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Transitions toward Clean and Reliable Power Systems

A Case Study of Ontario, Canada

Key Energy Security & Reliability Policy Considerations

Diversification:

Diversity of tools and resources, including sufficient dispatchable capacity, provides flexibility and helps to ensure power system reliability.

Demand:

Demand is a resource. Demand side and conservation measures can be highly effective in reducing energy use and act as a valuable reliability resource.

Planning:

Deliberate and robust policy is important for effective transitions, but it should be informed by independent expert system planning and supported by fair regulatory framework.

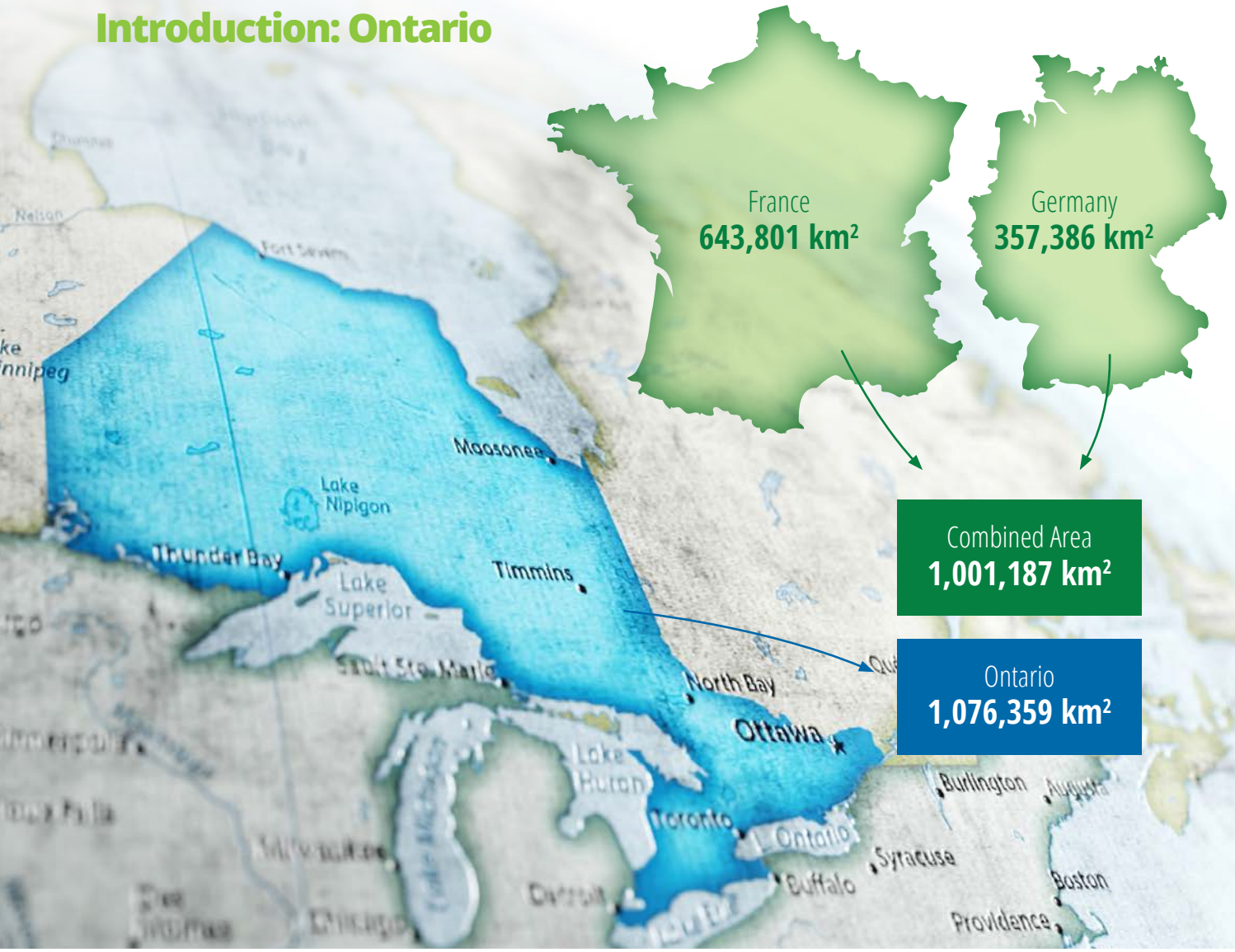
Pricing:

It is critical to ensure that price signals correctly communicate system needs and priorities, and the overall market design is well aligned with the system reliability needs.

Pain Points:

Infrastructure bottle necks should be addressed, particularly where multiple networks become interdependent. The Ontario case demonstrated this for electricity and gas networks, as it showed the criticality of ensuring sufficient natural gas pipeline and storage infrastructure to deliver peak loads to gas generators on demand, while also serving high heating loads.

Introduction: Ontario



The Canadian Province of Ontario is the home of Niagara Falls, Toronto Raptors, and one of the Coldest Capitals in the World – Ottawa.

14.5 Million Canadians live here, or nearly half of Canada's population.

Ontario is also big -- its land area is slightly larger than France and Germany combined, stretching from the 42nd parallel in the South (~ North of Spain) to the 56th in the North (~Alaska). That means seasonal temperatures can range between summer highs of above +35°C, and winter lows below -35°C. It also means very high energy needs.

While Ontario's electricity grid sees the highest demand peaks in the summer, with very long and cold winters, its winter peaks are only slight lower.

It now also has a clean and diverse energy supply mix, and a regulated market to reliably meet demand, with minimal emissions. Ontario is a Canadian leader in renewable energy. It has the most wind capacity in the country, and it is home to about 98% of all of Canada's solar power.[1]

Heating in Ontario is largely provided directly by natural gas, while cooling is powered by the electric grid, where natural gas too plays an important role. Even though it generates only about 10% of the total electricity used in the province, natural gas is a critical underwriter of the power system reliability in Ontario.

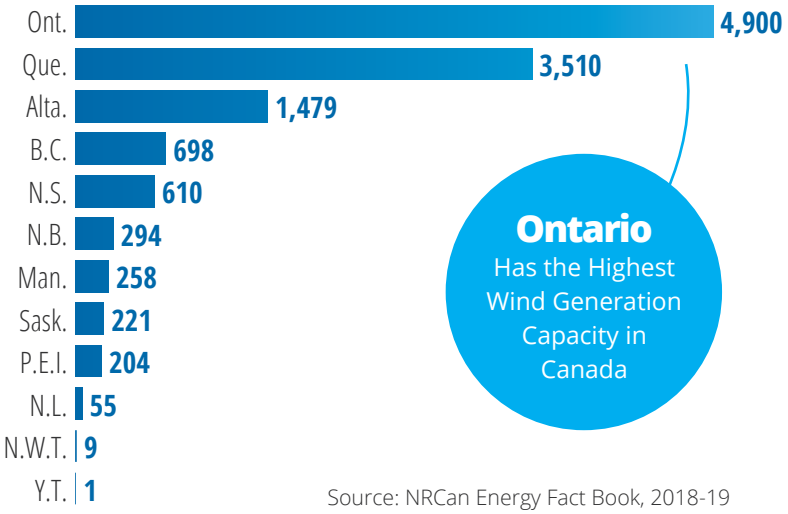
In addition, natural gas supplies feedstock fuel to the large heat intensive petrochemical and steel industries in Ontario.

This brief focuses on the value of gas in supplying security and reliability to the electrical system in the province.

[1] https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/energy-factbook-oct2-2018%20(1).pdf
https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/on-eng.html#s3

A Leading jurisdiction in North America in the Reduction of Emissions.

Fig 1. Canadian Wind Generation Capacity by Province (MW)

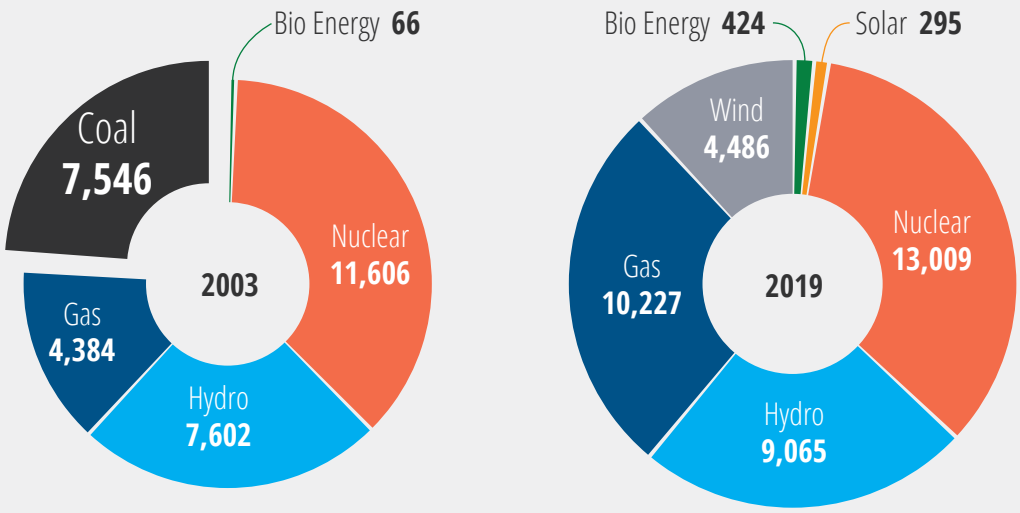


Source: NRCan Energy Fact Book, 2018-19

Ontario took the lead in sustainability and became a champion for the environment, long before the Paris Agreement was signed. Driven by a strong government commitment to emissions reduction and air quality goals, it was the first jurisdiction in North America to completely eliminate coal power generation.

The government-mandated phaseout of coal (2003- 2014) became the single largest greenhouse gas reduction initiative in North America and has reduced electricity sector GHG emissions by almost 90%. Ontario's emissions in 2016 were 10% below 1990 level, and its per capita emissions are 41% below the Canadian average. [2]

Fig 2. Ontario Generation Supply Mix (MW)



Source: IESO, 2019; Ontario Auditor General Report, 2015.

Coal closure policy required the province to replace a quarter of its generation capacity in under a decade and that was a major test of electricity security of supply and reliability.

Ontario used a phased approach to taking coal stations out of service and replaced them with a mix of renewables, natural gas, and nuclear resources.

The switch yielded enormous environmental value, with big reductions in emissions of both greenhouse gases and air pollutants. This was also significant at the national level, as Ontario is the second largest electricity producer in Canada, accounting for a quarter of all national generation.[3]

[2] Canada Energy Regulator https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/on-eng.html#s3
[3] Ibid

Ontario Fuel Switch by the Numbers:

Fig 3. Ontario Phaseout of Coal Power (MW)

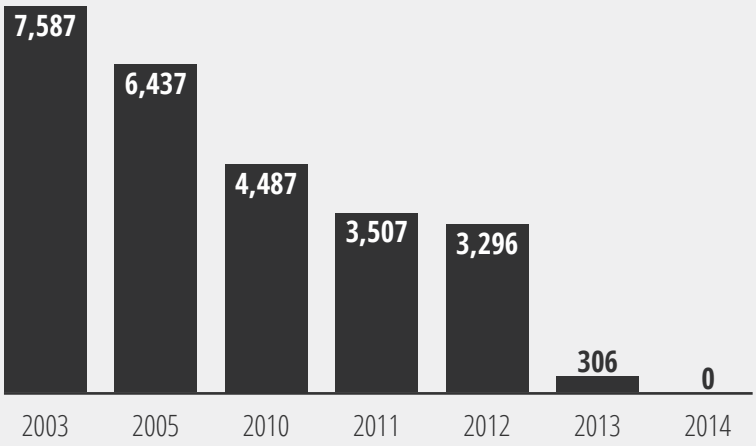


Fig 4. Replacement Generation Resources (MW)

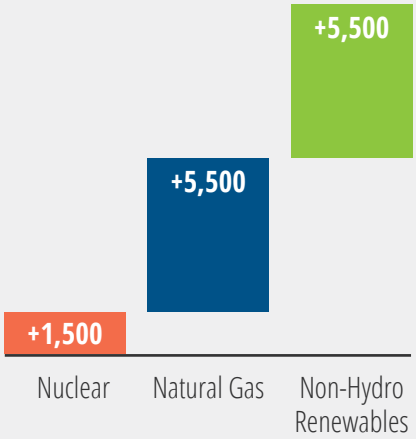


Fig 5. GHG Emissions and Pollutants (Index 2005 = 100)

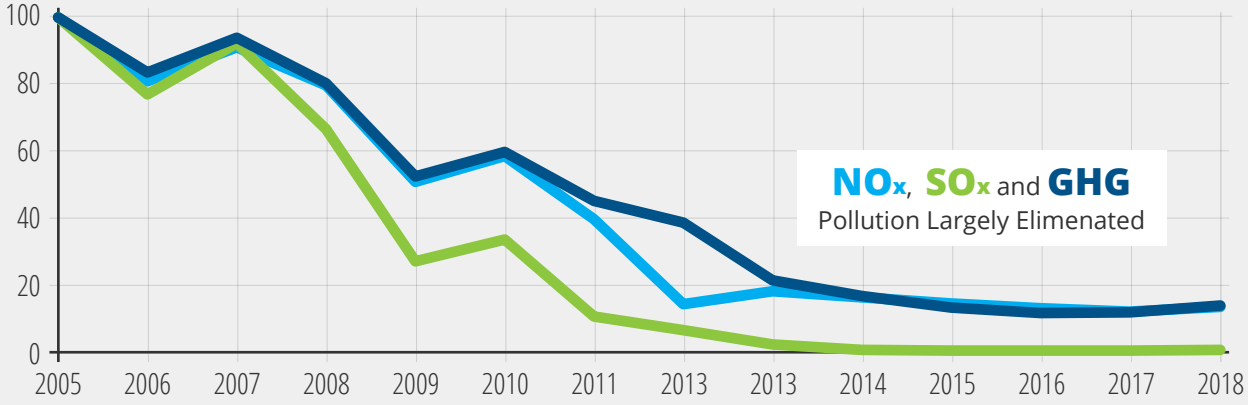
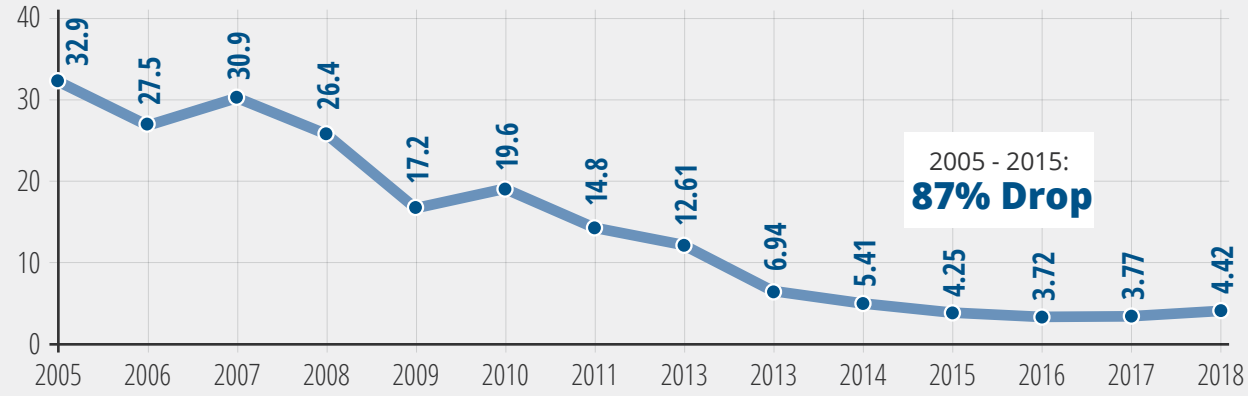


Fig 6. GHG Emissions (MT CO_2e)



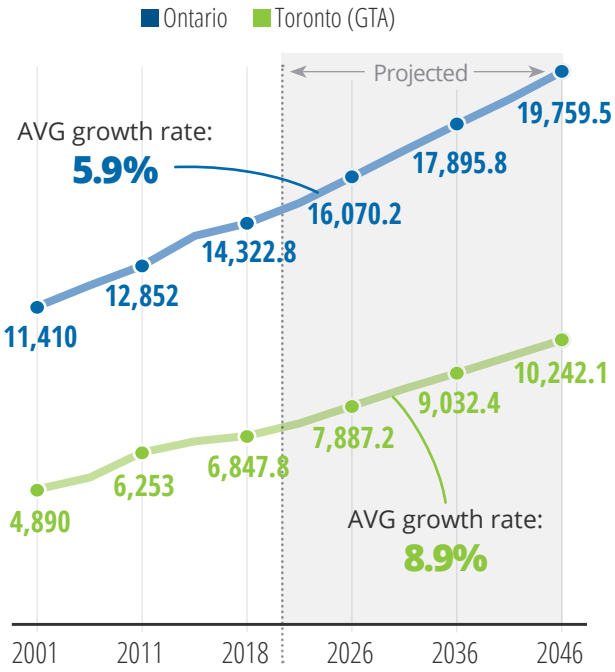
Data Source: Ontario Ministry of Energy, The End of Coal

Reducing Energy Use through Conservation

Ontario is a major industrial and economic hub, with large petrochemical, steel, financial and IT sectors. Many of Ontario's municipalities are rapidly growing, with the city of Toronto as the epicenter of urban growth (the 9th largest city in North America).

While Ontario's population has been growing at nearly 6% a year, and Toronto's almost double of that, its electricity demand has been dropping over the same period, thanks largely to the province's strong conservation and demand side management programs. So, despite its size and population share, Ontario ranked 11th in Canada for per capita electricity consumption and consumed 33% less than the national average in 2017.[4]

Fig 7. Population & Urban Growth (thousands)



Source: Ontario Ministry of Finance, 2018

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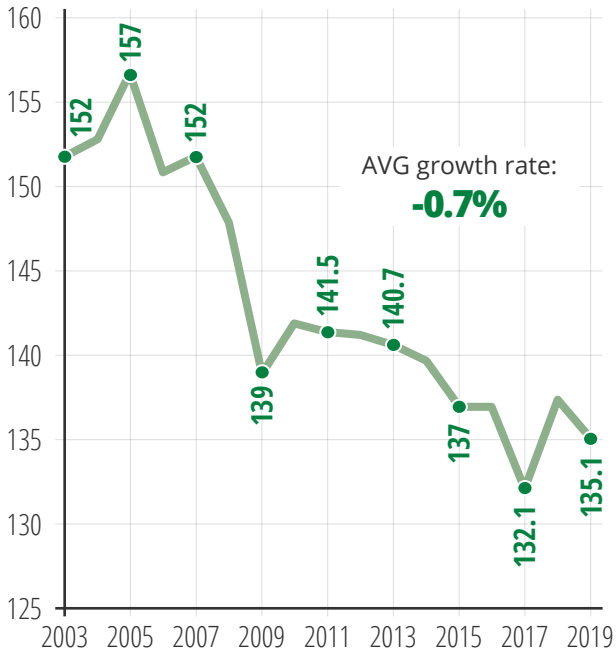
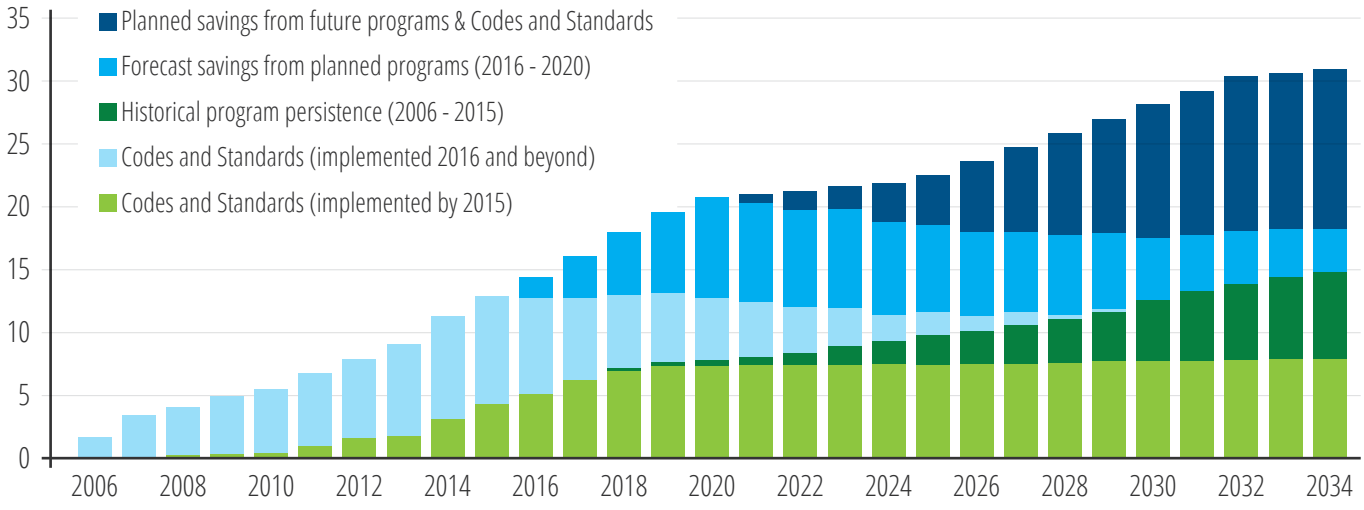
Fig 8. Ontario Electricity Demand (TWh)



Source: IESO

Fig 9. Conservation Savings (TWh)



Source: IESO

[4] Canada Energy Regulator 2019

Delivering Electricity Security of Supply

Having a reliable and responsive energy system that is able to seamlessly support the economy, power hospitals and data centers, and deliver everyday energy services – like, power, heating, cooling, and lighting – on demand, is essential for the province.

Prior to their closure, Ontario's coal plants supplied roughly a quarter of its electric capacity, and the short timeframe for taking them out of service made reliability considerations top of mind for the planners.

Despite the challenges, the province successfully replaced all of its coal generation in under a decade, and reliability today is better than it was before closing coal.

When assessing Ontario bulk grid's adequacy, the Environmental Commissioner of Ontario concluded that the current state "is a great improvement from the early to mid 2000s, when the province strained to meet demand on hot days, requiring occasional brownouts and public appeals to reduce electricity use. Investments in new electricity supply and conservation have significantly improved reliability and eliminated brownouts."[6]

Natural gas was a major component in making that possible, as it works with the province's otherwise carbon-free generation mix to ensure uninterrupted supply to the grid.

Reliability

Simplified, it is the assurance that any time someone flips the ON switch, whether it is on their home reading light, or a commercial data server, there will be sufficient electricity to power it without interruptions and at a stable voltage rating, until they turn the switch OFF.

While the user experience is simple and seamless, there is a demanding, 24/7/365 system operation effort behind it.

For the power system to remain stable and reliable, the amount of supply must almost perfectly match demand, voltage level must be kept within a stable range, and required reserve levels must be available at all times to cover any possible contingency.

In Ontario, the Independent Electricity System Operator (IESO) is responsible for ensuring reliability. The IESO operates the bulk power transmission system, schedules generators and determines quantiles needed to meet demand, while ensuring a perfect balance between the two and maintaining power quality.[5]

[5] The North American Electric Reliability Corporation (NERC) defines reliability as the ability to meet the electricity needs of end-use customers, even when unexpected equipment failures or other conditions reduce the amount of available power supply.

[6] http://docs.assets.eco.on.ca/reports/energy/2018/Making-Connections-05.pdf

Flexibility & Meeting Peak Demand

The ability of a generator to supply energy during times of highest demand, as well as its ability to follow system operator's dispatch instructions, is very important for reliability planning.

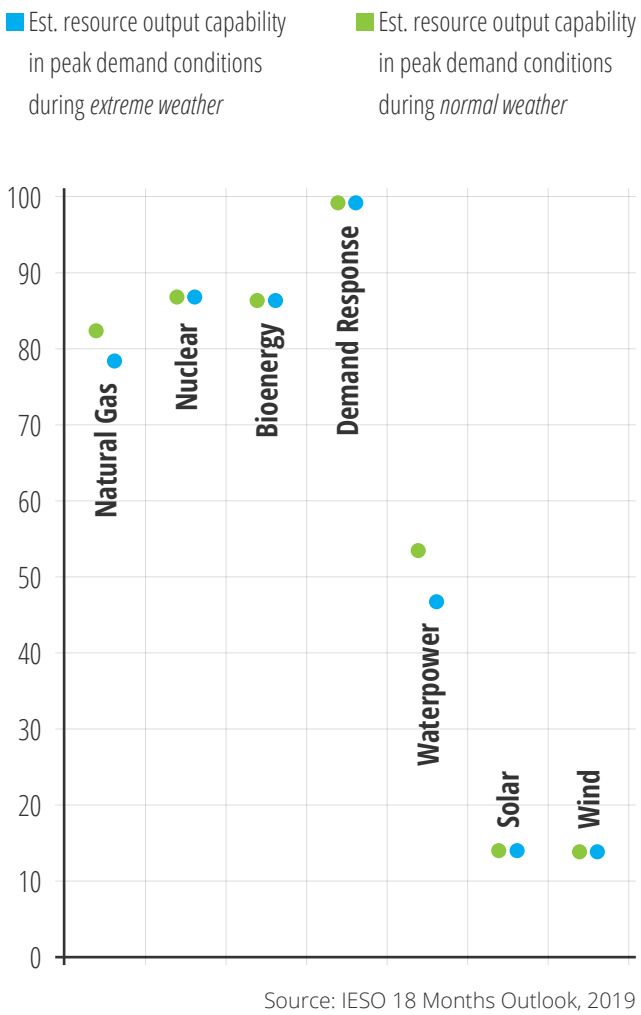
With a diversified portfolio of supply, the system operator has more options for flexibility and grid balance, because all resources have trade-offs – some can be intermittent, others costly, or stable but slow to respond, and having a variety of resources helps to make them work together well..

Natural gas is very flexible on both its energy output and its ability to contribute to peak demand, responding to dispatch, and thus its flexibility value is very high. Figure 10 demonstrates this in Ontario's case and shows how gas generation compares with other resources.

Gas can also ramp up quickly and generate energy for as long as the fuel is available. Ontario has an abundant supply of gas that is cost-efficient and available through a competitive market with ample storage capacity.

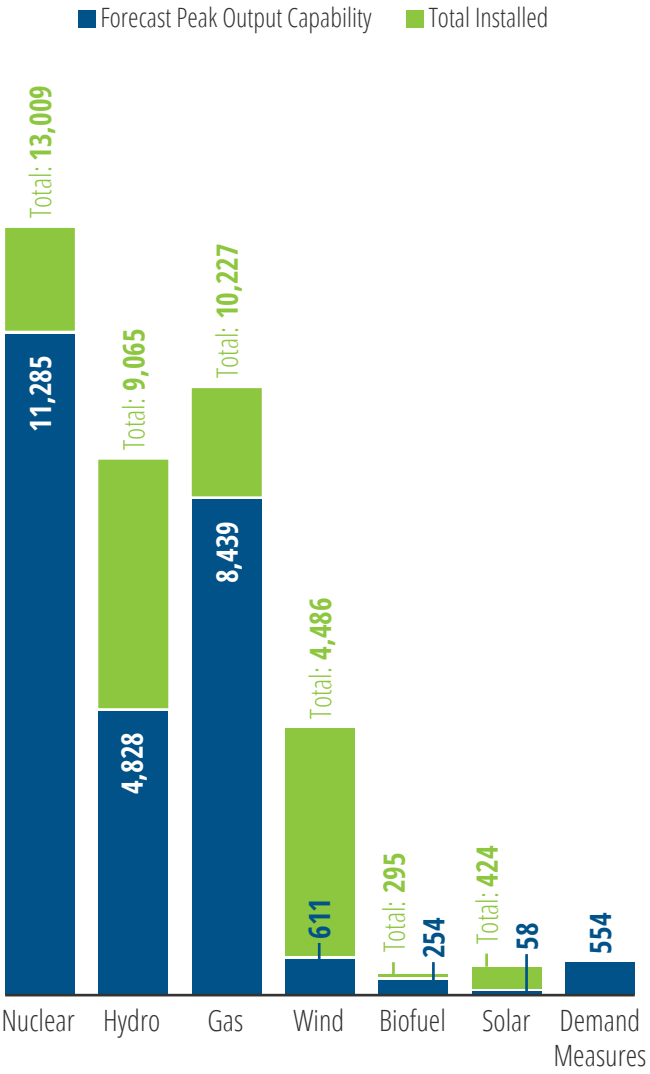
It is also important to highlight the valuable contribution of demand response, which contributes over half a Gigawatt to Ontario's peak demand with zero emissions, as seen in figure 11.

Fig 10. Ontario Installed Generation Resources Peak Conditions Output Capacity Factors (% of installed capacity)



Source: IESO 18 Months Outlook, 2019

Fig 11. Ontario Total Installed Capacity & Peak Contribution Capability (TWh)

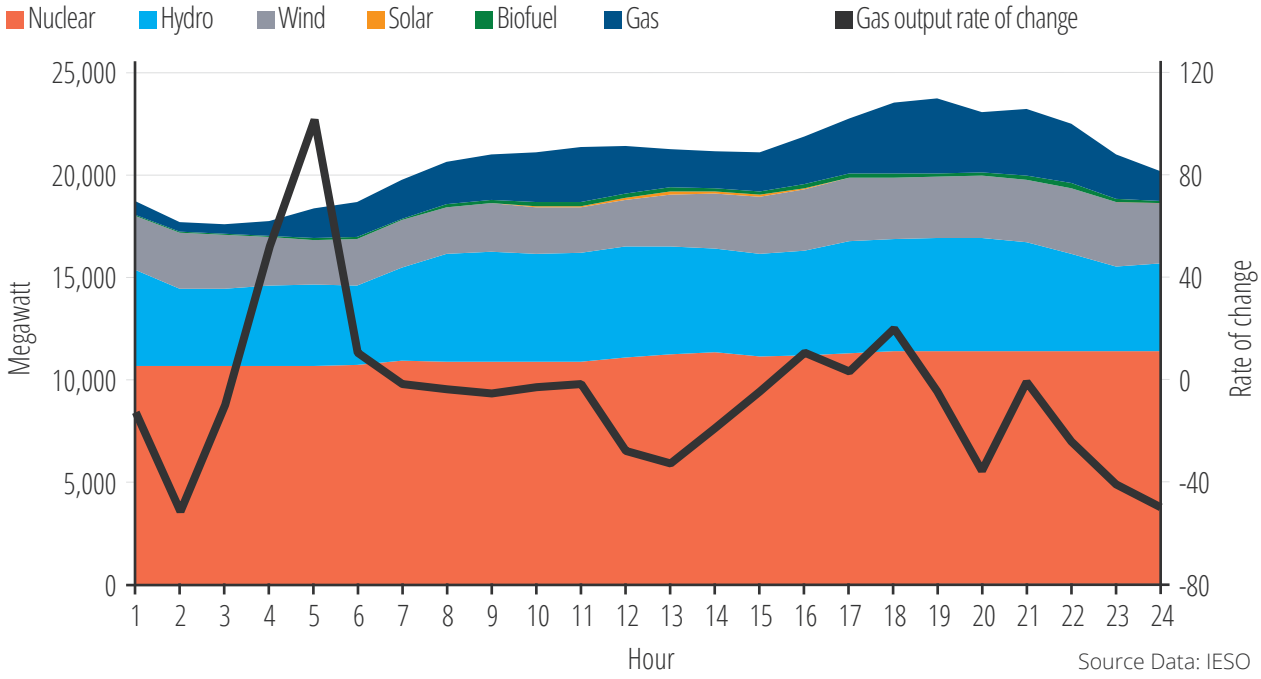


Source: IESO, 2019

Gas Ensuring Reliability and Energy Security: Case Examples

1. Extreme Winter Weather Shorter Peaks: Natural Gas Supplying Flexibility to Meet Peak Demand

Fig 12. Ontario Generator Output (left) **& Natural Gas Output Hourly Rate of Change** (right)
(January 5, 2018)



January 5, 2018 was a very cold winter day in Ontario, with - 23°C temperature in Toronto, and reaching -30's in the northern parts of the province. The windchill effect made it feel like -40 in many areas. Luckily, that resulted in high wind generation output, yet its output naturally varies even when it is near max generating capacity. Rapid response from gas generators helped to ensure that this variability is balanced, and the high grid demand was fulfilled in these extreme weather circumstances.

Figure 12 shows that both wind and gas were supplying a large portion of the peak demand, at times in roughly equal proportions – here the hourly variations are harder to notice. However, looking at the gas generation output trend line – the significance of gas ramping becomes more evident. The dark trendline shows how gas output was able to quickly move with demand, complementing wind production and ensuring a stable output.

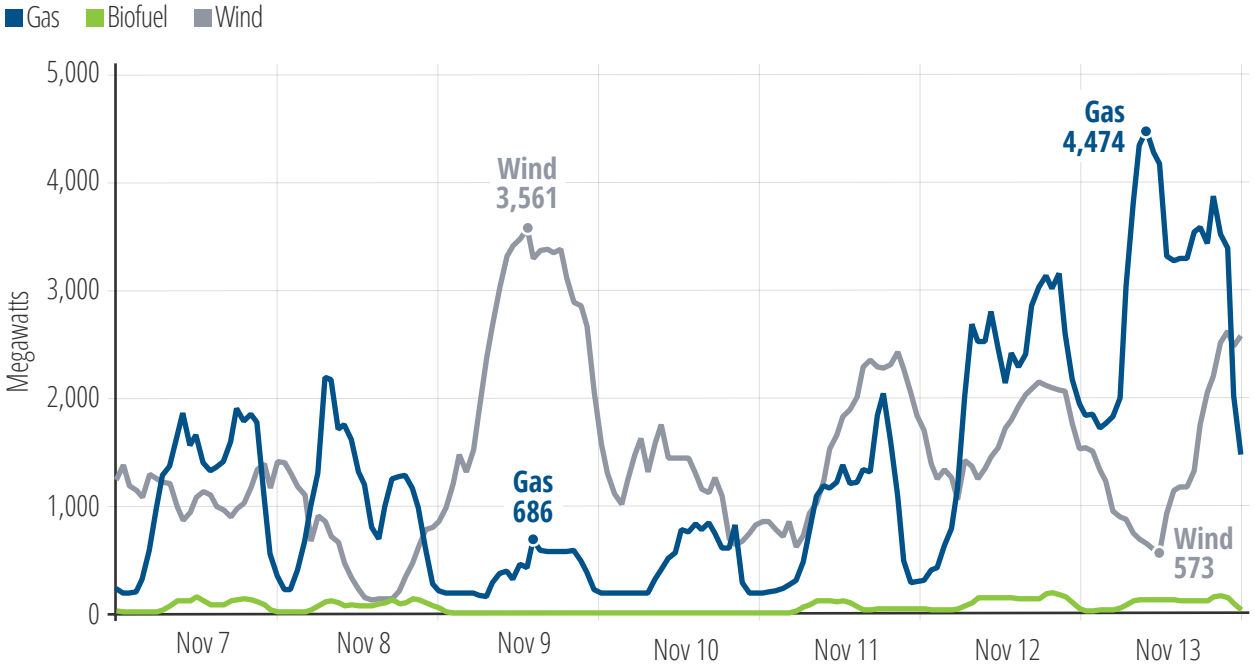
2. Extreme Winter Weather Longer Peaks: Natural Gas and Wind Power

Ontario also provides a great example of the gas and wind inter-operability. Solar energy serves a much smaller share of Ontario's electricity demand than wind, as the province has a much larger wind resource (long winters and many overcast days).

The charts in figures 13 and 14 show a snapshot from November of 2019, which had some record low temperatures in Ontario, with November 13th setting a record for the coldest one in over 30 years.

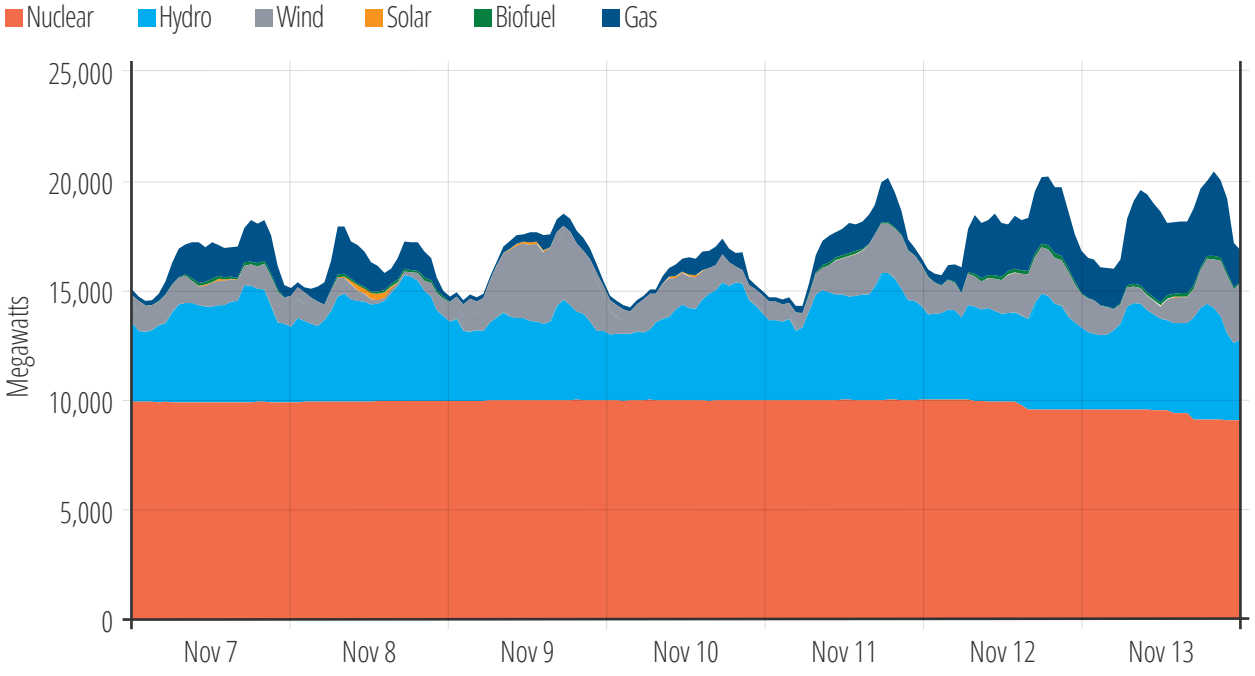
That was also a day, when demand was high, but wind output happened to be low, unlike in the previous example. As can be seen from the two graphs – the wind output that week ranged between 100 and 3,500 MW, with periods of low output lasting for up to 24 hours, as was the case on November 13th, 2019. This is a perfect example of how gas helped to ride through and offset these extreme weather conditions.

Fig 13. Hourly Output: Wind and Gas Interoperability (November 7-13, 2019)



Source Data: IESO

Fig 14. All Generation (November 7-13, 2019)

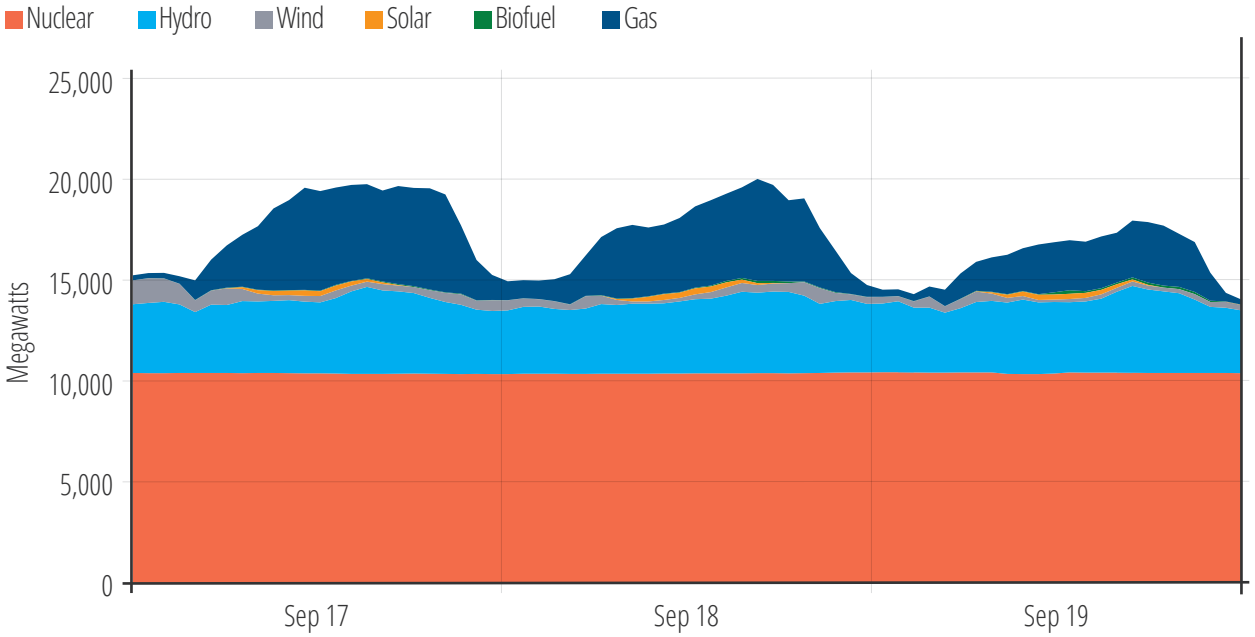


Source Data: IESO

3. Extreme Summer Weather: Ensuring Power Supply in Scorching Heat

On the other side of the temperature spectrum, September 18th was one of the top five hot summer peak days in 2018, and the role of gas in supplying the necessary energy to meet peak demand is even more evident here, as it served close to a quarter of demand for most of the two very hot days, helping to compensate for low wind and solar output during those days.

Fig 15. Generation Profile for Ontario Summer Peak. (low wind and sun conditions) (September



Source Data: IESO

Lessons and Policy Considertaions

Gas underwrites power system reliability.

Gas is highly flexible, responsive, and has a high peak capacity value. The examples of peak weather conditions shown above to demonstrate the critical role that natural gas is poised to play in supporting the global energy transition.

Ontario's electricity grid is 90% carbon-free, with gas helping to ensure that the grid continues to function reliably, as the share of variable renewables grows. In similar fashion, a pressing need for rapidly increasing the share of variable renewable generation in power systems around the world will translate to a growing demand for flexibility resources, and gas provides an excellent flexibility tool in jurisdictions where it can be accessed. At the same time, it helps to keep the air clean with almost no air pollutant emissions, and ongoing innovation in gas cleantech is enabling the reduction and eventual elimination of carbon emissions (already lowest among fossil fuels).

Pricing regimes are critically important for system reliability and getting them right during transitions is essential.

Ensuring that market price signals and system resiliency needs are balanced is critically important for a stable power system.

Ontario's electricity system has undergone a turbulent time, during the last major transition – that of market restructuring in the late 1990's. The transition away from a government-controlled monopoly to an open market, put energy security under pressure – from both economic and reliability fronts.

The combination of rapid market opening and stretched system resources with high summer demand led to a spike in prices and resulted in public outrage. That in turn pushed the government to freeze prices for several years and resulted in financial strain from debt and piled on system costs.
This unintended consequence of the rapid market opening exposed a gap between short-term market, price signals and long-term system capacity needs. Ontario moved to close this gap by adopting a hybrid approach – a regulated electricity market working in conjunction with long-term capacity planning and a regional reliability governance framework. Today, the province uses a combination of open market and contracting mechanisms, in order to ensure that the system is adequately supplied over the planning horizon.

With the global energy transition underway, jurisdictions around the world will also experience pressures, from rapid system change and growing gaps between real-time pricing signals and long-term reliability investment needs. Reliability planning will become even more essential. Ontario provides a great case study and a source of lessons for the importance of balancing the short and the long-term system capacity needs in market designs. In overcoming some initial challenges, Ontario developed several innovative tools, including capacity auction mechanisms, competitive renewables procurements, demand side measures, and competitive regulation services sourcing.

The underlying lesson for policymakers, as they are planning for energy transitions, is that strong reliability requires effective remuneration mechanisms, whether they are market-based, contractual, or hybrid, to secure sufficient system capacity.

Independent planning and prudent regulatory frameworks are as important as deliberate and clear policy

Deliberate and robust policy is important for effective transitions, but it should be informed independent expert system planning and supported by a fair regulatory framework.

In Ontario, government policy plays a strong role in setting energy sector direction, but there are also two other critically important actors who have been instrumental in its progress on reliability.

The IESO (Independent Electricity System Operator) operates the bulk power system and acts as the regional reliability coordinator, ensuring that the province meets North American reliability standards and complies with the stringent rules set by the regional independent authority, North American electric reliability organization (NERC).

The other important body is the Ontario Energy Board (OEB), an independent regulator, responsible for gas and power sector oversight. The OEB is an independent government agency, whose function is to promote a sustainable, reliable energy sector that helps consumers get value from their natural gas and electricity service.[7] Together, these three entities ensure a clean, reliable, and fair electricity system for the residents and business in the province.

Infrastructure bottle necks should be addressed through system planning, particularly where multiple networks become interdependent

The Ontario case demonstrated this for electricity and gas networks, as it showed the criticality of ensuring sufficient natural gas pipeline and storage infrastructure to deliver peak loads to gas generators on demand, while also serving high heating loads.

The linkage between reliability of the electricity and natural gas systems does not create a challenge, when addressed via the right planning and regulatory tools. Furthermore, it can be a strong enhancement for reliability when there is sufficient gas infrastructure capacity, combined with an effective scheduling mechanism. Ontario provides an excellent case study.

When the province was planning to grow its gas generation fleet to deliver coal closures, the regulator took proactive steps to ensure that did not result in unintended consequences, as it would increase the system interdependence with the natural gas network. The Ontario Energy Board conducted an assessment of the reliability implications from increasing the amount of natural gas generation in the system, preparing for the coal phaseout. In particular, the OEB conducted a study called Natural Gas Electricity Interface Review (NGEIR) in 2005. This review enabled Ontario's natural gas pipeline operators and utilities to design and offer new services for flexible, firm access to natural gas, in parallel with the expansion of the fleet.

These services are called the enhanced gas delivery and management (GD&M), allow subscribing generators to balance the delivery of gas with the expected burn profile, utilizing pipeline capacity and natural gas storage.[8]

As a result, Ontario is well equipped for weatherbased gas system constraints, despite having a large winter gas heating load.

Natural gas utilities offer high deliverability services to meet the variable nature of natural gas generation. The utilities designed the services to allow the generators to lock in a specific amount of variability in storage, balancing and transportation on firm contract, typically with medium- to long-terms (10+ years). The natural gas infrastructure supporting these services has the flexibility to manage the variable nature of generator consumption, but access to that flexibility is reserved for those generators that hold contracts for these natural gas services. For effective operation within the IESO market, generators were incented to purchase the system access. These high deliverability services are unique to Ontario and rely on the well-developed gas infrastructure within the Province. However, they can serve as a source of important regulatory principles for jurisdictions undergoing coal to gas fuel switching, or developing new local gas markets.

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[7] https://www.oeb.ca/about-us/mission-and-mandate/ontarios-energy-sector
[8] Investigating Gas-Electric Market Alignment in Ontario

Conservation & Demand Side Measures

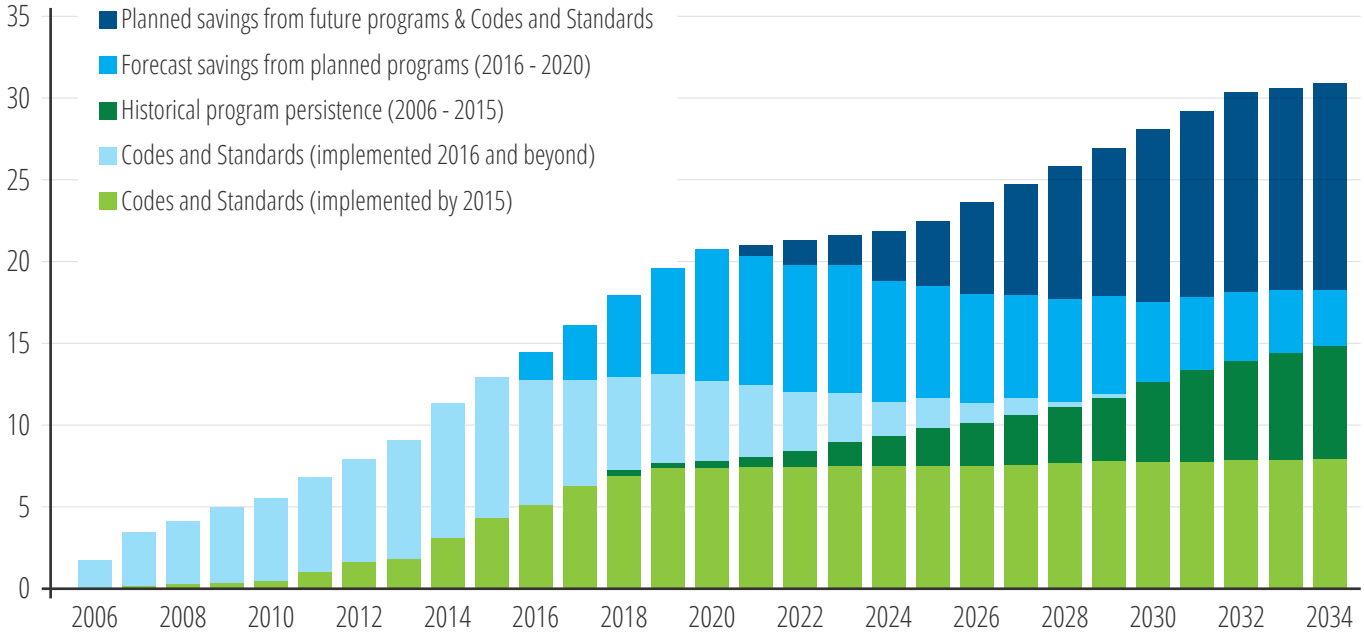
Demand is a resource, and Ontario is a prime example of the great potential for conservation and efficiency programs in achieving climate goals.

Since 2006, Ontario has been able to save roughly 20 TWh in electricity consumption, and by 2035, it is projected to surpass 30 TWh in savings.[9]

In addition, the IESO runs competitive auctions for demand-response, and in its most recent one, it secured close to 1 GW of capacity resource to support long-term reliability. The December 2019 demand response auction secured 858.7 MW of capacity for summer 2020 and 919.3 MW for winter 2020/21, to help ensure reliability of the system.[10]

Tools to help meet that demand include the IESO's demand-response auction, which provides a transparent and cost-effective way to select the most competitive providers of demand response, while ensuring that all providers are held to the same performance obligations.[11]

Conservation Savings (TWh)



Source: IESO

[9] IESO
[10] Ibid
[11] Ibid

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