Solid Biomass Fuels in Canada’s Low Carbon Energy Future

Solid Fuels Sub-Working Group
Clean Fuel Steering Committee

September 2019
About the Clean Fuel Steering Committee

The Clean Fuel Steering Committee (CFSC) is a government and industry collaboration whose objective is to assess and review investment conditions and identify measures required to increase investment in the domestic production of clean fuels and electric vehicle adoption to meet climate action commitments and help with the successful implementation of the Clean Fuel Standard (CF Standard). The CFSC includes four Sub-Working Groups: Solid Fuels, Liquid Fuels, Gaseous Fuels, and Electric Vehicles.

About the Solid Fuels Sub-Working Group

The Solid Fuels Sub-Working Group (SWG) represents one of four fuel streams within the CFSC. Since April 2019, the Solid Fuels SWG, co-chaired by the Canadian Forest Service and the Wood Pellet Association of Canada, has facilitated discussions among stakeholders to provide a comprehensive overview regarding the most important and pressing factors for the potential growth of bioenergy markets in Canada.

This report is the primary output of the Solid Fuels SWG and reflects the views of the industry members. The scope is limited to solid biomass fuels.

Solid Fuels Sub-Working Group Represented Organizations

Industry

ArcelorMittal Dofasco
Biothermic Wood Energy
Char Technologies
Ecostrat
Hearth, Patio and Barbeque Association of Canada
Kerr Wood Leidal
TorchLight Bioresources
Wood Pellets Association of Canada

Government of Canada

Natural Resources Canada – Canadian Forest Service
Natural Resources Canada – Innovation and Energy Technology Sector
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EXECUTIVE SUMMARY

In Canada, solid biomass is second only to hydropower in renewable energy production. The energy generated by solid biomass is significantly greater than that generated by wind, solar, geothermal, and tidal energy technologies combined. Solid biomass fuels include wood pellets, wood chips, crop residues such as straw, refuse (waste)-derived fuel, and biocarbon. Approximately 2/3 of solid biomass energy in Canada is consumed by industry for process heat and co-generated electricity and 1/3 is consumed in the residential sector for space heating. However, despite having the greatest solid biomass fuel potential and the largest heat consumption per capita of any major economy, Canada significantly trails European countries in solid biomass contribution to energy supply. In the European Union, solid biomass has an 84% share of the renewable heating and cooling market, the largest renewables market, and the amount of energy generated by solid biomass heating is equal to all renewable electricity generation, including hydropower, combined. The EU bioenergy sector, which accounts for 60% of EU renewable energy generation and is dominated by thermal applications, is responsible for over 210 Mt CO\textsubscript{2}e per year in greenhouse gas (GHG) reductions. This is the most of any renewable energy by far. Canada’s inability to reduce GHG emissions over the past two decades can be directly attributed to the country’s failure to follow the EU example and widely adopt solid biomass fuels.

Sustainable, clean, solid biomass fuels have the potential to significantly reduce Canada’s GHG emissions in a cost-efficient manner. To quantify this potential, the Solid Fuels Sub-Working Group (SWG) of the Clean Fuel Steering Committee developed two scenarios for rapidly increasing the contribution of solid fuels to Canada’s energy supply. It was determined that 87 million tonnes of new, sustainable solid biomass fuel could supply over 1,000 PJ of energy by 2030. This represents only 62% of the estimated sustainable solid fuel supply. Fuel switching 1,000 PJ from natural gas, heating oil, propane, and coal to solid biomass would reduce GHG emissions by 75 Mt CO\textsubscript{2}e per year, which represents 37% of the gap between Canada’s 2017 emissions and its 2030 Paris Agreement commitment. GHG reductions are low cost compared to alternatives, with an average capital cost of $41/t CO\textsubscript{2}e and a levelized combined capital and fuel cost of $58/t CO\textsubscript{2}e. However, the high upfront capital cost and long lifespan of solid biomass utilization and energy distribution infrastructure necessitates Government of Canada policy action to realize these cost-effective GHG reductions. A long-term commitment is required.

Several key factors are impeding investment in solid biomass fuel production, utilization, and energy distribution in Canada. These include the low cost of natural gas, the very low market penetration of district energy system (DES) infrastructure, limited municipality participation in DES ownership, erroneous air pollutant emissions assumptions, the capital recovery period for boilers, capital market risk perception, and policy challenges. These challenges include climate policy instability, a political prioritization of electrification, a lack of effective carbon leakage policies to drive GHG reductions in trade-exposed emitters, and feedstock access and risk perception.

The Solid Fuels SWG prepared ten recommendations for the Government of Canada to accelerate adoption of solid biomass fuels, thereby reducing GHG emissions and wildfire risk while creating ten of thousands of jobs.

1. Develop a Thermal Energy Decarbonization Strategy for Canada
2. Establish a $35 B, 10-year Infrastructure Fund for Municipal District Energy System Development
3. Permit End-Use Fuel Switching under the Clean Fuel Standard
4. Use Public Procurement to Kick-Start Solid Fuel Supply Chains
5. Prohibit Low-Efficiency Natural Gas Electricity Generation
6. Introduce Carbon Performance Standards for Steel and Cement
7. Incentivize Climate Smart Active Management of Canada’s Forests
8. Include Black Carbon Emissions from Wildfires & Slash Piles in the National Inventory Report
10. Support Initiatives to Reduce Investor Feedstock Risk Perception and Develop Supply Chains
1 THE ROLE OF SOLID BIOMASS FUELS IN CANADA

1.1 Introduction to Solid Biomass Energy in Canada

Globally, solid biomass is the dominant renewable fuel for thermal energy applications including space and hot water heating, process heat, and combustion-based electricity generation. It is also the primary source of renewable carbon, making it essential for decarbonization of steel production. In Canada, solid biomass is second only to hydropower in renewable energy production. The energy generated by solid biomass is significantly greater than that generated by wind, solar, geothermal, and tidal energy technologies combined. Solid biomass fuel availability also dramatically exceeds that of other carbon-based renewable fuels. As an example, the energy content of Canada’s wood pellet production is greater than that of ethanol, biodiesel, renewable diesel, and renewable natural gas combined. At the same time, solid fuels are typically much lower cost than liquids, gases, or electricity. As such, solid biomass has a leading role to play in cost-efficient decarbonization of Canada’s economy. Unfortunately, while European countries have recognized the importance of solid biomass for GHG reductions, Canada has been slow to embrace solid biomass fuels. This can largely be attributed to a lack of understanding of low-emissions, clean modern conversion technologies; inadequate enabling infrastructure, including district energy, development; inaccurate perceptions of fuel sustainability; and general political prioritization of high-cost electrification in climate and energy planning. Canada has the greatest solid biomass fuel potential per capita of any country, allowing the fuel to make a large contribution to GHG reductions.

Bioenergy consumption in Canada was 440 PJ in 2016. Of this, approximately 75%, or 330 PJ, was solid biomass heating and electricity. In comparison, wind, solar PV, tidal, and geothermal consumption combined totalled 88 PJ.\textsuperscript{1,2} Solid biomass energy consumption was dominated by industry, representing approximately 2/3 of consumption, and residential heating, representing approximately 1/3 of consumption. While growing at an annual rate of over 10%, solid biomass for commercial/institutional space and hot water heating represents only 1% of current bioenergy consumption in Canada.\textsuperscript{3}

Figure 1. Renewable Energy Consumption in Canada, 2016\textsuperscript{1,2}

\textit{Total Consumption: 1,500 PJ}

\textit{Blue shades = Electricity; Red shades = Heating/Cooling; Yellow Shades = Transportation}

\begin{itemize}
  \item Hydropower
  \item Onshore Wind
  \item Solar PV
  \item Solid Biomass
  \item Biogas & Liquids
  \item Solid Biomass
  \item Biogas & Liquids
  \item Heat Pumps
  \item Bio-based Diesels
  \item Ethanol
  \item Electricity - Road
\end{itemize}

\textsuperscript{1} National Energy Board, 2018. Canada’s energy future 2018 – an energy market assessment.
1.2 The Leading Role of Solid Biomass Fuels in the European Union

Solid biomass for heating dominates renewable energy generation in the European Union (EU). It has an 84% share of the renewable heating and cooling market, the largest renewable energy market (the other markets being electricity and transportation). The amount of energy generated by solid biomass heating is equal to all renewable electricity, including hydropower, combined. In fact, solid biomass heating and electricity generation account for 80% of bioenergy and almost half of all renewable energy in the EU. Bioenergy is responsible for 60% of renewable energy generation and over 210 Mt CO2e/yr reduction in the EU, the most of any renewable.4

Figure 2. Renewable Energy Consumption in the EU-28, 2016
Total Consumption: 8,200 PJ
Blue shades = Electricity; Red shades = Heating/Cooling; Yellow Shades = Transportation

1.3 Solid Biomass Fuel Applications

Space Heating/Cooling and Hot Water: Solid biomass combustion generates heat for heating residential and commercial/institutional buildings. This can be accomplished at the individual building level, such as pellet boilers for homes, or via central heating plants connected to district energy systems. Modern biomass clean combustion technology can reduce particulate matter emissions by 95% to 99.99% relative to uncertified wood stoves and fireplaces. Biomass combustion can also generate cooling (air conditioning) using absorption chillers.

District Energy Systems: In urban areas, it is not feasible to deliver solid biomass fuels to each individual building. An underground network of pipes delivers thermal energy (hot or cold) from a central biomass energy plant to multiple buildings. Energy is transferred to internal building energy systems using heat exchangers. As an example, 99% of buildings in Copenhagen, Denmark are connected to the city’s district energy system and energy generation/fuel combustion at an individual building level is prohibited. Biomass is the primary system fuel.

Process Heat: Industrial energy demand is dominated by process heat, typically in the form of steam. In Canada, most process steam is generated by combustion of natural gas. Large consumers of process heat in Canada include the oil sands (extraction/recovery) and producers of steel, pulp, and cement. Solid biomass is usually the most cost effective deployable, renewable, low carbon fuel for process steam/heat. The pulp and paper industry has already transitioned most of its energy systems from natural gas and other fossil fuels to biomass.

**Electricity Generation:** The heat from biomass combustion can be used to generate electricity using steam or other technologies. While stand-alone biomass power plants do exist, this is a relatively low efficiency use of a valuable renewable resource. A better approach is to co-generate electricity with heat (combined heat and power, or CHP) for district energy systems or industrial processes. One exception to the prioritization of co-generation is the use of wood pellets or other solid fuel in Canada’s existing coal-fired power-only generating stations. Fuel switching to solid biomass is the most cost-effective decarbonization approach for these plants if they are to be operated for the full length of their useful 50-year life.

**Renewable Reductant:** In the iron and steel industry, carbon, typically in the form of coke produced from coal, is used as a reductant to remove oxygen from the raw materials (e.g., iron ore). Steel and CO₂ are the primary reaction products. Biomass is the only source of renewable carbon. As such, the primary approach for decarbonization of the steel industry is displacement of coke with biocarbon, a low carbon intensity, renewable reductant produced from solid biomass using a slow pyrolysis process.

### 1.4 Solid Biomass Contribution to Canada’s Paris Agreement Commitment

Canada has committed to reduce the country’s annual greenhouse gas (GHG) emissions by 30% relative to 2005 emissions of 730 Mt CO₂e by 2030. Between 2005 and 2017, national inventory GHG emissions dropped by only 15 Mt CO₂e (2%), leaving a shortfall of 205 Mt CO₂e/yr. Given the importance of solid fuels to the EU’s decarbonization activities, the maturity of the thermal generation and heat distribution technology, Canada’s abundant sustainable solid biomass resources, and Canada’s leadership position in certified sustainably-managed forests, Canada should embrace solid biomass fuels as a key pillar for meeting the country’s Paris Agreement commitment. When contrasted with most decarbonization alternatives, solid biomass is usually lower cost, creates many more operating jobs in rural regions, and improves economic and infrastructure resiliency in the face of a changing climate. Biomass complements and enables electrification initiatives.

The Solid Fuel Sub-Working Group (SWG) of the Clean Fuel Steering Committee has prepared two 2030 scenarios describing the role of solid fuels within the energy sector. These scenarios, presented in Figure 3, take into consideration Canada’s Paris Agreement commitment and the high competitiveness, low technology risk, abundant fuel supply, and low all-in cost of fuel switching of solid biomass relative to other decarbonization options. The scenarios utilize National Energy Board (NEB; now Canada Energy Regulator) projections of 2030 energy demand, which is anticipated to be considerably higher than the 2017 modelling baseline.⁵

The scenarios include the following assumptions:

- The 2030 Reference Scenario energy demand projected by the NEB is used for all scenarios
- Solid biomass is used to replace fossil fuels and high-carbon electricity in space and hot water heating in residential and commercial sectors, and process heat in industrial applications
- Solid biomass is used to generate electricity in co-generation (with heating/cooling) and coal-displacement (at existing coal-fired power plants) applications only
- Wood pellets are the primary fuel for use in existing pulverized coal power plants
- Solid biomass does not contribute to GHG reductions in the transportation sector, except insofar as biomass reduces the carbon intensity of electricity used for EVs
- Residential and commercial natural gas consumers will not switch away from a utility model; heat from solid biomass must be delivered to buildings using district energy systems
- Wood chips, refuse-derived fuel, and crop residues (straw/stover) fuel district energy systems

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• Residential and commercial refined petroleum product consumers can fuel switch to wood pellets for individual building heating systems
• Fossil fuel consumption reductions are prioritized according to carbon intensity of the fuel being replaced, subject to technical limitations if applicable (i.e., reduce coal, then refined petroleum products, then natural gas)

Figure 3. End-Use Energy Demand - Current, Projection, and Potential
*National Energy Board 2018 Reference Scenario and CFSC Solid Fuels SWG 2030 Scenarios*

<table>
<thead>
<tr>
<th></th>
<th>2017 NEB (PJ)</th>
<th>2030 NEB (PJ)</th>
<th>2030 Moderate (PJ)</th>
<th>2030 High (PJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>11,431</td>
<td>12,313</td>
<td>12,313</td>
<td>12,313</td>
</tr>
<tr>
<td>Residential</td>
<td>1,446</td>
<td>1,527</td>
<td>1,527</td>
<td>1,527</td>
</tr>
<tr>
<td>Electricity</td>
<td>588 41%</td>
<td>630 41%</td>
<td>565 37%</td>
<td>519 34%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>630 44%</td>
<td>684 45%</td>
<td>641 42%</td>
<td>458 30%</td>
</tr>
<tr>
<td>RPP⁴</td>
<td>78 5%</td>
<td>65 4%</td>
<td>15 1%</td>
<td>15 1%</td>
</tr>
<tr>
<td>Biomass</td>
<td>150 10%</td>
<td>148 10%</td>
<td>305 20%</td>
<td>535 35%</td>
</tr>
<tr>
<td><strong>Commercial</strong></td>
<td>1,358</td>
<td>1,495</td>
<td>1,495</td>
<td>1,495</td>
</tr>
<tr>
<td>Electricity</td>
<td>448 33%</td>
<td>528 35%</td>
<td>523 35%</td>
<td>523 35%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>697 51%</td>
<td>738 49%</td>
<td>598 40%</td>
<td>374 25%</td>
</tr>
<tr>
<td>RPP⁴</td>
<td>212 16%</td>
<td>225 15%</td>
<td>150 10%</td>
<td>150 10%</td>
</tr>
<tr>
<td>Biomass</td>
<td>1 0%</td>
<td>3 0%</td>
<td>224 15%</td>
<td>449 30%</td>
</tr>
<tr>
<td><strong>Industrial</strong></td>
<td>6,007</td>
<td>6,841</td>
<td>6,841</td>
<td>6,841</td>
</tr>
<tr>
<td>Electricity</td>
<td>850 14%</td>
<td>959 14%</td>
<td>958 14%</td>
<td>958 14%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>2,774 46%</td>
<td>3,253 48%</td>
<td>2,966 43%</td>
<td>2,736 40%</td>
</tr>
<tr>
<td>RPP⁴</td>
<td>1,914 32%</td>
<td>2,165 32%</td>
<td>2,165 32%</td>
<td>2,121 31%</td>
</tr>
<tr>
<td>Biomass</td>
<td>330 5%</td>
<td>325 5%</td>
<td>684 10%</td>
<td>1,026 15%</td>
</tr>
<tr>
<td>Other</td>
<td>140 2%</td>
<td>139 2%</td>
<td>68 1%</td>
<td>0 0%</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td>2,620</td>
<td>2,449</td>
<td>2,449</td>
<td>2,449</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electricity Total⁵</th>
<th>2,299</th>
<th>2,462</th>
<th>2,462</th>
<th>2,462</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>1,380</td>
<td>1,505</td>
<td>1,505</td>
<td>1,505</td>
</tr>
<tr>
<td>Wind</td>
<td>117</td>
<td>219</td>
<td>219</td>
<td>219</td>
</tr>
<tr>
<td>Biomass</td>
<td>32</td>
<td>42</td>
<td>222</td>
<td>369</td>
</tr>
<tr>
<td>Solar</td>
<td>15</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Uranium</td>
<td>355</td>
<td>287</td>
<td>287</td>
<td>287</td>
</tr>
<tr>
<td>Coal</td>
<td>214</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>177</td>
<td>369</td>
<td>205</td>
<td>57</td>
</tr>
<tr>
<td>Oil/RPP⁴</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

⁴Refined Petroleum Products
⁵Domestic generation

Figure 4 provides a breakdown of the top 10 industrial sectors by total GHG emissions. The potential for new fuel switching to solid biomass fuels is summarized. It should be noted that the top GHG emitting sectors are not necessarily the largest consumers of energy. As an example, the pulp and paper sector is the third largest consumer of energy but only the ninth largest emitter. This is due to extensive use of solid biomass fuels for process heat and electricity.

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### Figure 4. Top 10 Canadian Industrial Sector GHG Emitters, 2016

<table>
<thead>
<tr>
<th>Sector</th>
<th>2016 GHG Emissions (Mt CO₂e)(^a)</th>
<th>2016 Energy Demand (PJ)(^b)</th>
<th>New Solid Biomass Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream Mining</td>
<td>64.2</td>
<td>1,049</td>
<td><strong>Significant.</strong> Approximately 90% of sector emissions associated with oil sands mining and <em>in situ</em> extraction. Solid biomass CHP at <em>in situ</em> projects most likely application.</td>
</tr>
<tr>
<td>Petroleum Refining</td>
<td>15.6</td>
<td>313(^c)</td>
<td>Very limited. Energy consumption dominated by still gas and petcoke. Solid biomass unlikely to be permitted at refineries.</td>
</tr>
<tr>
<td>Iron and Steel</td>
<td>15.1</td>
<td>221</td>
<td><strong>Significant.</strong> 62% of emissions are process and 38% are energy. Solid biomass can displace coke/coal in both these applications (subject to technical constraints on blending percentage).</td>
</tr>
<tr>
<td>Cement Industry</td>
<td>10.0</td>
<td>57</td>
<td><strong>Significant.</strong> 62% of emissions are process and 38% are energy. Solid biomass focus is energy emissions only. Large fuel flexibility.</td>
</tr>
<tr>
<td>Construction</td>
<td>7.1</td>
<td>93</td>
<td>Very limited. Almost all emissions in this sector are diesel fuel for equipment.</td>
</tr>
<tr>
<td>Other Manufacturing</td>
<td>4.9</td>
<td>141</td>
<td><strong>Significant.</strong> Solid biomass opportunity in space heating and process heat/steam generation.</td>
</tr>
<tr>
<td>Chemical fertilizer manufacturing</td>
<td>3.0</td>
<td>66</td>
<td>Very limited. Natural gas used as feedstock and integrated energy production.</td>
</tr>
<tr>
<td>Other Chemical Manufacturing</td>
<td>2.9</td>
<td>90</td>
<td>Very limited. Natural gas used as feedstock and integrated energy production.</td>
</tr>
<tr>
<td>Pulp Mills</td>
<td>2.3</td>
<td>286</td>
<td>Modest. Most pulp mills already large biomass consumers. Natural gas used as supplementary fuel.</td>
</tr>
<tr>
<td>Forestry</td>
<td>2.0</td>
<td>27</td>
<td>Very limited. Almost all emissions in this sector are diesel fuel for equipment.</td>
</tr>
<tr>
<td><strong>Total for ‘Significant’ Opportunities</strong></td>
<td><strong>94.2</strong></td>
<td><strong>1,468</strong></td>
<td>Thermal applications (oil sands extraction, steel, cement, and manufacturing) and carbon source for steel production</td>
</tr>
</tbody>
</table>

---

\(^a\)Excludes electricity-related emissions  
\(^b\)OEE estimates; Note different than NEB reporting and should not be used as comparable; NEB figures approximately double that of OEE; includes energy for electricity  
\(^c\)2013 figures (most up-to-date available)

Figure 5 identifies the potential feedstock types and demand for realization of the ‘Moderate’ Scenario presented in Figure 3.

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### Figure 5. Solid Fuels SWG 2030 Moderate Scenario New Biomass Demand

*Based upon National Energy Board end-use energy demand projections*

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>End-Use</th>
<th>Fuel Demand (Mt)</th>
<th>Fuel Energy (PJ)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wood Pellets (@17.2 GJ/t)</strong></td>
<td>Residential – displace heating oil, propane, and high carbon electricity</td>
<td>2.3</td>
<td>40</td>
<td>Boilers for single and multi-family residential buildings</td>
</tr>
<tr>
<td></td>
<td>Commercial – displace heating oil, propane, and high carbon electricity</td>
<td>1.2</td>
<td>20</td>
<td>Boilers for individual commercial/institutional buildings</td>
</tr>
<tr>
<td></td>
<td>Electricity – displace coal in pulverized coal power plants</td>
<td>9.6</td>
<td>165</td>
<td>2000 MW @ 8,000 hours per year is 16,000 GWh of generation; &lt;30% of current coal-fired generation</td>
</tr>
<tr>
<td><strong>Wood Chips (@11 GJ/t)</strong></td>
<td>Residential – displace all heating fuels with centralized plants &amp; district energy systems</td>
<td>5.9</td>
<td>65</td>
<td>DES for villages, towns, and cities to replace natural gas and other fuels</td>
</tr>
<tr>
<td></td>
<td>Commercial – displace all heating fuels with centralized plants &amp; district energy systems; some single building applications</td>
<td>10.3</td>
<td>113</td>
<td>DES for villages, towns, and cities to replace natural gas and other fuels</td>
</tr>
<tr>
<td></td>
<td>Industrial – displace natural gas for space and process heat</td>
<td>16.5</td>
<td>181</td>
<td>Individual plant needs (e.g., steam) plus space heating and connection to local DES</td>
</tr>
<tr>
<td></td>
<td>Electricity – co-generation of electricity in DES-connected and industrial CHP plants</td>
<td>7.6</td>
<td>84</td>
<td>Electricity co-generation when heat capacity exceeds 5 MW</td>
</tr>
<tr>
<td><strong>Refuse Derived Fuel/Solid Recovered Fuel (@10 GJ/t)</strong></td>
<td>Residential – displace natural gas with centralized plants &amp; district energy systems</td>
<td>4.0</td>
<td>40</td>
<td>DES for cities and large urban areas to replace natural gas</td>
</tr>
<tr>
<td></td>
<td>Commercial – displace natural gas with centralized plants &amp; district energy systems</td>
<td>6.0</td>
<td>60</td>
<td>DES for cities and large urban areas to replace natural gas</td>
</tr>
<tr>
<td></td>
<td>Industrial – displace coal, pet coke, and natural gas for process heat, particularly in cement production</td>
<td>10.0</td>
<td>100</td>
<td>Prioritize displacement of coal and pet coke for largest GHG benefit; high temperature combustion</td>
</tr>
<tr>
<td></td>
<td>Electricity – co-generation of electricity in DES-connected and industrial CHP plants</td>
<td>5.0</td>
<td>50</td>
<td>Electricity co-generation when heat capacity exceeds 5 MW</td>
</tr>
<tr>
<td><strong>Straw and Stover (@15 GJ/t)</strong></td>
<td>Residential – displace all heating fuels with centralized plants &amp; district energy systems</td>
<td>0.7</td>
<td>10</td>
<td>DES for villages, towns, and cities to replace natural gas and other fuels</td>
</tr>
<tr>
<td></td>
<td>Commercial – displace all heating fuels with centralized plants &amp; district energy systems; some single building applications</td>
<td>2.0</td>
<td>30</td>
<td>DES for villages, towns, and cities to replace natural gas and other fuels; SK, AB, MB and southern ON</td>
</tr>
<tr>
<td></td>
<td>Industrial – displace natural gas for space and process heat</td>
<td>4.0</td>
<td>60</td>
<td>Individual plant needs (e.g., steam) plus space heating and connection to local DES</td>
</tr>
<tr>
<td></td>
<td>Electricity – co-generation of electricity in DES-connected and industrial CHP plants</td>
<td>1.3</td>
<td>20</td>
<td>Electricity co-generation when heat capacity exceeds 5 MW</td>
</tr>
<tr>
<td><strong>Biocarbon/Biochar (@30 GJ/t)</strong></td>
<td>Industrial – displace coke and coal for as reductant and in high fuel energy content applications</td>
<td>0.6</td>
<td>18</td>
<td>Primarily for use in steel industry to displace coke; on-site biocarbon production would permit co-generation of heat and power (included in wood chips)</td>
</tr>
</tbody>
</table>

**Total** | 87.0 | 1,056
1.5 Feedstock Supply

Previous analyses completed for Natural Resources Canada have found Canada has more than sufficient sustainable, low carbon biomass feedstock to meet the demands of the ‘Moderate’ Scenario (Figure 6). The ‘High’ Scenario presented in Figure 3, which includes over 2,000 PJ of solid biomass fuels, would require Canada to improve the productivity of its forests by adopting active forest management. This is already practiced in much of Europe and the U.S. and would serve to increase the maximum sustainable harvest volume. Active forest management that seeks to maximize forest productivity and carbon storage in long-lived solid wood products, while supporting forest adaptation to a changing climate and increased wildfire and pest disturbance, is known as ‘Climate Smart Forestry’. Less than 1% of Canada’s forests are considered ‘actively managed’, presenting a very significant opportunity to improve forest productivity and carbon sequestration, thereby offsetting anthropogenic GHG emissions. An alternative source of solid biomass feedstock is biomass crops, such as switchgrass and short-rotation woody crops (SRWC), that are grown for energy purposes. In addition, agricultural crop yield, and by extension crop residue production, trends higher over time.

Figure 6. Moderate Scenario Feedstock Demand Relative to Annual Sustainable Availability

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Moderate Scenario</th>
<th>Sustainable Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tonnes</td>
<td>PJ</td>
</tr>
<tr>
<td>Forest Harvest Residues</td>
<td>13.1</td>
<td>225</td>
</tr>
<tr>
<td>Sustainable Timber Harvest</td>
<td>42.3</td>
<td>460</td>
</tr>
<tr>
<td>Crop Residues</td>
<td>8.0</td>
<td>120</td>
</tr>
<tr>
<td>Solid Waste (for RDF/SRF)</td>
<td>25.0</td>
<td>250</td>
</tr>
<tr>
<td>Total</td>
<td>88.4</td>
<td>1,055</td>
</tr>
</tbody>
</table>

2 INVESTMENT REQUIREMENTS AND GHG REDUCTIONS

The total capital investment and GHG reductions associated with the Solids Fuels SWG ‘Moderate’ Scenario are presented in Figure 7. Although the scenario represents a dramatic acceleration of solid biomass use in Canada and a very significant capital expenditure, the cost is a fraction of that required for electrification approaches that necessitate additional electricity generating capacity, transmission-distribution system re-development, and new electricity use (e.g., heat pump) infrastructure. In general, fuel switching to solid biomass fuels is relatively capital efficient because of the high capacity and operating factor of biomass and the ability to utilize existing infrastructure in many cases (e.g., coal-fired power plants, internal building heating systems). Note that costs associated with development of biomass supply chains are included in the assumed cost of delivered feedstock.

As identified in Figure 7, the average capital cost of GHG reductions is $41/t CO$_2$e and the levelized combined capital and fuel cost of reductions is $58/t CO$_2$e. This shows that many solid biomass fuels are potentially competitive with fossil fuels at a carbon price of $50/t CO$_2$e, which is not necessarily the case for many other alternative fuels and decarbonization options. However, it is also clear that solid biomass fuels have a higher upfront capital cost for utilization than comparable liquid and gaseous fuels and policy changes are required to address the different cost distribution between capital equipment/infrastructure and fuel. As an example, fuel switching from heating oil or high-carbon electricity to wood pellets results in a significant fuel cost savings but homeowners are faced with high upfront capital costs. In contrast, fuel switching from coal and coke to solid

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biomass is amongst the lowest capital cost decarbonization options available but the low cost of coal (and natural gas) increases the all-in cost of reductions relative to capital only.

Figure 7. Total Capital Investment and GHG Reductions for 2030 Moderate Scenario

<table>
<thead>
<tr>
<th>Infrastructure and Equipment</th>
<th>Capacity</th>
<th>Investment ($)</th>
<th>GHG Reductions (Mt CO₂e/yr)</th>
<th>Capital Cost of Reductions ($/t CO₂e)</th>
<th>Capital and Fuel Cost of Reductions ($/t CO₂e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Pellet Boilers</td>
<td>5.1 GWₜh</td>
<td>5.1</td>
<td>2.8</td>
<td>73</td>
<td>2</td>
</tr>
<tr>
<td>Commercial Non-DES Wood Chip/Pellet Boilers</td>
<td>3.8 GWₜh</td>
<td>4.3</td>
<td>1.9</td>
<td>80</td>
<td>-13</td>
</tr>
<tr>
<td>Biomass Combined Heat &amp; Power Plants for DES</td>
<td>4.0 GWₑ, 13.8 GW₁ₜh</td>
<td>32</td>
<td>26.8</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>District Energy Systems</td>
<td>39,000 km</td>
<td>110</td>
<td>Included Above</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>Industrial Biomass Combined Heat and Power Plants</td>
<td>3.2 GWₑ, 11.4 GW₁ₜh</td>
<td>25</td>
<td>27.4</td>
<td>23</td>
<td>47</td>
</tr>
<tr>
<td>Pulverized Coal Boiler Retrofits for Pellet Use</td>
<td>2 GWₑ</td>
<td>1.2</td>
<td>14.0</td>
<td>3</td>
<td>86</td>
</tr>
<tr>
<td>Wood Pellet Production</td>
<td>14.4 Mt</td>
<td>2.9</td>
<td>Included Above</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Biocarbon Production &amp; Use</td>
<td>0.9 Mt</td>
<td>0.9</td>
<td>2.5</td>
<td>17</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>181</td>
<td>75.4</td>
<td>41</td>
<td>58</td>
<td></td>
</tr>
</tbody>
</table>

3 POLICY OPTIONS

3.1 Successful Policies in Other Jurisdictions

Despite Canada having the greatest quantity of solid biomass per capita in the world, the country, outside of the pulp and paper sector, has been relatively slow to adopt modern solid biomass fuel technologies. The reasons for this include a lack of recognition by policy makers of the important role of solid biomass in decarbonization, erroneous beliefs on the air pollutant emissions performance of modern biomass technologies, and the low cost of the primary competitive fuels – natural gas and coal. However, a variety of successful policy measures have been used by other countries and could serve as examples for Canada’s federal policy development.

3.1.1 Sweden – Carbon Pricing

The carbon price in Sweden currently exceeds C$170/t CO₂e, which has a significant impact on the cost of fossil fuels.⁹ This has led municipalities, which often own and operate district energy systems, and industrial heat users to seek low carbon options. Solid biomass has become the dominant source of renewable thermal energy because it is typically the lowest cost low carbon option and delivers the performance attributes (e.g., deployability) required. The cost competitiveness of solid biomass relative to other thermal energy alternatives is particularly apparent when heat demands exceed that of a single-family detached building (e.g., commercial/institutional buildings, multi-family residential, district heating systems).

Canada is currently committed to a carbon price of C$50/t CO₂e in 2022. This is likely inadequate by itself to realize fuel switching from natural gas to solid biomass, although it will certainly make fuel switching from heating oil to solid biomass economically attractive when costs are amortized over the life of equipment. Carbon pricing at C$50/t CO₂e would need to be supported by other, targeted policies, such as those accelerating the development of district energy systems, to drive a significant reduction in domestic natural gas consumption.

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3.1.2 Denmark – District Energy Development

Denmark shows that a high carbon price is not necessary to decarbonize using solid biomass fuels when effective regulations are put in place. With a carbon price reaching only $40/tonne CO₂ as of 2018, Denmark’s bioenergy industry produces three times the amount of energy as wind and solar combined. Most generation is solid biomass-fuelled heat and combined heat and power (co-generation) plants. District energy, which supplies almost 70% of Denmark’s population with heat, is critical to distribution of this large bioheat generation. Fifty municipal-owned companies supply approximately 70% of district heating energy, with the remainder supplied by 340 district heating cooperatives owned by customers. The high penetration of district energy was made possible by the Denmark Heat Supply Act of 1979, which sought to promote the “most socioeconomic and environmentally friendly utilization of energy for heating buildings, supplying them with space heating and hot water and reduce the dependency of the energy system on oil.” The Act was revised in 1990, 2000, 2005, and 2014. Under the Act, the Minister for Energy can mandate building connection to a district heating supply network, ban installation of electric heating in new buildings, ban conversion of heating systems of existing buildings to electric heating, and require co-generation of electricity for heating plants larger than an established threshold. The results of the Act are clear — less than 25% of Denmark’s households have individual heat supply, approximately half of Denmark’s electricity is co-generated with heat, and GHG emissions have dropped dramatically. At the same time, Denmark’s energy security has increased markedly and the country is a leader in export of low carbon energy technologies.

Canada’s heating market is unique when compared with other northern countries; less than 1% of the population receive heat via district energy. In comparison, district heating has a market share of 70% in Russia, 68% in Denmark and Latvia, 55% in Sweden and Finland, and over 20% in Austria. Canada also has no national renewable heating/thermal energy strategy. While historically Canada benefited from natural gas production in Alberta, which was consumed in Ontario and Quebec and exported to the U.S., over 80% of natural gas consumed in these provinces will be supplied by U.S. producers by 2025. Canada needs to look at the example of Denmark as a way forward on decarbonization of the country’s large thermal energy demand.

3.1.3 United Kingdom – Renewable Heat Incentive

The Renewable Heat Incentive (RHI) is a UK Government scheme designed to support fuel switching to renewable heating technologies, including solid biomass boilers, in residential, commercial, and institutional space and hot water heating markets. Similar to an electricity feed-in-tariff, heat production is awarded a guaranteed tariff payment for each unit of energy generated. This tariff is in addition to any other revenue received by a renewable heat generator. The RHI has two streams: domestic, which is focused on residential installations, and non-domestic, which covers multi-family residential, commercial, and institutional buildings. Tariff payments to generators are sourced from the treasury, not a heating fuel rate base. This is because, unlike electricity where renewable tariffs are paid by electricity consumers, it is difficult to spread the costs of renewable heat adoption across a connected network of customers as, in many cases, a thermal network does not exist.

Launched in 2014, the Non-Domestic RHI is now over 5 years old and has made tariff payments of £1.3 billion (C$2.1 billion). There are over 20,000 participants and over 4.5 GW of capacity has been installed. Despite receiving the lowest tariff payment per unit energy, solid biomass boilers represent 86% of installations. Biogas and

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biomethane bring the bioheat total up to 90%. Under the newer, smaller, Domestic RHI, which has made tariff payments of £115 M (C$184 M), air source heat pumps have the greatest number of installations. However, solid biomass boilers have the largest energy generation share of the technologies considered. This is typical for solid biomass – the larger the building and the colder the temperature, and hence the greater the heat demand, the more competitive solid biomass becomes relative to alternatives.

Although payment from the treasury to heat consumers may not be the ideal approach for Canada, it is clear the UK recognized the need for a policy focused exclusively on heat if the country was to effectively decarbonize its energy system. Despite the fact Canadians consume double the amount of energy per capita for space heating of Britons, Canada has no national heat strategy or policy.

3.1.4 Massachusetts – Alternative Energy Portfolio Standard

The Massachusetts Alternative Portfolio Standard (APS) is a market-based policy that provides homeowners and businesses an incentive to install eligible alternative energy systems that lower GHG emissions and increase energy efficiency. Renewable heat producers generate one Alternative Energy Certificates (AECs) per MWh of net useful thermal energy. AECs can be sold to entities in Massachusetts with an APS compliance obligation, thus incentivizing installation and operation of renewable heat technologies such as biomass boilers.

The APS has similarities to the Clean Fuel (CF) Standard, but, unlike the CF Standard, supports end-use fuel switching in thermal applications for creation of compliance credits. Environment and Climate Change Canada can therefore use the APS as a proven model for the liquids and gaseous streams of the CF Standard. The APS policy has provided a powerful incentive for fuel switching from heating oil to wood pellets/chips and other low carbon heating options for GHG reductions, without a need for payments from the treasury. The Government of Canada should look to examples from other jurisdictions, such as Massachusetts, for market-based policy design for decarbonization of space and hot water heating. These demands account for 80% of residential sector energy consumption and should not be grouped in with decarbonization of electricity or transportation.

3.1.5 European Union – EU ETS and Industrial Allowances (developing)

The EU has recognized that decarbonization of electricity, space heating, and transportation is insufficient to meet the GHG targets established for 2030 and 2050. Decarbonization of industry is also required. However, high carbon prices or strict emissions controls on industry are likely to lead to plant closures within the EU and plant openings outside of the EU. Under this scenario, the consumption of goods and global production volume do not change, but production shifts to jurisdictions with lower or no GHG/carbon performance standards. This ‘carbon leakage’ needs to be addressed if industry is to decarbonize on a global basis and if the EU is to retain its industrial production and employment base. To date, the EU has provided 100% of Emissions Trading Scheme (ETS) emission allowances for free to industrial sectors at significant risk of carbon leakage. Free allowances account for approximately 90% of allowances under the current regime.

In July 2019, Ursula von der Leyen, the European Commission’s President-Elect, pledged to put forward a plan to reduce EU GHG emissions by 50% from 1990 levels. This plan would extend the EU ETS, reduce the allocation of free allowances, and impose a border ‘carbon tax’ to avoid leakage. A border carbon tax has never been implemented and is likely to face opposition from trading partners.

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Canada’s large industrial emitters, including steel and cement producers, are subject to the same carbon leakage risk as EU producers. As such, if Canada moves forward with more aggressive GHG emissions requirements for heavy industry under the CF Standard, the Government of Canada must also consider options for border tariffs/taxes on high carbon imports – particularly in the steel and cement sectors. Canada may want to collaborate with the EU as it develops its own border carbon tax to ensure regulatory consistency. As a smaller market and producer, Canada may benefit from following the lead of the EU.

3.2 Solid Fuel SWG Position on the Clean Fuel Standard

As currently designed, the CF Standard will drastically limit the GHG reductions from solid biomass fuel consumption relative to the potential decarbonization contribution of these fuels. Whereas Navius modelling of the CF Standard found a potential solid biomass fuel contribution of approximately 1 Mt CO₂e/yr, the reality is solid biomass fuels could readily deliver the full 30 Mt CO₂e/yr CF Standard reduction goal and more via end-use fuel switching in gaseous and liquid (stationary) classes. Solid biomass fuels can also do so for lower cost than assumed renewable diesel, renewable natural gas, and electrification compliance options. The CF Standard design generally assumes that gaseous fuels will be primarily displaced with other gaseous fuels and liquid fuels will be primarily displaced with liquid fuels or electricity. The policy is not designed to capture the significant opportunity in end-use fuel switching from gaseous or liquid fossil fuels to solid biomass in stationary thermal applications, despite this being by far the most efficient approach and widely adopted in the EU. The largest potential GHG reduction contribution of solid biomass in Canada is displacement of natural gas and heating oil in space and process heat applications. While solid biomass has an important role to play in displacement of coal and coke in steel and cement production operations, the energy content of solid fuels consumed in Canada is dramatically smaller than that of natural gas. Artificially limiting the contribution of solid fuels to national GHG reductions due to faulty policy design does not make sense.

The exclusion of coal-fired power plants from the CF Standard means existing plants are unlikely to fuel switch to solid biomass (e.g., pellets) from coal, despite this being the primary approach for reducing GHG emissions from similar plants in Europe. Federal and provincial policy has been designed to encourage fuel switching from coal to natural gas, which is only a temporary stop-gap measure and is inconsistent with the aggressive decarbonization required for Canada to meet its 2030 Paris Agreement commitments. Due to the technology design, firing natural gas in steam-driven pulverized coal power plants is highly inefficient and should not be encouraged. Power plants currently burning coal should be subject to the same GHG reduction requirements as other solid fossil fuel burning facilities in the 2023-2030 period.

The inclusion of solid fuels in the CF Standard, when additive to carbon pricing (Output Based Pricing System), will result in a high risk of carbon leakage in the steel and cement sectors. Canadian producers will be placed at an economic disadvantage in Canadian markets relative to U.S. and foreign producers with lower (or non-existent) GHG reduction requirements. Therefore, should Environment and Climate Change Canada proceed with solid fuel (coal, coke) inclusion in the CF Standard, it is essential the Government of Canada pursue implementation of an equivalent carbon performance standard for steel and cement products consumed in Canada. This must include a carbon levy/tax placed on imports to the Canadian marketplace so that Canadian producers are not disadvantaged. If not, Canada may need to follow the EU ETS (and OBPS) example and provide compliance credits for no cost to trade-exposed large emitters, thus eliminating the purpose of the CF Standard.

4 Barriers to Investment in Canada

The barriers to investment in solid fuel production, utilization, and energy distribution are primarily economic and political in nature. While there are some technical challenges associated with biocarbon production and displacement of coke as a reductant in steel production, thermal energy technology readiness and commercial
viability is not a barrier to investment. As noted above, solid biomass heating dominates the EU renewable heating and cooling market and the amount of energy generated by solid biomass heating is equal to all renewable electricity generation, including hydropower, combined. Clearly, clean, low carbon solid biomass space and hot water technologies are widely available and can be deployed in Canada at scale in a short time period if policy and economic conditions permit.

The following is a brief summary of the barriers to investment in solid fuel utilization and resulting energy distribution. Although fuel production is not a significant technical challenge, solid fuel producers face challenges accessing feedstock in some regions due to policy restrictions.

4.1 Low Cost Natural Gas for Building and Industrial Heat

Natural gas is the dominant thermal fuel in Canada. The contribution of natural gas to total fuel consumption is only slightly less than that of refined petroleum products and demand for natural gas is anticipated to exceed refined petroleum products (RPP) by 2030.\(^{18}\) While natural gas has a lower carbon intensity (CI) than RPPs when using a 100-year Global Warming Potential (GWP) metric, it actually has a CI higher than many RPPs when using a 20-year GWP. However, despite the large climate impact of Canada’s increasing natural gas consumption and the need to dramatically reduce natural gas consumption in order to meet Paris Agreement commitments, carbon pricing at $50/t CO\(_2\)e is unlikely to lead to fuel switching away from natural gas. This is because natural gas, in most of Canada, is so much lower cost than alternatives, especially when focusing on the cost of gas itself rather than the regulated pipeline distribution and transmission rates. Additional policies beyond $50/t CO\(_2\)e are required to make solid biomass fuels cost competitive with natural gas in Ontario, Quebec, and the western provinces. Nevertheless, solid biomass is the lowest cost low carbon heating option in most applications and policy support needs are modest compared to other thermal energy alternatives (e.g., heat pumps).

4.2 Lack of District Energy System Infrastructure

In urban areas, district energy system infrastructure is absolutely essential for solid biomass heating. It is simply not feasible, nor desirable, to deliver solid biomass to every building. Underground DES’ deliver the heating (or cooling) generated by solid biomass combustion. Therefore, DES’ are enabling infrastructure for solid biomass space and hot water heating. Without DES infrastructure in place, the heat market share for solid biomass fuels will be drastically constrained. Unfortunately, Canada is a standout amongst northern countries for lack of DES infrastructure. Less than 1% of the Canadian population is connected to a DES. In comparison, DES has a market share of over 90% in Iceland, 70% in Russia, almost 70% in Denmark, 55% in Sweden and Finland, and over 20% in Austria. Given the per capita heat demand of Canada is double that of the US or UK, these countries are not appropriate comparators (and Canada still lags these countries by several percentage points). Canada needs a dramatic DES build-out to decarbonize the building sector. DES allows the adoption of low carbon heating resources including biomass, waste heat (via heat pumps), geothermal, and solar thermal.

4.3 Limited Participation of Municipalities in Energy Infrastructure

In most European countries, DES’ are owned in whole or in part (public private partnerships) by municipalities. It is logical for a municipality already owning/operating potable water and wastewater systems to also operate a DES distributing heat using hot water. The additional income associated with heat sales supports the financial position of municipalities, promotes urban density, and places a large emphasis on utilization of local fuels and resources – thus encouraging local economic development. Canadian municipalities have historically not played a significant role in thermal energy systems despite many larger municipalities owning and operating electricity distribution systems. If Canada is to realize the DES build-out required for decarbonization of the building sector,

municipalities must play a leading role as heat utility owners and operators. This could be accomplished using public-private partnerships for development, with the private sector supplying the majority of capital required for build-out.

4.4 No Incentive for Power Plants to Choose Biomass over Natural Gas

Canada exports over 3 million tonnes of wood pellets per year to displace coal in European and Asian pulverized coal power plants yet consumes no pellets domestically for this purpose. With exceptions in Atlantic Canada, Canadian policy necessitates all coal-fired power plants cease operations by 2030 or fuel switch to a lower carbon fuel. Despite the large volume of wood pellets produced in Alberta and British Columbia, all coal-fired power plants in Alberta and Saskatchewan that plan to operate post-2029 are anticipated to fuel switch to natural gas. Since pulverized coal power plants are designed to consume a solid fuel and are single cycle, combustion of natural gas in these plants is low efficiency and only results in modest GHG reductions. In contrast, replacing coal with wood pellets reduces GHG emissions by over 85% on a life cycle basis. However, the four prairie coal-fired power plant owners – Capital Power, TransAlta, ATCO, and SaskPower – have been provided no incentive or requirement to fuel switch to low carbon fuel. In fact, generators in Alberta have been financially compensated by the provincial government for switching to natural gas. The lack of fuel switching to low carbon biomass fuels is an absolute lost opportunity. The situation is even more extreme in Nova Scotia and New Brunswick due to the much higher cost of coal in those provinces, a lack of natural gas access for most of the plants, and a lack of markets for low-grade wood fibre. The provinces are also planning to keep coal-fired plants open post-2029 by realizing GHG reductions in other sectors that are equivalent to shutting down the plants.

4.5 Long Cost Recovery Period for Residential Solid Fuel Heating Equipment

Over the 25-30 year life of a wood pellet boiler, the all-in cost of heat energy is typically lower than heating oil. However, the capital cost for a wood pellet boiler is much higher than comparable heating oil or propane boilers/furnaces. The savings comes from the lower cost of pellet fuel when compared to heating oil. A homeowner would realize cost savings over 25 years. However, homeowners do not typically stay in their residence for the life of a pellet boiler, making recovery of the upfront capital costs highly uncertain. A mechanism or policy is required to reduce the upfront costs of a wood pellet boiler for homeowners if widespread adoption is to occur. The CF Standard could provide a significant opportunity for market-based financial support for wood pellet boilers, but only if the current draft of the policy is altered to permit end-use fuel switching in stationary liquid and gaseous fuel classes.

4.6 Canadian Political Prioritization of Electrification

Despite the dominance of solid biomass heating in Europe, the fact that bioenergy accounts for over 60% of renewable energy in the EU, and Canada’s enviable status as the country with the most solid biomass per capita, Canada’s politicians have failed to encourage the use of solid biomass fuels. Investors are unlikely to allocate significant capital to solid biomass fuel utilization and energy distribution in Canada without clear and public support by Canada’s political leaders. Many politicians have endorsed electrification, sometimes with very little consideration of the costs or technical viability, but few to none in Canada have been outspoken champions for solid biomass thermal applications. If Canada is to realize low-cost thermal GHG reductions, Canada needs political champions for solid fuels.

4.7 Clean Fuel Standard Design to Address Industry Carbon Leakage

Solid biomass fuels offer significant potential for decarbonization of large industrial emitters, such as the steel, cement, and oil sands sectors. However, apart from waste-based fuels, solid biomass fuels are typically higher cost than the coal or natural gas they can displace. Companies producing globally-traded commodities have very
limited ability to absorb higher fuel or input costs and still remain competitive. Enhancing carbon reduction requirements of Canada’s largest industrial emitters without addressing carbon leakage may lead to carbon reductions in Canada due to plant closure but will not reduce global GHG emissions. This is reflected in the Output Based Pricing System design. However, a mechanism for ensuring Canada’s large emitters – steel and cement producers in particular – remain competitive under the CF Standard by limiting imports of high-carbon competitive products and properly valuing the lower carbon intensity of Canadian-produced products is essential for industrial decarbonization.

4.8 Climate Policy Instability

The lack of bi-partisan support for climate policies, such as carbon pricing, continues to impede investment in all low carbon fuels. The fact that climate policies have pitted left vs. right and urban vs. rural means investors face great uncertainty every four years – and every two years, when provincial elections are considered. Part of the problem lies with politicians that have presented very few GHG reduction solutions beyond electrification of transportation and heating. These are not practical solutions in many regions in Canada and, in some provinces such as Nova Scotia, Alberta, Saskatchewan, and New Brunswick, electrification will actually increase GHG emissions. Solid fuels can provide the dramatic GHG reductions desired by climate change policy advocates, while creating a dramatic number of jobs in forest management, forest operations, agriculture, fuel production, fuel logistics, energy plant operations, district energy system engineering, pipefitting, and other fields. This job creation opportunity, which is tied to managing and processing carbon-based fuels and distributing thermal energy via extensive piping networks, should garner bi-partisan support for solid biomass fuels.

4.9 Feedstock Supply Chains, Risk, and Access

Canada is the undisputed world leader in certification of sustainably managed forests. Of the world’s forests certified as sustainably managed, 38% are located in Canada. Approximately 94% of Canada’s forests are publicly owned, with 90% of those publicly-owned forests under provincial/territorial jurisdiction.19 Unfortunately, Canada’s leadership in sustainability and public ownership approach have not readily led to forest feedstock access for low carbon energy project developers, and by extension, development of solid fuel supply chains. Existing tenure agreements with forestry companies must not limit the access of solid fuel supply chain operators to unutilized, fuel-grade feedstocks. Solid fuels are an attractive market opportunity for low-grade wood, which enables primary forest products (e.g., lumber) production. Urban wood and used wood (end of life wood products) are also viable resources for solid fuels and their use aids development of a circular bioeconomy while reducing landfilling. Significant investment in forest and agriculture feedstock supply chains, including preprocessing, handling, storage, and transportation equipment and infrastructure, will be required to deliver on the large energy and GHG reduction potential of solid fuels. There is also a need for mechanisms to de-risk these feedstock supply chains and their impact on the cost of capital for associated energy projects. Higher perceived feedstock risk results in a higher cost of capital, which can derail promising projects. Mechanisms that lower feedstock risk for investors drive capital into these projects and support demand for solid fuels.

5 RECOMMENDATIONS TO THE GOVERNMENT OF CANADA

Listed below are the Clean Fuel Steering Committee Solid Fuels SWG policy recommendations to the Government of Canada. Adoption of these recommendations would dramatically accelerate the use of solid fuels in Canada.

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Leading Recommendations

1. **Develop a Thermal Energy Decarbonization Strategy for Canada**
Thermal energy demand in Canada significantly exceeds that of electricity and the average carbon intensity of thermal energy is notably higher than that of electricity. Canada should develop a national strategy for decarbonization of thermal energy, including space and hot water heating, process heat (and reductants, where applicable), and existing pulverized coal power plants. This strategy should take into consideration the all-in costs of thermal energy options and the ability of those energy options to complement decarbonization in other sectors, such as transportation. As an example of strategy precedent, Scotland has a Renewable Heat Strategy.

2. **Establish a $35 B, 10-year Infrastructure Fund for District Energy System Development**
Funding would be allocated to municipalities to participate as equity partners in district energy systems. It is envisioned that institutional capital (e.g., pension funds) would constitute the bulk of matching private sector capital and that public funding would cover approximately 1/3 of total capital costs. The Federation of Canadian Municipalities, which has already funded DES projects via the Green Municipal Fund, could be a delivery agent for the Government of Canada. Of the $160 B Investing in Canada Infrastructure Program, $9.2 B has been allocated to Green Infrastructure and this could be increased and targeted at DES. Partnership with the Canada Infrastructure Bank, which has been allocated $5 B for Green Infrastructure and could lend to private partners at a preferable rate, is strongly recommended.

3. **Permit End-Use Fuel Switching in the Clean Fuel Standard**
It is essential that ECCC enables low-cost compliance for the Clean Fuel Standard. This means permitting end-use fuel switching to solid fuels for stationary applications in gaseous and liquid fuel classes. Permitting end-use fuel switching would create a mechanism for financing wood pellet and wood chip boilers via the creation of compliance credits. This is an approach to replace fossil fuel furnaces and boilers that does not require taxpayer grant funding. The policy design could be very similar to that already designed for end-use fuel switching in transportation applications in the liquid fuel class.

4. **Use Public Procurement to Kick-Start Solid Fuel Supply Chains**
Heating buildings is responsible for over 60% of the Government of Canada’s GHG emissions. Unfortunately, PSPC and DND have been slow to adopt solid biomass heating due to Treasury Board Secretariat concerns regarding international (IPCC) carbon accounting protocols. The leading Government of Canada solid biomass fuel opportunity is Canada’s 27 Canadian Forces Bases; heating these bases is responsible for approximately 50% of inventory emissions, they are primarily located in rural, forested regions, and most already have district energy systems in place. Procurement of bioheat by the Governments of Prince Edward Island, New Brunswick, and the Northwest Territories has been highly successful.

Sub-Sector Specific Recommendations

5. **Prohibit Low-Efficiency Natural Gas Electricity Generation**
Canada’s existing regulation for the phase-out of coal-fired electricity generation, SOR/2012-167 (Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations), should be amended to prohibit all electricity generation from gas that does not meet an emissions performance of 420 g CO₂e/kWh by 2030 (i.e., eliminate temporary exemption provisions). Carbon intensity performance standards for coal-fired plants in the 2021 to 2029 period should also be implemented. This would establish a rapidly increasing demand for wood pellets for co-firing.
6. **Introduce Carbon Performance Standards for Steel and Cement**

While the cement and steel sectors will be subject to the CF Standard for the solid fuels they consume, the end products they produce will not be subject to the CF Standard. This could result in an uncompetitive position for Canada’s steel and cement producers and, eventually carbon leakage due to imported steel and cement displacing domestic product. Establishing carbon performance standards for domestically-consumed steel and cement consistent with the CF Standard carbon intensity requirements is essential to prevent carbon leakage. Canada may consider alignment with EU rules and a border ‘carbon tax’.

**Feedstock Recommendations**

7. **Incentivize Climate Smart Active Management of Canada’s Forests**

Canada has 0.5% of the world’s population and produces 2% of the world’s anthropogenic GHG emissions. However, it is home to 10% of the world’s forests and stores 12% of the world’s terrestrial carbon in the boreal forest. Ensuring Canada’s forests are managed to increase productivity, minimize wildfires, and maximize carbon storage in timber and long-lived solid wood products should be Canada’s primary climate responsibility. Solid biomass fuels can support this ‘Climate Smart’ active forest management by providing a market for poor quality, low vigour, and damaged timber that may be at wildfire risk or inhibits growth of healthy trees. As forests are largely public-owned, governments have a responsibility to ensure forests are managed on behalf of the public. A $2 B/yr fund, which represents only 1/5 of the costs of the Fort McMurray Wildfire, should be established to support active management of Canadian public forests.

8. **Include Black Carbon Emissions from Wildfires and Slash Pile Burning in Canada’s NIR**

Black carbon (soot) is a short-lived climate pollutant that is found in fine particulate matter (PM$_{2.5}$) emissions. By far the largest sources of black carbon emissions in Canada are forest wildfires and slash pile burning. Combusting biomass in an advanced energy facility can reduce black carbon emissions by 99.995% compared to open burning. The climate impact of wildfire and slash pile burning may be greater than Canada’s GHG emissions on a 20-year basis. Canada should follow the example of several countries and include black carbon emissions in Canada’s National Inventory Report. This should lead to valuation of avoided black carbon emissions, which would incentivize investment in solid fuel energy projects.

9. **Ban Landfilling and Export of Waste and Recyclable Plastics**

Several European countries, including Sweden, Denmark, and the Netherlands have banned landfilling of solid waste. Canada, in partnership with the provinces, should follow this example to reduce methane emissions. To ensure Canada’s waste and plastics are not exported to developing countries, a ban on exports (at least to countries other than the U.S.) should also be enacted. This would force Canada to deal with its waste problem via construction of best-in-class, clean, waste-to-energy plants. As in many European cities, these plants would provide heat and electricity to the urban areas where the waste is generated.

10. **Support Capital Market-Based Initiatives for Biomass Feedstock Supply Risk Mitigation**

Developing and de-risking biomass supply chains is essential to financing solid biomass fuel energy projects at a competitive cost of capital. Initiatives to establish fuel supply chain infrastructure and decrease capital market barriers to investment should be supported by governments, particularly for Canada’s public-owned forest resources. Integration of a risk ratings protocol with the Canadian Standards for Biomass Supply Chain Risk (BSCR Standards) could help reduce the cost of capital, while serving as the basis for development of other feedstock de-risking instruments including insurance and hedging mechanisms.

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20 Assumes 236,000 t/yr of black carbon emissions and a 20-year GWP of 3,200 (Bond et al., 2013. Bounding the role of black carbon in the climate system: A scientific assessment. JGR Atmospheres)
6 ANNEX: ASSUMPTIONS FOR INVESTMENT & GHGS

Estimates of the total capital investment requirement to meet the ‘Moderate’ scenario energy generation presented in Figures 3 and 5 are described below. Note that fuel cost differentials do not include carbon pricing or Clean Fuel Standard compliance costs/credits.

6.1 Residential Wood Pellet Heat Boilers

Total Capital Investment: $5.1 B
Annual GHG Reductions: 2.8 Mt CO\(_2\)e
Capital Cost of Reductions: $73/t CO\(_2\)e
Total Cost of Reductions: $2/t CO\(_2\)e

Assumptions:
- Capital cost: $1000/kW ($278/MJ/hr)
- Capacity factor: 25%
- Approximately 255,000 households @ 20 kW average
- Total installed capacity: 5.1 GW or 5,100,000 kW
- Fuel Savings: $5/GJ
- Equipment lifetime: 25 years

6.2 Commercial/Institutional Non-DES Wood Chip/Pellet Heat Boilers

Total Capital Investment: $3.8 B
Annual GHG Reductions: 1.9 Mt CO\(_2\)e
Capital Cost of Reductions: $80/t CO\(_2\)e
Total Cost of Reductions: -$13/t CO\(_2\)e

Assumptions:
- Capital cost: $1,000/kW ($278/MJ/hr)
- Capacity factor: 25%
- Total installed capacity: 3.8 GW or 3,800,000 kW
- Fuel Savings: $6/GJ
- Equipment lifetime: 25 years

6.3 Central Biomass Combined Heat and Power Plants (DES-connected)

Total Capital Investment: $32 B
Annual GHG Reductions: 26.8 Mt CO\(_2\)e
Capital Cost of Reductions: $30/t CO\(_2\)e

Assumptions:
- Capital cost: $1800/kW (gross thermal)
- Heat:Power ratio: 3.5
- Capacity factor: 65%
• Total installed capacity: 13.8 GW (net thermal); 17.8 (gross thermal)
• Total installed electrical capacity: 4.0 GW
• Electricity generation displaces natural gas generation
• No change in average delivered fuel cost (consideration of tipping fees for waste)
• Equipment lifetime: 40 years

6.4 District Energy Systems

Total Capital Investment: $110 B (75% is allocated to bioheat)

Annual GHG Reductions: None (enabling infrastructure for energy distribution)

Capital Cost of Reductions (DES bioheat capital contribution): $52/t CO₂e

Capital Cost of Reductions (DES + Central Energy Plants): $82/t CO₂e

Assumptions:

• Average urban population density (for DES) of 4,000/km²
• DES average network density of 0.25 people per meter DES line
• 20 km of DES pipeline per km²
• Average peak load per person of 5 kW (includes residential & commercial/institutional use)
• Average peak load energy density 20 MW/km²
• Full load equivalent hours of energy demand: 2,500
• Solid biomass provides 75% of DES energy supply
• Total network area: 1,940 km² (~3x area of City of Toronto)
• Total installed DES length: 39,000 km (Enbridge Ontario gas distribution network is 83,000 km)
• Average installed DES pipeline cost: $1,800/m
• DES energy transfer station cost: $5,000 per person (~$12,000 for single family detached home)
• DES lifetime: 60 years

6.5 Industrial Biomass Combined Heat and Power Plants

Total Capital Investment: $25 B

Annual GHG Reductions: 27.4 Mt CO₂e

Capital Cost of Reductions: $23/t CO₂e

Total Cost of Reductions: $47/t CO₂e

Assumptions:

• Capital cost: $1,700/kW (gross thermal)
• Heat:Power ratio: 3.5
• Capacity factor: 85%
• Total installed capacity: 11.4 GW (net thermal); 14.6 GW (gross thermal)
• Total installed electrical capacity: 3.2 GW
• Increase in fuel cost of $2/GJ (consideration of tipping fees for waste)
• Equipment lifetime: 40 years
6.6 **Pulverized Coal Power Plant Retrofits**
Total Capital Investment: $1.2 B  
Annual GHG Reductions: 14.0 Mt CO$_2$e  
Capital Cost of Reductions: $3/t CO$_2$e  
Total Cost of Reductions: $86/t CO$_2$e

**Assumptions:**
- Pulverized coal power plant (including storage) retrofit cost: $600/kW
- 2,000 MW coal-fired power plant conversion
- Increase in fuel cost of $7/GJ
- Equipment lifetime: 25 years

6.7 **Wood Pellet Production**
Total Capital Investment: $2.9 B  
Annual GHG Reductions from Pellet Use: 15.6 Mt CO$_2$e (included above)  
Capital Cost of Reductions: $9/t CO$_2$e (all-in pellet cost included in fuel costs above)

**Assumptions:**
- $200/t annual capacity
- 85% capacity factor
- 1 Mt of current capacity allocated to Canadian markets
- 14.4 Mt of additional capacity added

6.8 **Biocarbon Production**
Total Capital Investment: $860 M  
Annual GHG Reductions from Biocarbon Use: 2.5 Mt CO$_2$e  
Capital Cost of Reductions: $17/t CO$_2$e  
Total Cost of Reductions: $40/t CO$_2$e

**Assumptions:**
- $1,000/t annual capacity
- 70% capacity factor
- 860,000 t of new capacity by 2030
- Equipment lifetime: 20 years
- Biomass feedstock: $120/bdt, 35% biocarbon yield
- Coking coal: $190/t, 75% coke yield