MEASURES TO ADDRESS AIR POLLUTION FROM SMALL COMBUSTION SOURCES

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Abstract

This report reviews the perspectives for reducing emissions from small combustion sources in the residential sector, taking into account recent legislation and expectations on the future of solid fuel use in the residential sector in the EU. It highlights new technologies that enable effective reductions of emissions from these sources if applied at a larger scale, and different types of policy interventions that have proven successful for the reduction of pollution from small combustion sources in the household sector. Case studies address technological aspects as well as strategies, measures and instruments that turned out as critical for the phase-out of high-polluting household combustion sources. While constituting about 2.7% of total energy consumption in the EU-28, solid fuel combustion in households contributes more than 45% to total emissions of fine particulate matter, i.e., three times more than road transport.

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Disclaimer

Executive Summary

In 2005, households[1] contributed more than 45% to total PM2.5 emissions in the EU-28, and thereby three times more than road transport. However, there are large variations across Member States, with contributions ranging from below 10% in the Netherlands, Cyprus and Malta to almost 80% in Croatia, Latvia and Lithuania. 80% of emissions were caused by the combustion of biomass (wood), while the remainder occurred from coal combustion in a few countries (Poland, Ireland).

The National Emission Ceilings (NEC) Directive establishes for 2030 an emission reduction requirement for PM2.5 of 50%, relative to 2005, supported by provisions in the Ecodesign Directive for solid fuel combustion in small combustion devices, which also addresses organic gaseous compounds, CO and NO_x.

Despite these measures, it must be expected that by 2030 exposure to fine particulate matter will remain a significant threat to human health. Also the WHO guideline value for exposure to PM2.5 will not be fully achieved, especially in areas where solid fuel combustion in households will prevail.

In this context, this report reviews the perspectives for reducing emissions from household sources in the European Union.

A host of new technologies allow significant reductions of PM2.5 emissions, especially from biomass combustion. Representing current best available technology, these are commercially available, triggered by stringent national emission regulations for small combustion facilities in some countries. Wider application could significantly contribute to the emission reductions that are envisaged in the future.

Given the importance of regulation as a driver for technology development, the review of good practice examples reveals a wealth of experience throughout Europe. Successful policy interventions that have led to effective reductions of air pollutant emissions in the household sector include

- awareness campaigns, informal platforms, qualification of focus groups, product declaration and expert advice at the site,
- subsidies for thorough building renovation, for the switch to other fuels or the upgrade to new facilities,
- a ban of the use of solid fuels, as well as
- measures in combination to fight energy poverty.

Four case studies clearly demonstrate that successful solutions require an integrated approach. Actual improvements rarely occur overnight, but need a sustained process over several years. In areas with widespread and substantial exceedances of air quality limit values, a complete ban of solid fuels proved successful. However, such a ban should be accompanied by a scheme to support energy efficiency improvements before switching to alternate fuel systems.

End-of-pipe technologies, i.e. electrostatic precipitators, might be foreseen for existing facilities, however, shorter intervals for maintenance and regular checks for appropriate fuel have to be considered. Additionally, emissions can be reduced by changing the way wood is ignited, i.e., starting the fire on the top of the fuel stack; awareness campaigns could help to disseminate information about such practice.

[1] This study covers small combustion sources in the residential, commercial and agricultural sectors. For simplicity, these sectors are further referred to as the “household sector”.

List of acronyms

CLE	Current legislation
CO_2	Carbon dioxide
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Program of the Convention on Long-range Transboundary Air Pollution
EU	European Union
GAINS	Greenhouse gas - Air pollution Interactions and Synergies model
GDP	Gross domestic product
IED	Industrial Emissions Directive
IIASA	International Institute for Applied Systems Analysis
IIR	Informative Inventory Reports
kt	kilotons = 10^3 tons
MCP	Medium Sized Combustion Plants
NEC	National Emission Ceilings
NFR	'Nomenclature For Reporting' of emission inventories to EMEP/EEA
NH_3	Ammonia
NMVOC	Non-methane volatile organic compounds
NO_x	Nitrogen oxides
NO_2	Nitrogen dioxide
O_3	Ozone
PJ	Petajoule = 10^{15} joule
PM10	Fine particles with an aerodynamic diameter of less than 10 µm
PM2.5	Fine particles with an aerodynamic diameter of less than 2.5 µm
PRIMES	Energy Systems Model of the National Technical University of Athens
SO_2	Sulphur dioxide
TSAP	Thematic Strategy on Air Pollution
VOC	Volatile organic compounds

Contents

1 Context

In its Clean Air Programme for Europe (COM(2013)918 final), the European Commission has laid out a comprehensive approach to improve air quality in Europe. The main legislative instrument to achieve the 2030 objectives of the Clean Air Programme is Directive 2016/2284/EU on the reduction of national emissions of certain atmospheric pollutants, which entered into force on 31 December 2016 (the NEC Directive or NECD). The Directive calls for reduction of 50% of primary PM2.5 emissions, and to meet these, emissions especially from wood and coal combustion in the household sector will need to be reduced.

The recent Outlook in Future Emissions and Air Quality in the EU (Amann M., Anderl, et al. 2017), based on latest information of economic development and emission inventories, indicates that by 2030 exposure to fine particulate matter will remain a significant threat to human health. This comes despite the sharp decline in energy-related air pollutant emissions throughout the European Union that will result from the implementation of the NEC Directive and other source-oriented legislation. Also the WHO guideline value for exposure to PM2.5 will not be fully achieved, especially in areas where solid fuel combustion in households will prevail.

In view of the obligations for effective reductions of emission from the household sector that are implied by the NEC Directive and the need for further measures if the WHO guideline value for PM2.5 is to be met, this report reviews the perspectives for reducing emissions from household sources in the European Union. Section 2 reviews the current contributions of the household sector to total national primary emissions of PM2.5, an important constituent of fine particulate matter in ambient air, as well as the changes that can be expected for 2030 from the recent pieces of legislation. Section 3 presents new technologies that enable effective reductions of emissions from these sources. These are already well established on the market in some countries, and a wider application could achieve substantial cuts in emissions. Subsequently, Section 4 introduces successful examples of policy interventions that have led to effective reductions of air pollutant emissions in the household sector. Case studies address technological aspects as well as strategies, measures and instruments that turned out as critical for the phase-out of high-polluting household combustion sources. Finally, results and conclusions are laid down in Section 5.

2 The importance of pollution from household sources

The use of solid fuels in small combustion sources for the production of heat and hot water can cause high emissions of pollutants, such as fine particulate matter (PM_{10}, $PM_{2.5}$), SO_2, NO_x, VOC and benzo(a)pyrene, with negative impacts on human health.

In cold and moderate climate zones there is a long tradition of using solid fuels (coal and biomass), for heating. However, in many countries, coal and wood as the main heat supply source have been gradually replaced by cleaner forms of energy, including natural gas, district heat and electricity, although coal still constitutes an important fuel for household heating in some areas, due to social and other reasons. Also wood prevails as an important source of energy in many rural areas.

At the same time, there is an increasing trend of biomass use as a secondary or supplementary source for heating in so-called 'pleasure stoves', even in urban areas. In addition, some countries are actively promoting the use of biomass for heating as a climate policy measure, in order to increase the use of renewable energy sources.

2.1 The contribution of the household sector to total PM2.5 emissions

Overall, in 2005 biomass combustion in the residential sector accounted for 1.9% of total primary energy use in the EU-28, and coal combustion for 0.7% (Figure 2-1).

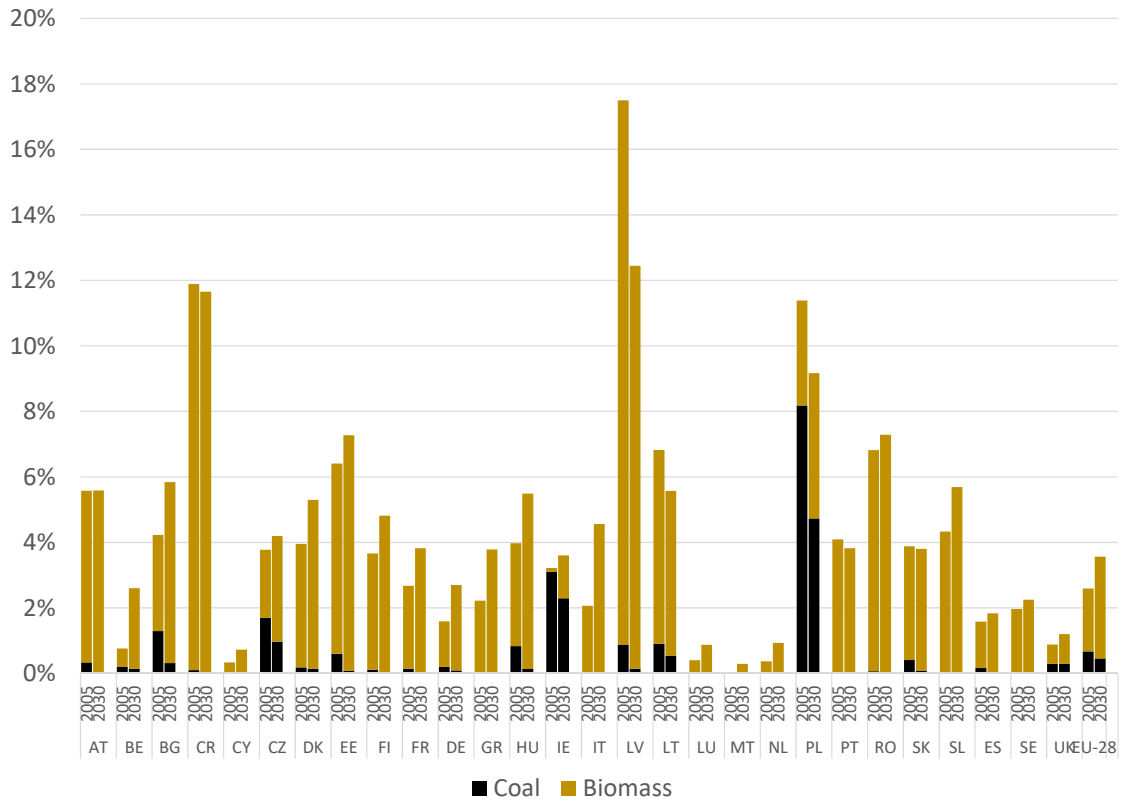


FIGURE 2-1: COAL AND BIOMASS USE IN THE HOUSEHOLD SECTOR AS SHARES OF TOTAL ENERGY USE, FOR 2005 AND THE PRIMES 2016 REFERENCE SCENARIO FOR 2030

Despite the small share in total energy consumption, in 2005 these 2.6% of energy use caused 46% of total primary emissions of PM2.5 in the EU-28 (biomass burning 36% and coal burning 10%), thereby outweighing emissions from the road transport by a factor of three.

There are large differences across EU Member States, owing to differences in climatic conditions, heating practices, fuel compositions, regulations, technological standards (of both buildings and heating systems) and climate policies that promote the use of biomass (Figure 2-2). While the household sector accounted for less than 10% of total PM2.5 emissions in the Netherlands, Cyprus and Malta, its share reaches up to 80% in Croatia, Latvia and Lithuania. In the EU household sector, about 80% of emissions emerged from the combustion of biomass. However, coal burning, while less important at the EU-level, contributed the majority of emissions in Ireland and Poland (Figure 2-2).

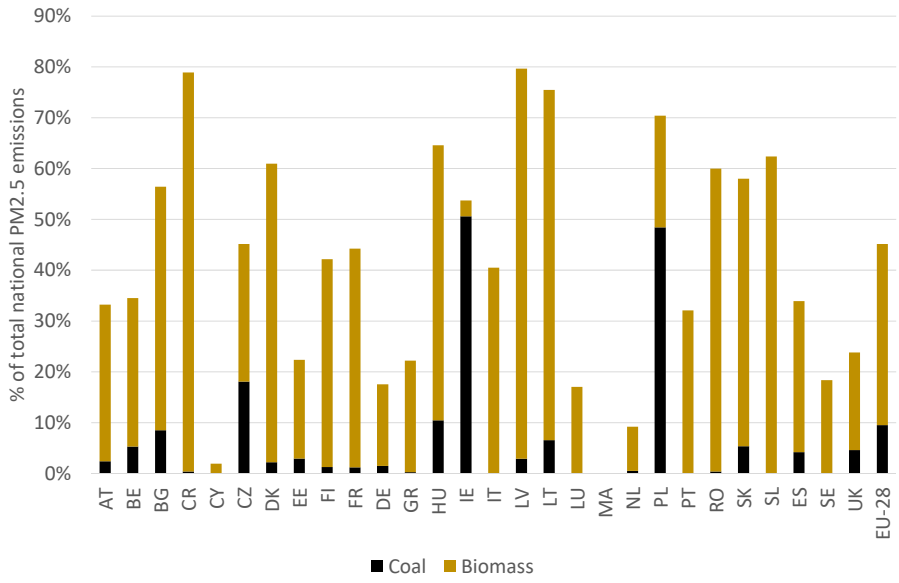
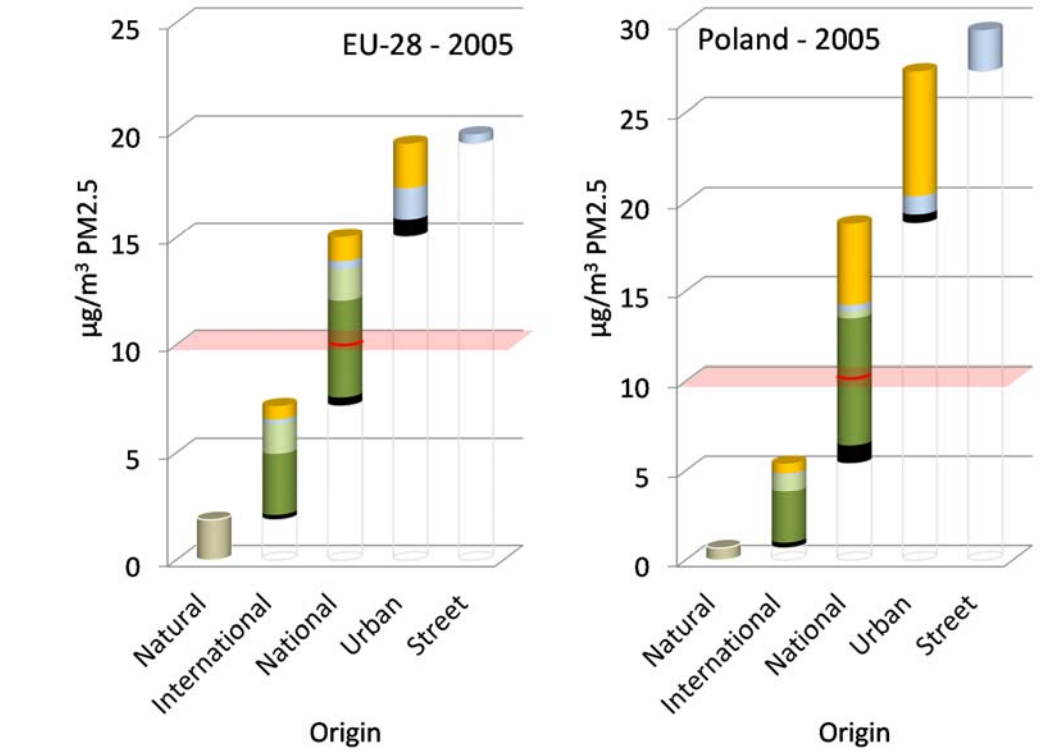


FIGURE 2-2: PERCENTAGE OF TOTAL NATIONAL PM2.5 EMISSIONS FROM THE COMBUSTION OF COAL AND BIOMASS (WOOD) IN THE HOUSEHOLD SECTOR IN 2005

The high share of emissions from the household sector in total primary PM2.5 emissions as well as their low release height make them an important contributor to ambient PM2.5 levels and population exposure. In 2005, across the EU it is estimated that, even at the urban traffic stations, about one quarter of PM2.5 concentrations originated from emissions of the household sector (left panel in Figure 2-3), and even more than 40% in areas with wide-spread heating with solid fuels (e.g., in Poland, Figure 2-3, right panel).



Note: These graphs present the contributions from different emission sources to ambient PM2.5, for the urban traffic stations that provided for 2009 sufficient data to the AIRBASE database of the European Environment Agency (EEA). The presentations follow the analysis presented in the TSAP Report #12 (Kiesewetter and Amann 2014)

FIGURE 2-3: SOURCES OF PM2.5 AT URBAN TRAFFIC STATIONS IN 2005; LEFT PANEL: AVERAGE OF ALL TRAFFIC STATIONS IN THE EU-28; RIGHT PANEL: POLAND

By 2030, the PRIMES 2016 REFERENCE scenario foresees for the EU-28 a 36% increase of biomass use in the household sector (inter alia due to enhanced renewable energy policies), while coal use is projected to decline by 42% (Figure 2-1; Figure 2-4.). In addition, recent EU legislation addresses, *inter alia*, emissions from solid fuel combustion in the household sector. Energy efficiency measures resulting from Ecodesign and Energy Labelling Regulations, as well as from the Energy Efficiency Directive (2012/27/EU) and Energy Performance of Buildings Directive (2010/31/EU), indirectly contribute to reductions of emissions by decreasing energy consumption in the European Union. The Commission Regulations of the Ecodesign Directive for solid fuel local space heaters (EU) 2015/1185[2] and (EU) 2015/1189[3] for solid fuel boilers specify emission limit values, supported by the Energy Labelling Directive 2015/1186 and 2015/1187 for small scale combustion with solid fuels. The NEC Directive established national emission ceilings for PM2.5, which imply for many countries emission reductions from these sources.

[2] COMMISSION REGULATION (EU) 2015/1185 of 24 April 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for solid fuel local space heaters

[3] COMMISSION REGULATION (EU) 2015/1189 of 28 April 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for solid fuel boilers

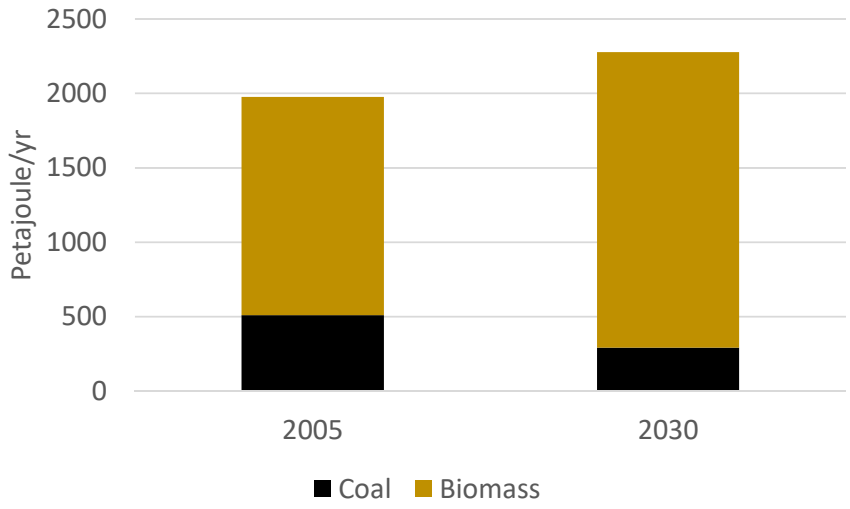


FIGURE 2-4: USE OF SOLID FUELS IN THE HOUSEHOLD SECTOR, EU-28, 2005 AND PRIMES 2016 REFERENCE SCENARIO FOR2030

Combining these new pieces of legislation with the recent projections of energy use, the 'Progress towards the achievement of the EU's air quality and emissions objectives' (Amann M., Anderl, et al. 2017) suggests for 2030 a 60% decline of PM2.5 emissions from the household sector, with a particularly steep decrease of emissions from coal burning owing to the continuing substitution of coal in households by cleaner fuels. However, as similar trends apply to other emission sources as well (e.g., transportation, industrial processes, etc.), the relative share of the household sector in total emissions will not change significantly (Figure 2-5).

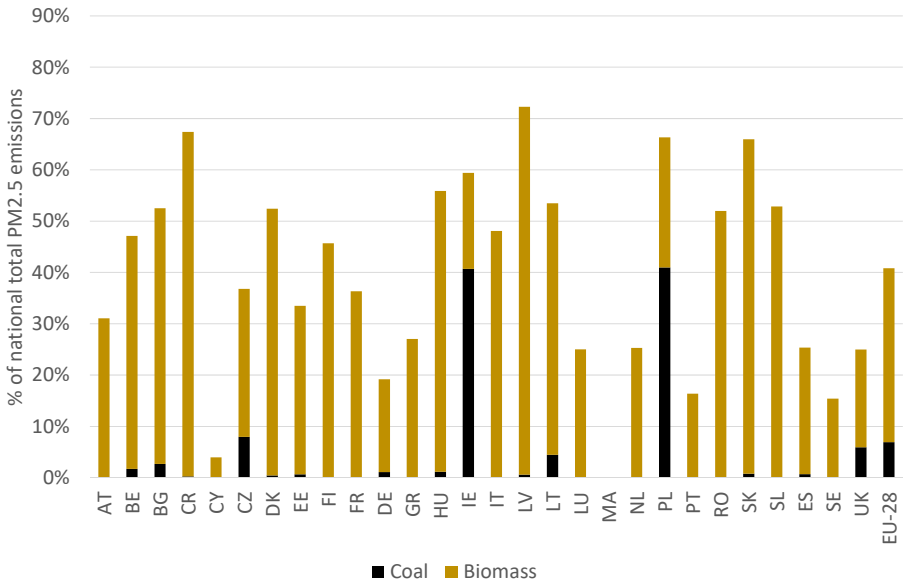


FIGURE 2-5: PERCENTAGE OF TOTAL NATIONAL PM2.5 EMISSIONS FROM THE COMBUSTION OF COAL AND BIOMASS (WOOD) IN THE HOUSEHOLD SECTOR IN 2030, AFTER IMPLEMENTATION OF THE NATIONAL EMISSION CEILINGS DIRECTIVE

2.2 Comparison of PM2.5 emission factors from biomass and coal combustion

As mentioned above, across Member State the different shares of the household sector to total national PM2.5 emissions are caused by a number of factors, including the prevalence of small combustion sources, the structure of fuel consumption for these sources, and social and regulatory conditions that affect the technological status of devices.

To this end, this section compares the (aggregated) emission factors[4] that are used in the GAINS model to reproduce the nationally reported emission figures for PM2.5 from small combustion sources in the household sector, based on published fuel consumption statistics. To stratify for differences in the composition of boilers and stoves, emission factors are presented separately for coal (coal is used only in a limited number of MS) and wood, and for boilers, stoves, and fireplaces. Note that the GAINS model employs more detailed source categories, the aggregated figures presented here are for comparative purposes only.

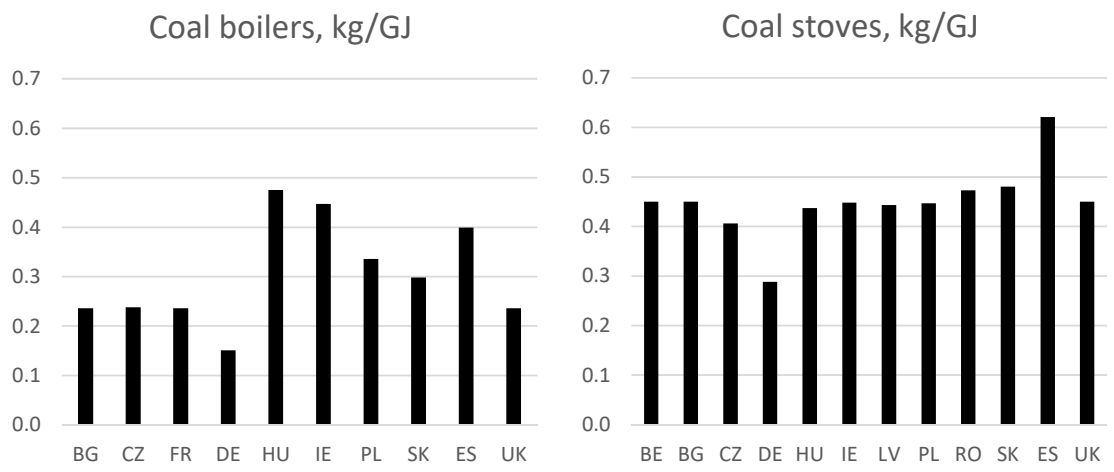


FIGURE 2-6: AGGREGATED EMISSION FACTORS FOR PM2.5 FOR COAL BOILERS AND COAL STOVES TO REPRODUCE THE EMISSION INVENTORY FIGURES OFFICIALLY REPORTED BY MEMBER STATES FOR 2005 WITH PUBLISHED FUEL STATISTICS

In general, there are large variations in emissions factors. For coal boilers, emission factors vary by a factor of three, with the lowest factors for Germany, which has stringent legislation implemented (see Section 4.2.1). Emission factors for coal stoves are more uniform, although the German value appear as the lowest again (Figure 2-6).

Similar observations emerge for wood combustion (Figure 2-7 to Figure 2-9), where even larger variability occurs across Member States. In principle, the figures reproduce different states and stringency of emission control legislation, as evidenced by the comparatively low values in Austria, Germany and Sweden.

In general, the comparison clearly illustrates that the benefits of stringent regulations for small combustion sources can be clearly seen in emission inventories, based on measurements that are carried out for representative conditions in a country.

[4] GAINS represents this sector by distinguishing several stove and boiler types with their specific emission factors. Here the fuel-weighted average emission factor is shown.

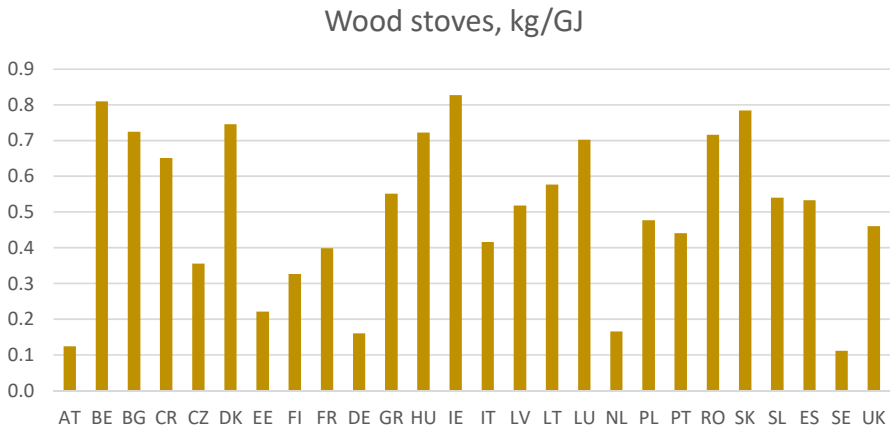


FIGURE 2-7: AGGREGATED EMISSION FACTORS FOR PM2.5 FOR WOOD STOVES THAT REPRODUCE THE EMISSION INVENTORY FIGURES OFFICIALLY REPORTED BY MEMBER STATES FOR 2005 WITH PUBLISHED FUEL STATISTICS

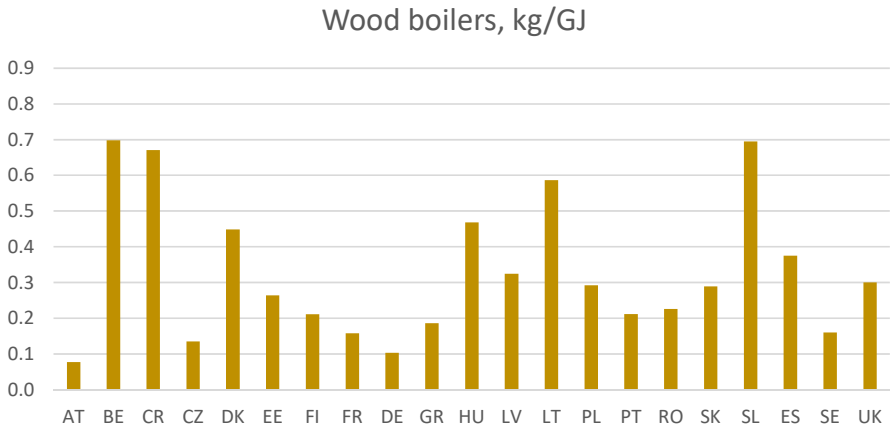


FIGURE 2-8: AGGREGATED EMISSION FACTORS FOR PM2.5 FOR WOOD BOILERS THAT REPRODUCE THE EMISSION INVENTORY FIGURES OFFICIALLY REPORTED BY MEMBER STATES FOR 2005 WITH PUBLISHED FUEL STATISTICS

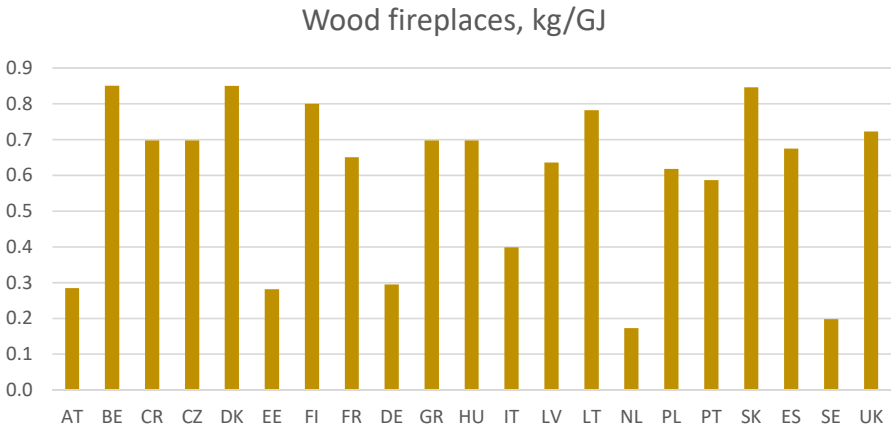


FIGURE 2-9: AGGREGATED EMISSION FACTORS FOR PM2.5 FOR WOOD FIREPLACES THAT REPRODUCE THE EMISSION INVENTORY FIGURES OFFICIALLY REPORTED BY MEMBER STATES FOR 2005 WITH PUBLISHED FUEL STATISTICS

It should be noted that emission factors for Denmark are considerably higher than for many other countries, despite the stringent legislation. This highlights an important caveat of such a comparison, which is related to different measurement methods that are used by countries to establish emission factors for their national inventories. Emissions of particulate matter can be defined as consisting of filterable (i.e., solid or liquid particles that are captured on the filter) and condensable fraction, i.e., formed from vapour upon cooling and condensation. Emission factors derived from dilution tunnel measurement are always higher than solid particle measurements, but the largest difference is for traditional stoves, boilers, fireplaces while the difference is much smaller for modern automatic and pellet stoves and boilers (van der Gon et al, 2015).

The current reporting of PM emissions is often inconsistent across countries where for residential combustion different measurement methods are used. Many of the measurements of combustion sources in Europe are only filterable, but some countries (e.g., Denmark, Norway and Switzerland) employ measurements of total particulate matter, using dilution tunnels, also for residential combustion sources. As this introduces major inconsistencies in emission inventories, the Task Force on Emission Inventories and Projections under the Convention on Long-range Transboundary Air Pollution is currently developing procedures for international harmonization.

3 New technologies and best available technology

This section provides an overview of some new technologies that can reduce air pollutant emissions from solid fuel combustion in installations for space heating and warm water preparation with a nominal heat output of less than 100 kW, i.e., for fireplaces, stoves, cookers and boilers in the residential, institutional, commercial and agricultural sector. It is for good reason a non-exhaustive list of new technologies, selected for broad information on the availability and tendencies on the market. In addition, it summarizes the state of development and application of end-of-pipe technologies for abatement of dust and particle-bound pollutants (e.g., benzo(a)pyrene). For the purpose of this study, only the emission-relevant parts are taken into consideration; fuel storage, buffer storage systems and distribution systems for heat and warm water are not included.

Based on literature data (e.g., the preparatory Study for the Ecodesign-directive of Lot 15[5] or EMEP/EEA Emission Inventory Guidebook 2016), market surveys, test reports and expert interviews, technologies have been selected which are considered best available technologies for the use of solid fuels in this sector. The main selection criteria were low emissions, high energy efficiency, state of technological development, application, market diffusion and costs.

As regards emissions, only results from testing under laboratory conditions have been used for assessing the performance of small combustion installations. The authors are aware that under real life operating conditions emissions will be significantly higher due to site- and fuel specific factors. However, it is assumed that the best performers under test-bench conditions are also among the lowest emitters under real life operating conditions.

Cost figures have been collected from manufacturers and are given as ranges to reflect differences in size and type as well as the price difference across Member States. In general, only investment costs are given, additional costs arising from installation, costs for fuel storage and heat distribution, operation, cleaning and maintenance as well as costs for the chimney are not included. Also excluded are costs which arise from combining the combustion installation with other zero-emission systems (e.g., solar heat).

Based on the selection criteria described above, four technologies of small scale combustion facilities have been chosen and are described in more detail:

- Wood chip boilers
- Pellet boilers
- Log wood boilers
- Log wood stoves

Under real life operating conditions, emissions will be much higher due to variations related to products of different manufacturers, fuel quality as well as quality of planning, installation, maintenance and operation. While a comprehensive understanding of real life performance is still lacking, it is expected that the selected technologies, when represented by type-approved products and properly implemented will cause comparable low emissions.

So far, the (EU-wide) application of end-of-pipe technologies (like electrostatic precipitators) is limited, mainly because of high investment costs, high expenses for cleaning and maintenance, lack of space and construction constraints, and the availability of efficient systems.

[5] Preparatory Studies for Eco-design Requirements of EuPs (II) [Contract N°TREN/D3/390-2006/Lot15/2007/S07.74922], Lot 15 - Solid fuel small combustion installations – Task 1 to 8, European Commission DG TREN, December 2009

TABLE 1: EMISSION LIMITS FOR ADMITTANCE OF SINGLE STOVES FROM 2022 ON AND OF CENTRAL HEATING FACILITIES FROM 2020 ON (REGULATIONS EU 2015/1185 AND 2015/1189 ACCORDING TO EU ECODESIGN-DIRECTIVE)

Type of small scale combustion facility	Fuel	Operation	Rated heat output	Reference	O_2-Reference value	Emission limits CO	Emission limits NO_x	Emission limits PM	Emission limits OGC
			[kW]		[%]	[mg/m³]	[mg/m³]	[mg/m³]	[mg/m³]
Single stove with open combustion chamber	Solid biogenic fuels	all	≤50 kW	2015/1185	13	2,000	200	50	120
Single stove with closed combustion chamber	Solid biogenic fuels	all	≤50 kW	2015/1185	13	1,500	200	40	120
Single kitchen stove	Solid biogenic fuels	all	≤50 kW	2015/1185	13	1,500	200	40	120
Single stove with open combustion chamber	Solid fossil fuels	all	≤50 kW	2015/1185	13	2,000	300	50	120
Single stove with closed combustion chamber	Solid fossil fuels	all	≤50 kW	2015/1185	13	1,500	300	40	120
Single kitchen stove	Solid fossil fuels	all	≤50 kW	2015/1185	13	1,500	300	40	120
Single stove with closed combustion chamber	Wood pellets	automatically	≤50 kW	2015/1185	13	300	200	20	60
Central heating facility	Solid biogenic fuels	manually	≤500 kW	2015/1189	10	700	200	60	30
Central heating facility	Solid fossil fuels	manually	≤500 kW	2015/1189	10	700	350	60	30
Central heating facility	Solid biogenic fuels	automatically	≤500 kW	2015/1189	10	500	200	40	20
Central heating facility	Solid fossil fuels	automatically	≤500 kW	2015/1189	10	500	350	40	20

3.1 Wood chip boilers with low-emissions

Innovation: Wood carburettor using updraft gasification with activated charcoal filter effect, enhanced fuel suction technology, ultra-low particulate matter emissions

Technology description: The wood gasification chamber is filled with wood chips. At the bottom a fire bed causes carbonization of the wood chips above. This layer works as an activated charcoal filter. Wood gas rises through the charcoal layer and the wood chips are finally burned. Additionally, innovative and enhanced fuel suction technology broadens the scope of application.

Rated heat output: 7 to 60 kW_{th}

Market launch of the described technology: 2016

Test bench emission for market approval: 0.9 mg/m³ PM and 5 mg/m³ CO at full load and 13 % flue gas oxygen level, 1.0 mg/m³ PM and 11 mg/m³ CO at partial load and 13 % dry flue gas oxygen level.

Investment costs (without costs for the storage of wood chips, for heat distribution and for the chimney and without planning and installation): 13,000 to 18,000 €

Technology distribution in Europe (non-exhaustive list): Germany, Austria, Italy, Belgium, Luxembourg, Hungary, Czech Republic, Spain, Slovenia, Slovakia, Poland, Sweden, The Netherlands, Lithuania, Ireland, United Kingdom, Greece, France, Estonia, Denmark

Applicability: This technology is regarded general applicable throughout the EU. It can be used in new or renovated smaller and larger buildings (low-energy building, single-family house, apartment building, agriculture, services) and for small district heating systems (micro systems). The application is most sustainable if the biomass is harvested locally to avoid additional emissions by transport.

3.2 Pellet boilers with low emissions, possibly in combination with zero-emission systems

3.2.1 Pellet boilers with low emissions

Innovation: Underfeed pellet combustion with integrated particulate separation using cyclone effect, enhanced lambda probe technology, low particulate matter emissions.

Technology description: Underfeed combustion reduces dust turbulence, the fire bed stays stable. An innovative broadband lambda probe and newly developed ceramic igniter elements reduce emissions due to enhanced combustion control. Special heat exchange elements result in low flue gas temperatures and 96 % combustion efficiency. Geometric design of the integrated particulate separation using the cyclone effect causes turbulence in combustion gas. Therefore heavy dust particles are separated.

Rated heat output: 8 to 35 kW_{th}, minimum capacity of specific design: 2.5 kW_{th}

Market launch of the described technology: Approximately 2009

Test bench emission for market approval: 5 mg/m³ PM and 11 mg/m³ CO at full load and 13% dry flue gas oxygen level.

Investment costs: (without costs for the storage of pellets, for heat distribution and for the chimney and without planning and installation): About 5,500 to 13,000 €

Technology distribution in Europe (non-exhaustive list): Germany, Austria, Italy, Belgium, Spain, Slovenia, Hungary, Sweden, Ireland, United Kingdom, France, Denmark

Applicability: This technology is regarded general applicable throughout the EU, preferably in well insulated buildings (new or renovated). It can be used in new or renovated smaller and larger buildings (low-energy building, single-family house, apartment building, agriculture, services). The application is most sustainable if the biomass is harvested locally to avoid additional emissions by transport, although pellets imported from outside Europe have a large market share.

3.2.2 Pellet boilers with low emissions and integrated electricity generation (Micro-CHP)

Innovation: Condensing pellet boiler with up to 107 % thermal efficiency, efficient combustion control, adjustable boiler temperature (28 °C to 85 °C), possibility to upgrade with Stirling engine for power generation and combination with solar thermal collectors and photovoltaics.

Technology description: The combustion process is optimized by a multi-segmented burner plate, an advanced combustion chamber sensor and pressure monitoring. Energy efficiency is increased by using condensing technology. The boiler provides user-friendly interface and dust-free emptying of the ash container. The system`s features can be extended by electricity generation by using a Stirling engine.

Rated heat output: 3 up to 18 kW_{th}

Market launch of the described technology: 2014 (2017 with power generation)

Test bench emission for market approval: 12 mg/m³ PM and 4 mg/m³ CO at 13 % dry flue gas oxygen level.

Investment costs: (without costs for the storage of pellets, for heat distribution and for the chimney and without planning and installation): About 9,000 to 11,500 € (without additional technologies such as Stirling engine or Photovoltaics)

Technology distribution in Europe (based on the distribution system of one manufacturer): Germany, Austria, Italy, Belgium, Czech Republic, Spain, Slovenia, The Netherlands, Ireland, United Kingdom, France, Denmark

Applicability: This technology is regarded general applicable throughout the EU, preferably in well insulated buildings (new or renovated). It can be used in new or renovated smaller and larger buildings (low-energy building, single-family house, apartment building, agriculture, services). The application is most sustainable if the biomass is harvested locally to avoid additional emissions by transport.

3.2.3 Pellet boilers with low emissions and integrated heat pumps

Innovation: Pellet boiler and heat pump hybrid system, combination with photovoltaics possible

Technology description: This product combines the use of pellets, ambient heat and electricity production. A software adjusts the system to the most economical or efficient operational mode, depending on the homeowners preferences.

Rated heat output: 10 to 16 kW_{th}, minimum capacity of specific design: 2.5 kW_{th}

Market launch of the described technology: 2016

Test bench emission for market approval: 17 mg/m³ PM and 9 mg/m³ CO at 13 % dry flue gas oxygen level.

Investment costs: (without costs for the storage of pellets, for heat distribution and for the chimney and without planning and installation): About 9,000 to 10,000 € (combination with a heat pump with a rated heat output of 10 or 16 kW_{th} for ambient air would cause additional costs of 4,000 to 6,000 €).

Technology distribution in Europe (non-exhaustive list): Germany, Austria, Italy, Czech Republic, Hungary, Slovakia, Slovenia, Belgium, The Netherlands, Ireland, United Kingdom, Spain, France, Denmark

Applicability: This technology is regarded general applicable throughout the EU, preferably in well insulated buildings (new or renovated). It can be used in new or renovated smaller and larger buildings (low-energy building, single-family house, apartment building, agriculture, services). The application is most sustainable if the biomass is harvested locally to avoid additional emissions by transport.

3.3 Log wood boilers with low emissions and integrated heat pumps

Innovation: Wood carburettor boiler with rotating combustion chamber and heat pump hybrid system, can be combined with photovoltaics

Technology description: This product combines the use of log wood, ambient heat and electricity production. This technology combines the efficiency (up to 94 %) of the wood carburettor (with temperatures of above 1,400 °C in the ember bed instead of only 1,000 for the improved combustion quality) and the economic viability of a heat pump. The hot combustion zone for exceptionally tolerant burnout characteristics is enabling the appliance to handle wood of varying quality. This technology provides a tolerant combustion for different levels of moisture content in hard and softwoods, as well as woodchips. A rotary combustion chamber for complete burnout with effective separation of airborne ash, ensuring the best possible emission values supported by an advanced Lambda probe and dual-controlled preheated secondary air. An automatic hot air ignition system further serves convenient operability with low emission in the combustion starting phase. Furthermore the automatically sustained ember is reducing the number of starts. For high combustion energy efficiency in every output range the facility is using downstream turbulators at the heat exchanger including semi-automatic cleaning. Regarding energy efficiency of the combined heat pump this part of the technology is very efficient for the use with an ambient air temperature higher than 7 °C and a low temperature heat distribution system with less than 35 °C. The intelligent management system automatically adjusts the system to the most economical or efficient operational mode, depending on the homeowners preferences.

Rated heat output: 14 to 30 kW_{th}, modulation down to 2,5 kW_{th}

Market launch of the described technology: Approximately 2014

Test bench emission for market approval: 11 mg/m³ PM and 89 mg/m³ CO at 13 % dry flue gas oxygen level.

Investment costs: (without costs for the storage of fuels, for heat distribution and for the chimney and without planning and installation; heat pump excluded): About 7,000 to 12,000 €

Technology distribution in Europe (non-exhaustive list): Germany, Austria, Italy, Czech Republic, Hungary, Slovakia, Slovenia, Belgium, The Netherlands, Ireland, United Kingdom, Spain, France, Denmark

Applicability: This technology is regarded general applicable throughout the EU, preferably in well insulated buildings (new or renovated). It can be used in new or renovated smaller and larger buildings (low-energy building, single-family house, apartment building, agriculture, services). The application is most sustainable if the biomass is harvested locally to avoid additional emissions by transport.

3.4 Log wood stoves with low emissions and high energy efficiency

Innovation: Log wood stove with two combustion chambers, high energy efficiency with up to 93 %, low particulate matter emissions compared to traditional stoves

Technology description: Two flames are burning in two directions: one upward and one downward. In the first upper combustion chamber the log wood is dried and gasified in an almost oxygen-free atmosphere at a temperature between 1,000 and 1,200 °C. In the second combustion chamber the resulting gases are converted into heat using fresh air. The system can be operated without using a fan. A 180 ° sluggishness separation of the fine particulate matter in the exhaust gases is applied in the lower combustion chamber to reduce emissions. The energy efficiency during a whole burning-hour is more than 90%. The technology is producing up to 40% less ash compared to usual stoves and provides constantly low emission of particulate matter and CO including at partial and minimum heat output load.

Rated heat output: 5 to 8 kW_{th}. The minimum heat output load is 2 kW_{th}.

Market launch of the described technology: 2007

Test bench emission for market approval: 20 mg/m³ PM and 625 mg/m³ CO at 13 % dry flue gas oxygen level.

Investment costs: (without costs for the storage of log wood and for the chimney and without planning and installation): About 2,500 to 6,500 €

Technology distribution in Europe (non-exhaustive list): Germany, Sweden, Austria, Italy, Greece, Latvia, Lithuania, Poland, Czech Republic, Hungary, Romania, Slovakia, Slovenia, Belgium, The Netherlands, Luxembourg, Ireland, United Kingdom, Spain, France

Applicability: This technology is regarded general applicable throughout the EU, preferably in well insulated buildings (new or renovated). It can be used in new or renovated smaller and larger buildings (low-energy building, single-family house, apartment building, agriculture, services). The application is most sustainable if the biomass is harvested locally to avoid additional emissions by transport.

3.5 Electrostatic precipitators

Innovation: Reduction of particulate matter in the flue gas of small scale combustion sources.

Technology description: Electrostatic precipitator (ESP) for the removal of fine particulate matter which is installed either at the exhaust pipe between the small combustion plant for solid fuels and the chimney or in the chimney itself. This ESP comprises the following main components: the filter

cartridge, the high voltage electrode with 15 to 20 kV and the temperature sensor. The ESP can be used up to a maximum exhaust temperature of 200 °C.

The facility needs a maintenance interval of one-time per year for the entire facility and four-times per year for the cartridge for the soot.

The electric power consumption in operation is typically between 20 and 50 W (Standby 0.5 W). The precipitation rate of particulate matter at the test bench of a high quality filter facility is between 57 % and 81 % with 73 % in average. It is expected that up to 70 % reduction of particulate matter will be achieved over longer operation periods.

The ESP can be applied at small combustion facilities for solid fuels with an appropriate rated heat output up to 100 kW_{th}

Market launch of this technology: 2014

Investment costs: (without costs of planning, installation, service and maintenance): About 800 to 4,000 €.

Technology distribution in Europe (non-exhaustive list): Germany, Finland, Sweden, Austria, Italy, Greece, France, United Kingdom, Belgium, The Netherlands, Luxembourg, Czech Republic, Hungary

Applicability: This filter technology is applicable at small scale combustion installations using solid fuels at smaller buildings of all thermal quality and for energy efficient renovated larger buildings. A successful application of this technology for emission reduction on medium and long-term would need high attention or control of quality of planning, installation, service, maintenance and of the proper use of manually operated facilities – especially on appropriated and admitted fuel.

4 Good practice examples and case studies

The good practice examples presented in this section demonstrate the positive impact of strategies and measures to implement new technologies and to promote the restructuring of heating system towards less polluting forms of heating across the EU 28. These examples show how strategies and measures impact on the implementation of new technologies and how the restructuring of heating systems towards less polluting systems can be achieved. The following is a non-exhaustive list of activities relevant to consider for the reduction of emissions from domestic heating:

- Administrative measures, including:
  - Awareness raising for appropriate operation of household combustion devices, trainings and information campaigns,
  - Registration of combustion facilities and inspections,
  - Provisions for proper installation and improved maintenance,
  - Emission standards for household combustion appliances: regulations of in-situ emissions (e.g., emissions limit values for the operational phase),
  - Ecodesign provisions for solid fuel stoves and boilers (addressing PM2.5, organic gaseous compounds, CO and NO_x.),
  - Energy-labelling provisions for solid fuel stoves and boilers (bench test for placing on the market),
  - Improved fuel standards (e.g., regarding sulphur content, moisture content, content of ashes and heavy metals);
- Strategies for phasing out high-polluting solid fuel combustion, including:
  - Substitution of solid fuels by zero-emission technologies (e.g., ambient heat), low air-emission technologies (e.g., natural gas) or district heating,
  - Fiscal incentives including scrapping schemes,
  - Bans and restrictions on solid fuel use;
- Strategies and measures to address energy efficiency, including:
  - Energy-efficient building renovation,
  - Improved heat management;
- Strategies and measures to address fuel poverty, including:
  - Measures to avoid fuel poverty, overcome investment hurdles, and avoid illegal (waste) burning,
  - Combined measures addressing energy poverty and non-discrimination of people with lower incomes.

In the following examples and case studies will be presented (Section 4.10).

4.1 Awareness raising, training, and information campaigns

Awareness raising campaigns for appropriate operation of household combustion devices can be found in many MS. In order to increase the citizens awareness of heating problem and to motivate them to change their behaviour, e.g., the Czech Republic, Germany, Sweden, South Tyrol and Austria compiled brochures, folders, and homepages with detailed information.

4.1.1 Environmental labelling

The Blue Angel is a certification for environmentally sound products and services in Germany and is recognised as a member of the international Global Ecolabelling Network (GEN).

The Global Ecolabelling Network (GEN) is a non-profit association of third-party environmental performance recognition, certification and labelling organisations. It was founded in 1994 to improve, promote and develop the eco-labelling of products and services, and has currently around 30 members. Only environmentally-friendly products and services proven to have lower environmental impact may carry a GEN member ecolabel. Criteria and product categories differ among the member countries, reflecting local and regional conditions, but all standards address multiple environmental attributes and most have requirements for items such as toxicity, air quality, energy use, reusability and recyclability, VOCs, carcinogens and other issues of concern.

Similar eco-labelling programmes have been introduced by Sweden (environment labelling 'TCO Certified' and 'Good Environmental Choice'), in Nordic countries (environment labelling 'Nordic Swan Ecolabel'), and the European Union with the 'EU Ecolabel'.

Since 1990, the Austrian ecolabel 'Österreichisches Umweltzeichen' provides guidance to consumers, manufacturers and public procurement on environment, health and quality.

Sources: GEN (2016);

- The Austrian Ecolabel – Das Österreichische Umweltzeichen (2017): Vision https://www.umweltzeichen.at/cms/de/home/vision/content.html
- Nordic Swan: http://www.nordic-ecolabel.org/about/

General evaluations of environmental labelling systems are provided in:

- http://ec.europa.eu/environment/ecolabel/documents/Report_from_the_Commission.pdf
- https://www.umweltbundesamt.de/publikationen/25-jahre-blauer-engel-aelteste-umweltzeichen-welt

4.1.2 Public education - Italy

The public sharing of local air pollution monitoring with households with biomass heating appliances has proved to increase the perception of health risk from emissions and the assimilation of information regarding good burning techniques amongst end-users in Italy. In addition, poor installations and fuel management practices were identified to cause significant poor indoor air quality. Results were discussed with the appliance owners leading to adoption of more effective practices to manage emissions from their appliances during the following even colder winter period.

Sources: AIRUSE (2016) ; Piccardo et al. (2014)

4.1.3 Awareness campaigns - Austria, Switzerland, Germany, Denmark

The Austrian campaign 'Richtig Heizen' (proper heating) was launched by the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW). This initiative is carried out in co-operation with the national organization of chimney sweeper ('Wärmetechnische Gesellschaft der Rauchfangkehrer'), the national association for tiled stoves ('Kachelofenverband') and the initiative 'Medicals for a Healthy Environment' ('Ärzte für eine gesunde Umwelt'). Additionally, similar information and awareness initiatives are established in Austria by some regional authorities, mainly by offering information on the Internet.

The aim of the campaign 'Richtig Heizen' is to provide technical information and support to the consumers regarding energy efficiency and emission reductions. For instance, an easy way to effectively reduce emissions from manually stoked wood stoves is the ignition technique from above. This campaigning is intended to improve the use of appliances for household heating and heating of buildings and for hot water preparation. In addition, the campaign aims to support decision makers to invest in emission free and low emission facilities.

The homepage provides an online-calculator, the folder 'Richtig Heizen' and informal events at exhibitions. The folders are also distributed by the national organization.

The LIFE project 'Clean Heat' by Deutsche Umwelthilfe and the Danish Ecological Council provides information on wood burning on their website. Information material, publications and movies were prepared to inform on the environmental impact of wood burning and proper operation wood stoves.

Sources: http://www.richtigheizen.at/, http://www.clean-heat.eu/en/home.html

Switzerland has established a similar awareness campaign, called 'Fair Feuern' (fair heating). The central idea of this initiative is the dissemination of knowledge about innovative ignition of fire in manually operated stoves with log wood starting the fire from the top. This reduces particulate matter emissions dramatically in the starting phase. The campaign also provides information on energy efficient operation with low emissions for all phases of the combustion cycle, as well as on maintenance of equipment and the storage of wood, on different biomass fuels, on good practice in planning of small scale combustion facilities with biomass and about regulations on these facilities. The initiative has been based on local initiatives triggered by air quality problems due to adverse dispersion conditions in valleys within the heating period.

Source: http://www.fairfeuern.ch/

4.1.4 The 'Smoke-man' campaign - Czech Republic

The comic figure 'Smoke-man' was created at the Energy Research Center (ERC) in Ostrava in the 1970s. The ERC also organizes an educational show 'Smokeman in action' for children and adults in order to instruct the public about proper combustion practices in local heating.

Smokeman arrives in a mobile boiler home, in different towns and offers practical and interesting demonstrations for kids like how to measure the flame temperature using a thermocouple or a thermal camera or conduct an experiment where the children learn how they can at home create a temperature inversion using kitchen salt, water and food dye. The audience learns about the basic types of combustion installations, their basic characteristics, how to choose proper wood and how to handle properly boilers, stoves and fireplaces.

In addition, Smokeman comics, a Website for demonstrating a show, interviews in Czech Radio Ostrava and TV and 'Smokeman's ten commandments' have been created.

Sources:

http://vec.vsb.cz/smokeman/o-smokemanovi/smokemanovo-desatero.html
http://vec.vsb.cz/smokeman/katalog-obrazku/clanek-32/462-komix1.pdf
http://vec.vsb.cz/smokeman/katalog-obrazku/clanek-32/463-komix2.pdf
http://www.tvnoe.cz/video/11032

4.1.5 The Interreg project PMinter - Austria and Slovenia

The EU-funded 'PMinter' project, which was completed in 2013, developed tools and air pollution control plans for air quality management and health protection in small- and medium-sized cities, in particular for Leibnitz and Klagenfurt (Austria) and Maribor (Slovenia). The project created a regional, problem-oriented, multiscale model system for air quality management for the border region between Austria and Slovenia, which then identified household heating (in particular emissions from woodstove combustion) as a major source of high PM_{10} concentrations in this region. Subsequently, a new Air Quality Management Plan was developed and implemented, accompanied by public awareness raising campaigns.

The air quality model simulations and the demonstration activities identified the following measures as highly efficient for reducing negative health impacts from wood combustion while at the same time pursuing climate protection objectives:

- Establishing biomass district heating systems in urban areas: Connecting households using old single stoves to district heating systems has a large potential to reduce the annual number of days with a daily mean PM_{10} value >50 µg/m³ in Klagenfurt;
- Guidelines for low-pollution heating-systems;
- Schemes to promote the replacement of old wood-fired ovens (the need to use modern biomass stoves);

- Information about efficient ways of heating to be provided by chimney sweeps (a programme for chimney sweepers was developed to improve their knowledge on wood burning and pollutant emissions from old and new combustion systems).
- A leaflet was drawn up to inform the owners of wood-fired stoves about low-pollution heating.

The project was accompanied by pro-active PR work, through folders, website, newsletters, public lectures, publications, a press conferences, reports on radio and TV.

Sources: PMinter (2013)

4.1.6 'Club of professionals of wood heating systems' - Région Grenobloise, France

In 2016, France launched a 'Club of professionals on wood heating systems' (Club des professionnels du chauffage au bois). These professionals have signed the 'Charte d' engagement' for clean air, stating their high qualifications in the field and their commitment to training and advising their customers to reduce the environmental impact of residential wood heating. They also inform their customers on subsidies offered by the state and local/regional authorities for replacement of non-efficient heating devices. Furthermore, they have placed a focus on raising awareness of the modalities of energy-efficient building renovation.

Source: 'Charte d' engagement' (2016) http://www.auvergne-rhone-alpes.developpement-durable.gouv.fr/IMG/pdf/2016-06-20_charte_Club_des_pros.pdf

4.2 Provisions for proper installation and improved maintenance

4.2.1 Inspection and maintenance of biomass appliances: Germany

In a number of countries, including Germany, chimney sweeps are required by law to inspect heating appliances on an annual basis. Appropriate installation, certification of the fuel storage, emission limit compliance are checked as well as the chimney is cleaned. Inspection and maintenance of biomass appliances shall be undertaken according to the manufacturer's specification to ensure efficient combustion and low emissions.

Source: AIRUSE (2016)

4.2.2 Regular inspection and requirements for new biomass appliances - Zürich

In the city of Zürich (Switzerland), small-scale biomass combustions with rated heat output from 0 to 40 kW_{th}, which are not covered by the canton of Zürich's inspection concept, are periodically checked for compliance with the CO emission limit value. For non-compliant equipment, adjustments of the heating system or exchanges of the boilers are mandatory, leading to substantial reductions of PM emissions.

The planning and installation of new biomass stoves and boilers has to minimize certain high-emission operating conditions (start, stop, partial load) by extending the continuous combustion phase. That is achieved by:

- mandatory installation of buffer storage for manually-stoked wood boilers,
- correct heat load dimensioning for automatically-stoked wood and pellet boilers,
- mandatory automated ignition for automatically-stoked wood boilers.

Compliance checks as part of the periodical inspections ensure that planning requirements are met and PM emissions are effectively reduced.

Source: UGZ (2011)

4.3 Emission standards for household combustion appliances

4.3.1 Stringent emission limit values for household solid fuel combustion - Germany

Since October 2010, the Aachen fuel ordinance sets stringent emission limit values for solid fuel local space heaters with a nominal heat output from 4 to 15 kW. Small combustion facilities in the urban area of Aachen have to comply with the following limit values:

- New stoves: 40 mg/m³ PM and 1,250 mg/m³ CO (dry flue gas, 273 K, 1,013 mbar at 13 % O_2)
- Existing stoves: 75 mg/m³ PM and 2,000 mg/m³ CO (dry flue gas, 273 K, 1,013 mbar at 13 % O_2)

All existing stoves exceeding the emission limits had to be retrofitted with filters or replaced by the end of 2014. A supplemental funding program was established to support the replacement of old solid fuel local space heaters. Many other cities in Germany, especially Munich, have implemented similar ordinances on the use of solid fuels in household appliances.

The 'Bundesimmissionsschutz-Verordnung' (1st BImSchV, amended March 2010) on small combustion facilities specified minimum requirements for the operation of small scale combustion plants. To enhance the replacement of older appliances, the German legislation provides a transition period as a function of the installation date of the equipment. Appliances installed prior to 1995 had to meet the current requirements by 2015; appliances installed 1995-2004 have to meet current requirements by 2019, and those installed 2005-2010 by 2025. Combustion plants using solid fuels may only be operated if they are in a good condition and are regularly checked by a chimney sweep. Open fireplaces may only be operated occasionally, and new masonry heaters must be equipped with dust abatement

Sources:

Aachen fuel ordinance (2010): Ordnungsbehördliche Verordnung über den Betrieb von Einzelraumfeuerungsanlagen für feste Brennstoffe (Aachener Festbrennstoffverordnung – FBStVO) vom 29.09.2010.
http://www.aachen.de/DE/stadt_buerger/umwelt/luft-stadtklima/festbrennstoff_verordnung/index.html

1st Federal Emission Control Act (2010): Erste Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Verordnung über kleine und mittlere Feuerungsanlagen - 1. BImSchV).
http://www.gesetze-im-internet.de/bimschv_1_2010/index.html

AIRUSE LIFE 11 ENV/ES/584 (2016): Abatement of emissions from domestic and agricultural biomass burning. Report 20, 12/2016.
http://airuse.eu/wp-content/uploads/2013/11/R20_AIRUSE-Abatement-biomass-burning.pdf

4.4 Replacement of solid fuels by district heating

4.4.1 Compulsory district heating for new buildings - Upper Austria, Styria (Austria)

The federal province of Upper Austria prescribes for new public buildings and new residential buildings with more than three flats connection to district heating if available (Oö. Luftreinhalte- und Energietechnikgesetz 2002 i.d.g.F). The city council might extend this obligation to all residential buildings if emissions from household heating contribute substantially to adverse air quality. A similar regulation is foreseen in Styria in areas where air quality has to be improved (Steiermärkisches Raumordnungsgesetz 2010).

4.4.2 Strategic extension of district heating: Vienna (Austria)

See case study in Section 4.10.4 for details

4.5 Financial incentives

4.5.1 Subsidies for the installation of energy-efficient technologies - Austria

Amongst other countries, Austria offers subsidies for installation of energy-efficient, climate- and environmental-friendly technology as well as energy-efficient buildings. Subsidy rates typically cover about 20% of total investments for an automatic heating system. New buildings that receive subsidies provided by the state government directly or by regional authorities in the framework of their housing and energy programmes have to install a heating system based on renewables. Only exceptions are gas condensing boilers, which have to be combined with a solar thermal system. Biomass stoves and boilers are common in Austria, especially in rural regions. Consequently, the installation rates of pellet boilers supported by government subsidies increased during the last ten years. In addition, the Austrian Government has also provided incentives for the production of high quality wood pellets.

The available post-evaluation of the program has not addressed the effectiveness of the level of subsidies to trigger energy-efficiency investments[6].

Source: AIRUSE (2016)

4.5.2 Replacement of solid fuels boilers - Czech Republic

Supported by the European Union, the Czech Ministry of the Environment offers up to 9 billion Czech crowns (appr. 340 million €) to subsidize Czech households for the replacement of old solid fuel boilers with environmental friendly equipment.

The maximum amount of 127.500 Czech crowns (appr. 4,900 €) is reserved for replacing single boilers for solid fuels with manual operation by a new gas condensing boiler, heat pump, biomass boiler or automatic combined boiler. Subsidies can also be used to use waste heat. Furthermore, subsidies are offered for flue gas treatment, for installation of new or refurbished heat distribution systems, as well as for improving the energy performance of the building, e.g., through partial replacement of windows or roof insulation. Also new high efficient coal heating system compliant with the Ecodesign conditions can be subsidized.

[6] http://iibw.at/documents/2017%20IIBW.%20Wohnbauf%C3%B6rderung%202016.pdf

Households in heavy polluted areas receive a maximum bonus of 7.500 Czech crowns (appr. 290 €). If the boiler subsidy is combined with a request for support under the New Green Savings program, another bonus of up to 40.000 Czech crowns (appr. 1,540 €) can be received. The New Green Savings program is focusing on energy savings and renewable energy sources in single family houses. The objective of this program is to reduce greenhouse gas emissions through the improved energy efficiency of buildings, the support of residential development with very low energy performance and the efficient use of energy sources.

Aiming at replacing old boilers in 100,000 households [7] until 2020, 3 billion Czech crowns (appr. 113 Mio €) have already been granted by the end of 2015. Considering the low interest for pure coal boilers in the first call, only automatic combined boilers for coal and biomass will be financially supported in the second call.

Information is provided by the region's website, in daily newspapers and via a special telephone line.

Sources:

https://www.sfzp.cz/clanek/873/2639/kotlikove-dotace-1-vyzva/

https://www.sfzp.cz/clanek/873/3263/kotlikove-dotace-2-vyzva/

http://www.novazelenausporam.cz

4.5.3 'Prime Air Bois' - Vallée de l'Arve (France)

Located in the département of Haute-Savoie in France, the Vallée de l'Arve covers 41 communes from Chamonix to La Roche-sur-Foron. This region experiences high levels of particulate matter levels, often exceeding the permitted thresholds. 50% of the emissions of PM_{10} are caused by the residential sector, and 90% of these emissions are attributable to wood burning for space heating.

In order to improve air quality across the Vallée de l'Arve, an Atmosphere Protection Plan (Plan de Protection de l'Atmosphère, PPA) was set up in 2012. The 'Fonds Air Bois' mechanism has been launched by the public authorities in 2013, to encourage households to replace their old furnaces by providing financial support of to 1,000 € per application. The programme aims to replace 25% or about 3,200 old appliances, about 2,200 households substituted their old wood-burning appliances until 2016. To accelerate the uptake, the subsidy has been increased to 2,000 € as of January 2017.

As of 2017, the new wood-burning appliances have to comply with the highest environmental performance standards (certification Flamme Verte, 7 étoiles). Old devices have to be disposed of correctly and proof of their destruction must be provided.

[7] The goal of the first call was to replace 20.000 boilers until 2018. This goal was already achieved in 2017, hence it can be expected that the overall goal for 2020 will be reached as well (http://www.opzp.cz/dokumenty/download/637-1-P%C5%99%C3%ADloha%20%C4%8D.%202_prezentace_zTK.pdf)

To support the programme, public awareness raising targets individuals and professionals (commercial firewood dealers and installer of wood burning appliances), providing 'good practices' guidance for more efficient and less polluting wood-burning heating.

Source: http://www.riviere-arve.org/projets/fonds-chaleur-air-bois.htm

4.6 Bans and restrictions on solid fuel use

4.6.1 Ban on use of wood burning fireplaces and stoves - Italy

Italy has not established country-wide emission limit values for biomass burning in appliances with a nominal heat output of less than 35 kW. However, some regions have adopted measures to address pollution from smaller appliances.

For example, since 2007 Lombardy prohibits, during the winter months and in certain areas where alternative heating systems are available, the use of wood burning fireplaces and stoves with less than 63% approved efficiency. Currently, compliance checking is done by local police ('vigili urbani'). It is foreseen to simplify checking by periodical controls of a certain percentage of appliances. A path for substituting old appliances by 2020 has been established, through banning of appliances with certain emission characteristics. Since 2015, new stoves must have an efficiency of at least 75% (80% if pellets fuelled). For details, see case study in Section 4.10.2.

Source: AIRUSE (2016)

4.6.2 Ban of bituminous coal - Ireland

See case study in Section 4.10.1.

4.6.3 Ban of solid fuel -: Poland

See case study in Section 4.10.3.

4.6.4 Ban of chimneys in allotments - Vienna (Austria)

In 1992 the City of Vienna partly lifted a ban to indwell year-round huts or houses in allotments. Thereafter, many huts or houses were adapted for year-round indwelling, which required heating systems to be installed. However, as biomass and organic waste is readily available in allotments, widespread use of biomass for heating purposes would have had an adverse impact on air quality in Vienna. Therefore in the respective law it was laid down that no chimneys for solid or liquid fuel appliances are allowed to be built in allotments (Wiener Kleingartengesetz 1996 i.d.g.F.), so that it is assured that all biomass or organic waste will be composted instead of being burned (either legally in a heating system or illegally in an open fire).

4.7 Strategies and measures to address building energy efficiency

4.7.1 Energy-efficiency in the clean energy transition

Energy efficiency is a key element of the clean energy transition and a top priority of the Juncker Commission. It is the most universally available source of energy and a key dimension of the Energy Union. Putting energy efficiency first reflects the fact that the cheapest and cleanest source of energy is the energy that does not need to be produced or used. This means making sure that energy efficiency is taken into account throughout the energy system. By using energy more efficiently, Europeans can lower their energy bills, reduce their reliance on external suppliers of oil and gas, help protect the environment and contribute to boost growth and jobs in the EU.

In November 2016, the European Commission launched the "Clean Energy Package for all Europeans" with three main goals: putting energy efficiency first, achieving global leadership in renewable energies and providing a fair deal for consumers. In this package, the Commission tabled two proposals to amend the Energy Efficiency Directive (EED)[8] and the European Performance of Buildings Directive (EPBD)[9]. The main objectives are to identify the 2030 energy efficiency target and to consequently adapt the existing legislation to this new challenge. In addition to these legislative proposals, the package includes a number of non-legislative measures to accelerate the mobilisation of private financing, in particular in the building sector with the "Smart Finance for Smart Buildings" Initiative[10].

An important way to improve energy efficiency in the EU is to tap the huge potential for efficiency gains in the building sector which is the largest single energy consumer in Europe, absorbing 40% of final energy. About 75% of buildings are energy inefficient and, depending on the Member State, only 0.4-1.2% of the stock is renovated each year. A number of public support schemes (around 200) are already running across Europe to support energy efficiency investments at-scale. These schemes encompass a wide variety of instruments including fiscal schemes, grants, subsidies, debt instruments or equity financing solutions. At the EU level, the European Structural and Investment Funds (ESIF) will allocate €18 billion to energy efficiency in the period 2014-2020, from which EUR 13.3 billion are planned to be dedicated to energy efficiency in public and residential buildings. In addition, the European Fund for Strategic Investments (EFSI) is a key instrument to boost investment in sustainable energy projects. The EU has also developed a number of other support schemes and funding programmes aiming to help businesses, regions, and countries successfully implement energy efficiency projects.

The two following sections give two illustrations of such schemes, respectively focused on new constructions and on renovation of existing buildings, in the residential area.

4.7.2 Nearly zero-energy buildings - Po region (Italy)

As part of the 'PREPAIR' (Po Regions Engaged to Policies of AIR) project funded by the EU-LIFE program, an action aims to develop professional expertise for a holistic approach to building works, specifically oriented to multi-family houses, involving all actors usually into the construction and installation service chain. This will support implementation of the Energy Performance of Buildings Directive (2010/31/EU),

[8] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC Text with EEA relevance.
[9] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings.
[10] https://ec.europa.eu/commission/sites/beta-political/files/smart-finance-smart-buildings-invesment-facility_en.pdf

which requires new buildings to be 'nearly zero-energy' by December 31, 2020 (noting that the requirement sets two different target dates: one by the end of 2018 for buildings occupied and owned by public authorities and another by the end of 2020 for all new buildings).

Source: http://www.lifeprepair.eu/index.php/actions/air-quality-and-energy-efficiency/?lang=en#toggle-id-2

4.7.3 Strategies and measures to address energy efficiency - Ireland

Ireland has established two grant programmes for homeowners: the 'Better Energy Homes' scheme offers grants to homeowners who invest in energy efficiency improvements like roof installation, wall insulation, installation of a high efficiency (> 90%) gas or oil fired boiler, heating control upgrades and solar panels. The second programme addressing energy efficiency is called 'Warmer Homes Schemes' and refers to poor households. More details on 'Warmer Homes Schemes' can be found in Section 4.9.4.

Source: SEAI – Sustainable Energy Authority of Ireland; http://www.seai.ie/Power_of_One/Grants_Available/

4.8 Energy-efficient building renovation

4.8.1 Building renovation in the EU legislation

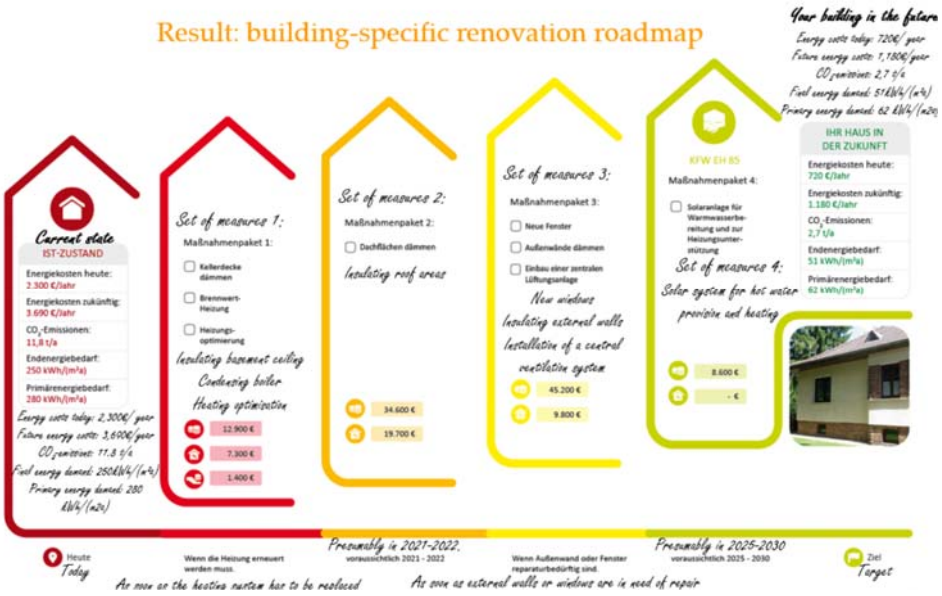
As mentioned in section 4.7.1, energy efficient building renovation is a key priority of the proposed revision of the Energy Performance of Buildings Directive, adopted as part of the Clean energy for All Europeans package (November 2016). One key element of this proposed revision is to require the Member States to define long-term renovation strategies in view of a decarbonisation of the EU building stock by 2050. It is expected that these strategies will boost the renovation rates in the European Union, leading to a steady improvement of building performances across Europe. An additional improvement, in relation to renovation of buildings, is that Member States will be required to link their financial measures for energy efficiency improvement to the savings related to the renovation measures, e.g. by comparing energy performance certificates (EPC) before and after renovation.

While this emphasis on renovation is particularly strong in the revision of the EPBD, the current EPBD (2010/31/EU) already included supporting measures, e.g. requiring Member States to take appropriate steps to catalyse the energy performance of buildings and the transition to nearly zero-energy buildings, and already highlighted in this respect the importance of financing.

Also required under the current EPBD, the Energy performance certificate (EPC) is the most widely used instrument to assess and document the energy performances of buildings in the Union. The EPC is a system of certification of energy performance of buildings that not only informs building owners about the energy performance of their buildings and applicable performance requirements, but also include recommendations for the cost-optimal or cost-effective improvement of the energy performance, covering both major renovation (of the building envelope or technical building system) and element-level renovation. This system is implemented in all EU member states and it has had a major impact on building energy efficiency, in particular by ensuring that building owners are well aware of the performances of their buildings and dwellings.Additional advisory schemes, like building renovation passport and roadmaps introduced in the next sections, can usefully supplement energy performance certification schemes, in view of informing on renovation opportunities

4.8.2 Building Renovation Passport and Individual Renovation Roadmap - Germany

The 'Individual Renovation Roadmap' (Individueller Sanierungsfahrplan, iSFP) is an advisory tool for owners of residential and non-residential buildings. It includes an on-site inspection carried out by an energy consultant to analyse the state of the building. The 'iSFP' then specifies how the building can be renovated to improve the energy efficiency. The 'iSFP' for non-residential buildings includes at least two renovation options – a step-by-step approach and a renovation all at once. The concept was initially developed and tested at small scale in Baden-Wuerttemberg, and is now adapted for the entire country, as part of the National Energy Efficiency Programme (see 3rd NEEAP of Germany) and the 'Federal Efficiency Strategy for Buildings' ('Energieeinspar-Gesetz, ESG') published in December 2015.



Source: BPIE (2016)

4.8.3 The 'Dwelling ID' (Woningpas) - Flanders (Belgium)

The Flemish Energy Agency (VEA), in cooperation with a network of stakeholders, developed a 'Renovation Pact' for 2014 to 2018, aiming at the improvement of the energy performance of the Flemish housing stock. One of the central actions is the creation of a 'Renovation advice', a roadmap which will be provided to building owners to assist forward-looking planning for renovations. By 2018, this will be integrated into the 'Building Passport Light', a unique digital document for each house that can be consulted by property owners and authorised third persons.

The renovation advice aims provide property owners insight into the logic of renovation steps as a means to achieve Flanders' long-term objective of an energy-efficient housing stock. By 2050, the existing building stock should become as energy-efficient as new buildings today.

Source: BPIE (2016)

4.8.4 Individual Building Renovation Roadmaps

In July 2017, a new project 'iBROAD2 funded by the EU 'Horizon 2020' program began to explore, design, develop and demonstrate the concept of individual Building Renovation Roadmaps.

Such Building Renovation Roadmaps should be used as a customised renovation plan with step-by-step renovation of individual buildings (iBROAD-Plan), combined with building-related information (logbook, iBROAD-Log). Energy auditors and end-users will gain knowledge and experience of deep renovation in individual buildings.

With the main focus on residential buildings, the project will analyse examples from Germany, France and Belgium (Flanders), and develop an integrated concept suitable for differing national conditions.

The iBROAD concept and tools will be tested in Bulgaria, Poland, Portugal and Germany, supported by auditor training. Furthermore, the project will provide feedback as input to the feasibility and replicability analysis of the model to other building typologies and EU Member States.

Source:

CORDIS – Community Research and Development Information Service (2017)
http://cordis.europa.eu/project/rcn/210338_en.html

4.9 Fuel poverty

In general, poverty can be defined as living with the uncertainty of being able to maintain or recover a secure financial status (EPEE – European fuel Poverty and Energy Efficiency 2009). The following sections discuss combined measures that address energy poverty and non-discrimination of people with lower incomes. In most cases, fuel poverty measures are combined with energy efficiency measures. However, as the impact on emissions is not always documented, it is likely that not all of such measures will indeed lead to a reduction of air emissions.

Measures to address fuel poverty are also helpful to reduce (illegal) burning of waste in domestic stoves. This is especially important in low income countries and rural areas.

4.9.1 Supporting energy efficiency - Saint-Josse (Belgium)

The project 'Guichet Primes', managed by the municipality of Saint Josse in partnership with the Region of Bruxelles Capitale, promotes the renovation of private buildings (mostly apartments) through subsidies or loans with low rates (using regional and municipal public aids) in order to allow low income families to improve their comfort and the energy performance of their homes.

In 2014 only 18 renovation subsidies were awarded but in 2016 the number of subsidies increased to 329 for a total amount of around €500.000 (divided between 81 buildings, housing and storefronts). Most subsidies were provided for building envelopes, roof insulation and roof renovation. A majority (74%) of subsidies was awarded to low-income households.

Sources:

http://sjtn.brussels/fr/urbanisme-logement/guichet-primes

http://sjtn.brussels/fr/actualites/bilan-tres-positif-pour-le-guichet-primes

4.9.2 Seasonal Health Interventions Networks (SHINE) - UK

The Seasonal Health Interventions Network (SHINE) is a project run by Islington Council (UK) aiming to reduce the number of Islington residents in or at risk of fuel poverty, as well as reducing excess seasonal deaths and hospital admissions in the borough.

Islington has long been regarded as an area which showcases best practice to address illness from cold. The council's Seasonal Health and Affordable Warmth (SHAW) team delivers schemes such as the Well Winter Campaign; Warmth on Prescription; and CRISP (Climate Resilience Islington South Project). It was responsible for setting up the Seasonal Health Interventions Network (SHINE), which was the first point of contact referral service of its kind to unite seasonal health concerns with housing, energy efficiency and affordable warmth, income and social isolation.

The schemes received over 12,000 recommendations and clients were able to benefit from up to 30 services on offer between 2010 and 2016.

The energy efficiency improvements to properties, through the 'Energy Doctor in the Home' visiting service, replacement boilers and insulation installed has resulted in reduced CO_2 emissions of 11,534 tonnes since the start of the scheme. Monetary savings have been calculated as 1,639,000 € since the start of the scheme.

SHINE has already found replication within London. A SHINE scheme is running in the neighbouring London borough of Hackney, and a similar model has been adopted by the other London boroughs of Lewisham and Wandsworth, and the City of Norwich. SHINE can be applied as a model that plays to existing local strengths, and to strengthen existing local services.

The Northern Exposure's Warmth at Home project managed by NEA (National Energy Action) Northern Ireland is funded by the Public Health Agency. It is an action based, community development project, designed to tackle the high levels of fuel poverty found in Belfast. It promotes energy efficiency services to tackle heating and insulation problems of low income households by working in partnership with statutory, community and voluntary organisations. It raises awareness of fuel poverty and solutions. It also raises awareness of energy efficiency by providing advice and support to local communities helping them to build capacity to tackle the factors causing fuel poverty. Additional NEA provides training to local communities in energy awareness and creating local champions who are able to deliver qualified energy advice. To raise awareness of fuel poverty, local and regional communication channels and other networks are used.

Energy Action Scotland (EAS) is a national charity working group to end fuel poverty in Scotland. It provides advice to households on heating, insulation and gas connection grants, energy, money and debt advice and concrete help on specific fuel bill problems and provides the UK Fuel Poverty Monitor.

Sources:

NEA (2017)

BCP – Best Climate Practices: Seasonal Health Interventions Network (SHINE) (Contest 2014). http://www.bestclimatepractices.org/practices/seasonal-health-interventions-network-shine/

4.9.3 Examples in South-Eastern Europe

In South East European countries, more than 30% of households are not able to adequately heat their homes at reasonable prices especially during wintertime. To provide onsite support to energy-poor households, the EU supported the project REACH (Reduce Energy use And Change Habits).

The project demonstrates how to tackle energy poverty through energy efficiency measures and how energy savings can be achieved. Low-cost energy efficiency measures help vulnerable households quickly and cheaply. Measures include energy efficiency lighting, insulation, information to support behavioural change and to help to reduce their energy bills. Additionally, teachers and students are also trained to become energy advisors. Thus, they gain experience and knowledge on energy efficiency.

REACH already exists in Bulgaria, Croatia, Slovenia and the Former Yugoslav Republic of Macedonia. In Slovenia, a scheme was started by the Slovenian Ministry of Infrastructure, the Ministry of Environment and Spatial Planning, Eco Fund and the Ministry of Social Affairs. It includes visits to energy poor households all over Slovenia, to provide energy efficiency advice from energy advisors.

In collaboration with social actors who identify the energy-poor households, energy advisors visited 1,600 homes and could give suitable energy efficiency advices.

Source: https://ec.europa.eu/easme/en/news/energy-inefficient-homes-hit-household-budgets-why-tackling-energy-poverty-important

4.9.4 Ireland

The 'Warmer Homes Schemes' (WHS) aims to improve energy efficiency and comfort conditions of homes occupied by vulnerable households in receipt of the National Fuel Allowance Scheme through the installation of draught proofing, attic insulation, low energy light bulbs and cavity wall insulation where appropriate.

Source: SEAI – Sustainable Energy Authority of Ireland http://www.seai.ie/Power_of_One/Grants_Available/

4.9.5 European Fund for Strategic Investments (EFSI)

The European Fund for Strategic Investments (EFSI) is an initiative by the European Investment Bank, the European Investment Fund and the European Commission, which aims at helping to overcome the current investment gap in the EU[11]. Overall, EFSI has a budget of EUR 21 billion for the funding of economically viable projects. One focus of the EFSI support is renewable energy and resource efficiency. Both private and public sector entities can apply for EFSI financing. Several projects, e.g., for nearly zero-energy buildings, improvements of social housing, improvement of building insulations have

[11] http://www.eib.org/efsi/what-is-efsi/index.htm

already been financed. Even though the main focus of these projects is on energy efficiency and climate change, it can be expected that these projects will also lead to a reduction of air pollutant emissions.

Source: European Fund for Strategic Investments (EFSI) http://www.eib.org/efsi/index.htm

4.10 Case studies

Five case studies provide more details for selected measures, based on available databases and compilations of best practice examples.

4.10.1 Case study 1: Dublin: Ban of bituminous coal for household heating

Case study 1		Ban of bituminous coal for household heating in Dublin
Member State / Region / City		Dublin (Ireland) and over the years in 20 other cities in Ireland
Background		PM levels were rather high in Dublin in the 1980s due to the widespread use of bituminous coal in space heating. The use of bituminous coal was thus banned in 1990.
Description		The prohibition on bituminous or 'smoky coal' was introduced in Dublin in September 1990 after several years of severe winter smog resulting from the use of coal for home heating. Over the years the ban has been extended to other cities and towns throughout Ireland. In September 2015, on the 25th anniversary of the initial ban, the Minister announced plans to extend the ban on smoky coal nationwide. The Minister expects that a process of consultation with the EU, government colleagues and coal suppliers will take place and that the ban is expected to take effect for the 2018 heating season.
Type of measures		Legal measure (S.I. No. 128/2016 - Air Pollution Act, S.I. No. 326 of 2012)
Timeframe		From September 1990 onwards
Implementation responsibility		Government of Ireland, city councils.
Impact of measures and interventions (potentially)	Air quality / emissions	Meanwhile, the ban applies in 26 cities and towns in Ireland. Air quality monitoring by the Environmental Protection Agency (EPA) has shown lower levels of PM_{10} in areas with smoky coal ban than in towns where the ban does not apply. The ban is expected to have resulted in 350 fewer annual deaths.
	Climate	Substitution of coal by carbon free energy carriers or energy carriers with less carbon intensity supports climate change mitigation targets of Ireland too.
	Energy	The substitution of coal stoves is often combined with a more energy efficient combustion facility, and the use of renewable energy, especially for hot water preparation in the summer.
	Fuel poverty	Coal as a cheap fuel using a cheap facility and is thus well popular in poor households. Needed investments and the substitution of coal combined with higher energy price can enhance fuel poverty, if there is no funding and advisory service for poor households (esp. for investments). Ireland has introduced the 'Warmer Homes Schemes' to address fuel poverty.
Legislation / reference		S.I. No. 128/2016 - Air Pollution Act (Marketing, Sale, Distribution and Burning of Specified Fuels)(Amendment) Regulations 2016. S.I. No. 326 of 2012: Air Pollution Act (Marketing, Sale, Distribution and Burning of Specified Fuels) Regulations 2012-2016.
General applicability		Especially in eastern Europe in countries with locally high coal use this measure should be applied; it will have a substantial effect on air quality.
Background information / references		http://www.housing.gov.ie/environment/air-quality/coal/extensions-smoky-coal-ban-will-bring-cleaner-air-fewer-deaths-and-can http://www.dccae.gov.ie/en-ie/environment/topics/air-quality/smoky-coal-ban/Pages/default.aspx Clancy et al. 2012: The Lancet, Vol 360, October 19, 2002

4.10.2 Case study 2: Lombardy: Wood burning in small appliances

Case study 2	Wood burning in small appliances
Member State / Region / City	Lombardy Region
Background	Wood burning causes about 47% of the total primary PM_{10} emissions, and 70% of benzo(a)pyrene emissions, respectively, in Lombardy Region, although only 7% of the buildings are heated by wood. Activities in Lombardy aim at improving the quality of the appliances, guaranteeing a proper installation of new stoves, avoiding waste burning and inappropriate fuels, and guaranteeing a good quality of wood pellets. Different steps were defined for the implementation of this process.
Description	Several regulations and activities address solid fuel burning in small appliances in Lombardy: • Since 2002 burning of coal and high sulphur content fuel oils in small appliances is prohibited. • Since 2007 stoves and fireplaces in the agglomerations Milano, Bergamo, Brescia and in all the municipalities < 300 m above sea level with an efficiency < 63% or CO emissions > 0.5% (ref. 13% O2) are forbidden from October 15 to April 15. Currently compliance checking is done by local police ('vigili urbani'); however, it is foreseen to simplify checking by periodical controls of a certain percentage of appliances. • Since 2014 rules on installation, maintenance and control are in place. The same rules apply to wood stoves as to natural gas appliances (installation according specific standards; periodical compulsory maintenance; registration in official database of all the stoves) • Since 2015 new stoves must have an efficiency of at least 75% (80% if pellets fuelled) • In 2016 Lombardy Region approved a system of classification of stoves based on PM, NO2, TOC (total organic carbon), and energy efficiency. During pollution episodes only stoves in the top category are allowed. • A progressive path of substitution of stoves is established: • 2018: ban of installing chimneys and stoves with less than '3 stars'; ban of use of old appliances with less than 2 stars; • 2020: ban of installing fireplaces and stoves with less than 4 stars and; ban of use of old appliances with less than 3 stars; • Incentives to replace old stoves and fireplaces with high performance appliances (total available resources in Italy are around € 500 million); • in areas where PM10 limit values and/or the benzo(a)pyrene target values are exceeded wood stoves will not account for achieving the target of 50 % energy from renewable sources from next year on; • In areas where one or more of the limit values for PM10 and / or the target value of benzo(a)pyrene are exceeded no EU structural funds aimed at the energy efficiency of installations can be used for installing biomass thermal plants; Beside these normative actions, Lombardy Region will implement a communication action on biomass burning primarily addressed at the inhabitants of the Po basin.

Case study 2		Wood burning in small appliances
Type of measures		Legal measures (Regional Government Resolution n. 1118/2013; Regional Government Resolution n. 3965/2015; Regional Government Resolution n. 6173/2015) and education/information measures
Timeframe for effectiveness of measure		Since 2002
Implementation responsibility		Lombardy Region
Impact of measures and interventions (potentially)	Air quality / emissions	PM_{10} emissions from household heating are expected to decrease by 65% in 2014 compared with baseline. This corresponds to 26.5% reduction of total PM_{10} emission in the region.
	Climate	No data available
	Energy	No data available but energy efficiency is mentioned, therefore an improvement is assumed.
	Fuel poverty	No detailed information available. In general, energy efficiency measures should lead to a reduction in fuel poverty.
Legislation / references		Regional Government Resolution n. 1118/2013; Regional Government Resolution n. 3965/2015; Regional Government Resolution n. 6173/2015
General applicability		The Communication activities will take place in Lombardy and in the other project partner countries.
Background information / references		Lombardy Region Website: http://www.regione.lombardia.it/wps/portal/istituzionale/HP/DettaglioRedazionale/servizi-e-informazioni/cittadini/tutela-ambientale/qualita-dell-aria/misure-di-limitazione-per-qualita-aria/misure-di-limitazione-per-qualita-aria LIFE PREPAIR on LIFE programme website: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=6102 LIFE PREPAIR on project website: http://www.lifeprepair.eu/

4.10.3 Case study 3: Poland: Ban of solid fuels

Case study 3		Solid fuel ban
Member State / Region / City		Poland (Krakow and Lesser Poland Voivodship)
Background		Krakow is one of the cities, and southern Poland is one of the regions in Europe that experience the highest PM levels. Household stoves burning coal are responsible for an estimated 88 % of the country's non-industrial air pollution. In the Lesser Poland Małopolska (Małopolska) low-stack emission (combustion of solid fuels in household boilers) contribute 55% to PM_{10} and over 70% to benzo(a)pyrene concentrations.
Description		In the city of Krakow and Małopolska the use of solid fuel is restricted from September 2019 on. In addition to banning solid fuels and mandating the replacement of coal-fired stoves, Krakow's air pollution reduction program also aims to expand the city's gas distribution network, modernize its district heating system and promote renewable energy sources for household heating, among other measures. Also, a LIFE project 'Implementation of Air Quality Plan for Małopolska Region – Małopolska in a healthy atmosphere' was established to support the implementation of the measures.
Type of measures		Legal measure, education/information
Timeframe for effectiveness of measure		September 2019 onwards
Implementation responsibility		City of Krakow, government of Małopolska
Impact of measures and interventions (potentially)	Air quality / emissions	No detailed information is available, but it can be expected that the ban on coal burning, the replacement of coal fires stoves and the switch environmentally friendly energy sources or modern solid fuel boilers to result in a substantial reduction in air quality (Krakow/ Małopolska).
	Climate	No detailed information is available, but it can be expected that the ban on coal burning, the replacement of coal fires stoves and environmentally friendly energy sources or modern solid fuel boilers result in a substantial reduction in greenhouse gas emissions (Krakow/ Małopolska).
	Energy	The solid fuel ban is accompanied by measures to improve the energy efficiency of buildings.
	Fuel poverty	Krakow offers targeted subsidies for low income households. The city draws on both regional and EU structural funds to support its air quality and energy poverty alleviation programs.
Legislation / references		https://www.bip.krakow.pl/_inc/rada/uchwaly/show_pdf.php?id=70415
General applicability		The measure can be applied to cities with a high share of coal heating. However, such a widespread replacement of coal burning facilities needs some years.
Background information / references		http://powietrze.malopolska.pl/en/life-ip/ Małopolska 2013a, 2013b

4.10.4 Case study 4: Vienna: Sustainable district heating and cooling

Case study 4		Sustainable district heating and cooling
Member State / Region / City		Austria / Vienna
Background		District heating is seen in Vienna as an environmental-friendly and efficient municipal heat service, especially heat generation from waste. The growing number of inhabitants and increasing energy efficiency of buildings, in particular of new buildings, and volatile energy markets are the main drivers of changes for district heating systems.
Description		District heating in Vienna was started in the 1960ies to supply heat to large buildings, and to use the heat of waste incineration plants for heating purposes. Core elements of district heating in Vienna are: • Producing electricity and heating together in an efficient process known as co-generation. • Using energy from thermal waste disposal. • Promoting the use of renewable energy sources. • Comprehensive energy advice on improving efficiency. • Decentralised types of production such as citizen solar power plants and technology combinations for solar power and geothermal energy (green heating products). Around one third of district heat that is fed into Vienna's district heating network is produced from thermal waste recycling, which provides the base-load thermal energy. Additional heat is produced by gas, biomass and oil power plants. In addition, a hot water storage tank was built in 2013. Also, a district cooling system with absorption refrigeration machines was built up in recent years, which provides cool water for cooling of large commercial buildings. The district heat network comprises of a pipe system of 1,180 km; in 2011 41% of principle residences were heated by district heat.
Type of measures		Technical
Timeframe for effectiveness of measure		Implementation began in the 1960ies.
Implementation responsibility		City of Vienna, Wien Energie GmbH
Impact of measures and interventions (potentially)	Air quality / emissions	No data available; however, it can be expected that overall PM emissions are much lower for district heating compared to individual appliances.
	Climate	It is estimated that about three million tonnes of CO_2 are saved each year
	Energy	No information available
	Fuel poverty	No information available
Legislation / references		https://www.wienenergie.at/eportal3/
General applicability		District heating systems can be implemented in high density built up areas, especially where heat from waste incineration and / or industrial waste heat is available.
Background information / references		City of Vienna, Wien Energie GmbH, Lucha et al. (2016)

4.10.5 Case study 5: Sweden: Development of district heating networks

The information for this case study was provided by the Swedish Environmental Protection Agency.

Case study 5	Development of district heating networks
Member State / Region / City	Sweden
Background	Prior to the development of district heating networks in Sweden, fossil fuels (particularly fuel oil) were the dominant fuel source for household heating. This resulted in significantly high levels of air pollution in Swedish cities and towns in the 1960s and 1970s. This visibly poor air quality in cities and towns was a major initial driver for the development of district heating networks, which has been widespread across Sweden. Nowadays, all major cities and towns in Sweden have district heating systems. Current national statistics lists about 500 systems, also including small district heating systems in small towns and villages.
Description	District heating was introduced, for health, efficiency and comfort reasons, in Sweden in the late 1940's to avoid the use of coke and sulfur containing oil close to where people live in cities and towns and at the same time support the production of electricity (combined heat and power production - CHP). This has enabled Swedish towns and cities to replace many inefficient, small-scale energy sources with a small number of highly efficient plants and thereby drastically reduce emissions of air pollutants. It was estimated in the 70-ties that concentrations of sulfur dioxide were 2-5 times less in towns where district heating was common in comparison to similar towns without district heating[12]. Since then heavy oil as a fuel has been abandoned because of sulfur, energy and carbon taxes. Today district heating and cooling is mainly based on the use of excess heat from the production of electricity or industrial processes and is considered one of the most environmentally friendly ways to use of biofuels. Also, other energy sources are used as for instance heat pumps that use heat from sea/river or sewage water. The most common heating method in multi-family dwellings and non-residential premises in Sweden is currently district heating. As a result of this and other changes the ambient air concentration of soot in the second largest city, Gothenburg, decreased from almost 50 µg/m³ 1965 down to about 5 µg/m³ in 1995[13]. Another example is from central Stockholm where SO_2 levels were dramatically reduced from more than 200 µg/m³ in 1965 to less than 25 µg/m³ in 1990. The environmental aspects of district heating have been described in detail[14]. It has been estimated that the whole energy need for heating in EU could be met by using excess energy from power production to district heating[15].

[12] Boström et al. Air pollution in Sweden (in Swedish) Naturvårdsverket rapport, SNV PM, 1521, 1982.
[13] Areskoug et al. Particles in ambient air –a health risk assessment, Scand J Work Environ Health, 2000;26 suppl:1
[14] Werner and Fredriksen, District Heating and Cooling, Studentlitteratur, Lund, Sweden, 2013.
[15] Connolly et al. Heat Roadmap Europe 2050, Euroheat & Power, 2013.

Case study 5, continued		Development of district heating networks
Type of measures		Technical, economic/fiscal and legal While district heating in itself is a technical measure, its development has been supported by economic/fiscal and legal measures such as the introduction of legislation on SO_2 and CO_2 taxes[16]. These taxes have provided economic incentives that have been vital in promoting a switch from heating in individual boilers with fossil fuels to district heating. There is also now a specific District Heating Act, but this was not passed until 2008 by which time district heating networks in Sweden were already widespread.
Timeframe for effectiveness of measure		Considering the whole process from planning of a district heating network to full implementation of the measure, the timeframe is >5 years.
Implementation responsibility		Local authorities in possible co-operation with energy companies. National level if there are legal obstacles and to provide supporting economic incentives such as taxes on more polluting sources.
Impact of measures and interventions (potentially)	Air quality / emissions	The development of district heating networks in Sweden since the 1940/1950's has undoubtedly led to very large reductions in air pollutant emissions from the household sector. This reduction has been a major contributing factor to the vast improvements in local air quality since the 1950's, as shown in the available long-term measurement series from Gothenburg and Stockholm.
	Climate	Large-scale reductions in greenhouse gases from the residential sector due to a more energy efficient heat production and the increased use of renewable and recycled sources. Prior to the introduction of district heating, fossil fuels were the dominant in the household heating sector. Today fossil fuels have been almost completely phased out and the development of district heating networks has been a key factor. Currently > 90 % of the energy produced from district heating in Sweden is from renewable/recycled energy sources.
	Energy	Key factor in the switch from fossil fuels to renewable/recycled energy for heating in the household sector.
	Fuel poverty	Due to other policies in Sweden fuel poverty is not an issue. In Sweden heating cost are required to be included in the rent and legal minimum heat standards have been set. This gives a strong incentive to landlords to invest in energy-efficiency measures such as increased insulation and energy-efficient windows. A system which, in contrast, allocates the energy bill to the tenant – who has little remit or incentive to carry out these measures – greatly increase the risk of causing fuel poverty.
Legislation / references		District Heating Act

[16] SO_2 tax act: http://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-1990587-om-svavelskatt_sfs-1990-587
CO_2 tax act: https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-1990582-om-koldioxidskatt_sfs-1990-582
Energy tax act: https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-19941776-om-skatt-pa-energi_sfs-1994-1776
More information can be found at:
https://www.skatteverket.se/foretagochorganisationer/skatter/punktskatter/energiskatter.4.18e1b10334ebe8bc8000843.html

Case study 5, continued	Development of district heating networks
General applicability	Technically feasible to implementation in other European countries, but requires significant initial infrastructure investments and effective incentives to switch to district heating. Political willingness is important.
Background information / references	A recent overview is provided in Werner (2017).

5 Conclusions

The recent outlook on future emissions and air quality in the EU (Amann M., Anderl, et al. 2017), based on latest information of economic development and emission inventories, indicates that by 2030 exposure to fine particulate matter will remain a significant threat to human health, despite the sharp decline in energy-related air pollutant emissions throughout the European Union that will result from the implementation of the NEC Directive and other source-oriented legislation. Also the WHO guideline value for exposure to PM2.5 will not be fully achieved, especially in areas where solid fuel combustion in households will prevail.

Emission inventories as well as source apportionment indicate important contributions from the household sector to total PM2.5 emissions as well as to PM2.5 concentrations in ambient air and population exposure. This applies both for 2005 and 2030, once recent legislation will be fully implemented.

In 2005, the household sector contributed about 40% to total PM2.5 emissions in the EU-28, and thereby three times more than road transport. However, there are large variations across Member States, with contributions ranging from below 10% in the Netherlands, Cyprus and Malta to almost 80% in Croatia, Latvia and Lithuania. 80% of emissions were caused by the combustion of biomass (wood), while the remainder occurred from coal combustion in a few countries (Poland, Ireland).

A host of new technologies allows significant reductions of PM2.5 emissions, especially from biomass combustion. These innovative small scale combustion technologies represent current best available technology, and their commercial availability has been triggered by stringent national emission regulations for small combustion facilities in some countries. In addition, integration of smart flue gas abatement technologies with other technologies is emerging.

Throughout Europe, there is a wealth of experience with successful policy interventions that have led to effective reductions of air pollutant emissions in the household sector. They include

- awareness campaigns, informal platforms, qualification of focus groups, product declaration and expert advice at the site,
- subsidies for deep building renovation, the switch to other fuels or the exchange to new facilities,
- up to the ban of the use of solid fuels, as well as
- measures in combination to fight energy poverty.

Experience clearly highlights the importance of an integrated approach. Actual improvements do rarely occur over night, but need a sustained process over several years. In areas with widespread and substantial exceedances of air quality limit values, a complete ban of solid fuels proved successful. However, such as ban should be accompanied by a scheme to support energy efficiency improvements before switching to alternate fuel systems.

End-of-pipe technologies, i.e., electrostatic precipitators, might be foreseen for existing facilities, however, shorter intervals for maintenance and regular checks for appropriate fuel have to be considered. Furthermore, ignition techniques from above for manually stoked wood stoves should be disseminated via awareness raising campaigns.

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