Institute for Public Policy Research

LETHAL BUT LEGAL

AIR POLLUTION FROM DOMESTIC BURNING

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and **Luke Murphy**

October 2018

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ACKNOWLEDGEMENTS

The authors would like to thank the following people for their participation in the research roundtables and for those who contributed or provided comments and feedback on the research: Abi Hynes, Brendan Mahon, Bridget Allison, Bruce Allen, Bruno Prior, Dr Gary Fuller, Harriet Edwards, James Higgins, Laura Almond, Lesley Rudd, Matthew Farrow, Paul McNamee, Professor Helen ApSimon, Rhys Taylor, Stephen Inch, Susie Willows and Tim Minett. IPPR would also like to thank CPL Industries Ltd for their support of this project.

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Citation
If you are using this document in your own writing, our preferred citation is:
Emden J and Murphy L (2018) *Lethal but legal: Air pollution from domestic burning*, IPPR. http://www.ippr.org/research/publications/lethal-but-legal

SUMMARY

The levels of air pollution to which domestic burning in the home is a prime contributor are lethal but legal.

Domestic burning in the home is the largest single contributor to $PM_{2.5}$, one of the most harmful forms of particulate matter (collectively known as PM_x). At 40 per cent of total emissions of $PM_{2.5}$ it is more than double that of industrial combustion (14 per cent) and more than three times that of road transport (12 per cent).

Of the 40,000 deaths linked to air pollution in the UK every year, 29,000 are caused by exposure to the pollutant $PM_{2.5}$. The long-term impacts of PM_x concentrations have also been quantified as being equivalent to 340,000 life years lost.

Up until very recently, public policy has focused on the lethal and illegal concentrations of air pollution predominantly arising from road transport in the form of NO_2 pollution. Yet $PM_{2.5}$, the main emitter of which is domestic burning of solid fuels including wood, are measured in concentrations that are legal but actually more lethal than NO_2.

The government's recent clean air strategy highlights the wider contributors to air pollution in the UK beyond transport and provides policy measures to tackle it. The government has therefore made some welcome progress particularly in regard to emissions from domestic combustion. But, with approximately 1.9 million households still using solid fuels including wood in their homes, this report argues that the health cost is too high for policy to not go further and faster.

The government has committed to a new Clean Air Act and a manifesto commitment to leave our environment in a better state than they found it. The Labour Party has also committed to a new Clean Air Act to deal with illegal air quality.

The environment secretary, Michael Gove, has said that Brexit is an opportunity to develop world-leading standards on air pollution. This report argues that this should include committing the UK to much stricter legal targets on air pollution, as supported by the scientific evidence, and include a target to reduce all PM_x emissions from the domestic sector to near zero as possible by 2050. All should be enshrined in a new Clean Air Act for the UK, and backed by a powerful environmental watchdog with the legal powers to take action if the targets aren't met.

It is an opportunity that must not be missed.

KEY FINDINGS

- The EU ambient air quality limits to which the UK is currently subscribed are significantly weaker than those guidelines set by the World Health Organisation (WHO) for $PM_{2.5}$ and SO_2, and they are also weaker for PM_{10} (annual average) and for ozone.
- In 2015, annual mean concentration of $PM_{2.5}$ across the UK's cities was recorded at or near the stricter limits on air pollution set out by the WHO Air Quality Guidelines (WHO AQG) and by now may be exceeding these limits. This

is already the case for some individual cities, including population centres such as London, Leeds, Nottingham and Sheffield.

- Emissions of $PM_{2.5}$ and PM_{10} across the economy have remained stubbornly consistent since around 2010, while emissions of BaP have returned to higher levels last seen in the 1990s.
- The domestic sector produces 40 per cent of the UK's $PM_{2.5}$ emissions and over a quarter of the UK's PM_{10}, the largest of any sector for both pollutants and, in the case of $PM_{2.5}$, almost three times more than road transport.
- In the UK, approximately 1.5 million households use wood for fuel and just under 400,000 households use coal and other solid fuels such as anthracite, solid smokeless fuel (SSF) and petroleum coke (pet-coke).
- The burning of wood is one of the largest emitters to PM_x. Further, although more data is required, early tests show that the emissions factors for PM_x in wet wood are substantially higher than in dried wood.
- On a per kilotonne basis, smoky coal actually emits more PM_x than wood but is burned in much lower quantities across the UK. Though the level of smoky coal consumed in the domestic sector is relatively small, industrial sales data suggests that coal consumption recorded by BEIS may be in the order of 35 per cent lower than actual coal sold.
- One of the main reasons driving a long-term increase in pollution emitted by wood and robust stove sales is the aesthetic value ascribed to wood-burning. Consumer choice must therefore be a key part of policymaking considerations.
- It should be possible to reduce domestic emissions to as close to zero as possible. However, the UK market for low carbon heating systems is currently very immature because successive governments have been dragging their feet on promoting alternative heating technologies.

KEY RECOMMENDATIONS

- Given the scientific evidence, and the opportunity to review our air pollution standards post-Brexit, we recommend that the government should improve on ambitions set out in the clean air strategy and update the UK's limit and target values (for PM_x, SO_2 and O_3), in line with the latest WHO guidance. The government should also reduce the number of times that concentrations can exceed standards (for PM_x, NO_2, SO_2 and O_3). Finally, it should set a short-term limit value for $PM_{2.5}$. These measures should be enshrined in a new Clean Air Act for the UK.
- The Clean Air Act should be robustly enforced by the proposed new environmental watchdog, which should have the powers to initiate legal action. The regulator should also be empowered to set new air quality standards swiftly in light of new scientific evidence, rather than having to rely on legislative change.
- As part of this overarching target, the government should commit to a long-term ambition to reduce all domestic PM_x emissions to as close to zero as possible by 2050. This will only be achievable with the promotion of low carbon forms of heating.
- Gaps in data affect the ability of the government to communicate the harmful effects of wood and coal burning. There must therefore be urgent improvements to the quality and granularity of data, particularly on the consumption of wet wood.
- In the short-term both the government in England and Devolved Administrations in Scotland, Wales and Northern Ireland must ban the sale of wet wood and non-smokeless coal by 2020. In the long-term alternative heating systems must be promoted to ensure the ambition to all but eliminate domestic PM_x is realised.

- The government should develop regulations for the efficiency of stoves that go beyond upcoming EU Ecodesign standards that will come into force in 2022. Currently, government ambitions simply align with Ecodesign, rather than exceed them.
- The government must mandate that all homes sold from 2025 onwards must be upgraded with more strictly regulated stoves by 2025, rather than current Ecodesign provisions.
- The government must provide private and social landlords with financial incentives to upgrade all appliances to the higher standard stoves with a deadline of 2025.
- Now that the health impacts of $PM_{2.5}$ are better understood, Defra should update Local Air Quality Management guidance to enable local authorities to monitor $PM_{2.5}$ concentrations in their local areas.
- The government should incentivise renewable alternatives by improving awareness and increasing subsidies for the Renewable Heat Incentive and support local authorities to create local heat zones that help to inform which low carbon heating systems would be most appropriate.

INTRODUCTION

Air pollution is now one of the greatest causes of global public health concern. The World Health Organisation (WHO) estimates that each year the effects of ambient (outdoor) air pollution cause approximately 6.5 million premature deaths worldwide.

The three major pollutants which have the most harmful health impacts are particulate matter (PM_x), nitrogen oxides (NOx), and ozone (O_3). Secondary but serious consideration must also be given to polyaromatic hydrocarbons (PAHs) or 'BaP'[1], Carbon Monoxide (CO) Sulphur Dioxide (SO_2) and dioxins, all of which have severe health and environmental impacts but are often found at lower concentrations.

By far the most serious pollutants in terms of premature deaths are particulate matters (known collectively as PM_x) and NO_2. As WHO has made clear, there are no safe limits for harmful pollutants like particulate matters. In the UK, the Royal College of Physicians' joint report with the Royal College of Paediatrics and Child Health found that an estimated 40,000 annual deaths are linked to air pollution. It is estimated that 29,000 of those deaths are caused from exposure to $PM_{2.5}$ in the UK – with NO_2 being responsible for the remainder – equating to 340,000 life years lost.

However, up until recently, the debate on air pollution in the policy environment has largely focused on outdoor pollution of NO_2, which predominantly comes from road transport. This is hardly surprising, given that concentrations of NO_2 in many of the UK's cities are in breach of EU law.

As the government's clean air strategy released earlier this year (Defra 2018a), and subsequent consultation on the cleaner domestic burning of solid fuels and wood (ibid) have recognised, other pollutants like PM_x need to be tackled urgently, even if they are technically under EU concentration limits. In particular, domestic pollution is a major contributor to these more dangerous pollutants. Combustion of solid fuels in the domestic sector was responsible for 40 per cent of all $PM_{2.5}$ produced in 2016, particularly as a result of wood-burning.

The level of ambition in the government's clean air strategy to go beyond NO_2 and address other harmful pollutants is promising. The measures targeted at reducing emissions from domestic combustion including a ban on smoky coal and a ban on the sale of wet wood, if properly implemented, will make a significant difference. Nevertheless, this report argues that the government should go further both in terms of the scale of its ambition and its policy commitments. The report is structured as follows:

- Chapter 1 reviews the status of air pollution in the UK and discusses the major associated health impacts and economic costs.
- Chapter 2 highlights the contribution of domestic burning to air pollution in the UK and explains why they are so high in this sector.
- Chapter 3 details the main policymaking challenges that must be considered when seeking to address domestic air pollution, and evaluates how effectively the government's new clean air strategy addresses these challenges.
- Chapter 4 discusses the policy approaches that could address these challenges, where the government's new clean air strategy leaves gaps in policy detail, and the policy recommendations which could fill them.

1 Benzo[a]pyrene – for the purposes of this report we use the term 'BaP' to refer to all PAHs as, within the NAEI, it is used as a marker to indicate the presence of other PAHs due to its high toxicity.

1. THE HEALTH IMPACT OF AIR POLLUTION

CHAPTER SUMMARY

- Emissions of $PM_{2.5}$ and PM_{10} in the UK have remained stubbornly consistent since around 2010, while emissions of BaP have been rising recently to levels last seen in the 1990s.
- European legislation, to which the UK is currently committed, sets limits on the permissible concentrations of many different types of pollutants. However, WHO Air Quality Guidelines are generally much stricter, as there is a much stronger focus on the health impacts.
- In 2015, annual mean concentration of $PM_{2.5}$ across the UK's cities was recorded at or near the stricter limits on air pollution set out by the WHO Air Quality Guidelines and by now may be exceeding these limits. This is already the case for some individual cities, including population centres such as London, Leeds, Nottingham and Sheffield.
- Evidence suggests that **40,000 deaths a year are linked to air pollution** in the UK. It is estimated that **29,000 of those deaths are caused from exposure to $PM_{2.5}$** – with NO_2 being responsible for the remainder.
- WHO estimates that ***indoor* exposure to pollutants such as $PM_{2.5}$** from second-hand smoke could **increase the risk of health impacts by between 20–50 per cent** (Bruce et al 2015), particularly in vulnerable groups such as children, older people and those with existing health conditions such as asthma.
- **The cost of air pollution to the NHS and the economy, in terms of working days lost due to ill health, is estimated at more than £20 billion every year.**

WHAT IS AIR POLLUTION?

Air pollution is defined as "the presence or introduction into the air of a substance which has harmful or poisonous effects' and is an important determinant of human health".[2]

This definition is supported by a wealth of evidence which suggests that poor air quality caused by high concentrations of air pollutants increases the prevalence of numerous health conditions including strokes, heart disease, lung cancer and chronic respiratory disease.

There are two broad types of air pollutant: particulate matter in the form of minute particles of dust and liquid droplets suspended in the air; and a wide range of gases including nitrogen oxides, sulphur dioxide, ozone, carbon monoxide and benzene (Cox and Goggins 2018). The most common types of air pollutants, their main sources and health impacts are outlined in table 1.1.

2 See for example: http://www.oxforddictionaries.com/definition/english/air-pollution

TABLE 1.1

List of most common air pollutants, their main sources and associated health impacts

Pollutant name	Main sources	Health impacts
Benzene	Evaporation and combustion of petroleum products	Cancer, leukaemia
Benzo[a]pyrene (BaP) BaP is one of a group of compounds known as Polycyclic Aromatic Hydrocarbons (PAHs) and is often used as a marker to indicate their presence	Vehicles exhausts and domestic wood and coal fires	Respiratory tract irritation, damage to reproductive system, gastrointestinal irritation, skin irritation – long-term exposure likely to cause cancer
Carbon monoxide (CO)	Road transport (particular petrol), combustion, industry – CO arises from incomplete combustion	Headaches, nausea, dizziness, decreased lung function
Heavy metals	Combustion, industrial processes	Nausea, diarrhoea, abdominal pain, irritation of eyes, nose, throat and lungs, brain and kidney damage, asthma, respiratory diseases, lung cancer
Nitrogen dioxide Generally referred to as NO_X but includes nitric oxide (NO) and nitrogen dioxide (NO2)	Transport, combustion	Lung irritation, decreased lung function and increased chance of respiratory infection – long-term exposure is associated with low birth weight babies and excess deaths
Ozone (O3)	Reaction of hydrocarbons, NO_X, and volatile organic compounds (VOCs) in sunlight	Harms lung function and irritates respiratory system; can increase incidence and severity of asthma and bronchitis – long-term exposure can lead to cardiorespiratory mortality
Particulate matter Collectively referred to as PM_X, the two most commonly mentioned types are those under 10µm in diameter (PM_{10}) and fine particles less than 2.5µm in diameter ($PM_{2.5}$)	Transport (exhaust, tyre and brake wear), combustion, industrial processes and construction	Linked to asthma, lung cancer, respiratory and cardiovascular diseases, infant mortality and low birth weight
Sulphur Dioxide (SO2) When combined with water vapour in clouds, the result is commonly referred to as 'acid rain'	Combustion (coal) and road transport	Causes of irritation of lungs, nose and throat, and exacerbates health

Source: SEPA 2018

AIR POLLUTION IN ENGLAND

In this report we focus largely on the most important pollutants produced by the burning of solid fuel in the domestic sector. Out of the pollutants mentioned in table 1.1 above, these are: $PM_{2.5}$, PM_{10}, BaP, CO and SO_2.

EMISSIONS, CONCENTRATIONS AND EXPOSURE

We use three key terms to describe the journey a pollutant takes from source through to the harmful impact it has on human health. These terms are as follows.

- **Emissions** relate to how much pollution is produced by a certain source. These pollutants can build up in the atmosphere to create overall background

pollution and, combined with local sources of emissions, contribute to local concentrations of pollution.

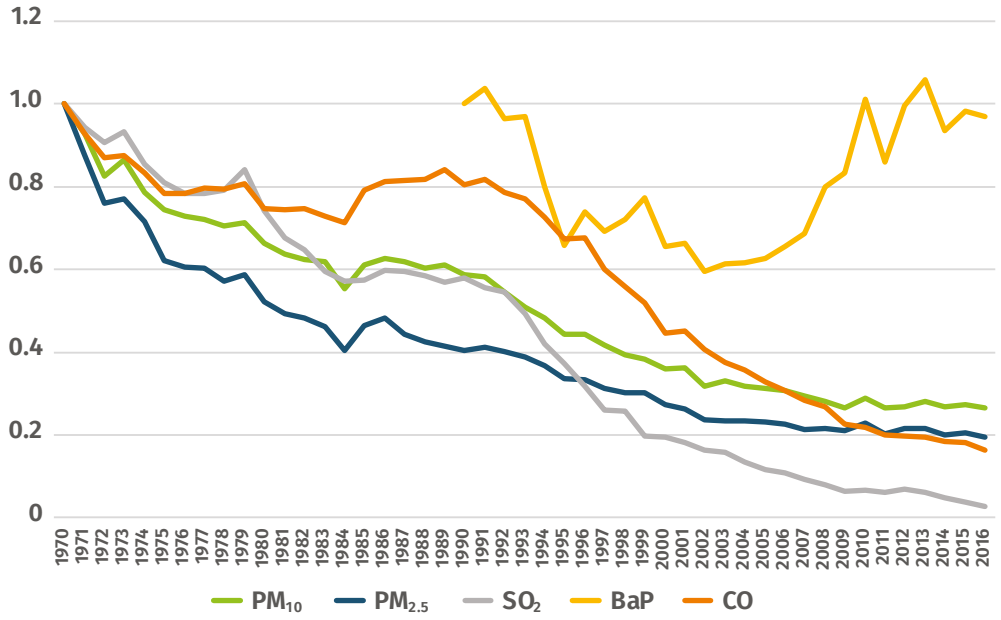
- The local **concentration** of pollution measures the build-up of pollution in specific areas such as busy roads or intensive agriculture. The concentration is not just affected by the amount of pollution emitted by a certain source, but also other factors such as the proximity to the source, the weather, chemical transformations in the air (reactions to sunlight for example) and geographical conditions (topography) (EEA 2015).
- The **exposure** to pollution refers to the people and wildlife that may be affected by high concentrations of pollution. As a result of this exposure, certain groups such as children, older people or those with pre-existing health conditions may experience adverse health impacts.

Emissions

As figure 1.1 shows, emissions of $PM_{2.5}$ and PM_{10} across the UK have remained stubbornly consistent since around 2010, while emissions of BaP have recently been rising to levels last seen in the 1990s.[3]

FIGURE 1.1: $PM_{2.5}$, PM_{10}, AND BAP EMISSIONS HAVE REMAINED STUBBORNLY HIGH SINCE 2000

Percentage change in emissions of major domestic-borne pollutions (1970–2016)



Note: Excludes international aviation, shipping and maritime emissions

Source: NAEI 2018a (adapted by IPPR)

Concentrations: Limits, guidelines and current status

While there is no such thing as a 'safe' pollutant, most activities and processes using some kind of machinery or technology emit pollution. Accordingly, European legislation, to which the UK is currently committed, sets limits on the permissible concentrations of many different types of pollutants, in an effort to balance economic activity while minimising as much as possible the harmful effects of the pollution produced.

3 Trace elements including Dioxins and heavy metals.

These guideline concentration limits have generally been translated into law via the European Union's Ambient Air Quality Directive 2008, and then into UK law through the Air Quality (Standards) Regulations 2010, with equivalent regulations in Scotland, Wales and Northern Ireland. This means that any area within the UK that breaches these limits is breaking both UK and (currently) EU law.

In addition to these legal limits, WHO also sets 'guideline levels' for the concentration of each pollutant (WHO 2005). These are generally much stricter than EU limits, as there is a much stronger focus on the health impacts caused by pollution.

A summary of both the EU legal limits and the WHO guidelines are shown in table 1.2.

TABLE 1.2

WHO guidelines are generally much stricter than the legally binding EU limits

Pollutant name	Averaging period	EU legal limit	Deadline	WHO AQG guidelines
NO_2	1 hour	200µg/m^3	January 2010	Same as EU limit
	1 year	40µg/m^3	N/A	Same as EU limit
PM_{10}	1 day	50µg/m^3	January 2005 (extended to January 2011)	Same as EU limit
	1 year	40µg/m^3	January 2005	20µg/m^3
$PM_{2.5}$	1 day	-	-	25µg/m^3
$PM_{2.5}$	1 year	25µg/m^3	January 2015	10µg/m3
$PM_{2.5}$	1 year	20µg/m^3	January 2020	10µg/m^3
BaP*	1 year	1ng/m^3	January 2005	0.12ng/m^{3**}
CO	8-hour daily mean	10µg/m^3	January 2005	Same as EU limit
SO_2	1 hour	350µg/m^3	January 2005	N/A***
	1 day	125µg/m^3	January 2005	20µg/m^3

***BaP is used as a reference marker for all Polyaromatic Hydrocarbons (PAH)**

****WHO reference value rather than official guideline**

*****Averaging period of 10 minutes used**

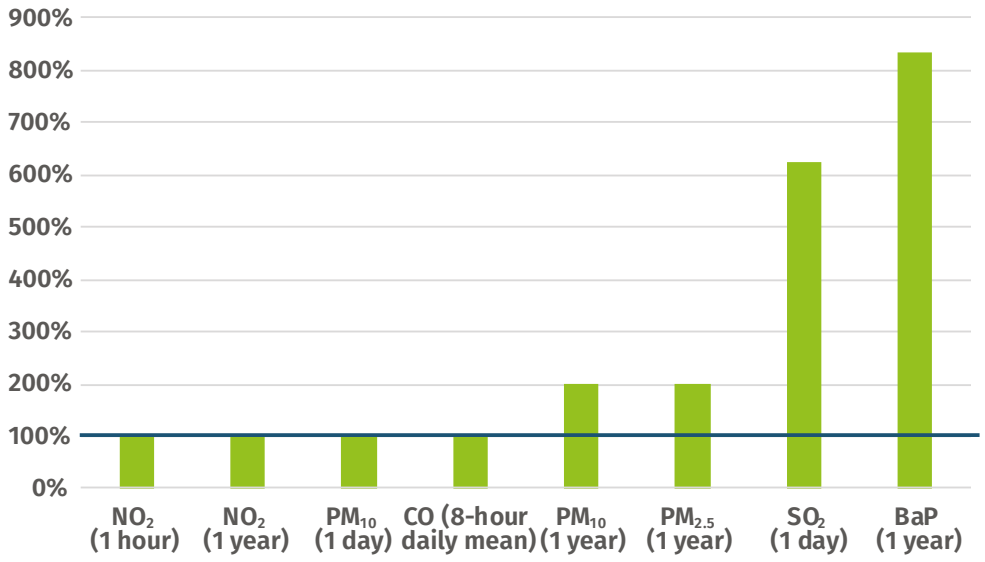
Source: EEA 2017

The EU ambient air quality limits to which the UK is currently subscribed are significantly weaker than the WHO guidelines for $PM_{2.5}$ and SO_2, and they are also weaker for PM_{10} (annual average) and for ozone. For PM_{10} (daily value) and NO_2, EU standards are aligned with WHO guidelines, and permit some occasions when limits are exceeded. This is summarised in figure 1.2.

The WHO considers $PM_{2.5}$ to be the most harmful air pollutant and their guidelines include a short-term value for $PM_{2.5}$ but the EU directive to which the UK is subscribed does not. As a consequence, the UK's standard relies only on a yearly average and high and harmful $PM_{2.5}$ emissions from household heating during the winter can be offset by the lower summer levels. Moreover, the annual limit value set by the EU (25µg/m3) is more than double the WHO guideline value (10µg/m3).

FIGURE 1.2: EU LIMITS ARE HIGHER THAN WHO GUIDELINES FOR SOME OF THE MOST HARMFUL POLLUTANTS

Difference between EU and WHO guidelines



Source: EEA 2017

Particulate matter

The most recent recordings for concentrations of $PM_{2.5}$ and PM_{10} in 2015 were within legal limits according to the Air Quality Standards Regulation 2010 – the legislation implementing the EU's Air Quality Directive 2008 (Goddard & Haves 2017). However, at the last time of recording in 2015, the UK as a whole was about to exceed the stricter limits on air pollution set out by the WHO Air Quality Guidelines (Jones et al 2017).

According to a recent report, the WHO limits have already been exceeded in certain cities (most frequently for $PM_{2.5}$), including population centres such as London, Leeds, Nottingham and Sheffield (Air Quality News, 2018). Evidence from King's College London in 2016 corroborates this further, showing that 13 out of 14 monitoring sites across London[4] recorded concentrations of $PM_{2.5}$ above annual mean guideline values from WHO (Mittal and Fuller 2017).

Polyaromatic hydrocarbons (BaP)

There are indications from European Environment Agency (EEA) reports that the average annual concentrations of BaP are also higher than WHO guidelines – and in some areas are even higher than EU limits (EEA 2017). While concentrations of BaP are typically several orders of magnitude (i.e. kilogrammes rather than kilotonnes) lower than other major pollutants, they are also highly carcinogenic (AQEG 2017) and therefore require strict policing to prevent them from becoming a significant source of premature deaths in future.

Carbon monoxide, sulphur dioxide and dioxins

Concentrations of CO and SO_2 in the UK are currently within EU air pollution limits (EEA 2017). However, both pollutants occasionally exceed WHO limits in specific locations across the UK (EEA 2017) and must therefore be contained. In the case of dioxins, while there are no EU limits set, other than those relating to

4 Those sites with a capture rate of >90 per cent.

food contamination (EFSA 2018), the UK Air Quality Expert Group (AQEG) notes their presence within wood (AQEG 2017), the combustion of which, as discussed below, is a key contributor to many of the pollutants mentioned in this report.

Exposure: The impacts of poor air quality

WHO estimates that each year the effects of ambient (outdoor) air pollution cause about 6.5 million premature deaths[5] worldwide. Of those pollutants listed in table 1.1, the three major pollutants causing these harmful health effects are particulate matter (PM_x), Nitrogen Oxides (NOx), and Ozone (O_3) (House of Commons 2018). Secondary but serious consideration must also be given to polyaromatic hydrocarbons (PAHs) or 'BaP', Carbon Monoxide (CO) Sulphur Dioxide (SO_2) and dioxins (AQEG 2017), all of which have severe health and environmental impacts but are often measured at lower concentrations (EEA 2017).

However, by far the most serious in terms of premature deaths is PM_x ($PM_{2.5}$ in particular) and NO_2. In the UK, the Royal College of Physicians' joint report with the Royal College of Paediatrics and Child Health found that annually an estimated 40,000 deaths are linked to air pollution. However, it is estimated that 29,000 of those deaths are caused from exposure to $PM_{2.5}$ in the UK (COMEAP 2010), with NO_2 being responsible for the remainder (RCP 2016). As further evidence, in the EU-28, in 2014 just under 400,000 premature deaths were attributed to long-term exposure to $PM_{2.5}$ compared to 78,000 premature deaths from NO_2 (EEA 2017).

INDOOR AIR POLLUTION

There is also a distinction to be made between outdoor and indoor pollution. Depending on the way in which people cook and heat their homes, concentrations of air pollutants within the home can be much higher than outdoor background pollution (and will also contribute to it) (Defra 2018b) (NICE 2017a). As such, though outdoor concentrations may be much lower in rural areas than in cities, within individual homes in these areas, indoor pollution concentrations may still present a significant health risk. For example, though further research is required, the WHO estimates that *indoor* exposure to pollutants such as $PM_{2.5}$ from second hand smoke could increase the risk of health impacts by between 20–50 per cent (Bruce et al 2015) particularly in vulnerable groups such as children, older people and those with existing health conditions such as asthma (Simoni et al 2015).

ECONOMIC COSTS

Translating this into economic costs, by Defra's own calculations, on a per tonne basis, PM_x has a larger financial cost than NO_2 in every sector of the economy. This is demonstrated in table 1.3, which references the 'damage cost approach' – a method to quantify the economic cost to society of different pollutants – and associated figures used by Defra from 2015.

5 There are several common measures used to quantify the health impacts of air pollution, including disability-adjusted life years (DALYs), years of lost life (YLL) and years lost to disability (YLD). All of these metrics can be equated in some capacity to the measurement of 'premature deaths' which is also commonly used. For the sake of simplicity, this is the term we refer to throughout this report.

TABLE 1.3

The economic costs of PM_X are much higher than NO_X in the UK.

Sector	Oxides of nitrogen (NO_X)			Particulate matter (PMx)		
	Central estimate	Low central	High central	Central estimate	Low central	High central
Agriculture	£5,050	£2,020	£8,080	£11,625	£9,103	£13,211
Waste	£10,858	£4,343	£17,373	£24,994	£19,570	£28,403
Energy supply	£1,263	£505	£2,020	£2,906	£2,276	£3,303
Industry	£13,131	£5,253	£21,010	£30,225	£23,665	£34,347
Domestic	£14,646	£5,859	£23,434	£33,713	£26,396	£38,311
Transport	£25,252	£10,101	£40,404	£58,125	£45,510	£66,052

Source: Defra 2015 (adapted by IPPR)

Taking an economy-wide approach, the RCP further estimates that the cost of air pollution to the NHS and the economy, in terms of working days lost due to ill health, is estimated at more than £20 billion every year (RCP 2016).

2.
AIR POLLUTION FROM DOMESTIC COMBUSTION

CHAPTER SUMMARY

- **The domestic sector produces 40 per cent of the UK's $PM_{2.5}$ emissions** and over a quarter of the UK's PM_{10} (and they've both been rising since 2007) the largest of any sector for both pollutants and, in the case of $PM_{2.5}$, ver three times more than road transport.[6]
- In the UK, approximately **1.5 million households use wood for fuel and just under 400,000 households use coal and other solid fuels such as anthracite, solid smokeless fuel (SSF) and petroleum coke (pet-coke)**
- The burning of wood is the largest contributor to PM_x emissions in the domestic sector. This is largely because of the greater *quantity* of wood being consumed as smoky coal produces higher emissions of PM_x on a kt/Mt basis compared to wood.
- Emissions factors for PM_x in wet wood are substantially higher than in dried wood.
- In terms of the impact on local concentrations, it is estimated that **between 23 per cent and 31 per cent of urban derived $PM_{2.5}$ in London and Birmingham came from the burning of wood alone**.
- Coal and coal derivatives are the largest contributors to SO_2 in the domestic sector. While domestic emissions of SO_2 produced by coal account for only around 15 per cent of total emissions, they have remained stubborn over time.
- Though the level of smoky coal consumed in the domestic sector is relatively small, industrial sales data suggests that coal consumption recorded by BEIS may be in the order of 35 per cent lower than actual coal sold.
- Alternative smokeless solid fuels such as anthracite have notably lower emissions factors for $PM_{2.5}$ and PM_{10}.
- Modern stoves reduce $PM_{2.5}$ emissions by up to nine times compared to an open fire, but, of the 1.5 million households using wood fuel, **43 per cent of respondents in the UK said they had an open fire in their house**, including 68 per cent of respondents in London and 67 per cent of respondents in Northern Ireland.
- Though stoves are more efficient than open fires, robust sales figures suggest they will also be the main appliance that facilitates an increase in levels of wood burning. This demand is largely driven by those households burning wood for its aesthetic value.
- 21–30 per cent of $PM_{2.5}$ comes from other countries, and the remainder derives from natural sources and international shipping. Addressing $PM_{2.5}$ is therefore an international as much as a domestic challenge.

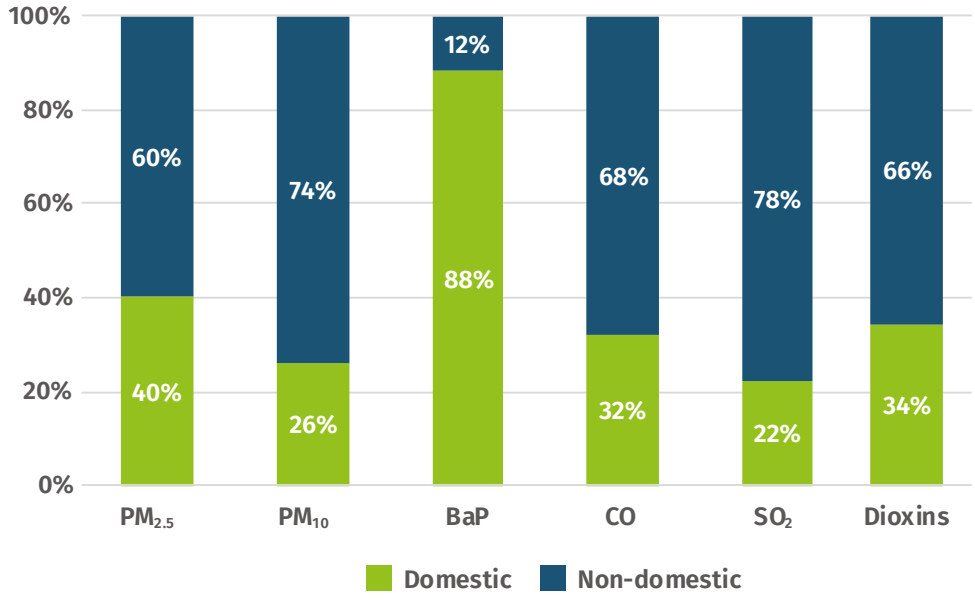
THE ROLE OF THE DOMESTIC SECTOR

The domestic sector is either the single largest or majority contributor to emissions for a number of pollutants as indicated by figure 2.1.

6 Calculations exclude international aviation, shipping and maritime emissions

FIGURE 2.1: THE DOMESTIC SECTOR IS A MAJOR CONTRIBUTOR TO MANY HARMFUL POLLUTANTS, ESPECIALLY $PM_{2.5}$

Percentage of pollutants from domestic vs non-domestic sectors, 2016



Note: Excludes international aviation, shipping and maritime emissions

Source: NAEI 2018a (adapted by IPPR)

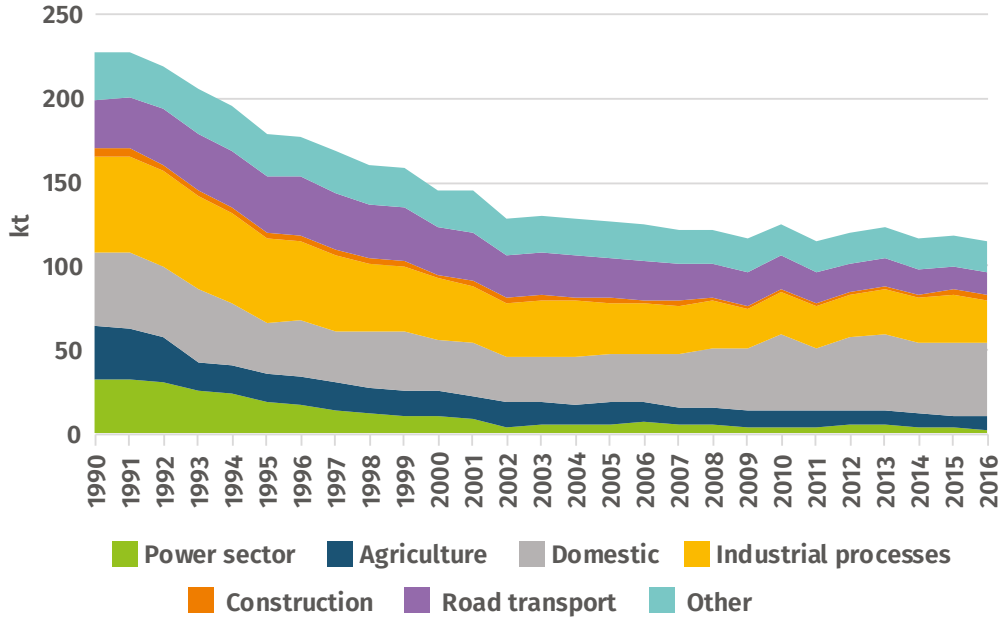
In particular, given the importance of particulate matter mentioned above, it is worth singling out how the domestic sector produces 40 per cent[7] of the UK's $PM_{2.5}$ emissions and over a quarter of the UK's PM_{10} – the largest of any sector for both pollutants and, in the case of $PM_{2.5}$, over three times more than road transport (Robinson 2015) (figures 2.2 and 2.3).

In terms of the impact that emissions from the domestic sector have on local concentrations of air pollutions, it is estimated that between 23 per cent and 31 per cent of urban derived $PM_{2.5}$ in London and Birmingham came from the burning of wood alone (Font and Fuller 2017). Furthermore, while PAHs (BaP is used as a marker to indicate the presence of other PAHs) pollutants are measured at much lower concentrations, it is also striking that the domestic sector is by far the largest generator of BaP pollution, as figure 2.1 shows. Moreover, as figure 1.1 shows, emissions of BaP have been steadily rising since 2004, returning to levels last seen in the 1990s. They can have severe health impacts making it important to address them within the domestic sector, as mentioned in chapter 1.

7 Calculations exclude international aviation, shipping and maritime emissions

FIGURE 2.2: THE DOMESTIC SECTOR IS THE LARGEST CONTRIBUTOR TO $PM_{2.5}$ OF ANY SECTOR*

$PM_{2.5}$ emissions by sector over time

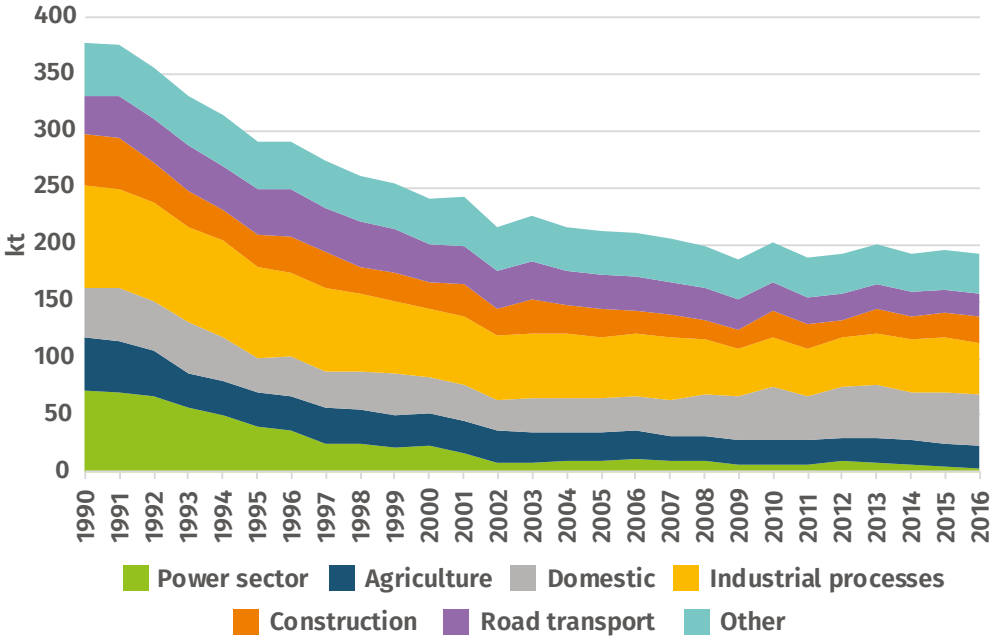


Note: Excludes international aviation, shipping and maritime emissions

Source: NAEI 2018a (adapted by IPPR)

FIGURE 2.3: THE DOMESTIC SECTOR IS ONE OF THE LARGEST CONTRIBUTOR TO PM_{10} OF ANY OTHER SECTOR*

PM_{10} emissions by sector over time



Note: Excludes international aviation, shipping and maritime emissions

Source: NAEI 2018a (adapted by IPPR)

WHY ARE THESE POLLUTANT EMISSIONS SO HIGH IN THE DOMESTIC SECTOR?

The main two reasons behind the high emissions of pollutants in the domestic sector: the types of fuel used, and the types of appliances in which they are burned.

FUEL TYPES

This section will elaborate on the fuel sources which are responsible for these emissions within the domestic sector. Primarily, these are solid fuels[8] and wood which together make up 7 per cent (BEIS 2017a) of domestic final energy consumption (Waters 2018). In the UK, approximately 1.5 million households use wood for fuel (BEIS 2016) and just under 400,000 households use coal and other solid fuels such as anthracite, solid smokeless fuel (SSF) and petroleum coke (pet-coke) (Waters 2018). However, as table 2.1 shows, these fuels emit some of the most harmful pollutants.

TABLE 2.1

Average UK emissions factors in the domestic sector by fuel type

Fuel	PM2.5 (kt/Mt)	PM10 (kt/Mt)	BaP (kg/Mt)	CO (kt/Mt)	Dioxins (g International Toxic Equivalent/Mt)	SO2 (kt/Mt)
Anthracite	1.9	1.8	30	159	27	15
Coal	9.3	9.1	1,550	140	24	23
Petroleum coke	1.9	1.9	30.9	165	29	142
SSF	1.8	1.8	330	151	24	16
Wood	7.6	7.4	1,176	47	7.2	0.16

Source: NAEI 2018b (adapted by IPPR)

Wood

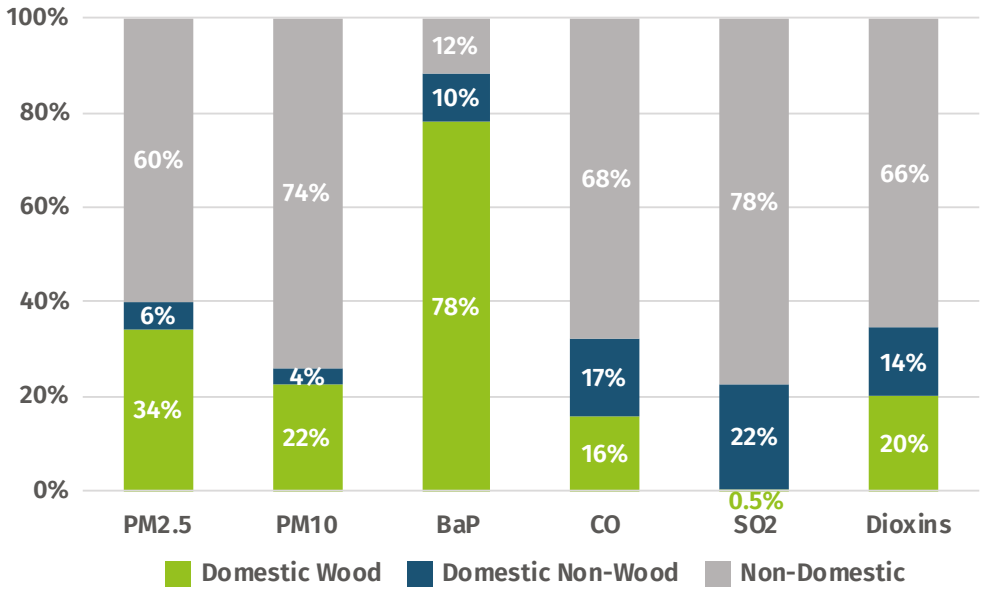
Wood is a large contributor to pathogenic pollutants including $PM_{2.5}$, PM_{10}, BaP, CO and dioxins (Defra 2018b). To develop figure 2.1 further, figure 2.4 shows that domestic combustion of wood makes up a significant proportion of total domestic emissions of these harmful pollutants.

Given their severe health effects mentioned in chapter 1, the emissions of $PM_{2.5}$ and PM_{10} caused by wood are particularly concerning. Indeed, since 2007, $PM_{2.5}$ and PM_{10} emissions in the domestic sector have been rising steadily, as figures 2.5 and 2.6 show.

8 The term 'solid fuel' is used in this report to describe carbon-based fuels that can be collected and burned at a household level.

FIGURE 2.4: WOOD IS BY FAR THE LARGEST CONTRIBUTOR TO PM_X AND BAP IN THE DOMESTIC SECTOR

Percentage of pollutants from domestic wood (2016)

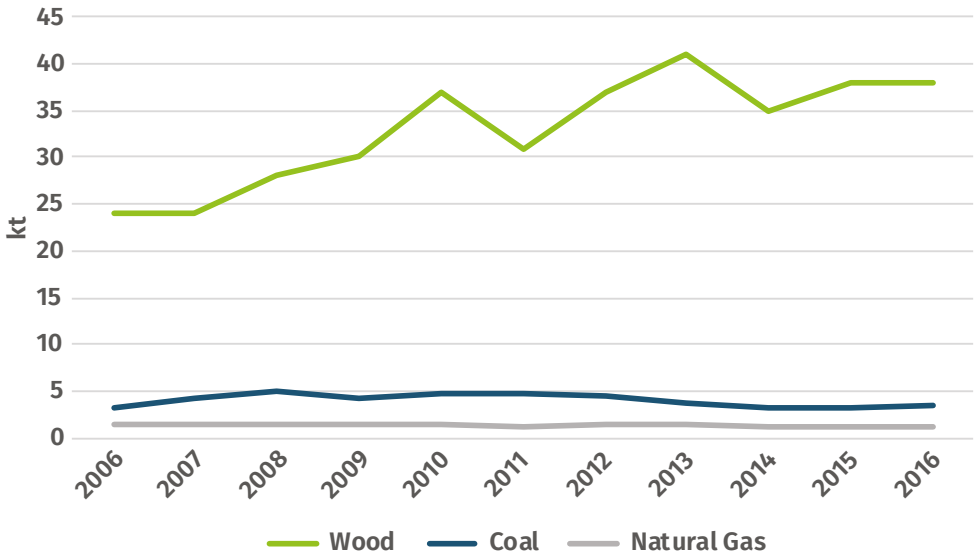


Note: Excludes international aviation, shipping and maritime emissions

Source: NAEI 2018a (adapted by IPPR)

FIGURE 2.5: $PM_{2.5}$ EMISSIONS HAVE BEEN RISING IN THE DOMESTIC SECTOR, CAUSED BY WOOD-BURNING

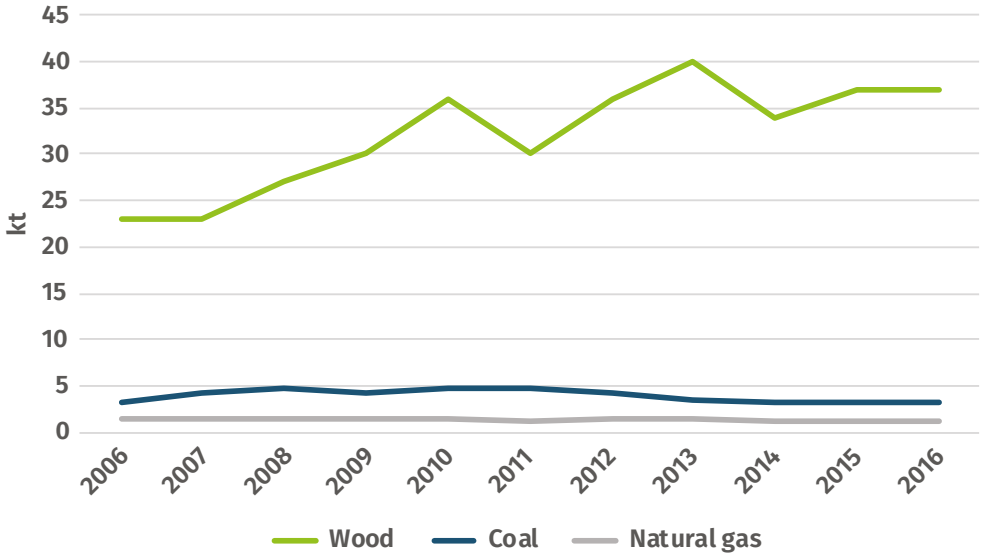
$PM_{2.5}$ emissions (kt) by fuel type (2006–16)



Source: NAEI 2018a (adapted by IPPR)

FIGURE 2.6: PM_{10} HAVE BEEN RISING IN THE DOMESTIC SECTOR, CAUSED BY WOOD-BURNING

PM_{10} emissions (kt) by fuel type (2006–16)



Source: NAEI 2018a (adapted by IPPR)

However, it is also important to note that not all wood burned has the same emission levels – wet wood is significantly more polluting than dried wood, and the emission levels can also vary depending on the type of tree being used (for example, hard or soft wood) (HETAS 2011). While National Atmospheric Emissions Inventory (NAEI) data is not available to differentiate the two wood types, industrial testing suggests that wood with a higher moisture content produces substantially higher emissions, as table 2.2 shows.

TABLE 2.2

Wet wood produces substantially more smoke than dried wood

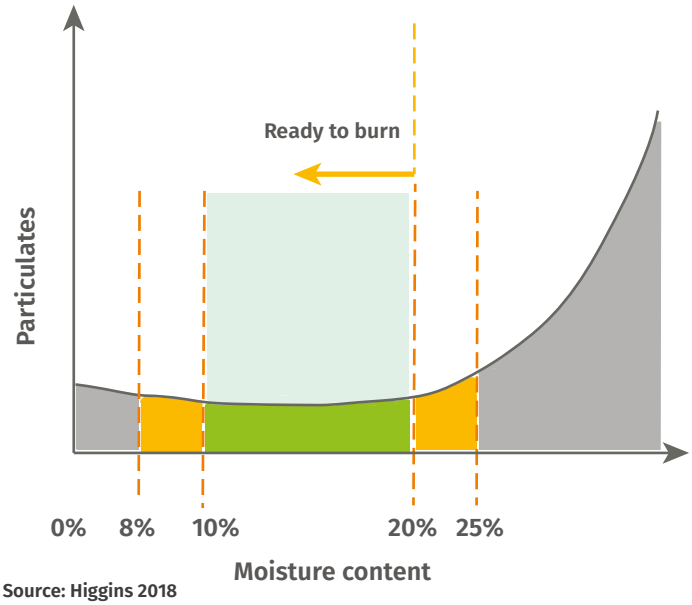
Fuel type	Test duration (h)	Weight of fuel burnt (kg)	Radiant output (kW)	Radiant output (kWh/kg)	Smoke emission (g/h)	Radiant efficiency (%)
Wet wood open fire	1.25	3.0	0.91	0.38	21.1	13.5
Dried wood open fire	0.93	2.5	1.68	0.62	4.6	13.9

Source: KIWA 2015; HETAS 2018

While further data granularity is required, both in terms of disaggregation of 'smoke emissions' and testing of wet wood and dried wood in different appliances other than an open fire, table 2.2 provides an early indicator of the magnitude of the difference between wet and dried wood.

This is further demonstrated visually within HETAS' *Ready to Burn* report, reproduced in figure 2.7.

FIGURE 2.7: BEYOND 25 PER CENT MOISTURE CONTENT, THE EMISSIONS OF PM_X RISE SIGNIFICANTLY



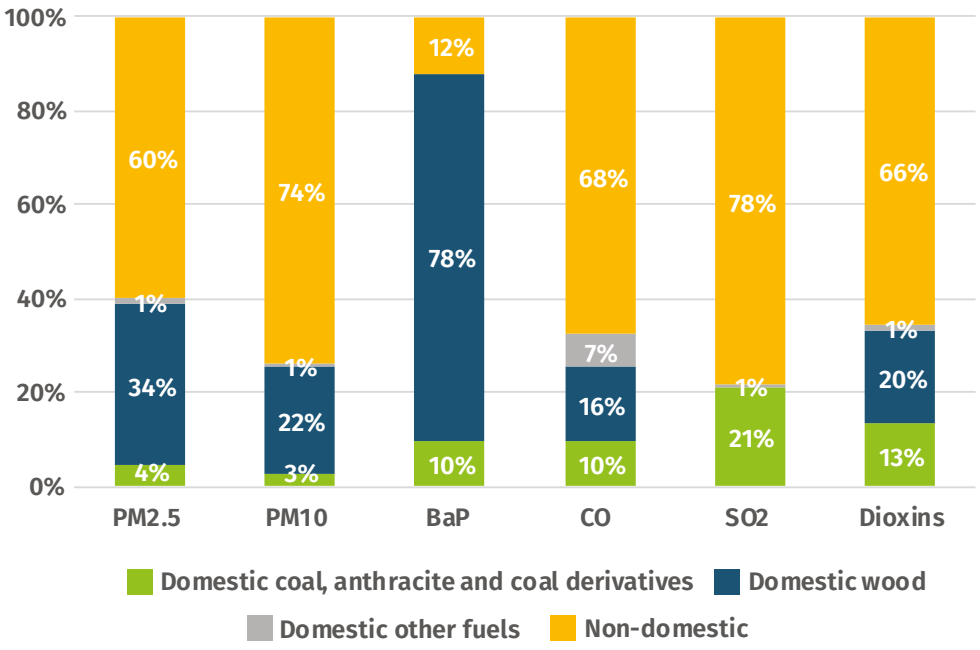
Source: Higgins 2018

COAL, ANTHRACITE, AND COAL DERIVATIVES

Coal, anthracite (a purer form of mined coal) and coal derivatives, including coke, petroleum coke and SSF are the largest contributors to SO_2 in the domestic sector.

FIGURE 2.8: COAL AND COAL DERIVATIVES ARE THE MAJOR SOURCE OF SO_2 IN THE DOMESTIC SECTOR

Percentage of pollutants from domestic coal, anthracite and coal derivatives (2016)



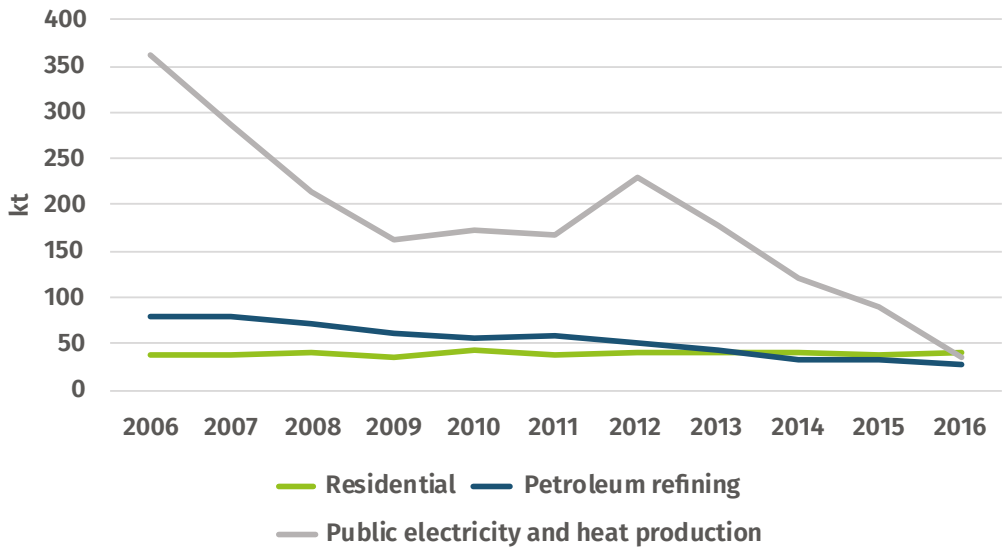
Note: Excludes international aviation, shipping and maritime emissions

Source: NAEI 2018a (adapted by IPPR)

The major source of SO_2 has traditionally come from power generation and industrial processes (NAEI 2018c). However, with the advent of flue-gas desulphurisation in the 1970s, combined with more recent decarbonisation legislation to close all unabated coal-fired power stations by 2025 (BEIS 2018), emissions of SO_2 from these sources have been steadily declining. As a result – although figure 2.9 shows domestic emissions of SO_2 produced by coal account for only around 15 per cent of the total, the absolute emissions have remained stubbornly consistent over, as figure 2.9 demonstrates.

FIGURE 2.9: SO_2 EMISSIONS FROM RESIDENTIAL COAL BURNING HAVE REMAINED THE SAME WHILE EMISSIONS IN OTHER INDUSTRIES HAVE FALLEN

SO_2 emissions from coal combustion (kt) by industry (2006–16)



Source: NAEI 2018a (adapted by IPPR)

However, as with wood, different types of coal and coal derivatives produce different ranges of pollutants. Unlike wood, however, NAEI emissions factors for different types of coal *are* available and reveal these differences (as table 2.1 shows). In particular, though all coal types have relatively high emissions factors for SO_2, it is worth noting the difference between coal – which can be thought of as 'smoky coal' – and alternative solid fuels such as anthracite, which have notably lower emissions factors for $PM_{2.5}$ and PM_{10}.

Indeed, though wood is the largest contributor to PM_x emissions, this is largely because of the greater *quantity* of wood being consumed. In fact, smoky coal produces higher emissions of PM_x on a kt/Mt basis compared to wood. Furthermore, though the level of smoky coal consumed in the domestic sector is relatively small, industrial sales data suggests that coal consumption recorded by BEIS may be in the region of 35 per cent lower than actual coal sold. Consequently, when considering how to minimise emissions of $PM_{2.5}$ and PM_{10} from the domestic sector, alternative solid fuels that have much lower emissions factors for PM_x present a potential option for fuel-switching.

APPLIANCES

Within the domestic sector, one of the major considerations behind the cause of particulate pollution is not just the fuel source but the appliance in which the fuel is burned. According to Defra, modern stoves reduce $PM_{2.5}$ emissions by up to

nine times compared to an open fire (Defra 2018c). Pollution emissions can vary dramatically depending on the appliance being used, as shown in table 2.3.

TABLE 2.3

Open fires produce nine times more $PM_{2.5}$ emissions than Ecodesign stoves

Appliance type	$PM_{2.5}$ emissions (g/MWh)
Solid fuel open fire	2,950
Non-Defra exempt stove	2,660
Defra-exempt/Ecodesign stove	335
Pellet fired boiler	216

Source: Defra 2018c

Yet according to the Domestic Wood Survey, of the approximately 1.5 million households using wood for fuel, 43 per cent of respondents in the UK said they had an open fire in their house, including 68 per cent of respondents in London and 67 per cent of respondents in Northern Ireland (BEIS 2016). While having an open fire is not the same thing as using one, and does not determine the source of fuel being used (gas, for example) – the prevalence of open fires across the UK could still result in higher emissions of pollution than if these homes had stoves instead.

At the same time, though stoves are more efficient than open fires, they are also projected to be the main appliance that facilitates an increase in levels of wood consumption (Font and Fuller 2017; Williams et al 2017). Indeed, industry data suggests that stoves sales are relatively healthy, with estimated sales of 150,000–200,000 per year and over 1 million stoves being sold between 2010 and 2015 (Font and Fuller 2017). Furthermore though Ecodesign stoves appear to be substantially less polluting than non-exempt stoves, there are still challenges with testing accuracy for these new designs, as discussed in chapter 3. As noted by the AQEG, this is also true for biomass boilers which are generally considered to be much less polluting than wood-burning stoves (AQEG 2017; Defra 2018c).

One of the main reasons for these robust numbers is the increasing attractiveness of wood-burning as an aesthetic proposition. In particular, the same study recording these stove numbers also found that pollution from wood-burning was highest during evenings and weekends, suggesting that stoves (and likely fireplaces too) were being used as an amenity, rather than a necessity (Font and Fuller 2017). This is further reinforced by responses to the Domestic Wood Survey, in which 27 per cent of respondents across the UK said that they burned wood for “aesthetic value” (BEIS 2016).

TRANSBOUNDARY POLLUTION

Despite high emissions of particulate matter from the domestic sector, Defra estimates that only around 50–55 per cent of annual average $PM_{2.5}$ concentrations come from human activity in the UK, with 21–30 per cent coming from other countries, and the remainder deriving from natural sources and international shipping (Defra 2018b). Although this is beyond the scope of this report, we recognise that addressing $PM_{2.5}$ is an international as much as a domestic challenge, and the UK is accordingly a signatory to the UN Convention on Long-range Transboundary Air Pollution (EEA 2018).

3. CURRENT POLICY AND POLICYMAKING CHALLENGES

CHAPTER SUMMARY

- Several **public data gaps exist on the consumption of wood, including: how much wood is actually used for domestic consumption**; how high the emissions factors of wet wood are compared to dried wood and for different types of wood; and how much of wood consumed has a moisture content higher than the HETAS standard of 15 per cent.
- The lack of regional consumption figures of solid fuels makes the *dependency* on different fuel types more difficult to understand.
- Primary dependency is a key consideration for policymakers. The Domestic Wood Survey found that, **of the estimated 1.5 million households in the UK using wood for fuel, at least 11 per cent of respondents cited wood as their primary source of fuel for all home heating, and 80 per cent said that they used wood for at least some heating**.
- There are serious challenges with the way in which stoves are tested because the testing for performance takes place in controlled regulatory scenarios that do not reflect real-life usage.
- Anecdotally, **smoke control areas have been poorly enforced by local authorities due to a lack of capacity**.
- **Despite over 700 Air Quality Management Areas (AQMAs) being designated since 1997**, most of these have been set up to look at NO_2, only 13 per cent to tackle PM_{10}, 5 in total to address SO_2 and **none to address $PM_{2.5}$**.
- One of the main reasons driving a long-term increase in pollution emitted by wood and robust stove sales is the aesthetic value ascribed to wood-burning. Consumer choice must therefore be a key part of policymaking considerations.
- Though anthracite is less polluting than bituminous coal and wet wood in terms of $PM_{2.5}$, it is also important to consider the greenhouse gas implications if all users of smoky coal or wet wood were to switch to using anthracite.
- **Reducing domestic emissions to as close to zero is possible but the UK market for low carbon heating systems is currently very immature** because successive governments have been dragging their feet on promoting alternative heating technologies.

THE GOVERNMENT'S NEW CLEAN AIR STRATEGY

Much of the debate in the UK on air pollution has focused on the impacts of NO_2 derived from road transport (GMCA 2018; City of London 2015). This focus has been understandable because the concentrations of NO_2 are above legal limits. As a consequence, the government has lost three court cases for failing to provide a plan deemed sufficient to tackle Britain's toxic air (Harvey 2018).

The recent announcement of the Defra's clean air strategy recognises the importance of broadening the scope of policymaking to include other significant contributors to air pollution. To this end, the government's new draft clean air strategy and their consultation on cleaner domestic burning of solid fuels and wood (Defra 2018a) are welcome developments, as they recognise the impact which the domestic sector has in producing harmful pollutants like PM_x.

Key policy proposals related to the domestic sector to address this include (Defra 2018a):

- committing to halving the population living in areas with $PM_{2.5}$ concentrations above WHO guidelines by 2025
- investing £10 million in improving modelling, data and analytical tools and bringing together local and national monitoring data
- providing consumer information on the health impacts of indoor air pollution
- ensuring that only highly efficient stoves are being sold by 2022
- restrictions on the sale of wet wood for domestic burning so that it can only be purchased in volumes up to a specified cut-off point
- applying sulphur standards and smoke emission limits to all solid fuels
- phasing out the sale of bituminous or traditional house coal
- working with industry to identify an appropriate test standard for new solid fuels
- giving new powers to local authorities to enforce air pollution flexibly including potential reform of the Local Air Quality Management system to drive action on PM_x emissions
- working with industry to identify appropriate tests for new appliances
- providing consumer information to reduce the pollution emitted from solid fuel burning.

The measures proposed by the government targeted at reducing emissions from domestic combustion including the ban on smoky coal and a ban on the sale of wet wood, if properly implemented, will make a significant difference in reducing emissions. Nevertheless, this report argues that the government could and should go further both in its stated ambitions but also policy initiatives to deliver on them. In this chapter, we summarise these policymaking challenges and evaluate the extent to which commitments specific to the domestic sector in the government's clean air strategy addresses them.

THE GOVERNMENT'S AMBITION

As highlighted earlier in the report, pollution like PM_x is more damaging to human health and the economy than NO_2, yet it has received less attention because it has not strictly broken legal limits. Recognising that EU limits are not strict enough, the government's clean air strategy sets out a target for England to halve the number of people living in areas with $PM_{2.5}$ concentrations over the WHO guidelines by 2025.

In order to minimise the harmful impacts of these pollutants, policy action will need to go beyond existing EU limits for the whole of the UK. As such, while the elimination of PM_x emissions at an economy-wide level would be impossible – not least because a substantial portion of these emissions come from transboundary pollution – it should be possible to reduce domestic emissions to as close to zero as possible.

Achieving this would require the promotion of alternative renewable heating systems. However, the UK market for low carbon heating systems is currently very immature because successive governments have been dragging their feet on promoting alternative heating technologies (Emden 2018). Consequently, long-term ambitions for reducing pollution in the domestic sector will also require a scale up in government ambition for low carbon heating policy.

DATA AVAILABILITY

In order to take well-informed and long-lasting policy action and initiate communication with the public, several data gaps will need to be addressed. In some instances, disaggregation may be all that is required – Defra may already have access to the data but could simply re-categorise it. In other cases, there are clear evidence gaps which must be substantiated.

DATA GAPS FOR WET WOOD

The most urgent data challenge relates to a lack of information about wood in general.

Specifically, there are data gaps in the following areas:

- how much wood is actually used for domestic consumption
- how high the emissions factors of wet wood are compared to dried wood and for different types of wood
- how much of the wood that is consumed has a moisture content higher than the HETAS standard of 15 per cent (HETAS 2011).

For the first data gap, this could potentially be resolved simply by disaggregating wood consumption from the 'bioenergy' category in BEIS energy consumption statistics. In addition, some data is already available that provides comparable emissions factors for wet and dried wood (as shown in chapter 2). However, while the magnitude of the difference between pollution from wet wood compared to dried wood should be an initial guideline for policymakers, it will also be important for Defra to conduct their own tests and develop official statistics to provide more accurate information in any communication they may have with consumers.

Furthermore, understanding what proportion of all wood being burned has a high moisture content remains a major challenge. According to the Domestic Wood Survey, two-thirds of wood purchases (over 70 per cent for rural areas), were not sourced from a general or large specialist supplier, making it difficult to track the moisture content of this wood (BEIS 2016). This data gap is particularly challenging, since knowing the moisture content and its source will help to determine both the immediate messaging to consumers and the overall policies to limit pollution.

To address the challenges of data availability, the government has committed to investing £10 million in improving modelling, data and analytical tools and bringing together local and national monitoring data.

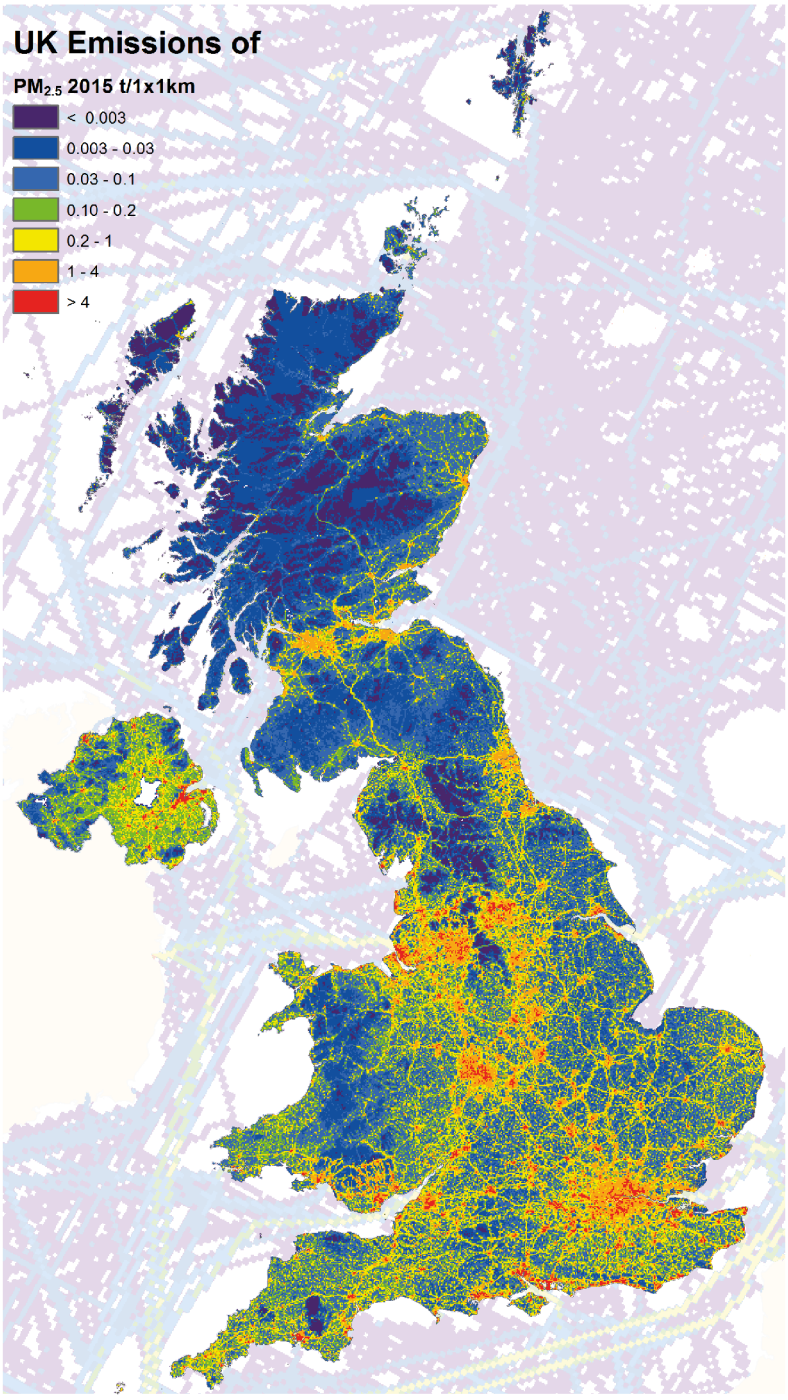
REGIONAL DEPENDENCY

Accessing data for the regional energy consumption of different types of fuel, the lack of disaggregation in current publicly available data limits our ability to determine the particular regional impacts that proposed policy changes might have. In particular, as discussed in chapter 2, while figures exist for the contributions that solid fuels make to pollution emissions, figures showing the regional energy consumption of each fuel, particularly for wood, are less accessible. This is problematic because while the pollution statistics show the

severity and *scale* of the challenge, the lack of regional consumption figures make the *dependency* on different fuel types more difficult to understand.

Nevertheless, there are regional differences in fuel consumption which can be inferred from the data that is available. For instance, the National Atmospheric Emissions Inventory produces emissions maps for different types of pollution which can be seen in figure 3.1 for $PM_{2.5}$ as an example.

FIGURE 3.1: $PM_{2.5}$ EMISSIONS ARE HIGHER IN URBAN AREAS BUT INDOOR CONCENTRATIONS MAY STILL BE A THREAT TO INDIVIDUAL HOUSEHOLDS



Source: NAEI 2018d

Though figure 3.1 may show higher emissions of $PM_{2.5}$ in urban areas, even if rural areas measure lower emissions of air pollutions and hence lower concentrations, they may be more dependent on the fuels producing them. Furthermore, as mentioned in chapter 1, even though rural areas record lower concentrations, indoor pollution concentrations may be much more harmful to individual households.

In particular, certain rural communities have a much higher level of solid fuel consumption on an absolute basis than urban areas. For example, the Highlands in Scotland use three times as much coal as the whole of Greater London. This is highlighted in tables 3.1 and 3.2, which show absolute coal and manufactured fuel consumption respectively.

TABLE 3.1

Top 10 levels of coal consumption by area

Region	Energy consumption (GWh)
Highland	120.6
Cornwall	112.1
Carmarthenshire	74.6
Powys	66.0
County Durham	65.4
Armagh City, Banbridge and Craigavon	61.1
Shropshire	59.2
Newry, Mourne and Down	55.1
Gwynedd	53.8

Source: BEIS 2017b (adapted by IPPR)

TABLE 3.2

Top 10 levels of manufactured solid fuel consumption by area

Region	Energy consumption (GWh)
Cornwall	62.6
Highlands	52.0
Carmarthenshire	34.6
Armagh City, Banbridge and Craigavon	31.2
Powys	30.7
Wiltshire	29.1
County Durham	28.9
Belfast	28.5
Shropshire	28.3
Newry, Mourne and Down	27.7

Source: BEIS 2017b (adapted by IPPR)

In many cases, those regions which have a higher absolute consumption of polluting solid fuels also have a higher relative consumption of solid fuels. These relative figures – shown in table 3.3 – demonstrate how these areas depend on these fuels more than others. In particular, it is notable that the Highlands, Powys,

Carmathenshire and Gwynedd have high energy consumption of non-wood solid fuels both in absolute terms and as a proportion of total energy consumption.

TABLE 3.3

IPPR analysis of BEIS sub-national final energy consumption statistics showing top 10 most reliant areas on coal and manufactured fuel for domestic consumption*[9]

Region	Coal % of total domestic consumption	Manufactured fuel % of total domestic consumption
Isles of Scilly	10.9%	5.9%
Na h-Eileanan Siar	9.4%	3.9%
Orkney Islands	8.5%	3.7%
Eden	7.0%	3.0%
Ceredigion	6.9%	3.2%
Highlands	6.0%	2.6%
Powys	5.9%	2.8%
Gwynedd	5.8%	2.9%
Carmarthenshire	5.0%	2.3%
Shetland Islands	4.8%	2.2%

Source: BEIS 2017c (adapted by IPPR)

***Many areas of Northern Ireland have very high levels of coal and manufacture fuel consumption but cannot be given a percentage total due to lack of data for electricity and gas consumption**

This consideration of regional dependency is particularly important when deciding on policies that may limit certain types of fuels, as there is a risk this could disproportionately impact these communities. The government's clean air strategy must therefore reflect not only that air pollution concentrations are measured regionally, but also that the impact of restricting their usage will disproportionately affect those areas that depend on them most.

PRIMARY DEPENDENCY

Policymaking sensitivity is also crucial when identifying whether there is a primary dependency for all heating or a secondary use as a luxury. For example, looking at wood consumption, despite the very small sample size, the Domestic Wood Survey found that, of the estimated 1.5 million households in the UK using wood for fuel, at least 11 per cent of respondents cited wood as their primary source of fuel for all home heating and 80 per cent said that they used wood for at least some heating[10] (BEIS 2016).

Furthermore, since figures relating to primary usage are not available for non-wood solid fuels – although it is assumed to be high for the sake of illustrating regional dependency in table 3.3 – and not rigorous for wood consumption, the primary dependency across all solid fuels is likely to be higher than 11 per cent.

Going further, once the level of dependency on solid fuel combustion as a primary source of heating by region has been determined, it is also very important to then compare these statistics with the levels of income and qualitative consultations

9 While it appears likely that consumption of wood would follow a similar pattern (greater use in rural areas), data availability in this area is poor, as 'bioenergy' statistics by sub-region include transport consumption and therefore obscures assumptions. Furthermore, it is assumed that in all cases the actual *use* of coal and manufactured fuels consumed at a domestic level is for home heating. However, this is never explicitly stated or separated both by region and by use.

10 Even though some of the people within these figures will have also responded that they burn wood for aesthetic value.

for these households in an effort to improve understanding of whether solid fuel consumption is by necessity or by choice.

It will be critical to ensure that people relying on solid fuel as their primary fuel source and those regions where solid fuel consumption is particularly high are included within data monitoring, in order to ensure that policies that target all fuels properly consider the impact on these groups. We note that the government has asked for views on how it should support those in fuel poverty with the transition away from high-carbon fossil fuels.

REGULATING FUEL SOURCES

The government has committed to implementing restrictions on the sale of wet wood for domestic burning so that it can only be purchased in volumes up to a specified cut-off point, applying sulphur standards and smoke emission limits to all solid fuels and phasing out the sale of bituminous or traditional house coal.

With respect to wood, the government has committed to limiting the sales of wood sold in smaller sizes of packaging – set at a volume of 2m³ to dried wood (i.e. with moisture content of less than 20 per cent) only. While this will cover a substantial proportion of wood burned in the UK through domestic sources, it will not cover those buying in larger quantities (not least because, as the government argues, wood sold in smaller quantities is more likely to be used immediately).

In regard to coal, the government has announced its intention to phase out the use of traditional house coal for domestic combustion and only allowing the sale of smokeless coal (or anthracite) and low sulphur manufactured solid fuel for the purpose of domestic heating. The government is consulting on the phase-out date (2019, 2020 or 2021 being the most likely), on a potential transition period of up to two years for industry and households to use up existing stocks, and on whether the ban should apply nationwide.

With regard to manufactured solid fuels, the government is proposing to extend the 2 per cent sulphur content limit (which currently only applies in smoke control areas (SCAs)) nationwide, with the intention to reduce it further over time. The government appears to favour a reduction to 1 per cent over a one to three-year period.

TRADE-OFFS

As mentioned in chapter 2, one of the main reasons driving a long-term increase in pollution emitted by wood and robust stove sales is the aesthetic value ascribed to wood-burning. As such, any regulations on the types of fuel and appliances being used would therefore impact on consumer choice. It will therefore be critical and challenging to manage this trade-off by providing sufficient justification for limiting choice through effective communication of the harmful effects of domestic pollution and the provision of alternative heating options.

In addition, though anthracite is less polluting than bituminous coal and wet wood in terms of $PM_{2.5}$, it is also important to consider the greenhouse gas implications if all users of smoky coal or wet wood were to switch to using anthracite. As table 3.4 demonstrates, simply switching from coal to anthracite or SSF would actually increase emissions. Though CO_2 emissions factors for dried wood using the same units of measurement are unavailable, these would also likely be lower than anthracite.

TABLE 3.4

The CO_2 emissions factors of solid fuels and oils*

	Emissions factors (kt/Mt)		
Fuel Name	**CO2**	**PM2.5**	**SO2**
Petroleum coke	890.67	1.90	142.00
Anthracite	878.00	1.80	12.00
Coke	837.25	1.70	12.00
SSF	790.00	1.60	16.00
Coal	718.07	9.10	16.00

IPPR analysis of the NAEI 2018b database

***CO_2 emissions factors for wood are not available in the data**

Moreover, even if a small increase in CO_2 emissions was considered within policymaking and counterbalanced by some other decarbonising activity, it may be difficult to persuade consumers to use solid fuel alternatives to wet wood because of the aforementioned aesthetic value ascribed to wood in general.

We do note, however, that the government is aware of the potential increase in carbon emissions that could arise from the proposed transition. As such, they are considering whether to encourage the increase of biomass by-product content within manufactured solid fuels – while ensuring they remain below emission limits – in order to limit additional emissions of carbon dioxide.

APPLIANCE REGULATIONS

Although stoves and biomass boilers are more efficient combustion units than open fires, there are serious challenges with the way in which stoves are tested. This is primarily because the testing for stove and biomass boiler performance takes place in controlled regulatory scenarios that do not reflect real-life usage (AQEG 2017). For comparison, though new types of stoves are being prepared for new Ecodesign provisions in 2022 (SIA 2018), they still cause much higher emissions than new trucks with particulate filters (Edwards 2017). Indeed, it was the view of the vast majority of stakeholders at our expert roundtable for this report that Ecodesign regulations did not go far enough in reducing pollution emissions through improved efficiency.

These issues are particularly sensitive since the buying of highly efficient stoves is likely to form a key part of communication to consumers as a way to minimise pollution emitted from solid fuel burning. Therefore, a lack of rigour in testing methods could undermine consumer confidence in the efficiency of stoves in a similar way to the recent lack of trust in diesel cars (Campbell 2018). Indeed, one of the main reasons why VW was able to falsify the results for the fuel efficiency of their cars (Hotten 2015) was the leniency of the testing methods in the first place (Archer 2016). For stoves, there is a risk of a similar public backlash not least given a stove installed is both an expensive process and is likely to remain in the home for at least 15 years.

The government has committed to ensuring that only highly efficient stoves are being sold by 2022 and to developing appropriate tests for new appliances. While the development of new and rigorous tests for appliances is welcome, the commitment to ensure stoves reach a certain efficiency by 2022 is no more ambitious than what is already required by EU law. Indeed, the Stove Industry Alliance (SIA) and main manufacturers are already making preparations to

introduce Ecodesign-ready stoves by 2020 (SIA 2018). Therefore, while new and more rigorous testing standards are welcome, Defra's commitment on stove efficiency will need to build on existing activities rather than simply restating these commitments.

LOCAL CAPACITY

Local authorities are required to monitor air pollution against national targets under the Environment Act 1995 (Environmental Law 2017). In addition to powers to control transport and industrial emissions, local authorities also have a range of powers to tackle domestic pollution, including:

- declaring the whole or part of their district or authority to be a smoke control area (HETAS 2018), which permits only certain types of fuel to be burned and bans the use of open fires (Gov.uk 2018)
- fining use or purchase of unauthorised fuel
- approving chimney heights.

While technically breaching the law in a smoke control area could result in a fine of up to £1,000 (ibid), anecdotally, smoke control areas have been poorly enforced by local authorities due to a lack of capacity. For example, despite the fact that most of the local authorities in London have a smoke control area in place that bans the use of open fires and certain types of solid fuels (Defra 2018b), according to the Domestic Wood Survey, of the approximately 1.5 million households using wood for fuel, 68 per cent of respondents said they had an open fire in their household. Though many of these respondents may well have open fires that burn gas rather than solid fuels.

In addition to this lack of capacity, the governance, engagement and surrounding policy guidance for tackling local air pollution is muddled at best. In particular, there are challenges with the Local Air Quality Management (LAQM) guidelines which will need to be addressed.

In particular, under the LAQM system, local authorities are required to monitor and assess air pollution within their local area and designate AQMAs where necessary (Defra 2016). However, they are not required to work collaboratively and do not need take a whole emissions approach to tackling pollution (ibid). Indeed, despite over 700 AQMAs being designated since 1997, most of these have been set up to look at NO_2 – only 13 per cent to tackle PM_{10}, five in total to address SO_2, and none to address $PM_{2.5}$, as table 3.5 shows (ibid).

TABLE 3.5

Most AQMAs across the UK have been set up to tackle NO_2

Pollutant	England	Wales	Scotland	Northern Ireland	London
Nitrogen dioxide NO2	495	39	29	18	34
Particulate Matter PM10	40	1	19	6	29
Sulphur dioxide SO2	5		1		

Source: Defra 2018d

The monitoring of NO_2 suggests local authorities have experience in setting up AQMAs, but now need to turn their attention to PM_x as well. The lack of attention to $PM_{2.5}$ in particular is a major problem with the LAQM system, because of the historic focus on the monitoring PM_{10} due to a lack of understanding of the health effects of $PM_{2.5}$. Now that impacts of the latter are much better understood, $PM_{2.5}$ has become a public health priority under current guidance the monitoring of

which, according to the Public Health Outcomes Framework, should therefore predominantly be led by the Directors of Public Health (Defra 2016). However, as a consequence, the role of local authorities is less well defined. As the framework states, it: "does not prescribe what the local authority role should be; it is for the local authority in consultation with its public health officials and others to consider how it wishes to define this role" (ibid).

The result has been less engagement in monitoring of $PM_{2.5}$ than local authorities-led AQMAs may have been able to achieve. For example, recent research using Wales as a case study has suggested that public health bodies and leaders do not interact with the LAQM guidance as much as they could (Brunt et al 2018).

Finally, despite recent NICE guidelines being issued to provide frameworks and advice on appropriate courses of action for local authorities and healthcare officials regarding air quality, the attention in this advice is once again mostly focused on road-side pollution rather than domestic combustion (NICE 2017b).

Taken altogether therefore, the LAQM guidance points to a systemic failure to address pollution stemming from domestic combustion. Moreover, even though there are specific health indicators for $PM_{2.5}$ in particular, there appear to be low levels of engagement from public health officials, and the governance of policy initiatives to tackle this pollution is not clearly defined.[11]

To support local government, the government has committed to giving new powers to local authorities to enforce air pollution flexibly based underneath a nationwide approach to smoke control. They also propose to consider reforming the LAQM system and give local authorities powers to address PM_x concentrations locally. However, while we welcome the attention given to PM_x concentrations, apart from a suggestion that local authorities could encourage local 'no burn days', it is unclear firstly what these powers would be and secondly how they would help to alleviate local authority capacity issues.

The government has committed to providing consumer information to reduce the pollution emitted from solid fuel burning while also committing to banning the sale of the most polluting fuels. As mentioned in chapter 4, we believe that this communication could be an effective way to increase public acceptance of changes that reduce consumer choice over the kinds of fuels and appliances which may be available to them. However, while the government has recognised the importance of ensuring that policies to reduce pollution also align with decarbonisation objectives, it will also be important for Defra and BEIS to work together to project the impact which policy changes will have on CO_2 emissions.

One of the most effective ways of addressing both these challenges is through the promotion of alternative renewable heating systems. However, while the government recognises how a renewable heat incentive that includes support for biomass could potentially be re-evaluated in future, there is currently a lack of clear policy support for alternative heating systems.

11 Additional regulations are in place at a national level regarding the sulphur content of smokeless solid fuels.

TABLE 3.6

Summary table of policymaking challenges and evaluation of government ambition in the clean air strategy

Policymaking challenge	Ambition	Evaluation
Overall ambition	Committing to halving the population living in areas with $PM_{2.5}$ concentrations above WHO guidelines by 2025	The ambition is promising but the government has not committed to introducing the stricter WHO targets or a longer term target for eliminating domestic pollution from solid fuel.
Data availability	Investing £10m in improving modelling, data and analytical tools and bringing together local and national monitoring data	While monitoring data will be a key part of assessing the problem, information about the *sources* of fuel (e.g. wet and dried wood) and the *usage* of that fuel (e.g. primary dependence or secondary amenity) will be crucial to informing policy
	Working with industry to identify an appropriate test standard for new solid fuels	Developing new standards for fuel burning must include emissions factors based on moisture content and different types of wood
	Providing consumer information on the health impacts of indoor air pollution	Greater data availability will help provide a more accurate message that does not have to be constantly updated in a way that would risk undermining consumer confidence
	Providing consumer information to reduce the pollution emitted from solid fuel burning	
Regulating fuel sources	Legislating to prohibit the sale of the most polluting fuels	Communication of health risks may help to justify limiting consumer choice but provision of long term renewable heat alternatives will also be crucial
Appliance regulations	Ensuring that only highly efficient stoves are being sold by 2022	This commitment goes no further than what is already a part of EU legislation
	Working with industry to identify appropriate tests for new appliances	Given the industry is already preparing for Ecodesign regulations, new and more rigorous testing standards will need to be developed
Local capacity	Giving new powers to local authorities to enforce air pollution flexibly including potential reform of the Local Air Quality Management system to drive action on PM_X emissions	It is unclear what 'powers' would be given to local authorities, particularly at a time when local authority capacity is already limited such that enforcement is difficult to maintain

Source: Defra 2018b

4.
A WORLD LEADER ON CLEAN AIR

> *"Leaving the EU provides us with an excellent opportunity to be even more ambitious about achieving cleaner air for the health of the nation, and for our environment and the biodiversity it sustains."*
> **Michael Gove, environment secretary 2018 (UKPOL 2018)**

As set out in the previous chapter, the clean air strategy sets out a number of ambitions and policy measures, particularly with regard to reducing emissions from domestic burning, which could have a significant impact. In particular, the ban on smoky coal and a ban on the sale of wet wood, if properly implemented, should make a significant difference. Nevertheless as we argue in this chapter, we believe the seriousness of the public health crisis means that the government should commit to going further and faster. In this chapter, we set out both the immediate and long-term actions to fill these gaps, grouping recommendations in five core sections:

- stricter air pollution targets post-Brexit in line with WHO guidelines
- behaviour change and communication, particularly on health impacts
- policies to encourage clean alternatives
- ambition beyond EU targets for stove regulations
- local government support.

OVERALL AMBITION: STRICTER AIR POLLUTION TARGETS POST-BREXIT

With questions over what EU environmental regulation may or may not be kept during Brexit negotiations, the commitment to halve the number of people living in areas with concentrations of $PM_{2.5}$ above the WHO guidelines by 2025 is a welcome ambition. However, in order to provide a longer term framework to air pollution policy and in recognition of the risks to public health, this report argues that the government must go further.

As set out in chapter 1, the EU ambient air quality limits to which the UK is currently subscribed are significantly weaker than the WHO guidelines most notably for $PM_{2.5}$ and SO_2. The European Respiratory Society has stated that the current directives to which the UK adheres "do not set appropriate objectives to meet meaningful air quality standards to protect human health" (ERS 2017). As a recent report by the European Court of Auditors (ECA 2018) found, the relevant EU directive (EC 2008) – which sets the limits to which the UK subscribes – did introduce the possibility of updating the limit value to 20µg/m3, but the EU Commission did not do so when it examined the issue in 2013. This is despite the fact that an assessment of the costs of doing so put the costs of compliance across the EU at €5 and €8 billion, and the monetised health benefits at between €37 to €119 billion per annum in 2020.

Moreover, the WHO's *Review of evidence on health aspects of air pollution* (WHO 2013) in 2013 found that scientific evidence supported stricter EU limit values for PM_{10} and $PM_{2.5}$, and regulating short-term averages (such as 24 hours) for $PM_{2.5}$ but no change has been enacted by the EU. In addition, a number of professional

medical organisations have called for the EU to take account of the latest scientific evidence and adopt the stricter WHO standards (ERS 2017; Anses 2017).

Given the scientific evidence and the opportunity to review our air pollution standards post-Brexit, we recommend that the government should update the UK's limit and target values (for PM, SO2 and O3), in line with the latest WHO guidance. The government should also reduce the number of times that concentrations can exceed standards (for PM, NO2, SO2 and O3) and it should set a short-term limit value for $PM_{2.5}$.

These measures should be enshrined in a new Clean Air Act for the UK. The Clean Air Act should be robustly enforced by the proposed new environmental watchdog which should also have the powers to initiate legal action. The regulator should also be empowered to set new air quality standards swiftly in light of new scientific evidence, rather than having to rely on legal changes.

Furthermore, the government should commit to a long-term ambition to reduce all domestic PM_X emissions to as close to zero as possible by 2050[12]. As discussed below, this will ultimately only be achievable if alternative heating systems are promoted in place of solid fuels. A commitment of this kind will therefore be useful in providing long-term certainty to the low-carbon heating industry which has hitherto been underperforming due to a lack of policy support.

DATA AVAILABILITY: BEHAVIOUR CHANGE AND COMMUNICATION

As mentioned in chapter 3, an immediate message to consumers of the long-term risks from wood smoke presents a challenge not only because of the lack of clear data on the health impact of indoor exposure, but also due to the growing popularity of wood-burning as a household amenity (Font and Fuller 2017).

Improving the quality and granularity of data available is key to communicating the most accurate message possible. Even without perfect data however, it should still be possible to communicate the risks of domestic solid fuel combustion and ways to reduce exposure to consumers. While commitments to do so in the clean air strategy are therefore welcome, the following more detailed types of messages will also need to be included:

- communication of how to store and burn wood correctly and warnings of health impacts labelled on wood being sold
- the health impacts of wood and coal smoke with emphasis on PM_X
- the importance of buying wood from a trusted source where possible
- checking the moisture content of wood and, if possible, favouring kiln-dried wood or other alternatives such as smokeless coal
- the importance of only buying the highest-efficiency stoves where possible
- the importance of having stoves serviced and chimneys swept
- advertising alternative heating systems which could be used instead.

As part of this communication, it would also be important for the sake of transparency to point out that the full effects of indoor pollution were not yet fully known but that, ultimately, there is no 'safe' limit for PM_X. This would not only help to avoid misleading the public but also increase consumer acceptability if stricter regulations were introduced at a later stage.

Furthermore, a WHO review of previous air quality educational campaigns has suggested that they may not be effective (WHO 2015) when only focusing on

12 The date of 2050 has been chosen in particular as it aligns with scenarios by the Committee on Climate Change that necessitate the inclusion of renewable heating technologies on the path to reducing the UK's CO_2 emissions by 80 per cent by 2050.

the negative aspects of wood-burning, due to the positive associations many consumers have with wood combustion in particular (Hine et al 2007). Therefore, it will be critical to provide consumers with an alternative, safer way of burning wood (and other solid fuels), or indeed communicate the advantages of alternative renewable heating systems altogether.

This communication will be particularly important in regions which are more dependent on solid fuels and individual homes that use them as their primary source of fuel. Both these groups will also need to be included and recorded in future data collection exercises in order to determine the impact which economy-wide fuel bans are likely to have.

FUEL SOURCES: POLICIES TO ENCOURAGE CLEAN ALTERNATIVES

In the short-term, a ban on the sale of wet wood and smoky coal must be adopted by government in England by 2020 and should also be considered by all Devolved Administrations. For wood, this will require strict enforcement of sales to ensure that they meet the HETAS standard of no more than 15 per cent moisture content. They year 2020 is chosen because this is the date when EU legal limits for $PM_{2.5}$ become stricter (thought still higher than WHO guidelines). Given the desire to go beyond EU regulations, 2020 is therefore an opportune moment to prove this ambition is being met by action.

While plans to ban and phase out the sale of wet wood and smoky coal respectively should help to reduce PM_X emitted in the domestic sector, as we suggest above, the long-term ambition should be to all but eliminate domestic emissions of PM_X altogether. The most effective way of achieving this is to change the heating system being used. Even if stoves are more efficient and we succeed in transitioning to fuel sources which emit less, air pollution concentrations can still increase if domestic burning overall increases. One simple mechanism for this would be to offer incentives to switch to a gas boiler, as a policy to run in parallel to those regulating solid-fuel appliances. However, as with new regulations for appliances, such a policy for gas boilers would only be a transitional step since it would fail to address the increasingly pressing challenge of decarbonising the heat sector.

As a first step, the UK government should improve awareness and subsidy levels for the Renewable Heat Incentive. In this regard, the government has so far failed to incentivise consumers to take-up anything near the expected number of technologies being supported under the scheme (NAO 2018). The communication of this policy and engagement with consumers is critical to turning these alternative heating systems into a fashionable preference.

In the longer-term, for those areas where there is sufficient population density or a clear economic rationale, other clean heating alternatives such as district heating may present a promising alternative which will require the involvement of local councils. As previous research from IPPR shows, in the UK the opportunity for heat networks in particular is vast, with the potential to create between 50,000-80,000 jobs (Emden et al 2017). Consequently, in order to provide a robust pipeline of future renewable heating projects, the government must support local authorities to develop city-level procurement bodies, undertake heat zoning and create broad local heat strategies.

Finally, as we discuss in chapter 3, given the risk that restrictions on solid fuels may have on those homes and regions that depend more heavily on these fuels – especially if used as a primary heat source – any local heat strategies will need to give priority to citizens who are most vulnerable to policy changes. As an example, across the UK, tenants in social housing have already had solar panels installed, paid for through private investment (where the profits of electricity sold into the

grid are received by these investors). These kinds of models could potentially be replicated for home heating systems in areas where policy changes to solid fuel access will affect primary fuel consumption.

APPLIANCE REGULATIONS: AMBITION BEYOND EU TARGETS

The two major causes of pollution in UK homes are the types of fuels and the types of appliances – as discussed in chapter 2. While the government has already started to take action on banning the sale of wet wood and phasing out domestic combustion of non-smokeless coal, it is also critical to ensure that the use of inefficient open fires is phased out and tighter standards are developed for new stoves. As mentioned in chapter 3, current plans in the clean air strategy on stove standards are no more ambitious than existing EU regulations. There are therefore a number of more ambitious policy options which could be adopted for both stove standards and open fires. These include the following.

1. Follow Ireland's example in 2014 (O'Sullivan 2016) and develop new standards for new-build properties, including the immediate banning of non-gas open fires in building designs.
2. By 2022, develop stricter standards for stoves than Ecodesign. The stove industry is already preparing for the sale of Ecodesign-compliant stoves by 2020 (SIA 2018) suggesting that they can go further.
3. Follow California's example (WHO 2015) and mandate that all houses must be upgraded with the most efficient kinds of stoves once they are sold by 2025.
4. For rented properties and social housing, financial incentives should be offered to landlords and housing associations accompanied with a deadline of 2025 to upgrade all open fires or stoves to the latest models.
5. Base testing of stove efficiency on real usage rather than controlled testing environments.

LOCAL CAPACITY: LOCAL GOVERNMENT SUPPORT

With the exception of developing heat networks, the policies suggested above are largely national in scope. However, local authorities will still play a critical role in monitoring their effects on air pollution, even if their role in enforcement is diminished by bans on the sale of smoky coal and wet wood. As such, there are several steps which must be taken to provide them with the capacity and resource to achieve this.

As an immediate priority, there must be greater integration between healthcare advice and local authority air quality plans. NICE guidelines must be updated to include studies on indoor exposure to pollutants from domestic combustion of solid fuels, particularly $PM_{2.5}$. From this point, the NICE guidelines must then be included within local authority air quality action plans to ensure that domestic pollution is a central part of their strategies.

Finally, LAQM guidance must be changed so that the monitoring of $PM_{2.5}$ falls under the responsibility of local authorities to manage so that they can create AQMAs for this pollutant, rather than being the responsibility of healthcare professionals. Of course, these two groups should clearly still be linked and able to provide consistent advice to the consumer.

5. CONCLUSIONS AND POLICYMAKING TIMELINE

Domestic burning in the UK is emitting lethal but legal pollution. The consequences for human health are severe, both outside and inside the home, even more so than the illegally high concentrations of NO_2 being recorded in many cities across the country.

The majority of domestic emissions of $PM_{2.5}$ and other harmful pollutants come from the increasingly attractive aesthetic proposition of wood-burning – though smoky coal may also play an understated role, in addition to the major contribution to SO_2 emissions it already makes in the domestic sector. Furthermore, despite the sale of increasingly more efficient stoves appearing to be relatively robust, open fires are still reported in many households, particularly in London and Northern Ireland, and there are serious questions around how well stove testing reflects real life usage.

In an effort to tackle these lethally high pollutant concentrations, the government's clean air strategy is a positive step that sets out ambitions and proposals to get pollution across the UK – including from the domestic sector – under control. However, in some areas it is not ambitious enough; in others, its ambitions are not accompanied by policy detail. Faced with limited data that would help us to understand the real extent of people's and regions' dependencies on solid fuels, or the true efficiency of stoves based on real-world usage; a lack of capacity to enforce air quality regulations at a local level; and a lack of alternative heating systems to draw consumers away from solid fuel burning – policymaking in this area is indeed a challenge.

But we are facing these challenges at a moment in UK politics that provides us with a great opportunity. While some of our recommendations reflect more long-term thinking, many can and should be implemented before the Brexit deadline on 29th March 2019. Though there is much uncertainty around which legislation may or may not be retained after the Brexit process (Burns et al 2018), air pollution is an area where there is an opportunity to develop stricter pollution thresholds than the EU and tighter standards for fuels and appliances.

While the clean air strategy starts to realise this, more ambition and more detail is required to secure the UK's position as a global leader on air quality.

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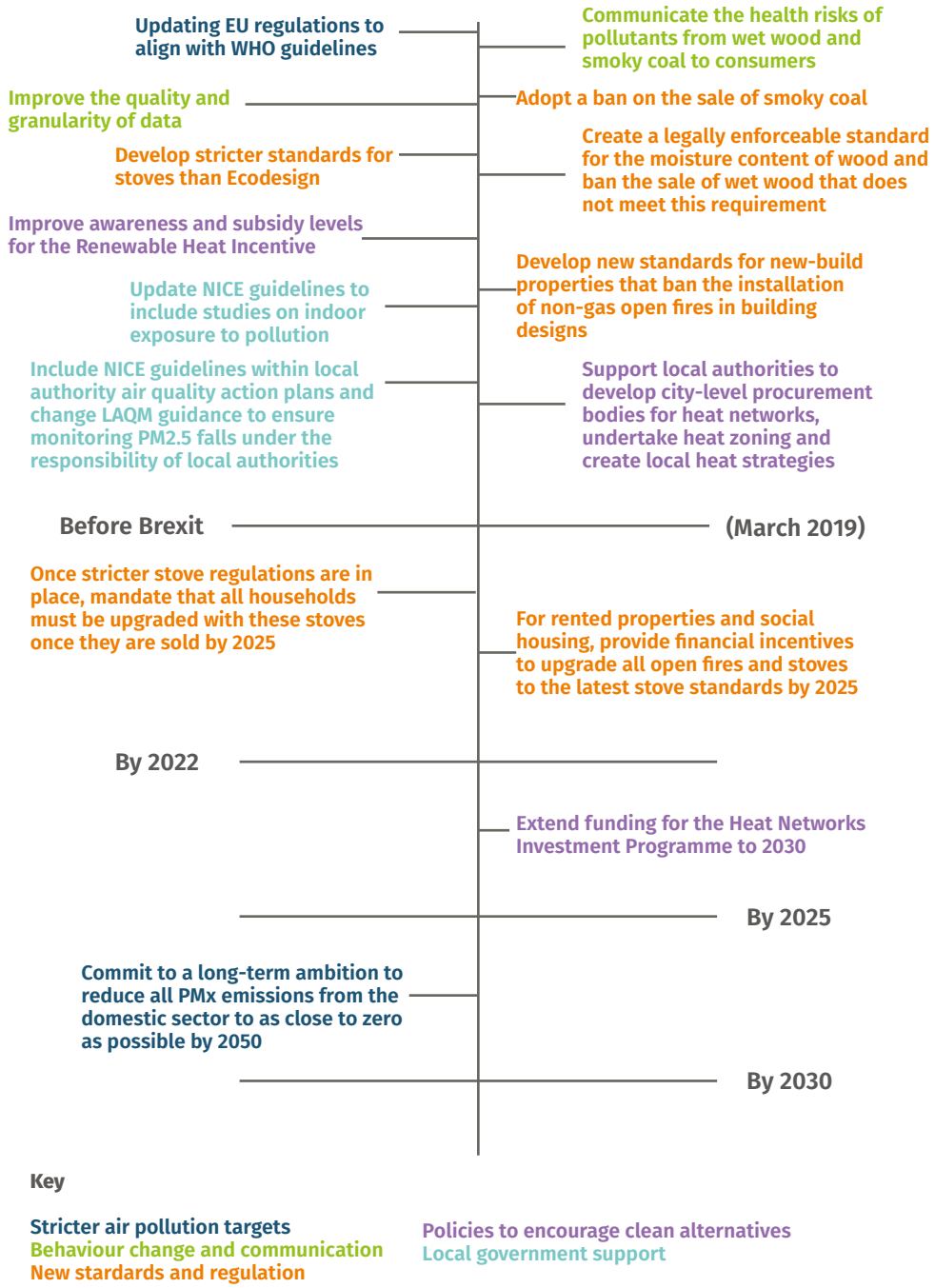
APPENDIX

FIGURE A.1

Timeline of recommendations



Source: IPPR 2018

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