Typology Approach
for Building Stock
Energy Assessment

TABULA

Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock

– TABULA Thematic Report N° 2 –

TABULA Project Team

February 2012

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Contents

1 Summary

Building typologies can serve as a basis for analysing the national housing sector. During the TABULA project which was introducing or further developing building typologies in thirteen EU countries, six of the European partners have carried out model calculations which aim at imaging the energy consumption and estimating the energy saving potentials of their national residential building stocks (IWU / Germany, NOA / Greece, POLITO / Italy, VITO / Belgium, STU-K / Czech Republic, SBi / Denmark).

The partners were choosing different modelling approaches depending on the available statistical data. Some defined a set of synthetical buildings reflecting building stock averages, others were applying a set of “generic” example buildings from the national TABULA typologies.

The results show that the model calculations can provide plausible projections of the energy consumption of the national residential buildings stock. The fit of model calculations and national energy statistics is satisfactory, deviations can often be explained and corrected by adapting standard boundary conditions of the applied calculation models to more realistic values.

Some partners made estimations of possible energy savings, e.g. by applying “standard” or “advanced” packages of energy saving measures to the whole building stock. In that way high potentials of energy savings and CO_2 reduction in the residential building sector could be documented.

In general, the analysis shows that building typologies can be a helpful tool for modelling the energy consumption of national building stocks and for carrying out scenario analysis beyond the TABULA project. The consideration of a set of representative buildings makes it possible to have a detailed view on various packages of measures for the complete buildings stock or for its subcategories. The effects of different insulation measures at the respective construction elements as well as different heat supply measures including renewable energies can be considered in detail.

The quality of future model calculations will depend very much on the availability of statistical data. For reliable scenario analysis information is necessary about the current state of the building stock (How many buildings and heating systems have been refurbished until now?) and about the current trends (How many buildings and heating systems are being refurbished every year?). The availability and regular update of the relevant statistical data will be an important basis for the development and evaluation of national climate protection strategies in the building sector.

2 Belgium

(by TABULA partner Vito / Belgium)

In Chapter 5 of our national scientific TABULA report [TAB2011], we described two detailed methodologies to estimate policy scenarios of residential energy use for heating and sanitary hot water by starting from a detailed, representative dataset of the dwelling stock. To model the Energy Balance of the Belgian, residential building stock we extended the 'Flemish model for residential energy consumption' (engineering model) with the two other Belgian regions, namely Wallonia and Brussels. We would like to point out that this extension contains the first steps in the integration of the three Belgian regions. Further development of the Belgian model is required to obtain more realistic results for Wallonia and Brussels.

As mentioned before, we use average datasets for **representative housing** to identify representative dwelling categories, which differ significantly from typical homes, in the sense that characteristics of the building geometry, construction elements and technical installations cannot, or can rarely, be mapped with a physical representation as found in an actual existing house.

In the next paragraphs, we will describe building characteristics and resulting energy consumption of six representative, building categories (base year 2006). These 6 types are obtained by aggregating/averaging the 216 dwelling categories of our original, detailed dwelling stock. The methodology and data sources of the latter, detailed model are described in Chapter 5 of our national scientific TABULA report [TAB2011].

2.1 Building Typology Approach

The analysis of the Belgian building stock of the year 2006 starts from a detailed dwelling stock comprising 216 representative dwelling categories (see Chapter 5 of our national scientific TABULA report [TAB2011]). This subdivision is based on:

- Dwelling age: <1945; 1946-1970; 1971-1990; 1991-2006;
- Type of dwelling: freestanding, semi-detached, terraced, flat;
- Type of heating installation: collective central, individual central, decentral ;
- Fuel type for space heating: natural gas, fuel oil, electricity, coal, LPG, wood.

For each category, **average energy related characteristics** are mapped, based on a lot of data sources which are described in Chapter 5 of our national scientific TABULA report [TAB2011]. For Flanders, these characteristics represent as much as possible the actual situation by using typical Flemish statistics. For Wallonia and Brussels, further development is required to obtain more representative results: so far, the number of housing units for each dwelling category is derived from regional statistics, but the corresponding energy characteristics of each type are copied from Flanders.

The properties of the 216 categories are averaged to obtain 6 representative dwelling types, which cover three dwelling ages (<1970, 1970-1990, 1991-2006) and two building sizes (single family or multi family house). Table 1 summarizes the frequencies of these 6 categories for Belgium expressed by number of housing units.

Table 1. Frequencies of the 6 aggregated, representative dwelling types in Belgian stock for the year 2006.

		Building period	Number of housing units
Single Family Houses	SFH I	until 1970	2 126 913
	SFH II	1970-1990	810 024
	SFH III	1991-2006	392 813
Multi Family Houses	MFH I	until 1970	656 743
	MFH II	1970-1990	319 895
	MFH III	1991-2006	216 397
TOTAL			**4 522 784**

2.2 Available Data

Besides the frequency of each dwelling category, energy characteristics of dwellings like insulation level (U-value of roof, wall, floor ,window), dimensions of the building envelope and system efficiencies of heating installations are required to model the residential, energy consumption. In Belgium, the primary data sources of building data are:

- General Socio-economic Survey performed in 2001 by the National Institute of Statistics NIS [NIS2001];
- Energy Advice Procedure database [EAP2011].

In Table 2,Table 3 and Table 4, you can find some important characteristics of the building envelope and the heating installations. As already mentioned, these characteristics are based on Flemish statistics. For Wallonia and Brussels, we assume the same properties - but different frequencies - for each dwelling category.

Table 2. Average properties of building envelope for the 6 representative dwelling types (per housing unit, year 2006).

Per housing unit		**SFH I**	**SFH II**	**SFH III**	**MFH I**	**MFH II**	**MFH III**
Building Dimensions							
Total building envelope area	m²	422,56	477,79	477,89	90,79	95,91	97,56
Compactness		1,51	1,36	1,36	3,00	3,00	3,00
% floor area	%	25%	27%	26%	22%	22%	22%
% wall area	%	37%	33%	33%	43%	43%	43%
% window area	%	10%	9%	10%	14%	14%	14%
% roof area	%	29%	31%	30%	22%	22%	22%
Average U-value							
U-value floor	W/m²K	1,04	0,95	0,76	1,00	0,85	0,58
U-value wall	W/m²K	1,89	1,56	0,81	1,78	1,52	0,78
U-value window	W/m²K	3,91	3,53	2,53	3,99	3,67	2,47
U-value roof	W/m²K	1,86	1,32	0,69	1,92	1,36	0,57

As you can see in the next tables, individual, central heating installations on natural gas and fuel oil are the most common heating installation within Belgium. On the other hand, district heating and heat pumps are very rarely applied in 2006.

Table 3. Overview of heating installations for 6 representative dwelling types per fuel type (% of number of housing units per fuel type, year 2006).

Energy Carrier	Heat generator		SFH I	SFH II	SFH III	MFH I	MFH II	MFH III	
Natural Gas	Central	Individual	26,0%	14,8%	12,7%	7,2%	4,4%	7,9%	
		Collective				2,4%	1,5%	1,2%	
	Decentral		15,3%	1,8%	0,5%	3,3%	0,6%	0,4%	100%
Fuel oil	Central	Individual	43,0%	23,6%	9,8%	2,5%	0,9%	0,5%	
		Collective				4,8%	1,9%	0,4%	
	Decentral		10,2%	1,4%	0,4%	0,4%	0,1%	0,1%	100%
Wood	Central		9,2%	5,5%	2,4%	1,0%	0,6%	0,4%	
	Decentral		54,0%	17,9%	6,8%	1,6%	0,4%	0,3%	100%
LPG	Central		18,1%	6,1%	4,9%	2,1%	1,1%	0,9%	
	Decentral		52,9%	7,6%	2,4%	2,8%	0,7%	0,3%	100%
Coal	Central		5,6%	1,9%	0,3%	0,6%	0,3%	0,2%	
	Decentral		77,2%	9,7%	1,6%	2,2%	0,4%	0,1%	100%
Electricity	Direct		19,3%	29,3%	12,3%	9,9%	9,7%	19,5%	
	Heat pump								100%

Table 4 summarizes the frequencies of the different fuel types for the 6 dwelling categories. These frequencies are derived from regional specific statistics [NIS2001] for Flanders, Wallonia and Brussels, and updated based on [REN2011].

Table 4. Overview of fuel types for 6 representative dwelling types (% of total number of housing units, year 2006)

Energy carrier	TOTAL	SFH I	SFH II	SFH III	MFH I	MFH II	MFH III
Natural gas	49%	21%	7%	4%	9%	4%	3%
Fuel oil	39%	21%	8%	3%	4%	2%	0%
Coal	2%	2%	0%	0%	0%	0%	0%
LPG	1%	1%	0%	0%	0%	0%	0%
Electricity	7%	1%	2%	1%	1%	1%	1%
Wood	1%	1%	0%	0%	0%	0%	0%
Total	**100%**	**47%**	**18%**	**9%**	**15%**	**7%**	**5%**

Besides the above presented information, other data like a detailed age subdivision of the heating installation stock and the corresponding system efficiencies, a distribution among insulation classes of each dwelling category, types of SHW installation etc. are also available in our detailed engineering model.

2.3 Energy Balance Method

To model the Energy Balance of the Belgian, residential building stock we extended the 'Flemish model for residential energy consumption' with the two other Belgian regions, namely Wallonia and Brussels. Starting from the extensive database of housing characteristics, this model calculates the energy consumption for each of the 216 dwelling categories based on the method of degree days. Accordance with reality is aimed for by taking into account the impact of households' behaviour and by calibrating the results with residential energy consumption of the Energy Balance in 2006. A more detailed description of the applied methodology is discussed in Chapter 5 of our national scientific TABULA report [TAB2011].

The Flemish model is used as a policy support instrument in defining future pathways for tightening energy-efficiency and climate legislations. We would like to point out that model extension from Flanders to Belgium is the first step in the integration of the three Belgian regions. Further development of the Belgian model is required to obtain more realistic results for Wallonia and Brussels.

2.4 Energy Balance of the Residential Building Stock

First steps were taken in the intergration of the three Belgian regions into an Belgian model, which estimates the residential energy consumption for heating and SHW by starting from a detailed representative dataset of the Belgian dwelling stock. The following table shows the results of the energy balance calculations for the Belgian Building stock in 2006. The final energy consumption is split into energy consumption for heating and sanitary hot water SHW per dwelling category. The results are expressed in the degree days (15/15) observed in Belgium during the year 2006, namely 1795 degree days.

The oldest group of single family houses SFH I (built before 1970) consumes energy for heating and sanitary hot water the most. This is in correspondence with their large frequency in the Belgian building stock.

Table 6 shows the total final energy consumption an related CO_2 emissions directly linked to the residential sector. The emissions of electricity have to be accounted for in the energy sector. As you can see, the major source of CO_2 emissions are fuel oil heating installations.

Table 5. Calculated, final energy consumption for Belgian, residential sector for heating and sanitary hot water ([TJ], year 2006).

	SFH I	SFH II	SFH III	MFH I	MFH II	MFH III
Heating [TJ/year]						
Natural gas	68 129	22 662	13 374	9 890	4 179	2 825
Fuel oil	90 573	33 101	10 571	4 954	1 980	274
Coal	8 955	835	97	162	64	12
LPG	2 297	621	168	86	28	9
Electricity	3 008	4 649	1 496	678	524	602
Wood	3 647	1 218	299	81	13	4
Sanitary hot water [TJ/year]						
Natural gas	3 959	1 531	1 055	1 787	954	774
Fuel oil	3 798	1 827	713	810	415	67
Coal	34	11	2	13	2	4
LPG	58	27	9	10	5	2
Electricity	3 899	1 246	349	1 000	431	278
Wood	33	18	7	8	2	1
Total [TJ/year]						
Natural gas	72 088	24 193	14 429	11 677	5 133	3 599
Fuel oil	94 371	34 928	11 284	5 764	2 395	341
Coal	8 990	846	98	176	65	16
LPG	2 355	647	178	96	34	11
Electricity	6 906	5 895	1 845	1 678	955	880
Wood	3 680	1 237	306	89	16	5
TOTAL	**188 390**	**67 746**	**28 141**	**19 480**	**8 598**	**4 851**
% TOTAL	**100%**	**36%**	**15%**	**10%**	**5%**	**3%**

Table 6. Calculated total final energy consumption and related CO_2 emissions of the Belgian, residential sector in 2006.

2006	TJ/year	kton CO_2/year
Natural gas	131 120	7 319
Fuel oil	149 082	10 932
Coal	10 190	945
LPG	3 321	207
Electricity	18 159	(Electricity sector)
Wood	5 332	
TOTAL	**317 205**	**19 403**

2.5 Comparison to National Statistical Data of the Residential Building Stock

A comparison of the model results with the national Energy Balance of 2006 is presented in Table 7. The sum of the Energy Balances of the three separate regions determines the national Energy Balance [REN2011].

As you can see, the model results fit quite satisfactory with the national energy balance. The deviation of the most important energy carrier - namely fuel oil - amounts only 5%. On the other hand, we obtain a deviation of about 10% for natural gas, despite our calibration of the model with the Energy Balance for this fuel type. But, for Flanders, model results and natural gas statistics differ only 3%, which shows that some model refinements are still required for the Walloon and Brussels region.
Related to the total final energy consumption of 333 095TJ, the deviations of each fuel type are below 5%. The difference of the total energy consumption is around 4.8%.

We would like to point out that the national statistics are also uncertain. For example, the total Belgian consumption of wood and – and to a smaller degree - of fuel oil are difficult to obtain. As a consequence these statistics are also estimations instead of real numbers.

Table 7 Comparison of model results with national Energy balance 2006 ([TJ], final energy consumption).

[TJ]	Model	Energy Balance	Deviation, related to:	
			Single Value	Total Value
Natural gas	131 120	146 033	10,2%	4,5%
Fuel oil	149 082	156 684	4,9%	2,3%
Coal	10 190	5 833	-74,7%	-1,3%
LPG	3 321	5 336	37,8%	0,6%
Electricity	18 159	10 429	-74,1%	-2,3%
Wood	5 332	8 780	39,3%	1,0%
TOTAL	**317 205**	**333 095**	**4,8%**	**4,8%**

2.6 Calculation of Energy Saving Potentials

In Chapter 5 of our national scientific TABULA report [TAB2011] we've described application domains of the model. The energy saving potential of various scenarios for renovation and demolition of existing houses, as well as for additional new-build houses up to 2020 can be examined. In contrast to the historic years, assumptions (no statistics) on future evolution of these driving forces are required. These assumptions are dependent on:

- evolution of the number of households;
- evolution of number of new dwellings;
- evolution of climate: usually, we assume a constant number of heating degree days to allow comparison between years;
- expected spontaneously implementation of reduction measures;

- expected, additional implementation of reduction measures driven by regional or European policy;
- ...

With periods of 2 years, projections of energy consumption and related CO_2 emissions can be made over a time horizon up to 2020. The energy savings of measures are addressed in detail, which involves insights per dwelling category and per measure.

For Flanders, we refer to the report [BRIFF2010] where energy saving potentials for different policy scenarios were estimated.

2.7 Perspectives and Conclusions

Within TABULA, fist steps were taken in the integration of the three Belgian regions to model the energy consumption for heating and SHW of Belgian households. Average, detailed datasets for representative housing are used to identify representative dwelling categories, which differ significantly from typical homes.
The model was based on the Flemish model for residential energy consumption (engineering model) which estimates the energy consumption of 216 dwelling categories by means of the method of degree days. Accordance with reality is aimed for by taking into account the impact of households' behavior and by calibrating the results with residential energy consumption of the Energy Balance in 2006.

The properties of the 216 categories are averaged to obtain 6 representative dwelling types, which cover three dwelling ages (<1970, 1970-1990, 1991-2006) and two building sizes (single family or multi family house). Building characteristics and the resulting energy consumptions are described in this chapter. A comparison of the calculated consumptions with the national Energy Balance shows a quite satisfactory fit. The deviation of the most important energy carrier - namely fuel oil - amounts only 5%. On the other hand, we obtain a deviation of about 10% for natural gas, despite our calibration of the model with the Energy Balance for this fuel type. For Flanders, model results and natural gas statistics differ only 3%, which indicates that some model refinements are still required for Wallonia and Brussels.

By modelling a representative, Belgian housing stock, we can examine the impact of various energy policy scenarios up to 2020 on the households energy consumption, for space heating and domestic hot water, and related CO_2-emissions. The model therefore serves as a policy support instrument in defining future pathways for tightening energy-efficiency and climate legislations.

Table 1: Sources / References Belgium

Reference shortcut	Short description	Reference
[TAB2011]	National scientific TABULA report	Cyx W., Renders N., Van Holm M., Verbeke S. (2011). IEE TABULA - Typology Approach for Building Stock Energy Assessment, VITO, Scientific report composed within the framework of the IEE funded TABULA project
[EAP2011]	Database of Flemish and Walloon dwellings	Vangeel S., Briffaerts K. (2011) Analyse EAP gegevens.
[NIS2001]	Database of National Institute of Statistics	General Socio-economic Survey (2001), National Institute of Statistics NIS
[BRIFF2010]	Report for Flemish government	Briffaerts, K., et al. Simulatie van het Vlaamse woningpark, het energiegebruik voor verwarming en sanitair warm water en de CO2-uitstoot in diverse energiescenario's tot 2020, VEA, 2010
[REN2011]	Report for federal government	Renders N., Duerinck J., Altdorfer F., Baillot Y. (2011). Emission reduction potential of the Belgian heating sector until 2030, VITO & ECONOTEC report.

3 Czech Republic

(by TABULA partner STU-K / Czech Republic)

3.1 Building Typology Approach

Six reference building-types were created to represent the housing stock for the purpose of Energy Balance analysis. This set of buildings is categorized by size and age as follows:

- single family house until 1979 ("SFH. 1");
- single family house from 1980 to 2001 ("SFH.2");
- single family house from 2002 to 2010 ("SFH.3");
- multi-family house and apartment block until 1979 ("APT.1");
- multi-family house and apartment block from 1980 to 2001 ("APT.2");
- multi-family house and apartment block from 2002 to 2010 ("APT.3");

The buildings are theoretical buildings based on the analysis of available statistical data and on the knowledge of historical standard requirements for the U values of the building envelope and the usual efficiency of the heating and DHW systems.

Table 2 gives an overview of the frequencies in each category of the Czech housing stock.
Table 3 gives an overview of the total conditioned floor areas and TABULA reference areas for each category.

Table 2: Overview of the frequencies in each category of the housing stock

	Construction period		
	Until 1979	1980-2002	Since 2002
Number of dwellings in SFH category	1649756	424172	139293
Number of dwellings in APT category	1277705	574438	165648
Total number of dwellings	**2927461**	**927500**	**304941**

Table 3: Overview of the floor areas in each category of the housing stock

	Construction period		
	Until 1979	1980-2002	Since 2002
Net floor area ($m^2.10^3$) in SFH category	159531	41017	13470
TABULA reference floor area ($m^2.10^3$) in SFH category	175484	45119	14817
Net floor area ($m^2.10^3$) in AP category	78042	35087	10118
TABULA reference floor area ($m^2.10^3$) in AP category	85846	38596	11130

3.2 Available Data

The statistical data of buildings were mainly obtained from the public database of the Czech Statistical Office (CZSO). Most of the figures are originating from the national census that was held in 2001. Only few data are available from Microcensus ENERGO 2004, these data are related mainly to the energy consumption in the households.

Public Database (VDB)

The Public Database (VDB) is developed as a fundamental and unified data source for presentation of statistical data designed mainly for the public. It contains solely aggregated statistical data covering all observed areas of statistics. It uses results of statistical data processing in the CZSO as well as statistical data from external and administrative sources especially from other work places of the state statistical service. It does not focus only on data covering the Czech Republic, additionally, it provides data for territorial administrative units of the CR (regions, districts, municipalities and cities, etc.) and also data from abroad.

VDB is created as a data mart drawing data from databases developed in the process of statistical data processing. Some data are presented in a different context in different outputs (tables, maps, graphs, etc.).

VDB includes the following:

- primary level – containing mainly database of aggregated statistical data
- secondary level – containing statistical outputs (statistical tables, maps, graphs)
- interface – applications securing transformation and input of data to primary database (including universal XML interface) and applications enabling access to data and outputs

ENERGO 2004

The microcensus ENERGO 2004 covered approximately 1 % of total 3.700 000 occupied dwellings. Thus the statistical population was approx. 40000 dwellings. The structure was defined adequately to the structure of the housing stock resulting from the census 2001.

The statistical population was processed and analysed using random two step approach by following strictly given criteria such as municipal/rural, SFH/MFH/AB, type of centralized/local heating, the frequency of fuel types.

It is worth mentionning that the mean value of energy consumption per dwelling, calculated from the sample data, amounts to 78.2 GJ/dwelling. According to "Energy balances of the Czech Republic in 2000, 2001 and 2002", CzSO February 2004, the specific energy consumption of households in last years was ranging within the limits 61.3 - 68.1 GJ/dwelling. Values calculated from energy balances lay in interval 78.2 +/- 15.6 GJ/dwelling. The above-mentioned data are not quite comparable because they refer to different years (with different number of heating degree days in heating season).The values of total energy consumption for the case of electricity and solid fuels combination, are extremely high and have an impact on average values of their overvaluation. Apparent overvaluation of solid fuels consumption is probably caused by inaccurate estimation of their consumption on the basis of their supplies but most probably even by noninclusion of efficiencies regarding the equipment on individual fuels and inaccurate estimation of remaining stocks.

Table 4: Frequencies of buildings according to number of dwellings and storeys

SFH total	Number of dwellings		APT total	Number of dwellings		
	1 dwell.	2-3 dwell.		2-3 dwell.	4-11 dwell.	12 dwell. and more
1 406 806	1 155 379	251 427	195 270	13 206	106 538	75 312
SFH total	Number of storeys in SFH		APT total	Number of storeys in APT		
	1-2 storeys	3-4 storeys		1-2 storeys	3-4 storeys	5 storeys and more
1 406 806	1 369 230	25 485	195 270	37 550	92 183	65 207

Source of data: national census 2001

Table 5: Average floor areas according to construction period and type of building

Building type	Average gross floor area (m2)		Average living area (m2)	
	per dwelling	per occupant	per dwelling	per occupant
1961				
SFH			35,29	10,29
APT			34,94	10,81
1970				
SFH	68,33	20,99	41,94	12,88
APT	55,67	18,34	35,68	11,75
1980				
SFH	77,25	25,82	49,44	16,53
APT	57,38	20,02	36,86	12,86
1991				
SFH	85,78	29,4	56,77	19,46
APT	59,77	22,51	38,16	14,37
2001				
SFH	96,67	33,63	63,03	21,93
APT	61,08	24,67	39,42	15,92

Source of data: national census 2001

The frequencies of dwellings and average floor areas are originating mainly from statistical data collection during national census 2001. The values are show in Table 4 and Table 5.
The data about heating and DHW systems were mainly collected during the microcensus ENEGO 2004.These values are presented in Table 6, Table 7, Table 8 and Table 9. The information about the level of refurbishments of the housing stock can be found in the chart Figure 1 and in Table 10 and Table 11.

Table 6: National estimate of heating systems according to type of fuel

Number of dwellings	Heating systems							
	Centralized heating				Space heating /local heating/			
	A	B	C	D	E	F	G	H
Fuel	Total centralized heating	Central heating	Collective heating	District heating	Complementary heating	Kitchen stoves	Stoves	Open Fires
Total	**3 489 122**	**1 931 195**	**386 680**	**1 171 248**	**32 522**	**73 220**	**812 772**	**61 461**
Electricity	0	0			28 480		364 723	
Gas	1 116 126	1 116 126			3 307		239 137	
LPG	3 859	3 859			0		2 848	
Heat	1 557 928	0	386 680	1 171 248	0			
Hard Coal	46 119	46 119			0	3 583	9 371	
Coke	37 299	37 299			0	184	2 205	
Wood	367 938	367 938			735	69 362	115 940	61 461
Other Fuels	359 854	359 854			0	92	78 549	

Source of data: National estimate based on microcensus ENERGO 2004

Table 7: Heat generation of domestic hot water systems

District heating	Collective heating	Electricity	Natural gas	
		Boiler or instant heater	Boiler DHW	Boiler DHW+heating
31,90%	10,90%	34,80%	12,60%	13,60%

Source of data: National estimate based on microcensus ENERGO 2004

Table 8: Energy consumption in statistical population of 40000 dwellings

Building categ.	Energy Carrier								
	Electricity	Gas	LPG	Brown coal	Coke	Wood	Other	DH	DHW
	MWh	MWh	kg	tons	tons	kg	tons	TJ	$10^3 . m^3$
SFH (1 dwell.)	55919,9	160615,3	132318,0	14900,9	816,0	19874424,0	1976,6	3,6	1,4
SFH (2-3 dwell.)	26520,7	89553,7	51729,0	6058,9	557,4	7955942,0	947,7	3,1	1,7
MFH	18268,7	49191,2	21465,0	1616,8	95,6	1763855,0	187,5	78,6	57,8
AB	33391,3	36002,3	6015,0	166,1	5,4	182209,0	36,9	465,6	448,2
Total	**134100,5**	**335362,5**	**211527,0**	**22742,7**	**1474,4**	**29776430,0**	**3148,7**	**551,0**	**509,1**

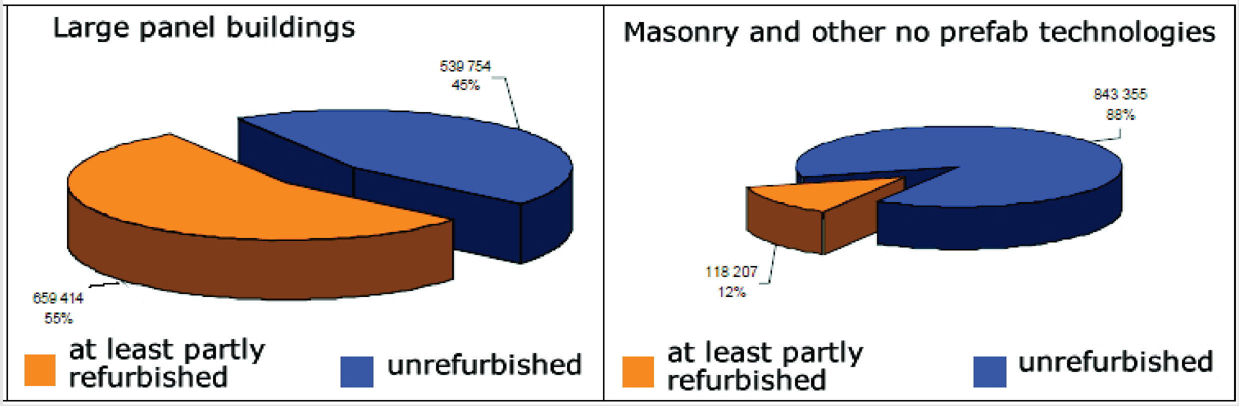
Source of data: National estimate based on microcensus ENERGO 2004

Table 9: Fuel consumption for the heat generation and delivery to the households (heating+DHW)

Fuel and technology	Decentralized heating (TJ)	District heating (TJ)	Total (TJ)
Brown coal	-		
Brown coal graded	17307,3		
Briquettes	2229,3	20056,6	39607,3
MULTI powder	-		
Lignite	-		
Lignite graded	14,1		
Black coal	-		
Black coal graded	2486,3	5068,2	8106,1
Black coal sediments and granulate	37,5		
Coke	514,1		
Wood			
Wood chips, wood waste	29481		
Wood pellets and briquettes		720,6	30202
Vegetal materials non agglomerated	-		
Cellulose extracts	-		
Other biomass	-		
MSW	-		
Industrial and hospital waste	-	1523,4	1523,4
Alternative and other fuels	-		
Carbon deposits	-	-	-
Fuel oil	-	1535,8	1535,8
Tar mixture	-		
Organic chemicals	-	296	1124,9
LPG	828,9		
Other liquid fuels	-		
Natural gas	88522,1	17278,8	105800,9
LFG	-	-	-
Other biological gas	-	-	-
Degazation gas			
Gasworks *gas*			
Coke oven gas		840,2	840,2
Blast furnace gas			
Oxygen steel furnace gas			
Other types of gas			
Electricity	25191,6	3,7	25195,3
Waste heat, recovered heat	-		
Nuclear fuel	-	-	812,3
Solar collectors	118		
Heat pumps	694,3		
TOTAL (TJ)	**167424,9**	**47323,4**	**214748,2**

Source of data: Energy statistics, MoIT 2007

Figure 1: Number of dwellings (partly) refurbished/unrefurbished in 2009



Source of data: PANELSCAN 2009

Table 10: Percentage of thermally refurbished envelope areas

	Large panel buildings (precast concrete)		Masonry buildings	
	SFH+TH	MFH+AB	SFH+TH	MFH+AB
Number of dwellings (1000)	neglected	1199,20	1632,1	961,60
Heated area related (1000 m2)	neglected	72048	157824	57773
Windows replacement or renovation	unknown	34 %	unknown	
External thermal insulation of the fasade	unknown	32 %	unknown	12%
Roof renovation	unknown	28 %	unknown	

Source of data: PanelScan 2009

Table 11: Average insulation thicknesses (eq EPS 70F) added to the refurbished elements and U values of new windows

	1998	2008	2012 *(estimation)*	Remarks
walls	50-60 mm	85 mm	100 mm	[1]
windows U values (W/m2.K)	2,3-2,8	1,4-1,8	0,8-1,2	[2]
roofs / upper floor ceilings	120 mm	160 mm	220 mm	[2]
basement / cellar ceiling	50 mm	75 mm	100 mm	[2]

[1] the source of data: Sdružení EPS ČR
[2] mainly based on estimations and standard requirements

3.3 Energy Balance Method

The energy balance model was created on basis of the statistical data collected mainly from the National census 2001 and from the Microcensus ENERGO 2004. The delivered energy and the energy demand for space heating of the considered six groups of buildings was calculated using national calculation method.

The methodology is based on the delivered energy needed under standard indoor and outdoor conditions. Energy consumption of the building is defined as amount of energy needed for the fulfilment of various demands related to the standard use of the building. The national calculation method is based on the simplified dynamic calculation. The energy demand was calculated from monthly values.

The national calculation software tool (NCT) was used for this purpose.The simplified process of calculation was divided into two steps:

1) calculation of energy demand of the synthetic buildings
2) calculation of of the energy required by the energy systems (heating and DHW systems). needed to produce the necessary heat and domestic hot water. The energy demand was calculated for a standard use of the buildings.

Following simplificatory assumptions were made in order to process the calculation:
- each synthetic building consisting of one conditioned zone only
- one climatic zone
- natural ventilation rate fixed at 0,5 h^{-1}
- internal temperature in the buildings considered as constant value
- average efficiency values used for heat generators, storage and distribution and heat emission in each group
- average annual consumption of DHW 23 m^3/occupant
- no air conditioning and mechanical ventilation considered as these systems are marginal for the housing sector
- partial reduction factors were used to estimate the reduced heat demand due to partial thermal refurbishments of the buildings

3.4 Energy Balance of the Residential Building Stock

The statistical tables presented above were used to define the average gross floor areas of synthetic buildings. The mean values of areas of the windows, floors, roofs/ceilings and exterior walls were estimated according to the expert knowledge of the geometrical properties of real buildings and their frequency. The U values were taken from the Czech standards valid in the period of building construction. The refurbishments play important role only in the groups APT2 and APT3.
The total reduced energy consumption is estimated to 20%. in the whole group APT2 and 10-15% in the whole group APT3. These estimations are quite modest with special regards to the fact that relatively many refurbishment projects did not meet the expectations for multiple reasons.
Most of the buildings in the groups APT2 and APT3 are heated with centralized heating thus it was possible to estimate the efficiency ratios. The heating systems in the groups of single family houses are variable: Table 8 and Table 9 were useful as a basis for the calculation of primary energy and the CO2 emissions. The overview of used values and results is presented in the Table 12.

Table 12: Overview of values used for 6 groups of buildings and the calculation results

	SFH1	SFH2	SFH3	APT1	APT2	APT3
	-1945	1946-1980	1981-2001	-1945	1946-1980	1981-2001
area (m^2)	68,7	86,6	109,7	352,0	684,0	842,9
A_{wall} (m^2)	85,4	93,1	110,6	290,0	520,8	574,3
A_{window} (m^2)	9,80	13,30	18,29	70	152	200,7
A_{floor} (m^2)	41,7	50,56	57,93	188	171	183,1
$A_{roof/ceil}$ (m^2)	50,8	63,2	72,42	216	196,65	210,6
U_{wall} ($W/m^2.K$)	1,4	1,1	0,6	1,4	1,1	0,6
U_{window} ($W/m^2.K$)	2,35	2,35	1,7	2,35	2,35	1,7
U_{floor} ($W/m^2.K$)	0,94	0,68	0,68	0,94	0,68	0,68
$U_{roof/ceil}$ ($W/m^2.K$)	0,9	0,51	0,31	0,9	0,51	0,31
Conditionned volume (m^3)	192,36	242,48	307,22	1353,6	1983,6	2389
Delivered energy ($kWh/m^2.year$)	328	261	146,5	304	215	164
Energy demand ($kWh/m^2.year$)	262	208	131	217	154	122
Number of dwellings	593 141	629 643	389 722	370 807	1 231 234	542 288
Total m^2	36382845	48797333	37674426	20082907	70648207	33122951
CO2 (T)	5490512	5876381	2613823	2936109	6542421	2600015
Total delivered energy (GWh)	11934	12736	5519	6105	15189	5432
TOTAL (PJ)	**204,73**					

3.5 Comparison to National Statistical Data of the Residential Building Stock

There is no national methodology available to calculate the national balance however the calculated results can be compared with PORSENNA report (2007). The most important boundary conditions of PORSENNA study are presented in the Table 13. The value E_a means energy delivered to the building (consumed energy). It is obvious that the calculated delivered energy is quite close to PORSENNA estimation.

The total calculated energy used for heating, DHW and lighting of the housing stock is **204,7 PJ**. PORSENNA estimation for the year 2007 is **174** PJ for the heating and **25** PJ for the DHW. Another source of data that can be compared with the calculated results is shown in Tab 8. The table published by the Ministry of Industry and Trade in 2007 shows total energy consumption for the heating and DHW which is **214,75 PJ.** The standard deviation of calculated result is ±2,5%.

The CO2 emissions were calculated by using general emission factors according to the Czech Decree No. 425/2004. The total CO_2 emissions are **26,059,000 T**. The CO_2 emissions calculated according to the Table 9 are **23,586,500 T.** The standard deviation of calculated result is ± 5%.

Table 13: PORSENNA boundary conditions of the housing stock

Construction period	Until 1979	1979-1985	1985-1992	1992-2002	Since 2002	LEH	PH
Completed dwellings	2927461	386199	324563	216746	122488	None	None
SFH	1649756	172601	138748	112823	62649	None	None
APT	1277705	213598	191605	169235	79735	None	None
E_a average (kWh/m2/year)	**280**	**220**	**195**	**170**	**120**	**50**	**15**
E_a SFH (kWh/m2/year)	**300**	**200**	**180**	**150**	**130**		
E_a MFH+AB (kWh/m2/year)	**260**	**230**	**200**	**180**	**110**		
U_{wall}	1,45-1,37	1,39-1,19	0,89-0,79	0,5	0,38-0,30	0,15	0,10-0,15
U_{roof}	0,89-0,83	0,93-0,79	0,51-0,43	0,41-0,36	0,3-0,24	0,12	0,10-0,12
$U_{ceiling/cellar/}$	0,47-0,43	0,47-0,43	0,47-0,43	0,34	0,3-0,24	0,12	0,10-0,12
U_{window}	2,9	2,9	2,9	1,8	1,7	1,20-0,80	0,80

3.6 Calculation of Energy Saving Potentials

According to the recently performed study “PANELSCAN” still over 45% of large panel buildings and approximately 90% of masonry and other buildings shall be refurbished. The energy saving potential is relatively high. It was estimated by experts that by achieving U values prescribed by the latest version of the Czech standard CSN 730540 following amount of energy can be saved:

20% of energy in average can be saved by applying ETICS (External thermal insulation composite systems) to the exterior walls.
10% of energy in average can be saved by roof insulation
25% of energy in average can be saved by windows replacement
heating control systems would bring savings ranging approximately between 5 and 15%
The losses can be reduced up to 50% by insulating properly the pipes.

The above mentioned percentage figures were considered in the calculation model and distributed over the categories of buildings. The results are shown in the Table 14.

The calculated overall energy saving potential is 83,6 PJ. The calculated CO_2 reduction potential is 10,6 mil tons.

The biggest energy saving potential can be obviously found in the group of the oldest single family houses. It is representing nearly one third of the total housing stock energy saving potential. However it is important to mention that this is the worst documented part of the housing stock especially as for the recent renovations and the quality of works done. Another interesting group is APT2 which consists mainly of large panel buildings with rather poor quality of insulation and high degree of cold bridges. These standardized buildings offer good opportunities for optimized and solutions that can be used repeatedly.

Table 14: Energy saving and CO2 saving potential in the housing sector

	SFH1	SFH2	SFH3	APT1	APT2	APT3
Number of dwellings	593 141	629 643	389 722	370 807	1 231 234	542 288
Total m^2	36382845	48797333	37674426	20082907	70648207	33122951
Total delivered energy (GWh)	11934	12736	5519	6105	15189	5432
CO2 (T)	5490512	5876381	2613823	2936109	6542421	2600015
Energy saving potential (GWh)	7757	4840	1105	3236	5316	978
CO_2 saving potential (T)	3568787	2233172	523333	1556306	2289783	468118

3.7 Perspectives and Conclusions

The selected building typology approach with above described calculation models has contributed to energy balance analysis of the Czech building stock and enabled to estimate the energy saving potential and the potential for reduction of CO_2 emissions. The calculated energy balance and energy saving potential are in quite good correlation with recently conducted study from PORSENNA It has been proved that a definition of six groups of average synthetic buildings with realistic determination of decisive parameters for energy behaviour is sufficient to estimate with reasonable degree of precision the energy consumption of the Czech building stock. The perspectives are mainly seen in the application of the same approach for fast and reliable analysis of different scenarios looked at the housing stock.

Table 15: Sources / References Czech Republic

Reference shortcut	Short description	Reference
VDB-Public database	Public Database of the Czech Statistical Office (CZSO) mainly using data from National census in 2001	Veřejná databáze Českého statistického úřadu (ČSÚ) obsahující především údaje ze sčítání domu a bytů v roce 2001
PORSENNA - Report 2010	Report from PORSENNA on the impact of additional thermal insulation of the buildings on the use of coal and gas.	Studie o dopadech zateplování budov na spotřebu uhlí a zemního plynu v České republice
PANELSCAN – Report 2009	Report from CERPAD on the technical conditions of the Czech housing stock	Studie Centra regenerace panelových domů o stavu bytových domů v ČR – PanelSCAN 2009
Report 2011	Technical University Ostrava 2011	Studie stavu teplárenství-VŠB TU Ostrava 2011
TABULA Scientific Report CZ	National scientific TABULA report 2012	Národní odborná zpráva z projektu TABULA 2012

4 Denmark

(by TABULA partner SBi / Denmark)

4.1 Building Typology Approach

The energy balance of the Danish residence buildings was calculated using synthetic average buildings, SyAv. These SyAv buildings were composed within each building period and building type (SFH, TH, AB). References to the buildings are shown in the table below.

Table 16: TABULA model

Building period	Single-family houses	Terraced houses	Block of flats
Before 1850	SFH.AvSy.01	RH.AvSy.01	AB.AvSy.01
1851-1930	SFH.AvSy.02	RH.AvSy.02	AB.AvSy.02
1931-1950	SFH.AvSy.03	RH.AvSy.03	AB.AvSy.03
1951-1960	SFH.AvSy.04	RH.AvSy.04	AB.AvSy.04
1961-1972	SFH.AvSy.05	RH.AvSy.05	AB.AvSy.05
1973-1978	SFH.AvSy.06	RH.AvSy.06	AB.AvSy.06
1979-1998	SFH.AvSy.07	RH.AvSy.07	AB.AvSy.07
1999-2006	SFH.AvSy.08	RH.AvSy.08	AB.AvSy.08
After 2007	SFH.AvSy.09	RH.AvSy.09	AB.AvSy.09

4.2 Available Data

In Denmark the two primary data sources of building data are:

1. The Danish building stock register (BBR)
2. The building Energy Performance Certification (EMO) database

The building stock register contains general information of **all** Danish buildings. Relevant for this project is mainly data of heated floor area and information of the heating installation type.

In 2010 the Energy Performance Certification database covered approx. 10% of the single-family houses, 14% of terraced houses and 13% of block of flats.

Both databases are continually updated. The BBR register is updated whenever an existing building is extended or a new building is finalised. The building energy performance experts report their certificate data directly into the EMO database, so at any given time the database contains information from all new and existing certificates. Data for this project were extracted in April 2010.

Data of building modernisation is not included in any of the databases as these only represent the latest data for a property or building. Furthermore, in the future the EMO database will contain data for buildings that have been certified more than once. Currently the validity period of Danish EPC certificates is settled to 5 years, so it has not become a problem yet.

4.3 Energy Balance Method

In Denmark a national Energy Balance method already exists. The model has been used in several studies of the energy saving potentials [SBi,1]. The knowledge of the different input data has been used to make a similar Energy Balance calculation using the TABULA approach.

The results were calculated using the reference EU boundary conditions (SUH.EU and MUH.EU) and an adjusted boundary for Danish conditions similar to the Danish Energy Balance Method.

The synthetically average buildings
The SyAv buildings were composed by average U-values extracted from the EMO database. U-values of ceilings, walls, floors and windows were calculated within each building period and building type using the equation:
$U_{avg} = \Sigma A_i * U_i / A_{tot}$

Where "i" is the reference to the specific construction

The corresponding areas of the building envelope constructions were achieved from the Danish energy balance method, which uses the same approach for the average U-values as described above.

4.4 Energy Balance of the Residential Building Stock

The results of the Energy balance calculation using the TABULA approach are presented below.

Net energy for heating (space heating)
The calculation result of the energy balance is very dependent on the assumed boundary conditions. The calculation of the space heating demand and the national statistic of the net heating energy consumption were used to calibrate the boundary conditions.
Comparisons of the national boundary conditions with the EU standard conditions are shown below for single-unit houses (SUH) and multi-family houses (MUH):

Table 17: Boundary conditions

	Single unit houses (SUH)				Multi-unit houses (MUH)	
	EU.SUH	DK.SUH_19	DK.SUH	DK.SUH_21	EU.MUH	DK.MUH
internal temperature	20	19	20	21	20	21
reduction factor, considering the effect of night set-back and unheated space, value at h_tr = 1 W/(m²K),	0.9	0.9	0.9	0.9	0.95	0.95
reduction factor, considering the effect of night set-back and unheated space, value at h_tr = 4 W/(m²K),	0.8	0.8	0.8	0.8	0.85	0.85
average air change rate, due to use of the building	0.4	0.45	0.45	0.35	0.4	0.7/0.6/0.5
room height (based on internal dimensions)	2.5	2.8	2.8	2.8	2.5	2.8
average internal heat sources per m² reference area	3	5	5	5	3	5
reduction factor external shading, horizontal orientation	0.8	0.8	0.8	0.8	0.8	0.8
reduction factor external shading, vertical orientations	0.6	0.6	0.6	0.6	0.6	0.6
frame area fraction of window	0.3	0.3	0.3	0.3	0.3	0.3
reduction factor, considering radiation non-perpendicular to the glazing	0.9	0.9	0.9	0.9	0.9	0.9

Results from space heating demand calculation

The results using the Danish boundary conditions are shown below. Energy consumption for hot water is not included in the presented results of energy demands for space heating.

Table 18 Space heating demand

[kWh/m²]	Single-family houses	Terrace houses	Apartment blocks
Building period	**DK.SUH**	**DK.SUH**	**DK.MUH**
Before 1850	199,6	198,6	198,4
1851-1930	204,9	215,8	209,8
1931-1950	214,1	219,2	209,4
1951-1960	191,6	192,4	168,6
1961-1972	160,2	155,6	152,1
1973-1978	141,7	133,5	146,9
1979-1998	124,2	118,0	143,9
1999-2006	82,0	82,2	98,3
After 2007	69,9	69,1	82,1

The difference between the EU and DK boundary condition was found to be approx.10 kWh/m² for the single-family and terrace houses. For the apartment block the DK boundary condition increases the net energy consumption mainly due to the higher assumed room temperature.

Energy demand for heating and hot water (Energy carriers)

Results from the TABULA approach are only presented for boundary conditions DK.SUH and DK.MUH.

Table 19: Energy Carriers [kWh/m²]

	Period	Building type	SFH DK.SUH	TH DK.SUH	AB DK.MUH
1	Before 1850	Total			
		District Heating	213	212	201
		Gas boiler	228	227	216
		Oil Boiler	237	235	216
		Electricity	197	196	189
		Heat pumps	76	76	57
2	1851-1930				
		District Heating	219	220	215
		Gas boiler	234	235	231
		Oil Boiler	242	244	231
		Electricity	202	203	202
		Heat pumps	78	81	60
3	1931-1950				
		District Heating	245	240	215
		Gas boiler	262	256	231
		Oil Boiler	270	265	231
		Electricity	227	222	202
		Heat pumps	81	83	60
4	1951-1960				
		District Heating	247	236	197
		Gas boiler	265	252	211
		Oil Boiler	273	261	211
		Electricity	229	218	185
		Heat pumps	81	81	56
5	1961-1972				
		District Heating	202	189	179
		Gas boiler	216	202	193
		Oil Boiler	224	210	193
		Electricity	186	174	168
		Heat pumps	73	65	52
6	1973-1978	Total			
		District Heating	174	153	164
		Gas boiler	186	163	176
		Oil Boiler	194	171	176
		Electricity	160	140	154
		Heat pumps	62	59	50
7	1979-1998				
		District Heating	141	118	153
		Gas boiler	150	126	164
		Oil Boiler	159	134	164
		Electricity	129	108	144
		Heat pumps	52	51	48
8	1999-2006				
		District Heating	94	94	104
		Gas boiler	95	96	112
		Oil Boiler	95	96	112
		Electricity	87	88	69
		Heat pumps	46	40	38
9	2007-2011				
		District Heating	48	48	57
		Gas boiler	49	49	57
		Oil Boiler	49	49	57
		Electricity	74	75	36
		Heat pumps	34	33	34

4.5 Comparison to National Statistical Data of the Residential Building Stock

The statistic of the energy consumptions of residential buildings is made every year by the Danish Energy Agency. The statistic includes both the net energy demands and the energy carriers.

In comparison of national statistic and the TABULA approach, the calculated total energy consumption for heating was climate adjusted according to the number of degree-days in each of the two methods.

Table 20: Number of heating degree days

Danish Statistic 2010	3.221
TABULA Approach – DK	3.118
Difference	3.3%

To calculate the total energy consumption the unit consumption in kWh/m² (internal floor area) was converted to external area using a factor 1.18 (according to the TABULA Excel sheet).

For calculations according to the TABULA approach boundary conditions DK.SUH and DK.MUH described above have been used. The results are shown below.

Table 21: Net Energy Demand for heating and hot water

[PJ]	Single-family houses and Terraced houses	Block of flats
Danish Statistic 2010	109,5	43,4
TABULA Approach – DK	113,3	44,5
Diff. to TABULA Approach - DK	3,4%	2,4%

Table 22: Energy carriers

[PJ]	Boundary	Single-family houses and Terraced houses	Block of flats
Danish Statistic 2010	DK.SUH / DK.MUH	132.012	46.207
TABULA Approach – DK	-	119.515	47.387
Diff. to TABULA Approach - DK	-	-9.5%	-2.6%

4.6 Calculation of Energy Saving Potentials

The technical energy-saving potential is calculated not taking into account different barriers as economy, constructive limitations or architecture.

The different measures follow the recommendations given by the Danish knowledge centre of Energy savings in Buildings.

Recommendations for energy saving measures are:

Table 23: Recommendations for energy saving measures

	Standard	Ambitious
Ceiling	300 mm	400 mm
Wall (outside)	>100 mm	>200 mm
Wall (inside)	50 mm	50 mm
Cavity wall	Filled	Filled
Floor on soil	250 mm	250 mm
Floor above cellar	>100 mm	>200 mm
Windows	with double energy glazing	with triple energy glazing

Energy saving potential is calculated for the two scenarios: Standard and Ambitious.

The results are presented in the table below.

Table 24: Net Energy Demand for heating and hot water

[PJ]	Single-family houses and Terrace houses	Apartment blocks
Reference	113,3	43.7
Standard measures	60.8	24.5
Ambitious measures	57.1	22.4

The total theoretical potential of energy savings are approx. 72 and 78 PJ for the standard and the ambitious measures, respectively. The corresponding CO2 reduction is 3.1 and 3.4 million tons CO2 respectively assuming the current mix of energy sources.
The energy-saving potential is a theoretical figure and not fully achievable for the whole building stock due to previously mentioned barriers of economy, technical and architectural limitations.

4.7 Perspectives and Conclusions

The energy-saving potential is high even considering years of campaigns promoting energy saving, the energy-saving subsidies given and energy saving audits, and the fact that in Denmark the energy consumption has not increased since 1980. The general perception is that much has been achieved and generally house owners claim that they are conscious of their energy consumption, but that further investment in energy-saving measures cannot pay for itself.

Table 25: Sources / References Denmark

Reference shortcut	Short description	Reference
[SBi,1]	The energy consumption of the Danish buildings in 2050	Danske bygningers energibehov i 2050

5 Germany

(by TABULA partner : IWU / Germany)

5.1 Building Typology Approach

The analysis of the German building stock of the year 2009 was carried out with a set of six synthetical average buildings which consider two building size classes(SFH: single family houses with one or two dwellings / MFH: multi family houses with three or more dwellings) and three construction year classes (I – III) according to different levels of energy saving regulations in Germany.[1] The first age band includes the buildings which were constructed until 1978, that means before the first German ordinance on thermal protection[2]. The two later periods (1979 – 1994 and 1995 – 2009) were chosen according to further development of this ordinance (more than one within each period) including the introduction of the more far-reaching energy saving ordinance in 2002.

Table 1 gives an overview of some basic data about the frequency of the six building types in the German building stock[3]:

Table 26: Frequencies of the building types SFH I,II,III and MFH I,II,III in the German building stock

		erection period	number of buildings	number of apartments	livings space in 1000 m²	Tabula reference area in 1000 m²
"Single Family Houses" (<= 2 apartments)	SFH I	until 1978	9610000	12450000	1285000	1413500
	SFH II	1979 - 1994	2710000	3160000	372000	409200
	SFH II	1995 - 2009	2670000	2980000	365000	401500
"Multi Family Houses " (>=3 apartments)	MFH I	until 1978	2340000	14820000	965000	1061500
	MFH II	1979 - 1994	440000	3910000	268000	294800
	MFH III	1995 - 2009	270000	2110000	160000	176000
			18040000	**39430000**	**3415000**	**3756500**

5.2 Available Data

More detailed information of the building types is given in the following tables. Table 27 shows the basic data of the thermal envelope, that means the areas and the U-values of the different elements wall, roof / upper floor ceiling, ground floor / cellar ceiling and windows.

[1] The more differentiated construction year classes of the German Building Typology were merged to form these three building age bands in order to keep the model manageable.

[2] Even before minimal thermal protection standards had been introduced. Those were not yet aiming at energy efficiency but primarily at health protection.

[3] The TABULA reference area was calculated according to the simplified assumption that it is 10 % above the German living space.

Table 27: Basic data of the six synthetical average building types SFH I,II,III / MFH I,II,III

		SFH I	SFH II	SFH III	MFH I	MFH II	MFH III
geometrical data							
(German) living space	m²	133,7	137,3	136,7	412,4	609,1	592,6
TABULA reference area	m²	147,1	151,0	150,4	453,6	670,0	651,9
number of dwellings		1,30	1,17	1,12	6,33	8,89	7,81
wall area	m²	143,5	134,5	121,5	302,6	466,2	385,8
roof area	m²	105,2	109,5	89,2	173,0	303,2	298,2
cellar ceiling area	m²	87,2	89,8	70,2	151,9	271,1	224,8
window area	m²	27,3	29,8	25,3	80,6	141,9	125,3
refurbished fraction of element area							
wall		20%	7%	0%	26%	15%	0%
roof		47%	24%	0%	48%	23%	0%
cellar ceiling		10%	3%	0%	11%	7%	0%
windows		36%	12%	0%	45%	24%	0%
U-values of the not refurbished fraction of the element area							
U-value wall	W/m²K	1,40	0,60	0,28	1,35	0,68	0,39
U-value roof	W/m²K	1,00	0,44	0,33	1,09	0,45	0,34
U-value cellar ceiling	W/m²K	1,24	0,68	0,41	1,45	0,69	0,43
U-value windows	W/m²K	2,70	2,70	1,60	2,70	2,70	1,60
U-values of the refurbished fraction of the element area							
U-value wall	W/m²K	0,35	0,26		0,34	0,27	
U-value roof	W/m²K	0,24	0,18		0,24	0,18	
U-value cellar ceiling	W/m²K	0,37	0,30		0,39	0,30	
U-value windows	W/m²K	1,60	1,60		1,60	1,60	
total number for projections to the German building stock							
(German) living space	Mio. m²	1285	372	365	965	268	160

Three main data sources were used to define the synthetical building types:

- Mean values of the element areas (e.g. wall area related to living space) were derived from an energy certificate data base of the German Energy Agency (dena) which included data from 487 energy certifcates which were issued according to dena's quality assurance scheme.
- The U-values of the not refurbished buildings were calculated as mean values from the respective generic types of the TABULA German building typology (considering the different frequencies of generic building types which belong to the same synthetical type SFH I – MFH III, respectively).
- The U-values of the refurbished element areas and the percentage of refurbished elements[4] were calculated by the data of a representative survey of the German building stock ("Datenbasis Gebäudebestand" [IWU 2010]) which includes the data of more than 7.300 questionnaires which were filled in by owners of residential buildings. In this survey a comprehensive data set was collected about the energy saving measures (insulation measures, heat supply

[4] In principle it would be possible to combine the results of the refurbished and not refurbished fraction of the respective building element area by calculating mean U-values of the building elements. But this would mean a loss of information and it would be misleading if it is intended to use the data sets – beyond TABULA – also for scenario analysis of future energy saving measures: In this case it has to be considered that in the near future at first those elements will be insulated which have not been refurbished before: So the energy savings will have to be calculated based on the insulation of those elements with high U-values whereas applying energy saving measures to mean U-values would not deliver proper results.

systems, solar systems) which were carried out – at the time of building construction or during later building modernisation.

The data of the representative survey were also used for the analysis of the heat supply structure of the building types. In Table Table 28 a rough overview is given, more detailed data were considered concerning the insulation of heat distribution systems[5], the type of heat generator (e.g. boilers), the application of solar systems and ventilation systems, for example.

Table 28: Heat supply structure of the building types SFH I – MFH III (overview)

percentages related to: dwellings in all residential buildings of the classes SFH I - MFH III		SFH			MFH		
Heat Generators for Space Heating		SFH I	SFH II	SFH III	MFH I	MFH II	MFH III
Heat Generators	***Energy Carrier***						
	District Heating						
	District Heating	1,4%	2,3%	3,6%	12,0%	22,2%	11,6%
	Building / Apartment Heating Systems						
Boilers	Gas	43,6%	48,1%	66,4%	52,5%	61,9%	77,9%
	Oil	39,4%	40,6%	18,7%	25,6%	12,7%	5,2%
	Biomass	4,1%	3,0%	2,9%	2,3%	0,5%	3,2%
	Coal	0,3%	0,0%	0,0%	0,1%	0,0%	0,0%
Heat Pump	Electricity	1,0%	1,7%	6,1%	1,3%	0,0%	1,4%
	Gas	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
CHP Enginge	Gas	0,0%	0,0%	0,0%	0,1%	0,0%	0,3%
direct electric	Electricity	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
	Room Heating Systems						
Stoves	Gas	1,4%	0,0%	0,0%	1,2%	0,1%	0,0%
	Oil	1,4%	0,3%	0,2%	0,9%	0,1%	0,0%
	Biomass	3,8%	0,3%	0,8%	1,3%	0,0%	0,0%
	Coal	0,7%	0,0%	0,0%	0,6%	0,0%	0,0%
direct electric	Electricity	2,9%	3,7%	1,3%	2,1%	2,5%	0,4%

	percentages related to: dwellings in all residential buildings of the classes SFH I - MFH III	SFH			MFH		
		SFH I	SFH II	SFH III	MFH I	MFH II	MFH III
	Summary: Energy Carriers						
	District Heating	1,4%	2,3%	3,6%	12,0%	22,2%	11,6%
	Gas	45,0%	48,1%	66,4%	53,8%	62,0%	78,2%
	Oil	40,8%	40,9%	18,9%	26,5%	12,8%	5,2%
	Biomass	7,9%	3,3%	3,7%	3,6%	0,5%	3,2%
	Coal	1,0%	0,0%	0,0%	0,7%	0,0%	0,0%
	Electricity	3,9%	5,4%	7,4%	3,4%	2,5%	1,8%

5.3 Energy Balance Method

In general, the energy balance model was developed on basis of the available statistical input data. The energy demand for space heating of the considered six building types was calculated according to a seasonal energy balance approach which is similar to the approach of the TABULA webtool or to other seasonal methods (e.g. [LEG]). Some additional assumptions had to be made here, e. g. the internal temperature of the buildings was not considered to be a constant value (e. g. 19,5 ^{o}C) as in usual seasonal balance methods, but according to practice experience [IWU 2003] it was considered that average room temperatures in non-modernised buildings are on average considerably lower than in those buildings which were already insulated (here assumed: temperature difference of about 3 K between buildings with a very low and a very good insulation level)[6].
The efficiency values of the different heat supply systems were set in the range of typical values which are used for energy balance calculations in Germany (close to the German TABULA heating system typology). In general, the energy balance model was developed on basis of the applied statistical input data. So some simplifications were made (e.g. different values of the efficiency of boilers were considered for constant temperature, low temperature and condensing boilers but

[5] Three different levels (“not refurbished”, “partly refurbished (typical measures)” and “modernised (advanced measures)” were considered for central distribution systems for space heating and hot water, respectively.

[6] This results in lower energy saving potentials than in the case with constant temperatures.

within those subsets different installation years were not considered separately). Additional assumptions were sometimes necessary: For example it had to be considered that in a considerable part of the German building stock wood fired stoves are applied as additional heating systems, but there is no information available about their contribution to space heating. Here it was assumed that they contribute with 15 % to the heat demand for space heating.

5.4 Energy Balance of the Residential Building Stock

The following tables show the results of the energy balance calculations for the German building stock 2009. The energy consumption values are shown in units of billion (10^9) kilowatt-hours (kWh). The heat consumption and the final energy consumption are depicted separately for the six building categories. The final energy of fuels (gas, oil, coal biomass) is related to the net calorific value to make possible a comparison with national statistics which usually use the net calorific value[7].

Table 29: Heat consumption of the German residential building stock (2009) for space heating and hot water (model calculations)

	SFH I	SFH II	SFH III	MFH I	MFH II	MFH III	total
heat consumption (10^9 kWh/a)							
useful heat for space heating	211,2	43,7	24,5	113,2	25,9	9,8	**428,3**
distribution losses for space heating	16,7	4,6	2,9	12,4	3,5	1,9	**42,0**
useful heat for hot water	21,8	6,3	6,2	11,6	3,2	1,9	**51,1**
distribution losses for hot water	19,3	5,4	3,9	12,1	3,1	1,9	**45,8**
total heat consumption	**268,9**	**60,0**	**37,6**	**149,3**	**35,7**	**15,5**	**567,1**

Table 30: Final energy consumption of the German residential building stock (2009) for space heating and hot water (model calculations, in case of fuels: net calorific value)

	SFH I	SFH II	SFH III	MFH I	MFH II	MFH III	total
final energy consumption for space heating (10^9 kWh/a)							
district heating	3,2	1,1	1,0	15,6	6,6	1,4	**28,8**
gas	106,6	22,9	17,6	73,3	19,6	9,6	**249,5**
oil	98,0	19,9	5,1	36,6	4,1	0,6	**164,4**
biomass	32,4	6,0	3,0	7,5	0,4	0,6	**49,9**
coal	2,2	0,0	0,0	0,8	0,0	0,0	**3,0**
electricity	8,0	2,3	1,4	3,9	0,9	0,3	**16,8**
total	**250,4**	**52,2**	**28,1**	**137,6**	**31,7**	**12,4**	**512,4**
final energy consumption for hot water (10^9 kWh/a)							
district heating	0,6	0,3	0,4	2,3	1,1	0,4	**5,1**
gas	18,6	5,7	5,6	12,0	3,3	2,8	**48,1**
oil	14,0	4,2	1,5	5,1	0,7	0,2	**25,7**
biomass	1,5	0,3	0,3	0,5	0,0	0,1	**2,8**
coal	0,0	0,0	0,0	0,0	0,0	0,0	**0,0**
electricity	5,1	0,8	0,7	3,5	1,1	0,4	**11,5**
total	**39,8**	**11,3**	**8,5**	**23,4**	**6,2**	**3,9**	**93,0**
total final energy consumption for space heating and hot water (10^9 kWh/a)							
district heating	3,7	1,3	1,4	17,9	7,7	1,8	**33,8**
gas	125,2	28,6	23,2	85,3	23,0	12,3	**297,6**
oil	112,0	24,1	6,7	41,6	4,8	0,8	**190,0**
biomass	33,9	6,3	3,3	8,0	0,5	0,7	**52,7**
coal	2,2	0,0	0,0	0,8	0,0	0,0	**3,0**
electricity	13,1	3,0	2,1	7,4	2,0	0,7	**28,3**
total	**290,1**	**63,4**	**36,7**	**161,0**	**37,9**	**16,3**	**605,4**

[7] In contrast final energy balance calculations within the TABULA project are usually related to the gross calorific value.

The value of electricity consumption includes electric energy used for heat generation (directly or by electric heat pumps) as well as auxiliary energy of the heat supply system (e. g. for pumps of distribution systems, device control, ventilation systems).

The following table shows the primary energy consumption and the CO2 emissions. The later are defined as direct emissions in the residential buildings or emissions in power plants and district heating plants which are related to the district heat or electricity delivered to residential buildings to cover heat supply. CO_2 equivalent values of other greenhouse gases are not considered.

Table 31: Primary energy consumption (left) and CO_2 emissions (right) of the German residential building stock (2009) for space heating and hot water (model calculations)

primary energy consumption (10^9 kWh/a)	
district heating	28,7
gas	327,3
oil	209,0
biomass	10,5
coal	3,6
electricity	82,1
total	**661,4**

CO_2 emissions (10^6 t/a)	
district heating	5,9
gas	60,1
oil	50,5
biomass	2,1
coal	1,1
electricity	16,7
total	**136,5**

5.5 Comparison to National Statistical Data of the Residential Building Stock

In Table Table 32 the model results are compared with the national energy balance (mean values of actual consumption of households). Because of the deviations of annual climate parameters a direct comparision with the consumption values of the single year 2009 did not appear appropriate, instead mean values of the period 2005 – 2009 are given. The source of the values is a publication of the German federal ministry of economy [BMWi 2011] which is based on the results of the “Arbeitsgruppe Energiebilanzen” (AGEB,German energy balance working group) .

Table 32: Comparison of model results with national energy statistics
(mean values 2005 – 2009, in case of fuels: net calorific value)

	National Energy Balance				
	Energy Consumption (10^9 kWh)				
	National Statistics average 2005-2009 (Energy Consumption of households)	**TABULA model**	**deviation**	related to: single value	related to: total value
district heating	43	34	-10	-22%	-1,63%
gas	272	298	25	9%	4,31%
oil	171	190	19	11%	3,29%
biomass	59	53	-6	-10%	-1,00%
coal	11	3	-8	-72%	-1,32%
electricity*	34	28	-6	-17%	-0,96%
Summe	**590**	**605**	16	3%	2,69%

* electricity for heating and hot water (estimations)

The table shows that the model calculations fit satisfactory with the values of the national energy balance. The deviations of the most important energy carriers gas and oil are about 10 %, some other deviations are highter (e.g. 22 % in the case of district heating)[8]. Related to the total final energy consumption of 590 billion kWh the deviations are all below 5 %. The deviation of the total value is around 2,7 %.
It has to be considered that – besides the questions of annual climate and time development since 2005 – the quoted national statistics are to some extent uncertain because the delivered values

[8] The high percentage deviation of the energy consumption of coal (72 %) does not play a considerable role because of the very small contribution of coal to the building stock energy balance.

can not be directly measured: Analyses have been done by AGEB for example to break down total values of energy consumption (e. g. of gas consumption) to the different consumption sectors (here: households). The value of electricity consumption which is here only related to space heating and hot water supply (and not including other household appliances) is especially uncertain. It was derived from a separate analysis by AGEB regarding the energy balance of the year 2008 [AGEB 2011].

5.6 Calculation of Energy Saving Potentials

Based on the described model an estimation of energy saving potentials in the German building stock for heating and hot water supply was carried out.
Two quality levels of energy saving measures were considered which are shown in Table 33[9].

Table 33: Assumed energy saving measures

	level 1	level 2
U-value of walls	0,24 W/m²K	0,16 W/m²K
U-value of roofs / upper floor ceilings	0,24 W/m²K	0,14 W/m²K
U-value of ground floors / cellar ceilings	0,3 W/m²K	0,2 W/m²K
U-value of windows	1,3 W/m²K	0,8 W/m²K (passive house windows)
insulation of heat distribution pipes (for space heating and / or hot water supply)	50 % second best, 50 % best level	100 % best level
heat supply by oil / gas boilers	100 % condensing boilers	100 % condensing boilers
replacement of room heating systems	no progress	100 % gas condensing boilers
application of heat recovery ventilation systems	no progress	100%
solar thermal systems (support of hot water supply and space heating)	no progress	100%
hot water generation	no changes	100 % by central heating system

Table 34 shows the results of the model calculations:

Table 34: Calculated energy savings by applying the level 1 and level 2 measures to the current (2009) German residential building stock

energy consumption (10^9 kWh/a)				related to 2009	
	actual (2009)	level 1	level 2	level 1	level 2
useful heat for space heating	428	198	86	46%	20%
distribution losses for space heating	42	31	20	74%	48%
useful heat for hot water	51	51	51	100%	100%
distribution losses for hot water	46	36	26	78%	58%
total heat consumption	**567**	**316**	**183**	**56%**	**32%**
total final energy consumption	**605**	**316**	**149**	**52%**	**25%**
total primary energy consumption	**661**	**357**	**179**	**54%**	**27%**
total CO_2 emissions (10^6 t/a)	**136**	**73**	**36**	**54%**	**27%**

9 In terms of thermal protection the first level roughly reflects the standards of the current German energy saving ordinance for modernisation measures, the second level is close to the passivehouse standard. Both are also similar to (but not identical with) the levels "typical" and "advanced" which were applied to the generic building types in the German TABULA typology brochure [IWU 2011].

At level 1 the achieved primary energy consumption and CO_2 emission amount to about 55 % of the original value, that means that the reduction of energy consumption and emissions is around 45 %.

At level 2 the heat consumption is reduced to about a third of the original value. Together with the additional changes of the heat supply structure this results in values of primary energy and CO2 emissions which are at about 27 % of the original value. Thus more than 70 % of primary energy and CO2 emissions could be saved by applying the level 2 measures to the complete building stock.

This exemplary model analysis demonstrates the energy savings which could theoretically be achieved in the building stock if in the first place a consequent thermal protection of the buildings and a thus reduction of heat consumption could be achieved. Of course this is only a hypothetical calculation of technical energy saving potentials according to different levels of quality. These calculations can be seen as a first test application of the model. It is intended to give a rough impression of the magnitude of energy saving potentials which could be attained if there was a consequent reduction of the buildings' heat demand, but the results are based on rough and simplified assumptions and thus can not be seen as a part of a realistic scenario.

In practice there are of course some obstacles in the building stock (for example but not only at historical monuments) which will not permit the general achieving of level 2 measures. In future scenario analysis realistic annual refurbishment rates will have to be considered as well as the influence of the new construction sector and demolition of buildings (of which the later does not play a major role in Germany until now). Besides, even more far-reaching changes in the energy supply structure, e.g. a more significant use or renewable energies should be taken into consideration.

5.7 Perspectives and Conclusions

The described model and the exemplary calculations demonstrate the application of the building typology concept to energy balance analysis of the German building stock. By defining a manageable number of six synthetical average buildings which reflect the current state of building modernisation and the current heat supply structure a satisfactory approximation of the energy consumption of the German building stock could be attained. Exemplary calculations of technical energy saving potentials were carried out to demonstrate first steps towards future applications of the model in the framework of scenario analysis.

Table 35: Sources / References Germany

Reference shortcut	Short description	Reference
[AGEB 2011]	Study of the national energy balance working group	Arbeitsgemeinschaft Energiebilanzen e. V., Anwendungsbilanzen für die Endenergiesektoren in Deutschland im Jahr 2008, Berlin, Februar 2011
[BMWi 2011]	National energy balance (published by German Minstry of economy)	Energiedaten – Zahlen und Fakten, Stand: 7.9.2010 (Excel-Tabelle), www.bmwi.de
[IWU 2003]	in this study a model for a typical user in residential buildings is defined, the models are based on analyses of several research studies	Loga, Tobias; Großklos, Marc; Knissel, Jens: Der Einfluss des Gebäudestandards und des Nutzerverhaltens auf die Heizkosten – Konsequenzen für die verbrauchsabhängige Abrechnung. Eine Untersuchung im Auftrag der Viterra Energy Services AG, Essen; IWU Darmstadt, Juli 2003
[IWU 2010]	Final report of the project „Datenbasis Gebäudebestand“	N. Diefenbach et al., Datenbasis Gebäudebestand – Datenerhebung zur energetischen Qualität und zu den Modernisierungstrends im deutschen Wohngebäudebestand, Institut Wohnen und Umwelt, Darmstadt, Dezember 2010
[LEG]	calculation procedure for the energy balance of buildings and supply systems	Leitfaden Energiebewußte Gebäudeplanung; Hg.: Hessisches Ministerium für Umwelt, Energie, Jugend, Familie und Gesundheit; Wiesbaden 1995
[Typology Brochure 2011]	German Building Typology Brochure	Loga, Tobias; Diefenbach, Nikolaus; Born, Rolf: Deutsche Gebäudetypologie. Beispielhafte Maßnahmen zur Verbesserung der Energieeffizienz von typischen Wohngebäuden; IWU, Darmstadt 2011

6 Greece

(by TABULA partner NOA/Greece)

6.1 Building Typology Approach

The Hellenic typology consists of **24 building types**, derived after a classification of the residential building stock in three **time construction periods – age bands** (prior to 1980, 1981-2000 and 2001-2010), two **sizes** (single family, multifamily) and four **climatic zones** defined according to the number of heating degree days (Zone A (601– 1100), Zone B (1101– 1600), Zone C (1601–2200) and Zone D (2201– 2620)). The buildings included in the typology are real examples that can be considered as representative of the corresponding classes. However, due to peculiarities in their initial construction or refurbishment actions taken on their envelope and/or system installations over the years, they may not reflect the typical buildings of their class. Thus, the set of buildings included in the TABULA typology has to be elaborated before it is used in the building stock balance model.

The derivation of the national energy balance was based on “**typical**” **buildings** defined for each of the 24 typology classes. In order to define the characteristics of the “typical” buildings in all the building classes of the Hellenic typology, it would be necessary to have detailed statistical data regarding the construction and system installations in the building stock. Due to the lack of official national data in the required level of detail, it was decided that the “typical” buildings used in this study would have the same architectural features as the “real examples”. In collaboration with experts active in the field of building construction, who also participate in the TABULA National Advisory Group (NAG), a mapping of the residential building stock at its current status was attempted regarding the most common construction types as well as systems for space and domestic hot water (DHW) heating. As a result, the Building Elements and the System sub-typologies were created, containing all the different types of opaque (walls, roofs, floors) and transparent elements as well as the system installations found in the Hellenic residential buildings. Different percentages were assigned to the various types of elements and systems reflecting their frequency of occurrence in the different parts of the building stock depending on the building size, age band and climatic zone [1].

The thermal characteristics of the typical building envelope (U-values for opaque and transparent elements as well as g-values for transparent elements) were derived as weighted averages using the frequencies of occurrence for all the existing types defined in the building element typology for each different class. Similarly, the installed system characteristics (performance coefficients for heat generation and distribution systems) were derived as weighted averages using the frequencies of occurrence for all the system types defined in the system typology for each different class.

6.2 Available Data

In order to form a building stock model it is necessary to determine frequencies for each building type. The main data sources for the derivation of the statistical data required for this analysis include:

- The Hellenic Statistical Service

- Existing and on-going studies
- National standards and regulations providing information on building construction types and heat supply systems
- Empirical data for the Hellenic building stock

Table 36 outlines the data that could be retrieved from the above sources regarding the Hellenic residential building sector.

Table 36: Available frequencies regarding the Hellenic residential building stock

Frequency	Description of data (availability: per building size, age band and climatic zone)
Building types of the national building stock	Number of buildings, floor area (m^2)
Insulation level and window types	Number/and percentage of buildings with - non-insulated walls/roofs - partly insulated walls/roofs
Centralization of the heat supply (for space heating)	Percentages of buildings
Heat generation (for space heating)	Percentages related to number of buildings with central heating sys-tems
Solar thermal systems	Percentages of apartments in SFH/MFH buildings
Air conditioning systems	Number of apartments in SFH/MFH buildings
Control of central heating systems	Number of buildings

However the level of detail of the above data is not sufficient for deriving the building stock model. Frequencies of buildings corresponding to the different element and system types are not available in sufficient detail, while information on their state of modernization (refurbishment action, year) is restricted to the insulation level (absent, partial or full). Moreover, heat generation systems are not reported in detail, neither for water nor for space heating, while no frequencies are available on heat distribution systems what so ever.

The gaps in the availability of frequencies are attributed to the absence of systematic collection of the data. Most of the statistical data on the residential building sector come from the latest Censuses carried out in 1990 [4] and 2000 [5]. These data include number and size of buildings as well as floor area per building age band and geographic region. Further analysis carried out in the framework of the national project "Evaluation of supporting policies for the advancement of the Ministry's policies in relation to the abatement of CO_2 emissions in the residential and tertiary Sectors', which was financially supported by the Hellenic Ministry for the Environment, Physical Planning and Public Works, Directorate Urban Planning & Housing - MEPPPW [2] and published in [3] resulted in frequency distributions of buildings according to their level of thermal insulation, the installed systems for heat generation and the presence of solar systems for hot water heating.

In the absence of sufficient official data for the derivation of the national energy balance model it was decided to use "typical buildings", as mentioned in the previous section. The thermo-physical properties of the envelope, as well as the expenditure coefficients per "typical" building, were derived as weighted averages per building class. The weighting factors for each category were well educated guesses derived in collaboration with NAG experts active in the field of construction and are, at present, a realistic estimate of the evolution of the construction and renovation trends over the years. Table 37 summarizes the resulting "typical" values of the thermal transmission coefficient for the main components of the building envelope for each of the 24 building classes of the Hellenic residential building typology.

Table 37: "Typical" values (weighted averages) of the thermal transmission coefficient (kWh/m²K) for the main components of the building envelope

	Single Family Houses (SFH)			Multi Family Houses (MFH)		
	-1980	*1980-2000*	*2000-*	*-1980*	*1980-2000*	*2000-2001*
Climatic Zone ***A***						
Wall	2.36	1.28	1.01	2.13	1.11	0.81
Roof	3.12	1.68	0.91	2.96	1.33	0.72
Floor	3.07	2.95	2.94	3.07	2.21	2.08
Window -U	4.89	4.82	3.33	5.14	4.88	4.40
- g	0.60	0.57	0.54	0.62	0.58	0.55
Climatic Zone ***B***						
Wall	2.02	0.96	0.86	2.06	1.09	0.75
Roof	2.72	1.09	0.70	2.85	1.28	0.62
Floor	2.60	2.02	1.93	2.13	1.52	1.00
Window -U	4.71	4.51	3.33	4.99	4.25	3.55
- g	0.59	0.56	0.54	0.61	0.51	0.55
Climatic Zone ***C***						
Wall	2.02	0.96	0.86	2.06	1.09	0.75
Roof	2.72	1.09	0.70	2.85	1.28	0.62
Floor	2.28	1.01	0.79	2.68	1.21	0.74
Window -U	4.71	4.51	3.33	4.99	4.25	3.55
- g	0.59	0.56	0.54	0.61	0.51	0.55
Climatic Zone ***D***						
Wall	2.61	1.02	0.86	2.00	1.02	0.75
Roof	3.06	1.15	0.71	2.76	1.20	0.62
Floor	2.47	1.00	0.79	2.10	1.06	0.66
Window -U	4.63	4.33	3.33	4.92	4.52	3.53
- g	0.60	0.56	0.54	0.61	0.56	0.55

Similarly, Table 38 summarizes the “typical” expenditure coefficients (based on the Higher Calorific Value) for the systems installed in the 24 buildings of the Hellenic typology, based on their size and time construction period. In this case, no distinction is made for different climatic zones, since they are applicable for the entire country.

Table 38: “Typical” values (weighted averages) of the expenditure coefficient (higher calorific value) for the space and water heating systems

	Single Family Houses (SFH)			Multi Family Houses (MFH)		
Energy carrier	***-1980***	***1980-2000***	***2000-2010***	***-1980***	***1980-2000***	***2000-2010***
Space Heating Systems						
Fuel	1.38	1.30	1.22	1.37	1.25	1.20
Electricity	0.97	0.64	0.29	0.94	0.71	0.28
Water Heating Systems -						
Fuel	1.33	1.26	1.31	1.35	1.26	1.31
Electricity	1.05	1.03	1.03	1.05	1.03	1.03

Finally, Table 39 summarizes the “typical” performance coefficients for the distribution system. In this case, no distinction is made for different building sizes or energy end use, so they are applicable for the entire building stock based on the time construction period.

Table 39: “Typical” values (weighted averages) of the performance coefficient for the distribution systems of single and multi family houses, according to the insulation level of the system.

Level of insulation	*Single / Multi Family Houses*		
	- 1980	***1980-2000***	***2000-2010***
Pipelines non/partly insulated	0.89	0.93	0.93
Pipelines well insulated	0.97	0.97	0.97

Further assumptions that were made for some parameters affecting the performance of the “typical” buildings are summarized in Table 40.

Table 40: Parameters affecting the energy performance of the "typical" buildings

Infiltration (m^3/hm^2_{window})	
Single glazing, wooden frame	13.45
Double glazing, wooden frame	11.15
Single glazing, aluminium/PVC frame	8.05
Double glazing, aluminium/PVC frame	6.05
Thermal bridges	
Prior to 1980	No
After 1980	Yes, medium ($U_{opaque\ elements}$+0.1 W/m^{2}K)
Space heating system controls	
Prior to 1980	no controls
After 1980	Zone thermostats, Indoor-outdoor temperature compensation
Performance of heat emission components – space heating	
heating medium: high temperature water (ie: radiators, convectors)	0.87
heating medium: low temperature water (ie: fan coils, underfloor systems)	0.91
Performance of heat emission components – DHW heating	
Local systems (ie. electric heaters)	0.98
Central systems	0.95
Performance of heat distribution systems – DHW heating	
Local systems (ie. electric heaters)	1
Central systems, insulated	0.92
Central systems, non-insulated	0.84
Domestic hot water lt/(person·day)	
	50

6.3 Energy Balance Method

In Greece, the "Regulation on the Energy Assessment of Buildings – KENAK" (Ministerial Decision D6/B/5825) was published in April 2010. It outlines the general calculation approach that is in accordance to European standards, the use of a reference building for benchmarking, the requirements for energy performance certificates (EPCs) based on an asset rating accounting for heating, cooling, ventilation, DHW and lighting, the minimum energy performance requirements and thermal envelope heat loss constraints, etc. In response to these requirements, the TEE-KENAK software was developed and is being used as the official national calculation tool for the implementation of KENAK. The TEE-KENAK software was developed by NOA for the Technical Chamber of Greece (TEE), based on a preceding energy performance assessment tool developed within the framework of a European project (www.epa-nr.org). The calculation engine of TEE-KENAK was upgraded to meet both the final European Standards and the national requirements incorporating the relevant national technical guidelines prepared by TEE, the concept of the reference building for benchmarking, technical libraries, weather data, user's guide etc. The calculations are performed according to EN 13790 (2008) for preparing an EPC and assessing energy conservation measures, taking into account the national technical guidelines (TOTEE). The TEE-KENAK software is used as a stand-alone tool for energy audits and benchmarking, and is also adapted by all commercial software companies that develop building design tools for engineers.

Calculations for heating/cooling demand are based on the monthly method, where most input information is provided as a monthly average or as a monthly total. Residential buildings are considered to operate on a default 18hr per day basis, throughout the year, based on the national technical guidelines. Lighting in the case of residential buildings is only considered as a fixed value

(=0.1W/m^2 heated space) and it only affects the energy demand without being included in the energy consumption breakdown report for the building.

The TEE-KENAK software provides results on the energy demand, consumption per energy-end use, primary energy and CO_2 emissions for a building in its actual state, but also for energy conservation measures/scenarios taken on the envelope and/or the electromechanical (E/M) installations. In the case of retrofit interventions, the investment cost is also calculated along with the resulting simple payback period and the annual savings on energy and operating cost.

Accordingly, the TEE-KENAK software was used for the calculation of the national energy balance of the residential sector. Average climatic data were used for each of the four climatic zones. TABULA focuses on the heating energy for space and DHW, which represents the greatest part of the total energy consumed by the residential sector. Therefore, the balance calculations are restricted to the heating energy consumption. Despite the penetration of solar collectors for domestic hot water preparation, the most common energy carrier serving as the main source or as an auxiliary source for DHW heating in Greece is electricity. A small percentage of buildings use a central oil boiler for DHW production. Among the 24 buildings included in the Hellenic typology only three use oil for water heating; the rest uses electrical heaters.

Moreover, in the available data from the published national energy balances the electrical energy consumption is not reported per energy-end use. Consequently, the officially reported electricity consumption includes additional energy consumed for lighting and household appliances and it is not possible to separate the part that corresponds to the consumption for space and/or DHW. Therefore, the **energy balance** in the present study is calculated taking into account only **thermal energy consumption**; electricity as well as the part covered by renewable energy sources, are excluded.

The procedure includes the following steps:
1) Use TEE-KENAK software for the calculation of the heating energy consumption of the 24 “typical” buildings representing each of the classes included in the Hellenic typology.
2) Use frequencies expressing the number of buildings per typology class to derive the total heating energy consumption per class.
3) Sum up the thermal energy consumption of all classes to derive the balance of the heating energy consumption in the residential building sector.

6.4 Energy Balance of the Residential Building Stock

The buildings considered in this study are permanent dwellings, with continuous occupancy throughout the year and do not include summer (vacation) dwellings. The permanent dwellings average about 68% of the total dwellings stock throughout the country [4]. The floor area of permanent dwellings for each of 24 residential buildings categories is given in Table 41. This data has been published in [3] and it is based on available information from:

- a detailed register of 6550 dwellings, which was performed during the period 1987–1988 [6]
- results of the 1990 census [4]
- the construction activities after 1990 [7]

The corresponding data for the period 2000-2010 was estimated based on the assumption that the annual growth rate of the number of dwellings during 2002–2010 is equal to the average of the two previous decades. During the 1980s, the average annual growth rate of the number dwellings was 1.65%, while during the 1990s it dropped to 1.46% [3].

The TEE-KENAK software was used for the calculation of the heating energy consumption of the 24 “typical” buildings representing each of the classes included in the Hellenic typology. Results are summarized in Table 41.

Table 41: Total floor area per building class in the Hellenic permanent residential building stock and calculation results for "typical" buildings using the TEE-KENAK software.
The (+) sign indicates that SFH buildings of the class use an oil boiler for both space and DHW heating.

Climatic Zone	Age Band	Total floor area - entire building stock (m^2)		Primary energy (*) ($kWh/m^2_{heated\ floor\ area}$)		Energy Demand (**) ($kWh/m^2_{heated\ floor\ area}$)		Energy Consumption (*) ($kWh/m^2_{heated\ floor\ area}$)	
		SFH	MFH	SFH	MFH	SFH	MFH	SFH	MFH
A	1	24010738	2987390	216.4	92.9	112.8	66.2	195.2	80.8
	2	16535476	6309271	219.9	61.7	152.5	56.3	197.3	52.8
	3 (+)	13226145	6119221	87.6	47.2	59.6	57.1	80	38.4
B	1	59222241	52591634	228.3	151.1	124.7	100.7	204.9	132.8
	2 (+)	30665932	38614093	98	89.1	61.6	69.3	89.5	78.6
	3	18726225	35037293	138.1	67.7	108.2	74	122.8	56.6
C	1	45250489	18500091	282.5	288.5	159.5	182.2	252.3	254.5
	2	23051218	19554006	183.3	131.90	140.4	101.3	162.3	115.70
	3 (+)	16257744	18483636	228.3	79.50	138.1	68.9	178.4	68.90
D	1	5193004	527809	566.9	327.10	301.7	299.4	511	458.00
	2	3184299	1248487	338.7	129.10	252.9	151.4	298.7	177.70
	3	2475032	1145100	221.7	112.80	170	97.5	197.5	98.10

(*):space heating only (auxiliary systems included), (**):space and DHW heating

In order to derive the thermal energy consumption for the entire residential building stock it was necessary to transform the total floor area into heated floor area. For this purpose, the heated floor area was calculated as a percentage of the total floor area given in Table 41. Specifically, it was assumed that the percentages of the total floor area that is actually heated are 70% and 80% for SFH and MFH buildings, respectively. This assumption is necessary in order to account for unheated areas, e.g. corridors, stairwells, cellars as well as basements that are usually unheated spaces.

Using the TEE-KENAK software with the data from Table 37 to Table 40 and taking into account the above assumptions, the energy balance for the residential building stock was derived. Results are summarized in Table 42. The "thermal" part of the energy consumption includes mainly space heating and only in three cases (buildings marked with the (+) sign in Table 41) where oil boilers are used for DHW preparation, it also includes water heating. The "electrical" part includes mainly DHW heating and the consumption of the auxiliary heating systems (e.g. pumps).

Table 42: Calculation results for different quantities of energy balance for permanent residential building stock (year 2010)

	Energy Consumption (Mtoe)			Energy Demand (Mtoe)			Primary Energy (Mtoe)			CO_2 (Mt)		
	SFH	*MFH*	*Total*	*SFH*	*MFH*	*Total*	*SFH*	*MFH*	*Total*	*SFH*	*MFH*	*Total*
Thermal	2.87	1.47	**4.35**							9.37	2.55	**11.91**
Electrical	0.31	0.39	0.70									
Space Heating				1.72	0.93	2.65						
DHW				0.25	0.35	0.60						
Total	3.19	1.86	5.05	1.97	1.28	3.25	3.87	2.55	6.42			

6.5 Comparison to National Statistical Data of the Residential Building Stock

The following analysis is based on national data on the energy consumption as reported by the Hellenic Ministry of Environment and Climatic Change – YPEKA [8] for the years 2000-2008 and CO_2 emissions taken from official reports of the European Union [9] for the years 2000-2007. Table 43 summarizes the official energy consumption and CO_2 balance reported for the Hellenic residential building sector.

Table 43: The official energy consumption and CO_2 emission balance reported for the Hellenic residential building sector [7-8]

Year	All energy sources (ktoe)	Electricity (ktoe)	RES (ktoe)	Thermal (ktoe)	Thermal (Mtoe) - permanent dwellings (*)	CO_2 emissions (Mt)
2000	4486	1222	801	2463	2.27	7.60
2001	4701	1251	801	2649	2.44	8.20
2002	4914	1356	800	2758	2.54	8.40
2003	5485	1414	799	3272	3.01	10.00
2004	5381	1449	801	3131	2.88	9.60
2005	5488	1451	803	3234	2.98	9.90
2006	5490	1520	816	3154	2.90	9.50
2007	5330	1544	921	2865	2.64	8.60
2008	5142	1559	777	2806	2.58	

(*) calculated values

In order to derive the thermal energy consumption of the permanent dwellings it was assumed that non-permanent dwellings, which represent 32% of the total residential building stock, operate for only 3 months per year. The values of the thermal energy consumption were adjusted accordingly.

The CO_2 emissions from households reported in [9] refer to space and DHW heating excluding the related electricity consumption [3]; therefore, they refer to the thermal part of the energy consumption. Based on the energy consumption and CO_2 emission data reported in Table 43, the average annual growth rate (AAGR) was derived. Specifically:

AAGR (thermal energy consumption)$_{2000\text{-}2008}$ = 1.46%
AAGR (CO_2 emission)$_{2000\text{-}2007}$ = 1.56%

Given that the present analysis aims to reflect the building stock for the year 2010, the corresponding values of the thermal energy consumption and CO_2 emissions were estimated using the corresponding AAGRs. The resulting values were:

- Estimated thermal energy consumption for permanent dwellings (2010) = 2.66 Mtoe
- Estimated CO_2 emissions from permanent dwelllings (2010) = 8.29 Mt

A comparison of the initial energy balance results presented in section 2.2.4 with the corresponding official national balance reveals an overestimation of about 63% in the thermal energy balance. As mentioned in section 2.2.3, the TEE-KENAK software performs the calculations based on a default 18hr per day operation of residential buildings throughout the year. In order to adapt the results in order to reflect the actual operating hours of residential buildings, the initial consumption and CO_2 emission results (Table 41) were adjusted on the basis of the following assumptions that were derived in collaboration with experts from NAG, who are active in the field of building construction and maintenance. At present, as there is no official reference on this issue, the following assumptions are considered to be a realistic approximation of the Hellenic residential building stock operating patterns:
-SFH buildings: 10% have an 18 hr and 90% have a 12 hr operation per day
-MFH buildings: 10% have a 12 hr and 90% have a 9 hr operation per day
The resulting adapted energy balance to reflect the actual operating hours is summarized in Table 44.

Table 44: Adapted calculation results for different quantities of energy balance for the permanent residential building stock (year 2010)

	Energy Consumption (Mtoe)			Energy Demand (Mtoe)			Primary Energy (Mtoe)			CO_2 (Mt)		
	SFH	*MFH*	*Total*	*SFH*	*MFH*	*Total*	*SFH*	*MFH*	*Total*	*SFH*	*MFH*	*Total*
Thermal	2.01	0.76	**2.77**							6.56	1.32	**7.87**
Electrical	0.28	0.39	0.66									
Space Heating				1.21	0.48	1.68						
DHW				0.25	0.35	0.60						
Total	2.29	1.15	3.44	1.46	0.83	2.29	2.71	1.32	4.03			

Comparison of the adapted calculated thermal energy balance (Table 44) with the officially reported value reveals that the adjustment improved the predictions significantly, as the overestimation dropped down to 4.2%. The CO_2 emissions were found to be underestimated by approximately 5%. These deviations are considered to be acceptable for the level of detail of the present study.

6.6 Calculation of Energy Saving Potentials

Transposition of the European Directive 2006/32/EC took effect in June 2010 by the national law N.3855/2010, introducing various energy efficiency improvement measures, energy service companies - ESCOs, third party financing - TPF and other instruments, in order to achieve by 2016 an overall national indicative target of 9% energy conservation. Applying this target to the thermal energy consumption of residential buildings it is found that it should reach 2.44 Mtoe in 2016. As discussed in section 2.2.5, the average annual growth rate over the period 2000-2008 is about 1.46%. Using this rate for the business as usual (BaU) scenario, the thermal energy consumption for 2010 and 2016 is estimated to reach 2.66 and 2.90 Mtoe, respectively.

Figure 2 illustrates the evolution of the annual thermal energy consumption for the Hellenic permanent residential building stock, with 2008 being the year with the most recent published data. Accordingly, the national indicative target of 9% for 2016 applied to the thermal energy consumption of permanent residential buildings requires savings of 0.54 MToe from 2005 data. Savings can be achieved through energy efficient measures and scenarios. In the framework of TABULA two different scenarios have been studied: the Standard and the Ambitious scenario, which target different levels of interventions in the buildings' thermal envelope and E/M installations with the exploitation of renewable energy sources (RES).

The "**Standard**" scenario aims at upgrading the buildings of the first two time construction periods (pre-1980, 1980-2000) to meet the national standards for major refurbishment of buildings, in accordance with KENAK for the four climatic zones. Buildings of the third time construction period (2000-2010) in all climatic zones are upgraded to rate B. Solar collectors are introduced or added as necessary to cover up to 60% of the DHW heating needs.

The "**Ambitious**" scenario aims at upgrading the buildings further, by incorporating higher performance technical solutions along with RES technologies, such as geothermal heat pumps (where possible) and thermal solar collectors to fully cover the DHW heating needs (if possible), as well as part of the space heating needs.

Figure 2: Evolution of the thermal energy consumption in permanent dwellings since 2000 and estimated for 2016 to reach the national indicative energy savings target of 9% in Greece

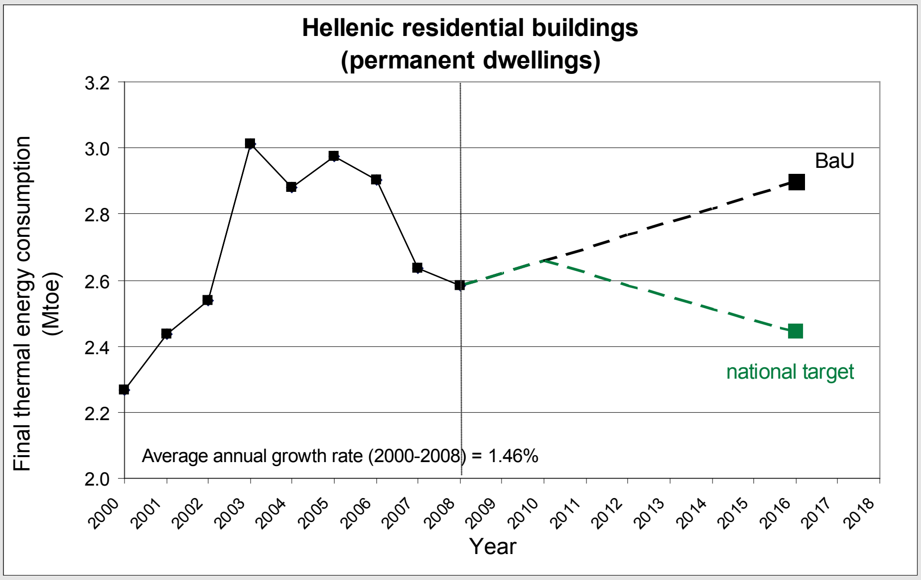


Table 45 summarizes the features of the two scenarios studied within the frame of TABULA.

Table 45: General description of Standard and Ambitious scenario

		STANDARD SCENARIO	AMBITIOUS SCENARIO
Envelope	Add insulation	U-values foreseen by KENAK for each element according to climatic zone	
	Replace windows	U-values foreseen by KENAK for each climatic zone Improve air tightness as necessary	Introduce double pane low-e
E/M Systems	Solar collectors	Cover up to 60% of DHW needs	Cover 100% of DHW needs + part of the space heating needs
	New boiler & controls	System efficiency foreseen by KENAK according to installed power	
	Pipe insulation	System efficiency foreseen by KENAK according to transferred power	
	Geothermal Heat Pump	--	Use this technology if existing installations permit it

The TEE-KENAK software was used in order to calculate the energy savings achieved by applying the two scenarios to the typical buildings. Results are summarized in Table 46. Note that in some cases the estimated thermal energy savings correspond to a fuel switch, for example, from oil to electricity (i.e. replacing an oil boiler with a geothermal heat pump). The data in Table 46 refer to final thermal energy consumption and do not reflect the resulting increase of electrical energy consumption or the increased primary energy consumption for power generation. This is also elaborated in the following discussion.

Table 46: Calculated savings in the thermal energy consumption and in the total primary energy from the application of the Standard and Ambitious scenario in the typical buildings. The (+) sign indicates that SFH buildings of the class use an oil boiler for both space and DHW heating.

Climatic Zone	Age Band	STANDARD SCENARIO				AMBITIOUS SCENARIO			
		Thermal energy consumption savings (%)		Total primary energy savings (%)		Thermal energy consumption savings (%)		Total primary energy savings (%)	
		SFH	*MFH*	*SFH*	*MFH*	*SFH*	*MFH*	*SFH*	*MFH*
A	1	80.7	80.8	79.5	72.0	100.0	100.0	94.9	97.9
	2	80.1	63.5	75.5	61.3	100.0	100.0	95.8	95.6
	3 (+)	12.6	33.9	12.1	48.1	62.8	90.3	61.8	94.3
B	1	80.2	76.8	76.2	70.4	100.0	100.0	95.5	91.5
	2 (+)	57.8	63.8	57.3	61.9	100.0	79.7	90.0	85.8
	3	26.4	29.0	29.5	40.7	46.8	60.5	60.7	74.1
C	1	79.3	80.0	75.5	73.4	100.0	100.0	95.4	86.6
	2	60.5	61.9	60.5	60.5	100.0	76.4	91.2	80.9
	3 (+)	37.6	42.3	43.0	48.6	57.0	66.3	66.6	77.8
D	1	80.3	76.9	77.8	74.0	100.0	85.5	94.3	87.5
	2	40.1	46.1	46.0	49.3	62.1	63.8	73.7	72.1
	3	42.2	30.4	45.7	41.4	59.3	62.0	67.8	76.1

The energy conservation achieved through the two scenarios is very high, as they represent a holistic approach towards energy efficiency, affecting both the envelope and the installed systems and including RES for covering part of the demand. Since the present analysis focuses to thermal energy consumption (i.e. electrical energy consumption is not considered) Table 11 summarizes the related results for the two scenarios. As expected, the savings resulting from the Ambitious scenario are higher than those of the Standard scenario. The use of geothermal heat pumps minimizes the thermal energy consumption leading to savings close to 100%. However, this is replaced by an increase of the total electrical energy consumption. This will be added to the electrical energy balance (i.e. primary energy for power generation), thus the overall impact of the Ambitious scenario on the total energy balance will be smaller. However, further analysis of the energy balance is not possible since there is no official data reported on the breakdown of primary energy use of power generation for the different end-uses.

Application of the Standard and Ambitious scenarios could lead to a significant reduction in the energy consumption of the residential building sector. However, application of such scenarios on the entire building stock is not practical due to the associated high investment cost. Therefore, a more realistic assessment was attempted by considering the potential application of these scenarios on a percentage of the residential building stock with different energy savings potential.

Taking into account the calculated energy savings reported in Table 11 and the target value of thermal energy consumption for 2016, the energy balance model was used in order to derive the percentage of the building stock that will have to adopt the Standard or the Ambitious scenarios to achieve the target savings. Indicatively, it was found that the national target could be reached by applying the Standard scenario in 15% of the residential buildings of the first age band (built prior to 1980) and 30% of the buildings of the second age band (built between 1980 and 2000). The same could be achieved by applying the Ambitious scenario in 10% and 25% of the buildings in the corresponding age bands.

Apparently, it is possible to derive different combinations that could satisfy this goal. In a more strategic approach, a cost-benefit analysis could indicate the most appropriate combinations of building classes in which the adoption of such scenarios would maximize savings for different investment costs, based on fund availability and national priorities. However, this is beyond the scope of the present study.

6.7 Perspectives and Conclusions

The present work was performed in order to examine the possibility of the using the Hellenic building typology created within the framework of TABULA in modelling the national energy balance. An energy balance model was set up and tested against officially reported data, with success.

The results of the present model in absolute terms should be evaluated taking into account the assumptions that were necessary to make, in order to overcome the lack of available data and statistics regarding the residential building stock at the required level of detail. However, collaborative work with NAG experts from the field of building construction and energy monitoring has made it possible to feed the model with the data by making well justified estimates, where possible.

Some of the most important sources of uncertainty are related with the definition of:

- building classes
- typical buildings
- thermal characteristics of the typical buildings
- system expenditure coefficients of the typical buildings
- operational characteristics, e.g. operating hours of the heating system
- estimation of the heated floor area for each typology class

In the future, as more information on the residential building stock becomes available through the exploitation of the new data that becomes available from the ongoing building energy audits and generation of EPCs throughout the country, it will be possible to minimise the above sources of uncertainty and feed the model with updated official statistical data.

Nevertheless, the typology concept has proved to provide a flexible tool for estimating the impact of energy saving scenarios on the energy performance of the residential building stock.

Table 47: Sources / References Greece

Reference shortcut	Short description	Reference
[1]	National Scientific TABULA Report	
[2]	National scientific report	D. Lalas, C.A. Balaras, A. Gaglia, E. Georgakopoulou, S. Mirasgentis, I. Serafidis, S. Psomas, “Evaluation of supporting policies for the advancement of the Ministry’s policies in relation to the abatement of CO_2 emissions in the residential and tertiary sectors”, 650 p., Institute for Environmental Research & Sustainable Development, National Observatory of Athens, and Ministry for the Environment, Physical Planning and Public Works, Directorate Urban Planning & Housing, November 2002 [in Hellenic].
[3]	Scientific paper	C.A. Balaras, A.G. Gaglia, E. Georgopoulou, S. Mirasgedis, Y. Sarafidis, D.P. Lalas. “European Residential Buildings and Empirical Assessment of the Hellenic Residential Building Stock, Energy Consumption Emissions and Potential Energy Savings”, Building & Environment, 42/3, 1298-1314 (2007).
[4]	Publication of the National Hellenic Statistical Service	NHSS. Results from the census of constructions—buildings of the December 1, 1990. Athens: National Hellenic Statistical Service; 2000 [in Hellenic].
[5]	Publication of the National Hellenic Statistical Service	NHSS. Results from the census of constructions—buildings of the December 1, 2000. Athens: National Hellenic Statistical Service; 2010 [in Hellenic].
[6]	Publication of the National Hellenic Statistical Service	NHSS. Research—energy consumption in households 1987–1988.Athens: National Hellenic Statistical Service; 1993 [in Hellenic].
[7]	Publication of the National Hellenic Statistical Service	NHSS. Statistics of building construction activity for the years 1995 and 1997. Athens: National Hellenic Statistical Service; 2000 [in Hellenic].
[8]	On line publication of the Hellenic Ministry of Environment and Climatic Change	http://195.251.42.2/cgi-bin/nisehist.sh?objtype=stats_query
[9]	Publication of the European Commission	EU energy and transport by figures. Statistical pocket book

7 Italy

(by TABULA partner POLITO / Italy)

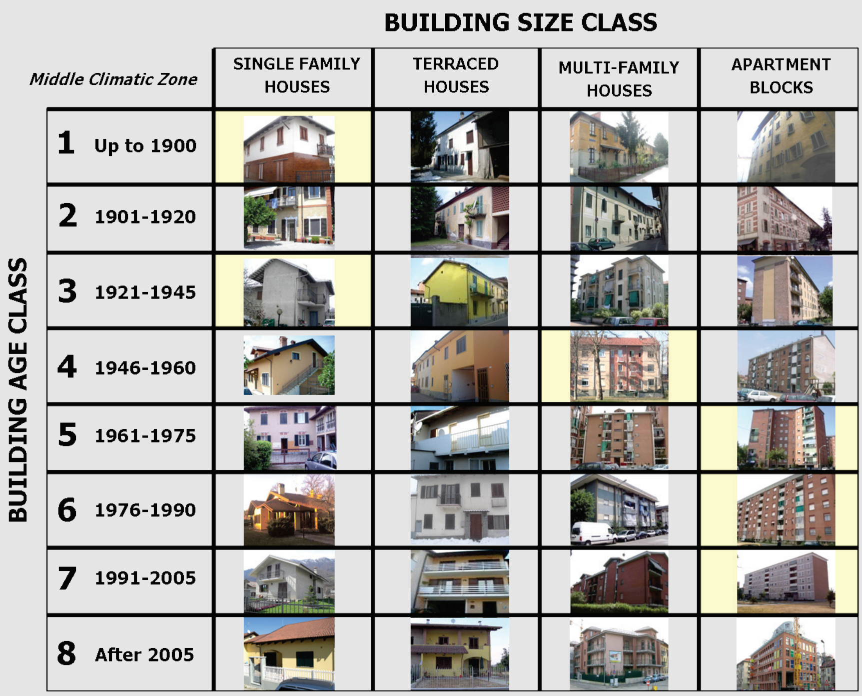
7.1 Building Typology Approach

The six reference building-types used for the Energy Balance analysis are chosen within the "Building Type Matrix". It has been defined for the "Middle Climatic Zone" that is the most representative of the Italian climate (about 4250 municipalities on a total number of 8100). The analysed building-types are the followings (see also Figure 3):

- single family house up to 1900 ("SFH.01");
- single family house from 1921 to 1945 ("SFH.03");
- multi-family house from 1946 to 1960 ("MFH.04");
- apartment block from 1961 to 1975 ("AB.05");
- apartment block from 1976 to 1990 ("AB.06");
- apartment block from 1991 to 2005 ("AB.07").

These reference buildings have been chosen according to statistical analysis: they are representative of a suitable significant portion of the entire national building stock considering both the construction age and the building size (i.e. number of apartments, floor area).
The first two reference buildings (*single family houses*) are "Theoretical Buildings" ("level 3"), characterized on the basis of statistical data (Piedmont Regional Database of Building Energy Performance Certificates). The other reference buildings (*multi-family house* and three *apartment blocks*) are "Example Buildings" ("level 1").
In Figure 3 the "Building Type Matrix" of the "Middle Climatic Zone" shows the "Example Buildings" through a photo of the real building and the "Theoretical Buildings" through a photo of a real similar building.

Figure 3: Italian "Building Type Matrix" for the "Middle Climatic Zone".
The building-types in the yellow cells are chosen as reference buildings for the Energy Balance analysis.



7.2 Available Data

National statistical Information about Buildings
Statistical information about buildings has been firstly obtained from the periodical report of the National Institute of Statistics (ISTAT - Report 2004).
Other interesting data have been extrapolated by the studies carried out by CRESME (Centre Economical, Social and Market Surveys in the Building Sector), in particular, CRESME Report 2006.
As regards national data about energy consumptions in buildings, the reference institution is ENEA (National Energy Agency): ENEA – Report 2008 has been analysed.
The following data summarize the main statistical information on the residential building stock in Italy:

- number of residential buildings: 11.226.595;
- number of apartments: 27.291.993;
- mean total living area: 96 m^2.

This information is also available split by Region (20 regions). Moreover, a number of additional data are available, both at national and at regional level.
In the present paragraph the information are given in terms both of National data and of “Middle Climatic Zone” data. The “Middle Climatic Zone” groups all those regions characterised by prevalent classification of the municipalities in the E Zone (from 2100 to 3000 heating degree-days). In those regions, the number of the municipalities falling in E Zone ranges from 58% (Marche region) to 87% (Lombardia region). In particular, Piedmont region is comprised within this group of regions with a percentage of 74% municipalities in E Zone.

Figures 3a and 3b show the number of buildings split by building age (related both to the national and the “Middle Climatic Zone” statistics).

Figure 4: National Statistics: buildings divided by their age

	Before 1919	1919-1945	1946-1961	1962-1971	1972-1981	1982-1991	After 1991
Dwellings	2.150.259	1.383.815	1.659.829	1.967.957	1.983.206	1.290.502	791.027

Figure 5: “Middle Climatic Zone” Statistics: buildings divided by their age

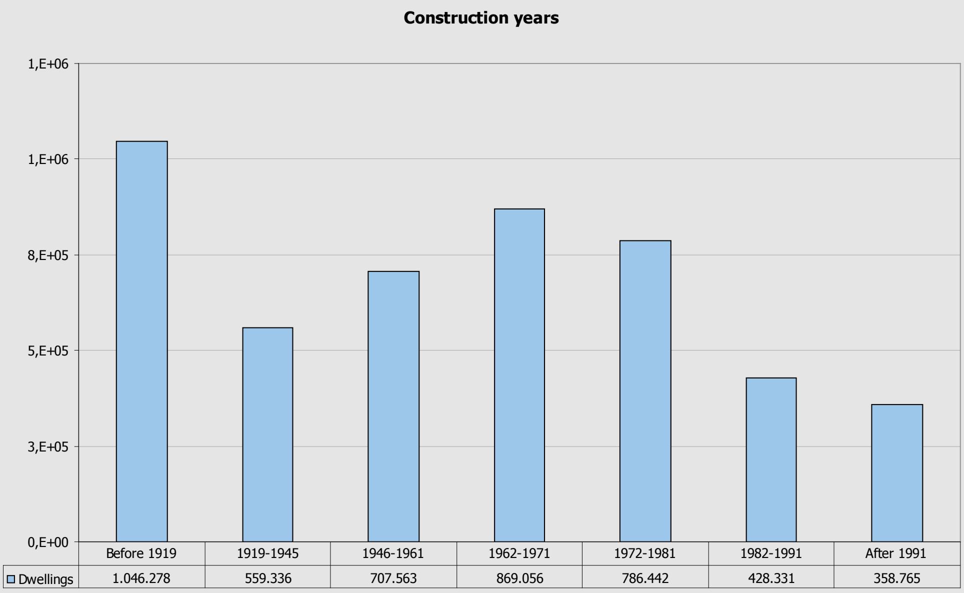


Figure 6 and Figure 7 show the number of apartments in buildings split by building age and number of apartments (related both to the national and the “Middle Climatic Zone” statistics).

Figure 6: National Statistics: number of apartments in residential buildings

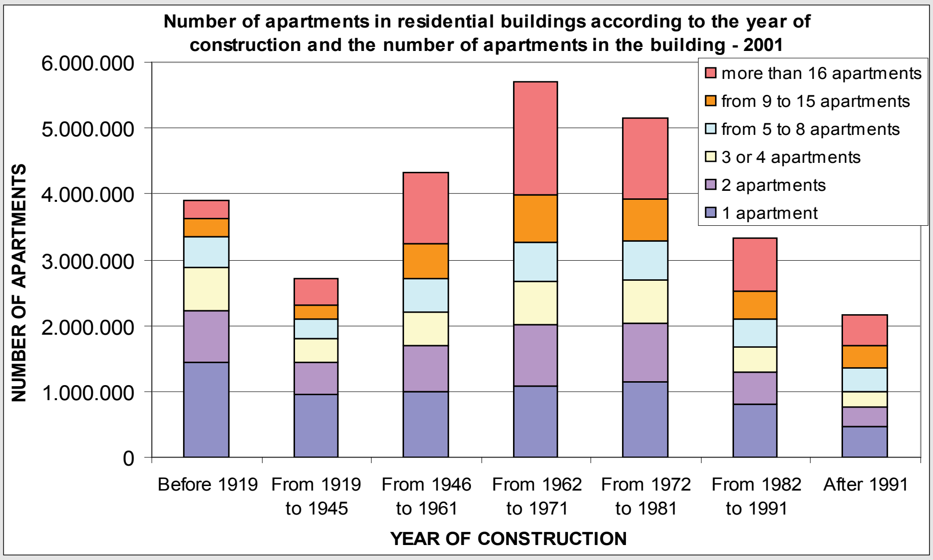
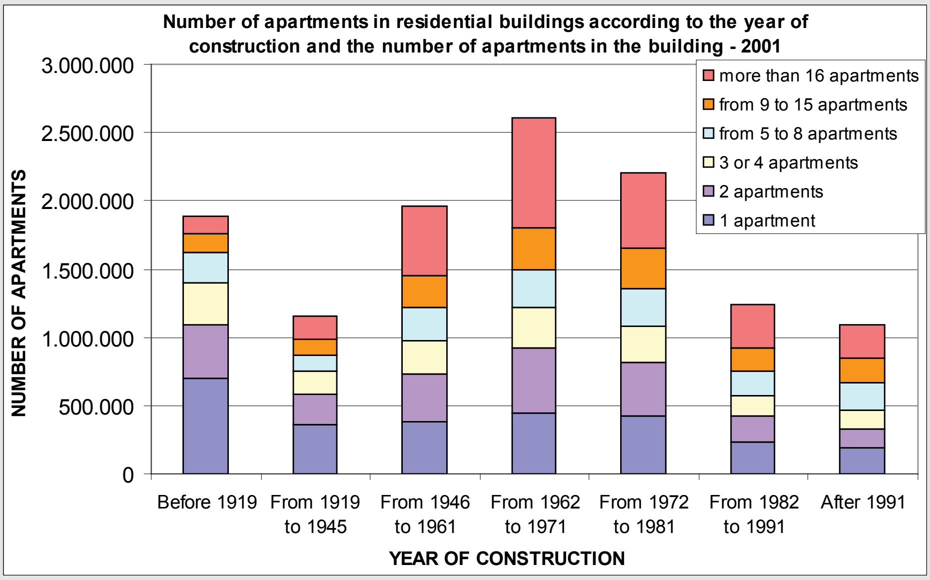


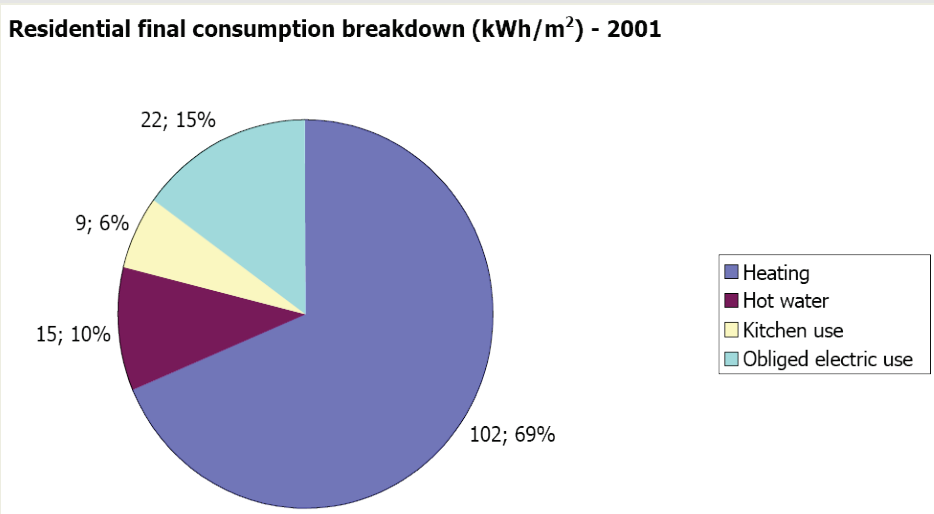
Figure 7: "Middle Climatic Zone" Statistics: number of apartments in residential buildings



Moreover other information are available in terms of statistics, in particular:

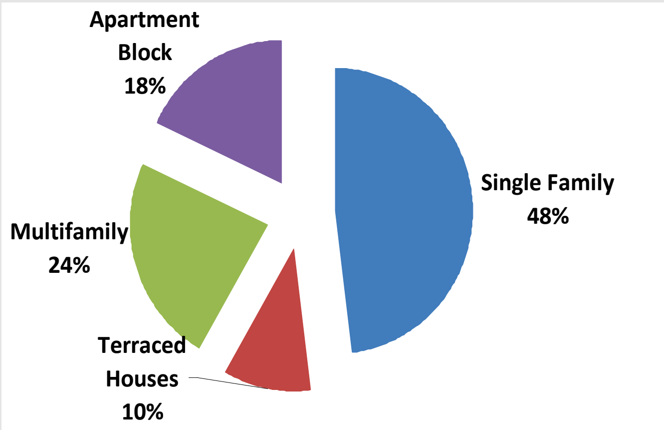
- number of buildings split by building size (expressed in terms of net floor area, m^2);
- retrofit/modernisation actions over the last 10 years (expressed in terms of actions related to building services, structural elements and non-structural elements);
- number of buildings divided by heating and domestic hot water systems (individual and centralized systems);
- number of buildings divided by type of fuel for space heating and DHW;
- breakdown of final energy uses in residential buildings (Figure 5).

Figure 8: Residential final consumption breakdown (national statistics)



In particular, data from Piedmont Regional Database of Building Energy Performance Certificates (more than 50.000 EP certificates, including apartments) are available. In Figure 9, the buildings shown by the certificates are divided in terms of percentage among single family houses, terraced houses, multifamily houses and apartment blocks.

Figure 9: Breakdown of building types (Piedmont region)



For these buildings, a number of statistical information are available, in particular:

- number of buildings divided by building age (see Figure 10);
- number of buildings divided by building size (expressed in terms of heated floor area, in m^2, and volume, in m^3);
- mean U-value for the opaque and transparent envelope divided by building age;
- primary energy demand for heating (kWh/m^2) divided by building age (Figure 11).

Figure 10: Frequencies of single family houses according to building age class (Piedmont region)

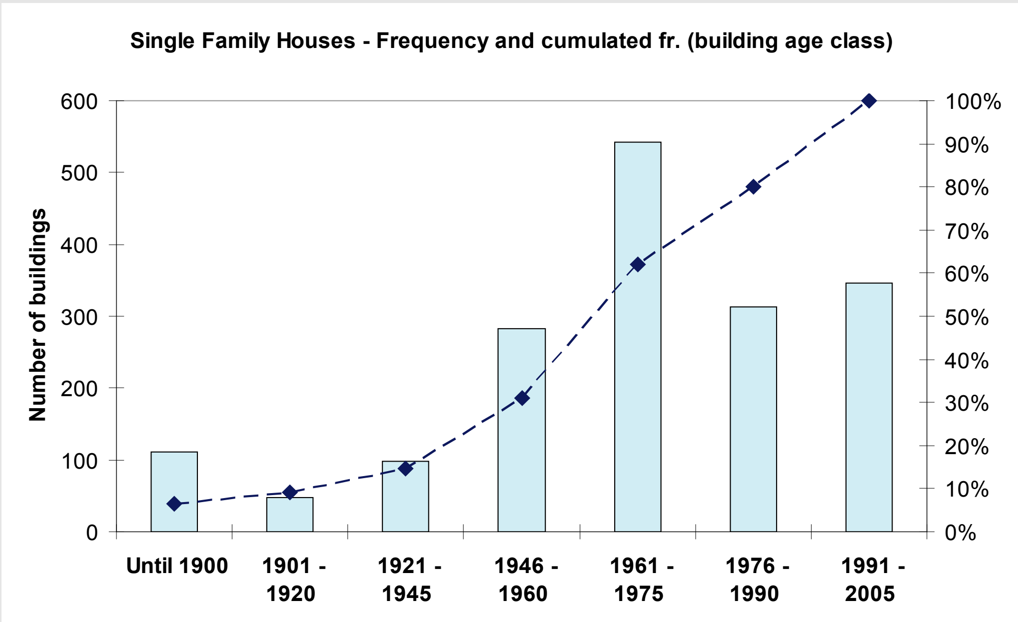
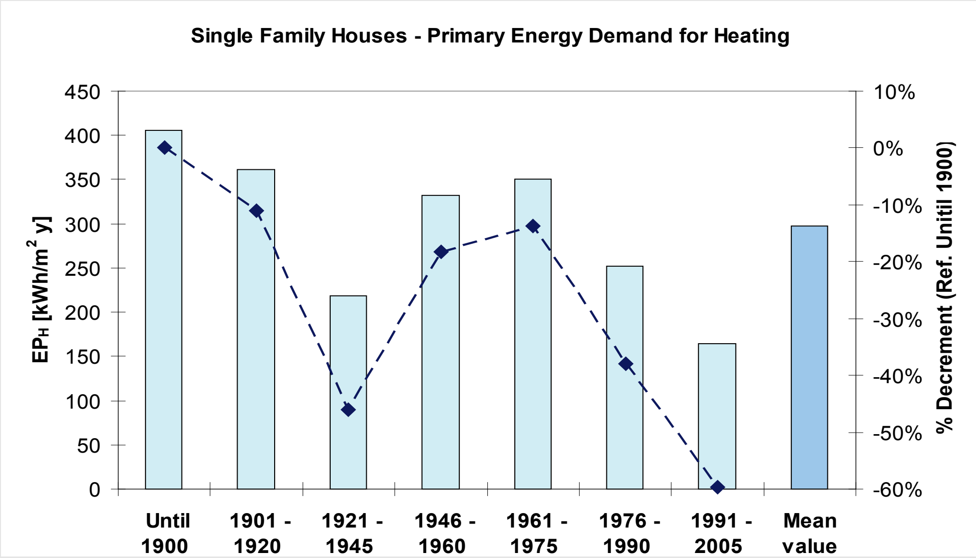


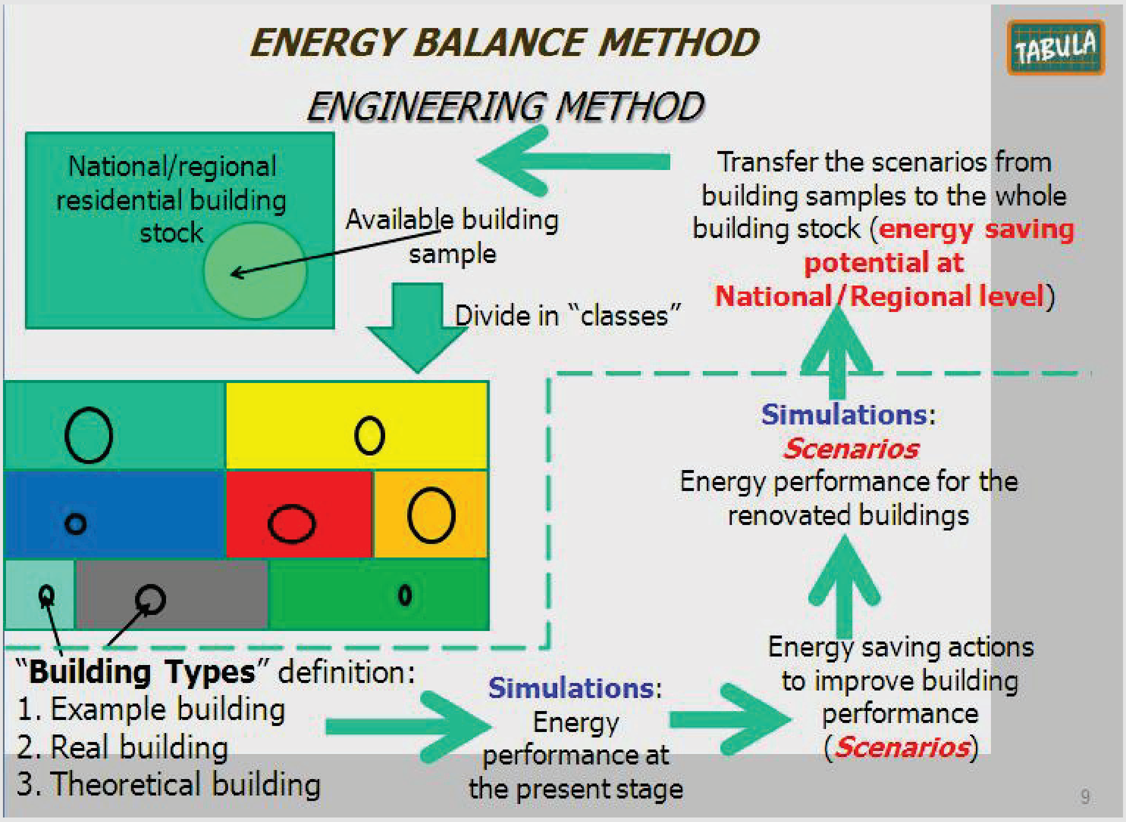
Figure 11: Primary energy demand of single family houses (Piedmont region)



7.3 Energy Balance Method

The procedure applied for Energy Balance Method is shown in Figure 12. Starting from global statistic at National and Regional level and from the corresponding available residential building sample for "Middle Climatic Zone" divided in "Classes" (in terms of Age and Shape), 6 reference buildings have been selected in order to obtain a relevant characterization of the analyzed buildings. They have been chosen as representative of a large portion of the national residential building stock as regards the "Middle Climatic Zone" (for age of construction and building size), as highlighted in Figure 3.

Figure 12: Procedure for energy balance



The official national calculation method (Technical Specification UNI/TS 11300 - National Annex to CEN Standards) for energy certificates has been applied for the evaluation of the energy demand of the selected reference buildings and to assess the energy saving potential due to energy retrofit actions according to 2 different scenarios (standard and advanced retrofit actions).
The retrofit scenarios have been firstly applied to the 6 selected reference buildings; than the obtained results have been statistically enlarged to the whole building stock of "Middle Climatic Zone": each reference building is in fact considered as representative of a suitable portion of the building stock. As a consequence, energy saving potentials have been assessed.

The following simplifications and assumptions have been adopted for the calculations:
- climatic data of the city of Turin (for "Middle Climatic Zone") from a national technical standard (UNI 10349);
- natural ventilation rate fixed at 0,3 h^{-1};
- simplified calculation of internal heat gains according to UNI/TS 11300-1 (fit for residential buildings);
- simplified calculation of building internal heat capacity according to UNI/TS 11300-1 (pre-determined value defined on the type of building components, heavy or light);
- simplified calculation of thermal bridges according to UNI/TS 11300-1 (pre-determined percentage increase of thermal transmittance);
- simplified calculation of indoor air temperature of unconditioned spaces according to UNI/TS 11300-1 (pre-determined value defined on the type of space);
- neither shading devices nor shutters installed on windows;
- reduction factor for shading by permanent obstructions fixed at 0,8 for all windows;
- reduction factor for window frame (frame factor) fixed at 0,2;
- pre-calculated efficiency values of heating and DHW systems according to UNI/TS 11300-2 (emission, distribution and generation subsystems).

7.4 Energy Balance of the Residential Building Stock

The results of the energy performance of the six selected reference building-types ("RBT") are shown in Table 48.
The following different quantities of energy balance are concerned:

- net energy need for space heating ($Q_{H,nd,RBT}$);
- net energy need for domestic hot water ($Q_{W,nd,RBT}$);
- primary energy demand for space heating ($Q_{H,p,RBT}$);
- primary energy demand for domestic hot water ($Q_{W,p,RBT}$);
- primary energy demand for space heating and domestic hot water ($Q_{H,W,p,RBT}$);
- CO_2 emissions (referred to both heating and DHW; $t_{CO2,RBT}$).

Table 48: Results of the calculations for different quantities of energy balance referred to the six reference building-types

		ORIGINAL STATE - Reference building-type (RBT)					
REFERENCE BUILDING-TYPE	$A_{f,n}$ [m²]	$Q_{H,nd,RBT}$ [kWh/m²]	$Q_{W,nd,RBT}$ [kWh/m²]	$Q_{H,p,RBT}$ [kWh/m²]	$Q_{W,p,RBT}$ [kWh/m²]	$Q_{H,W,p,RBT}$ [kWh/m²]	$t_{CO2,RBT}$ [kg/m²]
SFH.01	139	335	15,0	474	42,3	516	105
SFH.03	116	335	15,6	496	21,6	518	105
MFH.04	827	170	17,7	253	54,3	308	63
AB.05	2.450	134	18,2	224	52,6	277	56
AB.06	3.506	67,6	17,4	97,5	22,7	120	24
AB.07	2.879	62,9	17,1	79,0	23,2	102	21

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The energy performance of each reference building-type has been projected to the whole residential building stock of "Middle Climatic Zone" according to the available frequency data on dwellings (Figure 4b) split by construction age. Each reference building is defined as the most frequent building-type in the age of construction that it represents (see also Figure 6b). The results of the projection from the reference buildings (RBT) to the residential building stock (RBS) are shown in Table 49, in which the same energy quantities of Table 48 are considered.

Table 49: Projection of the energy performance of the six reference building-types (RBT) to the residential building stock (RBS) according to "Middle Climatic Zone" statistical data on the frequency of buildings

		ORIGINAL STATE - Projection to the residential building stock (RBS)					
REFERENCE BUILDING-TYPE	**FREQUENCY (number of buildings)**	$Q_{H,nd,RBS}$ [10^3 GWh]	$Q_{W,nd,RBS}$ [10^3 GWh]	$Q_{H,p,RBS}$ [10^3 GWh]	$Q_{W,p,RBS}$ [10^3 GWh]	$Q_{H,W,p,RBS}$ [10^3 GWh]	$t_{CO2,RBS}$ [10^6 t]
SFH.01	1.046.278	48,7	2,2	68,9	6,2	75,1	15,2
SFH.03	559.336	21,7	1,0	32,2	1,4	33,6	6,8
MFH.04	707.563	99,5	10,4	148,0	31,8	179,8	36,5
AB.05	869.056	285,3	38,8	476,9	112,0	588,9	119,6
AB.06	1.214.773	287,9	74,1	415,3	96,7	511,9	103,9
AB.07	358.765	65,0	17,7	81,6	24,0	105,6	21,4
	4.755.771	**808,1**	**144,1**	**1.222,9**	**272,0**	**1.494,9**	**303,5**

Each energy quantity expressed in kWh/m^2 (for RBT) in Table 48 is transformed in 10^3 GWh (for RBS) in Table 49 by multiplying it for the useful floor area of the reference building and the frequency (i.e. the number of buildings) in the building stock. The conversion from the energy quantity to the CO_2 emission is made considering a reference emission factor of the natural gas (230 g/kWh) as the most used fuel in Italy by statistics.

7.5 Comparison to National Statistical Data of the Residential Building Stock

The calculated energy consumption (RBS,CALC) can be compared with the available statistical data (RBS,STAT) of the residential building stock only as regards the primary energy for space heating because of the lack of consistent statistical values for the other energy quantities (net energy need for space heating and DHW, etc.). However an important reference statistical value is available: it represents the annual value of primary energy need for heating normalised to the unitary useful floor area ($Q_{H,p,RBS,STAT}$), as shown in Table 26.
So the comparison is made between $Q_{H,p,RBS,CALC}$ (kWh/m^2) and $Q_{H,p,RBS,STAT}$ (kWh/m^2); the former is obtained dividing the primary energy consumption of the building stock in 10^3 GWh (see also Table 49) by the total number of buildings and the useful floor area of a mean dwelling in the building stock.
The values of $Q_{H,p,RBS,CALC}$ and $Q_{H,p,RBS,STAT}$ are quite different; this is mainly due to a difference in the system operation time. In fact the calculation of the energy need for heating (according to National technical standards) is performed considering a continuous system operation (24 hours every day), while in reality it occurs a system intermittency. In order to compare the calculated value of energy consumption and the measured one (statistical value), the calculated value is corrected applying a reduction factor according to EN ISO 13790. This factor (called $a_{H,red}$ in the technical standard) considers both the real hours of heating operation (14 hours a day for E Zone) and the seasonal heat gains to heat losses ratio and the building thermal inertia. The thermal inertia is expressed through the time constant of the building. The values of these parameters are determined considering each reference building-type. The corrected calculated value ($Q_{H,p,RBS,CORR}$) is reported in Table 26. The difference between the corrected calculated value and the statistical value can be explained considering the internal set-point temperature: the value used in the calculation is 20 °C, while the real set-point temperature is often 1,5-2 °C higher, due to thermal comfort reasons.

Table 50: Comparison between the calculated value and the statistical data of primary energy for space heating with reference to the residential building stock of "Middle Climatic Zone"

		ORIGINAL STATE - Comparison with statistical data of energy consumption			
		Building stock - Calculated results (RBS,CALC)		*Building stock - Corrected results to consider real operation (RBS,CORR)*	*Building stock - Statistical data (RBS,STAT)*
FREQUENCY (number of buildings)	$A_{f,n,mean}$ [m²]	$Q_{H,p,RBS,CALC}$ [10³ GWh]	$Q_{H,p,RBS,CALC}$ [kWh/m²]	$Q_{H,p,RBS,CORR}$ [kWh/m²]	$Q_{H,p,RBS,STAT}$ [kWh/m²]
4.755.771	1.728	1.223	149	96	111

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7.6 Calculation of Energy Saving Potentials

For each reference building-type two refurbishment measures have been considered, a standard and an advanced one, for both the building envelope and the technical systems (space heating and DHW). The following standard refurbishment measures have been applied to the envelope:

- application of insulation material on walls to reach an U-value of 0,33 W/(m² K);
- application of insulation material on floors and roofs to reach an U-value of 0,30 W/(m² K);
- replacement of windows to reach an U-value of 2,00 W/(m² K).

The following advanced refurbishment measures have been applied to the envelope:

- application of insulation material on walls to reach an U-value of 0,25 W/(m² K);
- application of insulation material on floors and roofs to reach an U-value of 0,23 W/(m² K);
- replacement of windows to reach an U-value of 1,70 W/(m² K).

The considered U-values correspond to the requirements established by the new regulations on energy performance of buildings in Piedmont Region (D.G.R. n. 46-11968). These U-values are more restrictive in comparison to those established by the National legislation (Legislative Decree n.192/2005). The U-values applied for the standard refurbishment are the compulsory U-values in the Piedmont Region regulation, while the U-values applied for the advanced refurbishment are the optional U-values in the Piedmont Regional regulation.

As regards the refurbishment of the heating system, the following measures have been considered both for the standard and for the advanced level:

- replacement of radiators with radiant heating panels;
- insulation of the distribution subsystem;
- replacement or new installation of a heat storage (high insulation level);
- replacement of individual heating systems (per apartment) with central heating system.

As regards the standard refurbishment of the heating generator subsystem, the following heat generators have been considered for the six reference buildings:

- condensing boiler (SFH.01, MFH.04, AB.05, AB.07);
- air-to-water heat pump (SFH.03, AB.06).

As regards the advanced refurbishment of the heating generator subsystem, the following heat generators have been considered for the six reference buildings:

- geothermal heat pump (MFH.04, AB.07);
- geothermal heat pump coupled with thermal solar plant (SFH.03);
- condensing boiler coupled with thermal solar plant (SFH.01, AB.05);
- air-to-water heat pump coupled with thermal solar plant (AB.06).

The refurbishment of the DHW system has been hypothesized considering the following measures for both the standard and the advanced level:

- insulation of the distribution subsystem;
- replacement or new installation of a heat storage (high insulation level);
- in some case, replacement of individual DHW systems (per apartment) with central DHW system.

Moreover, as regards the standard refurbishment of the DHW generator subsystem, the following heat generators have been considered for the six reference buildings:

- condensing boiler and individual DHW production, per apartment (SFH.03, MFH.04, AB.06, AB.07);
- condensing boiler and central DHW production (SFH.01, AB.05).

As regards the advanced refurbishment of the DHW generator subsystem, the following heat generators have been considered for the six reference buildings:

- geothermal heat pump (MFH.04, AB.07);
- geothermal heat pump coupled with thermal solar plant (SFH.03);
- condensing boiler coupled with thermal solar plant (SFH.01, AB.05, AB.06).

The calculated energy saving potentials (primary energy) for the six refurbished reference buildings (RBT) and for the building stock (RBS) are shown in Table 51 and in Table 52, respectively for the standard and the advanced level of refurbishment. The CO_2 emission reducing potentials are indicated too. In order to obtain realistic values of the saving potentials (primary energy and CO_2 emissions reduction) due to the refurbishment of the residential building stock, the calculated value has been calibrated according to the real operation of the heating system (RBS,CORR) as done for the comparison with statistical data (see par. 2.4.4 and Table 50).

Table 51: Calculated energy saving and CO_2 emission reduction potentials by standard refurbishment (both for the reference building-types and the residential building stock of "Middle Climatic Zone")

			STANDARD REFURBISHMENT									
			Reference building-type (RBT)			Projection to the residential building stock (RBS)				Corrected results to consider real operation (RBS,CORR)		
REFERENCE BUILDING-TYPE	$A_{f,n}$ [m²]	FREQUENCY (number of buildings)	$\Delta Q_{H,p,RBT}$ [kWh/m²]	$\Delta Q_{W,p,RBT}$ [kWh/m²]	$\Delta Q_{H,W,p,RBT}$ [kWh/m²]	$\Delta Q_{H,p,RBS}$ [10³ GWh]	$\Delta Q_{W,p,RBS}$ [10³ GWh]	$\Delta Q_{H,W,p,RBS}$ [10³ GWh]	$\Delta t_{CO2,RBS}$ [10⁶ t]	$\Delta Q_{H,W,p,RBS,CORR}$ [10³ GWh]	$\Delta t_{CO2,RBS,CORR}$ [10⁶ t]	Δ% savings
SFH.01	139	1.046.278	392	14,1	406	57,0	2,1	59,0	12,0	38,8	7,9	**-76,7%**
SFH.03	116	559.336	421	3,5	425	27,3	0,2	27,6	5,6	17,8	3,6	**-80,6%**
MFH.04	827	707.563	208	33,8	242	121,7	19,8	141,4	28,7	98,2	19,9	**-77,2%**
AB.05	2.450	869.056	183	23,6	207	389,4	50,2	439,7	89,3	301,2	61,2	**-71,8%**
AB.06	3.506	1.214.773	71	2,5	73	300,7	10,6	311,3	63,2	204,4	41,5	**-56,1%**
AB.07	2.879	358.765	43	3,5	46	44,0	3,6	47,6	9,7	32,0	6,5	**-41,8%**
		4.755.771				**940,1**	**86,6**	**1.026,7**	**208,4**	**692,5**	**140,6**	**-65,3%**

Table 52: Calculated energy saving and CO_2 emission reduction potentials by advanced refurbishment (both for the reference building-types and the residential building stock of "Middle Climatic Zone")

			ADVANCED REFURBISHMENT									
			Reference building-type (RBT)			Projection to the residential building stock (RBS)				Corrected results to consider real operation (RBS,CORR)		
REFERENCE BUILDING-TYPE	$A_{f,n}$ [m²]	FREQUENCY (number of buildings)	$\Delta Q_{H,p,RBT}$ [kWh/m²]	$\Delta Q_{W,p,RBT}$ [kWh/m²]	$\Delta Q_{H,W,p,RBT}$ [kWh/m²]	$\Delta Q_{H,p,RBS}$ [10^3 GWh]	$\Delta Q_{W,p,RBS}$ [10^3 GWh]	$\Delta Q_{H,W,p,RBS}$ [10^3 GWh]	$\Delta t_{CO2,RBS}$ [10^6 t]	$\Delta Q_{H,W,p,RBS,CORR}$ [10^3 GWh]	$\Delta t_{CO2,RBS,CORR}$ [10^6 t]	Δ% savings
SFH.01	139	1.046.278	419	24,4	443	60,9	3,5	64,4	13,1	42,8	8,7	**-84,6%**
SFH.03	116	559.336	455	6,4	461	29,5	0,4	29,9	6,1	19,4	3,9	**-87,8%**
MFH.04	827	707.563	227	34,3	261	132,6	20,1	152,7	31,0	105,5	21,4	**-83,0%**
AB.05	2.450	869.056	196	38,0	234	417,3	80,9	498,2	101,1	349,9	71,0	**-83,4%**
AB.06	3.506	1.214.773	79	8,8	88	338,2	37,5	375,6	76,3	255,4	51,9	**-70,1%**
AB.07	2.879	358.765	57	4,0	61	59,3	4,1	63,4	12,9	42,3	8,6	**-55,3%**
		4.755.771				**1.037,8**	**146,6**	**1.184,3**	**240,4**	**815,4**	**165,5**	**-76,9%**

7.7 Perspectives and Conclusions

Conclusions

The performed study shows the high potentiality in terms of energy saving related to retrofit actions on existing buildings for the Italian "Middle Climatic Zone", grouping the highest portion of the Italian residential building stock.

In Italy in general, and in the Italian "Middle Climatic Zone" in particular, the statistical distribution of the number of buildings as a function of the construction age shows a high amount of buildings dated before the emanation of energy laws: as a consequence they are characterized by low energy performance and also the application of basic energy renovations may provide significant increases of the energy performance and consequent reductions of CO_2 emissions. In fact the standard refurbishment level already shows the high potentiality of energy savings up to 80%.

The proposed methodology is an useful tool to define a clear picture for the most representative climatic zone in Italy.

Perspectives

A possible increase of the accuracy of the results can be obtained enlarging the building types used as a reference for the National Energy Balance: to this aim statistics at National level are required for a more detailed division of the number of buildings according to the building typology. Moreover the same methodology could be applied also to the other two Italian climatic zones (Alpine and Mediterranean).

The same approach can be also performed for a deeper analysis at Piedmont regional level where more detailed data are available for a better description of the building-type used for "Regional Energy Balance".

In general the performed study allowed to define a clear methodology fit for National Energy Balance. The assessed energy consumptions and savings are sufficiently accurate when compared with actual energy consumptions based on National-Regional statistics.

Table 53: Sources / References Italy

Reference shortcut	Short description	Reference
...	national scientific TABULA report	…
ISTAT - Report 2004	Report from ISTAT - National Institute of Statistics.	Rapporto ISTAT 2004 – Istituto Nazionale di Statistica.
CRESME - Report 2006	Report from CRESME - Centre Economical, Social and Market Surveys in the Building Sector.	Rapporto CRESME 2006 – Centro Ricerche Economiche Sociali di Mercato per l'Edilizia e il territorio.
ENEA – Report 2008	Report from ENEA - National Energy Agency.	Rapporto ENEA 2008 – Agenzia nazionale per l'energia.
D.Lgs. 192/2005 – D.Lgs. 311/2006	National regulation on the transposition of the EBPD in Italy.	Decreto legislativo 29 dicembre 2006, n. 311, "Disposizioni correttive ed integrative al decreto legislativo 19 agosto 2005, n. 192, recante attuazione della direttiva 2002/91/CE, relativa al rendimento energetico in edilizia".
D.G.R. 46-11968 (2009)	Regional regulation (Piedmont Region) on minimum energy performance requirements of buildings.	Deliberazione della Giunta Regionale 4 agosto 2009, n. 46-11968. Aggiornamento del Piano regionale per il risanamento e la tutela della qualità dell'aria - Stralcio di piano per il riscaldamento ambientale e il condizionamento e disposizioni attuative in materia di rendimento energetico nell'edilizia ai sensi dell'articolo 21, comma 1, lettere a) b) e q) della legge regionale 28 maggio 2007, n. 13 "Disposizioni in materia di rendimento energetico nell'edilizia".
EN ISO 13790:2008	European Standard. Energy performance of buildings - Calculation of energy use for space heating and cooling	Prestazione energetica degli edifici - Calcolo del fabbisogno di energia per il riscaldamento e il raffrescamento
UNI/TS 11300-1:2008	National technical specification. Annex to CEN Standard EN ISO 13790.	Prestazioni energetiche degli edifici. Parte 1: Determinazione del fabbisogno di energia termica dell'edificio per la climatizzazione estiva ed invernale.
UNI/TS 11300-2:2008	National technical specification . Energy performance of buildings – Calculation of primary energy and efficiencies for space heating and domestic hot water.	Prestazioni energetiche degli edifici. Parte 2: Determinazione del fabbisogno di energia primaria e dei rendimenti per la climatizzazione invernale e per la produzione di acqua calda sanitaria.
prUNI/TS 11300-4	National technical specification. Calculation of the energy performance of buildings – Use of renewable energy sources for heating and domestic hot water (in preparation).	Prestazioni energetiche degli edifici. Parte 4: Utilizzo di energie rinnovabili e di altri metodi di generazione per riscaldamento di ambienti e preparazione acqua calda sanitaria (in corso di elaborazione).
UNI 10349:1994	National Technical Standard (UNI). Climatic data.	Riscaldamento e raffrescamento degli edifici. Dati climatici.

8 Slovenia

(by TABULA partner ZRMK / Slovenia)

8.1 Building Typology Approach

Slovenian TABULA Typology was elaborated with 4 building types (SFH - single family house, TH - terraced house, MFH - multifamily house and AP - apartment block) and 6 age classes:

- until 1945 (1) – pre WWII period
- 1945 – 1970 (2) – after WWII period, no thermal regulations
- 1971 – 1980 (3) – first national regulation on energy saving protection of buildings
- 1981 – 2002 (4) – revision of regulation
- 2003 – 2008 (5) – first energy performance calculation methodology based on European standards
- from 2009 (6) – latest energy performance regulations

For calculation of national energy balance only 2 condensed building types (single unit buildings - SUB and multi-unit buildings - MUB) were used, thus combining SFH + TH into SUB and MFH + AB into MUB respectably. Furthermore first to age classes were grouped into single year class (until 1970) living us with 5 age classes. This gives us 10 primary building types.

Table 54: Frequencies of 10 building types in 2009

Building type	number of buildings	number of apartments	living space in 1000 m2	TABULA reference area in 1000 m2	
SUH.01 (until 1970)	256.125	276.993	24.792	27.271	**Single Unit Houses**
SUH.02 (1971 – 1980)	90.189	96.958	9.718	10.690	
SUH.03 (1981 – 2002)	122.862	128.048	12.981	14.280	
SUH.04 (2003 – 2008)	23.961	24.668	2.844	3.129	
SUH.05 (from 2009)	146	158	14	15	
MUH.01 (until 1970)	17.650	178.890	9.344	10.278	**Multi Unit Houses**
MUH.02 (1971 – 1980)	3.165	66.905	3.216	3.538	
MUH.03 (1981 – 2002)	3.074	57.282	2.909	3.200	
MUH.04 (2003 – 2008)	1.408	21.630	1.274	1.401	
MUH.05 (from 2009)	18	1.161	71	78	
Building Stock total	518.598	852.693	67.164	73.881	

Source: Registry of buildings [REN]

Primary building types describe original state of buildings at the time of erection. Since then buildings have changed and for the calculation of current national balance we have to take into consideration changed, refurbished, present buildings. Thus we investigated sub typologies. Subdivisions ware made according to a) level of refurbishment (un-refurbished, medium or full refurbishment) or b) level of thermal protection of building at the time of erection (standard level, high standard level, or low energy level). Figure 13 on next page shows these subdivisions.

Figure 13: Division of primary building types into present state building types

28 building types where calculated in Slovenian national balance. Buildings representing these types where “real” example buildings (10 real geometries, ReEx) with assigned different “real” thermal insulation thickness and windows types to represent subdivisions.

8.2 Available Data

Registry of buildings of Slovenia [REN] is a large database. It includes all of the country buildings with some information interesting for energy calculations. This are: year of building erection, area and utilisation of building part (apartment)[10], year of windows, roof and wall refurbishment, number

[10] Utilisation of building part(s) is the information from which we can assume about utilisation of a building as a whole (examples of utilisation types of building part: apartment in single family house with one apartment (stand-alone), apartment in an apartment building of 21 to 50 apartments).

of storeys and type of heat generation. The database is constantly updating. For our calculation we used data from 2007.[11]

Combination of information about the year of refurbishment of wall, roof and windows with the knowledge about the level of refurbishment at that time gave us an insight into today state of those buildings. These steps where made with some assumptions:

- Roof: half of refurbishment with no thermal improvement, before 2002 → 10 cm of thermal insulation, after 2002 → 20 cm of thermal insulation,
- Walls: before 1996 → 5 cm of thermal insulation, after 1996 → 8 cm of insulation,
- Windows: before 1996 → U = 2,7 W/m^{2}K, after 1996 → U = 1,4 W/m^{2}K.

One building could have several refurbishment measure taken in the past. Combination of those measures gives us possibility to define such building as one of subtypes (blue arrows in Figure 13).

To divide newer buildings (from 2003) that have not been refurbished into 3 thermal protection levels (red arrows) we made further assumptions based on our experience.

Table 55: Frequencies of sub – building types (% of number of buildings in building type)

Building Type	Distribution	
SUH.04.Standard	55 %	Single Unit Houses
SUH.04.High_stand	40 %	
SUH.04.Low_E	5 %	
SUH.05.High_stand	95 %	
SUH.05.Low_E	5 %	
MUH.04.Standard	65 %	Multi Unit Houses
MUH.04.High_stand	35 %	
MUH.04.Low_E	5 %	
MUH.05.High_stand	99 %	
MUH.05.Low_E	1 %	

[11] In 2008 there was a large scale survey to gather information about existing buildings. From 2008 until now only new buildings are imputed. This leaves us with no information about refurbishment measures from 2006 until present.

Less data is available regarding systems installed.

Table 56: Frequencies of different systems for heating (% of number of buildings of residential buildings)

Building type	no heating	central heating	other heating	district heating	no data	**Total**	
SUH.01	5,7%	31,7%	11,4%	0,5%	0,1%	49%	**Single Unit Houses**
SUH.02	0,7%	14,8%	1,7%	0,2%	0,0%	17%	
SUH.03	1,4%	20,1%	2,0%	0,2%	0,0%	24%	
SUH.04	0,7%	3,6%	0,3%	0,0%	0,0%	5%	
SUH.05	0,0%	0,0%	0,0%	0,0%	0,0%	0%	
MUH.01	0,1%	1,9%	0,9%	0,4%	0,0%	3%	**Multi Unit Houses**
MUH.02	0,0%	0,4%	0,1%	0,1%	0,0%	1%	
MUH.03	0,0%	0,4%	0,0%	0,1%	0,0%	1%	
MUH.04	0,0%	0,2%	0,0%	0,0%	0,0%	0%	
MUH.05	0,0%	0,0%	0,0%	0,0%	0,0%	0%	
Building Stock total	9%	73%	16%	2%	0%	518.598	

Source: Registry of buildings [REN]

Data about Slovenian typology with its subtypes is dated in year 2007. To calculate energy balance for the year 2011 (Table 57) we had to take into consideration the average yearly rate of building modernisation (building moves from class SUH.01.Un_refur to class SUH.01.Med_refur), rate of building demolition (only in oldest year class) and rate of new buildings erection. Data for these trends was available from Registry of Buildings and National statistics.

Table 57: **Frequencies of building types (% of useful floor area in 1.000 m²) in 2011**

Single Unit Buildings	Floor area in 1.000 m2	Tabula reference area in 1.000 m^2	% of SUH	**Multi Unit Buildings**	Floor area in 1.000 m2	Tabula reference area in 1.000 m^2	% of MUH
SUH.01.Un_refur	9.790	10.769	18,9%	MUH.01.Un_refur	4.070	4.477	23,2%
SUH.01.Med_refur	10.314	11.345	19,9%	MUH.01.Med_refur	3.803	4.183	21,7%
SUH.01.Full_refur	4.238	4.661	8,2%	MUH.01.Full_refur	1.201	1.322	6,8%
SUH.02.Un_refur	5.302	5.833	10,2%	MUH.02.Un_refur	1.752	1.927	10,0%
SUH.02.Med_refur	3.137	3.450	6,1%	MUH.02.Med_refur	1.094	1.203	6,2%
SUH.02.Full_refur	1.101	1.211	2,1%	MUH.02.Full_refur	293	322	1,7%
SUH.03.Un_refur	8.615	9.476	16,6%	MUH.03.Un_refur	1.866	2.052	10,6%
SUH.03.Med_refur	3.947	4.342	7,6%	MUH.03.Med_refur	985	1.084	5,6%
SUH.03.Full_refur	518	570	1,0%	MUH.03.Full_refur	123	135	0,7%
SUH.04.Standard	1.673	1.840	3,2%	MUH.04.Standard	894	984	5,1%
SUH.04.High_stand	1.216	1.338	2,4%	MUH.04.High_stand	522	574	3,0%
SUH.04.Low_E	152	167	0,3%	MUH.04.Low_E	75	82	0,4%
SUH.05.High_stand	1.668	1.835	3,2%	MUH.05.High_stand	864	950	4,9%
SUH.05.Low_E	88	97	0,2%	MUH.05.Low_E	9	10	0,0%
	51.758	56.934	100%		17.549	19.304	100%

Source: Registry of buildings [REN]

8.3 Energy Balance Method

For each of 28 building types total energy use and primary energy consumption was calculated with software according to National methodology based on CEN standards [PURES] (Heating and cooling demand is calculated with monthly method according to EN ISO 13790:2008). Internal temperature was set to 20 °C with intermitted heating where heat generator is off for 25% of time.

Systems installed in each of the real example buildings where heating system and DHW preparation system that are most probable (based on experiences and not on reliable statistical data). For example: old single unit building has an old real example boiler that is located in unheated room. Energy carrier was chosen according to national statistic about energy use in buildings.

8.4 Energy Balance of the Residential Building Stock

Energy balance model calculated energy performance indicators for each of the 28 subtypes. In Table 58 are summarized some of those indicators into building type (heating need, final energy for domestic hot water preparation, electrical energy for lightning). Primary energy was calculated with factors from [PURES] and CO_2 emissions from data from Statistical office [STAT].

Table 58: Heat consumption of the Slovenian residential building stock (2011) for space heating, hot water and lighting

Building type	Heating need (Qnh)	DHW final (Qf,w)	lightning final (W,f)	Final energy (Q,f)	Primary energy	CO2 emissions
SUH.01	2.937 GWh	454 GWh	363 GWh	3.722 GWh	4.829 GWh	978 kt
SUH.02	2.094 GWh	113 GWh	209 GWh	2.538 GWh	3.085 GWh	956 kt
SUH.03	1.285 GWh	323 GWh	202 GWh	1.534 GWh	2.004 GWh	684 kt
SUH.04	154 GWh	57 GWh	36 GWh	199 GWh	264 GWh	71 kt
SUH.05	88 GWh	64 GWh	20 GWh	116 GWh	155 GWh	47 kt
MUH.01	1.262 GWh	145 GWh	290 GWh	1.767 GWh	2.363 GWh	792 kt
MUH.02	356 GWh	64 GWh	40 GWh	410 GWh	517 GWh	151 kt
MUH.03	280 GWh	57 GWh	36 GWh	325 GWh	436 GWh	162 kt
MUH.04	95 GWh	28 GWh	16 GWh	133 GWh	181 GWh	68 kt
MUH.05	28 GWh	15 GWh	9 GWh	45 GWh	64 GWh	25 kt
Total	8.580 GWh	1.320 GWh	1.219 GWh	10.791 GWh	13.898 GWh	3.934 kt

Table 59 shows primary energy consumption and CO2 emissions by energy carrier.

Table 59: Primary energy consumption and CO_2 emissions of the Slovenian residential building stock (2011) for space heating, hot water and lighting by energy carrier

Energy carrier	Primary energy	CO2 emissions
Oil	4.506 GWh	1.194 kt
Gas	1.066 GWh	213 kt
District heating	1.254 GWh	414 kt
Electricity	3.986 GWh	2.113 kt
Other RES	2 GWh	0 kt
Biomass	3.084 GWh	0 kt
Coal	0 GWh	0 kt
Total	13.898 GWh	3.934 kt

8.5 Comparison to National Statistical Data of the Residential Building Stock

For comparison purposes different statistical data for different time periods were investigated. These data includes also energy use for cooking and other home appliances that is not calculated in energy balance model. Methodology for energy performance calculation uses climatic data averages for last 30 years. To compare results of our model and national statistical data we took average of three available sources (Table 60).

There is large deviation in electricity and biomass consumption. This originates in DHW preparation (electricity, model calculates not realistic energy needs for DHW) and cooking (biomass is used in Slovenia for stoves for cooking).

Gas is used for cooking, but this is not evident from the results. Total energy consumption is very close to calculated results but considering the roughness of the model one can conclude that this is more of coincidence.

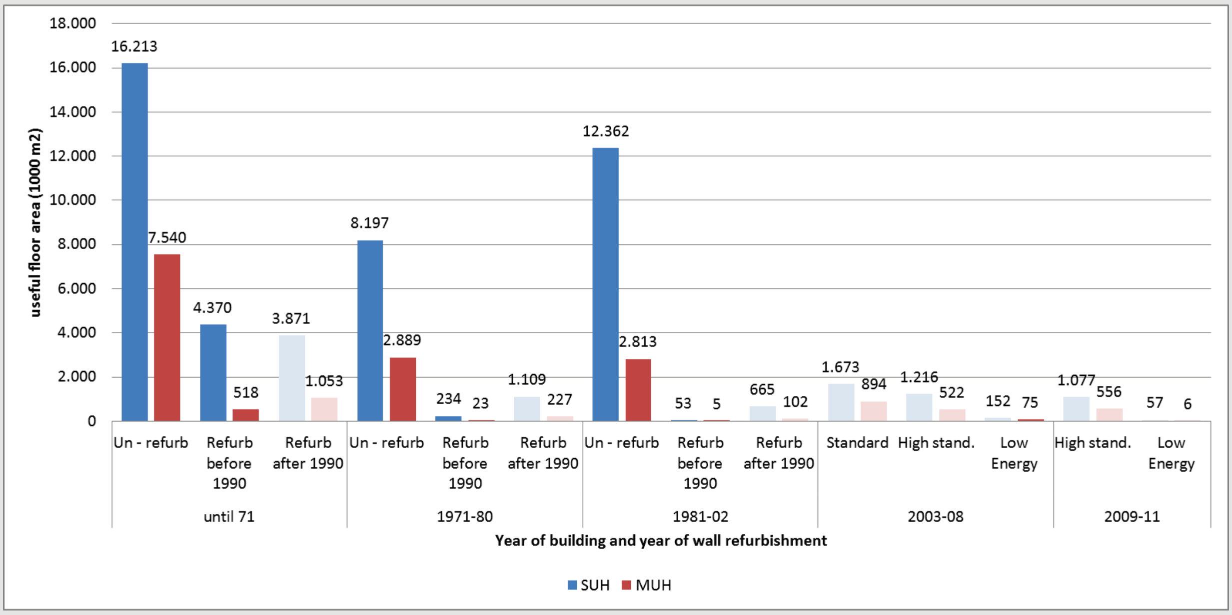
Table 60: Comparison of model results with national energy statistics

Energy carrier	National Action Program 2001 – 2005 (average) [AP]	Final energy consumption by energy source, households 2002 [STAT]	Energy balance households 2007 – 2009 (average) [STAT]	Average	Calculated	Deviation
Oil	4.943 GWh	5.462 GWh	3.477 GWh	4.627 GWh	4.506 GWh	-3%
Gas	1.049 GWh	805 GWh	1.268 GWh	1.041 GWh	1.066 GWh	2%
District heating	1.203 GWh	1.339 GWh	1.120 GWh	1.221 GWh	1.254 GWh	3%
Electricity	2.873 GWh	2.821 GWh	3.117 GWh	2.937 GWh	3.986 GWh	36%
Other RES	0 GWh	0 GWh	0 GWh	0 GWh	2 GWh	-
Biomass	3.847 GWh	3.770 GWh	3.768 GWh	3.795 GWh	3.084 GWh	-19%
Coal	58 GWh	219 GWh	0 GWh	92 GWh	0 GWh	-
Total	13.972 GWh	14.415 GWh	12.750 GWh	13.713 GWh	13.898 GWh	1%

8.1 Calculation of Energy Saving Potentials

Energy balance models are especially useful for calculation of energy savings. Slovenian model was used for designing different refurbishment scenarios of external wall. For these purpose new subtypes were defined (letter F was added). This new subtypes represent existing buildings with refurbished façade. Only buildings from 01, 02 and 03 year class would undergo refurbishment in upcoming years.

Figure 14: Potential for wall refurbishment (end of 2010), only buildings in first three year classes will undergo external wall refurbishment until 2020



Refurbishment measure was realistically set (8 cm of new thermal insulation if there was some kind of thermal insulation already present and 15 cm of new thermal insulation for building with no thermal protection). For example: SUH.01.Un_refur with no thermal insulation will be insulated with 15 cm and this will become new sub type SUH.01.Un_refur.F.

Then 2 scenarios where investigated: normal scenario and ambitious scenario. In 2010 1,9 % of residential building stocks walls where insulated (only 0,14 % with national subsidies). This was taken as a normal scenario. On the other hand more ambitious rate of 6 % was proposed. Algorithm based on past experiences and National Energy Program was built that describes fluctuation of buildings between building sub types.

Erection of new building, old buildings demolition and other type of refurbishment where taking into account as well.

Table 61 shows heated area of first SUH year class for present state and for two different scenario. One can observe big difference between numbers of old SUH that are still unrefurbished (first row of data, this buildings where build before 1971 and will be at least 50 years old in 2020).

Table 61: Example of total floor area per building type in 2011 and for two scenarios in 2020

Building sub type	**Area 2011 (1.000 m2)**	**Area 2020, 1,9% (1.000 m2)**	**Area 2020, 6% (1.000 m2)**
SUH.01.Un_refur	9.790	5.128	415
SUH.01.Un_refur.F		2.885	8.144
SUH.01.Med_refur	10.314	6.178	1.264
SUH.01.Med_refur.F		2.884	8.141
SUH.01.Full_refur	4.238	6.501	4.615
SUH.01.Full_refur.F		547	1.545
…	…	…	…

For both scenarios in 2020 energy balance was calculated as for 2011.

Table 62: Example of total floor area per building type in 2011 and for two scenarios in 2020

Energy carrier	2011	2020 1,9%	2002 6%
Oil	4.506 GWh	3.889 GWh	3.453 GWh
Gas	1.066 GWh	1.186 GWh	1.120 GWh
District heating	1.254 GWh	1.463 GWh	1.346 GWh
Electricity	3.986 GWh	3.913 GWh	3.864 GWh
Other RES	2 GWh	10 GWh	10 GWh
Biomass	3.084 GWh	2.812 GWh	2.491 GWh
Coal	0 GWh	0 GWh	0 GWh
Total	13.898 GWh	13.272 GWh	12.284 GWh
	0,0%	-4,5%	-11,6%

Analyse of saving potentials related to refurbishment of existing buildings external walls showed that we can achieve up to 11 % of savings. For these we would have to refurbish 6% of residential building stock each year. In other words until 2020 more than 54 % of building stock would have a new façade. This could only happen with large scale subsidies. It is an ambitious goal which should be considered, since refurbishments not only bring energy savings, but also economic growth, employment and lower CO_2 emissions thus lower emission penalties.

8.2 Perspectives and Conclusions

Tabula approach brought new concept to building typology and national balance calculations. By defining subtypes we were able to describe building not only at their original state but also in present modernized state. Energy balance calculated energy consumption by building type. This was taken as a starting point for different scenarios.

Statistical data for heating systems is at the same level as data about buildings. Energy performance database that is starting now will fill in these gaps. These will add accuracy to the calculation model.

Table 63: Sources / References Slovenia

Reference shortcut	Short description	Reference
EN ISO 13790:2008	European Standard. Energy performance of buildings - Calculation of energy use for space heating and cooling	Energijske lastnosti stavb - Račun rabe energije za ogrevanje in hlajenje prostorov
STAT	Statistical Journal of Slovenia	Statistični letopis 2010, (SI-STAT), Statistični urad Republike Slovenije.
NEP	National Energy Program	NEP 2004, Resolucija o nacionalnem energetskem programu
AN	National Action Plan	AN URE, Nacionalni akcijski načrt za energetsko učinkovitost za obdobje 2008–2016, RS, 2008
PURES	Rules on efficient use of energy in buildings	PURES 2010, Pravilnik o Pravilnik o učinkoviti rabi energije v stavbah in Tehnična smernica za graditev TSG-1-004 Učinkovita raba energije (Ur.l. RS, št. 52/2010, 30.6.2010)
REN	Registry of Buildings	Register nepremičnin Slovenije, 2009