



clean heat



Residential wood burning

Environmental impact and sustainable solutions

A campaign of:



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Wood burning is a two-edged sword: If wood is used in appliances that emit a comparatively low level of particulate matter such as other heat sources, it can contribute to the transition towards renewables in the heating sector. However, residential wood burning in stoves and boilers produces substantial amounts of health and climate-damaging particles. This background paper shall give an overview on the environmental impact of wood burning and provides solution approaches.

Role of wood burning in the European Union

Wood burning is a significant contributor of air pollution and the biggest source of fine particles – known for their harmful effects on human health. Outdoor air pollution due to particulate matter causes approximately 400,000 premature deaths in Europe every year, according to the European Environment Agency. In addition, it is responsible for serious diseases of millions of Europeans.¹ The associated socio-economic health costs amount to approximately 330-940 billion euro annually, according to the European Commission.² Therefore, the EU has set standards for air quality and national emission ceilings for many pollutants.

At the same time, with its 2030 targets, the European Union aims to reduce domestic greenhouse gases by at least 40% compared to 1990 and to increase the share of renewable energy to not less than 27%. About 65% of the total energy used by European households is required for heating.³ Solid biomass as a renewable source is considered to play a crucial role in the transition towards more climate-friendly heating sources.

Thus, we have already seen a renaissance of wood as fuel. But most of the more than 70 million solid fuel appliances in Europe are outdated. Especially stoves and other single-room appliances are often operated improperly and wood is frequently used in a very inefficient way. Therefore, these small appliances contribute disproportionately to overall emissions.

Our project Clean Heat aims to reduce emissions from wood burning and to bring these two conflicting issues – air quality and transition towards renewables – together.

Which are the most relevant pollutants and what are their health effects?

In an ideal world, combustion of wood only produces carbon dioxide, ashes and water. Unfortunately, perfect wood combustion doesn't exist and smoke from wood burning contains health hazardous substances: The most important pollutants are particulate matter (PM), soot or black carbon (BC), poly-aromatic

hydrocarbons (PAHs) and dioxins. In addition, wood burning causes nitrogen oxides (NOx) and carbon monoxide (CO).⁴

Fine particles (PM₁₀ und PM_{2.5}) are particles with a diameter less than 10 or 2.5 micrometers (µm). They are measured in units



of mass and PM₁₀ as well as PM_{2.5} are the relevant pollutants regulated by European and national legislation. In 2015, small scale domestic combustion has been responsible for more than 45% of total PM_{2.5} emissions in Europe.⁵ In residential areas with a high level of wood burning, concentrations of fine particles can reach the same magnitude as the concentration found on the most polluted streets during rush hour. Fine particles are responsible for most of the health damages. They can cause or aggravate cardiovascular and lung diseases, heart attacks and arrhythmias. And they can also cause cancer. Less particulate matter would improve Europe's air quality substantially: Meeting the WHO air quality guidelines (AQG) throughout the EU-28 would lead to yearly average PM_{2.5} concentrations dropping by

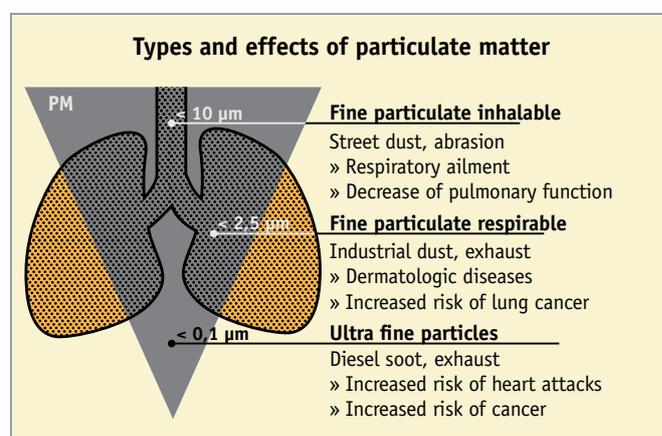


Figure 1: Types and effects of particulate matter | Source: Environmental Action Germany



about one third, resulting in 144,000 fewer premature deaths per year compared with the current situation.⁶

80-90% of the dust from biomass has grain size range below 1 µm.⁷ **Soot and ultrafine particles** smaller than 0.1 µm can penetrate deep into the lungs or even into the bloodstream. Basically, soot from wood burning is considered to be as harmful to health as soot from diesel engines.⁸ In addition, it contributes to climate change. Domestic heating (mainly wood burning) currently causes more than 50% of Europe’s black carbon emissions. Projections indicate an increase of the relative share to nearly 70% in 2030.

Poly-aromatic hydrocarbons (PAHs) are an organic substance group that is carcinogenic. For instance, benzo(a)pyrene (BaP) is typically formed as a result of wood burning and exposure to BaP pollution is widespread, in particular in Central and Eastern Europe. **Dioxins** are mostly caused by combustion processes. As they are very persistent, they accumulate in the environment and in the body. In Denmark, for instance, about 60% of dioxins emitted are from wood burning.⁹

Most complaints about wood burning are due to **smell**. The smell is caused by non-combusted volatile organic substances found in the smoke together with particles, tar compounds and dioxins. Smell is primarily a purely aesthetic problem and not harmful to health by itself. However, smell may be a clear indicator that wood smoke is found in harmful concentrations in the air.

How wood burning compares to other sources of pollution

Due to stricter regulation, all modern diesel vehicles are equipped with effective particle filters removing more than 99% of particles. By this, the role of road transport as source of pollution will gradually decline within the next decades. Already by now,

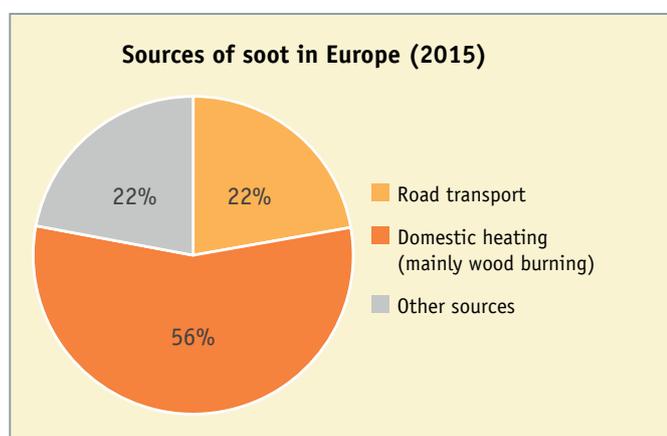


Figure 2: Sources of soot in Europe (2015) | Source: DUH, based on data from IIASA (Gains-Model 2014)

domestic heating – and in particular wood burning appliances – are responsible for the majority of Germany’s and Europe’s particle emissions (see figure 2). Despite the upcoming Ecodesign requirements for stoves and boilers on EU level, we will see a further relative increase if no additional action is taken.

If particle number instead of mass is considered in the comparison of stove and a modern diesel vehicle, the impact from wood burning is even more obvious: Danish measurements show that the number of ultrafine particles in smoke may be more than 230 times higher than outside the smoke column – even with optimal firing with small pieces of carefully stacked bone-dry wood in a modern eco-labelled wood stove (Nordic Swan label) connected to a brand new chimney. The exhaust of a small diesel truck with a well-working particle filter only contained about 1,000 particles per cubic meter (see figure 3).

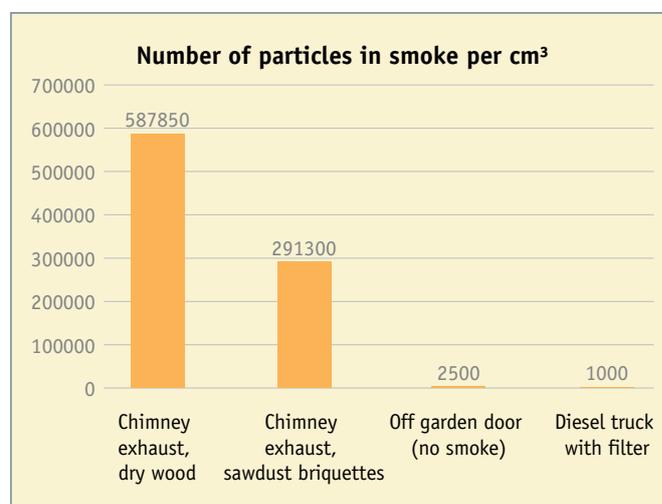


Figure 3: Number of particles in smoke in cubic centimetre | Source: The Danish Ecological Council (Kaare Press-Kristensen)

Indoor pollution

Many owners of stoves do not know, that wood burning also contributes to indoor pollution. This occurs if users pile the fire up and open the door as well as if the appliances are not tight. In new tight houses, there is another problem: The chimney draught “competes” with the draught from mechanical ventilation or the kitchen hood.

The Danish Building Research Institute and DEC have conducted several studies in buildings. The worst case was found in a living room with an old wood stove: Prior to starting the fire, a background pollution level of some 1,700 particles per cm³ was measured. After three hours of burning the concentrations of ultrafine particles from wood smoke in the living room attained some 30,000 particles per cm³ corresponding to levels found at roads with heavy traffic (see figure 4).

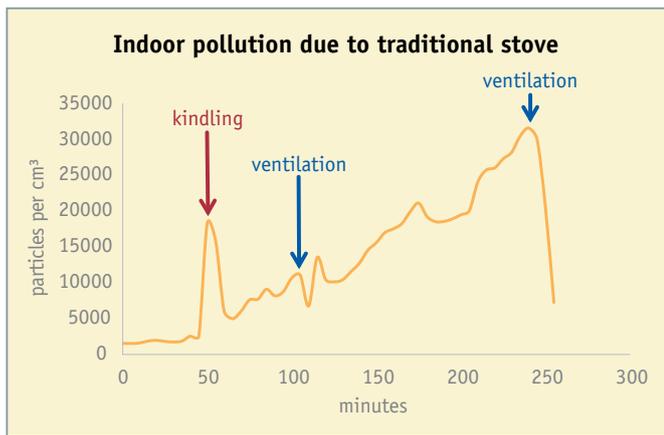


Figure 4: Concentration of ultrafine particles in the living room due to use of a traditional Danish firewood stove. | Source: The Danish Ecological Council

Wood as a climate-neutral source of heating?

Wood burning is defined as carbon neutral because trees assimilate the same amount of CO₂ throughout their lifetime as the amount released when wood is burned. But on closer inspection, it becomes clear that wood burning isn't climate-neutral at all:

- Wood burning produces **Short-Lived Climate-forcing Pollutants (SLCPs)**. The most relevant one is soot or black carbon. Although biomass burning only seems to have a slightly total warming effect in the long run,¹⁰ the negative impact on the climate is masked in many ways: Firstly, soot directly affects the immediate environment by absorbing sunlight. Secondly, there are substantial indirect effects due to its impact on cloud formation and precipitation as well as deposition on ice surfaces.¹¹ With regard to effects in the short term, the total climate impact of wood burning may even be worse than the use of fossil fuels in current heating systems – at least if wood is burnt in outdated or technically simple appliances. As soot particles are transported over large distances, they also harm sensitive ecosystems – such as the arctic – that are far away from the initial sources of pollution. Thus, the reduction of short-lived climate-forcing pollutants is a quick-acting remedy to decelerate climate changes and global warming.
- Often, wood burning is used to create a cozy ambience or as a **supplementary source of heating**. This applies for many local space heaters, especially if heat output is over-designed compared with their location. The heat output of such appliances often can only be adjusted poorly and excess heat is not absorbed by a buffer. Since wood is cheap fuel, home owners may consider **energy renovation and better insulation** as not profitable.

- If the **level of reforestation** isn't adequate and burning of wood take place faster than the new trees grow, wood burning does lead to increasing net CO₂ levels in the atmosphere. In addition, forests and forest floors serve as a crucial **carbon sink** – with regard to the global climate targets forests stand must not be reduced.
- If wood is imported or **transported over large distances**, CO₂ emissions from transport have to be considered as well. The same holds true for the energy-related carbon footprint, if wood is **technically dried**.

Wood burning and European air quality goals

The European Union has established health based standards and objectives for a number of air pollutants. In 2008, most of the existing legislation was merged in the **Ambient Air Quality Directive (2008/50/EC)**.¹² With regard to PM₁₀, the limit value of 50 µg/m³ must not be exceeded for more than 35 days per year. The limit value for PM_{2.5} has entered into force in 2015 and aims at a maximum concentration of 25 µg/m³ (yearly average).¹³ Many cities in the Member States have problems to meet these requirements. Therefore, the Commission already has started infringement procedures against many member states in order to enforce the air quality standards. Nevertheless, it has to be considered that EU limit values are much weaker than the guidelines of the World Health Organisation (WHO): In 2013, 9 out of 10 city residents in the EU were exposed to PM concentrations that exceeded the WHO value set to protect human health.¹⁴

Air pollution does not stop at national boundaries. In order to limit overall air pollution, the European Union has policies in place limiting also national totals of atmospheric emissions. The **National Emission Ceilings (NEC) Directive (2001/81/EC)** is currently being reviewed as part of the Clean Air Policy Package. It shall ensure that the current national emission ceilings will be tightened and that new standards for fine particles (PM_{2.5}) and methane (CH₄) will be integrated.¹⁵

The European legislation on **Ecodesign and energy labelling** aims at removing the least efficient products from the market in order to contribute to the EU's 2020 energy efficiency objective. Due to their health impact, the Ecodesign regulations for **solid fuel boilers (2015/1189/EU)** and **local space heaters (2015/1185/EU)** also include emission limit values that have to be met. Unfortunately, these requirements enter into force very late: in 2020 for boilers and in 2022 for local space heaters. While Ecodesign requirements presumably will be an improvement to the existing national regulations in some Member States, this holds not true for the forerunners: According to the German Government, the upcoming Ecodesign requirements for stoves will only be on a comparable level with the already existing German legislation. Requirements for boilers are expected to be even weaker than the German ones.¹⁶



Sustainable solutions and alternatives to wood burning

Together with other renewable energy sources, wood plays an important role in the replacement of fossil fuels in the heating sector. Nevertheless, it should only be used in efficient appliances with low emissions. In addition, the general reduction of heat requirements and other environmentally benign alternatives have to be considered as well:

- **Building efficiency and energy renovation:** The soundest measure is to minimize the heat consumption of houses by better insulation. Whether wood burning is a supplementary heat source (stove) or the primary heat source (boiler), the energy renovation of the home will effectively reduce the amount of wood burned and the related air pollution.
- **Environmentally friendly alternatives:** Renewables such as solar heat and geothermal energy, including efficient heat pumps, are recommended. Renewable or biomass based district heating from combined heat and power plants can also be an eco-friendly solution. In urban regions, surplus heat from industry may be used for heat supply.
- **Good stoves and boilers:** The health hazardous particle pollution from modern wood stoves and boilers connected to a good new chimney will under optimal conditions be much lower than the one of older appliances. Nevertheless, the pollution from new firing units is still much higher than the pollution from other heat sources, as figure 5 shows. A rule of thumb: The less influence of user behavior and fluctuating fuel quality and the more automatization, the less particle emissions will be produced. Therefore, pellet stoves and boilers are a comparable efficient and low-emission alternative. With regard to firewood appliances, stoves with smart electronic automation (in particular with regard to combustion air), two-stage combustion (gasification) or effective exhaust cleaning basically cause fewer emissions than standard appliances in the market.

- **Proper dimensioning and particle separators:** If a new stove is to be purchased, proper dimensioning and a smart integration in an overall heating concept is strongly required (e.g. buffer storage for excess heat). In addition, further development efforts have to be taken to improve combustion and exhaust cleaning technology. Especially for smaller appliances, there aren't many exhaust cleaning solutions and those offered in the market often do not deliver the emission reduction promised.
- **Optimal firing:** In contrast to automated (pellet) appliances, emission from firewood stoves considerably depend on user behavior and quality of the firewood used. According to a Swiss study, emissions may be up to 100 times higher if a stove is not operated properly. If the optimal combustion air supply is ensured and if only permitted and properly stored wood is burned, emissions can be reduced substantially. Wet, dirty or even treated wood as well as any waste must not be used. In addition, regular maintenance can help to avoid excessive emissions.

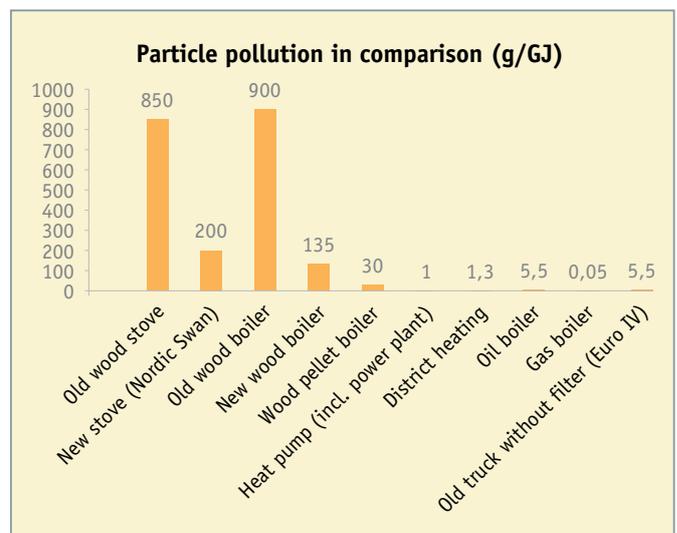


Figure 5: Particle pollution (PM_{2.5}) of different heat sources compared with a diesel truck (data from Denmark). | Sources: Helge Rørdam Olesen, DCE, University of Aarhus, Denmark.

Country focus Germany: situation and policy recommendations

Current situation

In Germany, there are about eleven million stoves and boilers for solid fuels. In 2015, domestic combustion was responsible for about 26,860 tons of PM_{2.5} and 8,240 tons of black carbon – far more than road transport. About 59,500 premature deaths are attributable to particulate matter.¹⁷ According to figures of the stove and heating industry, about 300,000 local space heaters are sold every year. Single-room firewood appliances cause almost 80% of total PM due to wood burning – among them, fireplace stoves are the most relevant ones.¹⁸ Due to the high number of private and municipal forest owners – two millions according to the Arbeitsgemeinschaft Deutscher Waldbesitzerverbände (AGDW) – there is a large number of people with access to wood.

Legislation and most relevant problems

Compared to other European countries, the small heating device ordinance (1. BImSchV) is relatively strict. It contains a list of fuels that can be burnt and defines the maximum moisture of firewood. In addition, the ordinance sets emission limit values for PM as well as for several further air pollutants. Since January 2015, new stoves and boilers have to comply with more stringent limit values ranging between 20 mg/m³ and 40 mg/m³, depending on type of appliance and fuel used.¹⁹

Nevertheless, there are **several flaws and loopholes** that reduce the effectivity with regard to emission reduction. Single-room appliances only have to meet emission limit values on the test bench in the course of the type approval. The measurement method does not reflect **real-world use**. Thus, there aren't enough incentives to develop more sophisticated technical solutions to reduce emissions in real-world. Boilers are subject to recurring measurements which are conducted every two years by a chimney sweeper on site. However, the **tolerance granted due to measurement uncertainty** (40% of the measured value can be subtracted; another 7 mg/m³ can be deducted due to fluctuating fuel quality) is much too high and substantially weakens the limit values.

The **transition period** for the shutdown, replacement or retrofitting of old stoves is much too long (until 2024 for local room heaters, the most relevant source) and implementation is not effectively controlled by the responsible authorities: according to HKI, only one fifth of old appliances affected by the 1. BImSchV have actually been replaced or shut down.²⁰ **Standards for retrofitting** of old appliances are specified in VDI industry standard (as extension of the requirements in the 1. BImSchV). Nevertheless, requirements for long-term durability and effectiveness of particle separators are not sufficiently clarified.

There are **numerous exemptions** regarding limit values and replacement for existing appliances such as historical stoves, stoves that are the only source of heat and open fireplaces. The latter only shall be used at eight days a month for a maximum of five hours – but it is completely vague, how public authorities and chimney sweeps are going to check compliance. In addition, there is **no effective market surveillance** by public authorities controlling whether the appliances produced and placed on the market conform to the type approval values (conformity of production, CoP). By this, false declarations and product counterfeiting are encouraged.



„The diesel scandal in the car industry has shown what happens if public authorities rely blindly on the manufacturer's data. Therefore, more realistic measurement procedures and effective market surveillance is crucial for stoves and boilers as well.“
Axel Friedrich, Expert for transport and air quality

Last but not least, the **complaint management** due to wood burning needs to be improved: Many people report that they are suffering from smoke in the neighborhood for years without obtaining assistance by local authorities. In addition, there is still no effective control and detection of abuse of fuel or illegal wood burning.

Policy recommendations

Cities and municipalities can reduce the impact of wood burning by local measures and thus improve urban air quality substantially:

- **Quicker replacement or shutdown of old appliances:** For instance, in Munich, old appliances already have to be replaced or shut down until the end of 2018. Like in the city of Aachen, further operation of these appliances is only allowed if they meet stricter emission limit values than the national legislation requires for old stoves.
- In highly polluted areas: **Ban on installation and on use of solid biomass appliances** (with possible exemptions for stoves and boilers with eco-label or comparable low particle emissions like other heat sources).
- **Local funding programs for the exchange of old stoves** (with ambitious emission and efficiency standards for new appliances).
- **Local information campaigns** to make consumers aware of the problem and to ensure proper use of stoves (e.g. seminars for stove owners like the city of Reutlingen is offering).

On national level in Germany, the following measures are required:

- **Ambitious eco-labels** for stoves and boilers to distinguish front runners in the market.

- **Requirements and economic incentives** for energy renovation and insulation of existing buildings have to be extended. The same holds true for funding programmes for solar heat, geothermal energy and pellet appliances, provided that they show a comparable low level of particulate matter like other heat sources.
- The German **market incentive programme** to promote the use of renewable energies in the heating market (MAP) should only support wood burning appliances with integrated particle separator.
- More resources and effective structures for **market surveillance** have to be established: At least 50 stoves and boilers have to be checked every year by public authorities if they conform to the type approval values.
- **Significant reduction of the measurement uncertainty** granted at the recurring measurements of boilers at site.

At European level or in other Member States, the following action is needed:

- Member States with emission limit values below the Ecodesign requirements should introduce more ambitious legislation to pave the way for the stricter standards (including ambitious regulation for the replacement/shutdown of old appliances).
- Harmonized and more **realistic measurement procedure** in the course of type approval of stoves and boilers within the EU, reflecting better the actual emission performance.
- Introduction of a robust **measurement procedure for particle number** and determination of adequate limit values (analogous to the development of emission standards in the traffic sector).
- **Stricter standards for air quality:** Both the European Union and the Member States should consider the WHO recommendations as standard for air quality. In addition, requirements for the maximum concentration of ultrafine particles should be introduced.
- **Better information for consumers:** Mandatory proof of origin for firewood and pellets and establishment of a European eco-label for stoves and boilers.
- Structural solution for the **problematic double role of chimney sweepers:** Clear separation of control activities and role as service provider or seller of stoves.

Wood is an important raw material and too precious to be burnt in inefficient stoves and boilers with the formation of much particulate matter and soot. The legislator pulls the strings to push ahead with the development of innovative and low-emission wood burning appliances by introducing ambitious standards and to pave the way for a successful transition towards renewables in the heat sector.

As of March 2016.

Endnotes:

- 1 European Environment Agency (2015): *Air quality in Europe – 2015 report*, p. 44.
- 2 European Commission (2013): *Questions and answers on the EU Clean Air Policy Package* (available on: http://europa.eu/rapid/press-release_MEMO-13-1169_en.htm).
- 3 European Commission (2014): *EU ENERGY, TRANSPORT AND GHG EMISSIONS – TRENDS TO 2050*, p. 37 (available on: https://ec.europa.eu/energy/sites/ener/files/documents/trends_to_2050_update_2013.pdf).
- 4 Compared to other sources, nitrogen oxide and carbon monoxide emissions from wood burning are not relevant.
- 5 Data source: *The Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)-Model of the International Institute for Applied Systems Analysis (IIASA)*.
- 6 European Environment Agency (2015): *Zahlreiche Europäer sind immer noch gesundheitsschädlicher Luftverschmutzung ausgesetzt*, p. 6. WHO air quality guidelines (AQG) for yearly PM_{2,5} concentrations: 10 mg/m³ (EU limit value: 25 mg/m³).
- 7 Fachagentur Nachwachsende Rohstoffe (FNR) (2013): *Handbuch Bioenergie-Kleinanlagen*, p. 118-119.
- 8 Verenum (2007): *Wirkung von Verbrennungspartikeln – Vergleich der Gesundheitsrelevanz von Holzfeuerungen und Dieselmotoren*, p. 61.
- 9 University of Aarhus (2014): *Scientific Report no. 102*.
- 10 Bond et al. (2013). *Total effect considering cooling effects of mineral dust and organic carbon vs. warming effect of soot*.
- 11 Dr. James E. Hansen, NASA Goddard Institute for Space Studies (2008) (available on: <http://www.russfrei-fuers-klima.de/kampagne/klimasch%C3%A4den/>).
- 12 European Commission: *Air quality – existing regulation* (available on: http://ec.europa.eu/environment/air/quality/legislation/existing_leg.htm).
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- 14 See endnote 6.
- 15 Europäische Kommission: *National Emission Ceilings* (available on: <http://ec.europa.eu/environment/air/pollutants/ceilings.htm>).
- 16 Deutscher Bundestag – Drucksache 18/4561 (2015): *Antwort der Bundesregierung auf Kleine Anfrage der Fraktion Bündnis 90/Die Grünen zum „Vollzug der Übergangsregelungen für alte Kleinfeuerungsanlagen und der Austauschpflichten für alte Konstanttemperaturkessel“*, p. 5.
- 17 See endnote 5.
- 18 See endnote 1.
- 19 Deutsches Biomasseforschungszentrum (2014): *Abschätzung des Anteils zentraler Holzfeuerungsanlagen an den Staubemissionen in Deutschland*, p. 8.
- 20 Umweltbundesamt (2013): *Heizen mit Holz*, p. 16-20; as well as: *Verordnung über kleine und mittlere Feuerungsanlagen (1.BImSchV)*.
- 21 HKI (press release, 29.2.2016): *Austausch älterer Feuerstätten läuft stockend – Industrie fordert konsequente Umsetzung der Bundesimmissionschutzverordnung*.

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clean heat

About Clean Heat

With our project Clean Heat, we aim at a significant reduction of particulate matter and soot caused by private wood burning. Together with our Danish partner DEC (Danish Ecological Council), we press ahead with technical and political solutions and provide information for consumers.

Clean Heat is co-financed by the LIFE programme of the European Commission. The project has started in autumn 2015 and will run until the beginning of 2019.



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