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BEST
Bioenergy and
Sustainable Technologies

Emissions from Biomass Combustion

Lessions learned from Austria

Webinar AVEBIOM, 23.2.2021

Dr. Christoph Schmidl

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Background: Climate Policy

Green Party in Government (since 2020) = „Game-Changer“

- Climate action is in the focus now
- The government program 2020-2024 decided to **phase-out domestic oil heating**
- Ambitious phase-out plan for fossil fuels in space heating:
  - For new buildings (from 2020)
  - For the **heating system change** (from 2021)
  - Mandatory replacement of boilers older than 25 years (from 2025)
  - Replacement of **all heating oil boilers until 2035 (~ 500.000 boilers in 15years)**


Aus Verantwortung für Österreich.

Regierungsprogramm 2020–2024

Background Infos

Concerns about the Bioenergy Pathway…

- **Biomass is the most important renewable energy source in Austria**. It also plays a central role in the further transformation of our energy system.
- In addition to the (un)disputed great importance for climate protection, **wood-burning systems are criticized for their emissions**.
- Research question: **How does the decarbonization of the heating sector affect (fine) dust emissions in Austria?**
- Aspects considered:
  - Status of dust emissions today
  - Outlook: How will emissions develop by 2050?

Research done to answer the Questions
= content of this presentation

- Review: What ist the **Status of Particle Emissions today**?
- Several Studies on **Real-Life Emission Evaluation** of modern Biomass Heating Systems to obtain realistic Emission Factors
- Study: **Recalculation of the Particle Emissions** based on new findings
- Renewable Energy Scenario: **How can the residential Heating Sector be decarbonized by 2050** (now 2040 ist the Target)?
- Combination of Scenarios: **How will Particle Emissions develop in the Renewable Energy Scenario?**
- Case Study: **Effect of Boiler Changeout** on CO_2 and Particle Emissions for randomly selected Cases

References for this Presentation

(several scientific Studies and official Data Sources)

- Schwarz, M.: **Factsheet Staubemissionen – Aktuelle Daten und Ausblick auf 2050**, BEST Research (2019)
- Haider et.al.: **Austria’s Informative Inventory Report** (IIR) 2019 Umweltbundesamt, Wien (2019)
- Kranzl, L., Müller, A., Maia, I., Büchele, R. und Hartner, M.: **Wärmezukunft 2050. Erfordernisse und Konsequenzen der Dekarbonisierung von Raumwärme und Warmwasserbereitstellung in Österreich.** Studie i.A. Erneuerbare Energie Österreich, Wien (2018)
- Schmidl, C. und Reichert, G.: **Das neue Holzwärmeszenario „Holz ersetzt Heizöl“**. WSED2020, Wels (2020)
- Sturmlechner, R.: **Real life emissions of domestic wood heating appliances – Results of a field campaign in the Clean Air by biomass project**. WSED next Conference, Wels (2019)

Status of Fine Dust Emission in Austria

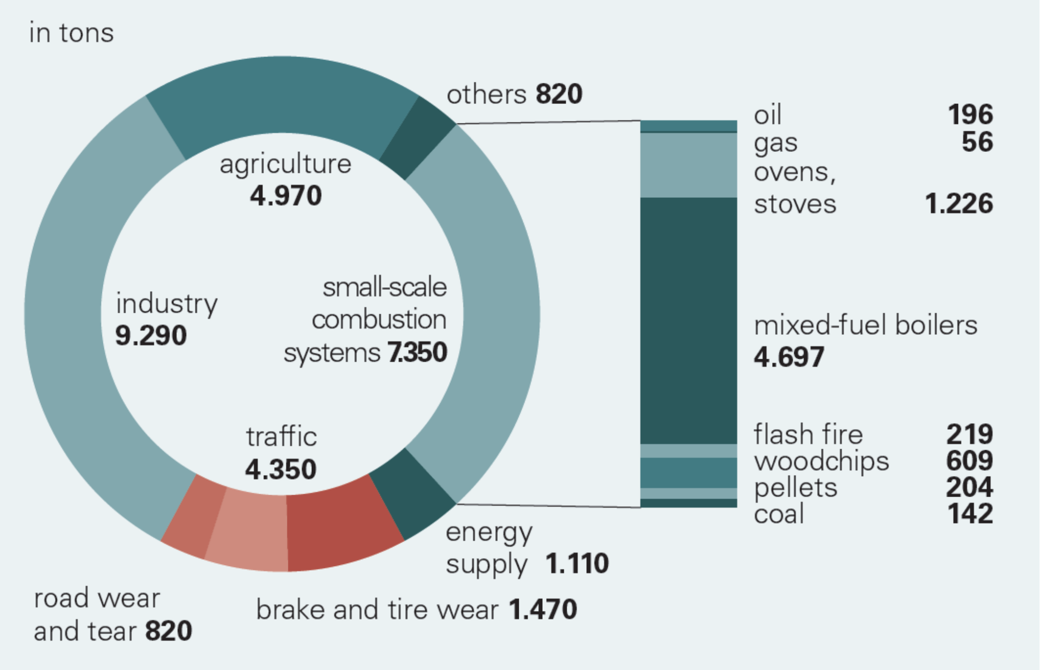
How to do Emssion Inventories…

- The emissions inventory adds up the emissions of environmentally relevant substances over a certain period of time (usually one year).
- The data is recorded according to sectors (e.g. transport, industry, agriculture, etc.).
- The calculation principle is simple:
  - Emission = emission factor (EF) * activity coefficient (a)
  - Example: Dust emissions (kg) = EF (kg / TJ) * fuel consumption per year (in TJ)
- Until a few years ago, this calculation was actually carried out with one EF for all biomass fuels and types of combustion
- Today, different EFs are used depending on the fuel and type of combustion (automatic / manual, old / new technology) and then added up.

Status of Particulate Matter Emissions in Austria

Data basis: Austrian Air Pollutant Inventory

- 26% of the PM10 emissions from small-scale combustion
- 68% from mixed-fuel boilers (= old firewood/coal technology)
- Modern boilers make up 3.6%, ovens and stoves 4.3% of total emissions
- Some uncertainties in the calculation ...

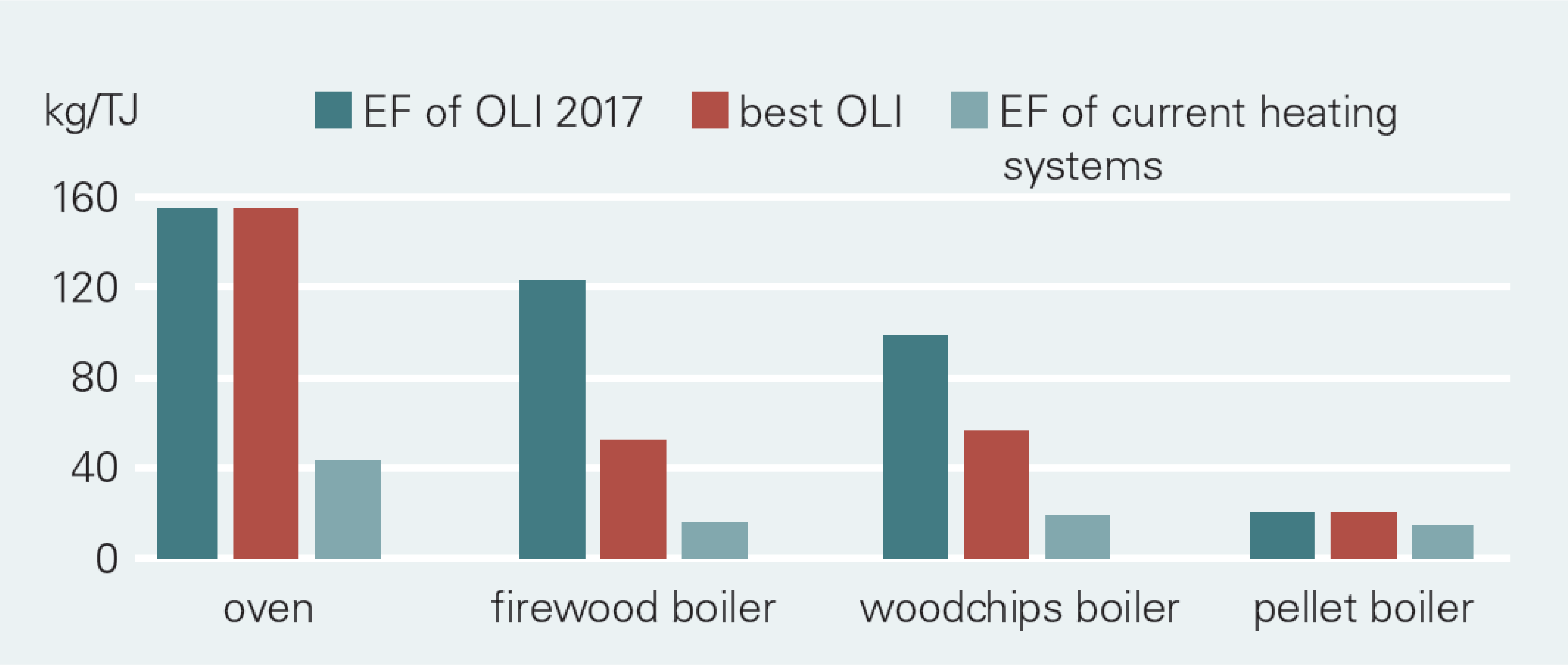


Emission Inventory Critics
(EI is not exact Science, Assumptions are required)

- Assumption of system inventory too old (proportion of mixed-fuel boilers too high)
- Assuming a service life of 40 years, only less than 50% of the logwood boilers should be old mixed-fuel boilers (not 90% as in the current Austrian Inventory)
- Emission factors used are mostly based on "standard values" in the EMEP / EEA air pollutant emission inventory guidebook (= European average values)
- Several research projects have shown: Austrian technologies are significantly better than the European average
- Recalculation of the emissions inventory:
  - with careful assumptions about the service life (40 years for WC and LW, 30 years for pellets, 20 years for stoves)
  - Emission factors from research projects over the past 10 years

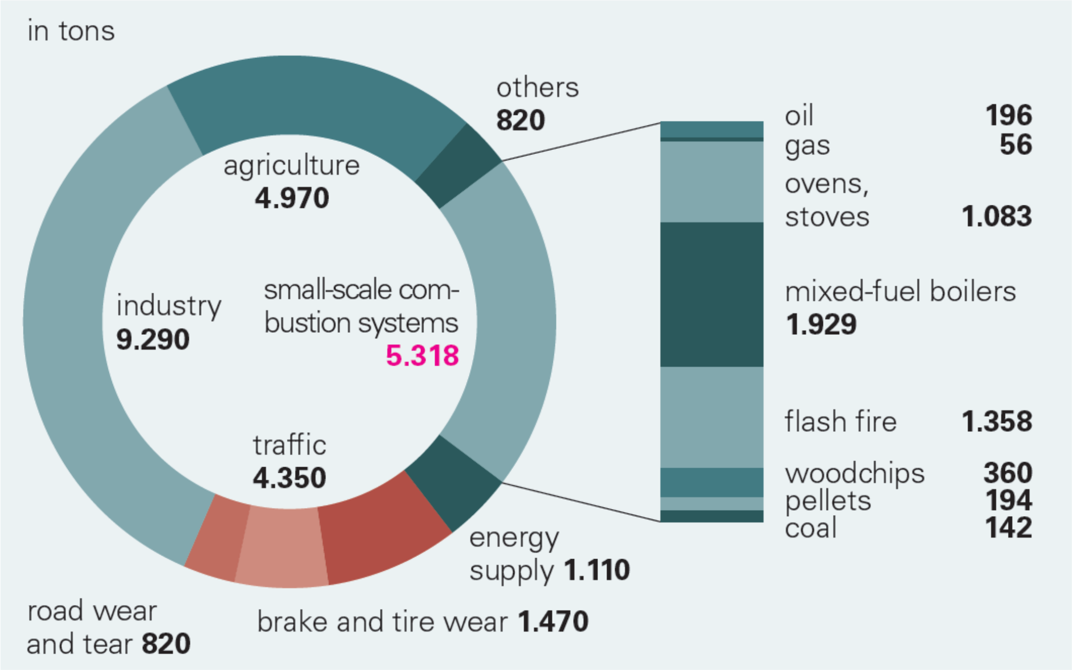
Emission Factor Comparison

Official Austria Dataset / Real Emission Factors (modern Systems)



Recalculation of PM10 Emissions
(Schwarz & Strasser, 2019)

- Realistic system inventory (service life)
- Emission factors of modern furnaces from research projects
- Reduction of emissions by approx. 2000 t / a
- Significant reduction in the contribution made by mixed-fuel boilers



Outlook: Development of fine dust emissions till 2050

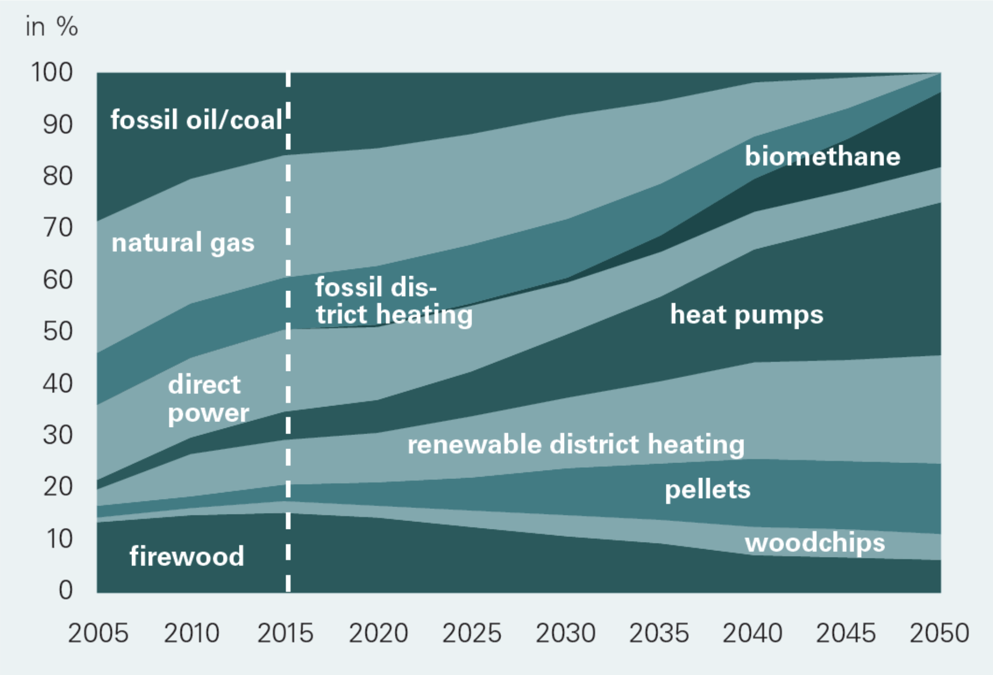
Base Scenario: Renewable Heat Austria (Study)

- Study by the Vienna University of Technology (Energy Economics Group) on behalf of Renewable Energy Austria from 2018
- Question: **How could an extensive decarbonisation of the space heating sector in Austria look like?**
- Approach:
  - Model of the building stock in Austria
  - Simulation of the energy technology mix on the way to decarbonising the space heating sector by 2050
  - Deriving measures to achieve the goals

Renewable Heat Scenario for Austria

(Kranzl et al., 2018)

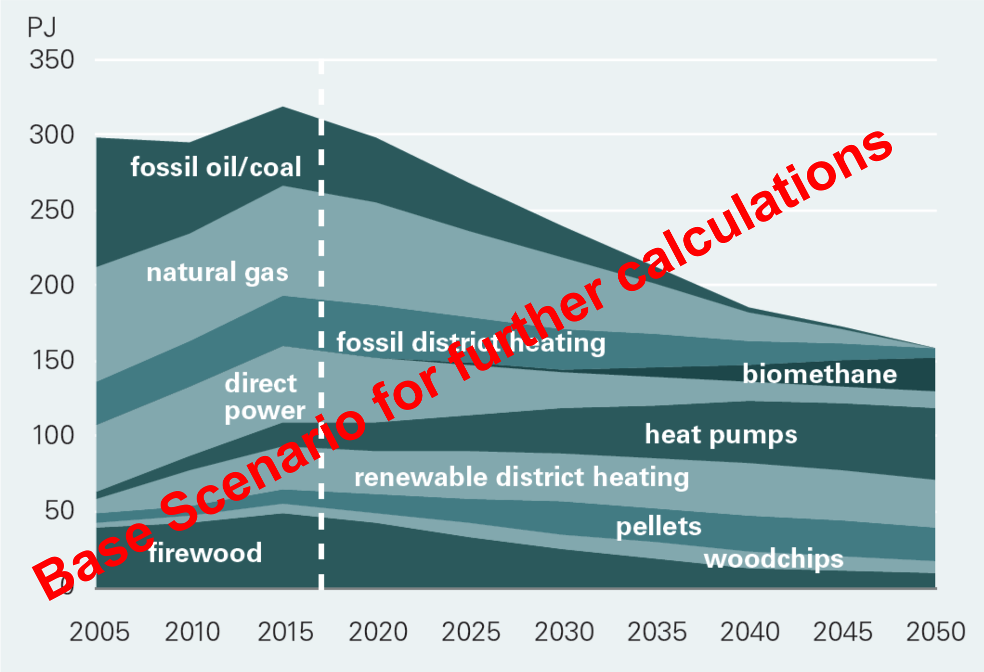
- Phase-out of oil and coal
- Reduction of gas and switch to renewable gas
- Reduction of direct electricity heating
- Sharp increase in heat pumps
- Increase in biomass (~20 → 30%)



Shares of heated living space in Austria

Renewable Heat Scenario for Austria
(Kranzl et al., 2018)

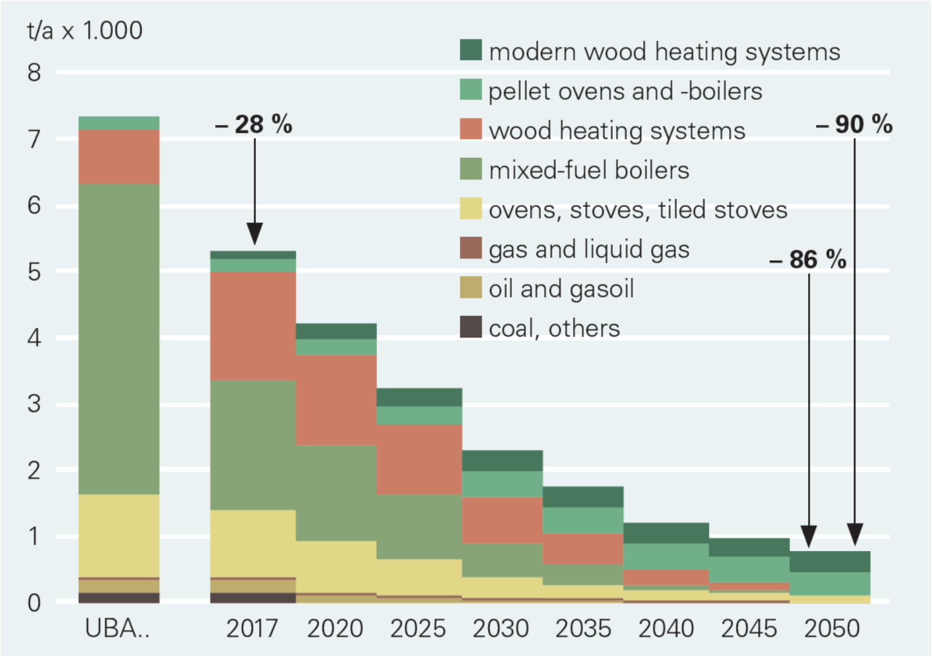
- Key: Energy efficiency of buildings (thermal renovation and new construction)
- Reduction in heating demand by almost 50%
- Higher relative share of heated area
- Higher numbers of installed systems
- But lower fuel consumption



absolute energy uses for space heating

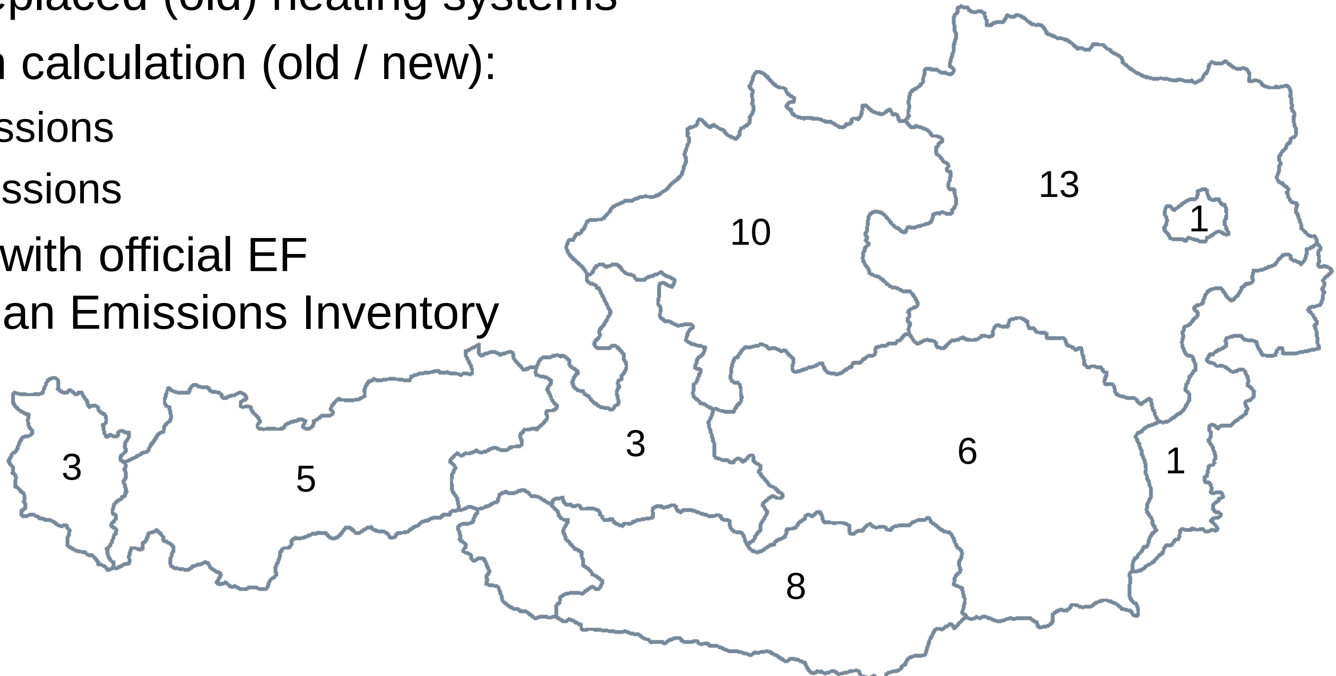
Development of fine dust emissions until 2050
(Schwarz and Strasser, 2019)

- Significant decrease in emissions from old technologies
- Reduction of 90% compared to official figures (UBA)
- Reduction of 86% compared to the corrected emissions inventory
- Main reasons:
  - Replacement of outdated systems with modern ones
  - Reduction of the HWB through thermal renovation / new construction

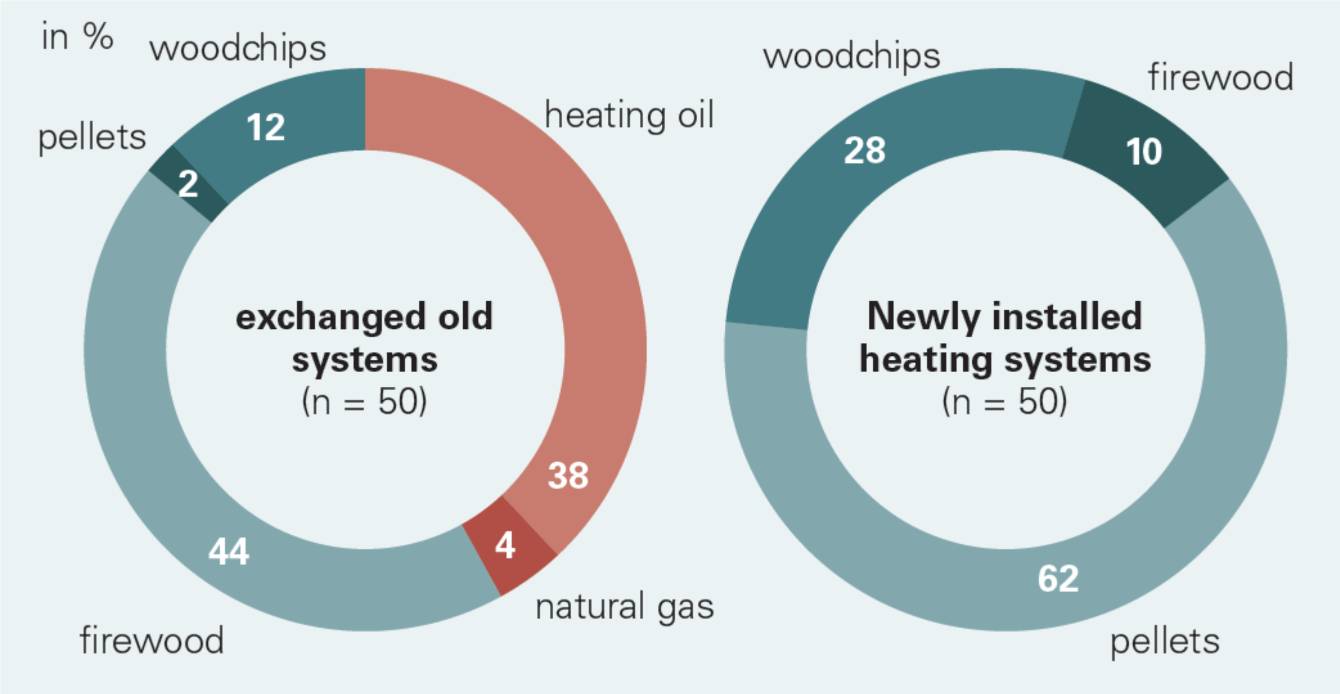


Case study: boiler replacement data from an Austrian boiler manufacturer

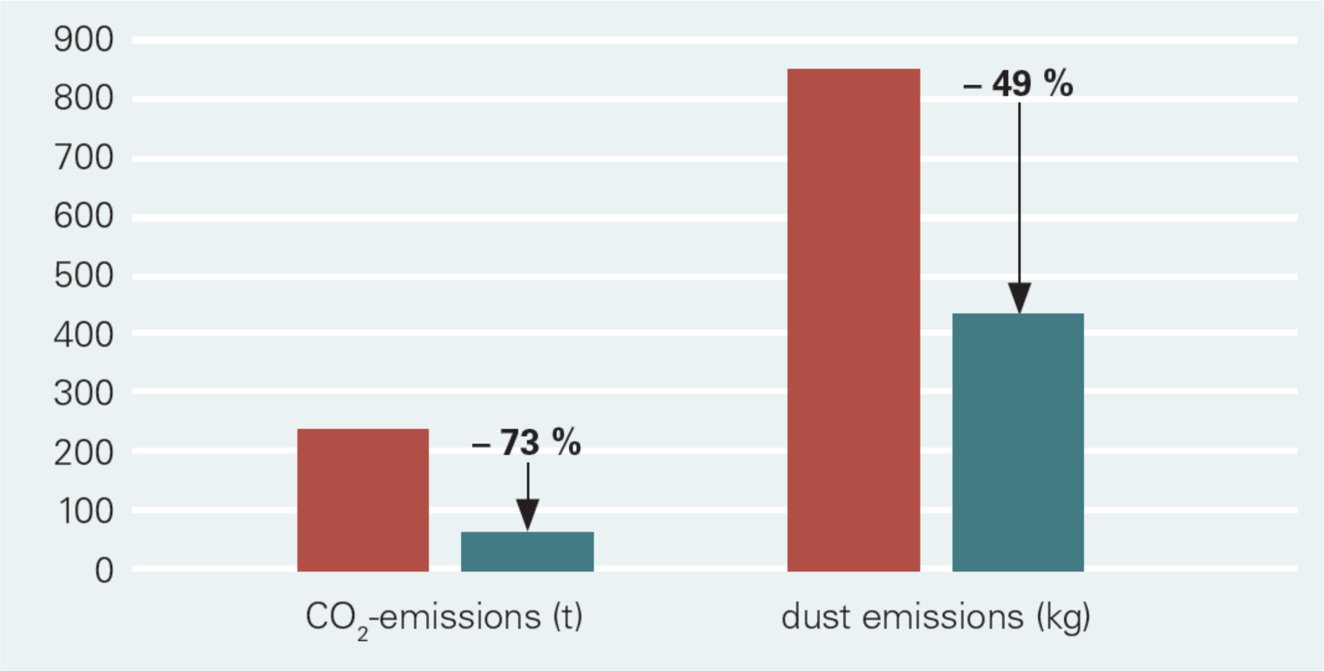
- 50 randomly selected newly installed wood heating systems
- Survey of replaced (old) heating systems
- Comparison calculation (old / new):
  - CO_2 emissions
  - Dust emissions
- Calculation with official EF
  of the Austrian Emissions Inventory



Fuel Shares of exchanged old and newly installed Systems



Effect of Boiler Change-out on CO_2 and Dust Emissions
(Emissions of fuel provision cains are included)



Summary and Conclusions

or „lessions learned“ from Austria

- Heat from **biomass plays a central role in the transformation** into a sustainable energy system
- Emissions from small-scale combustion systems are a **relevant source of particulate matter** emissions in Austria
- The current emissions inventory for Austria **overestimates the contribution**
- **Reduction of CO_2 AND dust emissions** can be achieved together
- In the future, **emissions will continue to decrease** significantly (80-90% till 2050).
- The keys to this are:
  - **Replacement of old heating devices** (boilers and stoves) with modern combustion systems
  - **Thermal renovation of buildings** (reduction of space heating requirements)

A short view to Spain…
(needs further elaboration if interesting)

2.1.5.1 Trend assessment

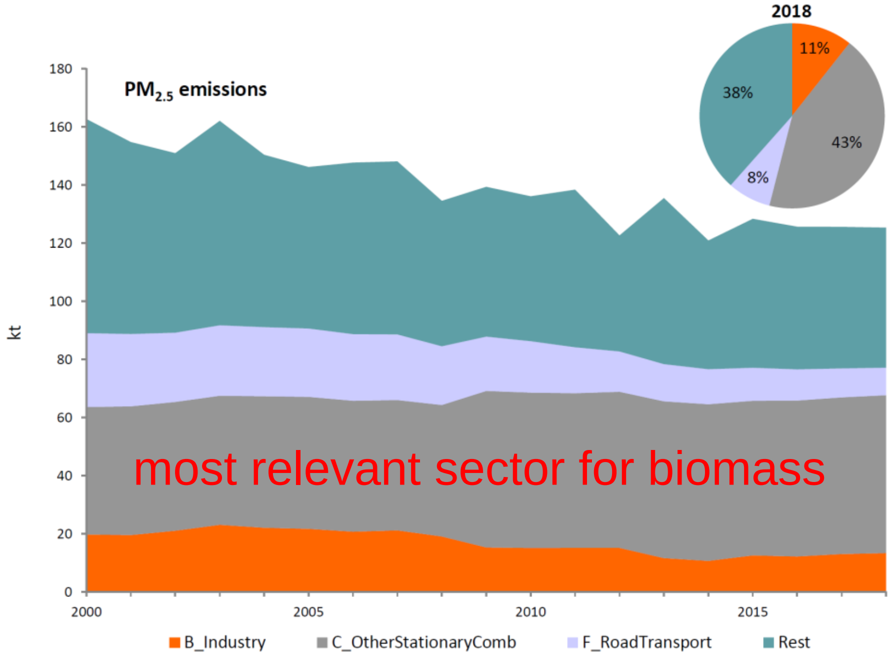
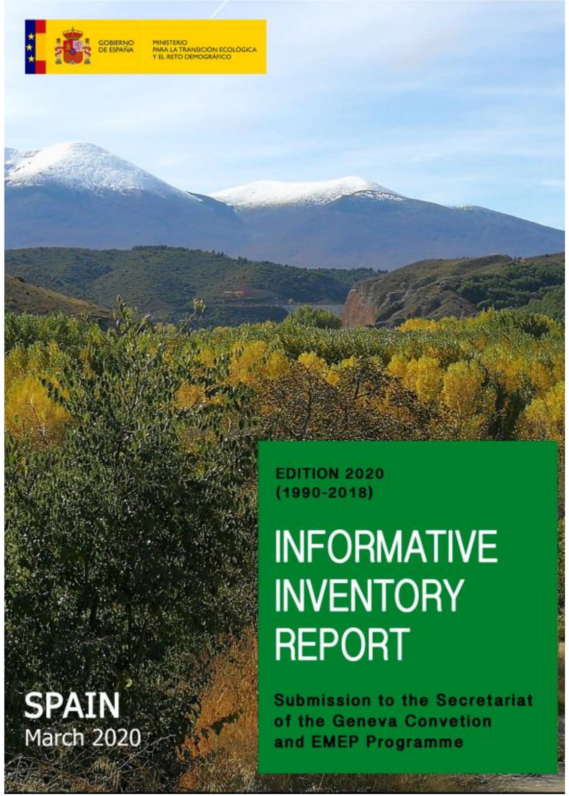


Figure 2.1.11 Evolution of $PM_{2.5}$ emissions by category and distribution in year 2018



https://www.ceip.at/status-of-reporting-and-review-results/2020-submissions

A short view to Spain…
(needs further elaboration if interesting)

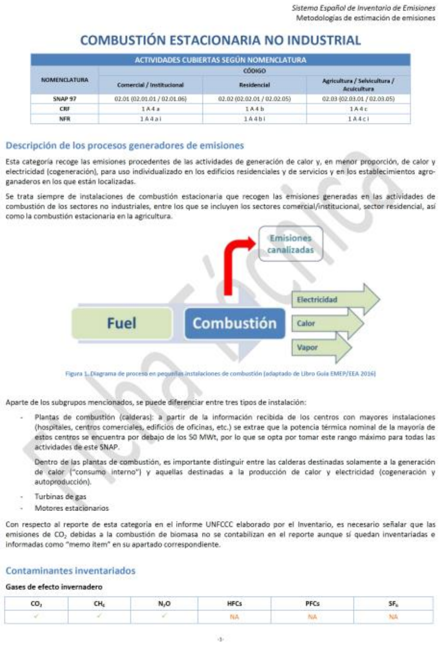
Some statements in the report:

- Small Stationary Combustion (C_OtherStationaryComb) was the largest contributing activity with 43.3% of total PM2.5 emissions, with Residential stationary combustion (1A4bi) accounting for 40.8% of the total.
- On the contrary, PM2.5 emissions coming from C_OtherStationaryComb have risen by 23.8% since 2000, despite the decrease in total fuels consumption (-1.3% since 2000), mainly due to the increase in biomass consumption (+27.5% since 2000) within the residential sector (1A4bi).

A short view to Spain…

(needs further elaboration if interesting)

- Emission factors for residential biomass combustion: 500-800 g/GJ
  - From EU Emission Inventory Guidebook 2019 (Tier 1 / 2)
- Comparison: Austria uses lower emission factors in the range of: 21 g/GJ (pellet boilers) – 164 g/GJ (stoves)
- **Question: available data for better EF (Tier 2/3?)**



Sistema Español de Inventario de Emisiones
Metodologías de estimación de emisiones

COMBUSTIÓN ESTACIONARIA NO INDUSTRIAL

ACTIVIDADES CUBIERTAS SEGÚN NOMENCLATURA			
NOMENCLATURA	CÓDIGO		
	Comercial / Institucional	Residencial	Agricultura / Selvicultura / Acuicultura
SNAP 97	02.01 (02.01.01 / 02.01.06)	02.02 (02.02.01 / 02.02.05)	02.03 (02.03.01 / 02.03.05)
CRF	1 A 4 a	1 A 4 b	1 A 4 c
NFR	1 A 4 a i	1 A 4 b i	1 A 4 c i

Descripción de los procesos generadores de emisiones

Esta categoría recoge las emisiones procedentes de las actividades de generación de calor y, en menor proporción, de calor y electricidad (cogeneración), para uso individualizado en los edificios residenciales y de servicios y en los establecimientos agro-ganaderos en los que están localizadas.

Se trata siempre de instalaciones de combustión estacionaria que recogen las emisiones generadas en las actividades de combustión de los sectores no industriales, entre los que se incluyen los sectores comercial/institucional, sector residencial, así como la combustión estacionaria en la agricultura.

Figura 1. Diagrama de proceso en pequeñas instalaciones de combustión (adaptado de Libro Guía EMEP/EEA 2016)

Aparte de los subgrupos mencionados, se puede diferenciar entre tres tipos de instalación:

- Plantas de combustión (calderas): a partir de la información recibida de los centros con mayores instalaciones (hospitales, centros comerciales, edificios de oficinas, etc.) se extrae que la potencia térmica nominal de la mayoría de estos centros se encuentra por debajo de los 50 MWt, por lo que se opta por tomar este rango máximo para todas las actividades de este SNAP.

  Dentro de las plantas de combustión, es importante distinguir entre las calderas destinadas solamente a la generación de calor ("consumo interno") y aquellas destinadas a la producción de calor y electricidad (cogeneración y autoproducción).
- Turbinas de gas
- Motores estacionarios

Con respecto al reporte de esta categoría en el informe UNFCCC elaborado por el Inventario, es necesario señalar que las emisiones de CO_2 debidas a la combustión de biomasa no se contabilizan en el reporte aunque sí quedan inventariadas e informadas como "memo item" en su apartado correspondiente.

Contaminantes inventariados

Gases de efecto invernadero

CO_2	CH_4	N_2O	HFCs	PFCs	SF_6
✓	✓	✓	NA	NA	NA

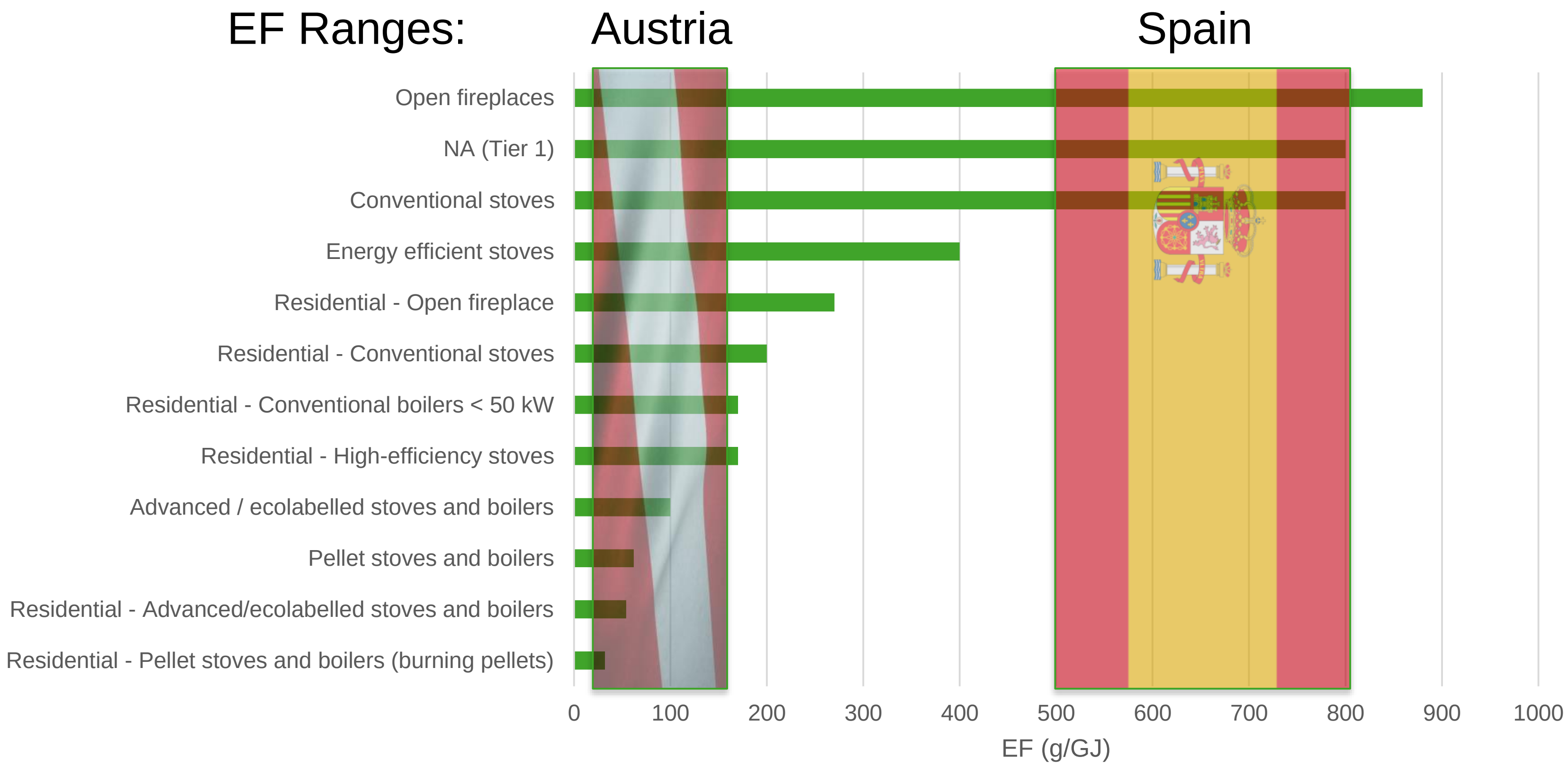
-3-

COMBUSTIBLE	METALES PESADOS									PARTÍCULAS			
	As (mg/GJ)	Cd (mg/GJ)	Cr (mg/GJ)	Cu (mg/GJ)	Hg (mg/GJ)	Ni (mg/GJ)	Pb (mg/GJ)	Se (mg/GJ)	Zn (mg/GJ)	$PM_{2,5}$ (g/GJ)	PM_{10} (g/GJ)	TSP (g/GJ)	BC (g/GJ)
Fuelóleo	0,002	0,001	0,2	0,13	0,12	0,005	0,012	0,002	0,42	1,9	1,9	1,9	0,1615
Gasóleo	0,002	0,001	0,2	0,13	0,12	0,005	0,012	0,002	0,42	1,5	1,5	1,5	0,0585
Gas natural	0,12	0,00025	0,00076	0,000076	0,1	0,00051	0,0015	0,011	0,0015	0,2	0,2	0,2	0,018
GLP	0,12	0,00025	0,00076	0,000076	0,1	0,00051	0,0015	0,011	0,0015	1,2	1,2	1,2	0,0648
Gas manufacturado	0,12	0,00025	0,00076	0,000076	0,1	0,00051	0,0015	0,011	0,0015	1,2	1,2	1,2	0,0648
Biomasa	0,19	13	23	6	0,56	2	27	0,5	512	470-740	480-760	500-800	74-75,2
Coque de petróleo	0,002	0,001	0,2	0,13	0,12	0,005	0,012	0,002	0,42	1,9	1,9	1,9	0,1615
Hulla y antracita	5	3	15	30	6	20	200	2	300	201	225	261	12,864
Hullas subbituminosas	5	3	15	30	6	20	200	2	300	201	225	261	12,864
Comb. patentado	5	3	15	30	6	20	200	2	300	201	225	261	12,864

Fuente: Libro Guía EMEP/EEA 2019, Capítulo 1A4, Tablas 3-4, 3-5, 3-6, 3-15, 3-16, 3-18, 3-43

Source: https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/sistema-espanol-de-inventario-sei-/02-combust-estacionaria-no-industrial_tcm30-430161.pdf

EF Comparison (from EMEP Guidebook):



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Additional Slides

Details on emission factors

Emission factors from the EU Emission Inventory Guidebook 2019

Table 3.6 Tier 1 emission factors for NFR source category 1.A.4.b, using biomass [4) 5)]

Tier 1 default emission factors					
	Code	Name			
NFR source category	1.A.4.b.i	Residential plants			
Fuel	Solid biomass				
Not applicable					
Not estimated					
Pollutant	**Value**	**Unit**	**95 % confidence interval**		**Reference**
			Lower	**Upper**	
NO_X	50	g/GJ	30	150	Pettersson et al. (2011)
CO	4000	g/GJ	1000	10000	Pettersson et al. (2011) and Goncalves et al. (2012)
NMVOC	600	g/GJ	20	3000	Pettersson et al. (2011)
SO_X	11	g/GJ	8	40	US EPA (1996b)
NH_3	70	g/GJ	35	140	Roe et al. (2004)
TSP (total particles)	800	g/GJ	400	1600	Alves et al. (2011) and Glasius et al. (2005) [1)]
PM_{10} (total particles)	760	g/GJ	380	1520	Alves et al. (2011) and Glasius et al. (2005) [1)]
$PM_{2.5}$ (total particles)	740	g/GJ	370	1480	Alves et al. (2011) and Glasius et al. (2005) [1)]
BC (based on total particles) [2)]	10	% of $PM_{2.5}$	2	20	Alves et al. (2011), Goncalves et al. (2011), Fernandes et al. (2011), Bølling et al. (2009), US EPA SPECIATE (2002), Rau (1989)

Emission factors from the EU Emission Inventory Guidebook 2019

Table 3.43 Tier 2 emission factors for source category 1.A.4.b.i, conventional boilers < 50 kW burning wood and similar wood waste [6)]

Tier 2 emission factors					
	Code	Name			
NFR source category	1.A.4.b.i	Residential plants			
Fuel	Wood and similar wood waste				
SNAP (if applicable)	020202	Residential plants, combustion plants < 50 MW (boilers)			
Technologies/Practices	Conventional boilers < 50 kWth				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable					
Not estimated					
Pollutant	**Value**	**Unit**	**95 % confidence interval**		**Reference**
			Lower	**Upper**	
NO_x	80	g/GJ	30	150	Pettersson et al. (2011)
CO	4000	g/GJ	500	10000	Johansson et al. (2003) [1)]
NMVOC	350	g/GJ	100	2000	Johansson et al. (2004) [2)]
SO_x	11	g/GJ	8	40	US EPA (2003)
NH_3	74	g/GJ	37	148	Roe et al. (2004)
TSP (total particles)	500	g/GJ	250	1000	Winther (2008) [3)] and Johansson et al. (2003) [4)]
PM10 (total particles)	480	g/GJ	240	960	Winther (2008) [3)] and Johansson et al. (2003) [4)]
PM2.5 (total particles)	470	g/GJ	235	940	Winther (2008) [3)] and Johansson et al. (2003) [4)]
BC (based on total particles)	16	% of PM2.5	5	30	Kupiainen & Klimont (2007) [5)]

EMEP/EEA 2019 guideline EFs

NFR	Sector	Table	Tier	Technology	Fuel	Pollutant	Value	Unit
1.A.4.b.i	Residential plants	Table_3-49_06	2	Residential - Pellet stoves and boilers (burning pellets)	Wood	TSP	32	g/GJ
1.A.4.b.i	Residential plants	Table_3-49_01	2	Residential - Open fireplace	Wood	TSP	270	g/GJ
1.A.4.b.i	Residential plants	Table_3-40	2	Conventional stoves	Wood and similar wood waste	TSP	800	g/GJ
1.A.4.b.i	Residential plants	Table_3-6	1	NA	Biomass	TSP	800	g/GJ
1.A.4.b.i	Residential plants	Table_3-41	2	Energy efficient stoves	Wood	TSP	400	g/GJ
1.A.4.b.i	Residential plants	Table_3-44	2	Pellet stoves and boilers	Wood	TSP	62	g/GJ
1.A.4.b.i	Residential plants	Table_3-39	2	Open fireplaces	Wood	TSP	880	g/GJ
1.A.4.b.i	Residential plants	Table_3-49_04	2	Residential - Advanced/ecolabelled stoves and boilers	Wood	TSP	54	g/GJ
1.A.4.b.i	Residential plants	Table_3-49_03	2	Residential - High-efficiency stoves	Wood	TSP	170	g/GJ
1.A.4.b.i	Residential plants	Table_3-49_02	2	Residential - Conventional stoves	Wood	TSP	200	g/GJ
1.A.4.b.i	Residential plants	Table_3-42	2	Advanced / ecolabelled stoves and boilers	Wood	TSP	100	g/GJ
1.A.4.b.i	Residential plants	Table_3-49_05	2	Residential - Conventional boilers < 50 kW	Wood	TSP	170	g/GJ

Official Austrian emission factors for residential biomass combustion

○ Holzöfen und Herde	164,4 kg/TJ
○ Grund- und Kachelöfen	111,1 kg/TJ
○ Wechselbrand Holzkessel	138,9 kg/TJ
○ Holzkessel im Naturzug	83,3 kg/TJ
○ Holzkessel mit Saugzuggebläse	55,6 kg/TJ
○ Hackgutkessel, konventionell	111,1 kg/TJ
○ Hackgutkessel, lambdageregelt	61,1 kg/TJ
○ Pelletofen	33,3 kg/TJ
○ Pelletkessel	21,1 kg/TJ

Der IEF für PM_{10} beträgt 94% davon, jener für $PM_{2.5}$ beträgt 90% des TSP.

EF for modern appliances (from recent research projects)

- moderner Ofen 45,9 kg/TJ
- moderner Scheitholzkessel 16,7 kg/TJ
- moderner Hackgutkessel 20,0 kg/TJ
- moderner Pelletkessel 15,1 kg/TJ

Analog zur Berechnung der OLI beträgt der IEF für PM_{10} 94% des TSP, jener für $PM_{2.5}$ beträgt 90%.