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Emissions from households and other small combustion sources and their reduction potential

TSAP Report #5

Version 1.0

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Executive Summary

To explore the potential contribution of Eco-design product standards to the achievement of the targets of the Thematic Strategy on Air Pollution, this report develops different scenarios for implementations of more stringent emission limit values to small combustion sources.

In 2005, small sources of solid fuel combustion contributed about one third to total EU-27 emissions of fine particles (PM2.5) and black carbon (BC), and less than 10% to total non-methane volatile organic compounds (NMVOC) and nitrogen oxides (NO_x).

For PM2.5, it is estimated that an implementation of Eco-design standards would lead to significant reductions of emissions from small sources compared to the baseline projection. If the discussed Eco-design standards were only introduced for air pollution emissions (without requirements for improved energy efficiencies), PM2.5 from these sources would decline by 38% in 2020 relative to 2005 level (compared to a 21% cut in the current legislation case). By 2030, the Eco-design standards would reduce PM2.5 emission by 70% relative to 2005 (the current legislation only by 40%), and in 2050 these standards would lead to 83% lower emissions, while the baseline results in only 50% relative to 2005. These calculations assume no premature scrapping of existing equipment.

These emission reductions would account for a sizeable fraction of the total PM2.5 emissions from all sectors in the EU-27. In 2020, introduction of the Eco-design standards would cut total PM2.5 by 7%, in 2030 by 16%, and in 2050 by almost 20%.

Black carbon emissions from small combustion sources, which have recently received increasing attention because of their negative health and climate effects, would be reduced by the Eco-design standards by 25% in 2020 and by 75% in 2050.

Although small combustion sources make only limited contributions to NMVOC emissions (8% in 2005), Eco-design standards could reduce these emissions in 2020 by 50% relative to 2005 (compared to a 25% cut envisaged for the baseline), by 80% instead of 50% in 2030, and by more than 90% compared to 60% in 2050.

Even larger emission reductions can be achieved if Eco-design standards would also affect energy efficiency standards, as highlighted by a scenario with ambitious assumptions on energy efficiency improvements for small sources. However, this scenario assumes rapid turnover of existing (inefficient) devices including premature scrapping before the end of its regular lifetime. In reality, such a scenario would be difficult to realize in the short run, since it would require a very fast replacement of the existing capital stock by new equipment and unlimited availability of pellets.

More information on the Internet

More information about the GAINS methodology and interactive access to input data and results is available at the Internet at http://gains.iiasa.ac.at/TSAP.

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List of acronyms

BAU	Business as Usual
BAT	Best Available Technology
BC	Black carbon
CAFE	Clean Air for Europe Programme
CHIMERE	A multi-scale model for air quality forecasting and simulation
CLE	Current legislation emission controls
CLRTAP	UN Convention on Long-Range Transboundary Air Pollution
CO	Carbon monoxide
EGTEI	Expert Group on Techno-Economic Issues
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long-range transmissions of air pollutants in Europe
ESP	Electrostatic precipitators
EU	European Union
EUP	Energy using products
GAINS	Greenhouse gas Air pollution INteractions and Synergies model
IIASA	International Institute for Applied Systems Analysis
MCE	Maximum Control Efforts scenario
MTFR	Maximum Technically Feasible Reduction scenario
NMVOC	Non-methane Volatile organic Compounds
OC	Organic carbon
PM2.5	Fine particles with an aerodynamic diameter of less than 2.5 µm
PM10	Fine particles with an aerodynamic diameter of less than 10 µm
PRIMES	-Energy model developed by the National Technical University of Athens
SME	Small and medium enterprises
NO_x	Nitrogen oxides
SO_2	Sulphur dioxide
TSAP	EU Thematic Strategy on Air Pollution
TSP	Total suspended particles

1 Introduction

In its 2005 Thematic Strategy on Air Pollution (TSAP), the European Commission outlined a road map to attain 'levels of air quality that do not give rise to significant negative impacts on, and risks to human health and environment' (CEC, 2005). It established health and environmental objectives and emission reduction targets for the main pollutants.

In 2011, the European Commission has launched a comprehensive review and revision of its air policy, in particular of the 2005 Thematic Strategy on Air Pollution and its related legal instruments. The review entails a more detailed evaluation of the different sources that contribute to current and future exposure (source apportionment) and an estimate of the potentials and cost-effectiveness of further emission reductions from these sources.

In recent years, air pollutant emissions from small combustion sources have grown in importance for three reasons. First, there is increasing concern about the threat to human health from the exposure to fine particulate matter. Combustion of solid fuels (wood and coal) in small stoves is a major source of primary emissions of PM2.5 to the atmosphere. Second, stringent emission control legislation has been established for other sources of pollution, so that over time (uncontrolled) small combustion sources are developing into the main sources of PM emissions. Third, greenhouse gas strategies and targets for renewable energy favour enhanced use of wood and other biomass in small combustion sources, which would lead to even higher emissions if combustion would not take place in most advanced installations.

Whereas emissions from large sources decreased as a result of recent EU legislation, small sources remain largely unregulated at the EU level. The Eco-design directive (EC 2008) provides the possibility to impose Eco-design requirements for energy-using products through implementing measures specific to each product group. Determination of these requirements is preceded by preparatory studies with the aim of identifying ways to improve the environmental performance of products.

A preparatory study for the Eco-design of small solid fuels combustion installations (Mudgal et al., 2009a-c) assessed the potential to reduce emissions from this installation category for a set of potential emission limit values.

As an input to the review of the Thematic Strategy on Air Pollution, this report assesses current and future emissions from households and other small combustion sources for the baseline scenario that is currently being developed for the review of the Thematic Strategy. It estimates to what extent implementation regimes of Eco-design product standards could reduce emissions in the future below those that are estimated for the baseline case. In a further step, analysis will then quantify the impacts of such emission reductions on a variety of air quality indicators including compliance with air quality limit values.

To explore the potential contribution of Eco-design product standards to the achievement of the targets of the Thematic Strategy on Air Pollution, this report summarizes the earlier study on possible limit values for Eco-design standards of Mudgal et al., 2009a-c. Possible implementation regimes of the standards presented in this report are translated into emission control scenarios for the GAINS (Greenhouse gas – Air pollution Interactions and Synergies) model (Amann et al., 2011) and applied to the activity and emission control projections that are prepared for the 2013 review of the Thematic Strategy on Air Pollution.

The remainder of this report is organized as follows: Section 2 describes the methodology of the assessment for the analysis. Section 3 introduces the different emission control scenarios that have been developed to derive the scope for further emission reductions in the domestic sector. It presents emission reductions that emerge from the different scenarios and discusses emission control costs. Finally, Section 4 summarizes the outcome of the study and formulates conclusions. Emission data for individual Member States are provided in the Annex.

This report presents draft findings from the first phase of the Service contract. It should provide a basis for consultations with experts from different stakeholders, whose feedbacks will be incorporated into the final version of the report to be presented by the end of 2012.

2 Methodology

To explore the potential contribution of Eco-design product standards to the achievement of the targets of the Thematic Strategy on Air Pollution, this report summarizes the earlier study on possible limit values for Eco-design standards of Mudgal et al., 2009a-c. Implementation regimes of the standards presented in this report are translated into emission control scenarios for the GAINS (Greenhouse gas – Air pollution Interactions and Synergies) model (Amann et al., 2011). The impacts of such changes are examined for two different pathways of economic activities and energy consumption:

- the TSAP-2012 baseline scenario that relies on the PRIMES 2010 reference scenario, which has been developed for the Communication of the European Commission on a 'Roadmap for moving to a competitive low carbon economy in 2050' (CEC, 2011), and
- a stringent climate policy (decarbonisation) case, i.e., the 'Global Action with Effective and Widely accepted Technology' scenario that has been developed with the PRIMES model for the communication of the European Commission on a 'A roadmap for moving to a competitive low carbon economy in 2050' (CEC, 2011).

This report focuses on emissions from solid fuel use (biomass and coal) in small combustion sources, and presents emissions of PM2.5, PM10, black carbon (BC) and ozone precursors (NMVOC and NO_x). Emissions of other air pollutants (SO_2, CO, organic carbon (OC) are also calculated, but not presented in the report. Detailed emission estimates for all pollutants and Member States are available from the GAINS online model via the Internet (http://gains.iiasa.ac.at/models/).

2.1 Emission factors suggested in the preparatory study for Eco-design

The preparatory study on the Eco-design of small solid fuels combustion installations (Mudgal et al., 2009a-c) assessed the potential to reduce emissions from this installation category. In particular, it presented the emission factors listed in Table 2.1 as an indication for potential emission limit values.

Table 2.1: PM (TSP) emission factors for conventional combustion equipment and for the best available technology as in the Eco-design study [mg/m^3]

Combustion device	*Conventional*	*Best Available Technology (BAT)*
Closed fireplace	164	60
Cooker	171	90
Stove	164	50
Boiler	138	40
Pellet stove	75	30
Pellet boiler	50	25
Coal stove	426	200
Coal boiler (automatic)	50	40

These emission factors refer to new installations tested under laboratory conditions as in the certification tests. Emissions under real life operating conditions have been shown to be significantly larger and depend on many site- and country-specific factors (Boman et al. 2011; Nussbaumer 2010).

The Eco-design study compares ‘conventional’ installations with the best available technology (BAT). For each type of combustion device, components that are typically included in the design of BAT installations are presented. Such components comprise, where relevant, primary and secondary air distribution and control, combustion chambers with lining, fan assisted heat exchange, advanced control loops, catalytic afterburning, boilers for indirect heating, as well as (for pellet stoves and boilers) automatic fuel feed and ash removal. Secondary abatement (electrostatic precipitators) is treated as a separate option and is not defined as BAT.

The Eco-design analysis has been conducted for the aggregated EU-27 using average conditions, but taking into account emission factors for each type of boiler or stove during certification in laboratory conditions. The authors emphasize the large uncertainties associated with measuring emissions of PM and NMVOC from small combustion installations. Emissions depend heavily on fuel quality (humidity) and the actual operating conditions. Consequently, real-life emissions are quite different from those measured in the laboratory. Besides, several test procedures exist and there is no agreement which procedure would provide results that are representative for real life emissions. Thus, the quantifications of the emission mitigation potentials in the Eco-design study are indicative only, and provide an order of magnitude estimate of the emission reductions achievable through implementation of the BAT technologies compared with the baseline case.

The assessment of the mitigation potential in the Eco-design study was performed done for a Business as Usual (BAU) scenario up to 2025. This scenario assumed a continuation of the current trends in sales of conventional stoves and boilers, representing the equipment currently available on the market. As an alternative, a ‘Best Available Technology’ (BAT) scenario was developed to demonstrate the effects of using combustion equipment with the best performance regardless of the costs to the consumers. A redesign cycle of four years was assumed. This gives the producers time to change their product portfolio to include production of installations with BAT characteristics. Under the assumptions adopted in the preparatory study, introduction of BAT would reduce emissions of PM in 2025 by about one fourth below the BAU level.

It should be mentioned that the activity scenarios (consumption of solid fuels) that have been used in the assessment as well as assumptions about the structure of boilers and stoves are different from those of the TSAP-2012 baseline scenario for the revision of the TSAP.

2.2 Emission estimates by the GAINS model

2.2.1 Emission calculation for residential and commercial sources

To estimate the impact of the indicative Eco-design standards on emissions, air quality and environmental impacts in the context of the TSAP revision, this report employs the Greenhouse gas – Air pollution Interactions and Synergies (GAINS) model (Amann et al., 2011). The GAINS model calculates emissions at the national level for different fuel and combustion device types. Estimates cover PM2.5, PM10, as well as ozone precursors (NMVOC and NO_x). Emissions of other pollutants (SO_2, CO, CH_4, BC and OC) are also calculated in GAINS, but are not discussed in detail in this report.

Emissions from fuel combustion in the residential–commercial sector in a given year are calculated according to the following formula:

$$Em_p = \sum_{fc} (FC_{fc} * EF_{fcp})$$

with:

- EM_p total national emission of pollutant *p*. [Unit: kt]
- FC_{fc} consumption of fuel *f* in combustion device *c*. [Unit: PJ]
- EF_{fcp} emission factor of pollutant *p* for combustion device *c* using fuel *f*. [Unit: g per MJ]

The emission factor EF_{fcp} is estimated for each combustion device type and takes into account (where relevant) add-on control technologies (e.g., cyclons or electrostatic precipitators for particles removal).

The GAINS model accounts energy use and emissions of the residential and commercial sector under the so-called DOMESTIC sector. This is split into residential (DOM_RES), commercial (DOM_COM) and other (DOM_OTHER) sources. The latter include other services, which are not included in the commercial sector as well as stationary sources from agriculture. Emissions from the DOMESTIC sector are calculated in GAINS based on sectorial energy projections from the PRIMES model (Capros et al., 2010).

The GAINS analysis reproduces national emission inventories for the year 2005 and provides emission projections up to 2050. Results up to 2030 are shown in this report at the national level. For 2050, only aggregated results for all Member States (EU-27) are presented.

Detailed estimates are available from GAINS online model over the Internet (http://gains.iiasa.ac.at/models/).

2.2.2 Emission control technologies considered in GAINS

GAINS calculates emissions of air pollutants for several types of combustion installations. The technologies/sources that are considered in GAINS for solid fuel combustion in small installations, i.e., boilers and stoves with different emission characteristics, are listed in Table 2.2.

Table 2.2 GAINS technologies for controlling emissions from solid fuel combustion in the DOMESTIC sector

Fuel	*Device type, technology*	*GAINS code*
Wood	Fireplace, improved	FPLACE-FP_IMP
Wood	Fireplace, new	FPLACE-FP_NEW
Wood, coal	Medium boiler automatic, cyclone	MB_A-MB_CYC
Wood	Medium biomass boiler automatic, high efficiency deduster	MB_A-MB_HED_F
Pellets	Medium boiler automatic, pellets	MB_A-MB_PELL
Wood, coal	Medium boiler manual, cyclone	MB_M-MB_CYC
Wood	Medium biomass boiler manual, high efficiency deduster	MB_M-MB_HED_F
Pellets	Medium boiler manually fed, pellets	MB_M-MB_PELL
Coal	Medium coal boiler automatic, high efficiency deduster	MB_A-MB_HED
Wood	Single house biomass boiler, improved	SHB_M-SHB_IMP_B
Wood	Single house biomass boiler, new	SHB_M-SHB_NEW_B
Wood	Single house biomass boiler automatic, high efficiency deduster	SHB_A-SHB_HED
Pellets	Single house boiler manual, pellets	SHB_M-SHB_PELL
Pellets	Single house boiler manual, pellets with electrostatic precipitator	SHB_M-SHB_PLESP
Coal	Single house coal boiler, new	SHB_M-SHB_NEW_C
Wood	Biomass stove for cooking, improved	STOVE_C-STV_IMP_B
Wood	Biomass stove for cooking, new	STOVE_C-STV_NEW_B
Coal	Coal stove for cooking, improved	STOVE_C-STV_IMP_C
Coal	Coal stove for cooking, new	STOVE_C-STV_NEW_C
Wood	Biomass stove for heating, improved	STOVE_H-STV_IMP_B
Wood	Biomass stove for heating, new	STOVE_H-STV_NEW_B
Wood	Biomass stove for heating, electrostatic precipitator	STOVE_H-STV_ESP_B
Pellets	Biomass stove for heating, pellets	STOVE_H-STV_PELL
Pellets	Biomass stove for heating, pellets and electrostatic precipitator	STOVE_H-STV_PLESP
Coal	Coal stove for heating, improved	STOVE_H-STV_IMP_C
Coal	Coal stove for heating, new	STOVE_H-STV_NEW_C

Note: High efficiency deduster - electrostatic precipitator or fabric filter

In GAINS, technologies are defined primarily along their reduction features for particle (PM) emissions. The possibility to reduce NO_x emissions from small sources is limited due to low combustion temperatures, as NO_x originates mainly from the nitrogen contained in fuels. Emissions of SO_2 are determined by the sulphur content of fuels and are relevant only for coal. SO_2 emissions from biomass use are small. In the GAINS calculations, technologies affect not only dust emissions, but also other pollutants (e.g., NMVOC, CO, CH_4). New combustion devices have lower specific fuel consumption and emissions. In addition, some boilers or stoves can use add-on control technologies like, e.g., electrostatic precipitators.

Emission factors in GAINS are based on peer reviewed literature (Klimont et al. 2002), and are periodically updated with latest information (Boman et al. 2011; Goncalves et al. 2010; EGTEI 2010; Kubica et al. 2007; Karvosenoja et al. 2006; Nussbaumer et al. 2008; Nussbaumer 2010; Pettersson et al. 2011; Schmidtl et al. 2011). In addition, country-specific information has been provided by national experts dealing with emission inventories and projections. GAINS data have been used in earlier studies to explore the emission reduction potential from small sources (Pye et al. 2004).

2.3 Comparison of GAINS emission factors with the Eco-design study

GAINS estimates emissions for real operating conditions taking into account country-specific factors. Calculations are performed for the energy consumption figures provided by the PRIMES scenarios. As the Eco-design study assumes different fuel consumption and a different split between major types of devices (fireplaces, medium boilers, small boilers, stoves), a comparison of the GAINS estimates of total emissions with the Eco-design study results is difficult to perform on a coherent basis.

However, it is possible and instructive to compare emission factors. Figure 2.1 displays emission factors for currently available combustion installations of the GAINS database with the factors from the Eco-design studies. The GAINS figures provide the average value for the EU-27 as well as the ranges (Min and Max) that occur for the 27 Member States. A comparison of the data for the BAT technology is given in Figure 2.2.

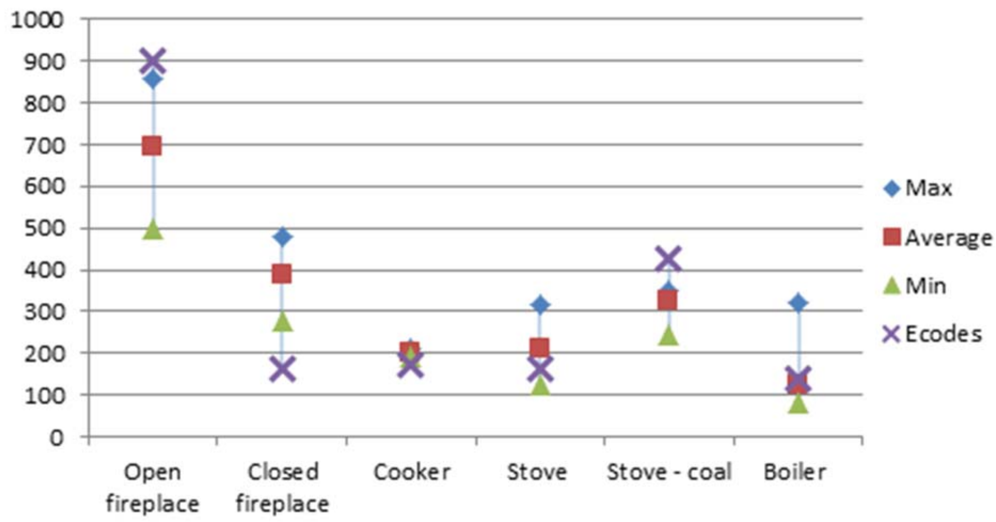

Figure 2.1: Comparison of PM (TSP) emission factors in GAINS (Min, Max, and Average for EU-27) with the emission factors of the Eco-design study for the standard technologies that are currently available on the market [mg/m3].

Differences between the minimum and maximum values for individual countries in the GAINS database are large, reflecting the high variability of emission factors due to local circumstances, even for the same type of combustion device. With the exception of coal stoves and pellet boilers, emission factors from the Eco-design studies are lower than those in GAINS. This is related to the fact that the emission factors represent different operating conditions (Eco-design – laboratory measurements during certification, GAINS – real life). Nevertheless, the comparison indicates a clear scope for emission reductions from a replacement of current combustion equipment in the domestic sector with more environmentally friendly devices. Taking into account all uncertainties and differences in the approach, the GAINS emission factors are broadly consistent with those of the Eco-design study, in particular with regard to the relative difference between the standard (currently on the market) and the BAT technology.

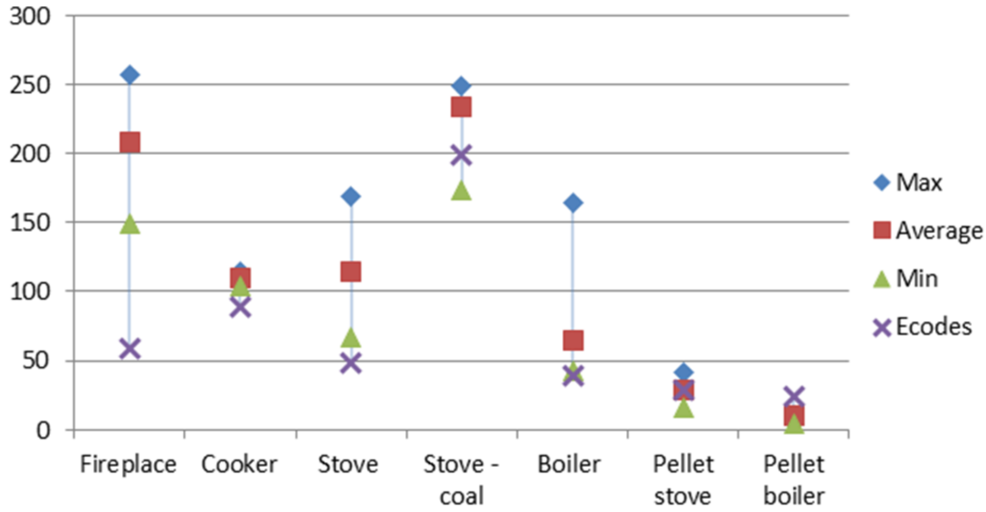

Figure 2.2: Comparison of PM (TSP) emission factors in GAINS (Min, Max, and Average for EU-27) with emission factors from the Eco-design study for the best available technologies [mg/m3].

3 Emission control scenarios

In order to quantify the potential magnitude in emission changes from an introduction of product standards for small combustion sources, the report develops different emission scenarios with different assumptions on the implementation of new emission standards for these sources.

For this purpose, six scenarios with the following characteristics have been developed:

- Baseline with current legislation: TSAP-2012 baseline fuel demand, current Legislation controls (includes national standards on boilers and stoves, where applicable)
- Decarbonisation with current legislation: TSAP-2012 decarbonisation fuel demand, current Legislation
- Maximum Technically Feasible Reductions (MTFR): TSAP-2012 baseline fuel demand, best available technology applied to new devices, without premature scrapping of existing devices
- Maximum Control Efforts (MCE): TSAP-2012 decarbonisation fuel demand, best technologies to all sources, with premature scrapping of existing devices
- Eco-design - baseline: TSAP-2012 baseline fuel demand, BAT standards from 2016 onwards (simulates a possible outcome of the Eco-design directive), without premature scrapping of existing devices
- Eco-design- decarbonisation: TSAP-2012 decarbonisation fuel demand, BAT standards from 2016, without premature scrapping of existing devices

3.1 Energy projections

This report re-examines the implications of the product standards presented in the preparatory study of Mugdal et al., (2009a-c) for the context assumed for the forthcoming revision of the Thematic Strategy. For this purpose, the draft TSAP-2012 baseline scenario presented in Amann et al. (2012) is used as a reference against which the impacts of the Eco-design standards are compared.

3.1.1 The TSAP-2012 baseline

The TSAP-2012 baseline employs the reference energy projection that has been developed for the 2009 update of the ‘EU energy trends to 2030’ report of DG-Energy (CEC, 2010). For the outlook to 2050, the TSAP-2012 baseline relies on the reference case of the 2050 ‘Roadmap for moving to a competitive low carbon economy’ of DG-CLIMA (CEC, 2011). Thereby, the scenario assumes that energy consumption in the residential and commercial sector follows the PRIMES reference projections. Emission controls for the domestic sector fully comply with the implementation of current legislation on air pollution controls in each country according to the foreseen time table.

3.1.2 The TSAP-2012 decarbonisation scenario

To explore the robustness of estimated impacts against different assumptions on energy development, the same emission controls are applied to a stringent decarbonisation scenario. For this purpose, the report uses the 'Global Action with Effective and Widely accepted Technology' scenario that has been developed with the PRIMES model for the communication of the European Commission on a 'A roadmap for moving to a competitive low carbon economy in 2050' (CEC, 2011). This simulates the development of the European energy system under a carbon price that results in an 80 % decrease of greenhouse gas emissions in 2050. Drastic improvements in energy efficiencies, a boost in biomass use and electrification of the transport system enable an almost complete phase-out of coal and oil (Figure 3.1).

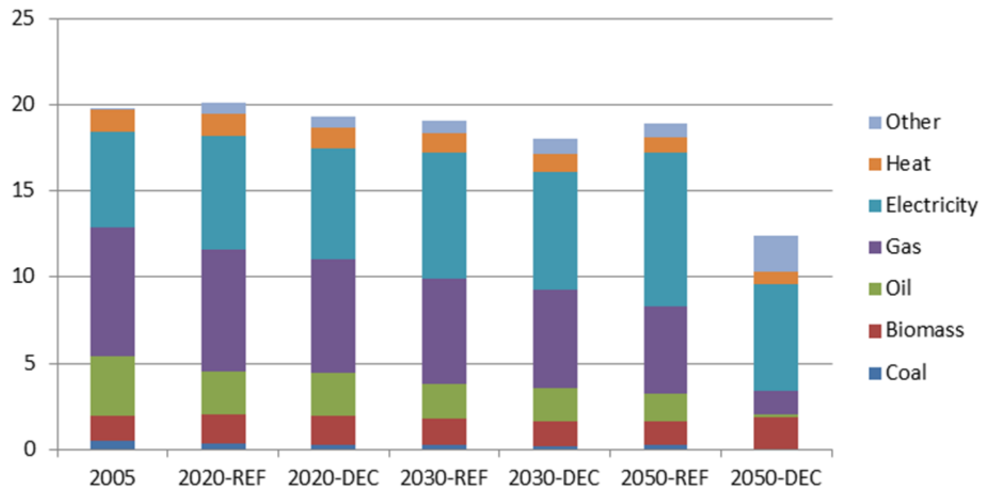

Figure 3.1: Comparison of projections of energy demand by fuel in the domestic sector until 2050, [EJ]. The TSAP-2012 baseline (REF) vs. the decarbonisation (DEC) scenarios.

In 2005, total final energy demand in residential and commercial sector was slightly less than 20 EJ. Gas, electricity and oil were the dominating fuels with shares of 38%, 28%, and 18%, respectively. Biomass accounted for about 7%, and the share of coal was below 3%. In the Reference scenario, demand increases up to 2020 by 2%, and then decreases until 2050 to 5% below the 2005 level. Electricity is the energy carrier with the fastest growth. Its share in 2050 reaches 47%. Shares of oil and gas decrease to 9% and 27%, respectively. Consumption of coal decreases until 2050 by more than 50%. After an initial increase until 2020 by 17%, biomass consumption decreases until 2050 to 6% below the 2005 level. In absolute terms, consumption of biomass was in 2005 1440 PJ, and that of coal about 500 PJ.

Aggressive energy efficiency improvements, as a part of the decarbonisation scenario, would lead to a decrease of total final energy demand until 2050 by 37% compared with 2005. Consumption of oil is reduced to about 10% of the baseline scenario, and coal is practically eliminated. The share of electricity exceeds 50% Biomass and other renewables reach 15% and 17% market share, respectively.

Consumption of solid biomass increases until 2050 by 480 PJ compared with the baseline. In 2005, about 90% of solid biomass and 80% of coal used in the domestic sector was consumed by households (residential consumers). In the baseline scenario, these shares prevail in the future. The decarbonisation scenario sees a fast decrease of coal consumption, especially in the residential sector.

The energy scenarios developed with the PRIMES model provide information on total consumption of solid fuels (coal and biomass) in the residential, service (commercial) and agricultural sectors. To calculate corresponding emissions of air pollutants, additional information is required about the structure of boilers and stoves and their evolution over time. This information is derived from the GAINS databases, which include country-specific data on the shares of individual combustion installations (boilers, stoves, fireplaces) in total solid fuel consumption in the residential-commercial sector. Information is derived from international statistics and has been systematically verified through contacts with national experts working on emission inventories and projections. These contacts were maintained through bilateral consultations within the CAFE (Clean Air For Europe) project as well as during the review of input data used for the calculations for the revision of the Gothenburg Protocol of the Convention on Long-range Transboundary Air Pollution (Amann et al., 2011). Details are provided in (Amann et al., 2001), (Klimont et al., 2002).

3.2 Key assumptions for different emission scenarios

3.2.1 A baseline scenario

As a reference, the analysis adopts the TSAP-2012 baseline scenario that has been developed for the revision of the Thematic Strategy on Air Pollution (Amann et al., 2012). This scenario assumes energy consumption in the residential and commercial sector as in the PRIMES reference scenario in the 2009 update of the 'EU energy trends to 2030' report of DG-Energy (CEC, 2010). It also assumes implementation of current legislation of air pollution controls according to the foreseen time tables. For small combustion sources, this scenario includes shifts of fuel use between different types of devices (fireplaces, boilers, stoves). Therefore, emission characteristics of source categories change according to (country-specific) replacement rates of the existing stock of installations. These rates are quite different for individual countries, and are influenced by how the typical modes of operations of the installations (e.g., mainly for 'decorative' purposes or as a major source of heat), climatic conditions, and country-specific legislation and policies. Emission standards and eco-labels introduced in some countries, as well as incentive programs offered to residential consumers, such as subsidies to accelerate the replacement of old equipment with the new one, will influence the adoption of newer technologies in individual countries.

3.2.2 A decarbonisation scenario

The same assumptions on the current emission control legislation as above have been applied to the TSAP-2012 decarbonisation scenario.

3.2.3 A 'Maximum Technically Feasible Reduction' (MTFR) scenario

A "Maximum Technically Feasible Reductions" (MTFR) scenario assumes replacement of existing installations by the best technologies available in GAINS. Most relevant, this scenario also considers a switch from wood fired boilers to pellet boilers. However, premature scrapping of installations is excluded, so that the new technologies can only enter the market to provide additional capacity or for replacement of devices that are retired at the end of their life time.

3.2.4 A 'Maximum Control Efforts' (MCE) scenario

A second scenario explores emission reductions that could be achieved from application of BAT to all relevant sources, irrespective of their age. In addition to premature scrapping, the scenario combines maximum efforts towards a decarbonisation of the energy system, in particular a fast rate of energy efficiency improvement, which also requires premature scrapping of inefficient devices. This scenario employs the energy projections of the 'decarbonisation scenario' discussed in (Amann et al., 2012)

3.2.5 Eco-design emission standards applied to baseline energy consumption

Another scenario quantifies the potential impacts of an application of the Eco-design emission limit values for small combustion installations fired with solid fuels standards. As emission standards for the Eco-design directive are still under discussion, and as the real-world emissions of possible values under different country conditions are unclear, this scenario applies the country-specific BAT emission factors in GAINS. However, electrostatic precipitators (ESP) for small boilers and stoves are not assumed in this scenario, as the Eco-design studies treat ESP for small sources as possible additions to and not as an integral part of BAT. Besides, recent studies do not confirm the performance of ESP installations for those types of sources, and costs are often prohibitively high. It is assumed that introduction of the new standards begins in 2016. In comparison, the MTFR scenario starts implementation in 2012, i.e., four years earlier, which makes a difference in emissions in the near future if a 6% replacement rate per year is assumed for existing devices.

3.2.6 Eco-design emission standards and tightened energy efficiency standards

As (perhaps more realistic) variant explores a further scenario where, in addition to the discussed emission standards also energy efficiency standards would be applied through an Eco-design directive. As lower energy consumption would have feedbacks to the entire energy system that cannot be properly treated within GAINS, this scenario employs an energy pathway that has been developed with the PRIMES model, which assumes maximum energy efficiency improvements (inter alia) in the domestic sector. In practice, this sensitivity case uses the energy use of the TSAP-2012 decarbonisation scenario (for details see Amann et al., 2012). This scenario assumes an environment with rapid improvements in the energy efficiencies even at the costs of a premature retirement of existing installations if they do not conform to the new standards. Again, introduction of the Eco-design standards is assumed to start in 2016.

Table 3.1: Key features of the emission scenarios analysed in this report

Scenario	*Baseline fuel use*	*Decarbonisation fuel use*	*CLE* [a]	*BAT* [b]	*Eco-design standards*	*Premature scrapping*
Baseline + CLE	X		X			no
Decarbonisation + CLE		X	X			no
Baseline + MTFR	X			X		no
Decarbonisation + MCE		X		X		yes
Baseline + Eco-design	X				X	no
Decarbonisation + Eco-design		X			X	no

[a] - Current legislation

[b] - Best Available Technology defined in the GAINS model

3.3 Emissions of the control scenarios

3.3.1 PM emissions

Emissions of PM2.5

In 2005, total PM2.5 emissions from small sources (the DOMESTIC sector) in the EU-27 amounted to about 616 kilotons, which made up for 34% of total PM2.5 emission in the EU-27. Dominating source of PM2.5 was the combustion of solid biomass, which contributed in 2005 nearly three quarters to total emissions. The share of coal was about 25%, while other small sources (liquid fuels) made insignificant (<1%) contributions (Table 3.2). 69% of PM2.5 emissions from small combustion sources emerged from residential stoves, followed by single family house boilers (16%) and fireplaces (11%). Larger boilers in the commercial sector added less than 3% to total emissions.

In the baseline with current legislation, PM2.5 emissions from small sources decrease by more than 20% until 2020, by 40% in 2030, and by 50% in 2050. The share of coal decreases to about 20% and is maintained until 2050. A marked exception is Poland, where coal was responsible for two thirds of PM2.5 emissions in 2005.

For comparison, the decarbonisation scenario with current legislation would lead to a stronger decrease of emissions until 2030 (nearly 50%). However, in 2050 emissions would be higher (by 36 kilotons) due to larger consumption of solid biomass in this scenario. The share of coal decreases to less than 10% and becomes negligible in 2050.

The scenarios assuming implementation of the Eco-design standards lead to significant reductions of PM2.5 emissions from small sources compared to the baseline projections. If only the Eco-design emission standards were introduced (without improved requirements for energy efficiencies), PM2.5 from small sources would decline by 38% in 2020 relative to 2005 level (compared to the 21% cut in the current legislation case). By 2030, the Eco-design standards would reduce PM2.5 emission by 70% relative to 2005 (the current legislation only by 40%), and in 2050 these standards would lead to 83% lower emissions, while the baseline results in only 50% relative to 2005.

If also existing devices with higher emissions would be replaced before the end of their regular life time, and if the new devices would comply with the energy efficiency requirements assumed in the decarbonisation scenario, the Eco-design standards would lead to even higher emission reductions. PM2.5 emissions from small sources would decline 44% instead of 38% in 2020, by 75% instead of 70% in 2030, and by 86% instead of 83% in 2050.

These emission reductions would account for a sizeable fraction of the total emissions from all sectors in the EU-27. In 2020, introduction of the Eco-design standards would cut total PM2.5 emissions by 10%, and by more than 15% in 2030 and afterwards

At face value, these estimates are higher than the figures presented in the Eco-design study (Mudgal et al., 2009a-c), which proposed for 2025 some 25% reduction compared to their business-as-usual case. The current study, based on the TSAP-2012 baseline scenario, suggests already baseline emissions to decline by 20% in 2020 and by 40% in 2030 as a result of current legislation, with changes in the fuel consumption patterns as the main driver. Relative to this baseline, the current study estimates that the Eco-design standards would cut PM2.5 emissions by an additional 18% in 2020, and by an additional 30% in 2030. The figure presented by Mugdal et al. (2009) (i.e., 25% in 2025) falls well within this range, although their precise assumptions about the baseline development are unclear.

The assumptions for the Maximum Technically Feasible Reductions (MTFR) scenario reduce PM2.5 emissions by nearly 58% in 2020 and by 87% in 2050. Largest reductions are achieved in the Maximum Control Efforts (MCE) scenario with 90% in 2020 and 95% in 2050 (Table 3.3). This is a combined effect of energy efficiency improvements in the MCE scenario, and unlimited penetration of technologies with lower emissions, which in practice means premature scrapping of existing installations. In reality, such a scenario would be difficult to implement in the short run, since it would require a very fast replacement of the existing capital stock by new equipment and unlimited availability of pellets.

Table 3.2 Current legislation emissions of PM2.5 by combustion installation type in EU-27, kilotons

		Current legislation					
		Reference			Decarbonisation		
	2005	2020	2030	2050	2020	2030	2050
Fireplaces	65.9	55.0	49.3	35.4	45.9	41.2	53.4
Medium boilers – automatic	12.8	10.0	9.9	8.6	13.2	9.9	5.9
Medium boilers – manual	7.4	3.3	2.2	1.0	1.5	1.1	0.6
Single house boilers – automatic	3.0	7.2	8.0	8.1	8.4	18.9	10.1
Single house boilers – manual	101.1	73.7	47.1	42.1	75.3	28.6	36.4
Stoves	422.0	331.8	252.4	211.0	294.5	209.9	236.5
Other - non solid fuels	3.7	2.7	2.2	1.8	2.6	2.1	1.0
Sum – Domestic	616.0	483.8	371.1	307.9	441.6	311.8	343.9
Share in national total emissions	34%	37%	32%	29%	37%	31%	35%

Table 3.3 MTFR and MCE emissions of PM2.5 by combustion installation type in EU-27, kilotons

	Max. Techn. Feasible Red. (MTFR)			Max. Control Efforts (MCE)		
	2020	2030	2050	2020	2030	2050
Fireplaces	35.3	28.8	15.0	18.0	16.3	22.0
Medium boilers – automatic	2.0	1.1	0.2	0.2	0.2	0.1
Medium boilers – manual	1.9	1.2	0.3	0.7	0.6	0.0
Single house boilers - automatic	4.7	4.8	1.8	1.0	11.9	1.1
Single house boilers – manual	47.0	25.2	21.1	27.2	1.6	1.3
Stoves	167.2	58.8	39.7	20.1	10.4	4.4
Other - non solid fuels	2.6	2.2	1.8	2.6	2.1	1.0
Sum – Domestic	260.6	121.9	79.9	69.7	43.0	29.7
Share in national total emissions	34%	21%	15%	12%	9%	7%

Table 3.4 Emissions of PM2.5 by combustion installation type in EU-27, kilotons for the Eco-design cases.

	Eco-design					
	Reference			Decarbonisation		
	2020	2030	2050	2020	2030	2050
Fireplaces	49.1	34.1	14.6	40.5	28.5	21.5
Medium boilers - automatic	7.5	3.5	0.9	9.9	3.2	0.3
Medium boilers - manual	2.8	1.5	0.4	1.3	0.7	0.1
Single house boilers - automatic	7.2	8.0	8.1	8.4	18.9	10.1
Single house boilers - manual	61.7	30.1	24.5	62.3	8.8	6.8
Stoves	253.5	111.9	55.7	222.6	87.4	44.6
Other - non solid fuels	2.7	2.2	1.8	2.6	2.1	1.0
Sum - Domestic	384.4	191.3	105.9	347.7	149.8	84.4
Share in national total emissions	35%	22%	14%	33%	18%	12%

Figure 3.2 compares emissions of fine particles for the scenarios and illustrates the emission reduction potential. More than three quarters of reduction in all scenarios is achieved through implementation of measures for stoves. In absolute terms, the reduction potential of MTFR measures (relative to the baseline + current legislation) is about 220 kt PM2.5 in 2020, 250 kt in 2030, and 230 kt in 2050. It is characteristic that in the longer-run the Eco-design scenario achieves comparable emission reductions. The mitigation potential of the MCE scenario in 2020 is nearly twice as high as that of the MTFR scenario. The difference between the MTFR scenario and the MCE decreases over time, but even in 2050 MCE emissions are 50 kilotons lower than in the MTFR case.

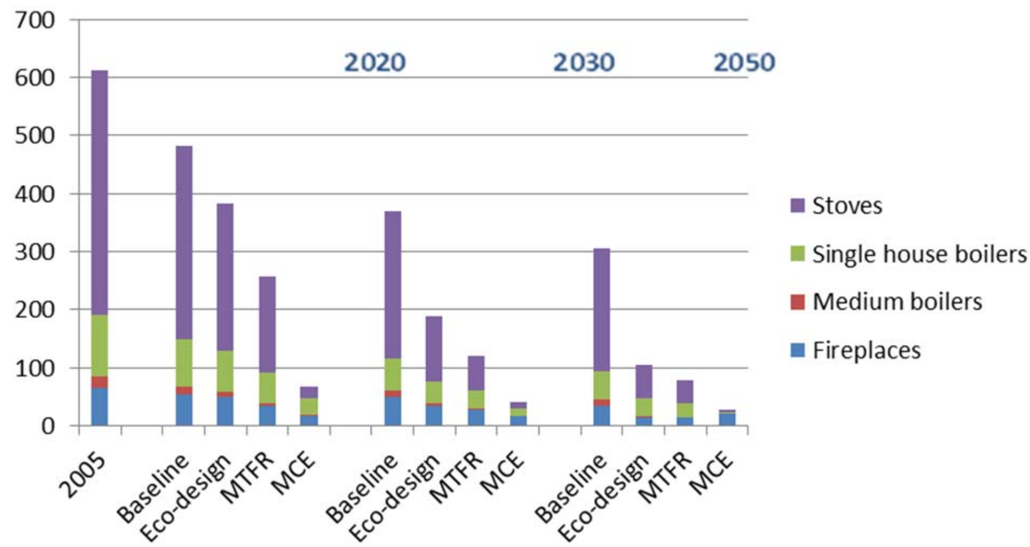

Figure 3.2 Comparison of scenarios of PM2.5 emissions, kilotons

Emissions of PM10

Table 3.5 to Table 3.7 present emissions of PM10. Absolute levels of emissions are less than five percent higher than emissions of PM2.5, and reduction potentials are similar. It is characteristic that the contribution of the DOMESTIC sector to total EU-27 emissions of PM2.5 is by about 10 percentage points lower than that of PM2.5. This is due to a higher relative difference between emissions of PM10 and PM2.5 for other (mainly non-combustion) sources, which contribute more PM10 to the total.

Table 3.5 Current legislation emissions of PM10 by combustion installation type in EU-27, kilotons

	Current legislation						
		Reference			Decarbonisation		
	2005	2020	2030	2050	2020	2030	2050
Fireplaces	68.1	56.8	50.9	36.5	45.9	41.2	53.4
Medium boilers - automatic	18.8	13.4	13.1	11.0	13.2	9.9	5.9
Medium boilers - manual	11.4	4.5	2.9	1.2	1.5	1.1	0.6
Single house boilers - automatic	3.1	7.5	8.4	8.4	8.4	18.9	10.1
Single house boilers - manual	106.2	77.4	49.4	44.1	75.3	28.6	36.4
Stoves	434.8	341.9	260.0	217.1	294.5	209.9	236.5
Other - non solid fuels	5.5	3.4	2.8	2.3	2.6	2.1	1.0
Sum - Domestic	647.8	504.8	387.4	320.7	441.6	311.8	343.9
Share in national total emissions	25%	26%	22%	19%	37%	31%	35%

Table 3.6 MTFR and MCE emissions of PM10 by combustion installation type in EU-27, kilotons

	Max. Techn. Feasible Red. (MTFR)			Max. Control Efforts (MCE)		
	2020	2030	2050	2020	2030	2050
Fireplaces	36.5	29.7	15.5	18.6	16.8	22.7
Medium boilers - automatic	2.7	1.4	0.2	0.2	0.2	0.1
Medium boilers - manual	2.6	1.6	0.5	1.0	0.8	0.0
Single house boilers - automatic	4.8	5.0	2.0	1.0	13.3	1.1
Single house boilers - manual	49.7	26.7	22.3	28.8	1.6	1.3
Stoves	172.1	60.2	40.5	20.4	10.6	4.4
Other - non solid fuels	3.3	2.7	2.2	3.2	2.6	1.0
Sum – Domestic	271.7	127.3	83.1	73.2	45.9	30.5
Share in national total emissions	22%	12%	8%	7%	5%	4%

Table 3.7: Emissions of PM10 by combustion installation type in EU-27, kilotons for the Eco-design cases.

	Eco-design					
	Reference			Decarbonisation		
	2020	2030	2050	2020	2030	2050
Fireplaces	50.7	35.2	15.1	41.8	29.5	22.2
Medium boilers - automatic	9.8	4.6	1.1	13.3	4.4	0.4
Medium boilers - manual	3.7	2.0	0.6	1.7	1.0	0.1
Single house boilers - automatic	7.5	8.4	8.4	8.7	20.5	10.5
Single house boilers - manual	64.9	31.8	25.8	65.4	9.2	7.0
Stoves	261.0	114.5	57.1	229.4	89.6	45.9
Other - non solid fuels	3.4	2.8	2.3	3.4	2.7	1.0
Sum - Domestic	401.1	199.3	110.4	363.8	156.9	87.0
% Share in national total emissions	23%	13%	8%	22%	11%	7%

Emissions of black carbon (BC)

Table 3.8 to Table 3.10 present emissions of black carbon. In 2005, about 140 kilotons of BC were emitted from sources in the residential and commercial sector, which account for 37% to total emission in the EU-27. 98% of the emissions in this sector originated from solid fuels combustion.

In the baseline scenario, BC emissions decrease by 30% up to 2030, i.e., to a lesser extent than the emissions of PM2.5 (40%). For the same year, the contribution of the small sources to total increases to about 63%, as emissions from other sources (diesel vehicles) decline.

The Eco-design measures reduce BC up to 2030 by almost 60 % compared with 2005 and by 77% in 2050 (Figure 3.3).

The MTFR scenario achieves further reductions compared with Eco-design. In absolute terms, this reduction is 24 kt in 2030, or 41% of the Eco-design level. The MCE scenario would cut BC emissions up to 2050 by nearly 80% compared with the emissions achieved in the Eco-design scenario. Thereby, the MTFR measures reduce emissions to 34 kt in 2030, which means a decrease by about 75% compared with 2005.The MCE scenario would cut BC emissions up to 2050 by 95%.

Table 3.8 Current legislation emissions of BC by combustion installation type in the EU-27, kilotons

	Current legislation						
		Reference			Decarbonisation		
	2005	2020	2030	2050	2020	2030	2050
Fireplaces	9.1	8.3	7.6	5.7	6.8	6.1	7.8
Medium boilers - automatic	0.5	0.7	0.7	0.7	0.6	0.5	0.8
Medium boilers - manual	0.5	0.4	0.3	0.2	0.4	0.2	0.1
Single house boilers - automatic	0.4	1.0	1.5	1.6	1.1	1.4	1.2
Single house boilers - manual	27.2	21.4	14.0	13.3	20.7	12.6	9.0
Stoves	100.1	89.1	73.2	63.2	85.8	69.3	73.1
Other - non solid fuels	2.4	1.6	1.2	1.0	1.5	1.2	0.3
Sum - Domestic	140.3	122.6	98.5	85.7	116.9	91.3	92.4
% Share in national total emissions	37%	58%	63%	62%	57%	61%	65%

Table 3.9 MTFR and MCE emissions of BC by combustion installation type in the EU-27, kilotons

	Max. Techn. Feasible Red. (MTFR)			Max. Control Efforts (MCE)		
	2020	2030	2050	2020	2030	2050
Fireplaces	7.9	6.9	4.5	5.3	4.8	6.2
Medium boilers - automatic	0.1	0.0	0.0	0.0	0.0	0.0
Medium boilers manual	0.1	0.0	0.0	0.2	0.0	0.0
Single house boilers - automatic	0.7	1.1	0.7	0.2	0.5	0.1
Single house boilers - manual	13.1	7.2	6.9	8.9	5.4	0.1
Stoves	56.8	17.2	13.4	9.2	7.8	0.1
Other - non solid fuels	1.6	1.2	1.0	1.5	1.2	0.3
Sum - Domestic	80.2	33.7	26.6	25.3	19.7	6.8
Share in national total emissions	56%	49%	48%	27%	32%	17%

Table 3.10 Emissions of BC by combustion installation type in EU-27, kilotons for the Eco-design cases.

	Eco-design					
	Reference			Decarbonisation		
	2020	2030	2050	2020	2030	2050
Fireplaces	8.1	6.9	4.5	6.6	5.6	6.2
Medium boilers - automatic	0.5	0.2	0.0	0.5	0.2	0.0
Medium boilers - manual	0.3	0.1	0.0	0.3	0.1	0.0
Single house boilers - automatic	1.0	1.5	1.6	1.1	1.4	1.2
Single house boilers - manual	18.0	8.4	7.5	17.2	6.5	0.8
Stoves	75.2	38.7	17.2	72.1	35.5	9.8
Other - non solid fuels	1.6	1.2	1.0	1.5	1.2	0.3
Sum - Domestic	104.8	57.1	31.8	99.2	50.4	18.4
Share in national total emissions	58%	55%	43%	57%	52%	33%

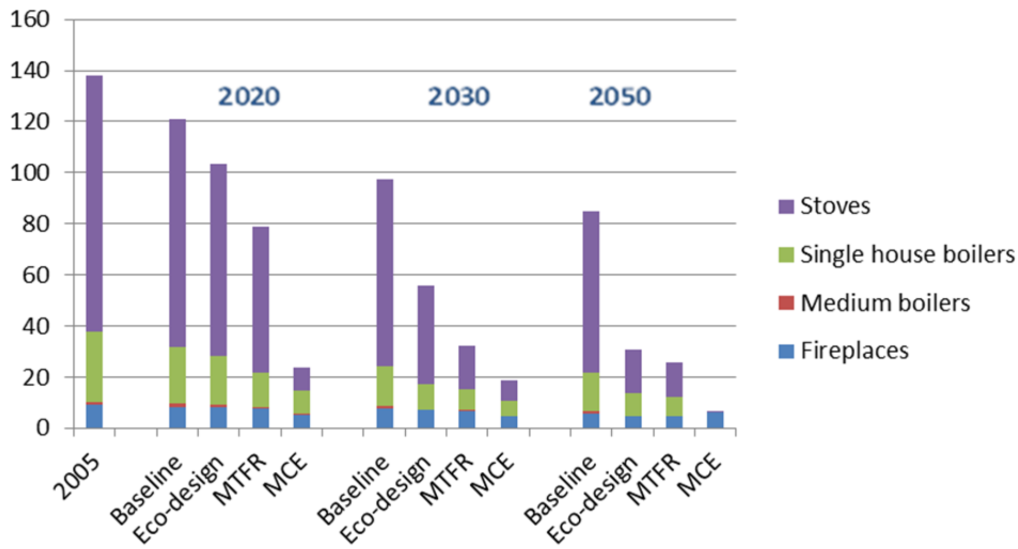

Figure 3.3: Comparison of scenarios of BC emissions, kilotons

3.3.2 NMVOC emissions

In 2005, NMVOC emissions from small sources (1.1 million tons) were approximately 80% higher than those of PM2.5, and accounted for about 10% to the total emissions of the EU-27.

Application of the Eco-design standards to small sources would reduce NMVOC emissions by nearly 50% in 2020 below the 2005 level in 2020, by 80% in 2030 and by more than 90% in 2050. About 70% of these emission reductions emerge from stoves.

The MTFR measures would lead to a further cut of NMVOC emissions by 58% in 2020 compared to the Eco-design values. In 2030, these additional reductions would increase to 41%. Even higher reductions would emerge from the MCE scenario (82% and 57%), although the difference between the MTFR scenario and the MCE decreases over time (Table 3.11 to Table 3.13).

Table 3.11 Current legislation emissions of NMVOC by combustion installation type in EU-27, kilotons.

		Current legislation					
		Reference			Decarbonisation		
	2005	2020	2030	2050	2020	2030	2050
Fireplaces	158.7	119.7	106.5	74.4	98.0	87.7	111.6
Medium boilers - automatic	3.6	4.8	4.9	5.2	5.1	4.1	5.2
Medium boilers - manual	3.9	2.7	1.9	1.0	1.3	1.0	0.8
Single house boilers - automatic	2.2	5.5	5.7	5.6	6.0	10.2	7.1
Single house boilers - manual	186.5	117.7	79.5	73.2	132.2	90.7	116.0
Stoves	749.0	553.9	380.5	301.3	501.4	339.1	400.1
Other - non solid fuels	30.0	26.6	22.7	18.9	25.6	21.5	8.5
Sum - Domestic	1133.9	830.7	601.7	479.7	769.5	554.3	649.2
Share in national total emissions	8%	9%	7%	5%	13%	10%	13%

Table 3.12 MTFR and MCE emissions of NMVOC by combustion installation type in EU-27, kilotons.

	Max. Techn. Feasible Red. (MTFR)			Max. Control Efforts (MCE)		
	2020	2030	2050	2020	2030	2050
Fireplaces	43.4	36.2	21.4	24.4	22.2	30.3
Medium boilers - automatic	2.0	2.1	2.0	2.2	1.8	1.8
Medium boilers - manual	1.2	0.7	0.3	0.4	0.4	0.1
Single house boilers - automatic	5.5	5.7	5.6	6.0	10.2	7.1
Single house boilers - manual	19.3	9.6	6.3	8.0	3.1	3.6
Stoves	144.7	46.9	36.1	37.0	30.6	34.8
Other - non solid fuels	26.6	22.7	18.9	25.6	21.5	8.5
Sum - Domestic	242.7	123.8	90.6	103.6	89.8	86.2
Share in national total emissions	6%	3%	2%	3%	3%	3%

Table 3.13 Emissions of NMVOC by combustion installation type in EU-27, kilotons for the Eco-design cases.

	Eco-design					
	Reference			Decarbonisation		
	2020	2030	2050	2020	2030	2050
Fireplaces	100.9	59.3	19.8	81.8	49.6	27.1
Medium boilers - automatic	4.0	2.7	2.0	4.3	2.3	1.8
Medium boilers - manual	2.2	1.0	0.3	1.0	0.6	0.1
Single house boilers - automatic	5.5	5.7	5.6	6.0	10.2	7.1
Single house boilers - manual	75.8	14.5	6.5	85.8	11.1	3.6
Stoves	363.8	102.8	40.3	325.3	92.0	46.9
Other - non solid fuels	26.6	22.7	18.9	25.6	21.5	8.5
Sum - Domestic	578.7	208.8	93.4	529.8	187.3	95.1
Share in national total emissions	10%	4%	2%	9%	4%	2%

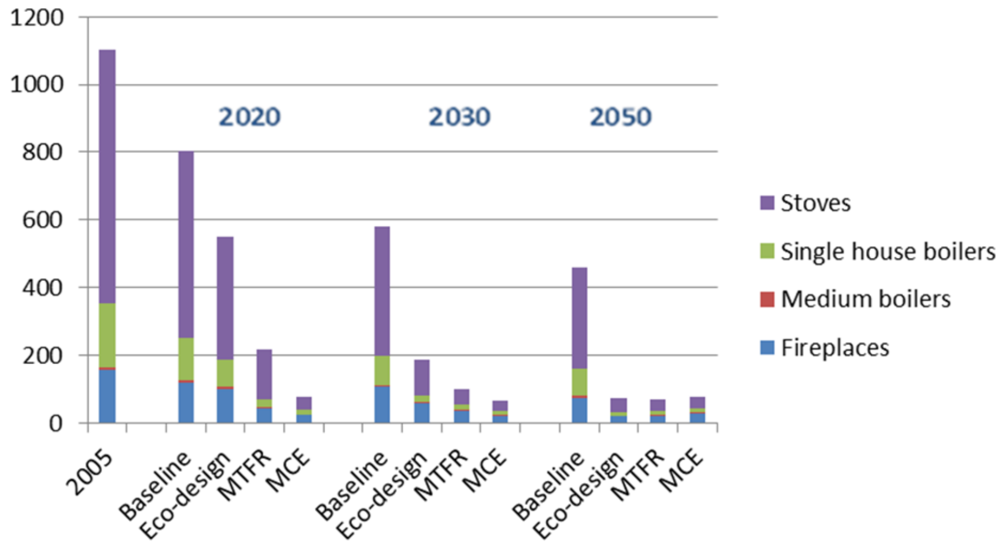

Figure 3.4: Comparison of scenarios of NMVOC emissions, kilotons

3.3.3 NO_x emissions

In 2005, the domestic sector contributed 6% to total NO_x emissions in the EU-27.

For the future, absolute emission levels will decrease as a consequence of the lower fossil fuel consumption in the sector and the emission controls imposed on oil and gas installations (Table 3.14). For the baseline with current legislation, emissions decrease by 2020 by 14% compared to 2005 and by 37% in 2050.

Emission factors for solid fuels remain constant also in the MTFR and the MCE scenarios, so that NO_x emissions are unchanged compared to the baseline cases. Also the Eco-design standards do not affect NO_x emissions in the setup of the current study.

Table 3.14: Emissions of NO_x in the domestic sector by scenario in the EU-27, kilotons

	kilotons				*% of national emissions*			
Scenario	2005	2020	2030	2050	2005	2020	2030	2050
Baseline, CLE	741	634	545	466	6%	11%	12%	12%
Decarbonization, CLE	741	605	509	240	6%	11%	12%	9%
MTFR.	741	479	410	352	6%	10%	14%	15%
Max. Control Efforts (MCE)	741	458	382	213	6%	10%	14%	13%

3.3.4 Comparison of scenarios

In 2005, coal was responsible for about 25% of PM2.5 emissions from the domestic sector in the EU-27. This share decreases to about 20 percent in the baseline scenario. In 2030, emissions from coal contribute 69 kilotons (or about 19%) of total emissions form small combustion sources. More than 70% of these emissions originate from Poland (49 kilotons). Other five countries (Czech Republic, France, Germany, Ireland, and UK) contribute 22% to total EU-27 emissions from coal (Figure 3.5, Figure 3.6).

In the emission control scenarios the share of coal emissions is higher than in the baseline, although absolute emission levels decrease over time and with increasing stringency of emission controls.

The emission control scenarios, including the Eco-design case, emissions from biomass combustion decrease significantly more than emissions from coal stoves and boilers, because of more efficient control measures (e.g., switch to pellets). Thus, overall, control of emissions from biomass are of can deliver larger reductions than measures for coal.

Emissions of PM2.5, PM10 and BC by country are presented in the annex to the report.

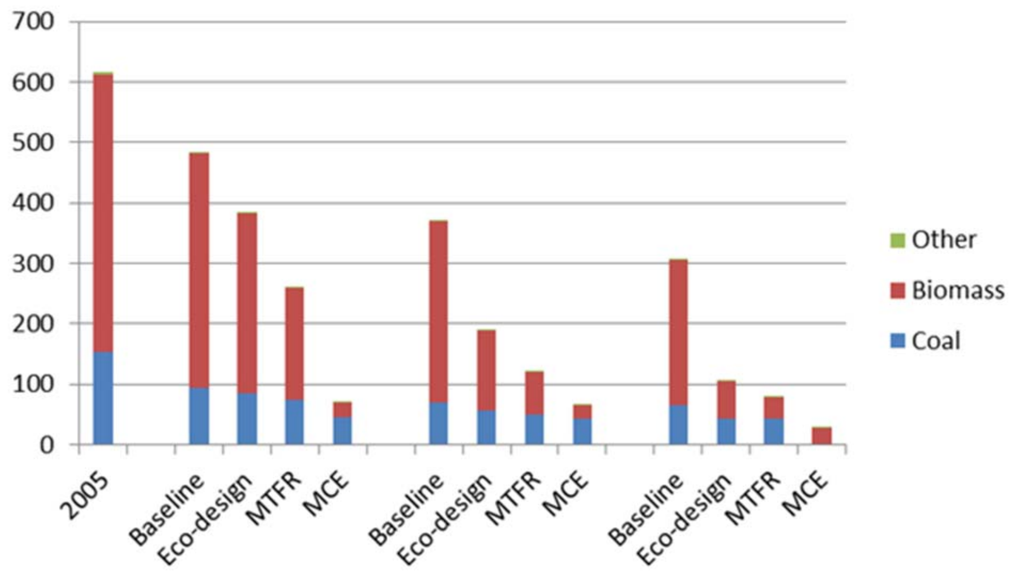

Figure 3.5: Emissions of PM2.5 by fuel type, EU-27, kilotons

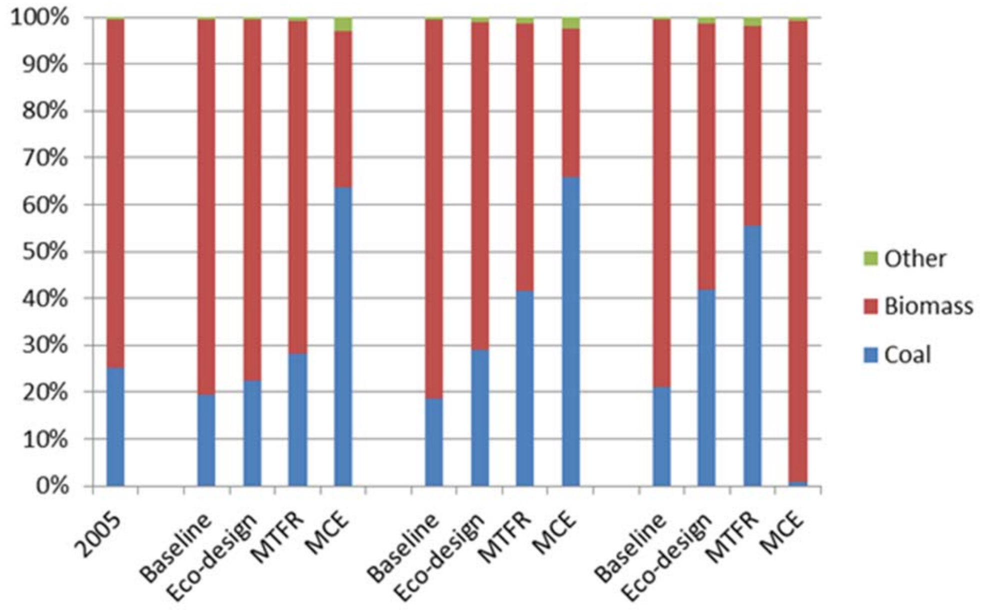

Figure 3.6: Contribution to total emissions of PM2.5 from the different fuel types

3.4 Emission control costs

Table 3.15 presents costs of PM controls from solid fuels combustion installations in the EU Member States (EU-27). By 2030, costs of implementing the MTFR measures (about 20 billion €/year) are five times higher than in the baseline with current legislation scenario; costs of the Eco-design scenario are about 40% lower. In the baseline, in 2030 costs of measures for small sources contribute about 45% to total costs of controlling PM emissions from stationary sources in the EU-27. This share increases to about 70% in the MTFR scenario. In the control scenarios, measures for stoves make up about 90% of the total costs.

Measures aimed at controlling PM emissions from small solid fuels installations simultaneously reduce emissions of NMVOC, CO and other pollutants. According to the GAINS methodology, no attempt has been made to split these costs into costs of controlling emissions of individual pollutants.

Table 3.15: PM emission control costs in the EU-27 by scenario [million Euro/year]

	2020				2030			
	Baseline	Eco-design	MTFR	MCE	Baseline	Eco-design	MTFR	MCE
Fireplaces	511	826	971	2421	484	1276	1332	2195
Medium boilers	12	22	46	58	14	37	49	47
Single house boilers	233	348	577	828	212	406	548	674
Stoves	4190	7583	13511	24069	4646	12892	20133	20010
Sum	4947	8779	15105	27376	5355	14611	22062	22926

4 Conclusions

To explore the potential contribution of Eco-design product standards to the achievement of the targets of the Thematic Strategy on Air Pollution, this report develops different scenarios for implementations of more stringent emission limit values to small combustion sources.

In 2005, small sources of solid fuel combustion contributed about one third to total EU-27 emissions of fine particles (PM2.5) and black carbon (BC), and less than 10% to total non-methane volatile organic compounds (NMVOC) and nitrogen oxides (NO_x).

For PM2.5, it is estimated that an implementation of the Eco-design standards would lead to significant reductions of emissions from small sources compared to the baseline projection. If the Eco-design standards were only introduced for air pollution emissions (without requirements for improved energy efficiencies), PM2.5 from these sources would decline by 38% in 2020 relative to 2005 level (compared to a 21% cut in the current legislation case). By 2030, the Eco-design standards would reduce PM2.5 emission by 70% relative to 2005 (the current legislation only by 40%), and in 2050 these standards would lead to 83% lower emissions, while the baseline results in only 50% relative to 2005. These calculations assume no premature scrapping of existing equipment.

These emission reductions would account for a sizeable fraction of the total PM2.5 emissions from all sectors in the EU-27. In 2020, introduction of the Eco-design standards would cut total PM2.5 by 7%, in 2030 by 16%, and in 2050 by almost 20%.

Black carbon emissions from small combustion sources, which have recently received increasing attention because of their negative health and climate effects, would be reduced by the Eco-design standards by 25% in 2020 and by 75% in 2050.

Although small combustion sources make only limited contributions to NMVOC emissions (8% in 2005), Eco-design standards could reduce these emissions in 2020 by 50% relative to 2005 (compared to a 25% cut envisaged for the baseline), by 80% instead of 50% in 2030, and by more than 90% compared to 60% in 2050.

Even larger emission reductions can be achieved if Eco-design standards would also affect energy efficiency standards, as highlighted by a scenario with ambitious assumptions on energy efficiency improvements for small sources. However, this scenario assumes rapid turnover of existing (inefficient) devices including premature scrapping before the end of its regular lifetime. In reality, such a scenario would be difficult to realize in the short run, since it would require a very fast replacement of the existing capital stock by new equipment and unlimited availability of pellets.

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Annex: Emissions from the DOMESTIC sector by country

PM2.5 emissions

PM2.5 of the baseline scenario

	DOMESTIC sector, kilotons PM2.5				% National total			
	2005	2020	2030	2050	2005	2020	2030	2050
Austria	8.2	5.3	4.0	3.9	36%	37%	32%	30%
Belgium	3.1	3.4	2.8	2.8	11%	16%	14%	13%
Bulgaria	14.1	11.6	7.8	4.9	27%	33%	26%	19%
Cyprus	0.1	0.1	0.0	0.0	2%	4%	3%	2%
Czech Rep.	15.7	14.8	12.2	11.0	34%	40%	37%	36%
Denmark	20.1	13.2	10.1	9.9	57%	56%	52%	51%
Estonia	7.7	4.2	3.0	2.9	38%	50%	44%	48%
Finland	9.1	8.6	6.9	5.3	28%	38%	35%	26%
France	144.6	87.8	61.9	51.2	42%	37%	29%	27%
Germany	23.2	23.7	24.1	23.4	16%	23%	24%	24%
Greece	13.4	10.2	6.6	4.8	24%	29%	22%	17%
Hungary	10.3	11.2	8.1	6.9	36%	47%	41%	38%
Ireland	4.9	3.5	3.0	3.7	35%	40%	41%	48%
Italy	29.8	28.4	24.8	13.9	21%	28%	26%	17%
Latvia	14.2	11.4	8.3	7.0	76%	76%	73%	70%
Lithuania	6.3	4.7	3.2	3.4	46%	43%	34%	37%
Luxembourg	0.2	0.1	0.1	0.1	7%	8%	7%	7%
Malta	0.0	0.0	0.0	0.0	1%	0%	0%	0%
Netherlands	2.6	1.8	1.8	2.2	10%	11%	11%	12%
Poland	171.5	147.8	113.9	93.5	74%	77%	74%	71%
Portugal	20.3	14.1	10.3	8.3	20%	22%	17%	15%
Romania	50.8	44.0	29.9	25.8	33%	40%	32%	31%
Slovakia	2.1	2.7	2.6	3.4	10%	24%	24%	31%
Slovenia	3.0	2.9	1.7	1.6	32%	45%	38%	37%
Spain	28.3	18.0	15.5	9.5	19%	17%	16%	10%
Sweden	3.8	2.6	1.9	1.6	12%	12%	9%	7%
UK	8.7	7.6	6.7	6.9	9%	12%	11%	11%
Total	616.0	483.8	371.1	308.0	34%	37%	32%	29%

PM2.5 of the MTFR scenario

	DOMESTIC sector, kilotons PM2.5			% National total		
	2020	2030	2050	2020	2030	2050
Austria	2.9	1.2	0.5	28%	14%	7%
Belgium	2.5	1.2	1.0	15%	8%	7%
Bulgaria	5.8	2.0	1.0	43%	23%	14%
Cyprus	0.0	0.0	0.0	3%	1%	1%
Czech Rep.	7.2	3.6	2.8	40%	29%	26%
Denmark	5.7	2.2	1.4	48%	29%	21%
Estonia	1.9	0.7	0.4	41%	22%	19%
Finland	4.6	1.5	0.8	35%	17%	8%
France	50.3	19.4	10.6	34%	17%	12%
Germany	16.1	10.8	6.2	22%	17%	11%
Greece	4.0	1.2	0.6	21%	8%	4%
Hungary	5.5	1.9	1.5	40%	21%	18%
Ireland	2.9	2.0	2.2	41%	38%	41%
Italy	16.0	8.2	1.9	21%	13%	3%
Latvia	5.0	2.0	1.0	74%	58%	44%
Lithuania	2.1	0.9	0.6	46%	29%	22%
Luxembourg	0.1	0.0	0.0	4%	2%	1%
Malta	0.0	0.0	0.0	1%	1%	0%
Netherlands	1.7	1.3	1.6	14%	12%	14%
Poland	84.1	46.1	36.9	71%	59%	56%
Portugal	5.5	2.0	1.0	27%	13%	8%
Romania	19.6	5.2	2.8	52%	24%	16%
Slovakia	1.1	0.4	0.3	15%	6%	6%
Slovenia	0.4	0.1	0.0	15%	6%	2%
Spain	10.1	4.4	1.8	16%	9%	4%
Sweden	1.3	0.6	0.2	8%	4%	1%
UK	4.5	3.1	2.8	10%	8%	6%
Total	260.6	121.9	79.9	34%	21%	15%

PM2.5 of the Eco-design scenario

	DOMESTIC sector, kilotons PM2.5			% National total		
	2020	2030	2050	2020	2030	2050
Austria	3.1	2.2	1.6	26%	20%	15%
Belgium	3.2	1.6	1.1	15%	8%	6%
Bulgaria	8.8	3.6	1.4	27%	14%	7%
Cyprus	0.0	0.0	0.0	3%	2%	1%
Czech Rep.	11.0	5.6	3.6	46%	33%	26%
Denmark	10.7	4.2	2.5	60%	40%	28%
Estonia	3.4	1.4	0.6	45%	26%	17%
Finland	6.6	3.3	1.6	34%	22%	10%
France	62.0	35.4	15.6	33%	22%	12%
Germany	19.2	16.0	11.2	23%	21%	16%
Greece	8.4	2.9	0.9	25%	11%	4%
Hungary	9.5	4.0	1.9	43%	26%	14%
Ireland	3.1	2.1	2.3	42%	36%	38%
Italy	23.8	11.4	2.9	26%	15%	4%
Latvia	8.8	3.6	1.5	71%	53%	33%
Lithuania	3.6	1.5	0.9	36%	20%	13%
Luxembourg	0.1	0.0	0.0	6%	3%	2%
Malta	0.0	0.0	0.0	0%	0%	0%
Netherlands	1.8	1.4	1.7	12%	10%	11%
Poland	125.5	60.9	40.2	74%	60%	52%
Portugal	11.3	3.8	1.6	18%	7%	3%
Romania	32.5	12.1	5.8	33%	16%	9%
Slovakia	2.2	1.2	0.6	20%	12%	7%
Slovenia	2.1	0.4	0.3	37%	12%	9%
Spain	14.8	7.6	2.6	17%	10%	4%
Sweden	2.3	1.2	0.7	12%	6%	4%
UK	6.6	4.0	3.0	12%	8%	6%
Total	384.4	190.8	105.9	35%	22%	14%

Emissions of PM10

PM10 of the baseline scenario

	DOMESTIC sector, kilotons PM10				% National total			
	2005	2020	2030	2050	2005	2020	2030	2050
Austria	8.7	5.5	4.2	4.1	25%	21%	17%	15%
Belgium	3.3	3.6	2.9	2.9	7%	8%	7%	7%
Bulgaria	15.0	12.2	8.1	5.1	19%	26%	20%	14%
Cyprus	0.1	0.1	0.0	0.0	1%	3%	2%	1%
Czech Rep.	16.7	15.4	12.6	11.4	28%	31%	27%	26%
Denmark	21.0	13.8	10.7	10.4	45%	39%	33%	33%
Estonia	8.0	4.3	3.2	3.0	28%	39%	33%	34%
Finland	9.6	8.9	7.1	5.5	20%	26%	22%	16%
France	149.6	90.8	64.0	52.9	34%	27%	21%	19%
Germany	24.8	24.9	25.7	24.5	11%	13%	14%	13%
Greece	14.0	10.6	6.8	5.0	17%	21%	15%	12%
Hungary	10.7	11.7	8.5	7.3	26%	32%	27%	24%
Ireland	5.2	3.8	3.1	3.9	25%	25%	23%	27%
Italy	30.8	29.3	25.6	14.4	16%	19%	17%	11%
Latvia	15.1	11.9	8.7	7.3	67%	64%	58%	54%
Lithuania	7.3	4.9	3.3	3.6	38%	31%	23%	25%
Luxembourg	0.2	0.2	0.1	0.1	6%	5%	4%	4%
Malta	0.0	0.0	0.0	0.0	1%	0%	0%	0%
Netherlands	2.9	1.9	1.9	2.3	7%	7%	6%	7%
Poland	181.6	155.4	119.6	97.8	60%	62%	56%	51%
Portugal	21.1	14.6	10.6	8.6	13%	16%	12%	10%
Romania	52.9	45.6	31.1	26.7	24%	32%	25%	23%
Slovakia	2.7	2.8	2.7	3.5	6%	14%	14%	18%
Slovenia	3.1	3.0	1.8	1.6	24%	34%	26%	24%
Spain	29.8	18.8	16.1	9.8	13%	11%	9%	6%
Sweden	4.0	2.8	2.1	1.7	8%	8%	5%	4%
UK	9.3	7.9	6.9	7.1	6%	7%	6%	6%
Total	647.8	504.8	387.4	320.7	25%	26%	22%	19%

PM10 of the MTFR scenario

	DOMESTIC sector, kilotons PM10			% National total		
	2020	2030	2050	2020	2030	2050
Austria	3.0	1.2	0.6	15%	7%	3%
Belgium	2.6	1.3	1.1	8%	4%	3%
Bulgaria	6.1	2.1	1.1	31%	14%	8%
Cyprus	0.0	0.0	0.0	2%	1%	0%
Czech Rep.	7.5	3.7	2.9	27%	17%	14%
Denmark	5.9	2.3	1.4	29%	14%	10%
Estonia	1.9	0.7	0.4	29%	13%	10%
Finland	4.7	1.6	0.9	20%	8%	4%
France	52.0	20.0	10.9	24%	11%	7%
Germany	16.8	11.4	6.6	12%	9%	5%
Greece	4.2	1.2	0.6	14%	5%	2%
Hungary	5.7	2.1	1.6	25%	11%	9%
Ireland	3.1	2.1	2.3	26%	20%	21%
Italy	16.5	8.5	1.9	14%	8%	2%
Latvia	5.2	2.0	1.1	56%	35%	22%
Lithuania	2.2	1.0	0.6	27%	14%	10%
Luxembourg	0.1	0.0	0.0	3%	1%	1%
Malta	0.0	0.0	0.0	0%	0%	0%
Netherlands	1.7	1.4	1.7	8%	7%	8%
Poland	88.2	48.3	38.4	53%	39%	34%
Portugal	5.7	2.0	1.0	18%	8%	4%
Romania	20.3	5.4	2.9	37%	14%	8%
Slovakia	1.2	0.4	0.3	8%	3%	3%
Slovenia	0.5	0.1	0.0	10%	3%	1%
Spain	10.5	4.5	1.8	10%	4%	2%
Sweden	1.3	0.7	0.2	5%	2%	1%
UK	4.6	3.2	2.8	6%	4%	3%
Total	271.7	127.3	83.1	22%	12%	8%

PM10 of the eco-design scenario

	DOMESTIC sector, kilotons PM10			% National total		
	2020	2030	2050	2020	2030	2050
Austria	3.3	2.3	1.7	13%	10%	7%
Belgium	3.4	1.8	1.2	8%	4%	3%
Bulgaria	9.3	3.8	1.5	21%	10%	5%
Cyprus	0.0	0.0	0.0	2%	1%	1%
Czech Rep.	11.4	5.8	3.7	32%	20%	15%
Denmark	11.1	4.4	2.5	38%	20%	13%
Estonia	3.5	1.4	0.7	34%	18%	10%
Finland	6.9	3.4	1.7	22%	12%	6%
France	64.1	36.6	16.1	23%	15%	7%
Germany	20.2	17.4	11.9	12%	11%	8%
Greece	8.7	3.0	0.9	18%	7%	2%
Hungary	9.9	4.2	2.0	28%	15%	8%
Ireland	3.3	2.2	2.3	25%	18%	18%
Italy	24.6	11.7	3.0	17%	9%	3%
Latvia	9.2	3.7	1.5	58%	37%	20%
Lithuania	3.7	1.6	0.9	25%	13%	8%
Luxembourg	0.1	0.0	0.0	4%	2%	1%
Malta	0.0	0.0	0.0	0%	0%	0%
Netherlands	1.9	1.4	1.7	7%	5%	6%
Poland	131.7	63.8	41.9	58%	40%	31%
Portugal	11.7	3.9	1.6	13%	5%	2%
Romania	33.7	12.5	6.0	26%	12%	6%
Slovakia	2.3	1.2	0.6	12%	7%	4%
Slovenia	2.2	0.4	0.3	27%	7%	5%
Spain	15.4	7.8	2.7	10%	5%	2%
Sweden	2.4	1.3	0.7	7%	4%	2%
UK	6.8	4.1	3.0	7%	4%	3%
Total	401.1	199.8	110.4	23%	13%	8%

Emissions of BC

BC emissions of the baseline scenario

	DOMESTIC sector, kilotons BC				% National total			
	2005	2020	2030	2050	2005	2020	2030	2050
Austria	2.7	1.9	1.3	1.3	37%	61%	67%	68%
Belgium	1.1	1.2	0.9	0.9	14%	36%	41%	42%
Bulgaria	3.2	2.9	2.1	1.3	54%	68%	66%	70%
Cyprus	0.0	0.0	0.0	0.0	2%	6%	8%	9%
Czech Rep.	3.5	3.9	3.3	3.0	36%	55%	62%	63%
Denmark	2.8	2.3	1.9	1.9	42%	57%	61%	62%
Estonia	1.2	0.9	0.7	0.6	64%	75%	78%	77%
Finland	3.5	3.5	2.8	2.2	47%	72%	77%	74%
France	30.3	24.3	19.6	16.2	44%	67%	70%	67%
Germany	6.9	7.2	7.0	7.1	19%	45%	54%	56%
Greece	2.6	2.1	1.4	1.0	31%	39%	35%	30%
Hungary	2.3	2.4	1.9	1.7	41%	64%	71%	71%
Ireland	0.8	1.1	0.9	1.2	22%	51%	66%	73%
Italy	4.9	5.0	4.3	3.0	14%	31%	38%	32%
Latvia	3.1	2.7	2.0	1.7	75%	84%	88%	88%
Lithuania	1.6	1.5	1.0	1.1	55%	66%	63%	68%
Luxembourg	0.1	0.0	0.0	0.0	4%	12%	18%	23%
Malta	0.0	0.0	0.0	0.0	2%	2%	0%	0%
Netherlands	0.5	0.5	0.5	0.6	6%	20%	24%	30%
Poland	41.3	35.1	27.6	25.2	82%	87%	92%	93%
Portugal	4.2	3.1	2.3	1.9	44%	53%	62%	58%
Romania	11.4	11.0	8.0	6.9	63%	69%	66%	65%
Slovakia	0.2	0.5	0.5	0.7	15%	45%	54%	68%
Slovenia	1.0	0.9	0.5	0.5	51%	72%	70%	68%
Spain	7.8	6.1	5.2	3.2	21%	33%	41%	33%
Sweden	1.1	0.5	0.4	0.3	18%	28%	24%	20%
UK	2.2	2.1	2.0	2.1	7%	21%	26%	26%
Total	140.3	122.6	98.5	85.7	37%	58%	63%	62%

Baseline emissions of the MTFR scenario

	DOMESTIC sector, kilotons BC			% National total		
	2020	2030	2050	2020	2030	2050
Austria	1.0	0.3	0.2	48%	35%	26%
Belgium	1.0	0.5	0.4	38%	34%	33%
Bulgaria	1.8	0.5	0.3	65%	43%	62%
Cyprus	0.0	0.0	0.0	5%	5%	7%
Czech Rep.	2.2	1.1	1.1	55%	63%	71%
Denmark	1.3	0.4	0.3	52%	35%	30%
Estonia	0.5	0.1	0.1	74%	66%	62%
Finland	1.9	0.4	0.2	64%	42%	32%
France	15.6	4.7	2.9	67%	52%	43%
Germany	5.0	2.5	1.8	45%	42%	37%
Greece	1.1	0.3	0.2	35%	17%	12%
Hungary	1.5	0.7	0.6	59%	62%	65%
Ireland	1.0	0.8	1.0	53%	69%	75%
Italy	3.9	1.9	0.5	29%	25%	9%
Latvia	1.5	0.4	0.3	81%	79%	80%
Lithuania	0.8	0.2	0.2	68%	57%	63%
Luxembourg	0.0	0.0	0.0	7%	6%	7%
Malta	0.0	0.0	0.0	3%	0%	0%
Netherlands	0.5	0.4	0.5	25%	30%	38%
Poland	26.1	14.1	13.3	85%	88%	91%
Portugal	1.6	0.4	0.2	46%	44%	33%
Romania	6.2	1.1	0.6	78%	50%	47%
Slovakia	0.3	0.1	0.1	38%	24%	35%
Slovenia	0.1	0.0	0.0	31%	14%	6%
Spain	3.6	1.2	0.6	29%	24%	17%
Sweden	0.3	0.1	0.0	22%	11%	6%
UK	1.6	1.1	1.2	20%	22%	21%
Total	80.2	33.7	26.6	56%	49%	48%

BC emissions of the eco-design scenario

	DOMESTIC sector, kilotons BC			% National total		
	2020	2030	2050	2020	2030	2050
Austria	1.2	0.6	0.3	51%	48%	36%
Belgium	1.1	0.7	0.4	35%	33%	26%
Bulgaria	2.5	1.2	0.5	67%	58%	44%
Cyprus	0.0	0.0	0.0	5%	6%	4%
Czech Rep.	3.2	1.9	1.2	62%	69%	68%
Denmark	1.9	1.0	0.5	59%	54%	38%
Estonia	0.7	0.3	0.1	71%	64%	39%
Finland	2.9	1.4	0.6	71%	67%	48%
France	20.1	10.2	3.9	71%	67%	46%
Germany	6.1	4.0	2.6	48%	50%	41%
Greece	1.7	0.7	0.2	35%	22%	10%
Hungary	2.1	1.1	0.7	60%	59%	50%
Ireland	1.0	0.8	1.0	58%	67%	74%
Italy	4.4	2.5	0.7	30%	28%	10%
Latvia	2.2	1.1	0.3	81%	79%	58%
Lithuania	1.2	0.6	0.2	61%	48%	29%
Luxembourg	0.0	0.0	0.0	10%	11%	8%
Malta	0.0	0.0	0.0	2%	0%	0%
Netherlands	0.5	0.4	0.5	23%	26%	31%
Poland	31.6	19.1	13.9	86%	88%	89%
Portugal	2.6	1.1	0.3	48%	43%	20%
Romania	9.1	3.9	1.5	65%	48%	29%
Slovakia	0.4	0.3	0.2	40%	37%	37%
Slovenia	0.7	0.1	0.0	65%	30%	17%
Spain	5.1	2.8	0.7	32%	32%	13%
Sweden	0.4	0.2	0.1	27%	16%	9%
UK	1.9	1.4	1.2	22%	23%	20%
Total	104.8	57.1	31.8	58%	55%	43%