



# **Life Cycle Assessment of Wood Pellet Use in Ontario's Nanticoke and Atikokan Generating Stations**



**Heather MacLean  
Jon McKechnie  
Yimin Zhang  
University of Toronto**

Source: Pellet Fuels Institute

OPG January 20,<sup>1</sup> 2009

# Outline

- Introduction
- Forest resource and pellet production
- Methods
  - Life Cycle Assessment and forest carbon accounting
  - Pathways studied: reference (coal, natural gas) and wood pellet
- Results for pathways studied
- Insights and conclusions

# Introduction

A landscape photograph capturing a sunset. The sky is filled with scattered, dark clouds that catch the low light of the sun, creating a palette of deep blues, purples, and oranges. The sun itself is a bright, glowing orb just above the horizon, casting a warm, golden light across the sky and reflecting on the surface of a body of water. In the foreground, the silhouettes of various trees, including tall evergreens and smaller deciduous trees, are dark against the bright horizon. The overall mood is serene and atmospheric.

# Study motivation

- Utilizing biobased resources in place of fossil fuels has the potential to make progress in addressing concerns over climate change, nonrenewable resource use, air pollution, and energy security
- Government of Ontario policy goals
  - Increase electricity generated from renewables
  - Eliminate use of coal for electricity generation by 2014
  - Sustainable forest management
  - Reduce greenhouse gas (GHG) emissions
  - Economic development

# Study objective

Determine whether the production and use, for electricity generation, of wood pellets from biofibre from the Great Lakes Saint Lawrence (GLSL) Forest region would result in a reduction in selected GHG and air pollutant ( $\text{NO}_x$ ,  $\text{SO}_x$ ) emissions on a life cycle basis compared to reference electricity generation pathways, namely, coal and natural gas

# Electricity generation pathways

- **Reference Coal Pathways:** Nanticoke and Atikokan Generating Stations (GS)
- **Reference Natural Gas Pathways:** “Representative” natural gas boiler and combined cycle facilities
- **Wood Pellet Cofire Pathways:** Co-fire rates of 10%, 20%, 30% of energy input at Nanticoke (all 8 units) and Atikokan GS (single unit)
- **Dedicated Wood Pellet Pathways:** Wood pellets utilized at 100% in one unit at Nanticoke and sole unit at Atikokan GS

# Great Lakes Saint Lawrence Forest

- Sustainably harvested biofibre supplied by forest management units
  - Allowable annual harvest (determined through sustainable forest management planning techniques, public consultation, environmental assessment)
  - ~7.5 million m<sup>3</sup>, avg. last 8 yrs ~4.3 million m<sup>3</sup>
- Harvest volume available from Crown forest for pellets is ~1.475 million oven dry tonnes (ODT)/yr
- Would create a market for available merchantable logs no longer marketable
- Achieving full implementation of forest management plan would enhance health of forest ecosystem

Source: OMNR

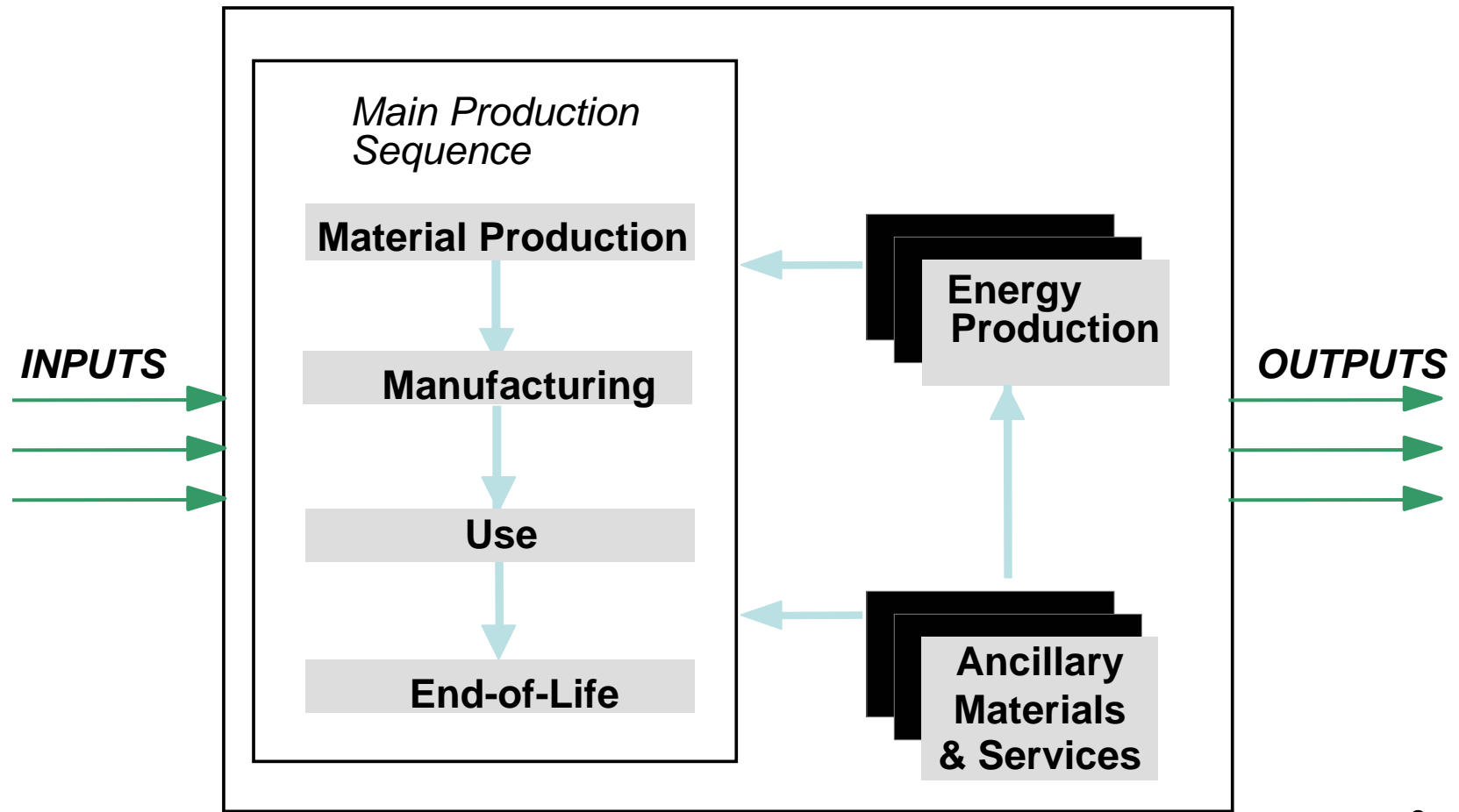


# Methods

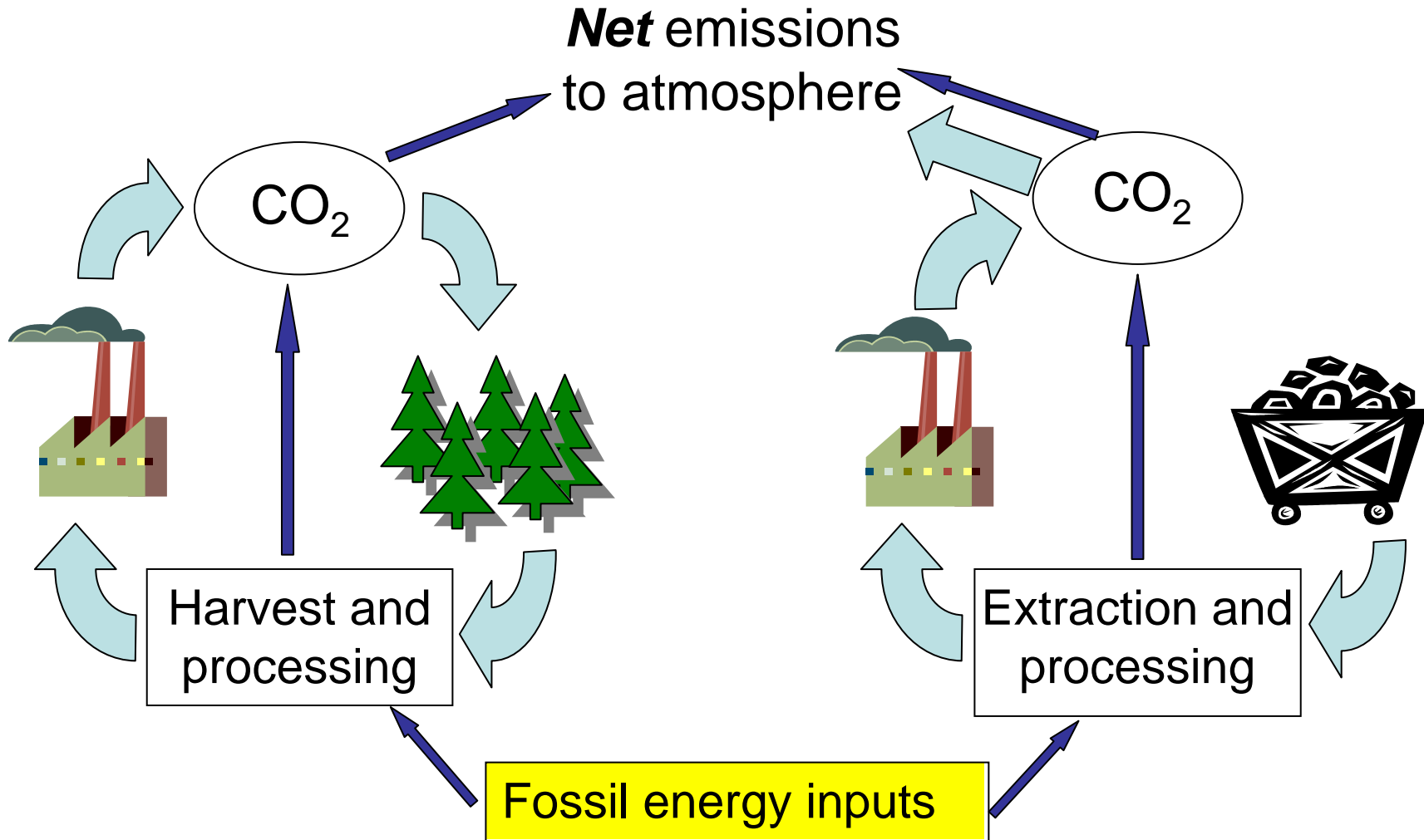
A landscape photograph of a sunset. The sky is filled with dark, layered clouds, some of which are illuminated from below by the setting sun, creating a mix of deep blues, purples, and oranges. The sun is positioned just above the horizon, creating a bright orange glow. In the foreground, the silhouettes of various trees and a dark field are visible against the bright sky. The overall mood is serene and dramatic.

# Life cycle assessment (LCA)

Provides a systematic assessment of the *environmental* implications of a product throughout its life cycle (ISO 2006)



# Carbon cycling and bioenergy



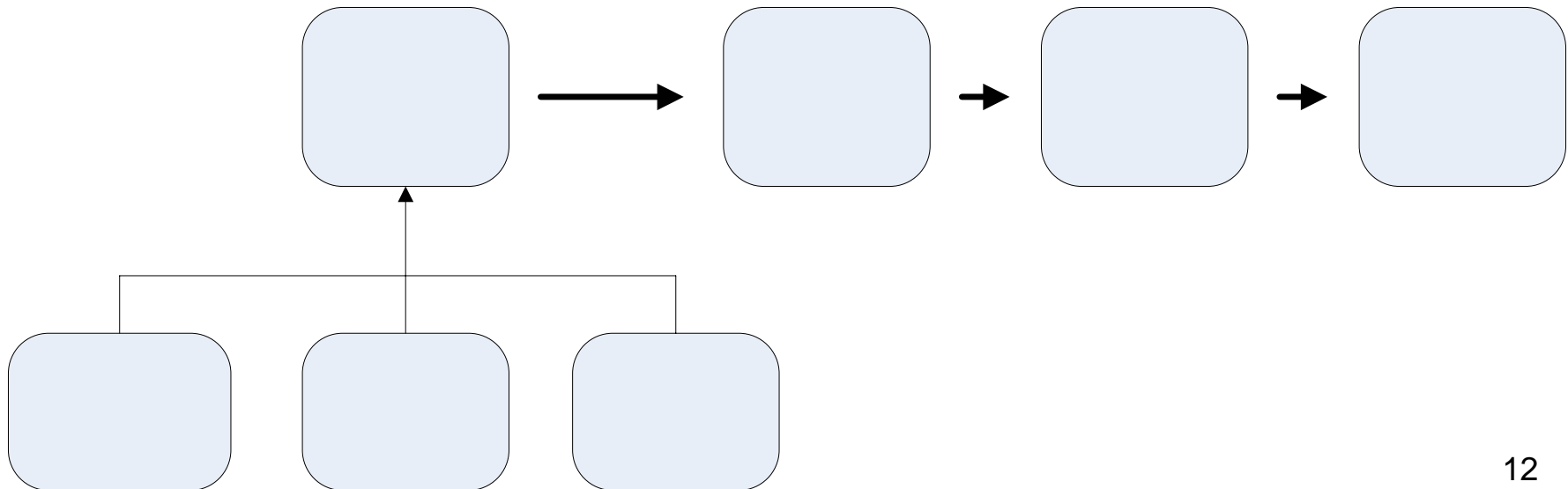
**Assumption:** CO<sub>2</sub> resulting from combustion of biofibre is exactly balanced by carbon incorporated during regrowth of the forest during the time period considered

# Forest carbon accounting

- The **forest area and the time frame** considered are important in defining whether forest carbon stocks are being replaced
  1. If considering a **forest management unit** encompassing 1000s of hectares then the time frame for replacement could be as little as 1 year (depending on amount of forest carbon removed)
  2. If considering a **single forest stand**, the time frame considered must be over a normal harvest rotation (Colombo and Chen, 2008)
- The **assumption in the study (C balanced between combustion and forest regrowth)** is based on;
  - Aggregated forest stock approach (1. above)
  - Forest being sustainably managed
  - Increasing harvest from current rates will not significantly impact carbon storage in forest

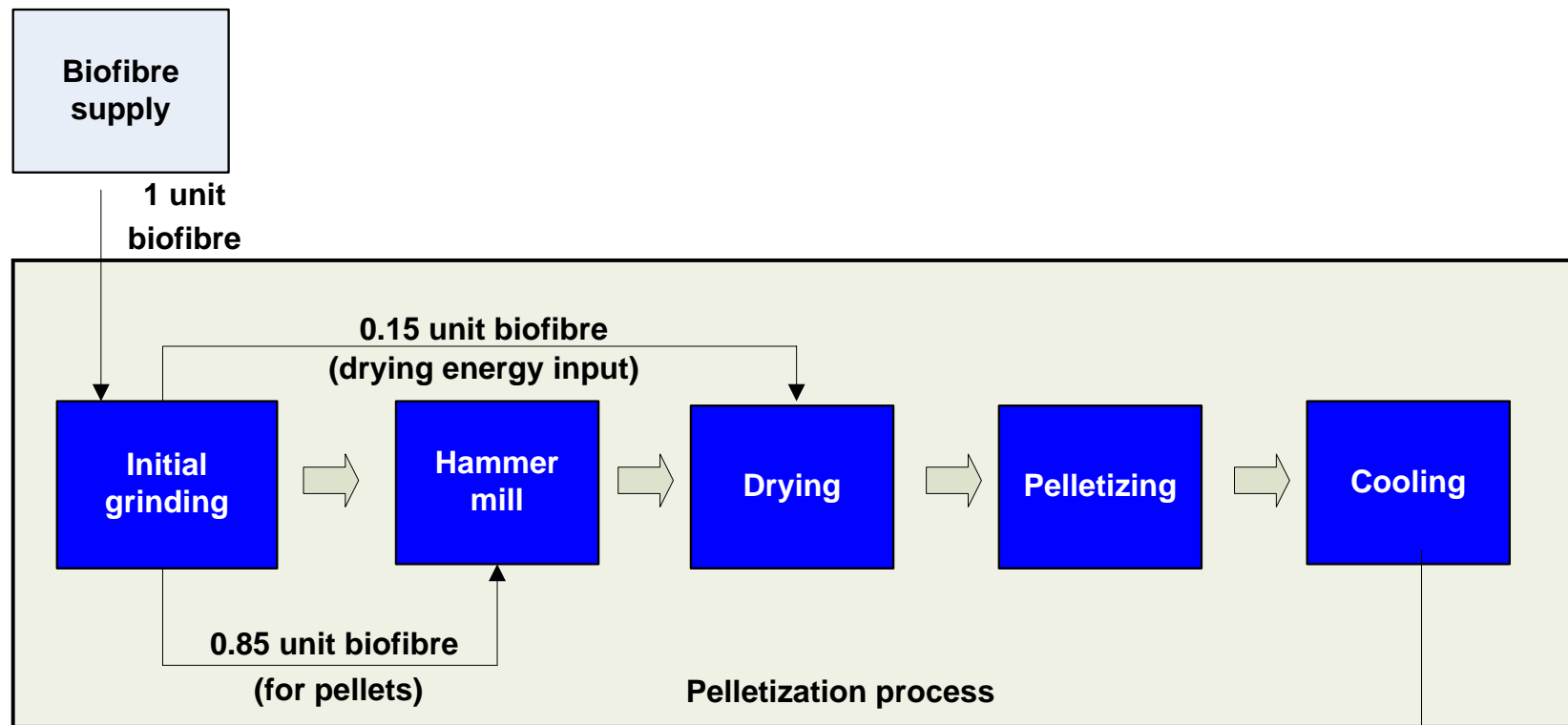
# Life cycle of wood pellet production

- Canada, Sweden, and US are leaders in production
  - Canada produced 1.2 million tonnes in 2006
- Forest biofibre harvesting data obtained from OMNR, FPIInnovations-Feric and NRCCan
- Harvest methods (selection 25%, shelterwood 25%, clearcut 50%), equipment and fuel use, and associated emissions (tops, branches left in forest)



# Pelletization process

Data from Northeastern U.S. state-of-the-art pellet producer, capacity of 12 ODT/hr



Electricity consumption 144 kWh/ODT pellet

ODT = oven dry tonne

Transport to power plants

# Results

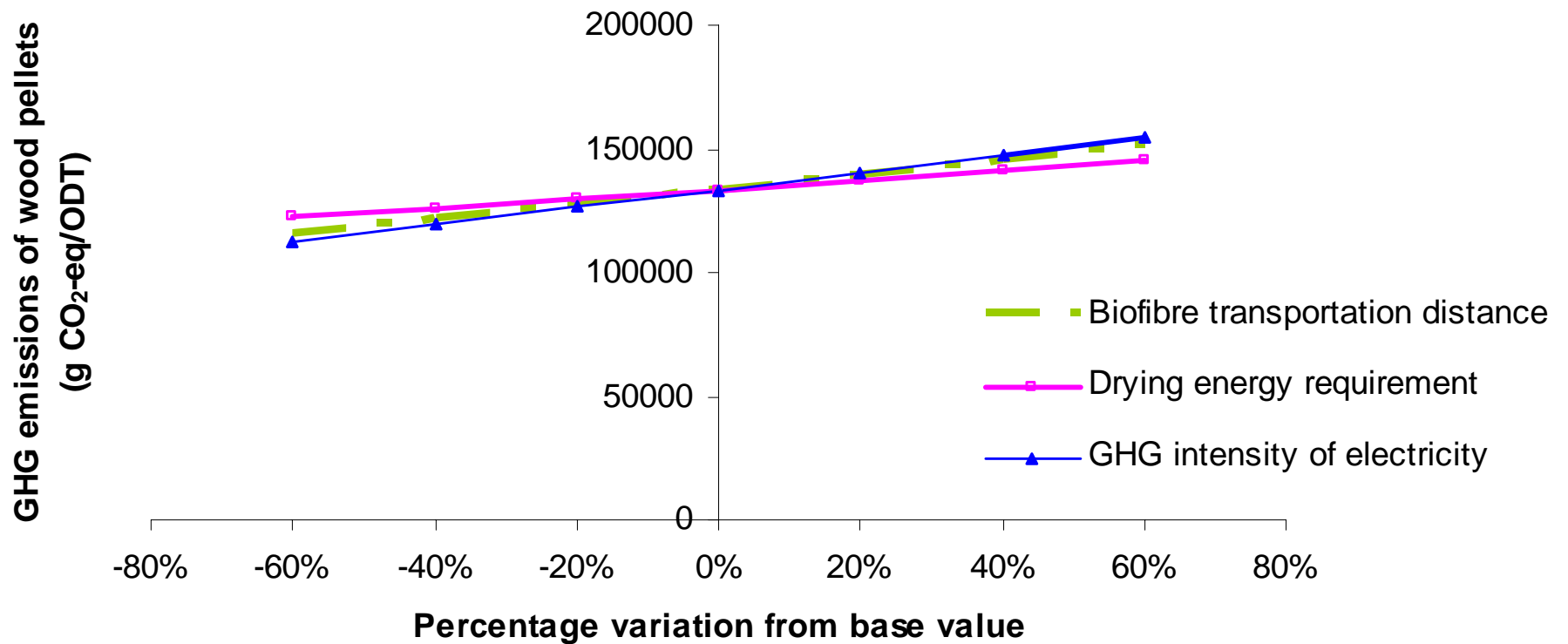


# GHG emissions associated with pellet production and transportation

~ 0.133 tonnes CO<sub>2</sub> eq. are associated with the production and transportation of 1 ODT of pellets

Activity	To Nanticoke (g CO <sub>2</sub> eq./ODT pellet)	To Atikokan (g CO <sub>2</sub> eq./ODT pellet)
Forest harvest	39,190	39,190
Forest road construction and maintenance	1,840	1,840
Forest renewal	1,380	1,380
Transportation to pellet facility	31,330	31,330
Pelletization	39,530	39,530
Transportation to generating stations	20,180	19,410
<b>Total: pellet production and transportation</b>	<b>133,440</b>	<b>132,670</b>

# Sensitivity analysis: GHG emissions associated with pellet production



# Annual wood pellet production

Production potential: 1.25 million ODT

10% cofire rate: ~ 0.92 million and 0.03 million ODT pellets to Nanticoke, Atikokan, respectively

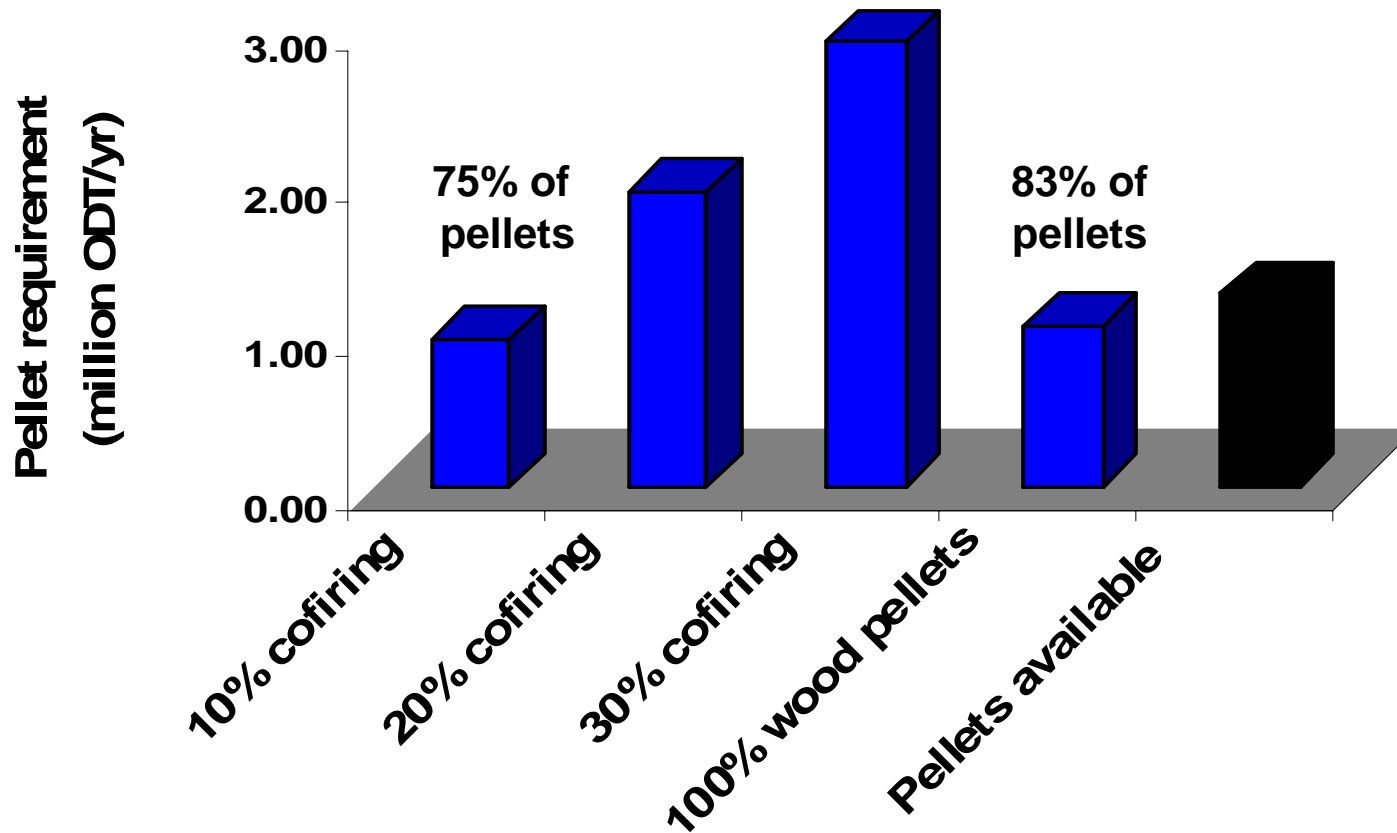


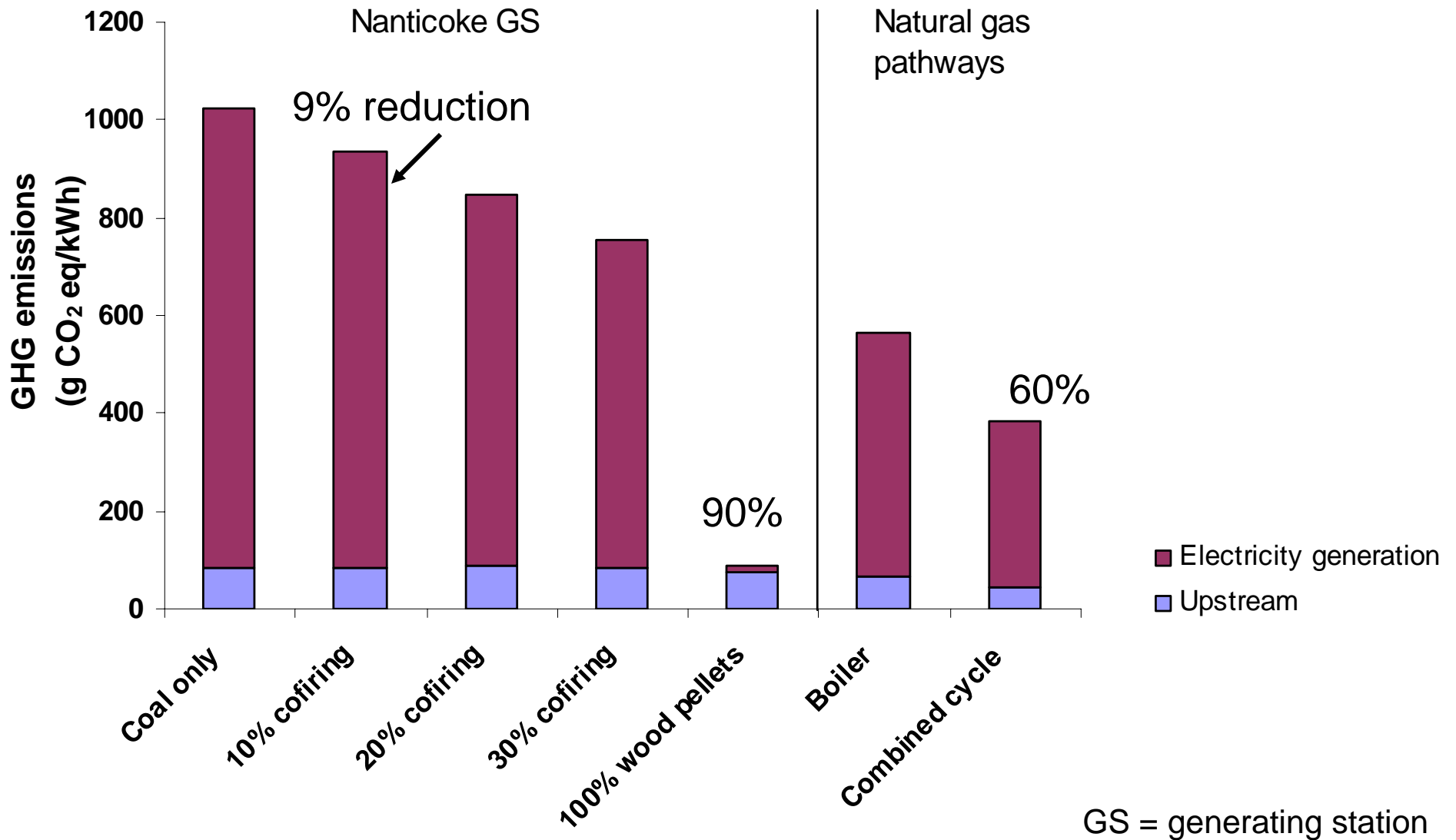
Figure indicates amounts required for both Nanticoke and Atikokan GS

# Life cycle GHG emissions (g CO<sub>2</sub>eq./kWh)

Pathways	Upstream activities	Generating station	Life cycle
<b>Reference coal-Nanticoke</b>	<b>61</b>	<b>940</b>	<b>1,000</b>
Reference coal- Atikokan	40	1,154	1,190
Reference natural gas - boiler	64	501	570
<b>Reference natural gas-combined cycle</b>	<b>43</b>	<b>343</b>	<b>390</b>
<b>Co-fire 10% Nanticoke</b>	<b>63</b>	<b>850</b>	<b>910</b>
Co-fire 10% Atikokan	43	1,044	1,090
<b>Pellet 100% Nanticoke</b>	<b>74</b>	<b>16</b>	<b>90</b>
Pellet 100% Atikokan	74	16	90

Life cycle totals may not add due to rounding

# Life cycle GHG emissions: Reference and Nanticoke wood pellet pathways



# Life cycle GHG emissions insights

- Vast majority of life cycle GHG emissions result from combustion of the fossil fuels in GS
- Displacement of coal with wood pellets results in reduction in CO<sub>2</sub> emissions. Assumption that the CO<sub>2</sub> resulting from the combustion of the wood pellets is exactly balanced by carbon incorporated during regrowth of the forest within the time period considered is important

# Putting things in perspective: some statistics

<b>Metric (annual basis)</b>	<b>All Pellets Used (13% co-firing)</b>
<b>Pellet production (million ODT)</b>	<b>1.25</b>
<b>Renewable electricity (TWh)</b>	<b>2.5</b>
<b>Renewable electricity as; % of Province's electricity generation</b>	<b>1.6</b>
<b>Coal displacement (million tonnes)</b>	<b>0.9</b>
<b>Reduction in GHG emissions (million tonnes CO<sub>2</sub> eq.)</b>	<b>2.1</b>
<b>% Reduction in GHGs resulting from Province's electricity generation</b>	<b>7</b>

# Alternative forest uses and carbon implications

- Consider whether proposed application is effective and efficient use of forest resource to make progress toward climate change and renewable energy goals
  1. Improving quality of GLSL forest
  2. Alternative bio-based energy systems
  3. Maintaining existing harvest rate to increase forest carbon stores



# Key messages

- Pellet production/use would;
  - Reduce GHG from coal GS
  - Decrease fossil fuel use/ increase renewable electricity production
  - Make progress toward full implementation of sustainable forest management plan
- However, this study examined only selected metrics
  - Other environmental, economic and social aspects need to be considered
- Would benefit from additional investigation of;
  - Alternative uses of GLSL Forest
  - Impact of increasing harvest rate on forest carbon storage
- Refine results following more detailed forest biofibre specification and engineering design

# Moving forward

- “In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit.” IPCC (2007)
- What are the inter-relationships between these approaches for reducing GHG emissions?

# Moving forward

- Quantify forest carbon storage ‘opportunity cost’ resulting from increased harvest rate
  - Forest carbon saturation
  - Natural age class distribution and ecosystem health
- Benefits of wood pellet production and use exist only relative to the displaced fuel
  - After 2014, coal is not an appropriate reference
  - Displacing cleaner generation sources will reduce the effectiveness of forest fibre utilization to meet GHG mitigation objectives

# Acknowledgments

- Ontario Power Generation
- Ontario Ministry of Natural Resources
- FPInnovations – Feric
- Ontario Ministry of Energy and Infrastructure
- Ontario Ministry of the Environment
- Warren Mabee, Queen's University

*Questions??*

**Additional slides**

# Life cycle NO<sub>x</sub> and SO<sub>x</sub> emissions (g/kWh)

Pathways	NO <sub>x</sub>	SO <sub>x</sub>
<b>Reference coal-Nanticoke</b>	<b>1.9</b>	<b>3.8</b>
Reference coal- Atikokan	2.0	4.7
Reference natural gas - boiler	1.3	0.1
Reference natural gas- combined cycle	1.0	0.1
<b>Co-fire 10% Nanticoke</b>	<b>2.0</b>	<b>3.2</b>
Co-fire 10% Atikokan	2.1	4.3



# Data quality issues

- Canada vs US surface mining of coal
- 100% pellet combustion in coal boilers
- Natural gas pathways
- Pellet production
- Carbon accounting baseline

# Pelletization: Key assumptions

- Data primarily from: Northeastern pellet producer, MNR, FPInnovations, NRCan, Ministry of Energy and Infrastructure
- Energy requirements from Northeastern pellet producer
  - Biofibre for drying: 15% of biofibre (adjusted for higher initial moisture content of input wood in our scenario)
  - Electricity: 144 kWh/ODT of pellets
- Transportation (pellet facility to GS)
  - Nanticoke: rail to port (180 km), vessel (890 km)
  - Atikokan: rail (1350 km)

# Putting things in perspective: some statistics

<b>Metric (annual basis)</b>	<b>10% Co-fire rate</b>	<b>100% Pellet Firing</b>	<b>All Pellets Used (Co-firing)</b>
Renewable electricity (TWh)	1.9	1.9	2.5
Ren. electricity as; % of coal GS elec. gen., % of Province's elec. gen.	6.7 1.2	6.7 1.2	9 1.6
Coal displacement* (million tonnes)	0.7	1.0	0.9
Reduction in GHG emissions (million tonnes CO <sub>2</sub> eq.)	1.7	1.9	2.1
Reduction as: % of coal GS GHG emissions % of Province's elec. gen GHG	6 5	7 6	8 7
SOx emissions reductions (tonnes) % of all coal GS SOx emissions	10,530 10	Not sufficient data	13,630 13

Atikokan: Lignite (SK), Nanticoke: Central Appalachian 1<sup>st</sup> then Power River Basin  
 Nanticoke capacity on 100% wood pellets reduced ~ 50% (to 250 MWe)  
 Based on 2007 Provincial electricity generation