New Climate Normals for Electricity Demand Forecasting

Photo credit: Photo Hydro-Québec

SUMMARY

"In the context of Hydro Québec, updating our climate normals based on temperature trends is not only simple and effective, but also absolutely necessary."

Alexandre Deslauriers, Demand forecast Team Leader at Hydro Québec Distribution[1]

Outside temperatures are an important factor in electricity demand in Quebec, because many households and businesses rely on electricity for heating and cooling. Hydro-Québec's distribution division, in collaboration with the Ouranos Consortium, studied these impacts in depth and implemented ways to incorporate recent changes in average temperature into energy and peak demand forecast.

CONTEXT

Temperatures are the principal criterion that determines when people start to heat or cool their homes and workplaces. In Quebec, this criterion has a direct impact on electricity consumption, as most people use electricity for heating and cooling. To meet demand, electricity providers like Hydro-Québec plan ahead using complex numerical models. Observed records of average temperatures are key components of these calculations. In the forecasting horizon, demand forecast models should use normal weather assumptions consistent with economic and demographic assumptions. In a warming climate with higher average temperatures than those of a few decades ago, observed records no longer provide the best statistical basis for demand forecasts. Hydro-Québec developed methods to improve demand forecasts that incorporate climate change trends. These methods are further refined for forecasting peak demand during the winter, as temperatures below -30°C are common in Québec.

ADAPTING CLIMATE RECORDS FOR IMPROVED DEMAND FORECASTS

Hydro-Québec's distribution division noted back in 2001 that average temperatures during 1991-2000 were clearly warmer than they had been between 1961 and 2000. Alexandre Deslauriers, Demand forecast team leader recalls: "The years around 2000 were certainly very hot in Quebec, which might have triggered our attention, but at the same time the Kyoto Protocol had just been adopted. These factors, along with an avant-garde spirit at Hydro-Québec, inspired us to explore further."[1] A study of the effects of higher temperatures on electricity demand revealed corresponding shifts in consumption and sales patterns during both winter and summer. Says Nadhem Idoudi, former Chief of the forecasting and characterization department and now Director of market risk management and analysis at Hydro-Québec: "We found that our sales often deviated from what we had predicted if they were based on a simple observed temperature mean."[1]

The distribution division wanted to better understand these findings and explore the potential relationship with climate change. As a founding member of the Ouranos Consortium on Regional Climatology and Adaptation to Climate Change, Hydro-Québec could readily provide its demand-forecast team with access to climate scenarios and services. In response to the team's request in 2004, Ouranos scientists developed a regionalized scenario of the evolution of monthly average temperatures using a single climate model simulation. At the distribution division, experts began to explore how to incorporate these long-term monthly temperature trends into demand forecasts, and whether the results would be useful. The results of this early exploration were unequivocal: "There was clearly a reduction in heating degree-days due to long-term warming,"[1] explains Alexandre, who uses the heating degree-day indicator to measure the heating consumption intensity.

To develop a way to use climate-model temperature data in Hydro-Québec demand forecasts, a more sophisticated assessment was completed in 2007. "Using the CMIP3 climate simulations—which were brand new at the time—we first identified where temperature trends begin to rise sharply in the time series," recalls Diane Chaumont, Coordinator of the Climate Scenarios and Services Group at Ouranos. Based on this analysis, 1970 was defined as a starting point for warming and used in the simplification of warming trends through the 2030s. The evolution of mean temperatures was established by fitting linear trends to the data from 1971-2040, using the deviation of this period's values from the average of 1901-1970. The analysis used the median value from 39 climate model simulations, yielding trend estimates for each month of the year (see Figure CS7.1).

Since 2007, the distribution division has used these trends to update the normal weather used in operational forecasting[2,3]. "We needed a way to represent the fact that the normals will continue to evolve and that the climate is no longer stationary, and to link this with demand and sales forecasts,"[1] says Nadhem. Figure CS7.2 illustrates the adopted procedure. A multiple of the annual-temperature increase due to the long-term trend is added to each year's value in the historical temperature record. The age of a record in years is equal to the number of times the annual increase

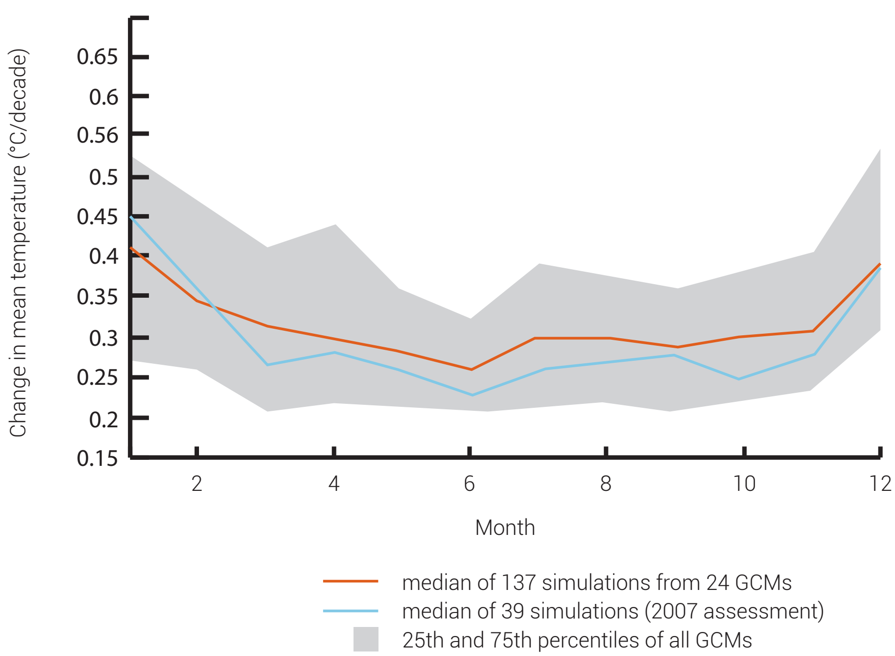
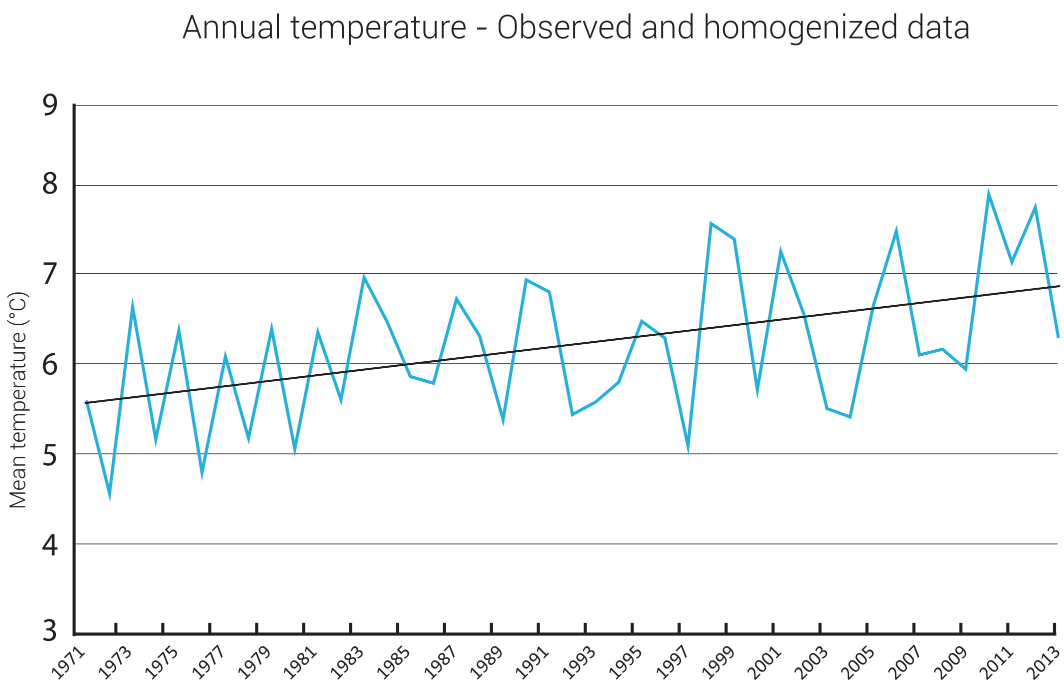


Figure CS7.1 Mean rate of temperature change per month through the 2030s for southern Quebec. Data from two assessments from 2007 (blue line) and 2012 (red line) show the stability of results. The grey area represents the uncertainty interval from all climate simulations between the 25th and 75th percentile.



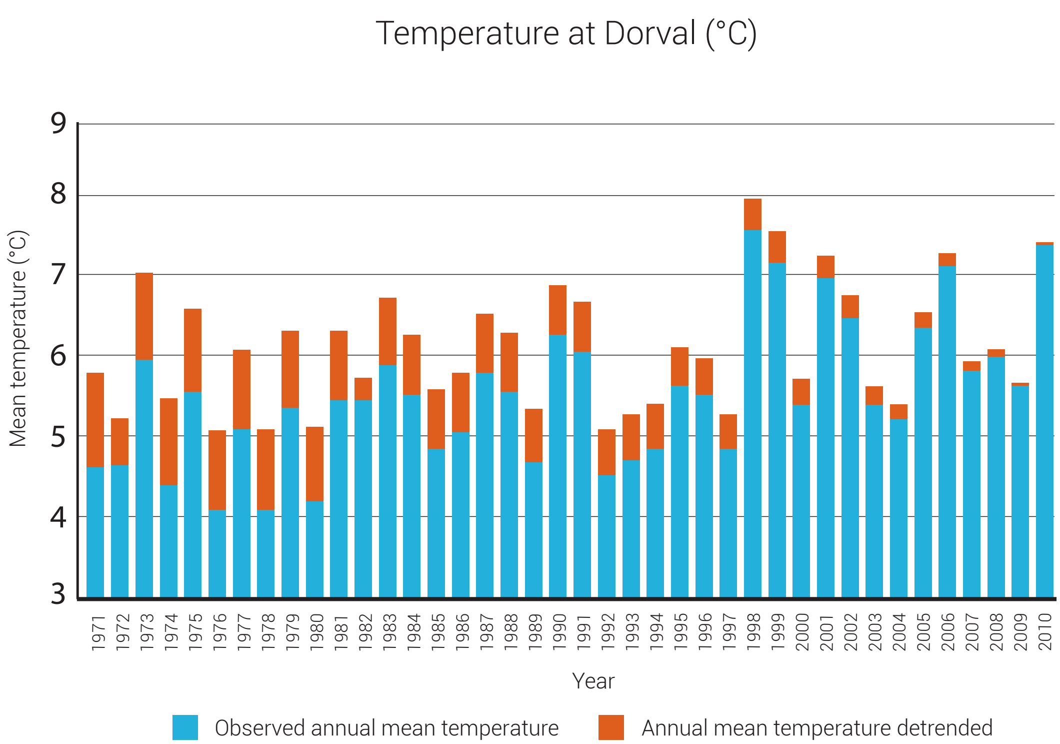


Figure CS7.2 Correction of a temperature/time series for the year 2010. The further a year is back in time, the larger the de-trending factor that must be applied.

needs to be added. As a result, the records for the cooler years of the past are raised to reflect today's warmer climate. A normal based on these corrected historical records provided a better-centered energy demand forecast than a normal based on uncorrected data. To keep its database current, Hydro-Québec requested an update of the climate assessment in 2012, this time based on a larger ensemble of 137 climate simulations. As can be seen in Figure CS7.1, the update confirms the robustness of the earlier assessment, with only minor differences in monthly trends.

Managing peak demand during Canada's cold winters represents another important challenge for Hydro-Québec. About three-quarters of households in Quebec rely on electricity for heating. Thus, the coldest days of the year usually coincide with the annual peaks in electricity consumption. "As we have started to correct our climate normals to reflect warmer temperatures, we should study the temperature effect specifically on high energy requirements for extremely cold winter days," explains Nadhem. "And buying electricity on the energy market at the last minute can be very expensive."[1] The 4th IPCC report[4]

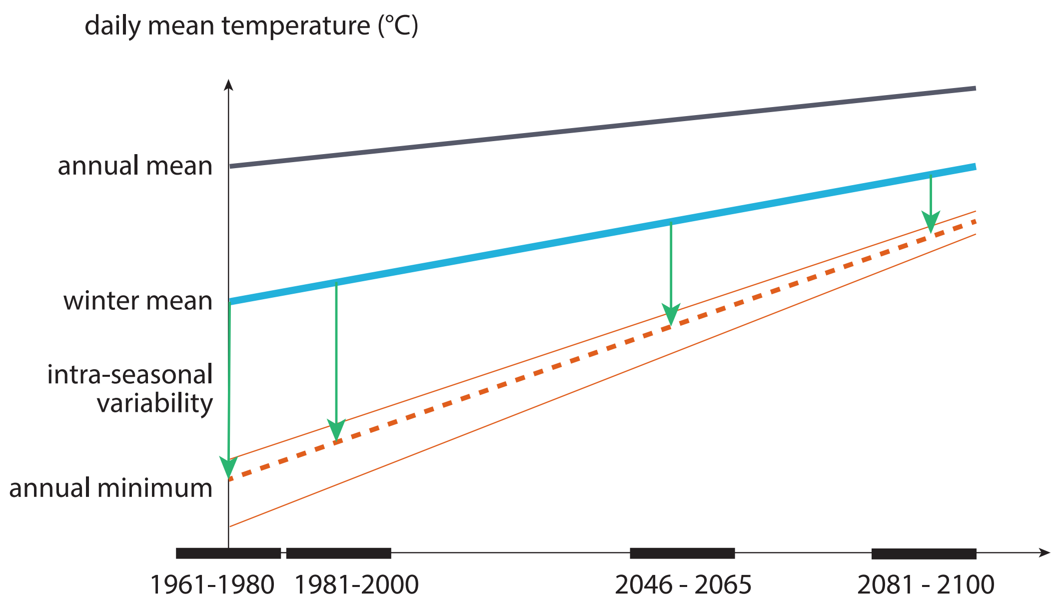


Figure CS7.3 Schematic of the different rates of change for annual mean temperatures, winter mean temperatures and extreme cold temperatures.

suggests that extreme temperatures may change at different rates than mean temperatures (see Figure CS7.3) "So we wanted to study temperature extremes and improve our ability to forecast winter peak demand,"[1] says Nadhem. Hydro-Québec again relied on the climate experts at Ouranos to explore this topic.Extreme events—rare by definition—are challenging to study and require the application of sophisticated statistical and mathematical skills. Barbara Casati of Ouranos dedicated several months to studying extreme weather events and shared the results with the scientific community[5].

Her research confirmed the hypothesis of faster warming of extreme cold temperatures in Quebec compared to mean winter temperatures. Hydro-Québec now incorporates these findings on the winter's coldest temperature's trends into its peak forecasting. The experts at Hydro-Québec expect that the model will improve the accuracy of their forecasts during winter, just as the model based on projected warming trends improved their forecasting during the rest of the year.

Figure CS7.4 Montreal in the morning of January 23rd, 2013. Minimum Temperature was -26.9 °C with a wind chill factor of -39°C (Environment Canada)

LESSONS LEARNED

When the forecasters within Hydro-Québec's distribution division started considering whether long-term temperature trends would have an impact on electricity demand and sales, many of their colleagues were sceptical. "Whenever we mentioned climate change," says Nadhem, "we always heard the same questions: 'Are you sure about this? Do you really think that next year will be warmer?' For many people, global warming remains abstract because it occurs gradually; temperatures don't always increase from one year to the next. We've found that graphics help people understand not only global warming, but also show why our forecast is well centered."[1] Nadhem supports these explanations with statistics that show the financial benefits that the new forecasting model has produced for Hydro-Québec over the years.

The in-depth study of the meteorological database in collaboration with climate experts yielded an unexpected benefit: they were able to explain anomalies in the record of historical temperatures. "The observed temperature data trend contradicted the climate models temperature trend," says Nadhem. "Looking more closely, we found anomalies in the observed data that coincided with the introduction of new measuring equipment in the 1990s."[1] This ultimately resulted in an improvement of their database by homogenizing the observed data. "We had always been confident that the observed data from a thermometer were good and consistent until we did a thorough analysis and found the homogeneity problem."[1]

The distribution division has since upgraded its forecasting approach[6]. "After 2012, we revised our entire forecasting system and began to follow an econometric approach," says Nadhem. "This approach integrates normal temperatures and accounts for their evolution over time." However, the team must still explain the climate's natural variability, such as the recent pattern of two very warm winters followed by two very cold winters (see figure CS7.4). They are convinced that the experience they've acquired has made them better forecasters. "All of our team has gained a lot of insight, and we pass this on and educate others at Hydro-Québec about climate change."[1]

The provincial electricity regulator made note of this information sharing and recommended that the forecasters at another Quebec energy company consult with Nadhem, Alexandre and their team to learn more about their approach to forecasting. Meanwhile, Hydro-Québec's distribution division continuously update their climatic normal to reflect impacts of climate change in demand forecast.

Author : Marco Braun, Ouranos | **Collaborators :** Élyse Fournier, Alexandre Deslaurier, Nadhem Idoudi | **Copy Editing :** Peter McKinnon
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AT A GLANCE

KEY TAKEAWAYS

1. **Demand forecast can be improved by incorporating temperature trends**

2. **Adaptation of demand forecast is simple and effective**

3. **Long-term collaboration with climate experts ensures continual updates of information and builds confidence in climate model data**

ORGANIZATION(S)
Hydro-Québec (Canada)

POWER SUB-SECTOR(S)
Distribution

ADAPTATION TYPE(S)
- Informational – Supply and demand forecasts

CLIMATE CHANGE IMPACT(S)
- Increasing temperature and changing extreme events

ADAPTATION COSTS
- Low

ADAPTATION BENEFIT(S)
- Improved demand forecast
- Modeled climate trends helped identify errors in observed station data

CONTACT DETAILS
deslauriers.alexandre@hydro.qc.ca
idoudi.nadhem@hydro.qc.ca

FULL REPORT
https://ouranos.ca/en/programs/energy-adaptation-case-studies/

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