility is risk neutral (at least in its dealings with consumers) and that the efficient risk-sharing arrangement will have the utility assuming all (or most) of this type of risk.[10]

A final point, possibly more important in theory than in practice, but interesting nonetheless, is that the relative prices of electricity result in bi-energy customers having a strict preference for seeing the temperature remain above -12°C. One effect of this is the potential for an avoidance problem, i.e., for some consumers it will be worthwhile to expend some effort and cost to avoid the situation where the temperature is below -12°C. Although outside temperature cannot be controlled, in practice the result can be achieved by tampering with the on-site thermometer and control mechanism in order to avoid the automatic switching from electric to backup heating and the jump to the higher price for non-heating electricity.[11] Recall that the large proportion of residential customers using electric heating, combined with the climatic conditions of the province of Québec, induce a strong correlation between temperature and peak daily demand. This implies that avoidance of the type described above would occur when it is most costly for the utility. The cost of avoidance should be seen as not only the marginal production costs for the customers in question, but also the consumption externalities due to increased pressure on reserve margins, increased demands on transport and distribution systems, and the ensuing implication for system-wide reliability.

A possible avoidance problem

10/ This argument takes on even more weight if dual energy is viewed as distributed capacity for the utility to use as a load management tool.

11/ This can be done for instance by placing a heat source near the thermometer. Of course this problem can be alleviated, at least partially, with a centralized switch where individual consumers would have not control over the measuring of temperature.

3.2 Proposed modification

In this section I propose a simple alternative tariff structure which is likely to act as a better incentive to consumers to subscribe to the bi-energy program. The modification closely parallels some of the implementation issues discussed by SSV.

An alternative tariff

As opposed to the current bi-energy tariff, the proposed tariff uses "positive incentives" to make the use of bi-energy attractive when the temperature falls below -12°C — a carrot rather than the currently used stick. This is accomplished in the following way: while keeping the temperature as a signal for the switch from electric heating to the backup source, charge all customers the same price for electricity at all times. In order to encourage consumers to subscribe to bi-energy they are offered a per-period rebate on their use of backup heating (i.e., per period of backup use). Since alternative energy sources (such as oil) have prices which are considerably more volatile than electricity, it is reasonable that the rebate be tied somehow to a price differential (in kWh equivalent) between electricity and alternative energy sources.[12] This would effectively transfer the associated risk of price increases from consumers to the utility. As both BB and SSV point out, the cost-benefit analysis and evaluation of these programs, and hence consumer adoption decisions, are sensitive to the volatility of crude oil prices. Freeing the consumer from all or part of this risk would seem to be desirable. Another argument in favour of this risk sharing arrangement is that even with the peak flattening effect of bi-energy, Hydro-Québec is sometimes forced to use more expensive thermal generation, or purchase from the interconnected grid. Since the energy displaced by bi-energy would in any case be supplied by thermal generation, the question of interest is really where the burden of risk should be placed. Because the rebate acts as an incentive for participation in the program, the actual size of the rebate must be fixed in order to achieve the desired amount of market penetration for the bi-energy program. Bi-energy subscribers would continue to receive a credit towards annual maintenance costs of the backup heating system.

A more transparent signal

I believe that a tariff modified in the above way offers a signal that is more transparent to consumers. First of all, with the elimination of differential pricing for bi-energy subscribers, electricity consumption and cost can be evaluated more simply. Second, a per period rebate, with a credible forecast of the expected number of bi-energy use-hours, gives an immediate

12/ Of course this rebate can vary in order to account for factors such as the size of the house, etc. Or, as suggested by SSV, it can be related to the customer's peak coincident load. My objective here is not to determine the specifics of the tariff but to discuss qualitative modifications.

estimate of the potential value of the program to a consumer. Since potential bi-energy consumers are in general converting from oil to electric heating, oil costs are assumed to be well known. The consumer's cost-benefit analysis of conversion would appear to be much more straightforward.

Since the modified tariff would charge all customers the same price for electricity at all times, the problem of allocative inefficiency due to differential pricing is eliminated. It remains true that the backup system has different costs than electric heating. However the *ex ante* calculation of the rebate could be used to select the market penetration consistent with the correct amount of backup (accounting for system externalities, etc.).

In terms of social cost, the positive incentive of the rebate would appear to be far superior to the negative incentive of the current tariff. A much more detailed analysis would be necessary to substantiate this rigorously, but the point is argued loosely as follows. First, the only expected consumer response to this type of tariff is the substitution of oil for electricity at $t<-12°C$. Secondly, in terms of the avoidance problem, the positive incentive can only lead to a much less costly externality than under the current tariff. In effect, any "cheating" that would occur in this case would be for a consumer to switch to his backup heating source while the temperature was above -12°C and hence the system was in an off-peak state (this is the case since the rebate's incentive is to make consumers want to switch to the backup). However, reducing total system demand during an off-peak period imposes no externality on the system. The distortion is limited to the local effect of paying to a consumer a rebate which may be greater than the benefit of that consumer's reduced consumption.

In practical terms it would seem much more difficult for consumers to "cheat" under the proposed tariff (i.e. switch to backup when the temperature is actually above -12°C) by cooling the thermometer than to cheat under the current tariff (i.e. not switch to backup when the temperature is actually below -12°C) by heating the thermometer. This leads us to think that the proposed scheme would result in less avoidance on the part of consumers (though the extent of cheating under the current system is not known). In summary, not only would the proposed tariff result in less avoidance, but also what avoidance there is would be less costly socially.

3.3 A numerical example

The goal of this paper is not to replicate either of the two previous cost-benefit analyses. However, a very simple numerical example to illustrate the comparison of the proposed tariff with the current tariff helps one to appreciate the argument made above. Three scenarios are compared:

1) the all-electric base case (as in BB),
2) current bi-energy, and
3) proposed bi-energy.

Using the same data as in BB[13] we arrive at the following expected annual costs to the consumer (total electricity and heating):[14]

Scenario	Cost ($)
1	1,299.19
2	1,200.11
3	1,414.85 - 1,042.3 X

where 1,042.3 is the expected number of hours of operation of the second space-heating source and X is the rebate (in $/hr) paid to consumers for each hour of use.

Scenarios 1 and 2 differ by very little because the equivalent price of heating oil used was 4.72¢/kWh, which is quite close to the second level price of electricity, 4.46¢/kWh.[15] The differences between the energy prices at temperatures below -12°C (higher for bi-energy subscribers) and energy prices above -12°C (lower for bi-energy subscribers), with the additional maintenance cost of bi-energy, almost cancel each other out.

My main interest though is in comparing the all electric base case with the modified bi-energy tariff. For this it is straightforward to compute the breakeven value of X. At X=$0.11 the expected annual costs to the consumer are identical for cases 1 and 3. This corresponds to a total expected rebate of $114.70 (not including the annual maintenance rebate of $55), which is not a frighteningly large amount. Even with a heating oil equivalent of 8¢/kWh, almost double the 1989 average price, the breakeven rebate is $0.26/hour, with a total rebate of $270.

It is important to stress again that this is the incentive needed to lead the average consumer to utilize more expensive oil-heating during utility peak periods, so it is really representative of the cost differential of the two sources of energy. From the utility's perspective the above rebate should look very appealling, since it is the cost of shedding 4721 kWh of peak demand. This works out to 2.45¢/kWh. Because the marginal cost of production during peak periods is generally quite a bit higher than this, my superficial cost analysis looks promising.[16]

13/ Although elements of the tariffs have been increased since 1990-1991 the structure of the tariff, and hence my (and BB's) arguments remain unchanged.

14/ Note that these results ignore price elasticity and any other income effects that a new tariff could have.

15/ The price of 4.72¢/kWh is based on the average heating oil price of 30.4¢/litre in 1989 and Hydro-Québec's estimation that 0.155 litres of heating oil provide the heating equivalent of one kWh (BB, p.155).

16/ Bernard and Chatel (1985) use the ratio of 15:1 for the marginal cost of peak to base energy production.

Of course the exact value of the rebate should be fixed to insure the desired level of market penetration for bi-energy. The higher the rebate, the greater the number of consumers who will find it attractive to adopt bi-energy. In addition I echo SSV's concern that "the most difficult problems associated with implementation of hybrid heating are likely to be behavioral" (p.174) and believe that the rebate needed to ensure customer response may be higher.

4. Conclusions

Dual energy programs can provide valuable distributed capacity for winter peaking utilities and greatly affect the economics of peak-load management. However, this analysis of BB and SSV indicates that the role of the tariffs as demand-side management tools needs to be considered more fully.

Advantages of a modified tariff

Hydro-Québec's bi-energy tariff structure could be modified in this light. The perceived benefits of this proposed tariff over the current bi-energy tariff are that it: 1) is arguably much simpler and should be easier for consumers to understand; 2) corrects the misallocation problem due to differential pricing in the current tariff; 3) transfers the risk related to price fluctuations of the alternative energy source from the consumer to the utility; and 4) corrects the potential avoidance problem due to the negative incentive of the current tariff. The proposed tariff makes no additional technological or informational demands on the market. In fact it appears that it could be implemented in a straight forward fashion.

Finally, it is important to point out that dual energy programs are a limited form of interruptible service for the residential sector. Efficient tariff structures will make dual energy programs more attractive to customers and will facilitate their use in the utilities' load management strategies. It is thus quite reasonable to envisage DEP genuinely being used as true "demand-side management" in response to dynamic demand fluctuations.

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