Health Impacts and Greenhouse Gas Reduction Caused by Using Wood Pellets for Domestic Heating in the City of Stuttgart

Friedrich R., Kampffmeyer T., Torras Ortiz S.
University of Stuttgart

Corresponding author:

Rainer Friedrich
Institute for Energy Economics and the rational use of Energy, University Stuttgart
Hessbruehlstrasse 49-a , 70565 Stuttgart
Tel: +49(0)711 68587812
Fax: +49 (0) 711 68587873
e-mail: Rainer.friedrich@ier.uni-stuttgart.de

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Abstract

Background

In Germany, the use of pellet firings is supported by policy, as this is an efficient measure to reduce CO2 emissions. However, a problem are the higher emissions of air pollutants, especially PM2.5, caused by pellet heating systems compared to systems with oil or natural gas. These higher emissions lead to higher concentrations of primary and secondary PM2.5 and thus to more health impacts.

Objective

We estimate as well the reduction of CO2 emissions as the increase in health impacts for different scenarios of a future enhanced use of pellet firings in Stuttgart (Germany) and analyse, whether the welfare gains due to the CO2 reduction outweigh the welfare losses of the additional health impacts.

Methods

The change in background concentration of PM2.5 and PM10 caused by additional pellet firings is estimated with a statistical approach. State of the art concentration-response functions are used to determine health impacts. Health impacts are monetized with a 'willingness to pay' approach. To assess CO2 emissions, marginal abatement costs to reach the EU long term objectives for climate protection are used.

Results

For pellet firings without dust filter, monetized health impacts are about as high as the monetary value of the avoided greenhouse gases. Only pellet firings with filter show a significant net benefit.

Conclusion

For Stuttgart, only pellet firings with dust filters should be permitted. Wood firings without filter, especially wood log firings, wood chip firings and open fire places should be banned.

Keywords: integrated assessment, health impacts, pellet firings, greenhouse gas emissions, damage costs, external costs

1. Introduction

In its national climate protection plan, the German government has set the aim of reducing German CO_2 emissions by at least 40% until 2030 compared to 1990. This is an ambitious aim; to limit negative macroeconomic impacts while pursuing this aim, it is important to choose the most efficient measures for reducing CO2 emissions, i.e. those, that have the least costs per t of CO_2 reduced. One of the most efficient measures for reducing CO_2 emissions is the use of wood pellet firings instead of oil or gas fired heating facilities. Although the emissions of greenhouse gases caused by pellet firings are not zero, as life cycle emissions including harvesting of wood and production and transport of pellets have to be taken into account, the CO_2 emissions of pellet firings are much lower than those of oil and gas firings. Thus different promotions and subsidies like the market incentive programme ("Marktanreizprogramm") or low interest loans from the government-owned KfW Bank are given to promote the use of pellet firnigs. These subsidies together with the expectation of the population, that fossil fuel prices will increase in the long run, has resulted in an increasing installation of pellet heating systems over the last decade, so that at the end of 2014 over 360 000 installed pellet fuel appliances in Germany have been installed.

However, a problem are the higher emissions of air pollutants caused by pellet heating systems compared to systems with oil or natural gas. Wood pellets are a solid fuel, which especially in smaller firings leads to more incomplete combustion than gaseous or liquid fuels and thus to more PM2.5, CO and NMVOC emissions. These higher emissions lead to higher concentrations of primary and secondary PM2.5 and thus to more health impacts. A larger number of epidemiological studies, that prove the relationship between the exposure to fine particles and health impacts have meanwhile been conducted, recently the World Health Organization initiated two metastudies that confirm this relationship and recommend concentration-response functions (WHO, 2013a and 2013b) for assessing health impacts caused by fine particles.

Thus the questions arises, how big the additional health impacts caused by a policy promoting wood pellet stoves are, and whether resp. under what conditions the benefits of a reduction of greenhouse gas emissions outweighs the additional health damage.

We analyze this question by estimating the health impacts and the reduction of CO2 emissions for two scenarios, where the number of additional installed pellet firings differs. As investigation area we choose the city of Stuttgart, Germany. The city center is situated in a small basin surrounded by hills and open only to one side. Due to this situation the average wind speed is very low. This sensitivity to air pollution explains, why Stuttgart is the city in Europe, where the PM10 limit – a daily average concentration of 50µg/m³ may only be exceeded during 38 days per year – is exceeded earlier than in any other EU city in each year. Thus we expect, that the health impacts caused by an emission of one kg of PM2.5 in Stuttgart are higher than in most other places in Europe.

2. Emission Factors

Particulate matter and CO_2 emissions produced by pellet boilers and other small boilers < 50 kW in the city of Stuttgart are estimated. For this purpose the installation of two different commercially available pellet boilers is assumed; these are firstly new standard boilers with average emission factors for air pollutants and secondly low emission boilers with the lowest emission factors currently available on the market. In addition, in a further scenario the boilers are equipped with a small scale electrostatic precipitator (ESP). The average electricity consumption of an ESP is estimated as 24 kWh/a (Struschka et al, 2010). With an average emission factor of 546 g CO2 per kWh produced in Germany in 2010 (UBA 2013) the ESP operation causes emissions of 13 kg CO2 per year and boiler. As more and more renewable energies will be used for electricity production in Germany in the future, this value will decrease in the future. For the further calculations, these emissions are considered as negligible.

The emission factors for particulate matter for different wood pellet firing techniques and the other heating installations are taken from (Struschka et al., 2010 and Struschka et al., 2007), they are shown in Table 1.

Table 1: average emission factors for particulate matter for different boilers (domestic and commercial boilers in Germany, 4-50 kW)

Boiler Type	TSP [kg/TJ]	PM10 [kg/TJ]	PM2.5 [kg/TJ]
Oil boiler	1,1	1,1	1,1
Natural Gas boiler	0,03	0,03	0,03
low emission wood pellet boiler	21	20	17
low emission wood pellet boiler with ESP[1]	6	6	5
Standard wood pellet boiler	33	32	28
Wood chip boiler	43	40	37

Tile stove (wood burning)	125	124	120
Manual feed wood boiler	90	83	71
Brown coal briquettes	83	79	71
Hard coal briquettes	265	252	228

1) ESP- small scale electrostatic precipitator

The CO_2 emission factors for direct and upstream emissions are shown in Figure **1**. The factors for the upstream emissions were retrieved from (UBA 2013), they include harvesting and transportation of biomass fuels, pellet production, extraction and distribution of fossil fuels. It is important to remark that direct emissions from burning of biomass fuels were considered to be carbon-neutral or having a net zero carbon footprint.

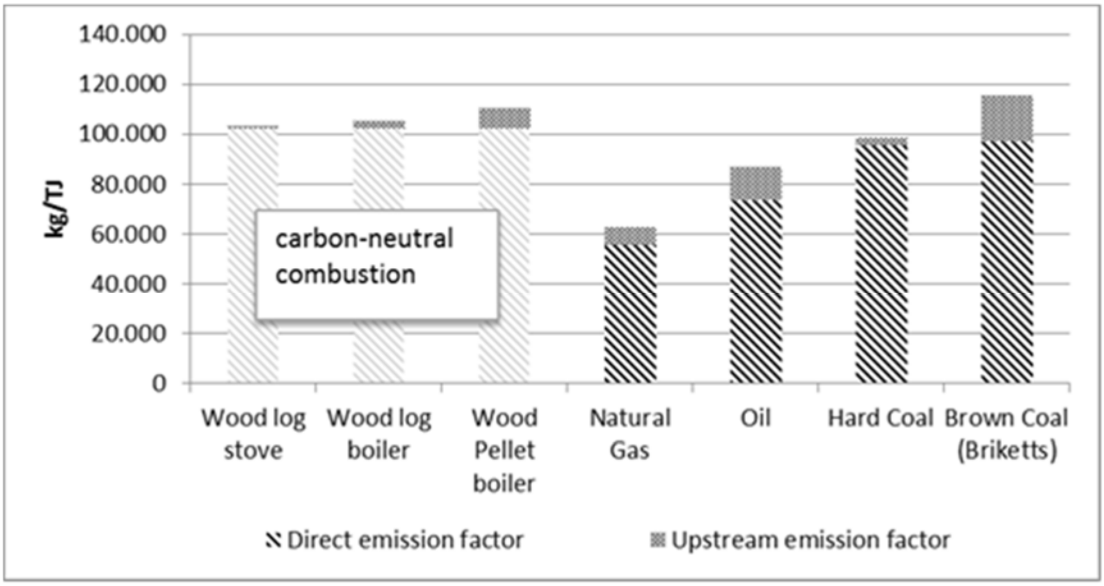

Figure 1: CO_2 emission factors for different domestic and commercial boilers, direct and upstream processes (Struschka et al.2007), (UBA 2013)

3. PM10 emissions in Stuttgart 2010

As base year for generating scenarios, the year 2010 was chosen. Until 2010 214 pellets boilers (2935 kW) were installed in Stuttgart. 209 boilers were used in residential buildings, the remaining 5 pellet boilers were installed in the commercial sector (based on BA 2009).

In 2010 606,000 people lived in Stuttgart in 73,200 buildings with 298,300 flats; the population has increased by 4% over the last decade (Federal Statistical Office, 2014). The PM10 emissions in the period 2000-2010 in Stuttgart are shown in Figure 2. Between 2002 and 2008 the PM10 emissions of small combustion plants increase continuously. This is caused by the rising use of solid biomass fuels like for example split logs and wood chips.

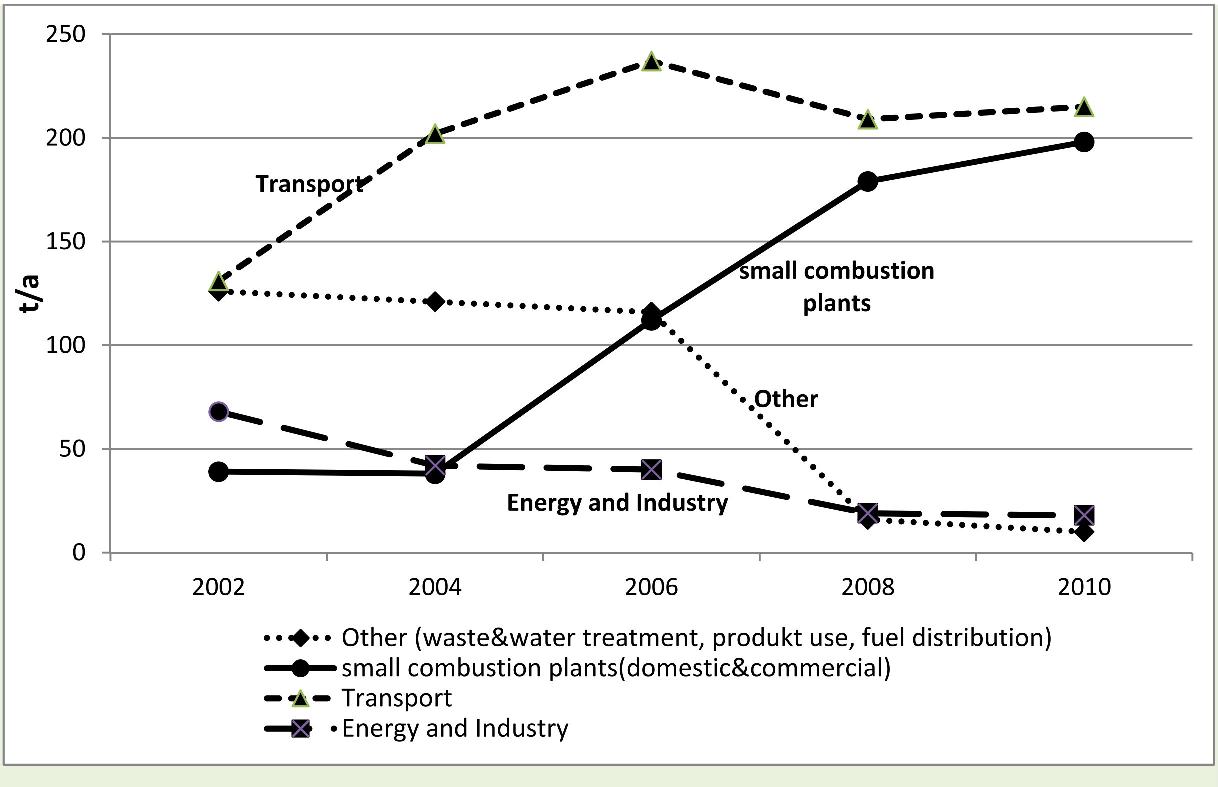

Figure 2. PM10 emissions in Stuttgart (LUBW 2014)

The share of pellets of 0.2% on the final energy consumption of small combustion plants in Stuttgart in 2010 is very low compared to natural gas with 77%, oil with 13% and solid fuels with 9.8%. After wood stoves and oil fired installations the pellet stoves are the third-largest source of PM10 emissions in Stuttgart as shown in Table 2.

Table 2: Share of fuels in small combustion plants (SCP) on PM10 emissions in Stuttgart 2010

	share of fuels on Emissions in %	share of fuels on heat consumption in SCP in %
Oil	4,6	13
Natural Gas	0,1	77
Wood Pellets	2,2	0,2
solid Fuels (coal, other biomass fuels)	93,1	9,8

4. Reference and Intervention Scenarios

The following analysis is focussing on the emission source sector ‘small combustion plants’ in Stuttgart, as pellet firings are only used in this sector. Three scenarios for the development of fuel use and of emissions in the sector small combustion plants for the years 2015, 2020 and 2025 are generated:

Business as usual scenario (BAU):

Fuel demand and supply for small combustion plants in Stuttgart is assumed to follow the same trend development as the development in the whole of Germany, estimated by a scenario generated with the energy model TIMES (Blesl (2008), Blesl et al. (2008) and Blesl et al. (2010)). The scenario used as trend scenario is taking into account the EU and German policies for reducing greenhouse gases. The resulting energy consumption by fuel is shown in Table 3. Caused by a stagnating population and by the renovation of buildings, the energy consumption in small combustion plants is continuously decreasing. Oil firings are reduced with the highest rate, while for gas and logs the reduction is more moderate; pellets are the only fuel with an increasing consumption. The reason is, that only wood pellets (and not wood logs) are promoted by policy and further on, that comfort and handling are much better for pellets than for logs. For the installation of pellet boilers the growth rate for future years is assumed to be similar than from 2001 to 2010, so that in 2025 about 600 pellet firings will be installed.

Pellet scenario:

A stronger growth of pellet boilers in Stuttgart than in the BAU scenario is assumed based on expectations of the German Wood Pellet Association (DEPV e.V.). The DEPV assumes a continuous annual growth rate of 20% and expects therefore for the year 2020 about one million pellet installations in Germany (DEPV 2009). For Stuttgart, a similar trend will result in about 8100 installed pellet firings in 2025. The pellet boilers will mainly replace oil firings, as in this case the room for the oil tank can be used for storing the pellets. The efficiency of both heating techniques (modern oil and pellets boilers) is in the same range between 93% and 95%. The energy consumption and number of pellet firings are shown in Table 4 and Fig. 3.

As there are significant differences across boilers regarding their emission factors (i.e., the amount of emissions released per unit), the pellet scenario is further diversified: in the ‘pellet scenario (standard boilers)’ firings with average emission factors are installed, in the ‘pellet scenario (low emission boilers)’ firings with the best available emission factors are used.

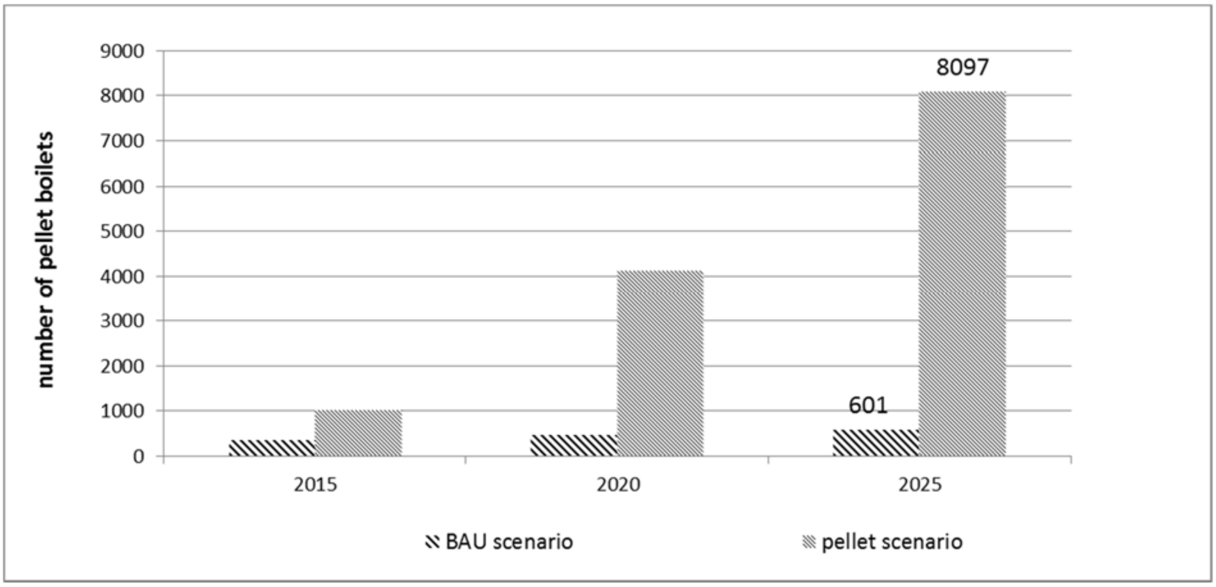

Figure 3: Development of pellet boilers in Stuttgart in the two scenarios (forecast-total stock), BAU = business as usual

Figure 4 compares the CO_2 emissions incl. upstream emissions from small combustion plants in Stuttgart for the two scenarios.

Table 3: Energy consumption in small combustion plants Stuttgart in the BAU scenario

Energy consumption in TJ	**2010**	**2015**	**2020**	**2025**
Oil	2461	1954	1374	1065
Natural Gas	10570	10153	9611	8368
solid fuels (wood, some coal)	1424	1382	1348	1276
Pellets	24	42	54	95
Total	**14479**	**13530**	**12387**	**10804**

Table 4: Energy consumption in small combustion plants Stuttgart in the pellet scenario

Energy consumption in TJ	**2010**	**2015**	**2020**	**2025**
Oil	2461	1889	1003	286
Natural Gas	10570	10136	9546	8282
solid fuels (coal, other biomass)	1424	1382	1348	1276
Pellets	25	123	490	960
Total	**14479**	**13530**	**12387**	**10804**

As shown in Fig 4, the CO_2 emissions from small combustion plants in Stuttgart will be reduced already in the BAU scenario, caused especially by less oil firings. In the pellet scenario, there will be a further CO_2 reduction, for instance in the year 2025 by 65.5 kt or 10.6%.

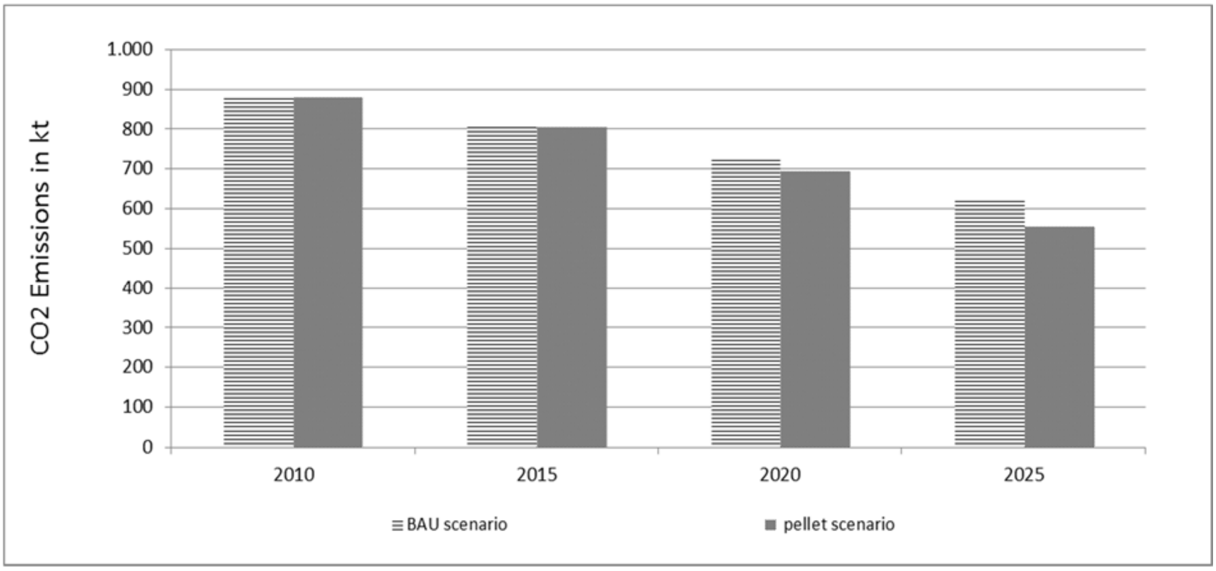

Figure 4: CO_2 Emissions in kt/a from small combustion plants in Stuttgart

On the other hand, PM2.5 and PM10 emissions will increase in the ‘pellet scenarios’ compared to the BAU scenario (Fig. 5). Increased use of pellets causes 2025 about 20 t/a more PM10 emissions compared with emissions in the BAU scenario. Thus, the share of PM10 emissions from pellets boilers on total PM10 emissions from small combustion plants in Stuttgart in 2025 in the pellet scenario will increase to 15%.

The development of the total PM10 emissions from small combustion plants in Stuttgart in the pellet scenario (standard boiler) is shown in Figure 5.

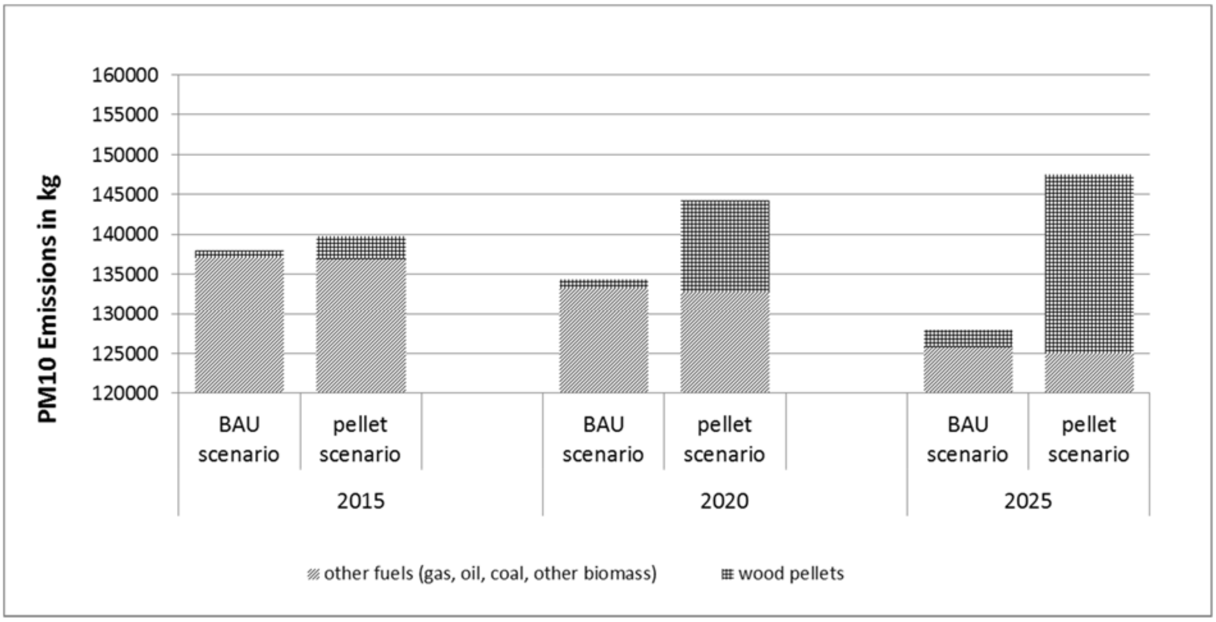

Figure 5: PM10 emissions from small combustion plants in Stuttgart (standard boiler)

The PM_{10} emissions during operation of a standard pellet boiler are nearly five times higher than emissions from a low emission boiler with dedusting system (ESP) as shown in Table 1. The calculated PM10 emissions for all small combustion plants and the scenarios with different boilers types and with and without dust filter are shown in Figure 6.

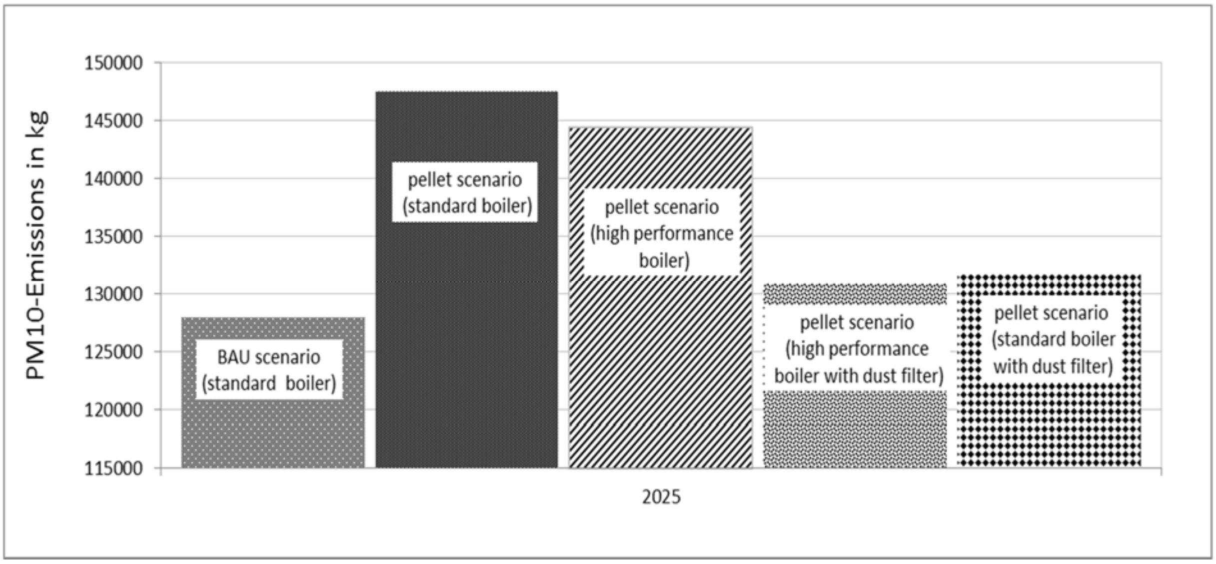

Figure 6: PM10 emissions from small combustion plants in Stuttgart (boiler type comparison) for 2025

5 Human health impacts

To estimate the health impacts, that are caused by the changes in PM2.5 and PM10 emission, the ‘impact pathway approach (IPA)’ is used (Bickel, Friedrich, 2005). The analysis starts with the changes in emissions calculated in Chapter 4. Then atmospheric models are used to estimate the change in concentrations caused by the emission change. Health impacts are then derived by applying concentration-response functions that are derived from epidemiological studies.

The next step is thus to estimate the changes in the background concentrations for PM2.5 and PM10 that are caused by the increase in emissions estimated in chapter 5. What is needed are the urban background concentration, as the concentration-response relationships used in the next step – see below – represent a relation between health impacts and the background concentration (and not the concentration in street canyons). Instead of using atmospheric models, which – especially if applied to urban areas – give not very accurate results, we use here a statistical approach. We chose two measurement stations, a rural station outside Stuttgart and an urban background station in Stuttgart, to carry out a multi-attribute regression analysis, where urban emissions and other parameters are related to the urban increment, which is the difference in concentration between the rural and the urban background concentration. We used the following equation:

$$C_{i\,UrbInc} = \varpi_i + \phi_i \frac{E_{iUE}}{A_{UE} \cdot U_{avg}} + \gamma\, C_{i\,rural} \qquad \text{Equation 1}$$

where

$C_{i\,\mathrm{UrbInc}}$ = urban increment of pollutant i;

$E_{i\,\mathrm{UE}}$ = total emission of pollutant i within an urban entity in tons;

A_{UE} = area of the urban entity in km^2;

U_{avg} = average wind speed in m/s;

$C_{i\,\mathrm{Rural}}$ = rural background concentration of pollutant i in $\mu g/m^3$;

ω_i, φ_i, and γ_i = multiple-regression parameters for pollutant i. For PM10 the parameters are 15.27, 0.24 and -0.53.

A more detailed description of this approach can be found in Torras Ortiz and Friedrich (2013).

Inserting the changes in PM10 and PM2.5 emissions changes in the background concentration are derived for the pellet scenarios.

The concentration-response functions used are derived from the WHO HRAPIE report (WHO 2013a). Results are changes in several health endpoints, e.g. years of life lost, new cases of chronic bronchitis, hospital admissions due to respiratory or cardiovascular diseases, cough days, days with restricted activities, bronchodilator use and more. The highest impact is chronic mortality due to the long term exposure to PM2.5. The concentration-response functions used are shown in Table 5 (WHO2013a, HEIMTSA 2011).

Table 5: concentration response functions used to estimate health effects of PM2.5 and PM10.

Health effect	**Relative Risk**	**Age Group**	**Population**	**Impact Function**
PM2.5				

Health effect	**Relative Risk**	**Age Group**	**Population**	**Impact Function**
Mortality (all cause)	6% (95% CI: 2%, 11%) change per 10 µg/m^3 PM$_{2.5}$	Adults 30 years and older	General Population	953 life years lost per 10 µg/m3 PM2.5 increase for one year per 100000 people aged >29 years
Work loss days (WLDs)	4.6% (95% CI: 3.9%, 5.3%) increase per 10 µg/m^3 PM$_{2.5}$	15-64 Years	General Population	20,700 (95% CI: 17,600, 23,800) additional work lost days per 10 µg/m^3 increase in PM$_{2.5}$ per 100,000 people aged 15-64 in the general population per year
Minor Restricted Activity Days (MRADs)	7.4% (95% CI: 6.0%, 8.8%) change per 10 µg/m^3 PM$_{2.5}$	18-64 Years	General Population	57,700 (95% CI: 46,800, 68,600) additional MRADs per 10 µg/m^3 increase in PM$_{2.5}$ per 100,000 adults aged 18-64 (general population) per year
Restricted activity days (RADs)	4.75% (95% CI: 4.17%, 5.33%) change per 10 µg/m^3 PM$_{2.5}$	18-64 Years	General Population	90,200 (95% CI: 79,200, 101,300) additional RADs per 10 µg/m^3 increase in PM$_{2.5}$ per 100,000 adults aged 18-64 (general population) per year
PM10				
Infant Mortality	4% (95% CI: 2%, 7%) change per 10 µg/m^3 PM$_{10}$	1 month to 1 year	General Population	5.8 (95% CI: 2.9, 10.2) additional infant deaths per 10 µg/m^3 increase in PM$_{10}$ per 100,000 live births, per year
Chronic bronchitis	22% (95% CI: 2%, 38%) change per 10 µg/m^3 PM$_{10}$	Adults aged 18 years and older	General Population without symptoms (90% of population)	86 (95% CI 7.8, 150) new cases of chronic bronchitis per 10 µg/m^3 increase in PM$_{10}$ per 100,000 at-risk adults aged 18 and older, per year
Cardiovascular hospital admissions	0.6% (95% CI: 0.3%, 0.9%) change per 10 µg/m^3 PM$_{10}$	All Ages	General Population	4.3 (95% CI: 2.2, 6.5) additional emergency cardiac hospital admissions per 10 µg/m^3 increase in PM$_{10}$ per 100,000 people (all ages) per year
Respiratory hospital admissions	0.9% (95% CI: 0.7%, 1.0%) change per 10 µg/m^3 PM$_{10}$	All Ages	General Population	5.6 (95% CI: 4.3, 6.2) additional emergency respiratory hospital admissions per 10 µg/m^3 increase in PM$_{10}$ per 100,000 people (all ages) per year
Asthma medication use among asthmatic children	0.4% (95% CI: -1.7%, 2.6%) change per 10 µg/m^3 PM$_{10}$	5-14 Years	Children with Asthma (14.4% of children aged 5-14 in EU27)	14,600 (95% CI: -62,050, 94,900) additional days of bronchodilator usage per 10 ug/m^3 increase in PM$_{10}$ per 100,000 children aged 5-14 years meeting the PEACE study criteria, per year
Bronchodilator usage among asthmatic adults	0.5% (95% CI: -0.5%, 1.5%) change per 10 µg/m^3 PM$_{10}$	Adults aged 20 years and older	Adults with asthma (10.2% of adults aged 20 and older in EU27)	91,300 (95% CI: -91,300, 274,000) additional days of bronchodilator usage per 10 µg/m^3 increase in PM$_{10}$ per 100,000 adults aged 20 and older with well-established asthma, per year
Lower respiratory symptoms including cough among children	3.4% (95% CI: 1.7%, 5.1%) change per 10 µg/m^3 PM$_{10}$	5-14 Years	General Population	186,000 (95% CI: 93,100, 279,000) additional lower respiratory symptom days per 10 µg/m^3 increase in PM$_{10}$ per 100,000 children aged 5-14, per year
Lower respiratory symptoms (including cough) in symptomatic adults	1.2% (95% CI: 0.1%, 2.2%) change per 10 µg/m^3 PM$_{10}$	Adults	Adults with chronic respiratory symptoms (30% of adults)	131,000 (95% CI: 11,000, 241,000) additional lower respiratory symptom days per 10 µg/m^3 increase in PM$_{10}$, per 100,000 adults with chronic respiratory symptoms, per year

To be able to compare resp. add the different health impacts, they are transformed in a common unit, DALYs (disability adjusted life years). DALYs are the sum of YOLL (years of life lost due to premature deaths) and YLD (years lived with disability). YLD are the product of the number of incidents times the average duration of an incident (in fraction of years) and a disability weight between zero and one representing the severity of the incident (e,g, new case of chronic bronchitis, cough day, hospital admission due to cardiovascular diseases) (see e.g. WHO, 2009). In 2015 a reduction of emissions and health impacts occurs for the scenarios with dust filters, as in the BAU scenario standard boilers are used, and the much lower emissions of boilers with dust filters compensate the effect of the higher number of boilers in the pellet scenario.

Table 6: additional DALYs caused by the pellet scenarios compared to the DALYs in the BAU scenario

Scenario	DALYS/a		
	2015	2020	2025
Pellet scenario (standard boilers)	6,5	35,0	69,4
Pellet scenario (low emission boilers)	5,1	29,5	58,5
Pellet scenario (standard boilers with dust filter)	-0,7*	6,3	13,2
Pellet scenario (low emission boilers with dust filter)	-1,1*	4,8	10,1

The pellet scenarios reduce the CO2 emissions by 6 kt in 2015, 32,5 kt in 2020 and 65,5 kt in 2025. The differences between the pellet scenarios are negligible, the dust filters will increase CO2 emissions in 2025 by about 0,1 kt. .

4. Assessment of results

We have thus quantified the benefits for climate protection, i.e. the reduction of CO_2 emissions, but also the additional health damage occurring when increasing the number of pellet firings. To find out, whether the overall environmental performance is positive or negative (i.e. the external costs are positive or negative), we have to compare the benefits caused by the CO_2 emission reduction with the health damage caused by the increase of emissions of air pollutants. The only way to do this with a quantitative method is to transform the indicators involved (t of CO_2 reduced, DALYs) into a common measurement unit. Here we choose monetary values (€), as these are defined independently from the assessment. For monetizing health impacts, the standard approach in environmental economics, i.e. contingent valuation, is used. The basic methodology is to measure preferences by asking a representative part of the population about their willingness to pay to avoid the health risk to be assessed. We use the results of a contingent valuation study from Desaigue et al. (2007) and use benefit transfer methods to transform the study result to the current year resulting in a monetary value of 60000 $€_{2010}$ (sd 37500$€_{2010}$ - 96000$€_{2010}$) per DALY for 2010. Assuming, that the willingness to pay increases with income and that the future economic growth rate will be 1,5 %/a, the values for future years are shown in Table 7 . For CO_2 emissions, a damage cost approach and contingent valuation cannot be used, as estimations of the marginal damage costs of releasing an additional t of CO_2 show a very big uncertainty range of more than 3 orders of magnitude. Instead we use a damage cost approach. The EU has stated as long term aim to contribute to limiting the increase of the earth's surface temperature compared to preindustrial times to 2° within an international strategy. This is equivalent to not exceeding a $CO_{2,eq}$ concentration of ca. 450 ppm. We can now replace the marginal damage costs by the marginal avoidance costs to reach this aim, thereby assuming that the set aim is pareto optimal. To estimate the marginal avoidance costs, we use a meta study of Kuik et al. 2009, who found marginal avoidance costs of 252 $€_{2010}$/t CO2e (143-443 $€_{2010}$/t CO2e) in 2050. The numbers in parenthesis represent the range, i.e. the highest and lowest value in the primary studies analysed. Discounting this rate with 5%/a results in the values for marginal avoidance costs as shown in Table 7.

Table 7: monetary unit values per DALY and per avoided t of CO_2

	2015	**2020**	**2025**
Damage costs per DALY in 1000€/DALY	63 (40-228)	72 (45-115)	81 (51-130)
Marginal avoidance costs in €/t CO_2	45 (26-81)	58 (33-103)	74 (42-131)

With these monetary factors we can estimate the monetary values for health impacts and climate benefits for the scenarios (Table 8). For the monetary values for the greenhouse gas emissions a range of values is given. For the estimation of the uncertainty of monetary values of the health impacts a geometric standard deviation of 2,78 is estimated (Spadaro and Rabl, 2008), this uncertainty covers the whole impact pathway from emissions to health impacts (and not only the monetary value). .

Table 8: Monetary values of additional health impacts and avoided greenhouse gas emissions for different pellet scenarios.

	2020	**2025**
Reduction of greenhouse gas emissions – all pellet scenarios in Mio $€_{2010}$	-1.89 (-1,07--3,35)	-4,85 (-2,76--8,62)
Additional health impacts for the pellet scenario (standard boilers) in Mio $€_{2010}$	2,51 (0,90-6,98)	5,61 (2,02-15,60)
Additional health impacts for the pellet scenario (low emission boilers) in Mio $€_{2010}$	2,12 (0,76-5,89)	4,73 (1,70-13,15)
Additional health impacts for the pellet scenario (standard boilers with dust filters) in Mio $€_{2010}$	0,45 (0,16-1,25)	1,07 (0,38-2,97)

Additional health impacts for the pellet scenario (low emission boilers with dust filters) in Mio $€_{2010}$	0,34 (0,12-0,94)	0,82 (0,29-2,28)

The results show, that the welfare losses due to health impacts caused by additional pellet firings without dust filter are as high or in tendency even a bit higher than the welfare gains caused by the reduction of greenhouse gases. Significant increases in welfare are only possible with low emission boilers with dust filters.

4. Conclusions

For the city of Stuttgart, the use of pellet firings without dust filter leads to severe health impacts caused by PM2.5 emissions. These impacts outweigh the benefits of the reduction of CO2 emissions. Thus, it would be favorable for Stuttgart to decide, that only pellet stoves with dust filters would be permitted in the city area.

Other types of wood firings, e.g. log firings, have higher emission factors than pellet firings (see Table 1), thus it is even more important to reduce or ban these types of firings that currently are the cause for more than 90% of the PM emissions of small combustion in Stuttgart.

Most other cities show better meteorological conditions, e.g. a higher average wind speeds, than the city of Stuttgart. Thus health impacts are lower. Thus there might be a tendency for a slight net benefit in other cities, indicating that pellet boilers with the best available low emission technology without filter might be used; however log firings without filter should still not be permitted.

References

BA (2009) Biomasseatlas- Online-Portal für die deutsche Biomassebranche, Betreiber: eclareon GmbH, Berlin, 2009, www.biomasseatlas.de. Acessed November 2009

Bickel, P. and R. Friedrich (2005) (eds.): Externalities of Energy – Methodology 2005 update, European Commission, Brussels, ISBN 92-79-00423-9
Available at : http://www.externe.info/externe_d7/?q=node/30

Blesl, M., 2008. EU 20-20 policy implications on the energy system of Germany – an analysis with TIMES PanEU. In Nadia Maizi, Jean-Charles Hourcade: Carbone et Prospectives Presses des Mines 2008

Blesl, M., Kober, T., Bruchof, D., Kuder, R., 2008. Contribution of technological and structural changes in the energy system in the EU-27 to achieve ambitious climate protection goals (in German). Journal of Energy Economics, Issue 4/2008, pp. 219 – 229

Builtjes, P., Stern, R., Theloke, J., 2008. PAREST Particle Reduction Strategies. PAREST Annual report, Project on behalf of the German Environmental Protection Agency (UBA)

DEPV (German Wood Pellet Association), 2009. Press release from 07.10.2009 in Stuttgart (http://www.depv.de/de/presse/pressearchiv/pressemitteilung_lesen/presse_archiv/2419290312/ last accessed 15 January 2014)

B. Desaigues, A. Rabl, D. Ami, Boun My Kene, S. Masson, M-A Salomon and L. Santoni. 2007. "Monetary Value of a Life Expectancy Gain due to Reduced Air Pollution: Lessons from a Contingent Valuation". Revue d'Economie Politique, Vol.117 (5), 675-698.

Federal Statistical Office and the statistical offices of the Länder, Germany (http://www.statistikportal.de/Statistik-Portal/ last visited 17 September 2014)

Friedrich, R., Reis, S., 2004. Emissions of Air Pollutants–Measurements,Calculations and Uncertainties, Springer, 335 pages

Friedrich, R., Wickert, B., Schwarz, U., Reis, S., 1999. Improvement and Application of Methodology and Models to Calculate Multiscale High Resolution Emission Data for Germany and Europe, in Emissions of Air Pollutants–Measurements, Calculations and Uncertainties, edited by Friedrich R., Reis, S., Springer, pp. 28-33

HEIMTSA 2011: D 5.3.1/2 Methods and results of the HEIMTSA/INTARESE Common Case Study, report for the EC FP7 project HEIMTSA;available at http://www.integrated-assessment.eu/sites/default/files/CCS_FINAL_REPORT_final.pdf

Heck, T., Krewitt, W., Malthan, D., Mayerhofer, P., Pattermann, F., Trukenmuller, A., Ungermann, R., 1997. EcoSense 2.0 – User's Manual. Universitat Stuttgart, IER.

Janssen, NAH., Gerlofs-Nijland, M., Lanki, T., Salonen, R., Cassee, F., Hoek, G., Fischer, P., Brunekreef, B. and Krzyzanowski, M., 2012. Health effects of black carbon. Copenhagen, WHO Regional Office for Europe (http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/air-quality/publications/2012/health-effects-of-black-carbon, last accessed 29 September 2014)

Krewitt, W., Trukenmueller, A., P. Mayerhofer, R. Friedrich. 1995 ECOSENSE – an integrated tool for environmental impact analysis H. Kremers, W. Pillman (Eds.), Space and Time in Environmental Information Systems. Umwelt-Informatik aktuell, Band 7, Metropolis-Verlag, Marburg (1995

Kuhlwein, J., Wickert, B., Trukenmuller, A., Theloke, J., Friedrich, R., 2002. Emission–modelling in high spatial and temporal resolution and calculation of pollutant concentrations for comparisons with measured concentrations. Atmospheric Environment 36, pp. 7–18

LUBW 2014. Luftschadstoff-Emissionskataster Baden-Württemberg für die Jahre 2000-2010, Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (LUBW), http://www.lubw.badenwuerttemberg.de/servlet/is/14159/?shop=true&shopView=11163, Accessed 11 November 2014

Milego, R., 2007. Urban Morphological Zones 2000 Version F1v0 – Definition and procedural Steps, European Environmental Agency Report, Barcelona, 11 pp

NEEDS. (2009). Report on the application of the tools for innovative energy technologies: NEEDS project funded by the Sixth Framework Program.

Samoli E. et al. (2008) Acute effects of ambient particulate matter on mortality in Europe and North America: results from the APHENA Study. Environmental Health Perspectives, 116(11):1480–1486.

SEE (City with Energy Effficiency, in German) Project, 2010. Project report, Capital City Stuttgart (http://www.stuttgart.de/img/mdb/publ/19227/62226.pdf last accessed 15 July 2014)

J. V. Spadaro and A. Rabl. 2008. "Estimating the Uncertainty of Damage Costs of Pollution: a Simple Transparent Method and Typical Results". Environmental Impact Assessment Review, vol. 28 (2008) 166–183

Struschka, M., Kilgus, D., Springmann, M., Baumbach, G., 2007. Efficient provision of current emission data for air pollution control, Institute of Combustion and Power Plant Technology, University Stuttgart, Research grant (FKZ) 205 42 322, Stuttgart, Germany

Struschka M., Goy, J., Schäfer, C., Kampffmeyer, T., Jenssen, T., König, A., Uzbasich, M., Eltrop, L., Friedrich, R., 2010. Beitrag von Pelletsfeuerungen zu den Emissionen von Feinstäuben, CO und VOC in Ballungsräumen (in German). Project report IFK in collaboration with IER, Universität Stuttgart Research grant (FZK) A24206, Stuttgart, Germany

TGA (Technical Building Services Magazine), 2013. TGA Professional planer newsletter (http://www.tga-fachplaner.de/TGA-Newsletter-2013-3/2012-3-mehr-Waermeerzeuger-verkauft,QUlEPTM5NTkwOCZNSUQ9MzAwMDI.html. Accessed 11 September 2014)

Torras Ortiz, S., Friedrich, R., 2013. A modelling approach for estimating background pollutant concentrations in urban areas. Atmospheric Pollution Research, doi: 10.5094/APR.2013.015.

UBA (German Federal Environmental Agency), 2013. Emission balance from renewable enrgy source – Estimation of emissions avoided in the year 2012 (in German), Climate Change 15/2013, German Federal Environmental Agency, Dessau, Germany

Vautard, R., 2006. Meteorology Data for Europe modelled with MM5. Data prepared for NATAIR project, unpublished results.

WHO (2009). Disease and injury country estimates. http://www.who.int/healthinfo/global_burden_disease/estimates_country/en/

WHO (2013 a). Health risks of air pollution in Europe – HRAPIE project. Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide. WHO Regional Office for Europe, Copenhagen (http://www.euro.who.int/__data/assets/pdf_file/0006/238956/Health-risks-of-air-pollution-in-Europe-HRAPIE-project,-Recommendations-for-concentrationresponse-functions-for-costbenefit-analysis-of-particulate-matter,-ozone-and-nitrogen-dioxide.pdf. Accessed 19 August 2014)

WHO (2013 b). Review of evidence on health aspects of air pollution – REVIHAAP Project. WHO Regional Office for Europe, Copenhagen (http://www.euro.who.int/__data/assets/pdf_file/0004/193108/REVIHAAP-Final-technical-report-final-version.pdf?ua=1)

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