ANNEX III – Description of methodology for households' heating

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ANNEX IIIa – Emission factors

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EUROSTAT GRANT FOR 2016: QUALITY IMPROVEMENTS OF AIR EMISSION ACCOUNTS AND EXTENSION OF PROVIDED TIME-SERIES

PART A.1
MAJOR IMPROVEMENTS OF DATA QUALITY FOR HOUSEHOLDS

The basic principle of the methodology

The methodology for households' heating is based on the principle of total energy demand (TED) per m^2 of occupied area with the implementation of aging structure of housing units linked to the energy construction standards and the implementation of climate factor. The overall data on wood and wooden briquettes consumption are compiled from the energy demand by applying available values of fuels consumption from national statistics. The final emission compilation includes the division of appliances used in the households into the structure of 6 types and related emission factors for particular type of combustion appliance.

The update of the total energy demand

The update of the methodology was carried out in consequential steps. All input data were revised and updated. The complexity and robustness of the methodology have been enhanced on the base of new data obtained from the questionnaire survey.

Households' data

i. Number of households

The important parameter entering the calculations is the number of households. The numbers of households have been obtained from the Population and Housing Census databases (SODB), which are available for the years 1991, 2001 and the latest in 2011. The absolute values of the occupied housing units (HU) divided on the flats in family houses[8] (FFH) and flats in the apartment buildings (FAB) were used in the new methodology. In comparison to the previous methodology, where the number of all housing units corrected by an estimated factor expressing the share of unoccupied housing units was used throughout the timeline.

The annual accrual of housing units for years between the census data of 1991 and 2001 have been extrapolated. After the year 2011, the numbers of occupied FFH and FAB have been determined by balance of housing units (available data of the annual increments of housing units / decrement of housing units) in the given year. The dynamics of gradual increase in the numbers of housing units is shown in the *Table 13.* The most significant increase is visible in the last 5 years, which reflects the construction expansion in the Slovak Republic.

[8]It is assumed that **vast majority of the family houses correspond to one housing unit (one flat).** However, there may be cases of more separate housing units (flats) in one family house. However, the maximum number of flats is 3 to be still considered as a family house. Or there are cases of semidetached house with common or separated heating. Regarding this, **the used labelling – flats in family house (FFH) – was preferred to use for covering of all cases for family houses** in the text.

ii. Share of housing units connected to district heating supply (DHS)

The households, which use the connection to district network supply of heat for the heating purposes, are not relevant for the balancing of solid fuel combustion, because the emissions are already covered by the national emission database – the source of air pollution registered in the National Emission Information System (NEIS).

The households in the Slovak Republic are characterized by a high proportion of housing units connected to the district heating supply network. The absolute majority being connected to network are merely the flats in the apartment buildings (FAB). The separation of households with the individual combustion of solid fuels for heating and hot water preparation was performed by the subtraction of the numbers of flats that are secured by supply from district heating from the total number of housing units. Based on these data, the total number of FFH and FAB that are heated by local or individual heating has been obtained. The share of FAB connected to CHP is presented in the *Table 13*. The data are gathered from the SOBD in years 1991, 2001 and 2011. The time-series data have been extrapolated.

iii. Average living area

The key parameter for determination of TED per m^2 is the average living area of the housing unit. The data on the average living area were taken from the national statistics of the ŠÚ SR and values are listed in the *Table 13*. The data available from SODB 1991, 2001 and 2011 are given also in more detailed distribution to the average living area of FFH and FAB. The ratio between the total average area of housing units (HU) in the Slovak Republic and the living area of the FFH, respectively, FAB has been obtained by using the following equations:

$$P_{FFH} = \frac{Avg\_A_{\boldsymbol{FFH}\ 2011}}{Avg\_A_{HU\ 2011}}$$

$$P_{FAB} = \frac{Avg\_A_{\boldsymbol{FAB}\ 2011}}{Avg\_A_{HU\ 2011}}$$

Where: P_{FFH} and P_{FAB} are parameters which express the ratio of the living area of flats in family houses ($Avg\_A_{\boldsymbol{FFH}\ 2011}$), respectively, the living area of flats in apartment buildings ($Avg\_A_{\boldsymbol{FAB}\ 2011}$) to the living area of all housing units ($Avg\_A_{HU\ 2011}$). The ratios were calculated in relation to the detail information from year 2011.

These parameters were used to preparation of average living area of flats in family houses ($Avg\_A_{\boldsymbol{FFH}\ (2011-x)}$) and the average living area of flats in apartment buildings ($Avg\_A_{\boldsymbol{FAB}\ (2011-x)}$) in particular years according to following equations:

$$Avg\_A_{\boldsymbol{FFH}\ (2011-x)} = Avg\_A_{HU\ (2011-x)} * P_{FFH}$$

$$Avg\_A_{\boldsymbol{FAB}\ (2011-x)} = Avg\_A_{HU\ (2011-x)} * P_{FAB}$$

Where: $x = (1, 2 \dots 21)$

The average living area of housing units $Avg\_A_{HU\ (2011-x)}$ for each year until 2011 has been extrapolated on the base of the census data from 1991, 2001, 2011. The living areas after 2011 have been calculated on the base of living area of finished new housing unit in particular year.

Table 13: The data on flats in family houses (FFH) and flats in apartment buildings (FAB) used in the computation of fuels use for the purposes of households' heating

Year	Number of FFH	Number of FAB	Share of FAB heated by DHS	Number of FAB without DHS	Average area of FFH (m^2)	Average area FAB (m^2)
1990	810 580	796 537	74.7%	201 524	84.7	59.9
1991	811 440	799 624	74.7%	202 305	85.9	60.7
1992	812 300	802 711	74.9%	201 802	87.1	61.5
1993	813 160	805 799	75.0%	201 289	88.3	62.4
1994	814 021	808 886	75.2%	200 766	89.4	63.2
1995	814 881	811 974	75.3%	200 233	90.6	64.0
1996	815 741	815 061	75.5%	199 690	91.8	64.9
1997	816 601	818 148	75.7%	199 137	92.9	65.7
1998	817 461	821 236	75.8%	198 575	94.1	66.5
1999	818 322	824 323	76.0%	198 002	95.3	67.4
2000	819 182	827 411	76.1%	197 420	96.5	68.2
2001	820 042	830 498	76.3%	196 828	97.6	69.0
2002	823 653	835 248	76.2%	199 156	97.5	68.9
2003	827 263	839 997	76.0%	201 498	97.3	68.8
2004	830 874	844 747	75.9%	203 854	97.2	68.7
2005	834 484	849 496	75.7%	206 224	97.0	68.6
2006	838 095	854 246	75.6%	208 607	96.8	68.4
2007	841 705	858 995	75.4%	211 004	96.7	68.3
2008	845 316	863 745	75.3%	213 414	96.5	68.2
2009	848 926	868 494	75.1%	215 838	96.4	68.1
2010	852 537	873 244	75.0%	218 276	96.2	68.0
2011	856 147	877 993	74.9%	220 727	95.9	67.8
2012	864 685	883 455	74.7%	223 373	94.9	67.5
2013	873 958	888 036	74.6%	225 810	93.9	67.2
2014	883 093	892 678	74.4%	228 276	92.9	67.0
2015	891 984	897 966	74.3%	230 921	92.0	66.7
2016	902 090	902 080	74.1%	233 278	90.9	66.5

iv. Age structure of housing units

The age structure of housing units has notable role within the calculation of TED. The improvements of the thermal and insulation properties of flats of family houses (FFH) and flats of apartment buildings (FAB) have been implemented into the calculations. The base is the annual variation in the age structure of housing units, which better reflects the changes. The dynamic of the structure was derived from the data of the increment and decrement of FFH and FAB with the assumption that decrement relates to the oldest housing units categories and the increment is logically linked to the newly constructed housing units. In compilation, it meant that each year certain number of old high-energy consuming housing units decreased, whilst the certain number of new housing units increased. It was assumed that new housing units were in comply with the currently valid energy standards for certain period.

The *Table 14* provides the age structure of FFH for each year since 1990. The division of the housing units into two categories has been done in starting year 1990 on the base of survey data, which included this information. The first category was constructed until 1980, the second was constructed during the period 1980 – 1990. In data of the year 1990, the share of constructed housing unit until 1980 represents 88.5% and housing units between the years 1980 – 1990 represents 11.5%. In summary it represents total housing stock in 1990. Analogical approach was applied for age structure of individual years, presented in the *Table 15*.

Table 14: Numbers of flats in family houses (FFH) by construction period

Numbers of FFH by construction period						
Year	Before 1980	1980-1990	1991-2000	2001-2010	2011-2015	2016-
1990	717 472	93 108				
1991	707 131	93 108	11 201			
1992	699 515	93 108	19 677			
1993	693 338	93 108	26 714			
1994	691 646	93 108	29 267			
1995	690 291	93 108	31 481			
1996	688 876	93 108	33 757			
1997	686 899	93 108	36 594			
1998	682 890	93 108	41 463			
1999	676 012	93 108	49 202			
2000	667 264	93 108	58 810			
2001	660 842	93 108	58 810	7 282		
2002	655 357	93 108	58 810	16 377		
2003	651 379	93 108	58 810	23 966		
2004	646 414	93 108	58 810	32 541		
2005	641 318	93 108	58 810	41 248		
2006	637 271	93 108	58 810	48 905		
2007	632 985	93 108	58 810	56 802		
2008	628 093	93 108	58 810	65 304		
2009	622 682	93 108	58 810	74 326		
2010	617 156	93 108	58 810	83 462		
2011	612 004	93 108	58 810	83 462	8 763	
2012	611 063	93 108	58 810	83 462	18 242	
2013	610 128	93 108	58 810	83 462	28 450	
2014	609 222	93 108	58 810	83 462	38 491	
2015	608 253	93 108	58 810	83 462	48 351	
2016	607 164	93 108	58 810	83 462	48 351	11 195

Table 15: Numbers of flats in apartment buildings (FAB) by construction period

Numbers of FAB by construction period						
Year	Before 1980	1980-1990	1991-2000	2001-2010	2011-2015	2016-
1990	705 042	91 495				
1991	698 514	91 495	9 615			
1992	693 705	91 495	17 511			
1993	689 806	91 495	24 498			
1994	688 737	91 495	28 654			
1995	687 882	91 495	32 597			
1996	686 988	91 495	36 578			
1997	685 741	91 495	40 913			
1998	685 563	91 495	44 178			
1999	685 544	91 495	47 284			
2000	685 409	91 495	50 507			
2001	685 357	91 495	50 507	3 139		
2002	684 989	91 495	50 507	8 257		
2003	684 347	91 495	50 507	13 648		
2004	684 080	91 495	50 507	18 665		
2005	682 673	91 495	50 507	24 821		
2006	680 636	91 495	50 507	31 608		
2007	676 809	91 495	50 507	40 184		
2008	672 877	91 495	50 507	48 866		
2009	667 814	91 495	50 507	58 678		
2010	664 624	91 495	50 507	66 618		
2011	663 528	91 495	50 507	66 618	5 845	
2012	663 214	91 495	50 507	66 618	11 621	
2013	662 903	91 495	50 507	66 618	16 513	
2014	662 601	91 495	50 507	66 618	21 457	
2015	662 278	91 495	50 507	66 618	27 068	
2016	661 915	91 495	50 507	66 618	27 068	4 477

v. Reconstruction of the housing units

Except of the construction period, the methodology takes into account the influence on the energy efficiency of housing units also by the reconstruction of FFH and FAB. The thermal properties of housing units can be improved by the insulation, change of the old windows or by the roof reconstruction etc. Few questions in the statistical survey were related to this area (if the reconstruction was performed, the period and the object of reconstruction). The *Table 16* provides resulting share of flats of family houses in relation to the construction date as well as the period of the reconstruction.

Table 16: The share of flats of family houses (FFH) by construction and reconstruction period resulted from the statistical survey

Construction period	Share	Share of FFH by construction and reconstruction period						
		Without reconstruction	Before 1980	1980-1990	1991-2000	2001-2010	2011-2015	2016
Before 1980	79.7%	32.4%	6.0%	4.5%	5.4%	11.3%	16.7%	3.3%
1980-1990	10.3%	5.9%	-	0.4%	0.3%	0.9%	2.3%	0.5%
1991-2000	6.0%	3.8%	-	-	0.1%	0.6%	1.3%	0.3%
2001-2010	3.3%	2.6%	-	-	-	0.3%	0.4%	0.1%
2011-2015	0.6%	0.6%	-	-	-	-	0%	0%
2016	0.1%	0.1%	-	-	-	-	-	0%

The system of matrices was created due to gradual increasing of energy efficiency. The matrix was calculated for each year since 1990. The presented data in the *Table 16* have provided the base for development of the matrices for individual years, where the share was used as initial condition and bounded by the year for which the matrix was counted. The share of housing units in each periods by the years was based on the *Table 14*.

- ***For 1990: The share of HU without reconstruction (built before 1980):***

$$SSh_{wr\_b1980\_1990} = Sh_{b1980} * \frac{Sh_{wr\_b1980}}{\sum Sh_{c\&r1990\_b1980}}$$

Where:
The $SSh_{wr\_b1980\_1990}$ represents the specific share of housing units for the year 1990 without reconstruction, built before 1980.
The Sh_{b1980} represents total share of housing units built before 1980.
The Sh_{wr_b1980} represents total share of housing units without reconstruction built before 1980, value of the *Table 14.*
The $\sum Sh_{c\&r1990\_b1980}$ represents the sum of housing units shares with and without reconstruction until 1990, which were constructed before 1980, value of the *Table 14*.

$$SSh_{wr\_b1980\_1990} = (88.5\%) * \frac{(32.4\%)}{(32.4\% + 6\% + 4.5\%)}$$

- ***For 1992: The share of HU with reconstruction in period 1991 - 2000 (built in period 1980 - 1990):***

$$SSh_{r2000\_b80-90\_1992} = Sh_{b80-90} * \frac{Sh_{r2000\_b80-90} * \frac{1992-1990}{10}}{\sum Sh_{c\&r1990\_b80-90} + Sh_{r2000\_b80-90} * \frac{1992-1990}{10}}$$

The principal approach is coherent. The related correction value of the reconstructed HU share, in the period 1991-2000, from the *Table 16* is ensured by the calculation for given year (1992 in example of the abovementioned equation). It has been calculated as follows:

$$SSh_{r2000\_b80-90\_1992} = (11.5\%) * \frac{(0{,}3\% * \frac{2}{10})}{(5.9\% + 0.4\%) + (0.3\% * \frac{2}{10})}$$

- ***For 2012: The share of HU with reconstruction in period 2001 - 2010 (built before 1980):***

$$SSh_{r2010\_b1980\_2012} = (70{,}7\%) * \frac{(11.3\%)}{(32.4\% + 6\% + 4.5\% + 5.4 + 11.3\%) + (16.7\% * \frac{2}{5})}$$

The example of the matrix for the year 2012 – the share of the constructed and reconstructed flats in family houses is listed in the *Table 17* below.

Table 17: The example of the matrix for the year 2012. The share of flats in family houses (FHH) by the construction and reconstruction period

Construction period	Share	Share of FFH by construction and reconstruction period for the year 2012						
		Without reconstruction	Before 1980	1980-1990	1991-2000	2001-2010	2011-2015	2016
Before 1980	70.7%	34.5%	6.4%	4.8%	5.7%	12.1%	7.1%	-
1980-1990	10.8%	7.6%		0.5%	0.4%	1.1%	1.2%	-
1991-2000	6.8%	5.2%			0.1%	0.8%	0.7%	-
2001-2010	9.7%	8.3%				0.9%	0.5%	-
2011-2015	2.1%	2.1%					0%	-
2016	0%	-	-	-	-	-	-	-

The modification of FFH matrix has been prepared as a base for the matrix of reconstructed FAB, because detailed data in division of the reconstruction period were not available for the FAB types of households. The matrix was based on the data in the publication of the Ministry of the Transport and Construction of the Slovak Republic.[9] The publication listed the values of the 50.4% renovated apartment buildings, respectively 33.4% of family houses in 2011. The derived estimation is presented in the *Table 18*.

Table 18: The pattern matrix for the share of the flats in apartment buildings (FAB) by the construction and reconstruction period

Construction period	Share	Share of FAB houses by construction and reconstruction period						
		Without reconstruction	Before 1980	1980-1990	1991-2000	2001-2010	2011-2015	2016
Before 1980	79.7%	16.4%	6.0%	4.5%	5.4%	17.1%	25.3%	5.1%
1980-1990	10.3%	4.1%	-	0.4%	0.3%	1.4%	3.4%	0.7%
1991-2000	6.0%	2.7%	-		0.1%	0.9%	1.9%	0.4%
2001-2010	3.3%	2.2%	-			0.4%	0.5%	0.1%
2011-2015	0.6%	0.6%	-				0%	0%
2016	0.1%	0.1%						0%

[9] Ministerstvo dopravy a výstavby, Stratégia obnovy fondu bytových a nebytových budov v Slovenskej republike , Bratislava, júl 2014; EN version: The Ministry of Transport and Construction, Residential and Non-residential Building Stock Renovation Strategy, Slovak Republic, Bratislava, July 2014

The analogical approach as FFH was applied for the development of the time-series FAB matrices. The example of matrix for given year 2012 is presented in the *Table 19*.

Table 19: The example of the matrix for the year 2012. The share of flats in family houses (FAB) by the construction and reconstruction period

Construction period	Share	Share of FAB by construction and reconstruction period for the year 2012						
		Without reconstruction	Before 1980	1980-1990	1991-2000	2001-2010	2011-2015	2016
Before 1980	75.1%	20.7%	7.6%	5.7%	6.8%	21.6%	12.8%	-
1980-1990	10.6%	5.7%		0.6%	0.4%	1.9%	1.9%	-
1991-2000	5.8%	3.5%			0.1%	1.2%	1.0%	-
2001-2010	7.7%	6.0%				1.1%	0.6%	-
2011-2015	1.3%	1.3%					0%	-
2016	0%	-	-	-	-	-	-	-

vi. Average total energy demand for the housing units

The average total energy demand together with the overall living area are decisive parameters for the computations of TED consumed in the households. The average energy demand expresses the amount of energy necessary for the heating and hot water preparation on 1m^2 for period of 1 year. The parameter of hot water preparation is estimated separately in the method.

The *Tables 20* and *21*, listed below, have been assembled pursuant to valid standards for energy efficiency of housing units related to particular construction periods. The tables have been completed by the calculated values of reconstructed housing units' energy efficiency for certain periods. The values have been calculated by equation:

$$ED_R = \frac{ED_{Cd} + ED_{Rd}}{2}$$

Where:
The ED_R represents the energy efficiency for certain periods.
The E_{Cd} represents the average of specific heat consumptions in the year of construction.
The E_{Rd} represents the average of specific heat consumptions in the year when it was reconstructed / renovated.

This manner of calculation has taken into consideration the fact, that renovation or reconstruction improve the thermo-insulation properties of housing units. Nonetheless, in the majority of cases, housing units do not achieve the parameters of brand new constructed ones respecting the related valid standards. Along with it, the assumption that modern and more efficient material was used is taken into account.

Table 20: The values of specific heat consumption of flats in family houses (FFH) by reconstruction period in kWh/m²/year

Construction period	Specific heat consumption of FFH by reconstruction period [kWh/m²/year]						
	Without reconstruction	Before 1980	1980-1990	1991-2000	2001-2009	2011-2015	2016 - 2020
Before 1980	180	180	120	105	90	90	90
1980-1990	162	-	162	96	81	81	81
1991-2000	120	-	-	120	60	60	60
2001-2010	80	-	-	-	80	40	40
2011-2015	60	-	-	-	-	60	30
2016 - 2020	30	-	-	-	-	-	30

Table 21: The values of specific heat consumption of flat of apartment buildings (FAB) by construction and reconstruction period in kWh/m²/year

Construction period	Specific heat consumption of FAB by construction and reconstruction period [kWh/m²/year]						
	Without reconstruction	Before 1980	1980-1990	1991-2000	2001-2009	2011-2015	2016 - 2020
Before 1980	180	180	155	142	125	115	103
1980-1990	130	-	130	117	100	90	78
1991-2000	103	-	-	103	87	77	64
2001-2010	70	-	-	-	70	60	48
2011-2015	50	-	-	-	-	50	38
2016 - 2020	25	-	-	-	-	-	25

The average energy demand for each year has been calculated on the base of joint data of the *Table 19* (respectively *Table 20*) on specific heat consumption and matrices data of the *Table 16* (respectively *Table 17*) on the share of housing units according to construction period. The calculation are defined by equation:

$$TED_{Year} = \sum (SSh_{Year\,x\,y} * ED_{x\,y})$$

Where:
The TED_{Year} represents the average total energy demand in certain year.
The $SSh_{Year\,x\,y}$ represents the share of housing units by the construction year (x) and reconstruction period (y).
The value of the $ED_{x\,y}$ represents energy demand of housing units by the construction year (x) and reconstruction period (y).

The parameter of hot water preparation has been estimated for the complete total energy demand. The value is published by SPP (a major energy supplier in the Slovak Republic): Ročné náklady na palivo a energiu (SPP – 2016).The historical years have been obtained by the estimation according to trend of total energy demand for heating.

The *Table 22* presents the obtained data of energy demand in division of heating and hot water preparation for flats in family houses (FHH) and also for flats in apartment building (FAB) according to updated methodology of TED with revised input data and newly developed parameters. The data are presented for all defined historical years.

Table 22: The energy demand of housing units by the individual processes in kWh/m²/year.

Year	FFH Heating	FFH Hot water	FAB Heating	FAB Hot water	FFH Total energy demand	FAB Total energy demand
Unit	[kWh/m2/year]					
1990	177.1	52.0	170.3	55.1	229.1	225.4
1991	176.0	51.7	168.8	54.6	227.6	223.5
1992	175.0	51.4	167.6	54.2	226.4	221.9
1993	174.2	51.1	166.5	53.9	225.4	220.4
1994	173.8	51.0	165.7	53.6	224.8	219.3
1995	173.3	50.9	164.9	53.4	224.2	218.3
1996	172.9	50.7	164.2	53.1	223.6	217.3
1997	172.4	50.6	163.5	52.9	223.0	216.4
1998	171.8	50.4	162.8	52.7	222.2	215.5
1999	171.0	50.2	162.2	52.5	221.2	214.7
2000	170.1	49.9	161.7	52.3	220.1	214.0
2001	168.4	49.4	159.4	51.6	217.8	210.9
2002	166.5	48.9	157.1	50.8	215.3	207.9
2003	164.8	48.4	154.9	50.1	213.2	205.0
2004	163.1	47.9	153.0	49.5	211.0	202.4
2005	161.4	47.4	151.0	48.9	208.8	199.9
2006	159.9	46.9	149.2	48.3	206.9	197.4
2007	158.4	46.5	147.2	47.6	205.0	194.9
2008	156.9	46.1	145.4	47.1	203.0	192.5
2009	155.4	45.6	143.6	46.5	201.1	190.1
2010	154.0	45.2	142.1	46.0	199.2	188.0
2011	150.7	44.2	138.2	44.7	195.0	182.9
2012	147.8	43.4	134.8	43.6	191.1	178.4
2013	145.0	42.6	132.0	42.7	187.5	174.7
2014	142.4	41.8	129.5	41.9	184.2	171.3
2015	140.1	41.1	127.2	41.2	181.2	168.4
2016	138.3	40.5	126.1	40.5	178.8	166.5

The total energy demand for entire Slovak Republic in TJ (respectively in PJ) for both FFH and FAB has been used in the consequent calculation. The TED values have been calculated by following equations:

$$TED_{FFH\_TJ} = \frac{TED_{FFH\_Year\_m2} * Flt_{FFH_{Num}} * Flt_{FFH_{Area}} * 3.6}{1000000}$$

$$TED_{FAB\_TJ} = \frac{TED_{FAB\_Year\_m2} * Flt_{FAB_{Num}} * Flt_{FAB_{Area}} * 3.6}{1000000}$$

$$TED_{TJ} = TED_{FFH\_TJ} + TED_{FAB\_TJ}$$

Where:

The variable $Flt_{FFH_{Num}}$ represents the number of the housing units in family houses in particular year

The variable Flt_{FAB_Num} represents the number of the housing units in apartment buildings in particular year.

The variables Flt_{FFH_Area} and Flt_{FAB_Area} represent the averages living area of the housing units areas in particular year.

The total energy demand is presented in the *Table 23.*

Table 23: The total energy demand

Year	FFH_Total energy demand	FAB_Total energy demand	Total energy demand
Unit	[TJ]		
1990	56 639	9 791	**66 430**
1991	57 115	9 881	**66 997**
1992	57 653	9 919	**67 573**
1993	58 224	9 962	**68 186**
1994	58 901	10 019	**68 920**
1995	59 586	10 077	**69 663**
1996	60 270	10 134	**70 404**
1997	60 940	10 189	**71 129**
1998	61 561	10 249	**71 810**
1999	62 109	10 309	**72 419**
2000	62 609	10 368	**72 978**
2001	62 777	10 315	**73 093**
2002	62 242	10 269	**72 511**
2003	61 789	10 230	**72 019**
2004	61 313	10 203	**71 516**
2005	60 849	10 174	**71 023**
2006	60 444	10 148	**70 592**
2007	60 043	10 116	**70 159**
2008	59 633	10 088	**69 721**
2009	59 215	10 058	**69 273**
2010	58 806	10 046	**68 852**
2011	57 619	9 849	**67 467**
2012	56 477	9 681	**66 158**
2013	55 400	9 545	**64 945**
2014	54 424	9 431	**63 855**
2015	53 519	9 334	**62 853**
2016	52 785	9 294	**62 080**

vii. Implementation of climate factor – number of heating degree days

The abovementioned process of TED estimation for the heating of housing units is valid under the normal conditions at the territory of the Slovak Republic. The standardised conditions are set in the Slovak technical standards. The energy demand of the buildings is determined to climate condition of 3422 heating degree days (HDD) taking into account 212 days of heating season at 20°C. However, the climate conditions vary inter-annually and that fact has the impact on the TED.

The other influence is the local geomorphology of the country. The distribution of average temperatures in the geomorphology of the Slovak Republic is very heterogeneous. There were chosen the representative sites that reflects the average conditions in the regions. One of the selection criteria was the share of solid fuel used for heating, which was obtained from Census SODB 2011. The selected representative locations are shown in the *Figure 8*.

The ratio of the households, which use solid fuels for heating in the individual regions has been used in the calculation of the overall climate parameter for the entire territory of the Slovak Republic as presented in the *Table 24*.

The *Table 25* shows the estimated average of heating degree days at the territory of the Slovak Republic and the resulting values of energy demand in the sector of households heating.

Table 24: The weights for calculations of climate factors

District_ID	District	Weight
1	BA	1.36%
2	TT	4.82%
3	TN	12.02%
4	NR	8.90%
5	ZA	22.92%
6	BB	22.94%
7	PO	16.05%
8	KE	10.99%

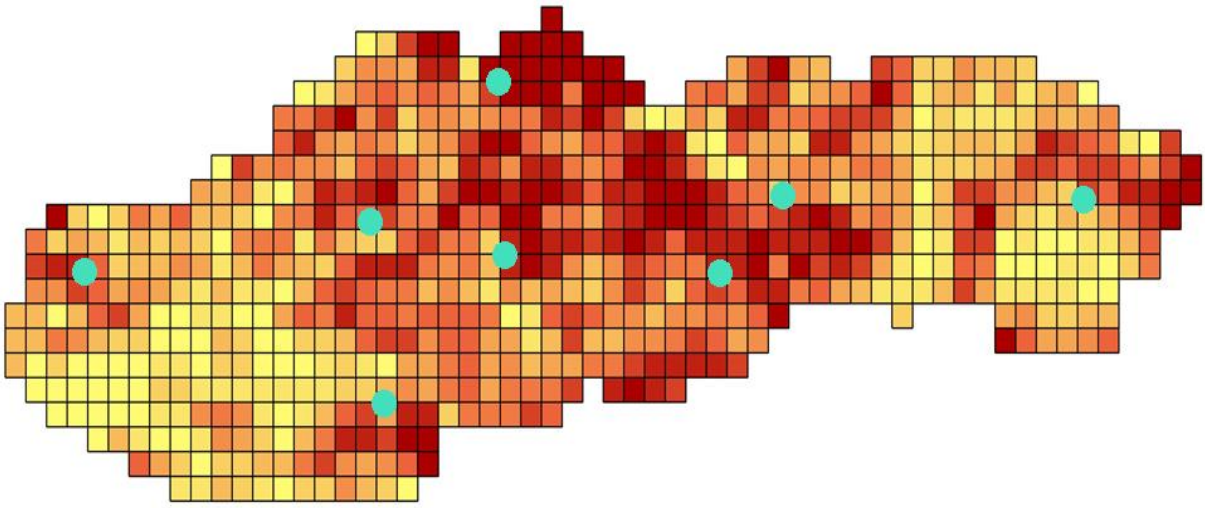

Figure 8: The selected representative localities for the determination of the climate factor on the base of the EMEP GRID map – emissions of the $PM_{2.5}$ from the sector of households' heating

Table 25: The total energy demand after the application of the climate factor

Year	Total energy demand (PJ)	Number of heating degree days	Ratio on normalized heating degree days (3422)	TED +Clima_factor (PJ)
1990	66.43	3855	1.13	**74.83**
1991	67.00	4245	1.24	**83.10**
1992	67.57	4058	1.19	**80.13**
1993	68.19	4002	1.17	**79.74**
1994	68.92	3691	1.08	**74.34**
1995	69.66	4080	1.19	**83.05**
1996	70.40	4303	1.26	**88.54**
1997	71.13	4194	1.23	**87.18**
1998	71.81	3995	1.17	**83.83**
1999	72.42	3864	1.13	**81.77**
2000	72.98	3523	1.03	**75.12**
2001	73.09	3916	1.14	**83.63**
2002	72.51	3863	1.13	**81.86**
2003	72.02	4077	1.19	**85.80**
2004	71.52	3990	1.17	**83.38**
2005	71.02	4134	1.21	**85.80**
2006	70.59	3917	1.14	**80.80**
2007	70.16	3687	1.08	**75.60**
2008	69.72	3649	1.07	**74.35**
2009	69.27	3655	1.07	**73.99**
2010	68.85	4023	1.18	**80.94**
2011	67.47	3704	1.08	**73.03**
2012	66.16	3802	1.11	**73.51**
2013	64.95	3783	1.11	**71.80**
2014	63.85	3211	0.94	**59.92**
2015	62.85	3572	1.04	**65.60**
2016	62.08	3714	1.09	**67.38**

viii. Fuel consumption

In the following steps of the methodology, the amounts of the consumed fuels for households's heating were entered in the calculations of emissions. The wood is very important and represents the significant part of fuels used in households. Therefore, the wood consumption is balance by the subtraction of existing verified data on other fuels from TED. The notable aspect is that improved data for wood consumption for heating purposes from the statistical survey relates only to one year and collected data were used for verification of calculated consumption.

ix. Existing data on solid fuels

The activity data on brown coal, hard coal, coke and coal briquettes are annually collected from fuel sellers into the registry of National Emission Information System (NEIS, the historical data before the year 2000 – REZZO 3). The data on natural gas consumption are provided by the distribution companies. Liquid fuels, which contribution in the total energy consumption is insignificant, are taken from the ŠÚ SR. The data on the electricity consumption on purposes of the heating and hot water preparation in households are obtained by the providers and distribution companies.

The *Table 26* presents the consumption of individual types of fuels in the time-series and the net calorific values considered for expression of fuel amounts.

Table 26: The consumption of fuels and used NCV for calculation of selected fuel types

Year	NEIS/REZZO 3 - Total consumption (t/year)				SPP (thous.m³)	NCV´s (t/TJ)						Total consumption (PJ)						
	Hard coal	Coke	Brown coal	C. Briq.	Natural gas	Hard coal	Coke	Brown coal	C. Briq.	Natural gas	Solid Biomass	Hard coal	Coke	Brown coal	C. Briq.	Natural gas	Liquid fuels	Electricity
1990	91 929	145 126	3 224 814	0	835 925	26.02	27.01	13.24	23.66	33.57	10.28	2.39	3.92	42.71	0	28.07	1.47	3.38
1991	53 234	116 095	2 994 045	0	895 937	24.80	26.35	12.83	22.00	34.05	10.48	1.32	3.06	38.42	0	30.50	1.43	3.65
1992	30 404	133 499	2 760 132	0	1 053 443	24.80	26.93	12.83	22.01	34.04	10.48	0.75	3.59	35.42	0	35.86	1.47	3.72
1993	23 318	56 577	2 190 000	0	985 187	24.94	28.31	12.27	23.91	33.87	10.48	0.58	1.60	26.87	0	33.37	1.38	4.01
1994	19 712	47 872	1 716 512	0	1 119 474	25.14	28.25	12.40	23.49	33.48	8.38	0.50	1.35	21.28	0	37.49	1.29	5.37
1995	31 059	45 369	1 449 320	0	1 245 054	24.99	24.79	11.44	23.33	34.02	9.97	0.78	1.12	16.58	0	42.36	1.06	6.71
1996	26 064	56 574	1 025 283	0	1 487 917	24.61	26.09	12.46	23.80	34.09	10.48	0.64	1.48	12.77	0	50.72	1.15	7.89
1997	11 008	47 697	763 373	0	1 643 558	24.80	26.35	12.83	22.00	34.04	10.48	0.27	1.26	9.80	0	55.95	1.06	8.06
1998	17 776	44 243	872 401	0	1 800 073	25.28	25.94	11.85	22.00	34.04	10.82	0.45	1.15	10.34	0	61.28	1.06	7.86
1999	16 584	41 605	736 603	0	1 929 703	25.22	25.96	12.10	21.43	34.15	9.88	0.42	1.08	8.91	0	65.90	0.97	7.89
2000	20 983	43 329	815 565	1 225	1 759 770	24.81	26.21	11.73	23.50	34.23	10.29	0.52	1.14	9.57	0.03	60.24	0.55	6.72
2001	18 307	37 204	696 029	4 791	2 050 207	25.20	28.13	12.09	23.67	34.18	10.28	0.46	1.05	8.41	0.11	70.07	0.55	5.94
2002	13 465	37 473	347 761	3 546	1 980 830	25.25	28.03	11.29	24.19	34.23	10.28	0.34	1.05	3.93	0.09	67.80	0.87	6.07
2003	24 115	44 809	298 679	3 979	1 987 018	25.40	28.24	11.44	23.00	34.26	12.28	0.61	1.27	3.42	0.09	68.08	0.41	5.98
2004	18 466	19 039	262 310	3 252	1 816 753	25.35	27.55	11.83	23.00	34.26	11.40	0.47	0.52	3.10	0.07	62.24	0.23	6.68
2005	25 524	10 781	247 445	1 868	1 731 750	25.58	28.34	10.75	27.72	34.20	9.90	0.65	0.31	2.66	0.05	59.23	0.32	5.24
2006	31 998	17 619	265 400	612	1 569 330	25.72	28.41	9.61	27.72	34.31	10.45	0.82	0.50	2.55	0.02	53.85	0.69	5.32
2007	22 412	15 687	176 665	831	1 355 894	25.15	28.33	11.15	27.72	34.27	10.75	0.56	0.44	1.97	0.02	46.47	0.51	4.60
2008	23 007	14 210	182 541	1 182	1 443 394	26.19	24.86	10.14	26.42	34.28	9.52	0.60	0.35	1.85	0.03	49.48	0.74	4.81
2009	23 406	13 920	141 772	4 178	1 463 071	25.81	26.11	10.19	26.42	34.40	10.76	0.60	0.36	1.44	0.11	50.33	0.74	4.95
2010	27 227	10 978	155 430	7 010	1 616 167	25.95	26.72	10.22	26.42	34.42	9.46	0.71	0.29	1.59	0.19	55.63	0.55	4.47
2011	30 687	7 719	135 504	10 921	1 423 751	26.14	28.05	10.26	26.42	34.51	11.45	0.80	0.22	1.39	0.29	49.13	0.28	4.24
2012	34 774	7 953	133 593	15 330	1 400 532	25.52	28.00	10.62	25.63	34.56	11.82	0.89	0.22	1.42	0.39	48.40	0.46	3.94
2013	37 132	7 888	110 945	18 102	1 401 930	25.39	29.18	10.62	28.00	34.64	11.89	0.94	0.23	1.18	0.51	48.57	0.37	3.83
2014	31 862	5 945	83 662	14 808	1 171 664	25.99	28.72	10.92	28.00	34.80	11.31	0.83	0.17	0.91	0.41	40.77	0.18	3.54
2015	37 365	5 245	85 358	20 379	1 322 462	26.30	28.05	11.19	28.00	34.95	11.39	0.98	0.15	0.96	0.57	46.23	0.18	3.63
2016	38 847	7 138	75 041	22 910	1 391 917	26.40	28.66	10.72	28.00	35.00	10.44	1.03	0.20	0.80	0.64	48.72	0.37	3.74

The natural gas for cooking was subtracted from its total consumption in the calculation. The estimated annual consumption on each gas connection is 1.4 GJ in average. The *Table 27* shows the overview.

Table 27: The natural gas consumption in division of the cooking and heating purposes

Year	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
NG cooking (PJ)	1.2	1.5	1.8	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.2	2.2	2.3	2.3
NG without cooking (PJ)	26.9	40.9	58.4	57.3	51.9	44.5	47.5	48.4	53.6	47.2	46.4	46.4	38.6	43.9	46.4

The methodology is counting with the effectiveness of the combustion process of 72% for the solid fuels; 88% for the gaseous and liquid fuels (liquid fuels used in households represents the LPG) and the effectiveness of heating by the electricity 99%.The resulting data on consumption is listed in the *Table 28* below.

Table 28: The overview of the final total consumption of the fuels in the households

Year	Total Fuels Consumption (PJ)							
	Hard coal	Coke	Brown coal	Coal briquettes	Natural gas	Liquid fuels	Firewood	Pellets & wood briquettes
1990	2.39	3.92	42.71	0	28.07	1.47	**15.59**	0
1991	1.32	3.06	38.42	0	30.50	1.43	**30.06**	0
1992	0.75	3.59	35.42	0	35.86	1.47	**22.32**	0
1993	0.58	1.60	26.87	0	33.37	1.38	**35.34**	0
1994	0.50	1.35	21.28	0	37.49	1.29	**27.06**	0
1995	0.78	1.12	16.58	0	42.36	1.06	**36.36**	0
1996	0.64	1.48	12.77	0	50.72	1.15	**35.71**	0
1997	0.27	1.26	9.80	0	55.95	1.06	**30.98**	0
1998	0.45	1.15	10.34	0	61.28	1.06	**19.59**	0
1999	0.42	1.08	8.91	0	65.90	0.97	**12.73**	0
2000	0.52	1.14	9.57	0.03	60.24	0.55	**11.72**	**0.03**
2001	0.46	1.05	8.41	0.11	70.07	0.55	**13.77**	**0.13**
2002	0.34	1.05	3.93	0.09	67.80	0.87	**18.20**	**0.13**
2003	0.61	1.27	3.42	0.09	68.08	0.41	**24.00**	**0.18**
2004	0.47	0.52	3.10	0.07	62.24	0.23	**28.28**	**0.17**
2005	0.65	0.31	2.66	0.05	59.23	0.32	**37.73**	**0.16**
2006	0.82	0.50	2.55	0.02	53.85	0.69	**36.70**	**0.05**
2007	0.56	0.44	1.97	0.02	46.47	0.51	**40.57**	**0.08**
2008	0.60	0.35	1.85	0.03	49.48	0.74	**34.75**	**0.09**
2009	0.60	0.36	1.44	0.11	50.33	0.74	**33.12**	**0.30**
2010	0.71	0.29	1.59	0.19	55.63	0.55	**36.70**	**0.56**
2011	0.80	0.22	1.39	0.29	49.13	0.28	**34.10**	**0.81**
2012	0.89	0.22	1.42	0.39	48.40	0.46	**35.33**	**1.15**
2013	0.94	0.23	1.18	0.51	48.57	0.37	**33.00**	**1.40**
2014	0.83	0.17	0.91	0.41	40.77	0.18	**27.73**	**0.96**
2015	0.98	0.15	0.96	0.57	46.23	0.18	**28.20**	**1.36**
2016	1.03	0.20	0.80	0.64	48.72	0.37	**27.07**	**1.47**

The wood consumption is based on the equation:

$$BM = \frac{TED - (NG * 0.88 + SF * 0.72 + LF * 0.72 + EL * 0.99)}{0.72}$$

Where:

The BM represents heating wood; TED represents total energy demand; NG represents natural gas; SF represent all solid fossil fuels; LF represents liquid fuels and EL represent the electricity.

The wooden briquettes were distinguish according to the ratio of the wood consumption to pellets and briquettes consumption obtained in the statistical survey. In the year 2016, it represents 5.16% of consumed solid biomass. The rising trend of using pellets and wooden briquettes was aligned with the rising trend of using coal briquettes.

The data presented in the *Table 28* shows that the most used fuels in the Slovak Republic are natural gas and fuel wood. However, in the 1990s, a significant portion of coal is occurring in historical statistics of the fuel mix.

x. Implementation of the households' appliances structure and calculations of emission from households

The obtained new key information from the statistical survey was the appliances structure used in the households. The data investigated in the survey were age, type, heating output, fuel consumption for individual appliance types. The resulting structure of heating appliances according to fuel types was presented in the *Table 7* in the description of the part PHASE III – Methodology of households.

The appliances have been distinguished into six general categories in order to apply specific emission factors. For the historical time-series, the system of matrices were developed to estimate the changes in structure of boilers and fuels. The matrix was developed for each year. The certain examples for years 1990, 2005 and 2016 are presented in the *Table 29*.

The calculations have been performed on the base of appliance type, related fuel used and in division on the operation at nominal thermal output of 15% and low thermal output of 85% with related emission factors as presented in the *Annex IIIa*. The estimated ratio was harmonized with the air modeller's methodology assumptions.

The information on the drying of wood in households before the combustion was investigated in the statistical survey, because the humidity has also impact on the emissions. The used breakdown from survey data is in ratio 90% of dry wood and 10% of wet wood.

The general equation for the calculation of individual air pollutants by the fuel type and appliance type:

$$Em_{APx} = F_y * Eq_{z\_share} * EF_{xyz}$$

Where:

The variable Em_{APx} represents emission of particular air pollutant *x;* F_y represents the fuel type *y*; Eq_{yz_share} represents the share of certain appliance *z* type for fuel *y*; parameter EF_{xyz} represents the emission factor for certain air pollutant x, fuel y and appliance z.

The combustion conditions are included in case of solid fuels in the calculation by the entering of the factor CCF in the equation (the values 0.85 or 0.15).

$$Em_{APx} = F_y * Eq_{z_{share}} * EF_{xyz} * CCF$$

The humidity of the combusted wood is also taken into account in the calculation by entering of the factor H_w in the equation (the values 0.9 and 0.1).

$$Em_{APx} = F_{wood} * Eq_{z_{share}} * EF_{xyz} * CCF * H_w$$

The calculations are done for time-series since the base year 1990.

Table 29: The overview of appliance structure matrices by the appliance type and fuel type in TJ for the years 1990, 2005 and 2016

1990	**Boiler type / fuel type**	BC	HC	C. Briq.	W. Briq.& Pellets	Wood	Other
1	Over-fire boilers	55.50%	53.80%	75.30%	55.00%	52.00%	46.40%
2	Under-fire boilers	38.00%	32.50%	21.40%	29.20%	18.70%	50.30%
3	Gasification boilers	*0.00%*	*0.00%*	*0.00%*	*0.00%*	0.10%	*0.00%*
4	Automatic boilers	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
5	Fireplaces, stoves, masonry/ built-in tile stoves	6.50%	13.60%	3.30%	15.80%	29.30%	3.30%
6	Modern masonry/built-in tile stoves and pellets stoves	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	∑	100%	100%	100%	100%	100%	100%
2005	**Boiler type / fuel type**	BC	HC	C. Briq.	W. Briq.& Pellets	Wood	Other
1	Over-fire boilers	52.80%	52.80%	75.30%	53.20%	49.20%	46.40%
2	Under-fire boilers	35.30%	31.50%	21.40%	27.50%	15.90%	50.30%
3	Gasification boilers	3.80%	1.40%	*0.00%*	3.50%	4.00%	*0.00%*
4	Automatic boilers	1.70%	0.60%	*0.00%*	*0.00%*	1.60%	*0.00%*
5	Fireplaces, stoves, masonry/ built-in tile stoves	6.50%	13.60%	3.30%	14.90%	28.60%	3.30%
6	Modern masonry/built-in tile stoves and pellets stoves	*0.00%*	*0.00%*	*0.00%*	0.90%	0.70%	*0.00%*
	∑	100%	100%	100%	100%	100%	100%
2016	**Boiler type / fuel type**	BC	HC	C. Briq.	W. Briq.& Pellets	Wood	Other
1	Over-fire boilers	52.80%	52.80%	75.30%	53.20%	49.20%	46.40%
2	Under-fire boilers	35.30%	31.50%	21.40%	27.50%	15.90%	50.30%
3	Gasification boilers	3.80%	1.40%	*0.00%*	3.50%	4.00%	*0.00%*
4	Automatic boilers	1.70%	0.60%	*0.00%*	*0.00%*	1.60%	*0.00%*
5	Fireplaces, stoves, masonry/ built-in tile stoves	6.50%	13.60%	3.30%	14.90%	28.60%	3.30%
6	Modern masonry/built-in tile stoves and pellets stoves	*0.00%*	*0.00%*	*0.00%*	0.90%	0.70%	*0.00%*
	∑	100%	100%	100%	100%	100%	100%