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# INDUSTRIAL ELECTRIFICATION POTENTIAL FOR DECARBONIZATION IN QUEBEC

## CanmetENERGY

In Varennes

PREPARED BY: SOSEH ZADOORIAN, ETIENNE BERNIER,  
OMAR MOSTAFA & ABDELAZIZ HAMMACHE  
FOR  
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# INTRODUCTION

## Quebec Context

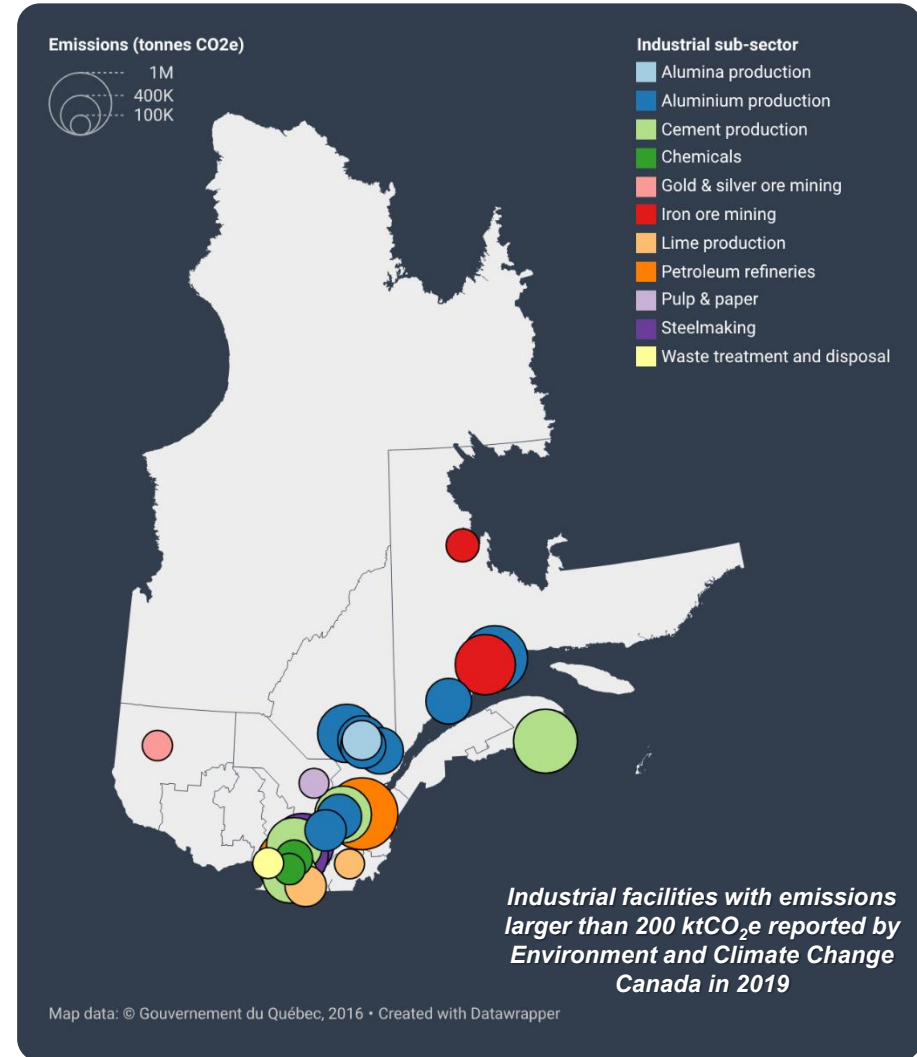
- Canada's **largest province by landmass** (eastern Canada)
- **Population** around **9 million**
- Quebec's **electricity grid** is almost entirely **carbon-free** (primarily hydroelectric power), with the largest electricity provider (**Hydro-Québec**) having a **generation capacity of 37 GW**

## Emissions & Climate Objectives

- **Total emissions** around **110 Mt CO<sub>2</sub>e** (including biogenic)
- **Industrial sector** accounts for **34% of total**
- By **2035**, **reduce emissions** by **37.5%** compared to 1990 levels
- By **2050**, **Carbon neutral**

## Scope of Study

- **Assess electrification potential:** GHG and fossil fuel reductions and additional electricity demand
- **This study** covers around **70% of industrial emissions (13 sub-sectors)**



# METHODOLOGY

## Step 1:

**Energy consumption** data broken down by energy carrier:

- Electricity
- Bioenergy
- **Fossil fuels**

## Step 2:

**Fossil fuel** data broken down by **fuel type**:

- Gases (e.g., natural gas)
- Liquids (e.g., diesel)
- Solids (e.g., coal)

**Fossil fuel** data broken down by **equipment/process type**:

- Process heat
- Non-energetic input
- Mechanical work

**Process heat** classified in three temperature levels:

- < 200°C
- 200°C – 700°C
- > 700°C

## Step 3:

**Electro-technologies** for each equipment/process selected based on:

- Process requirements
- Applicability

Then, ranked using multiple criteria

**Electrification potential** of each electro-technology assessed based on:

- Conversion efficiencies (fossil-based equipment/process and electro-technologies)
- Fossil fuel substitution rate
- Electricity and fossil fuels costs

## Step 4:

**Electrification scenarios** proposed for the assessment of a combination of electro-technologies for an entire sub-sector :

- Techno-optimistic
- High-TRL

Scenarios differentiated by two main factors:

- TRL of the electro-technologies
- Fossil fuel substitution rate

# ASSUMPTIONS AND LIMITATIONS

- **Scope** limited to major **key GHG emitting sub-sectors (13 sub-sectors emitting around 70% of total industrial emissions)**
- The analysis is based on data from 2019, which remains representative
- Industrial **energy** throughput **does not vary** with respect to:
  - Fluctuations in **production levels** over the years
  - Mill **closures** and **emerging industries**
  - The **deployment** of **new infrastructure**
  - **Capital investments**
  - Potential technological **efficiency gains**
- **Quebec's electricity** supply is **carbon-free**
- The **performance parameters (fossil-based and electro-technologies) do not improve over time**; they reflect the current state of technological knowledge

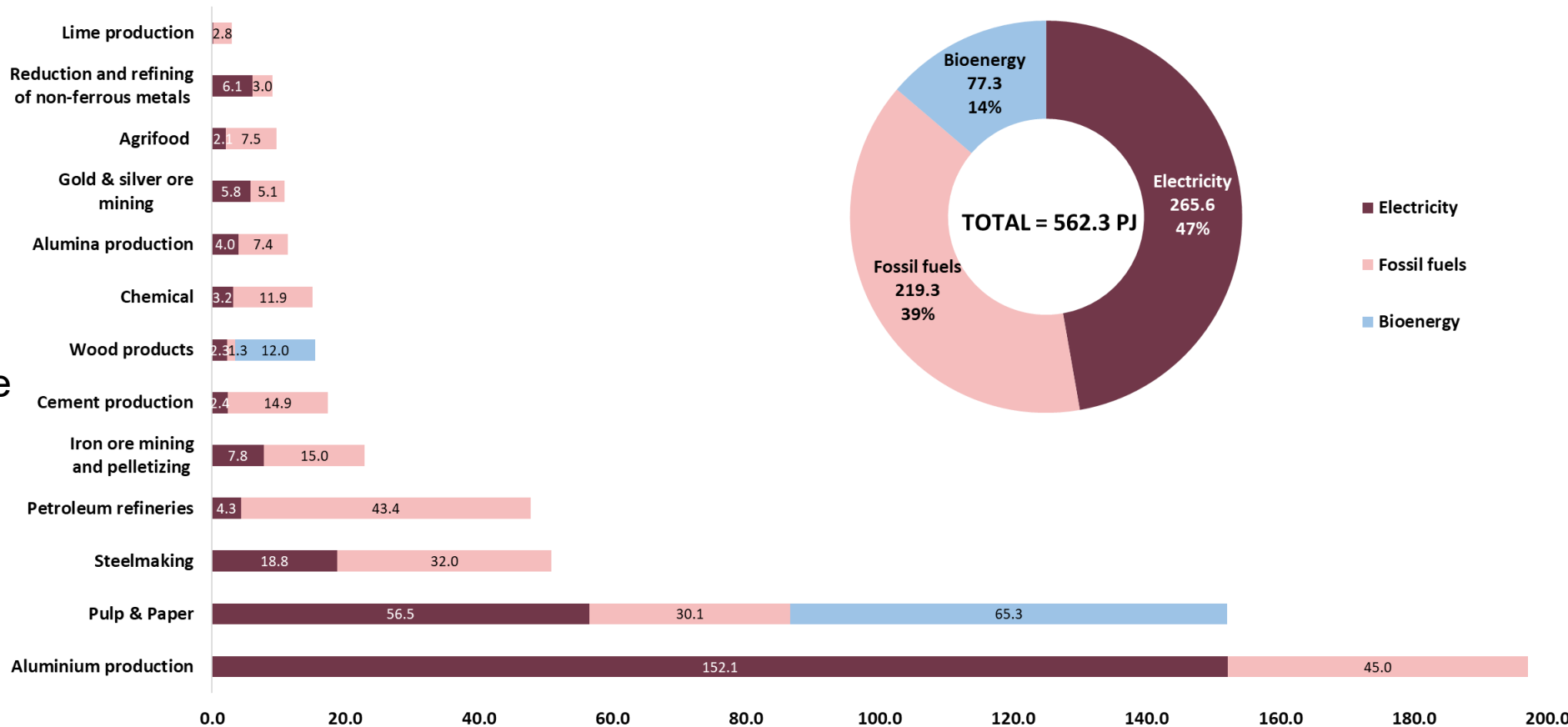
# ENERGY CONSUMPTION IN 13 INDUSTRIAL SUB-SECTORS

Key sub-sectors in terms of fossil fuel consumption are:

- Aluminum production
- Petroleum refineries
- Steelmaking
- Pulp & paper

Electricity consumption already accounts for a large share of energy use across the 13 sub-sectors

Aluminium production accounts for more than 57% of the total electricity consumption across the 13 sub-sectors, mainly due to the electrolysis process

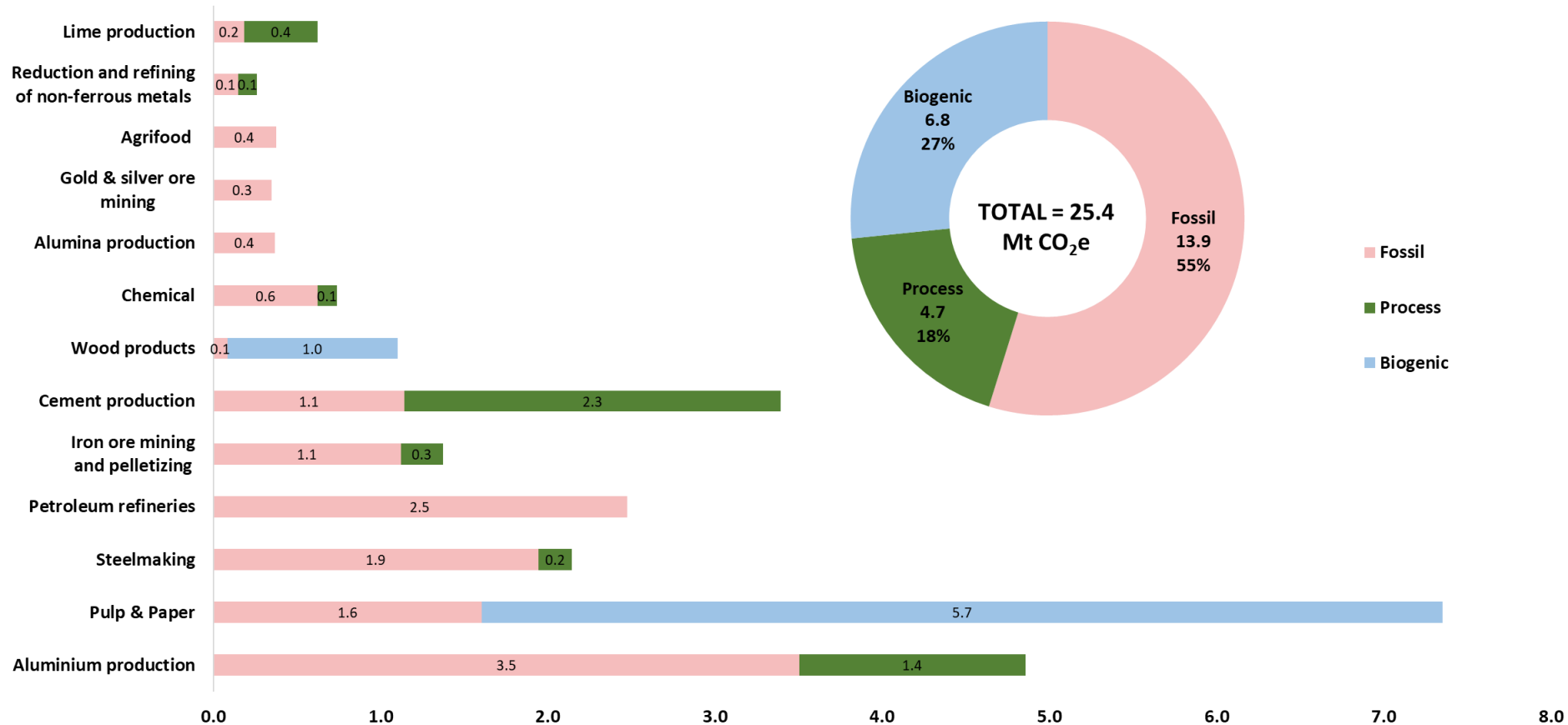


Energy consumption in petajoule (PJ)



# GHG EMISSIONS FROM 13 INDUSTRIAL SUB-SECTORS

- Key sub-sectors in terms of **process emissions** are:
  - Aluminum production
  - Cement production
  - Lime production
- Key sub-sectors in terms of **biogenic emissions** are:
  - Pulp & paper
  - Wood products

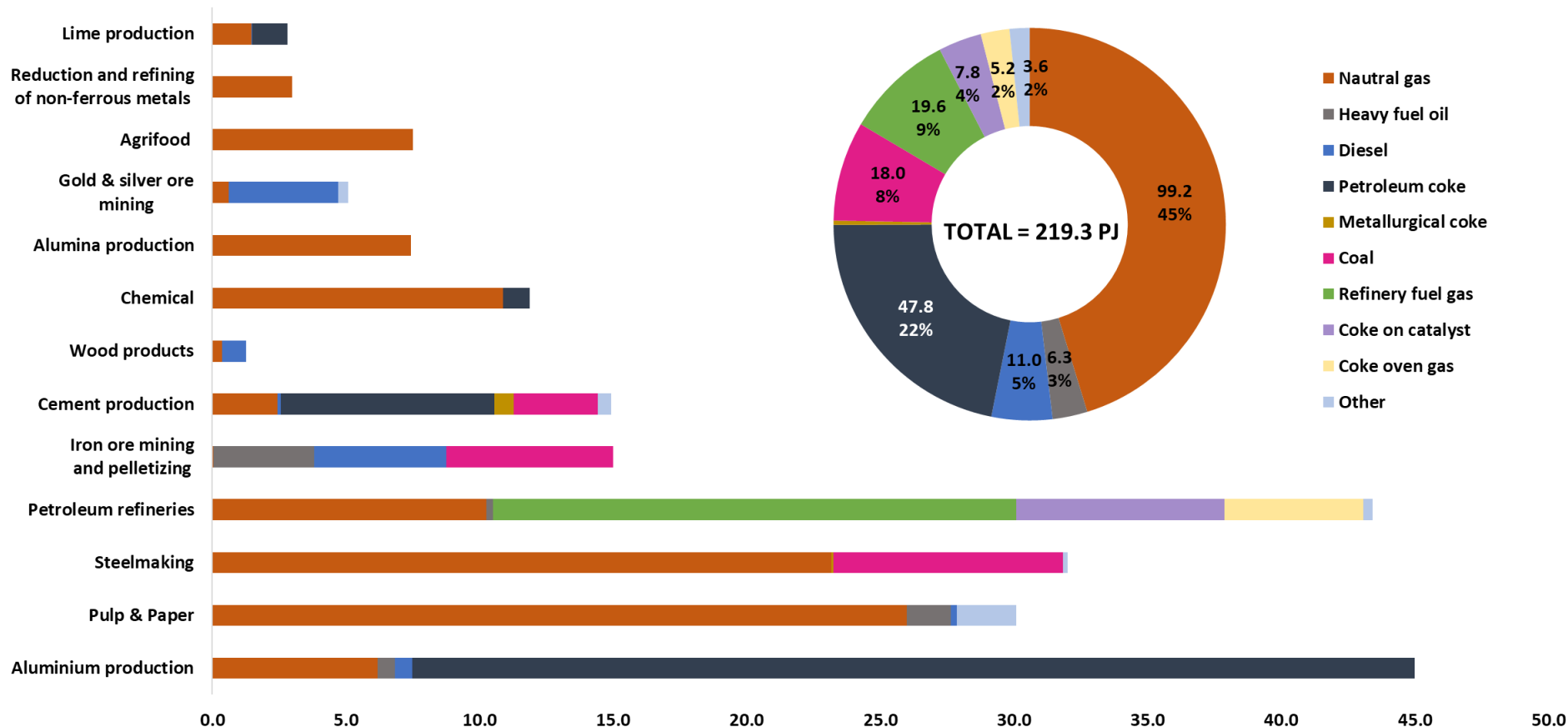


*GHG emissions in million tonnes of CO<sub>2</sub>e*



# FOSSIL FUEL CONSUMPTION BY FUEL TYPE

- **Natural gas** is the most used fossil fuel in the 13 sub-sectors, mainly for **low-temperature process heating** (about 40% of its consumption)
- More than **78% of petroleum coke** and more than **53% of coal** are used as **non-energy inputs** in the 13 sub-sectors

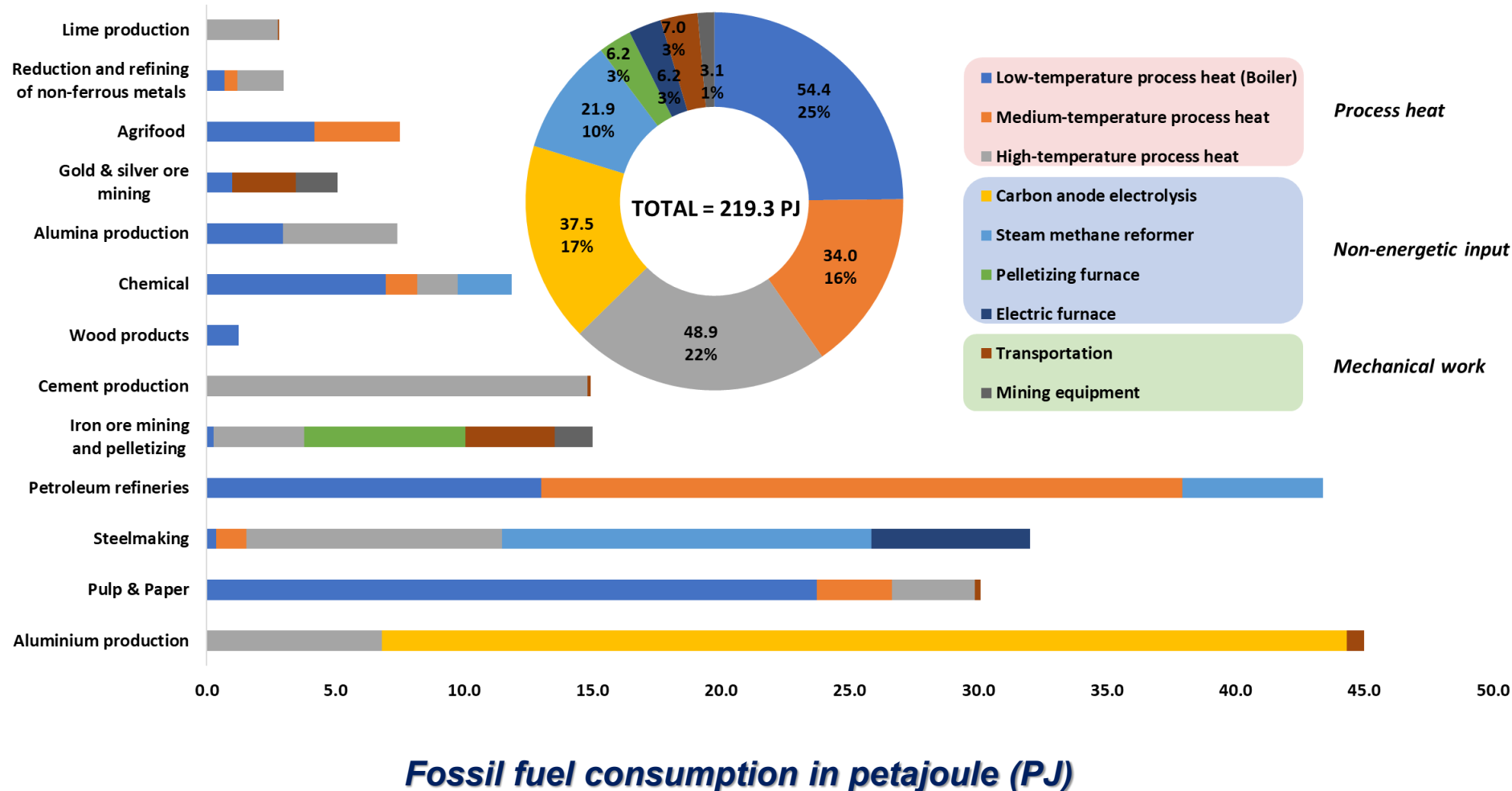


*Fossil fuel consumption in petajoule (PJ)*



# FOSSIL FUEL CONSUMPTION BY END-USER TYPE

- **Process heating** is the largest consumer of fossil fuel across the 13 sub-sectors, accounting for more than **63%** of the total
- **Non-energy** consumption accounts for about **33%** of total fossil fuel consumption
- **Electrification** projects are primarily aimed at **reducing fossil fuel** consumption in industrial heating, but other types of end users are also studied



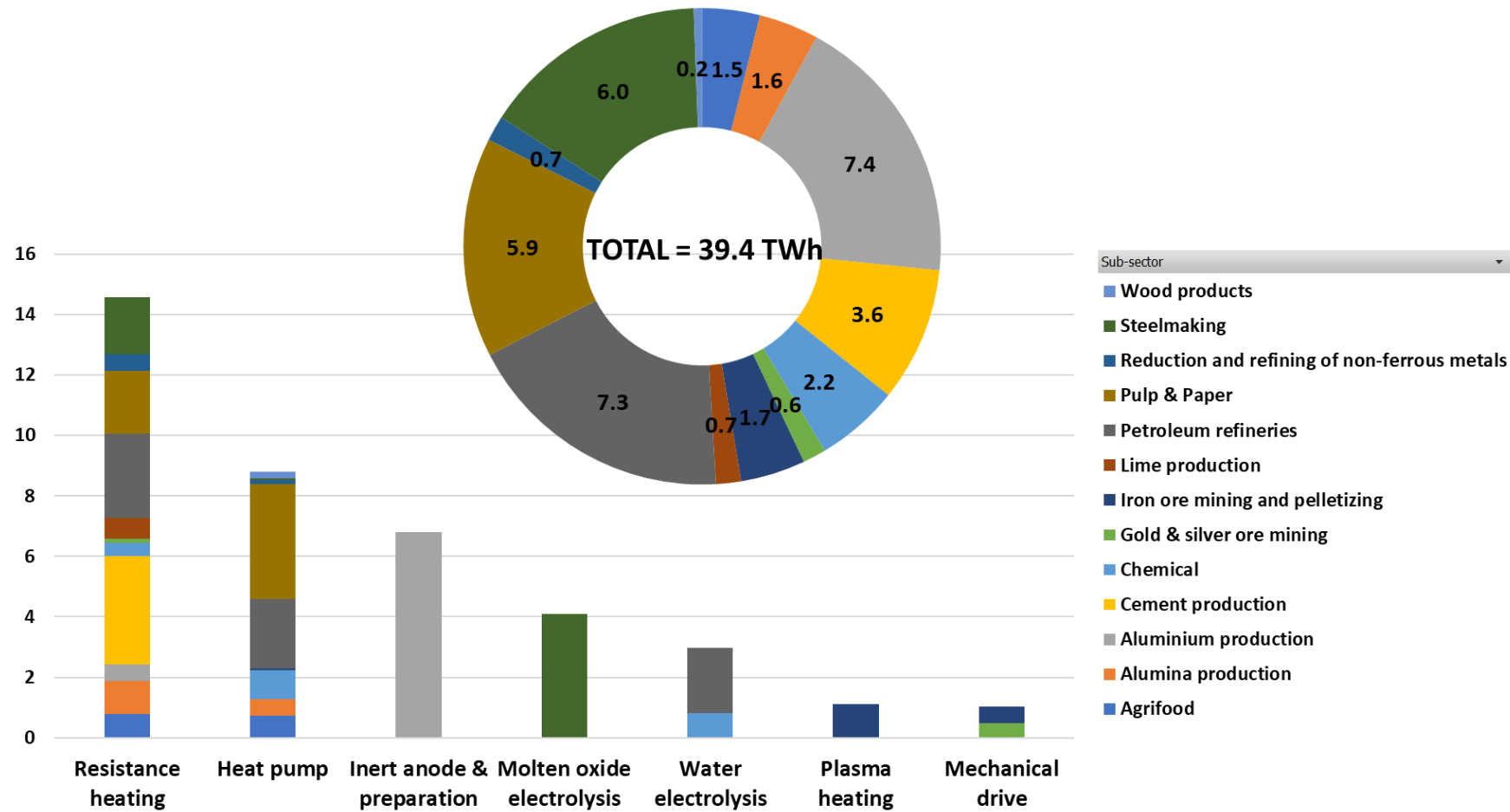
# IDENTIFIED ELECTRO-TECHNOLOGIES

End-use category	Fossil-fuel consuming equipment	$\eta_f$	Electro-technologies	TRL	$\eta_e$
Process heat (< 200°C)	Conventional boiler	85%	High-temperature heat pump	High	133%
Process heat (200 – 700°C & > 700°C)	Process heating such as cement kiln	85%	Electric resistance heating	High	98%
Process heat (> 700°C)	Process heating such as cement kiln	85%	Plasma heating	Medium	75%
Process heat (> 700°C)	Carbon anode baking (in aluminum production)	85%	Inert anode preparation	Low	234%
Non-energetic input	Carbon anode electrolysis (in aluminum production)	100%	Inert anode electrolysis	Low	164%
Non-energetic input	Steam methane reformer (For natural gas direct reduced iron or NG-DRI)	100%	Molten oxide electrolysis	Low	97%
Non-energetic input	Steam methane reformer (For natural gas direct reduced iron or NG-DRI)	100%	Water electrolysis for H <sub>2</sub> production (For hydrogen direct reduced iron or H <sub>2</sub> -DRI)	Medium – High	60%
Non-energetic input	Steam methane reformer	100%	Water electrolysis for H <sub>2</sub> production	High	70%
Mechanical work	Diesel truck	35%	Hybrid (battery + catenary) truck	High	83%
Mechanical work	Diesel train	35%	Hybrid (battery + catenary) train	High	86%
Mechanical work	Diesel drills (mining equipment)	35%	Electric drills	High	85%



# TECHNO-OPTIMISTIC ELECTRIFICATION SCENARIO

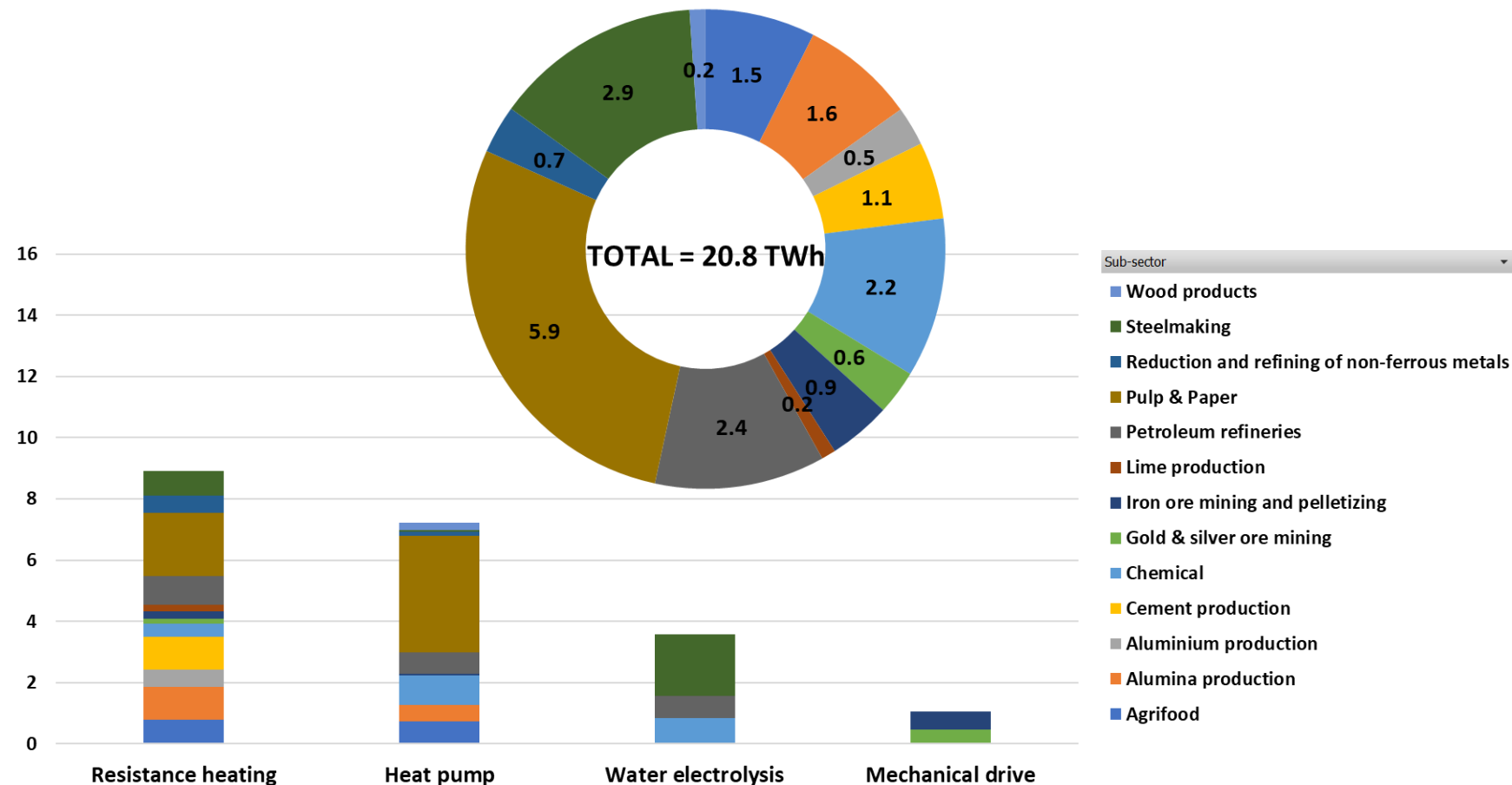
- An **electrification scenario** refers to a **portfolio of electro-technologies** that, collectively, replace fossil-fuel powered processes or equipment within a sub-sector
- **Two scenarios** are considered based on two electro-technology factors:
  - Technology Readiness Level (TRL)
  - Fossil fuel substitution rate
- In the **techno-optimistic** scenario, a **substitution** rate of up to **100%** is considered with **no restriction on TRL**



*Additional electricity demand in terawatt-hour (TWh)*

# HIGH-TRL ELECTRIFICATION SCENARIO

- In this scenario, electro-technologies with **high TRL** are selected only
- **0% substitution** rate is considered for **process gases** across all end-users
- **30% substitution** rate is considered for **high-temperature process heat** applications



*Additional electricity demand in terawatt-hour (TWh)*

# CONCLUSION



## Electrification

- Electrification potential for 13 industrial sub-sectors in Quebec was assessed
- Two electrification scenarios proposed based on TRL and fossil fuel substitution rate of the electro-technologies



## Constraints

- Transmission and grid capacity
- Peak load (especially in winter)
- Can be mitigated by demand response (ex., load shedding or load shifting)



## Alternatives

- Non-electric pathways (bioenergy, CCUS, etc.)
- BECCS or negative emissions opportunity
- Reasons to consider alternatives:
  - Hard to electrify processes
  - Lower CAPEX (retrofit)
  - Abate process emissions

Limit and reduce electrification potential in practice



# KEY TAKEAWAYS

- Electrification increases annual electricity demand by 20 to 40 TWh across two scenarios
  - Equivalent to 10 to 20% of current provincial electricity consumption
- Even after optimistic electrification scenario, process-related CO<sub>2</sub> emissions remain
  - Requires non-electric pathways to achieve a decarbonized industrial sector
- The results for two electrification scenarios are as follows:

<b><u>Scenario</u></b>	<b><u>Fossil fuel reduction</u></b>	<b><u>GHG emission reduction</u></b>	<b><u>Additional annual electricity</u></b>	<b><u>Additional annual energy cost</u></b>
	<b><i>PJ (%)</i></b>	<b><i>Mt CO<sub>2</sub>e (%)</i></b>	<b><i>PJ (%)</i></b>	<b><i>CAD \$M</i></b>
<i>High-TRL</i>	<i>96.0 (44%)</i>	<i>5.3 (21%)</i>	<i>74.7 (28%)</i>	<i>254</i>
<i>Techno-optimistic</i>	<i>187.1 (85%)</i>	<i>12.9 (51%)</i>	<i>141.8 (53%)</i>	<i>656</i>

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# FOLLOW US & CONTACT US



Contact info:  
Soseh Zadoorian  
Process Engineer  
[soseh.zadoorian@nrcan-rncan.gc.ca](mailto:soseh.zadoorian@nrcan-rncan.gc.ca)

Industrial Systems Optimization  
Energy Technology Sector  
Natural Resources Canada |  
Government of Canada



1615 Lionel-Boulet Blvd.  
Varenes (QC) J3X 1P7  
Phone: +1.450.652.4621  
[canmetenergy@nrcan.gc.ca](mailto:canmetenergy@nrcan.gc.ca)



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QUESTIONS?



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