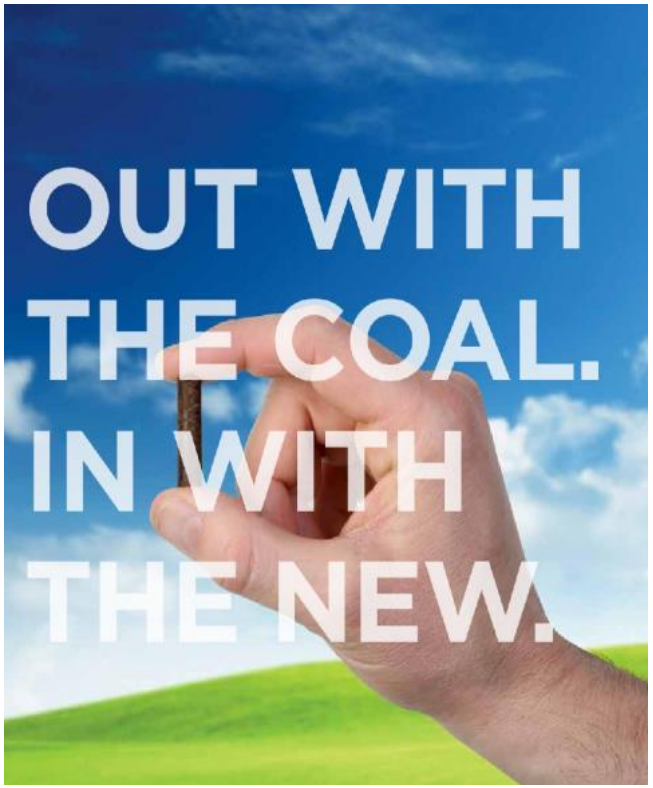
Ontario Power Generation's Biomass Journey

September 2017

ONTARIO POWER GENERATION

Agenda

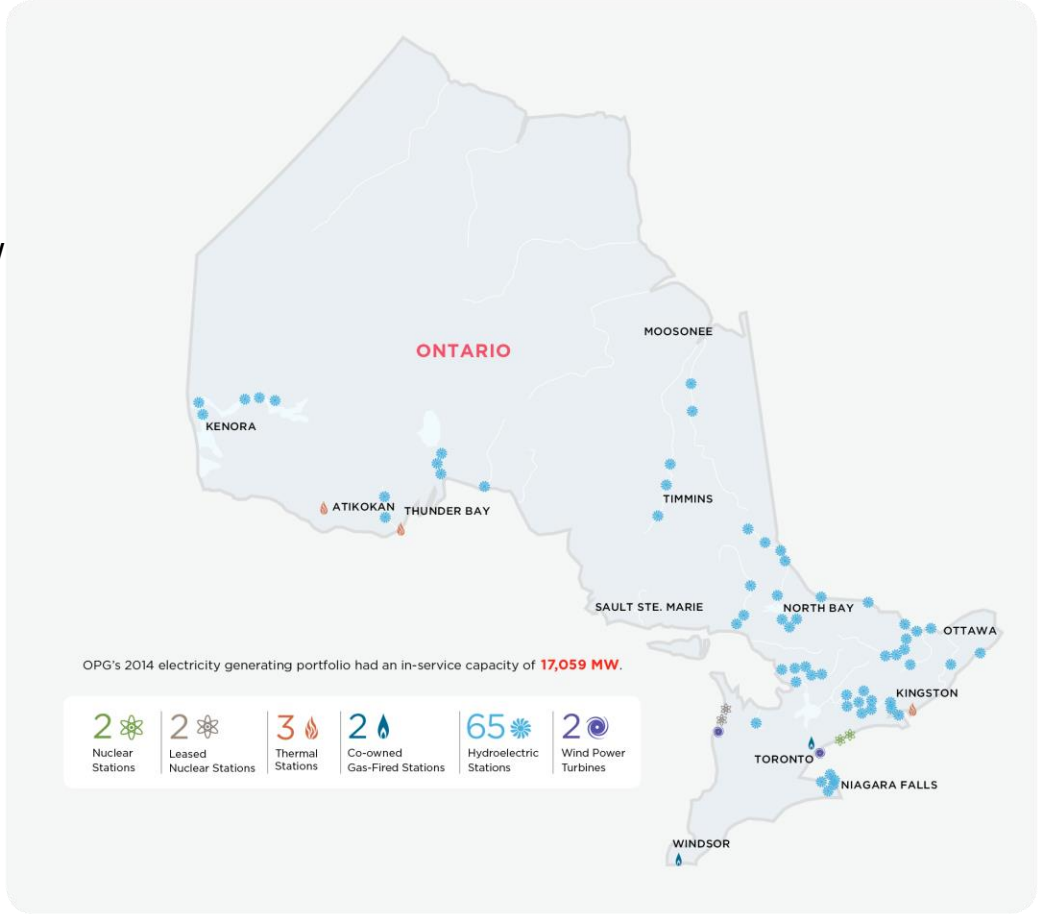
- About OPG
- OPG's Biomass Program Journey
- Advanced Biomass Fuels Overview
- Fuel Characterization Research
- Biomass Business Case and Policy Considerations



ONTARIO POWER GENERATION

OPG - Who and Where We Are

- Ontario's clean power producer.
- Approx. 17,000 MW generating capacity.
- 66 hydro, 3 thermal, 2 nuclear.
- 2 leased nuclear stations + co-ow
  2 gas-fired stations.
- Converted Atikokan and Thunder Bay GS to biomass.
- Produce about 50 per cent of Ontario's electricity.
- 99 per cent of the power we produce is free of GHG emissions
- About 9,200 regular employees.
- Over $44 billion in assets.
- Moderate overall price of power.



ONTARIO POWER GENERATION

OPG Thermal Operations

Thermal Stations provide a critical role in the electricity market by ensuring supply = demand. Thermal does this by providing: system capacity, peaking and ramping capability.

- Critical peaking and backup role.
- Three thermal stations: 2,464 MW.
- Lennox is dual-fuelled oil and gas.
- Atikokan and Thunder Bay converted to biomass -- completed on time and on budget.
- Two co-owned natural gas stations (1,130 MW): Brighton Beach and Portlands Energy Centre.
- Lambton GS and Nanticoke GS off coal in 2013. Station demolition projects underway.

ONTARIO POWER GENERATION

OPG Biomass Program History

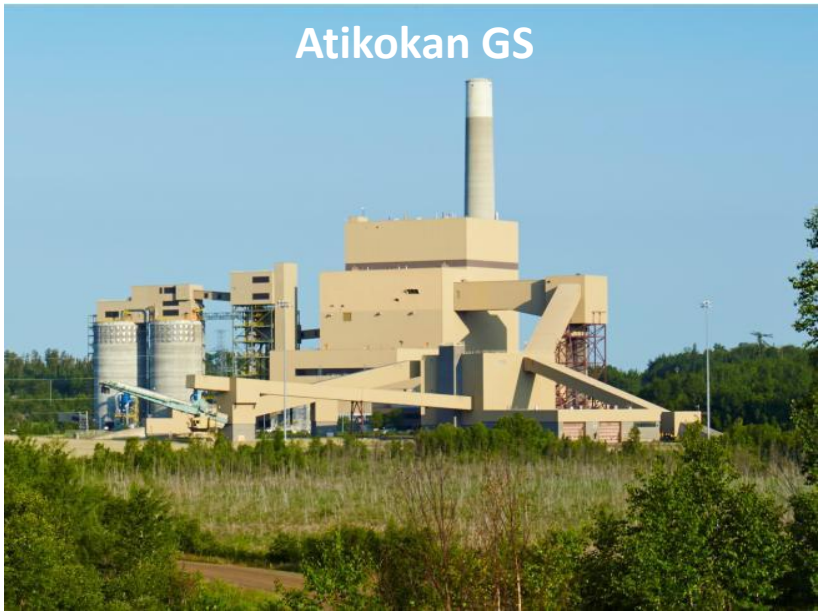
OPG is a pioneer in 100% coal-to-biomass conversions. Initial testing was small. The testing program was scaled-up following the initial proof of concept.

- Started testing at all Thermal sites in 2006.
- Direct Injection and Dedicated Milling.
- Wheat shorts and white wood pellets.
- Evaluation of second generation wood pellets began in 2010.
- Torrefied, carbonized and steam treated fuels.
- Lab scale and safety testing.
- Pilot scale milling.
- Full scale storage, handling, milling and combustion.

ONTARIO POWER GENERATION

OPG's Biomass Operations

OPG NW Ontario Thermal Stations are the largest biomass plants in North America operating on 100% Biomass Fuels.



- Built in 1985.
- Single unit (~200MW).
- Commercial operation on biomass fuel July 24, 2014.

- Built a 100MW Unit in 1963.
- Two additional units entered service in 1981 and 1982 (2x~150MW).
- One unit now converted to advanced biomass.
- Commercial operation on advanced biomass fuel February 9, 2015.

ONTARIO POWER GENERATION

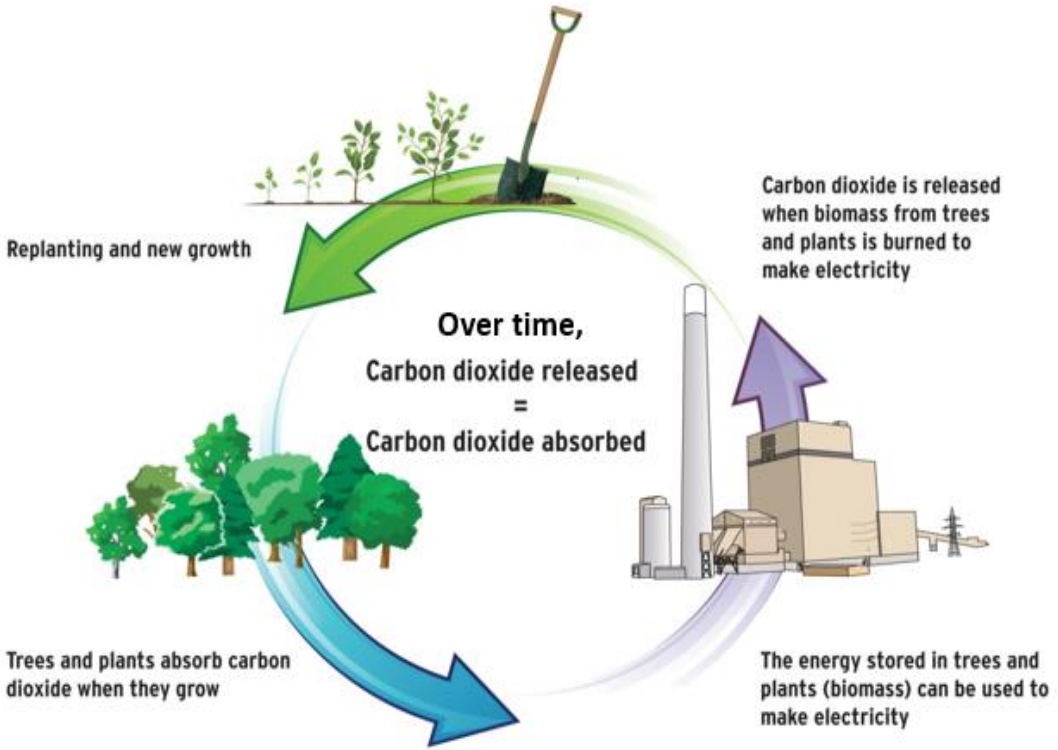
Biomass Sustainability

Sustainable forestry practices ensure biomass is renewable. OPG has worked to ensure biomass fuels used in Thermal plant operations meet the highest of sustainability standards.

- Two research papers completed by U of T conclude that there are significant GHG benefits compared to fossil fuels (80% - 90%).

- Fuel contracts require biomass to come from sources that meet the UNFCCC definition of renewable.

- Third-party chain of custody certification demonstrates that the wood fibre is sourced from sustainably managed forests.



Atikokan GS Biomass Conversion

ONTARIO POWER GENERATION

ONTARIO POWER GENERATION

What is Advanced Biomass?

Advanced biomass is a sustainable fuel produced to have properties similar to coal. The improved characteristics include: weatherability, improved durability and energy density.

- Similar to regular pellets but thermally treated to improve the fuel's properties in three main areas:

- **Weatherability** -- Hydrophobic (repels water) which allows it to be stored outside in the elements in greater quantities.
- **Durability** -- Creates less dust and can be handled much like coal using the same fuel handling systems.
- **Energy density** -- Has a higher energy density than white wood pellets which improves transportation economics and production capability (MW Capacity).

- Can be used at coal plants with minimal plant modifications.
- In early stages of commercial demonstration (was not an option for Atikokan GS).

Advanced Biomass Utility Benefits

Advanced biomass provides significant Utility benefits. This includes reduced conversion costs, retention of MW capacity, production flexibility and safety benefits.

- Lower Capital Cost of Conversion
  - Expenditures for new dedicated receiving and covered storage are not necessary.
  - Only minor costs are incurred in downstream handling and powerhouse systems.
- Dispatchable Renewable Generation
  - Onsite fuel storage provides greater flexibility.
- Increased Unit Capacity vs. White Pellets
  - Higher calorific value and smaller particle sizes translate to higher unit loads.
- Safety Benefits
  - Low dust generation and the ability to use wetting agents to manage dust result in significant safety benefits.
- Milling & Combustion Performance
  - Grinds similar to coal resulting in improved combustion.

ONTARIO POWER GENERATION

OPG Biomass Conversions

The use of Advanced Biomass fuels at Thunder Bay GS resulted in significant CAPEX savings, and a reduced project schedule. Advanced biomass was not an option for Atikokan GS.

Atikokan GS

- White Pellets
- Project Duration 18 months
- Conversion CapEx $170M
  $770/kW

Thunder Bay GS

- Advanced Pellets
- Project Duration 2 months
- Conversion CapEx: $6M
  $40/kW

ONTARIO POWER GENERATION

Fuel Characterization Research

OPG expertise is being utilized in collaborative research with NRCan to characterize Advanced Biomass Fuels, providing valuable information to utilities and fuel producers.

- Utilities require fuel characterization and comparative analysis to support conversion plans.
- Fuel producers require an understanding of how their product performs against utility requirements.
- 25 fuel suppliers have confirmed interest in participating to date. International interest from Utilities is promising.
- Initial testing includes lab scale determination of:
  - Chemical analysis
  - Physical characteristics
  - Safety/Weathering
- Additional Pilot and Full Scale Testing for promising samples:
  - Storage, Milling & Combustion

Natural Resources Canada | Ressources naturelles Canada

Canada

ONTARIO POWER GENERATION

ONTARIO POWER GENERATION

Why Convert to Biomass?

Electricity generated from biomass is a dispatchable renewable source of power. It can be cost effectively generated by repurposing existing coal plant infrastructure.

- Dispatchable Renewable Power
  - Thermal generated electricity provides a unique role in the energy mix, providing: system capacity, peaking and ramping capability, ensuring electricity supply = demand.
  - Use of biomass fuels can provide a 1:1 displacement of GHG's from other non-renewable thermal generating sources, such as natural gas and coal-generation.
- Use of Existing Infrastructure
  - Tangible assets include: the station, transmission and access to cooling water.
  - Intangible assets include: employee skills and experience, willing host communities (employment and taxation benefits).
- Socio-economic Benefits
  - Job creation in growing, harvesting, transporting and processing fuels for Utility use.
  - Economic stimulus and diversification benefits for remote and often struggling communities.

Business / Policy Challenges

- **Complex Business Case, which involves many Stakeholders**
  - Benefits include reliability, GHG reduction and socio-economic factors.
- **Complex and Counterintuitive Justification of Sustainability**
  - Work is required to educate stakeholders on the science of sustainability.
- **Electricity Procurement Practices**
  - Renewables, Generation and Ancillary services are often procured through separate processes. Biomass can provide all, but may not be competitive in any one area.
- **Competing with Other Generation Types**
  - Repurposed coal plants have a lower CAPEX, and higher marginal running cost than natural gas, impairing the ability to obtain dispatch in the market.
  - Wind & Solar typically dispatch whenever the resource is available.

Important Considerations for Policy Makers

- **A low GHG electricity system serves as important infrastructure to reduce emissions elsewhere across the economy.**
  - Renewable solutions often require increased electricity usage (i.e. EV's, Hydrogen).
- **The electricity system benefits from a diverse portfolio of generating resources.**
  - There is no single solution on the horizon. Biomass generation can play an important role in the mix, contributing to reliability and sustainability.
  - Biomass can help solve the problem of costly, longer-term electricity storage.
- **Infrastructure, Supply Chains, and Human Capital take time to develop.**
  - Policies which support a biomass growth strategy are required to move the industry forward.
- **Biomass provides the ability to balance economic and environmental considerations in transitioning to a low carbon future.**
  - Use of existing infrastructure reduces upfront costs, and protects jobs and communities.
  - Biomass fuel use can be slowly scaled up over time, displacing GHG emitting fossil fuels.
  - Significant diversification benefits and synergies to the forestry industry.

End of Presentation

Contact Info:

Rob Mager

E-mail: rob.mager@opg.com

Phone: 416-231-4111 Ext 4115

ONTARIO POWER GENERATION