Impacts of Solid Fuel Burning in Bristol: Policy Options for Reducing Emissions

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Experts in air quality management & assessment

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Executive Summary

Poor air quality is one of the greatest environmental risks to public health in the UK, as long-term exposure to air pollution can cause chronic conditions such as cardiovascular and respiratory diseases as well as lung cancer, leading to reduced life expectancy. This report provides evidence on emissions from solid fuel burning and sets out recommendations for policy approaches to reduce these emissions effectively. Emissions from solid fuel burning are potentially significant sources within large cities, including Bristol.

Emissions from solid fuel burning will mainly impact on concentrations of Particulate Matter (PM). PM has many different sources, both natural and anthropogenic, including solid fuel burning. In terms of the health effects, exposure to $PM_{2.5}$ (PM less than 2.5 micrometres in diameter) is the most important, although nitrogen dioxide and a number of other pollutants all add to the burden of disease, to a greater or lesser extent. Current evidence suggests that there is no safe threshold for exposure to $PM_{2.5}$.

Data on wood and coal use has been used to provide an estimate of the emissions resulting from solid fuel burning in Bristol. The limitations of using the currently available data sources are analysed, with the aim of understanding how this could be improved to provide more accurate calculations in the future.

In this project, two alternative methodologies have been used to estimate emissions, based on bottom up and top down approaches.

- Bottom up: emissions are calculated using location-specific activity data on solid fuel consumption combined with emission factors. The quality and certainty of the result is inherently linked to the availability of local data on solid fuel burning in Bristol.
- Top down: emissions are based on the scaling of published UK emissions data to the Bristol level. In this case, the uncertainty of the UK level data will be further increased by the scaling factor used.

Whilst both approaches have uncertainties associated with them, the evidence supports a strong case for further action. A number of policy options have been identified, including those that could be implemented in the short term (Package 1: improving baseline activity data, information and awareness raising and lobbying Government) and those which will need additional information and lead in time (Package 2: cleaner heating programme for primary and secondary users and enforcing the Smoke Control Area). It is recommended that Package 1 is initially

adopted, while Package 2 is developed, subject to further policy development from Defra.

It has not been possible to quantify the policy options identified, in terms of emissions reduction. In relation to the policy packages set out, the low impact policy option, even with an ideal data set, would be difficult to quantify. Projections from solid fuels will largely depend on the expected turnover of appliances, as well as the potential drive of new sales, particularly in relation to the uptake of domestic solid fuel burners. Projections of new sales and uptake of types of appliances are uncertain, particularly in light of recent government proposals to reduce solid fuel use, phase out the sale of traditional house coal and to ban the sale of unseasoned or wet wood in smaller volumes. It is also currently unclear how far campaigns both at national and local level will affect behaviour on solid fuel burning. The high impact policy option could be quantified in the future using bottom up emissions estimates, with a level of uncertainty attached.

Throughout the course of the study, stakeholder consultations have been undertaken, both locally and nationally, to investigate ways of refining data collation, and to discuss policy options with regard to feasibility of implementation.

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1. Introduction

1.1 Poor air quality is one of the greatest environmental risks to public health in the UK. Long-term exposure to air pollution can cause chronic conditions such as cardiovascular and respiratory diseases as well as lung cancer, leading to reduced life expectancy. Short-term exposure (over hours or days) to elevated levels of air pollution can also cause a range of health effects related to lung function, exacerbation of asthma, increases in respiratory and cardiovascular hospital admissions, and mortality. There are a number of other emerging links for air pollution and health, including dementia, a variety of mental health conditions, and adverse pregnancy outcomes.

1.2 In June 2019, the Mayor of Bristol presented plans in the Clean Air Day speech to tackle air pollution in Bristol[1] . This committed to raising awareness of, and enforcing the existing smoke control legislation in commercial and domestic settings.

1.3 This report provides evidence on the scale of emissions from solid fuel burning, and sets out recommendations for policy approaches to reduce these emissions. Emissions from solid fuel burning are a potentially significant source of pollution within large cities, including Bristol. This report aims to gain a better understanding of the impact of solid fuel burning within Bristol.

1.4 Air pollution can be quantified in terms of emissions (the amount of pollutants released into the atmosphere from a source) or the concentration of pollutants in a location (air quality). This report focusses on emissions. Emissions are related to concentrations, but not in a linear way, due to the effects of meteorology and atmospheric chemistry. Whilst it is exposure to elevated concentrations which cause the health effects, measures to reduce emissions will minimise these effects.

1.5 Emissions from solid fuel burning will mainly impact on Particulate Matter (PM). PM both as PM_{10} and $PM_{2.5}$[2] have many different sources, both natural and anthropogenic. These can be primary, with the particles emitted directly into the atmosphere, or secondary with particles formed from precursor gases through atmospheric reactions. Sources of primary particles include road and non-road vehicles, industrial sources and power stations, domestic heating and shipping. Natural sources of particles include sea salt. The formation of secondary particles happens over hours to days, thus secondary $PM_{2.5}$ is

[1] https://news.bristol.gov.uk/news/embargoed-until-speech-delivered-mayor-of-bristol-commits-to-protect-most-vulnerable-from-pollution

[2] PM_{10}, or course particles are particles that are less than 10 microns (μm) in diameter. $PM_{2.5}$, or fine particles, are particles that are less than 2.5 μm in diameter

found downwind (by tens or hundreds of kilometres) of the sources of emission. Reducing exposure to PM is particularly challenging, given the variety of sources.

1.6 Studies on health effects have historically focussed on $PM_{2.5}$ concentrations. In terms of the health effects of individual pollutants, exposure to $PM_{2.5}$ is the most important, although nitrogen dioxide, and a number of other pollutants, all add to the burden of disease to a greater or lesser extent. Current evidence suggests that there is no safe threshold for exposure to $PM_{2.5}$.

1.7 In addition to providing emissions estimates on solid fuel burning, the report sets out recommendations as to how, in future, Bristol City Council could improve on the data used in this report. The report concludes with policy recommendations based on the available data and experience from other local authorities.

1.8 The project has been undertaken by Air Quality Consultants Ltd, and Aether on behalf of Bristol City Council.

2. Policy and Local Context

National Policies

2.1 The Clean Air Strategy (Defra, 2019a) sets out a wide range of actions by which the UK Government will seek to reduce pollutant emissions and improve air quality. Actions are targeted at four main sources of emissions: Transport, Domestic, Farming and Industry. The Strategy highlights that emissions to air from solid fuel use are significant. Burning wood and coal in open fires and stoves makes up 38% of the UK's primary emissions of fine particulate matter ($PM_{2.5}$), and is, therefore, a potentially significant source of primary $PM_{2.5}$ which Bristol City Council could action to reduce. The Strategy contains a number of actions to be implemented at national level to reduce emissions from this sector, including:

- Legislating to prohibit the sale of the most polluting fuels;
- Ensuring that only the cleanest stoves are available for sale by 2022;
- Making changes to existing smoke control legislation to make it easier to enforce;
- Giving new powers to local authorities to take action in areas of high pollution;
- Working across government to look at opportunities to align work on air quality, clean growth and fuel poverty; and
- Develop a dedicated communication campaign targeted at domestic burners to improve awareness of the environmental and public health impacts of burning.

2.2 In February 2020, Defra published the response to its consultation on "cleaner domestic burning of solid fuels and wood" (Defra, 2018). This has proposed legislation to phase out the sale of traditional house coal over a two year period and to ban the sale of unseasoned or wet wood in volumes of less than $2m^3$. Sale of anthracite (smokeless coal) or manufactured solid fuels will continue, with a requirement that they conform to a standard of no more than 2% sulphur and emit no more than 5g smoke per hour. While a robust direct comparison is not possible (different metrics, different sampling techniques etc), these standards are considerably higher (in terms of sulphur content and allowed PM emissions) than those for road fuels and vehicle emission standards.

2.3 At the same time, the Environment Bill is proceeding through Parliament (HM Government, 2020). This proposes changes to the Clean Air Act 1993 which expand and clarify the application and enforcement of Smoke Control Areas (SCAs). The three key changes are:

- The decriminalisation of SCA offences through the introduction of a series of civil penalty notices which must be issued by the local authority as part of the

enforcement process (notice of intent, decision regarding the final notice and/or a final notice);

- The inclusion of non-seagoing vessels, such as canal or house boats, under the SCA provisions (they were previously exempt); and
- The creation of an offence to offer for sale any controlled fuel in England without providing information on their use in SCAs (e.g. that it is an offence to use a controlled fuel in a non-exempt appliance).

2.4 Although these measures arguably make it easier for local authorities to enforce provisions within the Smoke Control Areas, in practical terms, they are unlikely to provide a shift towards behavioural change, or greater enforcement.

2.5 A recent study (Environmental Research Group and NPL, 2017) which quantified wood smoke concentrations in cities in the UK based on measurements, concluded that on an annual basis the proportion of $PM_{2.5}$ arising from wood smoke ranged between 4 to 6% across urban areas. However, because the majority of $PM_{2.5}$ is not from primary emissions, it was estimated that emissions from wood burning contributed between 23 and 31% of the urban-derived $PM_{2.5}$ in London and Birmingham. Solid fuel use is therefore likely to be a major contributor of primary $PM_{2.5}$ emissions in Bristol, and one of the main locally-emitted sources of $PM_{2.5}$ that Bristol City Council has the potential to influence through local policy and interventions.

2.6 There is a very wide variation in emissions from wood burning, with a range of factors influencing the amount of pollution which is produced[3]. The two most significant factors that increase emissions of particulate matter are the moisture content of the wood and the appliance which is used (open fire, stove etc). Modern stoves circulate air within them in a way which significantly increases the efficiency of the combustion process, resulting in a cleaner burn than open fires. In open fires, the air flow is largely uncontrolled and this increases the extent of incomplete combustion. When trees are felled, they contain as much as 70% water, depending on the species. When wood with high moisture content is burned, the emissions of particulate matter are far higher than when burned dry. The heat output is also significantly reduced and the partly combusted wood smoke builds up on the inside of the stove and chimney, increasing the risk of chimney fires.

[3] Call for Evidence on Domestic Burning of House Coal, smokeless Coal, Manufactured Solid Fuel and Wet Wood (January 2018)

Local Policies

2.7 Bristol City Council is currently in the process of updating the Local Plan, with the latest draft version for consultation published in March 2019[4]. The latest Local Plan includes Draft Policy HW2, 'Air Quality', which states:

"Development with the potential to generate significant numbers of additional journeys will be expected to provide an appropriate level of sustainable transport improvements consistent with Draft Policy T1 'Development and transport principles' and Retained Policy DM23 'Transport development management', which may include a financial contribution to measures set out in the council's Air Quality Action Plan.

Development that has the potential for significant local emissions to the detriment of air quality will not be permitted unless it is essential for reasons of economic or wider social need. The development will be expected to provide an appropriate scheme of mitigation and will not be permitted in proximity to homes, schools, or other existing sensitive uses.

Development will not be permitted if mitigation cannot be provided to an appropriate standard with an acceptable design.

Development in designated Air Quality Management Areas should take account of existing air pollution and include measures to mitigate its impact on future occupiers consistent with other policies of the development plan such as those on climate change and urban design."

2.8 More generally, in relation to energy use in new developments, draft Policy CCS1 contains the following:

Development should mitigate climate change, working towards zero carbon, through measures including:

- *High standards of energy efficiency including optimal levels of thermal insulation, passive ventilation and cooling and passive solar design (Draft Policy CCS2 'Towards zero carbon development');*
- *The use of renewable and low-carbon energy supply systems and connection to low carbon heat networks (Draft Policy CCS2 'Towards zero carbon development');*

2.9 The above policies, in working towards zero carbon, should reduce the likelihood of any solid fuel burning in new properties[5].

[4] see https://www.bristol.gov.uk/planning-and-building-regulations/local-plan-review for details

[5] Although there may be a perception that decreasing carbon means increasing solid fuel, it is highly unlikely that new properties would be burning solid fuel as their primary heat source.

2.10 Until the new Local Plan is adopted, the current Core Strategy (Bristol City Council, 2011), adopted in June 2011, and the Site Allocations and Development Management Policies document (Bristol City Council, 2014) continue to apply. The Core Strategy includes one policy that is directly relevant to air quality; Policy BCS23 states that: *"Development should be sited and designed in a way as to avoid adversely impacting upon: Environmental amenity or biodiversity of the surrounding area by reason of … air … pollution …"*

2.11 The Site Allocations and Development Management Policies document was adopted in July 2014. The document includes a further policy that is directly related to air quality; Policy DM33: 'Pollution Control, Air Quality and Water Quality' provides further clarity on mitigation. The Local Plan process provides opportunity to ensure that solid fuel burning is not increased by new developments, but cannot control energy use in existing buildings. This may be through direct control over energy usage, and ensuring that new residential properties don't have solid fuel infrastructure.

Air Quality Action Plans

National Air Quality Plan

2.12 Defra has produced an Air Quality Plan to tackle roadside nitrogen dioxide concentrations in the UK (Defra, 2017); a supplement to the 2017 Plan (Defra, 2018a) was published in October 2018 and sets out the steps Government is taking in relation to a further 33 local authorities where shorter-term exceedances of the limit value were identified. Alongside a package of national measures, the 2017 Plan and the 2018 Supplement require those identified English Local Authorities (or the GLA in the case of London Authorities) to produce local action plans and/or feasibility studies. These plans and feasibility studies must have regard to measures to achieve the statutory limit values within the shortest possible time, which may include the implementation of a Clean Air Zone (CAZ). Bristol was one of these 33 local authorities and feasibility work for the CAZ is progressing. An Outline Business Case was submitted to Government in November 2019, and BCC are continuing to work to submit the Full Business Case. The CAZ is designed to reduce concentrations of nitrogen dioxide to acceptable levels, current plans submitted to government (see the Clean Air for Bristol Website for further details).

Local Air Quality Action Plan

2.13 Bristol City Council has declared an AQMA that covers the city centre and parts of the main radial roads. The AQMA was originally declared in 2001 for exceedances of the annual mean nitrogen dioxide and 24-hour mean PM_{10} objectives, and was subsequently updated in 2003, 2008 (to also include the 1-hour mean nitrogen dioxide objective) and 2011. The Council has developed an Air Quality Action Plan; adopted in 2004, which is contained within the Local Transport Plan and currently being revised to include work for

the Clean Air Zone. The Air Quality Strategy outlined in the plan focuses on information, promotion awareness and alternatives, network management, signing, partnership working, freight, major transport schemes and monitoring. The Strategy focusses on transport, and currently contains no actions on solid fuel burning.

Further Information about Pollutants, Health Effects and Sources

Particulate Matter

2.14 Particulate Matter (PM) is different from the gaseous pollutants in that it is not a clearly defined chemical compound. PM_{10} and $PM_{2.5}$ are the most commonly used units. They are measured as the mass of particles in a cubic metre below the stated size, 10 micrometres in the case of PM_{10} and 2.5 micrometres for $PM_{2.5}$. Both PM_{10} and $PM_{2.5,}$ have many different sources, both natural and anthropogenic. Particulate matter is a mixture of both *primary* and *secondary* components. Sources of *primary* particles include combustion processes, such as diesel engines, but can also include *mechanically derived* particles such as tyre, brake and road wear, windblown dusts (including, for example, dust from the Sahara) and sea salt. Mechanically derived particles tend to be larger in size (PM_{10}) whereas combustion derived particles are smaller ($PM_{2.5}$). *Secondary* particles can comprise a very wide range of components but, in terms of contributions to total measured levels of PM_{10} and $PM_{2.5}$, ammonium nitrate and ammonium sulphate are key components. Fine particles and, in particular, *secondary* particles can travel long distances and are known as *transboundary* pollutants. The formation of secondary particles happens relatively slowly (hours to days), thus secondary PM is found well downwind of the sources of emission of the precursor gases. This means that the particles measured in Bristol often originate elsewhere. The management of exposure to particles is particularly challenging, given the wide variety of sources.

2.15 Within the City of Bristol, previous work has shown that the population-weighted total $PM_{2.5}$ concentration in 2013 was 11.45 µg/m^3. Of this, the majority (81%) is anthropogenic, with 50% of the anthropogenic fraction being secondary $PM_{2.5}$, and 23% being regional primary. This leaves 27% of the anthropogenic fraction being effectively from local sources, which can be considered to be locally controllable. For comparison, the annual average at St Pauls urban background monitoring site in 2018 was 12 µg/m^3.

Health Effects

2.16 Particulate matter is the most important air pollutant in terms of human health effects. PM_{10} is thought to be able to penetrate into the upper airways, while $PM_{2.5}$ can penetrate deeper into the lungs. Both contain much smaller particles which, although they have very little mass, are far more numerous and can penetrate all areas of the lungs and even pass into the bloodstream, or directly into the brain. The impact of air pollution on health varies,

depending on the pollutants present, the time of exposure and the existing health of the person.

2.17 Some of the effects occur over a short period, from minutes to days – these are known as *acute effects* – whereas others result from long-term exposure, known as *chronic effects*. For some effects, air pollution is thought to have a *causal effect*, that is air pollution causes a condition that was not there before; for other effects, air pollution can *exacerbate* an existing condition, such as triggering an asthma attack.

2.18 PM is considered one of the key pollutants affecting public health and both long-term and short-term exposure is associated with adverse health effects. There is strong evidence that exposure to $PM_{2.5}$ results in increased hospital admissions and premature mortality due to cardiovascular and pulmonary diseases. These include ischaemic heart disease, stroke, chronic obstructive pulmonary disease, bronchitis and pneumonia in children and chronic bronchitis in adults, and lung cancer. Exposure to $PM_{2.5}$ may aggravate existing health conditions such as asthma.

2.19 In terms of non-cardio-pulmonary conditions, associations have been found between exposure to $PM_{2.5}$ and diabetes. Studies have also demonstrated that exposure to $PM_{2.5}$ is associated with pre-term birth and low birth weight and in children it leads to decreased development of lungs and lung function.

2.20 Particulate pollution has health effects even at very low concentrations – indeed no threshold has been identified below which no damage to health is observed. For this reason, $PM_{2.5}$ standards (the exposure-reduction approach) have been set to reduce population exposure in addition to air quality objectives which are aimed at hotspots.

Wood fuel and Greenhouse Gas Emissions

2.21 Wood is often described as a zero-carbon fuel; it is viewed as a renewable energy source in Europe and, in 2018, the US EPA declared that “forest biomass” was carbon neutral[6]. The theory is relatively simple: a tree (or other plant) absorbs carbon dioxide as it grows and burning the wood from that tree releases it back into the atmosphere. This occurs over a short timescale and results in no net increase in “modern” levels of carbon dioxide, especially as, when it dies, the tree will rot and release the carbon anyway. In contrast, burning fossil fuels (such as coal) release carbon which would otherwise have been locked away (sequestered).

2.22 However, the picture is more complex. Wood as a fuel can be close to carbon neutral but, under different circumstances, it can result in higher carbon emissions than coal. The

[6] https://www.epa.gov/sites/production/files/2018-11/documents/epa_usda_doe_response_to_congress_re_forest_biomass_11-1-18_1.pdf

variability depends on the source of the wood, the way in which it is harvested and processed, the fate of the land from which the wood was sourced and the method by which the wood is burned.

2.23 At one end of the scale, dead wood taken from managed forests and processed with minimum energy input, e.g. seasoned rather than kiln dried, will have very low carbon emissions. Emissions will be associated with cutting (e.g. with a chainsaw) and transportation, and with the removal of nutrients from the forest system (old growth, unmanaged forests hold far more carbon than managed forests and more again than plantation forest[7]). However, these emissions are very small when compared to the mining, processing and transport emissions for coal, oil or gas.

2.24 At the other end of the scale, wood which is turned into fuel pellets will have far higher process emissions. If the wood used is clear cut from old growth forest, to be replaced by agriculture, the loss of soil carbon tends to be very large and there is no compensating re-growth of trees. As wood is less energy dense than coal or oil, the energy output will be lower and thus more fuel is needed. For example, electricity generated using coal produces just over 1 tonne of CO_2 per megawatt hour of electricity produced, i.e. 1t/MWh. In general in the UK, electricity generated using biomass (mainly wood) produces around 0.1t.MWh, a tenth of the CO_2 emitted using coal. However, using a BEIS calculator[8], the worst-case scenario for biomass could produce just over 5t/MWh, five times higher than coal. This illustrates that comparing the CO_2 emissions from different combustion sources is rarely simple and depends on the detail of where and how the fuel is sourced and used.

2.25 Most people burning wood for heat in Bristol will be using whole logs rather than pellets which, if purchased commercially, will be sourced from either managed forests or plantations. As a result, the associated carbon emissions are likely to be very low. However, there are two further considerations which impact on the carbon performance of wood fuel.

2.26 Burning wood is a significant source of particulate matter. One of the components of Particulate Matter is black carbon (BC). Its colour, and ability to remain in the atmosphere for days to weeks, has led to its classification as a short-lived climate forcing (SLCF) agent, and the IPCC has described it as potentially the second most important climate

[7] Forest soils can hold up to twice as much carbon as the trees (https://www.fs.usda.gov/ccrc/topics/forest-soil-carbon) but this will only be achieved in undisturbed old growth forest.

[8] https://www.gov.uk/government/publications/life-cycle-impacts-of-biomass-electricity-in-2020

forcing agent after CO_2[9]. Wood smoke can be a significant source of BC, although the more efficient the combustion process, e.g. using a more advanced stove, the less BC is produced.

2.27 Potentially of greater importance is the degree to which the use of wood replaces the use of fossil fuels in home heating. Survey work undertaken as part of the ClairCity project[10] showed that for the great majority users in the Bristol area, wood is a secondary heating fuel, with the primary fuel being gas or, in some cases, oil. This suggests that most wood is burned for its aesthetic value and that it may not, therefore, be replacing the primary fuel to any great degree. Thus, the carbon emissions from wood are, at least partially, in addition to those associated with the main heating fuel. However, there is little evidence to demonstrate this either way and more work is needed to show whether there is a significant carbon benefit or penalty from secondary heating using wood fuel.

Other Local Sources

2.28 Bonfires may also cause episodes of elevated $PM_{2.5}$ concentrations, as is evident in the peaks lasting for several hours that frequently occur around Bonfire night, which vary in magnitude due to meteorological conditions. Analysis has revealed that peaks around Bonfire night are predominantly associated with $PM_{2.5}$, with very little $PM_{2.5-10}$ (AQEG, 2012). However, the impacts of bonfires are difficult to quantify, with figures in the NAEI acknowledged to be highly uncertain. Bonfires represent increased concentrations for a short duration and are thus likely to have a minimal impact on the annual mean concentration. Emissions from bonfires are not considered further in this report, but it is acknowledged that Southampton City Council has recently been awarded a grant from Defra to undertake a targeted awareness campaign focussed on both domestic burning and summer bonfires. The outcomes of this campaign may provide useful insight for Bristol City Council in the future.

2.29 House boats are another potential localised source of wood burning, as there are few alternatives to burning wood or coal. Houseboats are not explicitly included in this study in relation to the quantification of emissions, however, some of the policy recommendations may also be applicable. It is worth noting that Camden Council, in the Clean Air Plan 2019-2022, has pledged to produce guidance for canal boat users on the impact of wood and coal burning on local air quality, and disseminate this information with

[9] IPCC, Changes in Atmospheric Constituents and in Radiative Forcing, in Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 129, 163-64, and 185 (2007)

[10] Further details of this four year European Project can be found at http://www.claircity.eu/bristol/ Survey data obtained from Bristol City Council.

the support of the Canal and River Trust. They are also investigating the feasibility of installing electricity hubs at mooring locations to replace the need for wood and coal burning.

Burning treated wood

2.30 The analysis in this report assumes that all wood burned is clean, that is, not treated with paint, varnish, preservers, or other chemicals. However, it is known that burning treated wood results in a variety of additional pollutants emissions, depending on what it has been treated with and how it is burned (especially the temperature of combustion). Many wood preserving chemicals and paints contain chlorinated compounds which result in emissions of dioxins and furans when burned, both in the smoke and in the remaining ash[11]. In addition, some wood preservers contain arsenic which, again, can result in arsenic emissions in the smoke and a significant content in the ash. Therefore, burning treated wood could have additional health impacts, over and above those attributable to particulate matter and NO_2.

2.31 While the NAEI provides estimates for emissions from the burning of waste wood, these are highly uncertain, as discussed in AQEG's 2017 report *The Potential Air Quality Impacts from Biomass Combustion*[12]. The majority of such emissions are thought to result from open burning of waste wood, e.g. on bonfires, and there is no reliable data on the proportion of waste wood burnt on or in heating appliances. None of the data available to this project provides an indication of the level of domestic treated wood burning in Bristol and so it has not been able to provide an estimate of the emission of dioxins and other pollutants from such activity.

[11] Lavric E.D., Konnov, A.A., De Ruyck, J., Dioxin levels in wood combustion—a review, Biomass and Bioenergy, 26, 115–145, 2004

[12] Air Quality Expert Group; Defra 2017: https://uk-air.defra.gov.uk/library/reports.php?report_id=935

3. Data Sources

3.1 It is challenging to accurately assess the amount of wood which is burned in domestic settings in the UK. This is largely because of the highly diverse supply chain with wood easily accessible to many households without needing to go to a retailer. Attempts have been made to quantify the amount of wood burned in the UK; in 2015 the Department for Energy and Climate Change (DECC), now part of the Department of Business, Energy and Industrial Strategy (BEIS), carried out a survey to quantify wood use in the UK[13]. The results suggest that up to 6 million tonnes of wood (depending on the method of calculation) are burned every year. Evidence from the Forestry Commission, and anecdotal evidence from the wood industry, put this figure in the region of 3 million tonnes.

3.2 In addition to the uncertainty around the total volume of wood, there is also very limited data on the moisture content of wood when it is burned. Industry estimates suggest that around 80% of wood is burned wet; but other sources, such as the domestic wood use survey run by BEIS, suggest a much lower proportion, possibly as low as 20%. These differences provide some insight into the uncertainties associated with emissions of domestic solid fuel burning sources.

3.3 Data relating to new installations are available from HETAS (Heating Equipment and Testing Approval Scheme), which is the only specialist organisation approving biomass and solid fuel heating appliances, fuels and services. However, as it is not a requirement to register a new installation with HETAS, this will not cover all installations.

3.4 In addition, installations registered under the RHI (Renewable Heat Initiative) have been compared to provide context for numbers of installations from the BEIS survey. The RHI is a payment system in England, Scotland and Wales, for the generation of heat from renewable energy sources, introduced in 2011 under the Energy Act 2008. Through the Domestic RHI, generators of renewable heat for single domestic buildings are paid; the RHI tariff depends on which renewable heat systems are used and the scale of generation.

3.5 The National Atmospheric Emissions Inventory (NAEI) contains estimates of emissions to air of a variety of pollutants, split by sources and geographical area. This includes estimates at the national scale of solid fuel burning for both wood and coal.

[13] Details and outcomes can be found at https://www.gov.uk/government/publications/summary-results-of-the-domestic-wood-use-survey

4. Approach

4.1 Data on wood and coal burning has been used to provide an estimate of the emissions resulting from solid fuel burning in Bristol. The limitations of using various, currently available data sources is analysed to understand how more accurate calculations could be performed in the future.

4.2 Two alternative methodologies have been applied to estimate emissions; bottom up and top down.

- Bottom up: emissions are calculated using location-specific activity data on solid fuel consumption combined with emission factors. The quality and certainty of result is inherently linked to the availability of local data on solid fuel burning activity in Bristol.
- Top down: emissions are based on the scaling of published UK emissions data to the Bristol level. In this case, the uncertainty of the UK level data will be further increased by the appropriateness of the scaling factor used.

Bottom up approach

4.3 A bottom up approach provides emissions data specific to Bristol, which could be used to inform local policy in the future. However, data on solid fuel burning in Bristol is not currently available at detail required to produce robust and accurate calculations.

4.4 The standard approach to estimate emissions is to multiply activity data by an emission factor associated with the activity being measured (Equation 1).

Equation 1: Emission factor approach for calculating air quality emissions.

Air pollutant emissions = Activity * Emission factor

Activity - This is a measure of the activity which is taking place, in this case the amount of wood burnt (kWh) or coal burnt (tonnes of oil equivalent: toe).

Emission Factor (EF) - This is the emissions per unit of activity, which usually comes from the scientific literature. It is typically derived from measurement studies.

4.5 Activity data is a measure of a level of activity that results in emissions taking place over a given period of time. An emission factor is the mass of emission relative to a unit of activity. For example, estimating $PM_{2.5}$ emissions from the burning of wood involves multiplying data on the energy content of the fuel in kilowatt-hours (kWh) within a certain sector (e.g. domestic stoves), by the emission factor ($gPM_{2.5}$/kWh) for wood, which will depend on the appliance type and other factors such as type of wood and combustion conditions.

4.6 The accuracy and precision of the emission estimates relate largely to the quality of activity data that is available. Once key activity data are developed, it is possible to further refine the accuracy of estimates by refining the emission factor used. The approach for bottom up estimates has been to develop a methodology that will enable Bristol to further develop and "plug in" key local datasets as they become available. Realistically, it is expected that this will focus on the data of greatest importance i.e. the number of wood burners and operational hours, rather than more detailed information regarding the quality of fuel, or how long the wood has been seasoned. The greatest improvement to the bottom up estimates will be achieved through the identification of these key high-level activity data.

4.7 An Excel file has been developed for emissions in Bristol associated with wood and coal burning.

Top down approach

4.8 UK level emission estimates are available through the UK National Atmospheric Emission Inventory (NAEI)[14] which calculates emissions for the whole of the UK. This is a nationally verified dataset and is updated every year. The NAEI has been scaled to Bristol using national population data[15].

4.9 The NAEI can be used to compare against, and validate the totals resulting from the bottom up approach.

Input data for bottom up estimates

Wood burning activity data

4.10 Data on domestic wood burning has been derived from the 2016 wood use survey conducted by BEIS[16], which provides figures for the south west, but which is not broken down to city level detail. For context, the data for the south west in this survey is based on 1,024 respondents, 129 of which were wood fuel users.

4.11 This survey collected detailed information about various aspects of wood burning, from the type of wood used to the room of the house in which wood burning appliance is located. Not all of this data is relevant to calculating emissions. Of the information that

[14] https://naei.beis.gov.uk/data/data-selector?q=130402

[15] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland

[16] https://www.gov.uk/government/publications/summary-results-of-the-domestic-wood-use-survey

could potentially influence the emission calculation, only the following were used in this project:

- the % of households in the south west with wood burning appliances, split between open fires and closed stoves;
- the number of hours of use; and
- amount of wood used per hour (per appliance type).

4.12 The above data were selected as it was applicable to commonly-used emission factors from the literature[17].

4.13 The BEIS wood survey provides additional data that could be used in conjunction with more complex emission factors, found in specific, scientific papers or literature. Given the status of current, and likely future localised activity data, it is considered unlikely that these aspects should be built into the emissions calculations for Bristol, as the focus has been to generate a methodology that can be efficient, repeatable and fit for purpose in terms of policy analysis. For completeness, these further detailed survey criteria have been listed below:

- Types of wood fuel (logs, pellets, briquettes…);
- Additional fuels used (mains gas, coal, oil…);
- End use (all home heating, some home heating, all hot water…);
- Length of wood seasoning (< 6 months, 6 months < < 1 year, 1 year << 2 years…); and
- Age of appliance.

4.14 The data from the wood survey was scaled down from the entire south west region to the city of Bristol using national household projections data[18].

[17] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-4-small-combustion/view

[18] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/householdprojectionsforengland

Coal burning activity data

4.15 Data on domestic coal burning are available through the sub-national residual fuel consumption dataset[19] which is broken down to city level. The data for domestic coal burning in this source are calculated by collecting fuel consumption and emissions estimates from a large number of sources and mapping them across the UK using detailed local information on central heating and house type data[20]. These data are not appliance-specific, which would have made the calculation in this report more accurate.

Emission Factors

4.16 Emission factors have been taken from the 2019 European Monitoring and Evaluation Programme/European Environment Agency (EMEP/EEA) air pollutant emission inventory guidebook, using chapter 1.A.4 for small combustion sources[17]. Appropriate emission factors were used for wood combustion in open fires and for closed stoves and for coal combustion (non-appliance specific).

[19] https://www.gov.uk/government/statistical-data-sets/estimates-of-non-gas-non-electricity-and-non-road-transport-fuels-at-regional-and-local-authority-level

[20] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/833214/UK_sub-national_residual_fuel_consumption_for_2005-2017_Estimates_of_non-gas_non-electricity_and_non-road_transport_energy.pdf

5. Emissions Estimates

5.1 Emissions of PM_{10} and $PM_{2.5}$ due to residential, stationary combustion of wood and coal were taken from the UK National Atmospheric Emission Inventory (NAEI)[21] and compared with those calculated using the bottom up approaches. Table 1 presents the results obtained for the reference year, with the following sections providing discussion and context.

Table 1: Comparison of Bottom Up Calculations and NAEI Emissions Data

Activity	Pollutant	Estimated tonnes in Bristol 2014 (bottom up)	Estimated tonnes in Bristol 2014 NAEI (top down)[22]	Ratio
Wood Burning	PM_{10}	791	241	3.3
	$PM_{2.5}$	772	235	3.3
Coal Burning	PM_{10}	20	22	0.9
	$PM_{2.5}$	20	22	0.9

Domestic wood burning

5.2 Table 1 shows that the bottom up methodology applied in this study results in higher emissions of PM_{10} and $PM_{2.5}$ compared with the equivalent values obtained by scaling the NAEI data to Bristol. One explanation for this is the effect of scaling the number of wood burning appliances for the whole of the south west to Bristol based on the number of households; it is expected that the proportion of households with wood burning appliances will be higher in rural areas.

5.3 As seen in Table 2, emission factors used within the NAEI[23] are lower than those used in the bottom up methodology (EMEP emission factors) for particulate matter (PM_{10} and $PM_{2.5}$).

Table 2: Emission factors for wood burning (g/GJ)

Pollutant	EMEP EF for Open Fires	EMEP EF for Close Stoves	NAEI EF for 2014
PM_{10}	840	760	544

[21] https://naei.beis.gov.uk/data/data-selector?q=130402

[22] The top down figures can be put into context. NAEI 2017 figures show total emissions of PM_{10} in Bristol are 640 tonnes for PM_{10} and 413 tonnes for $PM_{2.5}$. ie solid fuel emissions are approximately a third of total PM_{10} and half of $PM_{2.5}$

[23] https://naei.beis.gov.uk/data/ef-all

Pollutant	EMEP EF for Open Fires	EMEP EF for Close Stoves	NAEI EF for 2014
$PM_{2.5}$	820	740	531

*EMEP EFs were used for the bottom up approach, the NAEI was used in the top-down approach

Coal burning

5.4 As seen in Table 1, emissions due to coal burning in Bristol as calculated from the sub-national statistics are comparable to the scaled NAEI values. This is because the sub-national statistics are partly compiled using the same methodology as the NAEI.

Future improvements and data verification

5.5 Data from the BEIS wood survey captures the total number of existing appliances but does not give information on changes year-to-year. It is expected that the ratio of different types of wood burning appliances will change with time, for example as more closed stoves and fewer open fires are installed. Future work to generate local activity data on domestic wood burning in Bristol should be targeted at improving key activity data as explained previously (such as numbers of wood stoves and operation hours). It should also aim to be repeatable in order to guide policy knowledge and intervention options based upon observed data trends.

5.6 In addition, alternative datasets that span multiple years could give more insight into these changes. Data are available on the number of Renewable Heat Incentive (RHI) applications and Heating Equipment and Testing Approval Scheme (HETAS) installations in Bristol. At the moment, RHI data is not broken down by year, but shows totals for specific time periods.

5.7

5.8 Table 3 shows that HETAS totals of new installations give a better indication of the estimated number of wood burning appliances in Bristol, as identified from the BEIS wood survey, than RHI totals. This implies that only a small proportion of households that install wood burning appliances submit an RHI application. It should be noted that the HETAS figures include only those appliances installed between 2007 and 2017, whereas the wood survey data represent the estimated total number of wood burning appliances. The numbers are for illustrative purposes, and not comparable with each other. HETAS data could potentially be used as part of projection calculations of emissions in future years, or to map the growth / decline of wood burning activity geographically across Bristol. However, more information is needed in order to assess whether the HETAS installation trends provide a realistic picture in terms of activity.

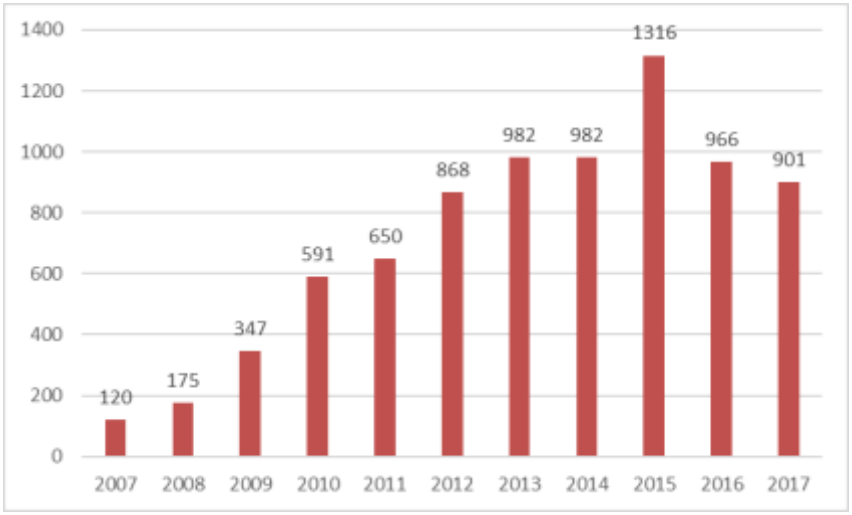
Table 3: Activity data on wood burning as indicated by RHI, HETAS and BEIS wood survey

Data Source	Unit	Value
Bristol RHI applications	Number of applications (2014-2019)	85
Bristol HETAS installations	Number of new installations (2007-2017)	7,917
Wood Survey scaled for Bristol	Scaled total number of wood burning appliances, 2014	23,421

5.9 HETAS maintains a register of installation work undertaken by approved installers, for solid fuel burning appliances or associated work, e.g. flue lining. Such installation data are provided by year and location and so provide a useful indicator of the pattern and rate at which solid fuel appliances are being installed. However, the data do not show whether the installation is "new" or whether an existing stove or fireplace is being replaced. Moreover, the records contain some anomalies, with some locations having multiple entries for what is probably the same installation (e.g. the hearth, stove and flue lining are recorded as separate entries). In addition, not all installations will be undertaken by HETAS accredited installers: the simple opening up of fireplaces is often done by construction companies and it is entirely possible to purchase and install a wood burning stove on a DIY basis.

5.10 Figure 1 shows the number of HETAS installations by year for Bristol for 2007 to 2017 (the latest year data are available), with repeat entries removed. The data show an increasing trend from 2007 to 2015, which appears to be reducing in subsequent years. As indicated previously, in the absence of further information, it is not possible to conclude with any confidence whether this trend reflects only HETAS registered installation or all installations, nor whether installations are new or replacements.

Figure 1: HETAS registered installations in Bristol, 2007-2017



NB. data for 2013 were partially recorded in 2014 and so installations have been averaged across both years

5.11 The HETAS installation data have been grouped into three time periods, 2007-2010, 2011 to 2014 and 2015-2017, and plotted geographically by Wards in Bristol (Figure 2). The total number of installations by ward, per unit of population, has also been plotted and is shown in Figure 3. Across the period, the highest number of installations were in the Westbury on Trym and Henleaze, Redland, Ashley and Bishopston and Ashley Down wards, and the lowest number in the Central, Filwood, Hotwells and Harbourside and Lawrence Hill wards. In general, this matches the distribution of the index of deprivation, with an inverse correlation between deprivation and the number of installations, for predominantly residential wards. There are clearly fewer installations in the city centre, reflecting its largely non-residential nature, and the higher proportion of apartments that are not well suited to solid fuel installation. These data do not translate into emissions reductions largely because data are not available on whether they are replacements to existing stoves or open fires, new installations, and what type of stove they represent.

Figure 2: HETAS installations in Bristol by ward, 2007-2010, 2011-2014 and 2015-2017

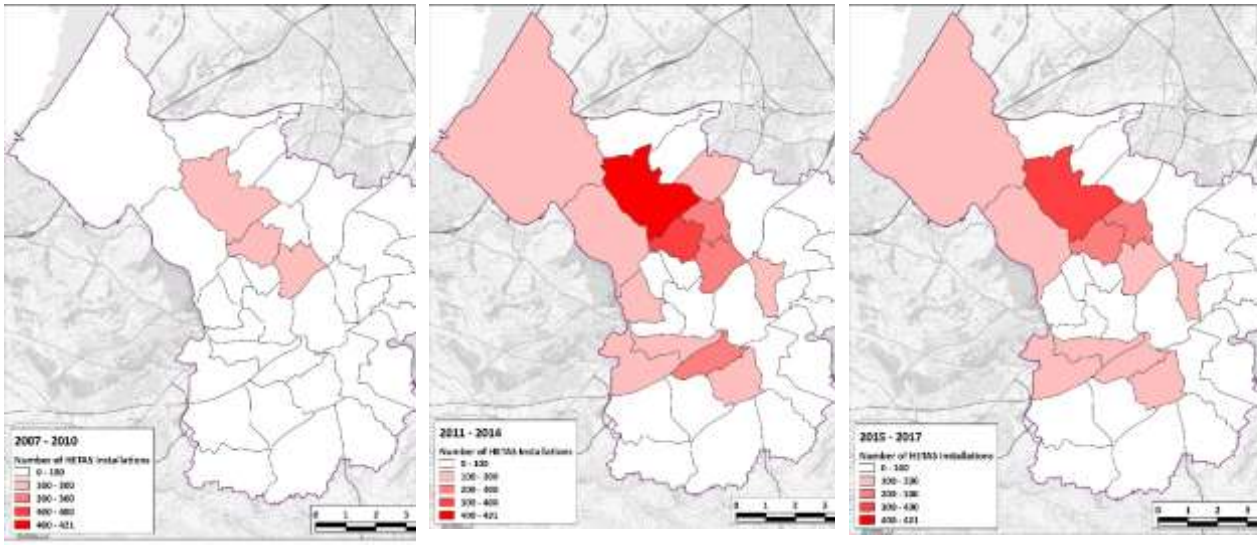
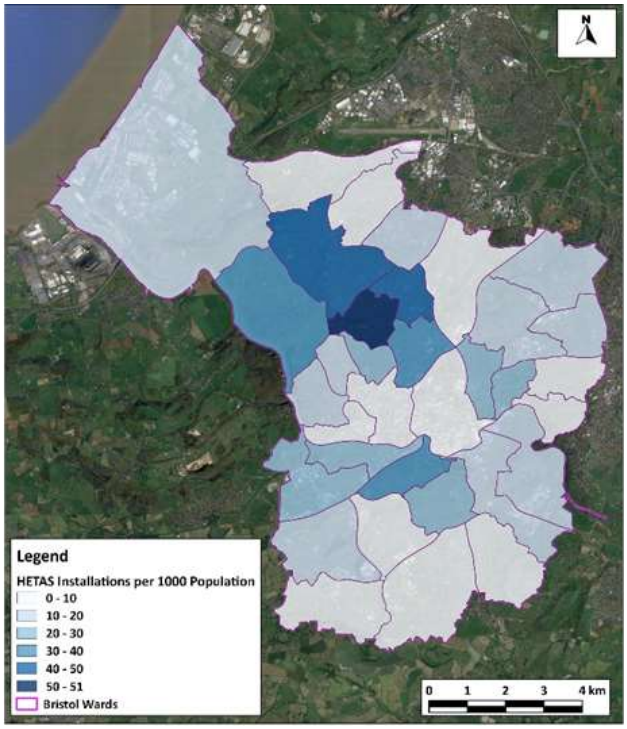


Figure 3: HETAS installations in Bristol by ward weighted by population, 2007-2017



6. Stakeholder Engagement

6.1 The project team has liaised with both Government (Defra) and local government (in particular the Greater London Authority and Brighton and Hove City Council). Defra was contacted to ensure that work being undertaken at national level, particularly in relation to solid fuel burning, was fully incorporated into this project.

6.2 In 2019, Defra conducted a nationwide survey into domestic solid fuel burning. This focussed on the frequency and type of burning undertaken and covered both heating and other sources, such as barbeques. The results of the survey have not yet been published, but a copy of the original survey questions is included in Annex 2. It should be noted that this survey was designed for a specific purpose, i.e. updating the assumptions used in the National Atmospheric Emissions Inventory, rather than for the development of policy options directly. For example, the issues of intention were not addressed, i.e. whether respondents intended to change their heating source (e.g. install or remove a wood burning stove) in the near future. Being a national survey, the coverage in any one region was relatively low, and even lower for individual towns and cities. As such, even if the results were available, they would still be highly uncertain at the Bristol level. Nevertheless, the survey provides a good starting point for the design of a similar survey in Bristol, should that option be adopted.

6.3 Brighton and Hove City Council also undertook a study into solid fuel use in the city, including survey work and provision of information to residents. The Council officers have provided details of the survey, the results, and some of the publicity material produced by the study. However, the survey had a limited response rate and did not address key issues such as the frequency of burning. Following discussions with the Council, it was decided that surveys undertaken would not be used in the Bristol context.

6.4 In addition, a meeting was held on 24th February 2020 involving a number of officers from Bristol City Council. The aim of the meeting was to both investigate ways of refining data available at national level to the Bristol level, and to discuss policy options in relation to feasibility of implementation in Bristol.

6.5 The following officers were present:

- Steve Crawshaw, Sustainable City and Climate Change Service
- Chris Swinscoe, Regulatory Services
- Peter Westbury, Planning (Major Planning Applications)
- Jonathan Martin, Licensing
- Dylan Davies, Pollution Control Team Leader

- Emma Tournier, Pubic Protection (Contaminated Land)
- Georgie MacArthur, Public Health Registrar

6.6 In addition, a telephone conversation was held with Jessica MacDonald (Policy and Public Affairs Officer) following the meeting.

6.7 In relation to solid fuel burning, the following points were made:

- BCC has written to Defra to get data from Ofgem on wood burning facilities that register for the Renewable Heat Incentive (RHI), but are not registered for an environmental permit (to identify the companies in order that they can regulated). There are approximately 35 of these facilities, but some of these may not burn wood;
- Domestic solid fuel burning was thought to reflect socio-economic factors (i.e. new stoves from HETAS data are clustered in Redland, Stoke Bishop, Cotham, and now moving into Southville and Easton);
- New homes are highly unlikely to have chimneys and so less likely to have wood burners installed (as would be at higher cost, and disruption);
- Very few complaints are lodged in relation to domestic burning and when they do they are difficult to investigate and enforce. There are, however, a number of groups and organisations who are actively campaigning against solid fuel burning;
- It was suggested that in relation to new powers under the Environment Act, BCC should be targeting wholesalers; and
- Information campaigns were discussed as a way forward, as well as lobbying government in partnership with other LAs including GLA. This could be undertaken using external organisations such as UK100.

7. Recommended Policy Options

7.1 The evidence presented in this report shows that wood burning emissions in Bristol are increasing, both in a relative and absolute sense. The two methodologies used (national and local), while uncertain, provide a clear indication that the reduction in other sources of particulate matter (for example, industrial, road traffic), wood burning has become a far more significant source. Residential wood combustion is now the most significant source of $PM_{2.5}$ emissions in the UK, according to the latest NAEI, and as $PM_{2.5}$ is a significant health concern, the need for policies to achieve $PM_{2.5}$ emissions reductions is clear.

7.2 It is acknowledged that work is needed to reduce the key uncertainties (see later section) at both national and local level. Nevertheless, there is sufficient evidence and data on the adverse health impacts caused by $PM_{2.5}$ and on the broad scale of the problem to create a strong case for further action. This section provides recommended policy options for Bristol City Council, which includes actions to improve the data on which estimates are based.

7.3 In addition to measures proposed by central Government, Bristol City Council could undertake the following actions to reduce emissions from solid fuel burning into the future.

- Baseline activity data improvement campaign;
- Information and awareness raising;
- Cleaner heating programme, primary users;
- Cleaner heating programme, secondary users;
- Enforcing the smoke control area; and
- Lobbying Government.

Option 1: Baseline activity data improvement campaign
Description

7.4 As has been noted in this report, the generation of accurate, local activity data on the use of solid fuel (including wood) is very challenging. Fuel can be sourced through multiple, unregulated sources, from specialist suppliers to retail outlets (e.g. garden centres, DIY stores, garages). While some information can be gleaned from HETAS installation data, not all installations use HETAS approved engineers nor do the data reveal anything about existing fireplaces and stoves or even whether installations are “new” or replace older fireplaces or stoves. Better activity data would provide a more detailed understanding of the issue as well as informing the most appropriate control measures.

Implementation

7.5 There are two key sources for improving activity data: users and installers. For users, survey data would greatly improve information on the type of fuel used and frequency (and quantity) of fuel use. A simple step would be to insert relevant questions in the Bristol Quality of Life survey24. A greater level of detail would be obtained through a dedicated survey. One possibility would be to repeat the survey undertaken by Defra but with a greater coverage for Bristol (the Defra survey was nationwide) and with the addition of some specific questions. A user survey was also undertaken by Brighton and Hove City Council and, while limited, it would be helpful to liaise further with BHCC to identify lessons learned.

7.6 Working with HETAS should allow more information to be gathered by registered installers. This need not be onerous and could include information on the type of equipment installed and whether it is replacing or supplementing existing equipment.

Advantages

7.7 Provides the basis for a more accurate quantification of the issue and thus better designed and more targeted measures to address it. Undertaking a survey will also act as an awareness raising activity in itself and would complement an information and awareness raising campaign (see Option 2).

Disadvantages

7.8 A detailed information gathering campaign will not, in itself, result in reductions in solid fuel emissions. It is also likely to be highly resource intensive and would only provide a snapshot of solid fuel use, with trends only being revealed through repeated activity.

Resource implications

7.9 This is likely to require a high level of personnel time and thus the resource implications are relatively high. Repeat campaigns to establish trends will also require resource input.

[24] The Quality of Life survey is an extensive annual residents survey for Bristol providing key indicators including measures of inequality and is a core source of performance metrics for policy within Bristol. The survey in 2018 was a random sample of 29,000 Bristol residents including a follow up mailing with paper survey option, and a third phase to boost numbers from low responding groups. There were approximately 3,500 usable responses with all the required fields completed. The survey consisted of 70 questions producing over 200 indicators on topics such as health, lifestyles, community, local services and living in Bristol

Other co-impacts

7.10 **Positive**: Data gathered would also assist in understanding GHG emissions in Bristol and provide greater clarity on the types and patterns of home heating used in the City.

7.11 **Negative**: None

Potential impact on emissions

7.12 None, of itself. This is an enabling measure which will allow the development of better policies and tracking their impacts.

Option 2: Information and awareness raising

Description

7.13 Advice on wood burning stoves highlights that reducing emissions will also provide other benefits to the householder. Burning dry wood will not only reduce emissions but maximise efficiency and reduce the risk of chimney fires. Government information contains advice around the following areas:

- Fuel use; considering burning less, buying 'ready to burn' fuel (this logo will provide a guarantee of good quality dry wood), season freshly chopped wood before burning (consider using a moisture meter), using approved solid fuels instead of house coal and not burning treated wood or household rubbish;
- Maintenance; service your stove annually and get your chimney swept;
- Choosing the right appliance; and
- Knowing the law in Smoke Control Areas

Implementation

7.14 Online, social media and printed material. BCC's communications and/or press office would need to be engaged in order to shape an appropriate communications strategy. Ideally, implementation would include a full evaluation process (*ex ante* baselining and *post hoc* impact assessment). BCC started to work on an information campaign, however, work on its development is currently on hold due to coronavirus outbreak. focussing on the impacts of solid fuel burning on health. The campaign follows a hierarchy, i.e. don't burn if you don't need to; burn minimally; use a compliant stove, and highlights comparisons to emissions from HGVs.

Advantages

7.15 Relatively simple to implement, although effective information campaigns can be difficult to design and execute.

Disadvantages

7.16 If viewed in isolation, could be seen as a token measure and, unless well designed, could result in little impact. Communication campaigns could be undermined by industry bodies.

Resource implications

7.17 Small to moderate, depending on the extent of the campaign and the resources already available within the Council.

Potential co-impacts

7.18 **Positive**: Encouraging correct stove and fireplace use will also have health and safety benefits (lower fire and carbon monoxide poisoning risks).

7.19 **Negative:** Lower wood fuel use could result in increased gas use which may result in a GHG emission increase. However, for "casual" wood users this impact is likely to be minimal. Where wood is used as a primary heat source, users could switch to gas heating (higher GHG emissions) or to electrical heating (including solar and ASHP) which has the potential to be zero carbon, although there may be issues around fuel poverty.

Potential impact on emissions

7.20 Small to moderate, depending on the design and thus effectiveness of the campaign. Where solid fuel is used as a primary heating source[25], it is unlikely that an information campaign will stop it, although it might prompt earlier decisions on the replacement or upgrade of solid fuel heating systems. It may also reduce the frequency of "casual" solid fuel use and/or promote the use of cleaner fuels and appliances.

Option 3: Cleaner heating programme, primary users

Description

7.21 Subsidise the upgrading of solid fuel heating systems to lower polluting alternatives, where they are the primary source of heat. This could, potentially, include upgrading open fires to more efficient stoves, and the upgrade of solid fuel systems to either gas or electric heating. An indication of the impact on emissions from individual units can be seen in the emission factors provided in Table 4, below.

Implementation

7.22 Grant funding for all or part of the costs of heating system upgrade. The precise parameters for the scheme would need to be carefully designed, including the level of support, both in terms of the proportion of costs covered and/or a cap on the total amount

[25] It is our understanding that any campaign by BCC would not target the fuel poor.

of support offered, whether means testing is included, the time period over which the scheme operates, etc. The scheme could be combined with efforts to move to low carbon heating in the City as part of a climate change mitigation programme.

Advantages

7.23 Directly addresses the source of emissions and potentially links to measures to move towards low carbon heating as part of a climate change mitigation strategy.

Disadvantages

7.24 This is a high cost measure and could be seen as rewarding polluting behaviour. Data from the ClairCity project[26] suggests that the great majority (greater than 90%) of solid fuel users use another fuel as their primary heat source, mainly gas. This measure may not, therefore, address the bulk of the problem.

Resource implications

7.25 Medium: will require funding and administrative resource but unlikely to cover a large number of properties if restricted to primary solid fuel users.

Potential co-impacts

7.26 **Positive:** improved energy efficiency will help address potential fuel poverty. Moving to lower carbon heating will reduce GHG emissions.

7.27 **Negative:** Moving from efficient wood fuel systems to gas could increase GHG emissions. Moving to electrical heating is likely to increase heating costs in the short to medium term.

Potential impact on emissions

7.28 Medium: will significantly reduce emissions from the properties/installations affected but these are a minority of solid fuel users.

Option 4: Cleaner heating programme, secondary users

Description

7.29 Subsidise the removal of solid fuel heating systems (fireplaces and stove), where they are a secondary source of heat (i.e. casual users). An indication of the impact on emissions from individual units can be seen in the emission factors provided in Table 4 (Section 8).

Implementation

7.30 Grant funding for all or part of the costs of heating system removal. The precise parameters for the scheme would need to be carefully designed, including the level of support, both in terms of the proportion of costs covered and/or a cap on the total amount

[26] Further details of this four year European Project can be found at http://www.claircity.eu/bristol/

of support offered, whether means testing is included, the time period over which the scheme operates, etc. The scheme could be combined with efforts to move to low carbon heating in the City as part of a climate change mitigation programme.

Advantages

7.31 Directly addresses the source of emissions and potentially links to measures to move towards low carbon heating as part of a climate change mitigation strategy.

Disadvantages

This is a high cost measure and could be seen as rewarding polluting behaviour. Also likely to be seen as subsidising relatively wealthy residents as evidence (see HETAS data in

Figure 2 and

7.32 Figure 3) suggests that installations are concentrated in areas with low levels of deprivation.

Resource implications

7.33 High: will require funding and administrative resource and likely to cover a large number of properties, although cost per unit will be less than for primary solid fuel users.

Potential co-impacts

7.34 **Positive:** Increased investment for installers and/or small construction companies.

7.35 **Negative:** Likely to increase use of gas (and other) heating and thus may increase GHG emissions, although there is no data on the extent to which casual wood fuel use offsets primary heat source use. Will divert Council resources from other social programmes more likely to be aimed at deprived communities. Perceived subsidies for less deprived communities may impact on the Council's reputation.

Potential impact on emissions

7.36 Medium: will significantly reduce emissions from the properties/installations affected. A high level of uptake would increase effectiveness, but this would require a significant shift in behaviours and preferences by residents; using solid fuel as a secondary heat source is voluntary and thus is likely to be a preferred choice. Measure could be more effective if combined with an information campaign differentiating between stove types.

Option 5: Enforcement of Smoke Control Areas
Description

7.37 The whole of Bristol is currently a Smoke Control Area (under the Clean Air Act 1993) and as such it is an offence to:

- Emit smoke from a chimney, unless using an authorised fuel or an exempt appliance
- Purchase an unauthorised fuel for use in the smoke control area unless in an exempt appliance
- Sell (by retail) unauthorised solid fuel for delivery in a smoke control area.

7.38 The strict enforcement of the Smoke Control Area is problematic in a number of areas: smoke emission must be witnessed; the provisions on sale and purchase are difficult to apply in a blanket form; and enforcement requires criminal sanctions. Enforcement is thus time consuming and would likely require dedicated resource.

7.39 The proposed amendments to the Clean Air Act through the Environment Bill will make enforcement a little easier, using civil sanctions and introducing an offence of “offer for sale” which could be more easily enforced. The inclusion of vessels under the Smoke Control Provisions will also provide a control mechanism for narrow and house boats. However, it remains to be seen what form these amendments will take in the final Act, once passed, and how enforceable they are.

Implementation

7.40 Allocation of staff time for both environmental health and trading standards towards enforcement. This may require the recruitment of additional resource. Enforcement through to prosecution will require legal team resource.

7.41 Likely to be most effective in combination with an information and awareness raising campaign.

Advantages

7.42 Directly addresses polluting activity. A small number of enforcement actions, which are actively publicised, could have a significant awareness raising impact, amplifying its effectiveness.

Disadvantages

7.43 Even with significant resource input, unlikely to be able to raise more than a few enforcement actions. Also, many of the popular wood burning stoves available on the market are “Defra approved”, i.e. exempt appliances, and thus would fall outside SCA enforcement.

Resource implications

7.44 High: in order to be effective, a significant enforcement resource required, with legal support. Could be run as a short-term campaign which would limit the overall requirement but is likely to result in “bounce back” behaviour over the longer term. Short term campaigns could be repeated to combat bounce back.

Potential co-impacts

7.45 **Positive:** None.

7.46 **Negative:** Likely to increase use of gas (and other) heating and thus may increase GHG emissions, although there is no data on the extent to which casual wood fuel use offsets primary heat source use. Will divert Council resources from other programmes.

Potential impact on emissions

7.47 Based on enforcement action alone, impact likely to be small. However, publicity around enforcement could amplify the impact to medium. Impact likely to be limited because enforcement of Smoke Control Areas is only an option where the stove in question is not Defra compliant (which is probably quite a low proportion as a large proportion of the stoves on the market are compliant).

Option 6: Lobbying Government

Description

7.48 Legislation to control solid fuel supply and smoke control regulations is outside of direct Council control. Bristol could work with, and lobby, central Government to influence policy changes that support air quality improvements in Bristol. UK100 is a network of local government leaders who have pledged to secure the future for their communities by shifting to 100% clean energy by 2050. UK100 connects local leaders to each other, and importantly to central Government on issues around energy. Bristol is already working with UK100, and this is the ideal route on which to lobby Government on specific issues around solid fuel burning. Part of the lobbying message could be for Government to work with HETAS to improve data on new installations (which may help with targeting the NAEI).

Implementation

7.49 Contributing to the overall lobbying effort, either directly or through existing groups (e.g. UK100), would provide a clear signal of intent by BCC as well as increasing the likelihood that such powers are granted.

Advantages

7.50 Clearer, more direct powers would greatly facilitate the control of solid fuel emissions in Bristol. A clear lobbying strategy would provide a demonstrable policy direction and could also help in the development of networks and relationships with other cities with the same objectives.

Disadvantages

7.51 None

Resource implications

7.52 This would require staff time, both in terms of the development of BCC's position and liaising with other organisations and individuals. This will vary depending on what phase the campaign in is but is not likely to exceed 0.5 FTE. BCC are already working with UK100 on other issues and have a member of staff dedicated to liaising with other organisations and individuals.

Potential co-impacts

7.53 **Positive:** increased profile for the City and a progressive agenda, prompting inward investment. Development of relationships with other, like minded authorities, enabling further exchange of information and more informed policy development.

7.54 **Negative:** Resource implications for the Council could divert resources from other social programmes.

Potential impact on emissions

7.55 None, of itself. This is an enabling measure which will allow the creation of more effective mechanisms for controlling solid fuel emissions.

Policy Recommendations

7.56 The policy options are presented as two packages, based on how quickly they could be implemented.

1. Package 1: This includes options 1, 2, and 6, improvement of baseline activity data, information and awareness raising and lobbying of Central Government, all of which could be started in the short term with relatively low levels of resource.

2. Package 2: This includes options 3, 4, and 5, subsidising the upgrade or removal of solid fuel burning systems or appliances and the strict enforcement of the Smoke Control Area. This package will need additional information and lead in time.

7.57 Both packages have resource requirements, although Package 2 will have the greatest requirement over the longer term. Gathering better activity data and lobbying both require high levels of resource, but these will be for shorter periods.

7.58 It should be noted that, in the Clean Air Strategy (Defra, 2019a), in addition to the provisions contained in the Environment Bill, Defra committed to "*explore powers for Local Authorities to go further in areas of high pollution, for example, we will continue to explore how we can give Local Authorities powers to increase the rate of upgrades of inefficient and polluting heating appliances. We will also consider what additional, stronger local powers would be effective to further reduce pollution from domestic burning where there is a clear case that action needs to be taken to protect human health*".

7.59 This gives rise to the following priorities for BCC: the need to improve baseline activity data and raise awareness of solid fuel burning as a source of pollution, and the need to help shape the provisions currently under consideration. On this basis, it is recommended that BCC adopt Package 1 and develop the detail of Package 2, subject to further policy development from Defra.

8. Impact Assessment

8.1 It has not been possible to quantify the effects of the recommended policy measures in terms of emissions or concentrations, as any such study would be highly uncertain. In order to quantify the benefits, a bottom up approach to estimate emissions should be used, in order that Bristol specific emissions can be varied. Projections from solid fuels will largely depend on the expected turnover of appliances, as well as the potential drive of new sales, particularly in relation to the uptake of domestic solid fuel burners. In addition to current estimates of emissions from the bottom up approach being uncertain, projections of new sales, and uptake of types of appliances are uncertain, particularly in light of recent government proposals to reduce solid fuel use, phase out the sale of traditional house coal and to ban the sale of unseasoned or wet wood in smaller volumes. It is also currently unclear how far campaigns both at national and local level will affect behaviour on solid fuel burning.

8.2 The next stage in the assessment of policy options would be to quantify the impacts on health, but this cannot be undertaken in a robust manner. The most complete estimation of air quality impacts on health from emissions reductions is the impact pathway approach, as described in Defra's Green Book[27] guidance. This approach multiplies the total reduction in pollutant emissions by the associated damage cost, but at this stage the reduction cannot be quantified. Although there is a need for clear and useful information for public, this needs to be balanced against the potential for uncertain estimates to provide a misleading impression of accuracy. However, in general terms, the greater the emissions reduction, the greater the relative health impacts, especially where those emissions are reduced in dense residential areas.

8.3 In relation to the policy packages set out above, Package 1, even with an ideal data set, would be difficult to quantify. Package 2 could be quantified in the future using bottom up emissions estimates, with a level of uncertainty attached.

8.4 To provide some context to the potential emissions reductions, Table 4 includes emissions factors for domestic wood burning appliances for comparative purposes. The figures are taken from the EMEP Guidebook which is the main source material for the preparation of national emission inventories in Europe. The guidebook allows for different levels of complexity in the preparation of inventories, with the emission factors in Table 4 being used with the most complex level. It should be noted that, in general, the UK does not have a recent history in using wood as a home heating fuel, in contrast with other

27 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

European countries where wood fuel provides a significant proportion of home heating, with central heating systems using wood being fairly commonplace. In the UK, urban wood stoves tend to be more modern and efficient.

8.5 The term “eco-labelled” is used in the EMEP guidebook to reflect specific schemes in place in various countries, including Nordic swan in Norway, Blue Angel in Germany, and Flammerverte in France. In the UK, Defra operates a scheme testing solid fuel appliances which can be exempted from the provisions on the Clean Air Act (sometimes marketed as Defra compliant). While not directly comparable – Clean Air Act exemption is based on a test for total smoke emission and the limits vary depending on the heat output of the stove – exempt stoves will generally operate in a range around that for eco-labelled stoves in the table.

8.6 Although it is acknowledged there is uncertainty associated with these emissions factors, if residents moved from open fireplaces or conventional stoves, there would be a large reduction if they moved to eco labelled stoves, and to a lesser extent to high efficiency stoves. Note that the EMEP emission factor for gas fired stoves (including “fake” fireplaces) is 2.2 g/GJ for TSP, PM_{10} and $PM_{2.5}$.

Table 4: Activity Emission factors for PM_{10} and $PM_{2.5}$ for domestic wood burning appliances (EMEP/EEA 2019)[28]

Emission factor (g/GJ)	Open fireplace	Conventional stove	High efficiency stove	Eco labelled stove[29]
PM_{10}	840	760	380	95
$PM_{2.5}$	820	740	370	93
TSP	880	800	400	100

[28] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-4-small-combustion/view

[29] Note that eco labelled stove different to eco design. Ecolabelling schemes for wood and biofuel based stoves are intended to earmark a set standard for improved efficiency and lower emissions, with a number of different schemes in place. Ecodesign is the European-wide programme to lower emissions due to come into force in the UK in 2022 (but many available now)

9. Uncertainty

9.1 Two alternative methodologies for estimating emissions from domestic solid fuel use have been used for this report: top down and bottom up. Each approach will have inherent, and slightly different, uncertainties. There are many components that will contribute to the uncertainty of emissions estimates, and these uncertainties may increase by applying a particular data set at a different spatial scale.

9.2 Although there is significant uncertainty around the figures presented in this report, they represent the current best evidence. Suggestions have been provided in the sections below in relation to ways of reducing these uncertainties.

9.3 The uncertainties are in five main areas:

- National activity data;
- Local activity data;
- Scaling national or regional datasets to Bristol;
- Emission factors; and
- Projections.

National Activity Data

9.4 The top down approach uses NAEI emissions scaled to the Bristol population. Uncertainty relating to the emission factors will be common to both the top down and bottom up approaches (see below) but the activity data used for the NAEI will have uncertainties, which are then increased by scaling. A recent report on the impact of domestic combustion on UK air quality (Mitchell, 2019) provides a high-level critical review of the contribution of domestic solid fuel burning to UK air pollution, with the intention of better understanding the uncertainties of current estimates. Evidence presented in the report indicates that there are large uncertainties in the methodology and data used to estimate the 38% contribution to UK PM_{10} emissions attributed to domestic burning in the 2019 Clean Air Strategy. The cumulative effect of these uncertainties is that the 38% value is likely to be inaccurate.

9.5 The table below shows the key uncertainties relating to national activity data, within the context of this project:

Table 5: Key uncertainties relating to national activity data

Description	Impact
Number of stoves/open fires in operation nationally	High. given recent trends (Air Quality Expert Group, 2017), there is likely to be an underestimate in the NAEI data
Type of appliances in use (e.g. CAA exempt, ecodesign etc)	High. Primary emissions of PM from advanced stoves (e.g. Ecodesign compliant) can reduce by nearly 90% when compared with an open fire.
Proportion of different fuels being burnt nationally (wet wood, dry wood, salvaged wood, coal, bituminous coal)	High. For example, emissions for wet wood are up to four times that of dry, so if estimates are incorrect of proportions of different fuels, this will have large effect on emissions estimate
Frequency of use (hours per year)	High. Wood consumption in the NAEI seems to be out of proportion in comparison with other countries (ie lower), although the UK has less of a tradition in using wood has home heating fuel since the development of the natural gas grid.

9.6 The emerging importance of domestic solid fuel use as a source of PM_{10} in the UK has prompted Defra to include this sector within the NAEI improvement plan (improvements to different parts of the NAEI are undertaken on an annual basis). The national user survey referred to in Section 6 of this report is part of that improvement plan. There have also been attempts to verify the importance of wood burning emissions through monitoring (using aethalometer signals, levoglucosan analysis, potassium analysis, etc.). However, each of these techniques has its own uncertainty and, in any case, cannot distinguish between wood burning on a fireplace or stove and open fires outdoors. However, none of these issues are within the purview of Bristol City Council.

Local Activity Data

9.7 Local activity data face the same issues as for national activity data and are not repeated here.

9.8 One additional area of uncertainty is the location of stoves and fireplaces in Bristol. This is clearly important for the mapping of emissions as a prelude to undertaking a more detailed assessment, both in terms of the impact of domestic burning on air quality and the development of measures to reduce it.

9.9 Local activity data is within the purview of the Council. It is recommended that two actions are undertaken to improve local activity data:

- Undertake a survey in Bristol to establish the proportion of households using solid fuel, what fuel they are using, the frequency of use and type of appliance. The survey could also be used to verify the geographical distribution of appliances. This survey should be repeated on a regular basis.

- Work with HETAS to obtain further information on registered installations, to include whether an installation is new, or a replacement and the type of appliance being installed (where possible). These data could be used to extrapolate data from the household survey of years when the survey is not carried out.

9.10 Local activity data could also be strengthened by further monitoring. Monitoring would need to be situated in locations which would capture potential solid fuel burning. Although any monitoring data would add to the evidence base, the data would only be relevant to that specific location and would not provide as much additional evidence as to the overall solid fuel burning activity as a survey. A table of monitoring techniques, and pros and cons of each is included in Annex 0.

Scaling National or Regional Datasets to Bristol

9.11 Using datasets for one geographical area and scaling them to fit another is relatively standard practice in the development of emissions inventories. However, uncertainties in the original dataset are amplified by scaling and an assumption is introduced whereby the average conditions applying to the original area are assumed to apply to the scaled area. For this study, two sets of scaled data were used, national data for the top down approach and BEIS wood survey data for the south west region for the bottom-up approach, both scaled to the Bristol level. The main uncertainties associated with this are described below.

Table 6: Key uncertainties relating to scaled data

Description	Impact
Scaling NAEI data to the Bristol level	Medium: assumes that Bristol has the same average rate of solid fuel use as appears nationally. The dataset will include areas where coal use remains relatively high and it is anticipated that all heating fuel use increases as one move further north in the country. However, the inclusion of other urban areas in the dataset mitigate some of this uncertainty.
Scaling BEIS wood survey data to the Bristol level	High: The dataset covers the whole of the South West and is predominantly rural in coverage. Wood fuel use is likely to be both more common and more frequent in rural areas. The small number of datapoints in the survey will also add uncertainty to the data.
Using household numbers as the scaling metric	Medium: assumes that emissions scale with household number whereas other factors, such as relative wealth or housing density may also be important factors in determining solid fuel use.

9.12 The net result of these uncertainties is that the bottom up approach is likely to produce a large overestimate compared to the NAEI data but that both are highly uncertain. The actions recommended to reduce uncertainty in local activity data will produce datasets which do not need to be scaled and will thus eliminate this source of uncertainty.

Emission Factors

9.13 All emission factors are an attempt to provide an average emission over time for the activity they are describing and thus will always be uncertain to an extent: an average implies that there are higher and lower figures in the emission profile and thus the emission factor may not represent any one unit. For example, an emission factor for woodstoves of a certain heat output range does not mean that any individual stove in that size range produces precisely that emission profile. Moreover, real world conditions will include variables which are not accounted for in simple emission factors, such as the type and condition of the wood fuel used (varying from kiln dried wood pellet to unseasoned logs), whether it is mixed with coal, the state of repair/maintenance of the stove and the conditions of use.

9.14 Greater detail in the activity data allows for the use of more sophisticated emission factors, thereby reducing uncertainty. The actions recommended to reduce uncertainty in local activity data will greatly assist in providing the required level of detail, with a priority on data relating to the primary type of fuel used (wood, coal or mixed), the type of wood fuel used (pellets, chips, seasoned logs, unseasoned logs, waste wood) and the size/capacity of the appliance used.

Projections

9.15 Predicting emissions in a future year will always be subject to greater uncertainty. There are uncertainties as the assumptions on which those predictions are based, and it is necessary to rely on a series of projections which relate to both activity and emissions factors

10. Summary and Recommendations for Future Action

10.1 Data on wood and coal burning has been used to provide an estimate of the emissions resulting from solid fuel burning in Bristol. The limitations of using various currently available data sources are analysed with the aim to understand how data could be collected in the future in Bristol to provide more accurate calculations.

10.2 In this report, two alternative methodologies have been applied to estimate emissions; bottom up and top down.

- Bottom-up: emissions are calculated using location specific activity data on solid fuel consumption combined with emission factors. The quality and certainty of result is inherently linked to the availability of local data on solid fuel burning activity in Bristol.
- Top down: emissions are based on the scaling of published UK emissions data to the Bristol level. In this case, the uncertainty of the UK level data will be further increased by the appropriateness of the scaling factor used.

10.3 Both national and local estimates, although uncertain, provide a clear indication that with other sources of particulates reducing (for example, industrial, road traffic), wood burning, in particular, is an increasing source (both relatively and absolutely). Residential wood combustion is now the most significant source of $PM_{2.5}$ emissions in the UK, according to the latest NAEI, and as $PM_{2.5}$ is a significant health concern, the need for policies to achieve $PM_{2.5}$ emissions reductions is clear. It is acknowledged that work is needed to reduce the key uncertainties at both national and local level. Nevertheless, there is sufficient evidence and data on the adverse health impacts caused by $PM_{2.5}$ and on the broad scale of the problem to create a strong case for further action.

10.4 In addition to proposals by central Government, Bristol City Council could undertake the following actions to reduce emissions from solid fuel burning into the future.

- Baseline activity data improvement campaign
- Information and awareness raising
- Cleaner heating programme, primary users
- Cleaner heating programme, secondary users
- enforcing the smoke control area, and
- lobbying Government

10.5 The policy options are presented as two packages, based on how quickly they could be implemented.

1. Package 1: This includes options 1, 2, and 6, improvement of baseline activity data, information and awareness raising and lobbying of Central Government, all of which could be started in the short term with relatively low levels of resource.

2. Package 2: This includes options 3, 4, and 5, subsidising the upgrade or removal of solid fuel burning systems or appliances and the strict enforcement of the Smoke Control Area. This package will need additional information and lead in time.

10.6 Both packages have resource requirements, although Package 2 will have the greatest requirement over the longer term. Gathering better activity data and lobbying may both require high levels of resource, but these will be for shorter periods.

10.7 This gives rise to the following priorities for BCC: the need to improve baseline activity data and raise awareness of solid fuel burning as a source of pollution, and the need to help shape the provisions currently under consideration. On this basis, it is recommended that BCC adopt Package 1 and develop the detail of Package 2, subject to further policy development from Defra.

10.8 It has not been possible to undertake a quantified assessment of the policy options presented. In order to assess policy options, the bottom up approach would need to be undertaken and this has not been possible. Even with perfect data, it is unlikely that the low impact policy package could be quantified.

10.9 Throughout the report, stakeholders have been consulted, both locally and nationally to both investigate ways of refining data available, and to discuss policy options in relation to feasibility of implementation. Uncertainties in all the data have been outlined and ways of improving underlying local data sets have been included in the recommendations.

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12. Glossary

AQC	Air Quality Consultants
AQMA	Air Quality Management Area
BAM	Beta Attenuation Monitor
CAZ	Clean Air Zone
Defra	Department for Environment, Food and Rural Affairs
Exceedance	A period of time when the concentration of a pollutant is greater than the appropriate air quality objective. This applies to specified locations with relevant exposure
EU	European Union
FDMS	Filter Dynamics Measurement System
FIDAS	Fine Dust Analysis System
IAQM	Institute of Air Quality Management
kW	Kilowatt
LAQM	Local Air Quality Management
µg/m^3	Microgrammes per cubic metre
NAEI	National Atmospheric Emissions
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	Nitrogen oxides (taken to be NO_2 + NO)
NPPF	National Planning Policy Framework
Objectives	A nationally defined set of health-based concentrations for nine pollutants, seven of which are incorporated in Regulations, setting out the extent to which the standards should be achieved by a defined date. There are also vegetation-based objectives for sulphur dioxide and nitrogen oxides
PM_{10}	Small airborne particles, more specifically particulate matter less than 10 micrometres in aerodynamic diameter
$PM_{2.5}$	Small airborne particles less than 2.5 micrometres in aerodynamic diameter
Standards	A nationally defined set of concentrations for nine pollutants below which health effects do not occur or are minimal
TEOM	Tapered Element Oscillating Microbalance

13. Appendices

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A1. Monitoring Techniques for Particulate Matter

Table 7: Monitoring Techniques for Particulate Matter

A1	Uses and outputs	Advantages	Disadvantages	Capital and resource costs
Gravimetric (filter based)	Mass measurement for single size fractions, depending on the inlet cut-off. usually records daily mean concentrations.	Reference method so ideal for compliance assessments. Allows analysis of particle composition post-sample using stored filters.	Requires dedicated housing and laboratory analysis (filter conditioning and weighing). Filter cartridges can be used to allow 14 days sampling. Cannot identify short term peaks (<24 hours). Can only be used for a single size fraction and only delivers mass measurement.	Capital: high, including dedicated housing. Resource: high, regular maintenance (filter change and calibration) and laboratory services
TEOM (Tapered Element Oscillating Microbalance)	Mass measurement for single size fractions, depending on the inlet cut-off. Continuous analyser, can be used for 1-hour averages (potentially less).	Continuous analysis, allowing remote access and near real time measurements	Requires dedicated housing. Has been shown to under read compared to gravimetric so requires correction.	Capital: high, including dedicated housing. Resource: medium, requires regular maintenance and specialist service support.
TEOM-FDMS (Filter Dynamics Measurement System)	Mass measurement for single size fractions, depending on the inlet cut-off. Continuous analyser, can be used for 1-hour averages (potentially less).	Continuous analysis, allowing remote access and near real time measurements. Includes built in correction for under reading TEOM. Has been shown to be equivalent to reference method so ideal for compliance assessments.	Requires dedicated housing. Complex system which has been known to have reliability issues.	Capital: high, including dedicated housing. Resource: medium, requires regular maintenance and specialist service support.
BAM (Beta Attenuation Monitor)	Inferred mass measurement (based on obscuration) for single size fractions, depending on the inlet cut-off.	Continuous analysis, allowing remote access and near real time measurements. Some models have been shown to	Requires dedicated housing.	Capital cost: high, including dedicated housing.

	Continuous analyser, can be used for 1-hour averages (potentially less).	be equivalent to reference method so can be used for compliance assessments.		Resource: Low-medium, requires servicing but generally more robust and reliable.
Light scattering (including FIDAS – Fine Dust Analysis System)	Inferred mass and particle number count based on light scattering for a predetermined range of outputs (e.g. PM_{10}, $PM_{2.5}$, particle number, size distribution). Continuous analyser, can be used for 1-hour averages (potentially less).	Monitors multiple fractions and metrics simultaneously. Continuous analysis, allowing remote access and near real time measurements. Some models have been shown to be equivalent to reference method so could be used for compliance assessments.	Requires dedicated housing. Inferred rather than direct mass measurement.	Capital: Medium to High Resource: low, minimal servicing required. Maintenance costs can be high if parts fail.
Aethelometer	Measures light absorption of filtered particles. Continuous analyser, can be used for 1-hour averages (potentially less). Can be used to determine concentrations of black carbon.	Continuous analysis, allowing remote access and near real time measurements. Samples and data can be used for further analysis, including estimates of wood smoke concentrations[30])	Does not measure mass and cannot be used for compliance assessment. Further data analysis requires specialist knowledge.	Capital: medium Resource: medium to low, its only consumable is a filter which needs to be replaced every one or two days in portable models, but larger units have a roll of filtration tape which usually lasts from months to years
Dark smoke/SO_2 bubbler	Manual measurement of light absorption of filtered particles.	Simple and cheap, could be used as an indicator of solid fuel use.	Does not measure mass and cannot be used for compliance assessment. Limited data output.	Capital: low, very simple and cheap methodology. Resource: Low, manual analysis required but relatively simple.

[30] Contribution of wood burning to PM_{10} in London. Fuller, Gary W. *et al;* ATMOSPHERIC ENVIRONMENT, Vol. 87, 04.2014, p. 87-94, but also see Harrison *et al*, Roy M (26 August 2013). "An evaluation of some issues regarding the use of aethalometers to measure woodsmoke concentrations". *Atmospheric Environment*. 80: 540–548.

A2. Professional Experience

Stephen Moorcroft, BSc (Hons) MSc DIC CEnv MIEnvSc MIAQM

Mr Moorcroft is a Director of Air Quality Consultants, and has worked for the company since 2004. He has more than 35 years' postgraduate experience in environmental sciences. Prior to joining Air Quality Consultants, he was the Managing Director of Casella Stanger, with responsibility for a business employing over 100 staff and a turnover of £12 million. He also acted as the Business Director for Air Quality services, with direct responsibility for a number of major Government projects. He has considerable project management experience associated with Environmental Assessments in relation to a variety of development projects, including power stations, incinerators, road developments and airports, with particular experience related to air quality assessment, monitoring and analysis. He has contributed to the development of air quality management in the UK, and has been closely involved with the LAQM process since its inception. He has given expert evidence to numerous public inquiries, and is frequently invited to present to conferences and seminars. He is a Member of the Institute of Air Quality Management.

Dr Clare Beattie, BSc (Hons) MSc PhD CSci MIEnvSc MIAQM

Dr Beattie is an Associate Director with AQC, with more than 20 years' relevant experience. She has been involved in air quality management and assessment, and policy formulation in both an academic and consultancy environment. She has prepared air quality review and assessment reports, strategies and action plans for local authorities and has developed guidance documents on air quality management on behalf of central government, local government and NGOs. She has led on the air quality inputs into Clean Air Zone feasibility studies and has provided support to local authorities on the integration of air quality considerations into Local Transport Plans and planning policy processes. Dr Beattie has appraised local authority air quality assessments on behalf of the UK governments, and provided support to the Review and Assessment helpdesk. She has carried out numerous assessments for new residential and commercial developments, including the negotiation of mitigation measures where relevant. She has also acted as an expert witness for both residential and commercial developments. She has carried out BREEAM assessments covering air quality for new developments. Dr Beattie has also managed contracts on behalf of Defra in relation to allocating funding for the implementation of air quality improvement measures. She is a Member of the Institute of Air Quality Management, Institute of Environmental Sciences and is a Chartered Scientist.

Tim Williamson, BSc (Hons) MSc MIEnvSci MIAQM

Mr Williamson has 25 years' experience in environmental policy support, development and analysis, mainly in air quality but also covering climate change and resource efficiency. He has broad experience of the field, having held positions in the public and private sectors, and for an environmental NGO, Environmental Protection UK. Tim has worked at the national level, leading multi-disciplinary evidence teams on air quality and, latterly, resource efficiency in Defra for 11 years. He has also worked both for and with local authorities, covering Local Air Quality Management and carbon reduction programmes. Tim has a strong track record in international work, having been involved in EU policy development and on projects supporting both the European Commission and European Environment Agency, and Governments in several parts of the world. He is a Member of the Institute of Air Quality Management and is a Chartered Scientist.

Richard Claxton (Senior Consultant, Aether)

Richard has considerable experience in national emission inventories, local air quality management and air quality assessments. He has gained first-hand experience of national emissions inventory compilation (UK, Barbados), as well as providing in-country support to the Irish and Icelandic environment agencies. Richard has planned and delivered a number of capacity building workshops for national representatives, including Turkey, Uzbekistan, Bosnia & Herzegovina and South Africa.

Richard is qualified as a reviewer of greenhouse gas inventories under the UNFCCC (waste sector and generalist) as well as for non-Annex I parties' Biennial Update Reports (BURs).

Richard has contributed to, and taken the technical lead on both international and local emissions inventory projects, as well as air quality assessments for proposed developments as part of the planning application process. Richard is also taking a lead role in developing innovative ways of presenting data relating to national emissions.

A3. Defra Questionnaire Survey on Solid Fuel Burning

A2.1 The following represent the survey questions used by Defra on the national survey of solid fuel burning. It is not suggested that these are used as are, but can be used as a starting point for a local survey. For example the questions relating to what appliance/ what has been burnt in the last 7 days, will be very dependent on when that question was asked. This should be framed in a different way (eg on an average 7 days in the winter/ summer). Also respondents with no wood burner should not necessarily be immediately screened out, but could be asked about future intentions in relation to solid fuel.

DEFRA: Research in to Burning in UK Homes

Screener question – ask all in Omnibus

The Department for Environment, Food and Rural Affairs (Defra) would like to ask some questions about anything you have burned at home. **Have you, or anyone in your household, burned anything at your property in the last 12 months? This can be anything you have burnt inside, for example on an open fire or a wood burner, or outside, for example on a bonfire, a barbecue or a chimenea** IF NECESSARY: This includes any burning by anyone in your household at your property in the last 12 months. **[SINGLE-CODE]**		
Yes – continue to survey		
No – screen out		

Question 1 – ask all eligible

Which of the following have you burnt at your property in the last 12 months? Please tell me for each if you have burnt these inside (e.g. on an open fire or wood burning stove) or outside (e.g. on a bonfire, barbecue or chimenea)? * IF NECESSARY: This includes any burning by anyone in your household at your property in the last 12 months. **[READ OUT; MULTI-CODE]**	
Material:	**Yes - Burned inside Yes – Burned outside No not burned inside or outside**
Wood: including logs, pellets, manufactured wood logs, briquettes and woodchips	
Coal: including anthracite, manufactured fuels and briquettes	
Charcoal	

Green or garden waste	
Waste wood	
Household waste or rubbish	
Peat	
Other (please specify): _____	

**If a respondent says "yes" to having burned something in the last 12 months at the screener question, and then select that they have not burned anything at Q1 they will be asked a check question to confirm whether they have burned anything in the past 12 months.*

Question 2A – ask all

How many kilograms of the following have you burned in the last 7 days? IF NECESSARY: Please provide your best estimate if you are unsure. IF NECESSARY: We are interested in any indoor or outdoor burning by anyone in your household in the last 7 days. INTERVIEWER: ENTER KG, USE BUCKET ESTIMATION IF KG UNKNOWN [READ OUT; MULTI-CODE]	
Material:	**Amount (KG):**
[SHOW IF "WOOD" AT Q1] Wood logs	
[SHOW IF "WOOD" AT Q1] Wood briquettes (IF NECESSARY: this could be wood or wood like, including artificial/manufactured wood logs)	
[SHOW IF "WOOD" AT Q1] Wood pellets	
[SHOW IF "WOOD" AT Q1] Woodchips	
[SHOW IF "CHARCOAL" AT Q1] Charcoal	
[SHOW IF "COAL" AT Q1] Smokeless coal	
[SHOW IF "COAL" AT Q1] Briquettes – coal or coal like	
[SHOW IF "COAL" AT Q1] Coal (house or bituminous coal)	
[SHOW IF "WASTE WOOD" AT Q1] Waste wood: including wood from fallen trees / branches or that has been discarded e.g. from building sites or skips	
[SHOW IF "GREEN OR GARDEN WASTE" AT Q1] Green or garden waste	
[SHOW IF "HOUSEHOLD WASTE OR RUBBISH" AT Q1] Handfuls of household rubbish	
[SHOW IF "PEAT" AT Q1] Peat	
Other (please specify): _____	
I haven't burnt anything inside or outside in the last 7 days – GO TO Q11 (RE-CONTACT)	
Don't know – GO TO Q11 (RE-CONTACT)	

Question 2B – ask for every material the respondent selected, but didn't know the weight of

And if you had to think of the [INSERT] you burned in the last 7 days, how many buckets do you think it would have filled? [SHOW BUCKET; READ OUT; MULTI-CODE]	
Material:	**Amount (Buckets):**
[SHOW IF SELECTED AT Q2A] Wood logs	
[SHOW IF SELECTED AT Q2A] Wood briquettes (IF NECESSARY: this could be wood or wood like, including artificial/manufactured wood logs)	
[SHOW IF SELECTED AT Q2A] Wood pellets	
[SHOW IF SELECTED AT Q2A] Woodchips	
[SHOW IF SELECTED AT Q2A] Charcoal	
[SHOW IF SELECTED AT Q2A] Smokeless coal	
[SHOW IF SELECTED AT Q2A] Briquettes – coal or coal like	
[SHOW IF SELECTED AT Q2A] Coal (house or bituminous coal)	
[SHOW IF SELECTED AT Q2A] Waste wood: including wood from fallen trees / branches or that has been discarded e.g. from building sites or skips	
[SHOW IF SELECTED AT Q2A] Green or garden waste	
[SHOW IF SELECTED AT Q2A] Handfuls of household rubbish	
[SHOW IF SELECTED AT Q2A] Peat	
[SHOW IF SELECTED AT Q2A]Other (please specify): _____	
Don't know – GO TO Q11 (RE-CONTACT)	

Q3 Burning appliance – ask all who have burned inside or outside in the last 7 days (Q2A/2B >0)

Which appliance have you used to burn inside in the last 7 days? IF NECESSARY: Which one best matches your appliance? If you are unsure an estimate is fine. IF NECESSARY: If you have several appliances indoors, please select the one that you have used the most in the last 7 days. [READ OUT; SINGLE-CODE]	
An open fire	
A burner or enclosed fireplace installed before 2000	

A burner or enclosed fireplace installed between 2000 and 2009	
A burner or enclosed fireplace installed after 2009	
A burner or enclosed fireplace – unsure of installation date	
A biomass boiler	
[OUTSIDE BURNERS ONLY] Bonfire	
[OUTSIDE BURNERS ONLY] Barbeque	
[OUTSIDE BURNERS ONLY] Chimenea	
Other (e.g. range cooker, pellet stove)	

Question 4 - ask all those with a burner or enclosed fireplace (Q3=2,3,4,5)

Thinking about your burner or enclosed fireplace, do you know if it is any of the following… IF NECESSARY: If you have more than one burner, please think about the one your household has used the most in the last 7 days. **[READ OUT; SINGLE-CODE]**	
An appliance approved by Defra for use in smoke controlled areas (IF NECESSARY: a Defra exempt appliance)	
An 'Ecodesign Ready' or Ecodesign appliance (IF NECESSARY: this means it conforms with EU legislation coming into force in 2022 to reduce emissions)	
Or neither a Defra exempt or Ecodesign appliance	
Don't know	

Question 5 – ask all who burned inside in the last 7 days (any "inside" at Q1)

In the last 7 days, at what times of day have you burned inside**?** READ OUT: You can select more than one answer [MULTI-CODE; READ OUT]
a. During the day Monday to Friday b. During the evening Monday to Thursday c. During the evening on Friday d. During the day at the weekend

e. During the evening at the weekend
f. Other (please specify)
g. Don't know

Question 6 – ask all who burned inside in the last 7 days (any "inside" at Q1)

For each day of the last week, roughly how many hours do you think your household's fire or burner has been lit for?

IF NECESSARY: Please give your best estimate if you are unsure.

IF NECESSARY: If left to die down overnight say so and think about the number of hours it was lit for before you went to bed (similarly if you let it die down when you left the house) (Interviewer to note left to die down).

IF NECESSARY: Think about the number of times you refuelled the fire (e.g. added coal/wood etc.) (interviewer to note number of times refuelled)

	(ENTER HOURS)
Monday	
Tuesday	
Wednesday	
Thursday	
Friday	
Saturday	
Sunday	

Question 7 – ask all who burned wood or wood related material in the last 7. (Route from Q2 – those that burned: Wood logs, wood or wood like briquettes, wood pellets, woodchips, waste wood)

Where did the wood that you burned in the last 7 days mostly come from?

IF NECESSARY: Please think of all wood you and your household burnt in the last week, whether this was inside or outside, and whether you sourced this or not.

IF MULTIPLE SOURCES: Please think of how you sourced most of the wood.

[SINGLE-CODE; PROMPT TO PRECODES]

Source:	
General supplier (IF NECESSARY: supermarkets, petrol station, DIY store)	
Specialist supplier (IF NECESSARY: supplier specialising in supplying wood for burning such as a tree surgeon)	
From my own garden (IF NECESSARY: This would be from trees. If you have burned fence posts or garden furniture, please select salvaged wood)	
Bought from landowner or farmer	
Fallen wood from trees in public places (IF NECESSARY: including parks, the forest)	
Salvaged wood: (IF NECESSARY: including wood that has been discarded e.g. from building sites or skips and old furniture/fence posts/other items from your home)	
Given by friends / family members / others	

Other (please specify): _____	

Question 8 – ask all who burned wood this week

8 – How would you describe the seasoning of most of the wood you burned in the last 7 days? By seasoning, I mean leaving the wood to dry for a period after the tree has been felled or cut. [SINGLE CODE; PROMPT TO PRECODES]	
Time period:	
It was seasoned when you bought or got it	
It was pre-dried when you bought or got it	
It was seasoned at home for less than 6 months	
It was seasoned at home for between 6-12 months	
It was seasoned at home for between 13-18 months	
It was seasoned at home for over 18 months	
It was unseasoned	
Other (please specify)	

Q9 - Ask those who have a burner or enclosed fireplace (Q3 = 2,3,4,5)

Q9 - When you used your burner in the last 7 days, did you mostly have the air controls… [READ OUT; SINGLE-CODE]	
Fully open	
Partially open	
At the minimum setting	
DO NOT READ OUT - I alter the settings frequently	
Don't know	

Q10 – Ask all

Q10 - Please could you look at this screen and tell me which of these represents your household's total income, before tax and any other deductions. This includes earnings from employment or self-employment, income from benefits and pensions, and income from other sources such as interest from savings.

Please just tell me the letter that applies to your household.

SHOW SCREEN

Annual	Monthly	Weekly	
Under £5,000	Under £420	Under £100	
£5,000 - £10,000	£420 - £830	£100 - £190	
£10,000 - £15,000	£830 - £1250	£190 - £290	
£15,000 - £20,000	£1,250 - £1,670	£290 - £390	
£20,000 - £25,000	£1,670 - £2,080	£390 - £480	
£25,000 - £30,000	£2,080 - £2,500	£480 - £580	
£30,000 - £40,000	£2,500 - £3,330	£580 - £770	
£40,000 - £50,000	£3,330 - £4,170	£770 - £960	
£50,000 - £60,000	£4,170 - £5,000	£960 - £1,150	
£60,000 - £70, 000	£5,000 - £5,830	£1,150 - £1,350	
£70,000 - £80, 000	£5,830 - £6,670	£1,350 - £1,540	
£80,000 or more	£6,670 or more	£1,540 or more	
Don't know			
Refused			

Q11 – ask all (who say “Yes” at the screener question)

The Department for Environment, Food and Rural Affairs would like to conduct further research to understand people’s fuel use and fuel costs.

Would you be willing for Kantar to keep a record of your details for up to 12 months for the purpose of re-contacting you to take part in future research on this subject in the next 12 months?

As with this survey, your responses will be completely anonymous and nobody will be able to identify from the results that you’ve taken part in the research, unless give your express permission to do so.

IF NECESSARY: Please be reassured that the purpose of this re-contact is for research only and that your answers remain confidential.

[SINGLE-CODE]		
Yes [Proceed to ask telephone number]		
No [end of survey]		

Q12 – ask those who agreed to re-contact

What is your full 11 digit telephone number, including the area code, that you would like to be contacted on?		
[enter number]		