Impacts of the sale of house coal and the most polluting manufactured solid fuels in Scotland

Final report

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Impacts of the sale of house coal and the most polluting manufactured solid fuels in Scotland

Final report prepared for the Scottish Government by

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EXECUTIVE SUMMARY

Introduction and options considered

As part of the Cleaner Air for Scotland 2 (CAFS2) strategy, various actions are being investigated by the Scottish Government to further reduce air pollution in Scotland. One action being considered is a potential ban on the sale of house coal and of manufactured solid fuels with a sulphur content greater than 2% for domestic use. The fuels under the proposed ban emit significant amounts of particulate matter ($PM_{2.5}$ – an important air pollutant) into the environment, and as such the ban aims to improve air quality in Scotland.

This project gathered evidence and undertook analysis to inform the development of a Business and Regulatory Impact Assessment (BRIA) concerning the proposal. A BRIA assesses the likely costs, benefits and risks of proposed legislation on the public and private sectors. This project explored the potential environmental, social and economic outcomes of the following three policy option scenarios:

- **Option 1: Take no action (i.e. the baseline)** - This is a 'do nothing' counterfactual against which the other options are assessed, and assumes no further change in policy that impacts on the consumption of the fuels in scope.
- **Option 2: Voluntary Approach** - An information campaign is implemented informing the public of the health impacts of solid fuel use in homes. This then leads to voluntary changes in behaviour around the domestic burning of solid fuels.
- **Option 3: Regulating the sale, distribution and marketing of fuels** - A ban of the sale of bituminous (or 'house') coal and high sulphur (>2% sulphur) smokeless fuels for domestic use is put in place.

To inform the analysis, a literature review was conducted which captured a range of sources, including the 2022 Defra Solid Fuel Burning and BEIS Residential Wood Survey and the 2019 Defra impact assessment of the same policy options for England. In addition, targeted stakeholder interviews were conducted, in particular with industry stakeholders to gather data on potential effects for Scottish firms.

Impact of proposals on air quality

The key objective of the policy option scenarios is to reduce the emission of harmful air pollutants and the resulting concentration of these pollutants that persist in the air. To explore these effects, detailed air pollution modelling was undertaken using a suite of best-practice tools. The main findings of the air quality assessment were that:

- Domestic combustion for heating and cooking of the solid fuels which fall in the scope of Options 2 and 3 contributed a relatively small amount (an average of 0.07%) to total $PM_{2.5}$ concentrations across Scotland in 2019. This compares to other more important sources of $PM_{2.5}$ pollution, the top three being transboundary (i.e. pollution coming in from sources outside Scotland), industrial and road sources.
- Introducing an information campaign under a voluntary approach (Option 2) is likely to have a limited effect on $PM_{2.5}$ concentrations, mainly as the response to an information campaign is anticipated to have low impact on the behaviour of individuals.

    - Where impacts do take place, there is likely to be a higher reduction in urban areas than rural, as there is a higher proportion of households using wet wood in urban areas compared to rural and (of all the solid fuel types covered in the scope of the Options) wet wood causes the most $PM_{2.5}$ emissions per tonne of fuel combusted.
    - The maximum reduction of 0.0013 µg m^{-3} for Option 2 was in Aberdeen; this reduction is 0.02% of total $PM_{2.5}$ concentrations and 0.3% of modelled domestic combustion concentrations in this location.
- A ban on house coal and high-sulphur smokeless fuel (Option 3) could lead to a larger reduction in $PM_{2.5}$ concentrations compared to Option 2. Although a ban would affect a narrower range of fuels (ban would not influence the burning of wet wood, which would also be anticipated to be affected by an information campaign under Option 2), the change is anticipated to be greater given this would be mandated.
    - The highest reductions are in anticipated in rural areas, where there is a higher prevalence of house coal use.
    - The maximum reduction of 0.020 µg m^{-3} for Option 3 was in Fort William; this reduction is 0.5% of total $PM_{2.5}$ concentrations and 15% of modelled domestic combustion in this location.

The analysis above looks at changes in air quality at particular locations – these impacts can also be viewed over a larger Lower-Super Output Area (LSOA). These results showed similar trends as the location-specific results:

- Overall, in the baseline (Option 1), $PM_{2.5}$ concentrations are lower in rural areas, than in more populated areas in the central belt and east coast.
- The impact of both policy options is relatively small (i.e. the difference between total concentrations between the Option 1 (baseline) and Options 2 and 3).
- There are limited decreases in average concentrations in most LSOAs for Option 2. The largest decreases (of an order of magnitude of around 0.001 $\mu g.m^{-3}$) are in urban areas, e.g., in central parts of Aberdeen and Edinburgh.
- There are larger reduction in concentrations in Option 3 than in Option 2 for many LSOAs, particularly in rural areas. The largest reductions (0.02 $\mu g.m^{-3}$) are seen in LSOAs in remote towns, e.g., Fort William and Kirkwall.

Evidence to support the Business and Regulatory Impact Assessment and key findings

The policy options aim to improve air quality in order to reduce the detrimental human and environmental health impacts that are associated with exposure to harmful air pollutants. Human health impacts can be assessed using different approaches –this study adopted a more detailed ‘impact pathway approach’ in order to produce a more robust assessment. The approach is more robust as it reflects to a greater extent the specific situation in Scotland, namely that given the use of solid fuels is highest amongst households in rural areas, there is likely to be a lower exposure and associated health impact caused by the emissions from burning these fuels (say relative to England, where these fuels are burnt in areas with typically higher population densities).

The assessment of human health effects is combined with other impacts associated with the policy options (i.e. other benefits and costs) in a summary ***'cost-benefit analysis' (or CBA).*** The result of the CBA intends to show whether the policy options would overall provide a net benefit (positive NPV) or net cost (negative NPV) for Scotland, and which would deliver a greater net benefit. The summary results are presented in the following table.

Table 1 Impacts of the policy options expressed in monetary terms, and overall NPV 2023-2032 (£2020 prices discounted to 2022). Numbers rounded to 3 s.f.; costs shown in red, benefits in green

Impact	Policy Option 2 (Information campaign)		Policy Option 3 (Coal ban and sulphur limit)	
Source for fuel price assumptions:	*Defra Impact assessment (2019)*	*Stakeholder engagement (2022)*	*Defra Impact assessment (2019)*	*Stakeholder engagement (2022)*
Fuel Costs	£263,000	*£142,000*	£8,020,000	*-£4,120,000*
Greenhouse gas Impacts	-£13,000	*-£13,000*	-£1,270,000	*-£1,270,000*
Health impacts	-£380,000	*-£380,000*	-£1,830,000	*-£1,830,000*
Implementation Costs	£64,800	*£64,800*	£96,400	*£96,400*
Total NPV	**-£65,200**	***-£186,200***	**£5,016,400**	***-£7,123,600***

Note: *Table shows that the results applying to sets of assumptions around the relative price of coal and manufactured fuels.

The CBA found that the voluntary approach of stimulating action through an information campaign (Option 2) results in a small, positive NPV (i.e. the option would deliver an overall net benefit for Scotland). The human health benefits through air quality improvements and reduction in greenhouse gas emissions are seen to outweigh the increased fuel costs and implementation costs of the policy. These effects stem from an assumed shift in the type of fuel used: from wet wood to dry wood, and from coal to manufactured solid fuels. Although there is a small reduction in the overall amount of fuel consumed (given cleaner alternatives are marginally more efficient), there is an increase in fuel costs as the unit price of cleaner alternatives (in particular dry relative to wet wood) is relatively higher.

For Option 3, the CBA findings show that whether a ban on domestic use of coal and limit on sulphur in smokeless fuels could deliver a net benefit or a net cost for Scotland depends on the fuel prices assumed in the analysis. I.e. the result is sensitive to the difference (if any) between the assumed prices of coal and manufactured fuels.

When using price data from the 2019 Defra Impact Assessment[1] (which considered the impacts of a similar ban for England), the costs of a proposed ban in Scotland outweigh

[1] Defra Impact Assessment

the benefits for the policy – the NPV is a net cost of £5.1m. This result is driven largely by the increased fuel costs associated with switching from relatively cheap coal to more expensive manufactured solid fuels not in scope of the ban (assumed prices of fuel in this scenario: £293 per tonne of coal vs. £358-406 per tonne for smokeless fuels).

However, this source of price data is now several years old. Targeted interviews with stakeholders were conducted as part of this study in 2022 in which stakeholders indicated that the prices of coal and alternative, less polluting/smokeless fuels have converged in recent years to be effectively the same or very similar. Assuming equivalent prices for coal and smokeless fuels results in a positive NPV of £7.1m for Option 3 as the fuel cost (under the 2019 Defra IA prices) then becomes a fuel benefit due to the underlying reduction in the total amount of fuel consumed given the greater efficiency of burning manufactured fuel relative to house coal.

This highlights the strong sensitivity of the overall result, and the conclusions drawn, to the fuel price assumptions used. Views on the relative prices were provided by the industry stakeholders as part of the study and hence could be considered more up-to-date – as such the assessment utilising these assumptions could be considered a more likely picture of impacts as of December 2022. This suggests that should the cost of coal and alternative, less polluting/smokeless fuels remain equivalent, Option 3 could deliver a net benefit for Scotland.

It is also important to note that other, additional benefits have also not been captured in the NPV and monetised assessment, such as reduction in emissions of SO_2 brought by the 2% sulphur limit on manufactured solid fuels, and reductions in indoor air pollution, both of which will deliver an additional benefit for human (and environmental) health.

Alongside the summary cost-benefit analysis, a number of ***specific impact tests*** have also been carried out to consider the potential for important effects or outcomes for specific groups in more detail.

The sector for which there would be greatest potential for effect was identified as Scottish businesses, in particular those involved in the supply and distribution of solid fuels. Based on data gathered from industry stakeholders, the impacts of either option on businesses are expected to be negligible. It was found that the vast majority of fuel suppliers already sell a wide variety of fuels (or can do so easily), including alternative fuels not subject to the ban. Hence they would be able to adapt easily to any behaviour change under either option with limited impact on their operations. Furthermore, there is no difference in profit margins between banned and alternative fuels.

For consumers, the most important impact will be the change in fuel cost, which (as identified in the cost-benefit analysis) is uncertain – there could be an additional cost, but using more up-to-date evidence around relative fuel prices, there could in fact be no additional cost. It is anticipated that given the negligible impacts on businesses as outlined above, the number of suppliers will remain fairly constant and no issues around access to fuels and cleaner alternatives have been identified.

The assessment also did not identify any non-negligible impacts for: intra-UK trade, international trade, competition or digital transition.

1. Introduction

1.1 Background

As part of the Cleaner Air for Scotland 2 (CAFS2) strategy, actions are being investigated by the Scottish Government to further reduce air pollution in Scotland. One such action being considered is the ban on the sale of house coal and manufactured solid fuels with a sulphur content greater than 2%. The proposed fuels under the proposed ban emit significant proportions of particulate matter ($PM_{2.5}$) in particular into the environment, and as such the ban could help reduce air pollutant concentrations in Scotland.

This project sought to explore the social and economic impacts of the following three policy option scenarios on different groups (including businesses and consumers):

- **Option 1: Take no action**- this is a ‘do nothing’ counterfactual against which the other options are assessed, and assumes no further change in policy that impacts on the consumption of the fuels in scope.
- **Option 2: Voluntary Approach**- Involves an information campaign informing the public on the health impacts of solid fuel use in homes.
- **Option 3: Regulating the sale, distribution and marketing of fuels**- A ban of the sale of bituminous (or ‘house’) coal and high sulphur (>2% sulphur) smokeless fuels.

This analysis informed a Business and Regulatory Impact Assessment (BRIA) concerning the potential introduction of either a voluntary approach or a ban on the sale of certain solid fuels. A BRIA assesses the likely costs, benefits and risk of proposed legislation on the public and private sectors. The assessment ensures the proposed legislation will not have unintended impacts. The assessment provides information about the intervention being considered; the options being assessed as part of the intervention; the potential impacts of the intervention on different groups including businesses; the costs and benefits of the proposed options.

This methodology for the project, and its deliverables, follow the relevant sections of the Business and Regulatory Impact Assessment (BRIA) template and associated Scottish Government guidelines[2].

1.2 This report

This report is the final report of the project. This report presents the findings of the analysis and recommendations to support the Business and Regulatory Impact Assessment. It follows the following structure:

- **Literature review** presenting the data sources reviewed and the main sources identified in the literature
- **Business and Regulatory impact assessment** presenting the assessment of the policy options, covering:
    - Screening of impacts and affected groups
    - Air quality assessment

[2] Scottish Government Business and Regulatory Impact Assessment template

- Economic analysis covering valuation of health impacts, estimation of cost impacts, and analysis of impacts on businesses, competitiveness, consumers and international trade
- Overall cost-benefit analysis and summary of findings.

2. Literature review

2.1 Identified Literature

The following data sources were established in the preliminary stages of the project. Exploring these data needs, in particular around their availability, accessibility, coverage and granularity, has been the focus of the first part of the project.

Table 2-1 Literature sources identified in project outset

Impact	Type of data	Data sources
Air quality assessment	Solid fuel use in Scotland (quantity – e.g. tonnes, or kWh)	Scottish Household Survey, UK Impact Assessment (IA), Defra and BEIS surveys
Air quality assessment	Breakdown of usage of different types of solid fuels	Scottish Household Survey, UK IA
Air quality assessment	Emission factors for different types of solid fuels	European Monitoring and Evaluation Programme (EMEP), National Atmospheric Emissions Inventory (NAEI)
Air quality assessment	Behavioural assumptions on change in fuel use in policy scenarios	UK IA, data from Scottish gov if available
Health impact assessment	Demographic data including information on income and deprivation	2011 Census data
Health impact assessment	Damage costs	Ricardo Health Impact Assessment (HIA) tool
GHG impacts	GHG emission factors for different types of solid fuels	EMEP
GHG impacts	GHG values for UK/Scotland	BEIS guidance
Cost analysis	Cost of different types of solid fuels	UK IA, data from Scottish gov if available
Cost analysis	Implementation costs	UK IA, data from Scottish gov if available
Impacts on business	Information on Scottish fuel supply firms (Number and size of businesses, types of fuels sold, supply chains)	Online research, stakeholder interviews

2.2 Reviewed data sets

2.2.1 Census data

A census has been conducted in Scotland in 2011[3] and 2022, gathering information about households, including the central heating system used. The data for the 2022 Census were not available for use in this study due to being not yet available. The 2011 Census contained information on the numbers of households using various central heating types (e.g., solid fuels) by Council area or smaller Output Area (Table QS415SC). The Census had high spatial resolution of solid fuel use by OA. Limitations were that: only central heating is covered, as data on secondary heating fuels would be relevant to this study; there was a single solid fuels category, as detail around the split of solid fuels between wood and coal would be useful; and household data may have changed since 2011.

2.2.2 Scottish Household Survey

The Scottish Household Survey (SHS)[4] is carried out annually and provides information about the composition, and characteristics of households in Scotland. Published data provided aggregated national information about travel, housing and demographics. The SHS contained recent data on household finances, e.g., income, but no information on heating or fuel use.

2.2.3 Scottish House Condition Survey

The Scottish House Condition Survey is the largest single housing research project in Scotland, and the only national survey to look at the physical condition of Scotland's homes as well as the experiences of householders.[5] The survey is published annually, and the most recent dataset is from 2019.

The Scottish House Condition Survey contained limited information on solid fuel use. Like the Census, the statistics presented only pertained to primary heating (not secondary), and there was no detail on proportions of different types of solid fuel (i.e., wood or coal types) being used for heating. In addition, the only spatial information was a split between urban and rural fuel use, so there is insufficient spatial resolution available for our analysis.

2.2.4 Home Analytics

The Home Analytics database provides information about households in Scotland, including the primary and secondary heat sources in homes, total heat demand of the property, and fuel poverty indicators. The heating sources are categorised by fuel type, including solid fuel. Under an agreement with the Scottish Government, an extract of properties in Scotland from the Home Analytics v3.8 dataset was provided by the Energy Savings Trust.

As there was no detail about the specific type of solid fuel (e.g., house coal, wood logs, etc.) being used in each home, it was not possible to derive emissions calculations from the Home Analytics dataset. However, the data set offered the best spatial information of

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[3] Scotland's Census
[4] Scottish Household Survey 2019: annual report
[5] Scottish House Condition Survey

all data sets reviewed, as it contained the locations of houses using solid fuel as primary or secondary fuel types. This information was used for scaling $PM_{2.5}$ emissions spatially across Scotland. This data source was preferred for spatial information, as it was more recent and detailed than the 2011 Census, which only included data on fuel type for primary heating.

2.2.5 National Atmospheric Emissions Inventory (NAEI)

The NAEI publishes emission information for sectors in the UK including residential emissions[6]. Mapped emissions for each sector were also available online to provide an estimate of spatial variation in emissions[7]. The NAEI published emission factors for domestic combustion (Table 1A4bi) by fuel type and year.[8] The NAEI have calculated relevant emission factors for the UK using EMEP/EEA emission factors (see below) with UK-specific data on domestic combustion technologies. NAEI emission factors for wood, coal and smokeless solid fuels were used in this study. Separate emission factors for wood based on moisture content are not available in the NAEI, so an emission factor for wet wood was derived from the literature. There were also no separate emission factors for solid fuels based on sulphur content, so it was not possible to calculate separate $PM_{2.5}$ emissions for high vs low manufactured solid fuels.

2.2.6 Defra Solid Fuel Burning and BEIS Residential Wood Survey

Defra and BEIS have conducted surveys on the use of wood in residential homes[9,10]. These surveys have provided information about the national and rural/urban disaggregation of fuel use (wood and coal/mineral fuels) from a national user survey.

The NAEI have reported that input activity data related to wood from the BEIS survey have been replaced with the updated 2020 Defra survey, as the methodology used in the 2016 BEIS survey led to the over-estimation of domestic fuel consumption. [11] This update was reflected in the DUKES calculations of calorific values related to domestic fuel consumption of wood.[12]

Thus, the 2020 Defra Solid Fuel Burning has been reviewed in greater detail. There were statistics available for Scotland, also split into urban and rural categories, of the amounts of wood and coal (kilotonnes) burned in one year (2019) as well as the number of households using each fuel type. It was also possible to calculate the percentage of wood burned wet and the percentage of house coal. As such, this dataset will be core in our analysis along with the Home Analytics database which provides spatial household data.

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[6] UK Informative Inventory Report 1990 to 2020
[7] National Atmospheric Emissions Inventory UK Spatial Emissions Inventory
[8] National Atmospheric Emissions Inventory emission factors detailed by source and fuel
[9] Research to understand burning in UK homes and gardens
[10] Summary results of Defra domestic wood use survey
[11] UK Informative Inventory Report 1990 to 2020 section 3/4/7/2/1
[12] Digest of UK Energy Statistics calorific values and density of fuels

2.2.7 EMEP/EEA Air Pollutant Emission Inventory Guidebook

The EMEP emission guidebook provides technical guidance to prepare national emission inventories, including emission rates for different domestic burning sources.[13] For more accurate emission factors, data related to domestic combustion technology types (e.g., stoves) were required. As the NAEI have already calculated appropriate emission factors based on UK technology, it was determined the NAEI emission factors were more suitable for this study.

2.2.8 DUKES calorific values

The Digest of UK Energy Statistics (DUKES)[12] calorific values and density of fuels are produced annually. These calorific values were required for determining the amount of energy produced by burning quantities of wood or coal. The calorific values were available by domestic fuel type and year. Emission factor units for $PM_{2.5}$ are in the amount of $PM_{2.5}$ per amount of net energy.

2.2.9 2019 Defra Impact Assessment for the proposed regulation of the sales, distribution and marketing of Wet wood (>20% moisture) sold in units up to 2m^3; Bituminous house coal; and Banning manufactured solid fuels with sulphur content over 2%

The Defra 2019 Impact Assessment[14] provides a summary of the potential intervention and options under the proposed Regulation in England. The report assesses the costs and benefits of two options – a voluntary approach supported by a communications campaign and an enforced ban on the solid fuels – against the baseline do nothing scenario. Several useful data are acquired from this study, such as information on behavioural responses, information on costs of specific sub-fuel types and implementation costs.

2.2.10 Other Guidance and Relevant Documents

We will refer to other relevant guidance throughout the report, including:

- Defra Air quality appraisal: impact pathways approach guidance for methods to calculate damage costs and policy impacts on health, economy and the environment[15]
- Green Book supplementary guidance for rules to evaluate greenhouse gas emissions[16]
- The Air Quality (Domestic Solid Fuels Standards) (England) Regulations 2020[17].

2.3 Summary of Data sources used in the analysis

Having conducted our initial literature review, Table 2-2 outlines the sources to be used in our analysis.

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[13] European Environment Agency air pollutant emission inventory guidebook 2019
[14] Defra Impact Assessment
[15] Defra air quality appraisal impact pathways approach
[16] UK Government Green Book supplementary guidance
[17] The Air Quality Domestic Solid Fuels Standards England Regulations 2020

Table 2-2 Key data sources determined from preliminary research

Impact	Data need	Potential sources
Air quality assessment	Total solid fuel use in Scotland	Defra Solid fuel burning survey
	Spatial distribution of households	Home Analytics database
	Breakdown of usage of different types of solid fuels	Defra Solid fuel burning survey
	Emission factors for different types of solid fuels	NAEI
	Behavioural assumptions on change in fuel use in policy scenarios	Defra 2019 impact assessment
Health impact assessment	Demographic data including information on income and deprivation	2011 Census, Home Analytics database (Scottish Index of Multiple Deprivation)
	Quantification and monetisation of health impacts	Defra – air quality appraisal guidance[18]
GHG impacts	GHG emission factors for different types of solid fuels	EMEP
	Carbon prices for UK/Scotland	BEIS guidance
Cost analysis	Energy prices of different types of solid fuels	Defra 2019 impact assessment
	Implementation costs	Defra 2019 impact assessment
Impacts on business	Information on Scottish fuel supply firms (Number and size of businesses, types of fuels sold, supply chains)	Online research, stakeholder interviews

[18] Defra air quality appraisal impact pathways approach

3. Business and Regulatory Impact Assessment

This section presents the substantiative evidence to support the Business and Regulatory Impact Assessment (BRIA) of the different policy options considering the sectors and groups affected by each option.

First we present two steps in the BRIA process which define the scope of the analysis and develop important inputs to the subsequent economic analysis, namely:

- Screening of impacts and affected groups
- Air quality modelling to support distributional impact analysis

The section then presents the outputs of the economic analysis, separated into sub-sections concerning different impacts and components of the BRIA:

- Assessment of costs and benefits

3.1 Summary of findings

A high level summary of findings of the BRIA is shown in Table 3-1.

Table 3-1 High level summary of BRIA findings

Impact	Policy Option 2 (Information campaign)	Policy Option 3 (Coal ban and sulphur limit)	Policy Option 2 (With fuel price sensitivity)	Policy Option 3 (With fuel price sensitivity)
Air quality	**-3,223 kg $PM_{2.5}$** There was a higher reduction in urban areas than rural, as there is higher use of wet wood in urban areas. The maximum reduction of 0.0013 µg m-3 for Option 2 was in Aberdeen; this reduction is 0.02% of total $PM_{2.5}$ concentrations and 0.3% of modelled domestic	**-75,456 kg $PM_{2.5}$** The highest reductions were in rural areas, where there is a higher prevalence of house coal use. The maximum reduction of 0.020 µg m-3 for Option 3 was in Fort William; this reduction is 0.5% of total $PM_{2.5}$ concentrations and 15% of modelled	**-3,223 kg $PM_{2.5}$** There was a higher reduction in urban areas than rural, as there is higher use of wet wood in urban areas. The maximum reduction of 0.0013 µg m-3 for Option 2 was in Aberdeen; this reduction is 0.02% of total $PM_{2.5}$ concentrations	**-75,456 kg $PM_{2.5}$** The highest reductions were in rural areas, where there is a higher prevalence of house coal use. The maximum reduction of 0.020 µg m-3 for Option 3 was in Fort William; this reduction is 0.5% of total $PM_{2.5}$ concentrations

Impact	Policy Option 2 (Information campaign)	Policy Option 3 (Coal ban and sulphur limit)	Policy Option 2 (With fuel price sensitivity)	Policy Option 3 (With fuel price sensitivity)
	combustion concentrations in this location	domestic combustion in this location	and 0.3% of modelled domestic combustion concentrations in this location	and 15% of modelled domestic combustion in this location

Impact	Policy Option 2 (Information campaign)	Policy Option 3 (Coal ban and sulphur limit)	Policy Option 2 (With fuel price sensitivity)	Policy Option 3 (With fuel price sensitivity)
Health impacts	-£380,000 Health impacts include reduction in incidence of a range of pathways including chronic mortality, hospital admissions, and various morbidities. Benefits are lower in policy option 2 due to smaller improvements in $PM_{2.5}$	-£1,830,000 Health impacts include reduction in incidence of a range of pathways including chronic mortality, hospital admissions, and various morbidities. Benefits are higher in policy option 3 due to larger improvements in $PM_{2.5}$	-£380,000 Health impacts include reduction in incidence of a range of pathways including chronic mortality, hospital admissions, and various morbidities. Benefits are lower in policy option 2 due to smaller improvements in $PM_{2.5}$	-£1,830,000 Health impacts include reduction in incidence of a range of pathways including chronic mortality, hospital admissions, and various morbidities. Benefits are higher in policy option 3 due to larger improvements in $PM_{2.5}$

Impact	Policy Option 2 (Information campaign)	Policy Option 3 (Coal ban and sulphur limit)	Policy Option 2 (With fuel price sensitivity)	Policy Option 3 (With fuel price sensitivity)
Greenhouse gas emissions	-£13,000 Impacts in greenhouse gas emissions driven largely by improvements in fuel efficiency of alternative fuels (Dry wood and manufactured fuels) Benefits are lower in policy option 2 due to relatively low fuel switching from the information campaign.	-£1,270,000 Impacts in greenhouse gas emissions driven largely by improvements in fuel efficiency of alternative fuels (Manufactured fuels) Benefits are higher in policy option 2 due to the large switch from coal to manufactured solid fuels.	-£13,000 Impacts in greenhouse gas emissions driven largely by improvements in fuel efficiency of alternative fuels (Dry wood and manufactured fuels) Benefits are lower in policy option 2 due to relatively low fuel switching from the information campaign.	-£1,270,000 Impacts in greenhouse gas emissions driven largely by improvements in fuel efficiency of alternative fuels (Manufactured fuels) Benefits are higher in policy option 2 due to the large switch from coal to manufactured solid fuels.

Impact	Policy Option 2 (Information campaign)	Policy Option 3 (Coal ban and sulphur limit)	Policy Option 2 (With fuel price sensitivity)	Policy Option 3 (With fuel price sensitivity)
Fuel costs	**£263,000** Increase in fuel costs driven by higher price of alternative fuels (When using fuel cost data based on the 2019 Defra impact assessment),	**£8,020,000** Increase in fuel costs driven by higher price of manufactured solid fuels compared with coal (When using fuel cost data based on the 2019 Defra	**£142,000** Increase in fuel costs driven by higher price dry wood compared with wet wood.	**-£4,120,000** Reduction in fuel costs driven by improved fuel efficiency of manufactured fuels compared with coal (When using fuel cost data

Impact	Policy Option 2 (Information campaign)	Policy Option 3 (Coal ban and sulphur limit)	Policy Option 2 (With fuel price sensitivity)	Policy Option 3 (With fuel price sensitivity)
	outweighing benefits in fuel efficiency.	impact assessment), outweighing benefits in fuel efficiency.		based on stakeholder interviews).

Impact	Policy Option 2 (Information campaign)	Policy Option 3 (Coal ban and sulphur limit)	Policy Option 2 (With fuel price sensitivity)	Policy Option 3 (With fuel price sensitivity)
Implementation costs	£64,800 Implementation costs for the information campaign based on data from the 2019 Defra impact assessment.	£96,400 Implementation costs for local authorities for the coal ban based on data from the 2019 Defra impact assessment.	£64,800 Implementation costs for the information campaign based on data from the 2019 Defra impact assessment.	£96,400 Implementation costs for local authorities for the coal ban based on data from the 2019 Defra impact assessment.

Impact	Policy Option 2 (Information campaign)	Policy Option 3 (Coal ban and sulphur limit)	Policy Option 2 (With fuel price sensitivity)	Policy Option 3 (With fuel price sensitivity)
Impacts on businesses	impacts on businesses are expected to be small. Suppliers already sell alternative fuels and there is no difference in profit margins between banned and alternative fuels.			

Impact	Policy Option 2 (Information campaign)	Policy Option 3 (Coal ban and sulphur limit)	Policy Option 2 (With fuel price sensitivity)	Policy Option 3 (With fuel price sensitivity)
Summary	**-£65,200**	**£5,016,400**	**-£186,200**	**-£7,123,600**

3.2 Screening of impacts and affected groups

Analysis was completed to characterise who currently uses solid fuels, in particular those to be regulated, in Scotland to assess which groups are likely to be affected the most.

3.2.1 Screening of impacts

The following impacts were screened in for the assessment based on the Scottish BRIA guidance:

- **Valuation of health impacts from reduced exposure to air pollution** the primary focus of the legislation, to reduce emissions of particulates and associated negative impacts on human health from burning of solid fuels domestically
- **Fuel cost impacts** driven by the swap from the more polluting fuels to alternative fuels either voluntarily due to the information campaign or due to the ban and sulphur limit. Different fuels have different prices per tonne but also different energy efficiencies which drives changes in costs.
- **Greenhouse gas impacts** driven largely by the difference in energy efficiency between fuels.
- **Implementation costs** of the policy for public authorities.
- **Distributional impacts considering impacts on different sectors and groups**, such as rural or urban populations, or households within different deciles of deprivation.
- **Impacts on Scottish firms** resulting from the shift in fuels, such as change in costs and change in profitability.
- **Impacts on competitiveness** resulting from the policy options leading to unfair advantages or disadvantages for certain businesses.
- **Impacts on consumers** driven by changes in fuel prices or availability.
- **Impacts on International trade** from changes to international supply chains driven by the policy options.

Note: Digital impacts have been screened out as not being relevant for these policy options.

3.2.2 Rural/urban

The Home Analytics dataset included the Scottish Government's eight-fold urban/rural classifications[19] for each property.

[19] Scottish Government Urban Rural Classification 2020

Table 3-2 and Figure 3-1 contains the breakdown of households using solid fuels as the main and secondary fuel sources within each of the eight urban/rural classes. 79% of households using solid fuel as the main fuel type are in rural classes (between six – eight). For all classes, considerably more households use solid fuels as a secondary fuel than as the main fuel, including in urban areas.

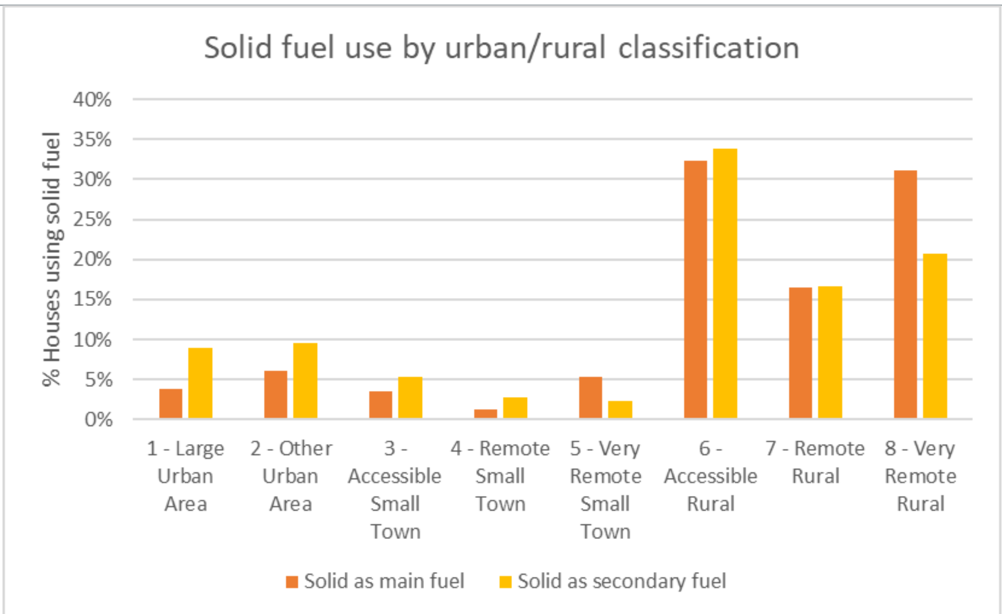
As only 21.1 thousand households use solid fuels as a main fuel type out of 2.8 million households (0.8%) included in the Home Analytics dataset, a small proportion of households would be highly affected by the proposed changes. 78% of the households with solid fuels as a main fuel type either use solid fuels as a secondary fuel type (7,020 households) or have no secondary heating system (9,526 households); these households would be most impacted by proposed changes.

Overall, households in rural areas are expected to be more affected by changes in regulations than those living in urban areas, as there is a higher use of solid fuels, particularly as the main fuel. For most households using solid fuels, impacts of the proposed changes would be limited, as most households use them as a secondary fuel. Additionally, a small number of households will be affected in a greater way due to using solid fuels as their primary fuel, while a far greater number will be affected in a smaller way due to using them as a secondary heat source.

Table 3-2 Number of houses using solid fuels by area classification from Home Analytics

Classification	Main fuel	% of main solid fuel houses	Secondary fuel	% of secondary solid fuel houses
1 - Large Urban Area	811	4%	13,783	9%
2 - Other Urban Area	1,279	6%	14,770	10%
3 - Accessible Small Town	736	3%	8,336	5%
4 - Remote Small Town	269	1%	4,300	3%
5 - Very Remote Small Town	1,134	5%	3,552	2%
6 - Accessible Rural	6,836	32%	52,488	34%
7 - Remote Rural	3,473	16%	25,960	17%
8 - Very Remote Rural	6,588	31%	32,217	21%
Total	21,126		155,406	

Figure 3-1 Solid fuel use in urban and rural areas



3.2.3 Location

Figure 3-2 and Figure 3-3 show the numbers of households using solid fuels (in the Home Analytics dataset) as the main and secondary fuel sources within each Lower Layer Super Output Area (LSOA).[20] LSOAs are spatial groupings of 2011 Census Output Areas that distribute population size consistently and enable population based analysis. LSOAs have smaller areas in urban locations than in rural since they represent consistent population sizes.

There are larger numbers of households using solid fuels in remote, rural areas, e.g., in the Highlands and Islands, for both main and secondary solid fuel use compared to urban areas. There are also more households using solid fuels as a secondary fuel type than as a primary fuel type in both rural and urban areas.

In urban areas, there is limited use of solid fuels as a primary fuel type; in many LSOAs in urban areas, solid fuels are only used as a secondary fuel type. Figure 3-4 shows the number of houses using primary and secondary fuels in LSOAs in the central belt, which includes Glasgow and Edinburgh, and Figure 3-5 shows urban areas on the east coast, including Aberdeen and Dundee. Urban areas such as Glasgow, Edinburgh and Dundee are in Smoke Control Areas, but Aberdeen is not.[21] There are LSOAs in Aberdeen with higher counts of households using solid fuels as a secondary fuel type than in Glasgow, Edinburgh and Dundee.

[20] Scottish data zone boundaries 2011

[21] Smoke Control Areas in Scotland

Figure 3-2 Number of houses with solid fuel as main fuel type by LSOA (from Home Analytics)

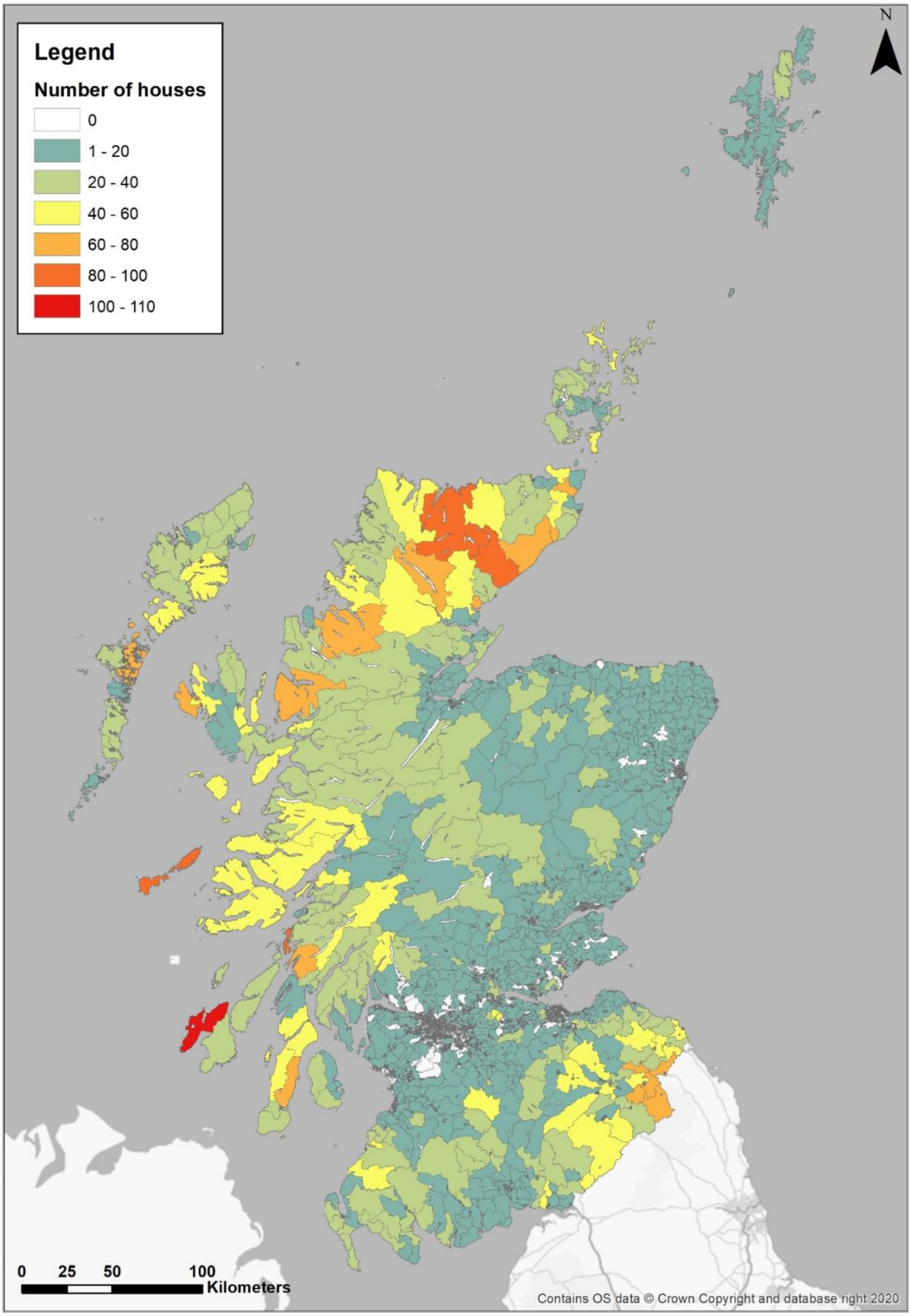


Figure 3-3 Number of houses with solid fuel as secondary fuel type by LSOA (from Home Analytics)

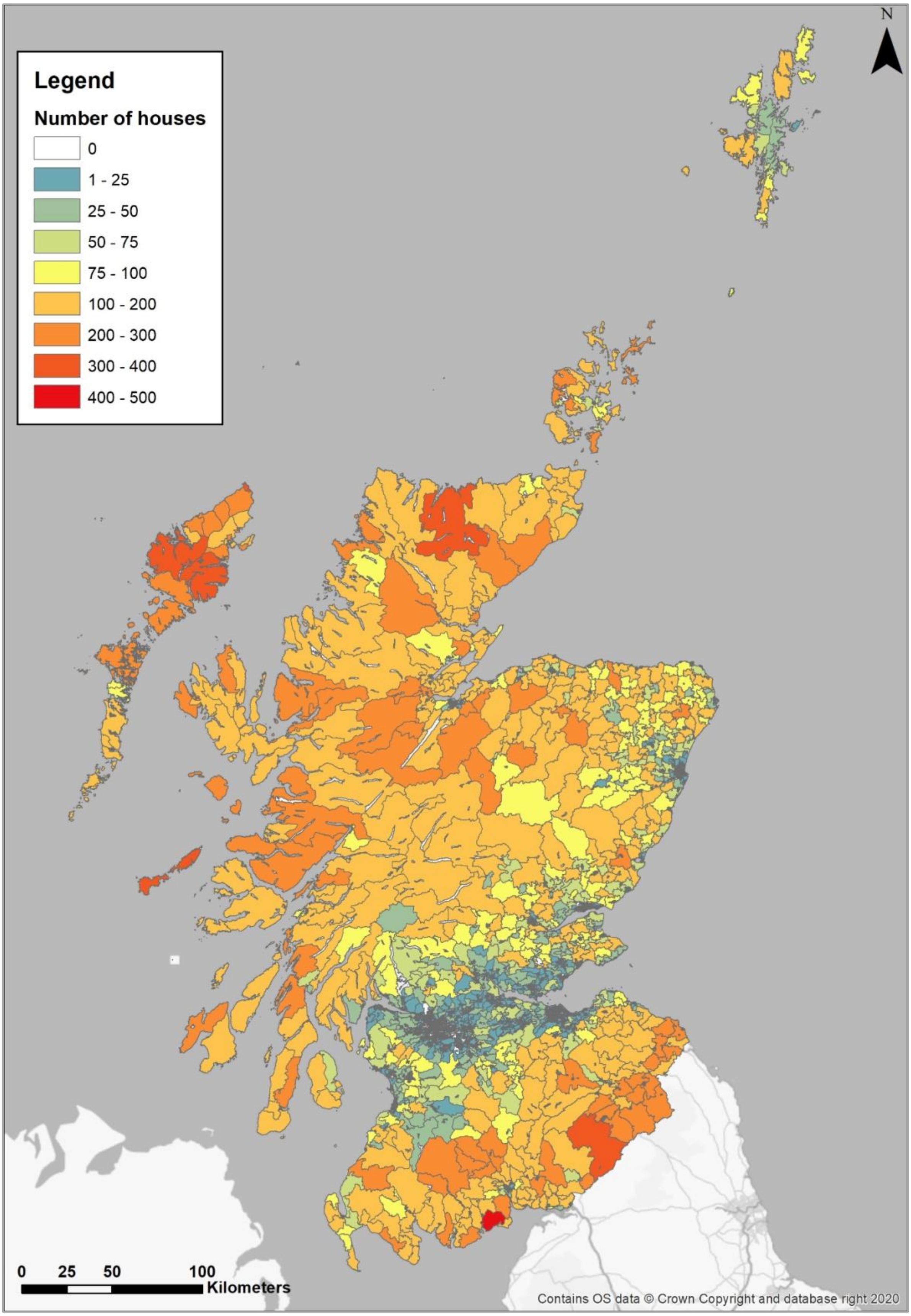
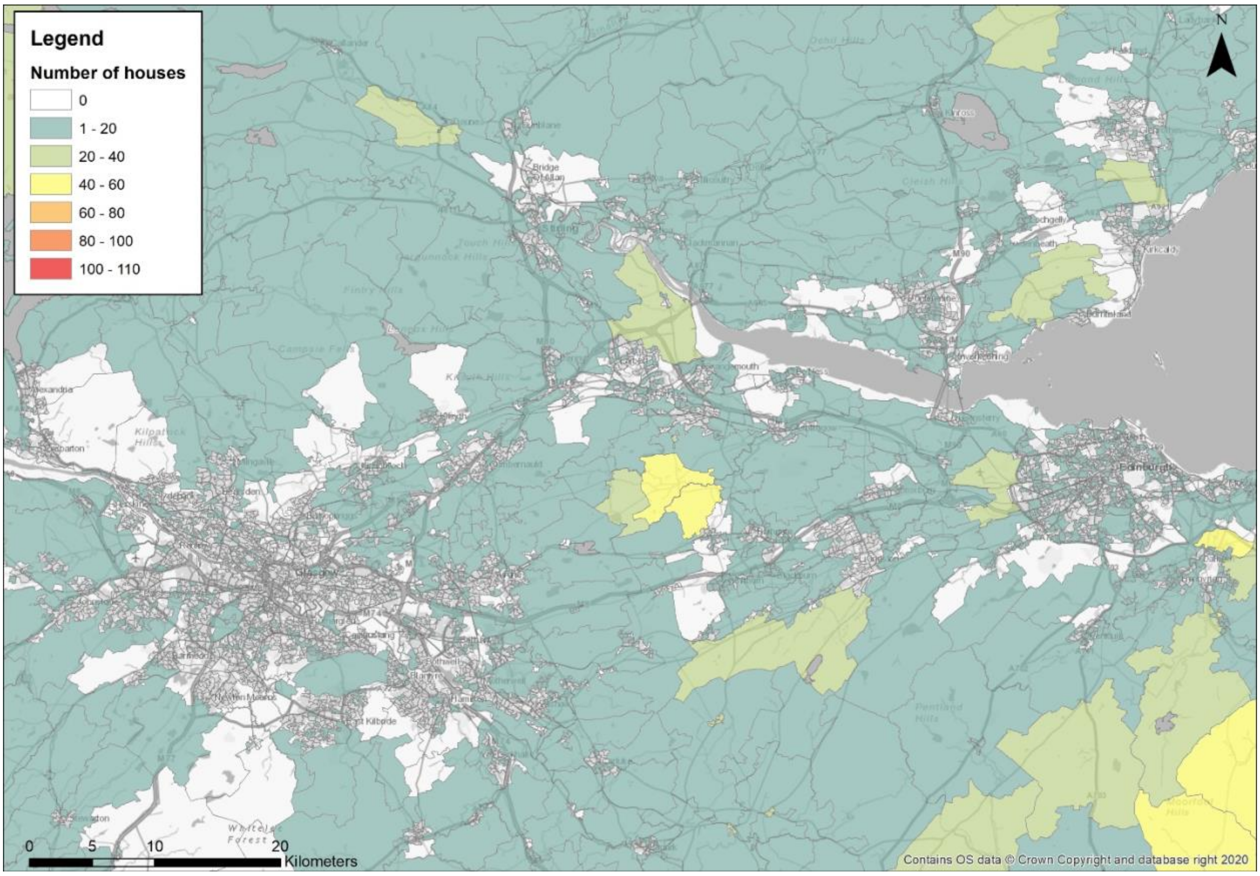


Figure 3-4 Number of houses with solid fuel as main fuel type (top) and secondary fuel type (bottom) by LSOA in the central belt, including Glasgow and Edinburgh (from Home Analytics)



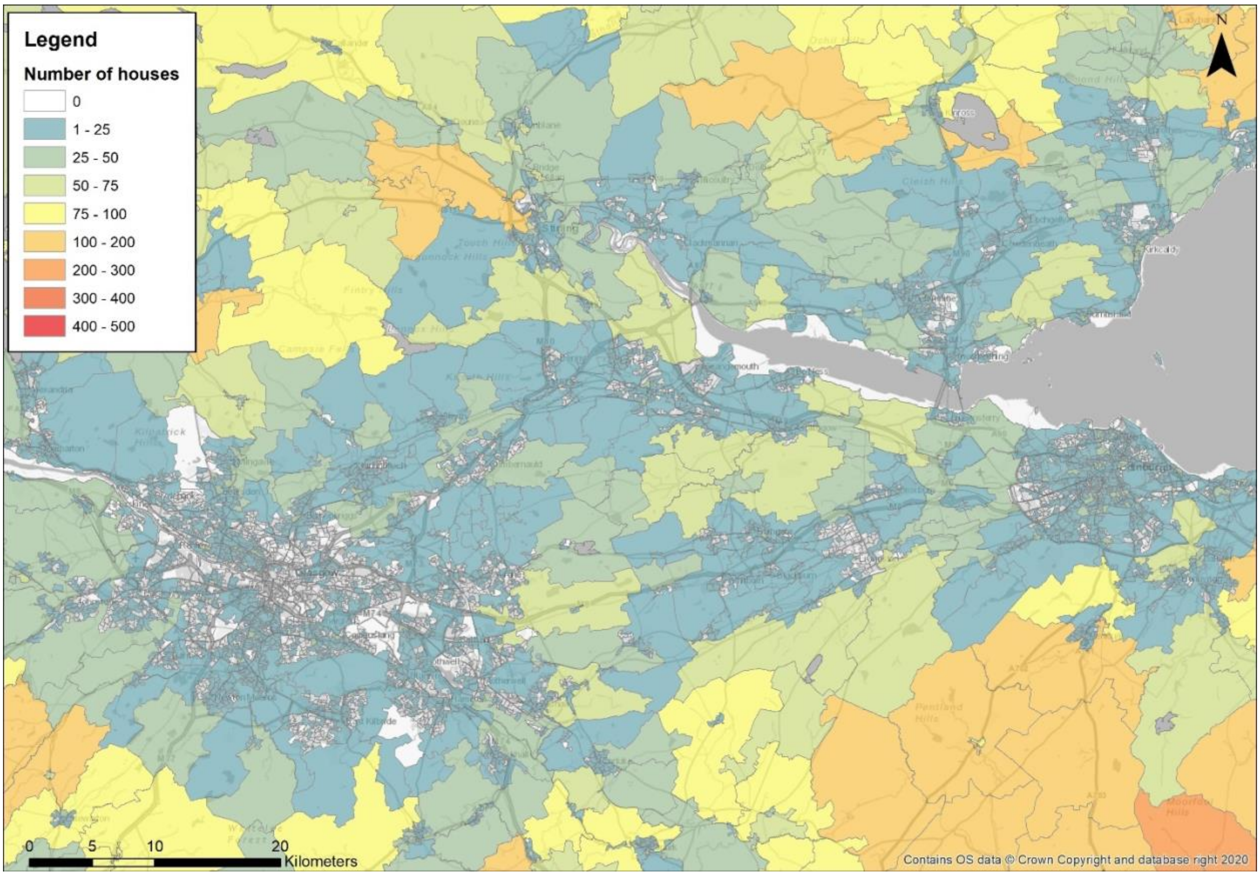
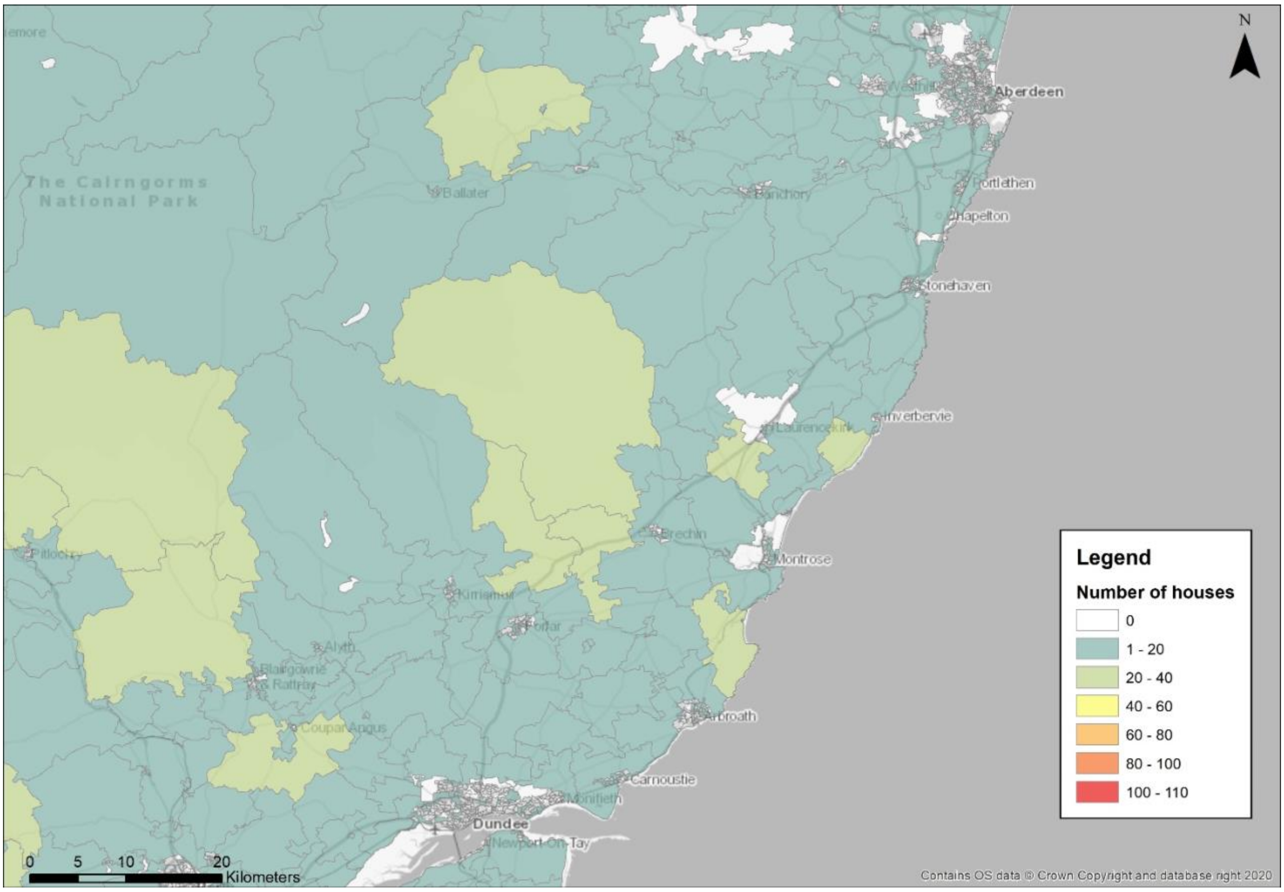
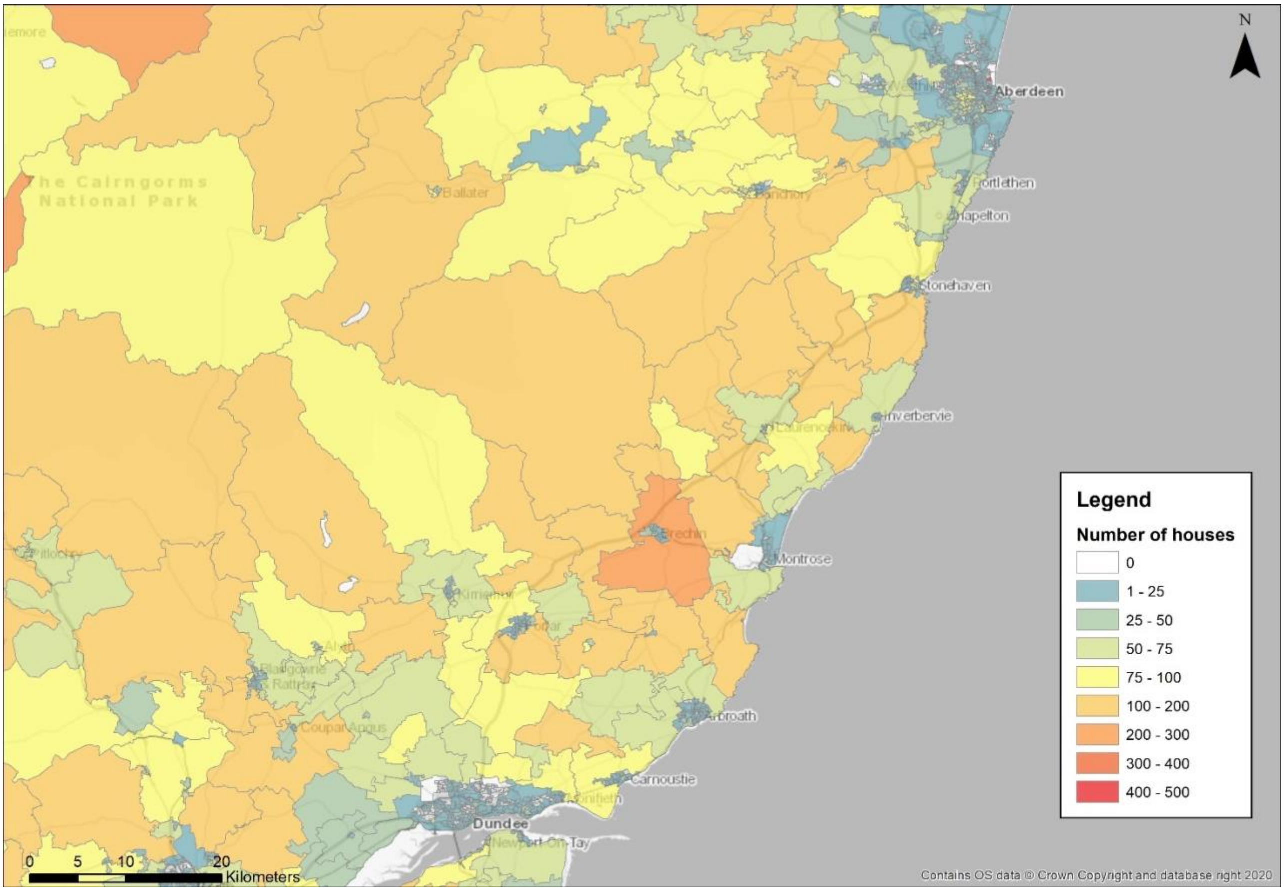


Figure 3-5 Number of houses with solid fuel as main fuel type (top) and secondary fuel type (bottom) by LSOA on the east coast, including Aberdeen and Dundee (from Home Analytics)





3.2.4 Demographic analysis

The Home Analytics dataset also includes the overall Scottish Index of Multiple Deprivation (SIMD) decile[22] of each property. Figure 3-6 and Table 3-3 contain the breakdown of households using solid fuels as main and secondary fuels by SIMD decile, where one is the most deprived and ten is the least deprived. The distribution of SIMD rank by overall population size is that 10% of the total population of Scotland falls within each of the decile groups. Thus, the distribution of solid fuel use across decile groups does not reflect the overall population distribution.

Most solid fuel users are in mid-range deciles between four and eight, with greater proportions of the population of solid fuel users in these deciles than in the population as a whole (Where population is spread evenly i.e. 10% per decile). Secondary solid fuel use is more prevalent in mid to least deprived deciles between four and ten, than in the most deprived groups.

Overall, changes in solid fuel regulations are expected to affect the mid to least deprived groups and have a limited effect on the most deprived groups.

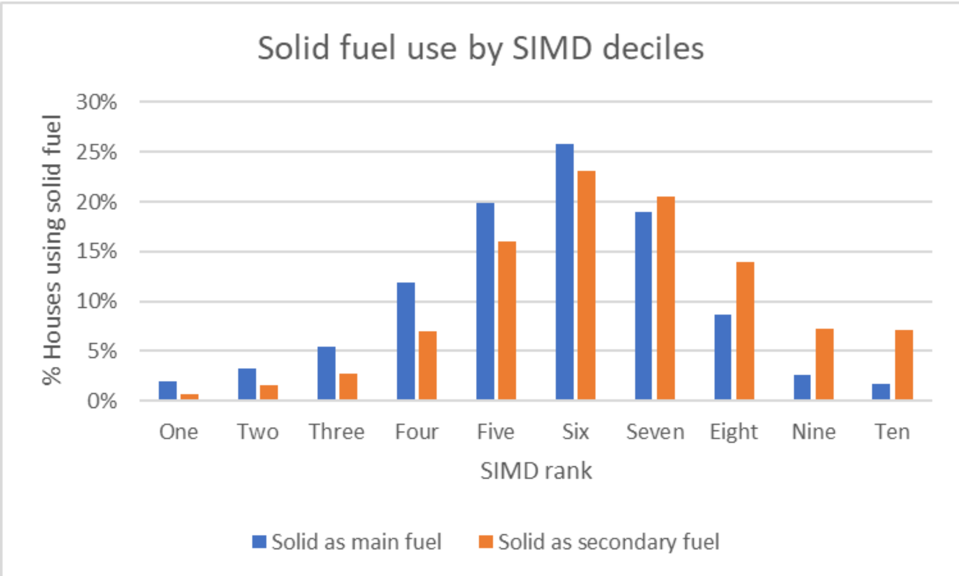
[22] Scottish Index of Multiple Deprivation 2020

Table 3-3 Number of houses using solid fuels by SIMD decile from Home Analytics

SIMD Decile*	Main fuel	% of main solid fuel houses	Secondary fuel	% of secondary solid fuel houses
One	410	2%	1,026	1%
Two	674	3%	2,342	2%
Three	1,159	5%	4,302	3%
Four	2,498	12%	10,934	7%
Five	4,192	20%	24,906	16%
Six	5,450	26%	35,971	23%
Seven	4,006	19%	31,965	21%
Eight	1,834	9%	21,724	14%
Nine	547	3%	11,252	7%
Ten	356	2%	10,984	7%
Total	21,126		155,406	

Note: * one is the most deprived and ten is the least deprived

Figure 3-6 Solid fuel use by SIMD deciles from Home Analytics



Other demographic information (e.g., age, sex) was not available in the Home Analytics dataset, nor were the 2022 Census results. However, the impact of the proposed regulations on air quality has been assessed in Section 3.5.2 for sensitive age groups (i.e., children under 16 and elderly over 65), in addition to SIMD-Income.

3.3 Air Quality Assessment

Any policies targeting emissions will have a knock-on impact on air quality. The impacts on air quality can be assessed using the impact pathway or damage costs depending on the availability of concentration or emissions estimates respectively. The damage costs are quicker to apply as they are less resource and data intensive than impact pathway assessments. However, damage costs are unable to reflect the full granularity of exposures, including assessment in specific spatial areas, and as a result the outcome from a damage cost assessment can be sensitive to the method and costs adopted.

Given the sector and options being assessed we anticipate that human exposure and health may be a significant factor to consider in the assessment of the scenarios. Specifically, as shown in the assessment of who is affected (Section 3.1), solid fuel use is greater in rural areas where less people live, hence exposure to the air pollution produced is lower. The rural areas of Scotland are also less densely populated, for example, therefore the selection and use of (for example) the 'national average' damage costs (or even the 'rural' damage cost) may lead to a less robust picture of exposure and impacts of the scenarios in Scotland.

For this study, we have followed the more robust impact pathway approach. By modelling air quality concentrations, rather than simply a change in emissions, a more robust understanding of the air quality impacts in Scotland can be produced, including spatial impacts of any changes as a result of the scenarios. This means the assessment of the costs and benefits of the scenarios can be assessed specifically for Scotland, taking into consideration local conditions.

3.3.1 Scenario modelling

The scenarios modelled were:

- **Option 1: Take no action (baseline)**- this is a 'do nothing' counterfactual against which the other options are assessed, and assumes no further change in policy that impacts on the consumption of the fuels in scope. This baseline scenario uses the emissions calculated directly from the input data.
- **Option 2: Voluntary Approach**- Involves an information campaign informing the public on the health impacts of solid fuel use in homes. This scenario assumes that 1% of house coal and 1% of wet wood (moisture content > 20%, applicable to wood logs) were changed to low-sulphur Manufactured Solid Fuel (MSF) and seasoned wood, respectively. This assumption matches Defra's Impact Assessment in England.
- **Option 3: Regulating the sale, distribution and marketing of fuels-** A ban of the sale of bituminous (or 'house') coal and high sulphur (>2% sulphur) smokeless fuels with 100% compliance. Wet wood is not included in the ban, so emissions from wood match Option 1 (baseline).

3.3.2 Emissions calculations

The results presented in Annex B of the Defra Solid Fuel Burning Survey[9] contained total quantities (kilotonnes) of wood and coal burned in Scotland in 2019; statistics included splits between urban and rural fuel use, the proportion of coal that was house coal, and the proportion of wood logs that was wet wood. Understanding the proportions of house coal and wet wood was required to derive more accurate Option 1 (baseline) emissions, and for modelling changes in fuel use (i.e., for coal and wood in Option 2 and for coal in Option 3). As the total quantities were projected from surveys conducted in the Defra Solid Fuel Burning Survey, any uncertainty in the calculations of total quantities has been carried into the modelling.

Table 3-4 includes the total amounts of coal and wood logs used as modelling input. Coal products included house coal, smokeless coal, and coal-like briquettes. Although data on other wood fuels such as wood pellets and chips were available in the survey, these fuel types would be unaffected in the scenario modelling, so the modelling input was restricted to wood logs to be able to compare the shift from wet to seasoned wood logs in the options modelling.

Table 3-4 Input domestic fuel amounts by urban or rural area[9]

Area	Fuel type	Total fuel 2019 (kt)	Quantity of wet wood or house coal (kt)	Percent wet wood or house coal
Urban	Wood	45.4	12.8	28%
Rural	Wood	52.4	10.9	21%
Urban	Coal	2.3	0.3	11%
Rural	Coal	19.1	11.5	60%

Total emissions by fuel type were calculated for urban and rural areas. The total quantities of solid fuel were converted to net energy using DUKES calorific values[12] - note that the calorific value for wet wood was provided in Annex A of the Defra Solid Fuel Burning Survey[9]. The moisture content of seasoned wood is assumed to be 20% to match DUKES/NAEI data, and the moisture content of wet wood is assumed to be 30% to match the Defra Solid Fuel Burning Survey.

Total $PM_{2.5}$ emissions were calculated from net energy using NAEI emission factors for each fuel type. For the wet wood emission factor, a ratio of average wet : seasoned wood emission factors was derived from a study by Price-Allison et al. (2021)[23]; this ratio of 2.93 was applied to the NAEI wood emission factor to calculate an emission factor for wet wood. The calorific values and emission factors used in this study are provided in Table 3-5.

Note that different emission factors for low or high sulphur manufactured solid fuel (MSF) are not available in the NAEI, so it has not been possible to calculate $PM_{2.5}$ emissions or model a change from high to low sulphur MSF. Hence our analysis of air pollution emissions and subsequent concentration changes captures only the impacts associated with the shifts away from coal and wet wood to low-sulphur (assumed) MSF and seasoned wood, respectively, and omits the impacts of the shift in consumption from high to low sulphur manufactured fuels. The largest effects on emissions are expected to be seen from the ban on house coal, as for example, 60% of coal burned in rural areas is house coal.

[23] Price-Allison, Andrew & Mason, Patrick & Jones, Jenny & Kumi Barimah, Eric & Jose, Gin & Brown, Aaron & Ross, Andrew & Williams, Alan. (2021). The Impact of Fuelwood Moisture Content on the Emission of Gaseous and Particulate Pollutants from a Wood Stove. Combustion Science and Technology. .

Table 3-5 Calorific values and emission factors

Fuel type	Calorific values (GJ/t net)	$PM_{2.5}$ emission factors (kt/TJ net)
House coal	25.14	0.00032
Manufactured Solid Fuel	28.11	0.000057
Seasoned wood	14.71	0.00047
Wet wood	12.57	0.00138

3.3.3 Spatial distribution of emissions

The total emissions by fuel type in urban and rural areas have been scaled spatially using the data from Home Analytics, which contains the location, urban/rural classification, and primary and secondary fuel types of each house. The Home Analytics data were filtered to include only the properties using the "Solid" fuel type as the main or secondary fuel. The "Solid" fuel type includes house coal, smokeless solid fuels, and wood logs. A separate "Biomass" fuel type was excluded from the analysis, as it includes other fuel types such as waste and biogas that are not included in the scope of the policy option being considered.

Home Analytics includes a property's 8-fold urban/rural classification[19]. This classification was simplified to a two-category urban/rural classification as emissions were calculated at the urban and rural level from the Defra Solid Fuel Burning Survey. The urban classes 1 and 2 with settlements of over 10,000 people comprised the urban category, and classes 3 to 8 with settlements of less than 10,000 people were considered rural. This categorisation matches the urban/rural classification used in the Defra Solid Fuel Burning Survey, which applies the ONS definition of urban/rural[24].

The number of households using solid fuels by urban/rural classification was used to distribute the total $PM_{2.5}$ emissions spatially across Scotland in a 1 km^2 emissions grid. The number of households using solid fuels as a primary fuel type was added to 10% of the houses using solid fuels as a secondary fuel type; this weighting reflects the estimate that a secondary fuel would provide 10% of the heat in a property[25]. Remote towns such as Fort William and Kirkwall have the highest weighted counts per 1 km^2 as many households use solid fuel as the main fuel (see Appendix 3 for maps of weighted house counts).

The sum of urban and rural properties within a square kilometre grid cell was used to calculate the proportion of each grid cell's contribution to the total numbers of households using solid fuels in urban and rural areas. This proportion was used to allocate the total $PM_{2.5}$ emissions for wood and coal in urban and rural areas across the emissions grid.

The same grid cell proportions were used to allocate the emissions of wood and coal sub-types (i.e., seasoned wood, wet wood, house coal, and MSF). Although there is uncertainty in this assumption, as for example there could be more houses burning house coal in certain rural areas than in others, this level of detail is not available in any of the data sources reviewed.

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[24] UK Government Rural Urban Classification

[25] UK Government Standard Assessment Procedure for Energy Rating of Dwellings Table 11 page 224

3.3.4 $PM_{2.5}$ concentration modelling - methodology

The calculation of $PM_{2.5}$ concentrations from domestic sources was calculated from this emission grids using a convolution kernel in Ricardo's RapidAir model[26]. Dispersion parameters specific to domestic heating, adapted from national PCM modelling[27] (see Table 3-6 for dispersion parameters and Figure 3-7 for the diurnal profile), were used to create a dispersion kernel to model the concentrations from domestic sources at a resolution of 1 km^2. Meteorological data for 2019 were processed from the Strathallan weather station, as this site is centrally located in Perthshire and considered suitable for modelling across Scotland. A wind rose showing the frequency of the wind speed and direction from which it originates is presented in Figure 3-8; in 2019, there were predominantly south-westerly winds.

Table 3-6 Dispersion kernel parameters adapted from PCM

Parameter	Value
Release height (m)	20
Surface roughness	0.5
Receptor height (m)	1.5

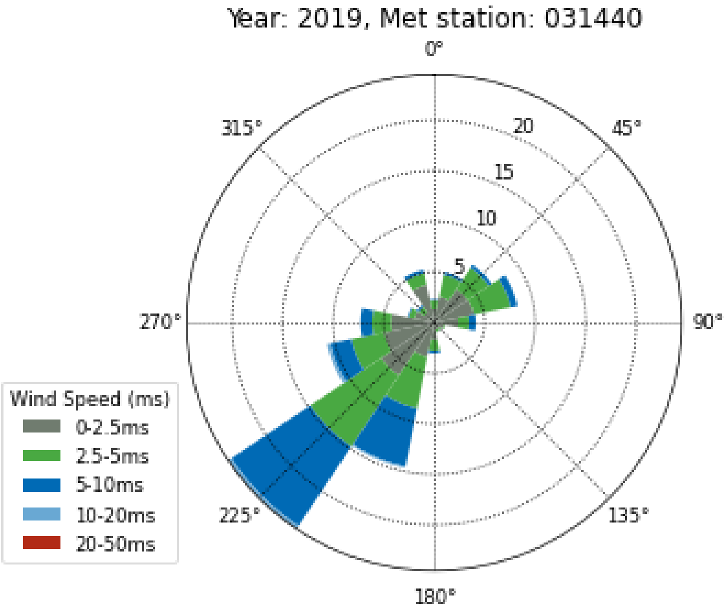
Figure 3-7 Diurnal profile for domestic combustion estimated from Coleman et al. (2001)[28]

[26] Masey, Nicola, Scott Hamilton, and Iain J. Beverland. "Development and evaluation of the RapidAir® dispersion model, including the use of geospatial surrogates to represent street canyon effects." *Environmental Modelling & Software* (2018).

[27] Technical Report on UK supplementary assessment under the Air Quality Directive, Air quality Framework Directive and Fourth Daughter Directive Appendix 4

[28] Assessment of benzo a pyrene atmospheric concentrations in the UK to support the establishment of a national PAH objective

Figure 3-8 Strathallan wind rose for 2019, showing winds predominantly from the south-west

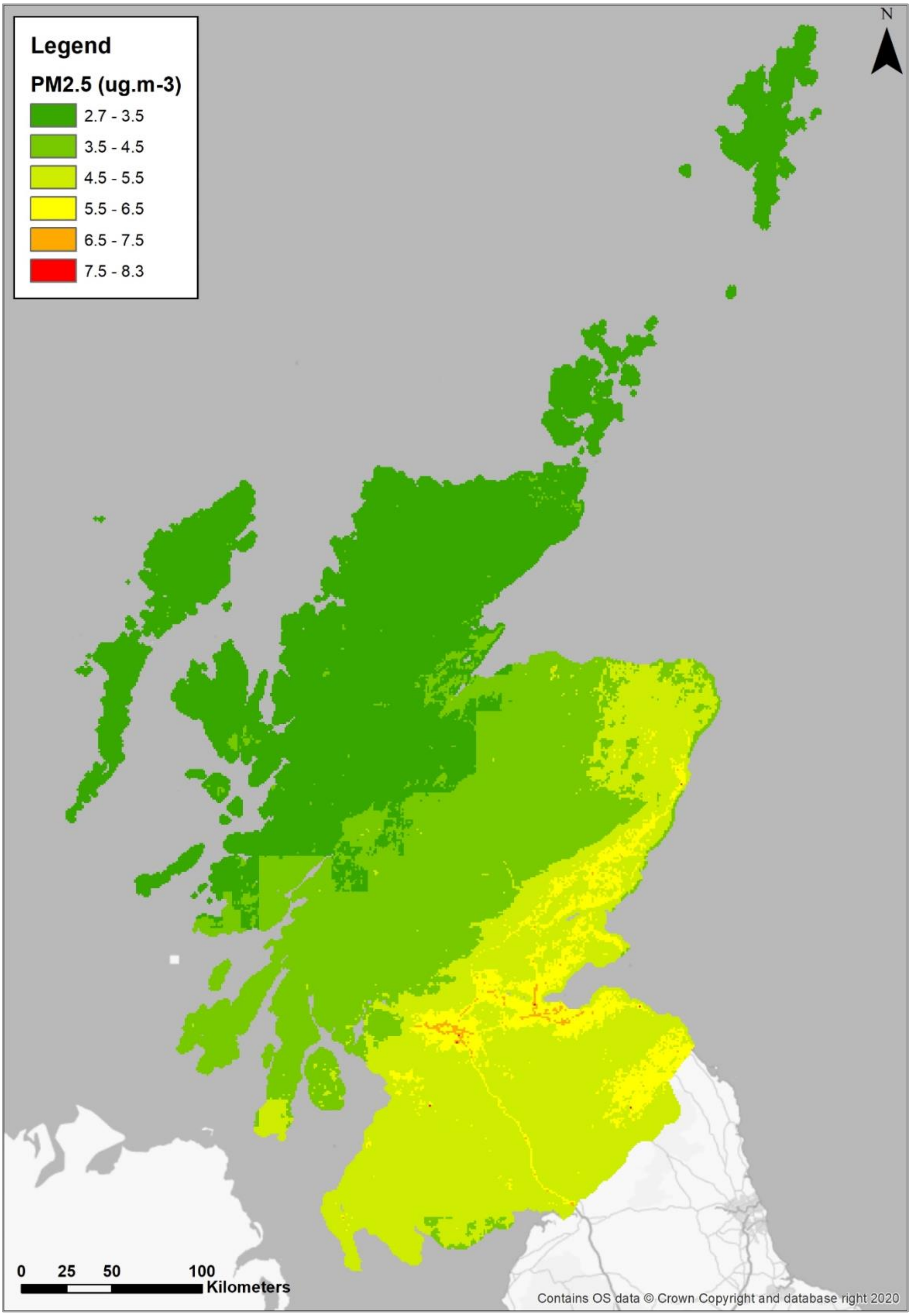


The total $PM_{2.5}$ concentrations were derived by adding the outputs from the dispersion modelling to the $PM_{2.5}$ background maps for Scotland in 2019 published by Defra[29]. Modelled baseline concentrations were subtracted from the domestic combustion sector of the background maps to ensure no double counting occurred. Figure 3-9 contains a map of adjusted background concentrations. This is a similar approach adopted during a previous project undertaken for Scottish Government to assess particulate concentrations from wood-burning biomass boilers.[30]

[29] Background mapping data for local authorities 2018

[30] Measurement and modelling of fine particulate emissions (PM_{10} and $PM_{2.5}$) from wood-burning biomass boilers

Figure 3-9 Adjusted $PM_{2.5}$ background concentrations (modelled domestic combustion removed) (µg m^{-3})



3.3.5 Options modelling methodology

Assumptions agreed with the Scottish Government for Option 2 and Option 3 regarding the change in fuel use were used to calculate $PM_{2.5}$ emissions:

- For Option 2 (a voluntary change): 1% of house coal (0.12 kt) and 1% of wet wood (0.24 kt) were changed to MSF and seasoned wood, respectively. The 1% change in quantities of fuel has been applied in the same way as in Defra's Impact Assessment in England.
- For Option 3 (the ban on house coal with 100% compliance), all coal was changed to MSF (0% house coal, or 11.7 kt). As wet wood is not included in the ban, emissions from wood matched the baseline.

The total quantities of solid fuel was retained as constant across the scenarios (i.e. between baseline and policy options). Although it is possible that there could be a small decrease in the quantities being burned in the scenarios because the less polluting fuel types have higher calorific values, this assumption could lead to $PM_{2.5}$ concentrations being underestimated. However, this improvement in efficiency has been examined in the below economic analysis.

Updated emissions for each options scenario were calculated using the assumptions described in Section 3.3.1.

The updated emissions for each options scenario were run through the 2019 RapidAir dispersion model, and modelled $PM_{2.5}$ concentrations were combined with the background concentrations.

3.3.6 Option 1 (Baseline) model results

Total Option 1 (baseline) emissions are presented in Table 3-7. Although there are more households using solid fuels in rural areas than in urban, households in urban areas mainly use wood rather than coal, and $PM_{2.5}$ emissions are higher for wood than for coal. There is also a higher proportion of wet wood being burned in urban areas than in rural areas (see Section 3.3.2).

Emissions from house coal are considerably higher than from MSF in rural areas. A ban on the sale of house coal would have a noticeable effect on emissions from house coal in rural areas.

Table 3-7 Total quantities of $PM_{2.5}$ emissions (g) by fuel type and area for the baseline

Location	Fuel	Type	Total $PM_{2.5}$ (g)	% of total emissions
Urban	Wood	Seasoned	225,185,625	21.8%
Urban	Wood	Wet	222,189,943	21.5%
Urban	Coal	House	2,029,425	0.2%
Urban	Coal	MSF	3,232,406	0.3%
Rural	Wood	Seasoned	286,563,187	27.8%
Rural	Wood	Wet	188,759,559	18.3%
Rural	Coal	House	92,190,650	8.9%
Rural	Coal	MSF	12,219,114	1.2%
Total			**1,032,369,909**	**100%**

Figure 3-10 shows the total $PM_{2.5}$ concentrations for Option 1 (baseline), and Figure 3-11 shows the modelled contribution from domestic combustion. Modelled domestic combustion contributes an average of 0.07% to total $PM_{2.5}$ concentrations, so it is difficult to interpret maps of total concentrations, which mainly reflect background concentrations. Exceedances of the Scottish 10 µg m^{-3} $PM_{2.5}$ annual mean objective were not predicted in any location.

The maximum modelled domestic solid-fuel combustion concentration of 0.43 µg m^{-3} was in Aberdeen, where the highest number of households using solid fuels in urban areas was located. The modelled domestic combustion concentration is 7% of total $PM_{2.5}$ concentrations in this location. Total rural emissions are distributed across a larger number of households and locations than urban emissions.

Figure 3-10 Total $PM_{2.5}$ concentrations (µg m^{-3}) for Option 1 (baseline)

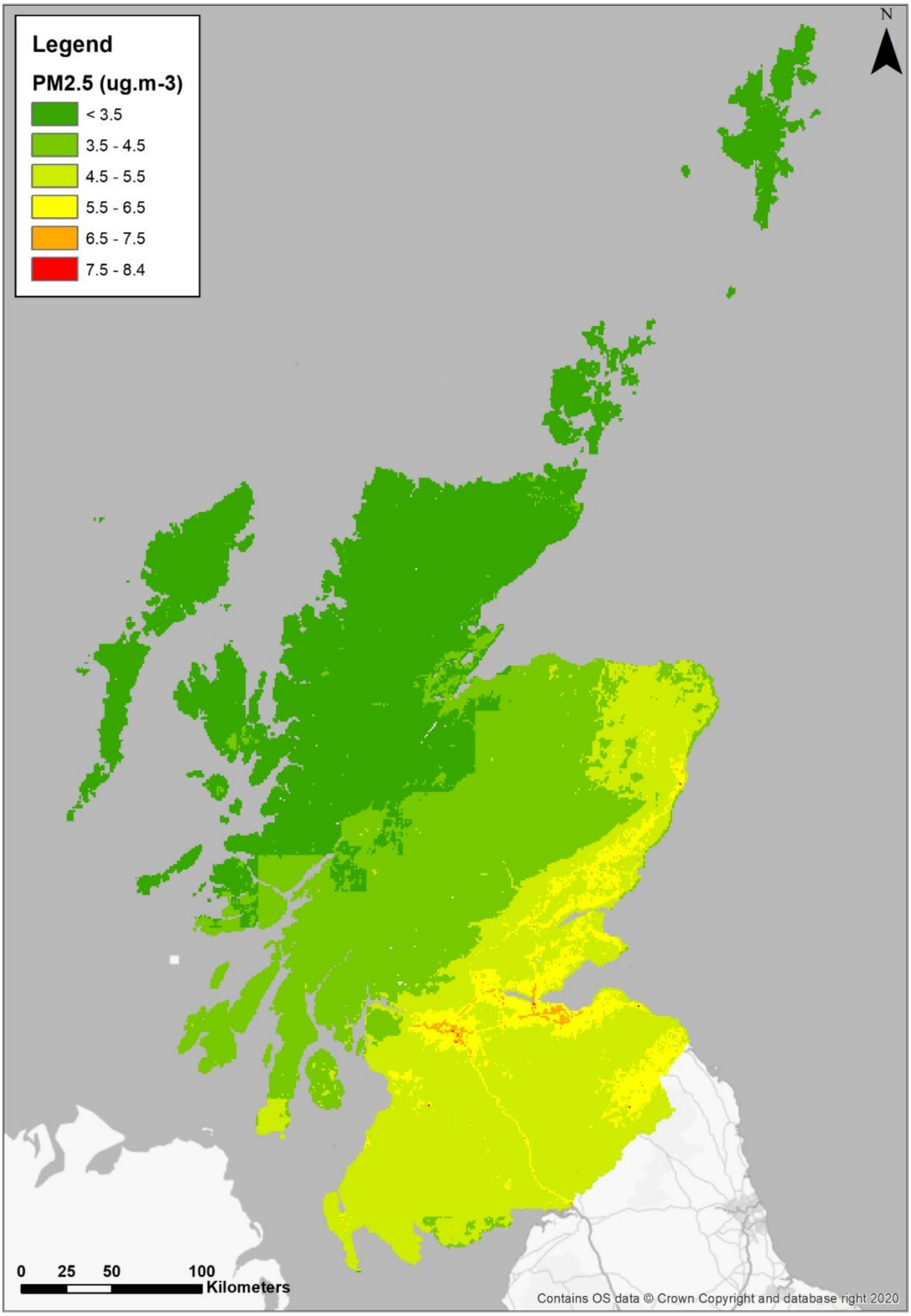
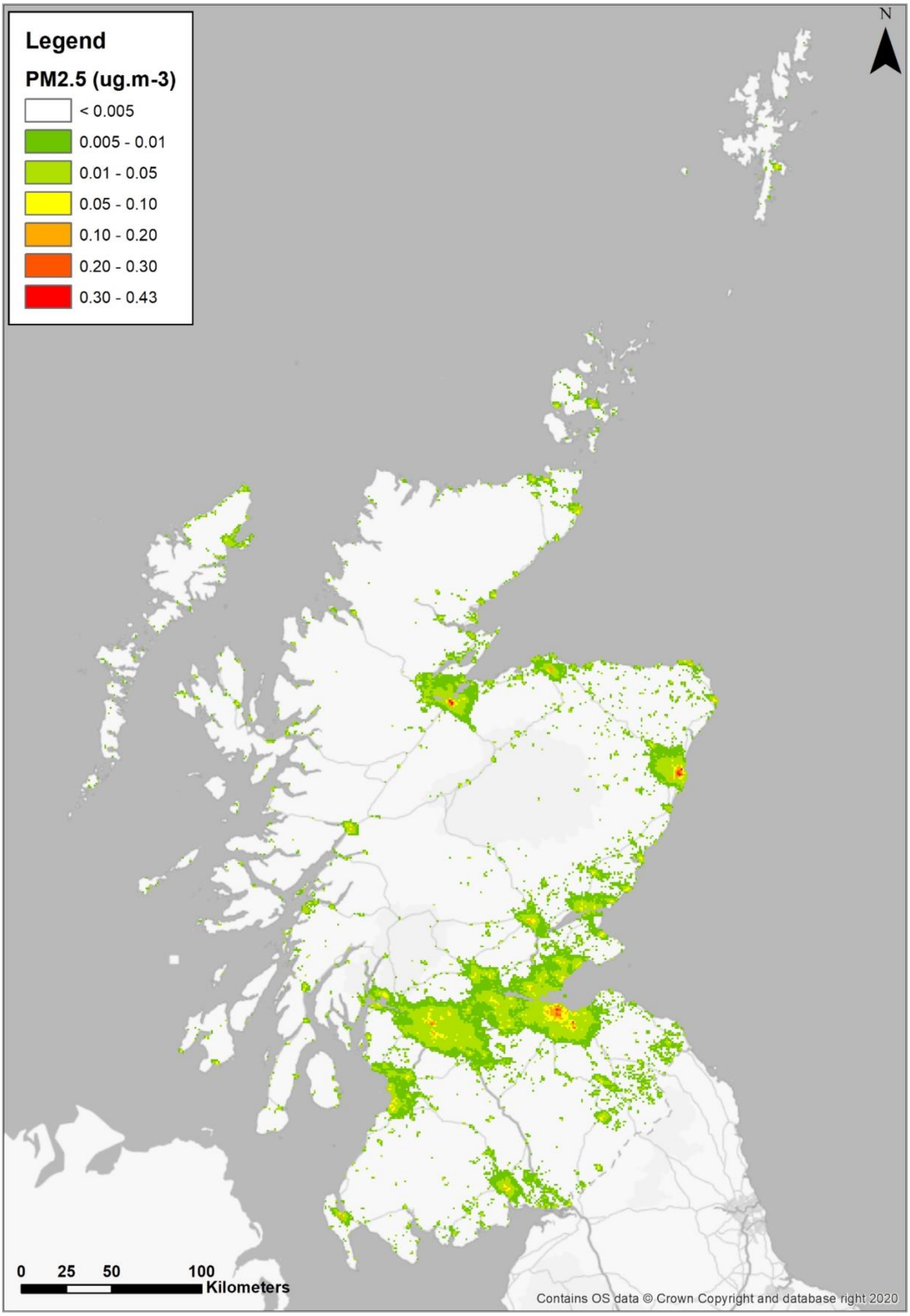


Figure 3-11 $PM_{2.5}$ concentrations (µg m^{-3}) of the modelled domestic combustion concentrations for Option 1 (baseline)



3.3.7 Option 2 and 3 model results

Table 3-8 contains the total $PM_{2.5}$ emissions by fuel type and location for Options 2 and 3 compared to Option 1 (the baseline). Each option reduces the total $PM_{2.5}$ emissions, with Option 3 having the largest impact because of the considerable reduction in coal emissions.

Table 3-8 Total quantities of $PM_{2.5}$ emissions (g) by fuel type and location for all options

Location	Type	Option 1 (baseline) $PM_{2.5}$ (g)	Option 2 $PM_{2.5}$ (g)	Option 2 change from Option 1 (g)	Option 3 $PM_{2.5}$ (g)	Option 3 change from Option 1 (g)
Urban	Seasoned wood	225,185,625	226,073,055	887,430	225,185,625	-
Urban	Wet wood	222,189,943	219,968,044	-2,221,899	222,189,943	-
Urban	House coal	2,029,425	2,009,131	-20,294	-	-2,029,425
Urban	MSF	3,232,406	3,236,447	4,042	3,636,575	404,169
Rural	Seasoned wood	286,563,187	287,317,096	753,909	286,563,187	-
Rural	Wet wood	188,759,559	186,871,963	-1,887,596	188,759,559	-
Rural	House coal	92,190,650	91,268,744	-921,907	-	-92,190,650
Rural	MSF	12,219,114	12,402,716	183,602	30,579,296	18,360,182
Scotland	Wood	922,698,314	920,230,158	-2,468,156	922,698,314	-
Scotland	Coal	109,671,595	108,917,038	-754,557	34,215,871	-75,455,724
Total		**1,032,369,909**	**1,029,147,196**	**-3,222,713**	**956,914,186**	**-75,455,724**

Figure 3-12 shows the difference in total $PM_{2.5}$ concentrations between Option 2 and Option 1 (baseline) as well as the difference between Option 3 and Option 1 (baseline).

For Option 2, the differences in concentrations are very small (< 0.0001 µg m^{-3}) in most locations. The largest differences are in urban areas, where there were the highest emissions of wet wood in the baseline distributed across smaller urban areas compared to rural. The maximum reduction of 0.0013 µg m^{-3} for Option 2 was in Aberdeen; this reduction is 0.02% of total $PM_{2.5}$ concentrations and 0.3% of modelled domestic combustion concentrations in this location.

There were larger reductions in total $PM_{2.5}$ concentrations across many parts of Scotland in Option 3 than in Option 2, although the difference in total concentrations between Option 1 (the baseline) and Option 3 are still fairly small. Option 3 has a larger effect in rural areas than in urban because there is limited use of house coal in urban areas. The maximum reduction of 0.020 µg m^{-3} for Option 3 was in Fort William; this reduction is 0.5% of total $PM_{2.5}$ concentrations and 15% of modelled domestic combustion in this location.

Figure 3-12 Reductions (positive) in $PM_{2.5}$ concentrations (µg m^{-3}) for Option 2

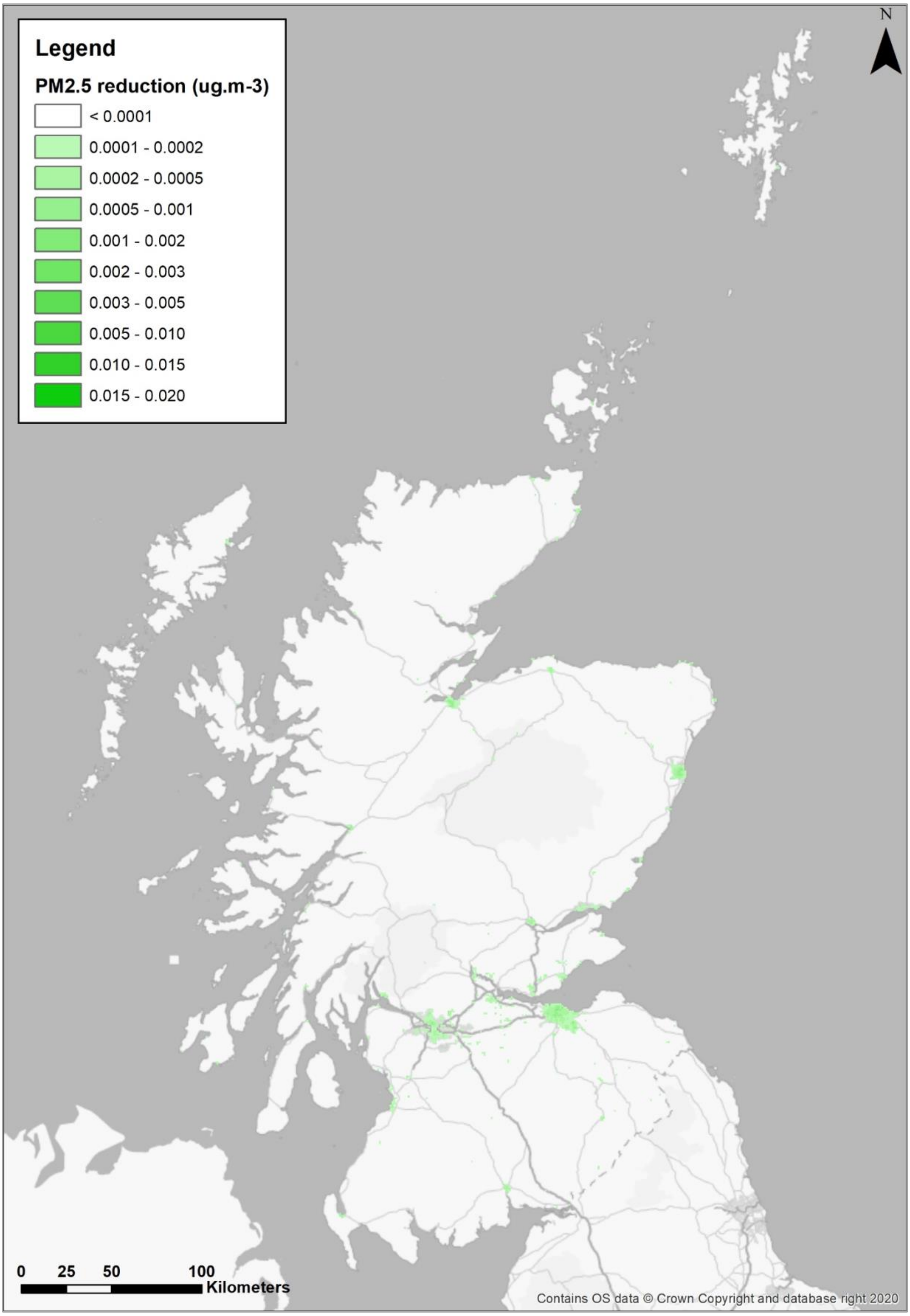
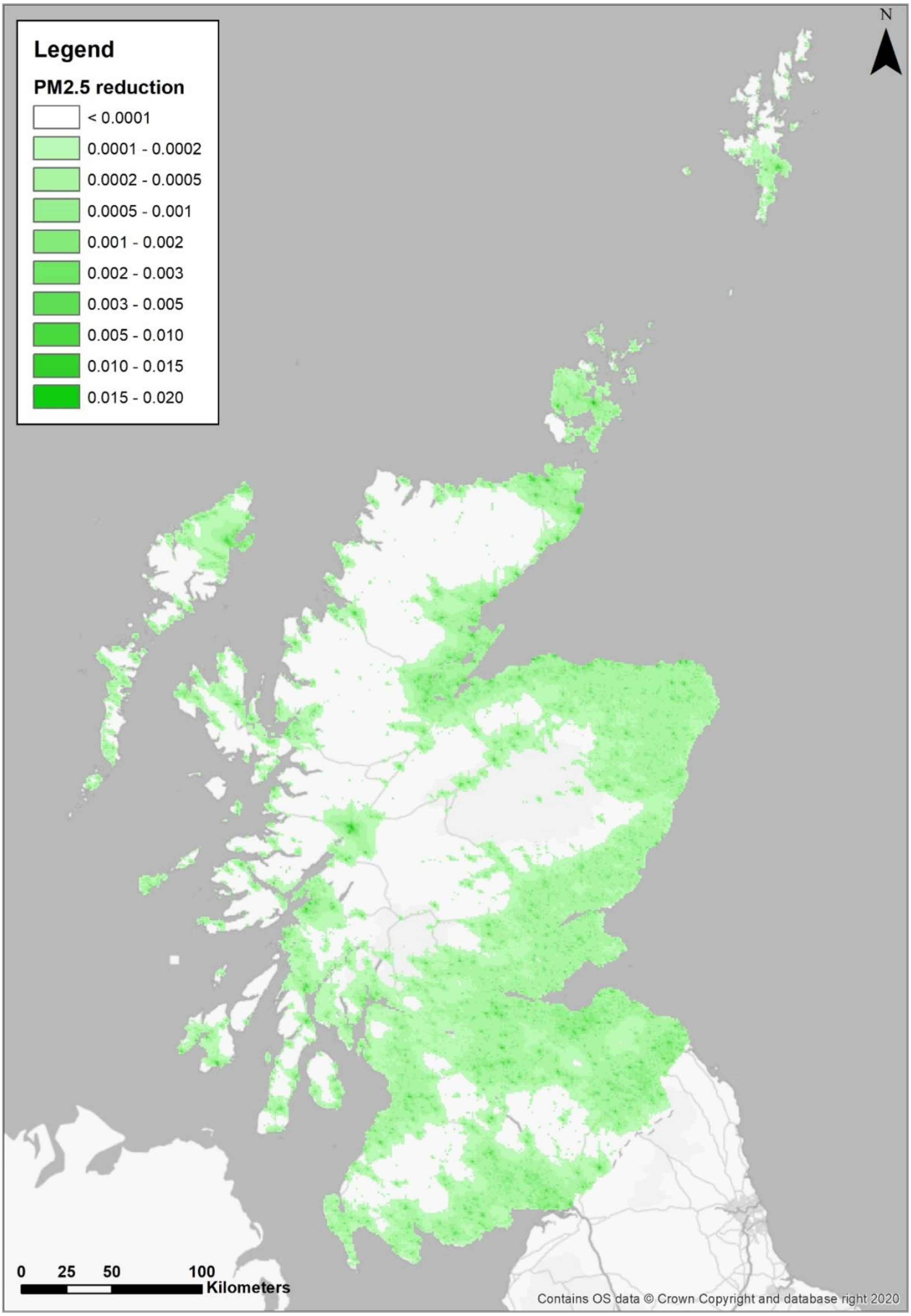


Figure 3-13 Reductions (positive) in $PM_{2.5}$ concentrations (µg m^{-3}) for Option 3



3.4 Assessment of costs and benefits

This section sets out the results of the assessment of costs and benefits, including monetising the change in emissions and their impact on air quality. The following methodological points have been used in accordance with HMT Green Book guidance:

- Prices converted to 2020 price year, with a discount year of 2022 (3.5% discount rate)
- Impacts have been calculated for the year 2023 and for a 10 year appraisal period from 2023-2032
- A 2% uplift for real wage growth has been applied to monetised health benefits
- 10 year appraisal period.

3.4.1 Valuation of health impacts from reduced exposure to air pollution

3.4.1.1 Overview and receptors

This section covers analysis of the health impacts associated with changes in exposure to air pollutants of Options 2 and 3.

There is a well-documented link between high levels of ambient air pollution and increased levels of adverse health effects. Due to the health concerns associated with air pollution, particularly $PM_{2.5}$, legislation has been introduced in Scotland to improve air quality. Studies strongly suggest that long-term (chronic) exposure to particles ($PM_{2.5}$) may damage human health and that these impacts (measured through changes in life expectancy) are substantially greater than the effects of acute exposure. Key receptors include all people exposed to local air pollution (e.g. residents, road users, pedestrians, the elderly/ children). In particular, the young, elderly and those with a pre-existing health condition are more at risk of exposure to air pollutants.

Health impacts are uplifted by 2% per year over the appraisal period in keeping with the Defra guidance: this recognises that willingness-to-pay to reduce detrimental health outcomes tends to increase with income and hence could be expected to rise over time with real income growth.

3.4.1.2 The impact pathway approach

Defra has produced guidance[31] to steer the assessment of air quality impacts on health and the valuation of associated economic costs. This guidance was designed to support evidence gathering to inform policy development or evaluation in the UK. Following this guidance, Defra produced a set of damage costs for air pollution, which summarise the impacts per tonne of emission. The assessment of health impacts in this report draws heavily on this guidance and is broadly consistent with the approaches used to produce the latest set of Defra damage costs (with slight variations as noted in the methodology section below), but also combined with Scotland-specific data, where available.

The first step overlays the gridded annual average modelled $PM_{2.5}$ concentrations (produced from the air quality modelling as described in section 3.3) with population grids to calculate population weighted concentrations for each scenario.

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[31] Defra impact pathways approach guidance for air quality appraisal

Aggregate population-weighted mean concentrations (PWMC) were derived using the following formula:

PWMC = (LSOA mean pollutant concentration * LSOA population) / Total population in domain

For the second step, the concentration response function (CRF) for each impact pathway (which defines a given health impact per unit change in the ambient concentration of a pollutant), is combined with the change in population weighted mean pollutant concentrations and the following parameters to define health impacts:

- the underlying risk rate of the health impact;
- the population data.

By adopting the UK average CRFs and baseline risk rates, we have remained consistent with the Defra damage cost calculation to assess the impact of varying levels of ambient air pollution on the health of the Scottish population. The CRFs reflect COMEAP[32] guidance and opinions, which in turn forms part of the Interdepartmental Group on Costs and Benefits (IGCB) and HMT Green Book appraisal guidance. The CRFs used in our analysis are part of the latest set of damage costs published by the IGCB[33]. These CRFs are presented in Table 3-9. The current estimation of effects may be an underestimate as the WHO recently recommended a higher CRF for the Chronic mortality of $PM_{2.5}$ than presented in the Table below.

Table 3-9: CRFs applied in damage costs (% per 10µgm-3 change in concentration for relevant averaging period)

					% or Odds ratio change per 10ugm^{-3} change in pollutant		
Pollutant	Pathway	Air pollution metric	CRF type	Reference change in concentration (ugm^{-3})	Low	Central	High
$PM_{2.5}$	Chronic mortality	Annual average	Relative Risk (RR)	10	4	6	8
$PM_{2.5}$	CHD	Annual average	Hazard Ratio (HR)	5	1.00	19.00	42.00
$PM_{2.5}$	Stroke	Annual average	Hazard Ratio (HR)	5	2.10	6.40	10.90
$PM_{2.5}$	Diabetes	Annual average	Relative Risk (RR)	10	2.00	10.00	18.00
$PM_{2.5}$	Lung cancer	Annual average	Relative Risk (RR)	10	4.00	9.00	14.00
$PM_{2.5}$	Asthma (Older Children)	Annual average	Odds Ratio (OR)	10	1.22	1.48	1.97

32 Committee on the Medical Effects of Air Pollutants (COMEAP)
33 UK Government air quality appraisal damage costs guidance

					% or Odds ratio change per 10ugm^{-3} change in pollutant		
Pollutant	Pathway	Air pollution metric	CRF type	Reference change in concentration (ugm^{-3})	Low	Central	High
PM_{10}	Respiratory hospital admission	Annual average	Relative Risk (RR)	10	0.8	0.8	0.8
PM_{10}	Cardiovascular hospital admission	Annual average	Relative Risk (RR)	10	0.8	0.8	0.8
PM_{10}	Chronic Bronchitis	Annual average	Relative Risk (RR)	10	1.02	1.32	1.71

In the results, PM_{10} pathways are adjusted for $PM_{2.5}$ using $PM_{2.5}/PM_{10}$ ratio in emissions.

Finally, the health impacts of policy scenarios are valued (i.e. presented in monetary terms) to show the economic impacts of changes in pollutant concentrations. The valuation of health improvements captures a number of economic effects, including the direct impact on the utility of the affected individual (commonly captured by the 'willingness-to-pay' of the individual to avoid the detrimental health outcome) and reduction in medical costs. Monetising the health impacts in this way is a common approach which allows the economic benefits of improved health outcomes to be compared to the costs of measures in a cost-benefit analysis. We have used monetary value for the health impacts consistent with those used by Defra to derive its air pollution damage costs.

The approach we have adopted is consistent with the latest published approaches from Defra. However, it is important to note that there will be caveats in applying the IPA at this level. Although the COMEAP guidance spans a wide range of health impacts, it does not capture all effects associated with air pollution. Furthermore, it is worth noting that outside the UK, different approaches are taken to quantifying health impacts, adopting different health pathways and CRFs (e.g. EU CAFÉ, US EPA approaches).

3.4.1.3 Sensitivity analysis

The estimation of the impacts of air pollution on health pathways is inherently uncertain. The methodology for assessing the different impact pathways (which are subsequently aggregated to form the damage costs) is based on a number of assumptions around which there is a distribution of probable outcomes. The benefits estimated under this project represent a best estimation of a 'central' damage cost estimate. However, there is uncertainty around the interpretation of changes in air pollution concentrations into impacts and the valuation of those impacts.

Key uncertainties in the damage costs are illustrated using sensitivity ranges around the central values. Given the importance of the impacts of long-term exposure to particulates in the overall damage cost calculation, these ranges explored the uncertainty around CRF for all pathways and valuation for all pathways. Some pathways are excluded altogether from the central analysis, and are only included in the high sensitivity analysis (e.g. chronic bronchitis) – again following the Defra guidance.

A mapping of the point on the CRF range for each impact pathway across each damage cost is presented in Table 3-10.

Table 3-10: Mapping of CRF bound chosen to each damage cost

		Damage cost sensitivity		
Pollutant	Pathway	Low	Central	High
$PM_{2.5}$	Chronic mortality	L	C	H
$PM_{2.5}$	CHD		C	H
$PM_{2.5}$	Stroke		C	H
$PM_{2.5}$	Diabetes			C
$PM_{2.5}$	Lung Cancer		C	H
$PM_{2.5}$	Asthma (Older Children)		C	H
$PM_{2.5}$	Productivity	L	C	H
PM_{10}	Respiratory hospital admission	L	C	H
PM_{10}	Cardiovascular hospital admission	L	C	H
PM_{10}	Chronic Bronchitis			C

Note: L = Low end of CRF bound; C = central point of CRF bound; H = high end of CRF bound

3.4.1.4 Results

Table 3-11 presents the change in population weighted concentrations of pollution under Option 2 for the single year of air quality modelling. The results show a reduction in the key pollutants considered within this study, $PM_{2.5}$.

Table 3-11: Changes in population weighted concentrations under the central option 2 scenario

Pollutant	Business as usual ($\mu g/m^{-3}$)	Option 2 scenario (µg/m-3)	Change ($\mu g/m^{-3}$)	% change
$PM_{2.5}$	5.63205	5.63191	0.00013	0.002%

Table 3-12 presents the monetised outputs of the single year analysis. This presents the health impacts associated with change in exposure modelled for the scenarios for the year 2019 (the air quality modelling year) – the health impacts will be larger if viewed over the lifetime of the measure.

Table 3-12: Monetised outputs of the HIA under option 2 for a central sensitivity case

Pollutant	Health pathways / CRFs for inclusion	Monetised output (£2020)[34]

[34] Total core scenario impact does not equal the sum of each pathway as the monetised output has been rounded to three significant figures

$PM_{2.5}$	Chronic mortality	17,529
$PM_{2.5}$	CHD	12,321
$PM_{2.5}$	Stroke	4,636
$PM_{2.5}$	Lung Cancer	299
$PM_{2.5}$	Asthma (Older Children)	9,130
$PM_{2.5}$	Productivity	1,531
PM_{10}	Respiratory hospital admission	177
PM_{10}	Cardiovascular hospital admission	108
	Total	**45,732**

The most significant impact comes from the reduction in Chronic Mortality, which has a total monetised benefit of over £17,000. The other significant benefits are from CHD and Asthma (Older Children) which have a monetised impact of over £12,000 and £9,000 respectively.

Table 3-13 presents the change in population weighted concentrations of pollution under Option 3.

Table 3-13: Changes in population weighted concentrations under Option 3

Pollutant	Business as usual (µg/m^{-3})	Option 3 scenario (µg/m^{-3})	Change (µg/m^{-3})	% change
$PM_{2.5}$	5.63205	5.63140	0.00064	0.011%

Table 3-14: Monetised outputs of the HIA under Option 3 for a central sensitivity case

Pollutant	Health pathways / CRFs for inclusion	Monetised output (£2020)[35]
$PM_{2.5}$	Chronic mortality	84,484
$PM_{2.5}$	CHD	59,381
$PM_{2.5}$	Stroke	22,345
$PM_{2.5}$	Lung Cancer	1,442
$PM_{2.5}$	Asthma (Older Children)	44,005
$PM_{2.5}$	Productivity	7,380
PM_{10}	Respiratory hospital admission	852
PM_{10}	Cardiovascular hospital admission	521
	Total	**220,411**

The most significant impact comes from the reduction in Chronic Mortality, which has a total monetised benefit of over £84,484. The other significant benefits are from CHD and Asthma (Older Children) which have a monetised impact of over £59,381 and £44,005 respectively.

[35] Total core scenario impact does not equal the sum of each pathway as the monetised output has been rounded to three significant figures

Air quality impacts were then assessed over the appraisal period. Air quality benefits are assumed to be the same year on year, with no change in baseline fuel usage over the appraisal period. Table 3-15 below provides the total health benefits of option 2 and 3 for a low, central and high sensitivity over the 10 year appraisal period. The high range in these results represents the sensitivity around the CRF for mortality and for the valuations of mortality and hospital admissions.

Table 3-15:Monetised HIA outputs of Option 2 and 3 under a low, central and high sensitivity case for the 2023-2032 appraisal period (£2020, discounted to 2022)

	Low	Central	High
Option 2 Monetised output (£2020)	78,675	380,335	1,193,200
Option 3 Monetised output (£2020)	379,179	1,833,071	5,750,775

The air quality health impacts analysis has captured a range of key health impacts directly associated with changes in concentrations of air pollutants. Alongside these effects, exposure to air pollutants has been associated with a wider range of health impacts that have not been included in this assessment. These include additional health impacts from SO_2 or NO_X improvements that have not been quantified and the potential health benefits from reductions in indoor pollution. The impacts on health of these other pollutants could not be quantified in this assessment because the impacts of the options on pollutants other than $PM_{2.5}$ have not been modelled. In particular, this is relevant for impacts on SO_2 which will arise from the introduction of the 2% sulphur limit on manufactured sold fuels. In the interviews with industry stakeholders, it was raised that a typical sulphur content for “high sulphur” manufactured solid fuels is 6%, while those manufactured in accordance with the 2% limit (Already in place in England) will typically be at the 2% limit. However, it is not possible to directly estimate the change in SO_2 emissions from this information, as there is not an established methodology to translate fuel sulphur content to sulphur emissions, and the proportion of manufactured fuels sold as high sulphur are currently not known. There is also likely to be a change in NO_X emissions which has not been quantified, Therefore, there are additional health benefits of the policy options resulting from the shift from high sulphur to low sulphur manufactured fuels that are not captured in the quantitative figures. Environmental pathways were also not considered in the valuation of impacts from reduced air pollution as they are less significant for $PM_{2.5}$ than for SO_2 and NO_X.

Also, in the target interviews, it was raised that the sulphur limit on manufactured smokeless fuels was considered to prevent a likely scenario that would occur in its absence. England already has in place a sulphur limit, and Ireland also from the 1st November 2022[36]. As such, it is likely that if the sulphur limit was not to be implemented in Scotland, high sulphur manufactured solid fuels would be moved to Scotland as it is one of the only remaining marketplaces. As such, more polluting fuels may become concentrated in Scotland with an increase in negative health impacts associated with them.

[36] According to industry stakeholders

3.4.2 Fuel cost impacts

We have estimated the societal changes in fuel costs resulting from the scenarios. This analysis has monetised the baseline usage of fuels, and the change in fuel use in the scenarios using fuel price data derived from the Defra 2019 Impact Assessment. Table 3-16 presents the retail fuels prices for the different fuel types based on a 2020 price year. Given the appraisal period for the assessment is 2023 – 2032 the coal prices have been adjusted in real terms for each year based upon the projected change in coal prices outlined in the BEIS supplementary guidance to the Treasury's Greenbook[37].

It should be noted that although the costs of the cleaner fuels are higher, there is an efficiency saving in consumption captured in the switch from coal to manufactured solid fuels, which is captured in the fuel usage estimates for each scenario. To note, the energy efficiency savings have not captured a switch from high manufactured fuel to low manufactured fuel, but have focussed only on the transition from wet wood to dry wood and coal to low sulphur manufactured fuel.

Table 3-16 Retail Fuel Prices (2020, £/tonnes)

Type of Fuel	Price (£/tonne)
Dry Wood	389
Wet Wood	239
Coal	293
Low Sulphur Manufactured Fuel	406
High Sulphur Manufactured Fuel	358

Source: 2019 Impact Assessment on the proposed England Regulation which provided prices referring to Defra estimates based on industry data from Call for evidence

Table 3-17 illustrates the change in use for the different fuel types as a result of the implementation of either the information campaign to support the voluntary shift in fuel use or the proposed ban on coal use, compared to the baseline scenario. The behavioural assumptions which underpin the change in fuel use have been described in section 3.3.

As shown, the introduction of the ban on coal will have a greater impact on quantity of fuel consumed. Due to the greater efficiency of dry wood (comparative to wet wood) and manufactured fuel (comparative to house coal), under both scenarios a lesser amount of the substitute fuel is required to ensure energy output remains consistent.

[37] UK Government Green Book supplementary guidance valuation of energy use and greenhouse gas emissions for appraisal

Table 3-17 Fuel use as a result of the policy options (kt)

Type of Fuel	Baseline (No Intervention)	Information Campaign – Option 2	*Change in Fuel Use – Option 2*	Proposed Coal Ban – Option 3	*Change in Fuel Use – Option 3*
Wet Wood	23.74	23.50	-0.24	23.74	0.00
Dry Wood	74.02	74.22	0.20	74.02	0.00
House Coal	11.71	11.60	-0.12	0.00	-11.71
Manufactured Fuel	9.65	9.75	0.10	20.12	10.48
Total	**119.12**	**119.07**	**-0.05**	**117.88**	**-1.24**

As a result of the information campaign there is expected to be a small transition away from the use of wet wood to dry wood, and a small shift in the use of coal towards manufactured fuel. As a result, a small cost of approximately £30,000 is expected to be incurred primarily driven by the higher retail price of dry wood.

There is a greater increase in fuel costs from the Option 3 (£878,000 in 2023). This is due to the higher retail price of manufactured fuel compared to coal according to data gathered in the Defra 2019 Impact Assessment. Table 3-18 presents the costs for the first year of the implementation of the policies (2023).

Table 3-18 2023 Change in costs as a result of the proposed policy options (2020, £, discounted to 2022)

Baseline (No Intervention)	Information Campaign – Option 2	*Change in Fuel Use – Option 2*	Proposed Coal Ban – Option 3	*Change in Fuel Use – Option 3*
£40,977,102	£41,007,166	**£30,064**	£41,854,719	**£877,617**

Note: Small differences in the change in impact are due to rounding

Additionally, the costs of both the information campaign and the proposed ban have been estimated for the 2023 – 2032 period (Table 3-19).

Table 3-19 Aggregated 2023 - 2032 Change in costs as a result of the proposed policy options (2020, £, discounted to 2022)

Baseline (No Intervention)	Information Campaign – Option 2	*Change in Fuel Use – Option 2*	Proposed Coal Ban – Option 3	*Change in Fuel Use – Option 3*
£356,786,496	£357,049,923	**£263,426**	£364,805,532	**£8,019,036**

Note: Small differences in the change in impact are due to rounding

As noted, the fuel prices have been based upon the retail fuel prices provided in the Defra 2019 Impact Assessment[38] exploring the costs of a similar coal ban. However, although the IA presents a higher price for manufactured fuel compared to coal, interviews with two industry stakeholders suggested that the price of manufactured fuel and coal have converged and become the same in recent years. As such, sensitivity analysis was undertaken around this information. The tables below provide the costs, in 2023, factoring in the views of the industry stakeholders and therefore setting an equivalent mid-point price level (£338/t) for both coal and manufactured fuels. As a result of equalising the coal and manufactured fuel prices the increase in costs under Option 2 is expected to decrease. In the case of the Option 3, following this price change there is now expected to be an overall fuel cost reduction (i.e. a saving) of approximately £450,000 in 2023. Option 2 still results in a net increase in fuel costs, as the price of dry wood is still significantly greater than wet wood, which outweighs the cost benefits brought from the greater energy efficiency of MSF compared with coal.

Table 3-20 2023 Change in costs as a result of the proposed policy options factoring in stakeholder views on fuel prices (2020, £, discounted to 2022)

Baseline (No Intervention)	Information Campaign – Option 2	*Change in Fuel Use – Option 2*	Proposed Coal Ban – Option 3	*Change in Fuel Use – Option 3*
£41,075,777	£41,092,558	**£16,782**	£40,625,199	**-£450,578**

Note: Small differences in the change in impact are due to rounding

Table 3-21 2023 - 2032 Change in costs as a result of the proposed policy options factoring in stakeholder views on fuel prices (2020, £, discounted to 2022)

Baseline (No Intervention)	Information Campaign – Option 2	*Change in Fuel Use – Option 2*	Proposed Coal Ban – Option 3	*Change in Fuel Use – Option 3*
£357,688,112	£357,830,177	**£142,066**	£353,571,055	**-£4,117,057**

Note: Small differences in the change in impact are due to rounding

[38] Defra Impact Assessment

3.4.3 Greenhouse gas (GHG) impacts

We have estimated changes in greenhouse gas emissions from the change in fuel use using emission factors for wood from the EMEP guidebook[39]. For coal and manufactured solid fuels, emission factors from the NAEI were used. This contains emission factors per GJ for different types of solid fuels. The calculation of total GHG emissions has been based upon the 'total fuel consumed multiplied by the emission factor of the pollutant', as per the guidance in the EMEP guidebook.

The resulting change in GHG emissions were monetised using BEIS guidance[40].

Table 3-22 shows the emission factors for biomass (used as an indicator for wood), coal and manufactured fuel for the relevant GHG pollutants. As presented below, the highest GHG emission factor is associated with the burning of coal through domestic combustion processes.

Table 3-22 Average Emission Factors per Fuel Type

Fuel Type	Category	Unit	Pollutant	Emission Factor	Source
Biomass (Wood)	Fireplace	mg/MJ	CO_2	91,210	EMEP guidebook
Biomass (Wood)	Woodstove	mg/MJ	CO_2	88,445	EMEP guidebook
Coal	Domestic combustion	$kgCO_2e$/Tonnes	CO_2	2632	NAEI
Coal	Domestic combustion	$kgCO_2e$/Tonnes	Methane	215	NAEI
Coal	Domestic combustion	$kgCO_2e$/Tonnes	Nitrous Oxide	37	NAEI
Manufactured Fuel	Domestic combustion	$kgCO_2e$/Tonnes	CO_2	2897	NAEI
Manufactured Fuel	Domestic combustion	$kgCO_2e$/Tonnes	Methane	233	NAEI
Manufactured Fuel	Domestic combustion	$kgCO_2e$/Tonnes	Nitrous Oxide	40	NAEI

Table 3-23 displays the GHG impact as a result of the scenarios compared to Option 1 (the baseline no intervention scenario). It should be noted that in terms of GHG emissions associated with wood burning, there is not expected to be an impact as a result of either policy measure, for wood burned in a fireplace or a woodstove. Although Option 2 is expected to lead to a small (1%) switch in the use of wet wood to dry wood, the emission factors provided in the EMEP guidance do not differentiate between the wood types. To note, the quantitative assessment has not captured the potential life-cycle impact of the fuels. For example, dry wood is typically dried through the use of a kiln, which will in turn

[39] European Environment Agency small combustion 2019

[40] UK Government Green Book supplementary guidance valuation of energy use and greenhouse gas emissions for appraisal

lead to a small amount of GHGs emitted through this process. However, given the transition from the use of wet wood to dry wood is relatively small, this is not expected to have a significant impact upon GHG emissions.

As shown below, there is expected to be a greenhouse gas emissions reduction as a result of both policy measures. A significantly greater saving, of approximately 10 times the amount, is expected as a result of Option 3. This is due to the increased efficiency of manufactured fuels and the subsequent lower amount needed.

Table 3-23 2023 Total Monetised impact of GHG Impact (2020, £(m), discounted to 2022)

Baseline (No Intervention)	Information Campaign – Option 2	Change in GHG impact – Option 2	Proposed Coal Ban – Option 3	Change in GHG impact – Option 3
£46,030,860	£ 46,029,475	-£1,385	£45,892,356	-£138,503

Note: Small differences in the change in impact are due to rounding

Table 3-24 2023 - 2032 Total Monetised impact of GHG Impact (2020, discounted to 2022)

Baseline (No Intervention)	Information Campaign – Option 2	Change in GHG impact – Option 2	Proposed Coal Ban – Option 3	Change in GHG impact – Option 3
£ 422,688,784	£422,676,065	-£12,718	£421,416,946	-£1,271,838

Note: Small differences in the change in impact are due to rounding

Sensitivity analysis has also been undertaken to determine the monetised impact of the change in GHG emissions using the low and high carbon costs provided through BEIS guidance[41]. The results of the sensitivity analysis are shown in the table below. As a result of the sensitivity analysis it can be determined that the GHG impact saving as a result of Option 2 will fall between approximately £690 – £2,080 in 2023. A greater saving of between £69,000 - £208,000 is expected as a result of Option 3. The benefits (savings) are greater over the 10 year appraisal period as shown in Table 3-26.

Table 3-25 Sensitivity Analysis: Total 2023 Monetised impact of GHG Impact (2020, £ discounted to 2022)

Carbon Price	Baseline (No Intervention)	Information Campaign – Option 2	Change in GHG impact – Option 2	Proposed Coal Ban – Option 3	Change in GHG impact – Option 3
Low	£23,015,430	£23,014,737	-£693	£22,946,178	-£69,252
High	£69,046,289	£69,044,212	-£2,078	£68,838,534	-£207,755

Note: Small differences in the change in impact are due to rounding

41 UK Government Green Book supplementary guidance valuation of energy use and greenhouse gas emissions for appraisal

Table 3-26 Sensitivity Analysis: Total 2023-2032 Monetised impact of GHG Impact (2020, discounted to 2022)

Carbon Price	Baseline (No Intervention)	Information Campaign – Option 2	Change in GHG impact – Option 2	Proposed Coal Ban – Option 3	Change in GHG impact – Option 3
Low	£211,344,392	£211,338,033	-£6,359	£210,708,473	-£635,919
High	£634,033,176	£634,014,098	-£19,078	£632,125,419	-£1,907,757

Note: Small differences in the change in impact are due to rounding

3.4.4 Implementation costs

Implementation costs are expected to include the cost to the Scottish Government to undertake an information campaign to promote the bans, and costs of enforcement of the ban.

In terms of the cost of implementing the ban on the use of solid fuel, based on the Impact Assessment for the ban in England, enforcement costs for local authorities are expected to be approximately £1.2M over an 11-year period (costs for this assessment are based on a 10-year appraisal period). There are currently 333 local authorities operating within England and 32 within Scotland. Based on the assumption that the enforcement costs associated with the ban are evenly split across and scale with the number of local authorities, it is estimated that each authority will incur costs of approximately £3,300 over the 10 year period. This approach has used cost information for specific local authorities, but it is expected that the implementation burden for each local authority will be relatively consistent across both England and Scotland, although there may be some variation, for instance between rural and urban authorities. Following this approach would result in total enforcement costs for Scottish authorities of £116,000 over the 10-year appraisal period.

In terms of the public information campaign to support the voluntary transition away from the use of solid fuels, the costs for England were estimated to be £220,000 over a three year period. Based on the same approach taken to calculate the implementation costs of the coal ban for Scottish authorities (proportioning the costs based on the difference in the number of England and Scotland local authorities), the cost to run the public information campaign in Scotland will be approximately £80,000 over a 10-year period..

We have also considered the cost implications associated with changes or upgrades to heating systems to use different fuels. However, from interviews with industry (CPL supplier and the Coal Merchants Federation), it was noted that coal based boilers are capable of utilising smokeless fuels. As such, there will be no costs associated with required upgrading of heating systems resulting from the ban of coal. This is consistent with the Defra 2019 Impact Assessment which does not account for boiler costs in the assessment.

3.4.5 Summary cost benefit analysis

The results of the quantitative analysis of the cost-benefit analysis suggest that Option 2 results in a positive NPV, with the benefits of the air quality improvements and greenhouse gas emissions brought by the small shift in usage (from wet wood to dry wood, and from coal to manufactured solid fuels) outweighing the increased fuel costs and implementation costs of the policy (Positive NPV of £65,200).

For the proposed ban of coal and limit on sulphur in smokeless fuels (Option 3), the central assessment suggests that the costs outweigh the benefits, driven largely by the increased fuel costs which are not outweighed by the health and greenhouse gas emissions benefits (Negative NPV of -£5,016,400). This in part reflects the specific pattern of air quality benefits associated with a ban in Scotland (which have been assessed here using a more detailed dispersion modelling- impact pathway approach): namely given the use of solid fuels is highest amongst households in rural areas, there is also therefore low population densities in areas with the biggest impacts (i.e. reductions in air pollution). As such the associated reduction in exposure, and health improvements, are potentially smaller.

However, with such a large shift in fuel usage represented by the ban from coal to smokeless fuels, the fuel prices used play a large role in the determination of the NPV of the policy. The fuel price data used for the main analysis was based on price data from the Defra 2019 Impact Assessment for the England coal ban policy, published in 2019, and projected over the appraisal period using BEIS fuel price projections. This price data had coal as being significantly cheaper than manufactured solid fuels (£293 per tonne of coal vs. £358-406 per tonne for smokeless fuels in 2019). Through the targeted interviews conducted as part of this study, stakeholders have indicated that the prices of these fuels have converged in recent years. As such, we conducted sensitivity analysis with equivalent prices, and this found a positive NPV of £7,123,600 for Option 3 (However, Option 2 is still an overall cost due to the increased usage of dry wood and its higher price). This highlights the strong sensitivity of the overall NPV result to the fuel price assumptions used. Given this data was provided by the industry stakeholders as part of the study, this could be considered a more up-to-date assessment of the impacts, but fuel prices will remain inherently uncertain going forward. However, stakeholders indicated that the current price equivalence is resulting from the England ban which will remain in place, and therefore prices are likely to continue to be equivalent.

Certain additional benefits have also not been monetised under the policy scenarios. Most notably, additional benefits from SO_2 brought by the 2% sulphur limit on manufactured solid fuels, and additional health benefits brought by reductions in indoor air pollution.

To the extent that the difference in prices between the banned fuels and their alternatives stays small (i.e. the price of manufactured solid fuels does not rise above the cost of coal, the NPV of the ban under Option 3 would also be positive under a central assessment.

Table 3-27 Breakdown of monetised impacts and overall NPV for the 2 policy options, 2023-2032 (£2020 discounted to 2022). Numbers rounded to 3 s.f.

Impact	Policy Option 2 (Information campaign)	Policy Option 3 (Coal ban and sulphur limit)	Policy Option 2 (With fuel price sensitivity)	Policy Option 3 (With fuel price sensitivity)
Fuel Costs	£263,000	£8,020,000	£142,000	-£4,120,000
Greenhouse gas Impacts	-£13,000	-£1,270,000	-£13,000	-£1,270,000
Health impacts	-£380,000	-£1,830,000	-£380,000	-£1,830,000
Implementation Costs	£64,800	£96,400	£64,800	£96,400
Total NPV	**-£65,200**	**£5,016,400**	**-£186,200**	**-£7,123,600**

3.5 Air quality results for the distributional analysis

3.5.1 Overview and approach

This section presents distributional analysis of health impacts. While the cost-benefit analysis includes the health impacts of the policy scenarios on society as a whole, distributional analysis estimates how these impacts may fall unevenly on certain populations geographically, and also certain demographics.

The approach to appraising each of the impacts closely follows the methodology set out in the TAG guidance. Namely, the ‘impact variables’ (describing how the impacts vary or are distributed across a geographic area) are overlaid with the ‘grouping variables’ (describing how different societal groups are distributed across the same area).

In most cases the appraisal is then made on the basis of splitting both the grouping and impact variables into quintiles, and then judging whether the impact on a given population group is proportionate to the representation of that group in the wider population. The categories included in this analysis are Index of Multiple Deprivation-Income, children, and elderly groups. The overlay of impacts and groups was then undertaken on a Lower Layer Super Output Area (LSOA) basis.

Average $PM_{2.5}$ concentrations by LSOA were calculated for each scenario in GIS using zonal statistics of the total $PM_{2.5}$ concentrations raster and the LSOA shapefile[20]. The LSOA boundaries represent 2011 Census data.

Figure 3-14 shows average Option 1 (baseline) $PM_{2.5}$ concentrations by LSOA. Figure 3-15 shows the concentrations by LSOA for the central belt, including Glasgow and Edinburgh, and Figure 3-16 shows the concentrations for the east coast, including Aberdeen and Dundee. We have included figures focusing on these areas because the LSOAs have smaller areas in the cities than in rural areas, and it is difficult to examine the results in a map covering all of Scotland. Large proportions of the population live in cities in the central belt and on the east coast.

Figure 3-14 Average $PM_{2.5}$ concentrations (µg m^{-3}) by LSOA for the Option 1 (baseline) across Scotland

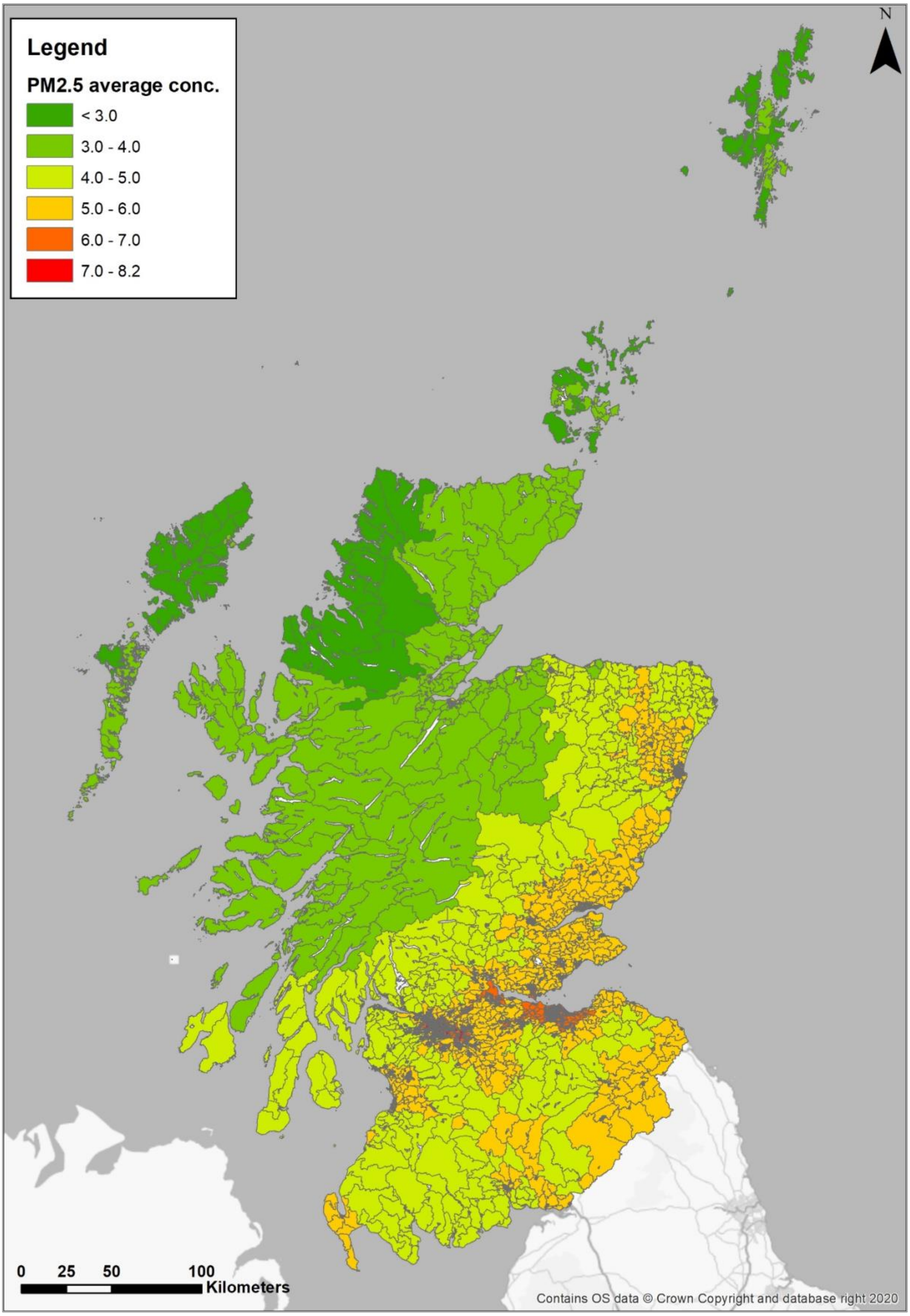


Figure 3-15 Average $PM_{2.5}$ concentrations (µg m^{-3}) by LSOA for the 2019 Option 1 (baseline) in the central belt

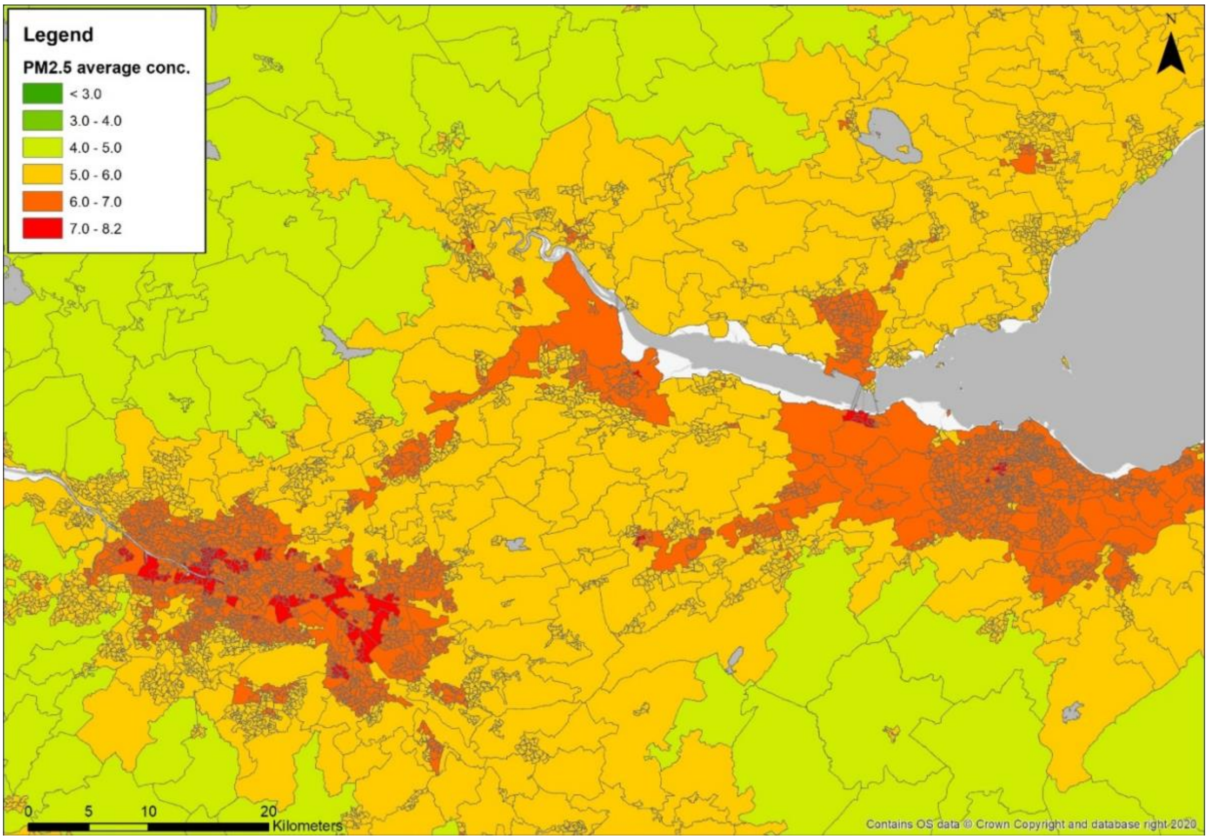
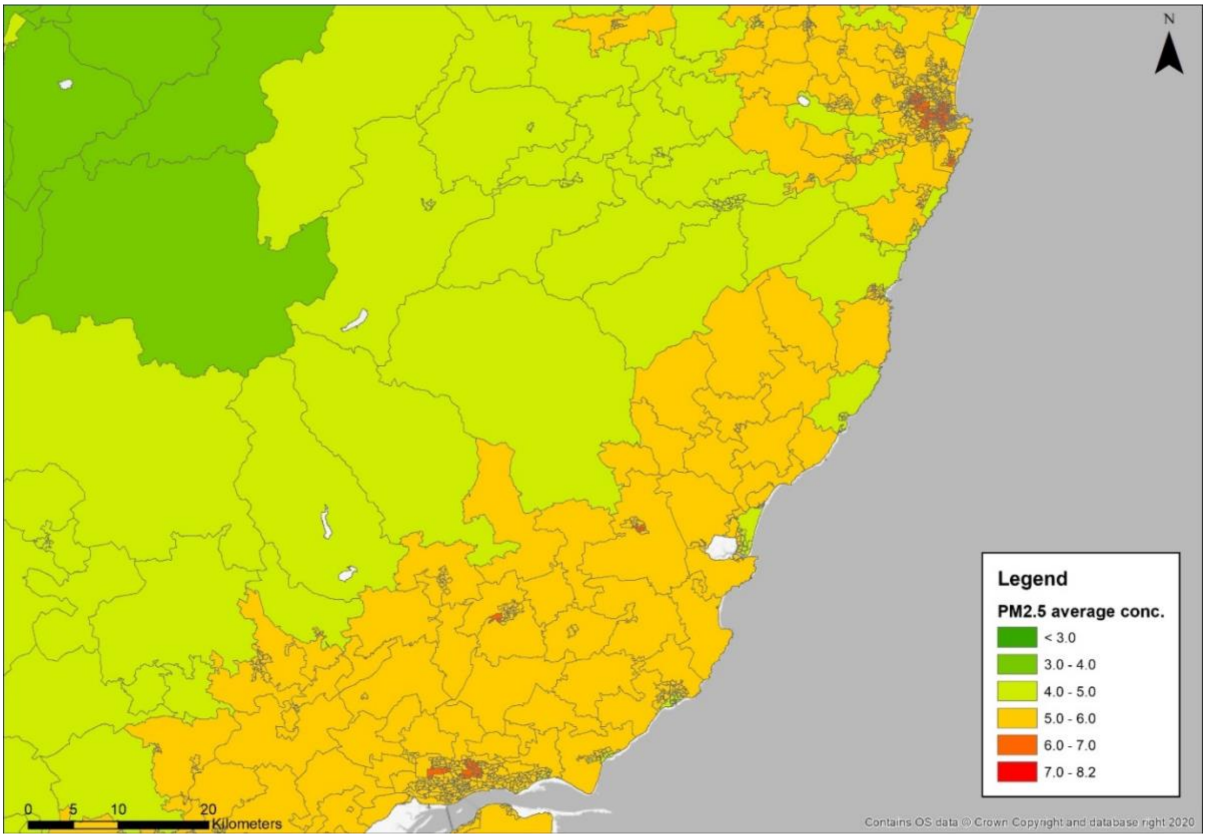


Figure 3-16 Average $PM_{2.5}$ concentrations (µg m^{-3}) by LSOA for the 2019 Option 1 (baseline) on the east coast



To evaluate the impact of the options on each LSOA, the change in the average pollutant concentrations for each LSOA was calculated by subtracting Option 2 and 3 in turn from the Option 1 (baseline) 2019 scenario. If the resulting change is positive, there is an improvement in air quality as a result of the option.

(2030 Option 1) – (2030 Option 2/3) = (Change in Air Quality)

Figure 3-17 shows the average reduction in total $PM_{2.5}$ concentrations across LSOAs for each scenario. There is a larger average reduction for Option 3 than for Option 2. Figure 3-18 through Figure 3-21 show the reductions in average total $PM_{2.5}$ concentrations by LSOA for Option 2 and Option 3. This analysis shows the following impacts:

- Overall, $PM_{2.5}$ concentrations are lower in rural areas than in more populated areas in the central belt and east coast. Differences between total concentrations between the Option 1 (baseline) and Options 2 and 3 are small.
- There is a limited decrease in average concentrations in most LSOAs for Option 2. The largest decreases (0.001 µg.m^{-3}) are in urban areas, e.g., in central parts of Aberdeen and Edinburgh.
- There is a larger reduction in concentrations in Option 3 than in Option 2 for many LSOAs, particularly in rural areas. The largest reductions (0.02 µg.m^{-3}) are seen in LSOAs in remote towns, e.g., Fort William and Kirkwall.

Figure 3-17 Average reduction (positive) in $PM_{2.5}$ concentrations (µg m^{-3}) across LSOAs

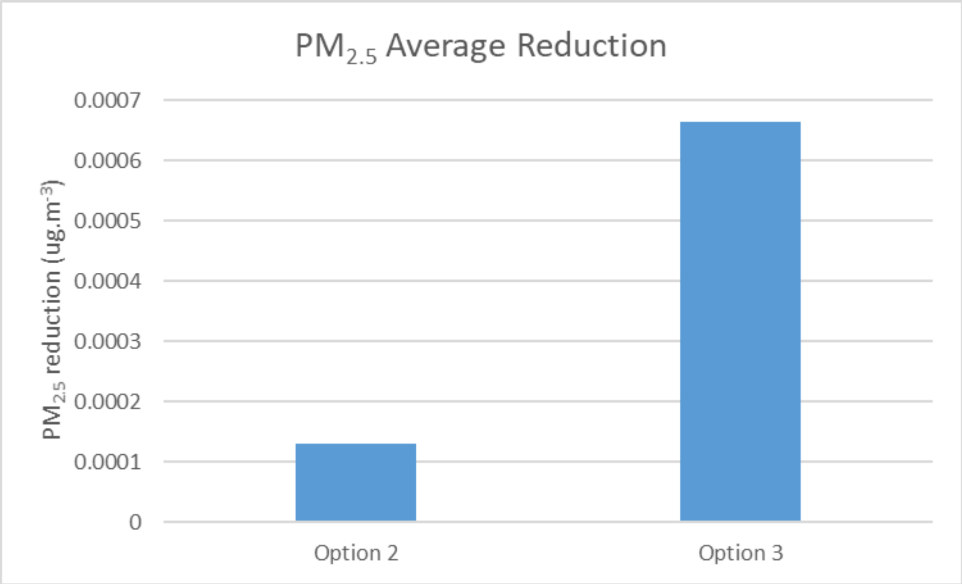


Figure 3-18 Reduction (positive) in average $PM_{2.5}$ concentrations (µg m^{-3}) by LSOA for Option 2

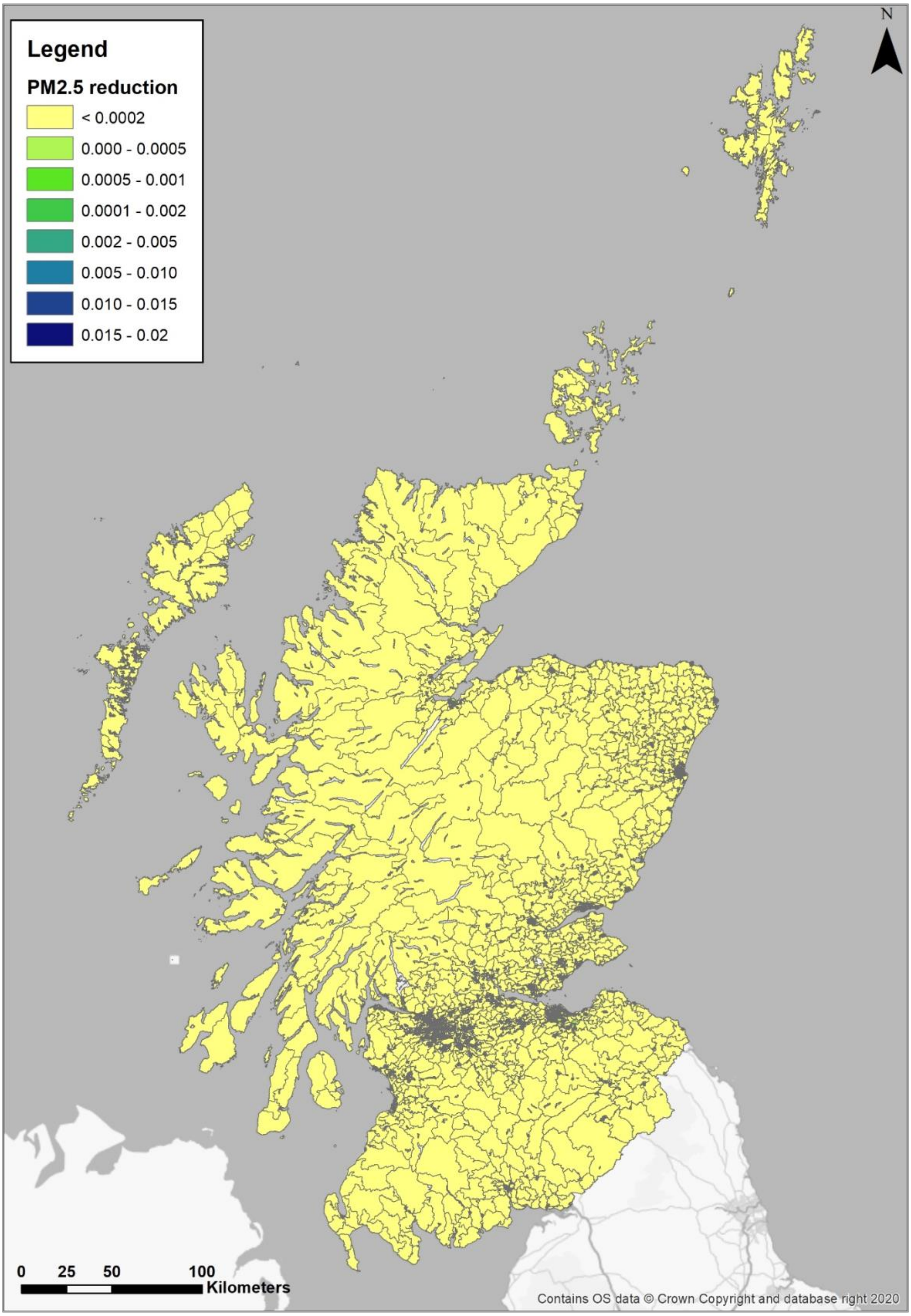


Figure 3-19 Reduction (positive) in average $PM_{2.5}$ concentrations (µg m^{-3}) by LSOA for Option 3

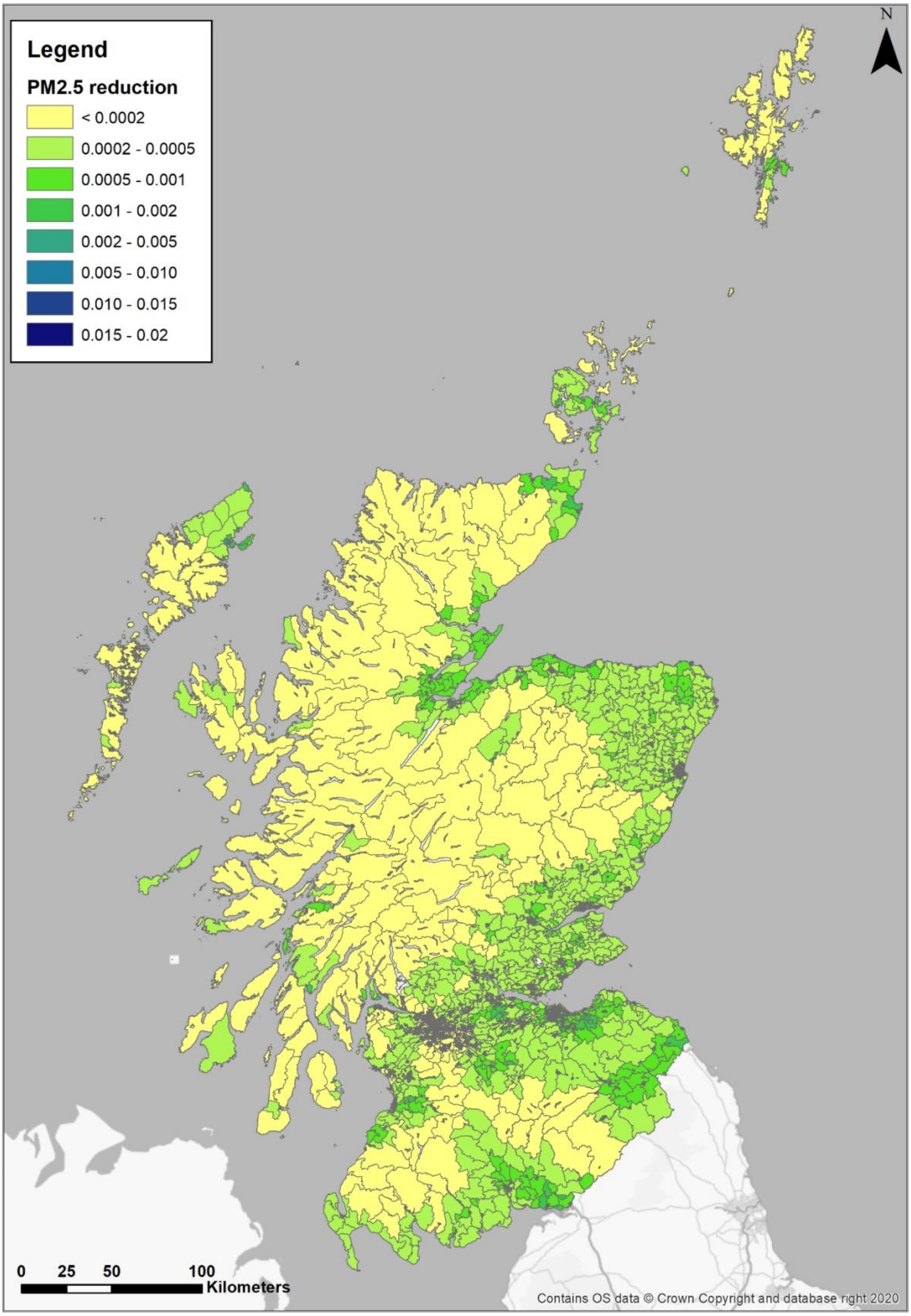
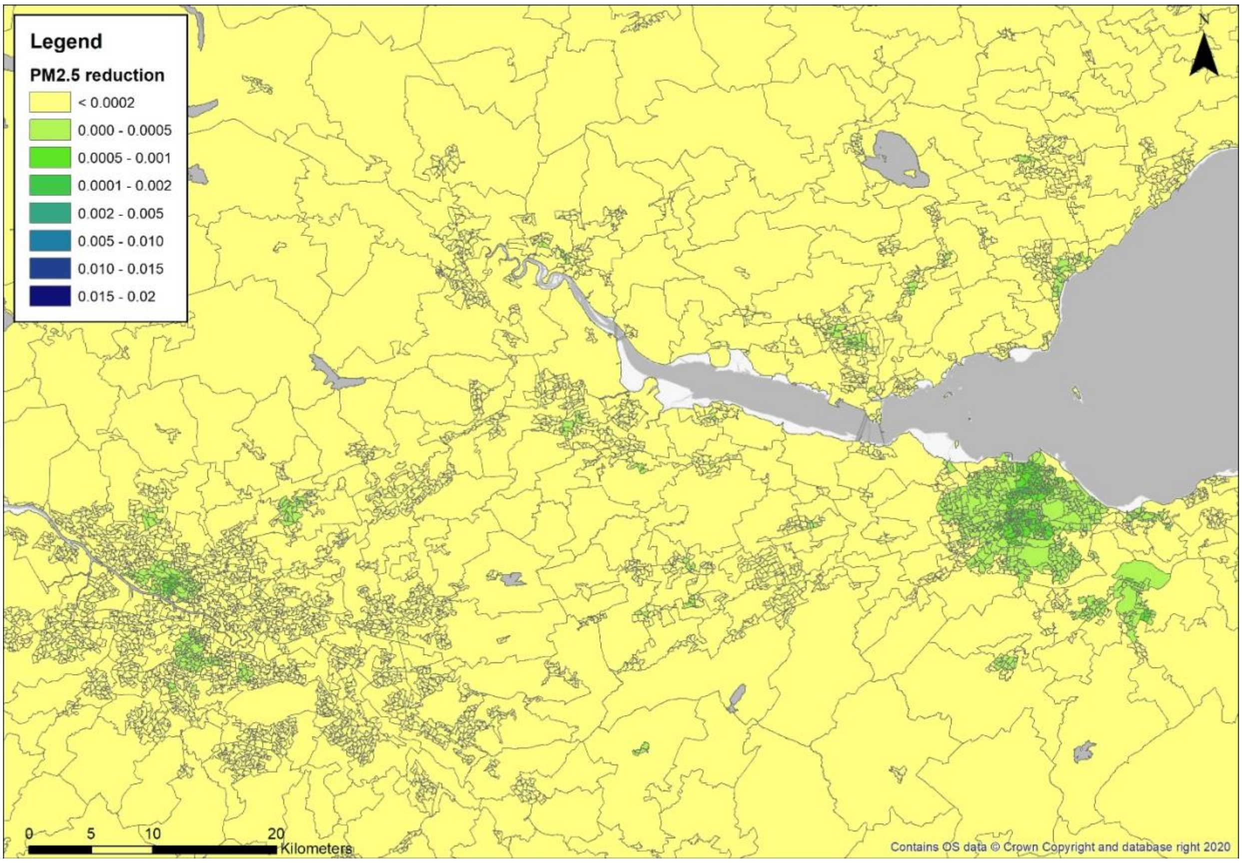


Figure 3-20 Reduction (positive) in average $PM_{2.5}$ concentrations (µg m^{-3}) by LSOA for Option 2 (top) and Option 3 (bottom) in the central belt



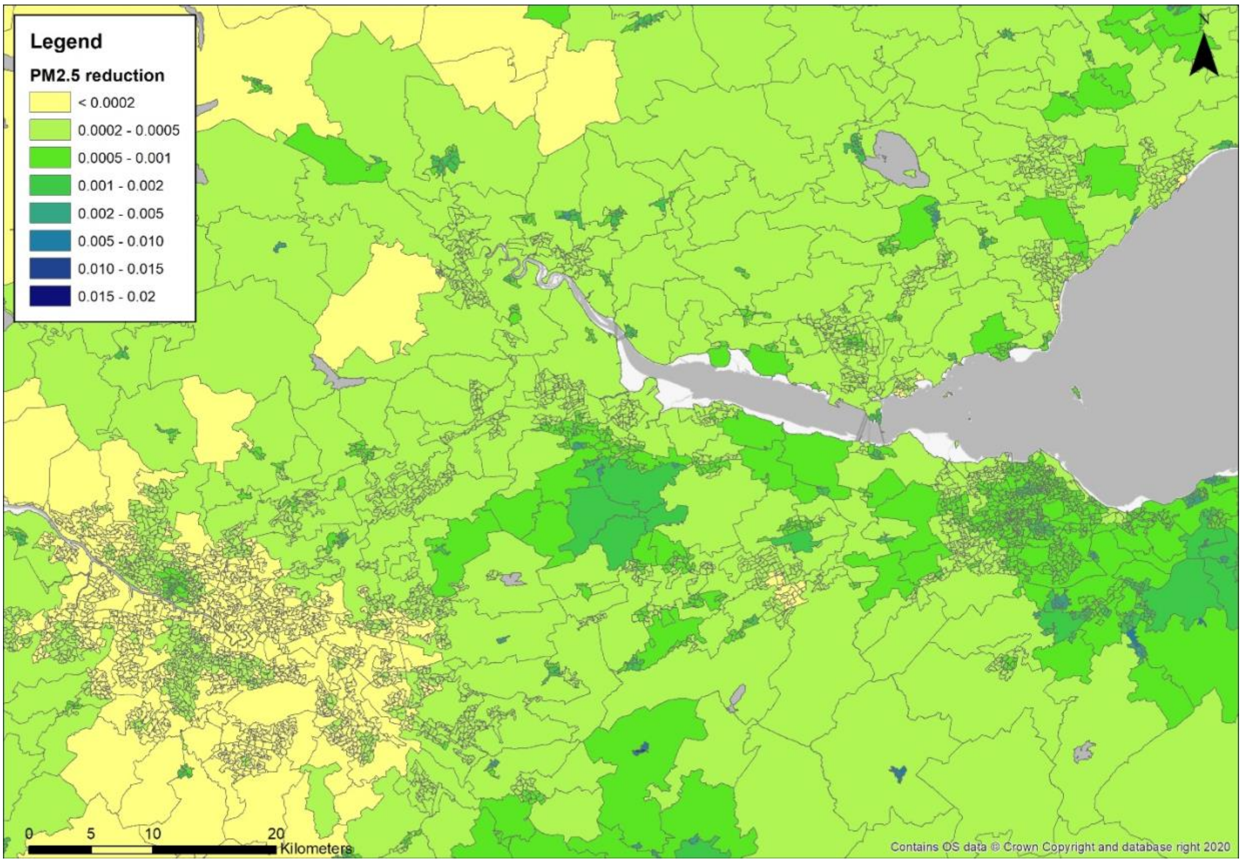
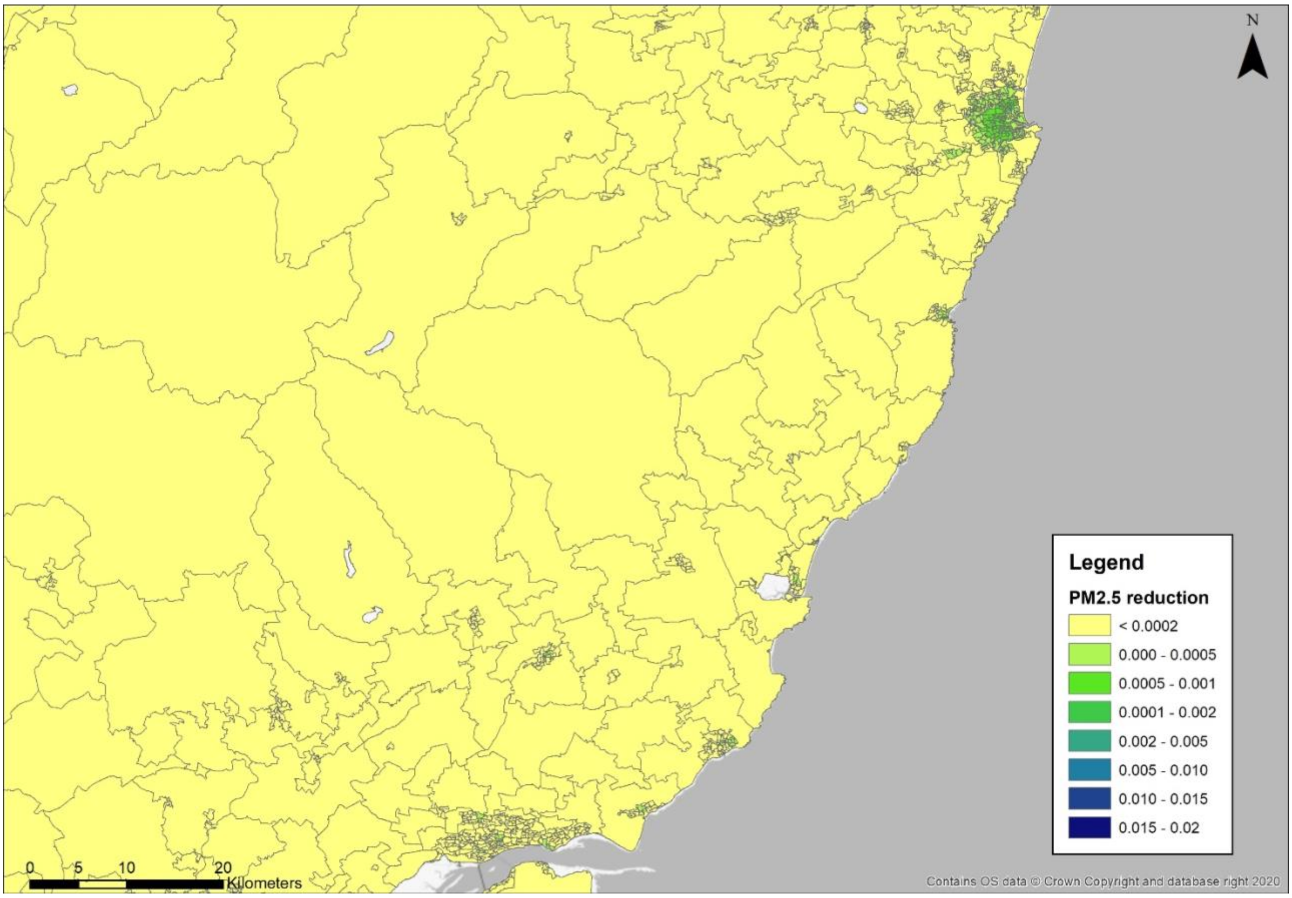
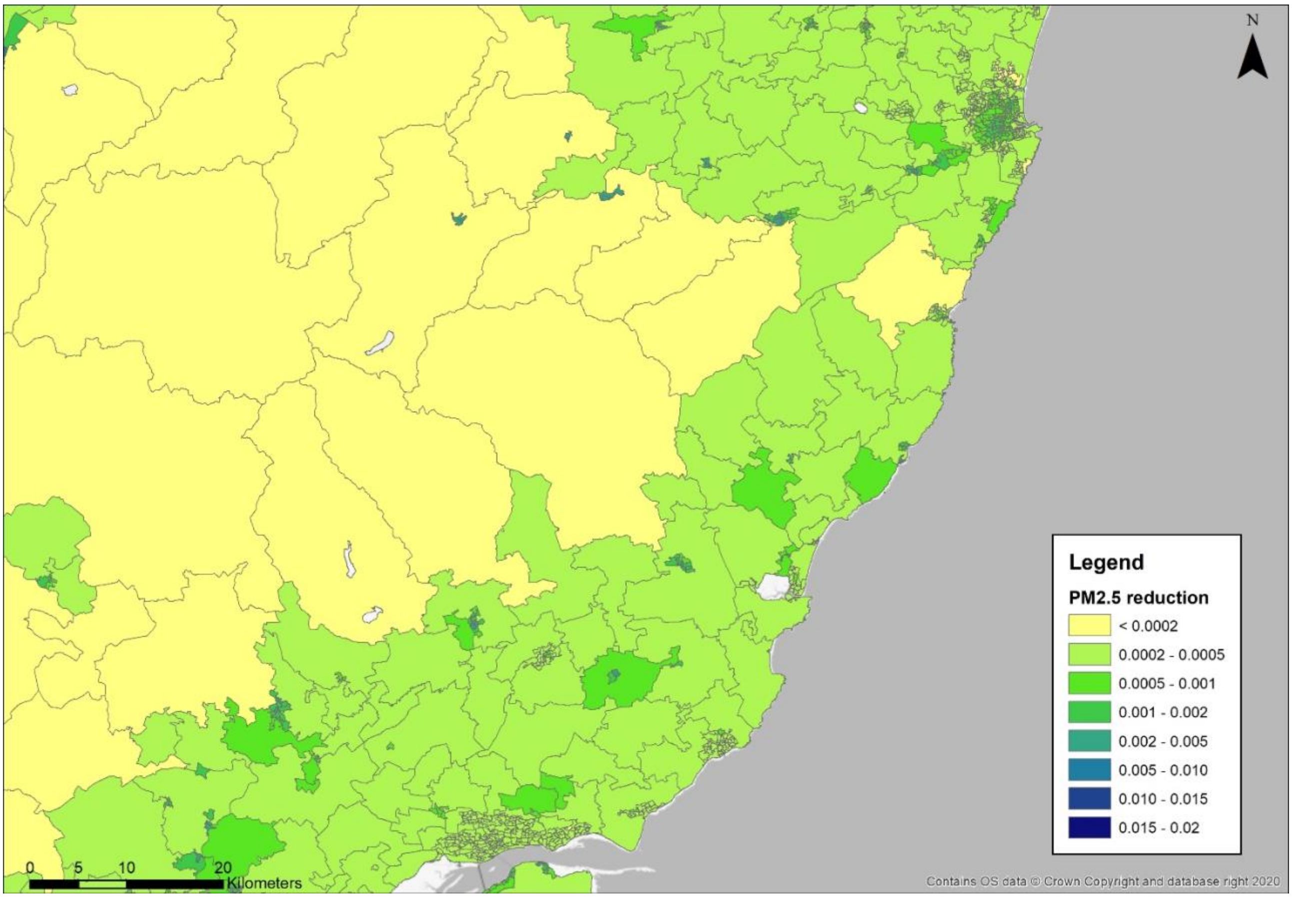

Legend
PM2.5 reduction
< 0.0002
0.0002 - 0.0005
0.0005 - 0.001
0.001 - 0.002
0.002 - 0.005
0.005 - 0.010
0.010 - 0.015
0.015 - 0.02
0
5
10
20
Kilometers
Contains OS data © Crown Copyright and database right 2020

Figure 3-21 Reduction (positive) in average $PM_{2.5}$ concentrations (µg m^{-3}) by LSOA for Option 2 (top) and Option 3 (bottom) in the east coast





3.5.2 Sectors and groups affected (Distributional impacts)

The following analysis explores the distribution of average $PM_{2.5}$ concentrations by LSOA for socioeconomic impact groups, with a focus on: low income groups (SIMD-Income), children under 16, and elderly (over 65). Mid-2021 population estimates were used to calculate the distribution of each age group across LSOAs in Scotland in quintiles[42]. The SIMD-Income ranks were used to determine the quintile distribution of SIMD-Income across LSOAs[22].

Figure 3-22 through Figure 3-26 show the distribution of quintiles for each category.

[42] Scottish Government population estimates summary

Figure 3-22 Distribution of SIMD-Income quintiles by LSOA (where 1 is most deprived and 5 is least deprived)

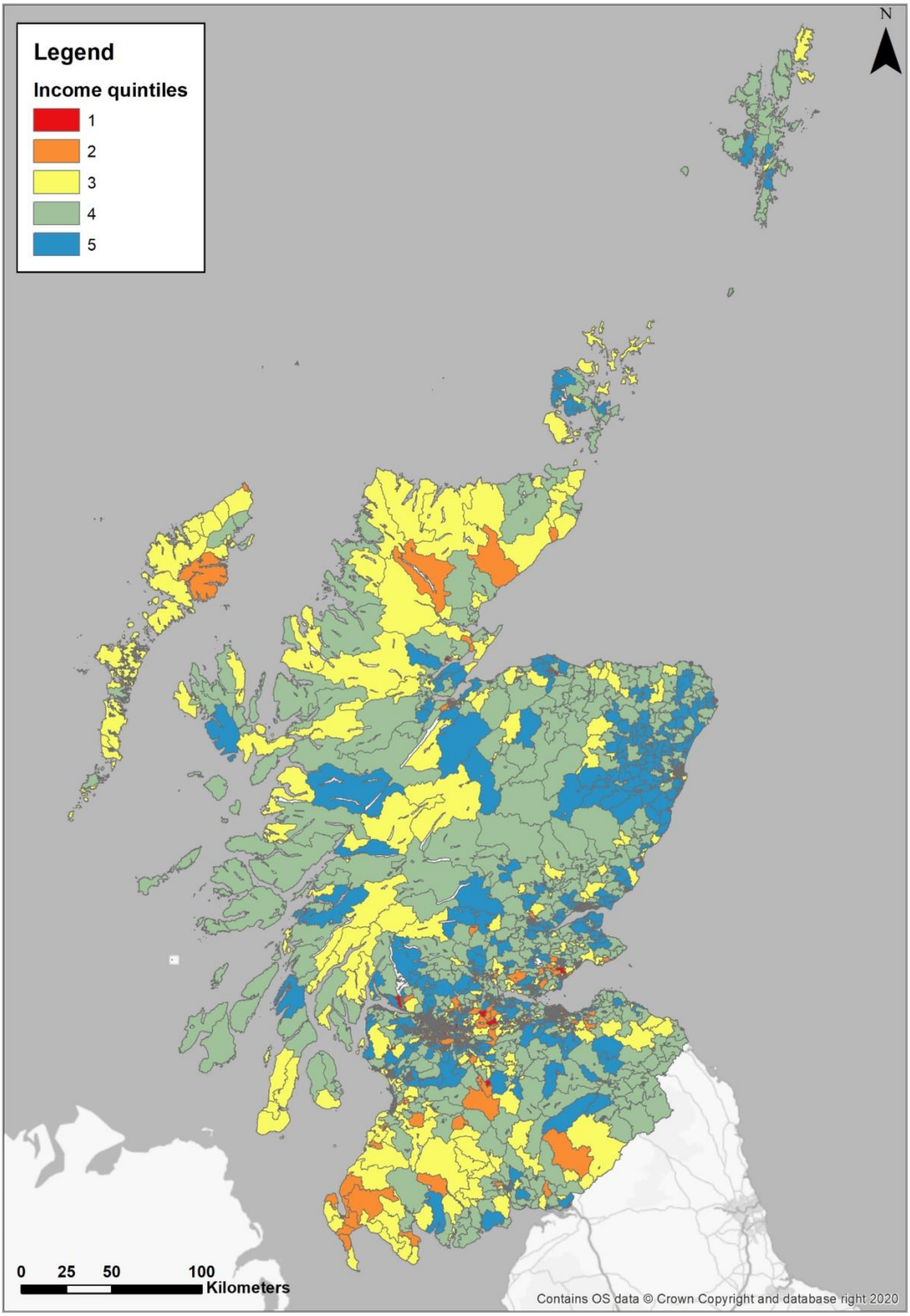


Figure 3-23 Distribution of SIMD-Income quintiles by LSOA (where 1 is most deprived and 5 is least deprived) in the central belt

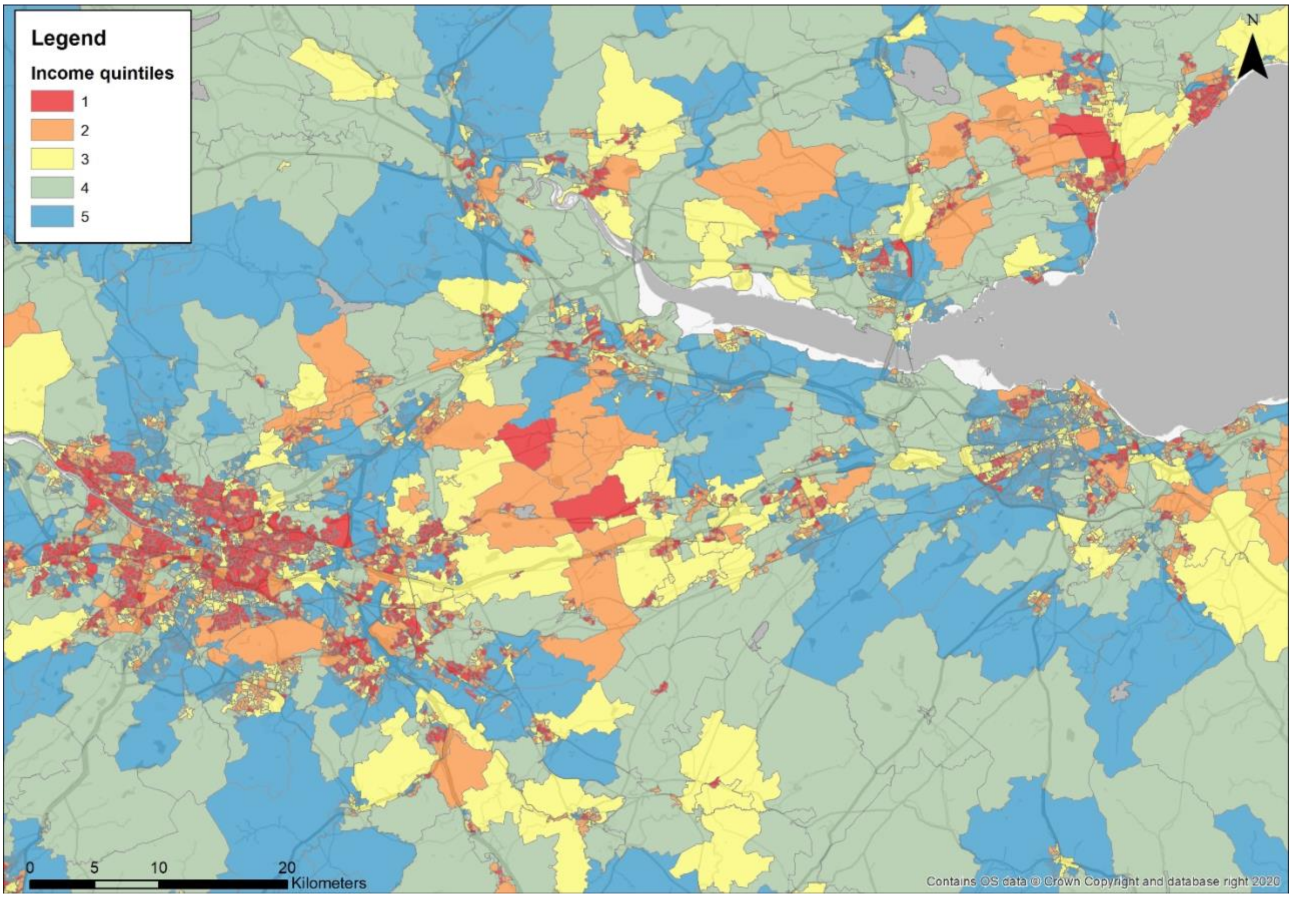


Figure 3-24 Distribution of children quintiles by LSOA (where 1 is the smallest proportion and 5 is the largest proportion)

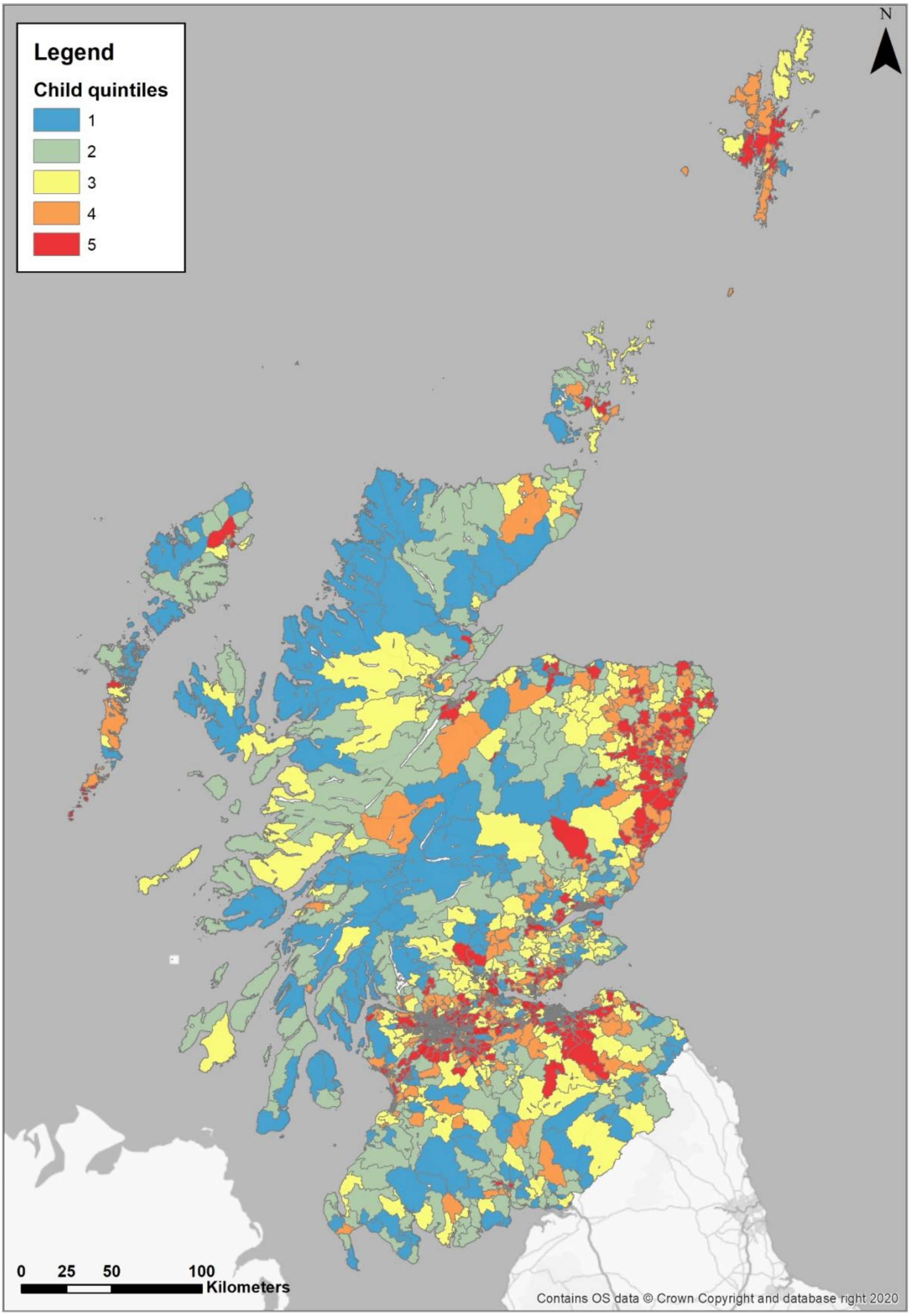


Figure 3-25 Distribution of elderly quintiles by LSOA (where 1 is the smallest proportion and 5 is the largest proportion)

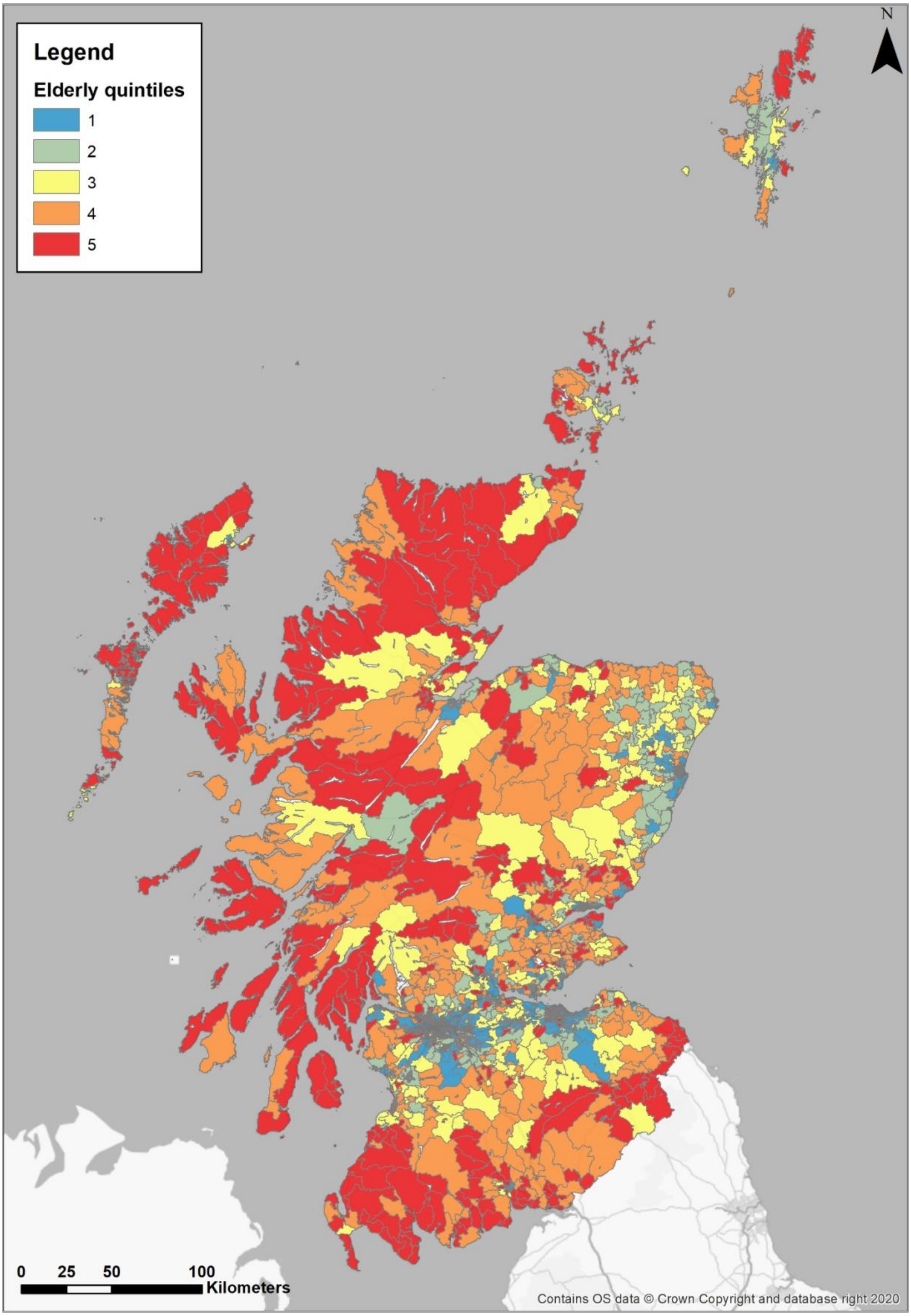
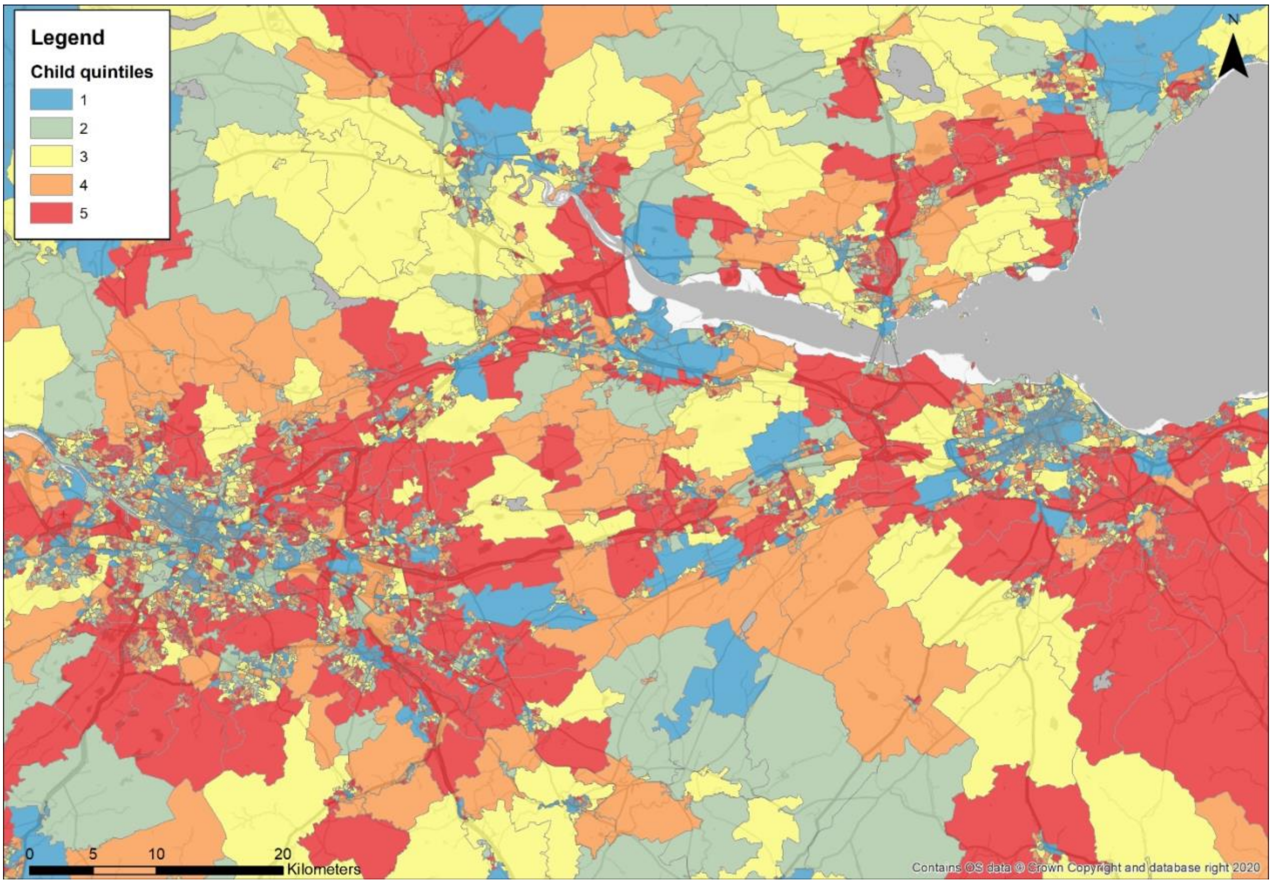
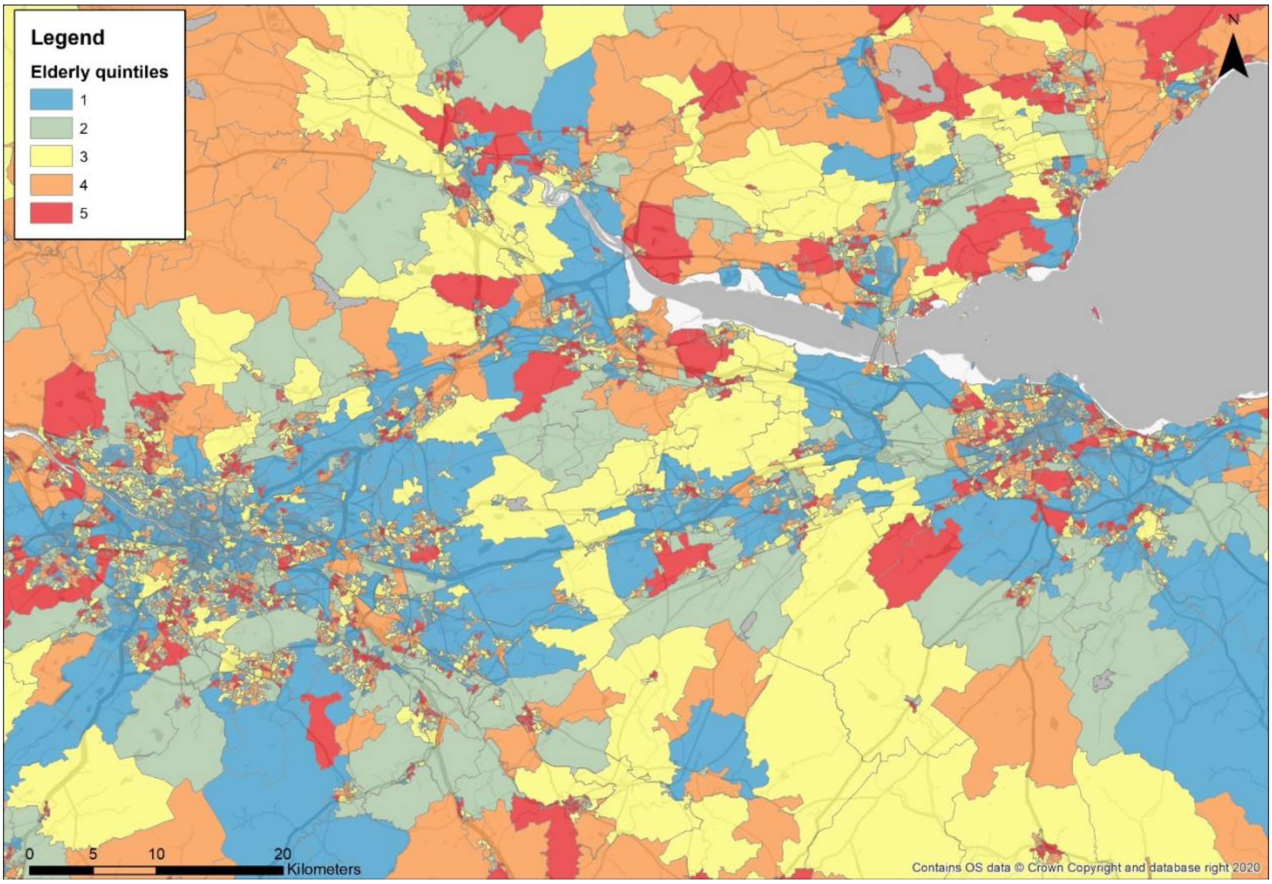


Figure 3-26 Distribution of children (top) and elderly (bottom) quintiles by LSOA (where 1 is the smallest proportion and 5 is the largest proportion) in the central belt





3.5.2.1 SIMD-Income

Table 3-28 through Table 3-30 present the average pollutant concentration, and average change in concentration under each of the options scenarios, split by SIMD-Income, proportion of children, and proportion of elderly quintiles respectively, relative to the Option 1 (baseline).

For Option 1 (baseline), the analysis shows that concentrations of $PM_{2.5}$ are highest for the most deprived groups, who tend to live in urban areas. Average reductions in concentrations between Option 1 (the baseline) and Options 2 and 3 are small for all quintile groups (0.00012 – 0.00091 µg m^{-3}). The options scenarios show the smallest reductions for the most deprived quintile group. The largest reduction was in Option 3 for mid-range quintile group 3. As the largest reductions were in rural areas, where less deprived quintile groups live, the ban on house coal would have a limited effect on reducing inequalities in pollution exposure by income group.

Table 3-28 $PM_{2.5}$ Quintile analysis – SIMD-Income quintile

Option	SIMD-Income	Most deprived				Least deprived
	Quintile domain	1	2	3	4	5
2019 Baseline	Average $PM_{2.5}$ concentration (µg/m^3)	5.8776	5.6995	5.4290	5.3826	5.6564
Option 2	Average $PM_{2.5}$ concentration (µg/m3)	5.8775	5.6993	5.4289	5.3825	5.6562
	Real difference in $PM_{2.5}$ concentration to baseline (µg/m3)	0.00012	0.00013	0.00012	0.00012	0.00016
	Relative difference in $PM_{2.5}$ concentration to baseline (%)	0.002%	0.002%	0.002%	0.002%	0.003%
Option 3	Average $PM_{2.5}$ concentration (µg/m^3)	5.8772	5.6987	5.4281	5.3819	5.6559
	Real difference in $PM_{2.5}$ concentration to baseline (µg/m^3)	0.00045	0.00077	0.00091	0.00068	0.00052
	Relative difference in $PM_{2.5}$ concentration to baseline (%)	0.008%	0.013%	0.017%	0.013%	0.009%

3.5.2.2 Children under 16 age group

The Option 1 (baseline) has the highest $PM_{2.5}$ concentrations for areas with the highest proportion of children, who tend to live in areas near cities. Like Income, average reductions in concentrations between Option 1 (the baseline) and Options 2 and 3 are small for all quintile groups (0.00011 – 0.00074 µg m^{-3}). The scenarios show the smallest reductions for the areas with the highest proportions of children. The largest reduction was in Option 3 for mid-range quintile group 3. As the largest reductions were in rural areas, where lower proportions of children live, the ban on house coal would have a limited effect on reducing inequalities in pollution exposure for children.

Table 3-29 $PM_{2.5}$ Quintile analysis – Children under 16

Option	Under 16	Lower proportion				Higher proportion
	Quintile domain	1	2	3	4	5
2019 Baseline	Average $PM_{2.5}$ concentration (μg/m^3)	5.6621	5.4711	5.5440	5.6516	5.7168
Option 2	Average $PM_{2.5}$ concentration (μg/m3)	5.6619	5.4710	5.5439	5.6515	5.7167
	Real difference in $PM_{2.5}$ concentration to baseline (μg/m3)	0.00020	0.00012	0.00012	0.00011	0.00011
	Relative difference in $PM_{2.5}$ concentration to baseline (%)	0.004%	0.002%	0.002%	0.002%	0.002%
Option 3	Average $PM_{2.5}$ concentration (μg/m^3)	5.6614	5.4704	5.5433	5.6510	5.7163
	Real difference in $PM_{2.5}$ concentration to baseline (μg/m^3)	0.00068	0.00072	0.00074	0.00063	0.00055
	Relative difference in $PM_{2.5}$ concentration to baseline (%)	0.012%	0.013%	0.013%	0.011%	0.010%

3.5.2.3 Elderly over 65 age group

Unlike the children quintile groups, the areas with the highest proportion of the over-65s have the lowest $PM_{2.5}$ concentrations in Option 1 (the baseline), as higher proportions of the elderly live in rural areas with better air quality than in cities. Average reductions in concentrations between Option 1 (the baseline) and Options 2 and 3 are small for all quintile groups (0.00010 – 0.00080 μg m^{-3}). Option 2 had the smallest reductions for the areas with the highest proportions of the elderly. The largest reductions in Option 3 were for areas with high proportions of the elderly, as there is more prevalent house coal use in rural areas. The ban on house coal reduces pollution exposure for the elderly.

Table 3-30 $PM_{2.5}$ Quintile analysis – Elderly (over 65)

Option	Under 16	Lower proportion				Higher proportion
	Quintile domain	1	2	3	4	5
2019 Baseline	Average $PM_{2.5}$ concentration (µg/m^3)	6.0634	5.7713	5.5627	5.3954	5.2527
Option 2	Average $PM_{2.5}$ concentration (µg/m3)	6.0632	5.7712	5.5626	5.3953	5.2526
	Real difference in $PM_{2.5}$ concentration to baseline (µg/m3)	0.00019	0.00014	0.00012	0.00010	0.00010
	Relative difference in $PM_{2.5}$ concentration to baseline (%)	0.003%	0.002%	0.002%	0.002%	0.002%
Option 3	Average $PM_{2.5}$ concentration (µg/m^3)	6.0629	5.7708	5.5620	5.3946	5.2519
	Real difference in $PM_{2.5}$ concentration to baseline (µg/m^3)	0.00045	0.00054	0.00075	0.00079	0.00080
	Relative difference in $PM_{2.5}$ concentration to baseline (%)	0.007%	0.009%	0.013%	0.015%	0.015%

3.6 Impact on Scottish firms

3.6.1 Introduction and method

This section presents an assessment of impacts on Scottish firms following the Scottish Government Business and Regulatory Impact Assessment template. It focuses on impacts on solid fuel suppliers, who are anticipated to be significantly impacted by the proposed Options. No other group of businesses is anticipated to experience a significant effect.

The approach to assessing impacts on Scottish firms took the following steps:

Step 1: Conduct research to profile the solid fuel supply sector in Scotland, gathering information on types of companies supplying solid fuels (e.g. quantity, size distribution, numbers of employees and range of fuels sold).

Step 2: Assess risks of impacts to fuel supply businesses. A key factor in risk to businesses is a supplier's options in response to a possible restriction. This in turn depends on their supply chains and if they already sell or have access to distribution of alternative less polluting fuels (such as dry biomass or low sulphur manufactured fuels). For example, where suppliers already sell both fuels subject to potential restriction and less polluting fuels, there may be less transitional risk. However, where suppliers sell a less diversified portfolio, or supplies of less polluting fuels are restricted or the market is structured in a way that presents barriers to new entrants, there may be higher risk to fuel supply firms. It was also important to understand differences in costs to suppliers and if they are able to pass this on to their consumers.

3.6.2 Profile of the Scottish fuel supply sector

A preliminary desk-based review identified a scarcity of publicly available information on the Scottish solid fuel supply sectors. To gather information, two targeted interviews were conducted (the information in the remainder of this section is based on the information gleaned in these interviews):

1. On the 24th October, with Wilma Brooks from the Coal Merchants' Federation
2. On the 15th November, with Jason Sutton the CEO of CPL, a large solid fuel supplier operating in Scotland and UK wide.

There are three main routes that consumers are supplied with solid fuels:

1. Merchants, from which fuel must normally bought by the pallet, and may be smaller local businesses or large national scale suppliers
2. Major retailers such as supermarkets and DIY stores, which are often themselves supplied by the large national suppliers
3. Online retail delivered by merchants usually by pallet.

The solid fuel supply sector in Scotland was noted to be diverse, with mixture of larger national suppliers and smaller local businesses. The Coal Merchants Federation has two categories of members: 'high sales' and 'low sales'.[43] 75% of members by number fall into the small category.

Both CPL and the Coal Merchants' Federation were of the opinion that all suppliers who sell coal will already also sell smokeless fuels, and as such would 'be ready' for the transition from coal to smokeless fuels that could be initiated by the proposed ban.

In terms of location of merchants, it was considered by the interviewees that the majority of suppliers to Scottish consumers are based in England (roughly 80% of suppliers based in England, and 20% split between Wales and Scotland). As such, the majority of suppliers for the UK as a whole have already stopped selling coal given the ban already in place in England.

In terms of supply chains, while there used to be indigenous Scottish coal mining often offering fuel at a discount to local people, the interviewees noted the vast majority of coal is now imported, and as such is subject to international prices. Smokeless fuels are manufactured in the UK from imported raw materials. There are three manufacturers of smokeless fuels in the UK: CPL, Oxbow, and M&G.

3.6.3 Impacts

Solid fuel suppliers may be affected in a number of ways as a consequence of the Options:

- Differences in quantities of different fuel sold (and overall quantity due to higher energy efficiency of alternative fuels)
- In swapping fuels sold, changes in material costs, revenue and profits
- Investment costs of purchasing of industrial dryer to produce dry wood may be an option chosen by some suppliers

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[43] Definitions of these categories were not possible to be disclosed

- Administrative and monitoring costs from enforcement of the regulation by public administration (Option 3).

Interviewees commented that the transition from coal to smokeless fuels from the England ban was a smooth process. Both CPL and the Coal Merchants Federation indicated that suppliers should not experience significant impacts from a proposed coal ban in Scotland as it is extremely likely that all suppliers already sell smokeless fuels. There is no difference in profitability between coal and smokeless fuels. There may be a slight decrease in fuel use and as such, solid fuel sales, as outlined in Section 3.4.2, however this was not regarded to be a concern by the industry stakeholders. As such they could easily adjust their business models and product portfolios in response. Interviewees believed it was highly unlikely that any would go out of business in response to a ban. The Coal Merchants Federation has already run a PR campaign targeting consumers in Scotland highlighting the benefits of smokeless fuels in Winter 2021, involving a leaflet campaign, and conducting television interviews, supported by Defra.

Suppliers of more rural and remote areas are more likely to be impacted as coal is likely to be a higher proportion of their sales, while suppliers serving cities and populated areas will already sell mostly smokeless fuels, especially in cities where there are smokeless zones. Some older local merchants may be more resistant to change in a similar way to consumers who may not wish to swap from coal due to having used it for decades.

In summary, the impacts of Option 2 or Option 3 on businesses are expected to be insignificant following discussions with industry stakeholders. In particular:

- The vast majority of suppliers are likely to already supply smokeless fuels and so will be able to easily transition away from selling coal. Indeed given many suppliers supply to Scotland and other parts of the UK, many have already stopped selling coal given the ban already in place in England (and NI??).
- Given coal is imported yet alternative, cleaner fuels involve processing in Scotland, there is unlikely to be a negative impact further up the solid fuel supply chain and in fact could have a positive impact for the UK more widely as there is greater demand for processing of manufactured fuels, potentially bringing more business and employment opportunities in this part of the supply chain.
- There is no difference in costs or profit margins for suppliers between coal and smokeless fuels.

3.7 Impact on competition

As in accordance with the Scottish appraisal guidance, we below present an assessment of impacts on competitiveness of the policy options. This is based on the following four questions as set out in the BRIA guidance.

Will policy options directly or indirectly limit the number or range of suppliers?

Neither policy option will directly reduce the number of suppliers in the market.

Based on discussion with the industry stakeholders, it is considered highly unlikely that suppliers will be put out of business in response to either Option 2 or 3. Many suppliers were noted to already sell smokeless fuels, and as such it is highly unlikely that the number of suppliers will be impacted indirectly.

Furthermore, any increase in administrative and monitoring costs are not considered to be large enough to either push new firms out of the market, or to disincentivise for new firms to enter the market. This remains the case when factoring in that the relative costs will be greater for smaller firms.

This analysis corresponds to the impact upon businesses' competitiveness assessed in the Defra 2019 Impact Assessment of the solid fuel ban in England. The assessment showed that there was expected to be a limited impact only upon the range of suppliers which will remain in the market, as most firms will be able to adjust to the measure and remain competitive.

Will policy options limit the ability of suppliers to compete?

No. The information campaign under Option 2 and the ban under Option 3 would both apply consistently across all solid fuel operators. Hence the ability for any one firm to compete would not be different to any other as all operators will work within the same requirements.

Will the policy option limit suppliers' incentives to compete?

No. The options do not directly affect the pricing or market dynamics for those solid fuels not subject to the ban. The ban will serve to remove part of the market for solid fuels, which may increase competitiveness for the supply of cleaner alternatives.

Will the measure limit choices and information available to consumers?

Yes but while the measure technically limits choices available to consumers as it removes the market for coal and high-sulphur fuels, interviewees suggest that alternatives should be readily available to the majority of consumers through similar supply routes. Furthermore, the use of alternative fuels is not anticipated to require significant modification or upfront investment by consumers to facilitate their use. Hence the transition for consumers from coal to smokeless fuels should be straightforward, regardless of their type of heating system.

3.8 Impact on International trade

Drawing on the information provided by interviewees, coal is currently all imported to Scotland, with no indigenous coal mining in Scotland. Smokeless fuels by contrast are made of imported raw materials in the United Kingdom. As such, the policy will lead to a reduction in coal imports to Scotland and possibly as a consequence for the UK as a whole. In substitution, it could lead to an increase in the volume of sales of manufactured solid fuels bought from the main UK manufacturers (3 based in England). Hence it is anticipated that there will be little difference to Scotland's trade balance, but a potential (small) positive impact on the UK's overall trade balance.

3.9 Impact on consumers

We have considered the key questions in the Scottish guidance on consumer assessments and believe the following questions to be relevant. We then include an analysis of each question in response.

Does the policy affect the quality, availability or price of any goods or services in a market? Does the policy affect the essential services market, such as energy or water?

Yes. The policy will remove the availability of coal and high-sulphur manufactured fuels from the market for consumers for their home energy heating.

As outlined in Section 3.2, households in rural areas are expected to be more affected by changes in regulations than those living in urban areas, as there is a higher use of solid fuels, particularly as the main fuel. Most solid fuel users are in mid-range deciles of deprivation.

Smokeless fuels are an alternative to coal (and low-sulphur fuel and alternative to high-sulphur) and offer benefits to the consumer through higher quality in the form of greater energy efficiency, and reduced air pollution (both indoor and outdoor).

At the time of the UK impact assessment of the same policy options considered as here for Scotland, coal was cheaper than smokeless fuels, and as such the ban results in an increase in fuel costs to the consumer, even when factoring energy efficiency. These costs will be born on average by people in more rural and remote communities, of middle income, who make greater use of solid fuels on average, as explored in Section 3.1. With that said, data gathered from industry stakeholders in the interviews has suggested that the price of coal and smokeless fuels has converged in recent years, driven in particular by the lack of indigenous UK coal production and therefore costs being driven by international prices of coal. As such, the sensitivity analysis conducted on fuel costs indicates that Option 3 is a net benefit to consumers in fuel cost reduction driven by the higher energy efficiency of smokeless fuels.

Furthermore, the use of alternative fuels is not anticipated to require significant modification or upfront investment by consumers to facilitate their use.

As noted above, interviewees suggest that suppliers of solid fuels are already likely to be able to offer cleaner alternatives. Hence these should be readily available to the majority of consumers through similar supply routes. As such, no significant risk for security of supply or a transition period is anticipated.

Some users of coal may find the ban challenging from the perspective of tradition, whereby they may have used coal for their heating for many years or decades, and as such will be hesitant to change even in the event of cost savings from energy efficiency. As such, the information campaign will be important to help notify such consumers of the benefits of smokeless fuels both in terms of energy efficiency but also health benefits.

Does the policy increase opportunities for unscrupulous suppliers to target consumers?

The policy does not impact the opportunity for unscrupulous suppliers. Because suppliers already sell alternatives, consumers will likely continue to use the same suppliers as before the policy option.

3.10 Digital impact

There will not be digital impacts from the policy options. The ban will not encourage or discourage digital technology.

4. Conclusions / findings

The main findings of the air quality assessment were that:

- Modelled domestic combustion contributed a relatively small amount (an average of 0.07%) to total $PM_{2.5}$ concentrations in the Option 1 (baseline).
- Option 2 had a limited effect overall on the reduction of $PM_{2.5}$ concentrations. There was a higher reduction in urban areas than rural, as there is higher use of wet wood in urban areas. The maximum reduction of 0.0013 µg m^{-3} for Option 2 was in Aberdeen; this reduction is 0.02% of total $PM_{2.5}$ concentrations and 0.3% of modelled domestic combustion concentrations in this location.
- Option 3 had a larger impact on reducing $PM_{2.5}$ concentrations than Option 2. The highest reductions were in rural areas, where there is a higher prevalence of house coal use. The maximum reduction of 0.020 µg m^{-3} for Option 3 was in Fort William; this reduction is 0.5% of total $PM_{2.5}$ concentrations and 15% of modelled domestic combustion in this location.

LSOA-average $PM_{2.5}$ concentrations showed similar trends to the overall air quality results:

- Overall, $PM_{2.5}$ concentrations are lower in rural areas than in more populated areas in the central belt and east coast. Differences between total concentrations between the Option 1 (baseline) and Options 2 and 3 are small.
- There is a limited decrease in average concentrations in most LSOAs for Option 2. The largest decreases (0.001 µg.m^{-3}) are in urban areas, e.g., in central parts of Aberdeen and Edinburgh.
- There is a larger reduction in concentrations in Option 3 than in Option 2 for many LSOAs, particularly in rural areas. The largest reductions (0.02 µg.m^{-3}) are seen in LSOAs in remote towns, e.g., Fort William and Kirkwall.

We have assessed PM impacts using a more detailed dispersion modelling and impact pathway approach compared with the Defra 2019 impact assessment, and as such the specific situation in Scotland is reflected: namely, given the use of solid fuels is highest amongst households in rural areas, there is also therefore low background concentrations of PM and low population densities in areas with the biggest impacts (i.e. reductions in air pollution). As such the associated reduction in exposure, and health improvements, are potentially smaller.

The cost-benefit analysis found that Option 2 results in a positive NPV, with the benefits of the air quality improvements and greenhouse gas emissions brought by the small shift in usage (from wet wood to dry wood, and from coal to manufactured solid fuels) outweighing the increased fuel costs and implementation costs of the policy (Table 4-1). For Option 3, the proposed ban of coal and limit on sulphur in smokeless fuels, the CBA findings depended on the fuel prices used for the analysis. When using price data from the 2019 Defra impact assessment, costs outweigh the benefits for the policy, driven largely by the increased fuel costs from coal being cheaper than manufactured solid fuels, which are not outweighed by the health and greenhouse gas emissions benefits (£293 per tonne of coal vs. £358-406 per tonne for smokeless fuels in 2019). Through the targeted interviews conducted as part of this study, stakeholders have indicated that the prices of these fuels have converged in recent years. As such, we also modelled the policy options with equivalent prices for coal and smokeless fuels, and this found a positive NPV of

£7,123,600 for Option 3. This highlights the strong sensitivity of the overall NPV result to the fuel price assumptions used. Given this data was provided by the industry stakeholders as part of the study, this could be considered a more up-to-date assessment of the impacts. Certain additional benefits have also not been monetised under such as additional benefits from SO_2 brought by the 2% sulphur limit on manufactured solid fuels, and additional health benefits brought by reductions in indoor air pollution.

Table 4-1 Breakdown of monetised impacts and overall NPV for the 2 policy options, 2023-2032 (£2020 discounted to 2022). Numbers rounded to 3 s.f.

Impact	Policy Option 2 (Information campaign)	Policy Option 3 (Coal ban and sulphur limit)	Policy Option 2 (With fuel price sensitivity)	Policy Option 3 (With fuel price sensitivity)
Fuel Costs	£263,000	£8,020,000	£142,000	-£4,120,000
Greenhouse gas Impacts	-£13,000	-£1,270,000	-£13,000	-£1,270,000
Health impacts	-£380,000	-£1,830,000	-£380,000	-£1,830,000
Implementation Costs	£64,800	£96,400	£64,800	£96,400
Total NPV	**-£65,200**	**£5,016,400**	**-£186,200**	**-£7,123,600**

Based on data gathered from industry stakeholders, impacts on businesses are expected to be small. Suppliers already sell alternative fuels and there is no difference in profit margins between banned and alternative fuels. Impacts on consumers will depend on fuel prices as availability and number of suppliers will remain constant.

The analysis has therefore found that Option 2 is a policy that brings benefits in health and greenhouse gas emissions that exceed the costs. Policy Option 3 results in health benefits of £1.8m over the appraisal period and greenhouse gas emissions benefits of £1.3m. Using fuel price data from the 2019 Defra impact assessment, fuel costs are found to increase and exceed the benefits of the scenario as a whole. However, using more up to date price data from stakeholders, a large overall benefit is brought by the policy when considering the greenhouse gas emissions benefits, air quality health benefits, and the fuel efficiency savings brought by the higher efficiency alternative fuels.

Appendix 1 Transcript of interview with Solid Fuels Scotland

- **What is the profile of the solid fuel supply sector in Scotland?**
  - **For example, what is the number and size (Number of employees) of companies, and where are they located? Are there different types of businesses serving different areas/ communities- e.g. those that supply urban areas vs. more remote communities?**
  - **What types of fuels are sold by these suppliers?**

In England and Wales Solid Fuels Association members join on how much they sell, however in Scotland there are just 2 categories of members, high sales and low sales.

No information on what fuels suppliers sell is available. All suppliers sell coal and smokeless fuels and so are ready for the transition.

In England, the transition from coal to smokeless fuels was straightforward- might be more difficult in Scotland as more rural/remote homes. In terms of remote area suppliers, only island of Orkney suppliers are members of Solid Fuels.

In terms of UK solid fuel suppliers, 4/5 suppliers are based in England, 1/5 split between Wales and Scotland. As English suppliers will stop selling coal fully in 2023, (Grace period of UK ban ends), this could lead to increased costs.

- **Do you have information on the prices of different fuels in Scotland?**

Since the England coal ban, coal price has increased. Coal used to be cheaper than smokeless fuel (although smokeless fuel lasts longer/is more efficient so this balanced out for consumers). Smokeless fuel however is now cheaper than coal. It is hard to get consumers to swap who are set in their ways however.

- **What would be the impact of a ban of coal and higher sulphur manufactured fuels, and potential reduced sales of wet wood, in terms of:**
  - **Ability to sell alternative fuels- Are they already sold, and if not, will it be possible to switch?**
  - **What are the costs of shifting sales to these alternative fuels, e.g. impacts on profitability?**
  - **What would be the impacts on supply chains of the ban- Would some go out of business? Would there be lost employment? Would this affect suppliers in certain locations more?**
  - **Any other increased costs?**

More remote suppliers will be more impacted as coal will be a higher proportion of their sales, also will be smaller/more vulnerable companies potentially. In cities/ populated areas, smokeless fuels will already be the majority of sales so small impacts of the policy.

England banned coal 2021 in outlets, only approved sellers could sell 2022-2023 before full ban

Coal is imported, smokeless fuels domestically produced (With imported raw materials). Hard to say if significant difference in profitability for suppliers between the two types of fuel.

The ban shouldn't put companies out of business, but lots of merchants are older and resistant to change.

Industry backs low sulphur fuels. High sulphur fuels do tend to be slightly cheaper- which could have been a benefit regarding the energy crisis.

High sulphur comes from the pet coke raw material in the fuel- high sulphur pet coke used to be much cheaper than low sulphur. However, the UK/ England policy reduced demand for high sulphur fuels and so increased cost.

Wood is a very different supply network, more informal supply which will often be wet. Formal Merchants already selling dry wood/ready to burn from main suppliers who kiln dry to supply England.

- **What are the supply chains of these fuels, are any reliant on international imports?**

Content of manufactured fuel comes from abroad (pet coke, anthracite). Electricity costs to make the fuels have gone up.

3 main fuel manufacturers in England, 1 in Ireland.

Coal is imported fully.

Other questions

Solid fuels consumers buy fuel in advance and therefore know the cost of their energy in advance. Compared to Gas and electricity which is harder to budget.

Some appliances can only run on coal i.e. not smokeless fuels (boilers). Scotland has more boilers than England, using solid fuel for whole house i.e. not as a secondary heating source.

Scotland remote areas don't have gas and so reliant on solid fuels.

Solid fuels association already did information campaign on smokeless fuels and their benefits- winter 2021, hired PR company, leaflets, tv interviews etc. Defra contributed/funded.

In England- any wood under 2 cubic metres has to be classed as "ready to burn" <20% moisture, usually kiln dried

Sales of wood have increased.

Appendix 2 Transcript of interview with CPL Industries

- **What is the profile of the solid fuel supply sector in Scotland?**
    - **For example, what is the number and size (Number of employees) of companies, and where are they located? Are there different types of businesses serving different areas/ communities- e.g. those that supply urban areas vs. more remote communities?**
    - **What types of fuels are sold by these suppliers?**

Diverse sector, made of larger national suppliers and smaller local/regional businesses.

Main ways for consumers to buy: Some sell through local merchants (mostly must buy a whole pallet which cost ~£500), also major retailers (supermarkets/DIY stores) which are often supplied by CPL. This is a growing route to market as price per unit is cheaper and consumers can buy smaller quantities- Especially for occasional city users. Internet retailers- Delivered through pallet network or local merchant. CPL also does this e-commerce side. CPL has 2 depots in Scotland.

CPL sells all fuel types- smokeless, coal, and wood products

Most national suppliers/groups will have already phased out coal (UK level supply chain). Regional retailers this may not be the case.

CPL national supplier but does sell coal in Scotland still (depot-driven)

- **Do you have information on the prices of different fuels in Scotland?**

Pricing has converged between retailers, merchants and local suppliers

Volatile commodity costs at the moment.

In the past discount Scottish coal from remaining mines- fuel of choice for many local people.
Now no indigenous coal mining in Scotland, so all coal at international prices.

Pricing between coal and smokeless fuels has now converged as subject to global prices. Coal actually now more expensive than smokeless fuels, including low sulphur.
People still use because of habit/tradition. Most of these users would not have a problem changing- actually smokeless fuels are cheaper £/kw. Consumers buy what they've always bought. Smokeless is less polluting and more cost effective- win win

High sulphur smokeless fuels- Scotland becomes the only place where allowed to be burned.

- England already sulphur limit
- Ireland from 1 Nov sulphur limit

High sulphur smokeless fuels if unchanged policy will be moved to Scotland as only market. CPL still sells some high sulphur fuels.

Petroleum coke and other raw materials for smokeless fuels imported, and manufactured in the UK. High sulphur pet coke is always cheaper.

3 producers of smokeless fuels in UK (CPL, Oxbow, M&G).

High sulphur would be typically 6% sulphur content
Low sulphur 2% i.e. at the limit

- **What would be the impact of a ban of coal and higher sulphur manufactured fuels, and potential reduced sales of wet wood, in terms of:**
    - **Ability to sell alternative fuels- Are they already sold, and if not, will it be possible to switch?**
    - **What are the costs of shifting sales to these alternative fuels, e.g. impacts on profitability?**
    - **What would be the impacts on supply chains of the ban- Would some go out of business? Would there be lost employment? Would this affect suppliers in certain locations more?**
    - **Any other increased costs?**

Would be surprised if any merchants that sell exclusively coal and not smokeless even in rural areas where not near smokeless zones.

CPL already focuses on dry wood.

More forestry in Scotland, wood moisture might be a more sensitive topic.

No difference in profit margins between coal and smokeless for suppliers. Fines raw material -> turning to briquettes similar cost to coal

Higher raw material costs for low sulphur gets passed on to consumers.

- **What are the supply chains of these fuels, are any reliant on international imports?**

Stated above.

- **Any reports or data on the above you are aware of would be much appreciated**

Other

Easier to control spend with solid fuels.
Energy security- Fuel just stored in home
Cost per kw hour competitive with heating oil for off grid users and gas for on grid. Easy to heat one room

Appendix 3 Spatial distribution of solid fuel use

This section includes maps to support Section 3.3.3.

The number of households using solid fuels based on the Home Analytics dataset, split by urban/rural classification, was used to distribute the total $PM_{2.5}$ emissions spatially across Scotland in a 1 km^2 emissions grid. The number of households using solid fuels as a primary fuel type was added to 10% of the houses using solid fuels as a secondary fuel type; this weighting reflects the estimate that a secondary fuel would provide 10% of the heat in a property[44].

The figures below display the weighted house counts per 1 km^2 across different regions of Scotland. Remote towns such as Fort William and Kirkwall have the highest weighted counts per 1 km^2 as many households use solid fuel as the main fuel. Aberdeen has the highest weighted count per 1 km_2 in urban areas as it has high numbers of properties using solid fuels as a secondary fuel type.

[44] Table 11, p. 224, https://www.bre.co.uk/filelibrary/SAP/2012/SAP-2012_9-92.pdf

Figure A3.1 Weighted house counts (number of houses using solid fuel as primary + 10% of secondary solid fuel houses) per 1 km^2 in urban areas (only urban areas displayed)

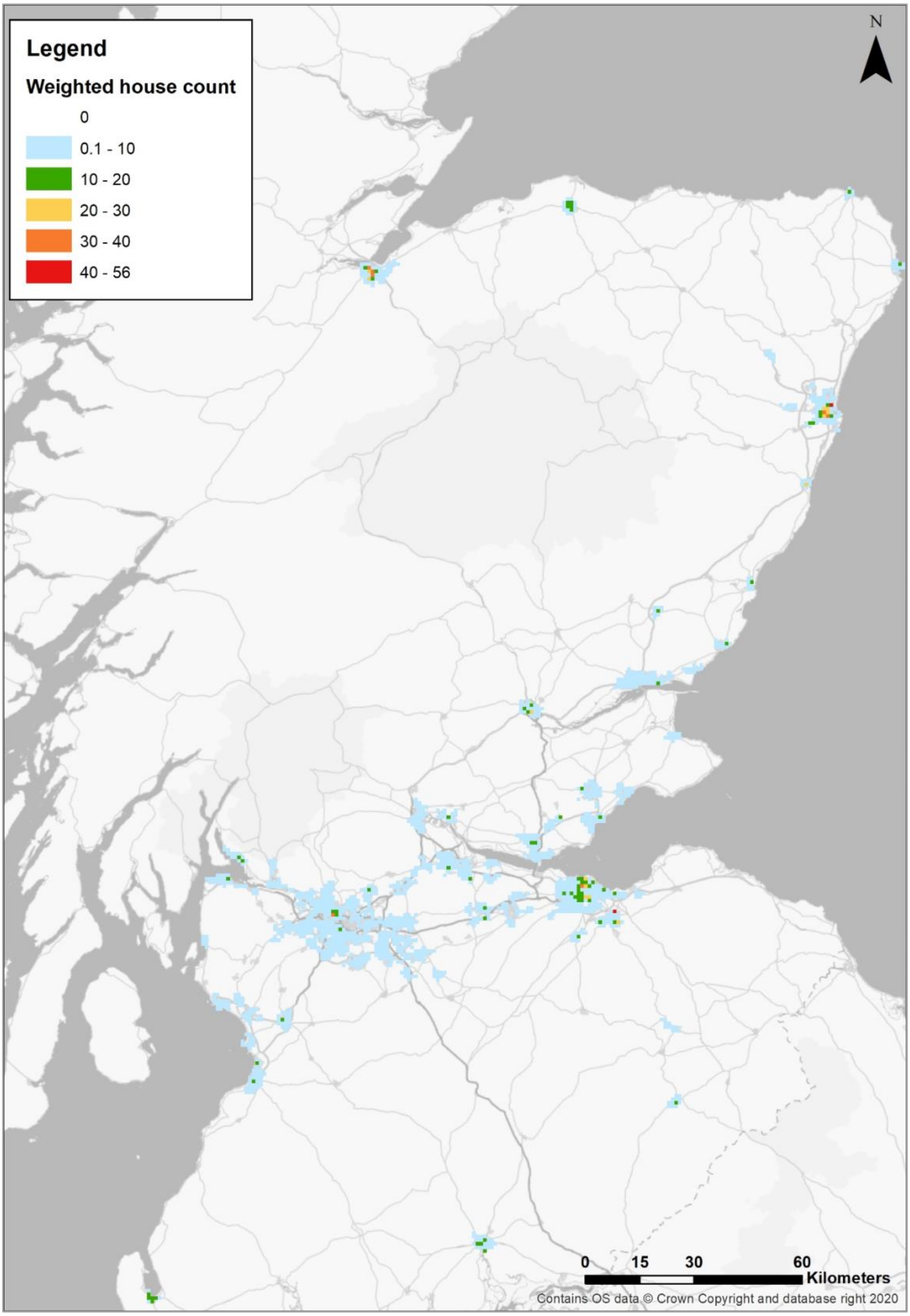


Figure A3.2 Weighted house counts (number of houses using solid fuel as primary + 10% of secondary solid fuel houses) per 1 km^2 in rural areas (Northern Isles and northeast coast)

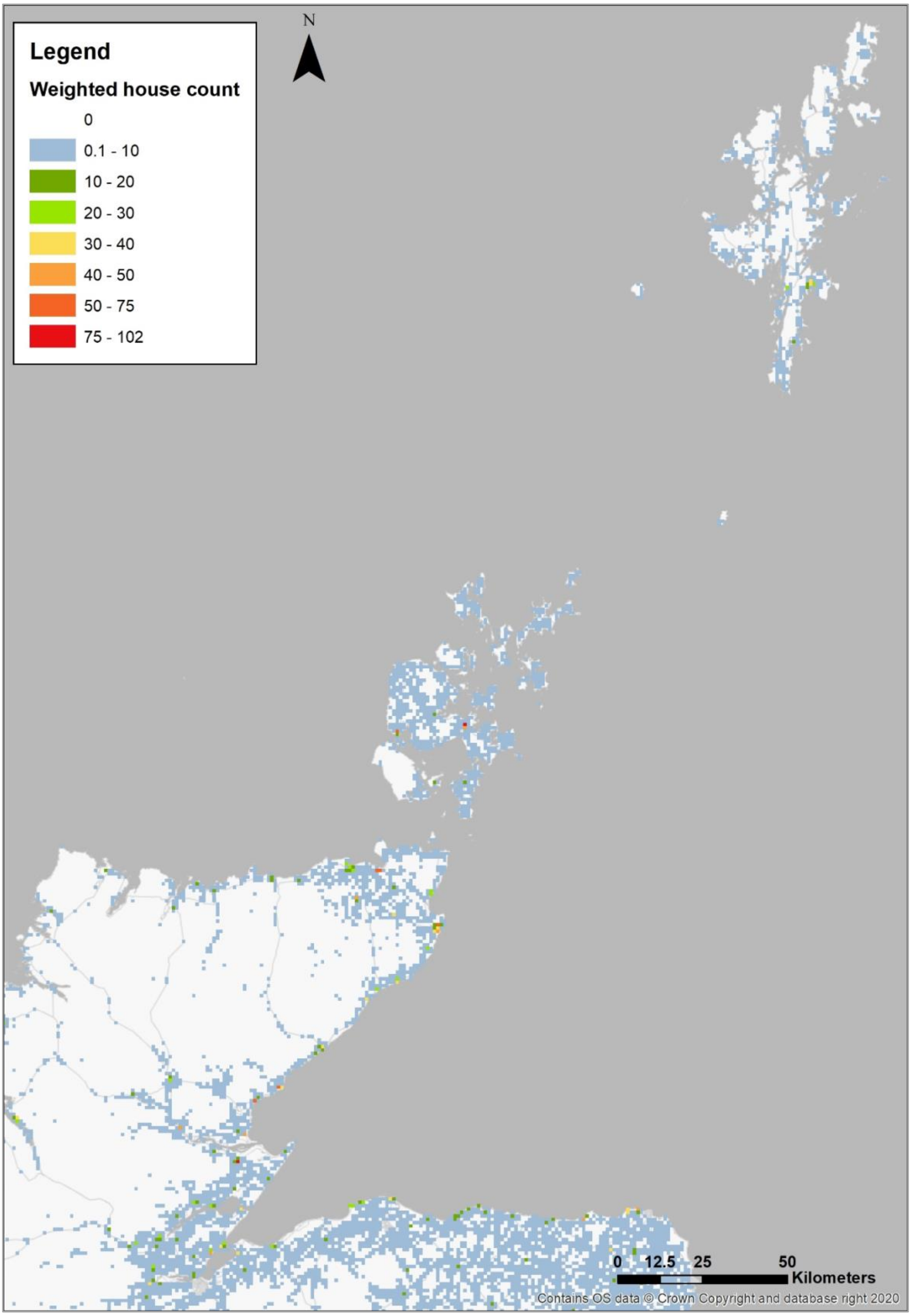


Figure A3.3 Weighted house counts (number of houses using solid fuel as primary + 10% of secondary solid fuel houses) per 1 km^2 in rural areas (northern mainland and Outer Hebrides)

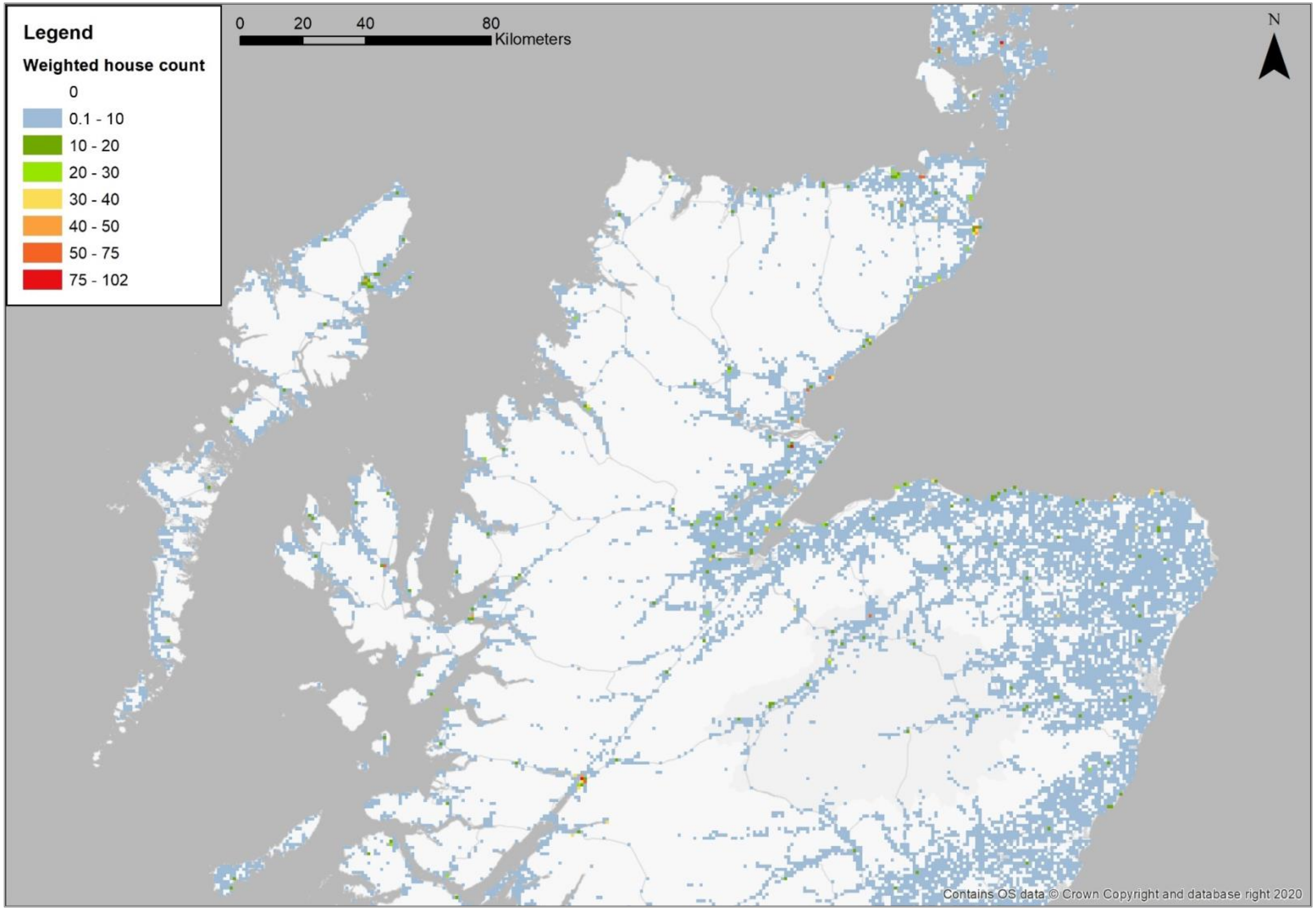
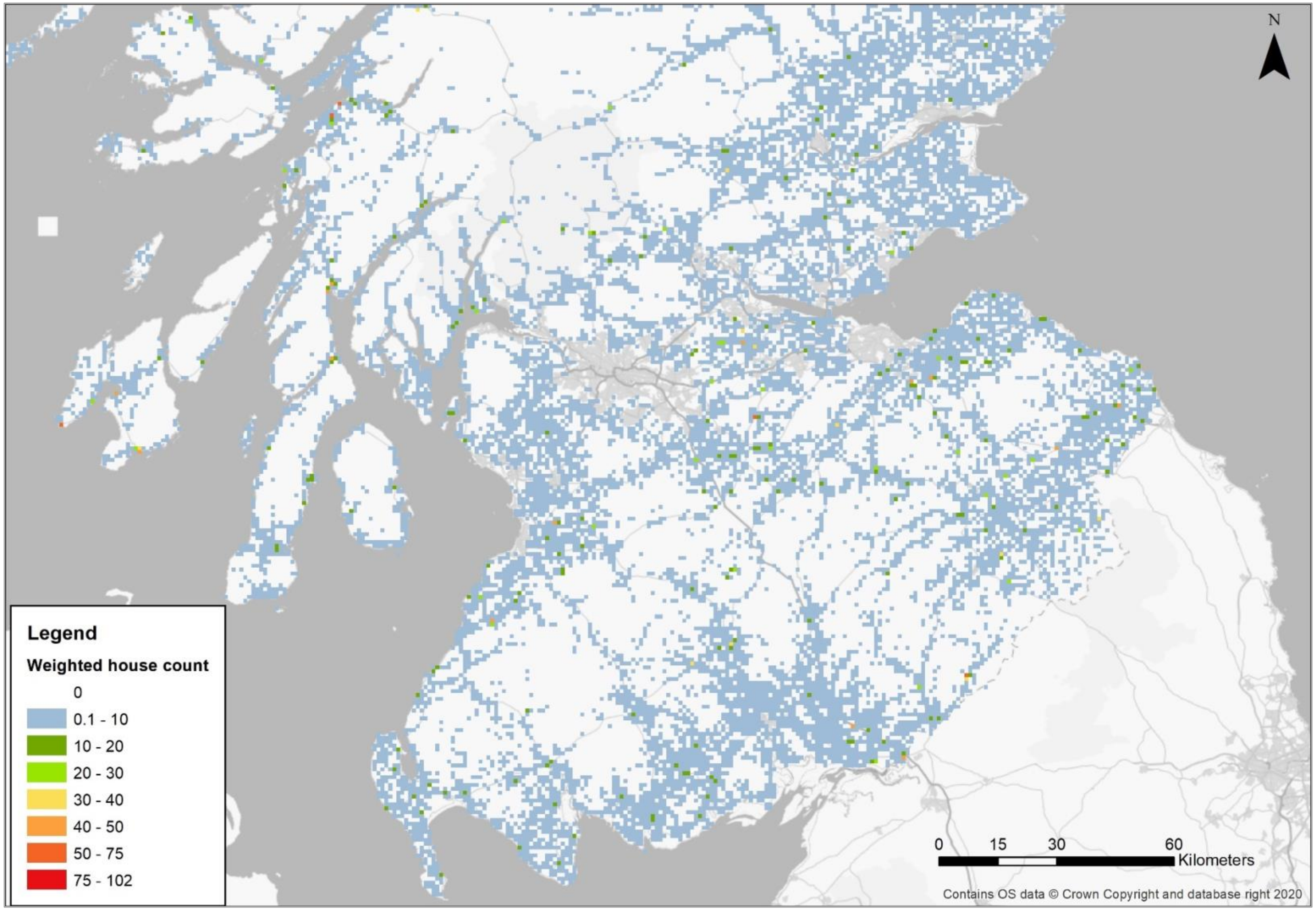


Figure A3.4 Weighted house counts (number of houses using solid fuel as primary + 10% of secondary solid fuel houses) per 1 km^2 in rural areas (central and southern Scotland)



N
Legend
Weighted house count
0
0.1 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 75
75 - 102
0 15 30 60 Kilometers
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