Public electric power and economic waste

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I. Introduction

In most countries electric utilities are public sector corporations and are subject to varying degrees of direct government control. A common form of organization for this sector is to have the government own the equity of the utility and then to allow it to operate in a fashion similar to that of a private business under a set of guidelines which determines the pricing policy and thus the profits of the corporation.

Such guidelines often state that the corporation is to operate in a manner so as to supply the economy's demand for electricity with a level of reliability consistent with good utility management and to charge the minimum rates for the electricity that will allow the utility to meet all its financial costs. In addition, most public electric utilities are not subject to corporation income taxes and their financial liabilities are either implicitly or explicitly guaranteed by the government in the event of default.

At the present time, over 90 percent of the electricity generation in Canada is carried out by provincial government owned electric utilities which operate under guidelines similar to those outlined above. If this industry were a relatively small user of the country's factors of production, then one would not be particularly concerned if this form of organization led to some economic waste. This, unfortunately, is not the case. At the present time in Canada approximately 15 percent of the total industrial capital stock is located in the public electric utilities. They have accounted for approximately 14 percent of the new gross capital formation in Canada during the last 10 years. All predictions indicate that this proportion of total gross investment undertaken by these corporations will increase substantially in the next decade.

The objective of this paper is to examine some aspects of the planning and pricing practices of the publicly owned electric utilities and to indicate how the economic welfare of the country could be improved through changes in these practices. We shall deal with two related sets of questions. First, what are the alterations made in the investment policies of the electric utilities that are a result of their exemption from corporation income taxation and the presence of a government guarantee of their debt? Second, what are the distributive and efficiency implications of the utilities' policies in Canada of pricing electricity so as to cover average financial costs instead of the marginal social costs of production?

II. Financial Interest Rates Versus the Social Cost of Government Borrowing as the Relevant Cost of Capital for Public Electric Utilities

Governments, public utilities, and the private sectors of the Canadian economy, when borrowing or selling shares to finance their investment projects, compete with one another in the capital markets for the savings available for Canadian investment. When public electric utilities or governments increase the share of the country's total savings that are used in their investment programs, they force the private industrial and household sectors to postpone some of their investment programs and in addition may induce some further saving. By postponing investment and consumption plans the private sector foregoes the rate of return (net of inflation, net of taxes) it would have earned on investment and the benefits it would have received from the additional current consumption. However, the Canadian economy as a whole loses not just the rate of return that the private investor gives up, but also the tax revenues that would have accrued to the government from the income generated by the additional private sector investment.

When a public electric utility competes in the capital market for funds, the utility's investments need only produce a gross rate of return equal to the net private return earned by investment in the private sectors of the economy in order for the public utility to successfully outbid the other sectors. However, the social cost of these funds is the gross of tax rate of return the private sector would earn on the investments that are foregone plus the time value of the consumption that is postponed.

Historically (1953 to present), the private manufacturing and non-manufacturing sectors of the Canadian economy have earned a private rate of return on their total invested capital of approximately 6 percent annually, net of inflation and taxes. In addition, these investments have produced on average tax payments (corporate income, property, and sales taxes) of approximately 6 percent of their net replacement value each year.[1] When the social rates of return from investment and consumption in the various private sectors of the economy are weighted by the proportions of the total funds that are obtained by government from these sectors, we find that the social opportunity cost of investment funds in the Canadian public sector is approximately 10 percent.[2]

Under the present financial organization of the public electric utilities, it is usually the case that only the interest payments for borrowed debt are included as a cost of capital and little or no attempt is made to include the opportunity costs of the capital which has been invested as equity by the provincial governments. This method of computing capital costs along with the fact that these utilities do not pay corporation income taxes leads to a situation where the gross rate of return that the public electric utilities need to earn from their investments to cover their financial capital costs will be significantly below the social opportunity cost of these investment funds to the economy.

Even if public electric utilities were required to pay income taxes on profits, the overall gross rate of return earned on investment in this sector would likely be lower than the social opportunity costs of capital. First, the public electric utilities may not be required by their government owners to earn the competitive return on the invested equity capital. Second, because the government is the ultimate guarantor against default of the public utilities debt the marginal cost of debt will be lower for publicly owned utilities than for privately owned utilities.[3] As a result, publicly owned utilities have a higher debt/equity ratio than their privately owned counterparts. The higher debt/equity ratio leads to a smaller tax base for the corporate income tax with government owned utilities than with privately owned utilities; thus, a smaller amount of income tax will be paid per dollar of investment. Because of the lower income tax liability faced by government owned electric utilities, they will not have to earn as high a gross rate of return from their investments in order to meet their financial cost of capital as do privately owned utilities. It is the implicit government guarantee of the debt against default that causes the market to accept a higher debt/equity ratio and that thus brings about a lowering of income tax payments and the financial cost of capital for government owned electric utilities. This occurs even if the government and privately owned utilities are faced with the same rates of corporate income tax on gross profits (net of interest payments and other costs).

III. The Nature of the Economic Loss

A waste of economic resources will result when public electric utilities do not earn a rate of return at least as large as the social opportunity cost of capital or when they do not price their output at rates which approximate the marginal costs of production. This paper identifies and analyzes four sources of economic waste generated by these policies. The first aspect of the economic loss we analyze arises because Canadian consumers are charged prices for electricity that are too low relative to the economic costs that incurred in its production. These lower prices induce domestic consumers to expand their demand for electricity to such an extent that the value of the benefits they receive from this incremental consumption is less than the social cost of production. When this condition occurs, a loss in economic welfare is experienced by the country taken as a whole.

The second source of economic loss to be evaluated in this paper arises from the fact that a large quantity of the electricity generated in Canada is used as an input for the production of exports. When electricity is priced below its social opportunity cost this subsidized input will either lead to higher profits for the foreign and domestic owners of the exporting firms or cause goods to be exported that would otherwise not be profitable to produce. From Canada's perspective the economic loss to the country is equal to the increase in profits accruing to the foreign owners of firms and the amount of subsidy that is required to offset the the cost of production of exports which would otherwise not be produced. In addition the use of a financial cost of capital below the social cost of capital in the planning of investment for an electricity system will lead to excessive amounts of capital to be invested in electricity generation systems. This source of economic waste is the third aspect of the problem evaluated below. Finally, in section IV we examine the nature of the economic inefficiency produced when the pricing policies of electric utility are not designed to reflect the incremental costs of production during peak and off peak periods.

(a) Economic Loss From Overconsumption of Electricity

When the relative price of electricity to other goods consumed in the economy is too low, not all the difference between what the price of electricity would be if the social opportunity cost of capital were to be earned on the capital invested in this sector and the price currently charged should be counted as an economic loss. Cheap electricity (produced at low rates of return) will result in an income transfer to electricity consumers in Canada from the government sector. This income transfer is made up of two parts. One part is an income transfer received by residents of the country either through direct consumption of electricity or through the consumption of goods produced by electricity. In Figure 1, Q_2 represents the total amount of electricity produced in Canada when the price is set at P_2, while Q_E is the quantity of electricity either exported directly or embodied in goods exported from Canada. The quantity of electricity consumed by Canadian residents is equal to $(Q_2 - Q_E)$; therefore, the income transfer received through the consumption of electricity by Canadian residents is only on this quantity $(Q_2 - Q_E)$ and represented by the area EFAC in Figure 1. This transfer of income in the form of cheaper electricity is a cost to the utility but is not a net social cost from the point of view of the country as a whole.

However, a separate economic efficiency loss occurs in addition to the income transfer because the price of electricity is set too low at (P_2) which covers only financial costs rather than the full social cost of electricity (P_1). This causes the quantity demanded to increase from Q_1 to Q_2.

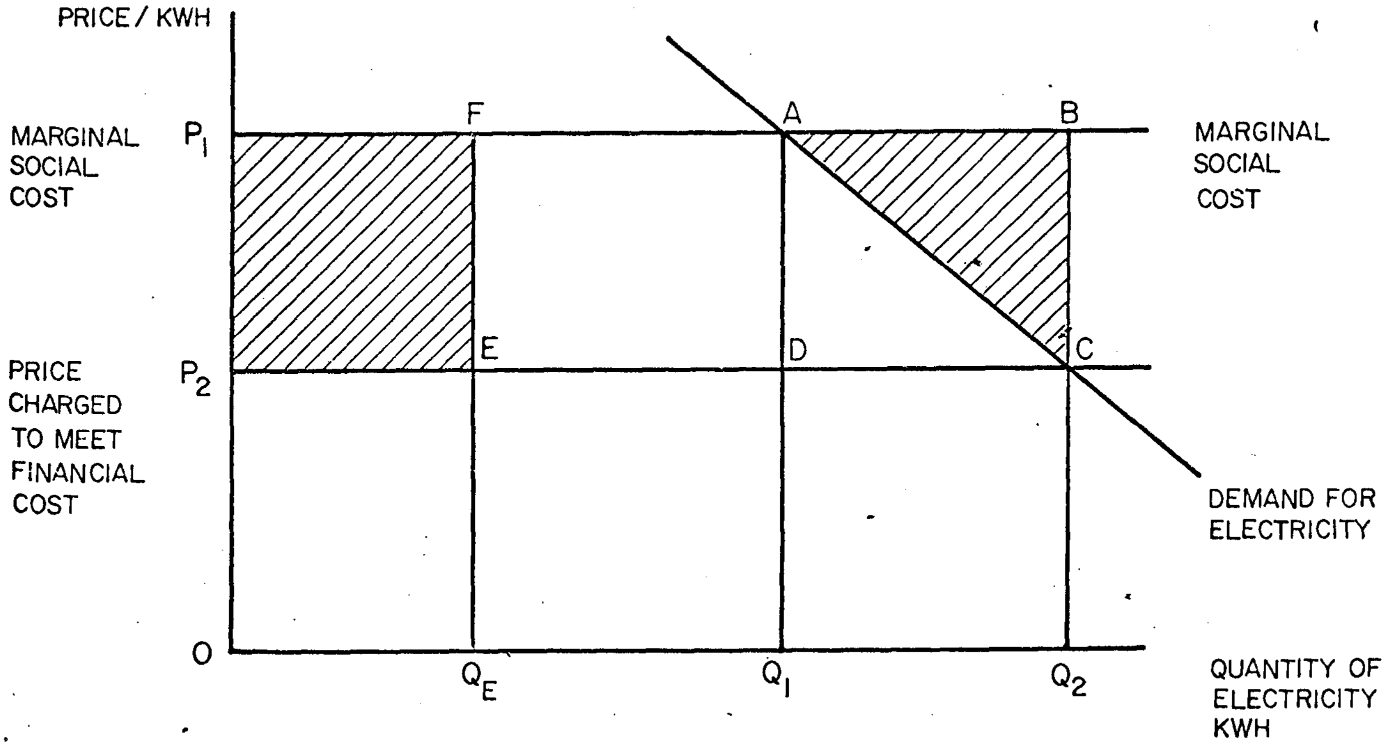
The additional electricity demanded $(Q_2 - Q_1)$ has a value to electricity consumers of $Q_1\ ACQ_2$ (the area under the compensated demand curve); however, its production cost is an amount represented by $Q_1\ ABQ_2$ (the area under the marginal cost curve). The amount that the incremental social costs $(Q_1\ ABQ_2)$ exceeds the incremental value to consumers $(Q_1\ ACQ_2)$ is equal to the economic loss, measured by ABC in Figure 1.

(b) Economic Loss from Exports of Goods Produced by Subsidized Electricity

The second source of economic loss occurs because Canada exports large quantities of primary products whose production tends to be electricity intensive. If this electricity is being sold for the production of these products at a price below its social opportunity cost, then there is an implicit subsidy being given to these exported products.

Figure I

ECONOMIC LOSS AND INCOME TRANSFERS FROM ELECTRICITY SOLD BELOW SOCIAL OPPORTUNITY COST



If this electricity subsidy resulted in higher profits to owners of the production facilities who are Canadian residents then there would be no economic loss, just an income transfer. However, in the case of Canada the industries that are electricity intensive and also export, such as pulp and paper, primary metals, and chemicals are predominately foreign owned. When this implicit electricity subsidy results in either higher profits to foreigners or serves as an offset to the financial costs of production then the entire amount of the subsidy is a resource cost to Canada. In the analysis that follows we assume that Canada loses by the full amount of the implicit electricity subsidy given to the exports of goods. The same losses occur if electricity is generated for direct export; however, there has been little net direct export of electricity from Canada to date.

The gross value of this subsidy is represented in Figure 1 by the shaded area P_1 FE P_2, where P_1 is the social cost of producing electricity; P_2 is the actual price of electricity which covers financial costs. The distance O Q_E represents the quantity of electricity either exported directly or embodied in goods that are eventually exported. If we assume that the electric power industry in Canada has expanded to the point where it can be approximately characterized by constant returns to scale, and the value of the subsidy is equal to the loss of resources by Canada then the economic loss from the export of electricity directly or indirectly in goods can be expressed as follows:

(1) Economic Loss From Export Subsidy = (Marginal Social Cost - Price Charged) (Quantity of Electricity Exported Directly or indirectly in exported goods)

or from figure 1

$$E.L. = (P_1 - P_2) Q_E$$

(c) Economic Loss from Inefficient Use of Capital in Production

The use of the financial cost of capital instead of its social opportunity cost as the relevant price of capital for investment planning in public electric utilities will cause investments to be made in generation facilities which are too capital intensive. Highly capital intensive technologies such as remote hydro dams, tidal power, and nuclear generation stations would become less attractive relative to fossil fuel generation stations if the social cost rather than the financial cost of capital were recognized as the correct cost to the economy of this capital. This choice of a more capital intensive technology for the generation of electricity in Canada will thus cause economic inefficiency as the marginal product of capital in this activity will be below the marginal social opportunity cost to the economy of releasing this resource to this sector.

To measure the amount of economic loss created by the inefficient use of capital in public electric utilities, it is necessary to estimate the increase in the quantity of capital used in electricity production in Canada over the amount that would be used if the investments were required to earn the social opportunity cost of capital.

(d) Estimation of Rates of Return for Publicly Owned Electric Utilities

In order to calculate the economic losses that have been incurred by the public electric utility industry it is necessary first to estimate the rates of return that have existed in this industry. Owing to data limitations, the rates of return for public electric utilities in Canada have been calculated for the period 1965 to 1973.

Estimation of the rates of return from the electric power industry and the value of its capital stock utilizes three sources of data. The first source is the electric power statistics for production, sales, balance sheet, and profit and loss statements of the publicly owned electric power producers by province.[4] The second source of data is the Census of Manufacturers data on the value added of electricity per dollar of output. The third set of data used are the estimates of the fixed capital flows and stocks for non-manufacturing by industry.[5]

Using the methodology for the calculation of economic rates of return as outlined in Appendix B the gross rates of return from capital in the public electric utility industry in Canada have been estimated for the years 1965 to 1973. The calculation of these rates of return are presented in Table 1 for the years 1965 to 1973. This investigation shows that the rate of return to capital, gross of all taxes but net of inflation, in the publicly owned electric power industry has averaged 3.46 percent over the nine year period 1965 to 1973.

(e) <u>Evaluation of the Economic Losses</u>

Appendix A contains a detailed discussion of the equations and data used to measure the efficiency losses that have occurred in the publicly owned electric utilities in Canada. Throughout this evaluation an attempt has been made to provide an underestimate of these efficiency losses. It is assumed that there is no net economic welfare effect by this

Table 1

Rates of Return From Public Owned Electric Utilities in Canada
(Millions of Dollars)

	1965	1966	1967	1968	1969
1. Net Fixed Assets, net current replacement value	8,908.37	10,203.05	11,324.23	12,274.66	13,621.10
2. Current Value of Working capital	432.48	556.62	757.44	750.75	769.15
3. Total Current Value Capital Stock (row 1 + row 2)[a]	9,340.86	10,759.68	12,081.67	13,025.41	14,390.25
4. Total Income to Capital[a] (Profits plus interest payments adjusted for economic depreciation)	245.18	245.46	263.11	287.74	338.03
5. Total Municipal, Provincial, and Federal Taxes	51.59	58.21	64.32	73.87	78.25
6. Gross of Tax Income to Capital (row 4 + row 5)	296.78	303.67	327.44	361.62	416.29
7. Rate of Return from Capital (row 6 ÷ row 3) as Percentage of Capital Stock	3.18	2.82	2.71	2.78	2.89
8. Capital's Share of Sales Taxes Paid on Sale of Electricity as a Percentage of the Current Value of the Capital Stock[b]	.80	.45	.66	.72	.67
9. Gross Rate of Return from Capital including Sales Taxes as Percentage of the Capital Stock (row 7 + row 8)	3.98	3.27	3.37	3.50	3.56

Footnotes at end of Table.

Table 1 (cont'd)

Rates of Return From Public Owned Electric Utilities in Canada
(Millions of Dollars)

	1970	1971	1972	1973
1. Net Fixed Assets, net current replacement value	15,568.85	17,273.43	18,958.85	21,485.58
2. Current Value of Working capital	837.57	970.73	1,098.40	1,066.54
3. Total Current Value Capital Stock (row 1 + row 2)[a]	16,406.42	18,266.16	20,057.25	22,552.12
4. Total Income to Capital[a] (Profits plus interest payments adjusted for economic depreciation)	341.20	394.44	431.60	572.94
5. Total Municipal, Provincial, and Federal Taxes	84.26	87.56	91.83	101.02
6. Gross of Tax Income to Capital (row 4 + row 5)	425.46	482.00	523.43	673.96
7. Rate of Return from Capital (row 6 ÷ row 3) as Percentage of Capital Stock	2.59	2.64	2.61	2.99
8. Capital's Share of Sales Taxes Paid on Sale of Electricity as a Percentage of the Current Value of the Capital Stock[b]	.66	.66	.66	.66
9. Gross Rate of Return from Capital including Sales Taxes as Percentage of the Capital Stock (row 7 + row 8)	3.25	3.30	3.27	3.65

[a] These data were obtained from Statistics Canada, Electric Power Statistics, Volume II, Catalogue No. 57-202 Annual 1965 to 1973. The adjustments to this data were made using industrial statistics from Statistics Canada, Fixed Capital Flows and Stocks, Manufacturing and Non-Manufacturing 1926-1972, unpublished 1972 to 1974.

[b] Glenn P. Jenkins, Op. Cit., pg. 72.

industry on the other sectors of the economy, while a casual empirical investigation would indicate that the over expansion of the electric utility sector has created an additional negative externality on the rest of the economy. This is expected because industries that use electricity intensively tend to be taxed relatively less than those which do not utilize electricity to as great a degree.

By assuming a low value for the degree of substitution between capital and fuel or labour in the electric utility (i.e. an elasticity of substitution of .5) when we would expect that the elasticity of substitution between the capital and fuel to be probably larger, a downward bias is introduced into our estimates of the value of the economic loss. A low value for the own price elasticity of demand for electricity will also reduce the estimated value of this economic loss. In the calculations which follow values for this parameter have been set at -1.0 and -.5. Most recent empirical estimates of this parameter have been in the range of -1.0. Therefore, the estimate of the economic loss using an own price elasticity of -.5 will be also biased downward.

From Table 2, column 1 we find that the value of the implicit subsidy to exports of goods through the lower price for electricity has risen to over $175 million dollars in 1973. This amount is an economic loss to Canadian residents unless it results in higher profits to Canadian owners of the firms which use this cheap electricity. This in general has not been the case because the heavy users of electricity such as primary metals, paper and allied, transportation equipment, and chemical products are largely foreign owned.

From 1971 to 1973 the economic loss from the over consumption of electricity and the inefficient use of capital in electricity production has averaged between $460 and $670

Table 2

Economic Losses Created by Present
Financial Policies of Publicly Owned Electric Utilities

Year	Economic Loss From Direct and Embodied Export of Electricity Table A-2, column 3)	Economic Loss From Over Consumption of Electricity and Inefficient Use of Capital (Table A-3, cols 4 and 5) Case A Price Elasticity of demand - 1.0	Case B Price Elasticity of demand - 0.5	Total Economic Loss Case A Medium Estimate	Case B Low Estimate
	(millions of dollars, current prices)				
1967	$ 46.66	$403.38	$296.82	$477.04	$343.48
1968	51.46	428.27	295.36	479.73	346.82
1969	67.68	450.67	310.80	518.35	378.04
1970	102.57	605.23	417.40	707.80	834.80
1971	108.34	655.92	452.36	764.26	560.70
1972	132.63	726.50	501.04	859.13	633.67
1973	176.96	633.24	436.72	810.20	613.68

million annually, depending on the assumption used concerning the price elasticity of demand. In Table 2 columns 4 and 5 we find that the total economic losses averaged over this period are estimated to have been at least $602 million annually and perhaps have been as high as $811 million.

These estimates for the value of the economic loss created by the present policies of the public electric utilities are of such a large magnitude that a re-examination of these policies by the governments involved is certainly warranted. These measures of the economic loss do not refer to a transfer of income from the electric utilities or provincial governments to consumers of electricity. This economic loss is a complete waste of Canadian resources resulting in a reduction in the total well being of Canadian residents through the misallocation by this sector of the scarce capital resources of the economy.

IV Electricity Pricing and Economic Welfare

(a) Determinants of the Cost of Electricity Supply

The general pricing policy of public electric utilities in Canada has been to charge rates according to customer class, i.e. household, commercial and industrial customers of different sizes, without differentiating between the time of day or season of the year in which the electricity is being consumed. However, the marginal cost of supplying electricity at a time when the system is operating near capacity is usually several times greater than the marginal cost of supplying the same quantity of electricity during a time period when there is excess generation and transmission capacity in the utility's system.

The reason for this wide differential in marginal costs is that in an electricity system there is a given maximum capacity to generate and transmit electricity that would only be changed by further investment in equipment which makes up a large proportion of the total costs of supplying electricity.

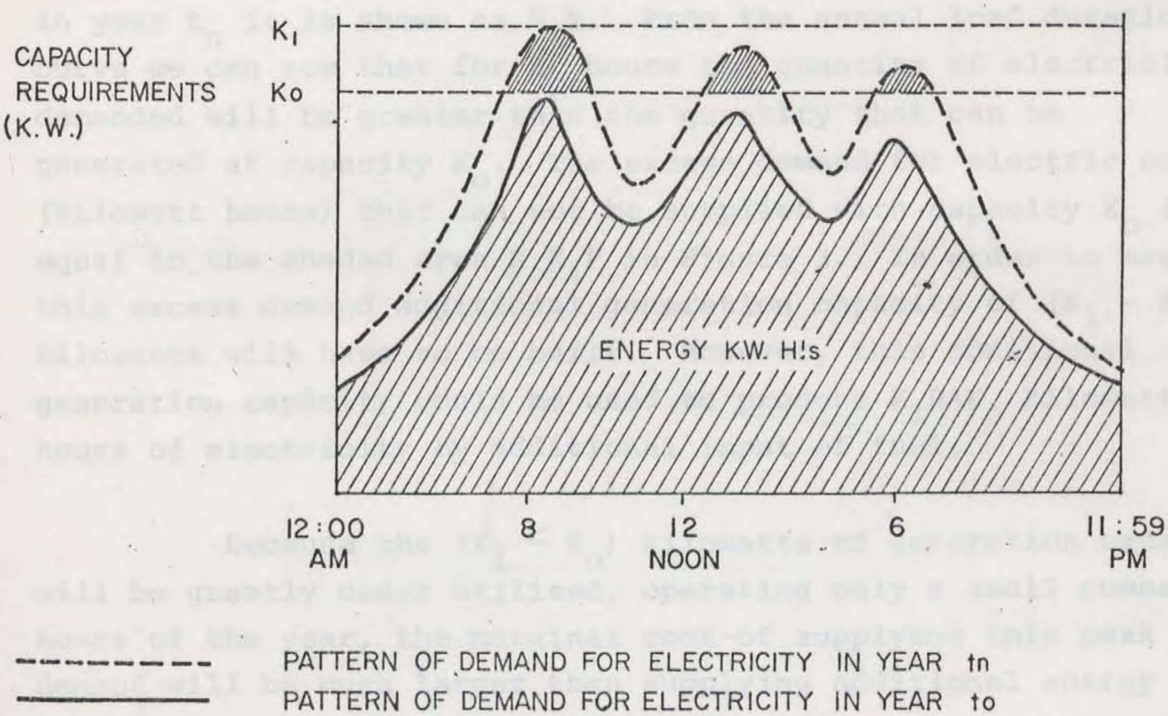
During most of the year the quantity of electricity being demanded is much less than it is at the few periods when demand for electricity is at its maximum. This pattern of demand is generally predictable: during the day there are certain hours when more electricity is consumed; at night there is less demand for electricity than during the day; more electricity is used during week days than week ends; consumption of electricity is greater during some seasons than others.

In Figure 2 the solid curve describes the pattern of demand during a typical peak day of the year (t_o). The electrical system has enough capacity (reserve plus operating) to generate a quantity of electricity equal to K_o kilowatts. However, there are only three periods of the day when the demand for electricity approaches the capacity constraint. During the other time periods when demand is below the maximum potential capacity of K_o, any additional electric energy can be produced at a cost equal to the marginal cost of the additional fuel required to generate the electricity. No additional capital equipment is required.

If through time the demand for electric energy increases so that the new pattern of demand is described by the curve for year t_n in Figure 2, we then find that for the three peak demand periods of the day the existing capacity of K_o will not be sufficient. Either additional investment of $(K_1 - K_o)$ must be undertaken or brownouts or blackouts will occur.

Figure 2

DAILY LOAD CURVE



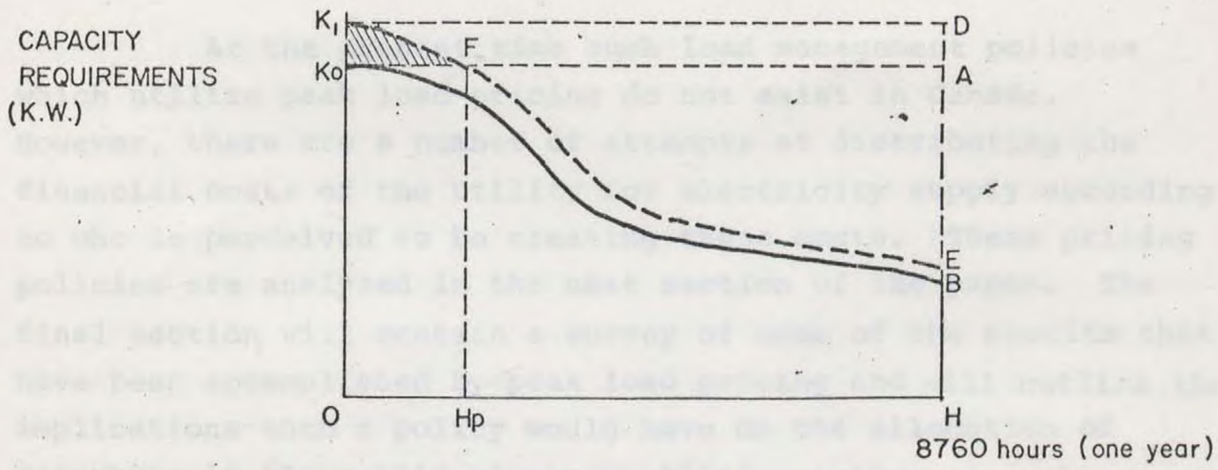
From the daily load curves for the year the electric generation capacity required to meet the demand for electricity during the 8760 hours of the year can be ranked to measure the total number of hours in the year that a given level of capacity or more is demanded. This is called a load duration curve and can be described by K_o B in Figure 3. As the demand for energy grows, the annual load duration curve will shift upward so that in year t_n it is shown as K_1E. From the annual load duration curve we can see that for H_p hours the quantity of electricity demanded will be greater than the quantity that can be generated at capacity K_o. The excess demand for electric energy (kilowatt hours) that can not be supplied with capacity K_o is equal to the shaded area K_oK_1F in Figure 3. In order to meet this excess demand additional generation capacity of $(K_1 - K_o)$ kilowatts will have to be built. However, this additional generation capacity could be used to produce K_1DAK_o kilowatt hours of electricity by additional input of fuel.

Because the $(K_1 - K_o)$ kilowatts of generation capacity will be greatly under utilized, operating only a small number of hours of the year, the marginal cost of supplying this peak demand will be much larger than supplying additional energy during the off-peak period when demand is less than the generation capacity available. For most electric utilities in the world, the marginal cost of supplying peak time electric energy is 3 to 5 times the cost of supplying additional off-peak electrical energy. A recent calculation of the ratio of peak marginal cost to off-peak marginal cost for a Canadian electric utility estimated this ratio to be approximately 3.5. Of course there will be considerable differences in this variable among electric utilities in Canada.[6]

The basic purpose of peak load pricing is to manage the shape of the load duration curve. By charging a price that

Figure 3

ANNUAL LOAD DURATION CURVE



approximates the marginal cost of supply during the time of the day or seasons of the year when the peak demand occurs, consumers will have an incentive to reduce their consumption during these periods; thus, the demand for generation capacity will be reduced relative to the total demand for energy. If at the same time the price of electricity is reduced during the off-peak periods to approximate better the marginal cost of supply, this will provide an incentive to increase consumption of electricity during these times and thus provide a better use of the utility's existing generation capacity.

At the present time such load management policies which utilize peak load pricing do not exist in Canada. However, there are a number of attempts at distributing the financial costs of the utility for electricity supply according to who is perceived to be creating these costs. These pricing policies are analyzed in the next section of the paper. The final section will contain a survey of some of the results that have been accomplished by peak load pricing and will outline the implications such a policy would have on the allocation of resources in the public electric utility sector.

(b) Present Electricity Pricing Policies in Canada

In Canada, a common practice of electric utilities is to divide customers into two categories: domestic and non-domestic. The domestic rate structure is characterized by a fixed charge, declining energy block rates, and a minimum monthly bill. The non-domestic rate structure is characterized by a fixed charge, progressive capacity demand charges, and declining energy block rates. Both categories may be subject to surcharges which depend on the particular circumstances of the customer.

Fixed charges can be regarded as essentially covering those costs that are constant per customer such as meter-reading, billing, accounting, and other services costs. The surcharges usually depend upon the extra cost incurred in servicing particular customers such as extra transmission lines, and transformers. The most interesting features of the current pricing policies are the increasing demand charge and the declining energy rate.

Increasing Demand Charges

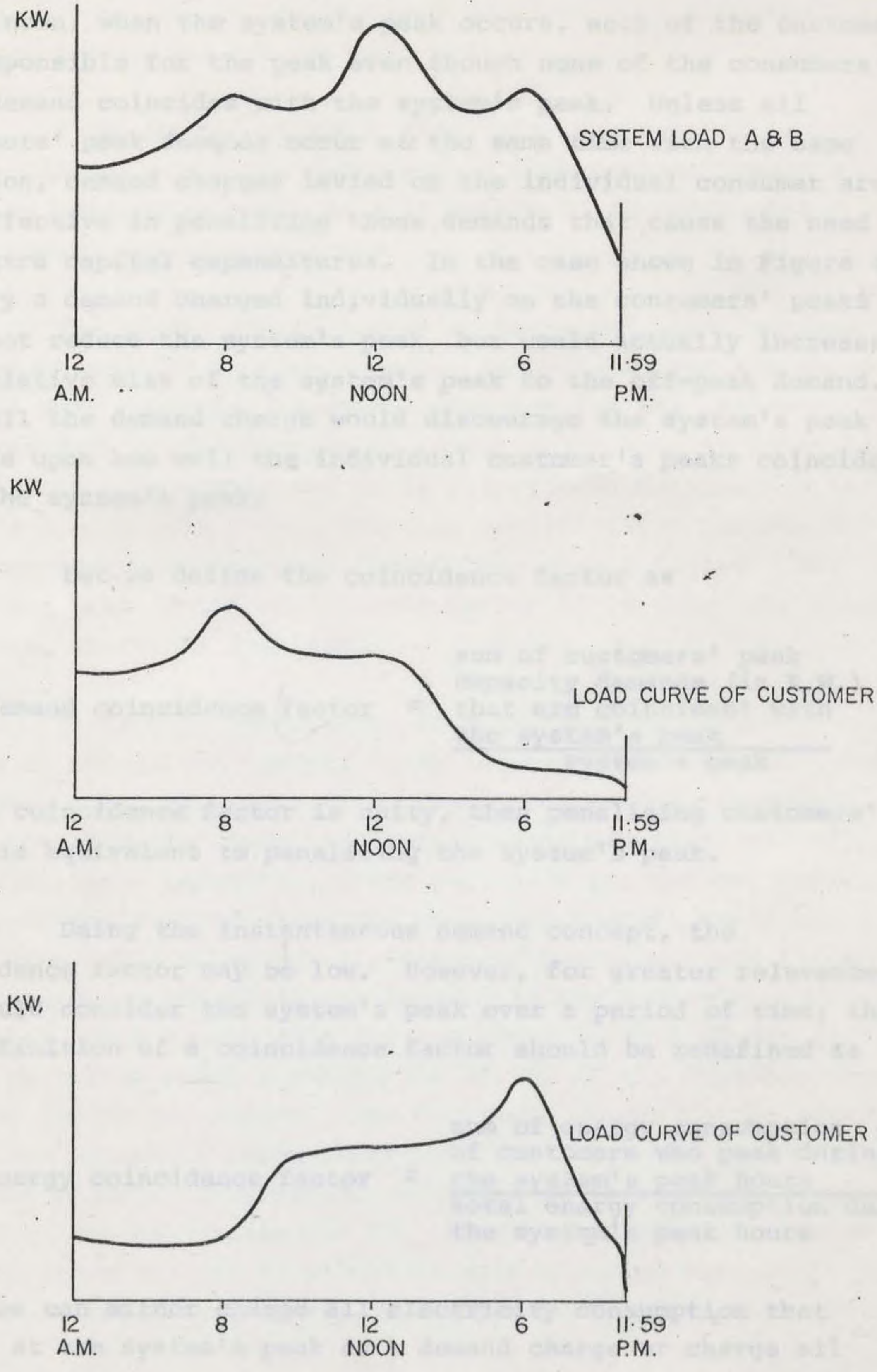
The demand charge is paid by a customer according to his maximum kilowatt (k.w.) demand during the metering period which is normally monthly or bimonthly. The purpose of this demand charge is clearly to put a penalty on the greater demand for generation capacity for any given energy demand. Since this charge applies to a customer regardless of the time at which an individual customer's peak may occur, the demand charge is distinctly different from what we usually call peak load pricing.

The major reason is that individual customer peak demand need not coincide with the system's peak. Peak load pricing refers to only the system's peak; the demand charge applies only to customer's peak. The following chart will illustrate the problem. Figures 4B and 4C are individual customers' demand for a day and 4A contains the sum of the customers demand throughout the day or the utility's system load.

Clearly, as in Figures 4B and 4C, each customer's peak does not itself constitute the system's peak. More importantly,

Figure 4

SYSTEM LOAD
CUSTOMER A & B



at 12 noon, when the system's peak occurs, each of the customers is responsible for the peak even though none of the consumers' peak demand coincides with the system's peak. Unless all customers' peak demands occur at the same time with the same duration, demand charges levied on the individual consumer are not effective in penalizing those demands that cause the need for extra capital expenditures. In the case shown in Figure 4, to levy a demand charged individually on the consumers' peaks will not reduce the system's peak, but would actually increase the relative size of the system's peak to the off-peak demand. How well the demand charge would discourage the system's peak depends upon how well the individual customer's peaks coincide with the system's peak.

Let us define the coincidence factor as

$$\text{Peak demand coincidence factor} = \frac{\text{sum of customers' peak capacity demands (in K.W.) that are coincident with the system's peak}}{\text{system's peak}}$$

If the coincidence factor is unity, then penalizing customers' peaks is equivalent to penalizing the system's peak.

Using the instantaneous demand concept, the coincidence factor may be low. However, for greater relevance, we should consider the system's peak over a period of time; then the definition of a coincidence factor should be redefined as

$$\text{Peak energy coincidence factor} = \frac{\text{sum of energy consumption of customers who peak during the system's peak hours}}{\text{total energy consumption during the system's peak hours}}$$

Thus, we can either charge all electricity consumption that occurs at the system's peak as a demand charge or charge all energy consumed during the system's peak hours at a higher price in order to penalize the system's peak.

It would be extremely difficult to establish the precise time at which the individual's peak occurs. Hence a peak load pricing proposal usually refers to an additional energy charge at the peak hours.

The demand charge levied on each individual consumer has a great deal of popular appeal. As one's demand increases, one uses more capacity; hence one must pay for it. However, this principle of fairness is no longer valid when it is applied to the group as a whole, nor is it relevant in determining the system's incremental cost. The true justification for its use must thus depend on the peak demand coincidence factor. The closer the peak demand coincidence factor is to unity the more the demand charge is justified.

It is also interesting to note that most demand charges in Canada are subject to an increasing block rate. For instance, in P.E.I., there is no demand charge for residential use of electricity. Small industrial users pay $1.07 per KVA per month; large industrial users pay $1.78 per KVA per month. In Quebec, residential users pay no demand charge, small and medium industrial users pay $1.85 per KW per month, and large industrial users pay $3.50 per month. In New Brunswick, industrial loads contracting for a minimum of 5000 KW pay $2.80 per KW per month. For a minimum of 15,000 KW the demand charge is $2.60 per KW per month.[7] The declining demand charge rates of the New Brunswick Power Commission are due to an industrial promotion policy. In general, utilities require larger KW users to pay an increasing rate per KW. However, given a particular level of capacity that is purchased with a demand charge the purchase of additional energy to increase the utilization of this capacity is generally priced according to a declining rate schedule.

It should be noted that a rising system marginal cost is not a justification for increasing demand block rates as it has been commonly thought to be. Similarly, an overall declining system marginal cost is not a justification for declining energy rates. It is the marginal cost of an additional unit of electricity generation at different hours of the day or seasons of the year that are relevant here.

Declining Energy Rates

In Canada, for any given demand category, electric energy consumption in kilowatt hours (kwh) has usually been priced so that the more an individual consumes the less he will pay for incremental amounts.[8]

One reason for declining energy rates is said to be that, for a given plant size, when more energy is produced, the capital charge allocated to each KWH falls. This again would be correct for a system which supplies a single customer. Both the peak demand charges and declining energy rates presently used in Canada are correct and consistent for an electric system that supplies only one customer.

But what is true for a single customer need not also be true for a group of customers. As we have seen above, an individual customer's peak demand need not constitute the system's peak and the sum of off-peak demand of all individual customers may cause the system's peak. It is the timing of consumption that is crucial to the shape of the system's expansion. An individual customer, whatever his peak demand as long as he consumes any electricity at all during the system's peak, is responsible for that peak.

The existing rate structure used by most utilities can be said to be customer-oriented. It was designed to treat each customer with fairness - those who need more capacity should pay more. It was also designed to exploit the economies of existing capacity through charging declining energy rates. While its designer has good intentions, such a pricing policy would be appropriate only if there was one customer. But the present rate structure is applied separately to a group of customers. As the existing utility rate structure does not penalize those who cause the system's peak, the rate structure is not fair to each consumer individually.

To prevent such distortion we can institute a demand charge which penalizes the system's peak and a declining energy charge which encourages better use of the existing capacity. With regard to society's demand as a whole, its peak occurs only at certain periods of the day, while the individual's peak may be spread over the whole day. Hence, it is unfair to charge an individual whose peak occurs at the system's off peak hours an extra demand charge because his peak is not responsible for the system's peak. It does not require any more capacity than what the system already has to meet the system's peak. It would be equally unfair not to charge a person an extra demand charge for his consumption during the system's peak simply because his personal peak occurs at other times. Let us imagine what happens if this particular customer whose peak occurs at the system's off-peak hours withdraws his consumption during the system's peak hours but increases his consumption during his personal peak hour. Clearly his reduction of consumption during the system's peak hours will reduce the system's capacity requirement and the increase of his personal peak consumption will not require the system to add any new capacity.

One way to correct the existing situation is to charge higher energy prices at the system's peak hours and thereby discouraging consumption during these hours and reducing the system's capital requirements. To encourage greater use of the available capacity, we should make prices in the off-(system) peak hours relatively less expensive than that of the peak hours.

In essence, this time related, or system's peak related rate structure adds no extra complication to the existing rate structure. It is the same two part - demand/energy - rates. It penalizes the demand which truly causes the system's capital costs to expand and provides a better utilization of the existing capacity.

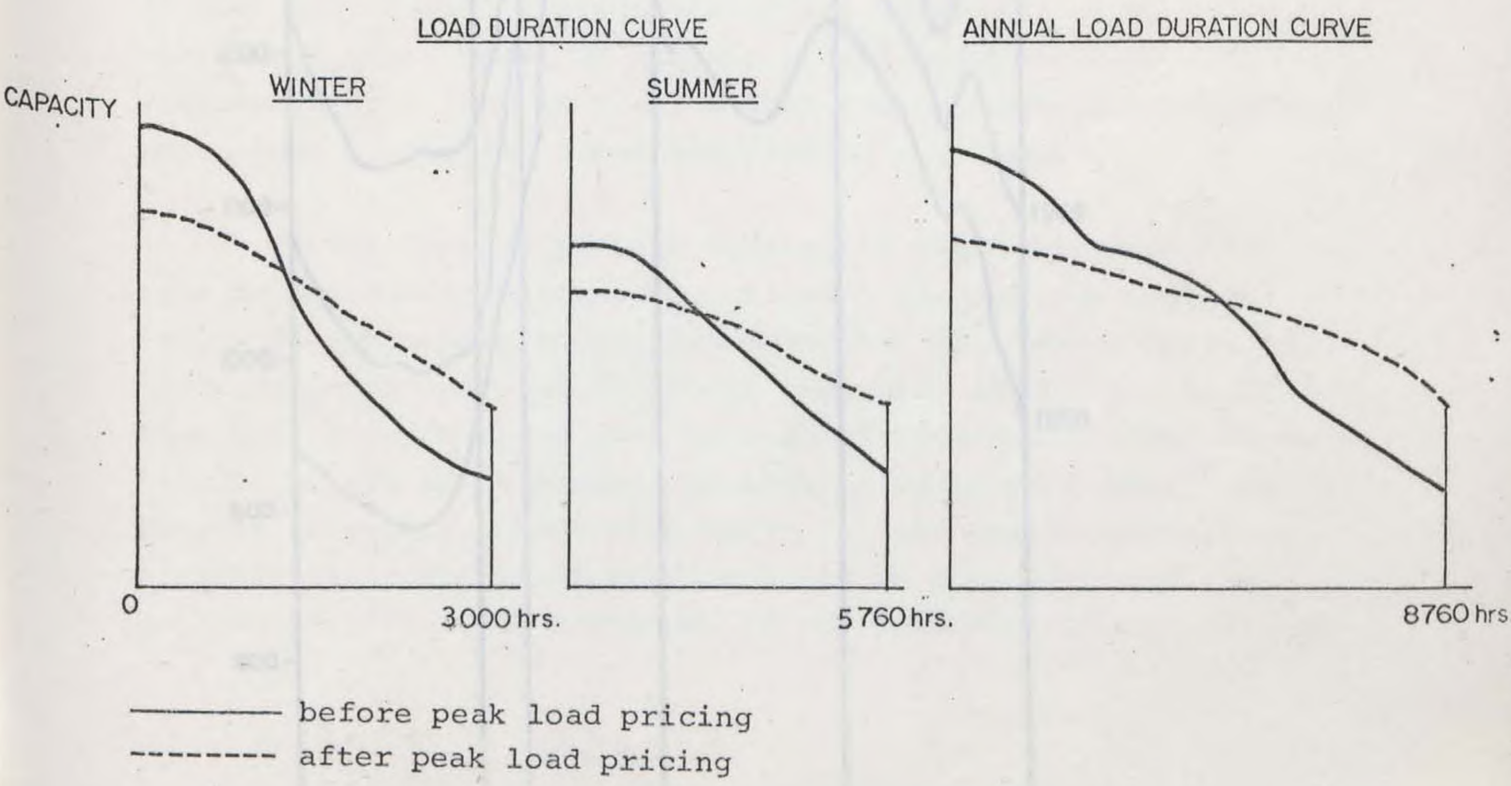
This approach of relating the demand and energy charges to the time periods where the system's peak occurs focuses on reducing the system's costs regardless of what the actual coincidence factor is. The current practice of demand charges which apply to individual customer peaks only manages to reduce the system's cost if the coincidence factor is close to unity, which is not the actual situation. Thus, by relating the current pricing practice to the time element, it would enable an electric power system to save more than what can be achieved under the current pricing scheme. By so doing, it should also enable society to eliminate some of the unfairness to the customers whose peaks are at the system's off peak hours but have been forced to pay a demand charge under the current pricing practice.

Electricity Consumption Production Costs and Load Management Policies

When a peak load pricing policy is introduced into an electricity system, it can be given to the consumer as an alternative to the existing pricing system or it may be unilaterally imposed by the utility. However, its impact will be to decrease the system's demand for peak capacity and to increase the demand for energy during the off peak hours. Figure 5 shows the typical reaction of demand as given by the change in the shape of the load duration curves for the summer (May to Nov.), winter (Dec. to April) and total year when the electricity rates are increased during periods of peak consumption and lowered during the off peak.

Figure 5

SEASONAL AND ANNUAL LOAD DURATION CURVES

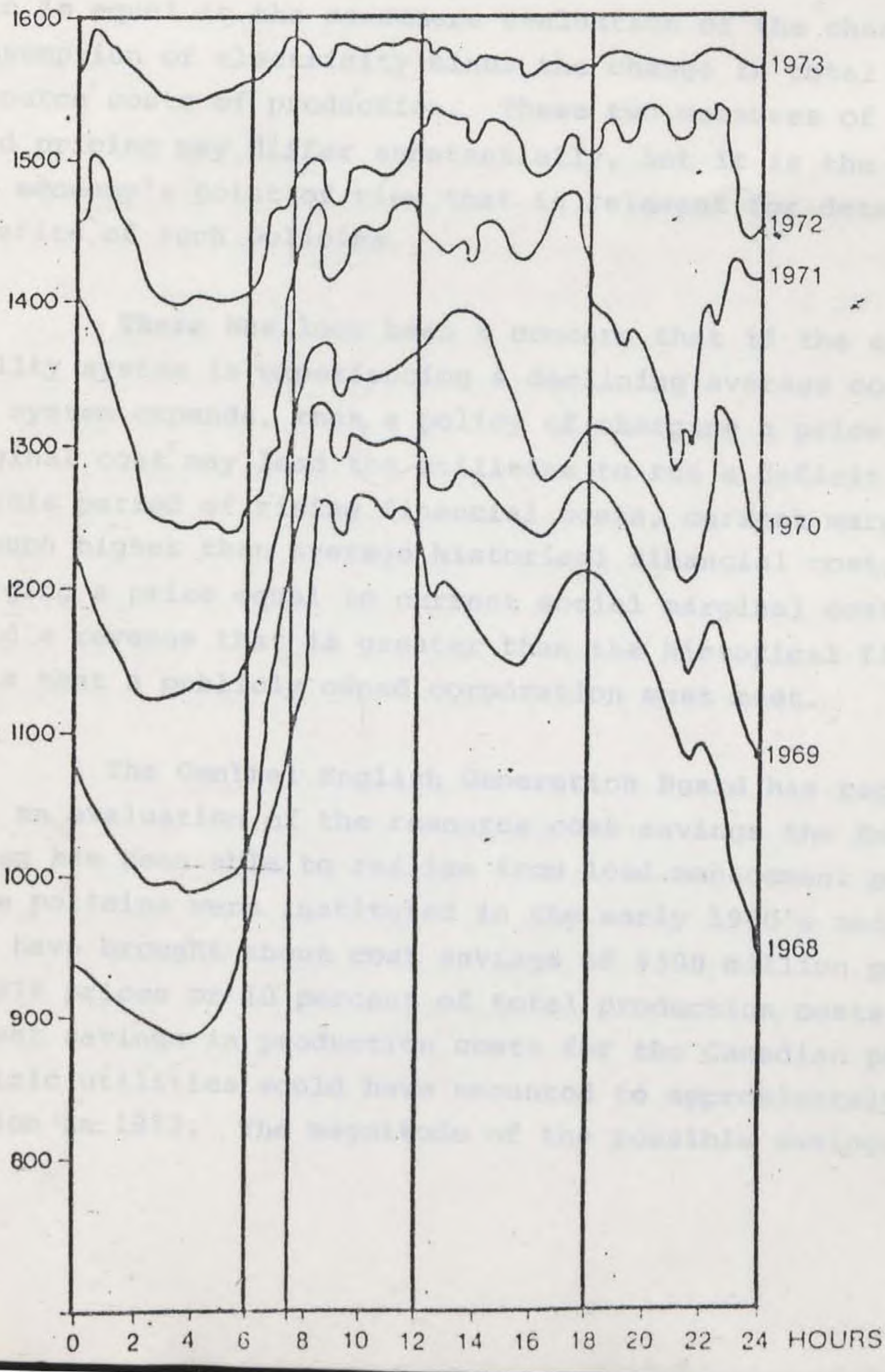


The recent experience of the Hamburg electric works is depicted in Figure 6 where the load duration curves are drawn for a typical peak day from 1968 to 1973. In 1968 Hamburg began an extensive load management policy which by 1973 had almost completely leveled the daily load curve.[9]

Figure 6

Hamburg Electric Works Daily Load Curve

Typical January Day



From the utility's point of view such load management policies reduce the financial cost of capital expenditures and fuel use during the peak hours but increase fuel expenditures at off peak hours. It is usually the case that total energy sales rise because of the expansion of electric demand during the off peak periods. The financial gain from the utility's point of view is the total of the decrease in costs plus the increase in sales revenues. From the economy's point of view, the economic gain is equal to the consumers evaluation of the change in the consumption of electricity minus the change in total social resource costs of production. These two measures of the peak load pricing may differ substantially, but it is the gain from the economy's point of view that is relevent for determining the net benefits of such policies.

There has long been a concern that if the electric utility system is experiencing a declining average cost curve as the system expands, then a policy of charging a price equal to marginal cost may lead the utilities to run a deficit. In fact, in this period of rising financial costs, current marginal cost is much higher than average historical financial cost; hence, charging a price equal to current social marginal cost will yield a revenue that is greater than the historical financial costs that a publicly owned corporation must meet.

The Central English Generation Board has recently made an evaluation of the resource cost savings the English system has been able to realize from load management policies. These policies were instituted in the early 1960's and by 1972 they have brought about cost savings of $300 million per annum in 1974 prices or 10 percent of total production costs.[10] A 10 percent savings in production costs for the Canadian public electric utilities would have amounted to approximately $200 million in 1973. The magnitude of the possible savings arising from load management policies warrants further research in the evaluation of the social costs and benefits of load management practices in Canada. Before definite conclusions can be made concerning the net economic benefits derived from marginal cost pricing it will be necessary to evaluate the total system costs for supplying electricity under alternative pricing policies.

Conclusions

In this paper we have reviewed the existing policies of the publicly owned electric utilities in Canada that are related to the utilities' evaluation of the cost of capital and their determination of the structure and level of prices charged for their output. Because publicly owned utilities are very lightly taxed and can borrow at preferential rates, we find that the financial cost of capital generally used as a parameter in their investment decisions is significantly below the social opportunity cost of these funds. This leads the utility to charge a price for electricity that, on average, is below the social cost of production. Also it will cause the electric utility to use too much capital relative to other factors such as fuel and labour in the production of electricity.

The lower price charged for electricity causes an over consumption of electricity relative to other goods in the economy, and the low financial cost of capital leads to a waste of scarce capital resources. In addition, the artificially low financial cost of capital will cause the financial cost of goods produced with electricity and exported to be below their social cost of production.

There is an economic loss associated with each of the impacts of these policies on the utilities operations. By 1973 the estimated economic loss to Canada from these policies was at least $600 million and could be as high as $800 million.

The last section of the paper has been concerned with the historical pricing policies of the electric utilities in Canada, and develops the rationale that underlies load management policies which use a set of peak load prices. From the experience of electric utilities that have undertaken such policies it has been found that households and industries do respond to price incentives and the economic gains from such policies have been very substantial.

Appendix A

Estimation of the Economic Losses Created by Public Electric Utilities

The implicit subsidy given to goods that are produced by electricity in Canada and subsequently exported was expressed in equation 1 as a function of the differences between the price of electricity when it includes the social cost of capital and when it includes only the financial cost. This expression can also be written as a function of the difference between the social opportunity cost of capital and the return this capital earns in the public electric utility, the components of value added in production and the public electric utility's capital stock as follows:

A-1 Economic Loss (1) $= (R_s - R_e)\left(\frac{V_\alpha + V_I}{V_T}\right) K_o$

A-2 where $V_I = \sum_{i=1}^{n} B_i \frac{E_i}{O_i}$

L = value of economic loss from exporting electricity both directly and embodied in goods

R_s = the social opportunity cost of capital used in public electric utilities

R_e = gross of return from publicly owned and operated electric establishments (gross of taxes but net of depreciation)

V_α = value of electricity exported directly

V_I = value of electricity embodied in goods which have been exported

V_T = the total value of electricity generated by the Canadian publicly owned electric utilities

K_O = net replacement value of total capital stock of publicly owned electric power establishments

B_i = value added of electricity in output from the ith industry

O_i = value of sales of output in the ith industry

E_i = value of goods exported by the ith industry

To measure the amount of economic loss created by the inefficient use of capital in public electric utilities, we can combine this loss with the loss discussed previously that is created due to the lower price based on financial cost. It is important to note that if no other distortions exist in any other factor market in the economy, this combined economic efficiency loss is evaluated as the difference between the marginal social cost of capital to the public electric utility sector and the marginal value of the capital as measured by the derived demand curve for capital in this sector.[11] The method used here to measure this economic loss from the misallocation of capital follows the approach developed by Harberger for the measurement of the deadweight losses created by non-neutral taxes or similar distortions.[12] The economic loss caused by the over consumption of electricity and the use of too much capital in the generation of electricity can be expressed as follows for the case where distortions exist in other factor markets and the derived demand curves for factors are linear:

$$\text{(A-3)} \quad \text{The Economic Loss (Dollars)} = -\left(\tfrac{1}{2} D_i^* \Delta K_i + \sum_{j \neq 1}^{m} D_j^* \Delta K_j\right)$$

where $\Delta K_j = \int_{D_i=0}^{D_i^*} \frac{\partial K_j}{\partial D_i} dD_i$

D_i^* is the difference between the social opportunity cost of capital and the rate of return earned by capital in the public electric utility sector expressed as a fraction of a dollar of capital and K_i is the net replacement value of the capital stock in the ith sector. The subscript j refers to industries other than public electric utilities.

Some of the distortions (D_j^*) in the other economic activities will have negative values in the subsidized or low taxed sectors; also the term $\frac{\partial K_j}{\partial D_j}$ will have a positive or negative sign depending on whether the output of the jth sector is a complement or substitute for the ith sector. Therefore, the sign of the second term in equation A-3 cannot be determined a priori. However, in the case of electricity we are able to make some prediction as to the likely sign this expression will take. The sectors which are heavy users of electricity will have the largest incentive to expand when the price of electricity falls. These are activities such as pulp and paper production, primary metal industries, non-metallic mineral products, chemical industries and street lighting. All these activities except chemicals produce less than the average amount of taxes, and therefore the distortions (D_j^*'s) associated with these activities are negative numbers.[13] Combining two pieces of information lead us to the conclusion that the additional welfare cost induced in the other sectors by the abnormal rates of return in electricity production (measured by $D_j^* \Delta K_j$ for each sector) may be significant. If the total stock of capital is inelastic in supply, the industries in Canada that do not use electricity intensively will expand less on the average than they would have if electricity was more expensive. These industries bear relatively high taxes; therefore, restricting their expansion will again create a further welfare loss. Because of the differential taxation of capital, the economic loss from this distortion would be greater than that measured only by the first term of equation (A-3). In the empirical estimation of the economic losses below the value of this loss will be biased downward by measuring the loss as follows:

(A-4) Economic Loss (2) $= -\frac{1}{2}D_i^* \Delta K_i$

For an industry where factor prices are fixed, the relationship between the demand for the factor and the demand for the output produced is as follows:

(A-5) $N_k = \alpha_k N_e - \alpha_o \sigma$

where N_k = the elasticity of demand for capital defined negatively.

N_e = the elasticity of demand for electricity defined negatively

σ = the elasticity of substitution between capital and other factors in the production of electricity defined positively

α_k, α_0 = the factor shares of capital and all other factors, respectively.

The expression for the economic loss (A-4) can be rewritten as follows:

$$\text{(A-6)} \quad -\tfrac{1}{2}D_i^* \, \Delta K_i = -\tfrac{1}{2}(R_e - R_m) \frac{\partial K}{\partial R} \frac{R_e}{K_O} \frac{K_o}{R_e} \frac{V_D}{V_T} (R_m - R_e)$$

$$\text{(A-7)} \quad \text{E.L. (2)} = \tfrac{1}{2}\left(\frac{R_e - R_m}{R_e}\right)^2 \frac{V_D}{V_T} K_o R_e N_k$$

Now substituting equation A-5 into equation (A-7) we obtain

$$\text{(A-8)} \quad \text{E.L. (2)} = \tfrac{1}{2}\left(\frac{R_e - R_m}{R_e}\right)^2 \frac{V_D}{V_T} K_o R_e \; (\alpha_k N_e - \alpha_o \; \sigma)$$

where E.L.(2) stands for the economic loss from the misallocation of capital investments in electricity generation and the over consumption of electricity because of the low return on capital in the public electric utility sector. V_D is the value of electricity produced by public electric utilities but consumed by Canadian residents and V_T is the total value of electricity produced by public electric utilities.

The measure of these economic losses only includes the inefficiency that is related to the proportion of the electric utility industry that supplies electricity for domestic consumption. By ignoring the misallocation of capital investments on the part of the electricity generation industry that produces electricity either directly or indirectly for export we are again biasing downward our estimates of the economic inefficiency associated with publicly owned electric utilities in Canada.

Table A-1

Value of Direct and Indirect Export of Electricity
From Canada
(Millions of Dollars, Current Prices)

	1967	1968	1969	1970	1971	1972	1973
Net Direct Exports[a]	-3.42	-3.45	6.32	16.88	28.01	53.39	100.99
Indirect Export of Electricity Embodied in Goods	73.11	84.53	101.45	138.33	135.75	146.63	183.22
Total Value of Electricity Sold	1,196.24	1,334.06	1,475.84	1,675.87	1,847.68	2,035.75	2,300.42

[a] Statistics Canada, Electric Power Statistics, 1967, 1973, Table 5.

Before we can solve equation A-1, we need to know the value of electricity directly exported and embodied in exported goods. We obtained the values of electricity used in production by industry in Canada and the corresponding value of shipments from the Census of Manufacturing Division of Statistics Canada. The value of exports by industrial sector was estimated by aggregating the value of commodities exported into industrial groups.[14] With this information, we were able to calculate the values for V_I which are presented in Table A-1. Using the rates of return in public electric utilities derived in Table 1 row 9, along with the current value of the capital stock in this sector, Table 1 row 3, and the value for electricity produced and exported from Table A-1, the economic loss from direct and indirect export of electricity can be estimated by solving equation A-1. The results are presented in Table A-2.

Table A-2

Economic Loss From Direct and Indirect Export of Electricity (Equation A-1)

Year	Social Opportunity Cost of Capital	Return in Public Electric Utilities	Value of Economic Loss (millions of dollars, current prices)
1967	.10	.0337	$ 46.66
1968	.10	.0350	$ 51.46
1969	.10	.0356	$ 67.68
1970	.10	.0325	$102.57
1971	.10	.0330	$108.34
1972	.10	.0327	$132.63
1973	.10	.0365	$176.93

To estimate the second component of the economic loss that arises from both the over consumption of electricity and the use of too much capital relative to other inputs in electricity generation (equation A-6), we must specify values for the own-price elasticity of demand for electricity, the elasticity of substitution between capital and other factors in production and the factor shares.

From a recent survey of over thirty estimates of the long run price elasticity of demand for electricity we have found that a mean estimate of this value is approximately -1.0. To provide a conservative estimate of the value of the economic waste we also use a value of -.5 for the own price elasticity of demand.[15]

Very few, and only rather inadequate studies, have been made of the elasticities of substitution between capital and other factors in the generation of electricity. However, this sector is almost unique in the degree of variation in the capital intensity of production depending on the relative costs of capital and fuel. Both oil fired plants and nuclear stations produce an identical product but the differences in capital intensity are very great. In the calculations that follow we use a conservative estimate of .5 for this parameter. The ratio of value added of capital to the total value of sales of this industry has been approximately .36 for the years 1967 to 1973. We now substitute these values into equation A-8 to estimate the economic loss because of the misallocation of capital in the economy. The results are presented in Table A-3.

Table A-3

Economic Loss from the Over-Consumption of Electricity and the Over Use of Capital in Production

(equation A-8)

Year	Social Opportunity Cost of Capital	Rates of Return Public Electric Utilities	Elasticity of Substitution	Economic Loss (millions of dollars, current prices) Case A Price Elasticity of demand -1	Economic Loss (millions of dollars, current prices) Case B Price Elasticity of demand -.5
1967	.10	.0337	.5	$430.38	$296.82
1968	.10	.0350	.5	$428.27	$295.36
1969	.10	.0356	.5	$450.67	$310.80
1970	.10	.0325	.5	$605.23	$417.40
1971	.10	.0330	.5	$655.92	$452.36
1972	.10	.0327	.5	$726.50	$501.04
1973	.10	.0365	.5	$633.24	$436.72

Appendix B

Methodology for the Calculation of Economic Rates of Return From Financial Statistics

Taxation laws, inflation, relative price changes, and the "conservative" rules of accounting are the primary causes of the discrepancy between accounting data and economic values. However, meaningful economic values for the gross rates of return from capital can be formed from the available accounting information by making a series of adjustments to the data.[16] The six basic corrections that need to be made are summarized as follows:

(a) The values of fixed assets are usually recorded in the accounts of corporations in original cost prices; therefore, inflation will lead to an increase in the nominal income of the firm while no adjustment would be made to the nominal value of the capital stock. From accounting data, an inflation would make it appear that the rates of return on the capital stock are rising while in fact they are not. To correct this, we have to adjust the value of the capital stock from original cost dollars to current replacement dollars so that both the nominal value of income and the capital stock reflect the existence of inflation.

We are able to make this adjustment to the accounting values of the fixed capital stock of the publicly owned electricity corporations by using the estimates constructed by Statistics Canada of the net stock of fixed assets for the total electric power sector in current replacement dollars and for the gross stock in original cost dollars. As the publicly owned electricity facilities make up over 90 percent of the total electric power sector, we can assume that depreciation rates are identical to the total sector and the timing of investments are similar. Therefore, we can derive the value of the fixed capital stock in the publicly owned part as follows:

$$\text{Net stock of fixed capital, publicly owned electric power, current replacement cost dollars} = \frac{\text{Net stock of fixed capital, total electric power, current replacement cost dollars}}{\text{Gross stock of fixed capital, total electric power, original cost dollars}} \times \text{Gross stock of fixed capital, publicly owned electric power, current replacement cost dollars.}$$

This procedure corrects the book value of the buildings and equipment in the publicly owned electric sector for changes in the nominal value of the capital stock due to inflation or shifts in relative prices, as well as adjusting the gross value for the economic depreciation that has taken place.

(b) In the calculation of rates of return from capital, it is the return from fixed assets and working capital required for the operation of the public electric power corporations which we are interested in, and not the financial assets which are held solely for their yield. To solve for the value of the operational assets, the value of these financial assets must be subtracted from the total value of assets in the industry.

(c) Depreciation expenses allowed for income tax purposes or set by accounting practice may diverge from the true economic depreciation if either the rates allowed are incorrect or if changes occur in the cost of replacing the asset. In order to measure the economic return from the capital stock of an industry, its profits must be corrected to reflect the economic depreciation expense and not the depreciation expense recorded in the financial statements.

To find the value of the economic depreciation for the publicly owned part of the electric power industry, we again use the information on economic capital consumption allowances in the estimates of the fixed capital flows and stocks prepared by Statistics Canada. From these data we can obtain values for the economic capital consumption allowance in current dollars for the total industry. Using these values we can calculate the economic capital consumption allowance for the publicly owned part of the industry in current dollars as follows:

$$\text{Economic capital consumption allowance in current dollars for public part of electric power industry} = \text{Economic capital consumption allowance in current dollars for the total industry} \times \frac{\text{Net capital stock public electric power current dollars}}{\text{Net capital stock total industry current dollars}}$$

The adjustment to current profits due to the correction of the depreciation expense is derived as follows:

$$\text{Adjustment to profits due to correction of depreciation expenses} = \text{Depreciation expense allowable for accounting purposes} - \text{Economic capital consumption allowance in current dollars for the public part of electric power industry}$$

(d) Debt charges and taxes paid by the industry, even though they represent expenses from the accountants point of view, are part of the value of product produced by the capital of the industry; therefore, they should not be deducted as an expense when calculating the income generated by the capital stock of the industry.

(e) The financial data in the profit and loss statements include income from financial assets as part of the firm's income. However, as these assets are not included as part of the capital stock of the industry, we must not include the revenue generated by these assets as part of the income of the industry's capital stock.

(f) Excise taxes on the output of an industry are in fact taxes on the gross value added of labour and capital, providing that inputs other than labour and capital enter into their respective products in fixed proportions. Therefore, a part of the sales taxes paid on the output of the publicly owned electric industry should be included as income produced by capital. The proportion is equal to the ratio of the gross value added of capital to the total gross value added of the industry.

Footnotes

1. Glenn P. Jenkins, "The Measurement of Rates of Return and Taxation from Private Capital in Canada", in Benefit Cost and Policy Analysis, W. Niskanen et al eds., Aldine, 1972, pg 228.
2. Ibid, pg. 228.

3. The marginal cost of debt rises with the debt/equity ratio of the firm because of the risk of default. For an empirical estimation of this effect see A.C. Harberger and M. Bailey, "Taxation of Capital", Brookings Institution, Ch. 5.

4. Statistics Canada, Electric Power Statistics, Volume II, Catalogue No. 57-202 Annual 1965 to 1969.

5. Statistics Canada, Business Finance Division, Fixed Capital Flows and Stocks, Non-Manufacturing, unpublished but available upon request.

6. H.B.F. Lim, "Measurement of Economic Gain From New Pricing Policies", Department of Regional Economic Expansion, 1976.

7. All these provincial rates are 1975 prices.

8. For the same amount KWH consumed, different categories may pay different prices due to demand charges.

9. W.A. Gilbert and K.V. deGrasse, "Prospects for Electric Utility Load Management", Public Utilities Fortnightly, August 29, 1975.

10. James G. Boggis, "An Electricity Pricing Experiment in England and Wales", paper presented to Seventh Annual Conference Institute of Public Utilities, Troy Michigan, May 5-6, 1975, pg. 8.

11. D. Wisecarver, "The Social Costs of Input-Market Distortions", American Economic Review, July 1974.

12. A.C. Harberger, "Taxation, Resource Allocation and Welfare", The Role of Direct and Indirect Taxes in the Federal Revenue System. Princeton, Princeton University Press, 1974, pp. 25-75.

13. Glenn P. Jenkins, "Analysis of Rates of Return from Capital in Canada", Ph.D. dissertation, University of Chicago, 1972, pg.44.

14. Statistics Canada, Trade of Canada, Exports, 1967 to 1973.

15. Henry B.F. Lim, An Evaluation of Studies on the Demand for Electricity, Department of Regional Economic Expansion, 1976.

16. For a comprehensive discussion of the problems involved when using data to measure economic variables see Glenn P. Jenkins, op. cit., pp. 22-27.

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