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NEW METHODOLOGY FOR CALCULATING THE EMISSION BALANCE FROM FUEL COMBUSTION IN HOUSEHOLDS

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Obsah

Introduction

The combustion of fuels in households for heating, hot water preparation, and cooking belongs to combustion sources with a nominal thermal power of up to 300 kW. These are so-called non-designated sources according to Act No. 201/2012 Coll. on air protection, which are monitored collectively for emission inventory based on statistical data. In the Emission and Stationary Source Register (REZZO), these sources are classified under the category REZZO 3 (CHMI, 2022). The methodology for emission inventory from these sources, based on the results of the Population and Housing Census (SLDB), has been developed by the Czech Hydrometeorological Institute (CHMI) since the 1990s and was used in its updated form until 2017 (Machálek et al., 2007). The revision of emission inventories according to Directive (EU) 2016/2284 of the European Parliament and of the Council in 2017 (TERT, 2017) and the results of the ENERGO 2015 statistical survey of Czech Statistical Office (CSO, 2017) led to requirements for a comprehensive change in the methodology for emission inventory from fuel combustion in households (Modlík et al., 2018). The main requirement was for data completeness and the standardization of fuel data used for reporting according to the parameters of the Convention on Long-range Transboundary Air Pollution (CLRTAP) and the United Nations Framework Convention on Climate Change (UNFCCC). The methodology was based on the original schema modified according to the results of the ENERGO 2015 survey, which detailed the fuel consumption and combustion device structure in Czech households for the first time. The updated methodology included national emission factors determined at the rated thermal output of boilers. Only in rare cases were national emission factors determined at reduced thermal output applied in air quality modelling.

In the new methodology compiled in 2023, computational procedures largely inherited from the previous methodology completed in 2018 (Modlík et al., 2018) were utilized. Significant changes were made to some key parameters affecting the overall emission calculation. These changes primarily included alterations in the representation of various boiler types over time since 1990, partially influencing the assumption of the future boiler composition until 2025 and the following years. These adjustments, as well as the newly established share of dried wood, were made based on the evaluation of data from the new ENERGO 2021 survey (CSO, 2022).

Another methodological change is related to comments from the Emission Inventory Preparation and Review Team (CEIP, 2022), which conducts checks on reported data. At their request, changes were made to the emission factors used. Unlike previous years, where emission factors determined at the rated thermal output of boilers and heaters were used, combined emission factors representing operation at reduced output are now utilized. Emission factors determined at the rated thermal output are attributed only to those devices where it is assumed that the combustion source is operated with an appropriate accumulator tank. The representation of boilers with accumulator tanks was determined based on the evaluation of data from Technical Condition and Operation Control Reports (KTSP forms). A comparison of both sets of emission factors in terms of the ratio of new combined emission factors to previous emission factors for rated output is in Annex A.

Methodology for the inventory of emissions from fuel combustion in households

The scheme of the national methodology for calculating emissions is in Figure 1. The basic variable data for the annual emissions calculation are fuel consumption quality parameters, representation of individual types of boilers, and the share of boilers operated with storage tanks. Permanent data mainly consist of a set of emission factors (CHMI, 2023).

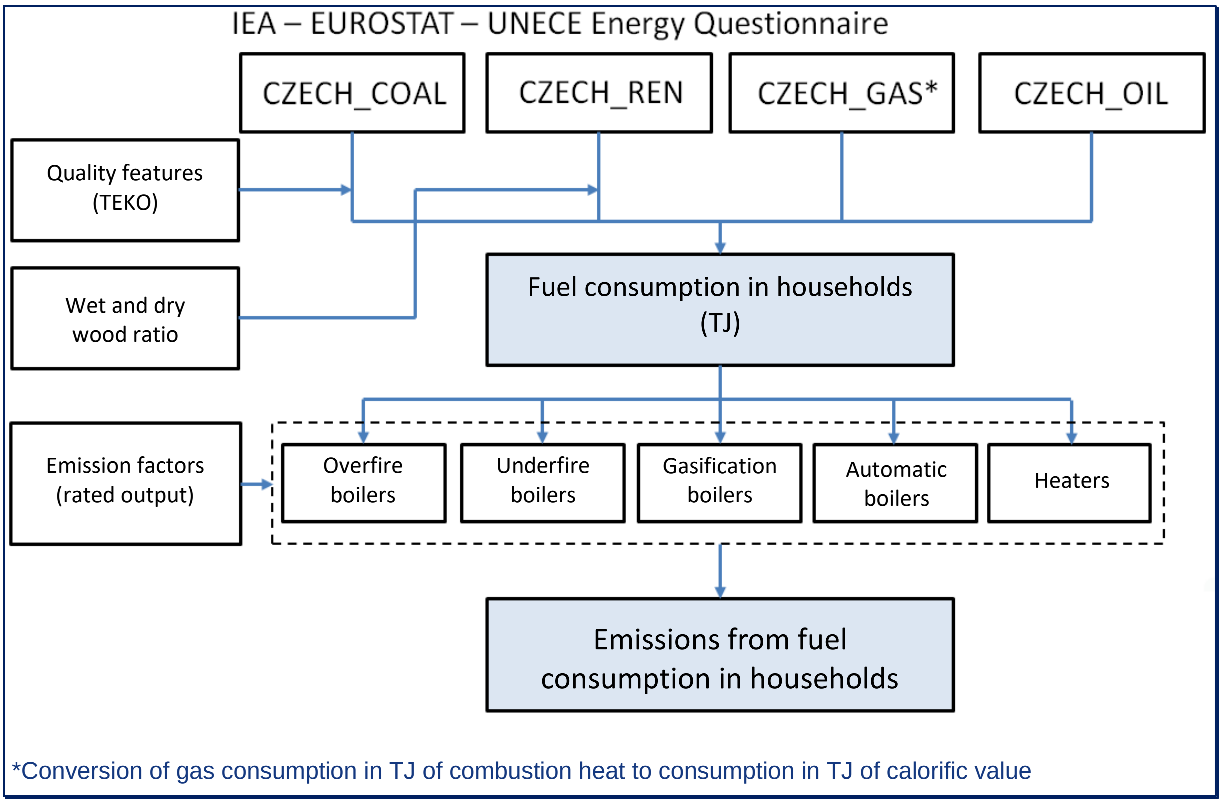

Figure 1: Calculation scheme of emissions from fuel combustion in households

Fuel consumption in Czech households

Fuel consumption in households at the level of the entire Czech Republic is determined by the Czech Statistical Office (CSO), which processes the data in the format of international IEA - EUROSTAT - UNECE questionnaires. The consumption of individual types of coal fuels for emission inventories comes from the CZECH_COAL questionnaire in natural units. The conversion of coal fuel consumption into energy units for emission inventory is carried out annually with the calorific value adjusted according to a specific investigation provided by TEKO (Tyle, 2022). The CZECH_REN questionnaire in energy units, according to statistical surveys of the Ministry of Industry and Trade (MIT), provides the consumption of bio-briquettes and pellets is singled out (Bufka et al., 2022). The calorific value of 45.9 $MJ \cdot kg^{-1}$ is used to calculate the consumption of propane-butane listed in the CZECH_OIL questionnaire. The data on the consumption of gaseous fuels from the CZECH_GAS questionnaire in energy units of combustion heat is converted to energy units determined from the calorific value for the emission inventory.

The development of fuel consumption in households (Figure 2) shows a not very favourable trend, a permanent increase in the total consumption of solid fuels since 2000. A change in the trend can only be expected in connection with the development of heat pump installations.

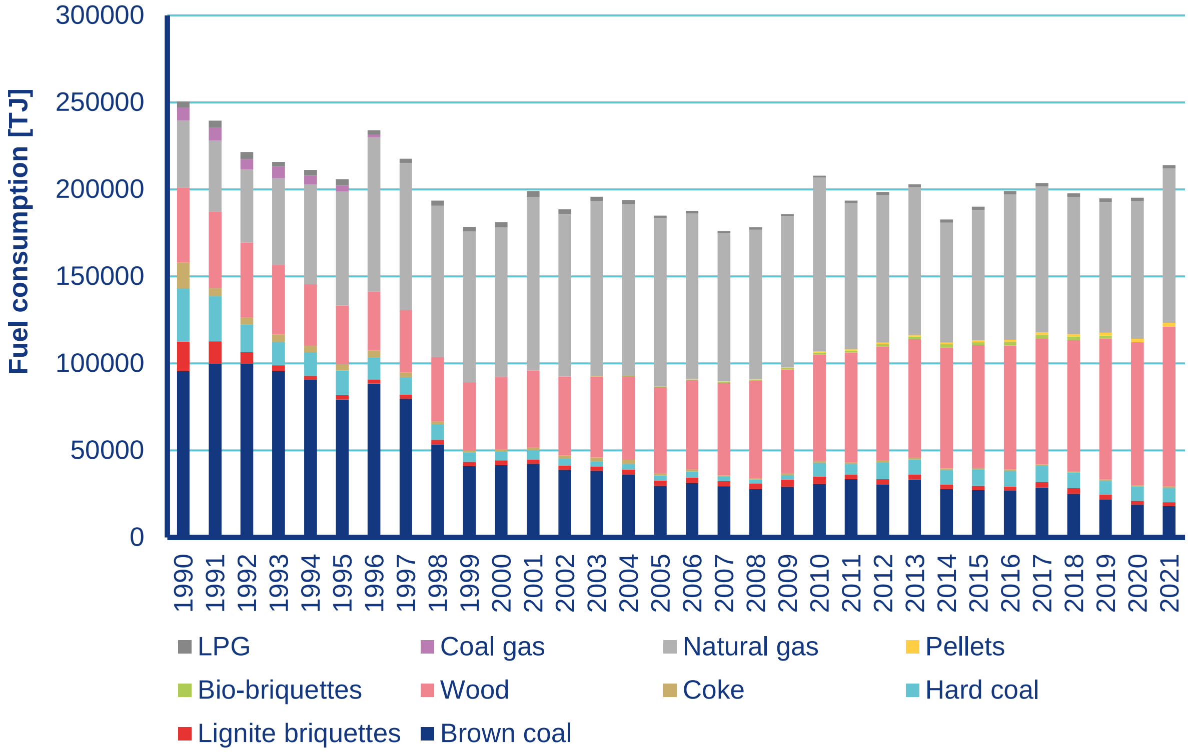

Figure 2: Fuel consumption, 1990–2021

Composition of boilers and proportion of heaters

Processing of the complete outputs of ENERGO 2021 was ensured by MPO, Department of Analysis and Data Support of Concepts at the turn of 2022 and 2023 (Modlík, 2024). The distribution of total fuel consumption according to the type of combustion equipment was carried out for the entire monitored period from 1990 and the projection using the detailed outputs of the ENERGO 2021 survey, as well as the determination of the proportion of stored wood. One of the most important outputs of the processing of ENERGO 2021 and other related documents incl. previous ENERGO 2015 was a retrospective determination of the share of individual types of boilers and the share of heaters for all types of monitored fuels in the entire time series since 1990. The new distribution of total fuel consumption by type of combustion equipment for the year 2021 and comparison with similar shares determined by the original methodology according to ENERGO outputs 2015 shows Table 1.

Table 1: Shares of fuel consumption by type of combustion equipment, ENERGO 2021 and ENERGO 2015

Type of fuel		Combustion device type [%]									
Fuel group	Fuel	Overfire boilers		Underfire boilers		Automatic boilers		Gasification boilers		Heaters	
		ENERGO 2021	ENERGO 2015	ENERGO 2021	ENERGO 2015	ENERGO 2021	ENERGO 2015	ENERGO 2021	ENERGO 2015	ENERGO 2021	ENERGO 2015
Coal	Brown coal	6.0	28.1	45.4	42.1	35.6	18.2	9.2	6.4	3.8	5.2
	Briquettes	35.3	56.0	36.9	25.9	5.7	2.9	12.0	3.1	10.1	12.2

	Hard coal	23.0	60.4	35.2	19.1	31.1	11.9	8.2	4.1	2.5	4.6
	Coke	76.7	88.1	8.3	10.1	12.6	0.4	0.0	0.0	2.3	1.4
Biomass	**Wood-dry**	31.7	35.5	13.3	22.0	3.1	2.0	19.9	13.0	32.0	27.6
	Wood-wet	27.5	36.2	13.0	17.9	7.6	1.4	7.6	8.9	44.2	35.6
	Bio-briquettes	23.8	20.1	9.5	11.9	2.8	2.8	11.0	7.8	53.0	57.4
	Pellets	5.8	0.8	0.5	0.9	40.0	41.3	3.5	0.0	50.3	57.0

The approach to dividing consumed wood according to the length of its storage was also re-evaluated. The Wood-wet category included wood that households do not store or dry for less than 6 months. Other wood is included in the category Wood-dry. Based on the evaluated information and expert assessment, the proportion of the Wood - wet category of the ENERGO 2021 outputs was set at 8% and for the Wood-dry category at 92%. For the older period (up to 2016), the share of Wood-moist was set at 15%.

A new parameter used to determine the value of the combined emission factor is the representation of combustion sources operated in reduced power mode (Table 2). The representation of combustion sources operated without storage vessels (or with an inadequate storage vessel) was determined for the entire time series from 1990 mainly using the outputs of KTSP according to Annex No. 18 to Decree No. 415/2012 Coll. From 2020, these data are reported through the Integrated System for the Fulfilment of Reporting Obligations (ISPOP).

Table 2: Proportion of resources operating at reduced and nominal power for 2021

Combustion Test Mode	**Reduced Output**	**Rated Output**
Type of Combustion Device	**[%]**	
Overfire boilers	90.0	10.0
Underfire boilers	90.0	10.0
Automatic boilers	86.5	13.5
Gasification boilers	45.5	54.5
Heaters	89.5	10.5

The development of the representation of basic types of gas boilers is shown in Table 3.

Table 3: Share of gas boilers by type

Type of device for burning gaseous fuels	**2015**	**2021**
Conventional boilers	85%	57%
Condensing boilers	15%	43%

Emission factors

The emission factors for the combustion of solid fuels, also used by the previous methodology, were derived from the results of VEC VŠB measurements (Hopan et al., 2014) at nominal and reduced heat output for the majority of monitored pollutants. Their values were determined for burn-through boilers, burn-off boilers, gasification boilers and automatic boilers. For the heater category, the same values of emission factors as for combustion boilers were used concerning the similar combustion principle. The emission factors of pollutants that were not measured and the emission factors for other types of fuel were taken from the Air Pollutant Emission Inventory Guidebook (EEA 2016) and the Journal of the MoE (MoE 2013). An overview of emission factors for the inventory of household sector emissions is available on the website of the emission balance (CHMI, 2024).

Model of emissions inventory and projection of emissions from fuel consumption in households

The model of nationwide emission inventory and emission projections from household fuel consumption is currently being processed in spreadsheet calculation (MS Excel). The breakdown of types of combustion sources and types of fuels used for emission inventory calculations is also used in this model for emission projections. The computational matrix includes all types of combustion devices listed in Table 1 and Table 3, intended for burning solid or gaseous fuels. Solid fuels are further divided into coal fuels, i.e., brown, and hard sorted coal, briquettes (including pellets), and coke, and biomass represented by wood biomass (stored-dry and unstored-wet), wood pellets, and bio-briquettes. Liquid fuels are not included in the national emission inventory because they represent a minority representation and are therefore not monitored by the household energy balance of the Czech Statistical Office. Gaseous fuels include the combustion of propane-butane and natural gas. From the perspective of used devices, natural gas boilers are divided into conventional and condensing ones. Their ratio is based on long-term sales monitoring and research by ENERGO. The matrix of used types of boilers and solid fuels currently includes all combinations between the specified fuels, four types of boilers, and one general category of heaters representing all types of stoves, fireplaces, heaters and other manually stoked combustion sources (Table 1). With the use of stove sales statistics, expansion of the matrix to detailed types of heaters is planned, such as hearth stoves, fireplaces, fireplace inserts, cook-stoves, etc.

The computational scheme for emissions inventory since 1990 and projections until 2030 (and beyond) is based on three variable parameters. The first relates to the development of the number of combustion sources according to the types of fuels used, into which in recent years, the transition to non-emission heating methods, primarily the use of heat pumps, has also been reflected. The second variable parameter includes annual changes in the number of boilers and heaters following sales statistics, which are reflected in their representation (Table 1) in the projection model, the replacement of boilers with heaters and vice versa is not yet considered. The third variable parameter regards the development of the representation of emission factors for reduced and rated output, derived from the assumption of the development of the number of boilers and heaters with an accumulator tank. Therefore, the third parameter significantly influences the historical development of emissions as well as their projection. All three of these parameters were retrospectively calculated for the year 1990 and updated for emission inventories in the time series until 2021 and for projections until 2050. The basic setting for the year 2021 is shown in Table 2 above. The development of the percentage representation in the years 1990–2030 is shown in Table 4. The last row shows the assumption of the change in the representation of older types of heaters by 2025 and 2030, based on sales statistics of new heaters meeting the requirements of the Eco-design.

Table 4: Development of the share of boilers operated at reduced heat output by type of combustion device and the share of heaters not compliant with Eco-design requirements in the period 1990–2020 and assumptions for development until 2030

Parameters of individual types of boilers and heaters for calculations		1990	2000	2005	2020	2025	2030
Share of reduced output for boilers and heaters [%]	Overfire	98	98	97	95	0	0
	Underfire	98	98	97	95	8	3
	Automatic	100	90	90	87	85	82
	Gasification	100	86	73	48	36	23
	Heaters	100	100	96	90	87.5	85
Share of heaters without Eco-design		100	100	100	100	80	60

The outputs of emission inventories from household fuel consumption are reported according to international requirements in sector 1A4bi Household: Heating, water heating, cooking. The share of this sector in total emissions of some pollutants is shown in Annex C.

Model of territorial distribution of fuel consumption for heating apartments

The methodology for determining fuel consumption at the level of basic territorial units is based the average annual heat consumption and the specific type of fuel for the average apartment. The most of the fuel consumption comes from the Household Energy Consumption Survey, which derived data on heating methods, types of fuel or energy for both primary and secondary heating methods, and the size of apartment floor areas. It was possible to use a completely new data set from 2021 onwards since the outputs used in 2021 (Czech Statistical Office, 2023) were based on the ENERGO 2021 statistical survey (Modlík, 2024). The new data set includes the territorial distribution of fuel consumption, including updated numbers of apartments, the distribution of apartments in single-family and multi-family houses, fuel shares for combinations of primary and secondary heating methods for apartments, and other parameters. The inputs used for the new computational model and a detailed description of its processing were published by the MIT in Modlík (2024).

The updating of key parameters of the model for subsequent periods will be carried out using sales statistics of boilers and heaters, information on boiler replacements based on subsidy evaluations, and updates to technical parameters (fuel calorific values, etc.). Annual updates to the number of newly completed apartments and their heating methods can be processed based on the numbers of new apartments and their heating methods, as determined from statistics on newly completed apartments, possibly also using data from fuel and energy distributors. Year-on-year changes in total fuel consumption will be calculated based on the nature of the heating season, which is annually expressed by the number of heating degree-days determined for each municipality with the region and altitude.

Comparison of the emission balance from fuel combustion in households according to ENERGO 2015 and ENERGO 2021

Total emissions of pollutants calculated using the new methodology utilizing combined emission factors are generally higher compared to the original methodology according to ENERGO 2015 and emission factors for combustion operation at rated output, with minor exceptions. A comparison of both sets of emission factors in terms of the ratio of new combined emission factors to previous mission factors for rated output is provided in Annex A. The highest differences are observed in emissions of PM, CO, and NMVOC (Annex B). The increase in particulate matter emissions is also reflected in higher emissions of heavy metals and POPs, for example, benzo[a]pyrene (BaP) emissions. Conversely, a slight decrease occurred due to lower combustion temperatures during reduced output for NO_X emissions.

The current model strongly considers the effect of gradually phasing out both types of manual stoker grate boilers and the increase in the share of environmentally friendly boilers (gasification and automatic fuel dosing boilers), typically operated with an accumulator tank. Additionally, favourable emission trends post - 2015 are also attributed to changes in the share of stored wood biomass.

Projection of emissions following the new emission balance of fuel combustion in households

The adjustments mentioned above to the methodology of calculating emissions from household fuel combustion also impact the results of emission projections up to the year 2030 and beyond. The most significant influence on the projections is the replacement of the boiler stock, which occurs in Czech households not only because of natural turnover but primarily as a consequence of the legally mandated cessation of operation of non-eco-friendly boilers (Act No. 201/2012 Coll., § 17). The projection includes the requirement that, as of September 1, 2024, only boilers meeting the conditions specified in Annex No. 11 of the Clean Air Act may be operated. Another important factor influencing the projected emission values is the assumption regarding the evolution of fuel consumption, particularly the reduction and gradual cessation of coal consumption, the increase in the share of biomass, and the adoption of non-emission heating methods. The results of the emission projection are provided in Annex D.

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List of Figures and Tables

Annex A – D

Annex A

Comparison of emission factors of the new and previous methodology

The comparison is presented in the form of the value of the share of the new combined EF and the previous EF for the rated power.

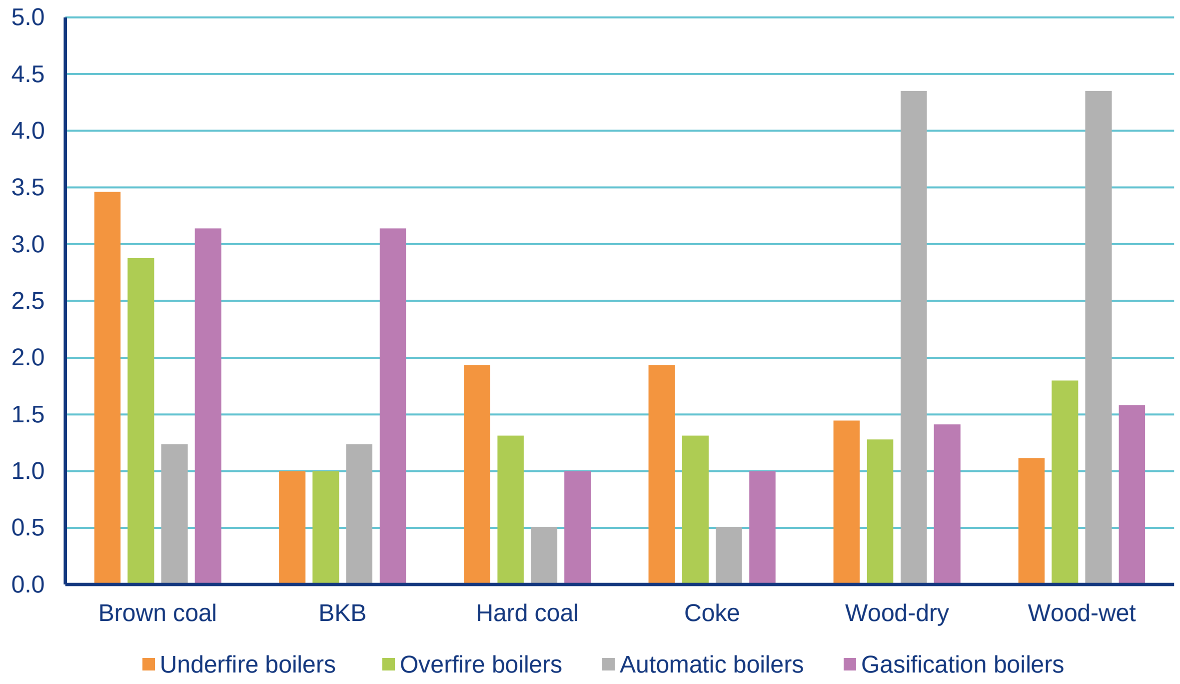

Figure A1: EF change index for CO

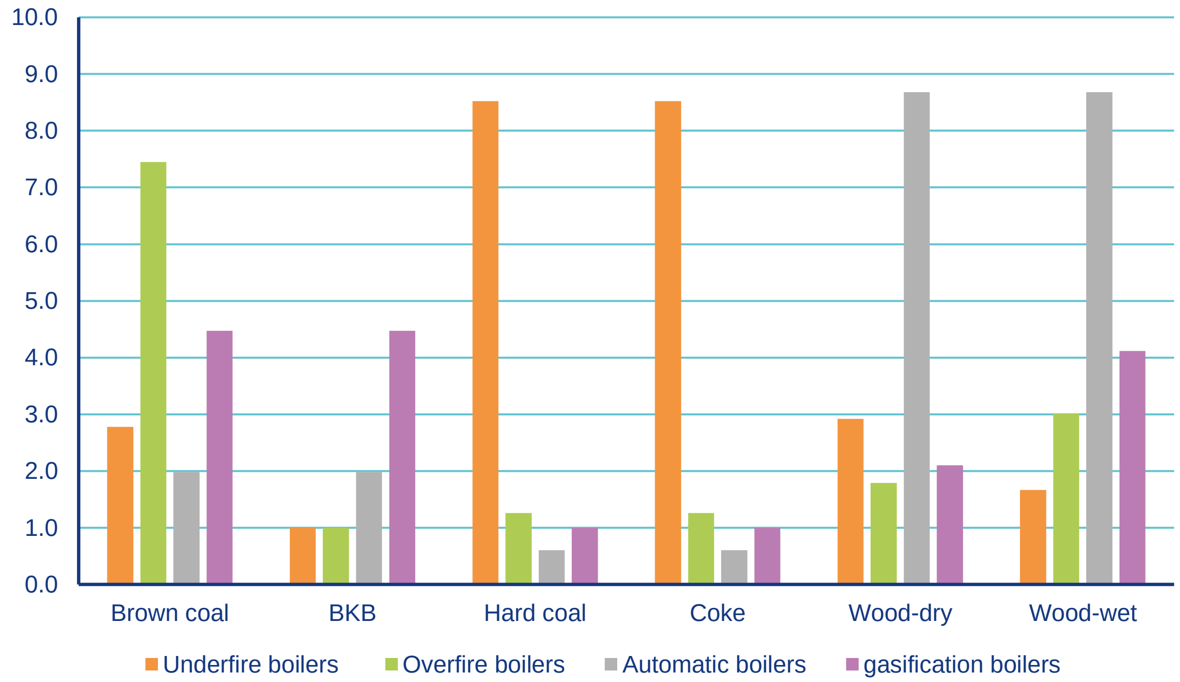

Figure A2: EF change index for NMVOC

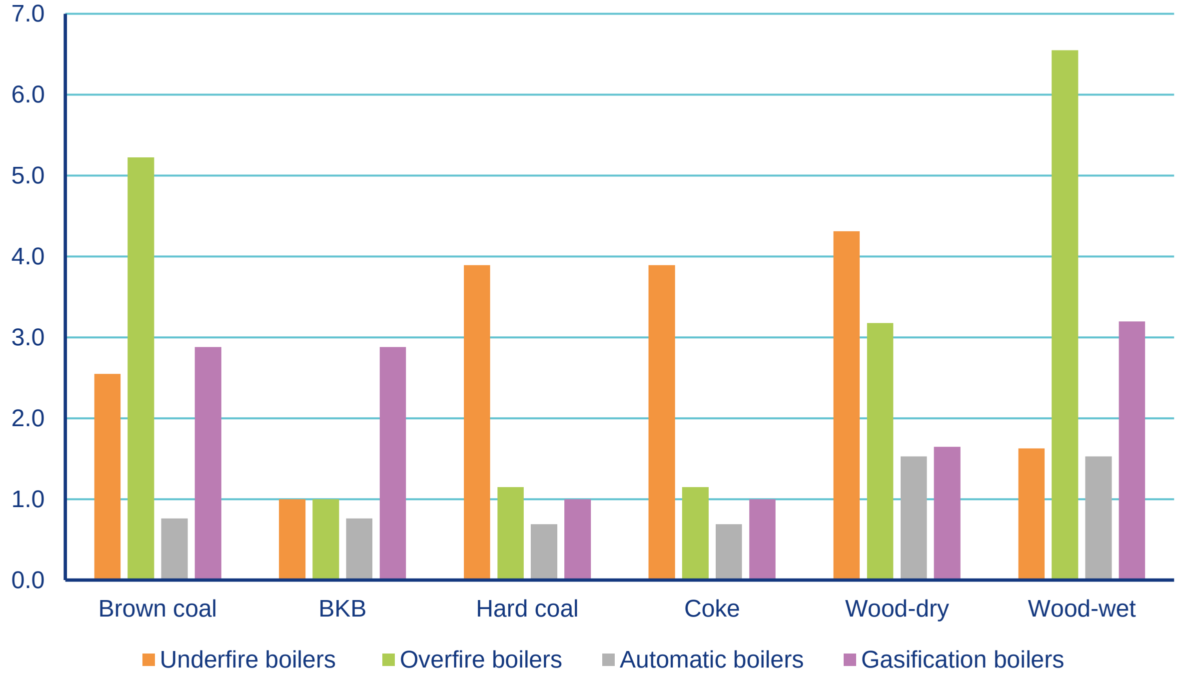

Figure A3: EF change index for TZL

Annex B

Comparison of the evolution of emissions of the 1A4bi sector according to the new and previous methodology

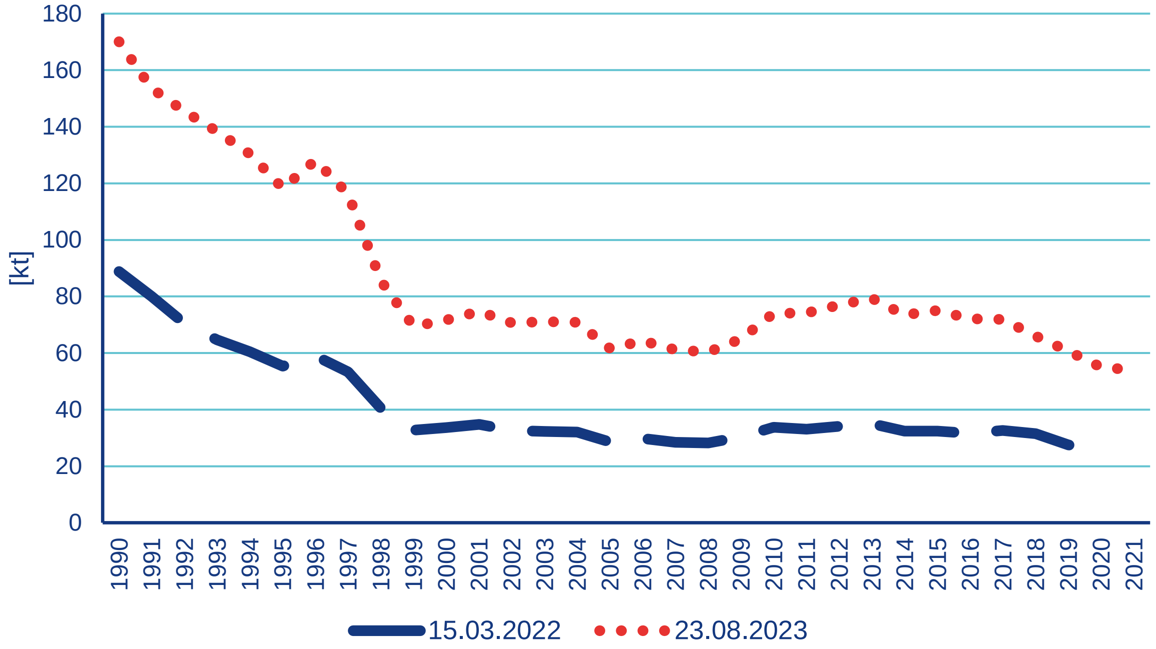

Figure B1: Comparison of the values of announced emissions of TZL sector 1A4bi 15/03/2022 and 23/08/2023, 1990–2021

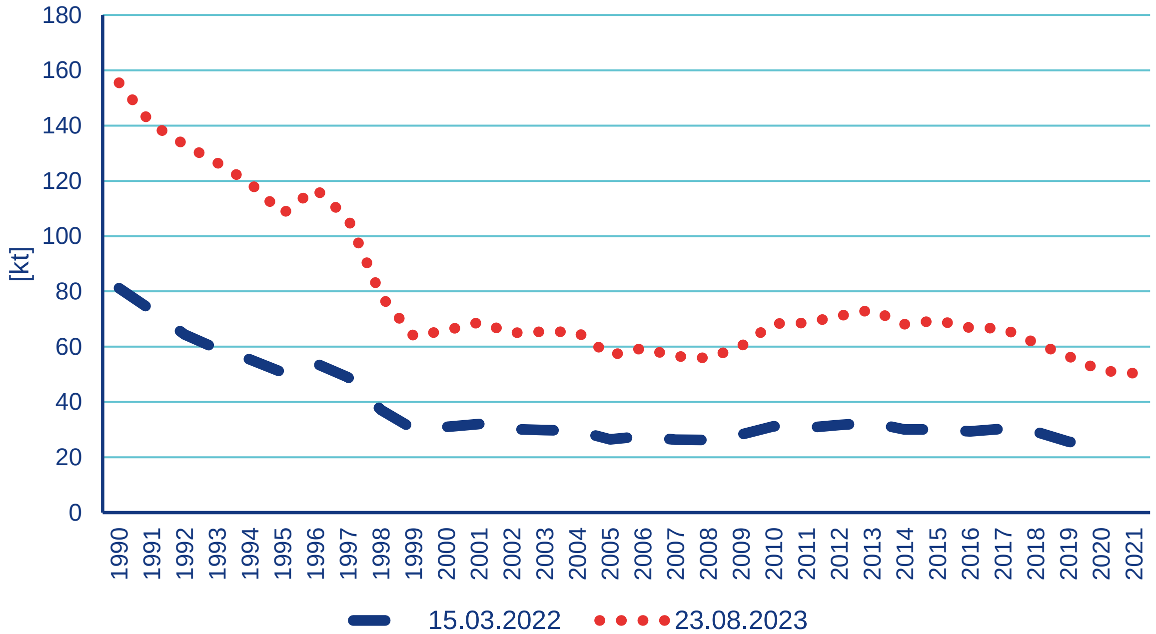

Figure B2: Comparison of reported PM10 emission values of sector 1A4bi 15/03/2022 and 23/08/2023, 1990–2021

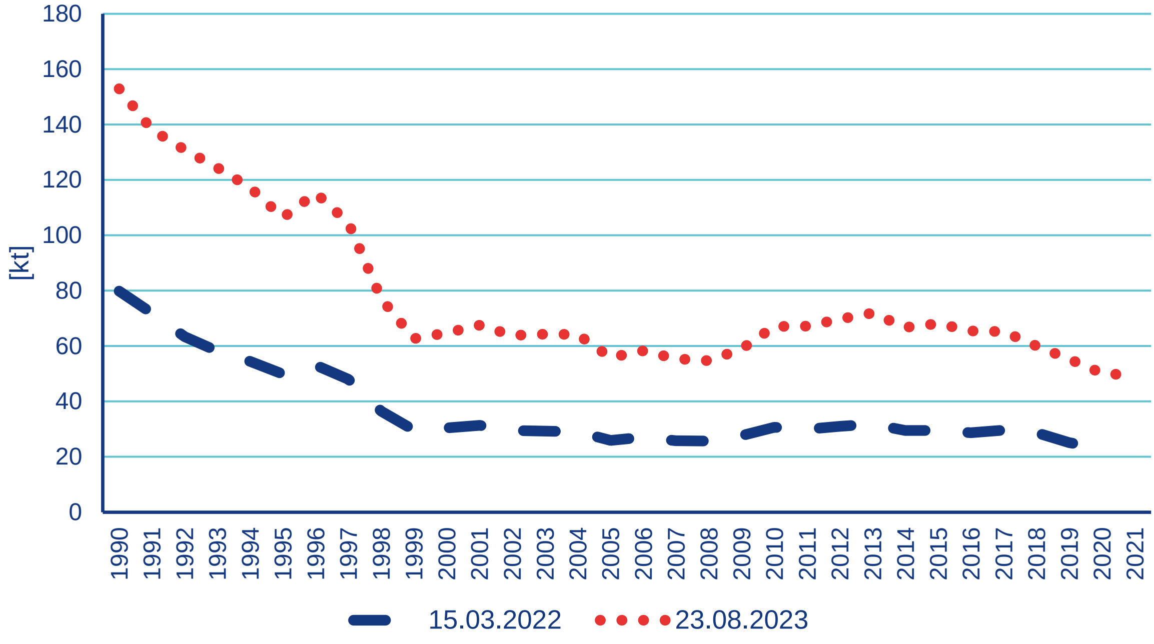

Figure B3: Comparison of reported PM2.5 emission values of sector 1A4bi 15/03/2022 and 23/08/2023, 1990–2021

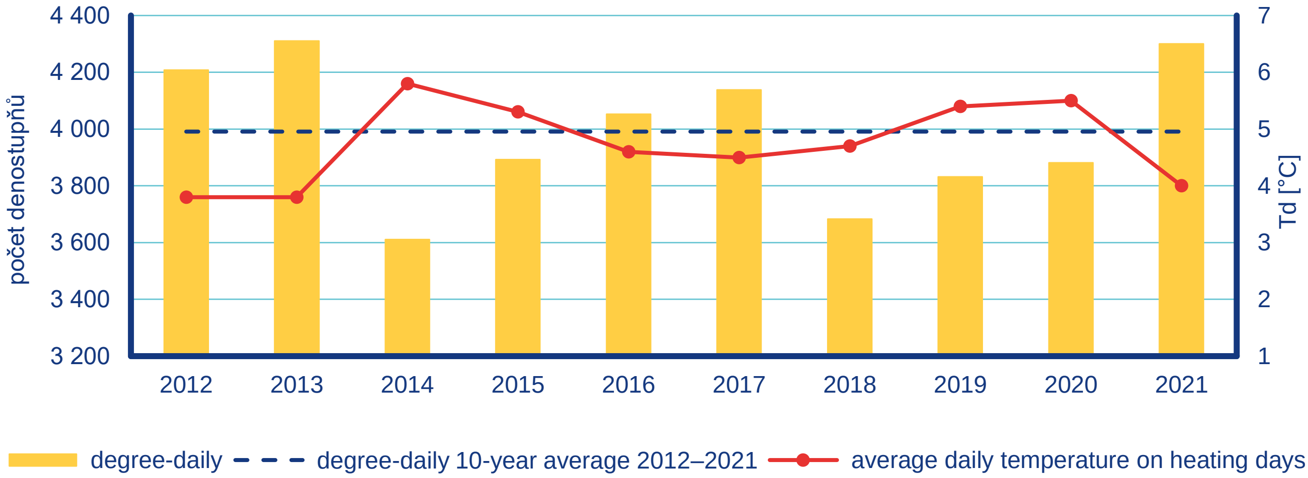

Figure B4: Number of degree-days and average daily temperature *on heating days, 2012–2021*

Annex C

Share of the 1A4bi sector in total emissions in the years 1990 - 2021

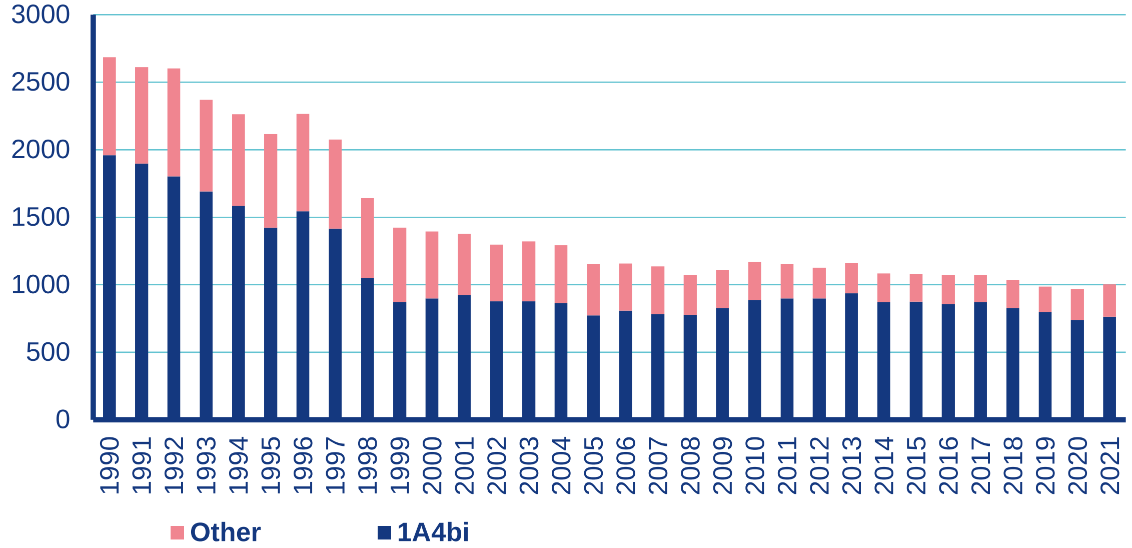

Figure C1: Development of CO emissions of the 1A4bi sector, 1990–2021

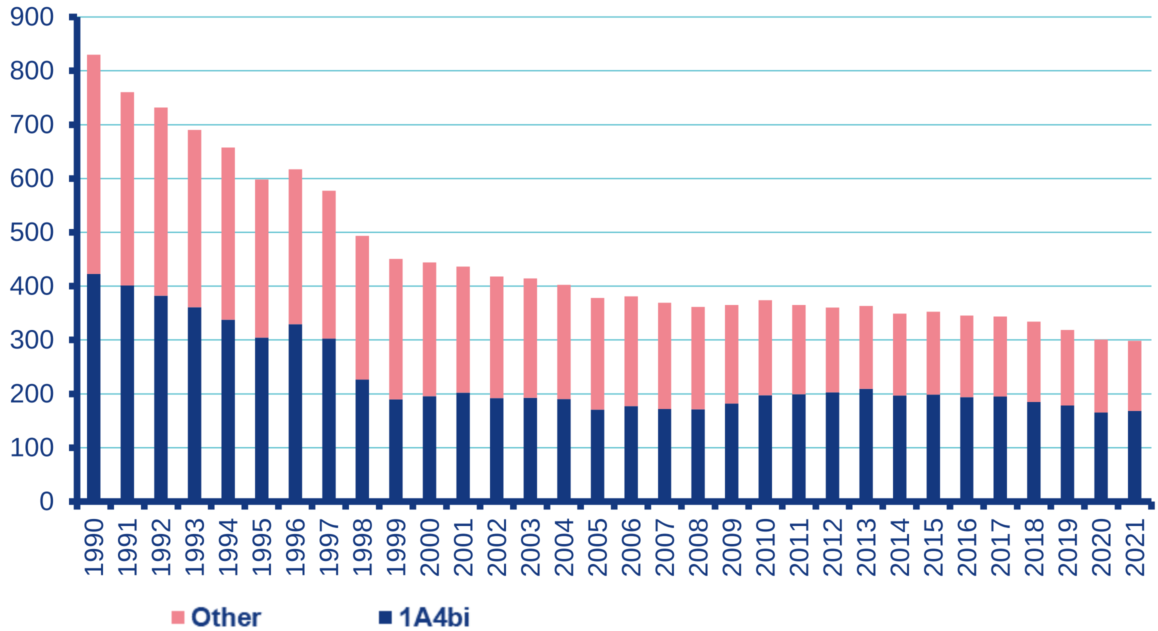

Figure C2: Development of NMVOC emissions of sector 1A4bi, 1990–2021

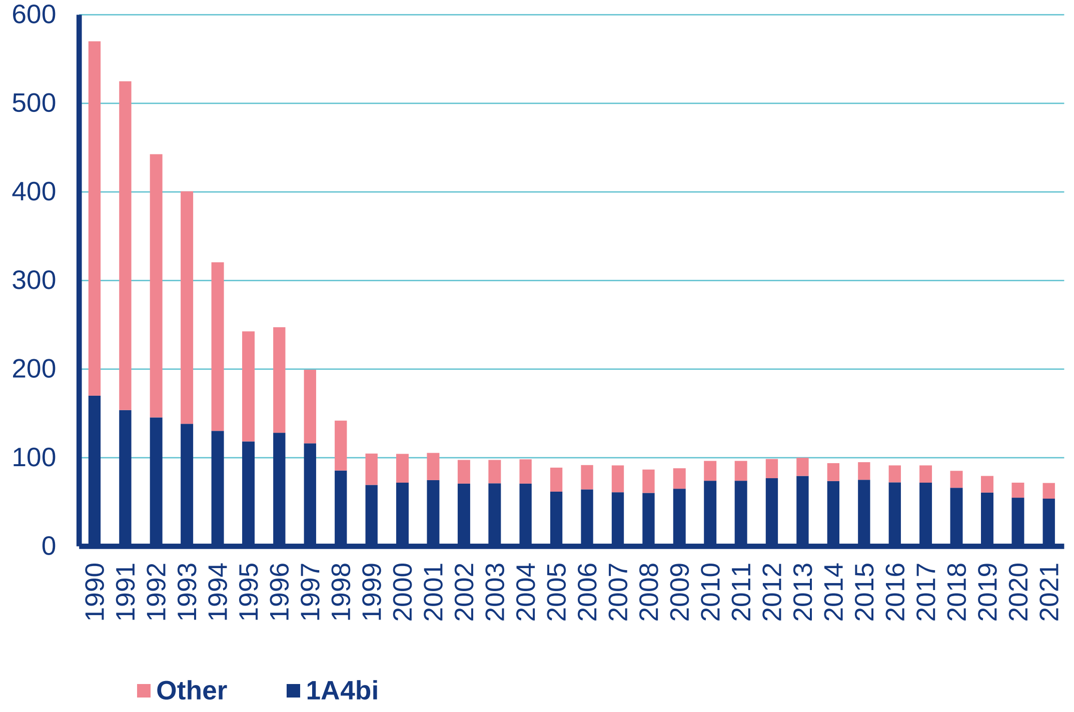

Figure C3: Development of TZL emissions of sector 1A4bi, 1990–2021

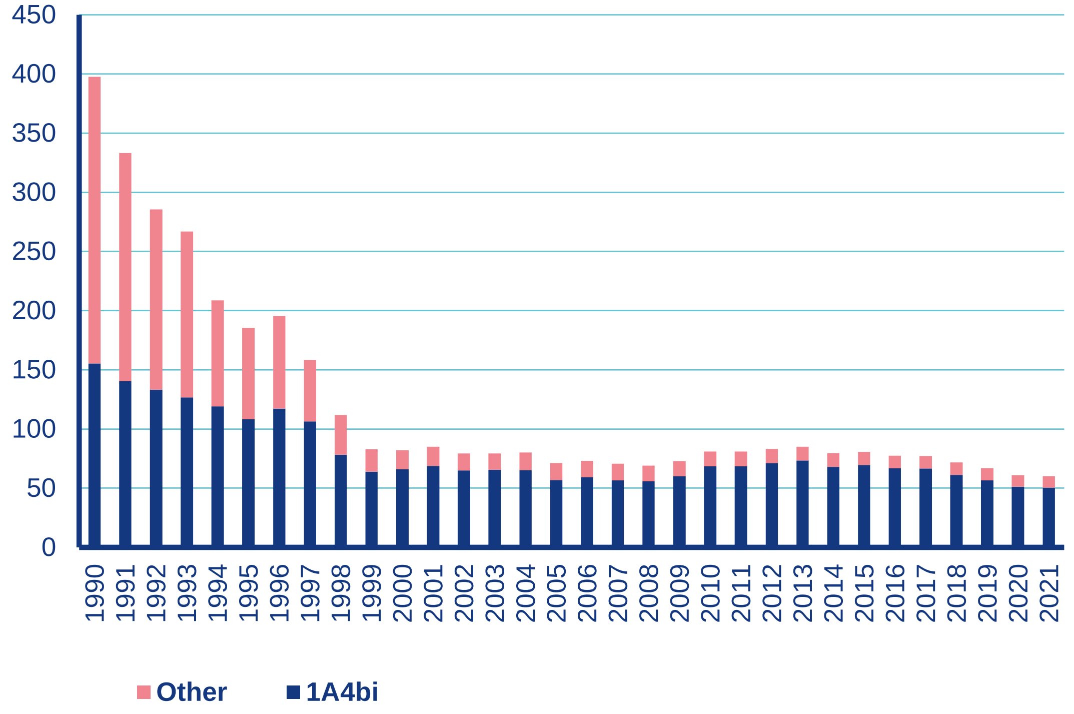

Figure C4: Development of PM10 emissions of sector 1A4bi, 1990–2021

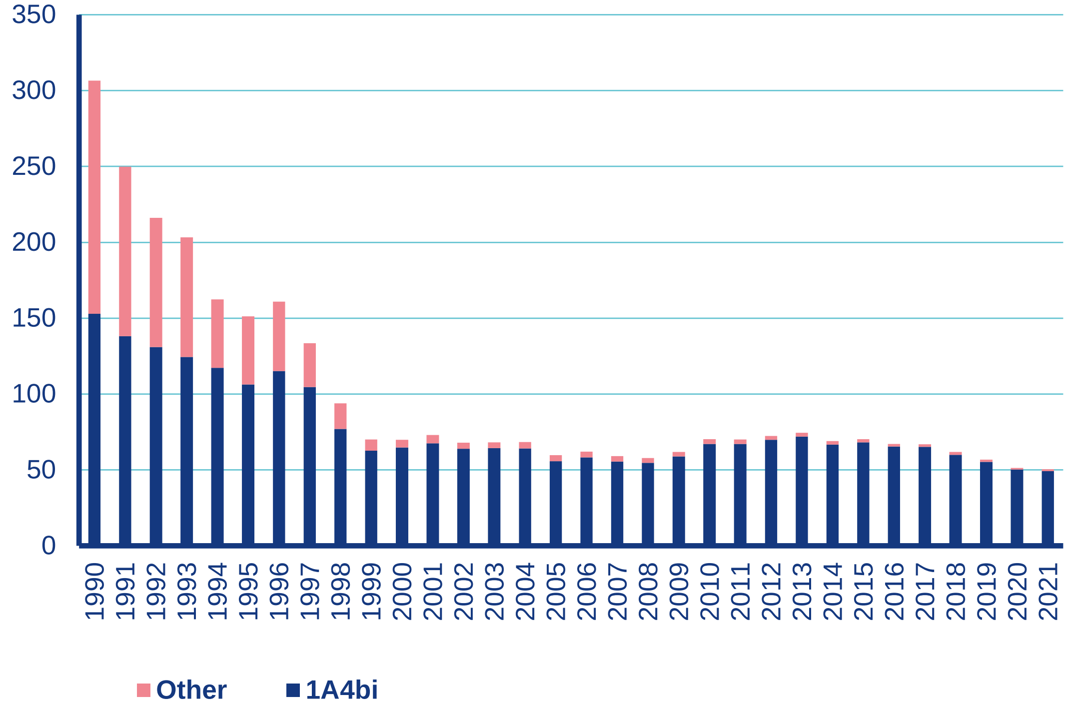

Figure C5: Development of PM2.5 emissions of sector 1A4bi, 1990–2021

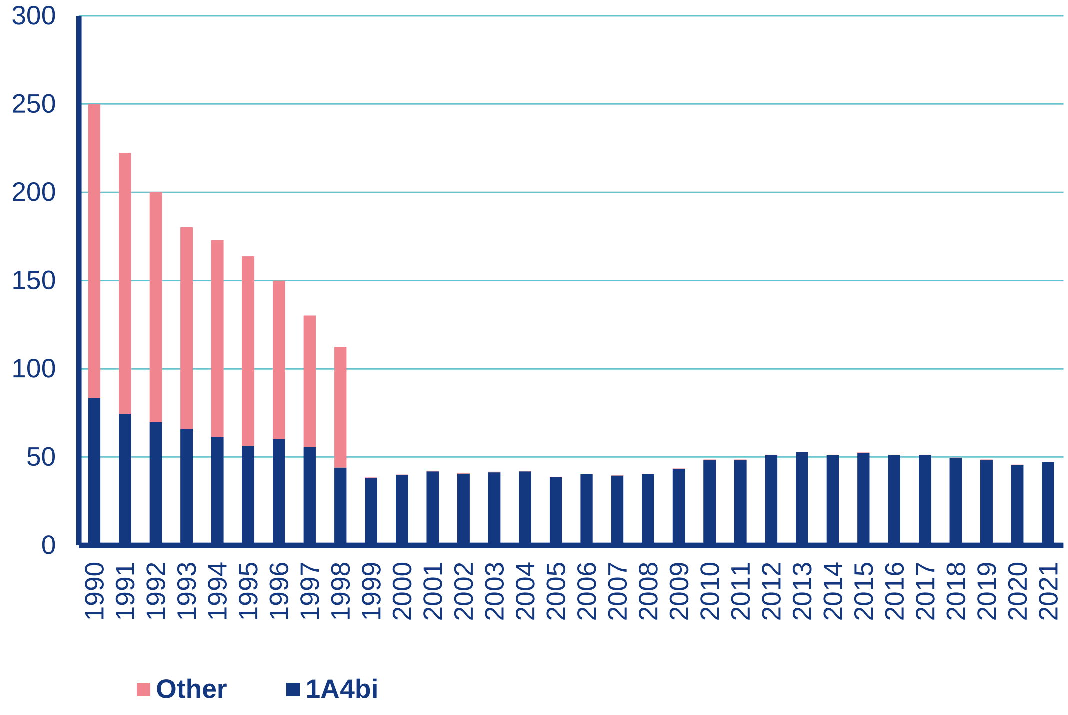

Figure C6: Development of PAH emissions of sector 1A4bi, 1990–2021

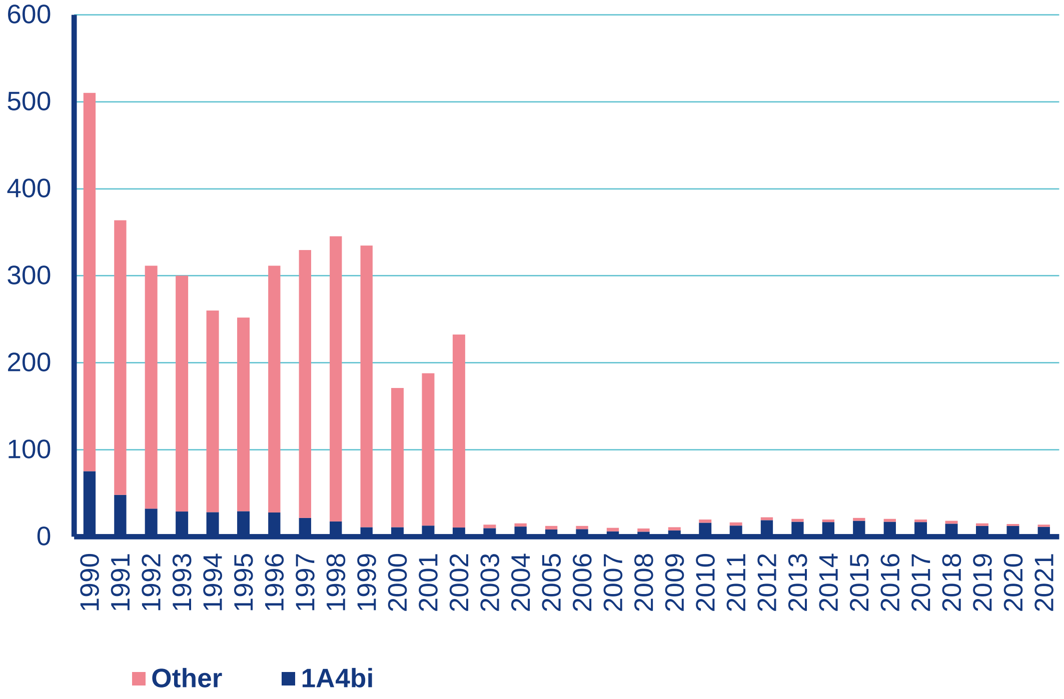

Figure C7: Development of HCB emissions of sector 1A4bi, 1990–2021

Annex D

Projection of emissions from fuel combustion in households

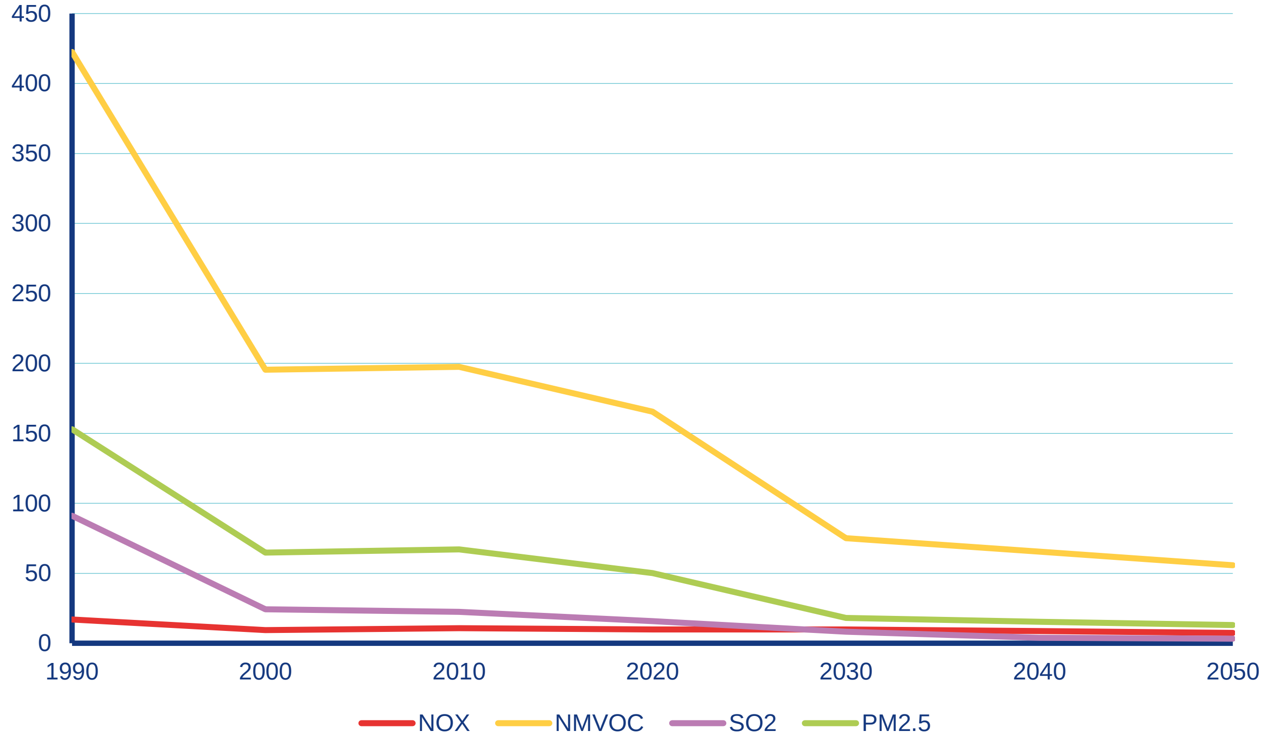

Figure D1: Historical development and projection of sector 1A4bi emissions of selected pollutants, 1990–2050