Hydro-Québec
TRIENNIAL REVIEW
OF RESOURCE ADEQUACY

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EXECUTIVE SUMMARY

This Report, Hydro-Québec Triennal Review of Resource Adequacy is submitted to the Northeast Power Coordinating Council (NPCC) and prepared in accordance with the **"Guidelines for Area Review of Resource Adequacy**", document B-8 revised 2/14/96. It shows that **Hydro-Québec has the ability to meet the NPCC reliability criterion** as stated below for the planning period **1998 through 2008**.

NPCC reliability criterion : " Each **Area**'s **resources** will be planned in such a manner that, after due allowance for scheduled outages and deratings, forced outages and deratings, assistance over interconnections with neighboring **Areas** and regions, and capacity and/or load relief from available operating procedures, the probability of disconnecting non-interruptible customers due to **resource** deficiencies, on the average, will be no more than once in ten years".

This report is based on the **1998 load forecast** and **considers the potential of available and committed resources** within the planning period. The in-service dates of new projects other than those that are committed are not shown in this report. Only the potential of uncommitted resources post 2000 is discussed.

The highlights of the report are as follow

Québec load is expected to grow at a lower rate than anticipated in 1995 (1,4% instead of 1,9%). Consequently, no new resources are required for the Québec load and current firm export obligations before the winter 2004-05. The margin over reserve requirement allows Hydro-Québec to increase short term exports.

Since the last review in 1995, no new commitments for major projects were made. Interruptible loads will be reduce starting in year 2000.

If need arise, a new interruptible load program reflecting market value could quickly be activated. In addition there are enough potential projects available by 2004-05 to maintain resource adequacy up to 2008. Also the current tie capacity with other neighboring areas allows Hydro-Québec to contract for import up to 2500 MW.

It is important to note that Hydro-Québec no longer counts on reserve sharing with other areas unless there are firm reservation or commitment for both generation and transmission. It is Hydro-Québec position that, with the new open market approach, generation and transmission must be secured on a commercial basis to ensure their future availability..

Finally reserve requirements is in the order of 12% of the annual peak load which is similar to the last Triennal Review.

TABLE OF CONTENTS

List of Figures

List of Tables

1 Introduction

This report is Hydro-Québec's resource adequacy review submitted to Northeast Power Coordinating Council (NPCC) and prepared in accordance with " Guidelines for Area Review of Resource Adequacy ", document B-8 revised 2/14/96.

Data presented covers years 1998 through 2007 and is in accordance with Hydro-Québec 1998 load forecast and the potential of available and committed resources for the period.

Since the last review, there were major changes in energy environment that have and will continue to have impacts in the Northeast : Federal Energy Regulatory Commission (FERC) had ruled for market's open access ; North American Electricity Reliability Council (NERC) is making way for North American Electric Reliability Organization (NAERO).

1.1 The most recent Hydro-Québec Review

The last NPCC review of Hydro-Québec resource adequacy was submitted in September 1995. Based on that review, NPCC concluded that Hydro-Québec was planning in accordance with the NPCC criterion for resource adequacy.

1.2 Load and Resource Comparison of the 1995 and 1998 Review

The 1995 internal peak load forecast showed an average compound growth rate of 1,9% for the period 1995-1996 through 2005-2006, after the impact of the energy conservation program that Hydro-Québec had at that time.

The 1997-1998 Québec normalized peak[1] load was about 31 400 MW to be compared to the 1995 forecast of 33 000 MW. The real peak load was only 29 210 MW due to the ice storm that hit Québec in January 1998. For the normalized peak load there was an average compound growth rate of 1,3% for the period 1994-1995 through 1997-1998. On the long term, the expected average growth rate of Québec load is 1,4%.

Taking into account firm exports, the annual peak load forecast[2] for the Hydro-Québec main system for 1998-1999 was 34 200 MW in 1995 as compared to 33 900 MW in 1998. These numbers appear quite similar. However, they are the results of two changes compensating each other : the decrease of the internal peak load is compensated by an increase in short term firm sales on external markets. This gives an expected total load growth rate of 0,7% between 1998-99 and 2007-08.

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[1] To be compared with forecast data, the real internal peak load is normalized by taking into account variances related to temperature and peak day.
[2] Annual peak load = Internal peak forecast + Firm exports - Isolated systems.

Figure 1 and Tables 1 and 2 show annual peak load forecasts and total resources for the 1995 and the 1998 reviews. Except for the Sainte-Marguerite 3 power station which is actually under construction and will be in service in 2001, there is no addition of resources shown for the 1998 resources. Other than that, the fluctuation in resources between 1999-2000 and 2002-03 are caused by the termination of several interruptible power contracts.

Figure 1

COMPARISON OF HYDRO-QUÉBEC PEAK LOAD FORECASTS
AND ESTIMATED TOTAL RESOURCES
IN THE 1995 AND 1998 PLANS

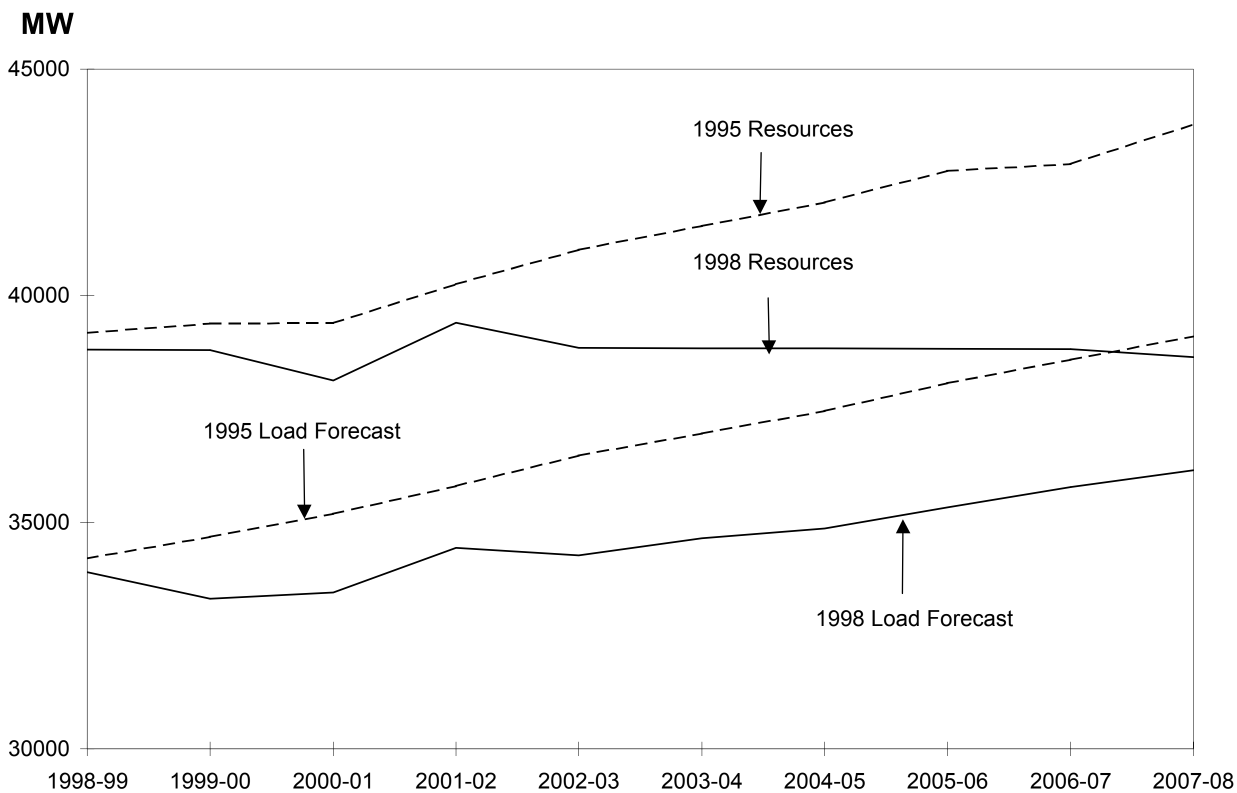

Table 1
COMPARISON OF ANNUAL PEAK LOAD[3] FORECASTS
BASED ON 1995 AND 1998 EXPANSION PLANS (MW)

YEAR	1995 FORECAST	1998 FORECAST	CHANGE IN LOADS
1998-99	34200	33900	-300
1999-00	34680	33310	-1370
2000-01	35190	33450	-1740
2001-02	35800	34430	-1370
2002-03	36470	34270	-2200
2003-04	36960	34650	-2310
2004-05	37460	34860	-2600
2005-06	38070	35330	-2740
2006-07	N/A	35780	N/A
2007-08	N/A	36150	N/A

Table 2
COMPARISON OF ESTIMATED TOTAL RESOURCES[4]
BASED ON 1995 AND 1998 EXPANSION PLANS (MW)

YEAR	1995 FORECAST	1998 FORECAST	CHANGE IN RESSOURCES
1998-99	39180	38810	-370
1999-00	39390	38800	-590
2000-01	39400	38130	-1270
2001-02	40250	39410	-840
2002-03	41010	38850	-2160
2003-04	41540	38840	-2700
2004-05	42060	38840	-3220
2005-06	42760	38830	-3930
2006-07	N/A	38820	N/A
2007-08	N/A	38650	N/A

[3] Annual peak load forecast includes firm exports and interruptible load.
[4] Resources include purchases and interruptible power shaving. For 1995, resources also included uncommitted project.

2 Resource adequacy criterion

2.1 Statement of Hydro-Québec Resource Adequacy Criterion

The Hydro-Québec system is planned in accordance with the following criterion :

> “ After due allowance for maintenance, forced outages, forecast uncertainty, spinning reserve requirements, interruptible loads, the probability of disconnecting firm customers due to generation deficiencies, on the average, will be no more than 2.4 hours per year. ”

This criterion slightly differs from the criterion that was used in 1995 review. With the structural changes that happened in the recent years and that will happen in the next years, Hydro-Québec does not want to rely on interconnection assistance to meet the criterion unless both firm capacity purchase and firm transmission reservation are made and paid for.

2.2 Details on Application of Criterion

The load model is based on hourly peaks. The criterion is therefore applied as 2,4 hours per year.

Due to the shape of load, most of the expected deficiencies are concentrated during winter months. This is illustrated in figure 2 which shows the monthly distribution of expected deficiencies for a typical hydraulic year[5]. From one month to another, loss of load probability varies significantly. For this reason, the criterion is applied annually.

The Hydro-Québec planning criterion does not account for emergency procedures such as voltage reduction and customer appeals. However these actions could be implemented to a certain extent and could actually reduce customer disconnection by Hydro-Québec.

A minimum amount of synchronized spinning reserve of 250 MW [6] is required to ensure safe operation of the system. Load shedding will be implemented to prevent the spinning reserve from dropping below that value. Therefore, this capacity is not considered available to supply load. This value is added to the required reserve as calculated by the probabilistic method. The spinning reserve used in the 1998 plan is the same that was used for the 1995 review.

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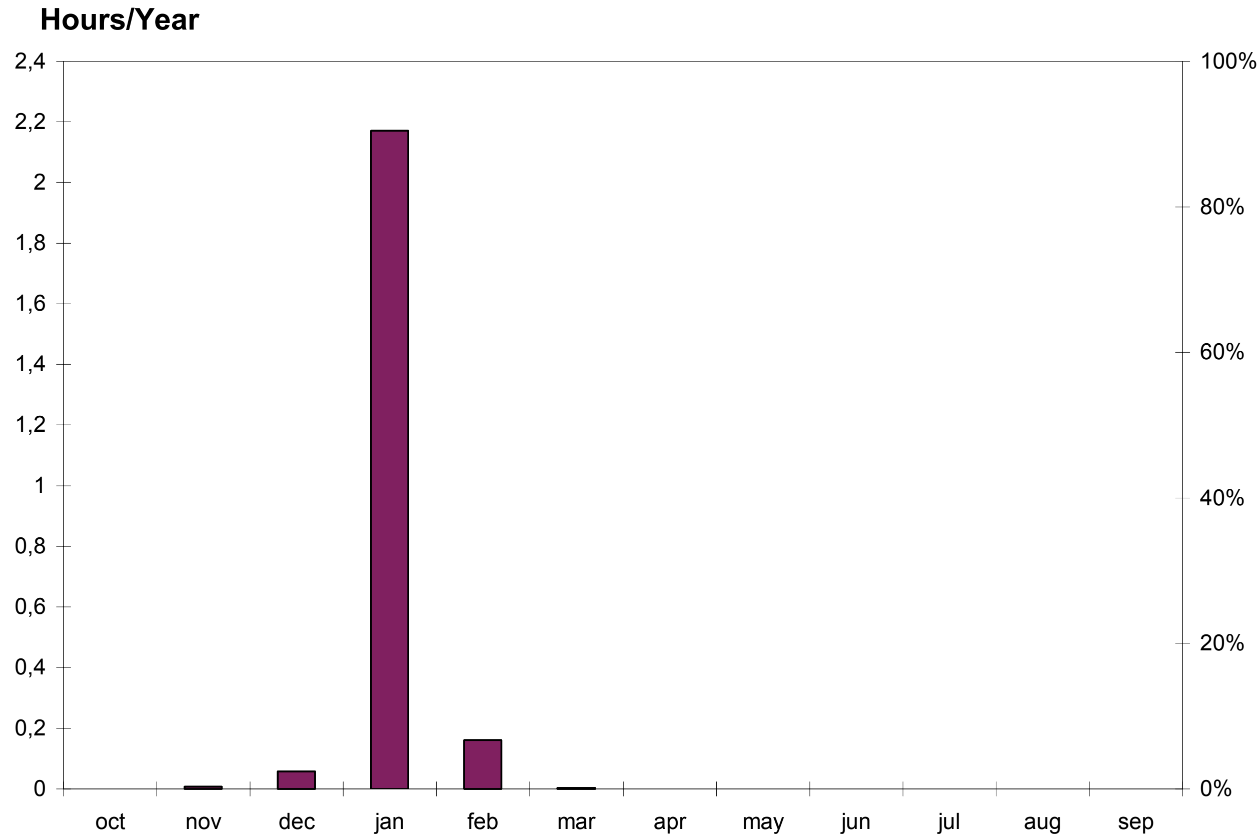
[5] The period of the hydraulic year is from October to September. Hydro-Québec annual forecast peak load occurs in January.

[6] See section 2.5.1 for more explanation

Figure 2
MONTHLY DISTRIBUTION OF EXPECTED DEFICIENCIES FOR A TYPICAL HYDRAULIC YEAR



The forecast forced outage rates are lower than in the 1995 plan due to programs to achieve a quality objective on generating units. The load forecast uncertainty factors had been revised. These changes are discussed in section 2.5.1.

In this document, reserve margin is expressed as a percentage of the annual peak load which includes both firm and interruptible loads as well as firm exports. The required reserve amounts to about 12% of the load. This reserve is supplied by two sources : the installed reserve (9%) and the industrial interruptible loads (3%).

2.3 Required installed Reserve

The Hydro-Québec required reserve percentage is not a planning criterion. It is a by-product of designing a system which meets both the energy and the capacity criteria for which a complete loss of load probability expectation (LOLE) evaluation is done year by year. As a result, reserve percentage may vary from year to year depending on system characteristics. These characteristics include :

- the load forecast and the expected load duration curve changes over the years ;

- type, size and timing of new resources ;
- existing and future generation unit availability (scheduled and unscheduled outage rates)

Table 3 shows the Hydro-Québec required reserve at the time of the annual peak for the years 1998-1999 through 2007-2008. These values are based on 1998 load forecast and are considered sufficient to meet the Hydro-Québec capacity reliability criteria.

Table 3
HYDRO-QUÉBEC REQUIRED RESERVE

		REQUIRED RESERVE	
YEAR	**ANNUAL PEAK LOAD (MW)**	**MW**	**%**
1998-99	33900	4200	12,4%
1999-00	33310	4370	13,1%
2000-01	33450	4380	13,1%
2001-02	34430	4440	12,9%
2002-03	34270	4220	12,3%
2003-04	34650	4240	12,2%
2004-05	34860	4260	12,2%
2005-06	35330	4280	12,1%
2006-07	35780	4310	12,0%
2007-08	36150	4280	11,8%

2.4 Comparison of Hydro-Québec and NPCC Criteria

The Hydro-Québec criterion is expressed in terms that differ slightly from the NPCC statement. However the reserve planned according to the Hydro-Québec criterion meets the NPCC reliability level.

To be able to compare the Hydro-Québec criterion with NPCC's, we have to take into account the following differences :

Load model

The NPCC criterion does not indicate how load should be modeled. Some NPCC members use daily peak load curves not considering forecast uncertainty, while others, like Hydro-Québec, use hourly peak curves with forecast uncertainty taken into account. The latter is a more severe constraint for Hydro-Québec.

Spinning reserve

The Hydro-Québec required reserve accounts for a minimum required amount of synchronized spinning reserve of 250 MW. Hydro-Québec will shed load before going under that amount. Under normal operation, a spinning reserve of at least 1 000 MW is maintained.

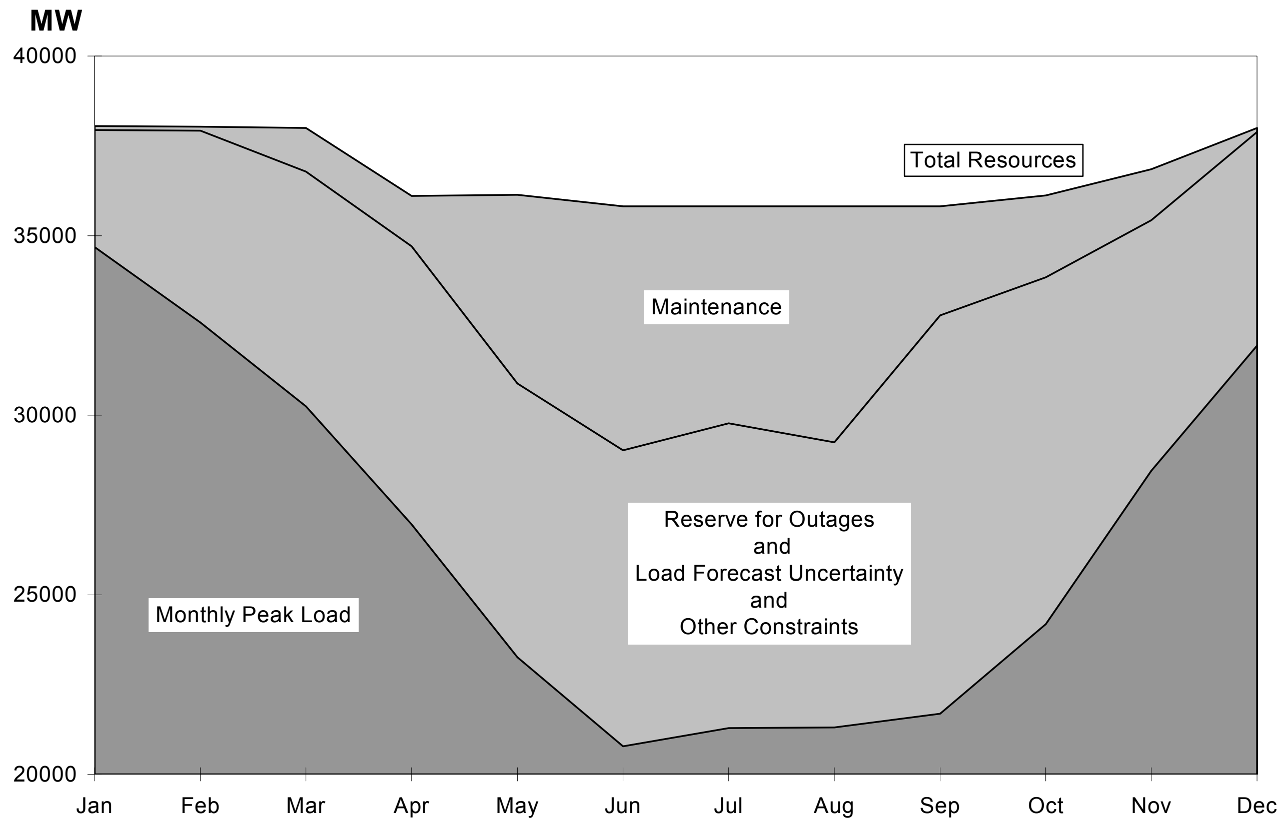
Basis for reliability evaluation

In the reliability evaluation, Hydro-Québec uses hourly peak loads as well as load forecast uncertainty with a long term standard deviation of 5.8%. The reliability criterion of 2.4 hours per year is applied annually.

With that methodology, Hydro-Québec applies a more severe reliability criterion mainly because of the use of the load forecast uncertainty, as was demonstrated in the previous reviews.

It is to be noted that because the Hydro-Québec system peaks in January, nearly all the loss of load risk is concentrated in that month (Figure 2). Loss of load probability in the other months is practically zero because of larger reserve after maintenance than during winter months (Figure 3). In comparison, a thermal system that peaks both in summer and winter will have a large part of its maintenance scheduled in spring and fall so that it can achieve a rather leveled LOLP, i.e. the risk of deficiency being more uniform throughout the year.

Figure 3
HYDRO-QUÉBEC MONTHLY RESERVE
YEAR 2002



2.5 Recent Reliability Study

As part of the normal planning process, reserve requirements are reevaluated each year to reflect the latest information. In addition to this, other studies may be initiated from time to time on specific themes.

Since the 1995 Review, the main hypotheses and parameters used for reliability evaluation have been reviewed. The results of this review are presented in next section.

No study was made for the evaluation of the capacity value of the interconnections given the position of Hydro-Québec on that subject : in an open access market there should not be any contribution of neighboring systems to the reliability taken into account unless both firm capacity purchase and firm transmission reservation are made and paid for.

2.5.1 Review of reserve evaluation hypotheses (1998)

Load forecast uncertainty

The load forecast uncertainty (LFU) has been revised in several ways. The revision is based on the following factors :

- the weather uncertainty component has been examined more accurately : its distribution does not fit the normal distribution ; extremes are within $\pm 3\sigma$;
- we continue to assume a normal distribution for the economic growth uncertainty ;
- when combined, these two uncertainty factors are very similar to a normal distribution with a slight asymmetry to the left ($P(x \leq 0)=0{,}5083$) ;
- the distribution table has been restricted[7] at $\pm 2{,}5\sigma$
- the LFU stops increasing after 3 years instead of 4 years previously, taking into account an easier access to capacity markets ; the values used are 5,2% for the first year, 5,5% for the second year and 5,8% after.

Spinning reserve

The spinning reserve value used in 1998 is the same that was used in 1995.

- the synchronized spinning reserve taken into account is 250 MW. In normal operating conditions 1 000 MW of spinning reserve must be maintained. However, the spinning reserve may be reduced to 250 MW before firm loads are interrupted. In addition, it is considered that the planned reserve associated with the load forecast uncertainty used will allow a spinning reserve of 1 000 MW to be normally maintained ;

Forced outage rates and maintenance factor

The projects to achieve a quality objective on generating units that were initiated in the early 1990's were maintained. The forced outage rates are revised accordingly.

- for existing hydraulic equipment, they are between 1,1% and 5,5% depending on the season and the " maturity " of the units ;
- for the Gentilly 2 nuclear unit, a new maintenance policy is enforced since 1992. This has resulted in a significant decrease of the forced outage rate of the unit.
- the forced outage rates of the peaking units are the same that was used in 1995 ;

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[7] The " restriction " adds all values outside the range $\pm 2{,}5\sigma$ at $\pm 2{,}5\sigma$. It differs of the truncation of the distribution.

- 0,4% of installed hydraulic generation units are considered on non scheduled maintenance during peak period .

2.5.2 Impact of Interconnections on Required Installed Reserve

In the present review, Hydro-Québec does not rely on interconnections to meet its criterion.

However, considering its large import capability, Hydro-Québec could make capacity purchases in the neighboring systems.

Import capability

Hydro-Québec has several interconnections with its neighbors. These ties can be either :

- synchronous ;
- HVDC ;
- radial (isolated generation/loads).

Table 4 shows the Hydro-Québec basic import capability at peak time by system and by type of interconnection for the years 1999 and after. Note that these numbers do not account for generation availability. However, they do account for known transmission constraints within systems, so that import capabilities shown may be less than the actual rating of the interconnections.

The 690 MW import capability for NEPOOL is based on the Comerford Des Cantons interconnection. Depending on system configuration, its capability can be reduced to 300 MW.

It should also be noted that the 200 MW Highgate interconnection is not considered available for capacity import at peak because of transmission constraints in the United States. However, during the January 1998 ice storm, the interconnection was used by Hydro-Québec to purchase electricity.

The 2 000 MW Nicolet terminal of the HVDC tie with NEPOOL is also not available for import because it is needed to transmit power from LaGrande complex to Hydro-Québec system.

Table 4
IMPORT CAPABILITY AT PEAK
(MW)

Neighboring system	Synchronous	HVDC	Radial	Total
CF(L)Co*	5 200			5 200
Alcan	700			700
MacLaren	150			150
Ontario Hydro			150	150
NewBrunswick Power		700		700
NYPP		1 000		1 000
NEPOOL		690		690
TOTAL	**6 050**	**2 390**	**150**	**8 590**

* Churchill Falls (Labrador) Corporation

3 Required and Planned Reserve

3.1 Most Likely Load Forecast

Table 5 shows both required and planned reserve for the period 1998-2007. Reserve is expressed as a percentage of the annual peak load. The latter include the firm demand and the industrial interruptible loads. The total available reserve includes the installed reserve and the interruptible-power shaving. The total reserve is smaller than required reserved starting in 2004-2005. In 2003-2004 the Hydro-Québec system is at criterion since the difference between required and total reserve is in the order of the LOLE model precision.

Table 5
COMPARISON OF REQUIRED AND PLANNED RESERVE
(AS PERCENTAGE OF TOTAL DEMAND)

		PLANNED RESERVE		
YEAR	**REQUIRED RESERVE**	**1=2+3 TOTAL RESERVE**	**(2) INSTALLED RESERVE**	**(3) INTERRUPTIBLE LOADS**
1998-99	12,4	14,5	9,0	5,5
1999-00	13,1	16,5	10,9	5,6
2000-01	13,1	14,0	10,8	3,1
2001-02	12,9	14,4	10,2	4,3
2002-03	12,3	13,4	10,4	3,0
2003-04	12,2	12,1	9,1	3,0
2004-05	12,2	11,4	8,5	2,9
2005-06	12,1	9,9	7,0	2,9
2006-07	12,0	8,5	5,6	2,9
2007-08	11,8	6,9	4,1	2,8

However, there are uncommitted available projects at that horizon. Table 6 shows the capacity available for the planning period. It includes hydraulic project under study and a new purchase program of independent power producer for renewable energy that was announced in 1996. These resources would increase installed reserve above required reserve. The dates will be adjusted when the projects will be committed. Over and above these projects there is also the possibility of repowering existing thermal units, constructing new combined cycle gas fired units, making purchases from outside of Québec and adding new interruptible loads at market conditions.

Also, since March 1998, Hydro-Québec and Newfoundland and Labrador Hydro have undertaken negotiations to conclude a Memorandum of Understanding establishing the parameters of agreements necessary for the further development of the hydroelectric potential of the Churchill River in the Labrador and related projects in Québec. These projects could add 2 200 MW on the Lower Churchill river as well as 1 000 MW of capacity at the Upper Churchill. There are ongoing negotiations and projected in-service date for both sites is around 2007-2010.

Table 6
UNCOMMITTED AVAILABLE CAPACITY

Year	**New Capacity available MW**
2000	20
2001	20
2002	20
2003	370
2004	390
2005	1030
2006	2500

Table 7 shows the capacity requirements and availability for the period 1998-2007. In that table, available generation includes existing hydraulic and thermal plants (see Table 12), scheduled improvements to existing capacity and also committed additions of generating facilities. Firm purchases include Alcan, Churchill Falls (Labrador) Corporation, New Brunswick Power and non-utility generation.

Table 7
CAPACITY REQUIREMENTS AND AVAILABILITY
(MW)
1998-2007

Hydraulic Year		**1998-99**	**1999-00**	**2000-01**	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**
Internal Peak Load & Exports	(1)	33960	33370	33510	34490	34330	34710	34920	35390	35840	36210
Isolated Systems	(2)	60	60	60	60	60	60	60	60	60	60
Annual Peak Load	**(1)-(2)=(3)**	**33900**	**33310**	**33450**	**34430**	**34270**	**34650**	**34860**	**35330**	**35780**	**36150**
Available and Commited Generation	(4)	30580	30580	30740	31610	31610	31610	31620	31620	31620	31460
Firm Purchases	(5)	6360	6350	6340	6330	6220	6210	6200	6190	6180	6170
Interruptible - Power Shaving	(6)	1870	1870	1050	1470	1020	1020	1020	1020	1020	1020
Total Resources	**(4)+(5)+(6)=(7)**	**38810**	**38800**	**38130**	**39410**	**38850**	**38840**	**38840**	**38830**	**38820**	**38650**
Installed Reserve	(7)-(3)=(8)	4910	5490	4680	4980	4580	4190	3980	3500	3040	2500
Required Reserve	(9)	4200	4370	4380	4440	4220	4240	4260	4280	4310	4280
Margin	**(8)-(9)=(10)**	**710**	**1120**	**300**	**540**	**360**	**-50**	**-280**	**-780**	**-1270**	**-1780**

3.2 High Load Forecast

Table 8 shows the projected Hydro-Québec high load forecast. The average compound growth rate for the period 1998-1999 through 2007-2008 is 1,6%.

Table 8
HYDRO-QUÉBEC ANNUAL PEAK LOAD FORECAST[8]

Year	High Load Forecast (MW)	Most Likely Load Forecast (MW)	Difference (MW)
1998-99	34200	33900	300
1999-00	34930	33310	1620
2000-01	35800	33450	2350
2001-02	36220	34430	1790
2002-03	36360	34270	2090
2003-04	37030	34650	2380
2004-05	37700	34860	2840
2005-06	38430	35330	3100
2006-07	39020	35780	3240
2007-08	39630	36150	3480

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[8] Annual peak load forecast includes firm exports and interruptible load.

Modeling was done with high load forecast. For that test, the load forecast uncertainty was reduced to 3%, which is the value used for weather forecast uncertainty. Table 9 shows a comparison of total reserve and required reserve. A deficit appears at year 2000-2001. As shown before, there are several uncommitted resources available. Options that could be available by 2000-01 in order to meet high load growth scenario over the ten years period include :

- new interruptible loads program ;
- new purchases at market prices ;
- installation of gas turbines or combined cycle units;
- repowering of existing thermal units.

Since a high load growth does not happen overnight, sufficient lead time is available to meet such scenario with the above mentioned new resources.

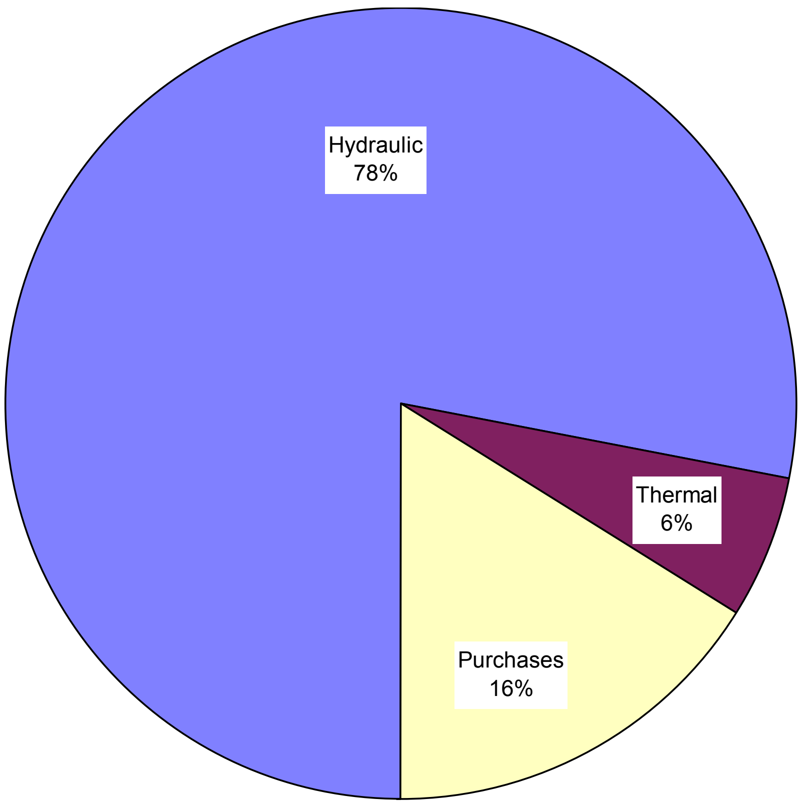
Table 9
COMPARISON OF REQUIRED AND PLANNED RESERVE
HIGH LOAD FORECAST
(AS PERCENTAGE OF TOTAL DEMAND)

		PLANNED RESERVE		
YEAR	**REQUIRED RESERVE**	**1=2+3 TOTAL RESERVE**	**(2) INSTALLED RESERVE**	**(3) INTERRUPTIBLE LOADS**
1998-99	9,3	13,5	8,0	5,5
1999-00	9,0	11,1	5,7	5,3
2000-01	8,5	6,5	3,6	2,9
2001-02	8,2	8,8	4,7	4,0
2002-03	7,6	6,9	4,0	2,8
2003-04	7,4	4,9	2,1	2,8
2004-05	7,3	3,0	0,3	2,7
2005-06	7,2	1,1	-1,6	2,7
2006-07	7,1	-0,5	-3,1	2,6
2007-08	6,9	-2,5	-5,0	2,6

4 Planned generating capacity mix

Hydro-Québec is mainly a hydroelectric system and plans to continue its hydraulic development. The breakdown by type of generation is shown in the following figure. The percentage of thermal generation is about 6% in 1998 while the percentage of hydraulic generation is 78%. It should be noted that with purchases, the hydraulic sources count for 93% since the purchases shown are mainly hydraulic and come from Churchill Falls (Labrador) Corporation.

Figure 4
CAPACITY MIX
PERCENT OF TOTAL
1998



5 Energy supply issues

5.1 Energy requirements and availability

Table 10 shows for the period 1998-2008 firm energy requirements for internal and external markets and forecast energy production by fuel type and purchases.

Table 10
HYDRO-QUÉBEC ANNUAL ENERGY[9] REQUIREMENTS AND RESOURCES
(BASED ON AVERAGE ANNUAL HYDRAULIC CONDITIONS)

				FORECAST ENERGY PRODUCTION BY FUEL TYPE			
	Internal Energy Requirement (TWh)	Firm Exports (TWh)	Total Demand (TWh)	HYDRO (TWh)	NUCLEAR (TWh)	OIL (TWh)	PURCHASES (TWh)
1999	166,5	17,4	183,9	150,7	4,7	0,2	32,8
2000	170,1	10,7	180,9	150,8	4,8	0,2	32,7
2001	176,1	4,0	180,1	151,6	4,3	0,2	32,6
2002	179,5	2,4	181,8	153,6	4,6	0,2	32,5
2003	181,7	2,4	184,1	153,6	4,6	0,2	32,4
2004	183,9	2,4	186,2	153,6	4,3	0,2	32,3
2005	186,1	2,4	188,5	153,7	4,6	0,2	32,2
2006	189,2	2,4	191,6	153,7	4,6	0,2	32,1
2007	191,6	2,4	194,0	153,7	4,3	0,2	32,0
2008	193,6	2,4	196,0	153,8	4,6	0,2	31,9

Projects that should be available to offset the reserve deficiencies starting in 2004-2005 will in most cases produce also energy. So the energy short fall starting in 2006 will be cover either by new hydro projects, combined cycle units, purchases, repowering of existing thermal units or a combination of these.

[9] Firm export includes losses.

5.2 Energy reserve

In a hydraulic system, water supply for generation does not always coincide with the demand pattern. A sufficient amount of energy reserve must be maintained in order to meet load requirements at all times.

The Hydro-Québec reservoirs have a total capacity of over 170 TWh including about 25 TWh from the Smallwood reservoir at Churchill Falls.

Part of this capacity is required within the year to fill the gap between energy demand and water supplies to the reservoirs in the winter. This reserve is called inter-seasonal reserve and varies yearly according to demand growth. The rest of the reservoirs is used as inter-annual reserve.

Actually, Hydro-Québec plans its energy supply to encounter a 2% risk of low inflow. For one year, that amount to a risk coverage of -39 TWh. For a two year period, the 2% risk is at -64TWh.

To cope with these variations, Hydro-Québec counts on different means: inter-annual water reserve in the reservoirs, operation of the Tracy thermal plant, purchases from neighboring areas and planned uncommitted export sales.

For the coming years, Hydro-Québec will continue to plan its system and to manage its reservoirs so that it could encounter a risk of having 64 terawatt-hours less than the average inflows over a two year period without having to shed load for energy shortage.

6 Description of generation reliability model

6.1 Load model

The annual peak load forecast covering the period 1998 through 2007 is given in table 11. The average growth load for the period is less than 1% a year.

Table 11
PEAK LOAD FORECAST
(MW)

YEAR	(1) Internal Peak	(2) Firm Exports	(3) Isolated Systems	(1)+(2)-(3) Annual Peak Load
1998-99	31580	2380	60	33900
1999-00	31420	1950	60	33310
2000-01	32090	1420	60	33450
2001-02	33430	1060	60	34430
2002-03	33800	530	60	34270
2003-04	34180	530	60	34650
2004-05	34550	370	60	34860
2005-06	35020	370	60	35330
2006-07	35470	370	60	35780
2007-08	35840	370	60	36150

6.1.1 Load Shapes

For the reliability studies, the year is divided into twelve months. Each month of every year has its own hourly-based load duration curve. This load modulation is applied on the firm demand and the interruptible loads.

The isolated system demand is subtracted from the load and is not accounted for in the loss of load probability evaluation. Accordingly, the diesel generation does not appear in the generation unit representation.

6.1.2 Load Forecast Uncertainty

In order to account for forecast uncertainty, the load duration curves are convolved with a distribution curve built from the historical data for the weather component and assumed normally distributed for the economic growth component. This operation is done for every month of every year.

6.2 Generating Unit Representation

6.2.1 Unit Rating

The following Table 12 details the existing capacity of Hydro-Québec as of January 1998.

Table 12
EXISTING CAPACITY AS OF JANUARY 1998

Station	Number of Units	Dependable maximum net capacity in January (MW)
1- Hydraulic plants		
Upper Ottawa River		
Rapide 7	4	48
Rapide 2	4	47
Rapide-des-Quinze	6	84
Rapide-des-Îles	4	133
Première Chute	4	116
Subtotal	22	428
Mid and Lower Ottawa River		
Chute-des-Chats	4	93
Bryson	3	63
Carillon	14	588
Rivière-des-Prairies	6	44
Subtotal	27	788
Gatineau River		
Paugan	8	233
Chelsea	5	149
Rapides-Farmers	5	61
Subtotal	18	443
St.Lawrence River		
Les Cèdres	18	150
Beauharnois[10]	36	1510
Subtotal	54	1660
St-Maurice River		
Rapide-Blanc	6	207
Trenche	6	281
Beaumont	6	265
LaTuque	6	177
Grand-Mère	9	151
Shawinigan 2 & 3	11	282
La Gabelle	5	131
Subtotal	49	1493
Bersimis River		
Bersimis 1	8	861
Bersimis 2	5	711
Subtotal	13	1571

Station	Number of Units	Dependable maximum net capacity in January (MW)
Aux-Outardes River		
Outardes 4	4	652
Outardes 3	4	742
Outardes 2	3	447
Subtotal	11	1842
Manicouagan River		
Hart Jaune	3	48
Manic 5	12	2443
Manic 3	6	1172
Manic 2	8	1038
Manic 1	3	196
McCormick	3	350
Subtotal	35	5248
La Grande River		
Brisay	2	327
Laforge 1	6	821
Laforge 2	2	283
LaGrande-1	12	1282
LaGrande-2	22	7472
LaGrande-3	12	2299
LaGrande-4	9	2661
Subtotal	65	15147
OTHERS[11]	40	120
2-Thermal Plants		
OIL		
Tracy	4	400
Subtotal	4	400
Gas Turbines		
Bécancour	4	431
Cadillac	3	162
La Citière	4	280
Subtotal	11	873
3. NUCLEAR		
Gentilly 2	1	675
Subtotal	1	675
Total Hydraulic		**28740**
Total Thermal		**1947**
Total Hydro-Québec		**30687**

10 Installed Capacity

11 Stations whose capacity is less than 30 MW.

6.2.1.1 Definitions

The capacity definitions used in reliability evaluation are as follows:

- Hydraulic stations larger than 30 MW

Dependable Maximum Net Capability (DMNC) is defined as the power that can be sustained during two consecutive hours per month, for the period October through May, and four consecutive hours per month, for the period June through September. This definition may seem optimistic but proper use of the reservoirs usually make this capacity available daily. DMNC varies from month to month. Beauharnois, Les Cèdres and Carillon generating stations are not modeled according to this definition. This is discussed in section 6.3.

- Hydraulic stations of 30 MW and less

These generating stations are run-of-the-river plants. DMNC is defined as the average power based on historical generation.

- Thermal stations

DMNC varies from one month to another to account for ambient temperature changes.

6.2.1.2 Procedure for Verifying Ratings

Ratings are based on historical values and are reviewed annually.

6.2.2 Unit Unavailability Factors

6.2.2.1 Types of Unavailability Factors

- Outages

Forced Outage Rate:

$$FOR = \frac{\text{Time on Forced Outage}}{\text{Time on Forced Outage + Time on service}}$$

- Maintenance

For each month, the total capacity of hydraulic stations in service at that time (i.e. available) is summed (except Beauharnois). Hydraulic capacity on maintenance is then calculated as a percentage of this total. Percentage varies from one month to another. Table 13 gives percentage values for each month.

Table 13
MAINTENANCE FOR HYDRAULIC UNITS

Month	Percentage of Maintenance
January	0,4
February	0,4
March	4,4
April	5,0
May	16,0
June	24,0
July	22,0
August	23,5
September	10,6
October	8,0
November	5,3
December	0,4

Thermal stations are on maintenance off peak during summer, each station having its own maintenance schedule.

6.2.2.2 Source of Unavailability Factors

Forced outage rates are based on historical values.

6.2.2.3 Maturity Considerations

The reliability model accounts for maturing units. Forced outage rates of new units are higher for the first three years.

6.2.2.4 Tabulation of Typical Forced Outage Rates

Table 14
FORCED OUTAGES RATES[12]

Type of equipment	**Outage rate**
Hydraulic	1,1% to 5,5%
Thermal, including nuclear	4% to 10%

6.2.3 <u>Purchases and Export Representation</u>

6.2.3.1 Purchases

Churchill Falls (Labrador) Corporation (CFLCo)

Table 15
BASE CONTRACT

HYDRAULIC YEAR	**Winter (MW)**	**Summer (MW)**
1998 +	4 083	3 870

In the purchase contract, there was a right for CFLCo to recall up to 300 MW. This recall has been fully exercised in 1998. However, Hydro-Québec and CFLCo signed a new agreement so that the capacity unused by CFLCo will be marketed by Hydro-Québec. This capacity is included in Hydro-Québec purchases. For 1998-1999, the capacity used in Labrador is about 130MW. We assumed this load will grow of 10MW each year.

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[12] Beauharnois, Les Cèdres and Carillon are not modelled according to these FOR's. This is described in section 6.3.

Alcan

Alcan has its own generating facilities in Quebec. However some of its loads are connected to the Hydro-Québec system and are included in the demand forecast. A corresponding power of 389 MW is delivered to Hydro-Québec until 1995-96. Starting in 1996-97, this capacity decreases to 283 MW.

Recently, Alcan announced that new aluminum smelter will be in service by the year 2001. Alcan and Hydro-Québec signed several contracts related to that new smelter. Hydro-Québec will provide energy to Alcan and Alcan will provide capacity to Hydro-Québec during its peak period. Part of the capacity will come from Alcan's installations in Quebec. The rest of the capacity will be available under the industrial interruptible power shaving program.

New Brunswick Power

Hydro-Québec has a contract to buy 300MW of peaking capacity from 1998 to 2001 and 200MW from 2002 to 2010.

Non Utility Generator

In 1999, 370 MW of capacity from non utility generator will be in service. Moreover, Hydro-Québec announced that it will purchase, starting in 2000, up to 30 MW a year of power produced by wind.

6.2.3.2 Export

Only firm power transactions are represented in the reliability model. Some power contracts which specifies that Hydro-Québec is not obliged to deliver capacity using thermal generation are not represented. Energy contracts are not included in the model because deficiency provisions do not oblige Hydro-Québec to deliver electricity at system peak.

In 1997 and 1998, Hydro-Québec signed several agreements for the usage of its reservoirs. When the return of energy is guaranteed, it has been modeled as a guaranteed capacity delivery.

6.2.4 Retirements

No retirements are planned for the period covered by this review. Older stations are rather overhauled.

6.3 Modeling of Limited Energy Sources

For most hydraulic stations, energy limitations are considered by using a different value of dependable capability (DMNC) for each month. However, there are three stations which require a different representation.

Beauharnois and Les Cèdres are two run-of-river stations operating in parallel on the St. Lawrence river. Their capability is dependent on water availability and varies according to seasons. Also, during ice cover formation, capacity output must be reduced. Furthermore, generation is also affected by navigation constraints on the St. Lawrence river.

Beauharnois is modeled with a probability distribution based on historical generation. This distribution accounts not only for hydraulic conditions but also for maintenance and forced outages.

Available water can be channeled through either Les Cèdres or Beauharnois. However, the latter station is more efficient. Priority is then given to generation at Beauharnois, leaving less water available for Les Cèdres. To account for this, Les Cèdres is modeled with a very high FOR of 33%.

Carillon is considered a peaking unit. Because of the small size of the reservoir, most of the maximal capacity could be available for two or three hours per day. An equivalent FOR of 21% proved to be an adequate representation of the situation in regard with the LOLE evaluation.