Typology Approach for Building Stock Energy Assessment. Main Results of the TABULA project

– Final Project Report: Appendix Volume –

TABULA Project Team

October 2012

(Deliverable D2)

www.building-typology.eu

Supported by INTELLIGENT ENERGY EUROPE

Contract N°: IEE/08/495

Coordinator: IWU Institut Wohnen und Umwelt, Darmstadt / Germany

Project duration: June 2009 - May 2012

Authors:

Tobias Loga (ed.) Nikolaus Diefenbach (ed.) Britta Stein (ed.)	IWU	Institut Wohnen und Umwelt / Institute for Housing and Environment	Darmstadt, Germany
Elena Dascalaki Constantinos A. Balaras Kalliopi Droutsa Simon Kontoyiannidis	NOA	National Observatory of Athens	Athens, Greece
Marjana Šijanec Zavrl Andraž Rakušček	ZRMK	Building and Civil Engineering Institute ZRMK	Ljubljana, Slovenia
Vincenzo Corrado Stefano Corgnati Ilaria Ballarini	POLITO	Politecnico di Torino - Department of Energy	Torino, Italy
Charles Roarty Michael Hanratty Bill Sheldrick	Energy Action	Energy Action Limited	Dublin, Ireland
Marlies Van Holm Nele Renders	VITO	Flemish Institute of Technological Research	Mol, Belgium
Małgorzata Popiołek Jerzy Kwiatkowski	NAPE	Narodowa Agencja Poszanowania Energii SA / National Energy Conservation Agency	Warszawa, Poland
Maria Amtmann	AEA	Austrian Energy Agency	Wien, Austria
Tomáš Vimmr Otto Villatoro	STU-K	STU-K	Prague, Czech Republic
Kim B. Wittchen Jesper Kragh	SBi	Danish Building Research Institute, AAU	Hørsholm, Denmark
Hubert Despretz	ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME)	Valbonne, France
Zdravko Georgiev	SOFENA	Sofia Energy Agency	Sofia, Bulgaria
Karin Spets	MDH	Mälardalens University	Västerås, Sweden
Leticia Ortega Begoña Serrano Lanzarote	IVE	Instituto Valenciano de la Edificación	Valencia, Spain
Milica Jovanovic Popovic Dusan Ignjatovic	Univ. Belgrade	University of Belgrade - Faculty of Architecture	Belgrade, Serbia

published by
Institut Wohnen und Umwelt GmbH
Rheinstr. 65 / D-64295 Darmstadt / GERMANY
www.iwu.de

October 2012

TABULA website: **www.building-typology.eu**

Contents

Appendix A - Elaboration of Residential Building Typologies in the Respective National Context – Country Reports

A.1. <AT> Building Typology in Austria

(by TABULA partner AEA / Austrian Energy Agency)

A.1.1. Set-up of the national building typologies

When the project started in May 2009, there was no common typology existing for the Austrian residential building stock. So the main work was to find the most helpful information out of different sources and to put this information together, to get an overall view of the national building stock. Based on reference sources, statistical data and the national advisory group, a harmonised approach for a structure of national typologies was developed. The two basic parameters – building size and construction period – compose the two principal axes of the matrix of the building typology and are the basis of the TABULA buildings.

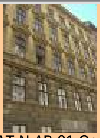
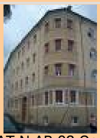
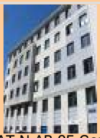
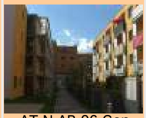
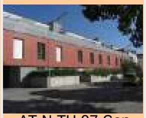
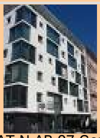
- The **building size** is defined in the four categories:
  SFH Single-family houses
  TH Terraced houses
  MFH Multi-family houses
  AB Apartment blocks
- The **construction periods** depend on the national (architectural) history and/or national statistics. In Austria it is a combination of both. In the Austrian Typology the following seven construction periods are used:
  I up to 1918
  II 1919–44
  III 1945–60
  IV 1961–80
  V 1981–90
  VI 1991–00
  VII 2001–10

The second task was to bring all results together by means of the national brochure and the European typology web tool. The brochure and the web tool can be used by energy experts and by the public as an information source about

- typical indicators describing each building and heat system type
- the frequency of building types and heating system types in the national respective housing stock.

The **building type matrix** in total consists of 28 basic reference buildings with common supply systems for heating and domestic hot water. These reference buildings are presented in the national brochure. For the WebTool 5 different common supply systems were proposed, so the calculation of the relevant energy indicators and the refurbishment of 140 reference buildings are possible.

Figure 1: "Building Type Matrix" – classification of the Austrian housing stock

	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	national (Gesamt-Österreich)	... 1919	generic (Standard / allgemein typisch)	 AT.N.SFH.01.Gen	 AT.N.TH.01.Gen	 AT.N.MFH.01.Gen	 AT.N.AB.01.Gen
2	national (Gesamt-Österreich)	1919 ... 1944	generic (Standard / allgemein typisch)	 AT.N.SFH.02.Gen	 AT.N.TH.02.Gen	 AT.N.MFH.02.Gen	 AT.N.AB.02.Gen
3	national (Gesamt-Österreich)	1945 ... 1960	generic (Standard / allgemein typisch)	 AT.N.SFH.03.Gen	 AT.N.TH.03.Gen	 AT.N.MFH.03.Gen	 AT.N.AB.03.Gen
4	national (Gesamt-Österreich)	1961 ... 1980	generic (Standard / allgemein typisch)	 AT.N.SFH.04.Gen	 AT.N.TH.04.Gen	 AT.N.MFH.04.Gen	 AT.N.AB.04.Gen
5	national (Gesamt-Österreich)	1981 ... 1990	generic (Standard / allgemein typisch)	 AT.N.SFH.05.Gen	 AT.N.TH.05.Gen	 AT.N.MFH.05.Gen	 AT.N.AB.05.Gen
6	national (Gesamt-Österreich)	1991 ... 2000	generic (Standard / allgemein typisch)	 AT.N.SFH.06.Gen	 AT.N.TH.06.Gen	 AT.N.MFH.06.Gen	 AT.N.AB.06.Gen
7	national (Gesamt-Österreich)	2001 ... 2009	generic (Standard / allgemein typisch)	 AT.N.SFH.07.Gen	 AT.N.TH.07.Gen	 AT.N.MFH.07.Gen	 AT.N.AB.07.Gen

A.1.2. Analysis of the specific building type data and frequencies

The **national statistic** dwelling and building census [1] by the Statistics Austria contains the number of buildings and the living area sorted according to building periods.

As the national statistics make no difference between multi-family houses and terraced-houses, there is no detailed information available and the category TH is therefore included in MFH. So for the Austrian typology, the frequency of buildings and square metres can only be displayed for three building sizes:

- Single-family houses: the numbers are taken out of “residential buildings with 1 to 2 dwellings”
- Multi-family houses: the numbers are taken out of “residential buildings with 3 to 10 dwellings”
- Apartment blocks: the numbers are taken out of “residential buildings with more than 11 dwellings”

The number of residential buildings for each building size and the total area of living space were taken out of an actualised evaluation of the statistical data, corresponding to the TABULA typology, including all building periods until December 2010.

Table 1: The classification of the Austrian building stock according to the TABULA requirements: number of residential buildings and square metres (living area in m²) on national level

Construction period		Building size		
		SFH	**MFH**	**AB**
-1919	number of res.-bui.	235,723	36,025	15,228
	Living area (m²)	30,583,052	14,145,992	16,932,197
1919-1944	number of res.-bui.	129,086	18,550	5,025
	Living area (m²)	14,350,763	6,161,368	4,318,376
1945-1960	number of res.-bui.	194,442	19,868	7,727
	Living area (m²)	22,944,091	7,001,308	7,317,536
1961-1980	number of res.-bui.	489,397	37,104	21,750
	Living area (m²)	65,375,704	14,739,613	28,912,454
1981-1990	number of res.-bui.	246,757	17,592	6,058
	Living area (m²)	33,945,697	7,728,972	8,345,633
1991-2000	number of res.-bui.	159,118	16,821	4,131
	Living area (m²)	22,186,226	7,389,169	4,777,708
since 2001	number of res.-bui.	173,525	18,405	4,636
	Living area (m²)	25,978,316	7,985,746	5,620,676
Missing data *	number of res.-bui.	116,063	5,617	2,617
	Living area (m²)	13,624,483	2,541,389	3,920,095

*The category "missing data" contains buildings of construction periods which are not relatable due to a gap in the data collection. Nevertheless, it is assumed that the majority of the buildings are part of the construction period 1991–2000.

Beside the two basic parameters – building size and construction period – the energy performance of buildings is determined by a number of other parameters including construction elements, geometry of the building, environment, age and kind of the energy-technical systems, as well as already implemented refurbishment measures.

In general, the information within reference sources is quite imprecise regarding the needed detailed information. In order to find precise buildings data, the Energy database ZEUS as well as input from experts during presentations and workshops were used.

A.1.3. Example buildings: data sources, definition of refurbishment measures

In order to choose "typical" reference buildings with the right parameters, there are different approaches possible:

- Example buildings (data of one optional existing building)
- Synthetic representative buildings (virtual building corresponding to statistical data)
- Average representative Buildings (existing building corresponding to statistical data)

For the Austrian typology, the concept of average representative buildings was used, to combine a top-down and the bottom-up approach. Top-down means that diverse existing general information [2, 3, 4, 5] on the Austrian building stock were combined and resulted in a draft building typology. Bottom-up approach means that precise building data was collected via an existing energy performance certificate database [6].

A.1.4. Use of the EPC database ZEUS to attain information about the national building stock

The Energy Performance Certificate EPC was first introduced in 2000 in the Austrian Provinces (Bundesländer) to gain subsidy schemes for new homes. ZEUS is the biggest national database and is implemented in three of nine provinces of Austria. The EPCs calculations are carried out by several software programs and are then uploaded to ZEUS by using a predefined XML format.

The database combines the collection of data with administrative purposes, as it simplifies the application for local subsidies. So it's based on the administration of subsidies and includes automated quality checks. The target group are energy consultants.

Together with a software company and the Provinces concerned, the needed information of the model buildings for the TABULA categories were analysed. The first step of the evaluation method was the export of the anonymized EPC data. In 2011 there were about 40,000 EPCs saved in the ZEUS databases, 93% residential buildings, 60% of them concerning new buildings and 40% reconstructed buildings.

In the second step, the EPC data was analysed based on predefined average values. In the table below, the average values of essential parameters can be found. According to these scopes of average values, we selected one typical building for each typology out of the database. That means, the average living area and the average data regarding the thermal envelope (heating demand and U-values) were calculated – and the most suitable building was declared as reference building to represent the building typology.

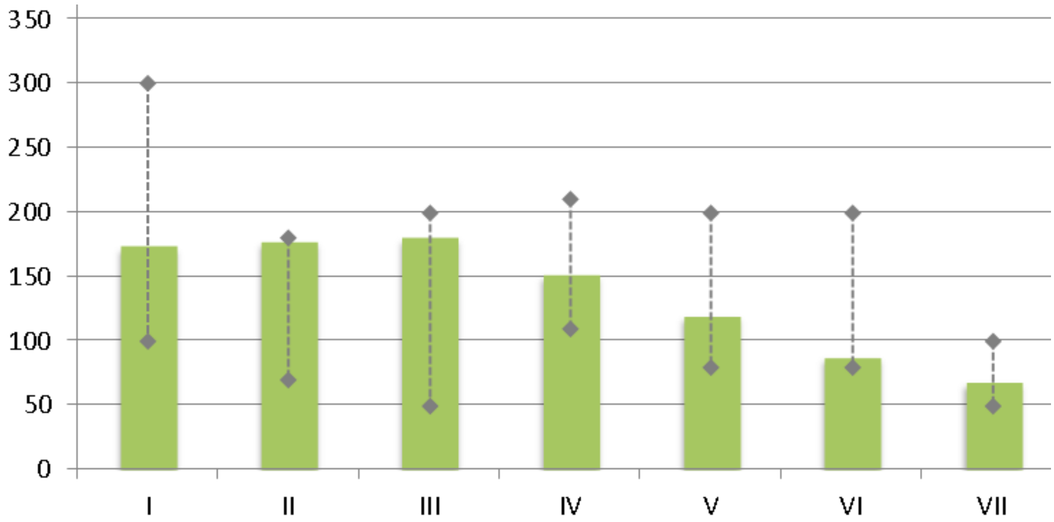
Table 2: shows the average values for different parameters in the construction periods I to VII.

Construction period	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
	-1918	1919-44	1945-60	1961-80	1980-90	1991-00	2001-10
SFH Single-family house							
Living area [m²]	125-155	110-140	110-140	125-155	140-170	145-175	145-175
Heating demand [kWh/m²a]	180-300	200-370	160-380	145-280	100-190	80-130	10-100
U-value [W/(m²K)]	1.0-1.8	1.1-1.45	1.0-1.2	0.6-0.85	0.35-0.8	0.3-0.7	0.2-0.6
MFH Multi-family house/ TH Terraced house							
Living area [m²]	400-800	280-680	280-680	400-800	400-800	350-750	350-750
Heating demand [kWh/m²a]	130-230	140-270	150-270	100-205	80-140	60-100	10-80
U-value [W/(m²K)]	1.0-1.8	1.1-1.45	1.0-1.2	0.6-0.85	0.35-0.8	0.3-0.7	0.2-0.6
AB Apartment blocks							
Living area [m²]	>800	>700	>700	>800	>800	>800	>800
Heating demand [kWh/m²a]	120-220	130-260	130-260	90-190	70-130	50-100	10-80
U-value [W/(m²K)]	0.9-1.7	1.0-1.4	0.9-1.1	0.5-0.8	0.35-0.75	0.3-0.7	0.2-0.6

In the next steps EPCs from before and after the refurbishment were identified. Sample IDs were evaluated and XML data were further investigated for quality purposes. Then, based on the ID, relevant buildings were identified. And in the last step all data of the relevant buildings were extracted. Some data information, especially the exact data of the building elements could only be taken out of the stored PDF file.

With the extracted data the contents of the database could be visualised and comparisons to the previous made assumptions were possible. It could be asserted that the database values correspond with the average values taken out of literature but changed their emphasis within this range. The following graphs show comparisons of the average heating demand (green bar) of the different construction periods taken out of the ZEUS EPC database with the range of literature data.

Table 3: Example of excel pivot table calculation: comparison of heating demand [kWh/m²a] of analyzed ZEUS building stock data (green bar) per construction period – including all building categories (SFH, TH, MFH, AB) – with literature data.

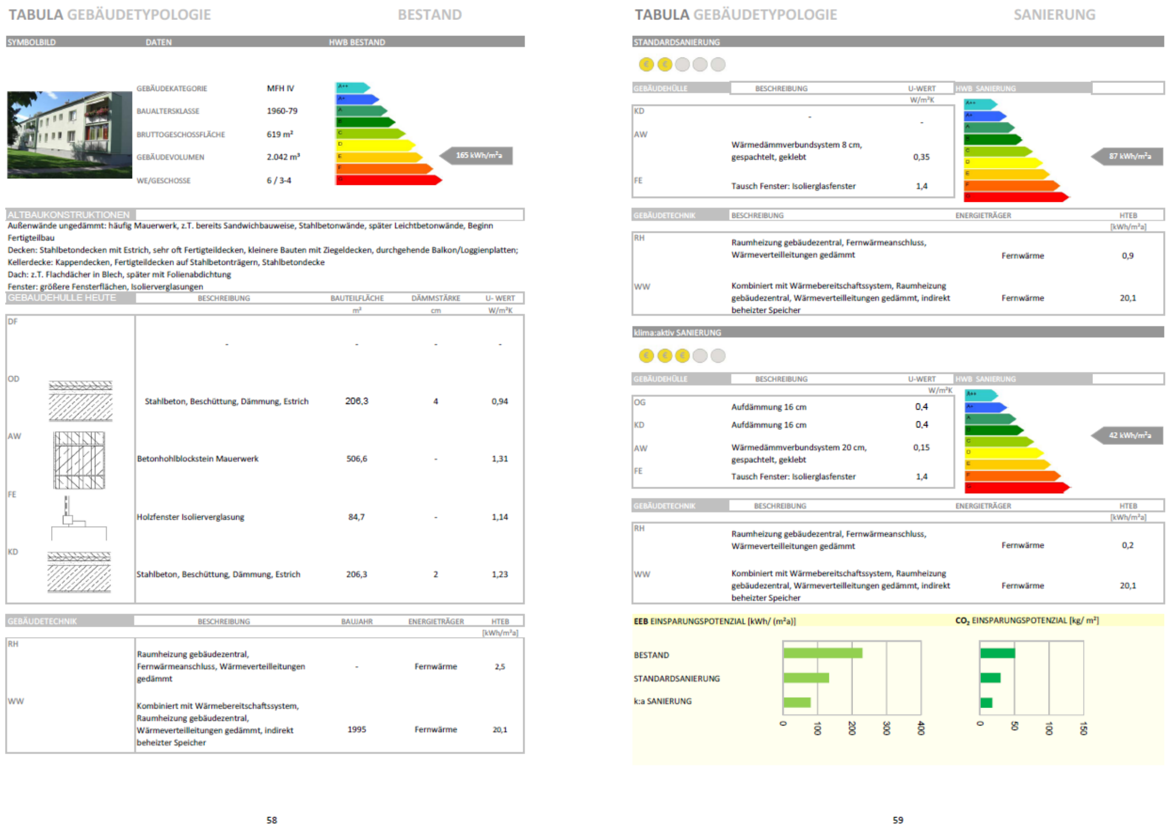


A.1.5. Concept of the typology brochures and utilisation of a website

The outcome of the national typology is available as brochure [7]. The datasets for the particular buildings are shown in the building data sheets. The Austrian brochure consists of 28 double-paged typology building descriptions. On the first data sheet, the status quo of the building is described. On the second data sheet two possible refurbishment variants, the final energy demand, its energy savings as well as the CO_2 emission reduction potential of different refurbishment measures are shown at the right double-page data sheet. For the brochure the calculations were checked with an energy certificate software, as well as the different refurbishment variants.

In the European Web tool [8] there are 140 reference buildings available for Austria, with all the information about the building envelope, five different supply systems to choose for each category, the energy-related indicators and results; for all the variants, the calculation of the possible refurbishment measures and energy reduction potentials is possible.

Figure 2: "Building Display Sheet" – existing state of an example building and impact of refurbishment measures (extract from the Austrian building typology brochure)

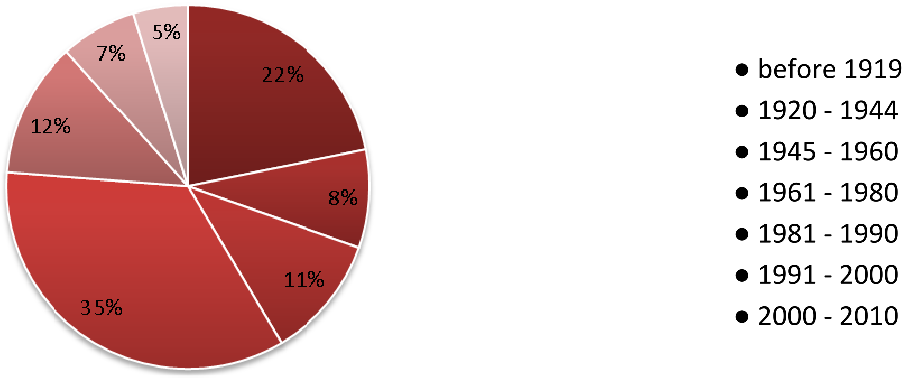


A.1.6. National energy balance calculation

The total energy efficiency depends on the type of heat source as well as on the distribution and storage systems for space heating and domestic hot water. Refurbishment measures that had been carried out already had been taken into consideration in the selection of model buildings. In the last decades, the energy system technologies improved significantly. Many of the technical facilities have been renovated in recent years or have been completely replaced. Therefore a correlation of the supply system with the construction year of the building cannot be expected. This fact has been taken into consideration in the selection of model buildings. The national distribution of heating system and energy carrier per typology were defined on the basis of statistical data. For carrying out the calculation, the following sources have been used:

- The 28 model buildings of the TABULA typology
- the statistical data "Gebäude- und Wohnungszählung" (dwelling and building census) of Statistics Austria
- the statistical distribution of heating systems and energy carriers in the Austrian building stock including already refurbished systems

Figure 3: Distribution of the national final energy demand per specific construction period (including all residential building categories)



On the basis of the TABULA building typology and the statistical model, the national final energy demand was calculated for Austria. The national statistic by Statistics Austria contains the number of buildings and the living area sorted according to building periods as well as information about the heating systems and energy carriers. For this, the three statistical most common energy carriers and heating systems were used.

To convert the theoretical calculated final energy demand from TABULA into the practical measured national final energy consumption, the “servicefactor” 0.65 was used. The national final energy consumption for the sector space heating and domestic hot water results in 61 and a half thousand GWh.

Based on the final energy results, a final energy reduction potential analysis was made. For the calculation the refurbishment measures are defined on two levels: a “standard refurbishment” according to the guideline no. 6 of the Austrian Institute of Civil Engineering, and an advanced stage defined according to the requirements of the national climate protection programme “klima:aktiv”. From the 2 million buildings in Austria about 1.5 million count among the category of one- and two-family houses, so there is evidence that the major potential lies in this category.

A.1.7. Perspectives for transfer of findings to non-residential buildings – Existing typology concepts and draft classification scheme

In Austria little information is available about the energy performance of non-residential buildings. There are two databases for non-residential buildings available, but because of the lower quantity of entries in comparison to residential building databases, it’s more difficult to draw conclusions. The **ecofacility** database is a benchmark database of the national klima:aktiv program [9] and was founded in February 2004. It is used by the klima:aktiv commercial building consultants for construction and renovation, to perform a first rough check within an energy consultation. After entering the data, the consultant is able to compare and evaluate the electricity, water and energy consumption. The online database assists the energy consultant by offering an automatic estimation of the energy efficiency of the building. In a second step, on the bases of a short report, the energy consultant gives general energy saving advices and then, in a third step, proposes necessary energy saving measures.

The **Austrian Statistical Office** provides only little information about non-residential buildings, and the requested data are not available. The **Immo-ZEUS** EPC-database [10] developed for non-residential buildings, contained in 2011 1690 data sets of non-residential buildings. Immo-ZEUS is available to all construction companies, real estate companies and Energy performance certificate advisers. It is an Internet software, which makes possible that the EPC data from the respective calculation programs is automatically transferred into an Internet address.

Within the TABULA project, the data of ZEUS and Immo-ZEUS databases were evaluated in order to check their usability for establishing a non-residential building typology.

It can be appointed that for more representative information from the databases, more buildings will have to be recorded.

A.1.8. Conclusions

In Austria the development of a building typology of residential buildings could successfully be accomplished by combination of available data information out of the ZEUS EPC database, reference sources and the national statistics.

The success of the project can specially be noticed because of the already occurred applications of the national building typology in national projects. For the following national and European projects the Typology was for example used for

- The ´European Buildings under the microscope study´[10],

for on-going projects of the Austrian Energy Agency:

- EPBD Art 5. cost optimal requirements for Austria
- Presumptions for the climate protection requirements calculations

and by energy consultants for showcasing refurbishment requirements in the first energy consultancy phase.

For the further work, more detailed EPC databases would be very helpful for refurbishment recommendations. Today on national level the statistical office is starting to integrate an EPC database into the GWR buildings and residences registry. But this service provider is still in the testing phase. It needs legislative changes concerning the analogue address system and concerning the notification of the Energy performance certificates to the GWR system. But this would be a key factor to roll out a national wide qualified EPC data collection including all provinces.

Table 4: National Activities Austria / Sources and References

Reference shortcut	Short description	Reference
[1]	National statistics	„Gebäude und Wohnungszählung", Statistik Austria 2011
[2]	Scientific paper	Default-Werte aus „Leitfaden Energietechnisches Verhalten von Gebäuden", April 2007
[3]	Scientific paper	„Leitfaden zum Umgang mit Energieeffizienz und weiteren Nachhaltigkeitsparametern in der Immobilienwertermittlung", Februar 2010
[4]	Book	„Atlas Bauen im Bestand", Hannover 2008, Institut für Bauforschung e.V.
[5]	Scientific paper	„Handbuch für Energieberater", 1994; „Altbaukonstruktionen Musteraufbauten", Mai 2009, Energieberatung.
[6]	Project website	http://www.energieausweise.net
[7]	Project website	http://www.energyagency.at/gebaeude-raumwaerme/aktuelle-projekte/tabula.html
[8]	Project website	http://webtool.building-typology.eu/webtool/tabula.html?c=all
[9]	Project website	http://www.klimaaktiv.at
[10]	Project website	http://www.immozeus.at
[11]	Project website	http://www.bpie.eu/eu_buildings_under_microscope.html

A.2. <BE> Building Typology in Belgium

(by TABULA partner VITO)

A.2.1. State of the art on building typologies in Belgium and data inventory

A.2.1.1 Use of building typologies in policy supporting research in Belgium (1990s – present)

An inventory of studies on building typologies carried out in Belgium prior to the TABULA project reveals that there currently is no generally accepted or referable Belgian building typology for residential buildings within Belgium, nor for other types of buildings. One of the impeding factors may be the fact that Belgium is a federal state which consists of three political entities, i.e. the Flemish, the Walloon and the capital region of Brussels with energy efficiency of buildings being a regional authority. As a consequence, there are only few data sources at the Belgian level and there is most often no consistency between surveys carried out and databases available for the different regions. This evidently impedes the development of housing typology at the Belgian level.

The inventory of past typology studies in Belgium however reveals several research projects where housing stock models, reference buildings and building typologies were derived. The national scientific report [TABULA NatSci BE 2011] provides detailed information on a selection of main building typology studies carried out for Belgium prior to the TABULA project. The overview provides valuable insights in both the development and application uses for building typologies and examines the methodology used for determining dwelling types and for selecting the building envelope and services characteristics. Two different approaches were identified on the basis of the literature study for Belgium:

- **The average dwelling approach** involves modelling a set of fictional buildings based on average values thereby creating a model the entire building stock. The established parameters are then iteratively adjusted to correspond to the total building stock energy consumption e.g. by means of data from the regional or national energy balance.
- **The typical dwelling approach** involves composing a set of typical dwellings closely related to existing buildings and existing building components, chosen for their reference value compared to the examined existing building stock. Considering that actual buildings and actual building characteristics are used as a basis, the typical dwellings allows to examine the impact of various saving measures on a specific individual dwelling type and are usually not intended for analyses at building stock level.

In most of the past typology studies examined for the Belgian context, a distinct choice was made to adhere to one of the approaches described above. In other cases, a more hybrid approach was followed. Within the course of the TABULA project, VITO has followed the dual approach as outline above. On the one hand, based on previous experiences with the development of a Flemish housing stock model, VITO has developed a **first version of a Belgian housing stock** containing 216 variations and open to further refinement. Secondly, **a set of 29 typical dwellings and 25 corresponding typical housing units** was developed in parallel. The housing stock model and the typical dwellings follow the same main division in dwelling types and age classes and therefore compatible.

A.2.1.2 Data inventory

As a basis for the construction of the Belgian TABULA typology and housing stock model, a detailed inventory of available data for Belgium was carried out. Evaluation of existing data sources demonstrates that sufficient data are available dealing with **general building characteristics**, allowing to determine the main discerning aspects of the building typology (dwelling types, age classes, frequencies). Main data sources in this perspective are the land registry statistics, the NIS building permit statistics and the NIS General Socio-Economic Survey from 2001 [VANN 2007].

For the **geometric characteristics** related to the building layout and the building envelope, the best available data sources are the EAP databases from Flanders and Wallonia, containing data from voluntary energy audits carried out by qualified energy experts. The EAP database of the Flemish Energy Agency contains data on approximately 1000 energy audits. The Walloon database contains data on approximately 10,000 audits. The Brussels Institute for Environment Management manages the data obtained from Energy Audits carried out in Brussels. The database for the Brussels region could however not be made accessible within the time frame of the TABULA project. A unique additional value of the EAP database lies in the fact that this data source contains both calculated energy performance according to the EAP steady state energy balance and a record of measured energy consumption based on yearly energy bills. The EAP-data allow to determine geometric characteristics such as the floor surface area (gross and net), number of storeys of the building, number of housing units, protected volume, transmission loss area of the opaque building envelope components (roof, floor, facades, doors), transmission loss area and orientation (of transparent building envelope components (windows, doors).

The EAP databases also allow to determine the **thermal and energy performance characteristics** for the building envelope components and building services for the average dwellings within the housing stock model. Further data related to the energy efficiency of the building envelope and services systems are available from targeted surveys conducted and commissioned by various parties from the 1990s up to the present dealing with housing quality and housing conditions. The historical context of building regulations since the 1990s also serves as a reference for determining building envelope and services characteristics. In 1992, the Flemish Insulation Decree ('92) was imposed and from 2006 onwards the Energy Performance of Buildings Regulations is in force as a regulatory framework. Available data sources dealing with the performance characteristics of typical building envelope components and the typical services systems are however particularly scarce. The mentioned available sources do not allow to uniformly define typical constructions for roofs, floors and walls, and to assign typical installation components for the various construction periods. For that reason, the sub-typologies for the typical building envelope and services components were based both on the available data sources as well as on expert judgement.

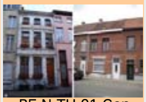
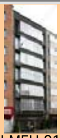
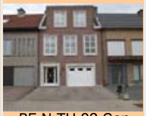
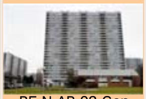
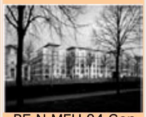
The **Energy Balances for the Flanders, Brussels and Walloon regions** are an additional source of information dealing with the total energy consumption of, amongst others, the residential sector. The Flemish Energy Balance is updated on a yearly basis by VITO for the Flemish government [AERN 2008] and forms one of the foundation stones for the Flemish contribution to the Belgian greenhouse gas inventory, internationally reported as part of the Kyoto protocol. The balances for the Walloon Region and the Brussels Capital Region compiled by ICEDD are also publically available [ICED 2008] [ICED 2007].

A.2.2. The Belgian TABULA building typology

A.2.2.1 Main typology matrix

For the main typology matrix of the harmonized European typology, VITO has identified 19 dwelling types defined by the combination of 5 age classes and 4 housing types, minus one. The age classes (pre 1946; 1946-1970; 1971-1990; 1991-2005; post 2005) are commonly used in various Belgian dwelling studies. The housing types consist of 2 single family housing types, i.e. the detached house and the terraced house and 2 multifamily housing types, i.e. the medium-height apartment building (between 4 and 8 storeys) and the high rise apartment building (more than 8 storeys). The pre 1946 high rise apartment building is considered uncommon for the Belgian context, which leads to 19 typical dwellings in the EU harmonized typology. Two extra variants to the main typology were furthermore defined for all age classes, namely the semi-detached single family house and the small multifamily house, leading **to 29 dwelling types** in total. Regional variations have not been made for the Belgian case, although further division of the main matrix of the typology per region (Flemish, Brussels, Walloon) has been considered for Belgium. This would make it possible to provide variants for e.g. specific building styles that are particular to certain regions. However, due to an absence of data permitting such variants to be clearly defined, a decision was made not to adopt a region-based division.

Figure 3: "Building Type Matrix" – Classification of the Belgian housing stock (generic building types)

	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	national (Belgie)	... 1945	generic	 BE.N.SFH.01.Gen	 BE.N.TH.01.Gen	 BE.N.MFH.01.Gen	
2	national (Belgie)	1946 ... 1970	generic	 BE.N.SFH.02.Gen	 BE.N.TH.02.Gen	 BE.N.MFH.02.Gen	 BE.N.AB.02.Gen
3	national (Belgie)	1971 ... 1990	generic	 BE.N.SFH.03.Gen	 BE.N.TH.03.Gen	 BE.N.MFH.03.Gen	 BE.N.AB.03.Gen
4	national (Belgie)	1991 ... 2005	generic	 BE.N.SFH.04.Gen	 BE.N.TH.04.Gen	 BE.N.MFH.04.Gen	 BE.N.AB.04.Gen
5	national (Belgie)	2006 ...	generic	 BE.N.SFH.05.Gen	 BE.N.TH.05.Gen	 BE.N.MFH.05.Gen	 BE.N.AB.05.Gen

A.2.2.2 Typical dwellings – Belgian typology brochure

In the national typology brochure featuring typical Belgian dwellings, focus lies on housing units rather than on the dwelling as a whole. This leads to certain changes in the typology matrix. Within the brochure, **25 typical dwelling units** are defined by the combination of 5 age classes and 5 housing unit types. The 5 age classes (pre 1946; 1946-1970; 1971-1990; 1991-2005; post 2005) remain unchanged. The 3 single family housing types, i.e. the detached house, the semi-detached house and the terraced house also remain valid. But for individual apartments a distinction is made between 2 apartment types, namely an enclosed and an exposed apartment. The enclosed apartment only has a front and back façade exposed to the outer environment, the exposed apartment has two extra outer envelope surfaces, a side façade and a roof. In the typology brochure, we thus take into consideration two extremes, the energy consumption for apartments at a different location within the building will consequently lie somewhere in between these two extremes.

The Belgian typology brochure contains 25 dwellings fiches, one for each dwelling type defined. For each dwelling type general characteristics, geometrical data, typical building envelope components (including their thermal characteristics) and typical services systems (including energy performance characteristics) are defined. Within the dwelling fiches, results of energy performance calculations are displayed for the current dwelling state and for two energy upgrade scenarios. The first energy upgrade scenarios follows current building energy regulations (EPB 2010), the second energy upgrade scenario is consistent with current low energy building standards within Belgium (Low Energy). Moreover, a comfort assessment and a financial assessment is carried out determining investment costs, reduction in energy costs and simple payback times for the two energy upgrade scenarios. Three classes for the payback times have been defined, i.e. a first class with a payback time of about 20 yrs (15-25 yrs), a second class with a payback time of about 30 years (25-35 yrs) and a third class with payback time above 35 years.

For the energy performance calculations, the legally binding Flemish EPW-methodology for new build residential buildings is followed taking into account energy consumption for space heating, hot water production and auxiliaries. A correction factor has been applied to the theoretically derived energy consumption since especially for older buildings the theoretical energy consumption tends to be much higher than the actual energy use. In short, occupants of old and badly insulated buildings often consume less energy than predicted, because they lower their desired comfort level (indoor temperatures, indoor air quality, …) in favour of lower utility bills. Vice Versa, the energy savings from energy renovation measures are often lower than expected: as the building and building systems become more energy efficient, occupants tend to increase their comfort demands, thus outweighing the expected energy conservations to a large extend. This mechanism is described in literature as the so-called "rebound effect" [HAAS 1998]. The correction factor was deduced from the extensive EAP database of 10.000 Walloon dwellings.

Figure 4: Ratio of actual energy use to calculated energy use in function of the average U-value of the building envelope [TABULA NatSci BE 2011].

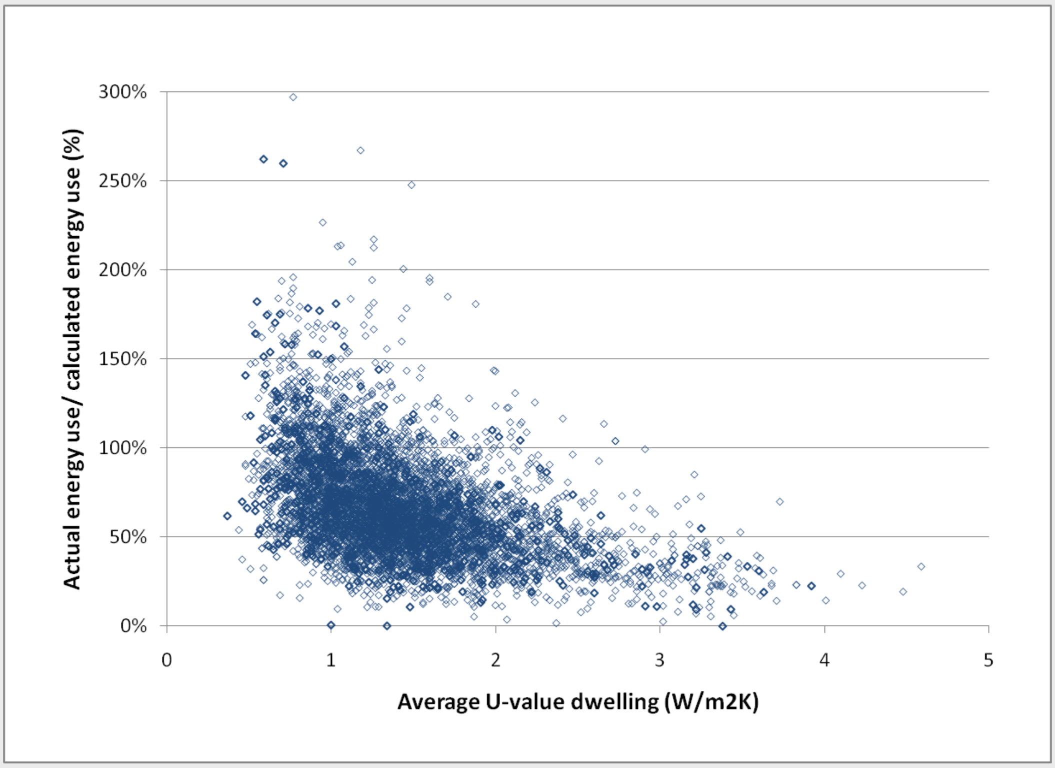


Figure 2 depicts the great divergence between actual energy use and theoretically calculated energy consumption. For buildings with high U-values (poorly insulated), the actual energy use is consistently much lower than the calculated value. In general, the correction factor becomes smaller (and thus the deviation between actual energy use and predicted energy use becomes bigger) when buildings are bigger and less insulated. This is consistent with the presumption that occupants are prepared to give in on their comfort demands as energy costs rise. The premises for the energy upgrade scenarios, energy costs, investment costs and the methodology for the financial assessment, comfort assessment, energy performance calculations and for determining the correction factor are explained in detail in the scientific report [TABULA NatSci BE 2011].

Figure 5: "Building Display Sheet" – Existing state of an example building and proposed refurbishment measures (extract from the Belgian building typology brochure [VITO 2011])

2. Type 2 - Halfopen bebouwing pre 1946

2.1 Beschrijving

Deze woningfiche heeft betrekking op driegevelwoningen daterend uit de periode voor 1946.

2.2 Details

Woningtype: **Halfopen bebouwing**
Bouwperiode: **Voor 1946**
Bruto vloeroppervlakte (m^2): **237 m^2**
Beschermd volume (m^3): **652 m^2**
Totale verliesoppervlakte (m^2): **447 m^2**

2.3 Huidige situatie

(1) Bouwkundige kenmerken (HS)

Component	Beschrijving	U-waarde (W/m²K)
Dak	Ongeïsoleerde dakconstructie pre 1946	1,7
Gevel	Ongeïsoleerde massieve buitenmuur pre 1946	2,2
Vloer	Ongeïsoleerde vloer op volle grond pre 1991	0,85
Raam	Houten raamprofielen - enkele beglazing - pre 1971	5
Deur	Buitendeur - ongeïsoleerd deurblad - pre 1991	4

(2) Systeemeigenschappen (HS)

Component	Beschrijving
Verwarming	Plaatselijke gaskachel pre 1985 - rendement 0,75
Warm water	Individuele doorstroom gasgeiser - leidinglengtes > 5 m
Ventilatie	Géén gecontroleerde ventilatie

Pagina | 9

2.4 Standaard renovatie (EPB 2010)

(1) Bouwkundige kenmerken (EPB 2010)

Component	Beschrijving	U-waarde (W/m²K)	Type Ingreep
Dak	Dakisolatie tussen kepers - 15 cm	0,3	Renovatiemaatregel
Gevel	Spouwisolatie of buitengevelisolatie - 8 cm	0,4	Renovatiemaatregel
Vloer	Vloerisolatie - 5 cm	0,4	Renovatiemaatregel
Raam	Geïsoleerde raamprofielen - verbeterde isolerende beglazing Ug 1,1 - na 2005	2	Vervangingsmaatregel
Deur	Buitendeur - geïsoleerd deurblad	2,9	Vervangingsmaatregel

(2) Systeemeigenschappen (EPB 2010)

Component	Beschrijving	Type Ingreep
Verwarming	Centrale verwarming - condenserende combiketel op gas - rendement 1,06	Vervangingsmaatregel
Warm water	Condenserende combiketel op gas – leidinglengtes > 5m	Vervangingsmaatregel
Ventilatie	Ventilatiesysteem C - natuurlijke toevoer en mechanische afvoer	Nieuwe installatie

2.5 Lage energierenovatie

(1) Bouwkundige Kenmerken (LE)

Component	Beschrijving	U-waarde (W/m²K)	Type Ingreep
Dak	Dakisolatie tussen kepers - 30 cm	0,15	Renovatiemaatregel
Gevel	Spouwisolatie of buitengevelisolatie - 15 cm	0,25	Renovatiemaatregel
Vloer	Vloerisolatie - 10 cm	0,25	Renovatiemaatregel
Raam	Verbeterde geïsoleerde raamprofielen Uf 2 - verbeterde isolerende beglazing Ug 1,1	1,6	Vervangingsmaatregel
Deur	Verbeterd geïsoleerde deurprofielen Uf 2 - verbeterd geïsoleerd deurblad	1,6	Vervangingsmaatregel

(2) Systeemeigenschappen (LE)

Component	Beschrijving	Type Ingreep
Verwarming	Centrale verwarming - condenserende combiketel op gas - rendement 1,06	Vervangingsmaatregel
Warm water	Condenserende combiketel op gas – leidinglengtes > 5m	Vervangingsmaatregel
Warm water	Thermische zonnepanelen - 5 m² - onbeschaduwd	Nieuwe installatie
Ventilatie	Balansventilatie met warmterecuperatie met volledige bypass - rendement 0,8	Nieuwe installatie

Pagina | 10

Supported by INTELLIGENT ENERGY EUROPE

The main tendencies and key conclusions derived from the analysis of the typical dwellings can be summarized as follows:

- Results demonstrate that the primary energy consumption for space heating is almost equal for the pre 1946, 1946-1970 and 1971-1990 construction periods when the correction towards actual energy consumption is applied. For the primary energy consumption for space heating, hot water production and auxiliaries combined slightly higher divergence is noted.
- Eight priority dwelling types can be discerned with an above average primary energy consumption, both specific (kWh/yr.m²) and in total (kWh/yr). Not surprisingly, 6 of these 8 dwelling types are the pre 1990 detached and semi-detached dwelling types.
- Relative energy savings potentials prove to be largely independent of the dwelling type. The EPB2010 energy upgrade leads to a reduction of approx. one third (32%) and the Low Energy upgrade of approx. two thirds (65%) in primary energy consumption compared to the current state corrected current energy consumption. When we focus only on space heating the reductions achieved are higher, respectively 39% and 76%. These reductions are logically partially annulled by the rise in auxiliary primary energy, therefore reductions are lower for the total primary energy consumption than for the primary energy consumption for space heating on its own.
- For most dwelling types, the low energy scenario leads to a more beneficial payback time than the EPB 2010 scenario. Only half of the dwelling types however achieve payback times below 35 years. Four out of eight priority dwelling types have payback times of around 20 years. The enclosed apartments all have high payback times above 50 years. Clearly cost-optimal renovation scenarios for apartment buildings differ from the integral EPB 2010 and Low Energy renovation packages examined within the TABULA study. Not surprisingly, the post '05 dwellings types also demonstrate payback times above 50 years.

A.2.2.3 Representative typology - energy balance calculations at the Belgian building stock level

Different methodologies exist to forecast the residential energy consumption of a specific region, as described in the Belgian scientific report [DUER2008]. VITO has broad and long-term experience with so-called **optimization models and engineering models,** incorporating a detailed representation of the building stock. In these models, average datasets are deployed to identify representative dwelling types. These representative types differ significantly from typical dwellings, 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.

To model the energy consumption for space heating and sanitary hot water of the Belgian, residential building stock VITO started from previous experiences with the development of the 'Flemish model for residential energy consumption' [BRIFF2010]. Within the TABULA project dwelling stock data for the two other Belgian regions, namely Wallonia and Brussels were collected and integrated into the model. Starting from an extensive database of housing characteristics, the model calculates the energy consumption for each of the 216 defined dwelling categories for the base year 2006 following the degree days method. Accordance with actual energy consumption is achieved by taking into account a correction factor based on EAP data as described above. Results are furthermore calibrated with the residential energy consumption from the 2006 Energy Balance. Further development of the Belgian housing stock model is foreseen to refine the results obtained for Wallonia and Brussels.

The Belgian housing stock model allows examination of various forecasting scenarios for renovation and demolition of existing houses, as well as for additional new built houses up to 2020. For this purpose, assumptions need to be formulated on the future evolutions of the housing stock related to societal drivers such as the evolution of the number and size of households, the evolution of the number, type and size of new dwellings and the demolition and refurbishment rates. With 2 year intervals, projections of energy consumption and related CO_2 emissions can be made up to 2020.

The subdivision into 216 representative dwelling categories is based on:

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

The properties of the 216 categories are then aggregated for use within the TABULA project obtaining 6 representative dwelling types, defined by three dwelling age classes (<1970, 1970-1990, 1991-2006) and two building types (single family or multifamily house). Table 5 summarizes the frequencies of these 6 categories for Belgium.

Table 5: Frequencies of the 6 aggregated, representative dwelling types within the Belgian stock for the year 2006 [TABULA NatBal BE 2012].

	Age class	Number of housing units	Frequency (%)
Single Family Houses	pre 1970	2,126,913	47%
	1971-1990	810,024	18%
	1991-2006	392,813	9%
Multi Family Houses	pre 1970	656,743	15%
	1971-1990	319,895	7%
	1991-2006	216,397	5%
Total		**4,522,785**	**100%**

Table 6 presents the final energy consumption for space heating and sanitary hot water for the Belgian residential sector in 2006 for the 6 dwelling types and for the various fuel types. The results are in accordance with the degree days (15/15) observed in Belgium during the year 2006, namely 1795 degree days. The pre 1970 single family houses account for almost 60% of the total final energy consumption for heating and sanitary hot water. This is in correspondence with their large frequency in the Belgian building stock (47%) and with their higher specific energy consumption compared to housing units in multifamily buildings.

Table 6: Final energy consumption for space heating and sanitary hot water for the Belgian residential sector in 2006 (TJ) [TABULA NatBal BE 2012].

	Single Family Houses			Multi Family Houses			TOTAL	% TOTAL
	pre '70	**'71-'90**	**post '90**	**pre '70**	**'71-'90**	**post '90**		
Natural gas	72.088	24.193	14.429	11.677	5.133	3.599	**131.119**	**41%**
Fuel oil	94.371	34.928	11.284	5.764	2.395	341	**149.083**	**47%**
Coal	8.990	846	98	176	65	16	**10.191**	**3%**
LPG	2.355	647	178	96	34	11	**3.321**	**1%**
Electricity	6.906	5.895	1.845	1.678	955	880	**18.159**	**6%**
Wood	3.680	1.237	306	89	16	5	**5.333**	**2%**
TOTAL	**188.390**	**67.746**	**28.141**	**19.480**	**8.598**	**4.851**	**317.206**	
% TOTAL	**59%**	**21%**	**9%**	**6%**	**3%**	**2%**		

The annual consumption of 317 205 TJ corresponds with 19 403 kton of CO_2 emissions per year directly linked to the residential sector. Emissions related to the use of electricity as an energy carrier for the consumption for space heating and sanitary hot water are excluded since these have to be accounted for in the energy sector. The major sources of CO2 emissions are fuel oil (47%) and natural gas (41%) heating installations.

A.2.3. Outlook towards planned further developments

During the course of the TABULA project, VITO developed both a typology of typical dwellings and typical housing units as well as a housing stock model for Belgium. The typical dwellings typology is a particularly valuable foundation stone for executing cost-optimal calculations towards near-zero energy for the various typical dwellings defined. NAV, the largest professional federation of architects in Flanders with more than 2300 members is committed to convert the Belgian TABULA typology brochure into a WebTool which will be made accessible from the NAV website (www.nav.be). The launch of the WebTool will be combined with a broad information campaign targeting their members and other building professionals within Belgium.

The essential element defining the relevance of a typology is the quality of data that form the basis for it. Data originating from the mandatory **energy performance certificates** issued upon sale or rental of existing residential buildings and from the EPCs of newly constructed or renovation dwellings are a particularly valuable information sources for researchers. The Flemish EPC database is considered as a particularly valuable information source offering the opportunity to create a much more representative sample of the housing stock than was ever the case for Flanders. In Flanders around and about 140,000 certificates are compiled in around one year's time. The EPC database currently contains information on almost 400.000 housing units, generated by about 3.900 energy experts (status in December 2011). The EPC-procedure for Wallonia and Brussels on the contrary has only come into force in 2010-2011 [TABULA EPCDat BE 2012].

Table 7: National Activities Belgium / Sources and References

Reference shortcut	Short description	Reference
[VITO 2011]	Belgian Building Typology Brochure	Van Holm, Marlies; Verbeke, Stijn; Stoppie, Jochem: Belgische woningtypologie. Nationale brochure over de TABULA woningtypologie. VITO, 2011 http://www.vito.be/NR/rdonlyres/23E2592E-00A9-4F5B-A3F1-1121249F7436/0/TABULA_NationalTypologyBrochure.pdf
[TABULA NatSci BE 2011]	National scientific report of the TABULA activities in Belgium	Cyx, Wouter; Renders, Nele; Van Holm, Marlies; Verbeke, Stijn: Scientific report. IEE TABULA - Typology Approach for Building Stock Energy Assessment, VITO, 2011 http://www.vito.be/NR/rdonlyres/EE7E9464-420F-43E7-B139-92318AC4F489/0/TABULA_ScientificReport_final_20110830_withAnnex3.pdf
[TABULA NatBal BE 2012]		Renders, Nele chapter "Belgium" in: Diefenbach, Nikolaus / Loga, Tobias (ed.): Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock (TABULA Thematic Report N° 2). Models for the national housing stock of 8 countries: Belgium, Czech Republic, Denmark, Germany, Greece, italy, Slovenia; IWU, Darmstadt / Germany 2012 http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf
[TABULA EPCDat BE 2012]		Van Holm, Marlies; Renders, Nele: chapter "Belgium" in: Diefenbach, Nikolaus / Loga, Tobias (ed.): Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock (TABULA Thematic Report N° 2). Models for the national housing stock of 8 countries: Belgium, Czech Republic, Denmark, Germany, Greece, italy, Slovenia; IWU, Darmstadt / Germany 2012 http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf
[VANN 2007]		Vanneste, D., Thomas, I. and Goossens, L., Sociaal-economische enquête 2001 - Woning en woonomgeving in België, FOD Economie, K.M.O., Middenstand en Energie, Algemene Directie Statistiek en Economische Informatie, 2007.
[AERN 2008]		Aernouts, K., et al., The Flemish Energy balance 2008. Energiebalans Vlaanderen 2008, VEA, 2010
[ICED 2008]		The Energy balance of the capital region of Brussels 2007. ICEDD: Energiebalans van het Brussel hoofdstedelijk gewest 2007; BIM, 2008
[ICED 2007]		The Walloon Energy balance. ICEDD: Bilan énergétique de la region Wallonne 2005; RW DGTRE, 2007
[HAAS 1998]		Haas, R., et al., The impact of consumer behavior on residential energy demand for space heating, Energy and Buildings, vol 27(2), pp 195-205, 2008
[DUER2008]		Duerinck J., Schoeters K., Renders N., Beheydt D., Aernouts K., Herold A., Graichen V., Anderson J., Bassi S. (2008). Assessment and improvement of methodologies used for Greenhouse Gas projections, Final report to DG Environment under service contract.VITO, Öko Institut, IEEP
[BRIFF 2010]		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

A.3. <CZ> Building Typology in the Czech Republic

(by TABULA partner STU-K)

A.3.1. Earlier experiences in Czech Republic

The Czech TABULA approach was partly drawn upon the regulatory definition of “reference buildings”.

The National Calculation Method for the energy performance of buildings is described in the decree N° 148/2007. This legal document refers to a number of voluntary technical standards and thus makes their requirements mandatory. The energy performance evaluation of buildings is based on the “reference building” principle (the reference building is a building of the same type, shape, dimensions, occupancy profile, etc. as the evaluated building, but the parameters of its envelope, systems, etc. comply with standard requirements).

Table 8: Building classes according to the Decree N° 148/2007

	Building class / kWh/(m^2.a)						
Type of building	A	B	C	D	E	F	G
SFH and TH	< 51	51-97	98-142	143-191	192-240	241-286	>286
MFH and AB	< 43	43-82	83-120	121-162	163-205	206-245	>245

In spite of few overlaps, the following correlations between the proposed Czech TABULA typologies age bands and building classes (as defined by Decree N°147/2008) have been proved by calculations for unrefurbished buildings (see Table 9):

Table 9: Building class equivalents to Czech TABULA matrix

Construction year class (Czech TABULA matrix)	Building class (Decree N° 148/2007)
Houses built before 1945	F,G
Houses built 1946-1960	E,F
Houses built 1961-1980	E ,(D)*
Houses built 1981-1994	D,(E)
Houses built 1995-2005	C,(B)

**The classes in brackets are significantly less frequent cases*

The calculated total energy consumption of the actual building has to be equal or lower than that of the reference building in order to comply with the Decree N° 148/2007. The fulfilment of standard requirements is achieved for buildings classified at least C.

A.3.2. Czech Building Typology

There hasn’t been any effort recognized recently to create a building typology for the purpose of evaluation of energy performance of certain types of buildings, however some reference can be made to the Decree N° 148/2007 (see above). The building types are ranged in TABULA matrix according to their size category and the construction period (see Fig.1).

The used construction technology (masonry, precast concrete) is not so much decisive for the energy behaviour of the building. The building conditions are considered as original, i.e. prior to the refurbishment. The definition of systems is more important, the accuracy in definition of systems is high in case of large panel buildings which were mostly constructed in the period 1957-1992 (MFH and especially AB categories). The definition of systems is approximate in case of SFH, TH and some MFH categories; there are no reliable information sources available.

The data collected was organized and summarized with the purpose of creating a building typology matrix that represented the Czech residential building stock. The proposed building typology consists of 24 building types divided into 6 construction periods and 4 building size categories:

Construction Periods

- Before 1920
- 1921 – 1945
- 1946 – 1960
- 1961 – 1980
- 1981 – 1994
- 1995 – 2005

Building Categories

- Single Family House (SFH)
- Terraced House (TH)
- Multi-family House (MFH)
- Apartment Block (AB)

A.3.2.1 Example buildings

Each cell of the building type matrix is representing one example building. The example buildings are defined as typical representatives of the building types having features that can be commonly found in houses of the respective age and size class. The parameters such as building envelope area, the heated area and volume, and the heat transfer coefficients are not necessarily average values for the buildings in the respective categories. Energy balances were calculated for example buildings (see below). For this purpose datasets of construction elements, envelope areas and different supply systems were collected in a common database (TABULA.xls file).

Two versions of the example building and supply system data were created:
- data according to the Czech national EPC procedure
- data according to the TABULA data structure (to enable cross-country housing stock comparisons)

A.3.2.2 Data availability and sources of information

Most of the acquired data were available in the following sources:

- Energy audits and energy certificates (MRA archives, STU-K archives, internet)
- Czech Energy Agency (ČEA) reports
- Czech statistical office (the last national census and micro census ENERGO 2004)
- Czech standards and legislation
- TZB-info web pages (Energy professionals)
- Ministry of Industry and Trade web pages
- Technical periodicals (Pozemní stavby)

The national EPC database is run by the Ministry of Industry and Trade (MOIT). The persons in charge of EPC elaboration are obliged to input data to this database but it is not possible for them to browse the database. The database is not publically accessible and unfortunately it is not possible to use it for the purpose of national building stock data acquisition.

A.3.2.3 Data Collection and Analysis

Most of the collected data are secondary quantitative data (figures, statistics presented in tabular or graphical form). Few data were reported in its original format (e.g. the tables from national standards and regulations). However most of the data were analyzed and re-interpreted like e.g. data supporting National Energy Balance Report findings.

Special attention was paid to the following aspects:

- origin of data,
- reliability of information
- age structure of the data
- consistency of data , like with like comparisons

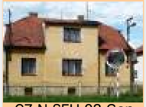
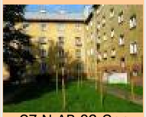
Some of the older energy consumption related data had to be recalculated to achieve compatibility with new regulations and standards. Unfortunately some statistical data were too old (National census 2001), it was necessary to use corrections based on expert knowledge and unofficial secondary data.

Scenarios were developed to study the energy performance of each building type in three different situations: current state, after a typical refurbishment, and after advanced refurbishment. These scenarios were designed combining each building type with typical building and system components, and were analyzed using the TABULA.xls spreadsheet. This analysis resulted in estimations of energy performance and potential energy saving measures for each case.

A.3.2.4 Limitations found, assumptions taken

Limitations were found especially in gathering data for smaller size categories of the housing stock.
It was necessary to estimate the degree of refurbishment of these buildings for different categories.
Other estimations were needed for the systems, their age, fuel type, and level of maintenance in order to define their efficiency and primary energy consumption.

Figure 6: "Building Type Matrix" – classification of the Czech housing stock

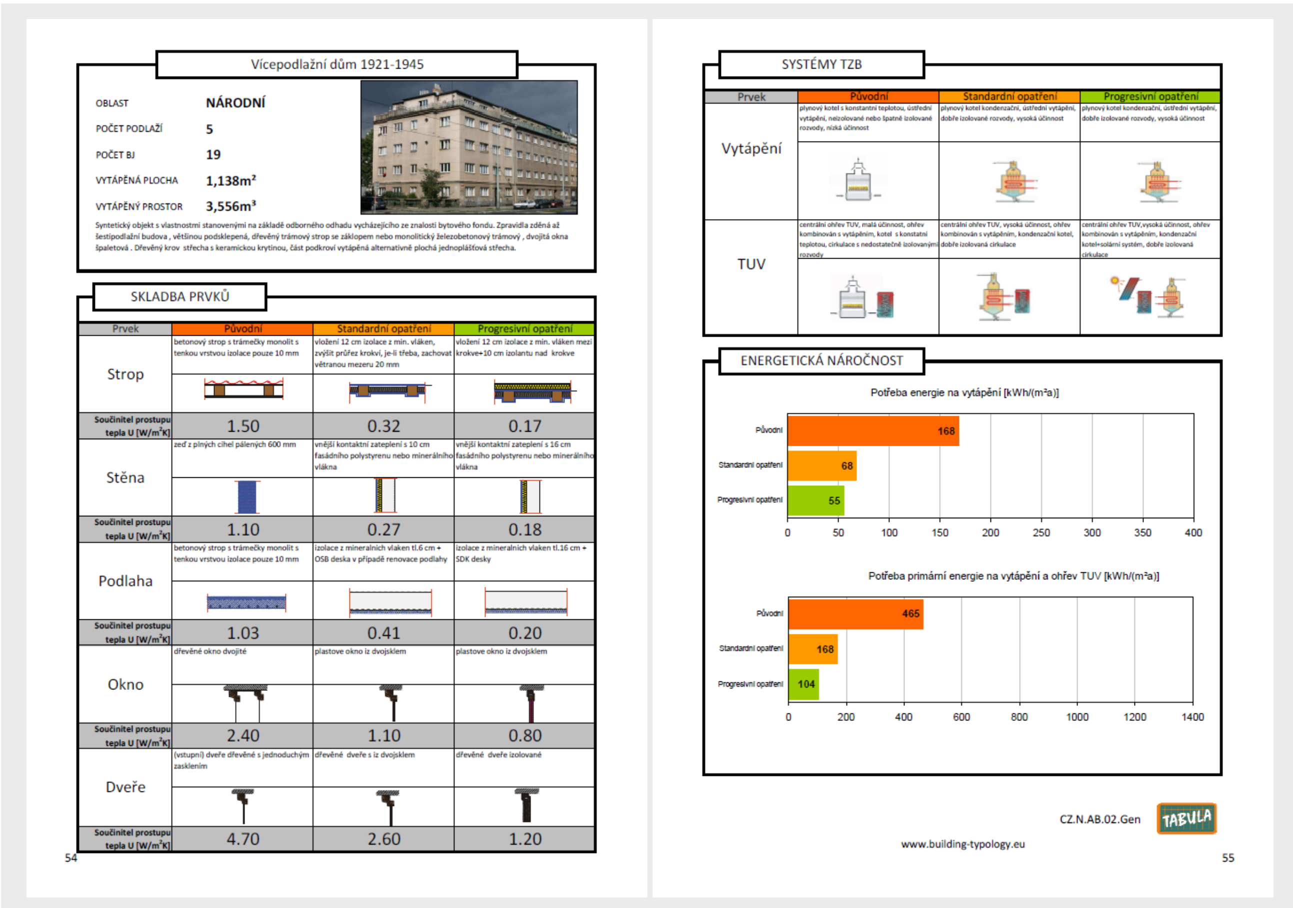
	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	national (Česka Republika)	... 1920	generic (Standard)	 CZ.N.SFH.01.Gen	 CZ.N.TH.01.Gen	 CZ.N.MFH.01.Gen	 CZ.N.AB.01.Gen
2	national (Česka Republika)	1921 ... 1945	generic (Standard)	 CZ.N.SFH.02.Gen	 CZ.N.TH.02.Gen	 CZ.N.MFH.02.Gen	 CZ.N.AB.02.Gen
3	national (Česka Republika)	1946 ... 1960	generic (Standard)	 CZ.N.SFH.03.Gen	 CZ.N.TH.03.Gen	 CZ.N.MFH.03.Gen	 CZ.N.AB.03.Gen
4	national (Česka Republika)	1961 ... 1980	generic (Standard)	 CZ.N.SFH.04.Gen	 CZ.N.TH.04.Gen	 CZ.N.MFH.04.Gen	 CZ.N.AB.04.Gen
5	national (Česka Republika)	1981 ... 1994	generic (Standard)	 CZ.N.SFH.05.Gen	 CZ.N.TH.05.Gen	 CZ.N.MFH.05.Gen	 CZ.N.AB.05.Gen
6	national (Česka Republika)	1994 ... 2005	generic (Standard)	 CZ.N.SFH.06.Gen	 CZ.N.TH.06.Gen	 CZ.N.MFH.06.Gen	 CZ.N.AB.06.Gen

A.3.3. Czech Typology Brochure

The Czech typology brochure individually presents each one of the building types from the Czech Building Type Matrix on a double page. The layout was designed to be simple and easy to understand for non-technical readers for whom the document is targeted.

The left side shows a photograph of a representative building of the corresponding category and construction period together with a small description and summary of the characteristics of the building envelope: number of floors, total amount of flats, total heating area and heating volume. Below there is a table that show the typical construction elements of the building in three stages: original condition and in two different levels of refurbishment “typical” and “advanced”. Each construction element is shortly described and illustrated, together with their typical overall heat transfer coefficient (U-value). The display of this table allows for fast comparison of the performance of different construction elements and their potential refurbishment options. The right side shows a table with the typical heating and domestic hot water systems. These systems are also shown in three stages: original condition and in two different levels of refurbishment “typical” and “advanced”. Below there are two graphs that represent the results from the analysis of the building using the TABULA.xls spreadsheet in terms of heat energy demand and total primary energy demand. There is a consistent use of colours (dark orange, orange and green) through out the two pages to guide the reader on what data represent “original”, “typical” and “advanced” conditions of construction elements, building systems and their respective energy demand calculations.

Figure 7: "Building Display Sheet" – existing state of an example building and impact of refurbishment measures (extract from the Czech building typology brochure [STU-K 2011])



A.3.4. National Energy Balance Calculation

Based on the analysis of available statistical data and on the knowledge of historical standard requirements, 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 national calculation method is based on a simplified dynamic calculation. The energy demand was calculated from monthly values, using the national calculation software tool (NCT). The simplified process of calculation was divided into two steps:

1) Calculation of energy demand of the synthetic buildings
2) Calculation 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.

The following simplified 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

The total calculated energy used for heating, DHW and lighting of the housing stock is 204.7 PJ.

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.

A.3.5. Definition of Average Buildings

The statistical data presented in the national energy balance report were used to define the average gross floor areas of synthetic buildings. The synthetic (average) building is defined as virtual building having geometrical parameters equal to mean values (e.g. the areas of the windows, floors, roofs/ceilings and exterior walls). These parameters 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 average refurbishment state of large panel buildings was successfully estimated using good quality secondary data from recently conducted study PANELSCAN. On the other hand it was very difficult to estimate the average refurbishment state of single family houses because this is the worst documented part of the Czech housing stock.

The average refurbishment state of buildings may be estimated through reading the real consumption data of defined groups of buildings prior and after refurbishment and comparing those data with calculations (e.g. data from EPC). This task would be quite challenging in the Czech Republic because of impossibility to use the national database. It seems to be more feasible to extract the data from the archives of housing companies and big housing co-operatives and perhaps also from the archives of energy specialists. It is estimated that average refurbishment state of apartment buildings would have less dispersion in quality of projects and specific energy consumption figures than the average refurbishment state of single family houses. This is due to the fact that the refurbishment processes are running under different conditions. Also user's behaviour is diverse in the above mentioned building categories. The owners of single family houses and individually heated flats are generally strongly motivated to reduce their energy consumption. On the contrary there is a lack of awareness and not enough motivation towards heating energy-saving behaviour in buildings connected to district heating network because in many cases there is no individual metering and the energy bills are issued per square meter of apartment. It has been observed that many apartment buildings do not reach the energy performance target values after refurbishment which can be partly explained by inappropriate user's behaviour.

A.3.6. Conclusion

Despite the lack of comprehensive/accessible data, it was possible to define a representative building matrix of the Czech housing stock following the concept of "example buildings" → **Building Matrix**

For each building type it was possible to assign representative construction and system elements for their typical conditions of the 24 types of buildings in three stages: original, typical refurbishment and advanced refurbishment. Comprehensive sub-typologies where created and documented. → **Tabula.xls**

Using the tools developed within the TABULA project it was possible to analyze those buildings, resulting in the Czech TABULA brochure that summarized that effort. The three scenarios where analyzed using the Tabula approach and reported →**Brochure**

The energy balance calculation was performed using 6 synthetic (average) building-types; the results were compared between the TABULA calculation method and the Czech national method (NKN tool). Results were comparable. →**Energy balance Report**

TABULA project deliverables offer possible applications in the energy strategic asset management tasks. It will enable the housing portfolio key actors to estimate energy saving potential of selected parts of the housing stock and propose solutions to optimize the energy refurbishment processes. Czech TABULA tool would enable to provide estimates with reasonable degree of accuracy on the actual energy consumption and saving potential in the national building stock.

Table 10: National Activities Czech Republic / Sources and References

Reference shortcut	Short description	Reference
[STU-K 2011]	Czech Building Typology Brochure	Villatoro, Otto/Vimmr, Tomáš: Příručka typologií obytných budov s příklady opatření ke snížení jejich energetické náročnosti - Česká republika; STU-K, Praha, 2011. http://www.building-typology.eu/downloads/public/docs/brochure/CZ_TABULA_TypologyBrochure_STU-K.pdf
[TABULA NatSci CZ 2012]	National scientific report of the TABULA activities in CR	Vimmr, Tomáš/Villatoro, Otto: TABULA: National Scientific Report - Czech Republic; STU-K, Praha, 2012
[TABULA NatBal CZ 2012]	National balance report of the Czech residential building stock	Vimmr, Tomas: chapter "Czech Republic" in: Diefenbach, Nikolaus / Loga, Tobias (ed.): Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock (TABULA Thematic Report N° 2). Models for the national housing stock of 8 countries: Belgium, Czech Republic, Denmark, Germany, Greece, italy, Slovenia; IWU, Darmstadt / Germany 2012 http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf

A.4. <DE> Building Typology in Germany

(by TABULA partner IWU / Institut Wohnen und Umwelt)

A.4.1. National Activities during the TABULA Project

On the national level different tasks have been concluded during the TABULA project in Germany.

- Adapt the classification scheme to fit the harmonised concept.
- Transfer data of exemplary buildings to the common structure.
- Define consistent heating systems and quantify their typical energy performance.
- Define a set of energy refurbishment measures and make energy balance calculations using the national method (EnEV) and the TABULA reference calculation procedure.
- Find factors to adapt the standard calculation to the typical level of measured consumption.
- Develop "Building Display Sheets" for demonstration of the energy performance and the potential savings of the exemplary buildings.
- Collect national building stock statistics by use of the common framework for statistical data.
- Elaborate a "Building Typology Brochure" including results of calculations, national statistics and building display sheets in German language.
- Use the typology approach for an assessment of the energy consumption of the whole residential building stock.
- Investigate the possibilities to apply a similar concept to the sector of non-residential buildings and describe the necessary steps.

The details and results of these activities are described in national scientific report from Germany [TABULA NatSciRep DE].

A.4.2. The Classification Scheme

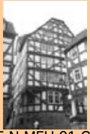
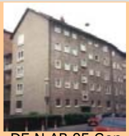
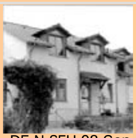
The construction year classes are oriented at historical breaks, time categories of statistical enquiries and changes in the energy relevant building codes. These periods have been defined in earlier investigations [IWU 1990] [IWU 2003]. Following this, the German building stock is subdivided into the following time bands:

Table 11: Characterisation of the different construction year classes

N°	Construction Year Class	Historical Period	Characterisation
1	A	... 1859	pre-industrial period, characterised by handcraft; built on experiences; hardly no legal requirements; use of locally available materials
2	B	1860 ... 1918	period of promoterism ("Gründerzeit"), rapid expansion of the cities and growing industrialisation; standardisation of construction principles; different regional manifestations -
3	C	1919 ... 1948	increasing industrialised production of building materials; use of cost efficient material-saving constructions; standardisation on national level
4	D	1949 ... 1957	simple building techniques of the post-war period; often use of debris materials; further development of construction standards (introduction of DIN 4108 – "Wärmeschutz im Hochbau" in 1952); introduction of social housing principles
5	E	1958 ... 1968	requirements on thermal insulation in force (DIN 4108 – "Wärmeschutz im Hochbau"); further industrialisation of building construction; development of panel buildings (GDR: "Plattenbauten")
6	F	1969 ... 1978	new industrial building techniques (sandwich elements); also introduction of pre-fabricated single family houses (lightweight constructions "Fertighaus"); thermal insulation becomes more relevant in consequence of the first oil crisis
7	G	1979 ... 1983	1st thermal protection ordinance (1. Wärmeschutzverordnung)
8	H	1984 ... 1994	2nd thermal protection ordinance (2. Wärmeschutzverordnung); GDR: further improved insulation ("Rationalisierungsstufe III") market introduction of low energy houses, supported by regional grant programmes
9	I	1995 ... 2001	3rd thermal protection ordinance (3. Wärmeschutzverordnung); consideration of a bonus in the tax in case of realisation of a low energy house
10	J	2002 ... 2009	energy saving ordinance ("EnEV 2002"), considering building and heat supply system; KfW grant programmes ("KFW-Energiesparhaus 60 and 40”, Passive Houses)
11	K	2010 ...	new requirements of energy saving ordinance ("EnEV 2009") on the level of low energy buildings new KfW grant programme regulations ("KFW-Effizienzhaus 70, 55 and 40”, Passive Houses)

Based on these construction year classes and the four TABULA building size classes the following building type matrix was developed:

Figure 8: "Building Type Matrix" – classification of the German housing stock (generic building types)

	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	National (nicht regional spezifiziert)	... 1859	Generic (Basis-Typ)	 DE.N.SFH.01.Gen		 DE.N.MFH.01.Gen	
2	National (nicht regional spezifiziert)	1860 ... 1918	Generic (Basis-Typ)	 DE.N.SFH.02.Gen	 DE.N.TH.02.Gen	 DE.N.MFH.02.Gen	 DE.N.AB.02.Gen
3	National (nicht regional spezifiziert)	1919 ... 1948	Generic (Basis-Typ)	 DE.N.SFH.03.Gen	 DE.N.TH.03.Gen	 DE.N.MFH.03.Gen	 DE.N.AB.03.Gen
4	National (nicht regional spezifiziert)	1949 ... 1957	Generic (Basis-Typ)	 DE.N.SFH.04.Gen	 DE.N.TH.04.Gen	 DE.N.MFH.04.Gen	 DE.N.AB.04.Gen
5	National (nicht regional spezifiziert)	1958 ... 1968	Generic (Basis-Typ)	 DE.N.SFH.05.Gen	 DE.N.TH.05.Gen	 DE.N.MFH.05.Gen	 DE.N.AB.05.Gen
6	National (nicht regional spezifiziert)	1969 ... 1978	Generic (Basis-Typ)	 DE.N.SFH.06.Gen	 DE.N.TH.06.Gen	 DE.N.MFH.06.Gen	 DE.N.AB.06.Gen
7	National (nicht regional spezifiziert)	1979 ... 1983	Generic (Basis-Typ)	 DE.N.SFH.07.Gen	 DE.N.TH.07.Gen	 DE.N.MFH.07.Gen	
8	National (nicht regional spezifiziert)	1984 ... 1994	Generic (Basis-Typ)	 DE.N.SFH.08.Gen	 DE.N.TH.08.Gen	 DE.N.MFH.08.Gen	
9	National (nicht regional spezifiziert)	1995 ... 2001	Generic (Basis-Typ)	 DE.N.SFH.09.Gen	 DE.N.TH.09.Gen	 DE.N.MFH.09.Gen	
10	National (nicht regional spezifiziert)	2002 ...	Generic (Basis-Typ)	 DE.N.SFH.10.Gen	 DE.N.TH.10.Gen	 DE.N.MFH.10.Gen	

A.4.3. Energy Performance of Exemplary Buildings

A.4.3.1 Building Data

The building type matrix in Figure 8 displays pictures of real residential buildings which are used for exemplary calculations. The datasets of the exemplary buildings were mainly collected by energy consultants during energy advice campaigns. The envelope datasets have earlier been documented [IWU 2003] and include the following information (according to the German calculation standards): basic data (floor area, number of apartments, number of storeys …), areas of building elements (wall, roof, ground floor, windows), U-values of building elements.

During the TABULA project the existing datasets were adjusted and transferred to the TABULA data structure. The existing set of construction pictures/drawings ([IWU 2004] [IWU 2005]) was improved and supplemented by a large number of further construction and measure types.

The new construction catalogue and the table of insulation measures are documented in the Appendices of the national scientific report [TABULA NatSciRep DE]. A table with envelope data are published in the German Typology Brochure [TABULA TypBro DE].

A.4.3.2 Supply System Data

As a source for the heat supply system types [IWU 2005] was used which includes tabled values for expenditure factors, losses from the supply, generation, storage and distribution system components. The values were adjusted (correction to gross calorific value and to the reference floor area) and transferred to the common data structure. The datasets are shown in Appendix D of the national scientific report [TABULA NatSciRep DE].

The components were combined to heat supply systems representing typical existing systems and refurbished systems. Pictures illustrating the respective system types were created.

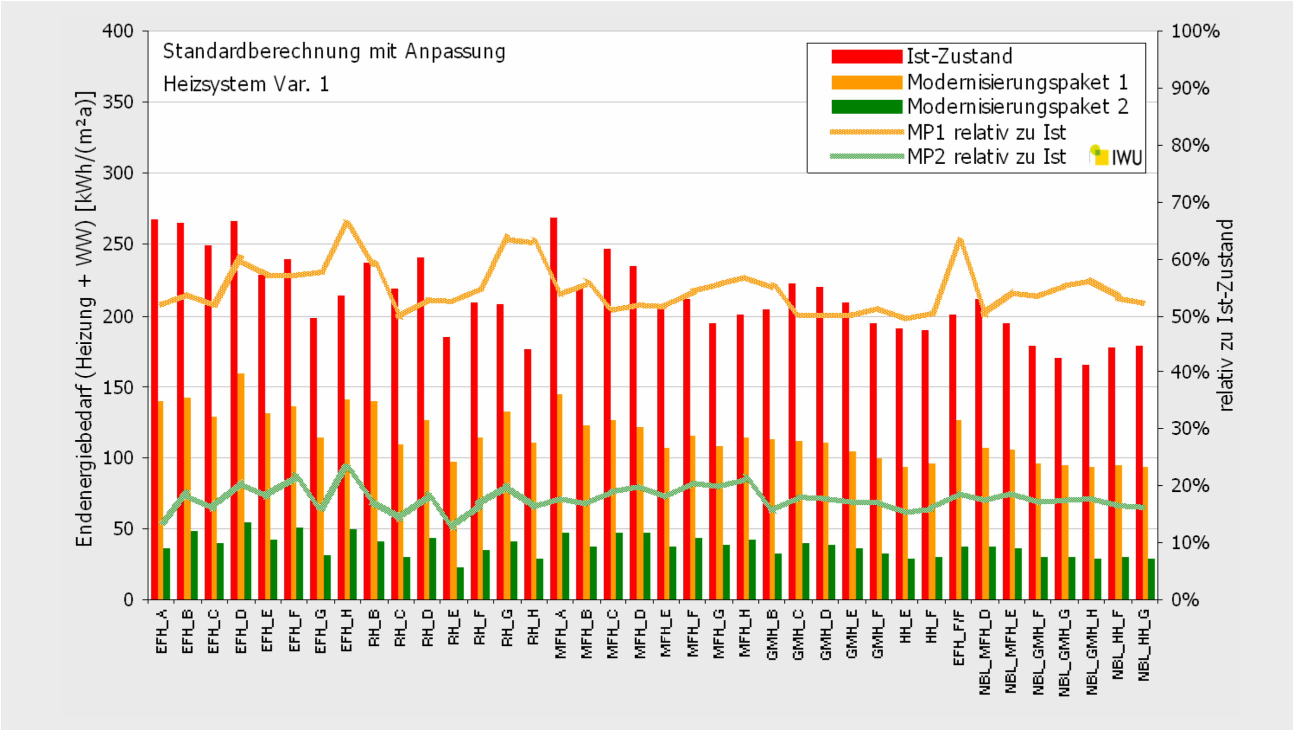
A.4.3.3 Energy Performance Calculation

The energy performance of the example buildings was calculated according to two methods: the national energy performance certificate method "Energieeinsparverordnung EnEV 2009" and the TABULA method. The calculations were performed by use of the Excel applications "EnEV-XL" for EnEV 2009 and "TABULA.xls" for the TABULA method.

The following figures are representing the energy performance indicators determined according to the TABULA method – including an adaptation to the typical level of measured consumption (see below). The values are related to the heated living space of the buildings.

Figure 9: Energy use for heating and DHW – before and after modernisation – example: central heating system / natural gas

Reference area: heated living space; calculation according to the TABULA method, including adaptation to the typical level of consumption



A.4.3.4 Adaptation factors used in the German Building Typology Brochure

Comprehensive studies about the relation of the measured consumption to the calculated energy use for all building types and standards do not yet exist in Germany. However, there are a number of indications from field enquiries focusing on building groups; especially an analysis of about 1700 existing buildings in the project „Ökologischer Mietspiegel Darmstadt“ [IWU 2006] as well as the evaluation of the energy certificate field test ("Energiepass-Feldversuchs") of the German energy agency dena [Gruber et al. 2005]. The result was in both cases similar: The measured energy consumption of these existing buildings is – especially for buildings with low energy standards – systematically much smaller than the calculated energy use.

Figure 10 shows the analysis results from the study [IWU 2006]: For different values of the calculated energy use the frequencies of the relations measured to calculated consumption are displayed. In case of an energy use for heating of about 150 kWh/(m²a) the peak of the distribution is at a ratio of 0.7. For higher values of the energy use the maximum of the curves are shifting towards 0.5.

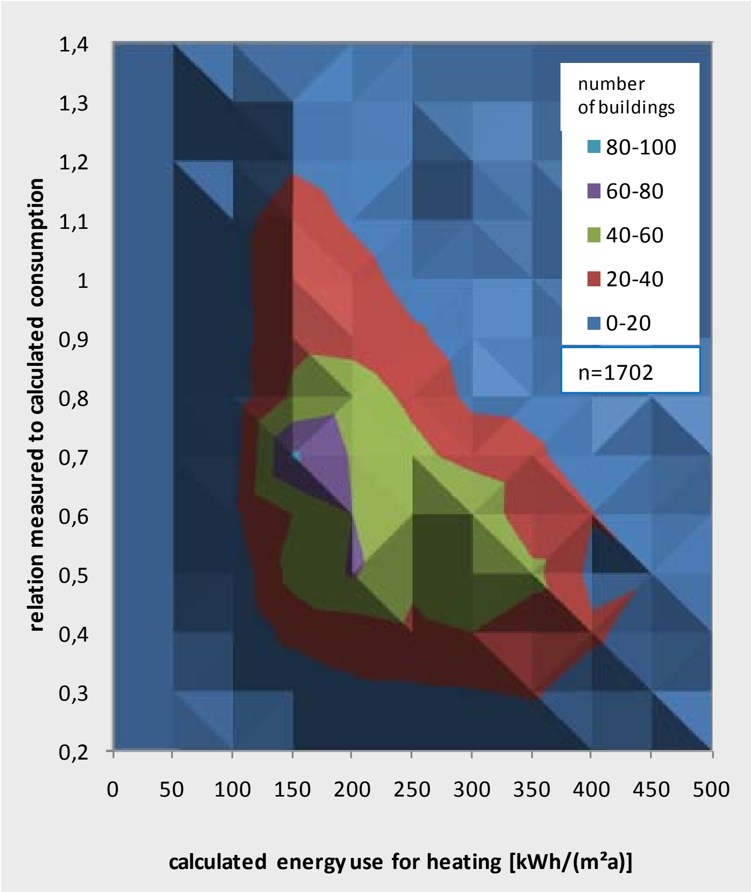


Figure 10: Analysis of the ratio measured to calculated energy consumption for 1702 buildings

Frequencies differentiated according to the calculated energy use; energyware natural gas, heating oil, district heating / all building sizes;
data from [IWU 2006b]

Starting from this analysis the TABULA adaptation factors used for the German building typology brochure were derived (Figure 11), taking into account a number of further aspects (for details consult [TABULA NatSciRep DE]). The approach should be considered as preliminary since – as mentioned above – the underlying data situation is not sufficient at the moment. In the future more comprehensive and systematical investigations will be necessary for different building, supply system and utilization types to deliver statistically verified adaptation factors.

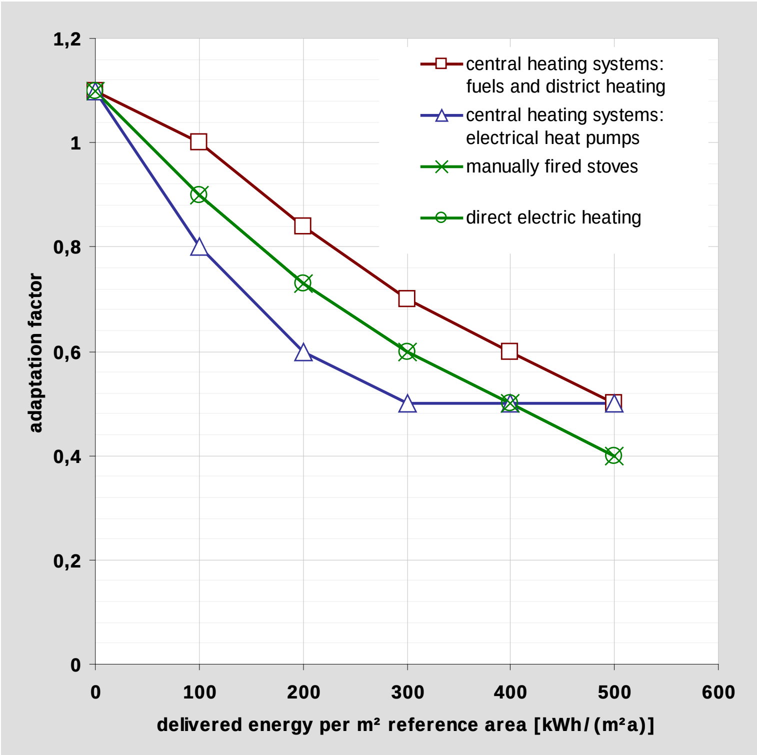
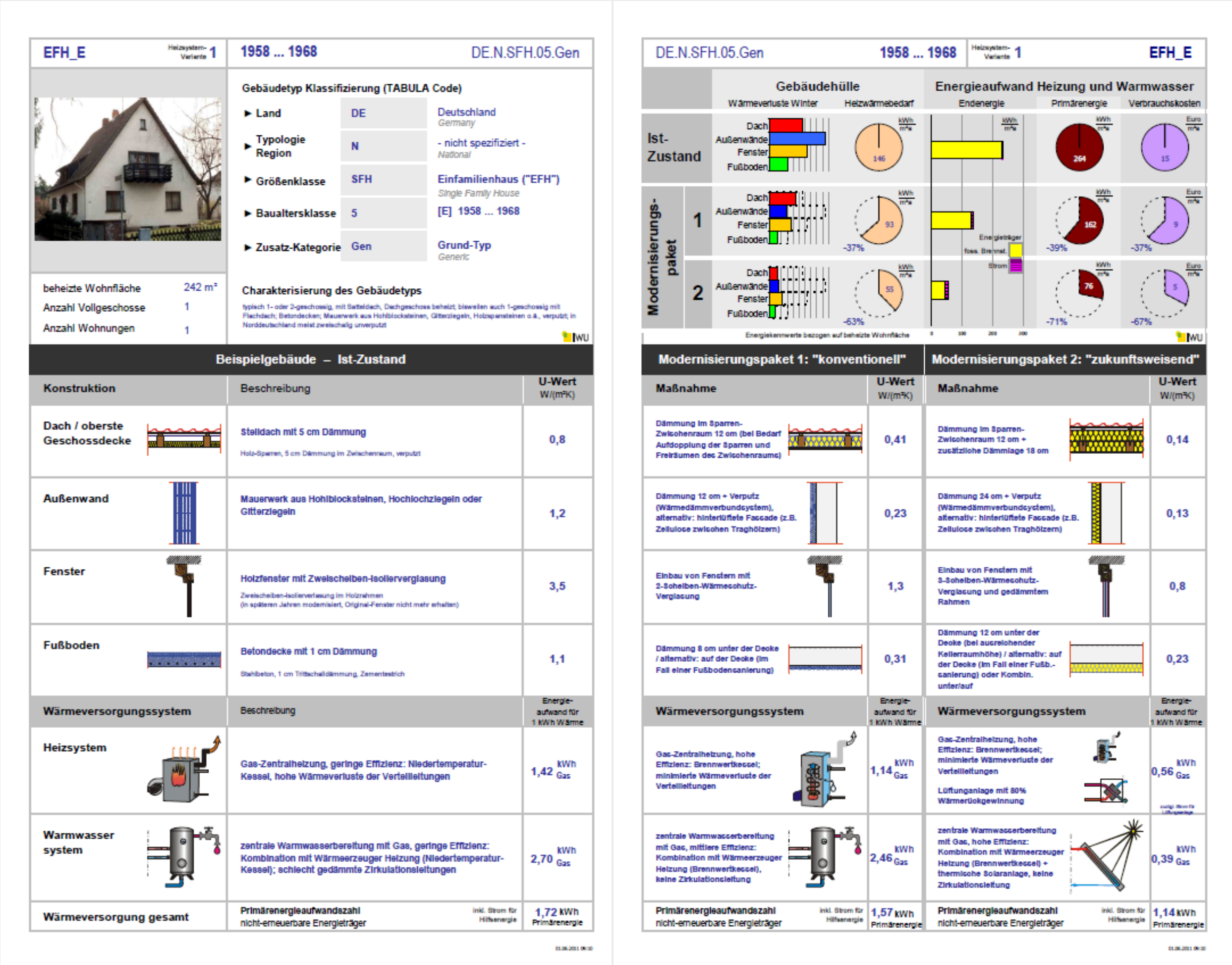


Figure 11: Approach for the factors to adapt the calculated energy use to the typical level of measured consumption – used in the German Building Typology Brochure

A.4.4. Building Display Sheets

An important element of the German Building Typology Brochure are the Building Display Sheets, showing for each exemplary building the existing state and the energy saving potential by implementation of energy saving measures (see example in Figure 12, the complete catalogue is published in [TABULA TypBro DE]).

Figure 12: "Building Display Sheet" – existing state of an example building and impact of refurbishment measures (extract from the German building typology brochure [TABULA TypBro DE])



A.4.5. EPC Database Evaluation

Different sources can be used to get information about the energy performance of national building stocks. Among these Energy Performance Certificates (EPC) are promising since the information is mainly relying on investigations by energy experts and the number of EPCs issued in the past years is rather large, due to implementation of EPBD. As regards Germany, a registration of energy certificates is not yet mandatory. In consequence, there is no official database containing all issued EPCs. However, the German energy agency dena introduced a quality mark for energy performance certificates in 2007 ("dena Gütesiegel Energieausweis"). A condition for participation is the transfer of the respective EPC dataset to an EPC database, run by dena [dena 2012]. An evaluation of the collected datasets was performed during the German part of the TABULA project (see example in Figure 13), the details are described in [TABULA EPCDataBase DE 2012].

-

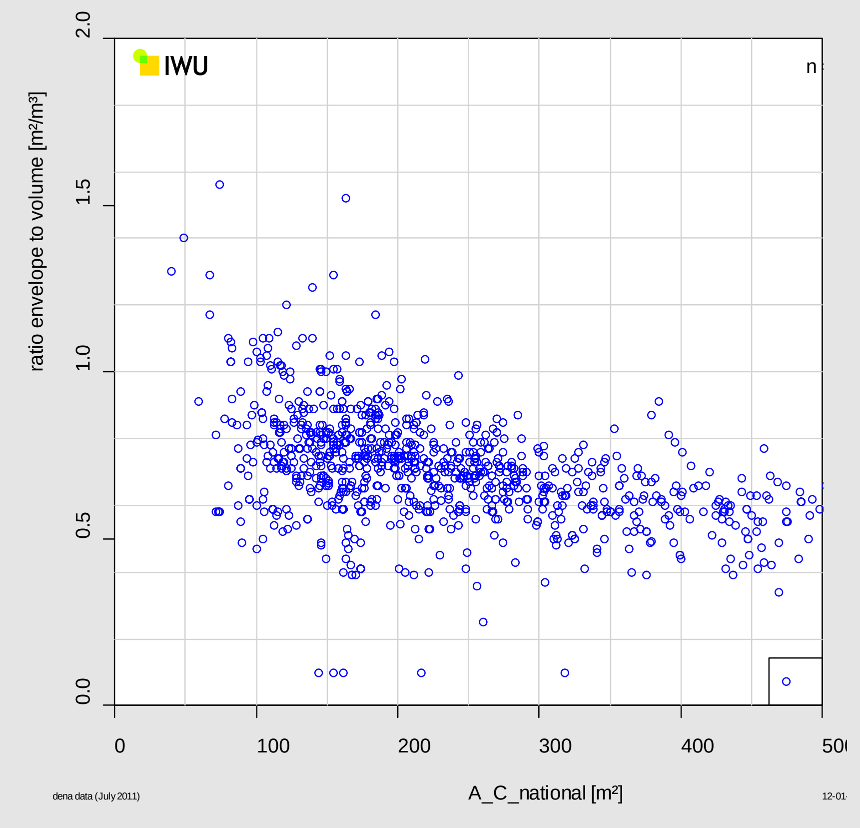


Figure 13:
Example for the evaluation of the dena EPC database: Correlation of the envelope to volume ratio and the EPC reference area / small buildings

As a résumé of the performed analyses it can be stated that an extension of the collected quantities and a higher grade of formalisation by introduction of further fixed categories (codes) for a number of data fields can be recommended. This would make it possible to expand plausibility checks of input quantities and to establish rough parallel computations for the control of the whole EPC calculation procedure.

Since the datasets are neither a random sample nor a complete census, information about the actual state of the German building stock cannot be drawn. However, some correlations of quantities are valuable in the context of building stock modelling, especially:

- correlation of the EnEV reference area with the heated living space;
- average envelope areas and their dependency on living space and other geometrical parameters;
- correlation of measured energy consumption and calculated energy use.

As regards the envelope area the respective evaluations described in this chapter have actually been used to set up the German building stock model (see chapter A.4.6 below and [[TABULA NatBal DE 2012]]).

Unfortunately, the number of datasets containing the actual measured consumption was not sufficient for an evaluation of the correlation. An extension of the quality assured data collection scheme to a larger fraction of energy certificates could help to provide this information.

A.4.6. Model of the National Residential Building Stock

The development of the German energy balance model during TABULA was prepared in the course of an earlier project which provided data about the state of energetic modernisation energy refurbishment in the national residential building stock by carrying out a countrywide survey of residential house owners [IWU 2010]. Some of the results are documented in the national statistical tables according to the TABULA concept (see [TABULA NatSciRep DE] and German "Country Page" at the TABULA website)

The results of the survey were a major input for the development of the national energy balance model during the TABULA project. 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.

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 the energy certificate data base of the German Energy Agency dena (see clause A.4.5 above).
- The U-values of the not refurbished buildings were calculated as mean values from the respective model buildings of the German building typology (see clause A.4.3.1 above) 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 were calculated by the data of a representative survey of the German building stock [IWU 2010].

From that starting point the national energy balance was calculated. In Table 12 the model results are compared with the national energy balance (mean values of actual consumption of households). The table shows that the model calculations fit satisfactorily 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 higher (e. g. 22 % in the case of district heating). 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 – the quoted national statistics are to some extent uncertain because the delivered values can not be measured directly. This applies at least to the break down of the total values of energy consumption (e. g. of the national gas consumption) to the different consumption sectors (here: to the household sector).

Table 12: Calculated energy savings by applying the level 1 and level 2 measures to the current (2009) German residential building stock (from: [TABULA NatBal DE 2012])

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%**

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.

A.4.7. Typology of Non-Residential Buildings

In Germany, a few efforts have been made to set up a non-residential building typology. Different approaches have been developed depending on diverse goals, objectives, and methodologies. An overview of the status has been described in the German section of the respective thematic report [TABULA NonRes DE].

As only very few reliable data on the quantities of non-residential buildings are available, no qualified results can be drawn yet for the entirety of non-residential buildings. Another difficulty is the complex calculation method used for non-residential buildings. For setting up a building typology that is supposed to be comparable to other countries a simplified and harmonized calculation method is needed. It is therefore important not only to gather more information about the existing non-residential building stock through studies and surveys, but also to explore how the obtained data may contribute to an applicable building typology.

In consequence, IWU proposes three major steps to set up a non-residential building typology in Germany (for details see [TABULA NonRes DE]):

1. ***Definition/Review of building categories***
   The building categories defined in earlier studies seem to be a good basis to proceed, but they have to be consolidated and modified. Further research is necessary to identify the most important energy influencing factor for each of the buildings categories. Since a significant share of the non-residential floor area in Germany seems to be located in buildings with mixed uses a combination of different categories must also be taken into account.
2. ***Determination of quantities***
   In Germany there is a need to gather substantial data concerning the quantities of buildings (in total and according to building categories and construction year classes), quantities of floor spaces, cubatures, building equipment, the state of the current building stock, the share of already refurbished buildings, building elements respectively renewed technical equipment, and current refurbishment trends. With respect to the statistical aspects a better, centralized and compatible structure for the data is required. Needed data might be derived from large surveys like the German census or e.g. the "Datenbasis Gebäudebestand" [IWU 2010]. A further development of the geographic information systems accomplished by a simultaneous improvement of the accessibility at least for scientific purposes would support in reducing the existing deficits. In any case, the introduction of a regular inquiry will be necessary to monitor the development and effects of the applied measures.
3. ***Assessment of energy performance indicators (example buildings)***
   For each of the buildings categories, example buildings are to be identified. For the assessment of comparable energy performance indicators, the calculation of energy balances will be necessary. The German method to calculate energy balances for non-residential buildings is complex, and very detailed knowledge – especially about the technical equipment of the building – is needed. For the typological approach a simplified calculation method is needed (for detailed proposals consult [TABULA NonRes DE].

A.4.8. Conclusions and Outlook

The German residential building typology is consisting of the above described concerted elements. Since it is an open concept, further aspects can easily be attached or generated:

- inclusion of further exemplary buildings, reflecting other geometries, special construction elements or measure types;
- exemplary refurbished buildings ("best practice examples"), including description and photographs of measures and achieved measured energy consumption;
- extension to new buildings, reflecting national requirements, depending on the type of heating system;
- inclusion of further indicators in the catalogue of refurbishment measures: costs, production energy and emissions;
- creation of typologies for local / regional stocks or for building portfolios, based on a similar concept, defining exemplary buildings for showcasing, and providing frequencies and average states for analogue building stock models;
- development of concepts for the continuous monitoring of building stock entireties, including the periodical collection of information about refurbishment processes and actual energy consumption of buildings before and after modernisation.

During the elaboration a number of items have been noticed which would be worth to be considered in future concepts and projects:

- The correlation of measured and calculated energy consumption should be investigated in more detail, which would require an elevation of a large number of buildings. The vision is to continuously monitor the measured consumption in combination with typological information for the whole stock.
- As regards the existing energy certificate database an extension of the plausibility checks by considering the results of statistical analyses is recommended. Also certain further quantities should be included in the datasets in order to enforce the quality assurance concept and to enable a parallel control computing of the certificate calculation.
- For the sector of non-residential buildings a national survey is needed to provide the necessary statistical information. The definition of the indicators to be collected should be determined by considering a simple energy balance model for non-residential buildings.

Table 13: National Activities Germany / Sources and References

Reference shortcut	Short description	Reference
[DATAMINE FR 2009]	final report of the IEE project DATAMINE, addressing the topic of data collection by use of energy performance certificates, including the common definition of datafields and a cross-country comparison of collected datasets	Loga, Tobias; Diefenbach, Nikolaus (ed.): DATAMINE – Collecting Data from Energy Certification to Monitor Performance Indicators for New and Existing Buildings. Final Report; IWU / NAPE / ESD / BuildDesk / POLITO / NOA / Vito / AEA / ZRMK / Ecofys SL / Energy Action / SOFENA; Darmstadt/Germany, January 2009 http://www.iwu.de/fileadmin/user_upload/dateien/energie/DATAMINE_Public_Final_Report.pdf
[dena 2012]	description of the quality mark for energy performance certificates of the German energy agency dena	http://www.zukunft-haus.info/de/planer-handwerker/energieausweis/dena-guetesiegel.html
[Gruber et al. 2005]	evaluation of the energy certificate field test of the German Energy Agency dena	Gruber, Edelgard; Mannsbart, Wilhelm (Fraunhofer-Institut für System- und Innovationsforschung (ISI)); Erhorn, Hans; Erhorn-Kluttig, Heike (Fraunhofer-Institut für Bauphysik (IBP)); Brohmann, Bettina; Rausch, Lothar; Hünecke, Katja (Öko-Institut e.V. - Institut für angewandte Ökologie): Energiepass für Gebäude - Evaluation des Feldversuchs. Zusammenfassung der Ergebnisse für die Deutsche Energie-Agentur; Karlsruhe 2005
[IWU 1990]	First definition of the German Building Typology / application for scenario calculations	Ebel, W. et al.: Energiesparpotential im Gebäudebestand; IWU, Darmstadt 1990
[IWU 2003]	German Building Typology: Systematic and datasets, revised version of typology used in [IWU 1990]	Deutsche Gebäudetypologie: Systematik und Datensätze, Institut Wohnen und Umwelt, Darmstadt, 2003
[IWU 2004]	method for the EP certificate field test in Germany, developed and documented on behalf of the German Energy Agency dena: including U-values of typical construction elements and efficiency values of typical supply system types	Loga, T.; Diefenbach, N.; Born, R.: Energetische Bewertung von Bestandsgebäuden. Arbeitshilfe für die Ausstellung von Energiepässen; Broschüre erstellt im Auftrag der Deutschen Energieagentur GmbH (dena); Darmstadt/Berlin, März 2004
[IWU 2005]	Simplified Energy Profile Procedure; developed methods: (1) envelope area estimation procedure / (2) typical U-values / (3) efficiencies of typical supply systems	Loga, Tobias; Diefenbach, Nikolaus; Knissel, Jens; Born, Rolf: Kurzverfahren Energieprofil. Ein vereinfachtes, statistisch abgesichertes Verfahren zur Erhebung von Gebäudedaten für die energetische Bewertung von Gebäuden; IWU, Darmstadt 2005; Bauforschung für die Praxis / Band 72; Fraunhofer IRB-Verlag, Stuttgart 2005
[IWU 2006]	study addressing the simplified energy assessment of buildings; includes inter alia a comparison of measured and calculated consumption for a building sample	Knissel, Jens; Roland Alles; Rolf Born; Tobias Loga; Kornelia Müller; Verena Stercz: Vereinfachte Ermittlung von Primärenergiekennwerten – zur Bewertung der wärmetechnischen Beschaffenheit in ökologischen Mietspiegeln; Institut Wohnen und Umwelt; Darmstadt 2006 http://www.iwu.de/fileadmin/user_upload/dateien/energie/werkzeuge/Vereinfachte_Ermittlung_von_Primaerenergiekenwerten-1.0.pdf
[IWU 2010]	documentation of a national survey of energy related building features based on a random sample (ca. 7500 house owners)	Diefenbach, N.; Cischinsky, H.: Rodenfels, M.; Clausnitzer, K.-D.: Datenbasis Gebäudebestand – Datenerhebung zur energetischen Qualität und zu den Modernisierungstrends im deutschen Wohngebäudebestand, Institut Wohnen und Umwelt, Darmstadt, Dezember 2010

[TABULA EPCDataBase DE 2012]	Evaluation of the quality assured EPC database of the German Energy Agency dena	Loga, Tobias: chapter "Germany" in: Loga, Tobias (ed.): Use of Energy Certificate Databases for National Building Typologies; with contributions by: AEA / Austria; VITO / Belgium; IWU / Germany; ADEME / France; Energy Action / Ireland; POLITO / Italy; NAPE / Poland; TABULA Thematic Report N° 1; IWU, Darmstadt 2012 http://www.building-typology.eu/tabulapublications.html
[TABULA NatBal DE 2012]	Set-up of a Residential Building Stock Model for Germany	Diefenbach, Nikolaus: chapter "Germany" in: Diefenbach, Nikolaus / Loga, Tobias (ed.): Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock (TABULA Thematic Report N° 2). Models for the national housing stock of 8 countries: Belgium, Czech Republic, Denmark, Germany, Greece, italy, Slovenia; IWU, Darmstadt / Germany 2012 http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf
[TABULA NatSci DE]	national scientific report of the TABULA activities in Germany	
[TABULA NonRes DE 2012]	Review of existing typology approaches for non-residential buildings in Germany and recommendations	Stein, Britta: chapter "Germany" in: Britta, Stein (ed.): Simplified Energy Assessment of Non-Residential Building Portfolios by following the Building Typology Approach (TABULA Thematic Report N° 3). Experiences and recommendations for the countries Austria, Germany, Greece, Poland; IWU, Darmstadt / Germany 2012 http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR3_D9_NonResidentialBuildings.pdf
[TABULA TypBro DE]	German Building Typology Brochure	Loga, Tobias; Diefenbach, Nikolaus; Born, Rolf: Deutsche Gebäudetypologie. Beispielhafte Maßnahmen zur Verbesserung der Energieeffizienz von typischen Wohngebäuden; IWU, Darmstadt 2011 http://www.building-typology.eu/downloads/public/docs/brochure/DE_TABULA_TypologyBrochure_IWU.pdf

A.5. <DK> Building Typology in Denmark

(by TABULA partner SBi /Danish Building Research Institute)

A.5.1. Establishing the Danish building typologies

A Danish typology for residential buildings was established in the TABULA project. Three different main building types were used: Single-family houses, terraced houses and block of flats. Each main building type was again split up in nine construction periods representing typical building tradition and insulation levels.

Within each main building type and construction period, a typical building has been selected from the energy labelling scheme database as a ***real example building.*** The selected buildings are buildings that have not yet been through any major energy upgrading (except windows and doors), since they were constructed. These model buildings can be used for promoting energy-saving potentials for homeowners.

Another main purpose of the building typology was to establish a tool capable of calculating different energy-saving scenarios for the entire residential building stock. To facilitate such a calculation ***average buildings*** were constructed. These theoretically designed building models are based on statistical data obtained from the Danish Energy Labelling Scheme and other sources of knowledge.

A.5.2. Identifying building types

The Danish building stock were divided into three types and nine periods of construction (Kragh & Wittchen, 2010). The building typology and construction types were judged to be uniform for each period of construction. Furthermore, building usage has been used to identify the three most common residential building types, namely: Single-family houses, terraced houses and block of flats. The reason for selecting these building types was that these types were the dominant building types in the EPC (Energy Performance Certification) database containing information collected in the course of building energy surveys since 2006. The construction periods were identified from acknowledged changes in building tradition in the early periods and from changes in the energy requirements stated in the Danish Building Regulations in more recent periods. The nine periods of construction and their corresponding energy-related changes in building tradition or the Danish Building Regulations' energy requirements are shown in Table 14.

Table 14: Building periods

The Danish building stock can be divided into 9 different age classes – depending on shifts in building tradition or shifts in energy requirements in the Danish Building Regulations. Each class is somewhat uniform with respect to construction principle and initial, specific energy standard.

Building period	Comment
Before 1850	shift in building tradition
1851 - 1930	shift in building tradition
1931 – 1950	cavity walls introduced
1951 – 1960	insulated cavity walls introduced
1961 – 1972	first energy requirements in BR61[1)]
1973 – 1978	tightened energy requirements in BR72[1)]
1979 – 1998	tightened energy requirements in BR78[1)]
1999 – 2007	tightened energy requirements in BR98[1)]
2007 – 2011	tightened energy requirements in BR06/08[1)]

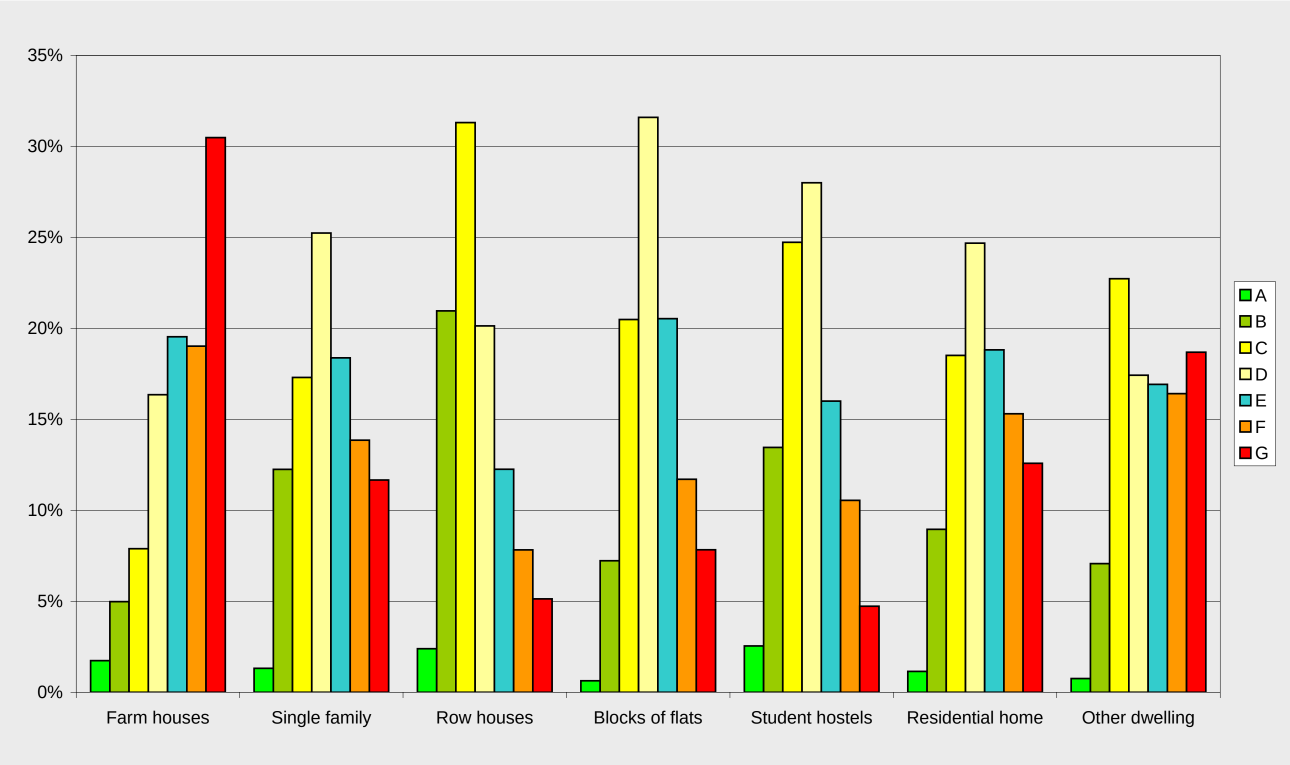
[1)] BR is a reference to the Danish Building Regulations and the following digits refer to the year when the BR came into force.

A.5.3. Extracting data and knowledge from the ECP scheme

Denmark has had a mandatory EPC scheme since 1997 when owner-occupied residential houses and flats needed a valid EP certificate (based on a calculated energy performance) when sold. Additionally, all large buildings (+1500 m²) needed to be certified every year based on a measured energy performance. From 1997 to 2006, a total of approx. 770 000 certificates were issued, including approx. 18 000 certificates for large buildings. Over the period, approx. 55 000 single-family houses were certified each year.

In the current EPC scheme (since 2006), the number of issued certificates (all based on calculated energy performance) is a total of approx. 258 000[1]. The total number of issued certificates in Denmark, since certification was initiated in 1997, is over 1 million.

Figure 14: Label distribution[1] on Danish dwellings as registered in the current (since 2006) EPC scheme

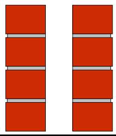
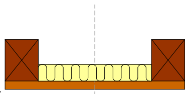
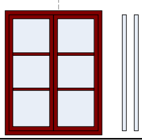


A.5.4. Building envelope data

The main source of information used to establish the typology buildings is the official handbook of the Danish EPC scheme (Danish Energy Agency, 2008). This handbook contains all knowledge necessary for issuing EP certificates for typically buildings. A complete list of constructions is found in the TABULA Excel sheets.

[1] December 2010.

Table 15: Examples of envelope constructions

Description	Illustration	U-value, [W/m²K]
30 cm brick (cavity wall), not insulated		1.60
Boards / rafter, 50 mm insulation		0.60
Farm-house window, wood profiles, glazing bars, double glazing		2.8

A.5.5. Boundary conditions

For Denmark only one climate zone is being used in the energy performance calculations. The specific climatic data are shown in the table below.

Table 16: Climate data of Denmark

Heating base temperature: heat demand is calculated in case that the daily average external temperature is below this value (TABULA standard value: 12 °C)	12 °C
Number of days per year during heating season with an average daily temperature is below or equal to the base temperature	246
Average outdoor air temperature during the heating season	4.2 °C
Average global irradiation on a horizontal surface during the heating season	447 kWh/a
Average global irradiation on a vertical surface oriented East during the heating season	313 kWh/a
Average global irradiation on a vertical surface oriented South during the heating season	524 kWh/a
Average global irradiation on a vertical surface oriented West during the heating season	313 kWh/a
Average global irradiation on a vertical surface oriented North during the heating season	150 kWh/a

Some of the boundary condition for the Danish typology was adjusted for Danish conditions. Table 17 compares the adjusted values and the EU standard values.

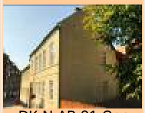
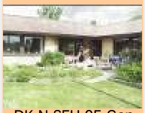
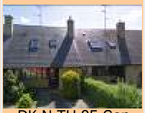
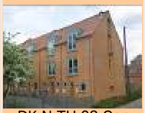
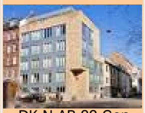
Table 17: Comparison of boundary conditions

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 [°C]	20	19	20	21	20	21
Reduction factor, considering the effect of night setback 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 setback 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 [1/h]	0.4	0.45	0.45	0.35	0.4	0.7/0.6/0.5
Room height (based on internal dimensions) [m]	2.5	2.8	2.8	2.8	2.5	2.8
Average internal heat loads per m² reference area	3	5	5	5	3	5
Reduction factor due to horizontal, external shading	0.8	0.8	0.8	0.8	0.8	0.8
Reduction factor due to vertical, external shading	0.6	0.6	0.6	0.6	0.6	0.6
Frame area (fraction of total window area)	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
Internal heat capacity per m² reference area [Wh/(m²K)]	45	100	100	100	45	100
Net energy demand for domestic hot water [kWh/(m²a)]	10	15	15	15	15	18

A.5.6. Example buildings

The real example buildings exist in reality and were selected from the EPC database as typical examples from the building period with respect to heated area, constructions, energy label etc. The selected buildings are shown in Figure 15.

Figure 15: "Building Type Matrix" – classification of the Danish housing stock

	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	national (Hele Denmark)	... 1850	Generic (Standard)	 DK.N.SFH.01.Gen	 DK.N.TH.01.Gen		 DK.N.AB.01.Gen
2	national (Hele Denmark)	1851 ... 1930	Generic (Standard)	 DK.N.SFH.02.Gen	 DK.N.TH.02.Gen		 DK.N.AB.02.Gen
3	national (Hele Denmark)	1931 ... 1950	Generic (Standard)	 DK.N.SFH.03.Gen	 DK.N.TH.03.Gen		 DK.N.AB.03.Gen
4	national (Hele Denmark)	1951 ... 1960	Generic (Standard)	 DK.N.SFH.04.Gen	 DK.N.TH.04.Gen		 DK.N.AB.04.Gen
5	national (Hele Denmark)	1961 ... 1972	Generic (Standard)	 DK.N.SFH.05.Gen	 DK.N.TH.05.Gen		 DK.N.AB.05.Gen
6	national (Hele Denmark)	1973 ... 1978	Generic (Standard)	 DK.N.SFH.06.Gen	 DK.N.TH.06.Gen		 DK.N.AB.06.Gen
7	national (Hele Denmark)	1979 ... 1998	Generic (Standard)	 DK.N.SFH.07.Gen	 DK.N.TH.07.Gen		 DK.N.AB.07.Gen
8	national (Hele Denmark)	1999 ... 2006	Generic (Standard)	 DK.N.SFH.08.Gen	 DK.N.TH.08.Gen		 DK.N.AB.08.Gen
9	national (Hele Denmark)	2007 ... 2010	Generic (Standard)	 DK.N.SFH.09.Gen	 DK.N.TH.09.Gen		 DK.N.AB.09.Gen

A.5.7. Average buildings

The average buildings (SyAv) were composed by average U-values extracted from the EPC database. U-values of ceilings, walls, floors, and windows were calculated within each building period and building type by using the equation:

$$U_{avg} = \sum \frac{A_i \cdot U_i}{A_{total}}$$

Where “i” is the reference to the specific construction.

The corresponding areas of the building envelope constructions were obtained from the Danish energy balance method (Wittchen et al., 2011), which uses the same approach for the average U-values as described above. The calculated area-weighted U-values are shown in Table 18.

Table 18: Calculated area-weighted U-values for each building type, building period and main thermal envelope construction

Average area-weighted U-values [W/m²K]					
Single-family houses	Building period	Floor	Wall	Ceiling	Window
	Before 1850	0.48	0.78	0.39	2.59
	1850 – 1930	0.71	0.85	0.42	2.55
	1931 – 1950	0.91	0.85	0.42	2.50
	1951 – 1960	0.68	0.85	0.36	2.50
	1961 – 1972	0.39	0.63	0.28	2.52
	1973 – 1978	0.31	0.49	0.26	2.47
	1979 – 1998	0.25	0.35	0.20	2.38
	1999 – 2006	0.16	0.27	0.15	1.79
	After 2007	0.12	0.21	0.12	1.58
Terraced houses	Building period	Floor	Wall	Ceiling	Window
	Before 1850	0.53	0.91	0.32	2.52
	1850 – 1930	0.83	1.00	0.43	2.56
	1931 – 1950	1.12	0.95	0.39	2.48
	1951 – 1960	0.73	0.94	0.41	2.50
	1961 – 1972	0.42	0.63	0.3	2.46
	1973 – 1978	0.32	0.46	0.29	2.45
	1979 – 1998	0.26	0.32	0.20	2.51
	1999 – 2006	0.17	0.28	0.16	1.78
	After 2007	0.13	0.23	0.13	1.55
Block of flats	Building period	Floor	Wall	Ceiling	Window
	Before 1850	0.51	0.83	0.32	2.61
	1850 – 1930	0.98	1.12	0.52	2.65
	1931 – 1950	1.18	1.22	0.53	2.63
	1951 – 1960	1.04	1.07	0.34	2.64
	1961 – 1972	0.71	0.77	0.30	2.48
	1973 – 1978	0.59	0.53	0.25	2.69
	1979 – 1998	0.30	0.35	0.22	2.51
	1999 – 2006	0.22	0.28	0.16	1.72
	After 2007	0.19	0.24	0.17	1.59

A.5.8. National energy balances

National energy balances have been calculated using the TABULA tool for each building typology (average buildings) and results multiplied by the total heated floor area representing each of the building typologies in Denmark. In this way, it was possible to establish an estimate for the national energy balance within each building typology (building type and building age class).

The total heated floor area of the Danish building stock has been extracted from the Danish Dwelling and Building Stock Register (BBR) supplemented with information from Statistics Denmark.

In Denmark, a national energy balance method already exists. The model has been used in several studies of the energy-saving potential (Wittchen et al., 2011). The knowledge of the different input data has been used to make a similar energy balance calculation model using the TABULA approach and the artificial average model buildings. The results from the existing energy balance model and the TABULA approach were very convergent.

A.5.9. Space heating demand calculation

The results obtained by applying the TABULA standard methodology and 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 19: Calculated energy consumption for space heating (not including DHW) [kWh/m² (internal floor area)]

Space heating demand [kWh/m²]	Single-family houses	Terraced houses	Blocks of flats
Building period	DK.SUH	DK.SUH	DK.MUH
Before 1850	177	176	159
1851-1930	182	192	173
1931-1950	206	211	173
1951-1960	208	198	155
1961-1972	166	153	139
1973-1978	126	131	134
1979-1998	108	87	123
1999-2006	66	67	86
After 2007	54	54	71

A.5.10. Comparison adjustments

When comparing the national statistic energy use statement with the TABULA approach, the calculated total energy use for heating was climate adjusted according to the number of degree-days. Table 20 compares the number of actual heating degree days in 2010 with the climatic data used in the TABULA tool.

Table 20: Number of heating degree days

Statistics (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 net- to gross-area factor of 1.18 (according to the TABULA methodology).

A.5.11. Comparison with official Danish energy statistics

Using data on the total building stock area for three residential building types, calculation results were compared with the 2010 Danish national statistics on energy consumption (Danish Energy Agency, 2010) in order to verify the model. The results are shown in Table 21.

Table 21: Calculated net energy usage compared with the corresponding national statistics on energy consumption in residential buildings

Net energy demand for heating and domestic hot water [PJ]	Single-family houses and terraced houses	Block of flats
Statistics Denmark 2010	109.5	43.4
TABULA approach – DK	113.3	44.5
Difference TABULA approach – DK	3.4%	2.4%

A.5.12. Calculated energy-saving potential for the Danish building stock

The technical energy-saving potential is calculated without taking into account different barriers such as economy, technical limitations or architecture.

The different measures follow the recommendations given by the Danish Knowledge Centre for Energy Savings in Buildings [www.byggeriogenergi.dk]. Standard recommendations comprises recommendations that building owners should implement as a minimum to meet the Danish Building Regulations or are being considered as good practice when renovating the building anyhow. Ambitious recommendations are measures that should be implemented if the building owner wishes to upgrade the building to near the Danish low energy standard. Recommendations for specific energy-saving measures are shown in Table 22.

Table 22: Recommended energy-saving measures

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

The energy-saving potential is calculated for both scenarios: Standard and Ambitious. The results are presented in the Table 23.

Table 23: Calculated theoretical/technical energy saving potential

Net energy demand for heating and domestic hot water [PJ]	Single-family houses and terraced houses	Block of flats
Reference (TABULA approach)	113.3	43.7
Standard measures	60.8	24.5
Ambitious measures	57.1	22.4

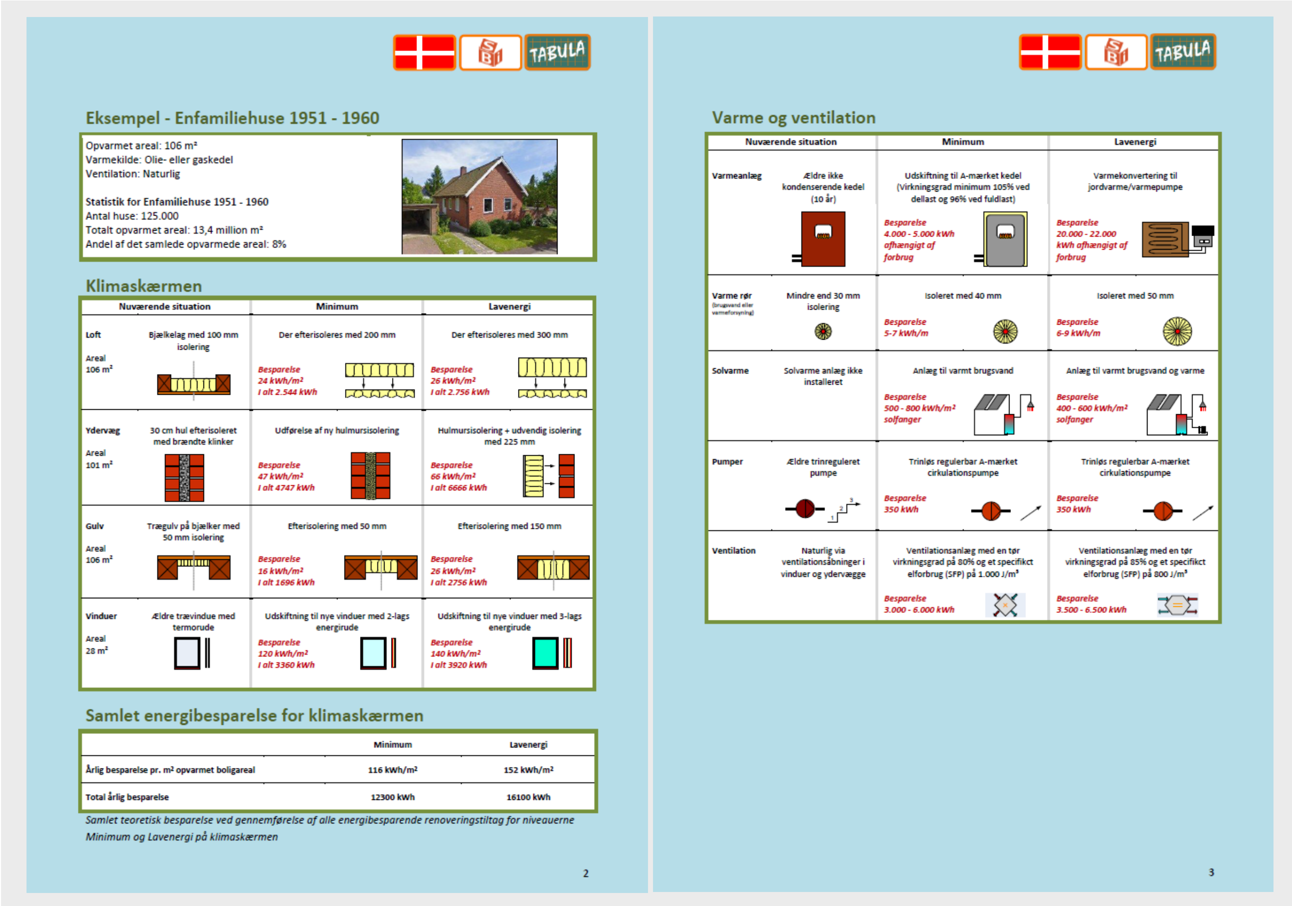
The total theoretical potential of energy savings for the three building types in whole Denmark are approx. 72 and 78 PJ for the standard and the ambitious measures, respectively. The corresponding CO_2 reduction is 3.1 and 3.4 million tons CO_2 respectively assuming the current mix of energy sources.

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.

A.5.13. Display sheets – example buildings

Each of the real example buildings are presented in a brochure called display sheets. The intention is that the display sheet should be used in Denmark for promoting energy upgrading and therefore the descriptions are in Danish. The display sheets give a brief and easy-to-understand overview of the energy upgrading possibilities for each of the example buildings. The display sheet contains information of the envelope constructions (area and U-values) at the current state and the possible savings at the two levels of measures given in Table 22. A corresponding overview is given with regard to the current state of the heating and ventilation installations.

Figure 16: "Building Display Sheet" – existing state of an example building and impact of refurbishment measures (extract from the Danish building typology brochure)



Eksempel - Enfamiliehuse 1951 - 1960

Opvarmet areal: 106 m²
Varmekilde: Olie- eller gaskedel
Ventilation: Naturlig

Statistik for Enfamiliehuse 1951 - 1960
Antal huse: 125.000
Totalt opvarmet areal: 13,4 million m²
Andel af det samlede opvarmede areal: 8%

Klimaskærmen

	Nuværende situation	Minimum	Lavenergi
Loft Areal 106 m²	Bjælkelag med 100 mm isolering	Der efterisoleres med 200 mm *Besparelse 24 kWh/m² I alt 2.544 kWh*	Der efterisoleres med 300 mm *Besparelse 26 kWh/m² I alt 2.756 kWh*
Ydervæg Areal 101 m²	30 cm hul efterisoleret med brændte klinker	Udførelse af ny hulmursisolering *Besparelse 47 kWh/m² I alt 4747 kWh*	Hulmursisolering + udvendig isolering med 225 mm *Besparelse 66 kWh/m² I alt 6666 kWh*
Gulv Areal 106 m²	Trægulv på bjælker med 50 mm isolering	Efterisolering med 50 mm *Besparelse 16 kWh/m² I alt 1696 kWh*	Efterisolering med 150 mm *Besparelse 26 kWh/m² I alt 2756 kWh*
Vinduer Areal 28 m²	Ældre trævindue med termorude	Udskiftning til nye vinduer med 2-lags energirude *Besparelse 120 kWh/m² I alt 3360 kWh*	Udskiftning til nye vinduer med 3-lags energirude *Besparelse 140 kWh/m² I alt 3920 kWh*

Samlet energibesparelse for klimaskærmen

	Minimum	Lavenergi
Årlig besparelse pr. m² opvarmet boligareal	116 kWh/m²	152 kWh/m²
Total årlig besparelse	12300 kWh	16100 kWh

Samlet teoretisk besparelse ved gennemførelse af alle energibesparende renoveringstiltag for niveauerne Minimum og Lavenergi på klimaskærmen

2

Varme og ventilation

	Nuværende situation	Minimum	Lavenergi
Varmeanlæg	Ældre ikke kondenserende kedel (10 år)	Udskiftning til A-mærket kedel (Virkningsgrad minimum 105% ved dellast og 96% ved fuldlast) *Besparelse 4.000 - 5.000 kWh afhængigt af forbrug*	Varmekonvertering til jordvarme/varmepumpe *Besparelse 20.000 - 22.000 kWh afhængigt af forbrug*
Varme rør (brugsvand eller varmeforsyning)	Mindre end 30 mm isolering	Isoleret med 40 mm *Besparelse 5-7 kWh/m*	Isoleret med 50 mm *Besparelse 6-9 kWh/m*
Solvarme	Solvarme anlæg ikke installeret	Anlæg til varmt brugsvand *Besparelse 500 - 800 kWh/m² solfanger*	Anlæg til varmt brugsvand og varme *Besparelse 400 - 600 kWh/m² solfanger*
Pumper	Ældre trinreguleret pumpe	Trinløs regulerbar A-mærket cirkulationspumpe *Besparelse 350 kWh*	Trinløs regulerbar A-mærket cirkulationspumpe *Besparelse 350 kWh*
Ventilation	Naturlig via ventilationsåbninger i vinduer og ydervægge	Ventilationsanlæg med en tør virkningsgrad på 80% og et specifikct elforbrug (SFP) på 1.000 J/m³ *Besparelse 3.000 - 6.000 kWh*	Ventilationsanlæg med en tør virkningsgrad på 85% og et specifikct elforbrug (SFP) på 800 J/m³ *Besparelse 3.500 - 6.500 kWh*

3

A.5.14. Future potential for the TABULA approach - Use in cost optimum calculations

According to the Energy Performance of Buildings Directive (Directive 2010/31/EU) (EPBD), European Member States (MS) are obliged to use reference buildings (building typologies) to evaluate cost-optimal energy-saving measures in new and existing buildings. Article 5 of the EPBD requires MS to establish the comparative methodology framework in accordance with EPBD Annex III and to differentiate between different categories of buildings. Annex III states that MS must define reference buildings that are characterised by and representative of their functionality and geographic location, including indoor and outdoor climate conditions. The reference buildings shall cover residential and non-residential buildings, both new and existing ones.

Application of the TABULA building typologies and building models represent a golden opportunity for kick-starting the establishment of a collection of reference buildings in the European MS (Wittchen, et al., 2011).

Table 24: National Activities Denmark / Sources and References

Reference shortcut	Short description	Reference
[SBi 2011]	Denmark Building Typology Brochure	Kragh, Jesper; Witchen, B. Kim: Dansk bygningstypologi. Eksempel bygninger med typiske forslag til besparelser; SBi, Hørsholm 2011 http://www.building-typology.eu/downloads/public/docs/brochure/AT_TABULA_TypologyBrochure_SBi.pdf
[TABULA NatSci DK 2012]	national scientific report of the TABULA activities in Denmark	Kragh, Jesper; Witchen, B. Kim: National scientific report of the TABULA activities in Denmark, SBi, Hørsholm 2012. http://www.sbi.dk/miljo-og-energi/energibesparelser/danish-building-typologies-participation-in-the-tabula-project/sbi-2012-01.pdf/downpub
[TABULA NatBal DK 2012]		Kragh, Jesper; Witchen, B. Kim: chapter "Denmark" in: Diefenbach, Nikolaus / Loga, Tobias (ed.): Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock (TABULA Thematic Report N° 2). Models for the national housing stock of 8 countries: Belgium, Czech Republic, Denmark, Germany, Greece, italy, Slovenia; IWU, Darmstadt / Germany 2012 http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf

A.6. <GR> Building Typology in Greece

(by TABULA partner NOA / National Observatory of Athens)

A.6.1. Status of EPBD implementation in Greece

The main legislative instrument for improving the energy efficiency of buildings in Greece is the national law N.3661/2008 (FEK 89/A 19.5.2008), which basically adapts the European Directive 2002/91/EC on the energy performance of buildings (EPBD), providing the general framework, with all major provisions mandated by EPBD. Among the landmark decisions in the development of N.3661/2008 was the agreement to follow the European standards.

Transposition of the European Directive 2006/32/EC on energy end-use efficiency and energy services took effect in June 2010 by the national law N.3855/2010 (FEK 95/A 23.6.2010), introducing various energy efficiency improvement measures, energy service companies (ESCOs) and third party financing (TPF) arrangements, in order to achieve by 2016 an overall national indicative target of 9% energy conservation. The national law on renewable energy sources - RES (N.3851/2010), in accordance to the European Directive 2009/28/EC on the promotion of the use of energy from renewables, mandates as of 2011 that new buildings have an annual solar fraction of 60% for domestic hot water (DHW) production from solar thermal systems. Accordingly, all public buildings by 2015 and all new buildings by 2020 should cover their primary energy consumption from RES, combined heat and power, district or block heating or cooling, and energy efficient heat pumps. In addition, N.3851/2010 sets some very ambitious national targets by 2020: reach a contribution of 20% from RES in the national gross final energy consumption (from 5% in 2007), 40% in gross electricity generation (from 4.6% in 2007) and 20% in final energy consumption for heating and cooling. In addition, N.3851/2010 extends the obligation to perform an energy design study to all new buildings, regardless of their size in accordance to the EPBD recast (Directive 2010/31/EC) and allows audits in individual units (properties) of a building (e.g. an apartment). The national law N.3889/2010 on the Green Fund (FEK 182/A/14.10.2010) mandates that residences with an annual use of less than four months (e.g. summer residences) should also comply with N.3661/2008 thus extending EPBD implementation to all types of buildings over $50m^2$.

The relevant Hellenic technical governing document is the “Regulation on Energy Performance in the Building Sector – KENAK” that was issued by the Ministry of Environment, Energy and Climatic Change (YPEKA), Ministerial Decision MD6/B/5825 (FEK 407/B/9.4.2010). KENAK outlines the general calculation method in compliance with the European standards and EN ISO 13790 (2008) and overall approach towards issuing an energy performance certificate (EPC). KENAK introduced lower U-values that replace the previous Hellenic Building Thermal Insulation Regulation - HBTIR (FEK 362/4.7.1979), which had been in use for 30 years without any adaptation. KENAK was supplemented by four technical guidelines (TOTEE 20701/1-4/2010) that were developed by the Technical Chamber of Greece (TEE) and approved by YPEKA (MD 17178 FEK 1387/B/2.9.2010). The technical guidelines were revised in May 2012, and published a new one on cogeneration (TOTEE 20701-5/2012).

Since October 2010, all new buildings must be at least class-B to obtain a building permit. Existing buildings that undergo major renovation ought to rate B or as close to B as possible given the restrictions imposed by technical, operational and economical factors that need to be clearly documented and well substantiated in the energy study that precedes the building retrofit action. An EPC is issued upon completion of the building that has been designed and constructed according to KENAK. Accordingly, all new buildings that have been constructed or renovated as of the end-2010 in Greece are audited by an energy inspector after their construction, in order to issue an EPC, assuring that they are at least class-B. As of January 2011, the EPC is compulsory for all buildings that are being sold. The requirement for an EPC for an entire building as well as for a building unit (e.g. an apartment) that is being rented out for the first time to a new tenant (in compliance with the EPBD recast) was enforced in January 2012. As of May 2012, the number of EPCs issued exceeds 120,000.

A.6.2. The TABULA project in Greece – The Hellenic typology

The Hellenic residential building typology includes 24 building types (Figure 17). The classification was based on three main parameters: the building age, size and climate zone. According to the year of building construction three categories were defined:

(1) Buildings constructed before 1980 (pre-1980), which is considered the border line for buildings without thermal insulation since they were constructed before the implementation of the first Hellenic Building Thermal Insulation Regulation (HBTIR)

(2) Buildings constructed during the period 1981–2000, which are considered to be partially or insufficiently insulated. Despite the introduction of the HBTIR since 1980, the integration of thermal insulation was problematic during the first decade of its implementation. For example, only recently the new buildings have thermal insulation on the load bearing structure to eliminate thermal bridges. Ordinary double glazing is also common practice in all new buildings and the most frequent refurbishment activity in existing buildings

(3) Buildings constructed after the year 2000. These are relatively new buildings with proper envelope thermal insulation, including the load bearing structure. Consequently, these buildings would not mandate major renovations but most probably they will not be in compliance with the new energy regulation – KENAK.

According to the building size, two categories were defined: single family houses - SFH (low-rise buildings with one or two floors) and multifamily houses - MFH. Climatic variability in Greece affects the regional construction trends regarding the energy performance of buildings. In line with KENAK and the related technical guidelines (TOTEE 20701-3/2010), there are four climatic zones defined on the basis of the heating degree days (HDD), namely: Zone A (601–1100 HDD), Zone B (1101–1600 HDD), Zone C (1601–2200 HDD) and Zone D (2201–2620 HDD). The classification of residential buildings, according to the time of construction (pre-1980, 1981–2001 and 2002–2010), type of building (SFH or MFH) and the four climatic zones resulted in a total of 24 different classes.

Supplementary sub-typologies regarding building elements and systems were prepared in accordance to the construction and system installation trends in the Hellenic residential building sector throughout the three age classes. The Hellenic "building element" sub-typology consists of 107 types of roof, floor, wall and window elements reflecting the most common construction types in the residential building stock. For each element type, the thermal transmission coefficient (U-value) is specified along with the corresponding period of application to the residential building sector. The U-values of the opaque elements are specified for three levels of thermal insulation (no insulation, partial and full) in accordance to the national technical guideline (TOTEE-20701-1/2010). The Hellenic "system" sub-typology consists of generation and distribution systems as well as auxiliary systems for space and DHW heating. The heat generation systems include boilers (condensing/non condensing, constant/low temperature), heat pumps, electric heaters, stoves, district heating and cogeneration systems. Boilers are differentiated according to the type of fuel (oil/natural gas), maintenance level and insulation degree. Expenditure coefficients are specified for a total of 67 heat generation systems for space heating and 50 for DHW production. Heat losses (kWh/m^2 reference area) are specified for 32 space heating and 25 DHW heat distribution systems. Typical values of auxiliary energy demand are supplied for the heating systems. Details on the supplementary sub-typologies are given in [1].

An example building was assigned to each of the 24 classes of the Hellenic building typology. Buildings included in the typology are actually real (existing) examples each considered to be representative of all buildings in the particular class. Datasets of the typology buildings were fed into the TABULA common database. They include general features (i.e. number of storeys, living area), geometrical data (i.e. building volume, envelope areas) and thermal properties of the envelope as well as heating system features. Details on the thermal characteristics of the building envelope and installed systems in the Hellenic typology buildings are elaborated in [1] along with the corresponding minimum requirements imposed by KENAK.

Two levels of refurbishment scenarios were defined for each building type: a “standard” and an “ambitious” scenario. Both scenarios include a combination of energy conservation measures (ECMs) on the building envelope and the installed heating systems. The standard scenario includes interventions on each building component (envelope and systems) in order to comply with the minimum requirements of KENAK foreseen in the case of major renovation. In the case of buildings constructed after 2000, major renovations are rather unlikely. Therefore, the standard scenario in this case includes a set of interventions upgrading the building to class-B. The ambitious scenario involves all the standard scenario interventions combined with an incorporation of RES technologies and innovative systems and techniques (solar collectors for DHW and space heating, geothermal heat pumps where possible) to further upgrade the building energy performance and environmental quality. A description of the measures included in the Standard and Ambitious scenarios is given in [1].

The calculations were performed using the official national software available by the Technical Chamber of Greece (TEE) for the assessment of the energy performance of buildings TEE-KENAK [2]. The software was used in order to assess the present state as well as the potential of the Standard and Ambitious scenarios proposed for each building typology.

Figure 18 summarizes the energy demand calculated for the 24 buildings of the Hellenic typology. Overall, the SFH present higher energy demand for space and DHW heating than MFH of the same age in the same climatic zone. This could be attributed to the fact that the majority of SFH are free standing buildings, while the majority of MFH are more sheltered as one or two of their facades are in contact with neighbouring buildings. Comparing buildings of the same age class it is obvious that, as expected, the colder the climate the higher the energy demand regardless their size.

Figure 19 and Figure 20 illustrate the impact of the two energy saving scenarios on the primary energy consumed by the Hellenic typology buildings for space and DHW heating along with the corresponding simple payback period (SPBP), estimated using fuel costs reported for the year 2010. As expected, in both cases, the highest energy savings are achieved for the buildings of the first age band that are older and have a poor initial energy performance. Interventions on these buildings exhibit the lowest SPBP. The lowest energy savings are achieved for buildings of the third age band, with energy related features close to the requirements of the new regulation. This fact combined with the high investment cost make these interventions less attractive for these buildings, as the corresponding estimated simple payback periods often exceed 20 years. Therefore, individual measures could prove more cost effective for this building category. The CO_2 emission reduction ranges from 17% to 80% for the Standard scenario and from 62% to 98% for the ambitious scenario.

Two-page display sheets (Figure 21) were prepared for each of the 24 Hellenic typology buildings. The first page of the display sheet includes a presentation of the building at its present state (photo, architectural features, envelope and system characteristics) and the corresponding energy performance indicators (energy demand, primary energy consumption, final energy consumption breakdown per fuel type, operational cost, CO_2 emissions) calculated using TEE-KENAK. The second page illustrates the calculated impact of the Standard scenario (upper half) and the Ambitious Scenario (lower half) on the energy performance (reduction in energy demand, final and primary energy consumption, operating cost) and the environmental profile (reduction of CO_2 emissions) of the building. The display sheets are included in the Hellenic Typology Brochure (in Hellenic). The first part of this report includes a description of the most

Figure 17: "Building Type Matrix" – classification of the Hellenic housing stock (4 climatic zones)

	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	Zone A (κλιματική ζώνη Α)	... 1980	generic	 GR.ZoneA.SFH.01.Gen		 GR.ZoneA.MFH.01.Gen	
2	Zone A (κλιματική ζώνη Α)	1981 ... 2000	generic	 GR.ZoneA.SFH.02.Gen		 GR.ZoneA.MFH.02.Gen	
3	Zone A (κλιματική ζώνη Α)	2001 ...	generic	 GR.ZoneA.SFH.03.Gen		 GR.ZoneA.MFH.03.Gen	
4	Zone B (κλιματική ζώνη Β)	... 1980	generic	 GR.ZoneB.SFH.01.Gen		 GR.ZoneB.MFH.01.Gen	
5	Zone B (κλιματική ζώνη Β)	1981 ... 2000	generic	 GR.ZoneB.SFH.02.Gen		 GR.ZoneB.MFH.02.Gen	
6	Zone B (κλιματική ζώνη Β)	2001 ...	generic	 GR.ZoneB.SFH.03.Gen		 GR.ZoneB.MFH.03.Gen	
7	Zone C (κλιματική ζώνη Γ)	... 1980	generic	 GR.ZoneC.SFH.01.Gen		 GR.ZoneC.MFH.01.Gen	
8	Zone C (κλιματική ζώνη Γ)	1981 ... 2000	generic	 GR.ZoneC.SFH.02.Gen		 GR.ZoneC.MFH.02.Gen	
9	Zone C (κλιματική ζώνη Γ)	2001 ...	generic	 GR.ZoneC.SFH.03.Gen		 GR.ZoneC.MFH.03.Gen	
10	Zone D (κλιματική ζώνη Δ)	... 1980	generic	 GR.ZoneD.SFH.01.Gen		 GR.ZoneD.MFH.01.Gen	
11	Zone D (κλιματική ζώνη Δ)	1981 ... 2000	generic	 GR.ZoneD.SFH.02.Gen		 GR.ZoneD.MFH.02.Gen	
12	Zone D (κλιματική ζώνη Δ)	2001 ...	generic	 GR.ZoneD.SFH.03.Gen		 GR.ZoneD.MFH.03.Gen	

common energy-retrofit interventions in the residential building sector along with their pros and cons [3]. This material along with the 24 two-page brochures for the buildings of the Hellenic typology is available for public access (www.energycon.org/tabula.html) in the form of an electronic booklet (in Greek).

Figure 18: ***Calculated thermal energy demand for space and domestic water heating for Single Family Houses (SFH) and Multi Family Houses (MFH)***

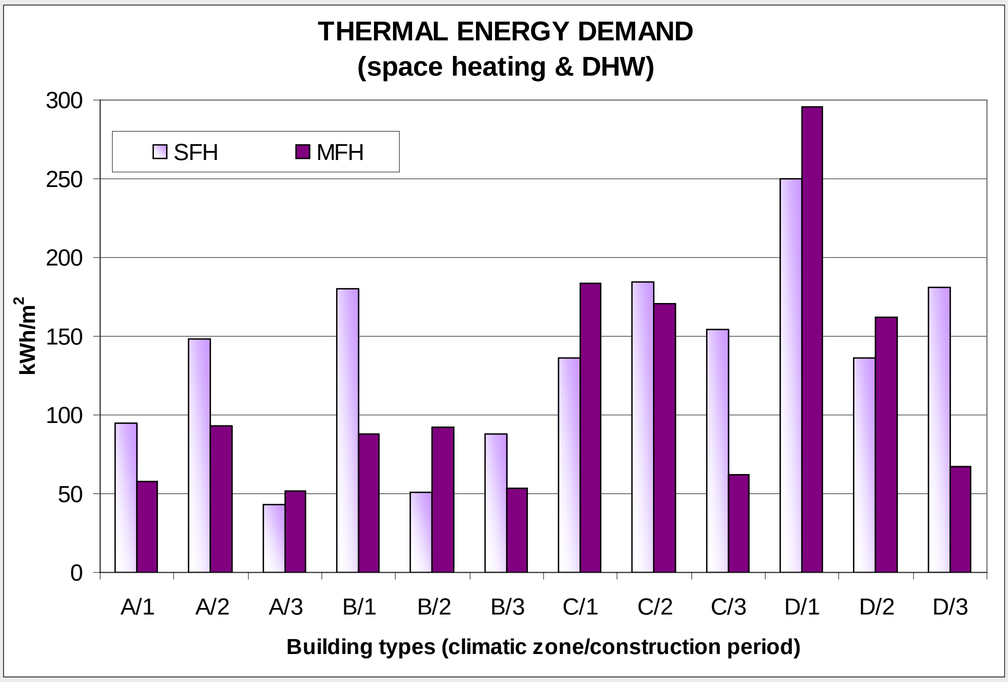


Figure 19: ***Impact of the Standard and Ambitious Scenarios on the Single Family Houses of the Hellenic typology.***

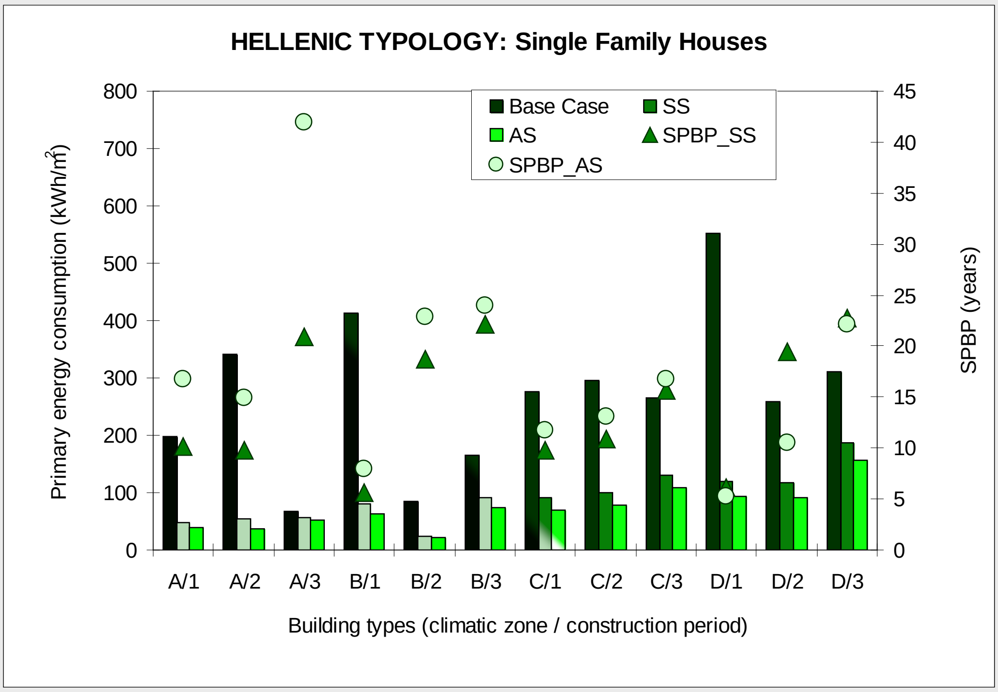


Figure 20: ***Impact of the Standard and Ambitious Scenarios on the Multi Family Houses of the Hellenic typology.***

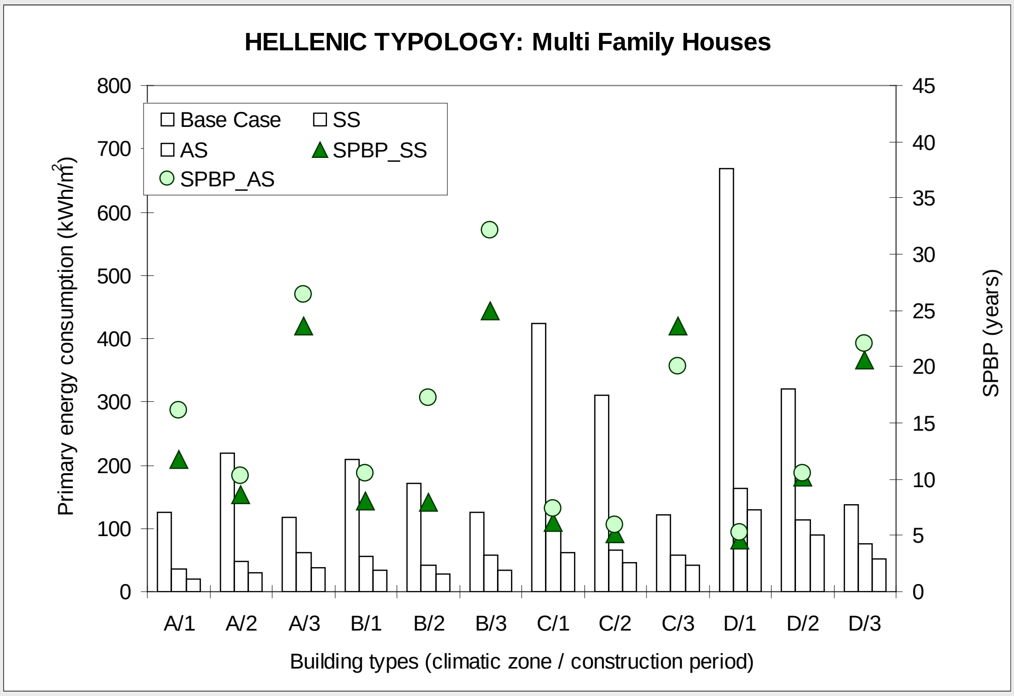
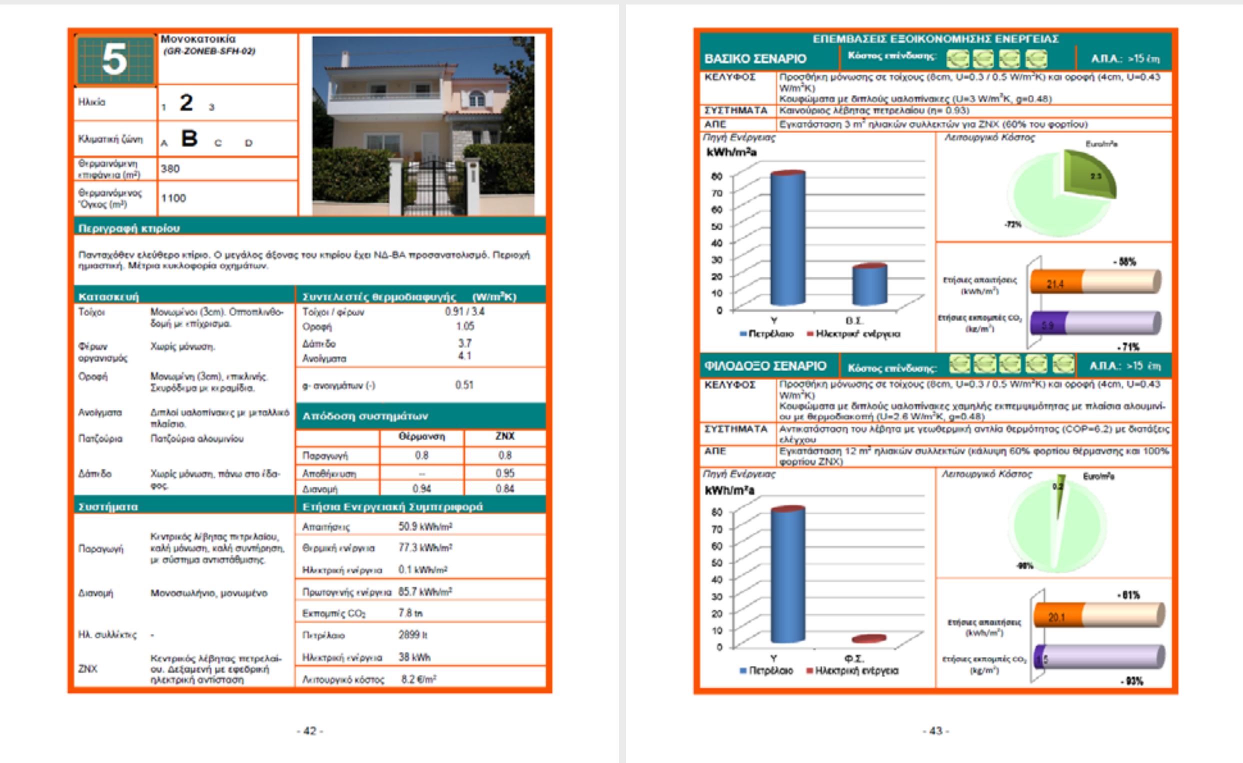


Figure 21: "Building Display Sheet" – existing state of an example building and impact of refurbishment measures (extract from the Greek building typology brochure [3])



The TABULA calculation tool was used to assess the energy performance of all 24 buildings included in the Hellenic typology as well as the impact of the Standard and Ambitious scenarios on their performance. Results were compared with the corresponding results from the Hellenic EPC method (TEE-KENAK). The differences in the calculation results given by the two tools (TABULA and TEE-KENAK) are attributed to the assumptions they are based on. A very important issue to take into account when comparing the results is the input related to climate. TABULA uses average values per climatic zone, whereas TEE-KENAK uses national climatic data that are based on meteorological measurements in the locations of the buildings. Thus, higher differences between the two methods are observed in the cases where the local climate significantly deviates from the average climate of the respective climatic zone. The differences are accentuated in the cases of non-insulated buildings, as they are more sensitive to the impact of the weather. Further discussion on the comparison of TABULA calculation method and the Hellenic EPC method can be found in [1].

A.6.3. Application of the typology concept in modelling the energy balance of the Hellenic building stock

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.

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 based on this data [4] 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.

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”. 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 the national advisory group (NAG) experts active in the field of construction and currently constitute a realistic estimate of the evolution of the construction and renovation trends over the years. “Typical” values of the thermal transmission coefficient for the main components of the building envelope as well as “typical” expenditure coefficients (using the Higher Calorific Value) for the systems installed in each of the 24 building classes of the Hellenic residential building typology are given in detail in [1].

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. The results were then used with the estimated frequencies in the building stock in order to estimate the national energy balance of the residential sector. Average climatic data were used for each of the four climate zones. The TABULA method 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 DHW 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 use 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 was calculated taking into account only thermal energy consumption; electricity as well as the part covered by renewable energy sources, were excluded.

Only permanent dwellings with continuous occupancy throughout the year were considered in the energy balance model. Permanent dwellings average about 68% of the total dwellings stock throughout the country. The floor area of permanent dwellings for each of 24 residential building categories [1] is based on available information from: a detailed register of 6550 dwellings, which was performed during the period 1987–1988, results of the 1990 census, and the construction activities after 1990. 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 of dwellings was 1.65%, while during the 1990s it dropped to 1.46% [4].

In order to account for unheated areas, e.g. corridors, stairwells, cellars as well as basements that are usually unheated spaces, 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. Furthermore, the calculated consumption and CO_2 emission results were adjusted to take into account the actual operating hours of the buildings. Given that there is no official statistical data available, the following assumptions were derived in collaboration with experts who are active in the field of building construction and maintenance. They are considered to be a realistic approximation of the Hellenic residential building stock operating patterns:

- SFH buildings: 10% have an 18 h and 90% have a 12 h operation per day
- MFH buildings: 10% have a 12 h and 90% have a 9 h operation per day

Details on the assumptions made for the calibration of the balance model to make it more representative of the Hellenic building stock are given in [7].

Comparison of the calculated thermal energy balance with the officially reported value revealed an overestimation of 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 study.

According to the transposition of the European Directive 2006/32/EC that took effect in June 2010 by the national law N.3855/2010, there is a national obligation to implement various ECMs in all energy end-use sectors, including buildings, in order to achieve by 2016 an overall national indicative target of 9% energy conservation. 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 ECMs. 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. 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). Apparently, it is possible to derive different combinations that could satisfy the national indicative target of 9% energy conservation by 2016. 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.

Extension of the typology concept to the non-residential building stock

An investigation of the possibility to extend the typology concept in the Hellenic non-residential building stock revealed that the TABULA typology concept could be expanded to apply to non-residential buildings. As there is a large variety of building uses and operational characteristics in the tertiary sector, it is necessary to classify buildings according to their use rather than their size. Accordingly, a preliminary classification could include the following building categories:

- Schools
- Offices / Commercial
- Hotels
- Hospitals

Additionally, the three construction year bands: pre-1980, 1981-2000 and 2001-2010 could be used, as in the case of residential typology, to reflect the different trends in the envelope construction before and after the national Thermal Insulation Regulation that came into effect in 1980. The four climatic zones A, B, C and D defined in the national regulation (KENAK) could also be used. Therefore, each typology related to a building use would include a total of 12 building classes (3 age bands x 4 climatic zones).

The most important barrier in expanding the typology concept to the non-residential building sector is the lack of official data on the building stock. Existing knowledge on the non-residential building stock is summarized in [8] with special focus on schools, a building use with complexity similar to that of residential buildings; limited operating hours, simplicity in installations and envelope construction.

Figure 22: eKIA: a web-based multimedia tool **(www.energycon.org/ekia.html)**

In an effort to facilitate dissemination of the typology concept in Greece, NOA has prepared eKIA, a web application in Greek, addressed mainly to home owners who wish to have a first assessment of the energy performance of a building and its potential for improvement through energy efficient measures.

Exploiting the Hellenic TABULA typology, users may browse through the 24 building types to choose the one that better approximates the building under assessment. Adaptation of the initially selected building from the available 24 Hellenic typologies, for a more realistic representation of the actual building, is possible by defining basic parameters such as the actual heated floor area and building volume, the total window area as well as the number of floors.

Further refinement is possible by providing some basic information related to the:

- actual envelope construction
- heating system
- cooling system
- solar collectors and PVs

The tool permits the user to derive a pre-assessment of a building's energy rating, along with the related performance indicators including energy demand, consumption (final and primary energy), operational cost and CO_2 emissions. Furthermore, the user can define energy saving measures/scenarios and assess their cost effectiveness. For each scenario, eKIA calculates the reduction in the energy consumption, CO_2 emissions, operational cost, as well as the corresponding investment cost and simple payback period. More detailed presentation of eKIA can be found in [1].

A.6.4. Conclusions and perspectives

The building typology concept was documented to provide a flexible tool for estimating the impact of energy saving scenarios on the energy performance of the Hellenic residential building stock. A major strength of the overall approach is that a building typology can be used for initial energy advice activities to give residential building owners a quick overview of the energy performance of a building similar to their own and demonstrate the effect of possible ECMs. The Hellenic typology can be used by the owners on their own or by a consultant in counselling sessions. On a national level, the typology concept has proved to provide a flexible tool for energy balance modelling. At present, the accuracy of such a model is prohibited by the lack of knowledge and limited statistical data availability. Some of the most important sources of uncertainty are related to 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, refurbishment rate of residential buildings.

The TABULA methodology can support national efforts towards defining reference buildings required by the EPBD recast for deriving cost-optimal energy saving measures for the residential building stock. The overall approach can also be extended to include the non-residential building stock. YPEKA, the Hellenic the ministry responsible for national EPBD implementation and its representatives involved in NAG have expressed a very strong interest about TABULA and its possible adaptation to facilitate the national efforts. The main barrier in this respect is the lack of information on Hellenic tertiary sector buildings. In the future, as more information on the residential building stock becomes available through the exploitation of the new data 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.

Table 25: National Activities Greece / Sources and References

Reference shortcut	Short description	Reference
[1]	National scientific report	E. Dascalaki, C.A.Balaras, P. Droutsa, S. Kontoyiannidis, National Scientific Report, D6.2, TABULA project, May 2012.
[2]	Software	TEE-KENAK, v.1.28.1.67, Technical Chamber of Greece, Athens, February 2011
[3]	Typology Brochure (booklet)	E. Dascalaki, P. Droutsa, C.A.Balaras, S. Kontoyiannidis Hellenic Building Typology Brochure, 88p., WP3, D5.2 National Typology Brochures, Final, May 2012
[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]	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).
[7]	Hellenic contribution to the common report (E. Dascalaki, C,A, Balaras)	N. Diefenbach, T. Loga (eds) Application of building typologies for modelling the energy balance of the residential building stock, 72p, Thematic Report 2, WP3, D8, February 2012.
[8]	Hellenic contribution to the common report (E. Dascalaki)	B. Stein (ed.) Typology Approaches for non-residential buildings in four European countries – Existing information, concepts and outlook, 33p., Thematic Report No3, WP3, D9 Final, May 2012.

A.7. <IE> Building Typology in Ireland

(by TABULA partner Energy Action)

A.7.1. Selection of Irish Building Types for the Irish Typology

Prior to the TABULA project, no formal building typology has been compiled in Ireland on either a national or regional level.

However, several reports published within the last 10 years such as ‘Homes for the 21st Century’ in 1999 (UCD Energy Research Group/ Energy Action) and ‘The Irish National Survey of Housing Quality 2001-2002’ (ESRI) contained useful building typology data. The Irish Census also contains some building-related national statistics. The introduction of the Irish Building Energy Rating (BER) method known as Dwelling Energy Assessment Procedure (DEAP) by the Sustainable Energy Authority of Ireland (SEAI) in 2007 following implementation of the Energy Performance of Buildings Directive also provided a natural reference point for the development of an Irish typology. In addition, the natural growth of BER/ EPC data within SEAI’s central Irish database of BER certificates over the duration of the project from 2009 to 2012 would prove a further source of reference data.

The Irish building typology was developed by combining data from both existing and new research sources, many of which have evolved since the legal requirement for the production of BER certificates for existing dwellings when sold or rented from 1 January 2009.

The Irish census (2006) gives a good summary of the number of Irish Dwellings based on year built. In addition to the 1.46 million Irish dwellings recorded in the 2006 census, approximately 160,000 further dwellings were built in the period 2007-2011.

The 2006 Irish census also gives a breakdown of the types of residential dwellings such as detached houses, semi-detached houses and apartments etc. It is important to note, that the Irish approach is to record each individual apartment or flat as a single dwelling. Similarly, the Irish method for calculating the energy performance of buildings produces an individual rating for each apartment unlike the practice elsewhere in Europe, where the apartment building is given a rating rather than individual apartments or flats.

Table 26 shows the breakdown by dwelling type of Irish residential buildings for different age bands provided in the 2006 census.

Table 26: Dwelling Type by Age Band (Census 2006)

Dwelling Type	Total	Detached house	Semi-detached house	Terraced house	Flat or apartment in a purpose-built block	Flat or apartment in converted house or commercial building	Bed-sit	Not stated
Before 1919	154,352	82,951	15,748	37,111	3,037	11,235	2,678	1,592
1919 to 1940	107,645	48,394	22,056	29,146	2,552	3,339	978	1,180
1941 to 1960	142,414	49,140	40,935	43,461	4,634	2,300	661	1,283
1961 to 1970	112,969	41,777	40,435	22,727	5,248	1,369	486	927
1971 to 1980	212,382	98,182	67,698	37,306	5,763	1,348	417	1,668
1981 to 1990	166,021	85,700	45,064	24,337	7,977	1,134	396	1,413
1991 to 1995	93,086	43,071	30,232	8,341	9,604	927	243	668
1996 to 2000	154,774	71,973	51,327	11,455	17,093	1,450	355	1,121
2001 or later	249,443	94,408	71,378	32,957	44,991	2,230	783	2,696
Not stated	69,210	10,392	13,487	10,681	8,967	4,674	1,754	19,255
Total	1,462,296	625,988	398,360	257,522	109,866	30,006	8,751	31,803

National energy efficiency programmes which part fund or fully fund thermal upgrades have been under way in Ireland for more than 10 years. Data on measures completed from 2000-2011 is provided in the table below.

Typically low incomes homes will have received one or two measures, e.g. roof insulation and cavity wall insulation. Private homes and social housing units will have received typically two to three upgrade measures, e.g. roof insulation, wall insulation and heating boiler and controls.

Table 27: Refurbishment Levels

	Low Income Houses	Private Houses	Social Housing Units	Total	Measures as % of Total Housing (1.6m)
2000-2006	11,000			11,000	0.7%
2007	4,000			4,000	0.3%
2008	5,000			5,000	0.3%
2009	15,000	20,000	1,200	36,200	2.3%
2010	20,000	40,000	1,800	61,800	3.9%
2011	25,000	50,000	3,000	78,000	4.9%
Totals	**80,000**	**110,000**	**6,000**	196,000	12.3%

Source: SEAI (2012) and DOECLG (2012)

When determining appropriate construction age bands for the Irish typology, the concepts developed within the Irish DEAP method were adopted. The age bands within Appendix S of the Irish DEAP method are shown in Table 28. These age bands are used for the purposes of assigning U-values and other data.

Table 28: Construction Age Bands for Irish Dwellings

Age band	Years of construction
A	before 1900
B	1900-1929
C	1930-1949
D	1950-1966
E	1967-1977
F	1978-1982
G	1983-1993
H	1994-1999
I	2000-2004
J	2005 onwards

The construction age bands in Table 28 are directly related to the Irish thermal insulation standards that were first introduced in the mid 1970s via the Building Regulations. The dates of the first draft regulations and subsequent revisions are shown in Table 29.

Table 29: Building Regulation Summary

Year of Regulations	Applicable age band	U values (W/m2K)		
		Roof	Wall	Floor
1976 (Draft)	F	0.4	1.1	0.6
1981 (Draft)	G	0.4	0.6	0.6
1991	H	0.35	0.45	0.45/0.6
1997	I	0.35	0.45	0.45/0.6
2002	J	0.25	0.27	0.37

Aside from construction age, wall type is also a significant distinguishing characteristic is Irish residential buildings. Table 5 below shows the spread of wall construction types across the age bands within the Irish DEAP method (Appendix S).

Table 30: Appendix S – Wall U values

Age Band	A	B	C	D	E	F	G	H	I	J
Wall type	Before 1900	1900-1929	1930-1949	1950-1966	1967-1977	1978-1982	1983-1993	1994-1999	2000-2004	2005 onwards
stone	2.1	2.1	2.1	2.1	2.1	1.1	0.6	0.55	0.55	0.37
225mm solid brick	2.1	2.1	2.1	2.1	2.1	1.1	0.6	0.55	0.55	0.37
325mm solid brick	1.64	1.64	1.64	1.64	1.64	1.1	0.6	0.55	0.55	0.37
300mm cavity	2.1	1.78	1.78	1.78	1.78	1.1	0.6	0.55	0.55	0.37
300mm filled cavity	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.55	0.55	0.37
solid mass concrete	2.2	2.2	2.2	2.2	2.2	1.1	0.6	0.55	0.55	0.37
concrete hollow block	2.4	2.4	2.4	2.4	2.4	1.1	0.6	0.55	0.55	0.37
timber frame	2.5	1.9	1.9	1.1	1.1	1.1	0.6	0.55	0.55	0.37

By clustering the age bands with the same default wall U values (as shown in Table 30 above), five distinct building construction age bands were selected (Table 31) to categorise Irish dwelling types within TABULA. For example, the 1994-2004 age band code 04 combines both the 1994-1999 and the 2000-2004 periods as the element U values were the same in both the 1991 and 1997 Building Regulations.

Table 31: Construction Age Bands – Irish Typology

Construction Year Class	Code
1800-1977	1
1978-1982	2
1983-1993	3
1994-2004	4
2005-onwards	5

In order to examine the frequency of houses with wall types within all the Appendix S categories, data was provided from SEAI's BER National Administration System in September 2010 for 115,00 BER (EPC) certificates that had been published by that date. The data provided was aggregated for the 5 construction age bands selected and the results in percentage terms (Table 32) helped identify the most common and least common construction types.

Table 32: Published Existing Dwelling BER Certificates by Wall Type Percentages (Sept. 2010)

Age Band	A-E	F	G	H-I	J
Wall type/ period	1800-1977	1978-1982	1983-1993	1994-2004	2005-onw
stone	31%	9%	9%	9%	4%
255mm solid brick	8%	2%	2%	3%	2%
325 solid brick	9%	2%	2%	1%	1%
300 cavity filled/empty	32%	72%	73%	68%	52%
solid mass concrete	9%	1%	2%	3%	7%
concrete hollow block	8%	11%	7%	4%	2%
timber frame	1%	1%	2%	8%	15%
other	2%	2%	2%	3%	17%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

In table 7, in the first age band up to 1977, most wall types were selected for the Irish typology as each has a distinct U value (except timber frame which was not common). In the other 4 age bands, the wall U values are identical for different wall types. For these 4 age bands, the 2 most common wall types were selected as the most representative to create the Irish typology.

In total, 29 Irish house types were created in TABULA and their distribution with the age bands and wall types are illustrated in Table 8 below.

Table 33: Distribution of the 29 House Types in the Irish Typology

Age Band	A-E	F	G	H-I	J
Wall type/ period	**1800-1977**	**1978-1982**	**1983-1993**	**1994-2004**	**2005-onw**
stone	3,4				
255mm solid brick	5,6				
325 solid brick	7,8				
300 cavity filled/empty	1,2	14,15	18,19	22,23	26,27
solid mass concrete	9,10				
concrete hollow block	11,12,13	16,17	20,21		
timber frame				24,25	28,29

One generic apartment type was created for each age band. The wall constructions selected were solid brick (1800-1977), cavity walls (1978-2004 inclusive) and concrete (2005 onwards).

An overview of all national building typologies in TABULA is provided by the “Building Type Matrix” that forms the presentation format of the TABULA webtool (Figure 22).

In the Irish Matrix, the generic types of single family houses, terraced/semi detached houses and apartment blocks are presented on the first page of the building type matrix as shown below. The generic building is a typical representative of the building type, meaning that it has features which can commonly be found in houses of the respective age and size class. There were no Irish entries made under multi-family houses.

As the first age band of Irish typology covers an extended period (1800-1977) due to the absence of Building Regulations, a second page of the Building Matrix was created to include these types in addition to the generic matrix types.

Figure 23: "Building Type Matrix" – classification of the Irish housing stock

	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	national	... 1977	generic	 IE.N.SFH.01.Gen	 IE.N.TH.01.Gen		 IE.N.AB.01.Gen
2	national	1978 ... 1982	generic	 IE.N.SFH.02.Gen	 IE.N.TH.02.Gen		 IE.N.AB.02.Gen
3	national	1983 ... 1993	generic	 IE.N.SFH.03.Gen	 IE.N.TH.03.Gen		 IE.N.AB.03.Gen
4	national	1994 ... 2004	generic	 IE.N.SFH.04.Gen	IE.N.TH.04.Gen		 IE.N.AB.04.Gen
5	national	2005 ...	generic	 IE.N.SFH.05.Gen	 IE.N.TH.05.Gen		 IE.N.AB.05.Gen

A.7.2. Irish Refurbishment Measures

As well as indentifying national residential building types, two stages of refurbishment of each dwelling type are examined in TABULA.

The first stage of refurbishment for Irish dwellings is broadly based on the standard for roof and wall insulation and heating system upgrades contained in the current national energy efficiency grant programmes (SEAI Better Energy Homes Scheme). The Stage 1 refurbishment also includes measures which are not part of the SEAI standard but which would be recommended for comprehensive refurbishment of existing buildings, namely the replacement of uninsulated wooden floors, the replacement of windows and the provision of spray foam cylinder insulation. The Stage 1 refurbishment measures are listed in Table 34.

Table 34: Stage 1 Refurbishment

Stage 1 Measures	Upgrade Standards
Roof U-Value	0.13W/m^{2}K
Flat Roof U-Value	0.22 W/m^{2}K
Wall U-Value	0.27 W/m^{2}K
Wooden Floor (replace)	0.25 W/m^{2}K
Window U-Value	2 W/m^{2}K
Door U-Value	2 W/m^{2}K
Space heat generator efficiency	90% gas, 90% oil
Water heat generator efficiency	90% gas, 90% oil
Heating controls	Full zone control
Cylinder Insulation	50mm, spray foam

The second stage of refurbishment is for a more advanced level of refurbishment. The measures for the stage 2 refurbishment are detailed in table 10 below. The U values for flat roofs, walls and windows have been reduced to match the backstop levels in the 2011 Building Regulations (Technical Guidance Document Part L) and renewable technologies are included for water heating and space heating.

Table 35: Stage 2 Refurbishment

Stage 2 Measures	Upgrade Standards
Roof U-Value	0.13 W/m2K
Flat roof	0.2 W/m^{2}K
Wall U-Value	0.21 W/m^{2}K
Windows U-Value	1.3 W/m^{2}K
Doors (PVC)	2 W/m^{2}K
Space heat generator efficiency	Heat pump: 380% min air, 400% ground
Water heat generator efficiency	Heat pump: 380% min air, 400% ground
Plus Solar thermal (4m^2 to 6m^2)	40% contribution of total energy (10% electric immersion)
Heating controls	Full zone control
Cylinder Insulation	50mm, spray foam
Mechanical Heat Recovery Ventilation	90% minimum efficiency

A.7.3. Irish TABULA Brochures

Individual brochures have been prepared for the 30 Irish dwelling types (29 house types and one apartment type) within the Irish typology in the form of double sided A4 sheets. All 30 individual brochures have also been compiled into one National Irish Typology brochure.

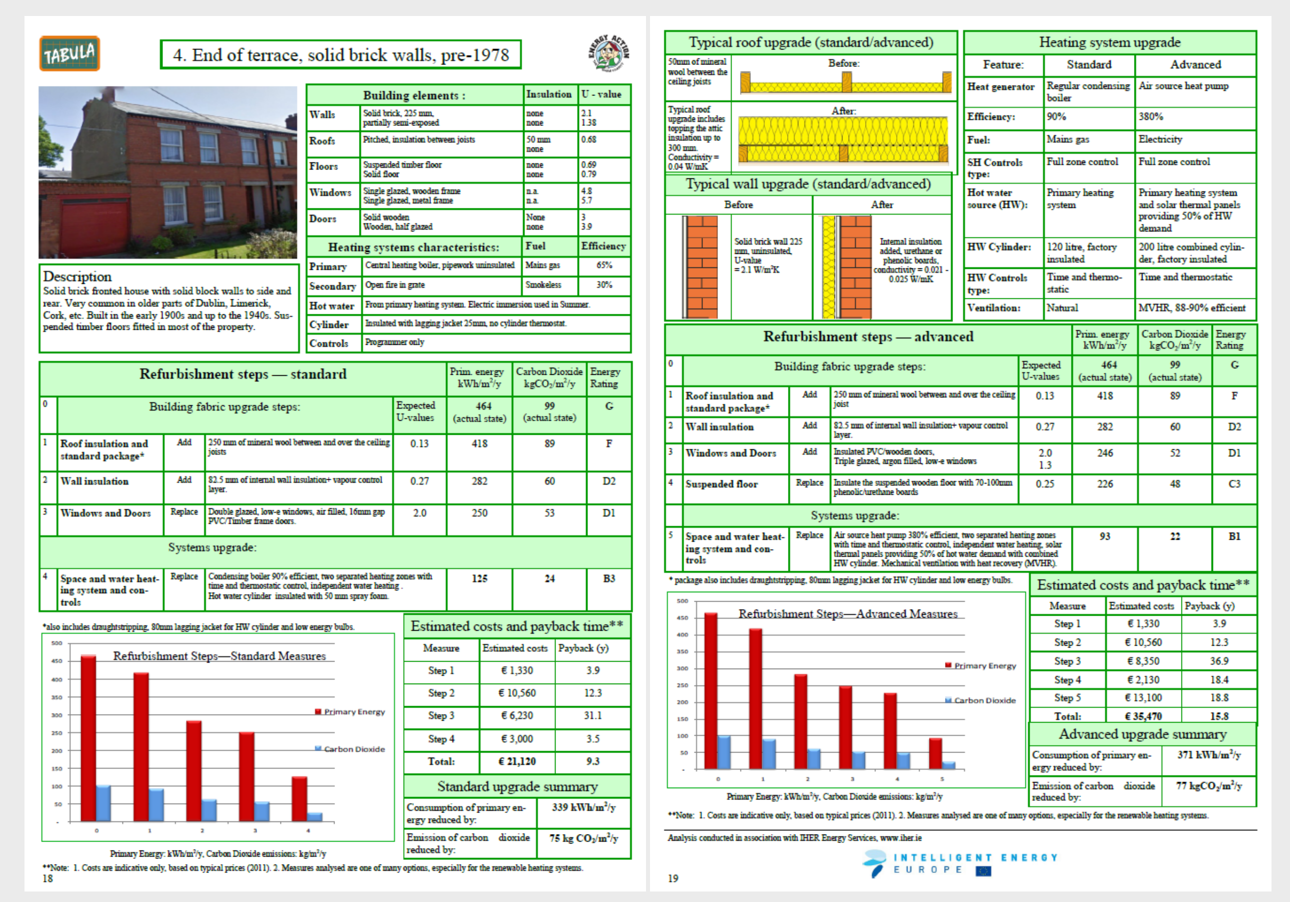
The energy analysis within the brochures is based on the Irish DEAP method. For each building type, sectional drawings and sketches are provided to illustrate many of the typical wall and roof constructions for both the original state and the refurbished state. These sectional drawings and sketches should provide homeowners, in particular, with some basic information relating to their dwelling that will enable them engage fully with potential refurbishment projects.

As well as indentifying these national house types, data on the two stages of retrofit are contained in each of the thirty brochures. In the case of the apartment type, a different approach was adopted for refurbishment analysis. Two variants on the main heating system were used, namely a gas boiler and an electric storage heating system. Standard refurbishment details for both heating systems are contained in the brochure for this dwelling type only.

The impact of the refurbishment measures are shown in each of the individual dwelling brochures in terms of reductions in primary energy use, carbon dioxide emissions and the corresponding BER grade (i.e. A to G rating band). The impact of each individual measure is shown separately to show the likely results from partial upgrades.

For each dwelling type, the cost of the recommended measures is shown as well the associated payback periods. The cost of measures are full costs and do not include any possible grants that may be available. The costs used are average industry costs gathered from a short survey of market prices in 2011. It was decided to use payback periods and not to include actual yearly running costs as the former can vary with regular energy price movements and make the brochure appear less relevant. The payback information can give a better impression of the value for money aspect of particular refurbishment measures. It must be noted, however, that the paybacks are based on calculated (asset-based) energy consumption values and not measured values. Research data from Belgium and Denmark indicates that measured consumption is typically just 50% of the calculated consumption for poorly rated dwellings. While published research data of this type is not available in Ireland, a similar relationship is expected. Thus, actual measured consumption and energy savings may be less in reality and payback periods would be longer.

Figure 24: "Building Display Sheet" – existing state of an example building and impact of refurbishment measures (extract from the Irish building typology brochure)



4. End of terrace, solid brick walls, pre-1978

Building elements :		Insulation	U - value
Walls	Solid brick, 225 mm, partially semi-exposed	none none	2.1 1.38
Roofs	Pitched, insulation between joists	50 mm none	0.68
Floors	Suspended timber floor Solid floor	none none	0.69 0.79
Windows	Single glazed, wooden frame Single glazed, metal frame	n.a. n.a.	4.8 5.7
Doors	Solid wooden Wooden, half glazed	None none	3 3.9

Heating systems characteristics:		Fuel	Efficiency
Primary	Central heating boiler, pipework uninsulated	Mains gas	65%
Secondary	Open fire in grate	Smokeless	30%
Hot water	From primary heating system. Electric immersion used in Summer.		
Cylinder	Insulated with lagging jacket 25mm, no cylinder thermostat.		
Controls	Programmer only		

Description

Solid brick fronted house with solid block walls to side and rear. Very common in older parts of Dublin, Limerick, Cork, etc. Built in the early 1900s and up to the 1940s. Suspended timber floors fitted in most of the property.

Refurbishment steps — standard					Prim. energy $kWh/m^2/y$	Carbon Dioxide $kgCO_2/m^2/y$	Energy Rating
0	Building fabric upgrade steps:			Expected U-values	464 (actual state)	99 (actual state)	G
1	Roof insulation and standard package*	Add	250 mm of mineral wool between and over the ceiling joists	0.13	418	89	F
2	Wall insulation	Add	82.5 mm of internal wall insulation+ vapour control layer.	0.27	282	60	D2
3	Windows and Doors	Replace	Double glazed, low-e windows, air filled, 16mm gap PVC/Timber frame doors.	2.0	250	53	D1
	Systems upgrade:						
4	Space and water heating system and controls	Replace	Condensing boiler 90% efficient, two separated heating zones with time and thermostatic control, independent water heating . Hot water cylinder insulated with 50 mm spray foam.		125	24	B3

*also includes draughtstripping, 80mm lagging jacket for HW cylinder and low energy bulbs.

Estimated costs and payback time**		
Measure	Estimated costs	Payback (y)
Step 1	€ 1,330	3.9
Step 2	€ 10,560	12.3
Step 3	€ 6,230	31.1
Step 4	€ 3,000	3.5
Total:	**€ 21,120**	**9.3**

Standard upgrade summary	
Consumption of primary energy reduced by:	339 $kWh/m^2/y$
Emission of carbon dioxide reduced by:	75 kg $CO_2/m^2/y$

**Note: 1. Costs are indicative only, based on typical prices (2011). 2. Measures analysed are one of many options, especially for the renewable heating systems.

18

Typical roof upgrade (standard/advanced)	
50mm of mineral wool between the ceiling joists	Before:
Typical roof upgrade includes topping the attic insulation up to 300 mm. Conductivity = 0.04 W/mK	After:

Typical wall upgrade (standard/advanced)	
Before	After
Solid brick wall 225 mm, uninsulated, U-value = 2.1 W/m^2K	Internal insulation added, urethane or phenolic boards, conductivity = 0.021 - 0.025 W/mK

Heating system upgrade		
Feature:	Standard	Advanced
Heat generator	Regular condensing boiler	Air source heat pump
Efficiency:	90%	380%
Fuel:	Mains gas	Electricity
SH Controls type:	Full zone control	Full zone control
Hot water source (HW):	Primary heating system	Primary heating system and solar thermal panels providing 50% of HW demand
HW Cylinder:	120 litre, factory insulated	200 litre combined cylinder, factory insulated
HW Controls type:	Time and thermostatic	Time and thermostatic
Ventilation:	Natural	MVHR, 88-90% efficient

Refurbishment steps — advanced					Prim. energy $kWh/m^2/y$	Carbon Dioxide $kgCO_2/m^2/y$	Energy Rating
0	Building fabric upgrade steps:			Expected U-values	464 (actual state)	99 (actual state)	G
1	Roof insulation and standard package*	Add	250 mm of mineral wool between and over the ceiling joist	0.13	418	89	F
2	Wall insulation	Add	82.5 mm of internal wall insulation+ vapour control layer.	0.27	282	60	D2
3	Windows and Doors	Add	Insulated PVC/wooden doors, Triple glazed, argon filled, low-e windows	2.0 1.3	246	52	D1
4	Suspended floor	Replace	Insulate the suspended wooden floor with 70-100mm phenolic/urethane boards	0.25	226	48	C3
	Systems upgrade:						
5	Space and water heating system and controls	Replace	Air source heat pump 380% efficient, two separated heating zones with time and thermostatic control, independent water heating, solar thermal panels providing 50% of hot water demand with combined HW cylinder. Mechanical ventilation with heat recovery (MVHR).		93	22	B1

* package also includes draughtstripping, 80mm lagging jacket for HW cylinder and low energy bulbs.

Estimated costs and payback time**		
Measure	Estimated costs	Payback (y)
Step 1	€ 1,330	3.9
Step 2	€ 10,560	12.3
Step 3	€ 8,350	36.9
Step 4	€ 2,130	18.4
Step 5	€ 13,100	18.8
Total:	**€ 35,470**	**15.8**

Advanced upgrade summary	
Consumption of primary energy reduced by:	371 $kWh/m^2/y$
Emission of carbon dioxide reduced by:	77 $kgCO_2/m^2/y$

**Note: 1. Costs are indicative only, based on typical prices (2011). 2. Measures analysed are one of many options, especially for the renewable heating systems.

Analysis conducted in association with IHER Energy Services, www.iher.ie

INTELLIGENT ENERGY EUROPE

19

The Irish TABULA brochure has been circulated to key Government Departments and agencies. Three of the dwelling types within the Irish TABULA typology are being included in the new Irish Retrofit Code of Practice that will be launched by the Department of Environment, Community and Local Government later in 2012.

A.7.4. Use of Energy Certificate Databases for National Building Typologies

All of the Irish house types were analysed using the Irish DEAP method.

The result of the DEAP analysis on the 29 house type and the one pre 1977 apartment type (entry no. 14) are shown in Table 36 below. The stage 1 refurbishment brings the houses (and apartment) to C1-B2 range. The stage 2 refurbishment brings the houses (and apartment) to B3-A3 range.

Table 36: BER Results Summary

no	Age Band:	House type	Current State	Stage 1	Stage 2
1	1900-1977	SFH.01.Gen	G	B3	B1
2	1900-1977	TH.01.Gen	G	B3	B1
3	1900-1977	SFH.01.Stone	G	C1	B1
4	1900-1977	TH.01.Stone	G	C1	B2
5	1900-1977	SFH.01.225SB	G	C1	B3
6	1900-1977	TH.01.225SB	G	B3	B1
7	1900-1977	SFH.01.325SB	G	B2	B1
8	1900-1977	TH.01.325SB	G	C1	B2
9	1900-1977	SFH.01.MassConc	G	C1	B3
10	1900-1977	TH.01.MassConc	F	B2	B1
11	1900-1977	SFH.01.Hblock	G	B3	B1
12	1900-1977	TH.01.HBlockFBF	G	B3	B1
13	1900-1977	TH.01.HBlockHBF	G	B2	B1
14	1900-1977	AB.01.Gen	G	B3 (Var 1)	C1 (Var 2)
15	1978-1982	SFH.02.Gen	E2	B3	B1
16	1978-1982	TH.02.Gen	E1	B2	B1
17	1978-1982	SFH.02.Hblock	E1	B3	B1
18	1978-1982	TH.02.Hblock	E2	B2	B1
19	1983-1993	SFH.03.Gen	E1	B3	B2
20	1983-1993	TH.03.Gen	D2	B3	B2
21	1983-1993	SFH.03.Hblock	D1	B2	B1
22	1983-1993	TH.03.Hblock	D2	B2	A3
23	1994-2004	SFH.04.Gen	D2	C1	B3
24	1994-2004	TH.04.Gen	C2	B2	B1
25	1994-2004	SFH.04.Tframe	C3	B3	B2
26	1994-2004	TH.04.Tframe	C3	B3	B2
27	2005-onw	SFH.05.Gen	C1	B2	B1
28	2005-onw	TH.05.Gen	B3	B2	B1
29	2005-onw	SFH.05.Tframe	C1	B2	B1
30	2005-onw	TH.05.Tframe	B2	B2	B1

The Irish TABULA project created its typical buildings from an existing store of research data. The EPC database was not used as the data available from that source was limited in the early stages of the TABULA project in 2009.
All of the EPCs (BER certificates) for the residential and non-residential buildings are registered and stored on the National Administration System (NAS). All energy assessors must be registered with SEAI in order to conduct surveys and issue EPCs.

The Irish TABULA project team worked with the SEAI management team responsible for NAS to examine how the EPC database resource could enhance the Irish building typology created within TABULA. SEAI undertook a redesign of its NAS database query tool in mid 2011 for this purpose. This redesigned query function produced some interesting results in October 2011 that allowed TABULA results to be cross-referenced with the national EPC database.

With the data provided from the National EPC database in October 2011 (based on 233,000 EPCs), it was possible to compare the research-based primary energy values (in kWh/m2/year) for each of the 29 house types (note that the Irish apartment type was not considered in this analysis) within the Irish building typology to average primary energy values (in kWh/m2/year) for those house types extracted from EPC database (Table 37).

Table 37: TABULA & EPC Primary Energy Comparisons (DEAP method)

TABULA House type	TABULA Typical Primary Energy Value (kWh/m2/a)	EPC Database Av. Primary Energy Value (kWh/m2/a)	Variation	Variation as % of TABULA typical Primary Energy Value
SFH.01.Gen	483.85	365.91	117.94	24%
TH.01.Gen	489.08	314.14	174.94	36%
SFH.01.Stone	618.18	440.14	178.04	29%
TH.01.Stone	607.41	410.36	197.05	32%
SFH.01.225SB	634.04	443.34	190.70	30%
TH.01.225SB	463.56	390.24	73.32	16%
SFH.01.325SB	453.53	383.00	70.53	16%
TH.01.325SB	631.70	381.47	250.23	40%
SFH.01.MassConc	656.59	507.00	149.59	23%
TH.01.MassConc	398.14	364.00	34.14	9%
SFH.01.Hblock	549.40	398.18	151.22	28%
TH.01.HBlockFBF	499.43	333.92	165.51	33%
TH.01.HBlockHBF	456.75	333.92	165.51	33%
SFH.02.Gen	365.73	237.96	127.77	35%
TH.02.Gen	317.67	262.15	55.52	17%
SFH.02.Hblock	321.72	258.70	63.02	20%
TH.02.Hblock	346.16	270.13	76.03	22%
SFH.03.Gen	302.52	271.60	30.92	10%
TH.03.Gen	293.97	260.88	33.09	11%
SFH.03.Hblock	250.87	232.27	18.60	7%
TH.03.Hblock	265.12	267.16	-2.04	-1%
SFH.04.Gen	292.27	244.87	47.40	16%
TH.04.Gen	179.55	227.11	-47.56	-26%
SFH.04.Tframe	214.70	265.98	-51.28	-24%
TH.04.Tframe	203.99	220.44	-16.45	-8%
SFH.05.Gen	171.12	162.20	8.92	5%
TH.05.Gen	149.74	167.26	-17.52	-12%
SFH.05.Tframe	162.37	147.36	15.01	9%
TH.05.Tframe	123.21	154.26	-31.05	-25%

Source: SEAI NAS (2011)

For the 13 dwelling types in the first age band (1800-1977), the average primary energy values of the EPCs within the NAS database are 27% lower than the TABULA typology values for the same dwelling types. In the next age band (1978-1982), the difference is similar at 24%. For the three most recent age bands, the variance is within 10% approx. and is less significant.

The differences of 27% and 24% in the two older age bands arise due to several factors including:

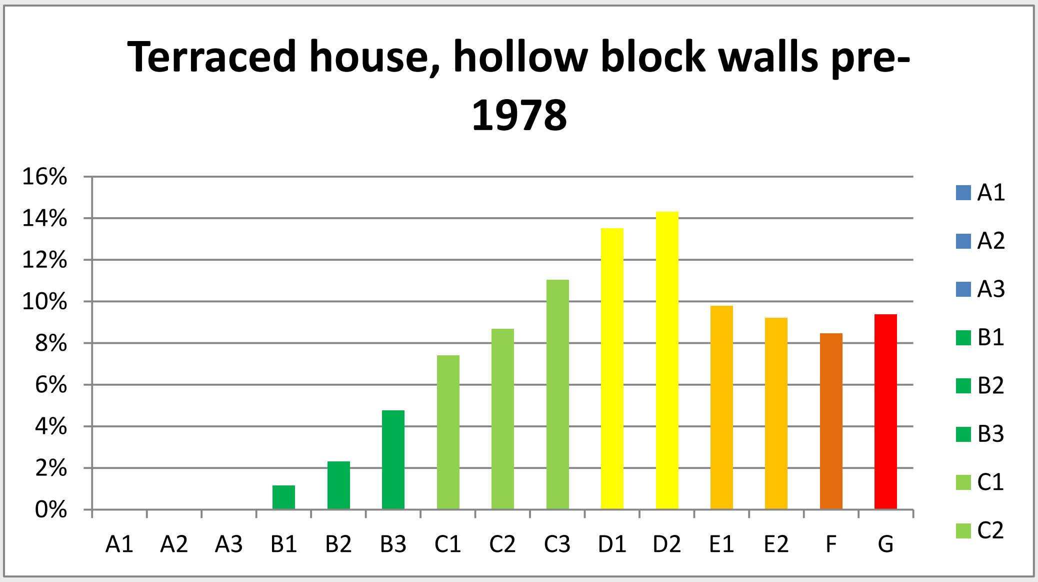
- the EPC database includes EPCs for many dwellings that have been retrofitted with energy upgrades. (In order to avail of grants from the Government for refurbishment works, post works EPCs are required.) Thus, many of the EPCs for the old dwellings will have better primary energy values than typical buildings of this age would have.
- each TABULA house type is based on a selected primary heating fuel type only. The average primary energy values within the EPC Database include all fuel types.

For the years 2007-2011, approximately 196,000 Irish dwellings (Table 27) had refurbishment measures installed under SEAI's energy efficiency programmes. Approximately 50% of these dwellings will have had EPCs published based on the post works primary energy values.

The chart inFigure 24 shows the range of published BER (EPC) scores (source SEAI: October 2011) for a Type 11 house, a pre 1978 terraced hollow block wall house. It is interesting to note that many of these dwellings have B, C and D ratings indicating that these properties will have already had some refurbishment measures carried under the current energy efficiency schemes. It is notable that there is a spike in the numbers of published BER certificates at the D1, D2 grades and a falling off thereafter. It is also interesting to note that within the brochure for type 11, the standard refurbishment of the building fabric brings the TABULA dwelling from a G to a D1 rating.

This pattern showing a spike of published BER certificates at the D1, D2 bands was consistent for all thirteen pre1977 dwelling types.

Figure 25: Analysis of Type 11 BER Scores from NAS, October 2011



With regards to the further development of the Irish building typology, the following key recommendations are proposed.

- **National EPC Database:** The statistics produced from the EPC database in October 2011 for 233,000 EPCs specifically for the TABULA project are extremely interesting and require deeper analysis, especially when cross-referenced to TABULA dwelling types.

  The Irish EPC database is a growing data source. However, it must be noted that it is not a scientific source of research data and indeed it is skewed in terms of the overall stock of dwellings because many of the EPCs refer to refurbished dwellings. (Note: More than 50% of EPCs published for existing dwellings in 2010 were for refurbished dwellings). A revised version of the Irish EPC software (DEAP) was issued in December 2011 that will enrich future EPC database information. In future, EPCs can be categorised by their purpose, e.g. if they were required for sale or rental purposes, for public housing or for grant purposes.

  Recommendation: A further study should be carried out in December 2012 or soon after as the automatic categorisation of EPCs by purpose will have been in effect for one year. This should demonstrate the average BER scores for refurbished and non-refurbished buildings respectively. The study should then examine what additional refinements should be made to the Irish building typology analysis conducted within TABULA.

- **National Energy Balance**: Further studies will be required to enable the creation and updating of national energy balance calculations as outlined above. Most importantly, as Ireland embarks on a major retrofit programme of its housing stock over the next 10 years, it is critical that a robust national energy balance calculation methodology is established.

  Recommendation: A national energy balance calculation should be completed by combining Irish building typologies developed in TABULA with frequency data for individual building types.

- **Irish Census Housing Data:** The building type related data in the Irish Census does not correspond to the Irish EPC methodology (DEAP) in terms of age bands. It also fails to query fuel types used for heating. This should be rectified in any future Irish Census. The Irish building type Census data as it currently stands has very limited use when conducting meaningful analysis on the energy performance of the Irish housing stock.

  Recommendation: The 2016 Irish Census should, as a minimum, revise the building age bands to match those in DEAP. The 2016 Irish Census should also include questions on the fuel used for heating. These two extra pieces of information will greatly enhance future national energy balance and typology studies.

- **House Condition Survey:** In order to get an accurate snapshot of the energy performance of Irish dwellings, a national house condition survey needs to be established and be conducted at regular intervals, e.g. every 5 years. The Scottish House condition was based on a survey of 15,000 dwellings every 5 years. This is now done via an annual rolling survey of 3,000 housing units.

  Recommendation: A national Irish House Condition survey should be designed and implemented on an ongoing basis to get an accurate assessment of the energy performance of the Irish housing stock.

- **Comparison of Measured and Calculated Consumption:** There is no published research data comparing measured (via meters) and calculated (asset-based BER method) consumption data for Irish dwellings. This data should be researched and made available to provide more accurate refurbishment information to building owners and building energy professionals.

  Recommendation: A research project should be conducted to establish an accurate calibration factor to enable a comparison of measured and calculated energy performance consumption.

- **Typology of Irish Commercial Buildings:** A typology of commercial buildings in Ireland has not been developed. Several European partners in TABULA have developed non-residential building typologies.

  Recommendation: An initial scoping study should be conducted to examine the parameters relating to a building typology of commercial buildings in Ireland.

Table 38: National Activities Ireland / Sources and References

Reference shortcut	Short description	Reference
[Tabula Broch IE 2012]	Building Typology Brochure Ireland	Badurek, Marcin; Hanratty, Michael ; Sheldrick, Bill. A detailed study of the energy performance of typical Irish dwellings; Energy Action, Dublin 2012
[Tabula NatSci IE 2012l]	TABULA Scientific Report Ireland	Badurek, Marcin; Hanratty, Michael ; Sheldrick, Bill. A summary report of the Irish TABULA project 2009 - 2012; Energy Action, Dublin 2012

A.8. <IT> Building Typology in Italy

(by TABULA partner POLITO / Politecnico di Torino - Dipartimento Energia / Department of Energy)

A.8.1. The TABULA Project in Italy

The aim of the TABULA Project in Italy has been the improvement of the existing residential building typology and its adaptation to the harmonised approach. A methodology was identified which allowed to define the building-types, as reference buildings functional for the assessment of the energy performance of the residential building stock and the evaluation of the impact in terms of potential savings of energy conservation scenarios at national or regional or local level.

In particular, the Italian contribution has been addressed to:

- the development of the harmonised structure of the Italian typology and the definition of input data of buildings, constructions and heating/DHW systems, which constitute the main data of the *webtool*;
- the application of the typology concept for the assessment of the energy performance of residential buildings and for the evaluation of the impact of energy conservation measures, through the calculation of the energy performance of the building-types;
- the use of the typology concept to create a model for the estimation of the national energy balance of the residential building stock using national statistical data;
- the use of energy performance certificate databases to identify the main features of the residential building stock by means of statistical analyses;
- the elaboration of the Italian *Building Typology Brochure*.

The research has been mostly addressed to the following target groups:

- national and international experts (e.g. scientists, energy managers, energy consultants);
- building designers (architects, building engineers, mechanical engineers);
- constructors;
- public bodies (local and national policy makers);
- local energy agencies;
- real estate holders (public, private).

The key actors of the project have been POLITO researchers and members of the *National Advisory Group* (NAG) which was set up at the beginning of the project. The NAG is a group of national experts in the field of energy and building technology that contributed to the development of the project by means of advices and supply of data. The Italian NAG includes experts from the following institutions:

- the Italian Ministry of Economic Development and the Italian Ministry of Environment;
- the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA);
- the local governmental bodies (e.g. Piedmont Region, Province of Torino, City of Torino);
- the main Technical Universities involved in past research projects on energy conservation in buildings;
- the local Orders of Engineers and Architects;
- the local constructors association;
- the local Social Housing Agency;
- the associations of energy auditors;
- the real estate holders.

A.8.2. Project Development and Main Results

A.8.2.1 Statistical data of the Italian building stock

The classification of the Italian residential building typology and the identification of building-types have been supported by statistical data about frequency distribution of the residential buildings, number of apartments in buildings split by construction period, frequency of building constructions and system typologies, most used energy carriers, etc. This information was got from national sources of statistical data, as the National Institute of Statistics (ISTAT, Report 2004 from Census 2001), CRESME (Centre Economical, Social and Market Surveys in the Building Sector, CRESME, Report 2006) and the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA, Energy Report 2008). The statistical data are usually referred to the national territory, but other data from National Institute of Statistics are also available split by Italian regions. At national level the following general information is reported:

- the whole Italian residential building stock is made of 11,226,595 buildings;
- the total amount of apartments is 27,291,993;
- the average floor area of an Italian dwelling is 96 m^2.

A.8.2.2 Italian Building Typology classification

As the TABULA Project is strictly aimed at assessing and improving the energy performance of the existing buildings, the typological concept focuses on building parameters related to energy consumption. The national "building typology" has been classified according to the following criteria:

- region/climatic area;
- building age;
- building size.

Italy is characterised by six different climatic zones according to Presidential Decree no. 412/1993, ranging from "A zone" to "F zone" according to the number of heating degree-days. Three climatic zones were considered to classify the National building typology in TABULA; they originate by grouping some climatic zones:

- *Middle climatic Zone*, corresponding to "E zone";
- *Alpine Zone*, corresponding to "F zone";
- *Mediterranean Zone*, corresponding to "A zone", "B zone", "C zone" and "D zone".

Eight age classes were identified for each climatic zone. Each *building age class* defines a precise historical period that mirrors significant geometrical and construction typologies from the energy point of view. The building age classes are the followings:

- *class I*, up to 1900 – the Nineteenth Century;
- *class II*, from 1901 to 1920 – the beginning of the Twentieth Century;
- *class III*, from 1921 to 1945 – the period between the two World Wars;
- *class IV*, from 1946 to 1960 – the Postwar period and the Reconstruction;
- *class V*, from 1961 to 1975 – towards the oil crisis;
- *class VI*, from 1976 to 1990 – first Italian regulations on energy efficiency;
- *class VII*, from 1991 to 2005 – recent regulations on the energy performance of buildings in Italy (from Law no. 10/1991 to Legislative Decree no. 192/2005);
- *class VIII*, after 2005 – more restrictive energy performance requirements (implementing decrees of Legislative Decree no. 192/2005 and regional laws).

Each age class is represented by building size classes. They refer to specific dimensional typologies, i.e. buildings characterised by a certain size and shape. The following classes have been identified:

- *single-family house, one or two floors single flat, detached o semi-detached house;*

- *terraced house, one or two floors single flat, terraced;*
- *multi-family house, small building characterised by a limited number of apartments (e.g. from 2 to 5 floors and up to 20 apartments);*
- *apartment block, big building characterised by a high number of apartments (e.g. more than 4 floors and more than 15 apartments).*

Figure 26: "Building Type Matrix" – classification of the housing stock of the Italian Middle climatic Zone

	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	Middle Climatic Zone (Zona climatica media - ZONA E)	... 1900	generic	 IT.MidClim.SFH.01.Gen	 IT.MidClim.TH.01.Gen	 IT.MidClim.MFH.01.Gen	 IT.MidClim.AB.01.Gen
2	Middle Climatic Zone (Zona climatica media - ZONA E)	1901 ... 1920	generic	 IT.MidClim.SFH.02.Gen	 IT.MidClim.TH.02.Gen	 IT.MidClim.MFH.02.Gen	 IT.MidClim.AB.02.Gen
3	Middle Climatic Zone (Zona climatica media - ZONA E)	1921 ... 1945	generic	 IT.MidClim.SFH.03.Gen	 IT.MidClim.TH.03.Gen	 IT.MidClim.MFH.03.Gen	 IT.MidClim.AB.03.Gen
4	Middle Climatic Zone (Zona climatica media - ZONA E)	1946 ... 1960	generic	 IT.MidClim.SFH.04.Gen	 IT.MidClim.TH.04.Gen	 IT.MidClim.MFH.04.Gen	 IT.MidClim.AB.04.Gen
5	Middle Climatic Zone (Zona climatica media - ZONA E)	1961 ... 1975	generic	 IT.MidClim.SFH.05.Gen	 IT.MidClim.TH.05.Gen	 IT.MidClim.MFH.05.Gen	 IT.MidClim.AB.05.Gen
6	Middle Climatic Zone (Zona climatica media - ZONA E)	1976 ... 1990	generic	 IT.MidClim.SFH.06.Gen	 IT.MidClim.TH.06.Gen	 IT.MidClim.MFH.06.Gen	 IT.MidClim.AB.06.Gen
7	Middle Climatic Zone (Zona climatica media - ZONA E)	1991 ... 2005	generic	 IT.MidClim.SFH.07.Gen	 IT.MidClim.TH.07.Gen	 IT.MidClim.MFH.07.Gen	 IT.MidClim.AB.07.Gen
8	Middle Climatic Zone (Zona climatica media - ZONA E)	2006 ...	generic	 IT.MidClim.SFH.08.Gen	 IT.MidClim.TH.08.Gen	 IT.MidClim.MFH.08.Gen	 IT.MidClim.AB.08.Gen

The elements defined to classify the building typology compose the axes of the so-called "Building Type Matrix". Each climatic zone is characterized by a matrix and each matrix consists of rows, representing the building age classes, and columns, representing the building size classes. Each cell in the matrix is filled with a "building-type", i.e. a building that is considered representative of that specific condition (climatic zone / construction age / building size).

The Italian "Building Type Matrix" has been developed for the E zone (*Middle climatic Zone*) that includes 4250 Italian municipalities on a total number of 8100 (see Figure 25).

A.8.2.3 Methodology for the definition of the Italian "building-types"

A representative building could be defined "typical" both for its geometrical features and for its construction and system typologies. These two different aspects have been considered separately for the definition of the building-types of the Italian "Building Type Matrix". Table 39 shows all the possible approaches identified for choosing the representative buildings. The approaches adopted for the Italian building-types are the ones in the highlighted cells of Table 39. Each representative building is chosen both from the point of view of its geometrical features and from its associated construction and thermal system typologies [TABULA NatSci IT 2012].

Table 39: Approaches used for defining Italian building-types

		BUILDING-TYPES (GEOMETRICAL FEATURES)		
		Real building (chosen according to experience)	Real building (chosen according to statistical analysis)	Theoretical building (chosen according to statistical analysis)
CONSTRUCTION AND THERMAL SYSTEM TYPOLOGIES	Real technology in the real building chosen			
	Technology chosen according to experience	***Multi-family houses*** *and* ***Apartment blocks*** *(classes from 1 to 7)*		***Single-family houses*** *and* ***Terraced houses*** *(classes from 1 to 8)* ***Multi-family houses*** *and* ***Apartment blocks*** *(class 8)*
	Technology defined from statistical analysis			

All the technological features (construction and thermal systems) of the Italian building-types were defined according to the experience, also taking advantage of the advices from experts of the sector, with the support of scientific-technical literature, statistical data and technical standards. A database of typical walls, windows, floors, heat generators, etc. was created and listed, considering the age of construction and the values of the performance parameters (e.g. U-value, system efficiency, etc.). The criterion of association of a technology to a building-type was based both on the building size class, if a given technology is related to dimensional aspect, and on the building age class, considering the period of greatest diffusion of a given technology in the country.

As regards the building-types definition from the geometry point of view (heated volume, floor area, compactness factor, etc.), it was performed according to both statistical analysis (identifying archetypes, named also *Theoretical Buildings*) for some building classes and by experience (identifying *Real Example Buildings*) for the others (see Table 39). The choice to take into account the experience was due to the lack of consistent statistical data in some cases.

A.8.2.4 Definition of refurbishment measures

Some refurbishment measures were considered for the building-types, except for those belonging to the eighth building age class (built after 2005). The retrofit actions on the building envelope and the retrofit actions on the thermal systems (heating and domestic hot water) were considered separately. The energy improvement measures were evaluated on two levels:

- "standard" refurbishment, considering the application of measures commonly used in the country;
- "advanced" refurbishment, considering the application of measures that reflect the best available technologies.

The following refurbishment measures were considered for the building envelope:

- application of insulation material on walls to reach an U-value of 0.33 W/(m2K) for the standard refurbishment and of 0.25 W/(m2K) for the advanced refurbishment;
- application of insulation material on floors and roofs (or ceilings) to reach an U-value of 0.30 W/(m2K) for the standard refurbishment and of 0.23 W/(m2K) for the advanced refurbishment;
- replacement of windows and doors to reach an U-value of 2.00 W/(m2K) for the standard refurbishment and of 1.70 W/(m2K) for the advanced refurbishment.

The considered U-values correspond to the requirements established by the new regulations on energy performance of buildings in Piedmont region (D.G.R. no. 46-11968), which is considered one of the most representative regions of the *Middle climatic Zone*.

As regards the refurbishment of the thermal systems, the following measures were 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);
- in some cases, replacement of individual thermal systems (per apartment) with a central thermal system.

Condensing boiler, district heating and air-to-water heat pump are the heat generator types taken into account for the standard refurbishment of the heat generator subsystem, while geothermal heat pump (also coupled with thermal solar plant), condensing boiler coupled with thermal solar plant and air-to-water heat pump coupled with thermal solar plant are those considered for the advanced refurbishment.

A.8.2.5 Energy balance of the residential building stock

Six reference building-types, suitably chosen within the "Building Type Matrix", were used for the energy balance analysis of the residential building stock [TABULA NatBal IT 2012]. They are the followings:

- 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").

In order to choose the six reference buildings, the statistical data were analysed for the *Middle climatic Zone*, which 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. Each reference building is defined as the most frequent building-type in the age of construction that it represents, according to statistical data [ISTAT 2004].

The official national calculation method (Technical Specification UNI/TS 11300) was applied for the evaluation of the energy demand of the selected reference buildings and to assess the potential energy saving due to energy retrofit actions according to two different scenarios (standard and advanced retrofit actions). The obtained results have been statistically enlarged to the whole building stock of the *Middle climatic Zone* according to the available frequency data on dwellings split by construction age.

The results of the energy balance are reported in Table 40 (for the standard refurbishment) and Table 41 (for the advanced refurbishment).

Table 40: Calculated energy saving and CO_2 emission reduction potentials by standard refurbishment (both for the reference building-types and the residential building stock of the Italian *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 41: Calculated energy saving and CO_2 emission reduction potentials by advanced refurbishment (both for the reference building-types and the residential building stock of the Italian *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]	$\Delta Q_{H,p,RBS}$ [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	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%

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 enactment of energy performance regulations: 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 a high potentiality of energy savings, up to 80%.

The calculated energy consumption (i.e. annual value of primary energy need for heating normalised to the useful floor area) in the original state can be compared with the available statistical data of the residential building stock [ENEA 2008]. The calculated values based on conventional climate, use, surroundings and occupant-related input data ($Q_{H,p,RBS,CALC}$) and the measured values ($Q_{H,p,RBS,STAT}$) are quite different (see Table 42); 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) considers a continuous system operation (24 hours every day), while in reality the system is operated with intermittency. In order to compare the calculated value of energy consumption and the measured one (statistical value), a reduction factor was applied to the calculated values according to EN ISO 13790. This factor (called $a_{H,red}$) 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 corrected calculated value ($Q_{H,p,RBS,CORR}$) is reported. 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 requirements.

Table 42: Comparison between the calculated value and the statistical data of primary energy for space heating with reference to the residential building stock of the Italian *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**

3.11.2.6. Use of energy certificate database and statistical analysis approach

As shown in Table 39 (Section 3.11.2.3), the building-types belonging to the classes of *multi-family houses* and *apartment blocks* of the *VIII* age class (after 2005), and to the *single-family houses* and *terraced houses* of all the building age classes are *Archetypes* or *Theoretical Buildings* as regards their geometrical features. The archetypes are characterised by average dimensional properties (gross heated volume, compactness factor, net floor area, number of floors, number of apartments) of a representative building sample according to statistical analysis. With reference to the *Middle climatic Zone*, the analysis was performed on the energy performance certificates database of Piedmont region, one of the most representative regions of the E climatic zone. The energy performance certificates database of Piedmont region contains records of more than 66,000 houses rated across Piedmont, resulting from the collection of EP certificates.

The database contains information on physical characteristics and energy use of each house. Each submission includes more than 40 information fields among which the following ones:

- location;
- construction period;
- compactness factor (ratio of thermal envelope area to gross heated volume);
- gross heated volume;
- net floor area;
- average thermal transmittance of windows;
- energy performance indicators (resulting from standard energy calculations).

The purpose of the EPCs database is also to gather the individual energy analyses data. Once an energy advisor successfully completes the energy assessment of a house, the resulting energy analysis data is collected and stored into the regional database.

The energy performance index (the energy performance of the building is defined as the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building) is evaluated by means of software tools based on the EPBD CEN Standards and on Italian technical specifications UNI/TS 11300.

In order to keep the quality of the data high, the global amount of data was restricted to only 7,104 EP certificates. Moreover, to harmonize the analysis, the EPCs were grouped into apartment blocks, multi-family houses, terraced houses and single-family houses.

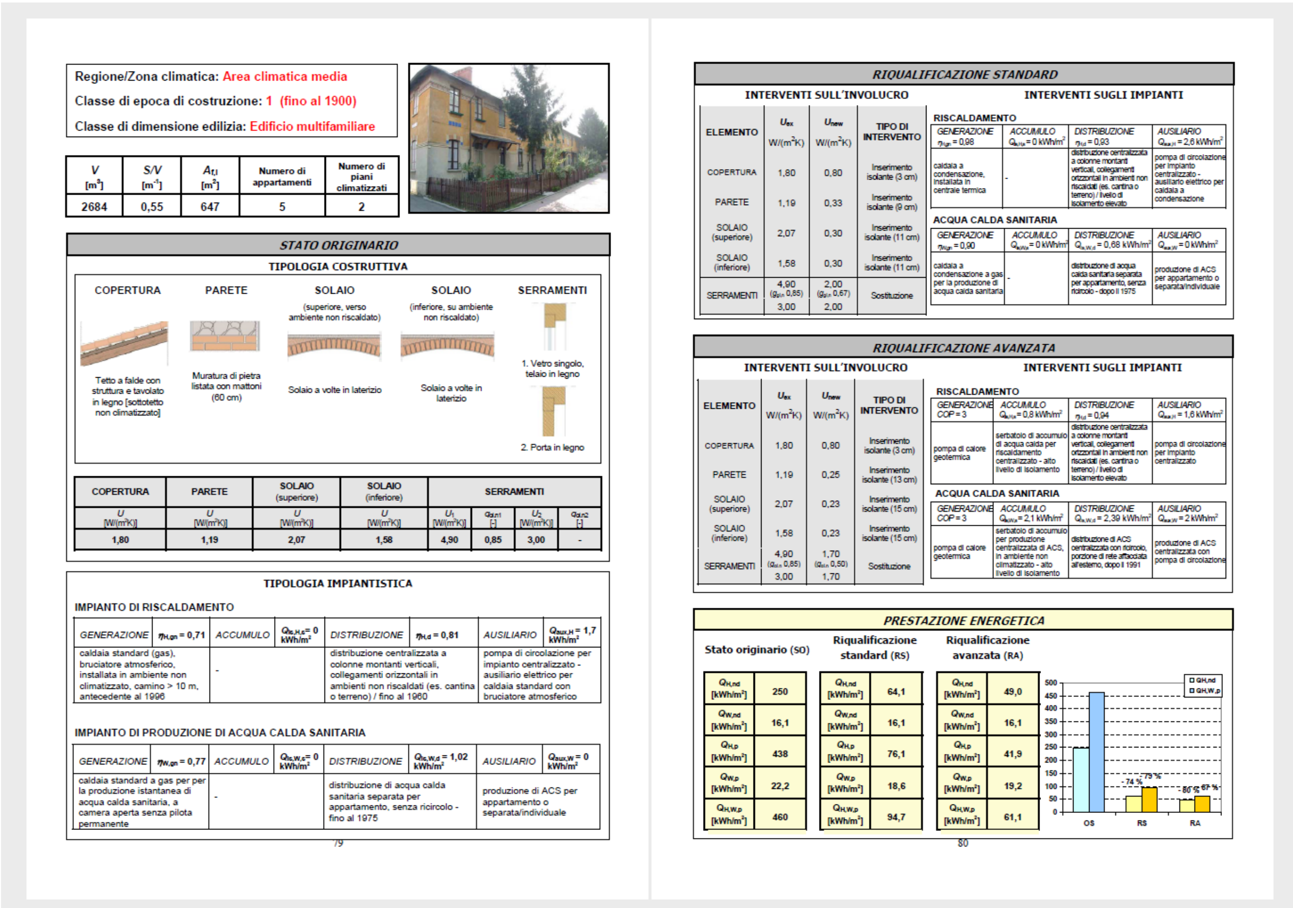
In particular, three approaches were investigated to define the reference buildings [TABULA EPCDat IT 2012]:

- the first approach identifies the real building having geometrical and thermo-physical characteristics close to the average of the building sample;
- the second method provides a building having the most probable features;
- the third approach makes groups containing buildings having similar profiles.

A.8.2.6 Italian Building Typology Brochure

The main outcome of the research at national level is the *Building Typology Brochure*, a project deliverable that contains information on the Italian residential building typology, its classification, the definition of building-types, the representation of types of construction elements and systems, the identification of re-furbishment measures to be applied to the building envelope and systems. Each building-type is repre-sented through a display sheet (see Figure 26), showing its construction and system features and the calcu-lated energy performance. The calculation is carried out according to the official national calculation method, and it is referred to before and after the application of two levels of refurbishment measures (standard and advanced).

Figure 27: "Building Display Sheet" – existing state of an example building and impact of refurbishment measures (extract from the Italian building typology brochure [POLITO 2011])



A.8.3. Conclusions and Future Analyses

According to the objectives of TABULA, the building typology concept will have many impacts at national level.

The building typology can be used by consultants for preliminary energy advice activities and it can be an appropriate instrument for housing companies to assess the energy performance of their building portfolio. It offers the possibility to supply a wide range of information for individual reference buildings, to assess their importance by projection to the whole stock or to subsets of the stock, and to quantify the potential of energy savings due to refurbishment actions. In this way it could address energy policy at national or local level.

The performed study has shown the high potentiality in terms of energy savings related to retrofit actions on existing buildings for the Italian *Middle climatic Zone*, grouping the highest portion of the Italian residential building stock. The assessed energy consumptions and savings are sufficiently accurate when compared with actual energy consumptions based on National or Regional statistics. 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 can also be applied to other Italian climatic zones (*Alpine* and *Mediterranean*) and can also be performed for a deeper analysis at regional level where more detailed data are available for a better description of the building-type used for “Regional Energy Balance”.

The building typology concept is the basis for future developments in this research field. For example, the following topics can be concerned:

- updating of the national residential building typology;
- extension of the analysis to other Italian climatic zones;
- extension of the building typology concept to non-residential buildings;
- use of reference buildings for performing “cost-optimal analyses”, i.e. analyses addressed to investigate optimal refurbishment actions and the energy performance level corresponding to the lowest cost during the estimated economic lifecycle of a building.

Table 43: National Activities Italy / Sources and References

Reference shortcut	Short description	Reference
[ATI 2010]	The Typlogy Approach of TABULA project	Corrado, Vincenzo; Corgnati, Stefano Paolo; Ballarini, Ilaria: L'approccio tipologico per la valutazione della prestazione energetica del parco edilizio nazionale: il progetto di ricerca TABULA; In Proceedings of 65th ATI National Congress, Chia Laguna Resort, Domus De Maria (CA), 13-17 September 2010
[POLITO 2011]	Italian Building Typology Brochure	Corrado, Vincenzo; Ballarini, Ilaria; Corgnati, Stefano Paolo; Talà, Novella: Building Typology Brochure – Italy. Fascicolo sulla Tipologia Edilizia Italiana; Politecnico di Torino, Torino 2011 http://www.building-typology.eu/downloads/public/docs/brochure/IT_TABULA_TypologyBrochure_POLITO.pdf
[ROOMVENT 2011]	Definition of building typologies	Ballarini, Ilaria; Corgnati, Stefano Paolo; Corrado, Vincenzo; Talà, Novella: Definition of building typologies for energy investigations on residential sector by TABULA IEE-project: application to Italian case studies; in Proceedings of Roomvent 2011, Trondheim (Norvegia), 19-22 June 2011
[BUILDING SIMULATION 2011]	Development of archetype buildings	Ballarini, Ilaria; Corgnati, Stefano Paolo; Corrado, Vincenzo; Talà, Novella: Improving energy modeling of large building stock through the development of archetype buildings, in: driving better design through simulation, Proceedings of Building Simulation 2011, Sydney (Australia), 14-16 November 2011
[TABULA NatSci IT 2012]	National scientific report on the TABULA activities in Italy	Corrado, Vincenzo; Ballarini, Ilaria; Corgnati, Stefano Paolo: National scientific report on the TABULA activities in Italy (TABULA Deliverable D6.2); 2012
[TABULA NatBal IT 2012]	TABULA project deliverable (D8)	Corrado, Vincenzo; Corgnati, Stefano Paolo; Ballarini, Ilaria: chapter "Italy" in: Diefenbach, Nikolaus / Loga, Tobias (ed.): Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock (TABULA Thematic Report N° 2). Models for the national housing stock of 8 countries: Belgium, Czech Republic, Denmark, Germany, Greece, Italy, Slovenia; IWU, Darmstadt / Germany 2012 http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf
[TABULA EPCDat IT 2012]	TABULA project deliverable (D7)	Corrado, Vincenzo; Corgnati, Stefano Paolo; Ballarini, Ilaria; Talà, Novella: chapter "Italy" in: Diefenbach, Nikolaus / Loga, Tobias (ed.): Use of Energy Certificate Databases for National Building Typologies (TABULA Thematic Report N° 1). …
[ISTAT 2004]	Statistical data	National Institute of Statistics (ISTAT); Report 2004, from Census 2001
[ENEA 2008]	Statistical data	National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA); Energy Report 2008
[CRESME 2006]	Statistical data	Centre Economical, Social and Market Surveys in the Building Sector (CRESME); Report 2006
[UNI/TS 11300]	National technical specification	Italian Organisation for Standardisation (UNI): UNI/TS 11300. Energy performance of buildings - Part 1: Evaluation of energy need for space heating and cooling; 2008 - Part 2: Evaluation of primary energy need and of system efficiencies for space heating and domestic hot water production; 2008 - Part 4: Use of renewable energy and other generation methods for space heating and domestic hot water production; 2012
[EN ISO 13790]	International technical standard	European Committee for Standardization (CEN): EN ISO 13790. Energy performance of buildings - Calculation of energy use for space heating and cooling; 2008
[PIEDMONT DGR 46-11968]	Regional regulation (Piedmont Region)	Piedmont Region: D.G.R. 46-11968. Regional regulation on energy performance requirements of buildings; 2009

A.9. <PL> Building Typology in Poland

(by TABULA partner NAPE)

Polish typology for residential buildings established for the TABULA project based on four different main building categories: single-family houses **(SFH),** terraced houses **(TH),** multifamily houses **(MFH)** and apartment blocks **(AB)**. Each category was split up between seven periods of buildings representing typical building tradition and insulation levels.

Main purpose of typology is:

1. to develop general overview of the Polish buildings energy performance
2. to allow certification experts compare their calculation of EP index with the average data for the similar building (it is important in the situation that in Poland we do not have any verification system of the certificates)
3. to help building managers, housing associations and housing owners make a decision about building modernization
4. to help energy auditors making choice of thermomodernisation measures proposed to the investors

For the purpose of the typology two types of buildings can represent the set of national buildings stock:

- **average building** - is a virtual building, composed “constructed” of the most typical elements for defined kind of building (e.g. brick, concrete, timber-frame, etc. with average insulation thickness).
- **example building** is a real building, representative for defined kind of building (according to the type and age).

The **average building** can be used to analyse the energy-saving potential for the entire building stock in a country or region by multiplying the heated floor area or number of buildings in the country/region. These results can be used by policymakers to make decisions on the implementation of various incentives to promote energy savings. The main purpose of the example building is the calculation of (cost-optimal) energy-saving measures for one real building, more or less similar to the example building. This information can for example be used to validate implementation of energy performance requirements for existing buildings.

A.9.1. Polish building matrix

Polish idea comprises both ideas mentioned above – average and existing building.

For each main building type and building period, an **average building** has been defined. Due to the agreement with Build Desk company NAPE received access to database of building certificates (made with Build Desk software). At the moment about 60000 buildings are registered in this database, in which about 10 000 represent existing buildings. Another 2 000 buildings are registered in NAPE database of buildings for which energy audits were done during last 10 years. All the considered buildings are buildings that have not been the subject of thermomodernisation.

When the average buildings for all buildings categories and construction age was defined, in the database most similar building has been found as a example building and used for the creation of building matrix.

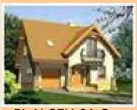
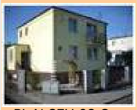
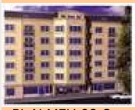
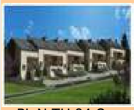
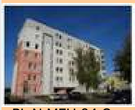
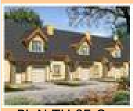
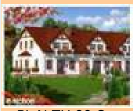
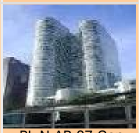
At the same buildings presented in building matrix are real (example) and simultaneously average buildings.

Polish building stock was divided into four types and seven periods of construction. Four types buildings are the same as adopted by the TABULA consortium, and represents most typical buildings in the Polish building set:

- single family (SF) – buildings with 1 apartment
- terraced (TH) – buildings with 2 – 4 apartments,
- multifamily (MFH) – buildings with more than 4 apartments – up to 8 floors
- tower buildings – apartment blocks (AB) - buildings higher than 8 floors

The construction periods were identified based on the building tradition in the early periods and from changes in the energy requirements defined in Polish regulations. Seven periods of construction and their energy-related requirements are presented in the figure 21.

Figure 28: "Building Type Matrix" – classification of the Polish housing stock

	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	national	... 1945	generic	 PL.N.SFH.01.Gen	 PL.N.TH.01.Gen	 PL.N.MFH.01.Gen	
2	national	1946 ... 1966	generic	 PL.N.SFH.02.Gen	 PL.N.TH.02.Gen	 PL.N.MFH.02.Gen	
3	national	1967 ... 1985	generic	 PL.N.SFH.03.Gen	 PL.N.TH.03.Gen	 PL.N.MFH.03.Gen	 PL.N.AB.03.Gen
4	national	1986 ... 1992	generic	 PL.N.SFH.04.Gen	 PL.N.TH.04.Gen	 PL.N.MFH.04.Gen	 PL.N.AB.04.Gen
5	national	1993 ... 2002	generic	 PL.N.SFH.05.Gen	 PL.N.TH.05.Gen	 PL.N.MFH.05.Gen	 PL.N.AB.05.Gen
6	national	2003 ... 2008	generic	 PL.N.SFH.06.Gen	 PL.N.TH.06.Gen	 PL.N.MFH.06.Gen	 PL.N.AB.06.Gen
7	national	2008 ...	generic	 PL.N.SFH.07.Gen	 PL.N.TH.07.Gen	 PL.N.MFH.07.Gen	 PL.N.AB.07.Gen

A.9.2. Data sources

From 1989 the official statistics about building stocks do not exists in Poland. Main Statistics Office presents each year data about new apartments (number, area) constructed but without information about their location (rural, urban), building type (single, multifamily). Construction of the walls, used windows or heating systems are not the subject of the statistics.

NAPE's knowledge of the buildings in the residential sector comes from three main sources:

- energy audits done by NAPE for the purpose of the Thermomodernisation Act during last 10 years – more than 2000 building in our database
- European projects NAPE was involved in - DATAMINE, InoFIN, GreenBUILDING
- certificates done by NAPE
- certificates registered in the Certificates database managed by the BUILD-DESK company
- data coming from the Save II project "Technical and economic assessment of possible improvements of energy efficiency of the residential building/heating systems in Poland - 2002".

Table 44: Building statistics for 2010

	construction period	*number of buildings*	*number of apartments*	*living space (1000 m²)*
SFH	up to 1944	865 913	865 913	69 424 228
	1945-1970	1 168 340	1 168 340	95 621 198
	1971-2002	1 831 142	1 831 142	218 138 583
	2002-2010	496 269	496 269	59 552 280
TH	up to 1944	156 206	312 412	20 486 590
	1945-1970	114 042	228 084	14 889 989
	1971-2002	108 890	217 780	16 676 935
	2002-2010	4 487	8 974	807 660
MFH1	up to 1944	176 859	867 558	46 506 695
	1945-1970	42 166	200 347	10 343 469
	1971-2002	32 310	160 784	9 487 010
	2002-2010	33 370	286 507	21 488 025
MFH2	up to 1944	42 444	700 719	35 462 223
	1945-1970	42 994	1 574 491	67 325 934
	1971-2002	85 965	3 585 142	185 664 884
	2002-2010	13 931	617 800	43 246 000
total		**5 215 328**	**13 122 262**	**915 121 703**

A.9.3. Standard and advanced modernisation

In the Polish Tabula project “standard modernisation” means the modernisation corresponds to the current technical requirements for new buildings, presented in Table 45 and Table 46.

Table 45: Energy efficiency requirements for new and modernized buildings – required by standard modernisation

Lp.	***Envelope***	***$U_{(max)}$ W/(m^{2}K)***
1	*External walls*	***0.30***
2	*Roofs*	*0.25*
3	*Floors*	*0.45*
4	*Windows*	*1.7*
5	*External doors*	*2.6*

Advanced modernisation is modernization at least 25% over present requirements – see table below.

Table 46: Requirements for advanced modernisation

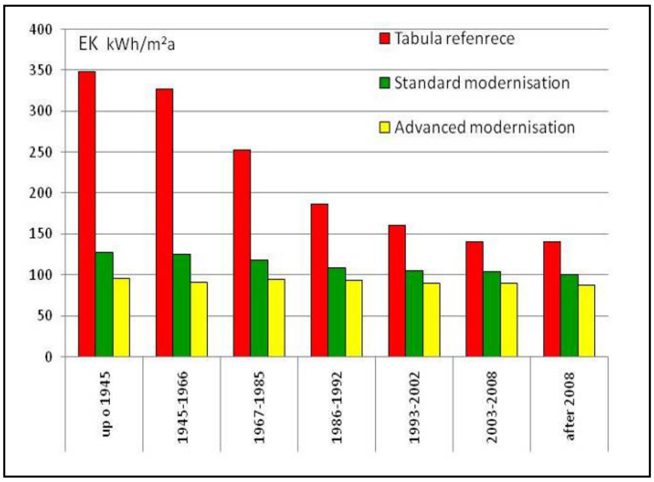
Lp.	***Envelope***	***$U_{(max)}$ W/(m^{2}K)***
1	*External walls*	***0.22***
2	*Roofs*	*0.18*
3	*Floors*	*0.33*
4	*Windows*	*1.3*
5	*External doors*	*1.9*

List of modernization measures considered in the analysis was as follows:

- **Window replacement** – replacement of old windows with poor U coefficient with energy efficient windows. Additional effect is the reduction of the air infiltration into the building.
- **Main door replacement** – replacement of old main door with poor U coefficient with the new ones.
- **Wall insulation** – additional layer of insulation on the outer side of buildings’ walls, considered insulation is the Styrofoam.
- **Roof insulation** – additional layer of insulation under the roof to reduce the U value.
- **Ground floor insulation** – insulation of ground floor means adding a layer of insulation to the building foundations or basement to reduce the U value.
- **Valves** – installation of thermostatic valves on the radiators.
- **Heat source** – modernisation of the heat source, improvement of the heat source and transmission efficiency. Potential energy savings represent maximum savings in case of modernisation of the heat source only and minimum savings in case of full scale modernisation.
- **Ventilation** – installation of windows with different air inlets is considered. Windows are equipped with a self-acting inlet (responding to differential pressure). This measure allows to reduce air infiltration into the building, with protection of good indoor climate conditions.

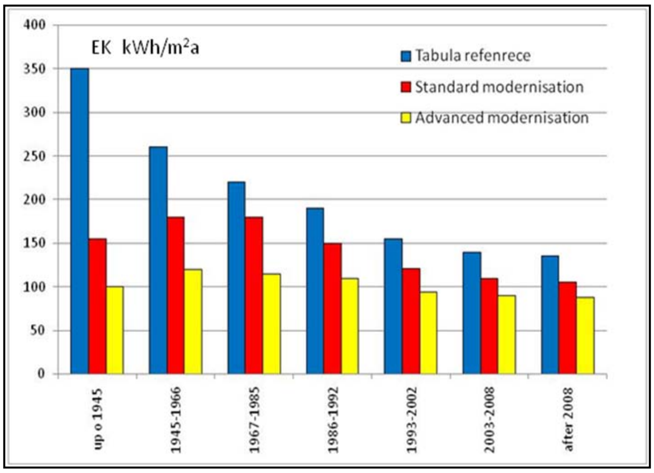
A.9.4. Reduction potential according to the calculation made by the TABULA Tool

Reduction potential in single family buildings



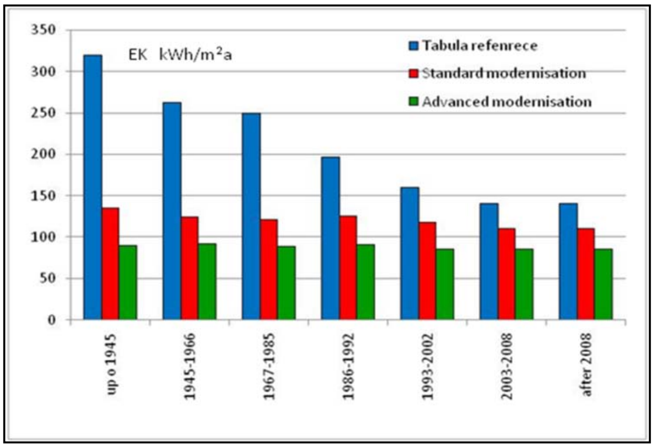
construction period	reduction potential SFH	
	standard modernisation	advanced modernisation
up to 1945	63,2%	72,7%
1945-1966	61,8%	72,2%
1967-1985	53,4%	62,8%
1986-1992	41,9%	50,0%
1993-2002	34,4%	43,8%
2003-2008	25,7%	35,7%
after 2008	29,1%	38,3%

Reduction potential in terraced houses



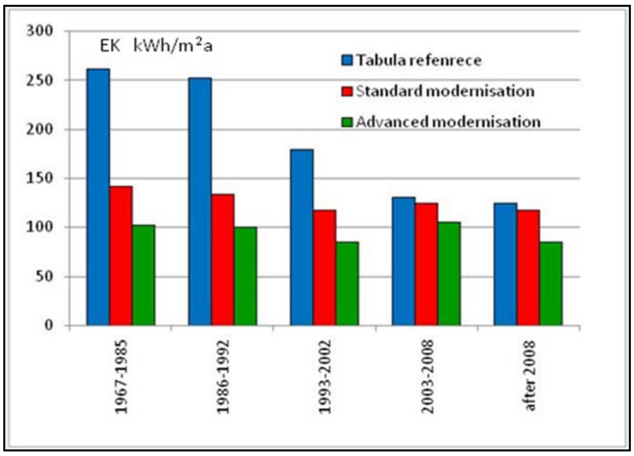
construction period	reduction potential TH	
	standard modernisation	advanced modernisation
up o 1945	55,7%	71,4%
1945-1966	30,8%	53,8%
1967-1985	18,2%	47,7%
1986-1992	21,1%	42,1%
1993-2002	21,9%	39,4%
2003-2008	21,4%	35,7%
after 2008	22,2%	34,8%

Reduction potential in multifamily houses



construction period	reduction potential	
	standard modernisation	advanced modernisation
up o 1945	57,8%	71,9%
1945-1966	52,7%	64,9%
1967-1985	51,6%	64,4%
1986-1992	36,5%	53,8%
1993-2002	26,3%	46,9%
2003-2008	21,4%	39,3%
after 2008	21,4%	39,3%

Reduction potential in apartment blocks



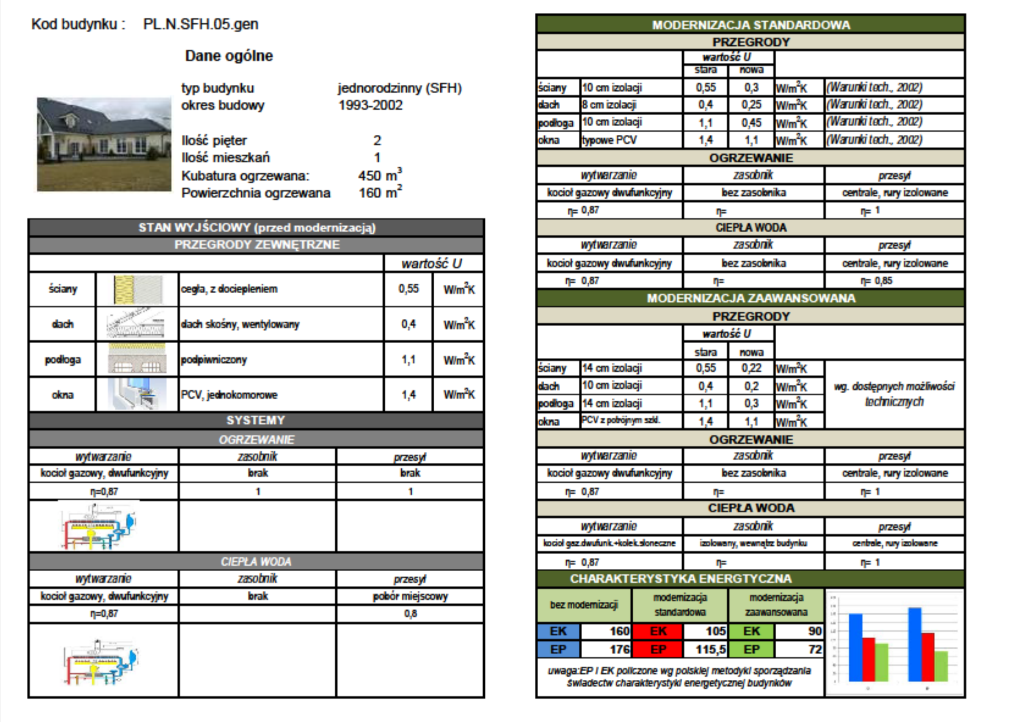
construction period	reduction potential	
	standard modernisation	advanced modernisation
1967-1985	45,6%	60,9%
1986-1992	46,8%	60,3%
1993-2002	34,1%	52,5%
2003-2008	4,6%	19,8%
after 2008	5,6%	32,0%

This means that in Poland, despite the thermomodernisation programme, is still a great space for further thermomodernisation, and energy reduction can reach about 40-50% of present consumption.

A.9.5. Brochure

For each building category a brochure has been developed. Each of them give a short and easy-to-understand overview of the energy upgrading possibilities for each example buildings, presenting information about envelope constructions (area and U-values), heating and hot waters system at the current state and the possible savings at two levels of measures – typical (in accordance to the "Technical Condition of the Buildings") and advanced.

Figure 29: "Building Display Sheet" – existing state of an example building and impact of refurbishment measures (extract from the Polish building typology brochure [PL_N_SFH.05])



Kod budynku : PL.N.SFH.05.gen

Dane ogólne

typ budynku	jednorodzinny (SFH)
okres budowy	1993-2002
Ilość pięter	2
Ilość mieszkań	1
Kubatura ogrzewana:	450 m^3
Powierzchnia ogrzewana	160 m^2

STAN WYJŚCIOWY (przed modernizacją)

PRZEGRODY ZEWNĘTRZNE

		wartość U	
ściany	cegła, z dociepleniem	0,55	W/m^2K
dach	dach skośny, wentylowany	0,4	W/m^2K
podłoga	podpiwniczony	1,1	W/m^2K
okna	PCV, jednokomorowe	1,4	W/m^2K

SYSTEMY

OGRZEWANIE

wytwarzanie	zasobnik	przesył
kocioł gazowy, dwufunkcyjny	brak	brak
η=0,87	1	1

CIEPŁA WODA

wytwarzanie	zasobnik	przesył
kocioł gazowy, dwufunkcyjny	brak	pobór miejscowy
η=0,87		0,8

MODERNIZACJA STANDARDOWA

PRZEGRODY

		wartość U stara	wartość U nowa		
ściany	10 cm izolacji	0,55	0,3	W/m^2K	(Warunki tech., 2002)
dach	8 cm izolacji	0,4	0,25	W/m^2K	(Warunki tech., 2002)
podłoga	10 cm izolacji	1,1	0,45	W/m^2K	(Warunki tech., 2002)
okna	typowe PCV	1,4	1,1	W/m^2K	(Warunki tech., 2002)

OGRZEWANIE

wytwarzanie	zasobnik	przesył
kocioł gazowy dwufunkcyjny	bez zasobnika	centrale, rury izolowane
η= 0,87	η=	η= 1

CIEPŁA WODA

wytwarzanie	zasobnik	przesył
kocioł gazowy dwufunkcyjny	bez zasobnika	centrale, rury izolowane
η= 0,87	η=	η= 0,85

MODERNIZACJA ZAAWANSOWANA

PRZEGRODY

		wartość U stara	wartość U nowa		
ściany	14 cm izolacji	0,55	0,22	W/m^2K	wg. dostępnych możliwości technicznych
dach	10 cm izolacji	0,4	0,2	W/m^2K	
podłoga	14 cm izolacji	1,1	0,3	W/m^2K	
okna	PCV z potrójnym szkł.	1,4	1,1	W/m^2K	

OGRZEWANIE

wytwarzanie	zasobnik	przesył
kocioł gazowy dwufunkcyjny	bez zasobnika	centrale, rury izolowane
η= 0,87	η=	η= 1

CIEPŁA WODA

wytwarzanie	zasobnik	przesył
kocioł gaz.dwufunk.+kolek.słoneczne	izolowany, wewnątrz budynku	centrale, rury izolowane
η= 0,87	η=	η= 1

CHARAKTERYSTYKA ENERGTYCZNA

bez modernizacji		modernizacja standardowa		modernizacja zaawansowana	
EK	160	EK	105	EK	90
EP	176	EP	115,5	EP	72

uwaga:EP i EK policzone wg polskiej metodyki sporządzania świadectw charakterystyki energetycznej budynków

A.9.6. Non-residential buildings

Official statistics presented by the Main Statistics Office is relatively poor- Annual Statistics Bulletin gives information only about new construction. Any information about energy quality of these buildings is not officially available.

NAPE's knowledge on the non-residential building sector comes mainly from:

- energy audits done for the purpose of the Thermomodernisation Fund. That fund was created on the basis of provisions of the Thermomodernisation Act, dating from 1998 (full name: "Act on Support for Thermomodernisation Investment in Buildings"), covers the rules for providing investors (building owners or administrators) with financial support, in the form of a premium which can cover up to 25% of a credit loan granted for the realization of thermal modernization investments,
- involvement in European projects related to this subject over the past 15 years (DEMOHOUSE, DATAMINE)
- Build-Desk certificates database.

In the available dataset of building most of buildings are schools and hospitals. Very poor information refers offices and industrial buildings, since they are not subject of energy audits.

Table 47: Non-residential building statistics in 2000 and 2010

	number of units in		number of buildings in	
	2000	***2010***	***2000***	***2010***
Trade	**430 656**	**371 000**	**143 552**	**123 667**
in which over 400 m2	3 838	8 946	3 838	8 946
Restaurants	**55 242**	**71 679**	**55 242**	**71 679**
Schools in which:	**33 944**	**28 538**	**46 794**	**38 874**
primary schools	16 766	13 922	16 766	13 922
secondary	16 868	14 216	25 378	18 952
universities	310	400	4 650	6 000
Health care in which:	**6 854**	**18 171**	**18 748**	**33 405**
Health care institutions	5 685	16 608	6 822	19 930
Hospitals	767	818	9 463	9 979
chronic medical care	126	327	378	981
Nursing homes	49	126	49	126
Hospices	26	59	26	59
Health resort treatment	201	233	2 010	2 330
Culture objects in which:	**10 344**	**9 808**	**11 866**	**11 430**
Libraries	8 900	8 400	9 790	9 240
Museums	632	782	1 264	1 564
Theatres	125	183	125	183
Cinemas	687	443	687	443
Hotels and similar facilities	**5 413**	**7 206**	**8 120**	**10 809**
Offices	n/a			
total			**284 322**	**289 863**

presents the number of buildings in 2000 and 2012. Since from 2002 the new energy efficiency requirements were introduced to the Polish Buildings regulation it can be assumed that all the buildings constructed after 2000 fulfil present obligation and energy standards. Buildings constructed before 2000 should be a subject of major or minor modernisation.

Percent of non-residential building constructed in the chosen time period is presented in the table 2.

Table 48: Non-residential buildings by constructed year (in %)

	before 1945	1945-1970	1971-1978	1979-1988	1989-1995	1966-1988	1989-2000	after 2000
Percent of buildings	28.1	28.9	17.8	14.9	4.9	1.5	2.0	1.9

For the future proceedings it is suggested to include, as a first step, only some categories of buildings:

1. school buildings - 50 in the NAPE database
2. hospitals – 31 in the NAPE database

For the chosen type of buildings the following data are available:

1. construction year
2. cubature
3. heating area
4. U-value for all building envelopes
5. Heating system

Therefore the first draft typology for non-residential building typology will contain:

1. Building types:
   - schools
   - hospitals
2. Construction year classes
   - before 1945
   - 1946 -1985
   - 1986-2000
   - after 2000
3. Heating systems
   - central DHS
   - local gas boilers

A.9.6.1 Proposed proceeding / link with current national activities

It is expected that the introduction of the EPBD Recast into Polish legal system:

1. makes the certificates for public buildings obligatory
2. the official database of issued certificates with free access will be establish

This should allow to widen the database and create in nearest future the consistent non-residential buildings typology.

A.9.6.2 Conclusions with respect to non-residential buildings

The following steps have to be implemented in the future to create non-residential buildings typology:

1. Create, based on different available sources, database for non-residential buildings;
2. Analyse of data to build up the typology, relevant to TABULA tool;
3. Create final building matrix for defined buildings category.

A.9.7. Conclusions

Estimated outcome of input of heat energy index that is a result of introduced obligation of heat energy certification of buildings shows great potential for possibilities of changes in field of heat energy efficiency and reducing heat energy consumption of buildings. All that gives possibility in the future of reducing costs of heat energy used for heating and preparation of usable, hot water.

Concluded research shows that significant majority of existing buildings, despite from thermomodernisation procedures like: replacing window and door carpentry, better isolation of external walls, do not fulfil rigorous requirements included in Infrastructure Ministry' Decree of 06 November 2008 [Dziennik Ustaw Nr 201, poz. 1240].

More complicated actions like better isolation of highest storey (alternatively loft), walls of heated basement or floor on the soil and remake of ventilation system that allows recycling heat of air removed from rooms, give chance to achieve appointed level of maximum heat energy use.

Proper execution of every pointed in heat energy audit solutions can contribute to reducing costs of heat energy delivery to the building by even 60-70%. Modification of supporting thermomodernisation governmental programs in way that facilitate grating the thermomodernization bonus in detached buildings, together with executing thermomodernisation processes of multiple family structures, will reduce significantly use of heat energy sources and at the same time will contribute to reduction of greenhouse gases emission.

Table 49: National Activities Poland / Sources and References

Reference shortcut	Short description	Reference
1	Statistics data	Statistical Yearbooks 2000-2010
2	Statistics data	Construction – activity results 2000-2010 – Main Statistic Office
3	Scientific paper	„SOCOOL" project - tri-generation units in offices, hospitals and commerce buildings
4	National scientific TABULA report	TABULA report for Poland
5	Technical paper	Laskowski L., Ochrona cieplna i charakterystyka energetyczna budynku; Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2008
6	Technical paper	Strzeszewski M Wereszczyński Nowa norma obliczania projektowego obciążenia cieplnego, poradnik, Warsaw 2008,
7	Technical paper	Robakiewicz M., Ocena cech energetycznych budynku, Wymagania, Dane, Obliczenia, Poradnik; Biblioteka Fundacji Poszanowania Energii, Warszawa 2009
8	Legal Act	• Rozporządzenie Ministra Infrastruktury z dnia 17 marca 2009 r. w sprawie szczegółowego zakresu i form audytu energetycznego oraz części audytu remontowego, wzorów kart audytów, a także algorytmu oceny opłacalności przedsięwzięcia termomodernizacyjnego;
9	Legal Act	Rozporządzenie Ministra Infrastruktury z dnia 17 grudnia 2008 r. w sprawie zmiany rozporządzenia zmieniającego rozporządzenie w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie
10	Legal Act	Rozporządzenie Ministra Infrastruktury z dnia 6 listopada 2008 r. w sprawie metodologii obliczania charakterystyki energetycznej budynku i lokalu mieszkalnego lub części budynku stanowiącej samodzielną całość techniczno-użytkową oraz sposobu sporządzania i wzorów świadectw ich charakterystyki energetycznej
11	Legal Act	Directive 2002/91/EC of the European Parliament

A.10. <SE> Building Typology in Sweden

(by TABULA partner MDH / Mälardalens University)

A.10.1. Building type

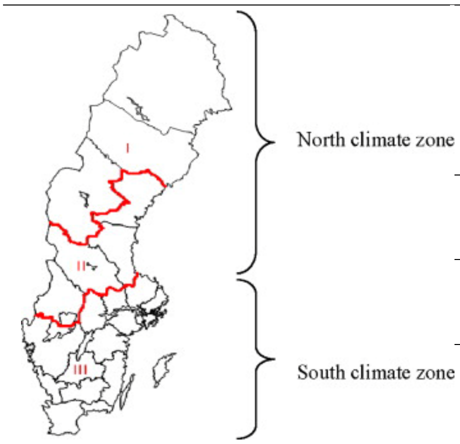
The Swedish building types in the Tabula project are divided into single family and multi-family houses and five different age groups. The division into the five age groups is made on the basis of official statistics available for Swedish building envelopes, see the BETSI report [Mattson 2010]. The study published in the report gives an average U-value for different parts of the building divided into the five different age groups.

Buildings in Sweden are very much characterized by typical properties regarding the thermal insulation depending on the approximate year of erection, and this is very much explained by the change of the building regulations over the years. For this reason it is found more accurate to use typical U-values for five different periods of age instead of using different typical specific constructions.

The size of the buildings is selected on the basis of the BETSI survey. A typical single family house according to BETSI is a house with a heated floor area of 160 m^2. In Sweden a floor area of 125 m^2 is also commonly used in energy calculations as a "normal single family house". According to BETSI a typical multi-family house in Sweden has one basement and three floors above the ground and a heated floor area of 1426 m^2; in Tabula 1420 m^2 was used.

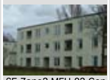
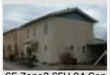
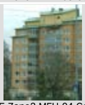
The building types in Tabula have also been divided into the three different climate zones in Sweden according to Boverket´s Building Regulations, BBR 2012. For the different climate zones in Sweden, there are different requirements for the building's specific energy use (kWh per m^2 floor area and year). This “specific energy use” basically refers to all purchased energy except for household electricity. The floor area used in the regulations is called A_{temp} and has a specific definition, but basically it is the total floor area inside of the outer walls heated to more than 10 °C.

Figure 30: Climate Zone I, II and III in Sweden [Ambrose 2010]



	The building's specific energy use (kWh per m^2 A_{temp} and year)	
	Dwellings that have a heating method other than electric heating	Dwellings with electric heating
Climate Zone I Norrbottens, Västerbottens and Jämtlands län	**130**	**95**
Climate Zone II Västernorrlands, Gävleborgs, Dalarnas and Värmlands län	**110**	**75**
Climate Zone III Västra Götalands, Jönköpings, Kronobergs, Kalmar, Östergötlands, Södermanlands, Örebro, Västmanlands, Stockholms, Uppsala, Skåne, Hallands, Blekinge and Gotlands län	**90**	**55**

Figure 31: "Building Type Matrix" – classification of the Swedish housing stock (3 zones)

	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	Climatic Zone III (Klimatzon III - södra Svewrige)	... 1960	generic	 SE.Zone3.SFH.01.Gen		 SE.Zone3.MFH.01.Gen	
2	Climatic Zone III (Klimatzon III - södra Svewrige)	1961 ... 1975	generic	 SE.Zone3.SFH.02.Gen		 SE.Zone3.MFH.02.Gen	
3	Climatic Zone III (Klimatzon III - södra Svewrige)	1976 ... 1985	generic	 SE.Zone3.SFH.03.Gen		 SE.Zone3.MFH.03.Gen	
4	Climatic Zone III (Klimatzon III - södra Svewrige)	1986 ... 1995	generic	 SE.Zone3.SFH.04.Gen		 SE.Zone3.MFH.04.Gen	
5	Climatic Zone III (Klimatzon III - södra Svewrige)	1996 ... 2005	generic	 SE.Zone3.SFH.05.Gen		 SE.Zone3.MFH.05.Gen	
6	Climatic Zone II (Klimatzon II - mellersta Sverige)	... 1960	generic	 SE.Zone2.SFH.01.Gen		 SE.Zone2.MFH.01.Gen	
7	Climatic Zone II (Klimatzon II - mellersta Sverige)	1961 ... 1975	generic	 SE.Zone2.SFH.02.Gen		 SE.Zone2.MFH.02.Gen	
8	Climatic Zone II (Klimatzon II - mellersta Sverige)	1976 ... 1985	generic	 SE.Zone2.SFH.03.Gen		 SE.Zone2.MFH.03.Gen	
9	Climatic Zone II (Klimatzon II - mellersta Sverige)	1986 ... 1995	generic	 SE.Zone2.SFH.04.Gen		 SE.Zone2.MFH.04.Gen	
10	Climatic Zone II (Klimatzon II - mellersta Sverige)	1996 ... 2005	generic	 SE.Zone2.SFH.05.Gen		 SE.Zone2.MFH.05.Gen	
11	Climatic Zone I (Klimatzon I - norra Sverige)	... 1960	generic	 SE.Zone1.SFH.01.Gen		 SE.Zone1.MFH.01.Gen	
12	Climatic Zone I (Klimatzon I - norra Sverige)	1961 ... 1975	generic	 SE.Zone1.SFH.02.Gen		 SE.Zone1.MFH.02.Gen	
13	Climatic Zone I (Klimatzon I - norra Sverige)	1976 ... 1985	generic	 SE.Zone1.SFH.03.Gen		 SE.Zone1.MFH.03.Gen	
14	Climatic Zone I (Klimatzon I - norra Sverige)	1986 ... 1995	generic	 SE.Zone1.SFH.04.Gen		 SE.Zone1.MFH.04.Gen	
15	Climatic Zone I (Klimatzon I - norra Sverige)	1996 ... 2005	generic	 SE.Zone1.SFH.05.Gen		 SE.Zone1.MFH.05.Gen	

A.10.2. Application

Based on the calculation program tabula.xls a brochure has been prepared. The brochure, which can be used by energy advisors, will give examples regarding how to lower the energy consumption. It contains in the first version one variant of each building type.

For each type of building the U-values and the area of the building envelope is shown. Monthly statistics for each building type is also based on a standard version of the ventilation, heating and hot water systems, see also the figure below. Two improved alternatives regarding the building envelope and the technical systems in the building are used for each building in order to demonstrate possibilities to lower the energy consumption.

Tabula WebTool offers possibilities to change the conditions regarding improvements for each building type for the building envelope as well as for the technical systems for ventilation, heating and hot water.

A.10.3. Statistics collection

The building types are chosen based on the statistical data of the existing building stock that is made in the BETSI report. In 2010 the National Board of Housing, Building and Planning (Boverket) published the report from the BETSI project (*Byggnaders energianvändning, tekniska status och innemiljö* which means "Build-ing´s energy use, technical condition and indoor environment"). The project used base information from the previous research program "Electricity conservation in existing buildings" (ELIB), published 1991.

The BETSI report gives information of the technical condition / status for the Swedish building stock and also provides information of the energy consumption as well as the design of the buildings. A lot of the information regarding Swedish buildings in the Tabula project comes from the BETSI report. The BETSI re-port also indicates that the data collected can be used for further studies in research and other projects.

Table 50: Example from the BETSI report – Average U- values for the concrete floor slab on grade in Multi-family houses during different time periods [Mattson 2010]

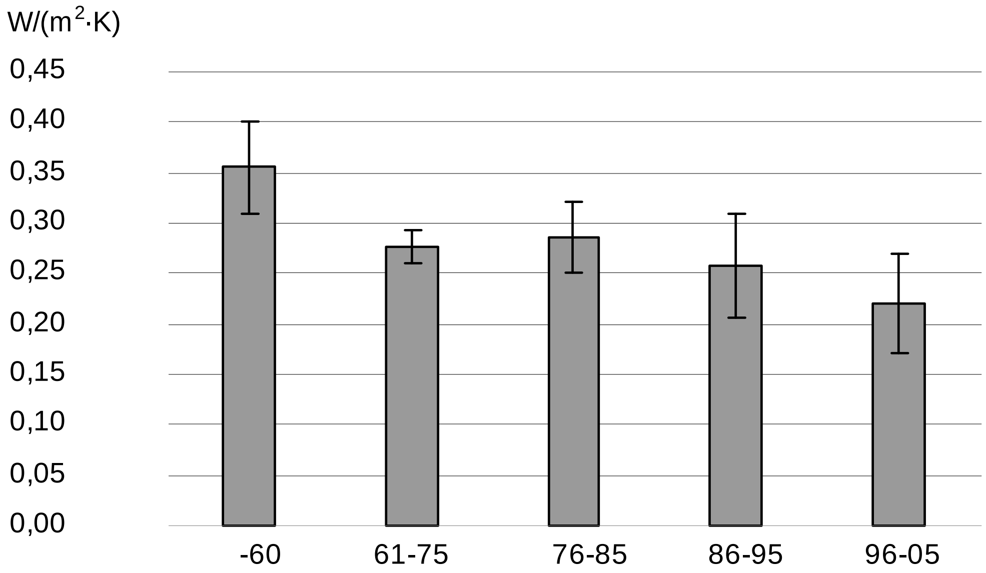
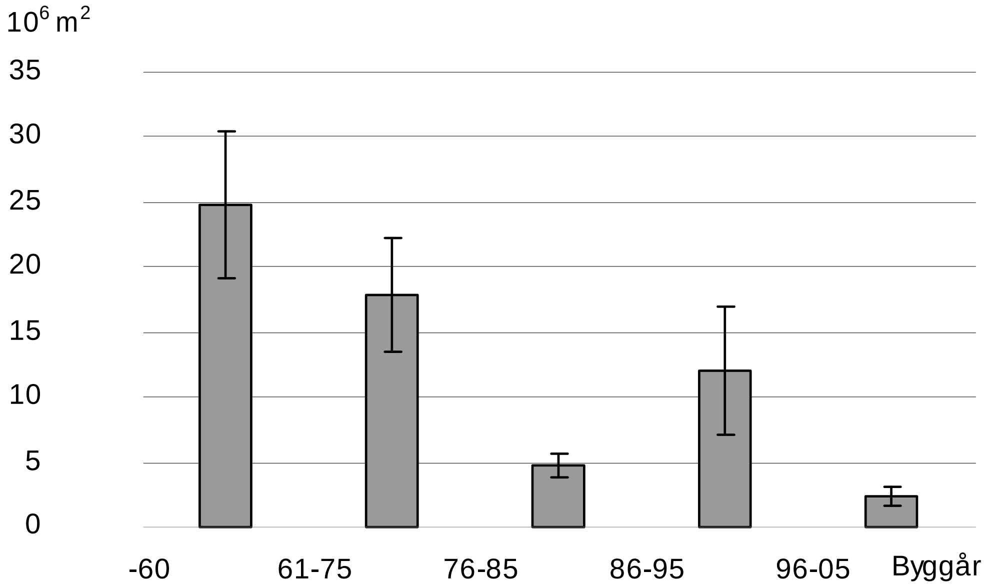


Figure 32: Example from the BETSI report – Total area for the concrete floor slab on grade in Multi-family houses during different time periods. The total floor area is 62 million m² [Mattson 2010]



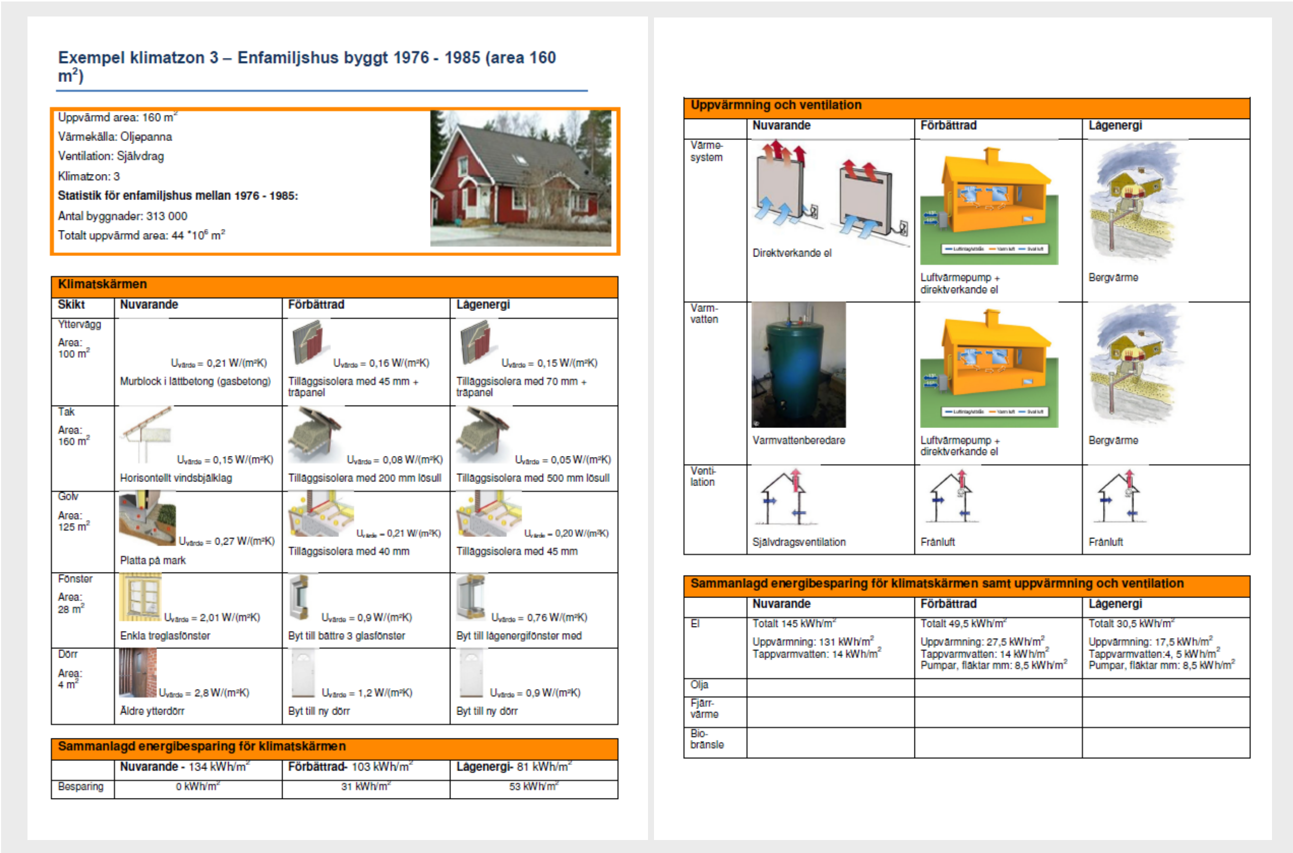
Statistics for Tabula has also been taken from the Swedish Energy Agency's official statistics. One example of statistics is from the survey of energy statistics in 2009 for one family and two family houses "Energy statistics for one family and two family houses in 2009", ES 2011:01.

Other sources have been the SCB, Statistics Sweden, which is a government agency that produces official statistics of Sweden.

A.10.4. Conclusions

These tools are useful in order to evaluate a variety of improvements for a building. In order to obtain an even more comprehensive tool, more data can be added into the tool.

Figure 33: "Building Display Sheet" – existing state of an example building and impact of refurbishment measures (extract from the Swedish building typology brochure)



Exempel klimatzon 3 – Enfamiljshus byggt 1976 - 1985 (area 160 m^2)

Uppvärmd area: 160 m^2
Värmekälla: Oljepanna
Ventilation: Självdrag
Klimatzon: 3
Statistik för enfamiljshus mellan 1976 - 1985:
Antal byggnader: 313 000
Totalt uppvärmd area: 44 $*10^6$ m^2

Klimatskärmen

Skikt	Nuvarande	Förbättrad	Lågenergi
Yttervägg Area: 100 m^2	$U_{värde}$ = 0,21 W/(m²K) Murblock i lättbetong (gasbetong)	$U_{värde}$ = 0,16 W/(m²K) Tilläggsisolera med 45 mm + träpanel	$U_{värde}$ = 0,15 W/(m²K) Tilläggsisolera med 70 mm + träpanel
Tak Area: 160 m^2	$U_{värde}$ = 0,15 W/(m²K) Horisontellt vindsbjälklag	$U_{värde}$ = 0,08 W/(m²K) Tilläggsisolera med 200 mm lösull	$U_{värde}$ = 0,05 W/(m²K) Tilläggsisolera med 500 mm lösull
Golv Area: 125 m^2	$U_{värde}$ = 0,27 W/(m²K) Platta på mark	$U_{värde}$ = 0,21 W/(m²K) Tilläggsisolera med 40 mm	$U_{värde}$ = 0,20 W/(m²K) Tilläggsisolera med 45 mm
Fönster Area: 28 m^2	$U_{värde}$ = 2,01 W/(m²K) Enkla treglasfönster	$U_{värde}$ = 0,9 W/(m²K) Byt till bättre 3 glasfönster	$U_{värde}$ = 0,76 W/(m²K) Byt till lågenergifönster med
Dörr Area: 4 m^2	$U_{värde}$ = 2,8 W/(m²K) Äldre ytterdörr	$U_{värde}$ = 1,2 W/(m²K) Byt till ny dörr	$U_{värde}$ = 0,9 W/(m²K) Byt till ny dörr

Sammanlagd energibesparing för klimatskärmen

	Nuvarande - 134 kWh/m²	**Förbättrad**- 103 kWh/m²	**Lågenergi**- 81 kWh/m²
Besparing	0 kWh/m²	31 kWh/m²	53 kWh/m²

Uppvärmning och ventilation

	Nuvarande	Förbättrad	Lågenergi
Värme-system	Direktverkande el	Luftvärmepump + direktverkande el	Bergvärme
Varm-vatten	Varmvattenberedare	Luftvärmepump + direktverkande el	Bergvärme
Venti-lation	Självdragsventilation	Frånluft	Frånluft

Sammanlagd energibesparing för klimatskärmen samt uppvärmning och ventilation

	Nuvarande	Förbättrad	Lågenergi
El	Totalt 145 kWh/m² Uppvärmning: 131 kWh/m² Tappvarmvatten: 14 kWh/m²	Totalt 49,5 kWh/m² Uppvärmning: 27,5 kWh/m² Tappvarmvatten: 14 kWh/m² Pumpar, fläktar mm: 8,5 kWh/m²	Totalt 30,5 kWh/m² Uppvärmning: 17,5 kWh/m² Tappvarmvatten:4, 5 kWh/m² Pumpar, fläktar mm: 8,5 kWh/m²
Olja			
Fjärr-värme			
Bio-bränsle			

Table 51: National Activities Sweden / Sources and References

Reference shortcut	Short description	Reference
[Ambrose 2010]		Ambrose Dodooa, Leif Gustavssona, Roger Sathrea, 2010: Building energy-efficiency standards in a life cycle primary energy perspective. Energy and Buildings Volume 43, Issue 7, Pages 1511-1810 (July 2011)
[Mattson 2010]		Björn Mattsson, Anders Carlsson, Meng Seng Te och Suzanne Pluntke, 2010: Energi i bebyggelsen – tekniska egenskaper och beräkningar – resultat från projektet BETSI. Boverket, Karlskrona

A.11. <SI> Building Typology in Slovenia

(by TABULA partner ZRMK)

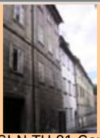
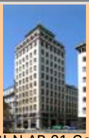
Some attempts to assemble building typologies have been made in the past. First there was a study in mid 90's. Study was concentrated on energy restoration of buildings. Then we had building typology that was used for statistical purposes and another that is used for CO_2 scenarios. The later is composed by only 2 types of construction (single family houses and apartment building) and multiple years of construction classes which correspond to energy efficiency levels. Not one of these tree typologies involves building systems.

A.11.1. Development of Slovenian Tabula Building Typology

Slovenian TABULA Typology was elaborated with 4 building typologies (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

Figure 34: "Building Type Matrix" – classification of the Slovenian housing stock

	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	national (Slovenija)	... 1945	generic (Tipična)	 SI.N.SFH.01.Gen	 SI.N.TH.01.Gen	 SI.N.MFH.01.Gen	 SI.N.AB.01.Gen
2	national (Slovenija)	1946 ... 1970	generic (Tipična)	 SI.N.SFH.02.Gen	 SI.N.TH.02.Gen	 SI.N.MFH.02.Gen	 SI.N.AB.02.Gen
3	national (Slovenija)	1971 ... 1980	generic (Tipična)	 SI.N.SFH.03.Gen	 SI.N.TH.03.Gen	 SI.N.MFH.03.Gen	 SI.N.AB.03.Gen
4	national (Slovenija)	1981 ... 2001	generic (Tipična)	 SI.N.SFH.04.Gen	 SI.N.TH.04.Gen	 SI.N.MFH.04.Gen	 SI.N.AB.04.Gen
5	national (Slovenija)	2002 ... 2008	generic (Tipična)	 SI.N.SFH.05.Gen	 SI.N.TH.05.Gen	 SI.N.MFH.05.Gen	 SI.N.AB.05.Gen
6	national (Slovenija)	2009 ...	generic (Tipična)	 SI.N.SFH.06.Gen	 SI.N.TH.06.Gen	 SI.N.MFH.06.Gen	 SI.N.AB.06.Gen

Several sources for acquisition of building data were foreseen. As the official national energy certification data base (planned as preferable source of data) hasn't been implemented yet) the reserve plan was activated:

The relevant building data were collected from:

- National real-estate Registry by National Surveying and Mapping Authority of the Republic of Slovenia (includes: the registry of buildings and registry of flats with some additional technical and renovation information),
- REUS survey – Energy use in households - (REUS from June 2010 is the 2nd annual survey of Sinergija group - public & commercial partnership of 40 partners) – the poll was made by exhaustive questionnaire on energy characteristics of building and user habits (1000 questions on energy-building-HVAC-electricity-renovation-behaviour-habits-values, in a representative sample for Slovenia N=1009, personal interviews – field survey), REUS also joined TABULA NAG
- classification of whole building stock is based on the National Real-Estate Registry (building type, age). The energy characteristics of the particular class are modelled based on several sources: REUS data, existing database of pilot energy certificates and energy audits; energy saving studies, partner expertise and statistical data.

Geometry of real example building was used to represent each building type. Envelope elements and systems installed where selected according to the period of building construction.

Figure 35: "Building Display Sheet" – existing state of an example building and impact of refurbishment measures (extract from the Slovenian building typology brochure [ZRMK 2011])

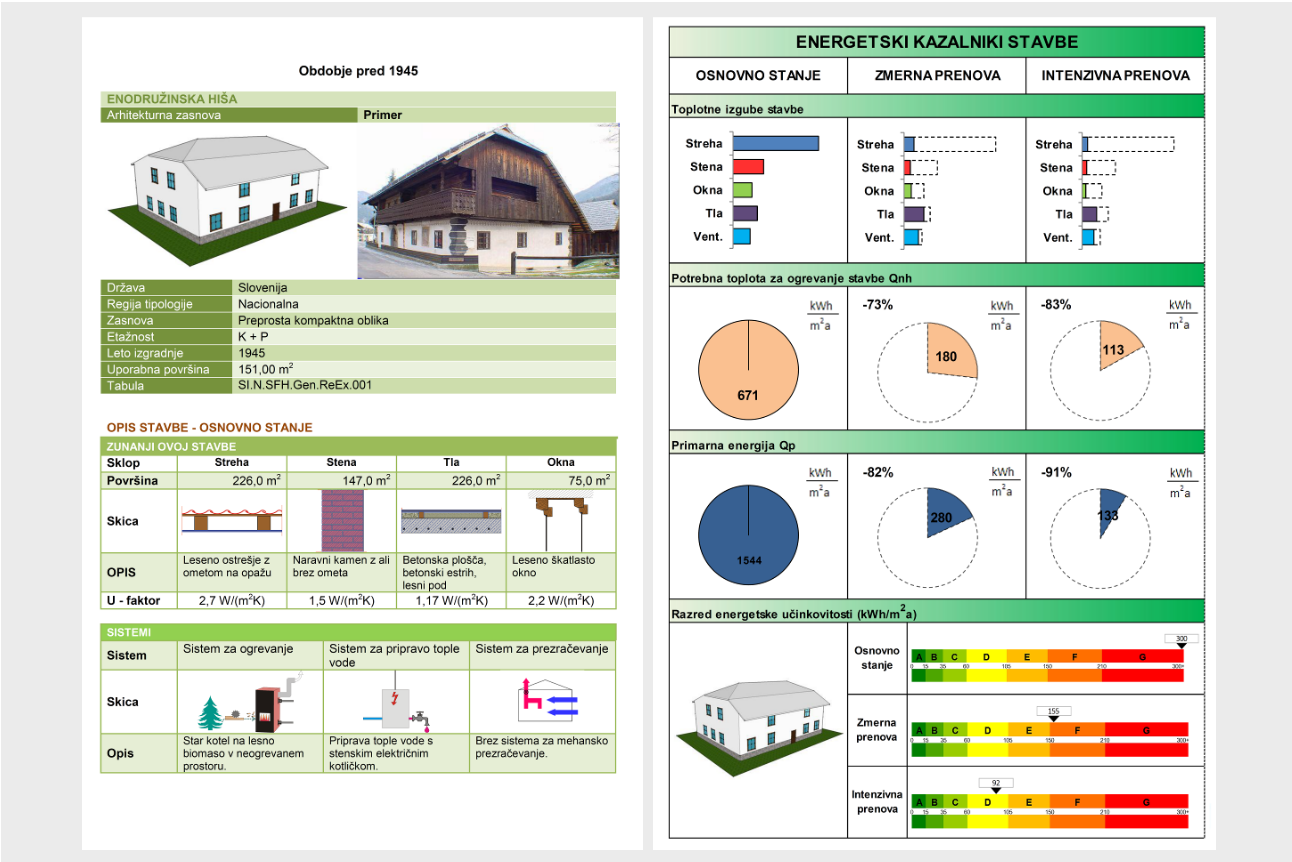


Table 52: Frequencies of 24 building types in 2009

Building type	number of buildings	number of apartments	living space in 1000 m2	TABULA reference area in 1000 m2
SI.N.SFH.01.Gen	140,605	150,283	13,474	14,822
SI.N.SFH.02.Gen	91,163	99,013	8,996	9,895
SI.N.SFH.03.Gen	82,684	88,604	8,919	9,811
SI.N.SFH.04.Gen	114,561	118,970	12,043	13,247
SI.N.SFH.05.Gen	21,567	22,093	2,571	2,828
SI.N.SFH.06.Gen	99	102	9	10
SI.N.TH.01.Gen	12,974	14,897	1,214	1,336
SI.N.TH.02.Gen	11,383	12,800	1,108	1,218
SI.N.TH.03.Gen	7,505	8,354	799	879
SI.N.TH.04.Gen	8,301	9,078	939	1,032
SI.N.TH.05.Gen	2,394	2,575	273	300
SI.N.TH.06.Gen	47	56	4	5
SI.N.MFH.01.Gen	10,693	60,531	3,647	4,011
SI.N.MFH.02.Gen	5,142	39,591	2,031	2,235
SI.N.MFH.03.Gen	2,105	16,238	866	953
SI.N.MFH.04.Gen	2,248	18,320	1,010	1,111
SI.N.MFH.05.Gen	1,152	9,233	562	618
SI.N.MFH.06.Gen	14	84	5	6
SI.N.AB.01.Gen	930	43,683	2,184	2,402
SI.N.AB.02.Gen	885	35,085	1,482	1,630
SI.N.AB.03.Gen	1,060	50,667	2,350	2,585
SI.N.AB.04.Gen	826	38,962	1,899	2,089
SI.N.AB.05.Gen	256	12,397	712	784
SI.N.AB.06.Gen	4	1,077	66	72
Building Stock total	518,598	852,693	67,164	73,881

Source: Registry of buildings [REN]

A.11.2. National Energy Balance

For calculation of national energy balance only 2 condensed building typologies (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.

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).

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

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).

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 aver-ages for last 30 years. To compare results of our model and national statistical data we took aver-age of three available sources.

Table 53: 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%

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).

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.

Table 54: Comparison between energy use 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%

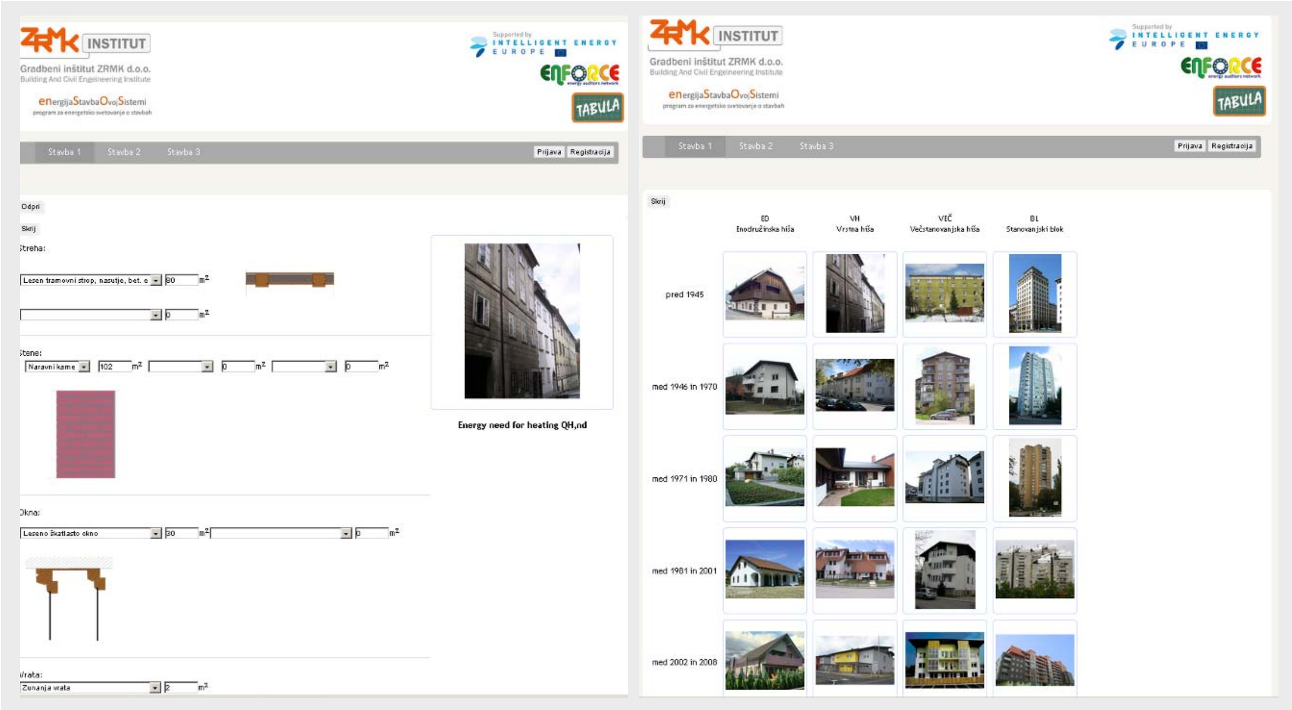
Analyse of saving potentials related to refurbishment of existing buildings external walls showed that we can achieve up to 11 % of savings. For these we would have to refurbish 6% of residential building stock each year. In other words until 2020 more than 54 % of building stock would have a new façade. 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 CO2 emissions thus lower emission penalties.

A.11.3. EnSoS Web Tool

EnSos Web Tool is an online application at http://gi-zrmk.eu/ensos/. Its users are energy advisors and home owners. They can in a few quick steps calculate energy consumption for their house and apply different refurbishment measures. Basic idea for the application was developed in Tabula project (Tabula Web Tool) with further modifications. In EnSos user first picks a building from Slovenian Tabula Typology that is similar to his own. In next step, he can change envelope elements and modify element envelope areas. There is a restricted list of envelope elements and systems installed from which a user can choose from. They are typical. Calculation is done according to Tabula methodology. User can save the building and then modify it and so make two different variations, different refurbishment scenarios.

By compression of existing state and refurbishment state, user can observe the impact of different measures and thus make preliminary decisions. Using Tabula developed typology for buildings, elements and systems enables a tool that doesn't require expert knowledge and extra time thus appropriate for general population. Its main outcome is a dissemination of refurbishment measures on existing buildings.

Figure 36: "EnSOS" Web Tool - screenshots



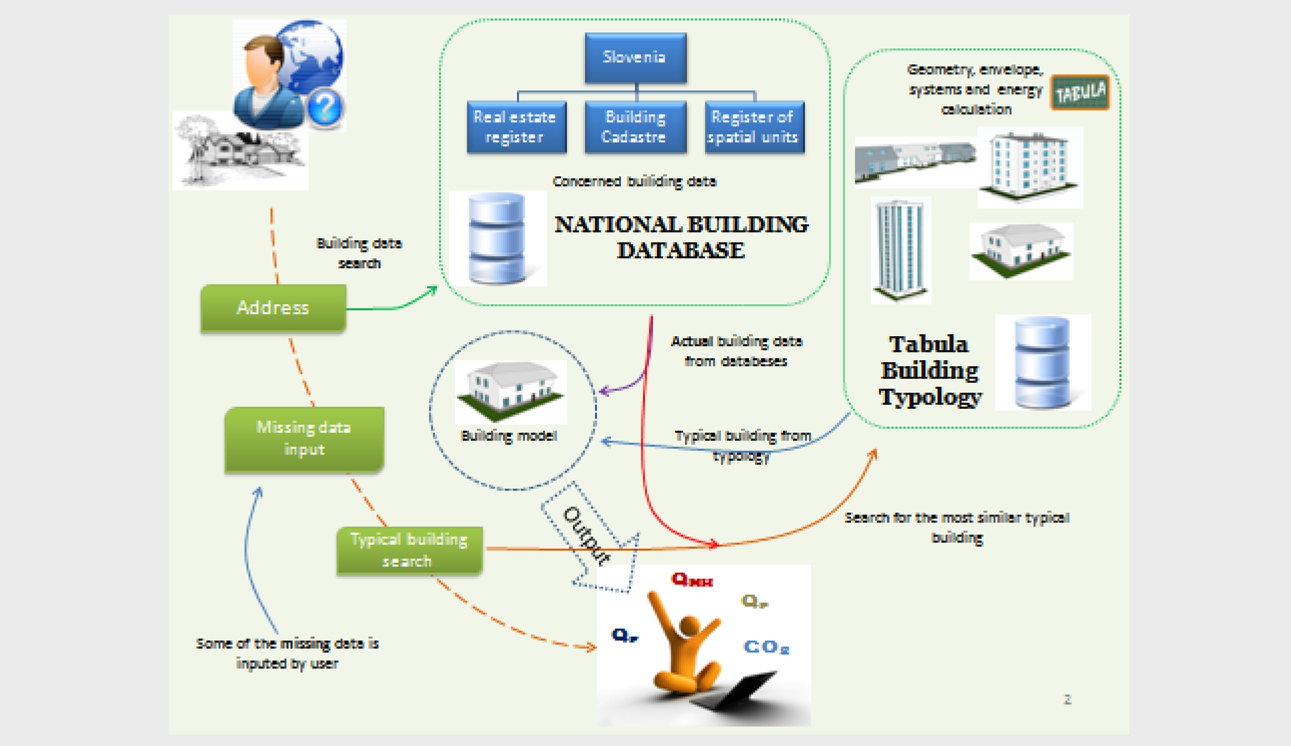
A.11.4. StavbiX Web Application

There is a large number of existing buildings and new constructions in Slovenia, for which the owners don't know what energy properties their buildings are showing. In comparison to new constructions, the bigger problem are proving to be with existing buildings, where the problems are in obtaining information and details of the analysis for the calculation of these properties. The goal of this application StavbiX [StavbiX] is to be used by the general public and that it offers information about the energy performance of building, using the building typology.

When designing the application, a key assumption was that the user supplies only information which is not already contained in existing public databases in order to facilitate the process of obtaining results. Precise details of buildings were obtained from the databases of the Geodetic Administration of the Republic of Slovenia. The obtained data were properly structured and a data model of buildings was designed, which the application offers to the user. A further procedure requires from the user only a basic description of the thermal building envelope. For example it is necessary to define the materials in structural elements of roof, wall and floor. Based on the data entered by the user and acquired from the model of buildings, the application seeks for a specific typical building, which is showing similar characteristics to the user one.

A thorough review of typical buildings from project Intelligent Energy Europe Tabula was made, which represents the latest building typology in Slovenia. The results of the project Tabula were used to design a specific procedure to search for a most appropriate typical building based on data specified by the user. This procedure takes into account the construction period of the building as well as building size. With all collected data, the building is first categorized in one of the six periods of construction and then on the basis of surfaces of structure elements and its heat transfer coefficient, seeks for the most similar typical building and assigns its energy indicators as a final result. We adapted the OntoWiki system to the algorithm requirements and made a prototype application. The last part of the application compares the actual data on delivered energy, derived from the E-TOOL project [E-TOOL], with results given by the application, with which we evaluated the nature of such allocation of energy indicators and gave reasons for the deviations.

Figure 37: "Stavbix Web Application" – operation process



A.11.5. Outcomes

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. This was taken as a starting point for calculating different refurbishment scenarios on a national residential building fund.

At the end of Tabula project a national EPC database in Slovenia is starting to form its shape (ZRMK being its developers). 12,000 assets rating EPC for residential buildings and measured EPC for non-residential buildings will be collected each year. This data will allow us future definition of average buildings for residential buildings and with it we will get better insight into our national residential fund. Based on Tabula project experiences we proposed that extra necessary data about the building is collected with the EPC (e.g. refurbishment measures, actual energy consumption).

Table 55: National Activities Slovenia / Sources and References

Reference shortcut	Short description	Reference
[TABULA SI Bro]	Slovenian Building Typology Brochure	Rakuscek, Andraz; Sijanec Zavrl, Marjana; Stegnar, Gasper: Tipologija stavb: energetska učinskovitost in tipične stavbe v Sloveniji, ZRMK, 2012, Ljubljana
[TABULA NatBal]	National Balance report	Rakuscek, Andraz; Sijanec Zavrl, Marjana: chapter "Slovenia" in: Diefenbach, Nikolaus / Loga, Tobias (ed.): Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock (TABULA Thematic Report N° 2). Models for the national housing stock of 8 countries: Belgium, Czech Republic, Denmark, Germany, Greece, italy, Slovenia; IWU, Darmstadt / Germany 2012 http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf
[TABULA NatSci]	National scientific report of the TABULA activities in Slovenia	
[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)
[E-TOOL]	IEE Project E-TOOL	IEE E-TOOL - Energy toolset for improving the energy performance of existing buildings, sofinancerji: EC pogoda št. EIE/04/182/S07.38670, MOP pogodba št. 2511-05-930229 in 2511-06-730153, izvajalci: koordinator Naturgas Midt-Nord, slovenski partner GI ZRMK, (2005-2007).
[StavbiX]	An application of OntoWiki technology to typification of buildings in Slovenia	Stegnar, Gašper: Uporaba tehnologije OntoWiki pri tipizaciji stavb v Sloveniji, 2012, Ljubljanja, Univerza v Ljubljani, Fakulteta za gradbeništvo in geodezijo http://drugg.fgg.uni-lj.si/3751/

A.12. <ES> Building Typology in Spain

(by TABULA associated partner IVE / Instituto Valenciano de la Edificación (IVE))

A.12.1. Spanish studies regarding building typology characterization

In relation to the typological characterization of the housing stock in Spain, there have been no too much detailed studies that include the entire Spanish territory. Spain is divided into autonomous regions that enjoy some autonomy and for this reason studies carried out in typology characterization field usually are autonomous, i.e. encompassing only one autonomous community, not the country as a whole. The climate variety of Spanish territory also influences because the types are not exactly the same in the whole country. The differences in building typologies are more pronounced in the rural architecture, but not so much in the multifamily buildings. Although a typological characterization with real data about the volume of buildings that are currently of each typology has not been made, an approximation of possible typologies has been carried out in two different projects: Retrofit (Intelligent Energy) and Rehenergía (Spanish Ministry of housing).

A.12.1.1 Current Spanish typology studies: Rehenergía project

The Rehenergia Project was a study to assess the existing building retrofit from an energy standpoint carried out in order to assess energy retrofit policies. It was an initiative promoted by the **Institut Cerdá**, along with various public and private institutions from different regions, including Comunidad Valenciana. The results of simulations carried out in 1730 buildings reflect very positive results: with a correct energy retrofit we could achieve reductions in CO_2 emissions from 10 to 30% and energy savings from 5 to 20%, which can be equivalent to cost savings from 500 to 2000 € in the energy bill of each apartment building.

To accomplish the objective of the project it was necessary to know the building stock. The definition of the building stock was based on the characterization of buildings, both from the architectural point of view as existing facilities. To characterize all existing buildings was found impossible, so the most representative types were reflected in order to expedite the study and allow replication of results. The criteria from which the types of building were established, responded to factors that can influence the energy demand of residential buildings as well as parameters that must be known to calculate the claim. There were established nine type buildings. The characterization of the type buildings was carried out by defining the components of the building envelope and their facilities.

Figure 38: Building typologies characterization. Rehenergía Project. Institut Cerdá

The materials of the facade vary by region and period construction of buildings, and with them their thermal behaviour.

The most representative facades were established:

- F1: stone masonry
- F2: brick factory
- F3: cavity wall made of perforated or hollow brick
- F4: cavity wall made of perforated or hollow brick with thermal insulation in the cavity
- F5: concrete blocks
- F6: Precast concrete panels

The thermal transmittance constructive front sections considered were:

Table 56: Façade U-values. Rehenergía Project. Institut Cerdá

Sección fachada	Composición	U (W/m²K)
F11	Mampostería de piedra granítica	2.22
F12	Mampostería de piedra calcárea	1.98
F21	Ladrillo macizo	1.75
F31	Ladrillo perforado, cámara de aire y tabique cerámico	1.58
F32	Ladrillo hueco, cámara de aire y tabique cerámico	1.41
F41	Ladrillo perforado, cámara de aire, aislante térmico y tabique cerámico	0.63
F42	Ladrillo perforado, cámara de aire, aislante térmico y tabique cerámico	0.60
F51	Bloques de hormigón	1.52
F61	Paneles prefabricado de hormigón tipo sandwich (aislante incorporado)	0.43

As in facades, in the project were established different types of roofing. The U-values of roofs were:

Table 57: Roofing U-values. Rehenergía Project. Institut Cerdá

Sección fachada	Composición	U (W/m2K)
C11	Pesada y no aislada	0.68
C12	Pesada y aislada	0.34
C13	Pesada y ventilada	1.74
C23	Ligera y ventilada	1.94
C22	Ligera y aislada	0.49
Ci21	Inclinada, ligera y no aislada	1.7
Ci22	Inclinada, ligera y aislada	0.49

In the project they also performed the characterization of the doors and windows.

The result of the characterization is an array of building types:

Table 58: Building types characterization. Rehenergía Project. Institut Cerdá

<table>
<tr><th rowspan="3">Disposición del edificio</th><th rowspan="3" colspan="2">Forma arquitectónica básica</th><th colspan="5">Factores variables</th></tr>
<tr><th rowspan="2">Sección constructiva fachada</th><th rowspan="2">Sección constructiva cubierta</th><th colspan="3">Aperturas</th></tr>
<tr><th>Vidrio</th><th>Marco</th><th>Elementos exteriores</th></tr>
<tr><td rowspan="10">Entre Medianeras</td><td rowspan="10">Bajo
(PB + 2)</td><td rowspan="10">T5</td><td>Mampostería de piedra granito
F11</td><td rowspan="2">Ligera ventilada
C23</td><td rowspan="10">Simple</td><td rowspan="4">Madera</td><td rowspan="4">Persiana madera</td></tr>
<tr><td>Mampostería de piedra calcárea
F11</td></tr>
<tr><td rowspan="2">Fábrica de ladrillo macizo
F21</td><td>C23</td></tr>
<tr><td>Pesada ventilada
C13</td></tr>
<tr><td>Fábrica ladrillo hueco, cámara de aire, tabique cerámico
F31</td><td rowspan="2">Pesada no aislada
C11</td><td rowspan="6">Metálico sin rotura de puente térmico</td><td rowspan="6">Persiana blanca</td></tr>
<tr><td>Fábrica ladrillo hueco, cámara de aire, tabique cerámico
F32</td></tr>
<tr><td>F31</td><td rowspan="2">C13</td></tr>
<tr><td>F32</td></tr>
<tr><td>Fábrica ladrillo perforado, cámara de aire, aislante térmico, tabique cerámico
F41</td><td rowspan="2">Pesada aislada
C12</td></tr>
<tr><td>Fábrica ladrillo hueco, cámara de aire, aislante térmico, tabique cerámico F42</td></tr>
</table>

The characterization of the facilities was focused on defining equipment and energy sources for heating, cooling, DHW and lighting of common areas. The characterization was developed based on: availability of facilities in the building stock, facility type, type of equipment and energy source used.

A.12.1.2 Current Spanish typology studies: Retrofit Project

Retrofit was an Intelligent Energy project carried out from January 2006 to December 2007. The aim of this project was to develop a web-based tool-kit for passive house retrofitting applied to social housing. The main goals achieved in this project were:

- A web-tool for each of the 14 countries participating: Austria-Belgium-Czech Republic-Denmark-Germany-France-Italy-Lithuania-Luxembourg-Portugal-Slovenia-Spain-The Netherlands-United Kingdom.
- For each country were described typical residential building categories.
- Typical energy saving measures, energy savings and economic feasibility are described in passive house retrofitting “packet solutions” for each building category.

The web-tool can be seen on: www.energieinstitut.at/retrofit

Typical examples are given for three building types (big multifamily house, small multifamily house, terrace house) and for three periods of construction (before 1960, from 1960 to 1979 and after 1970).

After the building categories of the tool-kit had been identified, the tool-kit gives information on: actual state, energy savings, PHR-Measures and energy costs and incomplete PHR.

The conclusions with regard to Spain were:

> «For both energy savings for heating and cooling and for energy costs the oldest buildings included have the highest potential for savings due to bad energy standard before retrofitting.
>
> The poorest result on both energy savings for heating and cooling and for energy costs reductions is for more new compact buildings.»

A.12.2. The Spanish TABULA building typology

A first version of a Spanish regional residential building typology was already developed by Valencia Institute of building in 2011 on the basis of the knowledge achieved during the past two decades through different research projects developed in the Valencia Region. The Spanish building typology was updated by Valencia Institute of building in 2012 according to new developments.

The new Spanish building typology contemplates three different climate regions, the Atlantic, Continental and Mediterranean climatic zones. This is because Spain has a very diverse climate throughout its territory. The climate of the southern and eastern coasts is called Mediterranean climate: mild temperatures and abundant rainfall except in summer. As we move into the interior the climate is more extreme, we find the Continental climate, which covers almost the entire peninsula: low winter temperatures, high and irregular rainfall in summer. The north regions have an Atlantic climate characterized by an abundance of rainfall throughout the year especially in winter and cool temperatures.

Figure 39: Spain climatic zones. Source: ISFTIC Images banc

The current Spanish building type matrix consists of 72 residential building types, 24 in each climate zone, classified by construction year and building size (see Figure 39).

Figure 40: Spanish Building Type Matrices

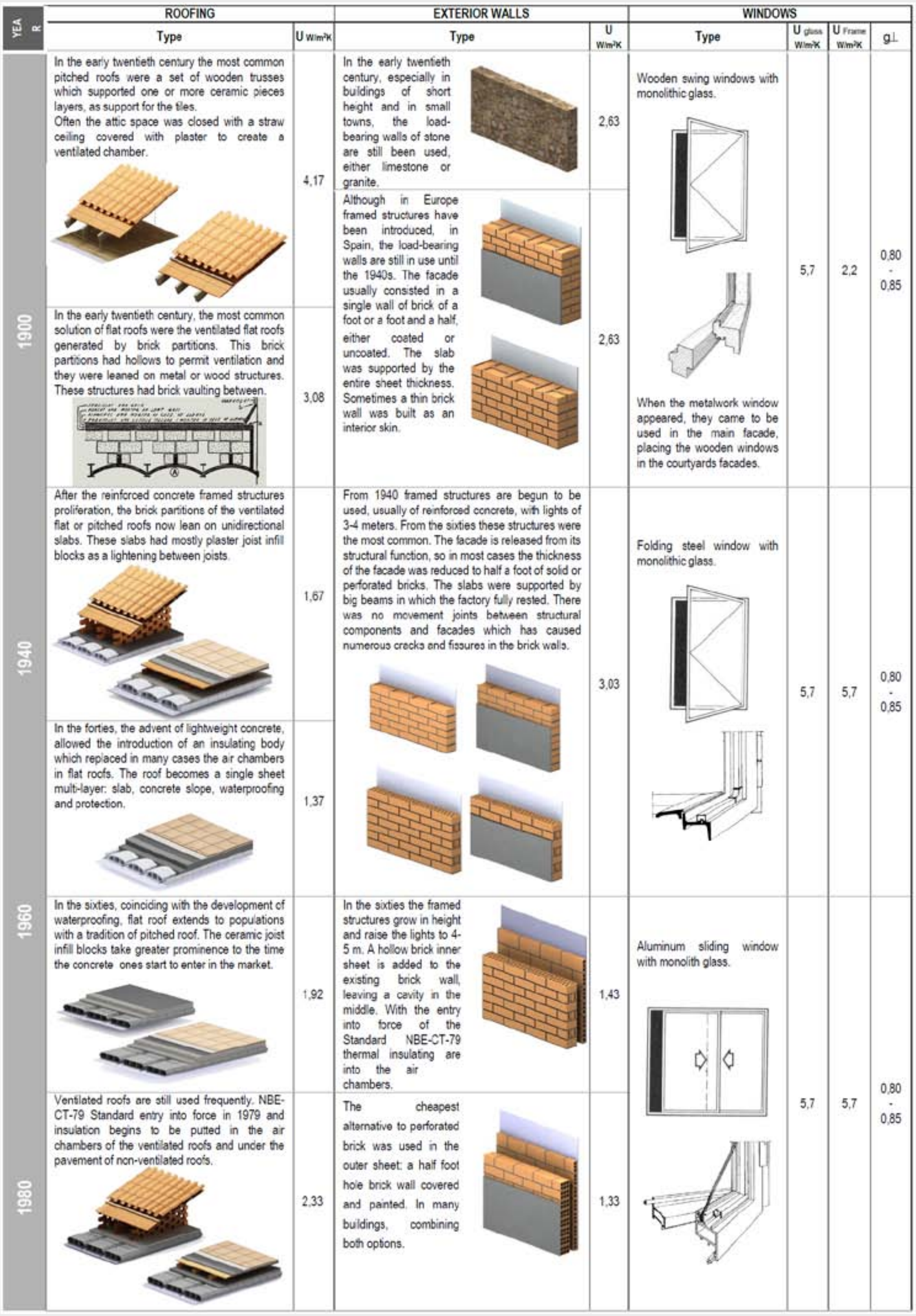
	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	Atlantic climate (Clima Atlántico)	... 1900	generic	ES.AT.SFH.01.Gen	ES.AT.TH.01.Gen	ES.AT.MFH.01.Gen	ES.AT.AB.01.Gen
2	Atlantic climate (Clima Atlántico)	1901 ... 1936	generic	ES.AT.SFH.02.Gen	ES.AT.TH.02.Gen	ES.AT.MFH.02.Gen	ES.AT.AB.02.Gen
3	Atlantic climate (Clima Atlántico)	1937 ... 1959	generic	ES.AT.SFH.03.Gen	ES.AT.TH.03.Gen	ES.AT.MFH.03.Gen	ES.AT.AB.03.Gen
4	Atlantic climate (Clima Atlántico)	1960 ... 1979	generic	ES.AT.SFH.04.Gen	ES.AT.TH.04.Gen	ES.AT.MFH.04.Gen	ES.AT.AB.04.Gen
5	Atlantic climate (Clima Atlántico)	1980 ... 2006	generic	ES.AT.SFH.05.Gen	ES.AT.TH.05.Gen	ES.AT.MFH.05.Gen	ES.AT.AB.05.Gen
6	Atlantic climate (Clima Atlántico)	2007 ...	generic	ES.AT.SFH.06.Gen	ES.AT.TH.06.Gen	ES.AT.MFH.06.Gen	ES.AT.AB.06.Gen
	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
7	Continental climate (Clima continental)	... 1900	generic	ES.CO.SFH.01.Gen	ES.CO.TH.01.Gen	ES.CO.MFH.01.Gen	ES.CO.AB.01.Gen
8	Continental climate (Clima continental)	1901 ... 1936	generic	ES.CO.SFH.02.Gen	ES.CO.TH.02.Gen	ES.CO.MFH.02.Gen	ES.CO.AB.02.Gen
9	Continental climate (Clima continental)	1937 ... 1959	generic	ES.CO.SFH.03.Gen	ES.CO.TH.03.Gen	ES.CO.MFH.03.Gen	ES.CO.AB.03.Gen
10	Continental climate (Clima continental)	1960 ... 1979	generic	ES.CO.SFH.04.Gen	ES.CO.TH.04.Gen	ES.CO.MFH.04.Gen	ES.CO.AB.04.Gen
11	Continental climate (Clima continental)	1980 ... 2006	generic	ES.CO.SFH.05.Gen	ES.CO.TH.05.Gen	ES.CO.MFH.05.Gen	ES.CO.AB.05.Gen
12	Continental climate (Clima continental)	2007 ...	generic	ES.CO.SFH.06.Gen	ES.CO.TH.06.Gen	ES.CO.MFH.06.Gen	ES.CO.AB.06.Gen
	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
13	Mediterranean climate (Clima Mediterráneo)	... 1900	generic	ES.ME.SFH.01.Gen	ES.ME.TH.01.Gen	ES.ME.MFH.01.Gen	ES.ME.AB.01.Gen
14	Mediterranean climate (Clima Mediterráneo)	1901 ... 1936	generic	ES.ME.SFH.02.Gen	ES.ME.TH.02.Gen	ES.ME.MFH.02.Gen	ES.ME.AB.02.Gen
15	Mediterranean climate (Clima Mediterráneo)	1937 ... 1959	generic	ES.ME.SFH.03.Gen	ES.ME.TH.03.Gen	ES.ME.MFH.03.Gen	ES.ME.AB.03.Gen
16	Mediterranean climate (Clima Mediterráneo)	1960 ... 1979	generic	ES.ME.SFH.04.Gen	ES.ME.TH.04.Gen	ES.ME.MFH.04.Gen	ES.ME.AB.04.Gen
17	Mediterranean climate (Clima Mediterráneo)	1980 ... 2006	generic	ES.ME.SFH.05.Gen	ES.ME.TH.05.Gen	ES.ME.MFH.05.Gen	ES.ME.AB.05.Gen
18	Mediterranean climate (Clima Mediterráneo)	2007 ...	generic	ES.ME.SFH.06.Gen	ES.ME.TH.06.Gen	ES.ME.MFH.06.Gen	ES.ME.AB.06.Gen

A.12.3. TABULA building elements characterization

A reduced number of publications on typical construction elements exist in Spain in which U-values are listed, classified by construction year, type, materials etc.

The Valencia Institute of Building has developed different retrofit guides for inspection and intervention. During the course of this research characterize the constructive components by periods has been necessary. Each component have been assigned a U-value to permit an energy evaluation and thus to study the best energy saving measures. The table figure below shows a summary of the work carried out by IVE in this field:

Figure 41: Building components and U-values



YEAR	ROOFING Type	U W/m²K	EXTERIOR WALLS Type	U W/m²K	WINDOWS Type	U glass W/m²K	U Frame W/m²K	g⊥
1900	In the early twentieth century the most common pitched roofs were a set of wooden trusses which supported one or more ceramic pieces layers, as support for the tiles. Often the attic space was closed with a straw ceiling covered with plaster to create a ventilated chamber.	4,17	In the early twentieth century, especially in buildings of short height and in small towns, the load-bearing walls of stone are still been used, either limestone or granite.	2,63	Wooden swing windows with monolithic glass. When the metalwork window appeared, they came to be used in the main facade, placing the wooden windows in the courtyards facades.	5,7	2,2	0,80 - 0,85
	In the early twentieth century, the most common solution of flat roofs were the ventilated flat roofs generated by brick partitions. This brick partitions had hollows to permit ventilation and they were leaned on metal or wood structures. These structures had brick vaulting between.	3,08	Although in Europe framed structures have been introduced, in Spain, the load-bearing walls are still in use until the 1940s. The facade usually consisted in a single wall of brick of a foot or a foot and a half, either coated or uncoated. The slab was supported by the entire sheet thickness. Sometimes a thin brick wall was built as an interior skin.	2,63				
1940	After the reinforced concrete framed structures proliferation, the brick partitions of the ventilated flat or pitched roofs now lean on unidirectional slabs. These slabs had mostly plaster joist infill blocks as a lightening between joists.	1,67	From 1940 framed structures are begun to be used, usually of reinforced concrete, with lights of 3-4 meters. From the sixties these structures were the most common. The facade is released from its structural function, so in most cases the thickness of the facade was reduced to half a foot of solid or perforated bricks. The slabs were supported by big beams in which the factory fully rested. There was no movement joints between structural components and facades which has caused numerous cracks and fissures in the brick walls.	3,03	Folding steel window with monolithic glass.	5,7	5,7	0,80 - 0,85
	In the forties, the advent of lightweight concrete, allowed the introduction of an insulating body which replaced in many cases the air chambers in flat roofs. The roof becomes a single sheet multi-layer: slab, concrete slope, waterproofing and protection.	1,37						
1960	In the sixties, coinciding with the development of waterproofing, flat roof extends to populations with a tradition of pitched roof. The ceramic joist infill blocks take greater prominence to the time the concrete ones start to enter in the market.	1,92	In the sixties the framed structures grow in height and raise the lights to 4-5 m. A hollow brick inner sheet is added to the existing brick wall, leaving a cavity in the middle. With the entry into force of the Standard NBE-CT-79 thermal insulating are into the air chambers.	1,43	Aluminum sliding window with monolith glass.	5,7	5,7	0,80 - 0,85
1980	Ventilated roofs are still used frequently. NBE-CT-79 Standard entry into force in 1979 and insulation begins to be putted in the air chambers of the ventilated roofs and under the pavement of non-ventilated roofs.	2,33	The cheapest alternative to perforated brick was used in the outer sheet: a half foot hole brick wall covered and painted. In many buildings, combining both options.	1,33				

Besides, the Valencia Institute of building has defined six different example buildings that allow the TABULA WebTool to be operative for these types of building.

The building datasets of these types are contained in TABULA.xls and include the following information:

- Climatic data of the different climatic zones established.
- Basic data of the building types (floor area, number of apartments …).
- Areas of building elements (wall, roof, ground floor, windows).
- Characteristics of building elements by age (U-values, components...).
- Characteristics of the different supply systems by age (heating, domestic hot water and ventilation systems).
- Refurbishment measures in two levels: standard and advanced measures.
- Calibration to the typical level of measured consumption for the different climatic zones.
- Information about the Spanish calculation method.

Figure 42: Spanish example buildings

Single family house from 2007 located in the Mediterranean climatic zone

Terraced house from 1980 to 2006 located in the Mediterranean climatic zone

Multifamily house from 1960 to 1979 located in the Mediterranean climatic zone

Multifamily house from 1901 to 1936 located in the Mediterranean climatic zone

Apartment block from 2006 located in the Mediterranean climatic zone

Apartment block from 1980 to 2006 located in the Mediterranean climatic zone

Table 59: National Activities Spain / Sources and References

Reference shortcut	Short description	Reference
La energía en España 2009		Gobierno de España, Ministerio de Industria, Turismo y Comercio, Secretaría general de energía, 2009
Consumo de energía y crecimiento económico		CJN Consultores, Comisión nacional de energía, Club español de la energía, 2002
Memoria anual 2008		Gobierno de España, Ministerio de Industria, Turismo y Comercio, Secretaría general de energía, Instituto para la diversificación y Ahorro de la Energía IDAE, 2009
Boletín Mensual de Estadística. Junio 2010		Instituto Nacional de Estadística INE, Junio 2010
Cener Centro nacional de energías renovables		CTE Plus. El potencial de ahorro de energía y reducción de emisiones de CO^2 en viviendas mediante incremento del aislamiento España 2005-2012
Gobierno de España, Ministerio de Fomento.		CTE - Documento Básico HE sección 1. Limitación de demanda energética
Intelligent Energy Europe		E-Retrofit-Kit. Tool-Kit for “Passive House Retrofit”
WWF, 2010		Potencial de ahorro energético y de reducción de emisiones de CO2 del parquet residencial existente en España en 2020

A.13. <RS> Building Typology in Serbia

(by TABULA associated partner University of Belgrade / Faculty of Architecture)

Serbia, represented by the Faculty of Architecture University of Belgrade, has joined the Tabula project as an associative partner in February of 2011, and has committed itself towards the developing the adequate national typology based on the principles defined in the TABULA project. The analysis process needed for gathering the relevant data for formulation of typology is somewhat different than postulates defined by the project mainly due to the specificity of Serbia characterized by the lack of adequate building data and appropriate energy polices.

Serbian new Law on Planning and construction from 2009 has, for the first time, introduced the need for building Energy Performance Certificates (EPC) issuance for new as well as for existing buildings. In the period to follow, a set of sub-low documents was developed in order to facilitate the procedure and, starting from September 2012, EPCs are to be included as the part of the obligatory construction documentation needed for obtaining the building permit for the new constructions and major renovations. Regulations can be considered as the framework for design, but the impact that the implementation phase will have especially in the on existing buildings treatment is largely unknown. Construction activity in Serbia has decreased dramatically in the last period with less than 1% [RZS 2003] of new buildings being constructed annually shifting the interest of energy efficiency implementation towards the treatment of existing buildings. Serbia has not structured its building fund nor defined the respective typology and it has been realized that such an activity has to be performed in order to define a starting point for the evaluation the potential of energy savings through the process of rehabilitation.

Some work in this field has been done through the research project in 2002, by the Faculty of Architecture [AF 2003], with focus on the multifamily houses of Belgrade.

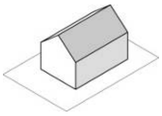
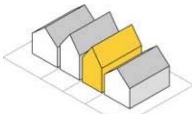
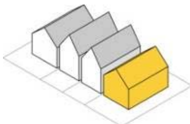
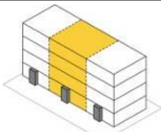
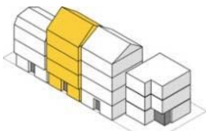
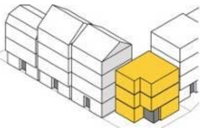
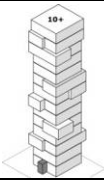
A.13.1. The data collection

Developing the typology of building fund depends largely on the availability of relevant data. In Serbia the most accurate data could be derived from the National Census which has been conducted every ten years. The methodology of census has been defined in the 1950s and improved ever since, but it but does not reflect the full spectrum of information needed for analysis of building fund. Last census (conducted in the autumn 2011) partly covered the building characteristics data. Data collection process was organized in two ways: to be collected in conversation with tenants usually giving the information about the structure of the residential units: the construction year of the apartment (building), the area of the apartment, the number of rooms, installation status (types of installation equipped: electrical, plumbing, sewage systems), fuel used for heating, and by direct observation of the building by the enumerator: type of the building (free standing single family house, free standing duplex house, semi-detached house, terraced house with at least three attached residences each with own entrance, multifamily house with 3-9 apartments, apartment block with 10 or more apartments) and external wall material (rigid or soft). Although, for the first time, census set some building categories and has gathered other valuable data (availability of the data for the public is planned for the December 2012) it had not facilitated the assessment of the quality of energy performance of buildings nor has it provided necessary information for deriving more detailed building typology. It was, therefore, decided that an independent survey (micro census), based on statistically relevant sample should be conducted enabling the creation of national residential building typology upon which the energy performance of the building stock can be assessed. It was also realized that this activity will have to try to structure and evaluate all specific architectural and urban parameters in design and construction reflecting the local characteristics of Serbia.

In the design phase of the survey it has been decided, due to the limited financial resources, that a two step procedure is to be applied. The design of the sample was done in the way that it respected the uneven distribution of housing in urban and rural areas yielding a certain percentage of investigation to the urban zones in order to get the adequate results.

Phase A of the survey has been conceptualized as an ad hoc survey conducted by the trained enumerators on site, equipped with the explanatory charts derived by the Faculty of Architecture in order to explain the nature and structure of the data.

Figure 43: Explanatory chart for urban disposition of the houses

SINGLE-FAMILY AND FAMILY HOUSES	1		**FREE-STANDING HOUSE** One-family house or a family house with 1-4 apart-ments. It is a free-standing structure on a separate lot. The house is fully detached.	
	2		**TERRACED HOUSE – CENTRAL** One-family house or a family house with 1-4 apart-ments. It is located on a separate lot in a row of similar structures. It shares two side walls with neighbouring houses.	
	3		**TERRACED HOUSE – END-TERRACE** One-family house or a family house with 1-4 apart-ments. It is located on a separate lot at the end of a row of similar structures. It shares one wall with the neighbouring house.	
MULTI - FAMILY HOUSES	4		**FREE-STANDING HOUSE** Multi-family house with more than 4 apartments with one entrance. It is a free-standing structure on a separate lot. The house is fully detached.	
	5		**FREE-STANDING HOUSE** Multi-family house comprising two or more identical units with separate entrances. It is a free-standing structure on a separate lot. The house is fully detached.	
	6		**TERRACED HOUSE – CENTRAL** Multi-family house with more than 4 apartments with one entrance. It is located in a row of different structures in a city block. The house shares two side walls with neighbouring houses.	
	7		**TERRACED HOUSE – END-TERRACE** Multi-family house with more than 4 apartments with one entrance. It is located in a row of different structures in a city block. The house shares one or two side walls with neighbouring houses.	
	8		**FREE-STANDING HIGH-RISE TOWER 10+** Multi-family house with more than 4 apartments with one entrance. It has more than 10 floors above the ground level. It is a free-standing structure on a separate lot. The house is fully detached.	

For this purpose the territory of Serbia was divided into zones defined by the census principles (6 zones, 25 administrative districts).The sample itself consisted of approx. 6000 residential buildings throughout Serbia (excluding the territory of Kosovo), and it was based on 2002 census migration data as well as ISM`s population estimation for 2009. Stratification according to the type of settlement urban/rural has also been preformed for all 25 administrative districts of Serbia. In this phase basic information about buildings have been recorded: address, type of the dwelling unit (Figure 43), complexity of ground plan (resulting in three categories: compact, elongated, non-compact), number of floors, number of apartments, total area of the building (estimation), opening ratio and type of openings (small percentage of individual openings (less the 50% of the facade), high percentage (more than 50%) and window ribbons (typical appearance of the construction from 1960s and 1970s), construction of the windows, photograph of the building (according to the preset principles) (Figure 44).

Phase B of the survey was considered as more in depth approach towards the data collection and it included interviews with residents. For this phase every 5th building which had been identified in the phase A was, in detail, analyzed, resulting in sample of approx. 1200 buildings. Questionnaires with explanatory charts were also derived for this phase, structuring the data that had to be collected in six sections according to the type:

- Building/House data: year of construction (in accordance to the predefined periods), existence and using of the loft and basement space
- Roof: type of the roof, has it been thermally insulated, thickness of insulation, type of the roofing (by material applied)
- Outer walls: main building material, average thickness of walls, existence of thermal insulation, thickness of insulation, completion of the facade
- Windows: age, condition (estimation), type, material, existence of the shutters/blinds
- Heating system: total area of the apartment, heated area, main heating system, number of furnaces/boilers, additional heating, fuel used for heating, are temperatures being kept at desired level during the heating period, has any part of the heating system been replaced in last five years and what would contribute to better heating in your apartment
- Demographic profile: number of household members, age profile

In this phase actual usage of the house has been recorded mainly through the utilization of loft and basement spaces (Figure 45) and what was also important for analysis size of the heated area corresponding to the overall area of the house.

Figure 44: Complexity of the ground plan, Window percentage and type

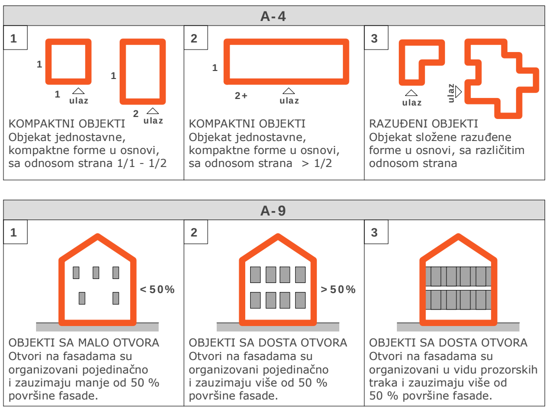
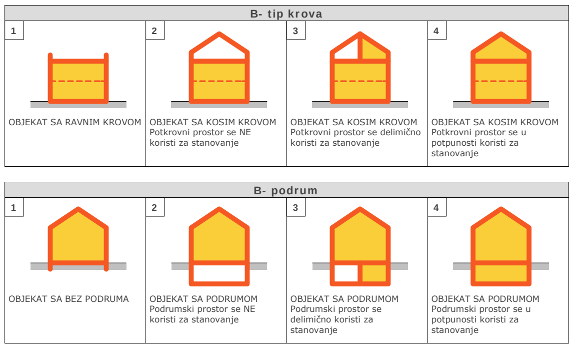


Figure 45: Utilization of attic and basement level



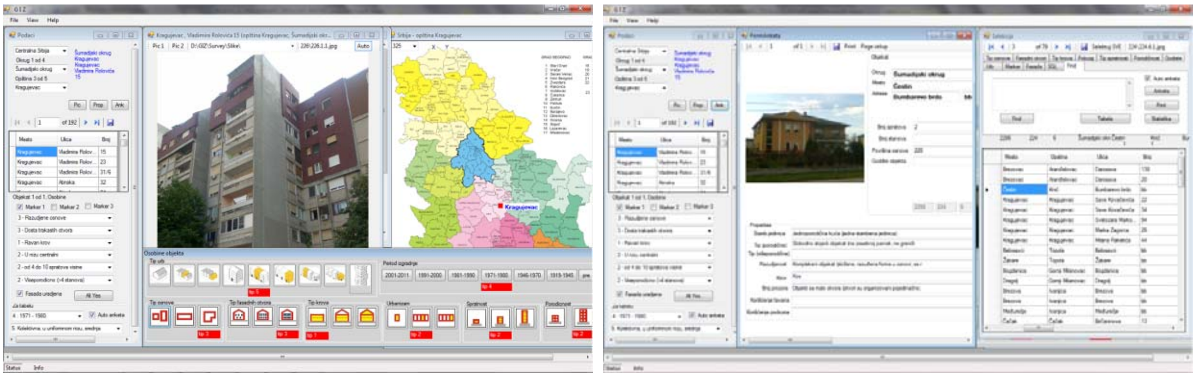
Construction year classes, analyzed in this phase, do not directly influence performance nor classification but provides a cross referencing towards the significant regulations and construction techniques applied and give direct connection to the statistical data gathered by the national census. In details, classification has been characterized by the introduction of thermal regulations. Special attention has been paid to socio–political events that have marked the creation and development of the building fund defining the relevant periods: World War I and II, especially period from 1945-70 which has been characterized as the most dynamic and fruitful changing the face of country. Transformation of economic system and breakup of Yugoslavia from the early 1990s meant that state controlled construction process was not in force and that whole construction activity has shifted towards individual initiative. Changing of the planning doctrine from large scale development (mass construction) to single building construction followed by reaffirmation of traditional city matrix.

The chosen periods were therefore chosen as: before 1919, 1919-1945, 1946-1970, 1971-1980, 1981-1990, 1991-2000, and 2001 to present.

A.13.2. The data analysis and typology definition

Statistical analysis of data has proved that standard procedures and methodology do not enable the formulation of a typology, but only provide the starting point for such activity. For this reason, additional analysis of the formed database has been executed using the newly created software. By performing a deeper analysis process it was possible to structure the data in the desired manner and to produce the projection charts and illustrative tables consisting of representative objects (Figure 46).

Figure 46: Building database analysis software (screen shots)



This activity has been performed for every defined region and local typology charts have been developed. In this way it was possible to “capture” the local characteristics of the building fund which, due to the different historical, cultural and constructional background, appeared to be very distinctive in certain periods. Selected buildings shown in this charts were considered as a representations, the visual illustration of statistical averages and detailed surveys of their characteristics were performed on site. In this way some 120 buildings were in detail analyzed and all needed data were gathered. Although it does not influence the typology spatial composition through the typical layout has also been defined and analyzed.

Figure 47: Typical building display datasheets

REGION 2_CENTRAL SERBIA	AF-106 C1

TYPOLOGY	ADDRESS
DETACHED SINGLE FAMILY HOUSE	Ul. Trnavska 27_b, ČAČAK

BUILDING LAYOUT	OPENINGS	ROOF TYPE	BASEMENT

CONSTRUCTION YEAR	1955.		
FLOORS	1		
LIVING UNITS	1		
TOTAL AREA	GROSS AREA_80 m²	NET AREA_63.8 m²	
HEIGHT	ROOM HEIGHT 250 cm	FLOR HEIGHT 275 cm	
THERMAL BRIDGES	SIGNIFICANT IMPACT		
HOT WATER SYSTEM	ELECTRIC INSTALLED		
HEATING		TYPE	ELECTRIC
		MANUFACTURED/INSTALLED	1955.
		COVERAGE/CONSUMPTION	1600kW zimi, 300kW leti
COMMENT			

FLOOR PLAN

01 - Corridor
02 – Living room
03 - Kitchen
04 - Bathroom
05 - Bedroom
06 - Bedroom

HEATED AREA

STRUCTURE	SKETCH	DESCRIPTION	U - value W/m²K
EXTERNAL WALLS		BRICK WALL 38 CM, PLASTERED BOTH SIDES	0.98
PARTITION WALLS to unheated area	-	-	-
PARTITION WALLS between units	-	-	-
GROUND FLOOR		PARQUET 2.2 CM, ASPHALT, SCREED 5 CM BITUMENOUS INSULATION 1 CM CONCRETE 10 CM, GRAVEL 10 CM	1.81
CEILING to unheated roof		RAMMED EARTH 10 CM, TIMBER BATTEN 4 CM, AIR GAP 4 CM, STRAW-PLASTER CEILING 5 CM	0.64
CEILING to unheated basement	-	-	-
ROOF	-	-	-
WINDOWS		WOODEN, DOUBLE FRAMED WITH SINGLE GLASS	3.50

By interpolating all six local typologies and cross referencing them with available statistical data from other sources a **preliminary residential building typology of Serbia** has been defined. This typology can be seen at Figure 47.

The defined typology is considered as preliminary since it was discovered that an additional statistical cross work has to be performed especially in the field of multifamily houses where representation percentages in analyzed survey were considered to be insufficient. Density and diversity of urban fabric requires a more in depth analysis which is the focus of current research.

The consumption properties of the defined types and improvement levels using the Tabula methodology is an activity that is currently in process and it is estimated that by the end of 2012 Serbian National building typology will be fully defined and elaborated.

Some changes to preliminary typology, as the result of new statistical findings and setting the benchmark for representation percentages are expected to take place modifying the typology but giving it more realistic and usable connotation.

Figure 48: "Building Type Matrix" – classification of the Serbian housing stock

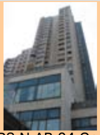
	Region	Construction Year Class	Additional Classification	SFH Single-Family House	TH Terraced House	MFH Multi-Family House	AB Apartment Block
1	National	... 1918	generic	 RS.N.SFH.01.Gen	 RS.N.TH.01.Gen	 RS.N.MFH.01.Gen	
2	National	1919 ... 1945	generic	 RS.N.SFH.02.Gen	 RS.N.TH.02.Gen	 RS.N.MFH.02.Gen	
3	National	1946 ... 1970	generic	 RS.N.SFH.03.Gen	 RS.N.TH.03.Gen	 RS.N.MFH.03.Gen	 RS.N.AB.03.Gen
4	National	1971 ... 1980	generic	 RS.N.SFH.04.Gen	 RS.N.TH.04.Gen	 RS.N.MFH.04.Gen	 RS.N.AB.04.Gen
5	National	1981 ... 1990	generic	 RS.N.SFH.05.Gen	 RS.N.TH.05.Gen	 RS.N.MFH.05.Gen	 RS.N.AB.05.Gen
6	National	1991 ... 2000	generic	 RS.N.SFH.06.Gen	 RS.N.TH.06.Gen	 RS.N.MFH.06.Gen	 RS.N.AB.06.Gen
7	National	2001 ... 2011	generic	 RS.N.SFH.07.Gen	 RS.N.TH.07.Gen	 RS.N.MFH.07.Gen	 RS.N.AB.07.Gen

Table 60: National Activities Serbia / Sources and References

Reference shortcut	Short description	Reference
[RZS 2003]	{ Statistical yearbook of Serbia 2003 }	{Statistički godišnjak Srbije 2003., Republički zavod za statistiku. }
[AF 2003]	{ Energy optimization of buildings in the context of sustainable architecture – study part I, AF}	{Jovanović Popović M., ur., 2003. „Energetska optimizacija zgrada u kontekstu održive arhitekture - deo I“, Arhitektonski fakultet Univerziteta u Beogradu. }
[AF 2004]	{ Energy optimization of buildings in the context of sustainable architecture – study part II, AF}	{Jovanović Popović M., ur., 2003. „Energetska optimizacija zgrada u kontekstu održive arhitekture - deo II“, Arhitektonski fakultet Univerziteta u Beogradu. }
[AF 2010]	{ Energy efficiency in buildings: assessment of energy performances of the Serbian building stock }	{Jovanović Popović M., ur., 2010. „Energetska efikasnost zgrada, procena energetskih performansi građevinskog fonda Srbije, interni izveštaj, Arhitektonski fakultet Univerziteta u Beogradu. }
[AF 2011]	{ Residential buildings in Serbia, preliminary typology }	{Jovanović Popović M., ur., 2011. „Stambene zgrade Srbije, preliminarna tipologija“, interni izveštaj, Arhitektonski fakultet Univerziteta u Beogradu. }

Appendix B - Building Typology Data: Cross-Country Comparison and Synthesis

B.1. Analysis of data sheets

During the TABULA project the partners from 13 countries provided data of exemplary buildings and systems for showcase calculations representing different national building and system types. The following data tables were used to collect this information:

Table 61: Analysed data sheets of the Excel workbook TABULA.xls

Sheet	Content
Tab.Building.Constr	national definition of construction elements + U-values
Tab.Building.Measure	national definition of insulation measures + thermal resistance
Tab.System.HG	heating system / generation
Tab.System.HS	heating system / storage
Tab.System.HD	heating system / distribution
Tab.System.HA	heating system / auxiliary energy
Tab.System.WG	domestic hot water system / generation
Tab.System.WS	domestic hot water system / storage
Tab.System.WD	domestic hot water system / distribution
Tab.System.WA	domestic hot water system / auxiliary energy
Tab.System.H	datasets of heating system types
Tab.System.W	datasets of domestic hot water system types
Tab.System.Vent	datasets of heating system types
Tab.System.EC	datasets of energy carrier specifications
Tab.Building	datasets of national building types
Calc.Building.Set	definition of variants and calculation of the energy need for heating
Calc.System.Set	definition of variants and calculation of the system efficiency

These sheets are part of the workbook TABULA.xls which was used as a database and programming template for the TABULA WebTool[2].

After the collection of these data an evaluation was performed which is documented in this report. At the time of the analysis the TABULA database comprised data from 12 countries: 429 datasets of real buildings and 1203 datasets of heat supply components.

The intention of the evaluation was:

- **Make a comparison of energy related features of typical buildings from different countries:**
  Show characteristics of the envelope areas, the thermal performance of construction elements, the typical and advanced insulation measures, the supply system efficiency. What is common? What is different?
- **Generate default values for rough estimations on supranational level:**
  In some cases components differ only slightly from country to country. Here the determination of averages seems an appropriate approach to deliver "common" values. These numbers can be used as default values in the case that national values have not (yet) been determined. In the future this might be helpful especially for experts of countries which did not participate at the TABULA project. Also simplified supranational considerations could rely on the default values.
- **Contribute to a high data quality:**
  Data acquisition and transformation is prone to errors. Especially the determination of the thermal envelope area and the conditioned floor area of a building is problematic: Double counting or omission of

[2] Information about the workbook: http://www.building-typology.eu/tabulapublications.html /
acess to the webtool: http://webtool.building-typology.eu/

areas, copy-paste errors, uncertainties as regards the correct position of the thermal envelope (e.g. in case of unheated spaces). The definition of key figures and the determination of their typical ranges and dependence of the main geometrical parameters may help in the future to flag implausible datasets. The knowledge about typical area relations may not only help to improve the data quality of the TABULA example building database but can also be useful in national EPC issuing.

B.2. Envelope Areas of Typical Buildings

The following table shows the conditioned floor areas and the thermal envelope areas of the example buildings from the different countries, averaged over all construction year classes and differentiated by building size class.

In addition the envelope areas per conditioned floor area were calculated for each envelope type. These indicators can be useful for a first quality assurance since they are usually positioned in a certain range. Apart from that, they also can serve as a preliminary basis for the definition of synthetical average buildings for the energy assessment of building stocks (as far as no deeper empirical investigation of the building stock is available).[3]

[3] see: TABULA Thematic Report N° 2 http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf

Table 62: Average thermal envelope areas of the example buildings per country and building size class and derived floor area related values

	AT	BE	CZ	DE	DK	FR	GR	IE	IT	PL	RS	SE	SI	Common	
SFH (single family houses)															
A_C_Ref	173	214	107	177	124	118	167	121	154	136	145	121	233	153	m²
	average thermal envelope area														
A_Roof	159	159	79	128	132	95	120	103	98	88	75	142	109	114	m²
A_Window	31	46	22	31	23	13	36	22	19	29	26	25	35	27	m²
A_Wall	226	209	144	167	122	103	233	131	226	113	184	200	173	172	m²
A_Floor	113	136	64	97	123	91	104	102	89	79	74	142	112	102	m²
	average thermal envelope area related to the conditioned floor area														
A_Roof / A_C_Ref	0,97	0,75	0,78	0,74	1,06	0,81	0,82	0,88	0,64	0,66	0,52	1,18	0,59	0,80	m²/m²
A_Window / A_C_Ref	0,18	0,22	0,20	0,18	0,19	0,12	0,22	0,18	0,13	0,21	0,18	0,21	0,16	0,18	m²/m²
A_Wall / A_C_Ref	1,33	0,98	1,38	0,98	0,98	0,88	1,42	1,09	1,51	0,87	1,27	1,68	0,78	1,17	m²/m²
A_Floor / A_C_Ref	0,69	0,64	0,64	0,57	0,99	0,79	0,70	0,87	0,57	0,59	0,51	1,18	0,58	0,72	m²/m²
TH (terraced houses)															
A_C_Ref	193	175	101	124	111	108	-	97	114	285	-	-	178	149	m²
	average thermal envelope area														
A_Roof	135	95	68	70	99	87	-	60	73	201	-	-	116	100	m²
A_Window	31	32	13	25	21	10	-	18	14	59	-	-	30	25	m²
A_Wall	291	121	59	75	82	37	-	83	96	242	-	-	126	121	m²
A_Floor	123	82	65	61	89	86	-	59	68	169	-	-	113	92	m²
	average thermal envelope area related to the conditioned floor area														
A_Roof / A_C_Ref	0,75	0,54	0,69	0,57	0,88	0,80	-	0,62	0,64	0,71	-	-	0,69	0,69	m²/m²
A_Window / A_C_Ref	0,17	0,18	0,13	0,19	0,19	0,09	-	0,18	0,13	0,21	-	-	0,16	0,16	m²/m²
A_Wall / A_C_Ref	1,57	0,69	0,59	0,59	0,70	0,35	-	0,85	0,83	0,86	-	-	0,70	0,77	m²/m²
A_Floor / A_C_Ref	0,62	0,47	0,65	0,50	0,78	0,79	-	0,61	0,59	0,60	-	-	0,67	0,63	m²/m²
MFH (multi-family houses)															
A_C_Ref	422	960	639	911	-	2072	946	-	884	2186	-	1207	1258	1148	m²
	average thermal envelope area														
A_Roof	212	280	251	327	-	304	254	-	357	602	-	470	281	334	m²
A_Window	61	410	90	154	-	572	248	-	116	469	-	180	179	248	m²
A_Wall	400	440	481	679	-	928	751	-	996	1509	-	800	772	768	m²
A_Floor	206	270	234	310	-	288	246	-	357	602	-	470	350	333	m²
	average thermal envelope area related to the conditioned floor area														
A_Roof / A_C_Ref	0,49	0,43	0,47	0,40	-	0,16	0,29	-	0,41	0,29	-	0,39	0,24	0,36	m²/m²
A_Window / A_C_Ref	0,15	0,51	0,15	0,18	-	0,27	0,26	-	0,13	0,22	-	0,15	0,17	0,22	m²/m²
A_Wall / A_C_Ref	1,03	0,60	0,93	0,75	-	0,52	0,85	-	1,15	0,74	-	0,66	0,76	0,78	m²/m²
A_Floor / A_C_Ref	0,49	0,42	0,43	0,36	-	0,15	0,29	-	0,41	0,29	-	0,39	0,34	0,36	m²/m²
AB (apartment blocks)															
A_C_Ref	971	12392	3412	6055	1200	3573	-	1064	2201	6384	-	-	6042	4329	m²
	average thermal envelope area														
A_Roof	353	735	458	566	415	547	-	367	490	780	-	-	1023	573	m²
A_Window	170	5074	732	924	272	850	-	179	326	1614	-	-	1154	1130	m²
A_Wall	787	4168	1646	4268	590	1218	-	761	2354	3756	-	-	2618	2217	m²
A_Floor	341	1148	458	591	405	516	-	342	473	674	-	-	863	581	m²
	average thermal envelope area related to the conditioned floor area														
A_Roof / A_C_Ref	0,37	0,10	0,19	0,17	0,40	0,16	-	0,34	0,23	0,12	-	-	0,14	0,22	m²/m²
A_Window / A_C_Ref	0,18	0,44	0,20	0,17	0,22	0,24	-	0,17	0,15	0,25	-	-	0,21	0,22	m²/m²
A_Wall / A_C_Ref	0,82	0,36	0,58	0,70	0,57	0,39	-	0,70	1,07	0,62	-	-	0,56	0,64	m²/m²
A_Floor / A_C_Ref	0,36	0,23	0,19	0,16	0,38	0,15	-	0,32	0,22	0,10	-	-	0,13	0,22	m²/m²

B.3. Example Buildings: Cross-Country Comparison of Average U-Values by Decades

The example-building database offers the opportunity to compare typical U-values for different time bands between countries. To attain this goal the following analysis has been conducted:

- For each example building average U-values have been determined for the four envelope types: roof, window, wall, and floor.
- Mean U-values have then been calculated for all relevant decades by averaging over the example buildings representing the four building size classes. In case that a change of construction year class occurs during a decade the average was based on the concerning two construction year classes weighted by the respective share of years.

The following mean U-values have been calculated by use of this procedure (data source: sheet "Tab.Building"):

Table 63: Average U-values of example buildings by country and decade

decade	AT	BE	CZ	DE	DK	FR	GR	IE	IT	PL	SE	SI
	U-values of roofs [W/(m²K]											
... 1900	1,46	2,42	1,55	1,46	0,52	0,85	2,88	1,01	2,15	0,83	0,34	1,63
1901 ... 1910	1,46	2,42	1,55	1,23	0,63	2,48	2,88	1,01	2,28	0,83	0,34	1,63
1911 ... 1920	1,39	2,42	1,55	1,20	0,63	2,46	2,88	1,01	2,28	0,83	0,34	1,63
1921 ... 1930	1,10	2,42	1,59	1,08	0,63	2,45	2,88	1,01	2,38	0,83	0,34	1,63
1931 ... 1940	1,10	2,42	1,59	1,08	0,82	2,45	2,88	1,01	2,38	0,83	0,34	1,63
1941 ... 1950	1,13	2,56	1,50	1,13	0,82	2,48	2,88	1,01	2,16	0,70	0,34	1,38
1951 ... 1960	1,15	2,70	1,40	1,14	0,42	2,30	2,88	1,01	1,95	0,57	0,34	1,14
1961 ... 1970	0,78	2,70	0,75	0,63	0,30	2,18	2,88	1,01	1,88	0,58	0,20	1,14
1971 ... 1980	0,78	0,90	0,75	0,54	0,30	2,08	2,88	0,82	1,45	0,60	0,20	1,11
1981 ... 1990	0,48	0,90	0,48	0,42	0,18	1,52	1,79	0,40	1,03	0,59	0,17	0,43
1991 ... 2000	0,29	0,55	0,40	0,38	0,18	1,40	1,79	0,34	0,70	0,48	0,12	0,43
	U-values of walls [W/(m²K]											
... 1900	1,10	2,20	1,34	1,68	1,10	1,60	2,30	2,04	1,39	1,73	0,70	1,83
1901 ... 1910	1,10	2,20	1,34	1,83	1,12	2,45	2,30	2,04	1,48	1,73	0,70	1,83
1911 ... 1920	1,25	2,20	1,34	1,79	1,12	2,22	2,30	2,04	1,48	1,73	0,70	1,83
1921 ... 1930	1,84	2,20	1,37	1,63	1,12	2,13	2,30	2,04	1,56	1,73	0,70	1,83
1931 ... 1940	1,84	2,20	1,37	1,63	1,21	2,13	2,30	2,04	1,56	1,73	0,70	1,83
1941 ... 1950	1,50	1,95	1,39	1,55	1,21	2,10	2,30	2,04	1,57	1,67	0,70	1,56
1951 ... 1960	1,27	1,70	1,40	1,24	1,03	2,42	2,30	2,04	1,58	1,60	0,70	1,29
1961 ... 1970	1,29	1,70	1,06	1,15	0,64	2,34	2,30	2,04	1,27	1,42	0,38	1,29
1971 ... 1980	1,29	1,12	1,06	0,92	0,47	1,06	2,30	1,78	1,04	1,15	0,34	1,02
1981 ... 1990	0,83	1,12	0,63	0,61	0,37	0,52	1,44	0,74	0,80	1,10	0,28	0,48
1991 ... 2000	0,39	0,60	0,50	0,47	0,35	0,46	1,44	0,61	0,60	0,41	0,27	0,48
	U-values of windows [W/(m²K]											
... 1900	2,2	5,0	2,4	3,0	2,7	4,4	4,7	5,3	5,1	5,0	2,3	2,4
1901 ... 1910	2,2	5,0	2,4	3,1	2,7	3,8	4,7	5,3	5,1	5,0	2,3	2,4
1911 ... 1920	2,1	5,0	2,4	3,2	2,7	3,8	4,7	5,3	5,1	5,0	2,3	2,4
1921 ... 1930	1,8	5,0	2,4	3,5	2,7	3,8	4,7	5,3	5,1	5,0	2,3	2,4
1931 ... 1940	1,8	5,0	2,4	3,5	2,6	3,8	4,7	5,3	5,1	5,0	2,3	2,4
1941 ... 1950	2,3	5,0	2,6	3,5	2,6	3,7	4,7	5,3	5,0	4,6	2,3	2,2
1951 ... 1960	2,7	5,0	2,8	3,5	2,7	3,7	4,7	5,3	4,9	4,2	2,3	2,1
1961 ... 1970	2,2	5,0	2,7	3,5	2,6	4,1	4,7	5,3	4,9	3,6	2,3	2,1
1971 ... 1980	2,2	3,9	2,7	3,5	2,6	3,8	4,7	4,8	4,1	2,6	2,1	2,2
1981 ... 1990	2,0	3,9	2,3	3,4	2,4	2,6	5,0	3,3	3,3	2,6	1,9	1,7
1991 ... 2000	1,3	3,5	1,9	2,4	2,3	2,2	5,0	2,9	2,8	1,8	1,9	1,7
	U-values of floors [W/(m²K]											
... 1900	1,25	0,90	2,00	1,47	0,84	3,34	2,88	1,44	1,70	2,07	0,34	1,80
1901 ... 1910	1,25	0,90	2,00	1,20	1,00	2,20	2,88	1,44	1,95	2,07	0,34	1,80
1911 ... 1920	1,21	0,90	2,00	1,16	1,00	1,97	2,88	1,44	1,95	2,07	0,34	1,80
1921 ... 1930	1,05	0,90	1,50	1,00	1,00	1,87	2,88	1,44	1,95	2,07	0,34	1,80
1931 ... 1940	1,05	0,90	1,50	1,00	1,32	1,87	2,88	1,44	1,95	2,07	0,34	1,80
1941 ... 1950	1,57	0,90	1,45	1,17	1,32	1,93	2,88	1,44	1,71	1,88	0,34	1,62
1951 ... 1960	1,92	0,90	1,40	1,78	0,75	2,00	2,88	1,44	1,48	1,70	0,34	1,44
1961 ... 1970	0,88	0,90	1,28	1,48	0,65	1,61	2,88	1,44	1,65	1,60	0,30	1,44
1971 ... 1980	0,88	0,90	1,28	0,95	0,42	0,63	2,88	1,35	1,33	1,45	0,30	0,97
1981 ... 1990	0,61	0,90	0,98	0,65	0,27	0,62	2,47	1,14	1,00	1,35	0,27	0,69
1991 ... 2000	0,40	0,70	0,74	0,52	0,25	0,55	2,47	0,94	0,80	0,94	0,22	0,69

Figure 49: Comparison of average U-values of roofs and upper ceilings

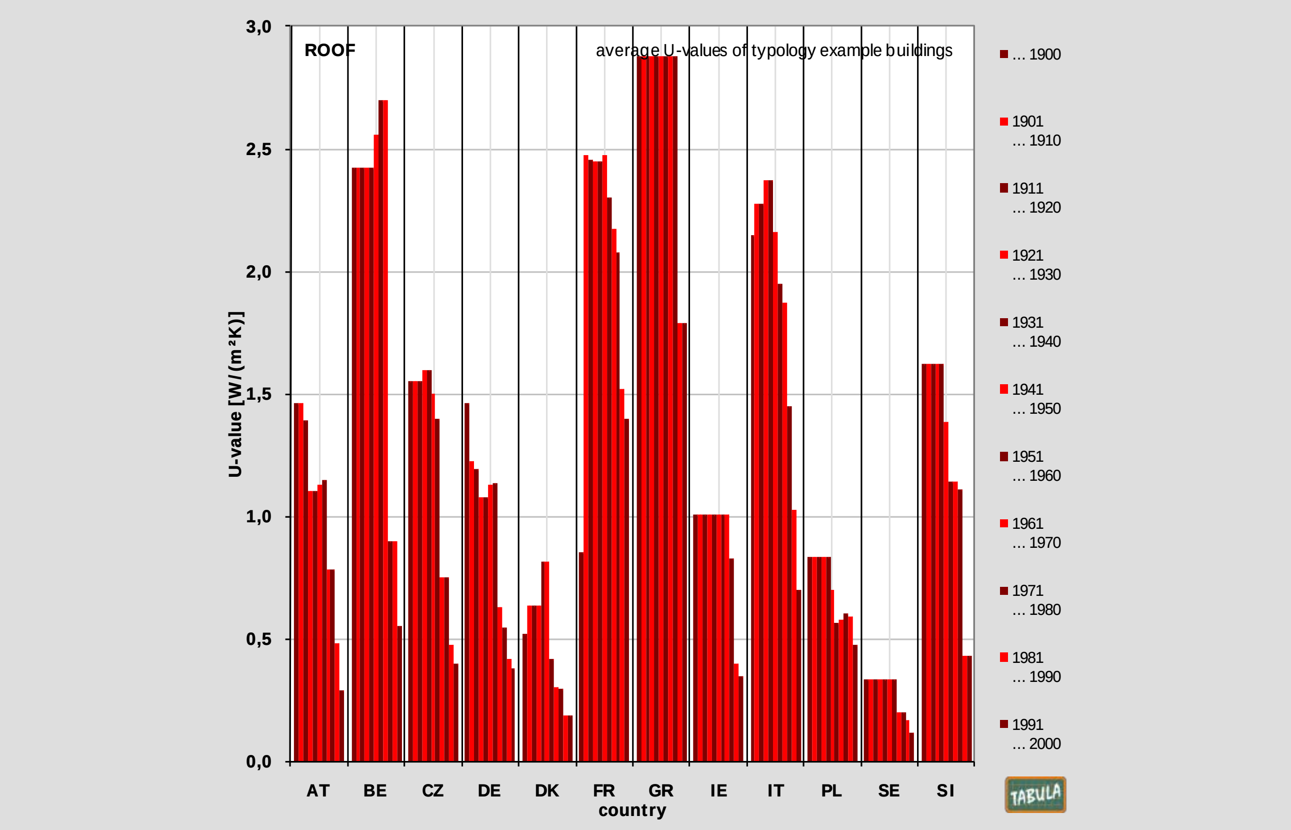


Figure 50: Comparison of average U-values of walls

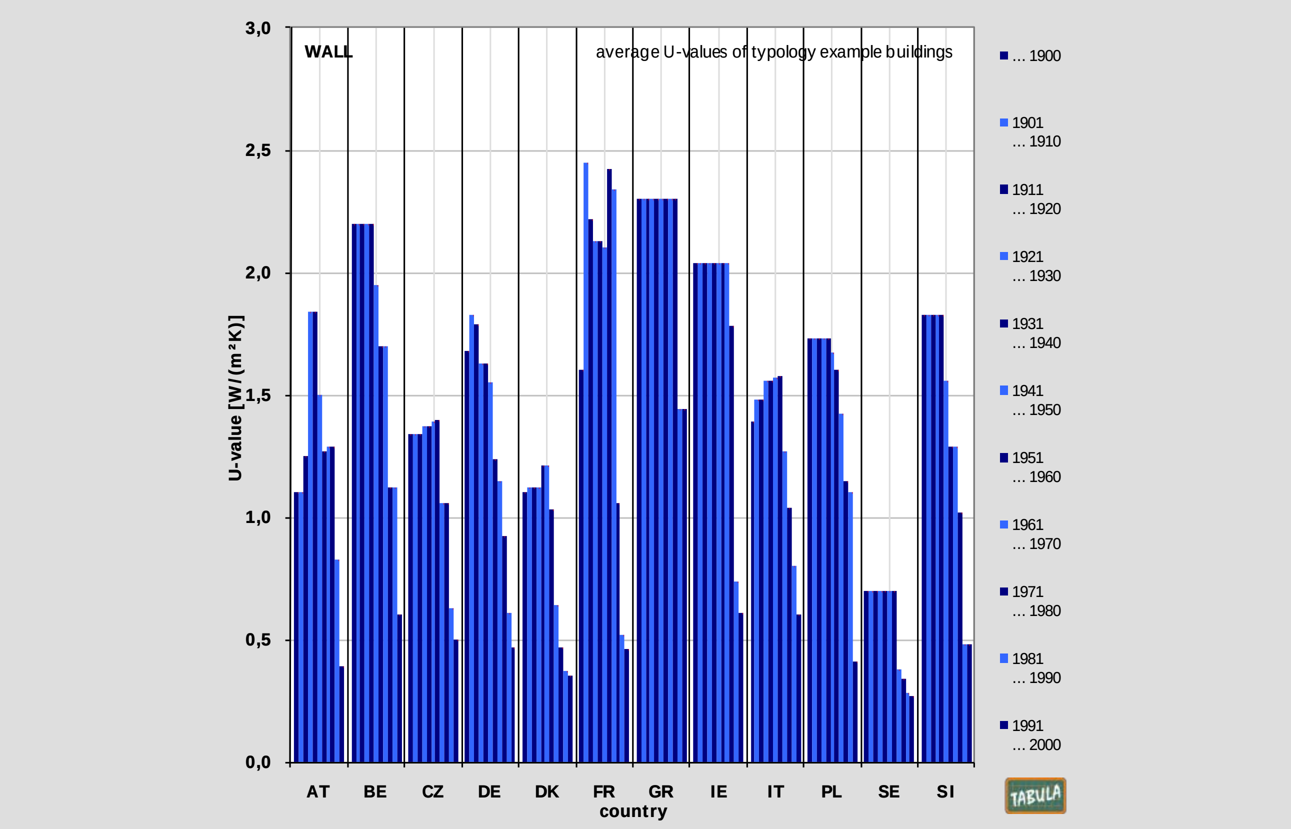


Figure 51: Comparison of average U-values of windows

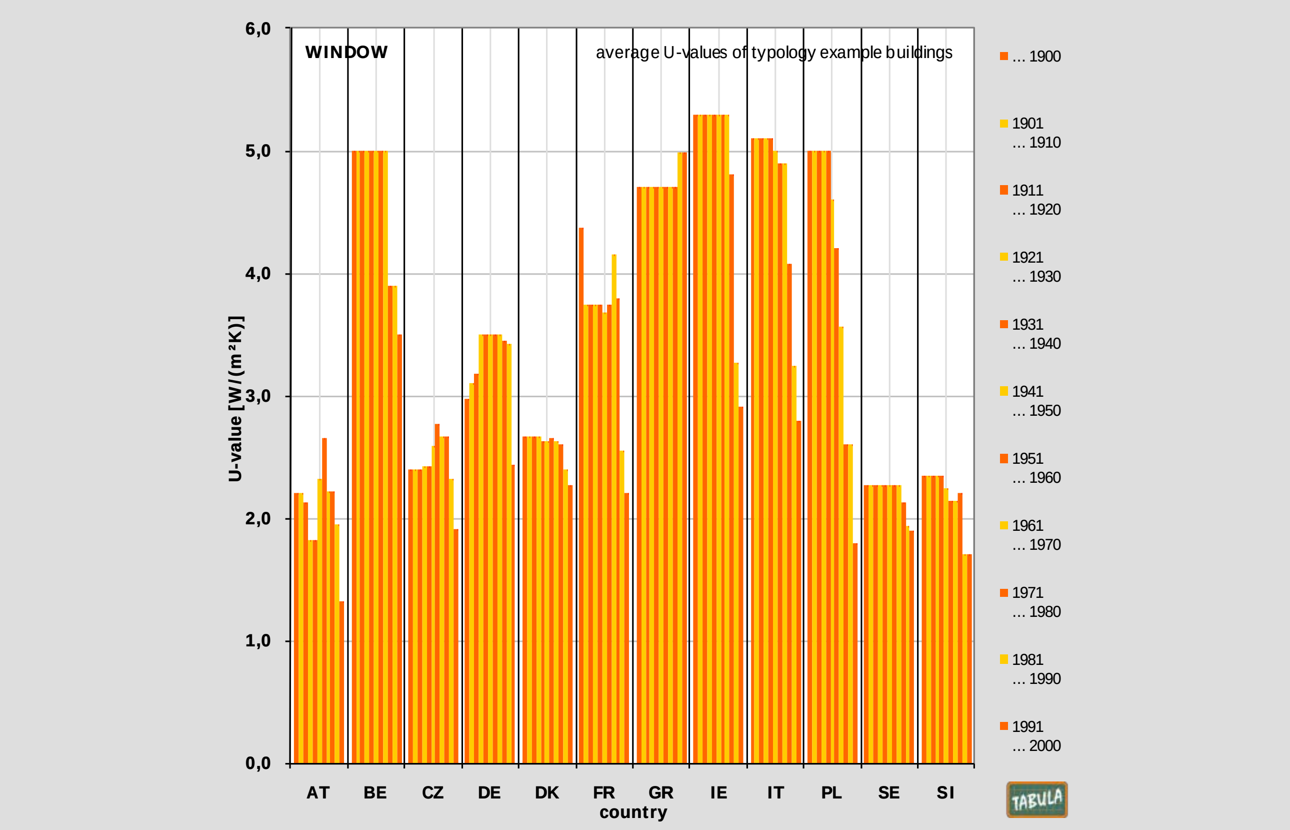
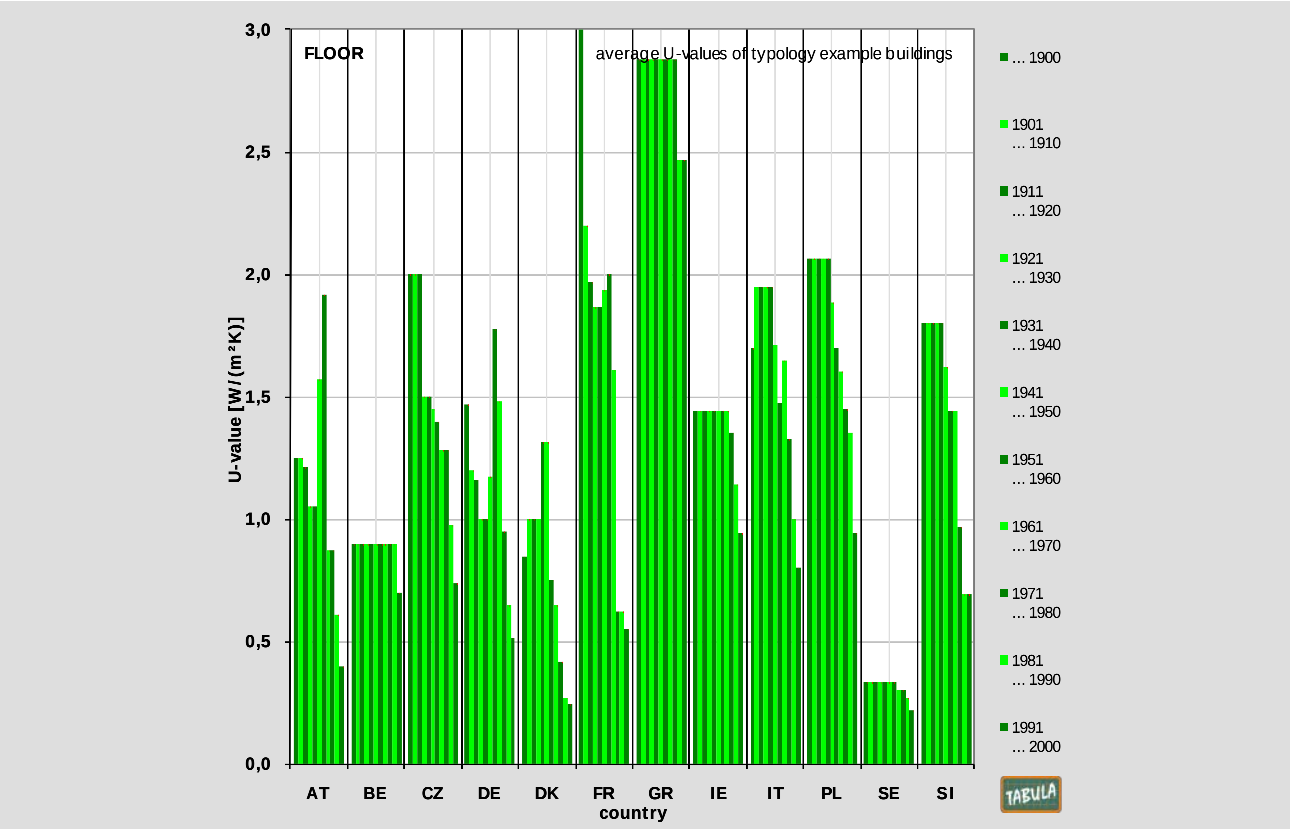


Figure 52: Comparison of average U-values of floors



B.4. Construction Database: Evaluation of U-values by Construction Type and National Period

The construction catalogue (sheet "Tab.Building.Constr") was analysed in the following way:

- For each building average U-values have been determined for the four construction types: roof, upper ceiling, wall, and floor. If the information was available a differentiation was made between massive (structures of masonry, concrete, steel, …) and wooden (timber frame, wooden beam ceilings, rafters, …) constructions.
- Mean U-values have then be calculated for each national construction year class by averaging over the example buildings representing the four building size classes of the respective time band.

The following table shows the results:

Table 64: Evaluation of the construction catalogue / opaque elements

Country Code	Construction Year Class Code	from ... to	Roof massive / wooden	Upper Ceiling massive / wooden	Wall massive / wooden	Floor massive / wooden
			U-Value [W/m²K]			
AT	AT.01	... 1918	1,4	1,50	1,50	1,25
	AT.02	1919 ... 1944	0,95	1,70 / 1,05	1,73	1,55
	AT.03	1945 ... 1960	0,90	1,70 / 0,78	1,27	2,30
	AT.04	1961 ... 1980	0,60	1,67	1,18	0,95
	AT.05	1981 ... 1990	0,49	0,65	0,83	0,70
	AT.06	1991 ... 2000	0,29	0,30	0,31	0,50
BE	BE.01	... 1945	3,50 / 1,70	-	2,13	1,43
	BE.02	1946 ... 1970	3,50 / 1,80	-	1,70	0,85
	BE.03	1971 ... 1990	1,10	-	1,53 / 0,50	0,85
	BE.04	1991 ... 2005	0,59	-	0,68 / 0,50	0,75
CZ	CZ.01	... 1920	2,60	1,20	1,42	2,02
	CZ.02	1921 ... 1945	2,12	2,20	1,43	1,50
	CZ.03	1946 ... 1960	1,23	1,45 / 1,30	1,43	1,24
	CZ.04	1961 ... 1980	0,71	1,53	1,15	1,26
	CZ.05	1981 ... 1994	0,41	0,60	0,76	0,85
	CZ.06	1994 ...	0,30	-	0,38	0,49
DE	DE.01	... 1859	1,95	1,00	2,10	2,90 / 1,20
	DE.02	1860 ... 1918	1,95	1,00	2,10	2,90 / 1,20
	DE.03	1919 ... 1948	1,68	0,80	1,55	1,05
	DE.04	1949 ... 1957	1,40	1,85 / 0,80	1,27	1,77
	DE.05	1958 ... 1968	1,10	1,85 / 0,80	1,27	1,57
	DE.06	1969 ... 1978	0,60	0,60	1,07 / 0,60	1,00
	DE.07	1979 ... 1983	0,50	0,50	0,77 / 0,50	0,80
	DE.08	1984 ... 1994	0,40	0,40 / 0,30	0,63 / 0,40	0,60
	DE.09	1995 ... 2001	0,35	0,35 / 0,27	0,53 / 0,30	0,45
GR	GR.01	... 1980	2,27	-	2,72	1,91
	GR.02	1981 ... 2000	1,82 / 0,68	-	0,86	1,21
	GR.03	2001 ...	0,67	-	0,80	1,25
IE	IE.01	... 1977	2,30 / 1,49	-	2,04	1,41
	IE.02	1978 ... 1982	0,40	-	1,10	1,15
	IE.03	1983 ... 1993	0,40	-	0,60	1,15
	IE.04	1994 ... 2004	0,35 / 0,31	-	0,55	0,84
IT	IT.01	... 1900	1,80	2,37	1,61	1,93
	IT.02	1901 ... 1920	1,80	2,41	1,61	1,82
	IT.03	1921 ... 1945	2,03 / 1,80	2,00	1,31	1,65
	IT.04	1946 ... 1960	2,03	1,65	1,82	1,65
	IT.05	1961 ... 1975	2,03	1,65	1,82	1,65
	IT.06	1976 ... 1990	1,08 / 0,95	0,97	0,79	1,11
	IT.07	1991 ... 2005	0,72 / 0,64	0,69	0,60	0,85
PL	PL.01	... 1945	0,90 / 0,77	-	1,75 / 0,40	2,00
	PL.02	1946 ... 1966	0,53	-	1,29 / 0,40	1,65
	PL.03	1967 ... 1985	0,53	-	1,29 / 0,40	1,45
	PL.04	1986 ... 1992	0,43	-	0,98 / 0,40	1,25
	PL.05	1993 ... 2002	0,43	-	0,29	0,90
SE	SE.01	... 1960	-	0,33	0,83 / 0,53	0,32
	SE.02	1961 ... 1975	-	0,21	0,36	0,30
	SE.03	1976 ... 1985	-	0,16	0,27	0,28
	SE.04	1986 ... 1995	-	0,14	0,20	0,25
	SE.05	1996 ... 2005	-	0,13	0,20	0,20
SI	SI.01	... 1945	2,70	1,40 / 1,00	1,50 / 0,70	2,05
	SI.02	1946 ... 1970	1,80	1,23 / 1,00	1,60	1,40
	SI.03	1971 ... 1980	0,90	1,00	1,10 / 0,26	0,96
	SI.04	1981 ... 2001	0,43	0,46	0,48 / 0,21	0,65

The analysis of the windows was based on the same procedure. In this case the differentiation concerns the numbers of panes, the type of glazing (standard / low-e) and the frame type (see Table 65). The column "Common" is reflecting the average of the available values.

Table 65: Evaluation of the construction catalogue / windows

Number of panes	Special glazing	Frame type	AT	BE	CZ	DE	DK	FR	GR	IE	IT	PL	SE	SI	Common
			U-Value window [W/m²K]												
1	-	not specified	-	-	-	-	-	-	4,7	-	-	-	-	-	4,7
	-	wood	4,6	5,0	-	3,9	4,4	4,2	-	-	4,9	4,5	-	5,2	4,6
	-	plastic	-	-	-	-	-	3,8	-	4,8	-	-	-	-	4,3
	-	metal	-	5,7	-	-	-	6,0	6,1	5,7	5,7	-	-	-	5,8
2	-	not specified	2,5	-	2,6	-	-	2,7	-	2,8	-	2,6	-	-	2,6
	-	wood	2,3	3,5	-	3,1	2,8	2,8	2,7	-	2,8	(1,8)	-	2,4	2,8
	-	plastic	(1,4)	(3,5)	-	(3,5)	-	-	3,1	3,1	-	(1,4)	-	2,6	2,9
	-	metal	-	4,3	-	4,3	-	-	3,9	3,7	3,7	-	-	-	4,0
	-	metal, thermal break	-	3,5	-	3,5	-	-	3,3	3,4	3,4	-	-	-	3,4
	low-e	not specified	-	-	1,3	-	-	-	-	1,9	-	-	-	-	1,6
	low-e	wood	-	1,6	-	1,5	1,7	-	(2,3)	-	2,2	-	-	1,5	1,7
	low-e	plastic	(1,2)	1,7	-	1,7	-	-	(2,9)	-	-	-	-	1,2	1,5
	low-e	metal	-	-	-	-	-	-	(4,0)	-	-	-	-	(1,5)	-
	low-e	metal, thermal break	-	-	-	1,7	-	-	2,9	-	2,4	-	-	-	2,3
3	-	wood	1,4	-	-	-	-	-	-	-	-	1,9	-	-	1,7
	low-e	wood	-	1,1	-	1,0	1,0	-	-	-	-	-	-	0,8	1,0
	low-e	plastic	-	1,1	-	1,0	-	-	-	-	-	-	-	0,7	0,9
	low-e	metal	-	-	-	-	-	-	-	-	-	-	-	0,9	0,9
	low-e	insulated ("passive house window")	0,8	0,9	-	0,8	-	-	-	-	-	-	-	-	0,8

Remarks
Values which deviate more than +/- 30% from the average are listed in brackets and are not considered in the column "Common".

The values are mostly very close, however in some cases large deviations can be observed. The deviations can in principle be explained by different window sizes, glazing distances, gas fillings and glass spacer types. Nevertheless, also errors might have occurred when entering the information into the data sheet.

This should be clarified by the partners during future data revisions.

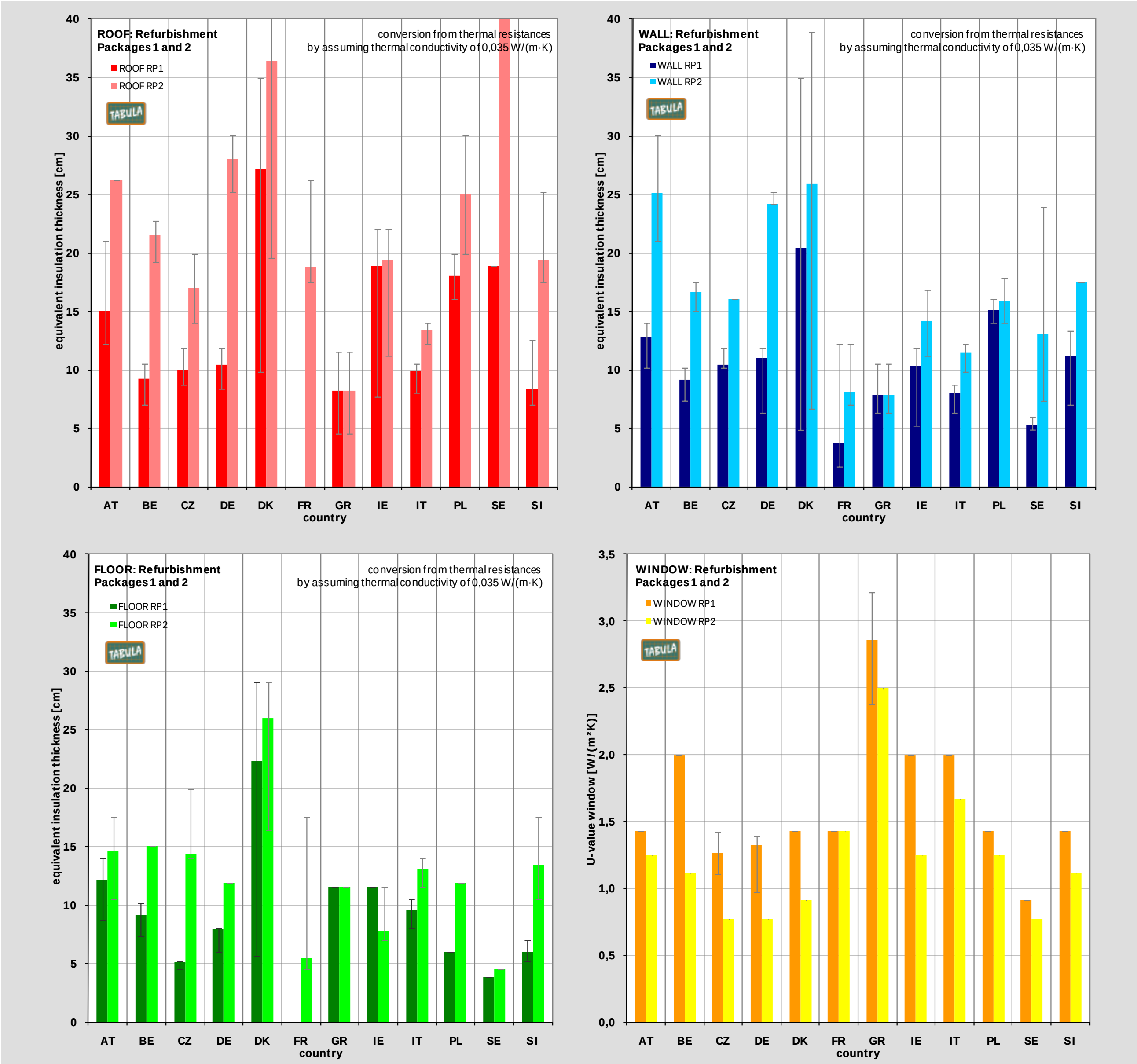
B.5. Measures for Upgrading the Thermal Envelope

The TABULA concept includes the definition of two levels of insulation measures:

- **Refurbishment Package 1: "Standard"**
  Package of measures for upgrading the thermal envelope and the heat supply system which are commonly realised during renovation;
- **Refurbishment Package 2: "Advanced":**
  Package of measures for upgrading the thermal envelope and the heat supply system, that are usually only realised in very ambitious renovations or research projects.

The insulation measure catalogue contains information about the type of measure and the thermal resistances. These values were transformed into equivalent insulation thicknesses in order to get more illustrative values (by applying a standard thermal conductivity of 0,035 W/(m·K)). The result is displayed in the following charts.

Figure 53: Comparison of standard and advanced refurbishment measures for each envelope type



B.6. Energy Performance of Typical Heat Supply Systems

B.6.1. Description of the Proceeding

The evaluation of supply system characteristics was performed on the basis of 1203 datasets from 12 countries. The values had been determined by each partner on the basis of national methods.[4] The following components were considered:

- HG – Heating Systems / Heat Generation
- HS – Heating Systems / Heat Storage
- HD – Heating Systems / Heat Distribution
- HA – Heating Systems / Auxiliary Energy
- WG – Domestic Hot Water Systems / Heat Generation
- WS – DHW Systems / Heat Storage
- WD – Domestic Hot Water Systems / Heat Distribution
- WA – DHW Systems / Auxiliary Energy
- Vent – Ventilation Systems
- EC – Assessment Factors of Energy Carriers

For each of these components the data analysis comprised the following steps:

- **Overview of existing data:**
  A data analyses was performed by use of the programme "R". Minimum, maximum and average values were determined for different subgroups differentiating between single and multi-family houses.[5]
- **Condensed values:**
  In order to reduce the complexity some of the existing subgroups of component types were merged in so called "condensed values" The averages and extreme values are now referred to as "poor", "medium" and "high" energy efficiency.
- **Simplified common values / default values:**
  As a last step the averages of each subsystem were transferred into a separate table ("default values / simplified common values"). These tabled values can in the future be useful for rough supranational estimations or in case that national values are not available. Nevertheless, the respective values should be provided for each country finally in order to reflect the specific national technology. It is intended to rerepeat this evaluation after a possible future update of the database in order to improve the reliability of the derived common values.

[4] see national scientific reports at: http://www.building-typology.eu/tabulapublications.html

[5] For details consult the specific work report available at the TABULA WebSite.

B.6.2. HG – Heating Systems / Heat Generation

Figure 54: Heat generation expenditure factors of heating systems (1)
boilers: <B_NC> non-condensing, <B_C> condensing, <B_WP> wood-pellets

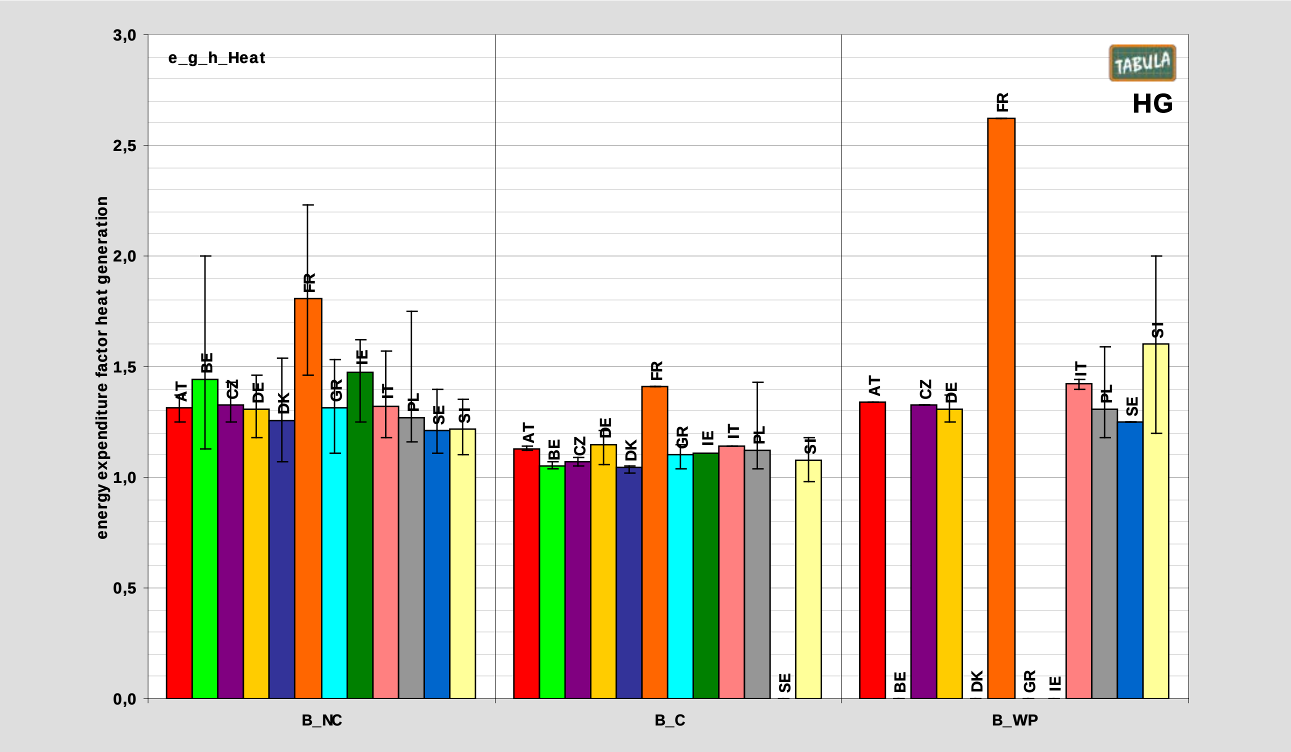


Figure 55: Heat generation expenditure factors of heating systems (2)
electrical heat pumps, heat sources: <HP_Air> external air, <HP_Ground> ground, <HP_ExhAir> exhaust air

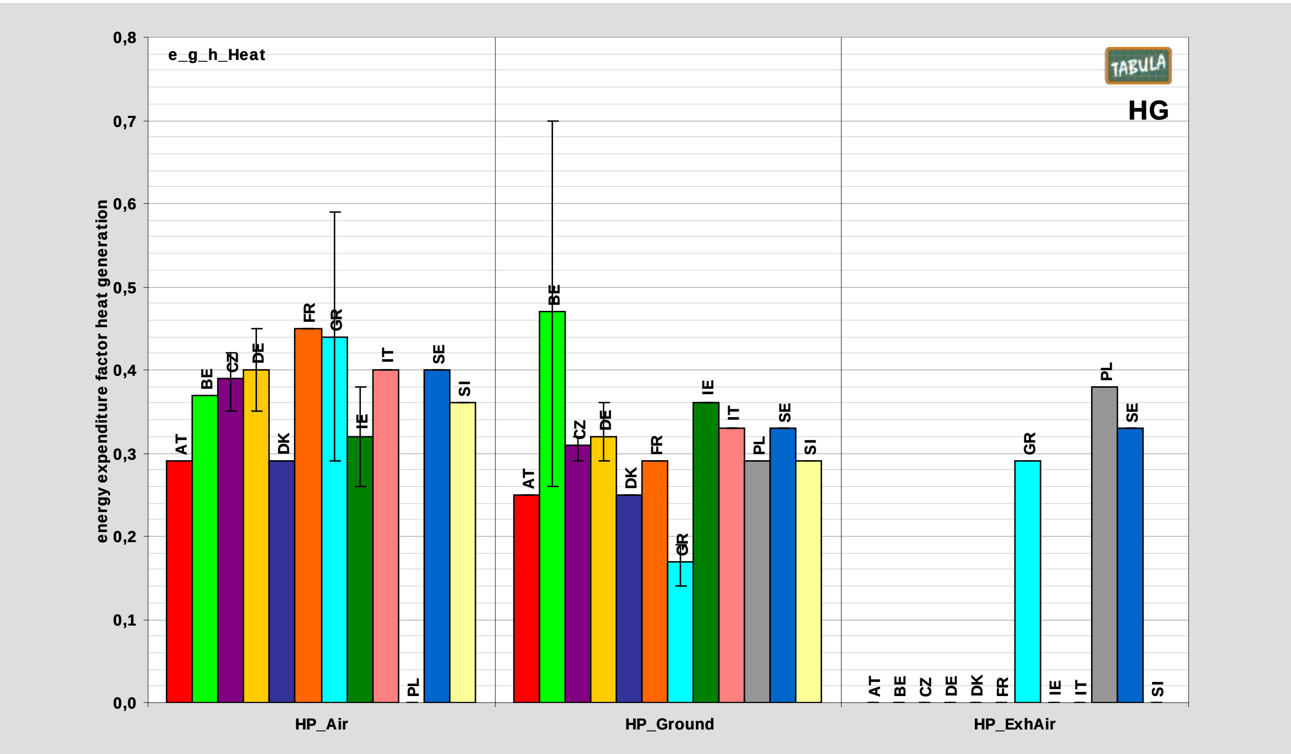
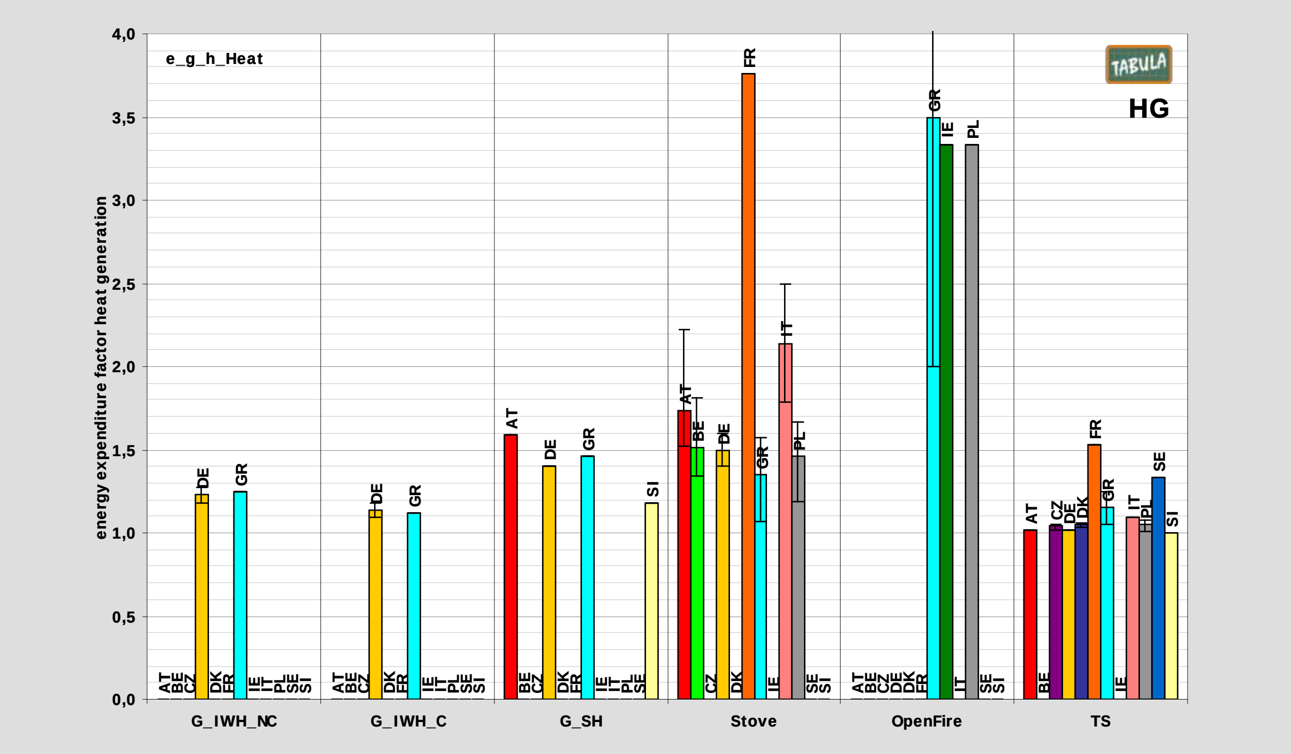
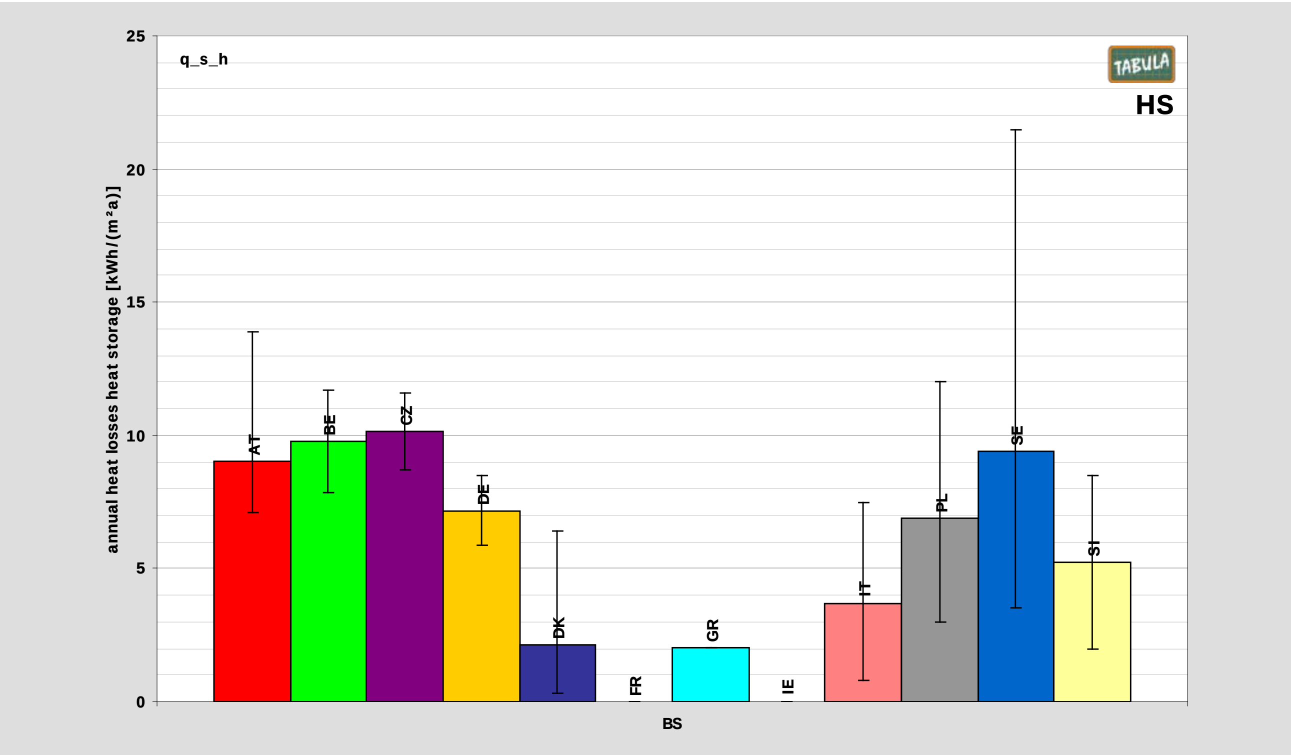


Figure 56: Heat generation expenditure factors of heating systems (3)
gas-fired instantaneous water heaters: <G_IWH_NC> non-condensing, <G_IWH_C> condensing; <G_SH> gas-fired space heater; <Stoves> stoves; <OpenFire> open fires; <TS> district heating transfer station



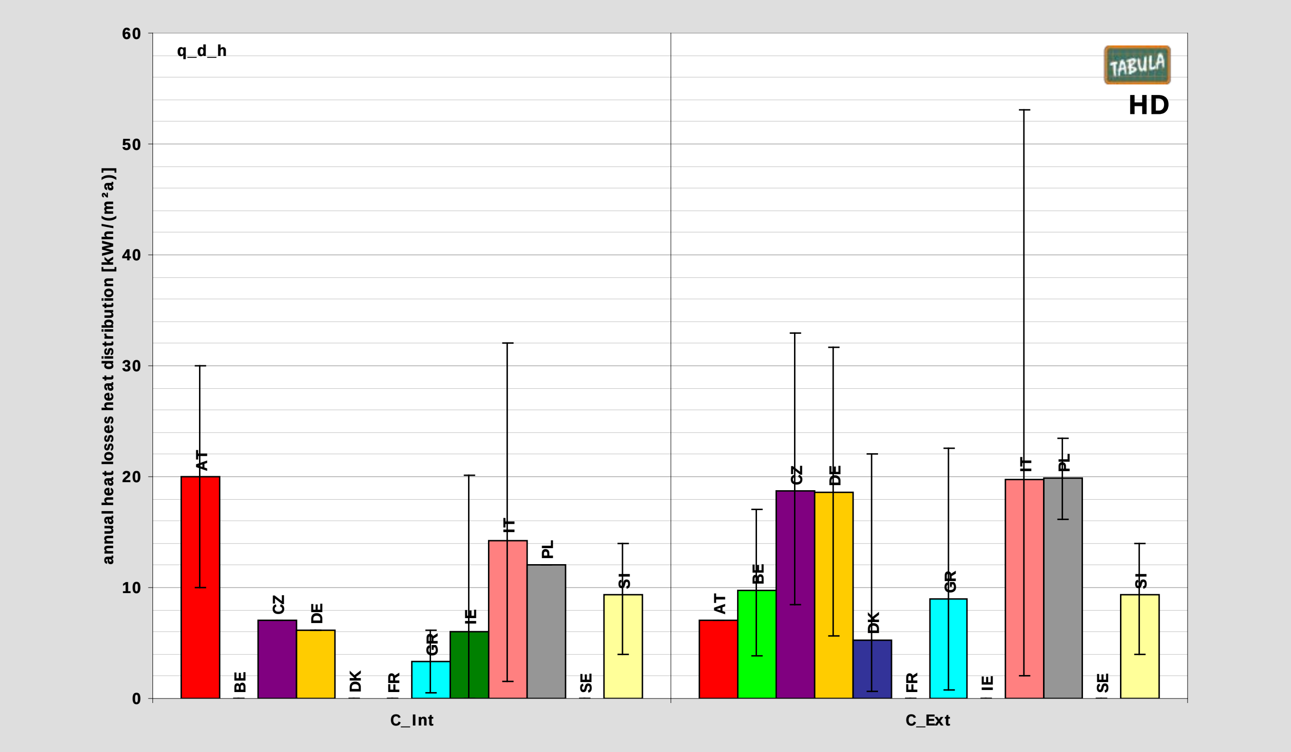
B.6.3. HS – Heating Systems / Heat Storage

Figure 57: Annual storage heat losses of heating systems
<BS> buffer storages



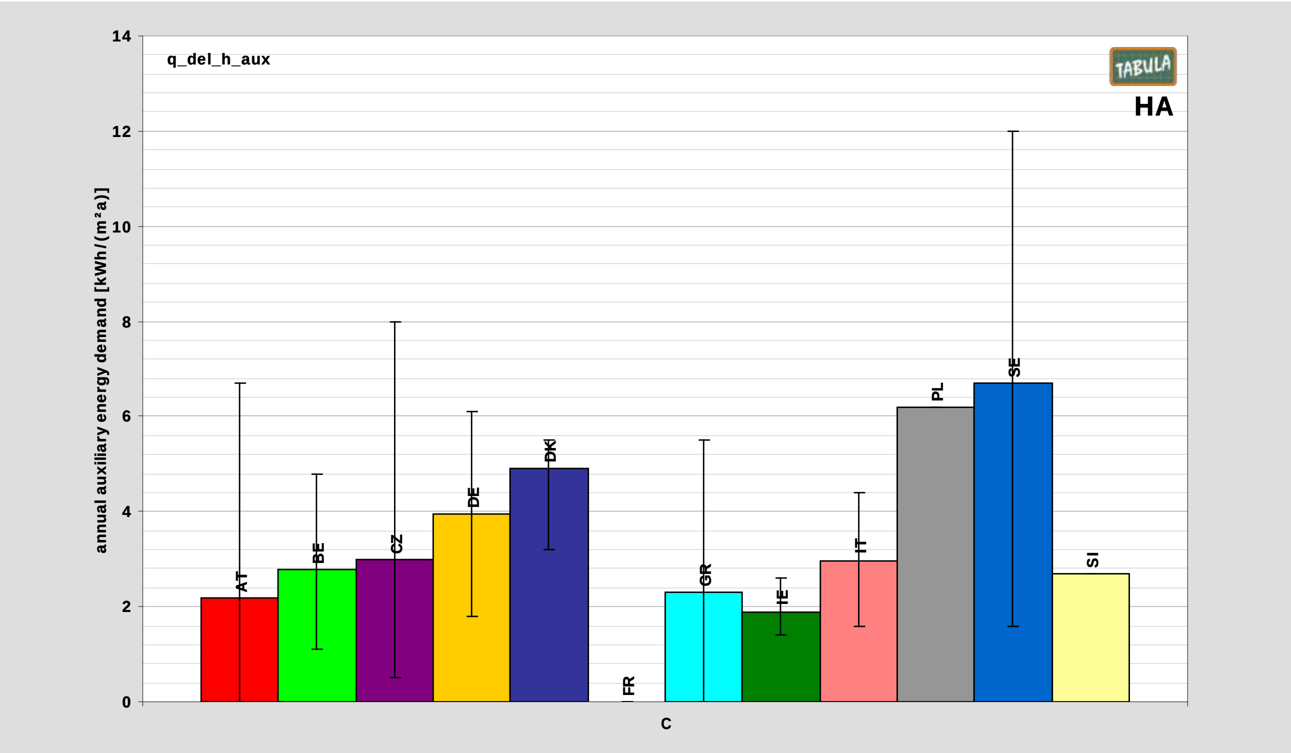
B.6.4. HD – Heating Systems / Heat Distribution

Figure 58: Annual distribution heat losses of heating systems /
central heating: <C_Int> all pipes inside of thermal envelope; <C_Ext> fraction of pipeline outside of thermal envelope



B.6.5. HA – Heating Systems / Auxiliary Energy

Figure 59: Annual auxiliary electricity demand of space heating systems /
<C> central heating systems



B.6.6. WG – Domestic Hot Water Systems / Heat Generation

Figure 60: Heat generation expenditure factors of DHW systems /
boilers: <B_NC> non-condensing, <B_C> condensing, <B_WP> wood-pellets

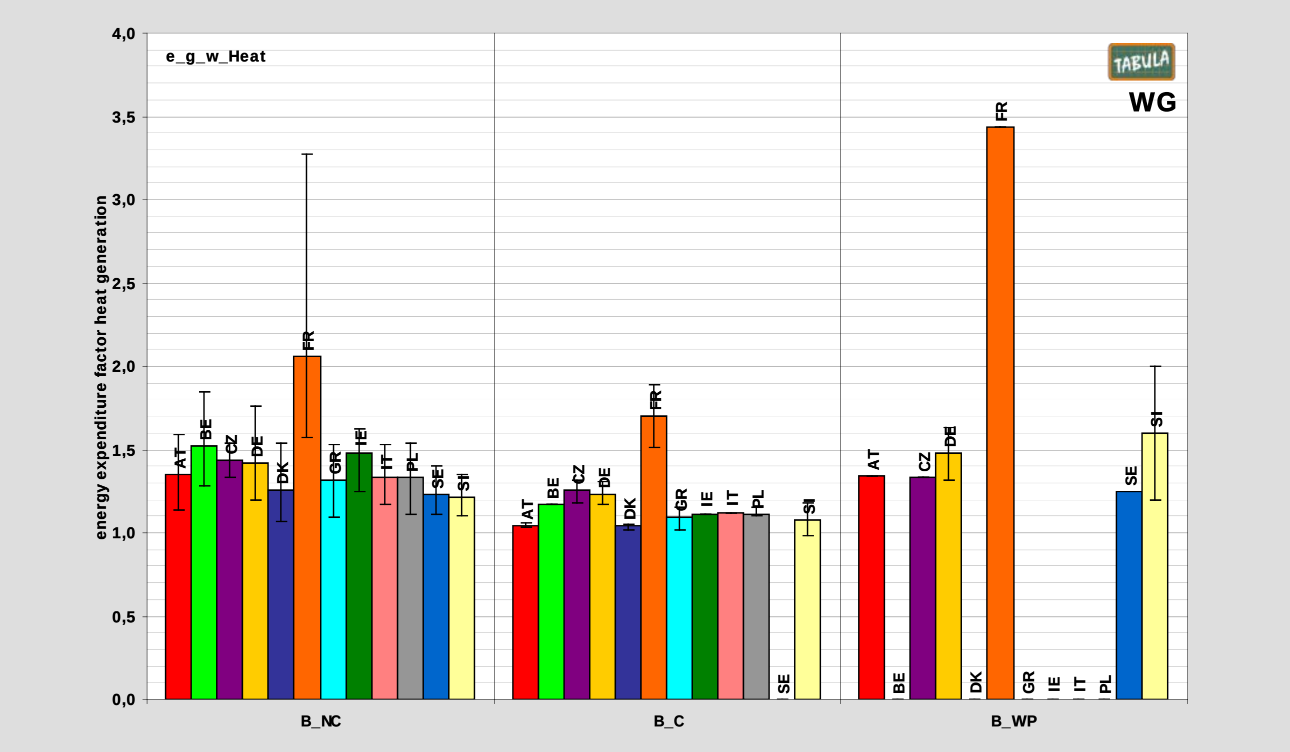


Figure 61: Heat generation expenditure factors of DHW systems /
<E_Immersion> electric immersion heaters, <E> or <E_IWH> electric instantaneous water heaters, electrical heat pumps, heat sources: <HP_Air> external air, <HP_Ground> ground, <HP_ExhAir> exhaust air, <HP_Cellar> cellar air

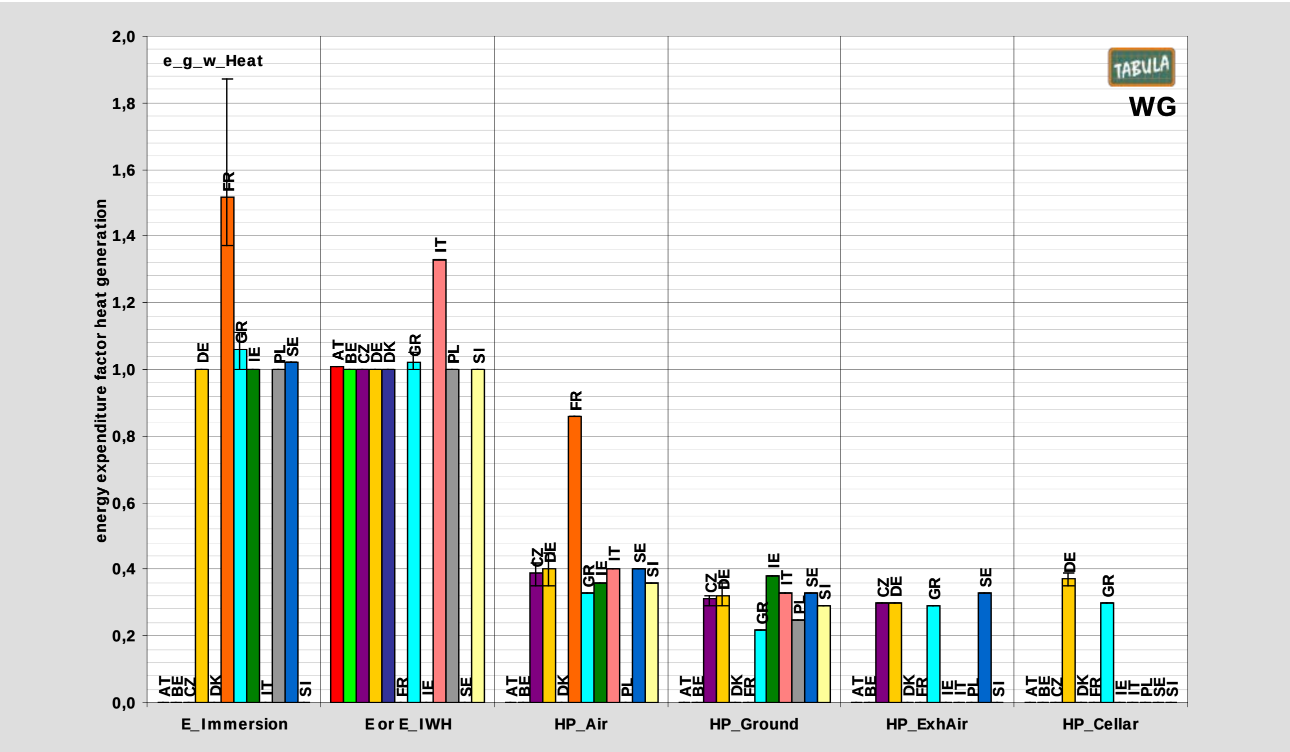
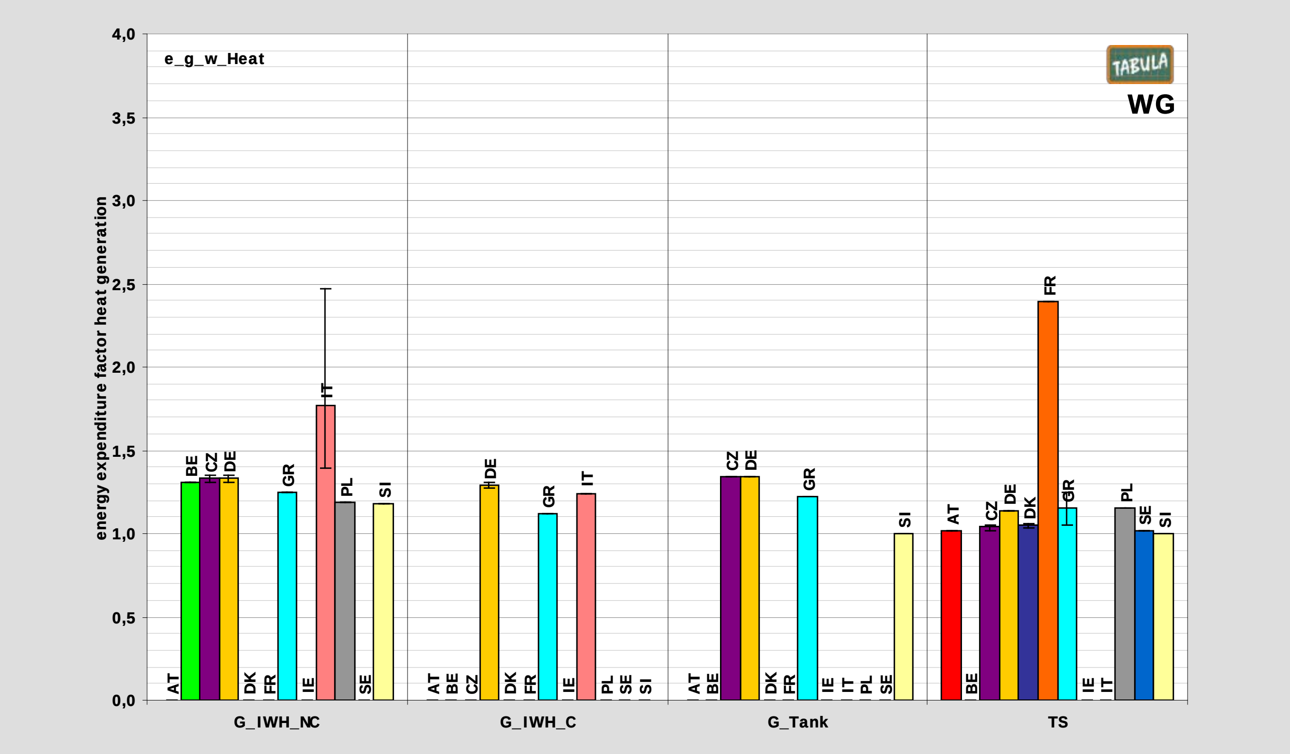


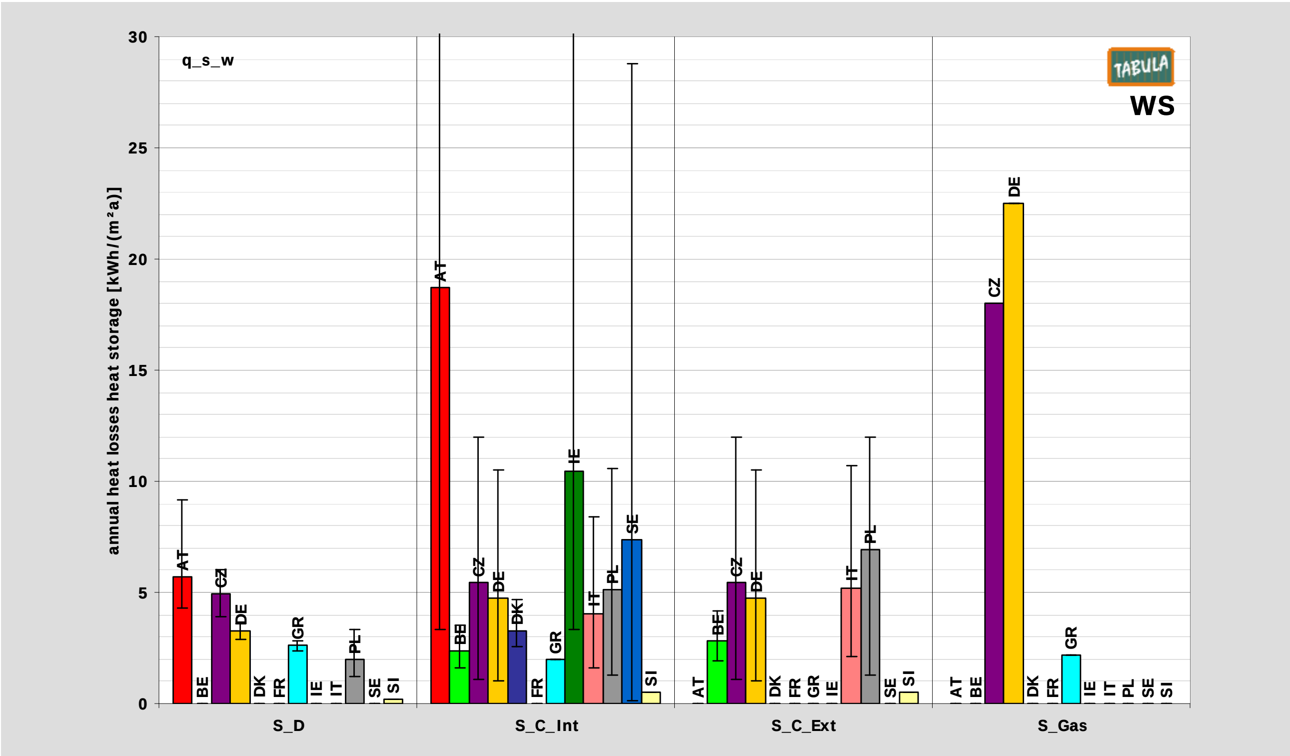
Figure 62: Heat generation expenditure factors of DHW systems /
gas-fired instantaneous water heaters: <G_IWH_NC> non-condensing, <G_IWH_C> condensing; <G_Tank> gas burner for directly heated DHW tank (not including storage losses), <TS> district heating transfer station

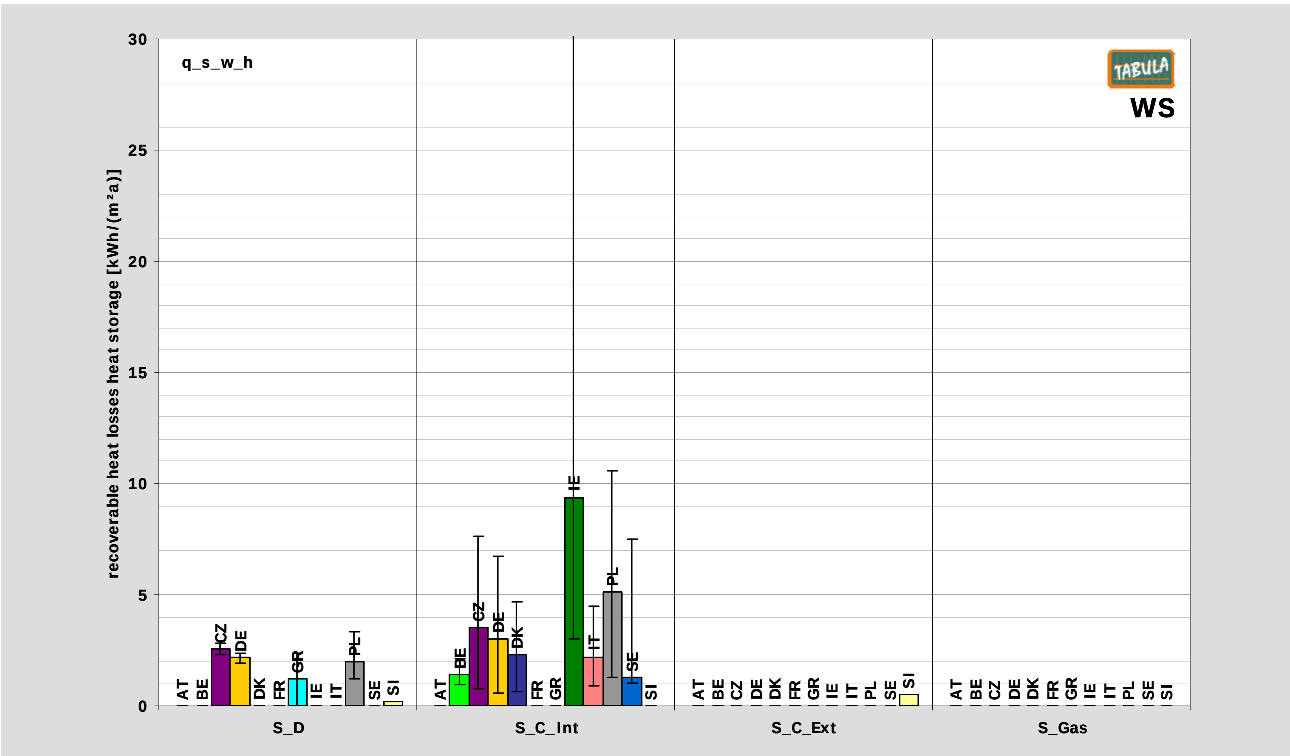


B.6.7. WS – DHW Systems / Heat Storage

Figure 62: Annual storage heat losses of DHW systems + recoverable fraction

<S_D> decentral electric hot water storage; <S_C_Ent> central hot water storage, inside of thermal envelope; <S_C_Ext> central hot water storage, outside of thermal envelope; <S_Gas> directly gas heated hot water storage

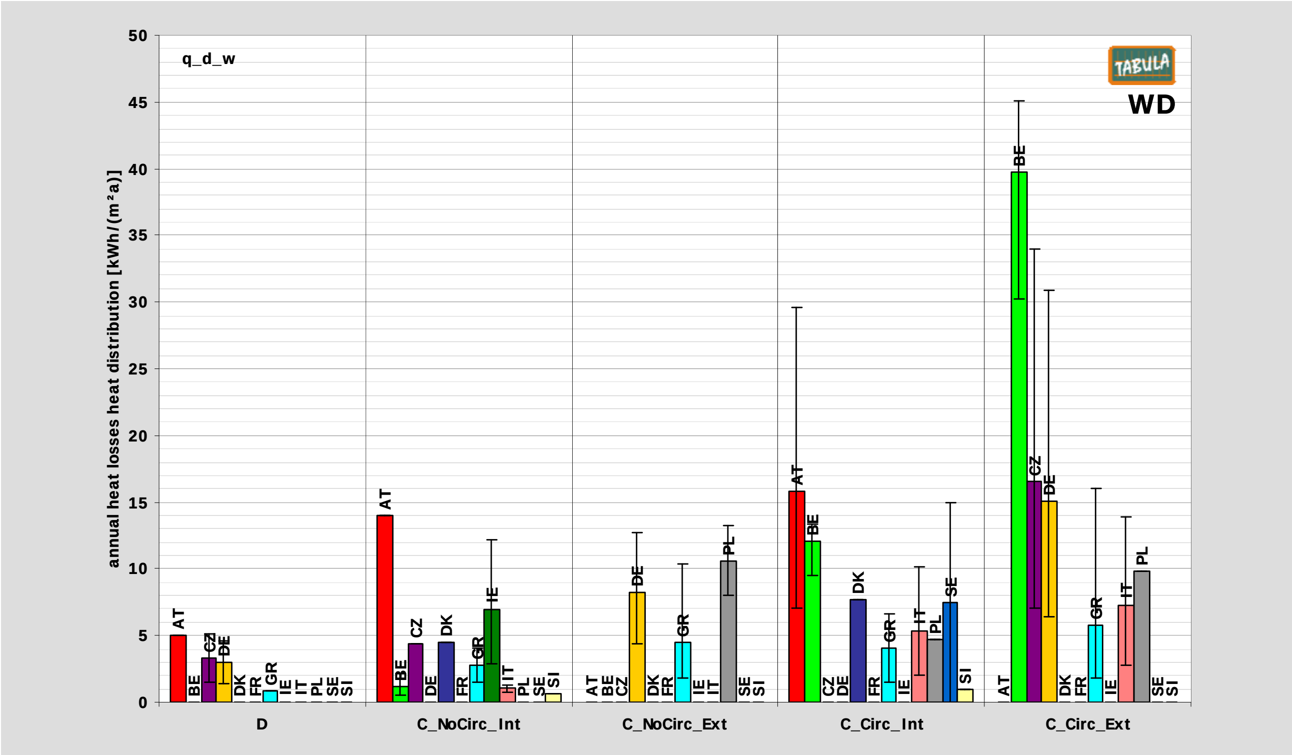


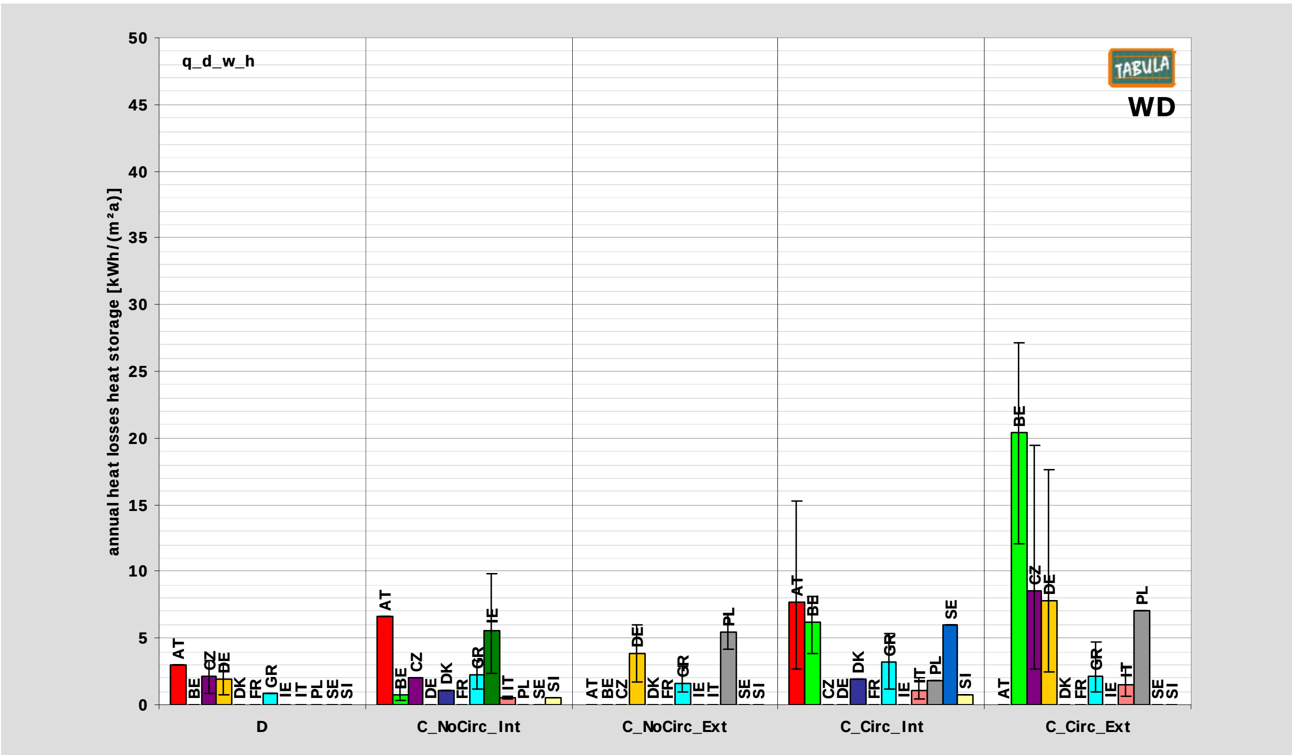


B.6.8. WD – Domestic Hot Water Systems / Heat Distribution

Figure 63: Annual distribution heat losses of DHW systems + recoverable fraction

<D> decentral DHW system; <C_NoCirc_Int> central DHW distribution, all pipes inside of thermal envelope, no circulation; <C_NoCirc_ext> central DHW distribution, fraction of pipeline outside of thermal envelope, no circulation; <C_Circ_Int> central DHW distribution with circulation, all pipes inside of thermal envelope; <C_Circ_Ext> central DHW distribution with circulation, fraction of pipeline outside of thermal envelope

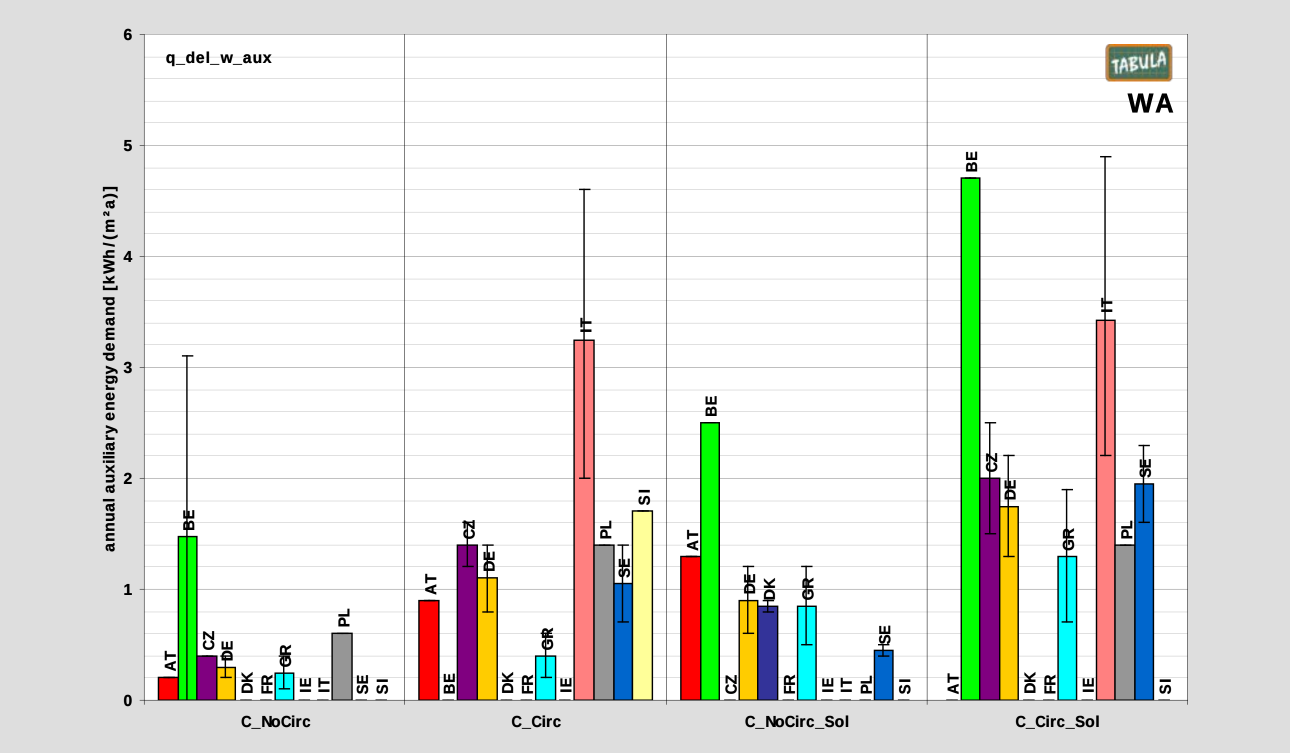




B.6.9. WA – DHW Systems / Auxiliary Energy

Figure 65: Annual auxiliary electricity demand of DHW systems /

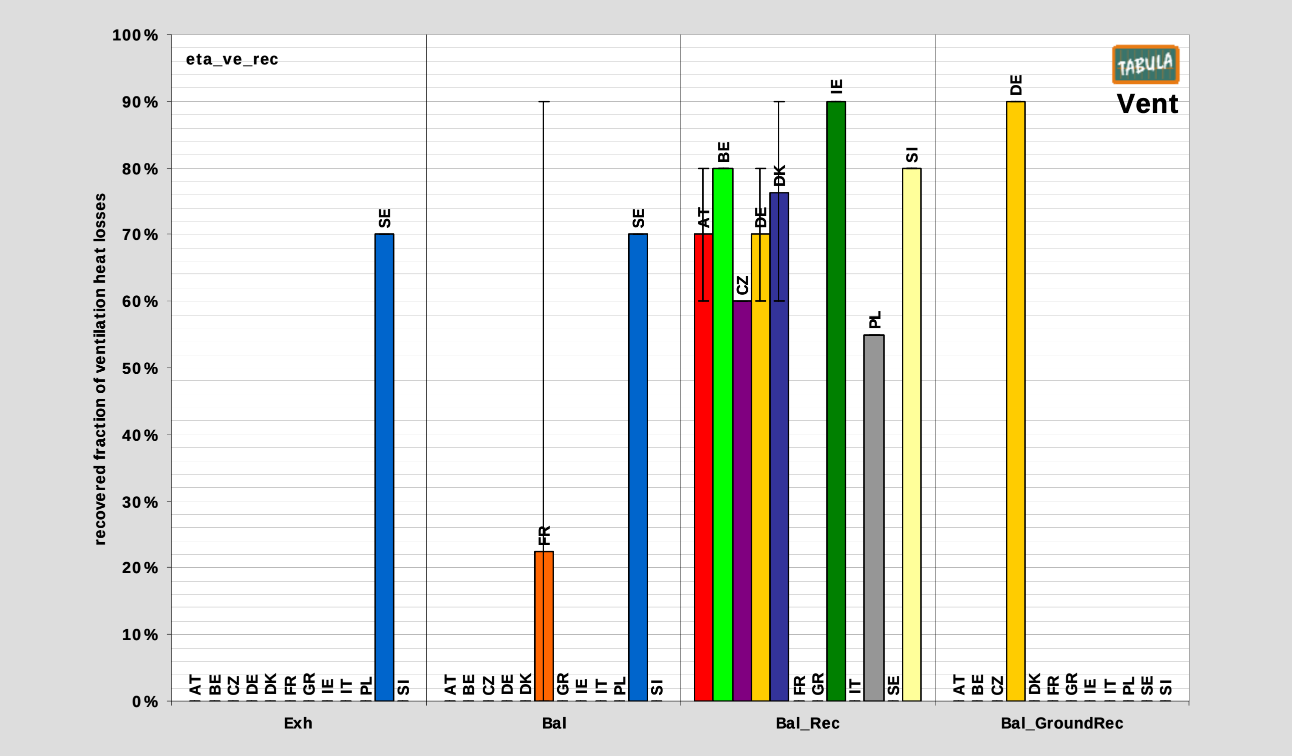
<D> decentral DHW system; <C_NoCirc> central DHW system, no circulation; <C_Circ> central DHW system with circulation; <C_NoCirc_Sol> central DHW system with solar thermal system, no circulation; <C_Circ_Sol> central DHW system with solar thermal system and circulation

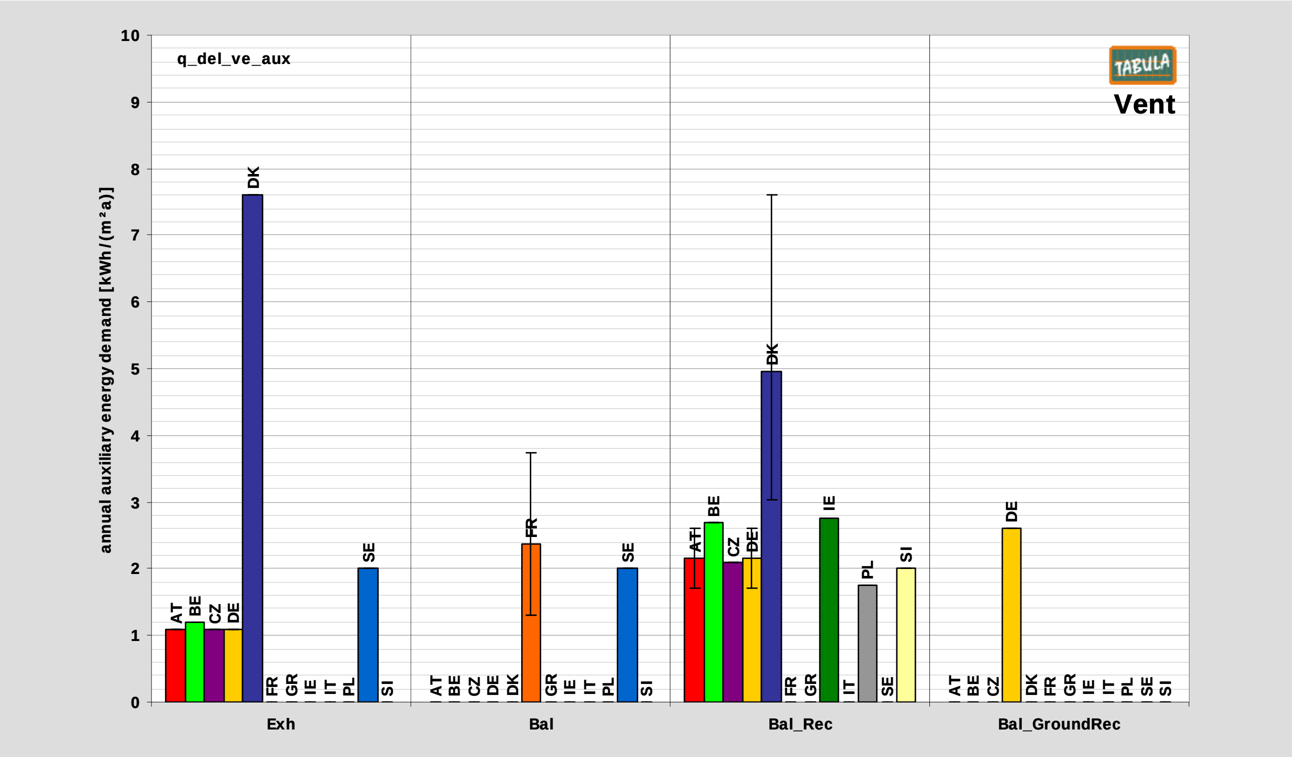


B.6.10. Vent – Ventilation Systems

Figure 65: Recovered fraction of ventilation heat losses + annual auxiliary energy demand of ventilation systems

<Exh> exhaust air system; <Bal> balanced ventilation system; <Bal_Rec> balanced ventilation system with heat recovery; <Bal_GroundRec> balanced ventilation system, preheated by ground heat exchanger + heat recovery





B.7. Benefits of the Data Analyses for Operational Purposes

B.7.1. Envelope Area Estimation Procedure

In addition to the above described evaluations an analysis of the correlation of the thermal envelope areas with the main geometrical parameters has been performed. The idea is to derive a procedure for the estimation of the thermal envelope area on the basis of the main factors as conditioned floor area, number of storeys, number of neighbours and heating situation of attic and cellar (which could be useful for plausibility checks during data intake and also for the rough energy assessment of large housing portfolios).

The general assumption is a linear dependency of

- window and façade areas on the conditioned floor area of the whole building;
- floor and roof areas on the conditioned floor area of a (complete) storey.

In case of conditioned cellar or attic areas the number of complete storeys has been supplemented by a fraction representing the heated area in these spaces:

- supplement of 1.0 for a completely and 0.5 for a partly conditioned cellar.
- supplement of 0.75 for a completely and 0.5*0.75=0.375 partly conditioned attic.

A one-storey single-family house with a completely heated attic would for example be considered as a building with 1.75 effective storeys.

The "reference area per effective storey" used in the charts below is the TABULA reference floor area $A_{C,ref}$ divided by the number of effective storeys, as defined above.

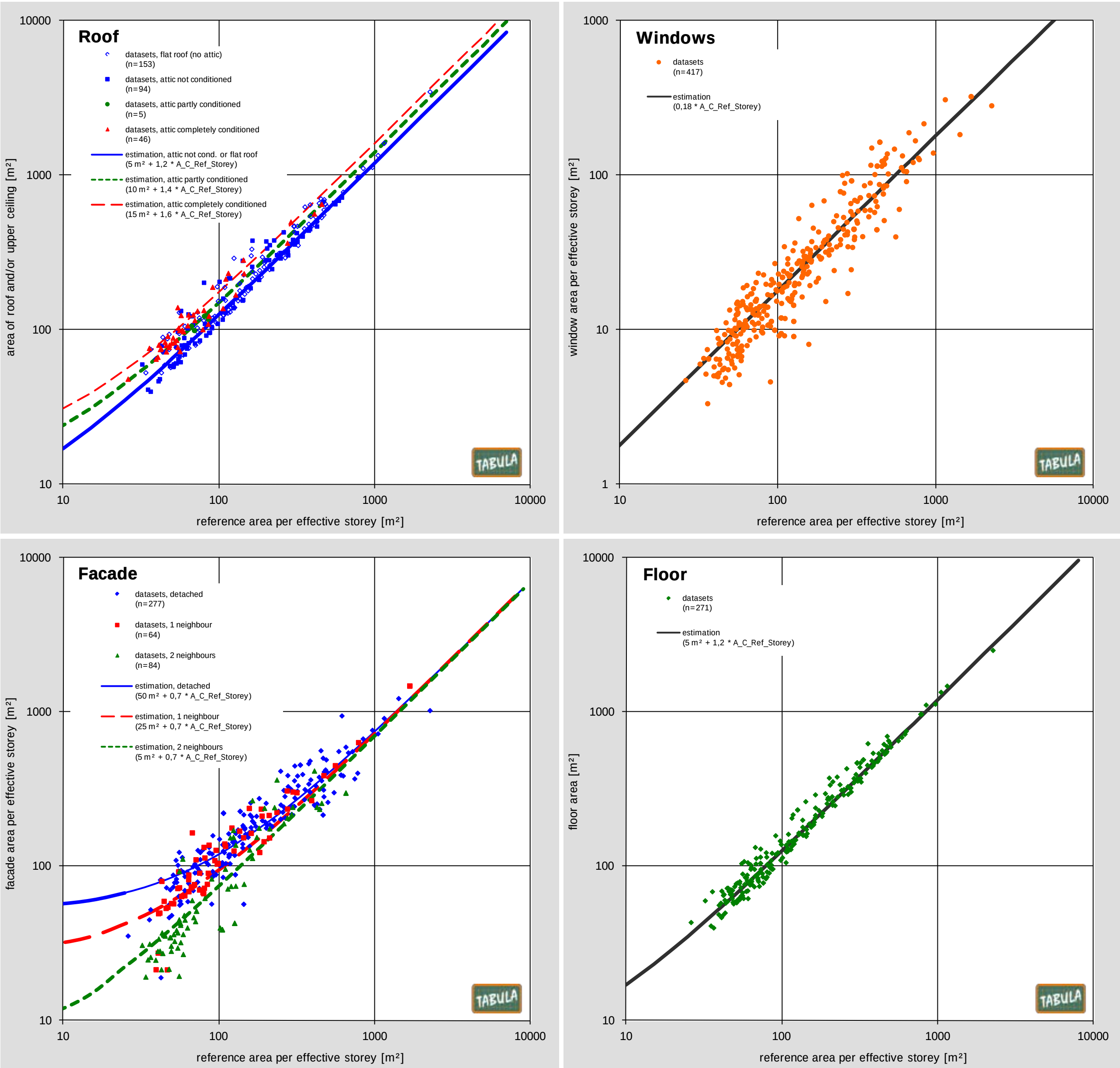
Table 66: Intercepts (b) and slopes (m) of the simplified model

Envelope type	Independent variable	Specification	b [m²]	m [-]
Roof	A_C_Storey	flat roof (no attic)	5	1,20
		attic not conditioned	5	1,20
		attic partly conditioned	10	1,40
		attic completely conditioned	15	1,60
Window	A_C_Ref		0	0,18
Façade	A_C_Ref	0 neighbours	50	0,70
		1 neighbours	25	0,70
		2 neighbours	5	0,70
Floor	A_C_Storey		5	1,20

The following charts illustrate how the simplified model lines are approximating the data points. Logarithmic scales are used for both axes in order to make the dependence also visible for smaller buildings[6].

6 On double logarithmic charts straight lines appear curved (with exception of the bisecting line).

Figure 67: Data points and simplified model lines (double-logarithmic plots)



B.7.2. Average U-values of different window types

The averages of the window U-values from all countries can also serve as default values in case that no values are available in the database. However, it is strongly recommended to supply and use the respective national values, if any possible. During the revision process of the next years further datasets and classifications should be provided by the partners. Also information should be supplemented from which time on (a) metal windows were typically fabricated with thermal breaks and (b) low-e glazing was dominant.

Table 67: Default U-values of different window types (averages of the values from all countries)

Number of panes	Glazing type	Frame type	Default U-value [W/(m²K)]
1	conventional	not specified	4.7
		wood	4.6
		plastic	4.3
		metal	5,8
2	conventional	not specified	2,6
		wood	2,8
		plastic	2,9
		metal	4,0
		metal, thermal break	3,4
	low-e	not specified	1,6
		wood	1,7
		plastic	1,5
		metal, thermal break	2,3
3	conventional	wood	1,7
	low-e	wood	1,0
		plastic	0,9
		metal	0,9
		insulated ("passive house window")	0,8

B.7.3. Average Energy Performance Values of different Heat Supply System Types

In a similar manner the average energy performance values of the different heat supply component types were determined on the basis of the national values. These tabled values can in the future be useful for rough supranational estimations or in case that national values are not available.

Table 68: Heat generation of heating systems / derived default values (simplified common values)

TABULA Code	Description	heat generation expenditure factor (heating systems)			electricity generation expenditure factor (heating systems)		
		delivered energy demand (H_S) devided by produced heat			electricity demand devided by produced heat		
		$e_{g,h}$			$e_{g,el,h}$		
		[-]			[-]		
	energy efficiency	**poor**	**medium**	**high**	**poor**	**medium**	**high**
B_NC	boiler, non-condensing	1,92	1,36	1,13	-	-	-
B_C	boiler, condensing	1,31	1,13	1,06	-	-	-
B_WP	wood-pellets boiler	2,12	1,52	1,31	-	-	-
G_IWH_NC	gas-fired instantaneous water heater, non-condensing	1,27	1,24	1,20	-	-	-
G_IWH_C	gas-fired instantaneous water heater, condensing	1,17	1,13	1,10	-	-	-
G_SH	gas-fired space heater	1,50	1,41	1,29	-	-	-
E_Immersion	electric immersion heater	1,08	1,03	1,00	-	-	-
E	direct electric heat generator	1,25	1,02	1,00	-	-	-
HP_Air	heat pump, heat source external air	0,50	0,37	0,30	-	-	-
HP_Ground	heat pump, heat source ground	0,52	0,31	0,21	-	-	-
HP_ExhAir	heat pump, heat source exhaust air	0,36	0,33	0,31	-	-	-
Stove	stove	2,96	1,92	1,40	-	-	-
OpenFire	open fire	4,44	3,39	2,44	-	-	-
TS	district heating transfer station	1,34	1,13	1,06	-	-	-
CHP	combined heat and power generation	1,67	1,67	1,67	3,33	3,33	3,33
Solar	thermal solar plant	0,00	0,00	0,00	-	-	-

Table 69: Annual heat loss of the space heating storage / derived default values (simplified common values)

TABULA code	description	heat loss of the space heating storage annual heat losses during heating season per m² reference area $q_{s,h}$ [kWh/(m²a)]		
	energy efficiency	poor	medium	high
-	no heat storage	0,0	0,0	0,0
BS	buffer storage	15,9	6,5	2,2

Table 70: Annual heat loss of the space heating distribution / derived default values (simplified common values)

TABULA code	description	heat loss of the space heating distribution annual heat losses during heating season per m² reference area $q_{d,h}$ [kWh/(m²a)]		
	energy efficiency	poor	medium	high
D	decentral system	0,0	0,0	0,0
C_Int	central heating, all pipes inside of thermal envelope	21,4	6,5	1,7
C_Ext	central heating, fraction of pipeline outside of thermal envelope	39,0	13,0	3,1

Table 71: Annual auxiliary electricity demand of space heating systems / derived default values (simplified common values)

TABULA code	description	auxiliary energy demand (electricity) of heating systems annual values in kWh per m² reference area for heat generation (blower, control), storage (pump), distribution (pump) and heat emission (fan), as far as available $q_{del,h,aux}$ [kWh/(m²a)]		
	energy efficiency	poor	medium	high
D	decentral system, no distribution ducts avail-able	0,0	0,0	0,0
C	central heating, distribution by pipeline	8,9	3,6	0,9

Table 72: Heat generation of dhw systems / derived default values (simplified common values)

TABULA Code	Description	heat generation expenditure factor (dhw systems)			electricity generation expenditure factor (dhw systems)		
		delivered energy demand (H_S) devided by produced heat			electricity demand devided by produced heat		
		$e_{g,w}$			$e_{g,el,w}$		
		[-]			[-]		
	energy efficiency	poor	medium	high	poor	medium	high
B_NC	boiler, non-condensing	2,49	1,41	1,14	-	-	-
B_C	boiler, condensing	1,56	1,19	1,08	-	-	-
B_WP	wood-pellets boiler	1,76	1,40	1,24	-	-	-
G_IWH_NC	gas-fired instantaneous water heater, non-condensing	1,96	1,34	1,23	-	-	-
G_IWH_C	gas-fired instantaneous water heater, condensing	1,27	1,22	1,17	-	-	-
G_Tank	gas burner for directly heated DHW tank	1,28	1,23	1,11	-	-	-
E_Immersion	electric immersion heater	1,52	1,10	1,03	-	-	-
E	direct electric heat generator, not specified	1,19	1,04	1,02	-	-	-
HP_Air	heat pump, heat source external air	0,65	0,44	0,38	-	-	-
HP_Ground	heat pump, heat source ground	0,35	0,30	0,26	-	-	-
HP_ExhAir	heat pump, heat source exhaust air	0,32	0,31	0,30	-	-	-
HP_Cellar	heat pump, heat source: cellar air	0,37	0,34	0,31	-	-	-
TS	district heating transfer station	1,81	1,22	1,10	-	-	-
CHP	combined heat and power generation	1,54	1,39	1,28	3,33	3,33	3,33
Solar	thermal solar plant	0,00	0,00	0,00	-	-	-

Table 73: Annual heat loss of the dhw heat storage / derived default values (simplified common values)

TABULA code	description	heat loss of the dhw distribution			thereof recoverable portion		
		annual heat losses per m² reference area			contribution to space heating per m² reference area		
		$q_{d,w}$			$q_{d,w,h}$		
		[kWh/(m²a)]			[kWh/(m²a)]		
	energy efficiency	**poor**	**medium**	**high**	**poor**	**medium**	**high**
S_D	decentral electric hot water storage	6,7	3,1	1,3	2,8	1,6	1,6
S_C_Int	central hot water storage, inside of thermal envelope	31,2	5,8	0,9	24,5	2,8	2,8
S_C_Ext	central hot water storage, outside of thermal envelope	10,2	4,3	0,9	0,0	0,0	0,0
S_Gas	directly gas heated hot water storage	18,4	14,2	8,2	0,0	0,0	0,0

Table 74: Annual heat losses of the dhw distribution / derived default values (simplified common values)

TABULA code	description	heat loss of the dhw distribution			thereof recoverable portion		
		annual heat losses per m² reference area			contribution to space heating per m² reference area		
		$q_{d,w}$			$q_{d,w,h}$		
		[kWh/(m²a)]			[kWh/(m²a)]		
	energy efficiency	**poor**	**medium**	**high**	**poor**	**medium**	**high**
D	decentral DHW system	4,5	3,1	1,6	2,0	1,1	1,1
C_NoCirc_Int	central DHW distribution, all pipes inside of thermal envelope, no circulation	9,7	4,4	2,1	2,4	1,1	1,1
C_NoCirc_Ext	central DHW distribution, fraction of pipeline outside of thermal envelope, no circulation	12,7	7,8	3,3	3,6	1,7	1,7
C_Circ_Int	central DHW distribution with circulation, all pipes inside of thermal envelope	20,3	7,3	2,1	3,6	1,4	1,4
C_Circ_Ext	central DHW distribution with circulation, fraction of pipeline outside of thermal envelope	35,0	15,7	5,7	7,9	2,5	2,5

Table 75: Annual auxiliary electricity demand of DHW systems / derived default values (simplified common values)

TABULA code	description	auxiliary energy demand (electricity) of dhw systems annual values in kWh per m² reference area for heat generation (blower, control), storage (pump), distribution (pump), as far as available $q_{del,w,aux}$ [kWh/(m²a)]		
	energy efficiency	**poor**	**medium**	**high**
D	decentral DHW system	0,0	0,0	0,0
C_NoCirc	central DHW system, no circulation	1,9	0,4	0,1
C_Circ	central DHW system with circulation	3,2	1,4	0,7
C_NoCirc_Sol	central DHW system with solar thermal system, no circulation	1,9	1,1	0,7
C_Circ_Sol	central DHW system with solar thermal system and circulation	3,9	2,4	1,3

Table 76: Performance of ventilation systems / derived default values (simplified common values)

TABULA code	description	heat recovery by ventilation systems overall performance ratio of heat recovery by the heat exchanger $\eta_{ve,rec}$ [-]			auxiliary energy demand (electricity) of ventilation systems annual values in kWh per m² reference area $q_{del,ve,aux}$ [kWh/(m²a)]		
	energy efficiency	**poor**	**medium**	**high**	**poor**	**medium**	**high**
Exh	exhaust air system	0,00	0,00	0,00	1,7	1,3	1,2
Bal	balanced ventilation system	0,00	0,00	0,00	3,3	2,2	1,5
Bal_Rec	balanced ventilation system with heat recovery	0,62	0,73	0,83	5,3	2,6	2,0
Bal_GroundRec	balanced ventilation system, preheated by ground heat exchanger + heat recovery	0,90	0,90	0,90	2,6	2,6	2,6

Appendix C - Database and Calculation of Example Buildings

Figure 68: Data sheet of example buildings

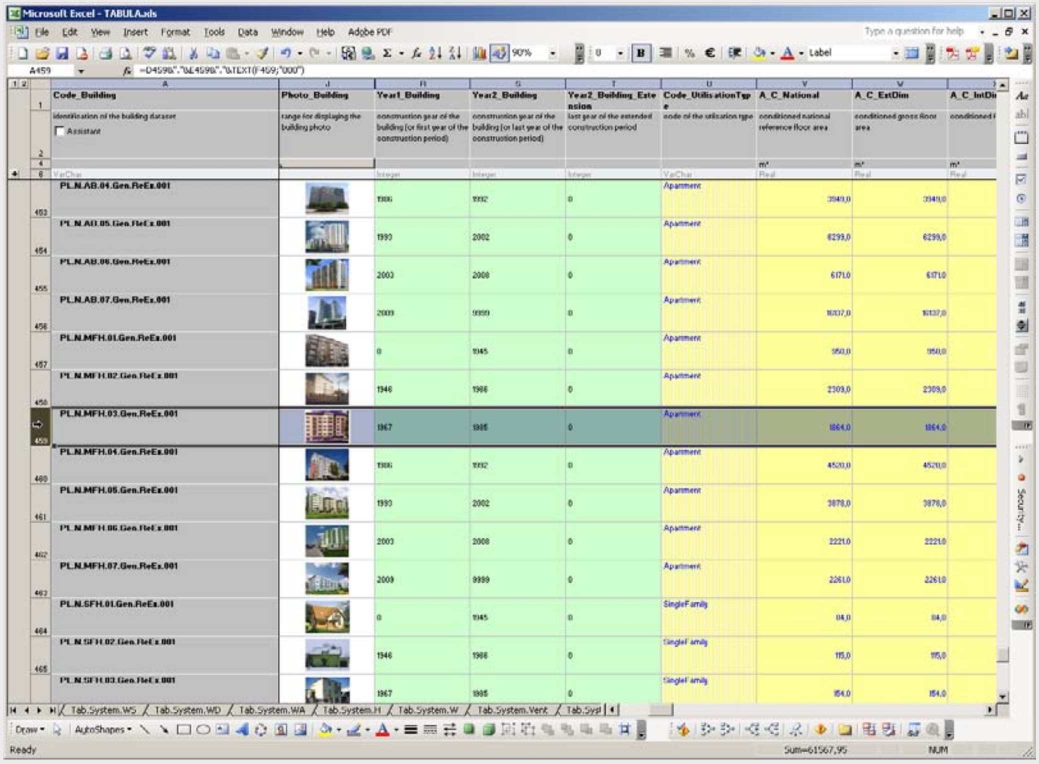


Figure 69: Data Sheet of construction elements

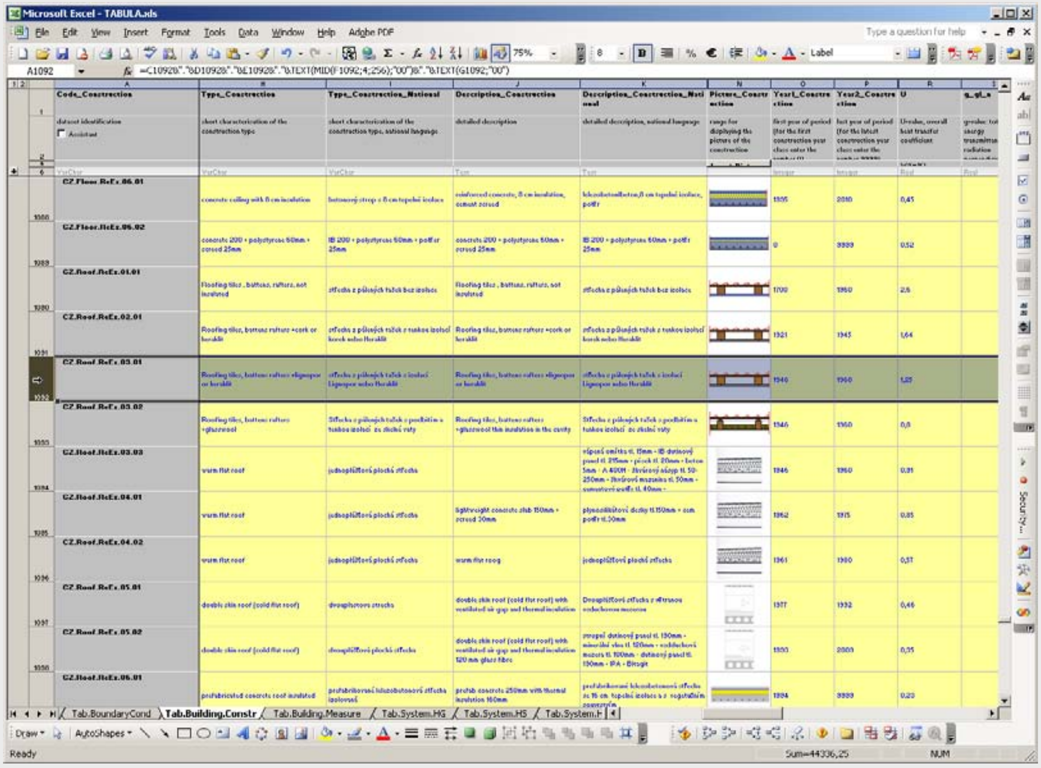
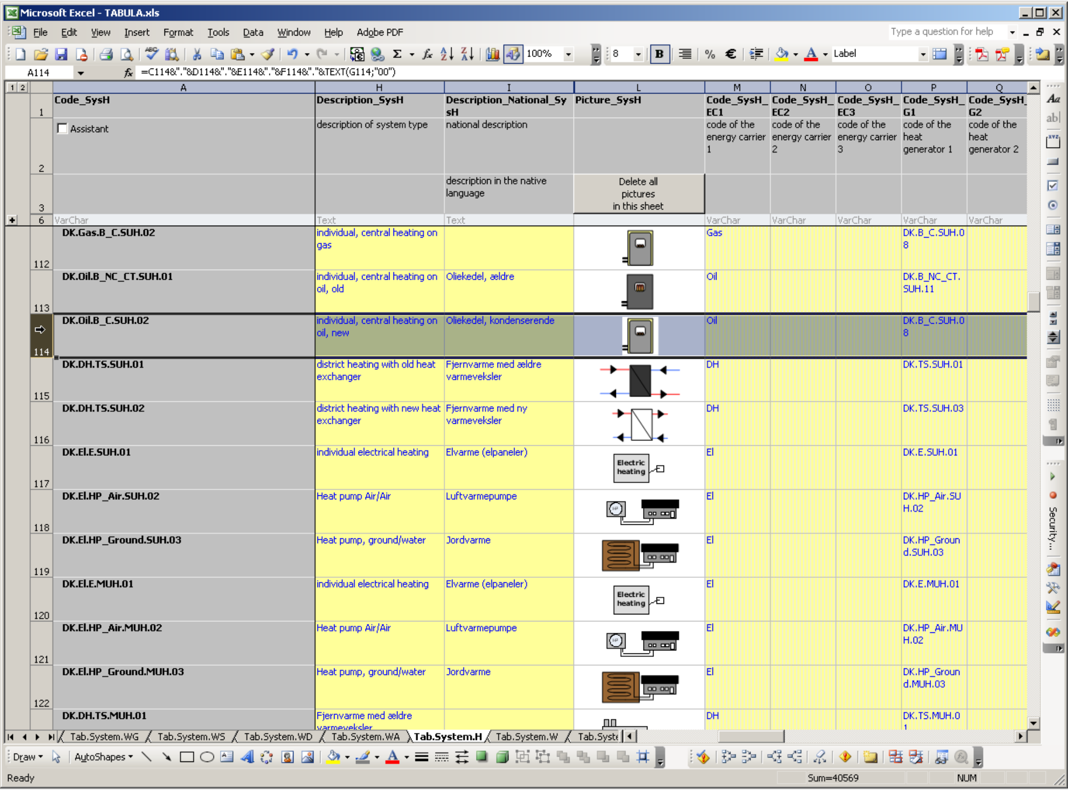
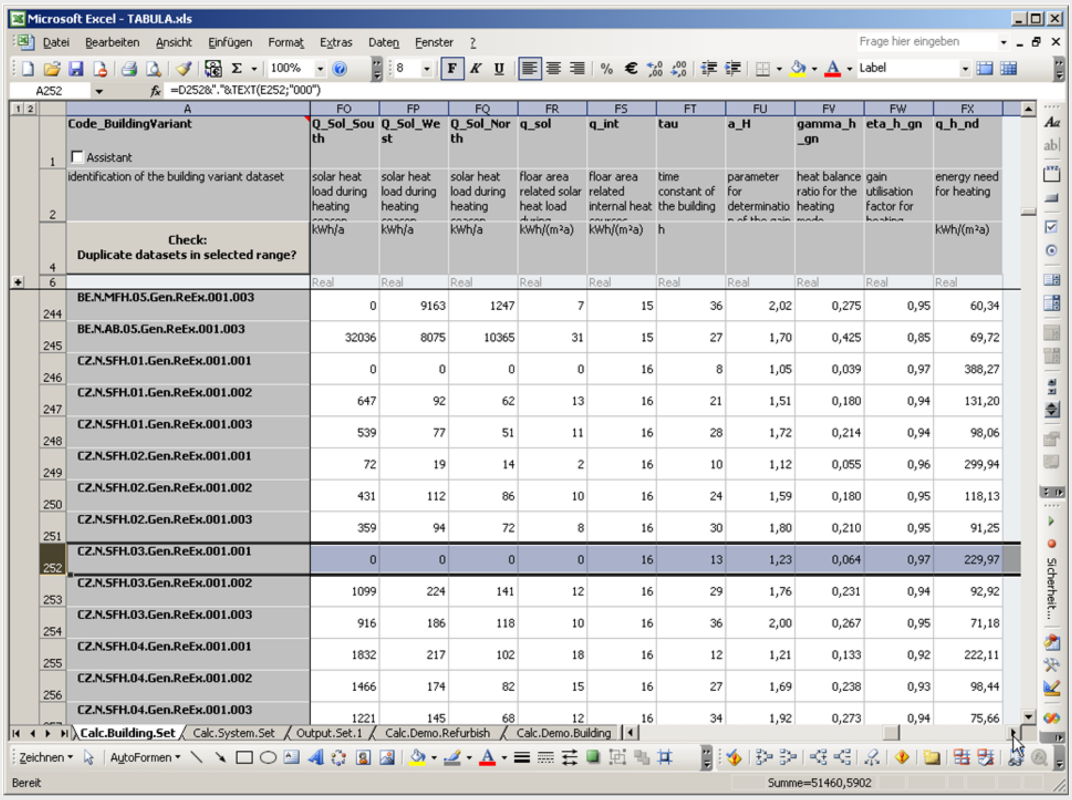


Figure 70: Data sheet of heat supply components (heat generators)



	Code_SysH	Description_SysH	Description_National_SysH	Code_SysH_EC1	Code_SysH_EC2	Code_SysH_EC3	Code_SysH_G1	Code_SysH_G2
2	Assistant	description of system type	national description	code of the energy carrier 1	code of the energy carrier 2	code of the energy carrier 3	code of the heat generator 1	code of the heat generator 2
3			description in the native language					
6	VarChar	Text	Text	VarChar	VarChar	VarChar	VarChar	VarChar
112	DK.Gas.B_C.SUH.02	individual, central heating on gas		Gas			DK.B_C.SUH.08	
113	DK.Oil.B_NC_CT.SUH.01	individual, central heating on oil, old	Oliekedel, ældre	Oil			DK.B_NC_CT.SUH.11	
114	DK.Oil.B_C.SUH.02	individual, central heating on oil, new	Oliekedel, kondenserende	Oil			DK.B_C.SUH.08	
115	DK.DH.TS.SUH.01	district heating with old heat exchanger	Fjernvarme med ældre varmeveksler	DH			DK.TS.SUH.01	
116	DK.DH.TS.SUH.02	district heating with new heat exchanger	Fjernvarme med ny varmeveksler	DH			DK.TS.SUH.03	
117	DK.El.E.SUH.01	individual electrical heating	Elvarme (elpaneler)	El			DK.E.SUH.01	
118	DK.El.HP_Air.SUH.02	Heat pump Air/Air	Luftvarmepumpe	El			DK.HP_Air.SUH.02	
119	DK.El.HP_Ground.SUH.03	Heat pump, ground/water	Jordvarme	El			DK.HP_Ground.SUH.03	
120	DK.El.E.MUH.01	individual electrical heating	Elvarme (elpaneler)	El			DK.E.MUH.01	
121	DK.El.HP_Air.MUH.02	Heat pump Air/Air	Luftvarmepumpe	El			DK.HP_Air.MUH.02	
122	DK.El.HP_Ground.MUH.03	Heat pump, ground/water	Jordvarme	El			DK.HP_Ground.MUH.03	
	DK.DH.TS.MUH.01	Fjernvarme med ældre varmeveksler		DH			DK.TS.MUH.0	

Figure 71: Spreadsheet for calculation of the energy need for heating of building variants (last columns of the row-by-row calculation)



	Code_BuildingVariant	Q_Sol_South	Q_Sol_West	Q_Sol_North	q_sol	q_int	tau	a_H	gamma_h_gn	eta_h_gn	q_h_nd
2	identification of the building variant dataset	solar heat load during heating season	solar heat load during heating season	solar heat load during heating season	floor area related solar heat load	floor area related internal heat	time constant of the building	parameter for determination	heat balance ratio for the heating mode	gain utilisation factor for heating	energy need for heating
4	Check: Duplicate datasets in selected range?	kWh/a	kWh/a	kWh/a	kWh/(m²a)	kWh/(m²a)	h				kWh/(m²a)
6		Real	Real	Real	Real	Real	Real	Real	Real	Real	Real
244	BE.N.MFH.05.Gen.ReEx.001.003	0	9163	1247	7	15	36	2,02	0,275	0,95	60,34
245	BE.N.AB.05.Gen.ReEx.001.003	32036	8075	10365	31	15	27	1,70	0,425	0,85	69,72
246	CZ.N.SFH.01.Gen.ReEx.001.001	0	0	0	0	16	8	1,05	0,039	0,97	388,27
247	CZ.N.SFH.01.Gen.ReEx.001.002	647	92	62	13	16	21	1,51	0,180	0,94	131,20
248	CZ.N.SFH.01.Gen.ReEx.001.003	539	77	51	11	16	28	1,72	0,214	0,94	98,06
249	CZ.N.SFH.02.Gen.ReEx.001.001	72	19	14	2	16	10	1,12	0,055	0,96	299,94
250	CZ.N.SFH.02.Gen.ReEx.001.002	431	112	86	10	16	24	1,59	0,180	0,95	118,13
251	CZ.N.SFH.02.Gen.ReEx.001.003	359	94	72	8	16	30	1,80	0,210	0,95	91,25
252	CZ.N.SFH.03.Gen.ReEx.001.001	0	0	0	0	16	13	1,23	0,064	0,97	229,97
253	CZ.N.SFH.03.Gen.ReEx.001.002	1099	224	141	12	16	29	1,76	0,231	0,94	92,92
254	CZ.N.SFH.03.Gen.ReEx.001.003	916	186	118	10	16	36	2,00	0,267	0,95	71,18
255	CZ.N.SFH.04.Gen.ReEx.001.001	1832	217	102	18	16	12	1,21	0,133	0,92	222,11
256	CZ.N.SFH.04.Gen.ReEx.001.002	1466	174	82	15	16	27	1,69	0,238	0,93	98,44
	CZ.N.SFH.04.Gen.ReEx.001.003	1221	145	68	12	16	34	1,92	0,273	0,94	75,66

Figure 72: Calculation Sheet

Thermal Insulation Measures — U-values

building — code DE.N.MFH.05.Gen.ReEx.001

		Roof 1	Roof 2	Wall 1	Wall 2	Wall 3	Floor 1	Floor 2	Window 1	Window 2	Door 1	
envelope area	$A_{env,i}$	0	971	2039	0	0	971	0	507	0	2	m²
Construction Element												
code			DE.Ceiling.ReEx.06.01	DE.Wall.ReEx.04.01			DE.Floor.ReEx.05.01		DE.Window.ReEx.06.03		DE.Door.ReEx.01.01	
U-value original state	$U_{original,i}$		0,60	1,20			1,60		3,50		3,00	W/(m²K)
included insulation thickness	$d_{insulation,i}$		5,0	0,0			1,0					cm
border type			Unh	Ext			Cellar					
additional thermal resistance	$R_{add,i}$		0,30	0,00			0,30					m²K/W
Refurbishment Measure												
code												
thermal resistance of refurbishment measure	$R_{measure,i}$		0,00	0,00			0,00		0,00		0,00	m²K/W
Result												
type of refurbishment												
thermal resistance before measures	$R_{before,i}$		1,97	0,83			0,93		0,29		0,33	m²K/W
	$R_{actual,i}$		1,97	0,83			0,93		0,29		0,33	m²K/W
	$U_{actual,i}$		0,51	1,20			1,08		3,50		3,00	W/(m²K)

Figure 73: Calculation Sheet

Energy Balance Calculation — Building Performance

Standard Reference Calculation - based on: EN ISO 13790 / seasonal method

building	DE.N.MFH.05.Gen.ReEx.001 (1958...1968)	reference area (conditioned floor area)	$A_{C,ref}$	3129,1 m²
climate	DE.N (Germany)			

code construction element	original U-value $U_{original,i}$ W/(m²K)	measure type	applied refurbishment measure	actual U-value $U_{actual,i}$ W/(m²K)		area (basis: external dimensions) $A_{env,i}$ m²		adjustment factor soil $b_{tr,i}$		$H_{tr,i}$ W/K
Roof 1					×		×		=	
Roof 2	0,60			0,51	×	971,1	×	1,00	=	493,8
Wall 1	1,20			1,20	×	2039,0	×	1,00	=	2446,8
Wall 2					×		×		=	
Wall 3					×		×		=	
Floor 1	1,60			1,08	×	971,1	×	0,50	=	524,9
Floor 2					×		×		=	
Window 1	3,50			3,50	×	507,5	×	1,00	=	1776,2
Window 2					×		×		=	
Door 1	3,00			3,00	×	2,0	×	1,00	=	6,0
thermal bridging: surcharge on the U-values				ΔU_{tb} 0,10	×	$\Sigma A_{env,i}$ 4490,7	×	1,00	=	$H_{tr,tb}$ 449,1

Heat transfer coefficient by transmission H_{tr} sum **5697**

	volume-specific heat capacity air $c_{p,air}$ Wh/(m³K)		air change rate by use $n_{air,use}$ 1/h		by infiltration $n_{air,infiltration}$ 1/h		$A_{C,ref}$ m²		room height (standard value) h_{room} m		W/K
Heat transfer coefficient by ventilation H_{ve}	0,34	× (	0,40	+	0,20	) ×	3129,1	×	2,50	=	**1596**

		internal temp. ϑ_i °C		external temp. ϑ_e °C		heating days d_{hs} d/a		Kd/a
accumulated differences between internal and external temperature	(	20,0	–	4,4	) ×	222	=	3463

		H_{tr} W/K		H_{ve} W/K		temperature reduction factor F_{red} (h_{tr} = 1,82 W/(m²K))		x 0,024 kKh/a		kWh/a
Total heat transfer Q_{ht}	(	5697	+	1596	) ×	0,92	×	83,1	=	**559250**

window orientation	reduction factors: external shading F_{sh}			frame area fraction F_F		non-perpendicular F_W		solar energy transmittance $g_{gl,n}$		window area $A_{window,i}$ m²		solar global radiation $I_{sol,i}$ kWh/(m²a)		kWh/a
1. Horizontal	0,80	×	(1 -	0,30	) ×	0,90	×	0,75	×		×	403	=	
2. East	0,60	×	(1 -	0,30	) ×	0,90	×	0,75	×	22,2	×	271	=	1709
3. South	0,60	×	(1 -	0,30	) ×	0,90	×	0,75	×	243,2	×	392	=	27032
4. West	0,60	×	(1 -	0,30	) ×	0,90	×	0,75	×	22,2	×	271	=	1709
5. North	0,60	×	(1 -	0,30	) ×	0,90	×	0,75	×	219,8	×	160	=	9968

Solar heat load during heating season Q_{sol} sum **40418**

	kh/d		internal heat sources φ_i W/m²		heating days d_{hs} d/a		$A_{C,ref}$ m²		kWh/a
Internal heat sources Q_{int}	0,024	×	3,00	×	222	×	3129,1	=	**50015**

internal heat capacity per m² $A_{C,ref}$ c_m = 45 Wh/(m²K)

time constant of the building $\tau = \frac{c_m \cdot A_{C,ref}}{H_{tr} + H_{ve}}$ = 19 h

parameter $a_H = a_{H,0} + \frac{\tau}{\tau_{H,0}}$ = 1,44

heat balance ratio for the heating mode $\gamma_{h,gn} = \frac{Q_{sol}+Q_{int}}{Q_{ht}}$ = 0,162

gain utilisation factor for heating $\eta_{h,gn} = \frac{1-\gamma^{a_H}}{1-\gamma^{a_H+1}}$ = 0,94

Energy need for heating $Q_{H,nd}$ $Q_{ht} - \eta_{h,gn} \times (Q_{sol} + Q_{int})$ = **474344** kWh/a

Figure 74: Calculation Sheet

Energy Balance Calculation — System Performance

Standard Reference Calculation - based on: EN ISO 15316 / level B (tabled values)

	code		$A_{C,ref}$	
building	DE.N.MFH.05.Gen.ReEx.001.001	conditioned floor area	3129,1	m²
system	DE.<Oil.B_NC_LT.MUH.01>.<El.E_IWH.Gen.01>.<-.Gen.01>.<Gen>			

Domestic Hot Water System

	code
system	DE.El.E_IWH.Gen.01

	code		value	thereof recoverable for space heating:	
energy need hot water		$q_{nd,w}$	15,0		
+ losses distrib.	DE.D.Gen.02	$q_{d,w}$	1,4	$q_{d,w,h}$	0,8
+ losses storage		$q_{s,w}$	0,0	$q_{s,w,h}$	0,0
		$q_{g,w,out} = q_{nd,w} + q_{d,w} + q_{s,w}$	16,4	$q_{w,h} = q_{d,w,h} + q_{s,w,h}$	0,8
			kWh/(m²a)		kWh/(m²a)

energyware for domestic hot water

	code	heat generator code	$\alpha_{nd,w,i}$		heat generator output $q_{g,w,out}$		expenditure factor $e_{g,w,i}$		delivered energy $q_{del,w,i}$		combined heat and power: expenditure factor electricity generation $e_{g,el,w,i}$		electricity production $q_{prod,el,w,i}$
1	El	DE.E_IWH.Gen.01	100%	x	16,4	x	1,00	=	16,4	:	0,00	=	0,0
2			0%	x		x	0,00	=	0,0	:	0,00	=	0,0
3			0%	x		x	0,00	=	0,0	:	0,00	=	0,0
					kWh/(m²a)				kWh/(m²a)				

auxiliary energy

		code	$q_{del,w,aux}$
aux	el	DE.D.Gen.01	0,0
			kWh/(m²a)

Heating System

	code
system	DE.Oil.B_NC_LT.MUH.01

	code		value	unit	gain utilisation factor for heating $\eta_{h,gn}$		ventilation heat recovery $\eta_{ve,rec}$		$q_{ht,ve}$
energy need space heating		$q_{nd,h}$	151,6	kWh/(m²a)					
– usable contribution of hot water system		$q_{w,h}$	0,8	kWh/(m²a)	94%	x			
– usable contribution of ventilation heat recovery		$q_{ve,h,rec}$	0,0	kWh/(m²a)	94%	x	0%	x	39,1
+ losses distribution and heat emission	DE.C_Ext.MUH.03	$q_{d,h}$	15,1	kWh/(m²a)					kWh/(m²a)
+ losses storage		$q_{s,h}$	0,0	kWh/(m²a)					
		$q_{g,h,out} = q_{nd,h} - q_{w,h} - q_{ve,h,rec} + q_{d,h} + q_{s,h}$	165,9	kWh/(m²a)					

energyware for space heating

	code	heat generator code	$\alpha_{nd,h,i}$		heat generator output $q_{g,h,out}$		expenditure factor $e_{g,h,i}$		delivered energy $q_{del,h,i}$		combined heat and power: expenditure factor electricity generation $e_{g,el,h,i}$		electricity production $q_{prod,el,h,i}$
1	Oil	DE.B_NC_LT.SUH.03	100%	x	165,9	x	1,23	=	204,1	:	0,00	=	0,0
2			0%	x		x	0,00	=	0,0	:	0,00	=	0,0
3			0%	x		x	0,00	=	0,0	:	0,00	=	0,0
					kWh/(m²a)				kWh/(m²a)				

auxiliary energy

			code	
heating system				$q_{del,h,aux}$
	aux	el	DE.C.MUH.01	1,8
ventilation system				$q_{del,ve,aux}$
	aux	el	DE.-.Gen.01	0,0
				kWh/(m²a)

Figure 75: Calculation Sheet

Energy Balance Calculation — Energy Carriers

	code		$A_{C,ref}$	
building	DE.N.MFH.05.Gen.ReEx.001.001	conditioned floor area	3129,1	m²
system	DE.<Oil.B_NC_LT.MUH.01>.<El.E_IWH.Gen.01>.<-.Gen.01>.<Gen>			

Assessment of Energywares

version of energy carrier specification — code: Gen

Standard Calculation

	delivered energy	total primary energy		non-renewable primary energy		carbon dioxide emissions		energy costs	
Heating (+ Ventilation) System	$q_{del,i}$	$f_{p,total,i}$	$q_{p,total,i} = q_{del,i} \cdot f_{p,total,i}$	$f_{p,nonren,i}$	$q_{p,nonren,i} = q_{del,i} \cdot f_{p,nonren,i}$	$f_{CO2,i}$	$m_{CO2,i} = q_{del,i} \cdot f_{CO2,i}$	p_i (energyware price)	$c_i = q_{del,i} \cdot p_i$
Oil	204,1	1,40	285,8	1,40	285,8	433	88,4	6,0	12,25
	0,0	0,00	0,0	0,00	0,0	0	0,0	0,0	0,00
	0,0	0,00	0,0	0,00	0,0	0	0,0	0,0	0,00
Auxiliary Electricity	1,8	3,31	6,0	3,14	5,7	617	1,1	15,0	0,27
Electricity Production / Export	0,0	1,30	0,0	1,30	0,0	420	0,0	8,0	0,00
Domestic Hot Water System									
El	16,4	3,31	54,3	3,14	51,5	617	10,1	15,0	2,46
	0,0	0,00	0,0	0,00	0,0	0	0,0	0,0	0,00
	0,0	0,00	0,0	0,00	0,0	0	0,0	0,0	0,00
Auxiliary Electricity	0,0	3,31	0,0	3,14	0,0	617	0,0	15,0	0,00
Electricity Production / Export	0,0	1,30	0,0	1,30	0,0	420	0,0	8,0	0,00
	kWh/(m²a)								

Summary and Expenditure Factors

	heat need q_{nd}	Σq_{del}	$e_{p,total} = \frac{q_{p,total}}{q_{nd}}$	$q_{p,total} = \Sigma q_{p,total}$	$e_{p,nonren} = \frac{q_{p,nonren}}{q_{nd}}$	$q_{p,nonren} = \Sigma q_{p,nonren}$	$f_{CO2,heat} = \frac{m_{CO2}}{q_{nd}}$	$m_{CO2,i} = \Sigma m_{CO2,i}$	$p_{heat} = \frac{c}{q_{nd}}$	$c = \Sigma c_i$
heating (+ ventilation) system	151,6	205,9	1,92	291,7	1,92	291,4	590	89,5	8,3	12,52
domestic hot water system	15,0	16,4	3,62	54,3	3,43	51,5	675	10,1	16,4	2,46
total	166,6	222,3	2,08	346,0	2,06	342,9	598	99,6	9,0	14,98
	kWh/(m²a)	kWh/(m²a)		kWh/(m²a)		kWh/(m²a)	g/kWh	kg/(m²a)	Cent/kWh	Euro/(m²a)

Typical Values of the Measured Consumption - Empirical Calibration

code: DE.M.01

The empirical calibration factor describes a typical ratio of the energy uses determined by measurements for a large number of buildings and by the TABULA method for the given value of the TABULA method.

application field	central heating systems: fuels and district heating
determination method	experience values
accuracy level	C = estimated (e.g. on the basis of few example buildings)

	empirical relation							current value
delivered energy (without auxiliary electricity) according to standard calculation method	0	100	200	300	400	500		220,5
adaptation factor	1,10	1,00	0,84	0,70	0,60	0,50	3	0,81

Summary (including subcategories)		Standard Calculation heating	dhw	sum	Typical Measured Consumption heating	dhw	sum
Gas	$q_{del,\Sigma gas}$	0,0	0,0	**0,0**	0,0	0,0	**0,0**
Oil	$q_{del,\Sigma oil}$	204,1	0,0	**204,1**	165,6	0,0	**165,6**
Coal	$q_{del,\Sigma coal}$	0,0	0,0	**0,0**	0,0	0,0	**0,0**
Bio	$q_{del,\Sigma bio}$	0,0	0,0	**0,0**	0,0	0,0	**0,0**
El	$q_{del,\Sigma el}$	0,0	16,4	**16,4**	0,0	13,3	**13,3**
DH	$q_{del,\Sigma dh}$	0,0	0,0	**0,0**	0,0	0,0	**0,0**
Other	$q_{del,\Sigma other}$	0,0	0,0	**0,0**	0,0	0,0	**0,0**
Auxiliary Electricity	$q_{del,\Sigma aux}$	1,8	0,0	**1,8**	1,5	0,0	**1,5**
Produced / Exported Electricity	$q_{exp,\Sigma el}$	0,0	0,0	**0,0**	0,0	0,0	**0,0**

Appendix D - TABULA WebTool Screenshots

Figure 76: WebTool: Building Types and Exemplary Buildings

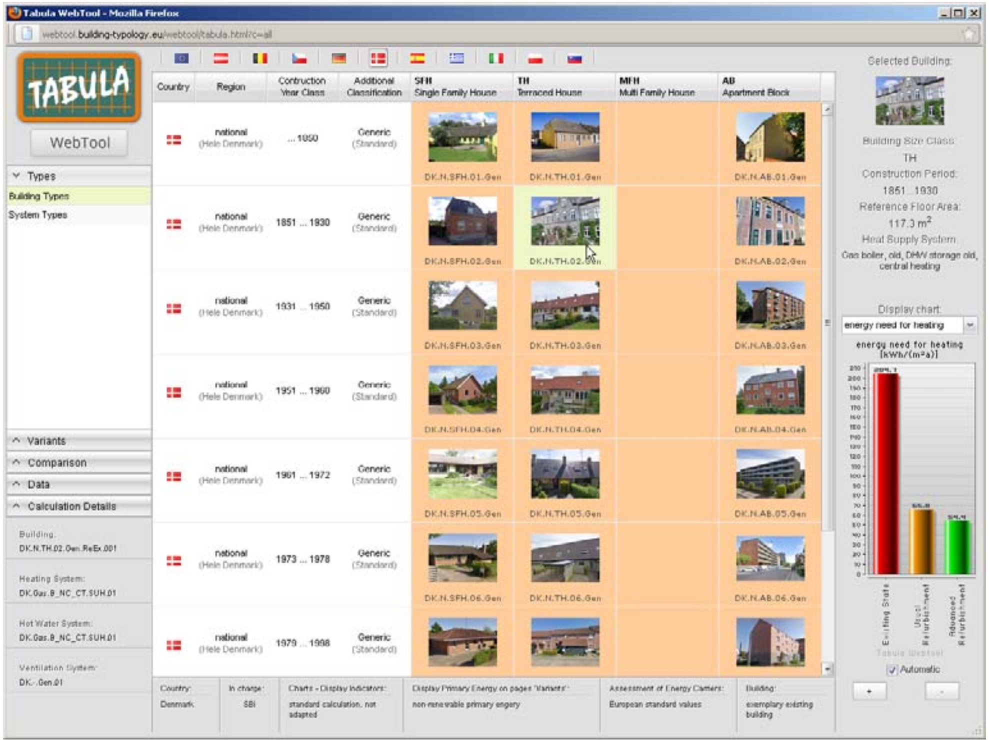


Figure 77: Exemplary Heat Supply Systems

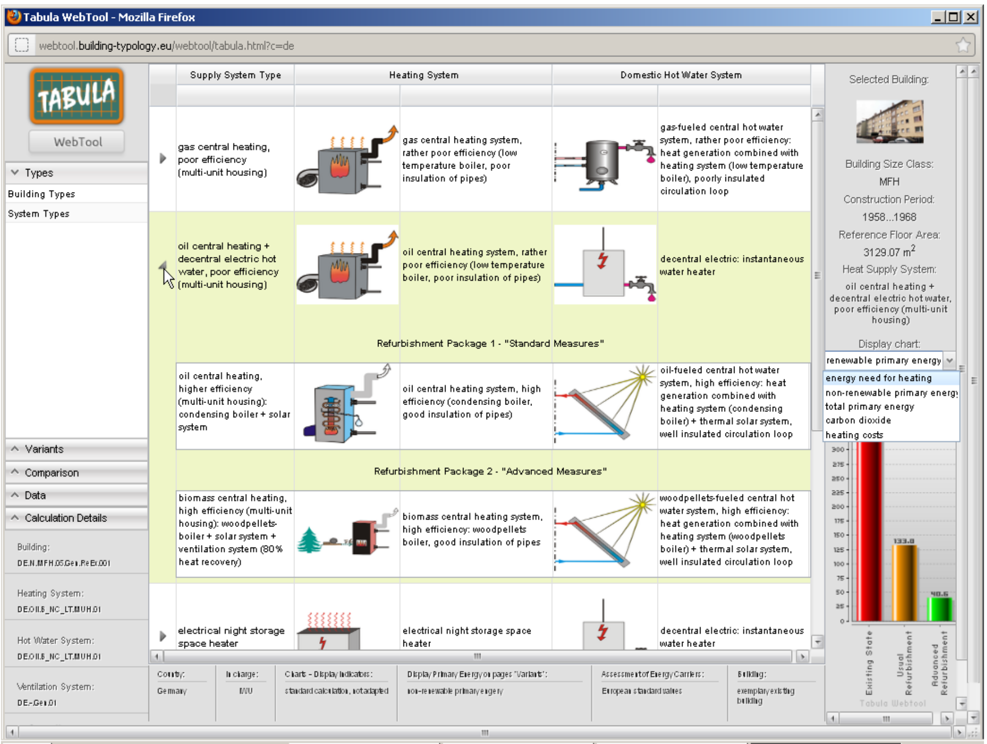


Figure 78: Energy Balance of Variant 1 / "Existing State"

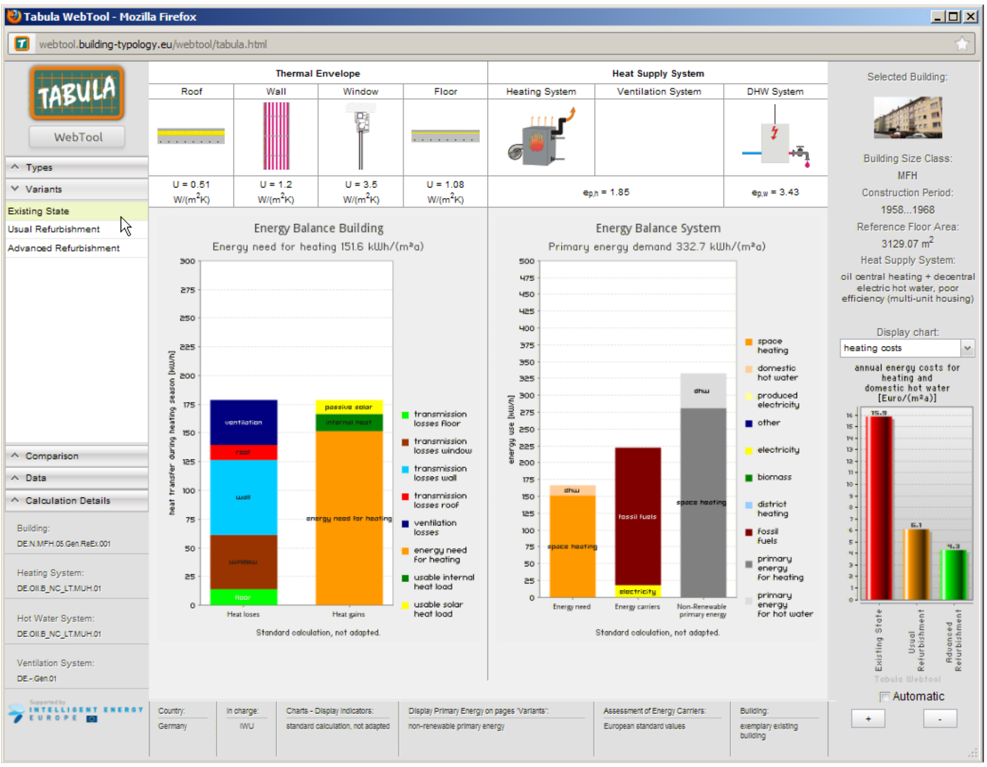


Figure 79: Energy Balance of Variant 2 / "Usual Refurbishment"

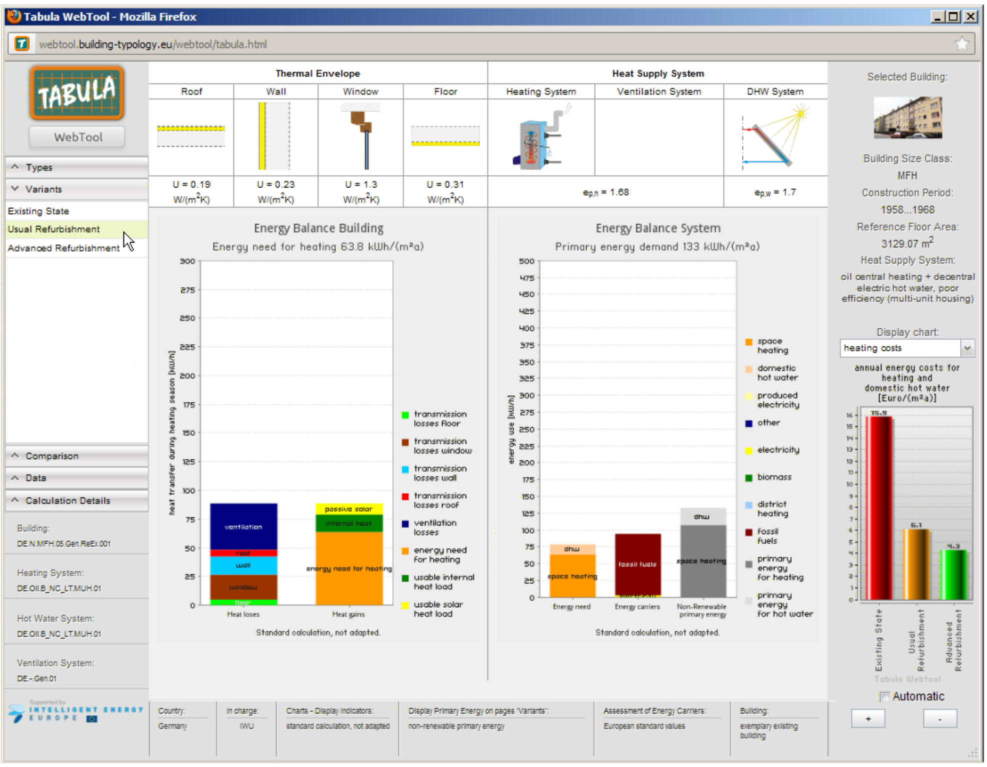


Figure 80: Energy Balance of Variant 3 / "Advanced Refurbishment"

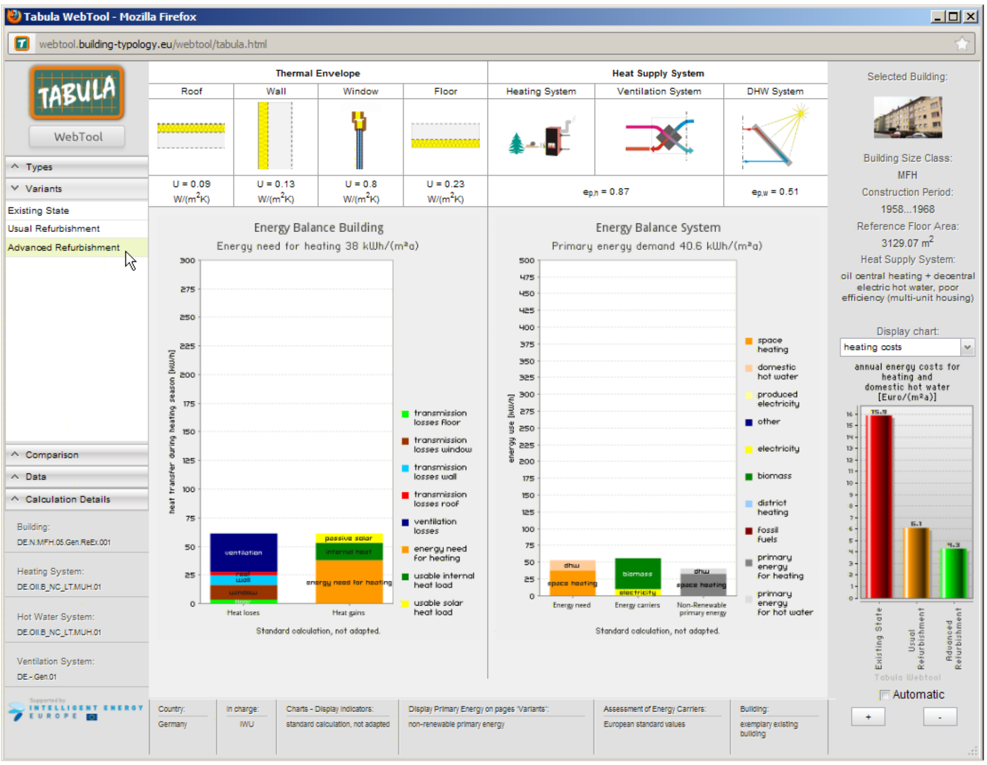


Figure 81: Data Overview for the selected Building

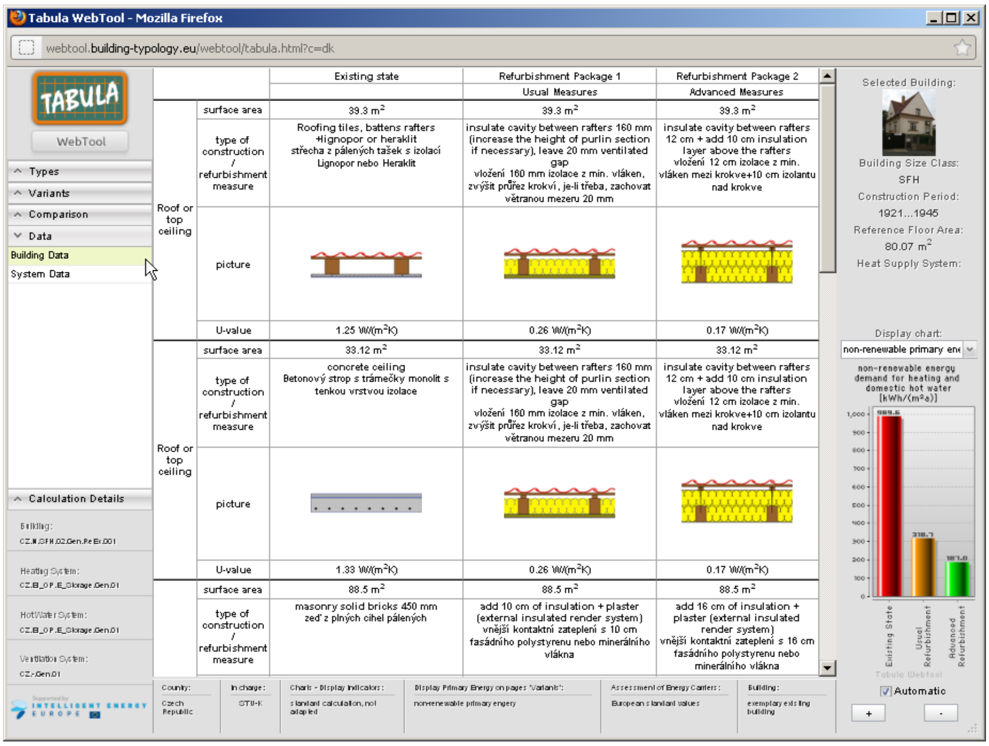


Figure 82: Online Calculation Sheets

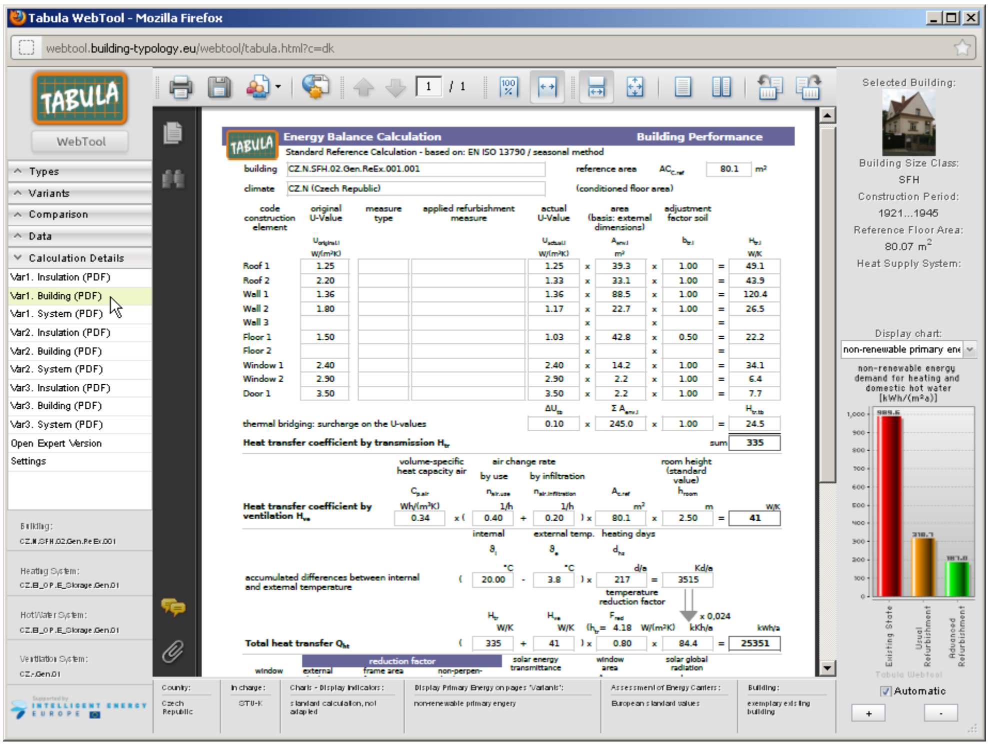


Figure 83: WebTool Expert Version