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Progress in the implementation of the 2018–2019 workplan

Code of good practice for solid fuel burning and small combustion installations*

Prepared by the Task Force on Techno-economic Issues

Summary

The draft code of good practice for solid fuel burning and small combustion installations based on best available techniques was prepared by the Task Force on Techno-economic Issues in accordance with item 2.3.8 of the 2018–2019 workplan for the implementation of the Convention (ECE/EB.AIR/140/Add.1 as amended). The document is being presented to the Working Group on Strategies and Review for consideration. It is expected that a final draft, incorporating any comments, made by the Working Group at its present session, will then be submitted to the Executive Body for the Convention for adoption at its thirty-ninth session (Geneva, 9–13 December 2019).

* The present document is being issued without formal editing.

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Contents

I. Introduction

1. The Executive Body at its thirty-seventh session (Geneva, 11–14 December 2017) adopted the 2018–2019 workplan for the implementation of the Convention (ECE/EB.AIR/140/Add.1), which included item 2.3.8, assigning to the Task Force on Techno-economic Issues the task to develop a code of good practice for solid-fuel burning and small combustion installations. This item was included in line with respective recommendation of the ad hoc policy review group of experts on the 2016 scientific assessment of the Convention[1] (policy review group) (ECE/EB.AIR/WG.5/2017/3 and Corr.1, para. 25(b)).

2. The initial document was developed by experts of the Italian Agency for new technologies, energy and sustainable economic development (ENEA) and regional environmental authorities of Lombardia, Friuli-Venezia-Giulia and Veneto regions in Italy and further elaborated and finalized by the technical secretariat of the Task Force on Techno-economic Issues[2] in cooperation with an expert from Belgium and with a contribution by other members of the Task Force lead by France and Italy.

II. Subject matter and scope

3. The 2018–2019 workplan item 2.3.8 on the development of a code of good practice for solid-fuel burning and small combustion installations based on BAT was included in line with respective recommendation of the policy review group. The policy review group provided a rationale for such a recommendation to the Working Group on Strategies and Review at its fifty-fifth session (Geneva, 31 May–2 June 2017) (see informal document no. 6).

4. In line with the task included in the workplan item 2.3.8 and the rationale presented by the policy review group, the present document covers the following deliverables:

(a) Good practices for domestic solid fuel heating installations;

(b) BAT for domestic solid fuel heating installations.

5. The current document focuses on wood biomass only. It provides an overview of guidance documents, codes of good practice and communication materials with respect to domestic solid fuel heating in several countries of the ECE region.

6. The current code of good practices can be applied to small solid fuel combustion installations for indoor heating with a rated thermal input of less than 100 kW and used in the residential sector. More particularly, this document focuses on domestic solid fuel local space heaters (fireplaces, stoves) and domestic solid fuel boilers in accordance with the above-mentioned rationale.

7. Domestic solid fuel heating is a major source of emissions of particulate matter including black carbon, dioxins/furans, PAH and B(a)P in the ECE region, resulting in poor local air quality conditions and significant negative effects on human health. This document responds to the need to inform the general public of:

[1] See Rob Maas and Peringe Grennfelt, eds., *Towards Cleaner Air: Scientific Assessment Report 2016* (Oslo, 2016) and United States Environmental Protection Agency and Environment and Climate Change Canada, *Towards Cleaner Air: Scientific Assessment Report 2016 —North America* (2016, online report).

[2] CITEPA, ADEME, KIT, UBA Germany.

(a) Available best practices for domestic solid fuel heating in order to minimize emissions and increase efficiency, reducing expenditures due to decreased storage needs and the use of wood, while reducing the negative impact on environment and human health;

(b) Best heating devices currently available on the market.

8. In particular, the old models of stoves and fireplaces are inefficient and can release considerably high levels of emissions. Nevertheless, even in the case of new highly performant domestic heating devices with low emissions and high efficiency, their incorrect use with non-optimal combustion can still cause high levels of emissions and reduce energy efficiency. Among the crucial factors of minimizing real-life emissions, besides the type of the combustion device, there are its proper sizing, installation, and use, which includes optimal combustion operation, proper start-up, no smouldering, maintenance and use of dry and clean firewood.

9. This document is targeting all Parties in the ECE region, with special considerations with respect to countries in Eastern Europe, the Caucasus and Central Asia added in chapter V. The document is in particular addressed to national and local authorities, and policy makers in general, serving as a background reference document for the development of awareness raising materials (leaflets and guidance) for end users at the regional, national or local level.

III. Definitions

A. Domestic heating installations

10. In this document, domestic heating installations are defined as solid fuel burning devices for local space or central indoor heating with a rated thermal input of less than 100 kW. This includes domestic fireplaces, stoves and boilers, manually or (semi-)automatically stoked, with or without heat storage capacity, with or without a connection to a central heating system, and using solid fuel of different type, shape and size.

B. Solid fuels

11. “Solid fuel” means a fuel that is solid at normal indoor room temperatures, including solid biomass and solid fossil fuel.

12. “Biomass” means the biodegradable fraction of products, waste and residues of biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste, sometimes in the form of pellets.

13. “Woody biomass” means biomass originating from trees, bushes and shrubs, including log wood, chipped wood, compressed wood in the form of pellets, compressed wood in the form of briquettes, and (compressed) sawdust.

14. “Non-woody biomass” means biomass other than woody biomass, including straw, miscanthus, reeds, kernels, grains, olive stones, olive cakes and nut shells.

C. Efficiency of the heating system

15. The ratio between the heat provided by the heating system and the energy content of the fuel is defined as the thermal efficiency of the heating system.

16. Greater efficiency is one mean to decrease emissions, however as higher efficiency is reached, emissions may not necessarily decrease at the same pace, especially with respect to black carbon emissions, considering that some high-efficiency units depend on lower temperatures for less fuel use, but with less complete combustion.

IV. Domestic solid biomass heating

A. Overview of existing guidance documents, codes of good practices and "burn wise" educational materials in several countries

17. Summary below provides an overview of existing guidance documents, codes of good practice and other materials existing within the ECE region, applied by the European Union and some other Parties to the Convention, designed to reduce emissions from residential wood combustion.

18. A new report provided by the International Institute for Applied Systems Analysis, which hosts the EMEP Centre for Integrated Assessment Modelling (CIAM) under the Convention, on measures to address air pollution from small combustion sources[3], released in February 2018, also contains relevant information on implemented actions and good practice examples to reduce air pollution from domestic solid fuel burning in the European Union, which included awareness and information campaigns, emission standards, replacement programmes, financial incentives, bans an restrictions, improved maintenance, and others.

Austria

19. An article has been prepared on proper heating in small scale combustion facilities by the Federal Ministry for Sustainability and Tourism[4]. Additional articles on heating in small scale combustion facilities with low air emissions[5] were published by other institutions and regional authorities in Austria.

Belgium

20. Information materials were developed in Belgium to raise awareness and strengthen capacity of the final users to burn solid fuel the correct way in space heating installations[6].

Denmark

21. Information material and publications were prepared to inform on impacts of wood burning, proper use of wood burning devices and other solutions[7].

[3] http://ec.europa.eu/environment/air/pdf/clean_air_outlook_combustion_sources_report.pdf.
[4] https://www.bmnt.gv.at/umwelt/luft-laerm-verkehr/luft/richtig-heizen.html.
[5] http://www.richtigheizen.at/ms/richtigheizen_at/links.
[6] https://www.lne.be/stook-slim.
[7] See the website of the Clean Heat campaign: https://www.clean-heat.eu/en/home.html. See measures targeting end-users: https://www.clean-heat.eu/de/aktivitaeten/infomaterial/download/clean-heat-recommendations-for-napcps-20.html.

France

22. In France, ADEME published a user guide for wood burning devices and a guide for households in order to choose their equipment[8].

Germany

23. Germany prepared information[9] useful to improve behaviour of operators burning wood. The German Ministry for the Environment has also developed a film on burning wood the right way[10]. The German Environment Agency developed a guide to clean and proper heating[11].

Italy

24. In Italy, a number of regional authorities, especially in the northern part of the country, where the use of space heating wood burning installations is quite spread, have developed awareness raising materials for final users[12].

Switzerland

25. "Fairfeuern"[13] (fair heating) is an information platform of Swiss environmental departments that provides information, advice and tips on correct planning and use of wood heating installations. Flyers and publications about fuels to be used and how to start a fire[14]were provided by the association "Wood Energy Switzerland" in German, French and Italian.

The United States of America

26. "Burn Wise" is a voluntary partnership program between the Environmental Protection Agency, other state agencies, manufacturers, and consumers to emphasize the importance of burning the right wood, the right way, in the right appliance[15].

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[8] https://www.ademe.fr/particuliers-eco-citoyens/habitation/construire/chauffage-climatisation/chauffage-bois.

[9] https://www.bmu.de/heizen-mit-holz/.

[10] https://vimeo.com/298615098/d274517a6b.

[11] https://www.umweltbundesamt.de/publikationen/heating-wood-a-guide-to-clean-proper-heating and https://www.umweltbundesamt.de/publikationen/heizen-holz.

[12] Lombardia region: http://ita.arpalombardia.it/ita/legna_come_combustibile/HTM/faq.htm.
Veneto region: http://www.arpa.veneto.it/arpavinforma/pubblicazioni/a-proposito-di-...-uso-della-legna-come-combustibile-1-edizione-2016.
The Autonomous Province of Bolzano in the region Alto Adige:
https://ambiente.provincia.bz.it/aria/riscaldare-con-la-legna-ma-bene.asp.
The Friuli Venezia Giulia Region:
http://www.arpa.fvg.it/cms/tema/aria/Multimedia/Dal-legno-al-fuoco.html.
Materials developed under the project Life PREPAIR:
http://www.lifeprepair.eu/index.php/comunicazione-sullutilizzo-della-biomassa.

[13] https://www.fairfeuern.ch.

[14] http://www.holzenergie.ch/ueber-holzenergie/richtig-anfeuern.html.

[15] For best practices, choosing appliances, installation and maintenance:
https://www.epa.gov/burnwise/burn-wise-resources-consumers.
For guidance documents:https://www.epa.gov/burnwise/burn-wise-guidance-documents.

Canada

27. The Canadian Council of Ministers for the Environment approved the code of practice for residential wood burning appliances[16] in 2012, which had been developed to address air pollution caused by residential wood burning. It provides guidance to support federal, provincial, territorial and municipal authorities. Canada has also developed a guide to residential wood heating[17] that provides information on how to heat safely with wood, dealing with installation, maintenance, safety, how to purchase and prepare wood for burning and how to burn wood efficiently.

Belarus

28. An informative brochure developed for Tirol region[18] was translated into Russian by a non-profit association for users in Belarus.

B. Key information and considerations

1. Impact of wood combustion on emissions, air quality, health effects

29. Domestic wood combustion leads to emission of a complex mixture of air pollutants. It is driven by a series of chemical reactions basically oxidizing the carbon and hydrogen present in the firewood to CO_2 and water. Incomplete combustion, mainly due to insufficient mixing of combustion air and fuel in the combustion chamber, a lack of available oxygen, too low temperatures and short residence times, results in emissions of CO, fine particulate matter, including BC, unburnt hydrocarbons (NMVOCs), PAH (including B(a)P), as well as POPs like dioxins/furans (PCDD/F) and, hexachlorobenzene (HCB). Different types of wood are characterized by different pollutant emissions in terms of relative percentage. Potassium Cation (K^+), Sulfate anion $(SO_4)^{-2}$, UFP, Zn, Fe, Al, total carbon (TC, mainly BC), levoglucosan and PAH are the main pollutants concerned. Their relative emissions may change significantly, for the same type of wood (e.g. beech), depending whether the wood is burnt in form of pellets or logwoods, especially for TC/BC and PAH emissions.

30. PAHs, especially B(a)P is recognized by WHO as dangerous for human health. VOCs are precursors of the ground level ozone, as well as NOx, also generated by the biomass combustion, mainly due to the content of N in the fuel. Both VOC and NOx are the pollutants covered by the Gothenburg Protocol. Particulate matter ($PM_{2.5}$) resulting from the combustion also affects human health, decreasing life expectancy.

2. Link with climate change and renewable energy objectives

31. Wood burning produces CO_2, but, in the frame of UNFCCC, it is considered as CO_2 neutral in the global balance (emission/ absorption), because the amount of CO_2 produced, when wood is burned, is assumed to be equal to the amount of CO_2 fixed by the trees and plants during their lifetime.

32. The BC resulting from the wood combustion is known as a short-lived climate forcer (SLCF). Although BC has a short atmospheric lifetime of only a few days or weeks, its contribution to current global warming is not insignificant. BC causes a direct warming effect by its absorption of incoming sunlight and an indirect warming effect by its deposition on snow and ice, reducing the reflectivity (albedo) of snow and ice and hence leading to accelerated melting. BC deposition is especially relevant in the Arctic and mountainous

[16] https://www.ccme.ca/files/Resources/air/wood_burning/pn_1479_wood_burning_code_eng.pdf.
[17] http://publications.gc.ca/site/eng/9.651307/publication.html.
[18] http://www. richtigheizen.tirol/fileadmin/richtigheizen/Downloads/Folder_8seitig_168x240_RU_web.pdf.

regions, as well as throughout the northern part of the ECE region during the cold months of snow and ice when heating with wood is intensified. Precisely, as BC has a very short residence time in the atmosphere, its reduction can have a noticeable positive impact on global warming in the very near term. Reduction of BC provides synergy aspects with the climate change policies.

3. Emission and energy performance of different types of domestic wood heating installations

33. There are several types of domestic wood heating installations used to provide heat in a home, and within each broad type, there are many variations. An overview of the most common wood heating devices used for domestic heating purposes, is provided below.

34. Small heating devices burning wood are usually classified based on their construction properties (factory or site built), combustion technology used, the shape of the firewood applied (logs, pellets), combustive air draught (up-draught, down-draught) and the heat distribution system (local, central).

35. Older single domestic heating devices are of a very simple design, while modern more advanced devices are improved versions of these old conventional ones. Small domestic wood heating devices can be classified as follows:

(a) Open fireplaces;

(b) Partially closed fireplaces;

(c) Closed fireplaces;

(d) Wood stoves;

(e) Pellet stoves;

(f) Mass stoves;

(g) Boilers.

36. Data on technology-specific emission factors for different domestic wood burning technologies can be found in the EMEP/EEA air pollutant emission inventory guidebook[19].

37. *Open fireplaces* are the simplest combustion devices mainly used for occasional supplementary heating in residential dwellings and primarily retained for aesthetic reasons and recreational use rather than space heating. In areas of energy or fuel poverty open fireplaces are sometimes used as primary heating source to reduce the energy bill. The open fireplace consists of a combustion chamber, which is directly connected to the chimney and has a large opening to the fire bed. The heat generated by the open fire is transferred directly into the room where the fireplace is located (by radiation and convection), without the use of distribution pipes distributing water or air. Open fire places typically come as part of the overall construction of the property.

38. Open fireplaces are characterized by high excess of the combustion air and incomplete combustion of the firewood, typically resulting in low energy efficiencies (around 10 to 15 per cent) and significant emissions of fine particulate matter and associated pollutants, higher than with other installations. Open fireplaces are definitely not state-of-the-art devices and generally use the least efficient and clean wood burning technology.

39. *Closed or partly-closed fireplaces* differ from the open fireplaces described above, as they are defined pre-fabricated devices, whereas open fireplaces are usually site built. They

[19] see part 4, chapter 1.A.4 (small combustion) of the 2016 edition.

can be free standing (installed as stand-alone units) or inserted in a recess (built-in a pre-existing open fireplace).

40. Partly-closed fireplaces are equipped with louvers and glass doors to reduce the intake of combustion air, but the distribution of combustion air is not specifically controlled. Combustion conditions compared with open fireplaces are therefore only slightly improved. Closed fireplaces are equipped with front doors, fully closing the opening towards the area being heated, and have air flow control systems. In closed fireplaces, the temperature in the combustion chamber can increase up to 400 °C or more and the retention time of the combustion gases in the combustion zone is longer compared with open fireplaces. All closed fireplaces have intakes for incoming air; modern units may also be equipped with automatic control valves, catalytic converters and fans directing additional heat into the living area.

41. Thanks to their combustion mechanics, closed fireplaces are characterized by higher energy efficiencies (often close to 55 per cent) and lower emissions than open fireplaces. Recent technology developments have improved the performance of the closed fireplaces, making these fireplaces a more efficient and cleaner wood-burning option, with efficiencies up to 80 per cent or more and with emission profiles resembling those of modern stoves.

42. *Wood stoves* come in many shapes, types and sizes. They can be divided into conventional radiating stoves, advanced or modern (catalytic, non-catalytic, hybrid) stoves, smart stoves (semi-automated), mass stoves (heat accumulating stoves) and stoves installed as inset or freestanding. Wood stoves are mainly produced in steel or cast iron, except for mass stoves which are usually built on site with bricks, stone or ceramic materials. Different kinds of firewood can be used, such as wood logs, wood chips and wood pellets. Mass stoves and pellet stoves are discussed separately in subsections below.

43. Wood stoves can be installed as a free standing unit or fitted within the firebox of masonry fireplaces. An insert can convert a conventional fireplace into a more effective heating system. Wood stoves are devices, in which the firewood is combusted to provide useful heat which is transmitted to its immediate surroundings (room heating) by radiation and/or convection. In some parts of the ECE region as a result of energy poverty freestanding wood stoves may also be used for cooking and heating water for bathing and cleaning.

44. Various combustion principles (like down-burning, up-burning, combinations) are used with regard to conventional radiating wood fired stoves. All these old-style devices typically have a low efficiency in the range of 40-50 per cent and high emissions of pollutants, mainly originating from incomplete combustion (PM, CO, NMVOC and PAH). Down-burning stoves (the majority of the older stoves) have higher emissions compared to up-burning stoves due to more incomplete combustion. The autonomy of the conventional stoves (the ability to operate without user intervention) is low.

45. Modern wood stoves using more advanced technologies are characterized by better efficiencies, lower emissions and less wood use compared to the traditional stoves. Stoves with advanced combustion technologies, characterized by improved air control, improved utilization of secondary air in the combustion chamber, multiple air inlets, preheating of secondary air, have efficiencies that range between 55 and 75 per cent. Stoves equipped with a catalytic converter reducing the PM emissions caused by incomplete combustion, are more expensive than non-catalytic stoves, but can hold a fire longer and tend to be more efficient (up to 75–80 per cent and more) and are cleaner. Hybrid stoves, using both non-catalytic and catalytic technology achieve efficiencies of 80 per cent and more.

46. The newest generation of wood stoves is more and more aiming at automation, using sensors and computer chips to adjust air flow electronically and as such diminishing the influence of the operator and wind speed. These (semi-)automated or so called smart stoves can be equipped with other functions or features like the possibility to be used as thermostatic stoves, where the user sets the desired temperature and overheating of the room is avoided,

or the possibility to alert the user when refilling of firewood is optimal. There are smart stoves that can be connected to WiFi, allowing the transmission of combustion data to the producer for checking and adjusting. Smart stoves are an emerging class that is gaining popularity.

47. In *pellet stoves* the fuel consists of wood pellets instead of wood logs. Pellets are mainly made of dried sawdust, compressed into small cylinders. Pellets are more homogeneous and have lower moisture content than wood logs, and therefore result in a better combustion quality. Moreover, the pellets are automatically fed into the combustion chamber by means of a loading device, adjusting the load according to the heat demand. Modern pellet stoves are also often equipped with an active control system for supply of the combustion air and thermostats to maintain a constant temperature in the room. Pellet stoves are installations with a higher performance compared to the traditional stoves. They can reach efficiencies of 70 per cent to more than 90 per cent for the best performing ones. Emissions from pellet stoves are considerably lower compared to the traditional wood stoves.

48. *Mass stoves* or *masonry stoves* are large heaters built with masonry, ceramic, bricks, tile or soap stone. The basic principal of masonry stoves is that they store the generated heat from the fire into the masonry thermal mass and then slowly release it by radiation into the building’s living space over a longer period of time. The flue is ducted in such a way that it travels a long distance through this mass. Because of the large thermal capacity of masonry materials they keep a room warm for many hours (8–12) or days (1–2) after the fire has burnt out, that is why they are called heat accumulating or heat storing stoves. Their combustion chamber can be equipped with horizontal strips or inclined, perpendicular baffles made of steel or fireproof material, which improve combustion quality and efficiency. Owing to increased residence time of fuels in the combustion zone there is a decrease in pollutant emissions compared to conventional radiating stoves. Their combustion efficiency ranges from 60 to 80 per cent and their autonomy from 8 to 12 hours. Masonry stoves are large and expensive installations. Site built masonry heaters tend to be even more expensive than factory-built masonry heaters as skilled masons need to be on site for several days to build it.

49. Wood-fired *boilers* are installations with capacities typically larger than wood stoves and fireplaces. They are equipped with one or more heat generators and provide heat to a water-based central heating system in order to reach and maintain the indoor temperature of one or more enclosed spaces at a desired level. They are used for indirect heating of one or more rooms. In wood-fired boilers wood logs, pellets or chips can be used as fuel. Automated log-fired boilers are available, but most automated wood-fired boilers use pellets or chips. Along with automated fuel loading modern automated pellet or chip-fired boilers also have automated sensors to control combustion (supply of combustion air). The burners can have different designs such as underfeed burners, horizontally fed burners and overfired burners. These automated boilers can achieve high efficiencies of 80 per cent or more, with emission levels that are much lower than traditional stoves, comparable to those of liquid fuel boilers.

4. Impact of sizing, placement, commissioning, use, maintenance and control of domestic wood heating devices on emissions and efficiency

50. Besides the type of the heating device, also its proper sizing and installation adjusted to the heat demand, as well as a good use and maintenance of the heating device, with sufficient attention to inspection and enforcement, are of great importance to keep emissions low and efficiencies high in real life operations. In particular for manual stoked devices the user plays an important role in the level of emissions and efficiency through the strong influence of use and maintenance of the heating device.

51. It is important that the heating device that is purchased is not only energy-efficient and environmentally friendly, but that it is also adjusted to the heating and energy demands of the residence. It is also important that the necessary attention is paid to the correct

placement of the device and the chimney, taking into account the immediate environment of the chimney, and that the device is properly adjusted, maintained and used correctly (for example, fired with correct air supply, correctly lit and at favourable atmospheric conditions).

52. The ignition phase is one of the most critical phases given that combustion temperature in this start-up phase is still low. The commonly used “bottom-fire” ignition method by which the fire is lit at the bottom produces about 75 per cent more emissions of fine particulate matter than the modern “top fire” ignition method. Also, the correct regulation of air supply by the user is critical in guaranteeing sufficient quality of the combustion process (and as such keeping emissions low). Smouldering the heating device, for instance, by minimizing air supply, produces 10 times more emissions of fine particulate matter than when operated at normal conditions. Unfortunately, this technique is still applied by a considerable share of users.

53. Poor maintenance of the heating device, the air supply or the flue gas channel in general leads to a too low air supply with a negative impact on the quality of the combustion process.

54. It should be noted here that the latest generation of wood stoves and boilers are increasingly focusing on automation, with automatic control of inter alia air supply, fire wood supply and ignition. As a result, the influence of user and wind speed decreases strongly and emissions are reduced.

5. Impact of quality of domestic firewood on emissions and efficiency

55. An efficient and low emitting fire also requires good firewood of the right shape and amount. Firewood for domestic heating exists in different shapes and forms (wood logs, wood pellets, wood chips, wood briquettes), each with its own characteristics, emission profiles (PM, PAH, BC), advantages and disadvantages. Wood logs are cheaper than pellets and briquettes. Often non-commercial (not purchased) firewood is used.

56. The type of firewood, classified as soft or hard wood, depending on its weight, shape, size, density, thickness, caloric value, bark share and moisture content, has an impact on the burning temperature and operation, the efficiency and level of emissions of the heating device. For combustion purposes, oak, ash, beech, maple, fruit trees (except the cherry tree) are all considered as high-quality firewood. The wood of chestnut, birch, and alder is of decent quality, and that of linden, poplar and willow is of acceptable quality.

57. The moisture content of wood has in particular a significant impact on emissions and efficiency of the combustion. Wood must be sufficiently dried before the use, preferably between a moisture content of 10 to 20 per cent for wood logs. The use of wood with a moisture content of ± 20 per cent can reduce emissions of fine particulate matter by 75 per cent compared to the use of wood with a moisture content of ± 30%. The consistent use of dry and qualitative wood contributes to the further reduction of domestic wood heating emissions. Wood pellets can be characterised as a stable and standardized fuel with a low moisture content of around 10 per cent. Wood logs are less homogenous in size, moisture content and bark share than wood pellets and require more attention in their use as firewood. The use of composite and treated wood must be avoided at all times.

58. Combustion of soft wood normally results in higher emissions than combustion of hard wood. Soft wood lights up easily, which is helpful in starting your fire, burns faster and develops a long flame. It is used in heating devices where a long round flame is required. Poplar, alder, chestnut and willow are examples of soft wood. Smaller sized wood logs also tend to burn faster, possibly resulting in higher emissions. The optimal size of wood logs should be indicated in the manual of the heating device.

59. Hard wood is more compact and is characterized by slower combustion and short flames. It needs more combustion air than soft wood. For these reasons, it is more suitable for domestic heating. Elm, oak, holly, beech, ash and locust are examples of hard wood.

60. Other elements to consider when choosing the right firewood adjusted to the wood heating system, are its origin, sustainable character, storage needs (larger for wood logs than for wood briquettes and pellets) and existence of a certification system.

C. Good practices for domestic wood heating

61. This section provides recommendations and good practices to support end-users in their choice of a heating device and to encourage its correct use. Good practices can be centred around four key pillars: burn the right wood, the right way in the right heating device, and maintain and clean the heating device or chimney on a regular basis.

62. Awareness raising campaigns to promote the use of safer, more energy efficient and less polluting heating devices and the application of best burning techniques can be in general a good tool to reduce emissions and negative impacts from domestic wood heating. The following subsections provide information on good practices that could be recommended within such communication campaigns. However, not all listed recommendations can be applied to all types of heating installations (fireplaces, stoves, boilers). Some further differentiation is still required.

1. Selection of heating installation

63. In order to reduce the environmental impact and to improve energy efficiency, one should carefully consider the type, the size and installation requirements of the heating device. The use of the following practices is recommended:

(a) Choose a heating installation that is using best available techniques to reduce emissions and increase efficiency. Emissions from automated heating installations, with automatic control of air supply, feed and ignition, and, as a consequence, decreased influence of user and wind speed, are considerably lower than those from manually operated heating devices;

(b) Choose a heating installation that matches the size of the space to be heated and is adjusted to its function (primary or additional heating source). The heat demand should be calculated based on the volume of the room(s) to be heated, with due consideration of heat dispersion, degree of isolation of the building and outdoor temperature. A heating installation that is too large for the room will overheat the space quickly and will have to be operated with slow, smouldering fires much of the time to avoid overheating the room, resulting in high emissions and low efficiency. An undersized heating installation can be damaged by frequent over-firing to keep up with the heat demand. Heating installations of correct size will use less firewood;

(c) Choose a heating installation that is certified or provided with an energy label of high energy efficiency or an eco-label, if possible. The certification or labelling guarantees appropriate quality of the heating installation and compliance with safety regulations and/or minimum efficiency and emission requirements;

(d) Choose a heating installation in function of the available indoor or outdoor storage capacity for storing the firewood (logs, pellets, chips);

(e) Avoid installing an open fireplace. Heating with an open fire place is inefficient, which results in significant emissions and poor indoor air quality and can cause a fire if burning material leaps out;

(f) Ask for a user manual when purchasing a heating installation. The user manual should be easy to read and to use and should contain all necessary information that is specific for that heating installation, especially as regards its proper use;

(g) Foresee that the combustion air for the heating installation is extracted from outside the house, through proper piping. This ensures safer operation and reduces heat loss. Requirements concerning insulation, airtightness and ventilation of energy-efficient buildings should be taken into account for the management of air intake for the heating installation;

(h) Use licensed/qualified technicians for the installation of the heating device;

(i) Ensure a good placement of the flue gas channels and chimney. The chimney has to extend above the ridge of the roof and adjoining buildings. The diameter of the flue gas channels must be adjusted to your heating installation in order to avoid a bad chimney draft and the risk of a chimney fire. Have your flue gas channels and chimney installed by a specialized technician. Corners in the flue gas channel and horizontal lines should be avoided;

(j) Ensure that discharge conditions for exhaust gases are in accordance with state-of-the-art technologies.

2. Selection of firewood

64. The choice of firewood to be used as fuel in the heating installation is essential for the proper operation of the heating installation and for reducing the impact on air quality and the environment. The recommended good practices are provided below.

For the use of traditional wood logs:

65. Burn dry seasoned wood. Wood burns best with a moisture content of 15–20 per cent. Dry wood lights up and burns easily. It results in lower emissions than when wet wood is used. With increasing moisture content of the wood, ignition becomes more difficult, combustion temperature and energy efficiency decrease, and emissions increase due to more incomplete combustion. Wood that is too dry may also increase emissions of soot particles. A cheap and easy way to check the moisture content of the wood and to make sure it is ready to burn is to make use of a wood moisture meter. Measure the moisture content inside the wood log after the wood log has been split, test the newly split side. Dry hardwoods have the best combustion efficiency and produce less smoke and emissions.

66. Do not burn wet or green unseasoned wood, since it generates more smoke than dry wood. Properly seasoned wood is generally darker, shows some slits in the logs, feels lighter than wet wood and generates an empty sound when hitting against other logs.

67. Purchase seasoned wood in summer (June and July) and leave it to continue to dry under the sun, sheltered from the rain. Non-commercial wood, collected by end-users, should be split into logs, stacked and covered and left to dry for at least one or two years or drying seasons before being used, depending on the type of wood and ventilation of the woodpile. Hard woods require more time for sufficient drying than soft woods.

68. Stack the split wood outside the house, in a sheltered place off the ground and in an orderly way with good air flow beneath and between the logs. The upper part of the stack should be covered to protect the wood from rain and snow, to allow the seasoning process to continue. The sides of the stack should not be covered, since that would hinder good air flow.

69. To the extent possible, keep the wood ready for daily use in a warmed place. Wood burns better when not cold.

70. Use only clean and untreated wood, with a minimum share of bark. Sand and/or mud on the wood make it less efficient for combustion. Avoid, discourage or forbid the use of

composite and treated wood (painted, coated, processed with wood protection products, plywood), synthetic materials (plastic coated paper, plastic packaging materials) and all forms of waste (from building demolition or renovation, from packaging, from furniture, household trash), including for lighting the fire. The combustion of such materials causes increased emissions of harmful and toxic substances like heavy metals, VOC and POPs and may also damage the heating installation and chimney. It should be highlighted as a general rule that wastes and waste wood should never be burnt in a domestic heating installation.

71. Place the right amount of wood in the heating installation and use the right quality and size of wood, as indicated in the manufacturer's instructions. Do not overload the heating installation as to avoid damaging the internal coating materials of the installation because of too high temperatures. The optimal size of the wood should be indicated in the user's manual.

72. Use logs of similar size, preferably split rather than in round logs. Split wood seasons faster than whole wood.

73. Use split wood logs of proper size that fit in the firebox of your heating installation. Follow the manufacturer's instructions. In general, avoid the use of logs that are longer than 40 cm and wider than 15 cm. Smaller logs allow for a better storage and drying before their use, as well as better combustion. Open space between the combustion chamber wall and the wood logs will help improve combustion.

74. Use locally cut firewood to minimize fuel consumption for transport, as well as to reduce the risk of introducing potentially harmful insects in new areas. When purchased, use preferably wood that is provided with a certification/label, if available. This will minimize potential negative impact on environment, climate and biodiversity.

For use of wood pellets:

75. For pellet stoves and boilers, choose pellets of high and stable quality (no impurities, no bark, low ash content, high caloric value, moisture content around 10 per cent) that meet the manufacturer's recommendations. This will reduce emissions during combustion. Buy preferably pellets that are certified (for example, DINplus, ENplus) and/or labelled (for instance, PEFC or FSC). Certified wood pellets must comply with strict technical standards. Labels like the PEFC and FSC guarantee that the wood used for the production of the pellets comes from sustainably managed forests. Check that not too much wood dust is present in the pellet bags. High quality pellets are well pressed and not shredded. Pellets are dense, require less storage needs and are most suitable for the use in automated heating installations.

For use of artificial wood logs (sawdust logs), wood briquettes, wood chips:

76. In case of the use of sawdust logs or wood briquettes or other forms of firewood than traditional wood logs or pellets, consult the manufacturer's instructions in the manual before their use. Use only the fuel recommended by the manufacturer. Do not use artificial logs or briquettes in a heating installation that is designed for the use of traditional logs. The higher energy content of sawdust logs or wood briquettes may overheat heating installations designed for traditional logs. Store sawdust logs, briquettes and wood chips indoors.

3. Fuel loading

77. Good burning requires correct loading of the combustion chamber. The following practices are recommended for manual loading with wood logs:

(a) Load the wood logs horizontally and "front head" when the combustion chamber is narrow;

(b) Load the wood logs horizontally and "side head" when the combustion chamber is wide, but shallow;

(c) Load the wood logs vertically when the combustion chamber is narrow, but high;

(d) In mass stoves (heat storage stoves), load the wood logs horizontally and “front head”;

(e) In squared combustion chambers, load the wood logs in a crossed manner, with about 4–8 cm free space between the logs, allowing for a good air flow;

(f) Consult the manufacturer’s manual for any loading instructions specific for the heating installation;

(g) Keep the firing burning, especially when the heating installation (stove) serves as a primary or the only heating source. Add logs before the flames disappear. Most of emissions arise during the start-up phase, and a hot stove burns more efficiently with lower emissions.

4. Lighting the fire

78. The ignition phase is a critical phase of the firing cycle for ensuring good combustion and efficiency of the heating installation and for keeping emissions low. The following practices for manual fire lighting for local space heaters like stoves and fireplaces are recommended:

Before lighting the fire:

79. Check air supply and flue gas channel. Make sure that sufficient air is fed into the house. If needed, switch off the kitchen ventilation. Ideally, the heating installation should be connected to external air supply. The larger the installation, the more combustion air is needed. Check whether there is sufficient upwards draft (air flow) in the flue gas channel, for example by putting your hand in it, and lighting a match or some paper, if physically possible.

Lighting the fire:

80. Never fully fill the combustion chamber: when lighting the fire, fill up to maximum half of the combustion chamber.

81. Place the most flammable material at the top of carefully stacked pieces of dry wood and light the fire from above, at or just below the top. There are less emissions released during the ignition phase when this so called top-down fire method (Swiss method) is used, since it reduces incomplete combustion. The ticker wood logs are placed at the bottom. For a few heating installations the recommended practice for lighting the fire is the bottom-fire method with the fire being lit from below. Check the manufacturer’s manual for instructions.

82. Use dry kindling (dry sticks) or natural firelighters as flammable material to start the fire at the top. Avoid using newspaper for lighting the fire. Newspaper is printed and the ink burns with it. Do not use gasoline, kerosene or charcoal as fire starter.

83. Open the air supply of the heating installation completely when you light the fire. Reduce the air supply a bit as soon as the fire burns well and a good hot fire has been established. Make sure that the flames do not get smaller. If the heating installation sucks in too much air (oxygen), the firewood burns too bright: it will not have sufficient time to burn completely and the chimney will suck in sparks. If the air supply is too low, emissions of soot particles and other harmful substances, such as carbon monoxide, will increase. Close air supply only when the embers remain with no flame, so to avoid a quick cooling of the heating installation.

84. Put new wood on the fire in time, when the combustion temperature is still high and before flames are disappearing.

85. Add small quantities or pieces of wood regularly to avoid overloading and close the door as quickly as possible. This ensures optimal burning with fewer emissions of harmful substances.

86. Load larger pieces of split wood only after there is a vigorous fire or a suitable bed of embers is formed.

87. Control the amount of heat being released by controlling the loading of the firewood, rather than by trying to control the air supply.

88. When not loading, keep the front door of the heating installation closed and locked, also for safety reasons, unless the manufacturer recommends keeping it cracked during start-up.

5. Combustion

89. Poor combustion results in reduced energy efficiency and higher emissions of air pollutants, especially of fine particulate matter, and creates creosote build-up on the interior surfaces of the chimney flue reducing the chimney draft and creating a chimney fire hazard. There are three phases of wood combustion, mainly in reference to the temperature of the process: drying, pyrolysis, gasification and combustion.

Drying

90. When wood is heated, water begins evaporating from the surface of the wood. Evaporation typically starts below 100 °C. Up to a temperature of 150–200 °C wood loses the water it contains. As evaporation occurs, the temperature in the combustion chamber temporarily decreases, slowing the process of combustion and decreasing the thermal efficiency of the heating installation. This is the main reason for not using unseasoned wood. The wetter the wood is, the more energy will be required to dry it and the lower the efficiency of wood combustion. High moisture contents in wood lead to incomplete combustion, reduced thermal efficiency and increased emissions of air pollutants.

Pyrolysis

91. At a temperature of around 200 °C, wood starts to break down into volatile substances and solid carbon. The volatile fraction of wood evaporates. The volatile fraction is more than 75 per cent of the whole mass of wood. At around 400 C°, most of the volatile components are evaporated.

Gasification and combustion

92. This phase, starting between 500 and 600 °C and continues up to about 1000 °C, consists of complete oxidation of gases. Combustion is completed when all wood components have completed their chemical reaction with oxygen. However, a 100 per cent complete combustion of wood is a pure theoretical concept due to limiting conditions, such as the right degree of mixture between air and fuel is quite difficult to achieve in a short time interval. When ideal conditions for complete combustion are missing, emissions of harmful substances increase.

93. In reality, during combustion the three phases do not occur in distinct moments of time but overlap in a complex way.

94. The main reasons for incomplete combustion are:

(a) Incorrect or poor mixing of the combustion air and firewood in the combustion chamber, for example caused by improper loading of logs;

(b) Lack of combustion air (oxygen) that is available in the combustion chamber, for example caused by insufficient air supply;

(c) Combustion temperature is too low, for example, due to the use of unseasoned firewood;

(d) Residence time in the combustion chamber is too short.

95. Incomplete combustion is shown by incomplete oxidation of gases and an increase in the organic and inorganic unburned fractions. As a consequence, emissions of carbon monoxide (CO), particulate matter (PM), as well as volatile organic compounds (VOC) may increase.

96. In recent decades, technology innovation has gradually increased the efficiency of wood heating installations (stoves), with substantial reductions in CO and other harmful emissions. For solid fuels, achievement of optimal burning conditions, for complete combustion, however remains difficult, especially compared with natural gas combustion, for which a good mix of combustion air and fuel gas, and also turbulence, are considerably easier to achieve. This is the reason for CO and VOC emissions from wood combustion to be significantly higher than those from natural gas combustion, even with the most efficient wood heating installations. On the other hand, natural gas use in stoves produces greenhouse gases emissions from CO_2 and from fugitive methane emissions, which impacts climate as well as air quality through tropospheric ozone formation. All heating sources therefore bring trade-offs. Increased automation can significantly reduce emissions from wood combustion, including of black carbon, which is also a climate forcer.

97. In the light of the above considerations, recommended good practices, in particular for manually operated heating installations like stoves, are the following:

(a) Ensure that a high temperature in the combustion chamber is achieved as soon as possible and maintained. This allows for an optimal and efficient performance of the heating installation and as such will reduce emissions of harmful pollutants, reduce production of ashes, increase efficiency and reduce creosote build-up in the chimney. Optimal and efficient burning will result in lower fuel costs to the consumer;

(b) Keep the flame vivid and “warm”. Blue, yellow-red or light red flames indicate good combustion. Red or dark red flames are an indicator of poor combustion;

(c) Do not keep the fire smouldering. Dirty glass doors or dirty smoke from the chimney are the signs that the fire needs more air, the firebox temperature is not hot enough or the firewood is too wet;

(d) Check the smoke leaving the chimney (visual control). With a good combustion, the smoke at the chimney exit should almost be transparent. If it is dense and coloured yellow or dark grey, combustion is not taking place correctly and adjustments are needed in the fuel and/or operation of the heating installation;

(e) Make sure that the smoke from wood burning does not smell. A good combustion of the firewood in the heating installation should not generate smoke that smells. Smoke that smells points to a significant amount of harmful substances that are generated and emitted due to bad combustion;

(f) If possible, measure the temperature in the chimney. The temperature of the flue gases in the chimney should be around 150–200 °C. If it’s lower, there is a risk of condensation in the chimney;

(g) Check the colour of the ashes. In good combustion conditions, ashes are grey or white. Ashes that are dark and heavy or the head of the fireplace that is black and dirty are the result of poor combustion. This is also a strong indicator for possible creosote build-up in the chimney, which greatly increases the chance of a chimney fire. Such fires, because they often burn for some time before being detected, frequently result in severe home damage and mortality;

(h) Remove regularly ashes from the heating installation unit by a proper installation equipped with a cover and opening allowing proper air intake.

6. Extinguishing the fire

98. Recommended good practices, in particular for manually operated heating installations like stoves, are as follows:

(a) If a glowing biomass remains, lower the air supply further, but not to the point that the ember visibly begins to smoke;

(b) Collect the glowing biomass for better combustion;

(c) Wait until the ember is burnt, before completely shutting off the air supply.

7. Maintenance and inspection

99. Like all technical installations, a wood-fired heating installation also requires regular maintenance and inspection. Proper maintenance and inspection will contribute to cleaner (less emissions of pollutants, less ashes), more efficient, money saving and safer burning.

100. Recommended good practices are as follows:

(a) Remove ashes on a regular basis or as needed - from daily to every week or three weeks - depending on performance of the combustion. Too much ash in the firebox can negatively impact the performance of your heating installation (for example, clog air intakes). Leaving some ash (2 cm) in your firebox will keep your ember hot and make it easier to restart your fire with fewer emissions compared to the complete new ignition process.

(b) Clean the firebox and area around the firebox on a regular basis.

(c) Have a qualified technician to inspect and maintain your heating installation and chimney on a regular basis, preferably, at least once a year, and more frequently when used as a primary heating source in a cold climate. Qualified technicians should regularly check the heating installation and chimney to detect possible damage or malfunctions. The chimney should be cleaned at least once a year for removal of creosote deposits. The seals and possible contamination of the fresh air supply installation of the heating installation must also be checked. In some countries local authorities are authorised to carry out visual inspections of wood-fired heating installations.

(d) Follow the instructions and frequency of maintenance as recommended by the manufacturer, check the manufacturer's manual.

D. Best available techniques for domestic wood heating installations

101. Following references contain useful information on BAT for domestic wood heating installations:

(a) Guidance document on control techniques for emissions of sulphur, nitrogen oxides, volatile organic compounds, and particulate matter from stationary sources (ECE/EB.AIR/117) with information on domestic heating installations in section VII.A;

(b) Report of the International Institute for Applied Systems Analysis "Measures to address air pollution from small combustion sources" (February 2018);

(c) EMEP/EEA air pollutant emission inventory guidebook 2016, chapter on small combustion;

(d) Preparatory studies on solid fuel heating installations for the eco-design directive;

(e) European wood-heating technology survey: an overview of combustion principles and the energy and emissions performance characteristics of commercially available systems in Austria, Germany, Denmark, Norway and Sweden (April 2010).

Best available combustion technologies

102. The technology for domestic wood heating installations has evolved significantly during the last decade in several parts of the ECE region. Examples of technological improvements are as follows:

(a) Higher air-tightness that allows better air control. Robust and compact heating installations with high quality welding lines reducing the risk of incorrect/undesired incoming air, and with a solid small chamber door with a reliable and improved locking mechanism;

(b) Improved air control: air control with addition of primary air at the bottom, secondary air at the height of the flames and sometimes also tertiary air within the top of the flames;

(c) The use of heat-reflective materials in the combustion chamber, which increases the starting temperature. The use of refractory material, as coating in the combustion chamber, protects the materials and reduces heat losses;

(d) A post-combustion chamber that ensures that flue gases burn longer and better. There are two combustion chambers: a main combustion chamber and a secondary post-combustion chamber, in particular for boilers;

(e) A better tuning of the air supply to the desired heating capacity;

(f) Automation of air supply and combustion. Heating installations equipped with electronic or thermal/mechanic systems;

(g) Option to equip local space heaters like stoves with heat recovery system to increase its efficiency or to connect it to a heat storage system to improve heat distribution.

103. Advanced and innovative technologies for domestic wood heating installations are the following:

(a) New advanced stoves equipped with improved air control, reflective materials, two combustion chambers;

(b) New smart stoves with automated control of air supply and combustion, thermostatic control, Wi-Fi connected to collect and send combustion data to the manufacturer for better service;

(c) New advanced masonry stoves, operating at high efficiencies and low emissions;

(d) New advanced pellet boilers: full automated boilers (electronic control of air supply, lambda sensors), condensing boilers, using standardized pellets;

(e) Wood carburettor boilers using log wood or chip wood;

(f) Equipment with heat accumulating reducing stop/start frequencies and operation at partial load that generates higher emissions than operation at full load;

(g) Other: flue gas recirculation, reverse combustion, gasifier.

V. Situation in Eastern Europe, the Caucasus and Central Asia

104. The fuel profile for the domestic heating and appliances sector has been rather diverse varying largely across countries and within those in Eastern Europe, the Caucasus and Central Asia. For example, in the Russian Federation, the population in different regions use natural gas, heavy oil, hard coal, fire wood and even waste as fuel for heating and cooking. Moreover, small sources of emissions such as private home heating systems, cooking stoves and other appliances that use coal, firewood or other fuels, have not been considered by national environmental regulatory frameworks in the region at large.

105. Starting some 10 years ago, the issue of air pollution in cities and urban areas gained attention across countries, which led to a number of initiatives aimed at assessment of key air pollution sources and possible ways to tackle emissions. More specifically, in the Russian Federation, several major industrialized cities conducted complex air pollution assessments in 2010–2018, addressing industrial, transport, and domestic sources of air pollutants. Several studies clearly showed significant contributions of small domestic burning of fuels, primarily coal, firewood, and heavy oil, into the air pollution. The pollutants generated by the combustion of the mentioned fuels adversely affect human health and the environment.

106. Small combustion devices used in the region are very different in design. In some cases, the devices are used not only for heating but also for cooking. Masonry stoves are typical for rural areas and small cities, although boilers have become more popular. Often masonry stoves are fitted within fireplaces. At the moment, there are no nationally adopted guidance documents, codes of good practice or educational campaigns held in countries in Eastern Europe, the Caucasus and Central Asia.

107. Despite recent developments, there is still a large room for improvement of understanding of a problem. Countries differ in their capacity to fully address and potentially regulate this sector. Awareness-raising and capacity building aimed for this sector can be further considered.

VI. Conclusions and recommendations

108. This code of good practice provides a series of recommendations and practical advice which, if adopted, although on voluntary basis, might significantly reduce emissions from woody biomass burning for space heating and its adverse effects human health and the environment. At the same time, the related emission reductions of black carbon will contribute to reduced impact on climate. Moreover, the final users will benefit from reduced expenses as result of the increased efficiency of installations and subsequently reduced amount of wood burnt.

109. The Parties are invited to make use of this code of good practice as a background reference document to develop informative materials in their respective national languages with the aim to disseminate information to the largest community of final users.

110. In the future, envisaging availability of additional information on solid fuels, other than wood biomass, and also on new innovative technologies, this code of good practice can be further expanded.

List of abbreviations and acronyms

ADEME = Agence de l'Environnement et de la Maîtrise de l'Énergie (French Environment and Energy Management Agency)

Al = Aluminium

B(a)P = Benzo[a]pyrene

BAT = Best Available Techniques

BC = Black Carbon

CO = Carbon Monoxide

CO_2 = Carbon Dioxide

CIAM = Centre for Integrated Assessment Modelling

CITEPA = Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique (Interprofessional Technical Centre for Studies on Air Pollution)

EMEP = European Monitoring and Evaluation Programme

Fe = Iron

FSC = Forest Stewardship Council

GAINS = Greenhouse Gas and Air Pollution Interactions and Synergies

HCB = Hexachlorobenzene

KIT = Karlsruhe Institute of Technology

kW = Kilowatt

N = Nitrogen

NOx = Nitrogen Oxides

O_3 = Ozone

OC = Organic Carbon

PAH = Polycyclic Aromatic Hydrocarbons

PCDD/F = polychlorinated dibenzo-p-dioxins and dibenzofurans

PEFC = Programme for the Endorsement of Forest Certification

PM = Particulate matter

$PM_{2.5}$ = Particles with equivalent aerodynamic diameter less than 2.5 µm

PM_{10} = Particles with equivalent aerodynamic diameter of 10 µm or less

POPs = Persistent Organic Pollutants

SLCFs = short-lived climate forcers;

UBA = Umweltbundesamt (German Federal Agency for the Environment)

UFP = Ultrafine particles with equivalent aerodynamic diameter less than 0.1 µm

ECE = United Nations Economic Commission for Europe

UNEP = United Nations Environment Programme;

UNFCCC = United Nations Framework Convention on Climate Change

VOCs = Volatile Organic Compounds;

WHO = World Health Organization

Zn = Zinc