Canadian Council of Ministers of the Environment
Le Conseil canadien des ministres de l'environnement

GUIDANCE MANUAL ON MANAGING AIR EMISSIONS FROM SMALL SOLID BIOMASS COMBUSTORS

PN 1631
ISBN 978-1-77202-081-6 PDF

NOTES TO THE READER

The Canadian Council of Ministers of the Environment (CCME) is the primary minister-led intergovernmental forum for collective action on environmental issues of national and international concern. The 14 member governments work as partners in developing nationally consistent environmental standards and practices.

CCME would like to thank ENVINT Consulting, Canadian Biomass Energy Research Ltd., and Aigner Energie Contracting GmbH for their contributions to the development of this document.

PREFACE

This guidance manual is meant to provide key principles and options for managing air emissions from small solid biomass combustors (SSBCs) in Canada. An SSBC is defined as any wood combustor between 50 kW and 5 MW of thermal output intended for multi-unit residential, commercial or institutional, or small industrial applications. These limits are not absolute, because some applications require slightly larger or smaller sizes and are still within the scope of this manual. Small wood combustors, such as those used in single-family homes, are excluded from the scope. Cogeneration units are not included in the scope, but air heaters (furnaces) and hydronic heaters (boilers) are. The focus is strictly on wood fuels that conform to the specifications in the CAN/CSA-ISO 17225 standard series (grades A and B). Agricultural and other biomass-derived fuels are not considered.

This manual distinguishes between three size classes based on thermal output: those up to 150 kW, those between 150 kW and 1 MW, and those larger than 1 MW. Those with a nominal output capacity of less than 150 kW are covered by CSA standard B415.1 or the European standard EN 303-5. The next class size up is that of package boilers with up to 1 MW thermal output. These are well covered by European standard EN 303-5. Units above 1 MW are mostly custom-built boilers, for which no standard exists. Instead, this manual proposes a set of rules. The key approach to regulating emission from SSBCs is mandating that equipment be compliant with existing technical standards and that only fuel that meets vendor specifications and the specifications of Canadian wood fuel standards be burned. There are different air emission reporting standards related to in-stack air emission limits (e.g., reference temperature, oxygen level, etc.) across jurisdictions and technologies. Readers are advised to consult with their jurisdictional federal, provincial or territorial authority regarding the applicable air emission reporting standards of interest for in-stack air emission limits.

This manual offers a three-tier approach with stricter rules at higher-tier levels. Tier 1 is most suitable for rural and northern communities with low population density; tier 2 applies to more densely populated areas or those with sporadic air quality concerns; tier 3 is meant for larger urban agglomerations and areas that already experience high pollution levels. Environmental regulators can choose the appropriate air emission management strategy to meet the requirements of the local situation.

Figure 1 Basic Regulatory Approach Taken for SSBCs

	SSBCs - 50 kW to 5 MW_{th}		
Size classes	Small SSBCs <150 kW_{th}	Package SSBCs 150 - 1,000 kW_{th}	Custom SSBCs >1000 kW_{th}
Reference standards	CSA B415.1-10	EN 303-5	n/a
Emissions regulated	PM	PM, CO	PM, CO, NOx
Permitting mechanism	Model permit	Model permit	Permit based on uniform criteria

Readers are advised to confirm and refer to the latest version of the technical standards for equipment and fuels developed by CSA, US EPA, EN or ISO. At the time of writing this guidance manual, the CSA standard B415.1-10 “Performance testing of solid-fuel-burning heating appliances”, which was published in 2010 and reaffirmed in 2015, is under review and a new version is expected to be published in 2021. Similarly, a revised EN 303-5 standard is expected to be published in 2021. ISO 17225 series solid biofuels standards are likewise reviewed every five years; updated versions are under development and are likely to be published in 2021.

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GLOSSARY AND ACRONYMS

CAAQS	Canadian Ambient Air Quality Standards
CAC	Criteria air contaminant
CAN/CSA-ISO	A National Standard of Canada adopted by CSA from ISO
CO	Carbon monoxide
CSA	Canadian Standards Association
EN	European Norm
Flue gas cleaning equipment	Post-combustion (secondary) cleaning, i.e., any filtering or air contaminant removal equipment
ISO	International Organisation for Standardization
Moisture content (wet basis)	Percentage of water in biomass relative to its total mass content (completely dry plus water)
N_2	Nitrogen gas
Nominal	Rated (heat output), as defined on the boiler plate (maximum output may exceed nominal output)
NO	Nitric oxide
NO_X	Oxides of nitrogen, primarily NO and NO_2
NO_2	Nitrogen dioxide
O_2	Oxygen gas
PM	Particulate matter, meaning solid and liquid particles suspended in flue gases
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than 2.5 microns (µm)
SCR	Selective catalytic reduction
SSBC	Small solid biomass combustor, i.e., biomass-fuelled boilers and furnaces for applications larger than residential size, such as single detached homes, but smaller than industrial size
US EPA	United States Environmental Protection Agency
VOC	Volatile organic compound

UNITS AND CONVERSIONS

°C	Degree Celsius, sometimes referred to as Centigrade
% wt.	Percent based on weight; the mass fraction of a chemical, such as nitrogen, divided by the total mass of all chemical components
GJ	Gigajoule, an energy unit. 1 GJ is 1 billion Joules (J); 1 J = 1 Ws (Watt second). 1 GJ = 3.6 MWh = 0.94 MMBtu. To convert GJ to MWh, multiply by 3.6. To convert MWh to GJ, divide by 3.6. 1 GJ is equal to slightly more than the energy content of two propane cylinders like the ones used on most gas barbeques. 1 GJ is equal to the energy content of 28 litres of gasoline (at 20°C).
kg	Kilogram; 1 kg = 2.2 lb
kPa	KiloPascal; 1 kPa = 1,000 Pa = 0.145 PSI
kW	Kilowatt, a power or capacity measurement unit. 1 kW = 1,000 W
kWh	Kilowatt hours, an energy measurement unit
m^3	Cubic metre
mg	Milligram
mg/sm^3	Milligram per standard cubic metre; a unit of concentration of a pollutant in flue gases, corrected to 101 kPa and 20°C
MJ	Megajoule, an energy unit. 1 MJ is 1 million Joules (J); 1 J = 1 Ws (Watt second) 1 MJ = 3.6 kWh = 0.94 MMBtu. To convert MJ to kWh, multiply by 3.6. To convert kWh to MJ, divide by 3.6.
MMBtu	One million British Thermal Units
MW	Megawatt, a power or capacity measurement unit. 1 MW = 1,000 kilowatts (kW) = 1,000,000 W
MWh	Megawatt hours, an energy measurement unit. 1 MWh = 1,000 kilowatts for one hour (kWh)
MWth	Megawatt thermal, indicating thermal capacity rather than electric power
PSI	Pound-force per square inch; 1 PSI = 6.89 kPa
sm^3	Standard cubic metre, the volume of a (flue) gas at standard conditions

KEY PRINCIPLES

The following key principles are intended to guide the development of approaches to managing air emissions from SSBCs in Canada.

1. Minimize impact of air emissions from small solid biomass combustors on human health and the environment.

According to the World Health Organization, air pollution represents the single largest environmental risk to human health. SSBCs can be a significant source of air pollutants, such as fine particulate matter ($PM_{2.5}$), that can lead to health issues such as asthma attacks, chronic bronchitis and increased risk of heart attack. However, modern SSBC technology incorporates consideration of the quality of solid biomass fuel, combustion chamber design and emission control technology that can greatly reduce air emissions. The adoption of cleaner-burning solid biomass fuel and automated combustion technology will help jurisdictions ensure that the Canadian Ambient Air Quality Standards (CAAQS) for $PM_{2.5}$ are not exceeded and can help reduce other air pollutants such as polycyclic aromatic hydrocarbons.

2. Enable consistent Canada-wide use of cleaner small solid biomass combustion technology.

Significant advancements have occurred over the last decade in both the design of SSBCs and improved standards for solid biomass fuel. These advancements have led to near-complete combustion and a significantly cleaner emissions profile from SSBCs. Canada-wide guidance that recognizes these developments will assist jurisdictions to develop policy, guidance and regulations that effectively manage air emissions from this sector. In addition, manufacturers and importers of SSBCs have expressed support for consistent technology standards across Canada for both solid biomass fuels and combustors to facilitate streamlined approvals and permitting processes.

3. Support the implementation of standards for solid biomass fuels and small solid biomass combustors in order to minimize air emissions.

High-quality solid biomass fuels simplify the achievement of low air emissions when using SSBCs. However, lower-quality solid biomass fuels can also be combusted cleanly if sufficient attention is given to combustion chamber design and process and emissions control. Recognizing the interplay of fuel quality, combustion chamber design and emissions control can encourage the use of high-quality solid biomass fuels, while still allowing SSBCs to burn lower-quality solid biomass fuels in certain situations.

4. Enable reductions in GHG emissions.

Biomass is increasingly being considered as a cost-saving energy solution, particularly in communities not served by natural gas. Depending on the source of the solid biomass fuel, reductions in greenhouse gas emissions may be achieved by switching from fossil fuels to sustainably sourced solid biomass fuel. SSBCs may also enable the beneficial use of low-value wood fibre that would otherwise be open-burned or landfilled.

1.0 INTRODUCTION

Biomass or wood combustors are seeing a renaissance in Canada, partly for ecological reasons, partly due to the lower cost of woody biomass fuel. Biomass is considered a low-carbon fuel, reducing lifecycle greenhouse gas emissions when compared to fossil fuels. Biomass combustors also use a local rather than an imported resource, thereby stimulating local economic development. Despite all these advantages, however, biomass combustors are perceived as polluting, and as creating more local air emissions than most gas- or oil-fired heating devices.

Recent advancements in biomass combustion technology and wood fuel quality standards make it possible to minimize both global greenhouse gas and local air pollutant emissions. This guidance will assist Canadian provincial and territorial jurisdictions in effectively managing air emissions from SSBCs.

1.1 Background

Winter smog and reduced ambient air quality from biomass combustion during the heating season has been a matter of concern in larger urban agglomerations and in communities where topography and meteorology combine to trap pollutants and lead to high local air pollutant concentrations. In order to improve air quality, some jurisdictions have outlawed all wood-burning appliances, while others have banned outdoor wood heaters in particular due to their high pollutant emissions.

Modern wood-burning units have increased in sophistication. Relative to older units, they have better combustion controls and feature designs more conducive to the complete burnout of the fuel. Commercial-size boilers often have automatic controls that govern the combustion process, including fuel input rate, two-staged combustion and flue gas oxygen monitoring that make it possible to optimize the amount of combustion air while keeping combustion temperatures high. Some modern units include secondary flue gas controls to further reduce emissions. In addition, wood fuel qualities have been standardized in the past few years. It is now easier to identify the fuel parameters for which the combustor is designed. Lastly, suppliers have started to employ best design practices that help minimize emissions.

The regulatory framework for small- to medium-scale wood combustion and gasification units[1] in Canada is patchy, partly due to the split jurisdictional responsibilities for energy and air pollution. Regulations even differ regionally, where special meteorological conditions exist (e.g., the Prince George area in British Columbia), or sub-regionally, with Metro Vancouver and Montreal having their own policies. Many municipalities have bylaws pertaining to wood combustion units.

This guidance manual is based on a regulatory and policy scan that identified current policies and regulatory approaches to permitting SSBCs in Canada, Europe and the United States. It also integrates feedback received from stakeholders after a webinar on the planned guidance manual in

[1] Gasification units convert organic or fossil-fuel-based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. This is often known as "product gas," which can then be cleaned and used for a variety of purposes, such as electricity generation in a reciprocating engine. These units should not be confused with two-stage solid fuel combustors that are the subject of this guidance manual and are often incorrectly described as gasification units. In reality, two-stage solid fuel combustors use a two-stage combustion process within a single heat energy-generating device such as a hot water boiler.

September 2018. The guidance is designed to align with existing approaches and will enable regulators to arrive at a more coherent approach to permitting SSBCs across Canada. The use of tiers with different degrees of stringency allows regulators to select appropriate levels of requirements that better reflect their situation rather than a one-size-fits-all approach.

1.2 Scope and Limitations

This guidance manual covers SSBCs, such as biomass-fuelled boilers and furnaces larger than residential size (typically above 50 kilowatts of nominal thermal output) and smaller than industrial size (typically under five megawatts of thermal output). They are used in the commercial, institutional, multi-unit residential and light industrial sectors, and in agriculture. Solid biomass includes wood and wood-derived biofuels processed into a form that is appropriate for clean and effective combustion. Suggested wording to define eligible wood fuels is provided in Appendix 6.

This manual does not cover re-permitting or the upgrading of existing SSBCs but focuses on new installations. The scope is further explained in Table 1 below.

Table 1 Scope and Applicability of this Guidance Manual

Aspect	Details
Equipment type	• Types covered here include biomass combustors for space and process heat. • Electricity generation and cogeneration are not covered, apart from units that generate power from waste heat*. • Units may use air, water, oil or other substances as heat transfer mediums.
Equipment size	• The typical size of equipment targeted by this guidance manual is between 50 kW and 5 MW of nominal thermal output. • Slightly smaller or slightly larger sizes could be permitted according to this guidance manual if they are essentially similar to the equipment type targeted.
Sector of application	• The application covers equipment that heats commercial or institutional buildings, small-scale industrial processes, apartment complexes or a number of buildings (e.g., district heating). • Neither small residential nor large industrial wood-burning equipment is the intended focus of this guidance manual.
Fuel types	• Only solid woody biomass fuels, such as firewood, wood pellets, wood chips and wood briquettes, that are included in the CAN-ISO 17225 solid biofuels standards Parts 1 to 5 are covered in this guidance manual. • Fuels made out of agricultural by-products and herbaceous biomass are not covered in this guidance manual.
Topics	• This guidance manual is only concerned with air emissions. • Safety aspects are not addressed. • Ash disposal aspects are not addressed.

* Gas internal combustion engines that fire product gas from a biomass gasifier have very different emission profiles than combustors designed for space and process heating. Systems that use waste heat in the exhaust gas to produce a small amount of electricity (e.g., using a Stirling engine or Organic Rankine Cycle turbine or a thermoelectric generator) could be permitted using this guidance manual.

1.3 Tiered Approach

This guidance manual employs a stepped or tiered approach. The tier 1 requirements cover a basic level of regulation across all types of SSBCs. For specific air sheds or jurisdictions, more detailed or stricter regulations (tiers 2 and 3) are offered. Regulators can choose to follow the guidance provided or go beyond what is recommended. This tiered approach reflects current Canadian realities, in which some jurisdictions have fairly sophisticated regulatory frameworks and others have no regulation at all or deal with new installations on a case-by-case basis.

Table 2 Regulatory Tiers Used in this Guidance Manual

Levels	Typical situation
Tier 1	• Minimal exposure of population to particulate matter (PM) • Jurisdictions currently without regulations for SSBCs • Rural areas or areas with low population density • No public concern about using wood fuels
Tier 2	• Areas with medium population density • Jurisdictions with basic regulations for SSBCs in place • Areas where there is some public concern about using wood fuels • Buildings close to SSBCs can be protected by increasing stack height
Tier 3	• Exposure of large population to SSBC emissions • Urban areas or areas with high population densities • Areas with poor air quality • Areas with existing elevated public concern about using wood fuels

1.4 Standards as a Regulatory Tool

This guidance manual relies on technical standards to a great degree. Standards by themselves are voluntary documents; however, these standards may be referred to in building codes, provincial or territorial regulations and municipal bylaws. Readers are advised to confirm and refer to the latest version of the technical standards for equipment and fuels developed by CSA, US EPA, EN or ISO.

1.4.1 Standards for Equipment Performance and Emissions

The three biomass combustion emission standards[2] used in Canada are:

- CSA B415.1: This standard is designed for SSBCs with up to 150 kW of heat output. Originally designed for wood stoves, the updated 2010 version includes boilers, such as compact boilers and indoor and outdoor boilers, and furnaces. CSA B415.1 is frequently referred to in federal and provincial building codes and municipal bylaws. It contains limits for PM (filterable) and includes efficiency measurement protocol.

[2] This guidance manual refers to standards as amended from time to time, rather than to specific versions. Regulations will not need frequent updating if they refer to the latest version of a standard. However, if the changes are major, the references may not make sense anymore.

- US EPA Certification, according to the Wood Heater Rule (US EPA New Source Performance Standard, 40 CFR Part 60, Subpart QQQQ), is deemed to be equivalent to CSA B415.1. The US Wood Heater Rule was updated in May 2020 to reflect changes in technologies and regulators' preferences (see US EPA 2020). It covers wood burning appliances, such as stoves, hydronic heaters (boilers) and furnaces. It contains limits for PM (filterable) and refers to test method for efficiency measurements in the CSA B415.1.
- EN 303-5: This European standard covers small- to medium-sized SSBCs with up to 500 kW of heat output. It was last updated in 2012 and it is expected that the revised version will be published in 2020/2021. This standard is already used in Canada; for instance, EN 303-5:2012 is referenced in Ontario's, Prince Edward Island's and the Northwest Territories' legislation on SSBCs. It contains limits for carbon monoxide (CO) and PM and also prescribes minimum efficiency requirements. It covers fewer wood heater types than the CSA standard. The EN standard also includes design specifications for safety, which are not the subject of this guidance manual.

Test protocols, such as fuel types and qualities, how to load fuel into appliances, burnout rates and methods to capture and measure PM for the CSA B415.1 standard and the US EPA Wood Heater Rule are the same. Both standards use dilution tunnels and employ US EPA Method 5G, 5H or G1. PM emission results from these two standards can therefore be considered comparable. Test protocols and sampling methods prescribed in the EN 303-5 standard are different than those used in CSA B415.1 and US EPA. EN 303-5 employs PM sampling at elevated temperatures in the stack. Therefore, PM emission results from EN 303-5 are not directly correlated to PM emission results from CSA B415.1 and the US EPA Wood Heater Rule. A further comparison of the three standards is presented in Appendix 1.

1.4.2 Fuel Standards

Fuel standards are common for fossil fuels, but relatively new for woody biomass fuels. Fuel standards only indirectly deal with emissions insofar as uniform fuels can lead to reduced air emissions when combusted. CAN/CSA-ISO 17225-1 to 17225-5 is a series of international woody biomass fuel standards that have been adopted in Canada (Natural Resources Canada 2017). Table 3 provides a list of woody biomass solid biofuels standards available from CSA. The ISO 17225 series provides specifications for woody biofuels that can be used in SSBCs. These standards are useful tools in defining fuel quality parameters and determining whether a certain fuel is suitable for a given SSBC. CAN/CSA-ISO 17225 was released in 2015 and was subsequently adopted by Ontario in 2017 but has not yet seen widespread adoption in Canadian regulations.

Table 3 Canadian Standards Association Adopted Solid Biofuel Standards for Woody Biomass

Standard No.	Standard Title	Scope of the Standard
CSA/ISO 17225-1	Part 1: General requirements	The fuel quality classes and specifications for solid biomass fuels
CSA/ISO 17225-2	Part 2: Graded wood pellets	The fuel quality classes and specifications of graded wood pellets for non-industrial and industrial use
CSA/ISO 17225-3	Part 3: Graded wood briquettes	The fuel quality classes and specifications of graded wood briquettes
CSA/ISO 17225-4	Part 4: Graded wood chips	The fuel quality classes and specifications of graded wood chips
CSA/ISO 17225-5	Part 5: Graded firewood	The fuel quality classes and specifications of graded firewood

In 2019 ISO published a new fuel standard for graded hog fuel, ISO 17225-9. This type of fuel can be considered for SSBC from 3 to 5 MW in size but should not be used in units less than 3 MW.

The foundation of grading solid biofuels in the ISO 17225 standards is based on the origin and source of woody biomass. While a limited number of sources are eligible for grade A, sources for grade B are broader, see Table 4.

Table 4 Classification of Origin and Sources and Quality Classification (Grade) for Woody Solid Biomass Fuels under CSA/ISO 17225-1

Classification of Origin and Source			Grade A	Grade B
Woody biomass	1.1 Forest, plantation and other virgin wood	1.1.1 Whole tree without roots	✓	✓
		1.1.2 Whole trees with roots		✓
		1.1.3 Stem wood	✓	✓
		1.1.4 Logging residues	✓	✓
		1.1.5 Bark (from forestry operations)		✓
		1.1.6 Segregated wood from gardens, parks, roadside maintenance, vineyards, fruit orchards and driftwood from fresh water		✓ ✓
	1.2 By-products / residues from wood processing industries	1.2.1 Chemically untreated wood by-products, residues and wood constituents	✓	✓ ✓
		1.2.2 Chemically treated* wood by-products, residues and wood constituents		
	1.3 Used wood	1.3.1 Chemically untreated used wood		✓
		1.3.2 Chemically treated** used wood		

*chemically treated wood residues can be sourced from wood processing and the production of panels and furniture (glued, painted, coated, lacquered or otherwise treated wood), as long as they do not contain heavy metals or halogenated organic compounds as a result of treatment with wood preservatives or coating.
** chemically treated used wood shall not contain heavy metals more than in virgin wood or halogenated organic compounds as a result of treatment with wood preservatives or coating.

In the case of woody raw materials belonging to chemically treated property grade B, the actual origin or manufacturing process from which the woody raw material is sourced shall be clearly stated (e.g., residues from laminated wood production) according to Table 1 in CAN/CSA-ISO 17225-1.

EXAMPLE 1: Wood chips of property grad B2 produced from 99% in mass stemwood from spruce, and 1% in mass glued wood from wood beam production (amount of glue <0.1% in mass).

EXAMPLE 2: Wood pellets of property class B produced from 99% in mass sawdust from spruce and 1% in mass glued wood from wood beam production (amount of glue <0.1% in mass).

Fuel standards allow for a commoditization of the fuel: all vendors providing wood fuels to those specifications can then compete on a level playing field. Although formal certification to a standard is usually only required for industrial-scale wood fuels, such as wood pellets, a declaration by the vendor that the fuel conforms to the specifications of a standard, backed up by laboratory results, will assure users that the given fuel meets the fuel specifications of their combustion equipment and aligns well with the intent of this guidance manual.

Inspecting smaller SSBCs on a regular basis, prescribing fuel standards, and employing best available fuel handling and storage practices can become important whenever a complaint is made to authorities. In such a case, an inspector can come on site to verify both fuel quality and storage practices and determine whether a given SSBC is in compliance or not. Changes to fuel use and other practices can then be imposed.

Certification versus compliance

Equipment certification serves the purpose of avoiding expensive on-site emissions testing. Model testing is only possible when a unit is mass-produced and when uniform operation can reasonably be expected based on the use of common operating practices and standardized fuels.

Certification to either CSA B415.1 or equivalent standards is recommended for small SSBCs. For package boilers, full certification to EN 303-5 is not required but compliance (selective testing) with specific sections referred to in this guidance manual should be demonstrated through third-party laboratory reports.

1.5 Model Testing and Individual On-Site Testing

Most SSBCs are serially manufactured or produced on demand, based on identical design. It can be reasonably expected that all SSBCs from the same series using the same design perform similarly, provided the same fuel is used and operating practices are similar. A sample unit from a specific series that is successfully tested in a laboratory leads to general approval of the entire series under a given standard. The manufacturer guarantees that all other units sold under the same series name are built to the same design and are in compliance with the standard.

Certification means third-party laboratory confirmation that the unit tested complies with all the conditions laid out in the standard. Laboratories in Canada and the United States are able to test according to CSA B415.1 or the corresponding US EPA Wood Heater Rule. The laboratory must be accredited according to ISO 17025[3], but no special accreditation related specifically to the SSBC technical standards is necessary.

For custom-built SSBCs, compliance with a given emission limit or with a regulation will have to be proven by the manufacturer or tested on site.

1.6 Regulations and Permitting

SSBCs can be regulated by issuing site-specific permits or by a set of requirements that automatically leads to approval, provided the requirements are met. The former generally requires inspection on site, whereas the latter may rely on compliance with a standard. A permitting system requires more input and effort from the applicant and from the permitting authority as compared to a regulation, which may only require forms to be filled in to obtain approval. Regulations can refer to standards that detail the requirements that have to be met. Standards are updated regularly to reflect changes in the marketplace, best practices and technologies[4].

1.7 Air Pollutants to be Regulated

1.7.1 General

Biomass combustion creates emissions of air pollutants. These emissions are a by-product of incomplete combustion or a result of the chemical elements present in the fuel. Both can be mitigated by controlling and optimizing the combustion process. Emissions can be measured in specialized laboratories or by certified stack testers on site. Both can be expensive undertakings and increase operating costs. Certain types of air contaminants can be monitored continuously by specialized equipment. In order to allow for the SSBC market to develop, requirements for measuring and monitoring need to be reasonable and should focus on those that are easiest to monitor while providing adequate effectiveness with respect to the emissions to be regulated.

The use of wood fuels meeting the CAN/CSA-ISO solid biofuels standards in association with manufacturers' fuel specifications will minimize air emissions of contaminants such as heavy metals and halogenated compounds.

1.7.2 Carbon Monoxide and Particulate Matter

Some emission contaminants are easier to measure and monitor than others. An increase in CO emissions generally indicates incomplete combustion and indicates that other pollutants are also increasingly emitted. CO can therefore be used as a surrogate for other emissions.

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[3] ISO/IEC 17025 (Testing and Calibration Laboratories) enables laboratories to demonstrate that they operate competently and generate valid results.

[4] In Europe, the preferred approach for decades has been model permitting for small- and medium-sized SSBCs and customized permits for larger-size units. EN 303-5 has been used to harmonize regulations across EU member states and to work in tandem with Commission Regulations 2015/1185 (https://publications.europa.eu/s/jcHq) and 1189 (https://publications.europa.eu/s/jcHp).

Controlling CO and PM implies that operators need to ensure complete combustion, which also implies a reduction in other pollutants[5], such as black carbon (European Monitoring and Evaluation Programme 2017, p. 183 and 190), polycyclic aromatic hydrocarbons[6] (PAHs) and volatile organic compounds (VOCs) (see also Nussbaumer 2017, figures 10 and 11). While at a national level, SSBCs may be minor contributors to air pollution, locally they can be significant. Because the increased requirements for stack testing and monitoring can be rather costly, regulating these other types of pollutants is deemed feasible only for larger-scale plants not covered in this manual.

1.7.3 Oxides of Nitrogen

Because the combustion temperature in SSBCs generally does not exceed 1,000°C, almost all the oxides of nitrogen (NO_X) emitted originates from nitrogen contained in the fuel. Biomass fuels with low nitrogen content therefore produce low NO_X emissions (Mitchell *et al.* 2016). With wood fuels, the share of bark in the fuel is usually the cause of higher nitrogen and ash content. This suggests that low-ash wood fuels can be expected to also lead to lower NO_X emissions during combustion. Limiting fuel nitrogen content is one way of controlling NO_X emissions. When low-ash woody fuel is used, NO_X emissions per GJ of fuel input will be comparable to those from oil boilers.

Another way of reducing NO_X emissions is selective catalytic reduction (SCR). This method uses a catalyst to react injected ammonia or urea to chemically reduce NO_X. It can achieve up to a 94% reduction, but the technology is too expensive for most SSBCs due to their small size. In addition, catalysts have a finite life in flue gas and some ammonia slips through without being reacted, creating a new emissions problem. Appendix 3 provides more detail and a background on NO_X from biomass combustion.

1.8 Regulating by Size Class or by Equipment Class

A common approach is to establish categories with distinct regulatory requirements. SSBCs can be categorized by size (i.e., capacity), by equipment type or by application; see Table 5 below. Table 6 further explains the various equipment types contained within the first category of Table 5.

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[5] CO, although toxic, is not itself a major concern with SSBCs, and direct impacts are deemed negligible. It is, however, of great concern as an indicator of incomplete combustion. It is also easy to measure and can therefore be used as a proxy for other emissions.

[6] Both CO and PAH emissions are reduced in parallel with combustion temperatures over 800°C; see van Loo and Koppejan (eds.) 2008, 299–300.

Table 5 Equipment Types and Size Classes

Equipment class	Design and market characteristic	Application	Output capacity
Compact boilers, furnaces, indoor and outdoor boilers	• Compact units, frequently with integrated fuel storage • Some are sold by non-specialized retailers	• Large residential units • Apartment complexes • Small commercial use	• Typically <150 kW • Some as large as 800 kW
Package SSBCs	• Sold as complete packages including ancillary equipment • Same or similar design for each series • Some upgrades are possible • Sold by specialized retailers	• Institutional or commercial use • Large apartment complexes • Small industrial use	• Typically 150 to 1,000 kW • Some up to 1,200 kW • Rarely < 100 kW
Custom SSBCs	• Designed and built to meet custom requirements • Small number of sales does not justify mass production • Larger capital cost justifies custom design • Sold by manufacturers	• Agricultural use • District heating • Industrial use • Steam (as opposed to hot water) • Difficult fuel	• Typically > 1,000 kW • < 1,000 kW for special applications and fuel types only

Table 6 Definitions of Small Solid Biomass Combustors Equipment Types

Equipment type	Typical heat output	Description
Compact boilers	15–150 kW	• Mass-manufactured off-the-shelf product • Based on a common design, no customization • Automated or manually fed boiler with computerized combustion control • Size of one to two large refrigerators • Built-in control panels • Smaller sizes with built-in fuel storage • Tight fuel quality requirements
Space heating furnaces	15–100 kW	• Serves to heat air (as opposed to water) • Central heating unit for one large or several smaller rooms
Indoor and outdoor boilers	20–200 kW	• Includes indoor log boilers and outdoor hydronic heaters • Manually fed (rarely automated) • May or may not have refractory for better combustion • Uses firewood (cordwood) • Limited combustion controls
Package SSBCs	100–1,000 kW	• Manufactured in series based on a common design • Automated fuel stoking and combustion control • Some limited customizations may occur in terms of added or omitted features • Output rating and general design are identical for all units of a series
Custom SSBCs	>1,000 kW	• Often based on a common design but adapted to the needs of each customer • Produced on demand, no predefined output ratings • Design and operation vary from one client to the next, no identical units

- Regulation by equipment type: The advantage of categorizing by equipment type is that most units on the market are certified to a specific standard (CSA, US EPA or EN). Ontario Guideline A-14 uses this approach. The disadvantage is that equipment types are difficult to define accurately. Owners or sellers might argue their equipment should fall under a different equipment class.

- Regulation by application: This allows for imposing stricter requirements on larger or more complex (e.g., industrial) applications that tend to be more capital expensive and burn larger amounts or different types of fuel than smaller applications, such as space heating. Regulation by application is difficult to define. The British Columbia Ministry of the Environment and Climate Change Strategy distinguishes between "comfort heating" and "process heating."

- Regulation by size class: This approach sets clear, unambiguous capacity thresholds that determine which regulatory requirements should be met. The Canadian market under 500 kW is largely served by imports from Europe and the United States that meet their own national standards. Imposing size classes might, for instance, force an American supplier that was previously governed by the US EPA standard to meet a Canadian or even a European standard.

1.9 Regulation by Input Capacity or by Output Capacity

Some regulations and some standards set thresholds according to fuel input energy, others by heat energy output. For hydronic SSBCs, i.e., units generating hot water, heat energy can be easily measured. For hot air furnaces and especially for stoves, fuel input is easier to measure. Canadian standard CSA B415.1 uses both approaches, depending on equipment type.

Most SSBCs employ hot water boilers. Most SSBCs on the market state their capacity based on heat output. This is a rating in kilowatts (kW) that can easily be found on boilerplates and equipment specifications supplied by vendors. For these reasons, this guidance manual uses heat output as a metric when speaking of equipment size. A tool for converting between various standard conditions is available on the CCME website as an Excel file (also see Appendix 4).

2.0 RECOMMENDED PERMITTING RULES

2.1 Introduction

This guidance manual recommends permitting based on model certification for small- and medium-sized SSBCs (a "regulation") and customized permits for larger-size units. Table 7 describes the general approach suggested for different equipment sizes.

Table 7 Regulatory Approach Proposed in this Guidance Manual

Heat output	Regulatory approach
<150 kW	• Model certification. • Acceptable certification includes US EPA New Source Performance Standard (40 CFR Part 60, Subpart QQQQ), CSA B415.1 or EN303-5 (only one certification* is required). • Conformity with specifications in fuel quality standards based on CAN/CSA-ISO 17225. • Additional requirements apply for tiers 2 and 3. • Two or more units can be combined to arrive at a total capacity of more than 150 kW; each individual unit nonetheless remains in this category.
≥150 kW – 1 MW	• Automated operation only. • Needs to be in compliance (as evidenced by accredited third party laboratory results) with selected requirements from EN 303-5 (full certification is optional). • Conformity with specifications in fuel quality standards based on CAN/CSA-ISO 17225. • More stringent requirements apply for tiers 2 and 3. • Two or more units can be combined to arrive at a total capacity of more than 1,000 kW; each individual unit nonetheless remains in this category.
>1 MW	• Individual permits based on recommended emission limits for each tier. • Regular tune-ups and emissions monitoring required. • Conformity with specifications in fuel quality standards based on CAN/CSA-ISO 17225. • More stringent requirements apply for tiers 2 and 3. • Secondary flue gas treatment and emissions monitoring is required in all cases.

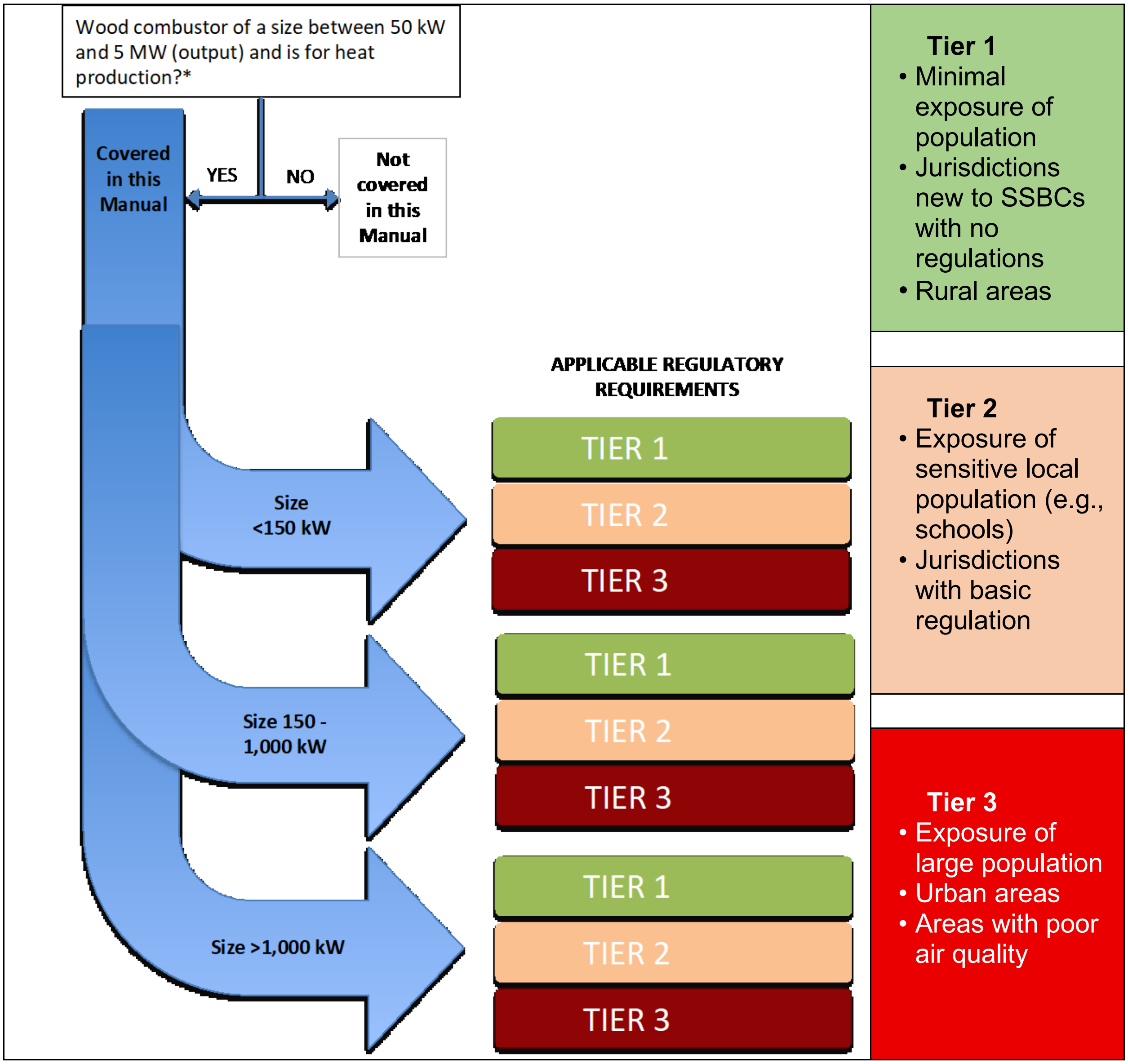
* Jurisdictions can choose which performance standard to implementation, refer to the Appendix 1 for comparison.

Figure 2 illustrates the suggested approach, the details of which are provided in subsequent sections and tables.

The emission limits for compact and package boilers are based on existing standards. For package boilers, less stringent limits are applied to tiers 1 and 2 than to tier 3. This reflects the technological performance of state-of-the-art secondary particulate controls: a simple cyclone will reduce emissions to under 150 mg/m^3 (class 3 in EN 303-5:2012) and a multicyclone can be used to achieve about half this emission level. The class 4 level is prescribed for tier 3 and is the current lowest level achieved by equipment manufacturers worldwide. Class 5 is even stricter and will be required in Europe as of 2020. At this time most marketed package boilers do not yet achieve class 5 performance for PM emissions but can meet the limits for thermal efficiency and carbon monoxide emissions. Any regulatory application of class 5 limits should be considered with care as was done in Ontario where class 5 limits were applied for thermal efficiency and carbon monoxide but not PM.

The particulate emission limit for custom boilers is likewise based on EN 303-5:2012, using class 4 for tier 1 (achievable with low-ash fuels and a multicyclone) and more stringent levels for tiers 2 and 3. The latter will require adding secondary PM control equipment, such as electrostatic precipitators or baghouses. The NO_X limit is based on what can be achieved with low-nitrogen wood fuels, as elaborated in Appendix 2. The CO limit is taken from EN 303-5:2012.

Figure 2 Regulatory Approach of this Manual



*Some cogeneration units may fall under the scope of this manual; see Table 1. Upper (5 MW) and lower (50 kW) limits are indicative, and somewhat larger or smaller units may also be included in regulations based on this manual.

2.2 Other Considerations in Regulating Small Solid Biomass Combustors

2.2.1 Installation of Multiple Units within One Heating Plant

At a given site, two or more small combustors may be installed, rather than a single larger unit. Technically, this is advantageous because biomass boilers have a limited turndown ratio. Two or more boilers can respond better to load changes, reducing the number of cold starts that create emission peaks.

In theory, an applicant might decide to install multiple units to avoid the stricter emission limits of the next larger size class. In practice, however, buying a single boiler is often less expensive than buying two or more smaller ones. It is therefore not recommended to regulate two SSBCs differently from a single boiler. Size classes used in this guidance manual should be applied to each individual boiler installed, rather than to an entire boiler plant.

2.2.2 Uncertified and Non-Compliant Units

- Uncertified units already in use are not the focus of this guidance manual. New units that are uncertified or not in compliance with the chosen performance standards would not be permissible based on the principles used for the proposed regulatory approach: Small units (<150 kW thermal output) not certified to a current version of either CSA B415.1 or the US EPA Wood Heater Rule or EN303-5 would be illegal and should not be allowed to be sold or installed. This should also pertain to moving such units from one address to another (used units).
- Medium-sized units with over 150 kW of thermal output capacity (package SSBCs) that do not comply with the air emission limits referred to below as defined in EN 303-5 would not be permitted.

Non-compliant package boilers could, however, be admissible if their emissions can be shown by on-site stack testing to be below the recommended limits. For such units, no laboratory proof in accordance with EN 303-5 would be necessary to show the model is compliant. Instead, stack testing would have to be provided in accordance with provincial or territorial emission limits and sampling procedures. Conversion from cold to hot testing may be required. This alternative procedure would therefore require a site-specific permit, rather than an automatic permit based on model testing.

2.2.3 Heat Storage

Heat storage buffers the difference between demand and supply of heat. This leads to a more even operation of the combustor, lowering emissions. Minimizing on/off cycling also reduces air emissions.

Heat storage (e.g., hot water tanks) is recommended in principle for all SSBCs but is challenging in practice. Because they use solid fuel, they are generally slower to respond to a change in heat demand than oil or gas boilers. Especially for manually batch-fuelled SSBCs that use firewood, responding to changing heat loads is difficult or impossible. Automated units can modulate the fuel input and heat output better; in this case, heat storage may be considered beneficial but not necessary.

Heat storage is most important when heat demand fluctuates frequently, such as for sanitary hot water heating or space heating. There might be situations where an SSBC only provides heat at a constant baseload level (e.g., to heat a swimming pool) and then would not require heat storage. In addition, many manufacturers will include heat storage in their designs to meet ever-stricter emission limits. Achieving existing and upcoming limits can be made easier by adding heat storage. For these technical reasons, legally regulating heat storage either is not necessary or would become very complex due to the need to consider uncommon uses or exceptional situations. Instead, regulators should refer to good engineering practice and best practice guidelines[7].

2.2.4 Dispersion Modelling

Dispersion modelling provides a means to estimate the increase in pollutant concentrations that will result from a new facility such as an SSBC. Currently, some Canadian jurisdictions require dispersion modelling assessments of all new SSBCs. Others have no dispersion modelling requirements.

For smaller SSBCs, the cost of a dispersion modelling study can add significantly to the total cost of the project. Such a study is likely not necessary, as satisfactory ground level concentrations can easily be achieved by a combination of certified emissions levels, stack height and modest setbacks from sensitive receptors. Dispersion modelling can be mandated as screening-level modelling or as refined or advanced modelling. At the time of this writing, screening-level dispersion modelling was available at a cost of approximately CAN $5,000 to $10,000, depending on the complexity of the terrain and emission sources. This up-front expense can be justified for large installations that typically have investment needs above $1 million. It should be based on vendor-specified emission levels (i.e., combustor emissions with or without additional control equipment, as submitted by the applicant) rather than on theoretical emission factors. Given there is ample experience with dispersion modeling in many Canadian jurisdictions, it is not expected to provide significant new insights[8]. This manual only recommends dispersion modelling for custom SSBCs.

Best Practice Guidance

There is currently no national guidance on designing and operating SSBCs.

Many aspects related to these issues are difficult to cover in regulations, given the great variety of circumstances, designs and applications of SSBCs.

As SSBCs are used more widely in Canada, the need to create technical guidance is becoming urgent. The creation of a best practices manual would greatly assist regulators and is therefore highly recommended as a complement to this guidance manual.

2.2.5 Stack Height and Setbacks

Adequate stack height for emissions sources such as SSBCs can help ensure good dispersion of the flue gas and residual emissions. Adequate stack height helps prevent building downwash where emissions are mixed into the ambient air immediately beside the source and can be inadvertently reintroduced into a building with fresh air intakes.

Setbacks between an emissions source and sensitive neighbouring receptors can be a tool to minimize the pollutant concentrations at the receptors. Requiring overly large setbacks could rule

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[7] Best design and operating practices for SSBCs had not yet been defined in Canada. However, design guidelines exist. For instance, see Alberta Agriculture and Forestry 2014.

[8] Regulators with less experience could perform their own screening modeling for the first set of new installations in order to gain more certainty concerning the impact of SSBCs.

out many SSBC applications and is not recommended. On the other hand, modest setbacks can still provide some level of protection to adjacent receptors and may be recommended in some cases. Modest setbacks may also have the benefit of minimizing complaints.

The situation may vary widely from one site to another, making it difficult to mandate general requirements. Parameters that may impact the need for a minimum stack height and setbacks include wind velocity, wind direction, roof shape, the size of adjacent buildings, and the topography of the surrounding terrain. The location of an SSBC and related fuel storage is generally determined by the local terrain and by the design of the building to be heated, including requirements to secure passage for fire trucks or utilities. The Canadian building code and many provincial and territorial building codes already require minimum chimney heights[9]. Likewise, local authorities may impose setback rules.

This manual does not specify stack height or setbacks. Compact and package boilers should be installed based on best practices; provincial, territorial and municipal authorities should develop setback and stack height requirements for custom boilers and may also impose them on smaller boilers where deemed necessary.

2.2.6 Tune-Ups

Regular tune-ups should be required. These can be carried out by qualified operators or by service personnel, depending on their qualifications. Operating manuals provided by SSBC manufacturers provide instructions specific to the equipment at hand. A tune-up includes, as a minimum, boiler and combustor cleaning and verification of sensors, such as oxygen probes and temperature sensors. A portable combustion gas analyzer could be used to check the CO emission levels. Most vendors offer service contracts that include regular tune-ups, necessary repairs and preventative maintenance.

2.2.7 Emissions Monitoring

Emissions monitoring refers to the continuous or periodic measurement of emissions at short intervals. This guidance manual recommends constraining emissions monitoring to carbon monoxide (CO) measurements in the exhaust. This can be done directly, using CO sensors, or indirectly, by estimating the approximate CO level using oxygen sensors and comparing the measured value to the set point. An emissions monitoring device may or may not be part of a combustion control system, i.e., the device may or may not have a feedback mechanism that influences oxygen supplies.

To remain technology-neutral, this guidance manual does not prescribe a type of emission control technology. In some cases, especially for custom SSBCs, stack monitoring of CO and oxygen levels can be used to provide a track record of how well the SSBC is operating. Exhaust measurements, taken at short intervals, need to be stored on a data storage device with storage

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[9] According to the Ontario Building Code (1992), "(1) A chimney flue shall extend not less than
(a) 900 mm above the highest point at which the chimney comes in contact with the roof, and
(b) 600 mm above the highest roof surface or structure within 3 m of the chimney."

capacity for at least 12 months. This data must be available for inspection and can be used to inform operators of whether tune-ups may be necessary or whether the SSBC is operating as designed.

2.2.8 Irregular Operations

Regulators may have to deal with complaints about excessive air emissions that are often the result of inadequate operation, malfunctioning emission control equipment, or the use of inappropriate fuels. Regulatory authorities should address such situations by conducting inspections and verifying whether best practices have been followed. These cases are not covered in this guidance manual, as they require a case-by-case analysis. Modifications to permitting conditions or the design of the SSBC and associated equipment may have to be imposed to remedy the situation.

2.3 Small Solid Biomass Combustors Up to 150 kW Nominal Heat Output

This section provides an overview of equipment types with an output capacity of up to 150 kW. For SSBCs of this size class, the main air contaminant of concern is PM, which is also a proxy for incomplete combustion. High levels of smoke frequently indicate bad design, insufficient combustion air supply, poor fuel quality or improper operation practices.

2.3.1 Compact Boilers

These boilers are mass-manufactured and can be certified under existing standards. They can use wood chips as a fuel, though pellets are more common. For compact boilers, compliance with either the latest version of CSA B415.1 or US EPA Wood Heater Rule of 2020 or EN 303-5 will limit air emissions. This guidance manual suggests enforcing certification rather than compliance under either standard. Compliance with or certification under the European standard is assumed to entail compliance with the CSA standard.

> Compact boilers typically have a heat output of 150 kW or less. Units larger than 150 kW of nominal output should be considered package boilers and need to comply with a different set of requirements.

2.3.2 Furnaces

Furnaces heat air, as opposed to water or liquid. Emission requirements and methods to measure emissions are well covered by Canadian standard CSA B415.1 and the US EPA Wood Heater Rule 2020 but are not explicitly covered in European standard EN 303-5, which is intended for boilers.

This manual recommends that wood furnaces be regulated according to the latest version of CSA B415.1 or the US EPA Wood Heater Rule 2020 if their rated output is under 150 kW, while larger units would have to comply with the emission limits for package boilers.

2.3.3 Indoor/Outdoor Boilers

2.3.3.1 Outdoor Hydronic Heaters

Outdoor boilers, or hydronic heaters, are batch-stoked using firewood (cordwood) as a fuel. The fuel, the fuelling method and the combustion control are not amenable to modulating heat output levels and may cause elevated smoke emissions, especially during and after re-stoking. Some models are now US EPA- or CSA-certified and would therefore be authorized under tier 1 rules. tier 2 requires automated fuel stoking and automated combustion control. Few if any models qualified under tier 2 at the time this guidance manual was written. Outdoor boilers are not recommended for sensitive airsheds and their installation and use are therefore not recommended under tier 3.

2.3.3.2 Indoor Log Boilers

Indoor log boilers burn firewood (cordwood) and usually are equipped with a refractory lining, which leads to better fuel combustion and lower emissions. These units can be certified under CSA and US EPA standards. They are usually hand-fuelled and would therefore not be eligible for tier 2. Tier 3 prescribes the use of wood pellets and therefore excludes the use of cordwood-fuelled appliances.

2.3.4 Recommended Regulatory Conditions

Table 8 specifies the recommended requirements for small SSBCs under 150 kW of nominal heat output.

Table 8 Recommended Minimum Requirements for Small SSBCs under 150 kW (Compact SSBCs)

Aspect	Requirements		
	Tier 1	Tier 2	Tier 3
PM emissions	Certified* to US EPA 2020 or CSA B415.1or EN 303-5 Class 3		
CO emissions	None		
Other emissions	None		
Emission modelling	None		
Operation	• Automated or manually fuelled • Automated or manual combustion controls	• Automatic fuelling • Automatic combustion controls	
Fuel quality	Grade A fuels only (as defined in CAN/CSA-ISO 17225-2, 17225-3 and 17225-5 series) within vendor specifications	Grade A1, A2 wood pellets only (as defined in CAN/CSA-ISO 17225-2)	
Monitoring	None		
Tuning	Refer to best practice guidance or manufacturer's recommendation		
Stack testing	None		

* Jurisdictions should refer to the most recent version of the performance standards

2.4 Package Small Solid Biomass Combustors with 150 to 1,000 kW of Nominal Heat Output

These systems are serial manufactured, with no or little customization. They are referred to above as package SSBCs (Table 6) and use pellets, wood briquettes or wood chips as fuel. While most of these units are boilers, they can also be manufactured as air heaters or furnaces or modified from boilers to air heaters or furnaces. While there are no Canadian or United States standards for these sizes of package SSBCs, the European standard EN 303-5 covers boilers of this size class well (up to 500 kW) and is therefore referred to below. Certification to this standard is not required but evidence must be provided that the units are in compliance with selected emission limits stated in this standard. A certified third-party laboratory report based on a test conducted in compliance with the procedures referred to in EN 303-5 can be used if the unit is not already certified.

Table 9 Recommended Requirements for Package SSBCs 150 to 1,000 kW (Package Boilers)

Aspect	Requirements		
	Tier 1	Tier 2	Tier 3
PM emissions*	Meet EN 303-5 class 3 limit for PM (150 mg/m^3)**	Meet 50% of the EN 303-5 class 3 limit for PM (75 mg/m^3)**	• Meet EN 303-5 class 4 limit for PM (60 mg/m^3) or • Emission dispersion modelling results showing acceptable impact on ambient air quality**
CO emissions*	Meet EN 303-5 class 5 limit for CO (500 mg/m^3, 6-hour average)**		
Other emissions	None		
Emission modelling	None		Emission dispersion modelling for PM, CO
Operation	• Automatic fuelling • Automatic emission or combustion efficiency controls	• Automatic fuelling • Automatic combustion controls	
Fuel quality	Grade A or B fuels only (as defined in CAN/CSA-ISO 17225-2, 17225-3 and 17225-4), within vendor specifications		
Monitoring	None		
Tuning	Refer to best practice guidance or manufacturer's recommendation	Annual tune-ups	
Stack testing	• None**Complaint-based testing only		CO and O_2 testing for units ≥500 kW every two years

* The concentrations refer to in-stack emissions concentrations corrected to 0°C, 101.3 kPa and 10% O_2.
** A commissioning stack test can be performed whenever SSBCs are not model-tested to EN 303-5, in accordance with existing provincial and territorial sampling and measurement procedures. A summary of European standard EN 303-5 (2012) is provided in Appendix 1.

2.5 Custom Small Solid Biomass Combustors (typically over 1,000 kW of nominal heat output)

These systems are built to customers' specifications and can be boilers (using a variety of heat transfer fluids), air heaters or furnaces. They frequently include some means of air pollution control (e.g., a cyclone, multicyclone, electric precipitator or fabric filter[10]) and are designed for a typical fuel to be used, which may not always correspond to the terms specified in CAN/CSA-ISO fuel standards (CAN/CSA-ISO 17225).

[10] See Appendix 2 for an explanation of these technologies.

An NO_X limit is recommended that can be achieved using low-nitrogen fuels, such as wood pellets and chips with little bark. To use wood fuels with higher nitrogen content, SSBCs need to be equipped with primary or secondary NO_X control measures in order to achieve the recommended limit. Regulators may instead choose to request screening-level NO_X dispersion modelling, which should show whether the unit unduly impacts ambient NO_X concentrations.

Table 10 Recommended Requirements for Custom SSBCs over 1,000 kW

Aspect	Requirements		
	Tier 1	Tier 2	Tier 3
PM emissions*	60 mg/m^3	40 mg/m^3	20 mg/m^3
CO emissions*	500 mg/m^3		
Other emissions*	• NO_X as nitrogen dioxide (NO_2): 400 mg/m^3 or • Screening-level dispersion modelling to assess impact		
Emission modelling	None		Emission dispersion modelling for PM, CO and NO_2
Operation	Automated fuelling and combustion controls		
Fuel quality	Grade A or B fuel (as defined in CAN/CSA-ISO 17225), within vendor specifications		
Monitoring	Continuous stack monitoring of O_2 and CO		
Tuning	Annually		
Stack testing	Commissioning test (CO and PM)	• Commissioning test (CO and PM) • Every five years	• Commissioning test (CO and PM) • Annually or as required by director

* The concentrations refer to in-stack emissions concentrations corrected to 0°C, 101.3 kPa, 10% O_2; average of three independent half-hour measurements at both maximum rated output and the vendor-specified minimum output level (or at 30% output if not specified).

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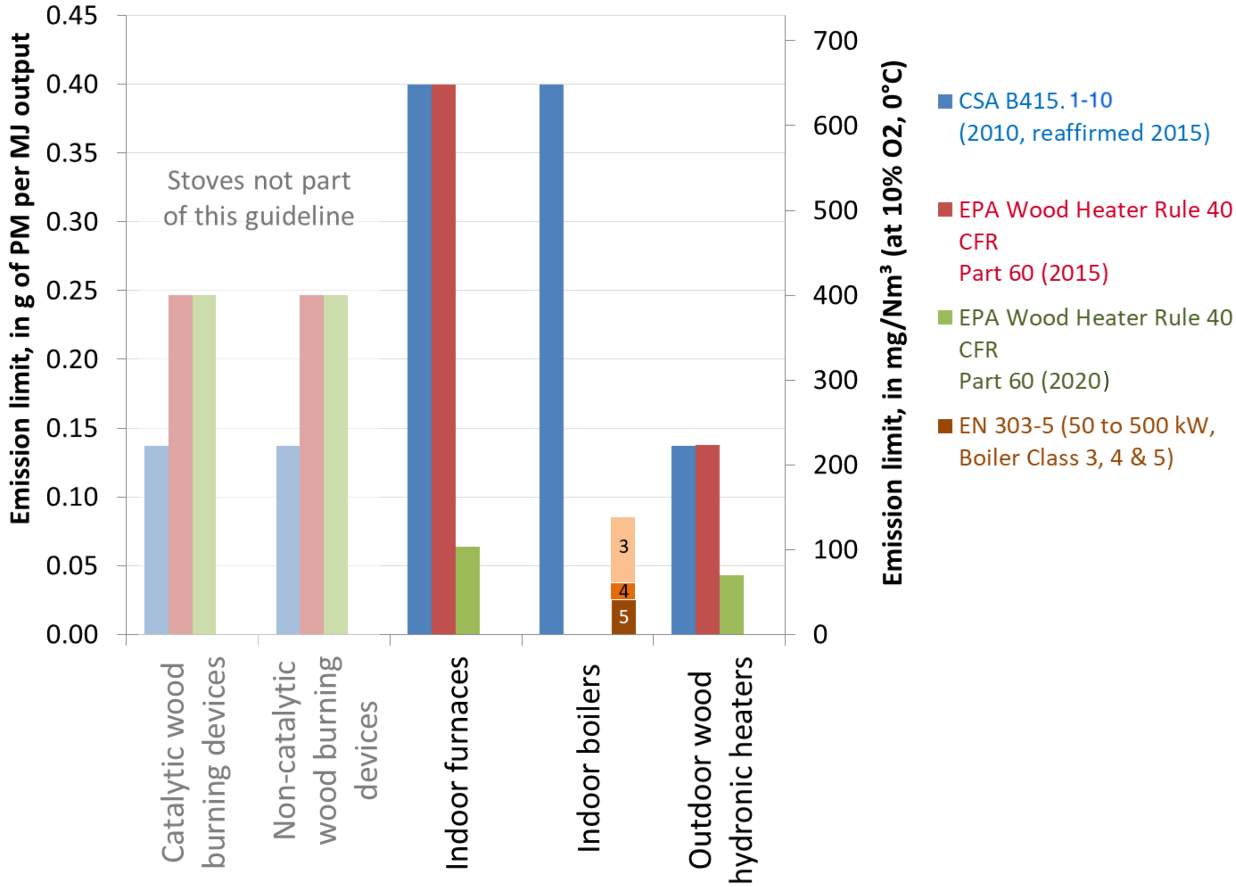
APPENDIX 1: OVERVIEW OF STANDARDS

Figure 3 Comparison of Standard CSA B415.1-10, US EPA 40 CFR Part 60 and EN 303-5



Standard CSA B415.1-10

- Only standard in Canada dealing with the performance of wood combustors.
- Based on the US EPA Standards of Performance for New Residential Wood Heaters, Section 60-532 of the 1988 Clean Air Act, subpart AAA.
- Regulates PM only — hourly rates or per MJ of fuel input. Contains no efficiency requirements and no carbon monoxide emission limits.
- Meant for small units up to about 150 kW output; primarily designed for convection-style stoves and hot air furnaces, and for hot water boilers.
- Has a boiler efficiency test method which is also referred to in the US EPA 2020 standard.
- PM is measured using a dilution tunnel approach and the method is expected to capture all filterable matter plus condensable.
- At the time of writing this guidance manual, CSA B415.1-10 is under significant review.

US EPA New Source Performance Standards 2020

- Became effective as of May 15, 2020
- regulates for PM emissions for residential hydronic heaters and forced air furnaces
    - hydronic heaters
        - 0.043 g/MJ heat output (for each individual burn rate) using crib wood and wood pellets
        - 0.064 g/MJ heat output (for each individual burn rate) using cord wood
    - forced-air furnace
        - 0.064 g/MJ heat output (for each individual burn rate)
- boiler efficiency test methods rely on those published in the CSA B415.1-10; no minimum efficiency requirements but results are made available to customers on a public website
- PM is measured using a dilution tunnel approach and is expected to capture all filterable matter plus condensables.

European Standard EN 303-5:2012

Table 11 EN 303-5

Heat Output, in kW	Boiler Class (=Tiers)	Thermal Efficiency, in % of LHV*	Carbon Monoxide, in mg/Nm^3**	Particulate Matter, in mg/Nm^3 **
Up to 50	3	82	3,000	150
50 to 150	3	82	2,500	150
150 to 500	3	82	1,200	150
Up to 500	4	84	1,000	60
Up to 500	5	89	500	40

* LHV: Lower Heating Value of the fuel ** at 10% O_2 and 0°C

- Boiler class = tiers; different levels of stringency that can be required by the regulator.
- Lower classes get eliminated over time; requirements are becoming stricter.

Method EN303-5 samples PM directly in the stack and maintains filter temperature at elevated temperatures during sampling. This is expected to capture only filterable PM.

APPENDIX 2: OVERVIEW OF AIR POLLUTION CONTROL TECHNOLOGIES FOR SMALL SOLID BIOMASS COMBUSTORS

For industrial plants, air pollution control devices can sometimes be as large and as complex as the combustion units themselves. For SSBCs, air pollution controls are smaller and rely on three key concepts that have an impact on emissions:

1. Choice of fuel. Cleaner, low-moisture and low-ash fuels result in lower particulate emissions. Fuels low in other critical components (halogens, heavy metals, nitrogen, sulphur) prevent other criteria air emissions from occurring.
2. Good design of the combustor, including features such as staged combustion and flue gas recirculation, which lead to lower emissions.
3. End-of-pipe (or secondary) emission control equipment, mainly aimed at particulate emissions but sometimes also at nitrogen oxides.

Using a refractory combustion chamber rather than a metallic one (the latter are still used in some outdoor wood boiler designs) will improve combustion efficiency by increasing temperatures and reducing CO and unburned hydrocarbon emissions. Advanced systems also have automated fuel feed systems, which serve to adjust the fuel feed rate to the heat demand and regulate the amount of fuel inside the combustion chamber. Controlling the stoking process—in combination with automated combustion air supply, temperature and residual oxygen levels—makes it possible to optimize the combustion process and minimize the emission of pollutants.

This appendix is concerned with the second and third points in the above list only and provides a short introduction to commercially available pollution control options suitable for SSBCs.

Staged combustion. Wood combustion is a multi-stage process, starting with heating the fuel, drying, devolatilization, char combustion, and then oxidation of the syngas. Each process differs in regard to the types of chemical reactions that occur, with different levels of oxygen required. By spatially separating the oxidation stage from the previous stages, it is possible to optimize the design for the different process steps and provide the optimum levels of oxygen at different stages of the process.

This can be used to limit NO_X formation, optimize combustion efficiency and minimize particulate emissions. Advanced SSBCs (e.g., package boilers and compact boilers) control the combustion process through automation, relying on oxygen, temperature, negative static pressure and sometimes other sensors to monitor and adjust the combustion process. Controlling oxygen levels also serves to reduce NO_X emissions, given that the combustion reactions tend to reduce NO to N_2 when oxygen levels are near-stoichiometric.

Flue gas recirculation. Some of the flue gas is extracted downstream of the boiler or heat exchanger, sent back to the combustion chamber and mixed with the combustion air for the primary and secondary combustion zones. Recirculation of cooled flue gas reduces the flame temperature by diluting the oxygen content in the combustion air because the flue gas contains very little oxygen compared with fresh air. When mixed with combustion air, recirculated flue gases lower the average oxygen content of the air, starving the NO_X-forming reaction of one of the ingredients it needs.

Cyclones. Cyclones apply a centrifugal force to the flue gas stream to mechanically separate particles from the flue gas. A cyclone may be added or may already be integrated into an SSBC by design. Particulate removal efficiency is generally low overall (<80%) and even lower for the smaller-sized fractions, such as breathable particulates below 2.5 microns ($PM_{2.5}$). Cyclones are low-cost and affordable for package boilers and are often used as a pre-treatment step before a fabric filter or electrostatic precipitator in larger custom SSBCs.

Multicyclones. Multicyclones combine several small cyclones to achieve higher separation efficiencies. They will typically achieve particulate emission concentrations of fewer than 75 mg/m³ (101.3 kPa at 11% O_2). For even lower particulate emission concentrations, more complex and more expensive flue gas controls are required. In this scenario, a multicyclone can be used as a pre-treatment step before a fabric filter or electrostatic precipitator in larger custom SSBCs.

Fabric filter. Flue gases are sucked through sock-shaped fabric tubes that filter out particulates, partly by the "cake," the filtrate forming on the outside of the sock. As the pressure drop increases, the cake needs to be removed by a soot blower. This reduces the effectiveness of the fabric filter momentarily. Fabric filters are notorious for catching on fire from carryover sparks in the flue gas, which is why a cyclone or multicyclone is often used as a pre-treatment step.

Socks made out of stainless steel reduce this fire hazard but are not as effective as those made out of fabric media. Fabric filters tend to clog up even with slightly moist fuel, especially in the start-up phase when condensation occurs. Some fabric filters are equipped with fast abort gates that allow sparks to be bypassed. Bypasses may also be used during the start-up process.

Electrostatic precipitators. Particulates in the flue gas are first ionized (electrically charged). As the flue gases travel between two large electrostatically charged plates, the particles are drawn to one of the plates. The particles settle there by weak attraction forces and are periodically removed by a rapping device that shakes the cake off. Electrostatic precipitators used to be only available for SSBCs above 1-MW capacity. A number of European companies have developed electrostatic precipitators for SSBCs with capacity below 500 kW and even below 50 kW.

Wet scrubbers. In scrubber technology, water droplets "scrub" particles from the flue gas. The particles are removed through collision and interception with the droplets. The efficiency of removal increases with an increasing number of droplets and a higher relative velocity between the droplets and the flue gas. Smaller droplets and higher velocities can remove more PM particles, but more and smaller water droplets and a higher velocity create a higher-pressure drop, which in turn causes higher energy demand.

A wet scrubber will also remove some NO_X. Adding hydrogen peroxide or alkali can increase NO_X absorption. Scrubbers are usually only used if acid components (e.g., hydrogen chloride or sulfur dioxide) or condensable particulates such as VOCs in the flue gas have to be precipitated as well. Wet scrubbers produce liquid waste that needs to be disposed of.

Wet electrostatic precipitators are a combination of scrubber technology and electrostatic precipitators.

Selective catalytic reduction. SCR uses a catalyst to react injected ammonia to chemically reduce NO_X to N_2. It is one of the most effective NO_X abatement techniques and can achieve up to a 94% reduction in emissions. Materials made with a platinum, tungsten, titanium or vanadium oxide base are used as catalysts, which is necessary to make this method work with the low flue gas temperatures from wood combustion (non-catalytic reduction is not suitable). This technology has a high initial cost. In addition, catalysts have a finite life in flue gas and some ammonia slips through without being reacted. The pollution control equipment thus pollutes the air with ammonia.

SCRs are not used on SSBCs due to their complexity and cost, and the risk of creating another air emissions problem due to ammonia emissions. The danger of the catalyst poisoning by alkaline compounds and heavy metals contained in the flue gas may require very high levels of dust removal in addition to SCR.

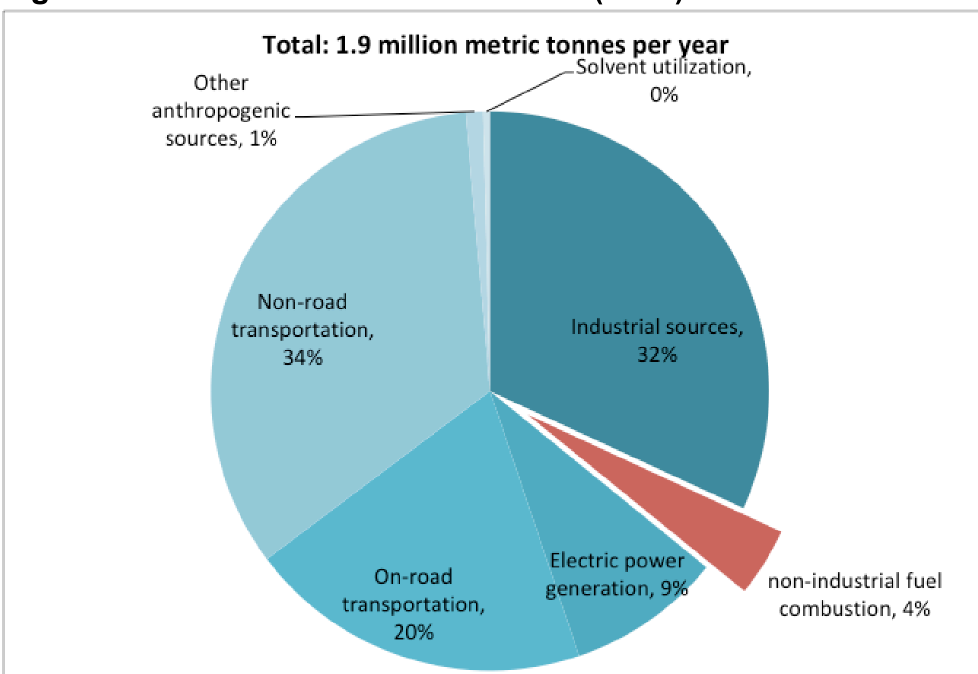
APPENDIX 3: BACKGROUND TO NO_X EMISSIONS FROM SMALL SOLID BIOMASS COMBUSTORS

Oxides of nitrogen, sometimes abbreviated NO_X, are a mixture of gases that are composed of nitrogen and oxygen, i.e., nitric oxide (NO) and NO_2. NO_X emissions are of concern in terms of photo-chemical smog. When exposed to bright sunlight and warm temperatures, NO_X is a precursor to ground-level ozone generation. NO_X also contributes to acid rain and to the formation of secondary PM. There are also direct health impacts from NO_X.

In Canada, non-road and on-road vehicles account for the greatest portion of NO_X emissions, followed by the upstream petroleum industry. Only 4% of the national NO_X emissions come from non-industrial fuel combustion, such as heating systems fuelled by gas, oil and biomass.

NO_X emissions from wood-fired boilers are similar to those of natural gas and oil boilers, when compared based on fuel energy input or on a per GJ-basis; see Table 12. Heating appliances' contributions to ozone formation are of lesser concern relative to many other sources of NO_X because these appliances are mainly used for space heating during the winter months when ozone formation potential is low.

Figure 4 Canadian Sources of NO_X (2014)



Source: Government of Canada (2016) [Canada-United States Air Quality Agreement: Progress Report 2016: Section 3 - Canada.ca], reproduced with permission.

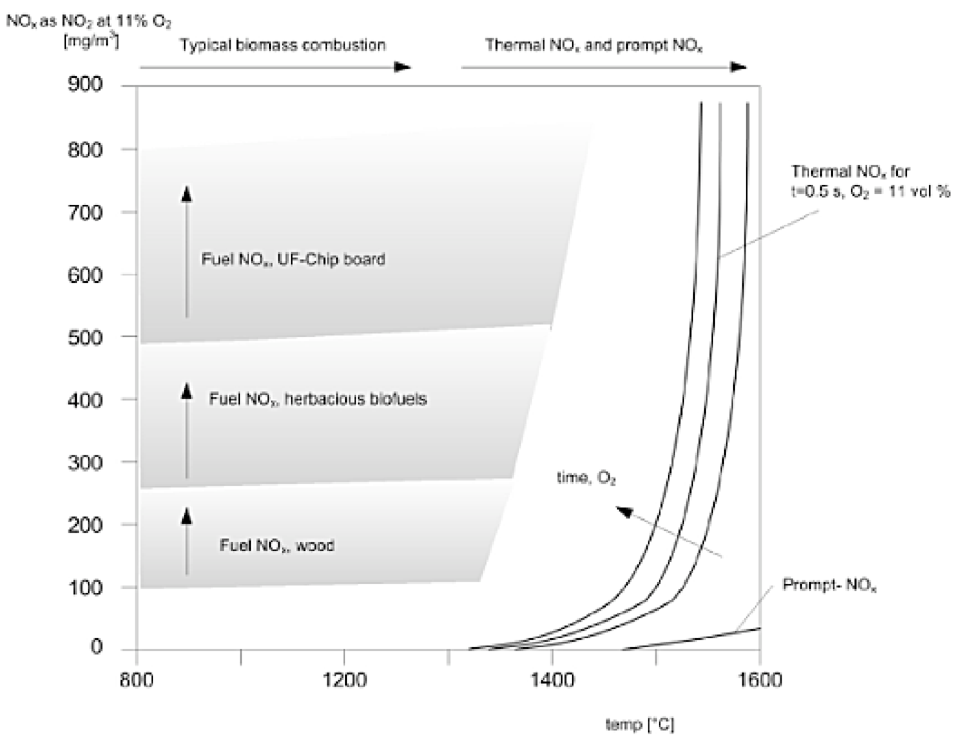
Table 12 Typical NO_X Emissions from Heating Fuels

Fuel	Mechanism	Fuel	Typical NO_X emissions
Wood fuel	Fuel-NO_X	Bark and wet wood Dry wood	95 mg/MJ 211 mg/MJ
Heating oil	Thermal NO_X	Oil	100–120 mg/MJ
Small natural gas burners	Thermal and prompt NO_X	Natural gas	40–70 mg/MJ

Source: AP-42 emission factors (US EPA 1995). AP-42 factors may be taken from various sources and do not always represent expected trends. For example, bark would usually lead to higher NO_X emissions than white wood. The values shown here suggest an inverted relationship, which does not correspond to the findings laid out in this appendix. The AP-42 numbers are used here because of their authoritative source but, in this case, do not necessarily represent the exact situation likely to be found in the context of SSBCs, although these numbers are useful to illustrate the approximate emission levels from wood combustion.

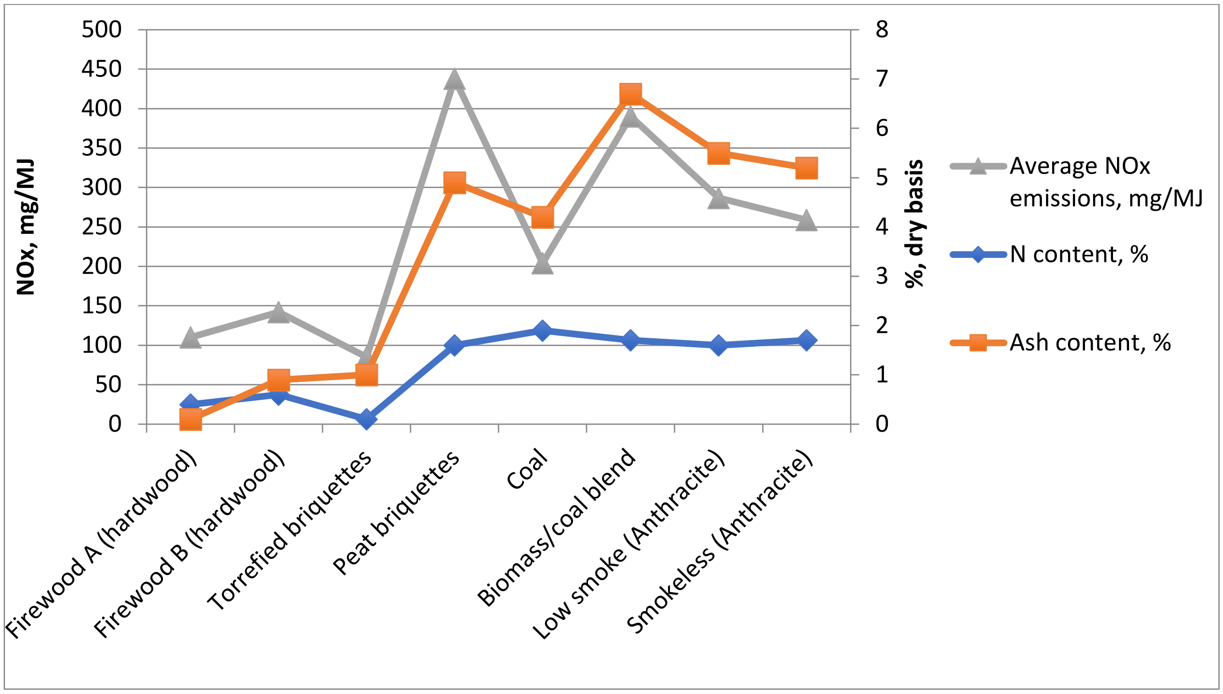
Because the combustion temperature in SSBC generally does not exceed 1,000°C, almost all the NO_X emitted originates from nitrogen contained in the fuel; see Figure 5 below. Biomass fuels with low nitrogen content therefore produce low NO_X emissions (Mitchell *et al.* 2016). Figure 6 establishes the correlation between fuel ash content and NO_X emissions for wood stoves. With wood fuels, the share of bark in the fuel is usually the cause of both higher nitrogen and higher ash content. This suggests that clean, low-ash wood fuels can be expected to also lead to lower NO_X emissions during combustion.

Figure 5 Fuel, Thermal and Prompt NO_X



Source: Nussbaumer (1998), reproduced with permission (copyright Swiss Federal Institute of Technology – Zürich and Verenum Research).

Figure 6 Relationship Between Fuel-N, Ash Content and NO_X Emissions



Source: Graph created for this guidance manual using Mitchell, E. J. S. *et al.* 2016.

Fuel nitrogen content is generally low with clean wood (0.1% to 0.2% nitrogen on a dry weight basis) but can be high (0.3 to 1.0%) whenever high contents of bark or resins are present (see Figure 7). Lower-quality and lower-cost fuel that contains bark is mainly used in industrial wood combustors that are designed to handle irregular fuel. To function properly, compact boilers and package boilers generally require wood pellets or homogenous, fairly dry, uncontaminated fuels of a particle size of maximum 45 mm (P45 according to ISO 17225-4)[11]. These vendor-imposed[12] quality criteria are typically not achievable with higher bark content: bark will frequently break rather than be cut like stem wood. This results in a larger amount of fine material in the chipped fuel.

As mentioned, limiting fuel nitrogen content is one way of controlling NO_X emissions. If the nitrogen content is known, the resulting NO_X emissions can be estimated. For wood fuel with nitrogen content below 0.1%, NO_X emissions below 200 mg/m³ are achievable (at 10% O_2 content, 0°C and 101.3 kPa), which is the limit value specified in the European Ecodesign Directive[13].

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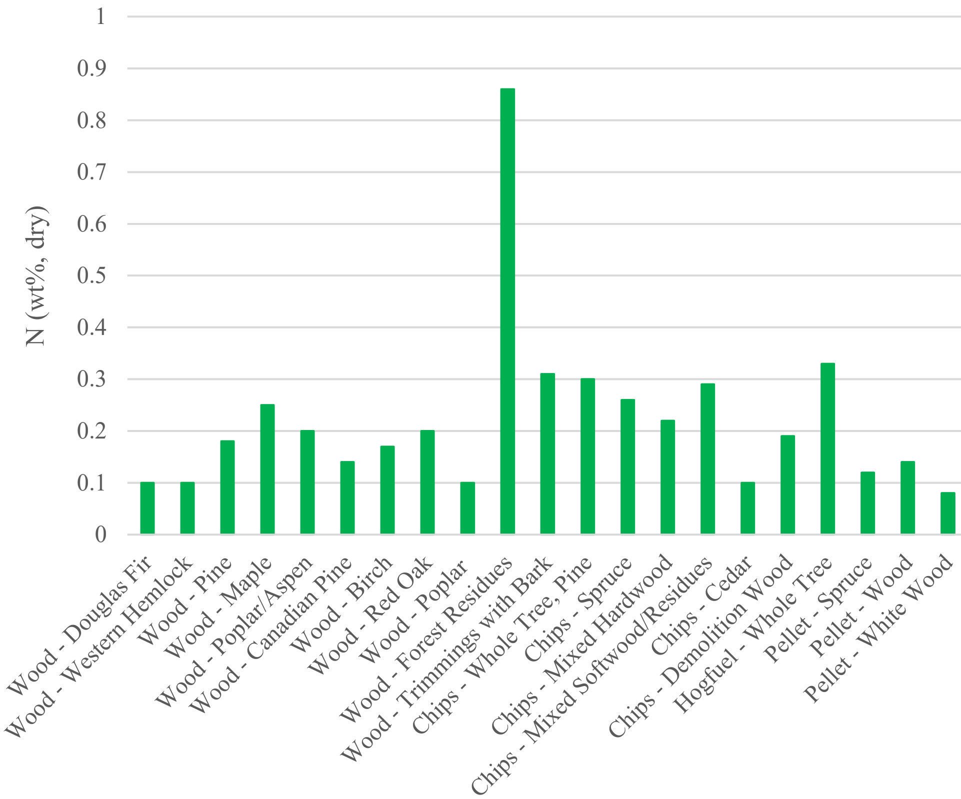
[11] Cordwood boilers use cordwood that might contain bark. These boilers do not qualify under the higher regulatory tiers, applicable to situations where NO_x may be a local air quality concern.

[12] As per fuel specifications provided in equipment documentation. Using fuel that does not correspond to vendor specifications may lead to technical problems, exceeded emission limits and voided warranties.

[13] European Union Regulation 2015/1185 with regard to eco-design requirements for solid fuel local space heaters (including indoor stoves, cookers and water heaters but not for hot air furnaces or outdoor wood burners).

Figure 7 Nitrogen Content of Woody Biomass



Note: Nitrogen content data for the range of biomass materials in the graph were taken from Phyllis biomass database, https://phyllis.nl/Browse/Standard/ECN-Phyllis.

Methods for reducing NO_X emissions from SSBCs

Two key mechanisms are used in modern SSBCs to reduce NO_X formation:

- Staged combustion: Air staging induces the reduction of NO to generate N_2 by forming a fuel-rich primary combustion zone and supplying the remainder of the stoichiometric air required for complete combustion at the subsequent combustion zones.
- Flue gas recirculation entails recirculating a portion of the relatively cool exhaust gases back into the combustion zone in order to lower the flame temperature. This method can also reduce NO_X formation by creating a synergy of local mixing effects and additional reducing agents due to the flue gas recirculation into the primary zone, supporting the reduction of NO_X precursors in the primary combustion zone.

These technologies lead to lower NO_X emissions than would be expected based on fuel nitrogen content. With most woody feedstock types, NO_X emissions per GJ of fuel input are comparable to those from oil boilers (see Table 12).

SCR uses a catalyst to react injected ammonia or urea to chemically reduce NO_X. It can achieve up to a 94% reduction and is one of the most effective NO_X abatement techniques. However, this technology has a high initial cost. In addition, catalysts have a finite life in flue gas and some ammonia slips through without being reacted, creating a new emissions problem. A catalytic system to reduce NO_X in exhaust gas requires, at the same time, very high removal efficiencies for dust, to avoid catalyst poisoning. The costs to implement such a system can become prohibitive for an SSBC.

A distinction should be made between certified package SSBCs and custom-made SSBCs. The former are permitted based on model testing results. Controlling NO_X emissions for these classes of SSBCs mainly relies on the use of clean wood fuels and good design practices. Suitable flue gas cleaning devices are only available in the size classes of custom boilers, typically above 3 MW of output capacity.

With specified fuels, the performance of package SSBCs can be expected to be similar in the field as under testing conditions. Compliance with limits during laboratory tests should be sufficient to obtain a permit. NO_X limits should not be imposed on units rated under 150 kW capacity. The Canadian standard CSA B415.1-10 and the US EPA Wood Heater Rule do not specify NO_X limits.

SSBCs with a capacity ranging from 150 kW up to 1 MW should be required to comply with the emission limits set out in the European standard EN 303-5. Since this standard only applies to boilers up to 500 kW, it must be adapted to units larger than 500 kW, as Ontario has done. This standard describes the test and measurement procedure but does not impose NO_X limits. It does, however, specify low CO and PM limits that represent the state of the art. This requires advanced designs with flue gas recirculation and staged combustion that lead to reduced NO_X emissions. The efficiency criteria stated in the standard requires low oxygen concentrations in the flue gas, which, in small-scale combustion, typically support and correlate with lower NO_X emissions.

EN 303-5 is currently under revision to be adapted for the requirements of the EU regulations, (EU) 2015/1187 for efficiency labelling and (EU) 2015/1189 for the definition of minimum requirements for solid fuel boilers. The standard does not provide emission limits—as they are defined in (EU) 2015/1189—but describes a procedure to compare measurements with fuels of varying nitrogen content.

A flexible approach is recommended for custom SSBCs over 1 MW of thermal output. The following options are recommended for tier 3 only (urban areas and airsheds with high pollutant background concentrations) because NO_X emissions from SSBCs are not expected to cause much concern in tier 1 and 2 situations:

- Emission dispersion modelling can determine whether, where and when air quality objectives will be violated. This might lead to restrictions, secondary control equipment, curtailments or outright denial of a permit.
- Regulating and enforcing fuel quality are other options for controlling NO_X emissions. This could take the form of outlawing fuel with high nitrogen content, such as bark or wood containing resins, or chemicals containing nitrogen. It could also take the form of requiring the use of manufactured fuel, such as grade A pellets known to have low nitrogen content. However, this is not a preferred approach since it restricts project developers with respect to the means they can use to achieve NO_X emission goals. With a limit value (see next

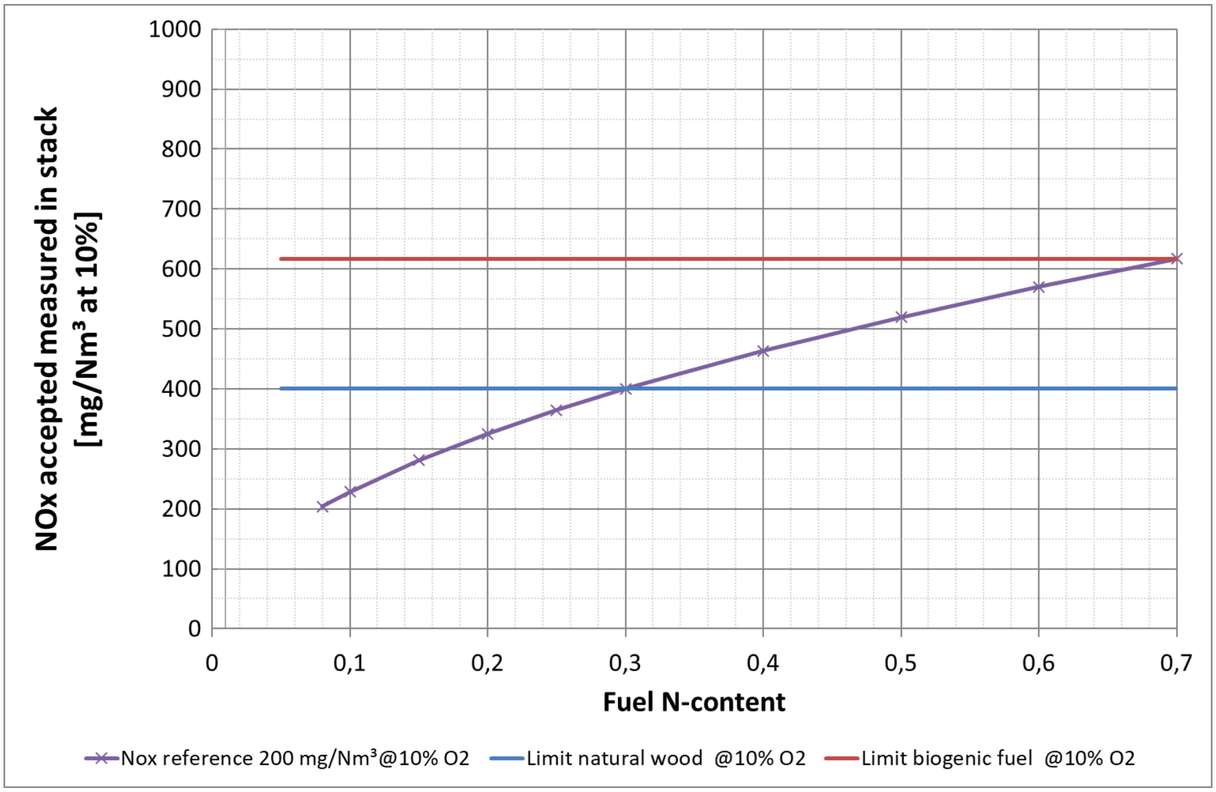
point), the permit applicant can choose to prevent NO_X emissions by selecting a low-nitrogen fuel or by controlling stack emissions.

- The third option is to set NO_X emission limits. Clean fuels and state-of-the-art design should lead to emissions under 200 mg/m³ for NO_X (at 0°C, 10% O_2, 101.3 kPa) or 221 mg/m³ (at 20°C, 8% O_2, 101.3 kPa). In this case, regulators should leave open the option to use low-nitrogen fuel or to use fuel containing larger amounts of bark in combination with NO_X controls, such as SCR. Testing should be mandatory upon commissioning and then at defined intervals, to verify performance.

Recommendations for a suitable NO_X limit are based on the method used in European standard prEN 303-5:2018 to state NO_X emission limits for the tested solid fuel boilers. The standard, to be published in 2020, uses a formula to estimate NO_X emissions based on fuel-N content by calculating the NO_X emissions to a reference value of 200 mg (10% O_2, 101.3 kPa, 0°C and fuel nitrogen content of 0.08% wt) defined as a seasonal efficiency (calculated as the weighted average of full-load and part-load emissions[14]). As Figure 8 illustrates, the formula suggests that a limit of 400 mg/m³ (10% O_2, 101.3 kPa, 0°C) can be achieved with most wood fuels in the range of 0.08% wt to 0.3% wt. Untreated wood fuels (see Table 1) typically have nitrogen content of up to 0.3% (see Figure 7), resulting in 400 mg/m³. This is a natural limit, which would require that only clean wood fuels be used in SSBCs. Higher-nitrogen fuels would entail the need for secondary NO_X controls. A lower limit would limit the choice of fuels to only white wood, which would strongly reduce opportunities for larger SSBCs to be built and operated economically. As such, this limit is deemed suitable for tiers 1 to 3.

[14] The formula used is 0.85*NO_X at part load +0,15*NO_X at full load.

Figure 8 Biomass Nitrogen (N) Content Versus NO_X Emissions



Note: Measured NO_X values that refer to NO_X emissions of 200 mg (10% O_2, 101.3 kPa, 0°C and a nitrogen content in the fuel of 0.08% wt) according to prEN 303-5:2018.

Source: Calculations based on European standard prEN 303-5:2018, and the German and English versions of prEN 303-5:2018 (DIN EN 303-5: 2018 05).

APPENDIX 4: STACK GAS CONCENTRATION CONVERSION TABLE

(Separate Excel file)

This Excel file converts different standard conditions, meaning it shows the resulting emission limit based on different parameters for oxygen content, temperature and pressure.

APPENDIX 5: ILLUSTRATIVE IMAGES OF SMALL SOLID BIOMASS COMBUSTORS AND SIZE CLASSES

Five types of biomass combustors are on the market:
1. Residential (single-home) appliances (<50 kW)
2. Compact boilers and furnaces (<150 kW)
3. Package boilers (150-500 kW, some up to 1 MW)
4. Customized boilers (> MW)
5. Outdoor wood boilers.

Each covers a certain segment and size.

1. Residential (single-home) appliances (excluded from this manual)

Photo by Sven Brandsma posted on Unsplash.com

Photo by Rachel Claire posted on Pexels.com

1. Stoves and fireplaces or fireplace inserts. Typically these heat indoor air directly and are not used as water boilers.
2. Output capacity of (usually much) less than 50 kW.
3. Manually or automatically fed (typically with cordwood if manual and with wood pellets if automatic).
4. Several thousand sold each year.
5. Mainly Canadian and American products.
6. Outside the scope of this manual.

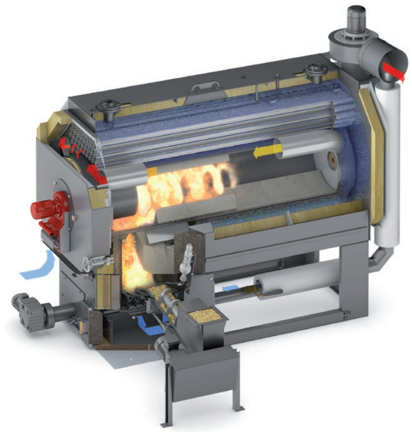
2. Compact boilers and furnaces

Photo courtesy of Fink Machine, reproduced with permission.

Photo by Steven Law, reproduced with permission by Confederation College, Thunder Bay, Ontario

1. Sized to heat small commercial or mid-size residential buildings and can either heat the indoor air directly or heat water in a boiler.
2. Performance linked to fuel quality and consistency; equipment designed for specific fuel quality specs.
3. Output capacity of less than ≈150 kW.
4. Most pellet stoves and some cordwood stoves include daily fuel storage.
5. Size of a large fridge.
6. Manually fed (cordwood) or automatically fed (pellets).
7. Designed for a specific fuel; performance is linked to this fuel.
8. Mass-produced in Europe. Few Canadian or American manufacturers, except for outdoor wood boilers.
9. Very small market, due to equipment cost and import restrictions.
10. This size class would also cover outdoor boilers that are produced in North America and for which air emissions are often a concern.

3. Package boilers




Photos courtesy of Fink Machine, reproduced with permission.

1. Output capacity typically 150 kW to 500 kW, some up to 1 MW or more.
2. Primarily used to heat water in a boiler but may be used as an air heater for industrial heating purposes.
3. Pre-engineered, automated boilers typically using wood pellets or wood chips fed from an integrated wood fuel storage facility.
4. Sold as complete packages, including most upstream and downstream components, such as fuel storage and flue gas fan.
5. Design usually approved and certified by an independent agent.
6. Serial-manufactured on demand in Europe; few Canadian or American manufacturers.
7. Small market, due to price and non-tariff trade barriers.
8. Designed for specific, well-defined types of fuel, but may be (mis-)used to burn unwanted residuals.

4. Customized boilers

Photo courtesy of Fink Machine, reproduced with permission.

Photo courtesy of ENVINT Consulting, reproduced with permission.

1. Capacity typically above 1 MW.
2. Primarily used to heat water in a boiler but may be used as air heaters for industrial heating purposes.
3. Mainly hot water boilers, some steam boilers.
4. Used in large residential or commercial buildings, district heating, commercial greenhouses and sometimes in industrial facilities, such as sawmills with kilns or veneer plants.
5. Consist of pre-designed components, assembled or even built on site due to transport logistics.
6. Frequently, the entire plant is custom-built to specific requirements.
7. Rarely certified to a specific emission standard because each unit is built differently.

5. Outdoor wood boilers

Photo courtesy of Dr. F. Preto, Natural Resources Canada, reproduced with permission.

1. Most common wood boilers in Canada.
2. Generally uncontrolled, i.e., without any combustion or air or emission control.
3. Poor design results in high emission of particulates (smoke) and other air pollutants.
4. Outdoor wood boilers are prohibited or heavily restricted in several states in the US.
5. This guidance manual excludes uncertified outdoor wood boilers and similarly polluting wood heaters since they do not meet the rules defined above.
6. A significant number of outdoor wood boilers are now certified by the US EPA.

APPENDIX 6: SUGGESTED WORDING FOR SPECIFYING ELIGIBLE WOOD FUELS

(a) Wood briquettes that are grade A1, A2 or B as set out in the standard CAN/CSA-ISO 17225-3, published by CSA Group and entitled "Solid biofuels – Fuel specifications and classes – Part 3: Graded Wood briquettes."

(b) Wood pellets that are:

  i. grade A1, A2 or B as set out in the standard CAN/CSA-ISO 17225-2, published by CSA Group and entitled "Solid biofuels – Fuel specifications and classes – Part 2: Graded Wood pellets"; or,

  ii. premium or standard grade as set out in the document entitled "Pellet Fuels Institute Standard Specifications for Residential/Commercial Densified Fuel," published by the Pellet Fuels Institute.

(c) Wood chips that:

  i. have a moisture content, reported on a wet basis, that does not exceed 50% when used as fuel; and,

  ii. are grade A1, A2, B1 or B2 as set out in the standard CAN/CSA-ISO 17225-4, published by CSA Group and entitled "Solid Biofuels – Fuel specifications and classes – Part 4: Graded wood chips."

(d) Firewood that is grade A1, A2 or B as set out in the standard CAN/CSA-ISO 17225-5, published by CSA Group and entitled "Solid biofuels – Fuel specifications and classes – Part 5: Graded firewood."

Additional information on the Canadian wood fuel standards can be found in Natural Resources Canada's Technical Bulletins at: www.nrcan.gc.ca/energy/renewable-electricity/bioenergy-systems/biofuels/7399.