The Evolution of Electricity Demand in Northeastern North America

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This paper reports on exploratory scenarios concerning the long-term evolution of electricity demand in the residential, commercial and industrial sectors of the northeastern United States and eastern Canada. The factors affecting the evolution of electricity demand are also compared across regions. The analysis is based on the use of MEDEQ, a model developed by INRS-Energie and the Ministry of Energy and Resources of Québec. The results show that the market for Québec's electricity production is substantial. This analysis is a part of a larger project intended to provide models that will describe energy demand and supply in Québec and in the provinces and states bordering it, so that the potential benefits of electricity exports between these regions can be evaluated.

A long terme, le marché de l'exportation de l'électricité du Québec entre en compétition avec l'accroissement de la demande interne et plusieurs déterminants peuvent jouer en faveur de l'un ou l'autre marché. Cet article présente quelques scénarios d'évolution de la demande électrique du Québec et des Provinces ou Etats limitrophes (Etats de New-York, Nouvelle-Angleterre, Ontario et provinces de l'Atlantique) en essayant de montrer quels sont les facteurs qui influencent la demande électrique de ces régions. A la lumière des résultats, deux types de conclusions peuvent être tirés: en premier lieu, on peut déterminer le marché potentiel d'exportation pour l'électricité du Québec. En deuxième lieu, l'analyse des différents comportements par région permet de déceler les tendances en matière de consommation d'électricité par usage.

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1. Introduction

During the last few decades the province of Québec has become an important electricity exporter to adjacent provinces and states. Between 1971 and 1987 annual exports rose from 5.4 to 28.8 billion kWh. Currently these sales represent an important component of the province's balance of payments. In 1987 the income generated by electricity exports was close to $1 billion and the sales themselves represented about 20% of the province's demand for electricity.

Contrary to all other Canadian provinces and probably most of the world, hydroelectric power is presently the most important single energy source, satisfying about 40% of Québec's energy requirements. All analysts who have considered the question agree that this share will continue to grow in the long run, even if Québec is already very electrified. Since the province's potential for additional sources of hydroelectric power is limited, a good grasp of the possible evolution of Québec's electricity demand and that of its neighbouring regions is essential to evaluate the potential benefits of electricity exports.

We have developed a model (called MEDEQ), that uses a common approach across regions, to forecast the long-term evolution of electricity demand by sector (residential, commercial and

industrial) in the northeastern states of the US and the eastern provinces of Canada. In the US, New York and the New England states are considered. Within Canada, Ontario is a potentially large market for Québec hydroelectricity. Its electricity demand and that of the Atlantic provinces are both analyzed here. The latter, as a smaller market, is often neglected. Comparisons of various factors that may influence the development of electricity demand in all of these regions are also presented.

2. Methodology

To insure that scenarios are consistent, the regional energy forecasts are based on a common framework of assumptions and methods. Since methodological differences have been eliminated, this allows for more meaningful comparisons of trends in energy consumption in each state and province.

The MEDEQ model is well-suited to take into account a broad set of relations (political, economic and technological) that exist between the pattern of economic growth and long-term energy demand. MEDEQ was implemented for the state of New York and the New England states in collaboration with local energy departments. For the eastern provinces and Ontario, the analysis is done at a higher level of aggregation and relies on studies and regular publications of provincial electric utilities and governments.[1]

MEDEQ is an end-use model developed by INRS-Energie[2] that has been used for many years to analyze medium and long-term energy demand in Québec. This system analysis model has also been used in the elaboration of energy policies (pricing, conservation and environmental policies) and the evaluation of the possible impacts of new technologies. A version of the model is in preparation for the city of Montréal, to assist in the design of municipal policies (Labonté, 1990).

The model is based on a mathematical representation of the overall mechanisms of the evolution of energy demand. The principal distinguishing characteristic of this kind of model stems from the importance attributed to technology in the creation and development of energy demand. The model is very disaggregated, with energy demand represented at the level of end uses and processes. Demand is considered in terms of both useful and final energy, in order to isolate the influence of substitution among energy forms that have different end-use efficiencies.

MEDEQ is different from other end-use models in several important ways. First, it specifically incorporates a role for the price of energy in the choice of technology. Second, explicit modelling of certain financial considerations, equipment characteristics and grant policies provide added dimensions to the choice of technology; even certain constraints related to energy production are incorporated in the model. Third, personal incomes are allowed to affect the evolution of appliance and dwelling stocks. Finally, all sectors are linked together into a coherent whole, which is not a common feature of this type of approach.

3. Description of the Reference Scenario

The reference scenario is characterized by a moderate rate of economic growth. Economic activity is assumed to grow at real annual rates varying between 2.2% and 3.2%, depending on the region. Following a downward trend after 1985, world oil prices are assumed to grow at a lower rate than in the past and reach $30 (US), at 1988 prices, in 2006. For most of the regions, this hy-

1/ See, for example, Ontario Hydro (1989) and National Energy Board (1987). A detailed list of references is provided in Labonté (1989).

2/ The first version of MEDEQ was developed in cooperation with *La Direction générale de l'analyse économique et financière de Ministère de l'Energie et des ressources du Québec* (DGA) and the *Institut d'économie et de politique de l'énergie* (IEPE) in Grenoble, which has implemented the related MEDEE 3 approach in France. Several other organizations have also actively participated in the research endeavour. The methodology is presented in Lafrance (1989). Over the years, the results of many projects using the MEDEQ model have been published by the Québec Ministry of Energy (1984; 1987; 1990).

Table 1: Annual Growth Rate of Real GNP, Population and Household by Region (1974-2006)

	GNP		Population		Households	
	1974-86	1986-2006	1974-86	1986-2006	1974-86	1986-2006
Atlantic provinces	3.0	2.6	0.7	0.6	3.0	0.3
Québec	2.9	2.5	0.7	0.4	3.0	1.3
Ontario	3.4	3.2	1.1	0.6	1.6	1.5
New England	3.5	2.2	0.3	0.6	1.1	1.5
New York	2.2	2.3	-0.2	0.4	0.4	0.9

Sources: Statistics Canada; New York State Energy Office; Rudden (1988).

Table 2: Relative Energy Prices by Sector and Region (1986-2006)

Sector & region	Oil/Electricity		Gas/Electricity	
	1986	2006	1986	2006
Residential				
Atlantic provinces	0.57	0.65	-	-
New York	0.32	0.39	0.26	0.36
New England	0.32	0.39	0.26	0.36
Ontario	0.58	0.77	0.40	0.60
Québec	0.77	0.98	0.71	0.84
Commercial				
Atlantic provinces	0.31	0.40	-	-
New York	0.27	0.38	0.23	0.33
New England	0.27	0.38	0.23	0.33
Ontario	0.43	0.53	0.32	0.43
Québec	0.54	1.05	0.64	0.93
Industrial				
Atlantic provinces	0.29	0.50	-	-
New York	0.32	0.39	0.35	0.47
New England	0.32	0.39	0.35	0.47
Ontario	0.38	0.63	0.48	0.62
Québec	0.48	0.69	0.46	0.69

Sources: Ministère Energie et Ressources Québec; National Energy Board; New York State Energy Office; Rudden (1988).

Note: Natural gas is not available in the Atlantic provinces.

Table 3: Share of Electricity by End-Use Sector and Region (1974-2006)

Sector & Region	1974	1986	2006
Residential			
Atlantic provinces	10	29	37
New York	10	17	23
New England	13	20	26
Québec	22	50	73
Ontario	17	29	32
Commercial			
Atlantic provinces	22	37	52
New York	23	35	38
New England	20	33	36
Québec	36	53	72
Ontario	29	39	39
Industrial			
Atlantic provinces	28	39	43
New York	16	26	26
New England	12	28	33
Québec	34	57	55
Ontario	16	21	22

Sources: Statistics Canada; New York State Energy Office; Rudden (1988).

pothesis means that, at the level of final consumers, electricity is not very competitive with other energy forms, even if it is expected that the gap between electricity and fuel oil prices will be reduced in the long run. In our model, the relative price of electricity plays an important role in the penetration of electric heating since competition between alternative fuel choices is based partly on relative energy prices. Another important factor is the availability of natural gas. For the simulations where this is an important consideration, we have assumed that the geographic availability of natural gas is held constant over time.

Following a decrease and then stagnation in the growth rate of population in the northeastern states during the 1970s, a rising mean rate has been observed during the last decade. We assume that this upward trend will continue until 2006, with the average annual rate at 0.9% for

Table 4: Forecast of Electricity Demand by End-Use Sector and Region (petajoules/year)

	Electricity Demand in 1986				Additional Demand by 2006			
	Residential	Commercial	Industrial	Total	Residential	Commercial	Industrial	Total
Atlantic	32	20	45	97	15	15	47	77
New York	127	149	101	377	41	42	42	125
New England	120	96	96	312	43	19	37	99
Ontario	140	125	161	426	36	39	131	206
Québec	147	89	252	488	69	47	151	267
Total	566	479	655	1700	204	162	408	

Source: MEDEQ Simulations.

New York State and 1.5% for the New England states. In Canada, we expect a lower population growth rate for Québec, which is a departure from historical trends. In Ontario and the Atlantic provinces, a higher population growth rate is forecast. It should be noted, however, that for all regions, we assume that the number of people per household will fall until 2006.

Finally, the industrial sectors of all regions are assumed to have larger increases in their levels of economic activity than the corresponding commercial sectors. In Québec, energy intensive industries are projected to be of increasing importance, but the opposite is true of the role of these industries in the northeastern states.

These and related assumptions are summarized in Tables 1 and 2. A more detailed description of our assumptions can be found in Surprenant (1988; 1989).

4. Total Electricity Demand Per Region

In the base case scenario, the growth of electricity demand exceeds that of energy in general. Overall, the increase in electricity use reaches 50% for the Canadian provinces and 30% for the northeastern states in the US, consistent with average compounded growth rates of between 1.4% and 3.0% per year. These growth rates are lower than their historical averages in all regions. The results presented in Table 3 indicate, however, that in all regions except Québec, electricity is still only the second most popular form of energy used in the residential, commercial and industrial sectors.

An analysis of Table 4 allows us to conclude that the main potential market for Québec electricity exports is the province of Ontario, which is almost as important as all of the other regions together. Québec accounts for about 30% of the total electricity demand of the region under study, while Ontario accounts for 25%, and New York State and the New England states are of roughly equal importance (each at about 20% of total electricity demand).

Our first conclusion is thus that Hydro-Québec can aim at three electricity markets of approximately equal importance: Québec, Ontario and the northeastern states, which represent 34%, 27% and 29% respectively of the additional demand for electricity in 2006. The Atlantic provinces clearly offer less scope as a future market for electricity produced in Québec.

Our second conclusion brings out the particular context of the evolution of energy demand in Québec. That province is already one of the most electrified societies in the world. In light of this fact and given a reasonably favourable economic context, one can expect that the other regions under study should experience stronger growth in electricity demand in the future. To clarify this, let us examine the evolution of per capita electricity consumption in Québec and the state of New York. While this indicator should rise significantly in Québec during the simulation period (from 76 gigajoules (GJ) per inhabitant in 1986 to 105 GJ per inhabitant in 2006), the poten-

Table 5: Relative Weight of Each End-use Sector by Region (% of total consumption)

Sector	New York	New England	Ontario	Québec
Residential				
1974	30	30	20	22
1986	28	39	22	23
2006	25	28	18	18
Commercial				
1974	17	14	15	14
1986	16	15	15	13
2006	17	14	13	11
Industrial				
1974	18	25	35	35
1986	14	16	35	35
2006	19	18	42	44

Sources: Estimated from Statistics Canada; New York Energy Office; Rudden (1988); MEDEQ Simulations.

tial for growth is much stronger in New York State since the value of this indicator is still at 26 GJ per inhabitant in 2006, roughly only one-third that of the province of Québec in 1986.

5. Electricity Demand by Sector

The results for end-use sectors (residential, industrial and commercial) bring out important factors that affect energy consumption in northeast North America. First, there are certain similarities in the evolution of energy demand across regions. The most striking of these is the growing importance of the industrial sector between 1986 and 2006. The share of the residential sector, on the other hand, declines everywhere. However, Table 5 indicates a different structure of sectoral energy demand in Québec and Ontario than in the northeastern states. Especially in Québec, the weight of the industrial sector is an indicator of the importance of energy-intensive industries in overall energy consumption patterns. At the other end are New York and the New England states, where very few additional energy-intensive plants are expected. This suggests that the industrial sector will account for most of the growth in electricity demand in Québec and Ontario between 1986 and 2006,[3] while the role of the three sectors will be approximately of equal importance in the northeastern states.

Table 6: Penetration of Electricity in Residential Heating (1986)

	Atlantic	New York	New England	Ontario	Québec	US
Penetration (%)	27	7	17	19	59	19

Sources: Statistics Canada; US Department of Energy.

Table 7: Energy Demand by End-Use in 1986: Residential (GJ/household)

End-Use	New York	Québec	New England
Heating*	68	77	82
Water heating	24	15	20
Electric appliances & lighting	16	22	16

* Wood not included

Source: MEDEQ Simulations.

5.1 The Residential Sector

As one would expect, electricity consumption per household (Table 6) is much higher in Ontario and Québec than in the northeastern states, due to the higher penetration by electricity in space and water heating. Overall, however, the levels of end-use energy consumption by the residential sector are not too different from one region to the next (Table 7). It should be noted that the penetration rate of electricity for space heating in New York and the New England states has been below the US national average. This is related to the fact that in these states the penetration of electricity in the space heating market corresponds essentially to heat pump installations, which is a high-income phenomenon.

As already noted, one of the fundamental characteristics of the Québec electricity market is

3/ A detailed discussion of the penetration of energy-intensive industries in Québec is presented in Lafrance (1988).

the strong penetration of electricity in the residential sector. This process is already well under way and should be almost complete by the end of the simulation period. Since other forms of energy will likely satisfy only 27% of residential energy requirements by 2006 (as opposed to 50% in 1986), electricity will by then have almost exhausted its room for growth. The space heating market in fact provides the impetus to this increased penetration of electricity in the Québec residential sector as old housing is gradually converted to electric heating and almost all of the new dwellings are equipped with electric heating systems.

The results also reveal that in other regions new needs for electricity are mainly related to appliance use and lighting. This situation should be welcomed by electric utilities, since the resulting annual distribution of demand would be rather uniform, thus reducing the problems associated with peak management. As an example, consider the case of space and water heating. In Québec, these uses accounted for about 65% of total annual electricity demand in 1986. In New York State, the comparable figure barely reached 15%.

Finally, low price elasticities of demand in the residential sector also explain part of the results obtained. The model was used to simulate the effects of a series of variations in electricity prices relative to those prevailing in the base case scenario. The resulting estimates of price elasticities are -0.34 and -0.14 in Québec and the northeastern US respectively. Many factors explain these low values. In Québec, the intrinsic value of electricity (reliability, cleanliness, convenience) has been shown to be as important as the more traditional economic factors (equipment costs, energy prices) in explaining the choice of heating systems.[4] In other regions, the main determinant appears to be the very high relative price of electricity, which reduces the possibilities for substitution.

5.2 The Commercial Sector

The energy needs of the commercial sector are roughly similar to those of the residential sector, with space heating accounting for slightly more than 50% of the total demand. In spite of this common feature, the results of our analysis reveal quite different behaviour in these two sectors.

In the commercial sector, the demand for new buildings is directly related to the expansion of economic activity. In the residential sector, on the other hand, the demand for new housing depends primarily on population growth. Since the expansion of economic activity far outstrips that of population in most regions, it is reasonable to expect that the growth of energy demand will be more sustained in the commercial sector.

The role played by the various energy forms is also something that varies sharply between these two sectors. Although natural gas has taken over in regions where it is available, electricity has acquired a foothold in the heating market of the commercial sector. Even with lower prices, fuel oil and natural gas do not appear to have any strong advantage over electricity in this market. Hence, in New York State electric heating is favoured in certain types of buildings (such as hotels where its share is about 20%), even though electricity prices far exceed those of alternative energy forms. An analysis of the situation in Québec can shed some light on this puzzle.

For years, the penetration rate in Québec for electric heating in new buildings has been more than 70%. According to analyses done by INRS and Hydro-Québec, the popularity of electricity over other forms of energy can largely be explained by the former's higher reliability, its low maintenance costs, its easy installation (particularly for decentralized heating and cooling), its lower equipment costs, etc. Builders and developers frequently pay more attention to these desirable characteristics than to the cost of purchasing the energy itself, which they simply pass on to consumers. A similar process could well be occurring in certain segments of the commercial sector in the northeastern states.

Table 3 reminds us that the overall outcome in the commercial sector is that the share of electric-

4/ See Surprenant (1984) for a detailed analysis.

ity in total energy demand rises. Again one notices just how strong the penetration of electricity is in Québec: by 2006 the share of electricity in the commercial sector reaches 72%. A more limited increase in electricity's share is evident in Ontario and the northeastern states (up to 35-40% by 2006).

It is also important to note that in 1986 the Québec commercial sector produced only about one-half as much output as the northeastern states with the same unit of energy (Table 8). Throughout the period under study, energy consumption per dollar of output will fall in all regions. Electricity consumption per dollar of output will, however, stay quite constant until 2006.

Table 8: Energy Consumption per Thousand Dollars of Industrial Output (GJ/thousands of $ 1971)*

Region & Sector	Total energy		Electricity	
	1986	2006	1986	2006
Commercial				
New York	3.6	2.7	1.2	1.0
New England	4.5	3.3	1.4	1.2
Québec	7.9	5.6	4.1	4.0
Industrial				
New York	11.1	9.0	2.9	2.3
New England	8.6	6.0	2.4	1.9
Québec	47.1	43.2	26.8	23.7
Total				
New York	12.7	11.0	2.3	1.9
New England	10.4	6.7	2.8	2.4
Ontario	40.0	31.0	8.0	6.3
Québec	41.1	33.8	15.9	15.4

* Expressed in units of currency of the home country

5.3 The Industrial Sector

For Québec our model indicates the existence in the industrial sector of a phenomenon similar to that encountered in the commercial sector, namely that energy demand and the growth in economic activity are less closely associated than they were in the past. Over the simulation period, the ratio of the growth in energy demand to that in industrial activity in Québec is 0.86. Between 1961 and 1974, the ratio was equal to 1.0. For other regions, this ratio remains at about 0.6 throughout. These results are based on the very rapid expansion of highly energy-intensive industries, such as aluminum production, in Québec.

The gap between energy demand and economic growth is also evident in measures of industrial energy consumption per thousand dollars of output (Table 8). A decline in energy requirements of 10-30% to 2006 can basically be attributed to improvements in industrial energy efficiency. Moreover, this indicator brings out the differences in industrial structure across regions. Contrary to the case of Ontario and Québec, the northeastern states are no longer considered to be strong candidates for attracting primary industries. During the last 20 years, most of the primary metal plants have disappeared from these states. The development of industrial economic activity is thus more dependent on secondary industries, which tend to be less energy intensive.

In Québec, announced projects and likely future trends for the establishment of highly energy-intensive industries in primary metals (aluminum, magnesium, ferro-alloy metals, etc.), chemical products (chlorine, chlorate, hydrogen, etc.) and non-metallic products (glass, ceramics, refractors) should increase the relative weight of the industrial sector in the province's total energy demand picture. In comparison to other regions, Québec's industrial sector is already very energy intensive: 79 GJ per inhabitant in 1981 and 68 GJ per inhabitant in 1986. Industries considered dependent on electricity consumption alone accounted for 54% of Québec's total industrial energy demand in 1986.[5] In the base case scenario, the importance of these industries could reach 62% of the province's total energy demand by 2006, with energy consumption per inhabitant reaching 100 GJ. These results are primarily explained by the consequences of the adoption of new electro-technologies (Labonté, 1990) and changes in the pattern of energy use in the pulp and paper industry, which promotes the use of thermo-mechanical processes to replace the existing sulphite-based production technology.

5/ See Lafrance (1988).

Our results can also be seen from a different perspective. By 2006, the annual demand for electricity created by Québec's new highly electricity-intensive plants will reach 26 TWh. This is comparable in size to the province's current electricity exports to neighbouring provinces and states. Overall, in a context in which environmental issues are becoming more and more important and in which there is a relative decline in the province's hydroelectric potential, one should expect more public discussion about what type of industrial/energy strategy to favour in the future.[6]

Finally, two other conclusions concerning the role of electricity in the industrial sector also emerge:

- following a steady rise in the share of electricity since 1974, we should observe a stabilization of this share in most regions (Table 3); the size of the share, however, should vary across regions; and
- except for Québec, we do not forecast any significant penetration by electricity of the heating market in the industrial sector.

6. Conclusion

The results of simulations of energy demand for the northeastern states and the eastern provinces (including Ontario) using the MEDEQ model allow us to draw a number of conclusions. First, even if it will not reach values observed in the past, the growth rate of electricity demand should continue to be positive in all of the regions under study. Overall this growth will generate an additional demand for electricity of about 215 TWh per year by 2006, which can be divided among three main markets of approximately the same size: Québec, Ontario, and the northeastern states (New York and the New England states).

A second conclusion is also evident. Any increase in the share of electricity in Québec must overcome the fact that electricity is already the most important source of energy in the province. Since the share of electricity is much further away from any saturation point in other regions, it seems reasonable to conclude that they offer good prospects for market expansion for Québec electricity, especially if electricity prices become more competitive.

It should also be noted that, in our results, the higher electricity demand in Ontario and Québec comes primarily from industrial activities. In the northeastern states, on the other hand, the higher demand is quite evenly distributed across end-use sectors.

All of these results confirm the hypothesis that the development of Québec's remaining hydroelectric power potential is not limited by demand. To meet all of the additional energy demand generated in our base case scenario by 2006, at least 40,000 MW will be needed, assuming that the hydroelectric option were to be chosen. This would exceed the province's economically viable potential hydroelectric sites; it also ignores the fact that some existing old power plants will have to be shut down. From Hydro-Québec's perspective, a regional marketing strategy should be pursued and expansion plans should be centred around the development of hydroelectric sites since these are more likely to be economically feasible.

Energy self-reliance and harnessing the impact of this energy-driven growth are objectives of the Québec government. These goals could well be incompatible with other objectives related to the protection of the environment, which could lead to some changes in Hydro-Québec's expansion plans. The development of hydroelectric sites and the increased penetration of electricity in the energy marketplace can affect the environment in many ways. In Québec, the construction of dams and the establishment of energy-intensive industries may well have undesirable environmental consequences. In other regions, however, the increased use of electricity may become an attractive option if emission controls become more severe. These various possibilities certainly require more attention and are currently at the top of our research agenda.

6/ A detailed analysis of these issues appears in Lafrance (1990) and Labonté (1990).

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