Typology Approach
for Building Stock
Energy Assessment

TABULA

Use of Energy Certificate Databases as Data Source for National Building Typologies

– TABULA Thematic Report N° 1 –

TABULA Project Team

October 2012

www.building-typology.eu

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1 Summary

According to the TABULA concept a building typology constitutes a framework for assessing the energy related features of the national building stock. It provides a classification scheme defining national building types and assigns exemplary buildings for showcasing energy saving measures. The knowledge about the frequencies of building types enables furthermore the elaboration of building stock models for the projection of the energy consumption and for estimating saving potentials.

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. In a certain number of countries central databases are available which facilitate the data access. During the IEE project DATAMINE different ways of using EPC data for building stock monitoring were developed and applied.[1]

During the set-up of national residential building typologies eight TABULA partners checked the possibility to use EPC databases from their countries as information sources. The results of these investigations are summarised in this report. In some cases more detailed information is available in the national scientific reports of the respective partners.[2]

In general it can be stated that a precondition for the use of EPC data is that the database has a homogeneous structure containing not only general but also detailed information about buildings and supply systems. This was the case in all considered databases. As regards Austria, Belgium and Italy the existing databases are not covering the whole countries but only one or several regions. In case of Germany registration of EPCs is not mandatory, so only a certain subgroup was available which is part of a quality assurance scheme.

Summarised the databases turned out to be useful for defining model buildings, especially as regards the geometrical data. By averaging the envelope areas for the different national building types a basis for building stock models is formed.[3]

The average U-values and the refurbishment state can in principle also be extracted. Nevertheless, the fact has to be considered that issuing of EPCs is only required at certain occasions as selling, renting or refurbishments. Since a systematic correlation of the refurbishment state and these occasions cannot be excluded this information of the EPC database cannot be assumed to be representative. In consequence, additional data sources like a supplemental random based survey (or a census in the best case) appear to be necessary to determine the implementation rates of energy saving measures.

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[1] see Final Report of the IEE Project DATAMINE: http://env.meteo.noa.gr/datamine/DATAMINE_Final_Report.pdf

[2] see http://www.building-typology.eu/tabulapublications.html

[3] see TABULA TABULA Thematic Report N° 2: "Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock. Models for the national housing stock of 8 countries; http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf

Nevertheless, further information not necessarily requiring a representative sample, can be drawn from the databases. In three of the evaluated databases the measured energy consumption was available in addition to the asset rating. So, TABULA partners from Belgium and from Denmark derived information about the correlation of measured and calculated consumption. In case of Germany the number of datasets was too small to find significant numbers.

For the future the TABULA partners recommend to include all relevant typological aspects in the EPC databases in order to facilitate the quality assurance of input data and calculation results. The knowledge about the correlation of distinct quantities can especially be helpful to give indications about the plausibility of thermal envelope areas. An extension of EPC databases to also include the actual measured consumption would be an important means to derive factors for the adaptation of the calculated energy use to the typical level of measured consumption, as being part of the TABULA concept.

2 <AT> Austria

(by TABULA Partner N° 9: AEA / Austria)

2.1 Description of the EPC Database

Databases in Austria

In Austria, the submission of Energy Performance Certificates (EPC) has been the precondition to receive public subsidy for construction or renovation of residential buildings for many years now. Since the transposition of the EPBD into the area of provincial competence, EPCs according to EPBD have been used to apply for social housing subsidies as well.

On a national level, an amendment of Austria's law concerning buildings and residences registry (GWR) appoints Statistics Austria to act as service provider in setting up energy databases.

Another initiative that was put in place in the course of the implementation of the EPBD 2002/91/EC is the online database ZEUS, wich was established in the Province of Salzburg to handle housing subsidy procedures. Meanwhile it is also used by the provincial administrations of Carinthia and Styria. Moreover, in October 2008, ZEUS hast been opened to the private building sector as well.

The EPC-center Vorarlberg has implemented another EPC database which is used only within this province.

GWR System (GWR = Buildings and Residences register)

The new Adress GWR II System is operating since March 2010. Compared to the former GWR I Online System, it has been improved (e.g. input mask) and expanded in response to the building codes of the 9 Austrian federal provinces and the Residential Act. Moreover, the GWR EPC database has been integrated into the GWR system, although the GWR EPC database is not yet operating.

The GWR Act assumes two versions how to enter EPC data into the GWR EPC database. In those provinces, that are already operating a provincial EPC database, the records may be transferred from the internal database (e.g. ZEUS) to the GWR via a technical interface. In provinces without a provincial EPC database, the GWR system requires manual data entry. The first entry of EPC data should be carried out during the process of acquiring the building permit from the building authorities.

Procedures to enable the aquisition of EPCs

In 2010 the amended GWR Act has come into force. One of its major improvements is the establishment of an EPC database, which, however, is not yet working, for reasons of testing and for legal reasons as well. EPC issuers of each province have to be obliged by law to notify each EPC issued to GWR. At the same time, they have to be authorized by law to look at their EPCs in GWR at any later point of time as well. For that, the data fields to be filled in as well as the access permission for EPC issuers will have to be defined by law.

The EPCs already recorded in the ZEUS database will be entered into the GWR in the course of permission procedures and funding of new buildings or renovations.

- When automatically reading in the EPCs, analogue addresses have to be identified, in order to assign an own GWR number to each object.

- On buildings level, 99.7% of the objects existing are already recorded. On residences level, the data stock is by far smaller. A uniform nationwide system of numbering the apartment doors would be necessary, as it is existing only in two provinces, so far. Not until all provinces will have established a uniform door numbering, the GWR EPC database will be able to come into operation.

- Furthermore, there are considerations concerning a kind of harmonized building description form to be filled in by architects and builders. All GWR-relevant data would have to be entered into this form, thus simplifying the procedure of transferring e.g. area data from digital plans into GWR.

Time schedule for putting the GWR EPC into operation

The test environment with the technical interfaces (webservices) for address search is already existing. The webservices for transferring the EPC data are near completion. Not until the above mentioned 3 requirements will be met, the GWR EPC database will be able to come into operation.

ZEUS database

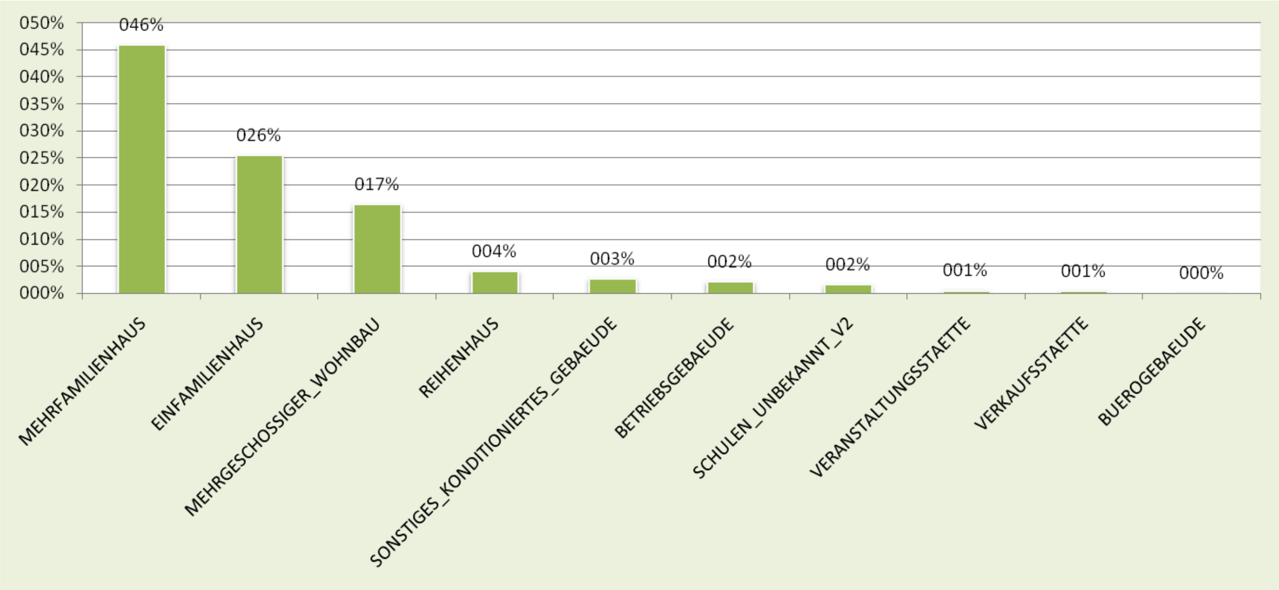
The ZEUS database having become the widest-spread EPC database in Austria over the past 6 years, covering three provinces and being open to the private sector as well, only this Austrian database was analyzed in more detail and its data stock used for the TABULA project, after having been anonymized, of course.

According to the EPBD 2002/91/EC, the Austrian OIB directive 6 was developed. This national directive became effective for new buildings as from 1st of January 2008 and for existing buildings as from 1st of January 2009. It has to be implemented by each of Austria's nine federal provinces by executing the federal state laws.

In Austria, the housing subsidy schemes are the responsibility of the nine Austrian Provinces, thus being handled in nine different ways, including the requirements for obtaining building permission and housing subsidy. The EPC was first introduced in 2000 in the Provinces to gain subsidy schemes for new homes. It contains the description of the thermal building envelope: the configuration of the layers is described, the area is named and the thermal characteristics are documented via U-values. The basis for the calculation of EPCs are the national standards "ÖNORM B 5055 – B 5059" where the thermal characteristics are defined and the calculation process is standardised. These EPCs are calculated by professionists like architects or technical engineers.

Since the implementation of the EPBD 2002/91/EC, all EPCs stored in ZEUS meet the minimum requirements – also useful for the TABULA project. In general, the information needed for TABULA is covered by the datasets stored via ZEUS. At the moment, about 60 % of EPCs of new buildings and 40 % of EPCs for reconstructed buildings are stored in the ZEUS databases. In detail, the stored data can be found in the annex "ZEUS XML datastructure" (German-speaking). As a matter of fact, the biggest lack of information lies within the technical information: the technical data for heating and domestic hot water often is not available (perhaps for that reason that the older subsidy schemes did not require a description of the technical equipment, but only of the thermal envelope).

Figure 1: quantities of available residential (first four columns: MFH, SFH, AB, TH)) and non-residential categories (non conditioned buildings, service buildings, schools, event buildings, shops, offices) within the ZEUS database



2.2 Analysis of the EPC Datasets and the use for the TABULA project

“Landesregierung” Salzburg, “LandesEnergieVerein” Styria and “energie:bewußt” Kärnten, operator of the ZEUS instances have the opportunity to evaluate data in course of EPC calculation such as decrease of heating energy demand or increase of thermal quality of building envelope during a defined period of time. The implementation of ZEUS in other federal provinces is currently under discussion.

In Austrian provinces which are using ZEUS, the electronic submission of the EPC is the precondition to receive a public subsidy for construction or renovation of residential buildings. Consultants use ZEUS as archive and to keep their EPCs organized. Building owners (companies and privates) access their EPCs via ZEUS via secure link.

Companies (e.g. property developers) can implement their own approval process inside ZEUS for EPCs that are stored on behalf of their company.

ZEUS is a software for electronic data management of Energy Performance Certificates. It’s an online database to archive and process EPCs electronically via internet. The EPCs are calculated by software programs. Mainly used software programs provide a direct interface to ZEUS. This allows pushing EPCs to ZEUS by click. The certificate itself (PDF version) and a number of data as result of the calculation are transferred online into the ZEUS database.

Based on the TABULA matrix, the EPCs of provinces Salzburg and Styria were used for evaluation. 22.000 EPCs from the years 2003 to 2010 were analysed. The data evaluation method consisted of the following steps:

- **Retrieve existing data stock**
  All EPC data, stored via XML within ZEUS, of Salzburg and Styria is exported and made anonymous. The EPC data is provided by two Excels sheets to identify the relevant EPCs and apply statistical functions and calculations and classified as raw data. All EPCs of Salzburg and Styria from 2003 to 2010 count: 22,000.

- **Prepare existing data stock**
  The EPC raw data is analysed based on the predefined representative model buildings. Sample categorizations concerning the heating energy demand (HWB), gross floor area (BGF) and status (in progress, done), as well as building age class are made to qualify all possible EPCs.

- **Refine data stock**
  Creation dates of EPCs range from 2007 to 2010 because of the usage of comparable data standards for this time period (comparable XML versions).
  EPCs at this stage count: 18,500.

- **Consolidate data stock**
  At the data consolidation stage, buildings were identified where EPCs exist before and after redevelopment. Sample IDs were evaluated and XML data was further investigated for quality purposes.
  EPCs sample count: 36

- **Identify relevant IDs of EPCs for further investigations**
  Identification of relevant buildings was based on the representative model buildings.
  Final EPCs count: 86

- **Extract all Data of identified EPC IDs used in the XML data structure and PDF**
  All data of the final identified EPCs were extracted. As mentioned, the XML data structure and in succession ZEUS keeps the bigger part of all EPC data. Some data is stored in the PDF only. So PDFs were made anonymous and data of building elements was extracted.

2.3 Conclusions

ZEUS and its data interfaces will be improved further. The interface development for XML version 4 is in the next run. Experts and involved parties are invited to attend discussions about further innovative steps. For national evaluations or investigation projects like TABULA especially the interface between the database and the EPC calculation program is essential for a specific data analysis.

Working with the database within the TABULA project, it was identified that for precise data analysis all the exact information about the geometries of the buildings and its orientations is used to be stored in the XML version. Until today these informations are stored in the EPC PDF only. Furthermore, there is no possibility so far to load the XML data into an EPC calculation program to facilitate and allow for a fast data input in order to change and adapt the stored EPCs for investigation purposes.

The main focus will remain on establishing a homogenous data interface standard and way of processing and storing EPCs. The usability of EPC maintenance user interfaces will be increased so that development methods will be aligned to be able to deal with future challenges.

3 <BE> Belgium

(by TABULA Partner N° 7: Vito / Belgium)

3.1 Description of the EPC Database

EPC certification scheme

- In Flanders, the **EnergiePrestatieCertificaat (EPC)** for existing residential buildings is mandatory when putting a dwelling on the market for sale since the 1st of November 2008, and, when putting a dwelling on the market for rental since the 1st of January 2009. The governmental agency in charge is the Flemish Energy Agency (Vlaams Energieagentschap – VEA).
- In Brussels, the Energy Performance Certificate for existing buildings is called **EPB-certificaat** (Flemish term) or **Certificat PEB** (French term). The certificate is complusary since the 1st of May 2011 (sale) and the 1st of November 2011 (rental). The institute in charge is the Brussels Instituut voor Milieubeheer (BIM), also called Institut Bruxellois pour la Gestion de l'Environnement (IBGE).
- In the Walloon region the **Certificat PEB** was been implemented in the period June 2010 – June 2011 by the Service Public Wallonie DG04 (Direction générale opérationnelle de l'Aménagement du territoire, du Logement, du Patrimoine et de l'Énergie).
- VITO has been involved in the development of the EPC calculation procedures for energy certification of existing residential buildings in Flanders and Wallonia, together with partners such as the Belgian Building Research Institute (BBRI). Currently, VITO is also involved in the development of the **EPC methodology for non residential buildings**. In this case, a common methodology is under development for both the Flemish, Brussels and Walloon region.

Role of the EPC databases

The main goal of the EPC Certificate is to inform potential buyers or tenants on the energy performace of the dwelling. The certificate is composed by a recognized energy expert who has undertaken a course and succeeded in the examination.

Since the EPC certification scheme has only recently been implented in both the Brussels and Walloon region, EPC databases for these regions are not yet available.

For the Flemish region, it is expected that data originating from the mandatory **Energy Performance Certificates** will become accessible in the year 2012, providing data on a large fraction of the pre 2006 housing stock (since the database only contains data on dwellings dating from before the 2006 EPBD legislation). The Flemish Energy Agency will most likely grant access to the database for parties involved in the Steunpunt Wonen en Energie. It is however not yet clear whether other parties (universities, research institutes, sector federations) will be granted access. In any case, several parties hope for equal access to the database for all experts involved in EPBD matters.

Current number of buildings (new/existing; residential/non-residential) / annual growing rates

The 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 dwellings/EPCs, generated by about 3.900 energy experts (status in December 2011).

3.2 Description of the EAP/PAE Databases

The EAP database for Flanders and the PAE database for Wallonia contain detailed information about dwellings for which the owners or residents have commissioned a **voluntary energy audit**, carried out by a qualified energy expert in the past years. 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 IBGE/BIM manages the data obtained from energy audits carried out in Brussels. This database for the Brussels region could not be made accessible by IBGE/BIM within the time frame of the TABULA project. This gives us detailed data on the energy performance and building envelope and services characteristics for a total of approximately 11,000 inspected houses in the Flemish and Walloon regions.

The EAP databases contain detailed information, provided by qualified energy experts, on the building dimensions (building envelope and floor surface areas, protected volume), the building envelope composition and thermal performance (insulation thickness, estimation of the U-value) and the heating and hot water systems installed. The expert calculates the characteristic energy consumption of the house for heating and hot water production following the EAP procedure and then provides customized energy savings advice. Considering that these audits were commissioned by owners or residents on a voluntary basis, rather than on a mandatory basis, we are aware of the fact that the EAP databases do not contain a representative sample of the actual housing stock. The EAP databases however currently represent the largest available databases in Belgium on the existing housing stock.

3.3 Analysis of the EAP/PAE Datasets

Average building, envelope and services characteristics

The data from the EAP databases are of use to derive **average geometrical characteristics** for both the various dwelling types and for their building envelope components. The geometrical characteristics in question include average roof, floor, façade, window and door surface areas, either bordering an outside environment or bordering a heated or unheated indoor space, as well as protected volume and gross floor surface area. Furthermore, the EAP data offer an insight into the **average orientation of the glazed surfaces**. Finally, the data allow to determine **average envelope and services performance characteristics** for various building periods and dwelling types. For example, average U-values can be derived, which are primarily useful for defining **representative dwelling types** with average characteristics intended for national or regional energy balance calculations. The results of these estimations are presented in the Tabula Report 'Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock' [TABULA TR2 BE].

Correction factor for actual energy consumption

The calculation methodology within the Tabula project as well as the Belgian EPB and EPC energy certification software relies on steady state monthly energy balances. We consider it necessary to make some corrections to this theoretically derived energy consumption figures. Especially for older buildings, the theoretical energy consumption tends to be much higher than the actual energy use. Using this unaltered values would lead to a great overestimation of the of the actual energy conservation resulting from renovation measures. In order not to present unrealistic energy savings and payback periods, we choose to add a **correction factor** to the straightforward energy consumption calculated with the steady state energy balances. This correction factor was deduced from the extensive **EAP database of 10.000 Walloon dwellings**. This database incorporates both calculated energy performance according to the EAP steady state energy balance and a record of **measured energy consumption** (based on yearly energy bills). Disregarding the energy used for cooking, this data allowed us to correct the theoretically derived energy consumption for space heating and domestic hot water to match better with reality. Although the energy consumption of the buildings in the national brochure was calculated with the Flemish EPB methodology for new dwellings, we consider it fair to use the correction factor which is based on calculations with the Walloon EAP software, because both steady state calculation methods have many similarities.

A multifactor statistical analysis of the dataset resulted in a formula for a correction factor which depends on the average U-value of the building, the expenditure coefficient of the heating system, and to a lesser extent on both the surface of the exposed building enclosure and the internal volume of the building.

Figure 1: Ratio of actual energy use to calculated energy use in function of the average thermal transmittivity of the building enclosure

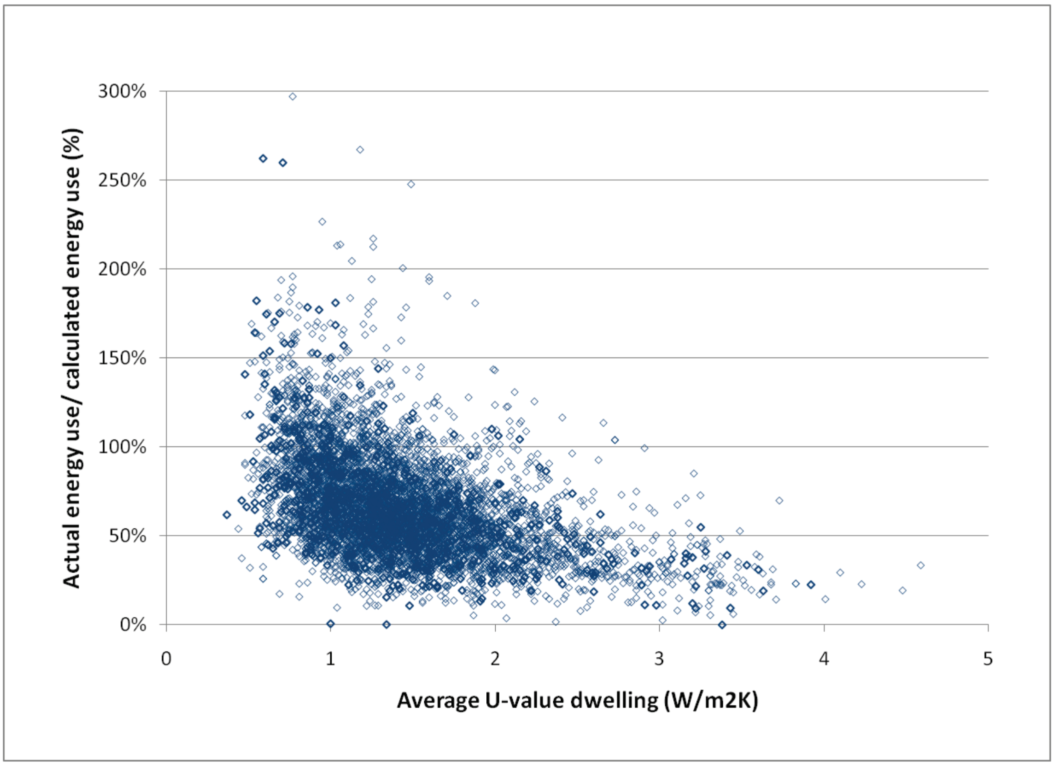


Figure 1 depicts the great divergence between actual energy use and theoretically calculated energy consumption. For buildings with high U-values (poorly insulated), the actual energy use is consistently much lower than the calculated value. In general, the correction factor becomes smaller (and thus 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 the cost of the energy consumption rises.

Table 1 summarizes the correction factors used for the Belgian national typology. The deviation between actual energy use and predicted energy use is bigger for the oldest building classes. For buildings erected after 2005, and for the renovated buildings according to the standard and advanced level, the correction factor is fixed to 100%, which means that the calculated energy use is supposed to match with the actual energy use.

Table 1: Correction factors for actual energy use in the Belgian national typology brochure (Current state)

Dwelling type	Pre 1945	1946-1970	1971-1990	1991-2005	Post 2005
Detached	34%	38%	45%	60%	100%
Semi-detached	41%	45%	50%	64%	100%
Terraced	42%	45%	52%	67%	100%
Appartment – enclosed	46%	48%	48%	59%	100%
Appartment – exposed	50%	51%	59%	81%	100%
Average correction factor	41%	44%	49%	63%	100%

3.4 Conclusions

The mandatory EPC certificate databases can have an important contribution to the building of a representative database of the entire existing dwelling stock. This more complete view of the housing stock is a prerequisite in defining proper policy recommendations.
To guarantee this view and the effective policy support, a high level of database transparency is necessary. On the one hand, this requires that all relevant stakeholders involved in EPBD matters get access to these databases. On the other hand, standardization or uniformization of the different databases (EPC, EAP, ...) and beyond the regions within Belgium (Flanders, Brussels, Wallonia) will increase their accessibility. As we already mentioned, Belgium has two different types of certificate databases for existing dwellings, namely EPC and EAP, which also differ between the three Belgian Regions. Moreover, the certificates of new buildings (EPB or PEB) are collected in – again – a different database. Each database has its own definitions, assumptions, type of saved data, etc. This large variation hampers a good comprehension of the current state of the housing stock by the different stakeholders.

Besides transparency, one has to aim at a high level of quality of the collected data. This quality can only be guaranteed by stimulating a continuous learning process for the software users (mainly energy experts) as well as for the software developers. Concerning the energy experts, this can be achieved by having a proper manual of the certification software, by getting the opportunity to give or receive feedback and by getting courses on a regular base, etc. are some examples to improve this learning process. The feedback of the energy experts (eg. FAQ, evaluation surveys etc.) will assist the software developers in achieving a continuous improvement of the certification program.

Table 2: Sources / References Belgium

Reference shortcut	Short description (in English)	Concrete reference (in respective language)
[TABULA NatSciRep BE]	TABULA National Scientific Report for Belgium	Scientific Report - IEE TABULA - Typology Approach for Building Stock Energy Assessment. W. Cyx , N. Renders, M. Van Holm en S. Verbeke, VITO, 2011
[TABULA TR2 BE]	TABULA Report on Energy Balances – Belgian case	Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock (TABULA Thematic Report N° 2). N.Renders, VITO, 2011

4 <DE> Germany

(by TABULA Partner N° 1: IWU / Germany)

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 these collected datasets was performed during the German part of the TABULA project. In the following chapters the main results of the analyses are presented – the complete report is documented in [TABULA NatSciRep DE 2012] (in German).

4.1 Description of the EPC Database

Various commercial software applications for the calculation according to the energy certificate regulations are available in Germany. Despite this fact there is only one application for issuing the certificate (that means: printing the officially designed PDF). This "EPC Printing Utility" is designed and disseminated by the German energy agency dena. Before an EPC can be issued (printed) the "EPC Printing Utility" receives a well defined set of data from the individual calculation programme via an interface.

A quality assured EPC can only be printed by an EPC issuer who has registered for the dena EPC quality mark. In this case plausibility checks are applied, an overview of the main input and output quantities is given (see Figure 2) and the dataset of the respective building is transferred to the dena EPC database, tagged as "quality assured". Apart from this forced transfer also a voluntary submission of non-registered datasets is possible by pressing a button "Send files to dena".

The data fields of the interface are specified in a document published on the dena website [dena 2009].

At the time of evaluation (July 2011) the dena database contained the following numbers of residential buildings' datasets:

- certificates without registration and quality assurance: n ≈ 20 000
- quality assured and registered certificates: n ≈ 1 300
  ("dena Gütesiegel Energieausweis")

Figure 2: Standardized display of main calculation results by quality certified energy performance certificate ("dena Gütesiegel Energieausweis") [EPC QA]

DOKUMENTATION zum Energieausweis

Technische Details

dena
Deutsche Energie-Agentur

Gebäudedaten: Musterstr. 123b, 12345 Musterstadt
Ausstellerdaten: Musterfirma GmbH, 12345 Musterstadt

dena-122153-BT2VY
Datum: 03.10.2009

4

Technische Details

Kenngrößen Allgemein			vorhanden	Variante 1	Variante 2
thermische Hüllfläche	A	[m²]	893	893	893
Gebäudenutzfläche	A_N	[m²]	575	575	575
Wohnfläche	WFL	[m²]	479	479	479
beheiztes Nettovolumen	V_i	[m³]	1.438	1.438	1.438
beheiztes Bruttovolumen	V_e	[m³]	1.796	1.796	1.796
Kompaktheit	A / V_e	$[m^{-1}]$	0,50	0,50	0,50
spez. Jahres-Primärenergiebedarf	Q_P	[kWh/m²a]	249,9	220,9	30,3
EnEV Anforderungswert für Neubau	$Q_{P\,EnEV\,N}$	[kWh/m²a]	83,0	83,0	83,0
EnEV Anforderungswert für Modernisierung	$Q_{P\,EnEVM}$	[kWh/m²a]	116,0	116,0	116,0
spez. Transmissionswärmeverlust	HT'	[W/m²K]	1,18	1,08	0,51
EnEV Anforderungswert für Neubau	HT'_{EnEVN}	[W/m²K]	0,50	0,50	0,50
EnEV Anforderungswert für Modernisierung	HT'_{EnEVM}	[W/m²K]	0,70	0,70	0,70
spez. Endenergiebedarf	Q_E	[kWh/m²a]	222,0	195,9	85,2
spez. Heizwärmebedarf	Q_H	[kWh/m²a]	140,7	129,7	65,4

Kenngrößen Allgemein			vorhanden	Variante 1	Variante 2
Anlagenaufwandszahl, primärenergetisch	e_P	[–]	1,63	1,55	0,39
Kohlendioxid-Emissionen	CO_2	[kg/m²a]	56,4	49,9	7,0
Länge Heizperiode	t_{HP}	[d/a]	185	185	185
Luftwechselrate	n	h^{-1}	0,70	0,70	0,70
Wärmebrückenzuschlag	ΔU_{WB}	[W/m²K]	0,10	0,10	0,10

Kenngrößen Gebäudehülle					
Dach / oberer Abschluß	Fläche A_D	[m²]	133	133	133
Dach / oberer Abschluß	U-Wert U_D	[W/m²K]	0,98	0,13	0,13
Außenwand	Fläche A_{AW}	[m²]	534	534	534
Außenwand	U-Wert U_{AW}	[W/m²K]	0,90	0,90	0,22
Fenster / Türen	Fläche A_W	[m²]	96	96	96
Fenster / Türen	U-Wert U_W	[W/m²K]	1,65	1,57	1,57
Bodenplatte / unterer Abschluß	Fläche A_B	[m²]	131	131	131
Bodenplatte / unterer Abschluß	U-Wert U_B	[W/m²K]	1,01	0,25	0,25

Kenngrößen Anlagentechnik	vorhanden	Variante 1	Variante 2
Anlagensystem Heizung	Standardkessel	Standardkessel	Sonstige
Energieträger Heizung	Erdgas	Erdgas	Holz-Pellets
Anlagensystem Warmwasser	Mit Heizung kombiniert	Mit Heizung kombiniert	Mit Heizung kombiniert
Energieträger Warmwasser	Erdgas	Erdgas	Holz-Pellets
Anlagensystem Lüftungsanlage	nicht vorhanden	nicht erneuern/einbauen	zentrale Anlage
Lüftungskonzept			Lüftungsanlage mit WRG

Kenngrößen Anlagentechnik			vorhanden	Variante 1	Variante 2
Baujahr Heizung			1982		
Leistung Heizung	P_H	[kW]	72,5	72,5	35,9
solare Unterstützung Heizung		[%]			
Primärenergiefaktor Energieträger Heizung	f_P	[–]	1,10	1,10	0,20
Aufwandszahl Erzeuger Heizung	e_g	[–]	1,21	1,22	1,39
Deckungsanteil Heizung		[%]	100	100	100
Wärmeverluste Heizung Verteilung	$q_{H,d}$	[kWh/m²a]	5,8	1,7	1,4
Wärmeverluste Heizung Speicherung	$q_{H,s}$	[kWh/m²a]	0,0	0,0	0,0
Baujahr Lüftungsanlage					
Wärmerückgewinnungsgrad Lüftungsanlage		[%]			80

Kenngrößen Anlagentechnik			vorhanden	Variante 1	Variante 2
Baujahr Warmwasser					
Leistung Warmwasser	P_{TW}	[kW]	72,5	72,5	35,9
solare Unterstützung Warmwasser		[%]			70
Primärenergiefaktor Energieträger WW	f_P	[–]	1,10	1,10	0,20
Aufwandszahl Erzeuger Warmwasser	e_g	[–]	1,28	1,31	1,39
Deckungsanteil Warmwasser		[%]	100	100	31
Wärmeverluste Warmwasser Verteilung	$q_{TW,d}$	[kWh/m²a]	17,5	10,0	10,0
Wärmeverluste Warmwasser Speicherung	$q_{TW,s}$	[kWh/m²a]	1,6	1,6	1,6
Baujahr Solaranlage					
Bruttokollektorfläche Solaranlage		[m²]			20

4.2 Analysis of the EPC Datasets

The below described analyses have been performed by IWU in the framework of the TABULA project. The aim of this evaluation was to

- check which information can be drawn with respect to the energy state and the energy consumption of typical German residential buildings and carry out exemplary analyses;
- make an assessment of the data quality and give recommendations for plausibility checks;
- give recommendations for the further development of the data structure with respect to the improvement of the certificate quality and to possible utilisations for building stock monitoring.

The evaluation has been performed by use of the software "R" for statistical computing. Only quality assured datasets were evaluated. An export of datasets was performed by dena at three different times:

Table 3: Export of datasets for evaluation

Data export by dena	Time of export	Number of datasets
1st export	May 2009	268
2nd export	April 2010	657
3rd export	July 2011	1280

Each of these data tables was analysed by IWU. A respective evaluation report was elaborated and submitted to dena. The results shown below are extracted from the final report, which is documented in the national scientific report [TABULA NatSciRep DE 2012] (appendix in German language).

Age of the Buildings

An overview of the number of datasets by construction year bands is given by Table 4. The chart of Figure 3 displays the frequencies of construction years on the time axis. The dominant fraction of buildings was built between 1950 and 2000. Further accumulations can be recognised in the area around 1930 and 1900. About 12% of the datasets come from buildings which were constructed after 1995.

Table 4: Analysed datasets by construction year periods

Year of construction	number of building datasets
until 1978 [4]	934
from 1979 to 1994	196
from 1995	150
Sum	1280

[4] thereof 65 buildings with inplausible indicators; these datasets were not considered in the analyses differentiating by construction year class

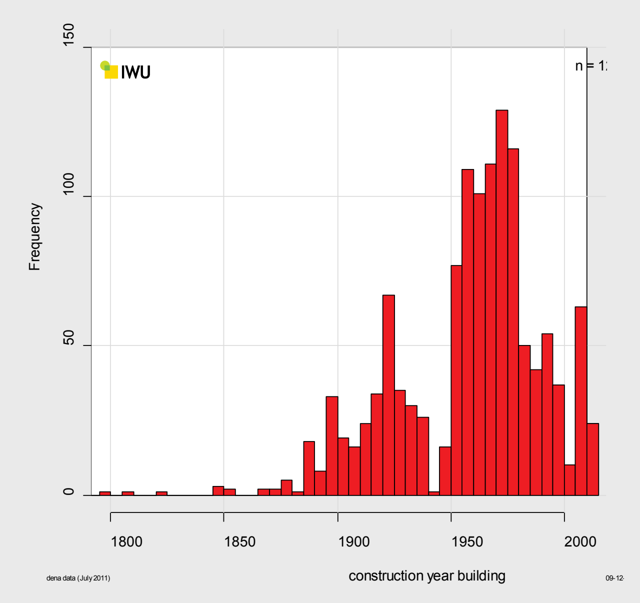


Figure 3:

Frequencies of construction years / all buildings

U-values

The following tables show the medians and averages of the U-values differentiated according to envelope element type and construction year period. In the charts of Figure 4 the frequency distributions of buildings constructed until 1978 are displayed (further distributions are shown in the original report).

Table 5: Median of U-Values [W/(m²K)]

Construction Year	Roof	Wall	Window	Floor
until 1978	0,62	1,20	2,74	1,00
from 1979 to 1994	0,36	0,60	2,61	0,65
from 1995	0,20	0,25	1,18	0,31

Table 6: Average U-values [W/(m²K)]

Construction Year	Roof	Wall	Window	Floor
until 1978	0,77	1,15	2,64	1,05
from 1979 to 1994	0,40	0,64	2,37	0,71
from 1995	0,23	0,28	1,28	0,36

The averages and distributions are similar to those of the evaluations performed for the database of the climate protection fund ProKlima Hanover in the framework of the IEE project DATAMINE [IWU 2008] [DATAMINE FR 2009]. For the buildings constructed from 1995 it must be noted that not all years are represented in the same way (see frequencies in Figure 3).

Figure 4: Frequencies of U-values for the roofs, windows, façades (wall + window), floors / buildings constructed until 1978

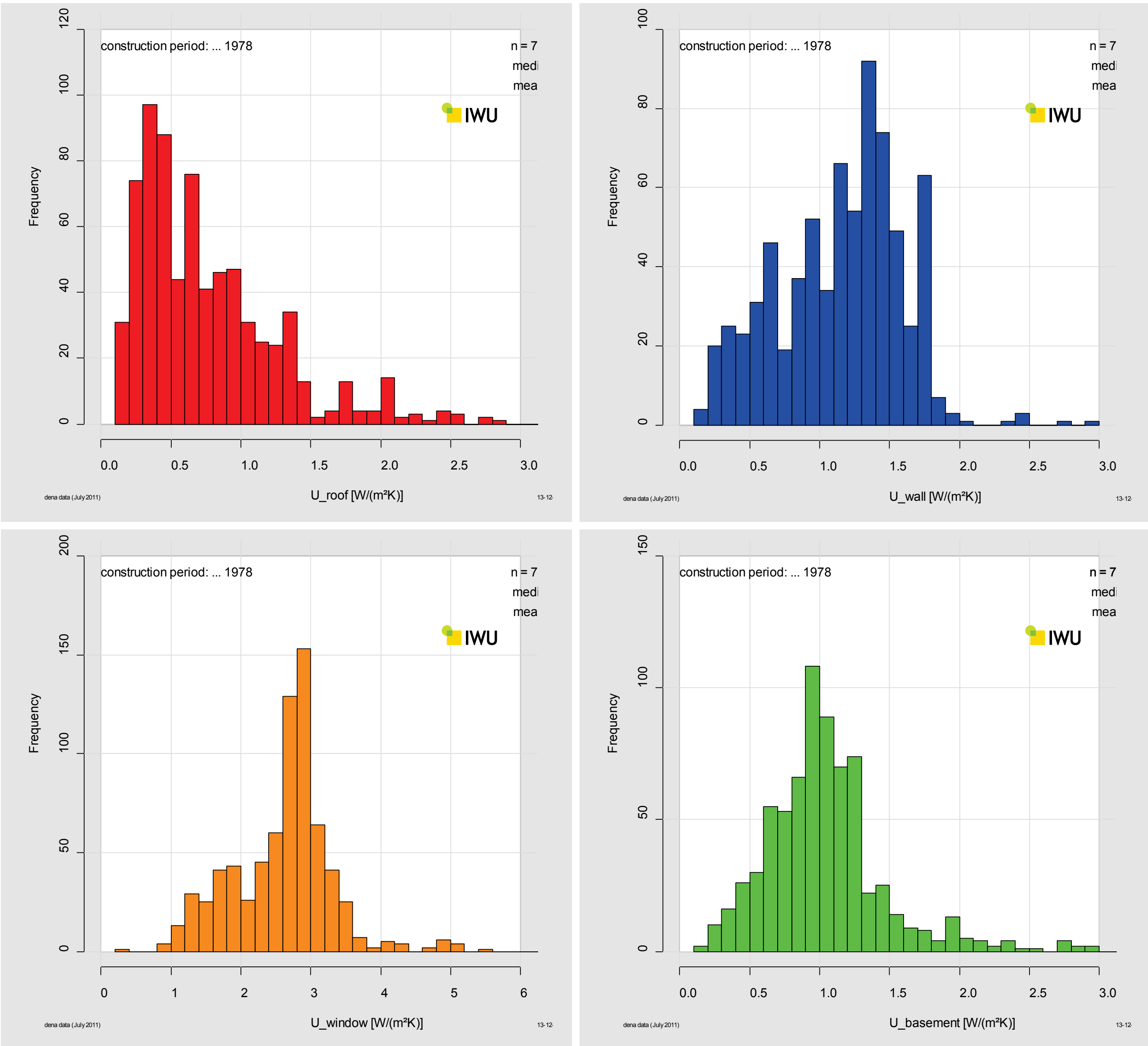


Figure 5 shows the dependence of the thermal envelope area quality on the construction year of the building. The development on the time axis seems plausible. Starting from the 1970s the thermal transmittance is declining remarkably. Some very low values of older buildings can be explained by already implemented insulation measures

Figure 5:

Heat transfer coefficient by transmission per m² reference floor area, plotted versus the construction year of the buildings

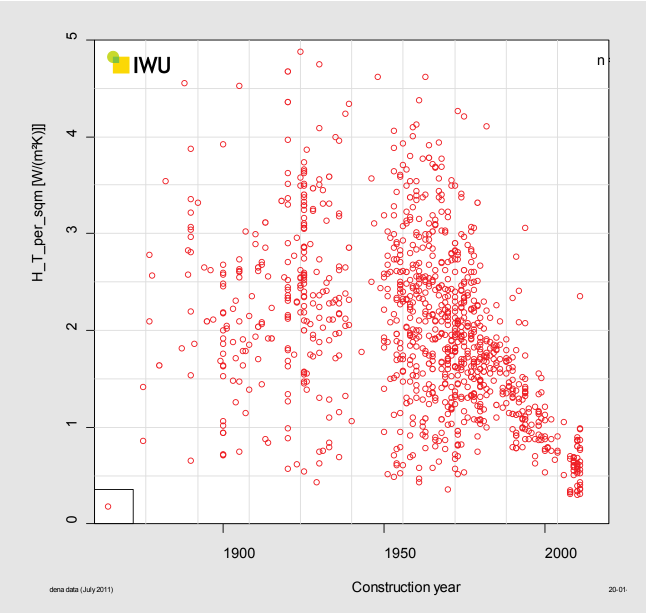
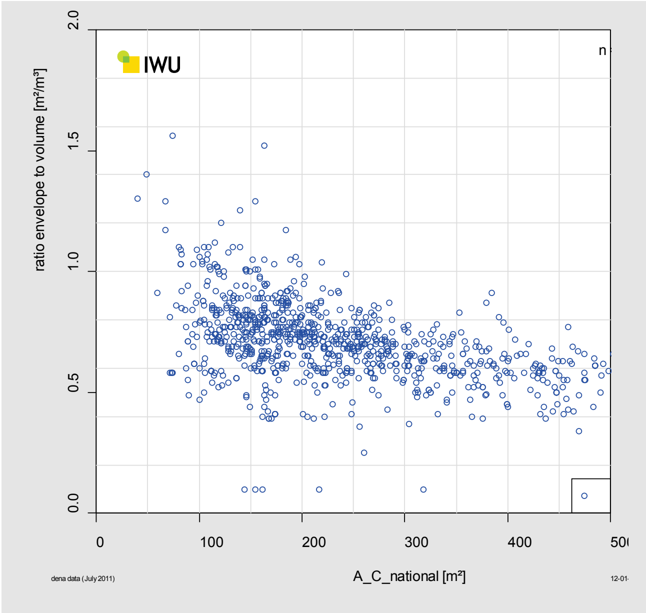


Figure 6:

Correlation of the envelope to volume ratio and the EPC reference area / small buildings



Envelope Areas

Ratio of total envelope area to building volume

In Figure 6 the correlation of the envelope to volume ratio with the EPC reference area is shown for the buildings below 500 m² reference area. For most of the buildings the ratio is between 0.5 and 1.0 m²/m³. Only very few are higher than 1.1 m²/m³.

Some outliers with a value of 0.1 m²/m³ are noticeable which must be caused by calculation or export errors. Furthermore there are about 100 datasets with A/V_e = 0 m²/m³ (not shown in the chart). In the future such errors could be avoided by an extension of the plausibility check.

Surface Areas by Envelope Type

In order to find typical floor area related values for the different envelope types the real living space of the buildings was used as reference (instead of the EPC reference area which is derived from the building volume). As a result of the analyses the charts in Figure 7 show ratio of surface area to living space for the different element types. The following table gives an overview differentiating by two building sizes and three construction periods. These quantities have been used for the energy balance model of the national housing stock [TABULA TR2 2012][5].

[5] Actually the values from the 2nd data export were used for the model. The results of the 3rd export shown here slightly differ from these.

Table 7: Ratio of element areas to living space

	Single-family and terraced houses (buildings with 1 or 2 apartments)			Multi-family houses (3 or more apartments)		
Construction Year	... 1978	1979 ... 1994	1995 ...	... 1978	1979 ... 1994	1995 ...
	Ratio of element areas to living space [m²/m²]					
Roof	0.83	0.75	0.70	0.43	0.48	0.44
Window	0.22	0.23	0.22	0.19	0.22	0.22
Wall	1.04	0.94	0.97	0.76	0.72	0.74
Façade (wall + window)	*1.26*	*1.17*	*1.19*	*0.95*	*0.94*	*0.96*
Floor	0.68	0.64	0.58	0.37	0.45	0.37

Figure 7: Ratio of construction element area to living space for roofs, windows, façades (wall + window), and floors

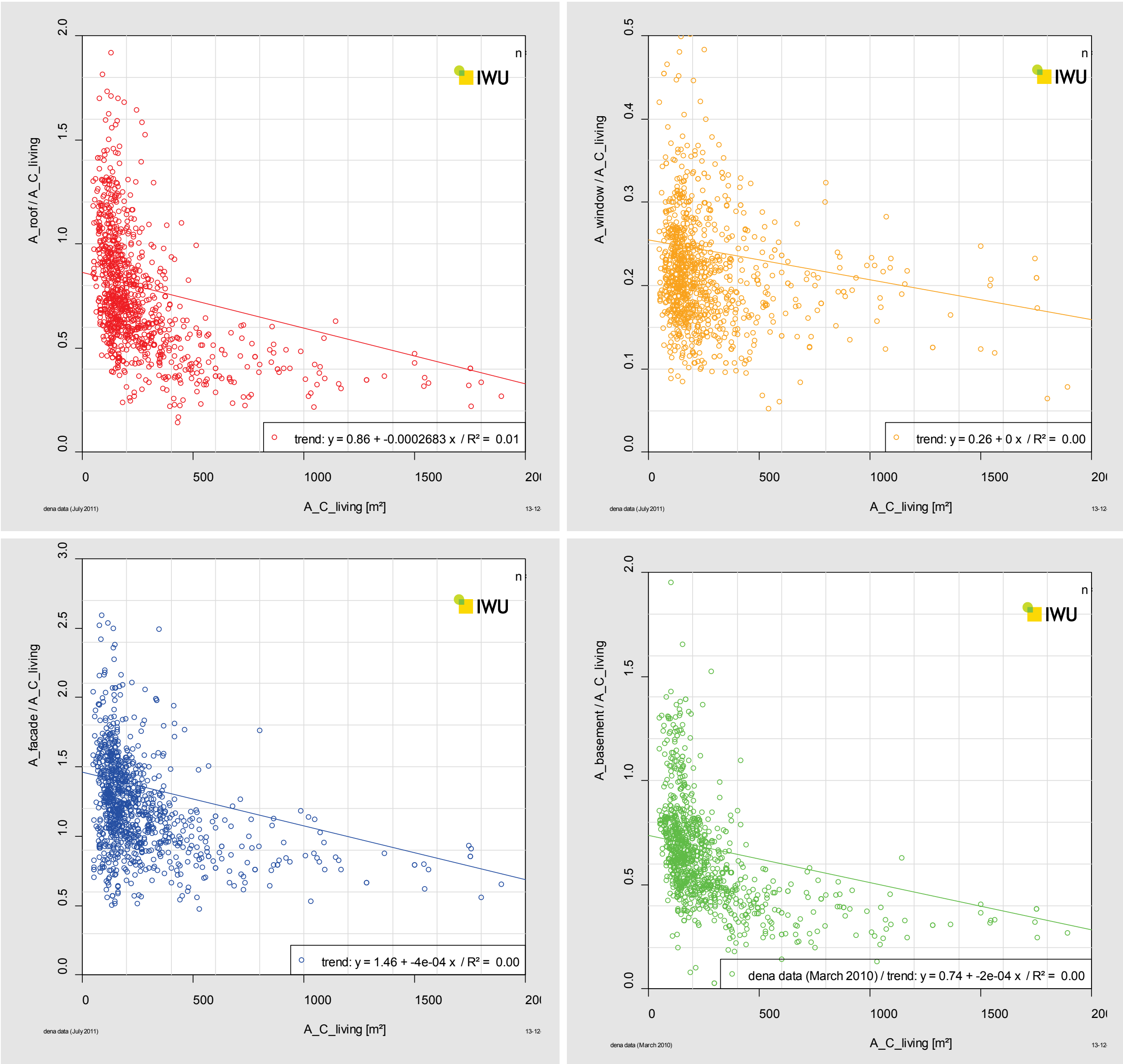
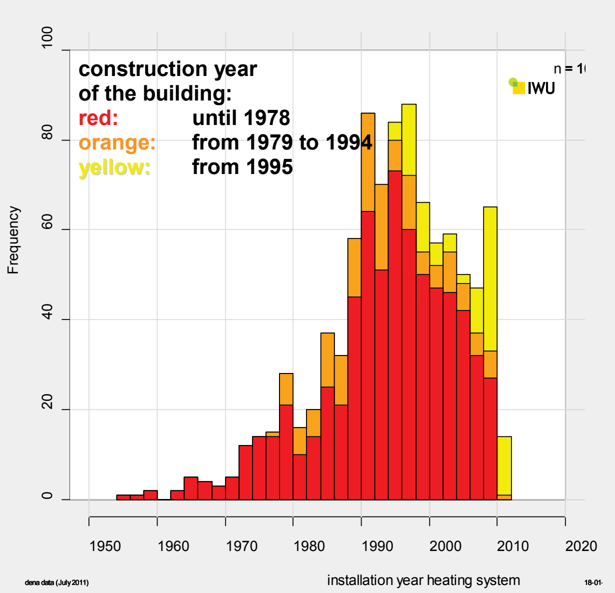
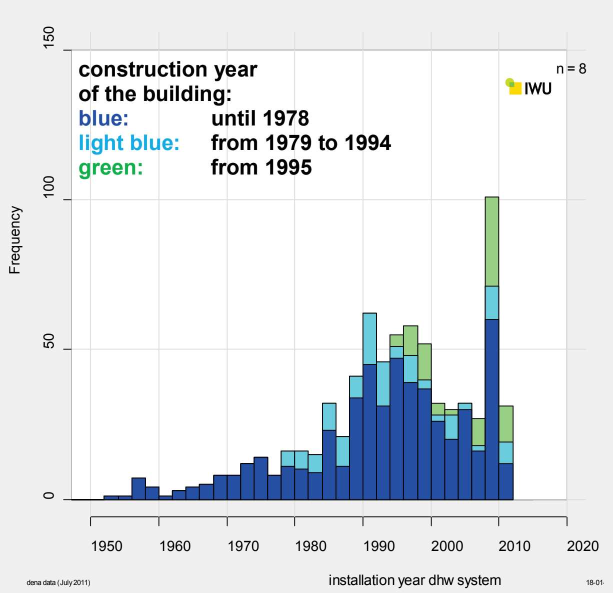


Figure 8: Frequencies of installation years and system types

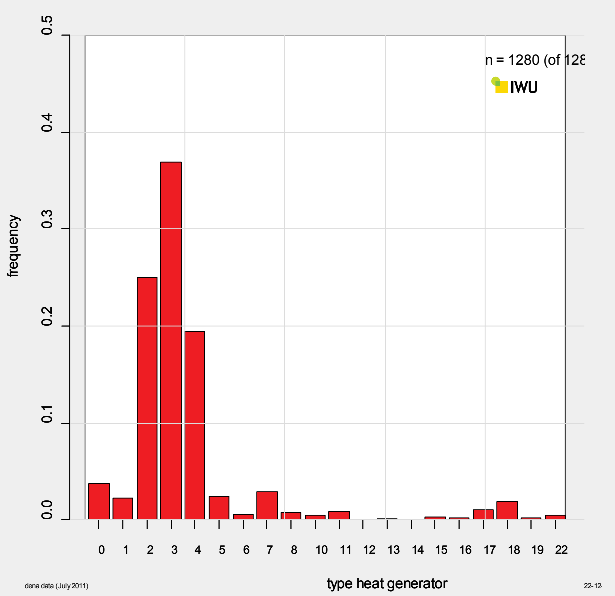
Space heating systems (n = 1070)	**DHW systems** (n = 865)

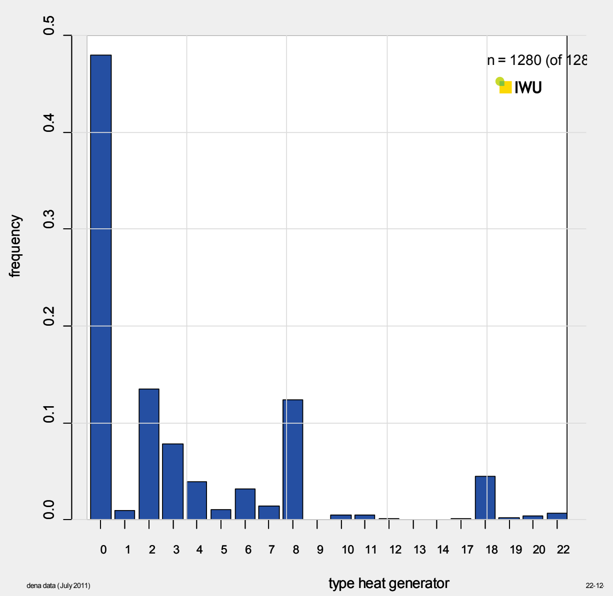
System installation year





Heat generator types (explanation of codes in Table 8)





Heat Supply Systems

The installation year was analysed for 1070 space heating systems and 865 DHW systems. The charts in Figure 8 are displaying the frequencies of installation years – separately for three periods of building constructions. It can be stated that in case of the old buildings (built until 1978) 15% of the heat generators are older than 20 years. In case of the DHW systems this fraction is larger – but in this case also decentral devices are included. For the newer buildings the installation years of the systems are nearly identical with the construction years of the buildings.

60% of the heat generators are constant and low temperature boilers (sum of types 1 to 3), 20% of are condensing boilers. Other heat generators are rather rare. About 50% of the DHW systems are operated in combination with the heating system heat generator. Further 24% have been indicated as "boiler". It can be assumed that in most of these cases also a combination of DHW and heating system do exist. In about 14% of the buildings a decentral DHW system is installed, the dominant heat generators are electrical instantaneous water heaters.

Table 8: Definition of the system types [dena 2009]

Erzeuger Heizung

Übergabewert	dena-Kurzbezeichnung	Erläuterungen	DATAMINE
1	Sonstige Kessel	Kesseltypen, die nicht unter die folgenden drei Kesselbezeichnungen fallen	b_nc
2	Standardkessel		b_nc_ct
3	Niedertemperatur-Kessel		b_nc_lt
4	Brennwert-Kessel		b_c
5	Nah-/Fernwärme	Anschluss an Nah- und Fernwärmenetze, auf deren Steuerung der Eigentümer keinen Einfluss hat	dh
6	Elektro-Speicher, zentral		el_d
7	Elektro-Speicher, de-zentral	dezentrale Elektro-Speichergeräte, Elektro-Nachtspeichergeräte	el_d
8	El.-Direkthzg./Durchlauferh.	Elektro-Direktheizgerät bei Heizsystemen Elektro-Durchlauferhitzer bei Warmwassererwärmung	el_d
9	Sonstige Wärmepumpen	Wärmepumpen, die nicht unter die folgenden Bezeichnungen fallen	hp
10	Wärmepumpe Außenluft		hp_air
11	Wärmepumpe Erdreich		hp_soil
12	Wärmepumpe Abluft		hp_exair
13	Wärmepumpe Grundwasser		hp_water
14	Wärmepumpe, mehrere	Kombination mehrerer verschiedener Wärmepumpen	hp_other
15	Einzelofen, ölbefeuert	Ölbefeuerter Einzelofen mit Verdampfungsbrenner	stove
17	Einzelofen, Holz		stove
18	Einzelofen/Durchlauferh., Gas	Gasraumheizer	stove
19	Kraft-Wärme-Kopplung	Kraft-Wärme-Kopplung (vom Eigentümer verwaltetes BHKW)	chp
20	Solarthermische Anlage	thermische Solaranlage	solar
21	Dampferzeuger		steam
22	Sonstige	Sonstige Beheizungen	other

Erzeuger Warmwasser

Übergabewert	dena-Kurzbezeichnung	Erläuterungen	DATAMINE
0	Mit Heizung kombiniert		
1	Sonstige Kessel	Kesseltypen, die nicht unter die folgenden drei Kesselbezeichnungen fallen	b_nc
2	Standardkessel		b_nc_ct
3	Niedertemperatur-Kessel		b_nc_lt
4	Brennwert-Kessel		b_c
5	Nah-/Fernwärme	Anschluss an Nah- und Fernwärmenetze, auf deren Steuerung der Eigentümer keinen Einfluss hat	dh
6	Elektro-Speicher, zentral		el_d
7	Elektro-Speicher, de-zentral	dezentrale Elektro-Speichergeräte zur Warmwassererwärmung	el_d
8	El.-Direkthzg./Durchlauferh.	Elektro-Durchlauferhitzer	el_d
9	Sonstige Wärmepumpen	Wärmepumpen, die nicht unter die folgenden Bezeichnungen fallen	hp
10	Wärmepumpe Außenluft		hp_air
11	Wärmepumpe Erdreich		hp_soil
12	Wärmepumpe Abluft		hp_exair
13	Wärmepumpe Grundwasser		hp_water
14	Wärmepumpe, mehrere	Kombination mehrerer verschiedener Wärmepumpen	hp_other
15	*Einzelofen, ölbefeuert*	*(unüblich zur Warmwassererwärmung, ggf. ausblenden)*	*stove*
16	*Einzelofen, Steinkohle*	*(unüblich zur Warmwassererwärmung, ggf. ausblenden)*	*stove*
17	*Einzelofen, Holz*	*(unüblich zur Warmwassererwärmung, ggf. ausblenden)*	*stove*
18	Einzelofen/Durchlauferh., Gas	Gasdurchlauferhitzer	stove
19	Kraft-Wärme-Kopplung	Kraft-Wärme-Kopplung (vom Eigentümer verwaltetes BHKW)	chp
20	Solarthermische Anlage	thermische Solaranlage zur Warmwassererwärmung	solar
21	Dampferzeuger		steam
22	Sonstige	Sonstige Warmwasserbereitungssysteme	other

4.3 Conclusions

The database of the German energy agency dena is a good instrument for tracking and improving the quality of issued energy certificates as well as of the whole certification process. The central data collection is the precondition for plausibility checks of input and output quantities.

The examples for statistical analyses shown in this chapter reveal the correlation of different input quantities. The knowledge about these systematical dependencies can be used do define plausibility checks of different quantities. This might be helpful especially in the case of the thermal envelope area since its determination is rather error-prone.

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 from the EPC database. 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 [TABULA TR2 2012].

Unfortunately, the number of datasets containing the actual measured consumption was not sufficient for an evaluation of the correlation of measured energy consumption and calculated energy use[6]. An extension of the quality assured data collection scheme to a larger fraction of energy certificates could help to provide this information.

[6] An analysis of the ratio measured to calculated consumption of 900 non-quality assured datasets from the dena database has recently published by dena during the national TABULA event:
http://www.iwu.de/fileadmin/user_upload/dateien/energie/ake48/IWU-Tagung_2012-05-31_Bigalke_dena_BedarfVerbrauch.pdf
However, there is no way to prove which fraction of these datasets are reflecting real energy certificates and real consumptions (it cannot be excluded that there is a certain fraction of test datasets).

Table 9: Sources / References Germany

Reference shortcut	Short description (in English)	Concrete reference (in respective language)
[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 2009]	specification of EPC printing utility interface, by German energy agency dena	dena Energieausweis für Wohngebäude. Definition der Schnittstelle; Stand: 15.09.2009 / Schnittstellenversion: 3.2.5 http://www.zukunft-haus.info/de/planer-handwerker/energieausweis/expertenbereich/software/informationen-fuer-softwarehersteller.html?up=1&cHash=9c4269a35f
[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
[EPC QA]	example for an quality-certified energy performance certificate, including additional information	http://www.zukunft-haus.info/fileadmin/zukunft-haus/energieausweis/Muster_GS_EA_WG.pdf
[IWU 2008]	IEE project DATAMINE / detailed description of the German model project, focusing on monitoring of a regional grant programme	Loga, Tobias; Diefenbach, Nikolaus: DATAMINE – Modellprojekt proKlima-Altbau. Monitoring eines Förderprogramms mit Hilfe von Energiepass-Daten; IWU Darmstadt, Januar 2008 http://www.iwu.de/fileadmin/user_upload/dateien/energie/datamine_MP1_de_German_Ergebnisse_01-2008.pdf
[IWU 2012]	Analyses of the Energy Performance Certificate Database of the German Energy Agency dena (Detailed Work Report)	Loga, Tobias; Diefenbach, Nikolaus: Analyse von Datensätzen aus der Datenbank der dena zum Gütesiegel Energieausweis; Werkbericht Januar 2012 / Datenstand Juli 2011; IWU, Darmstadt 2012; published as an Annex in: [TABULA NatSciRep DE 2012]
[TABULA NatSciRep DE]	report, describing the details and results of the German TABULA project activities	Loga, Tobias; Diefenbach, Nikolaus; Stein, Britta; Born, Rolf: TABULA Scientific Report Germany. Further Development of the German Residential Building Typology; IWU, Darmstadt 2012
[TABULA TR2]	TABULA Thematic Report N° 2	Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock. Models for the national housing stock of 8 countries; by Vito / Belgium, STU-K / Czech Republic, SBi / Denmark, IWU / Germany, NOA / Greece, POLITO / italy, ZRMK / Slovenia; TABULA Thematic Report N° 2; IWU, Darmstadt 2012 http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf

5 <DK> Denmark

(by TABULA Partner N° 13: SBi / Denmark)

5.1 Description of the EPC Database

The Danish energy labelling scheme for small residential buildings (EM) has been running since 1997 and stipulates that a building has to be certified whenever it is sold. Certification according to the EM scheme was based on calculated net energy rating, but covered only small residential houses and owner-occupied flats. In 2006, the scheme was changed according to the requirements in the European Directive on the Energy Performance of Buildings (EPBD) to a new energy performance (EP) certification procedure according to which the primary energy performance of all building types must be calculated. Thus information gathered during the course of building energy audits is much more comprehensive and adequate for estimating the energy-saving potential. This information is collected in one national database (EMO database) holding data for both input and output for the energy performance calculations. It is thus possible to extract information from the database to reconstruct the building model used to perform the calculations for any certified building.

The annual growth rates of issued certificates in 2009 and 2010 are shown in the table below. Other building types (non-residential buildings) are also certificated according to the same method, but not included in the table.

Table 10: Annual growth rates of the EP certification scheme

Certification year	2009	2010
Farm houses	1,159	2,379
Single-family houses	28,303	40,743
Terrace houses	9,793	10,626
Apartment blocks	7,235	9,330
Office and Trade buildings	3,128	2,884

The total number and areas of certificated properties are shown in the next table. In the TABULA project, farm houses have been included in the single-family house typology.

Table 11: Number of certification scheme and the total building stock area (April 2010)

Building Type	No. of certificates	Certificated area	Total building stock area	Certificated share
	[-]	[m²]	[m²]	[%]
Farm houses	3,125	601,525	22,288,805	2.7
Single-family houses	96,392	14,540,141	155,288,565	9.4
Terrace houses	22,395	4,876,719	35,191,925	13.9
Apartment blocks	7,370	9,849,870	78,087,914	12.6
Office and trade buildings	2,330	5,028,800	67,243,558	7.5

In May 2011, the number of certificated buildings covered approx. 10 % of the total building stock and is therefore assumed being representative for the whole building stock.

5.2 Analysis of the EPC Datasets

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

$U_{avg} = \Sigma A_i * U_i / A_{tot}$

Where "i" is the reference to the specific main construction type (ceiling, wall, floor and window).

All data available at the time of extracting the data from the EMO databases was used in the creation of the synthetic average building. Extraction is done in the "living" database, meaning that any new extraction of data will give a slightly different result, but a result which will be a better average as the database contains a growing share of the total building stock.

The calculated area-weighted U-values calculated for the TABULA project are shown in Table 12.

Table 12. Calculated area-weighted U-values for each building type

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

If the geometric typology of a building type is known or estimated, a model for the synthetic average building can be established. Results from calculations on this reference model can be expanded to the entire country by multiplying with the volume of the entire building stock known from national statistics. This result can, if necessary, be calibrated according official to information found in the national energy statistics (if it is sufficiently specified, which is the case for Denmark). This calibration verifies that the EP model for the synthetic reference model is acceptable.

The average U-values of constructions extracted from the database is importen information for estimates of the potential energy savings in the building stock as a whole. The area distribution on the other hand is more interesting for analyses of what buildings having the highest potential for energy savings.

Figure 9 show the area distribution of U-values for external walls registered in the Danish Energy Performance Certificate database. The left y-axis shows the percentage area of all registered external walls with an U-value within any given interval (x-axis). The right y-axis shows the area weighted average U-value (horizontal green bars) for each of the intervals. E.g. 38 % of the total lightweight external wall area has an U-value in the interval between 0.2 and 0.3 W/m²K and the average U-value of all external walls within the same interval is 0.27 W/m²K.

Figure 9: Area-weighted distribution of U-values for different types of external walls registered in the Danish Energy Performance Certificate database for single family houses constructed in the period between 1931 and 1950.

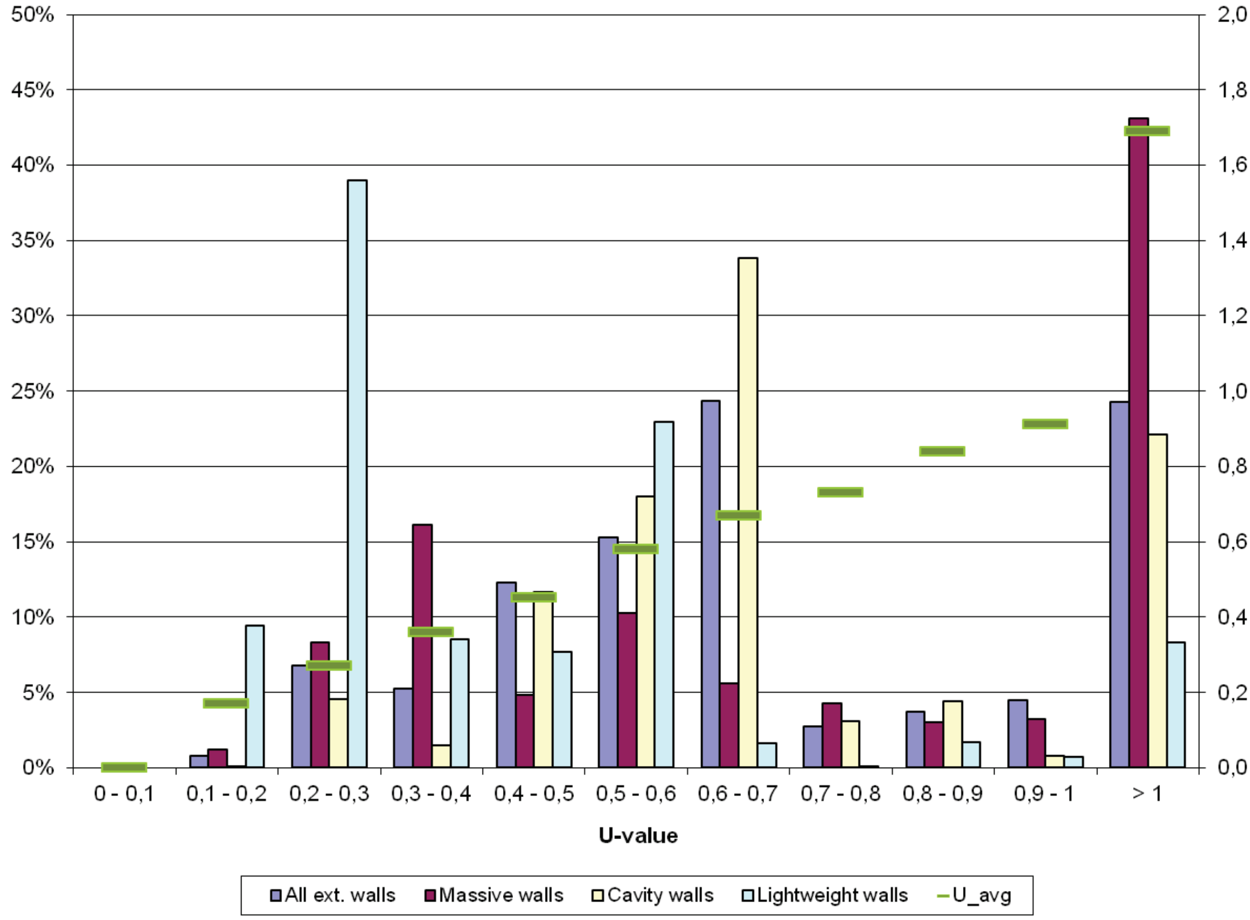
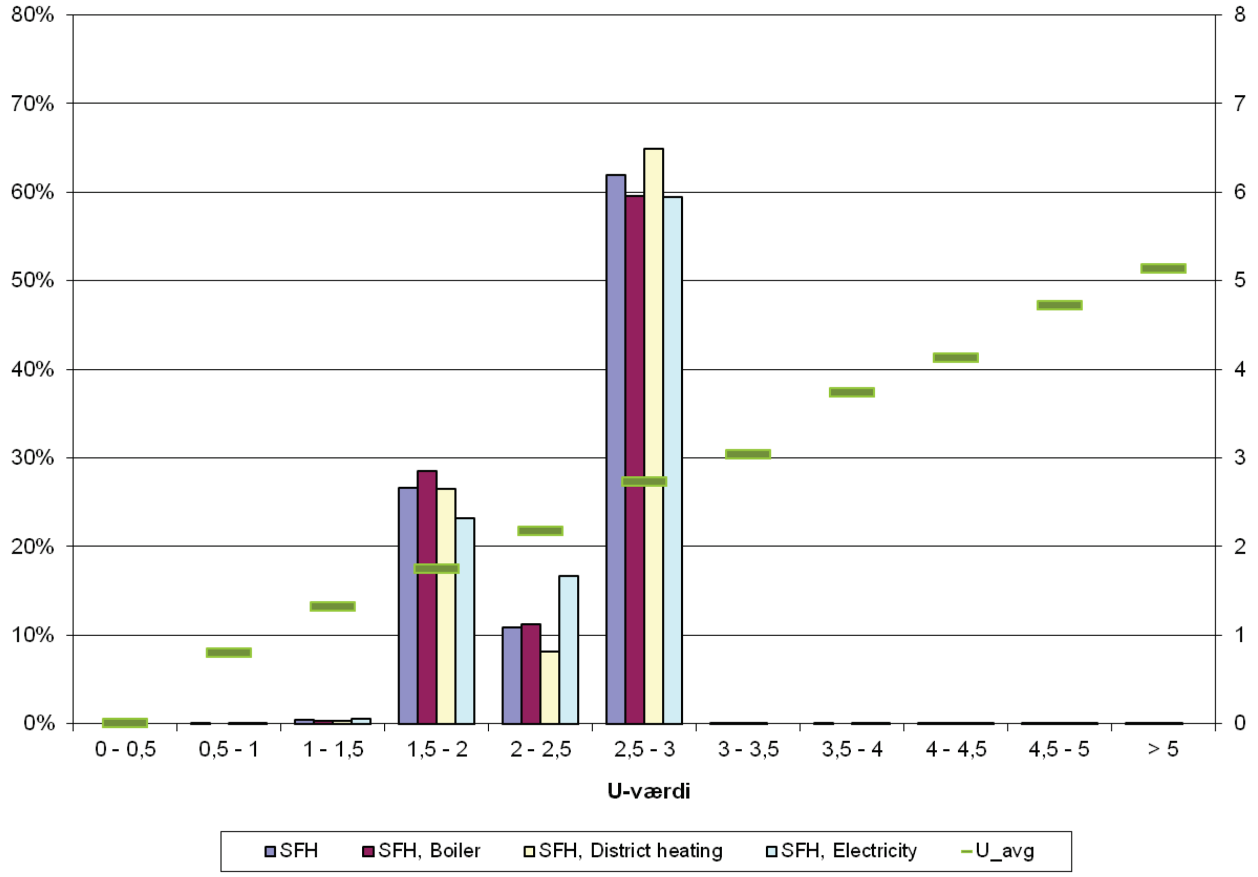


Figure 10 show the same area-weighted U-value distribution graph as for the external walls, but in this case for houses constructed in the period between 1979 and 1998. This indicates that even for recent build houses there is a large potential for energy savings by replacing the windows with state of the art materials.

Figure 10: Area-weighted distribution of U-values for windows registered in the Danish Energy Performance Certificate database for single family houses constructed in the period between 1979 and 1998. Information has been separated depending in the heating systems in the houses.



Having established knowledge about the U-value distribution and the average U-values for all constructions in the Danish Energy Performance Certification database, it is possible to set up a model to analyse the potential weak points in the different construction age classes. In this model the relative heat loss factor (P-factor) through the different parts of the thermal envelope for each building type and construction period are calculated. **Error! Reference source not found.** shows the relative heat loss factor for Danish houses in the periods 1931-1950 and 1979-1998 based on average U-values.

Figure 11: Relative heat loss factor (P-factor) through different parts of the thermal envelope in Danish houses constructed in the periods 1931-1950 and 1979-1998 respectively.

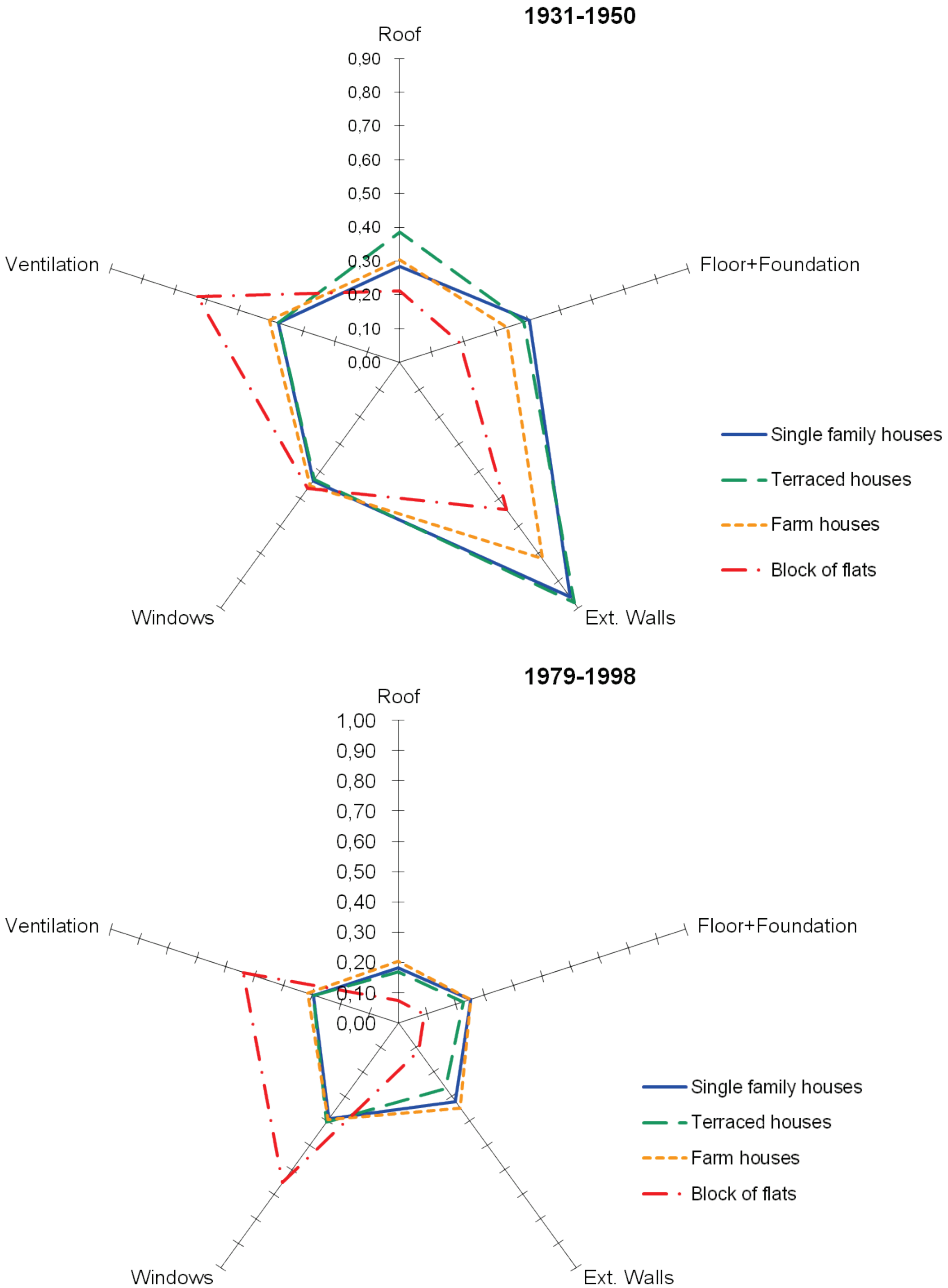


Figure 12 and Figure 13 shows the calculated space heating demands (using the extracted U-values from the EPC database) and the corresponding total space heating demand for the entire residential building stock.

Figure 12: Calculated space heating demands for the average residential buildings.

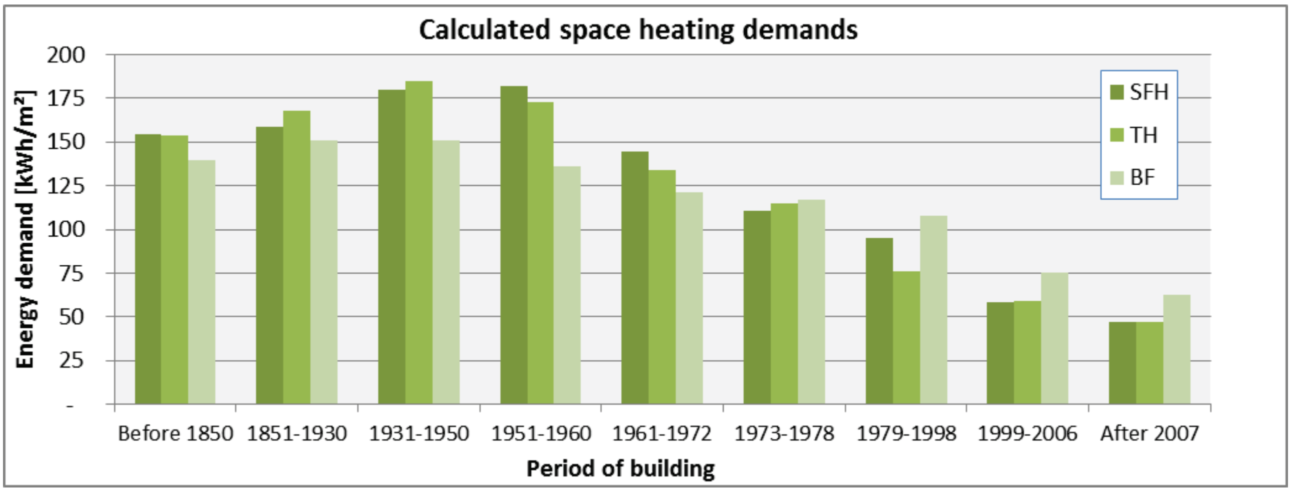
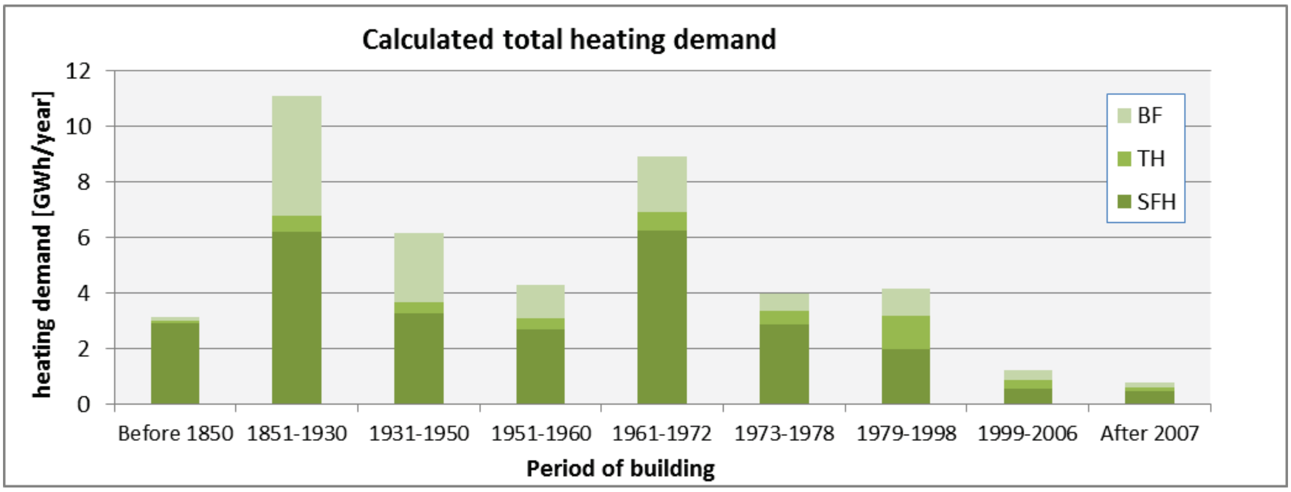


Figure 13: Total space heating demand for the entire residential building stock.



5.3 Conclusions

The utilisation of EPC data recorded in more or less centralised and more or less uniform data-bases have no value without being used. The certificate must be generally accepted or, even better, generally used by the house owners. Therefore the value of the data recorded in the database hinges on an EPC audit being consistently carried out and reported in conjunction with any property transaction, by any building upgrading and for large buildings regularly, even without change in ownership or user.

This can be implemented by means of different incentives driven by legislation or by promoting exposure of the EP certificate. If however, the value of the certificate is evident for every building owner, not only in the situation of property transactions but also when considerations are made about energy performance improvements. Even better, if energy improvements are generated by high quality EP certificates – for instance promoted by economic incentives – a generally accepted certificate will continuously qualify the EPC database.

Having said that, it must be emphasised that it is of high importance that information is collected in one central (regional or even better national) database. Naturally data must be of high quality, which leads back to education and skills of the building energy performance expert. Furthermore data must be comprehensive that it is possible to extract enough information from the database to redo the energy performance calculation.

Use of professional database management tools will ease analyses and reporting of information from the database. Further, it makes it possible to make repeated extracts from the database and follow the development of input parameters for the average building as the share of certified buildings increases.

Table 13: Sources / References Denmark

Reference shortcut	Short description (in English)	Concrete reference (in respective language)
EM	The Danish energy labelling scheme	Energimærkningsordningen, april 2010, Fællessekretariat for eftersyns- og mærkningsordningerne. www seeb.dk
BBR	The Danish Building Stock Register	Danish Enterprise and Construction Authority (2010). The Building Stock Register, 2010. Located at www.bbr.dk.
SEEB	Handbook for energy experts, including a list of commonly seen constructions and installations in Danish buildings.	Håndbog for Energikonsulenter. www.maerkdinbygning.dk
SBi 2011	National report on the Danish work in TABULA.	Wittchen K.B. & Kragh J., 2011. Danish building typologies - Participation in the TABULA project. Danish Building Research Institute, Aalborg University. SBi 2012-01. ISBN: 978-87-92739-00-1..
SBi 2011	Identification of building typologies in the Nordic countries for sustainable renovation.	Wittchen K.B. (editor), Mortensen L., Holøs S.B., Björk N.F., Vares S., Malmqvist T. Building typologies in the Nordic countries - Identification of potential energy saving measures. Danish Building Research Institute, Aalborg University. SBi 2012-04. ISBN: 978-87-92739-03-2.
eceee 2011	Analyses of the potential energy savings in the Danish building stock based on Energy Performance Certificate database statistics.	Wittchen K.B. Kragh J & Jensen O.M. Energy saving potentials – a case study on the Danish building stock. ECEEE 2011 SUMMER STUDY • Energy efficiency first: The foundation of a low-carbon society p 1355-1363. June 6-11, 2011. Belambra Presqu'île de Giens, France. ISBN: 978-91-633-455-8.
SBi 2010	Analyses of means and related costs to achieve 75 % energy savings in the Danish building stock.	Kragh J. & Wittchen K.B. 2010. Danske bygningers energibehov i 2050. Statens Byggeforskningsinstitut, Aalborg Universitet, Hørsholm. SBi 2010:56, ISBN: 978-87-563-1495-4.
SBi 2009	Analyses of the potential energy savings in the Danish building stock based on Energy Performance Certificate database statistics.	Wittchen K.B. Potentielle energibesparelser i det eksisterende byggeri. SBi 2009:05. Statens Byggeforskningsinstitut, Aalborg Universitet (2009).
SBi 2004	Analyses of potential savings on heating in Danish residential buildings.	Wittchen K.B. (2004). Vurdering af potentialet for varmebesparelser i eksisterende boliger. Dokumentation 057. ISBN: 87-563-1202-4. Statens Byggeforskningsinstitut, Hørsholm.

6 <FR> France

(by TABULA Partner N° 5: ADEME / France)

6.1 Description of the EPC Database

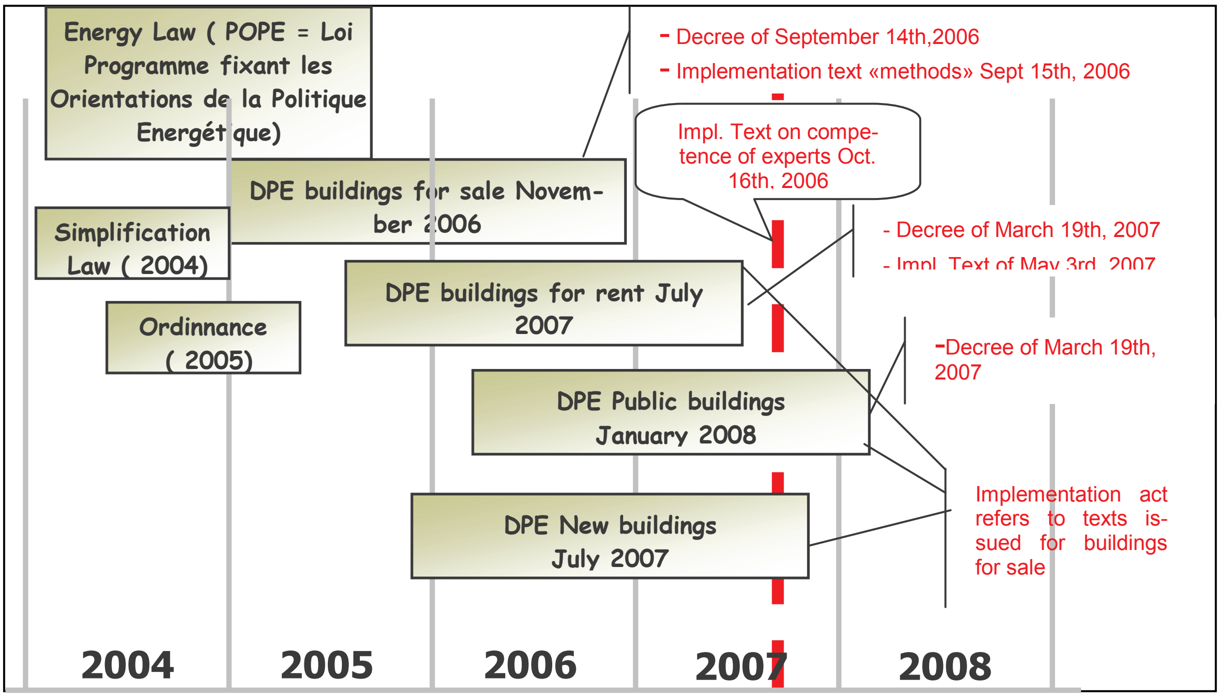
EPC certification scheme

The energy performance certificate of buildings (called DPE , French acronym for "Diagnostic de Performance Energétique" which means Energy Performance Diagnosis") has been set up in the period September 2006 –January 2008, through a number of application decrees and implementation texts (arrêtés) as shown on the following figure.

Certificates are now compulsory for all transactions types and are part of the transaction act which is signed under responsibility of an estate officer (Notary). The document must respect a specific template according to the transaction and the type of building. Some of the variations are indicated in Table 14.

Since November 2007, only certified auditors may carry on the corresponding inspection and issue the Energy performance Certificates.

Figure 14: Energy Performance Certificates legal context



The most important texts relating to DPE implementation are the following:

- Decree n°2006-1147 of September 14th, 2006 relating to energy performance certificate and diagnosis of natural gas internal distribution and systems in buildings for sale
- Decree no 2007-363 of March 19th, 2007 relating to energy feasibility studies, to thermal characteristics and energy performance of existing buildings and to energy performance certificate of new constructions.

- Implementation act of September 21st, 2007 relating to energy performance certificate of new constructions in France mainland
- Decree 2006 – 1653 establishing the validity duration of DPE to10 years
- Decree 2006 – 1114 on competence of experts

These different texts lead to a rather complex scheme, summarised underneath, where the DPE document and contents depend on both the type of transaction and the nature of building including its heating system.

Table 14: Variations in EPC (DPE) according to transaction and building types – Source: personal expertise

transaction	Building type	Enforcement date	Calculation mode	Labelling scale(s) referring to annex	Specific requirements
sale	Individual housing	16/09/2006	3CL (asset rating) except for constructions before 1948 (energy bills)	Type A	
	Apartment / indiv heating				
	Apartment / coll heating		Energy bills		
	Non residential		Energy bills	Type B	
Rental	Individual housing	01/07/2007	3CL (asset rating) except for constructions before 1948 (energy bills)	Type A	Renovation recommendations are not indicated on the issue communicated to the tenant
	Apartment / indiv heating				
	Apartment / coll heating		Energy bills		
	Non residential	Implementation text not issued, planned to be released in end 2011			
New construction	Individual housing simplified solutions	01/07/2007	3CL	Type A without climate label	No recommendations
	Other		THC_E		
Display in Public buildings	Offices, administration.	01/01/2008	Energy bills	Type C1	
	permanent occupation			Type C2	
	Other			Type C3	

Role of the EPC database

From the first Decree of September 2006 on, it has been the intention of the Public Authority to collect the DPEs but it has only been made compulsory in the Grennelle Law n°2[7] (issued July 2010) for DPE auditors to transfer the DPEs to a central data base which is to be managed by ADEME. Implementation Decree 2011-807 of July 2011 [1] gives the organisational details of the DPE data base and sets its starting date no later than July 2012 .

This database, as indicated in that Decree [1], is intended to:

provide an information to the general public and offer the possibility to compare a building performance indicator to a cluster of similar buildings

[7] « Art. L. 134-4-2. – Les personnes qui établissent les diagnostics de performance énergétique les transmettent à des fins d'études statistiques, d'évaluation et d'amélioration méthodologique à l'Agence de l'environnement et de la maîtrise de l'énergie, qui rend disponibles auprès des collectivités territoriales concernées les résultats statistiques de ces études, selon des modalités définies par décret en Conseil d'État

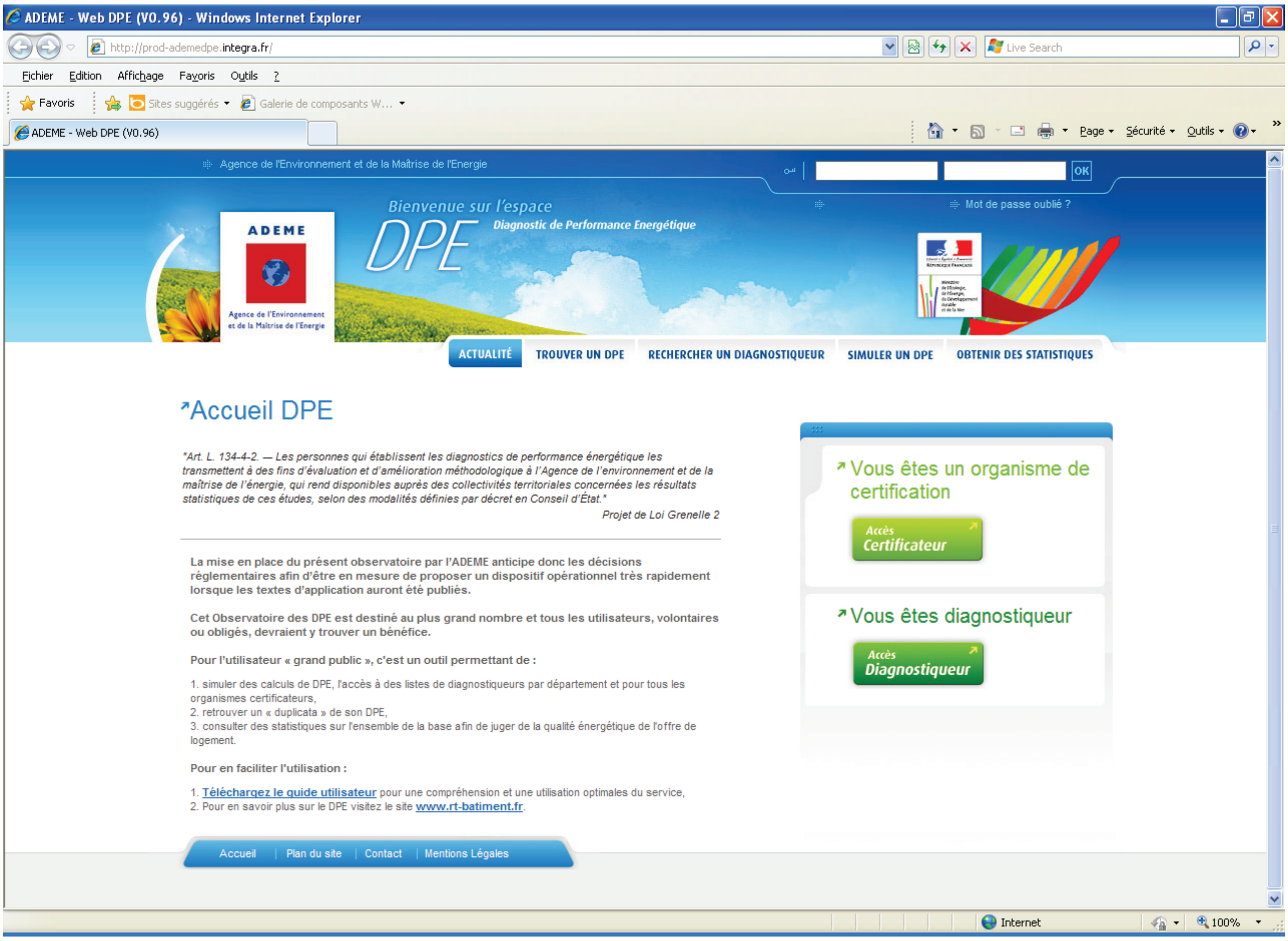
Afford local authorities to retrieve data concerning their geographical hold

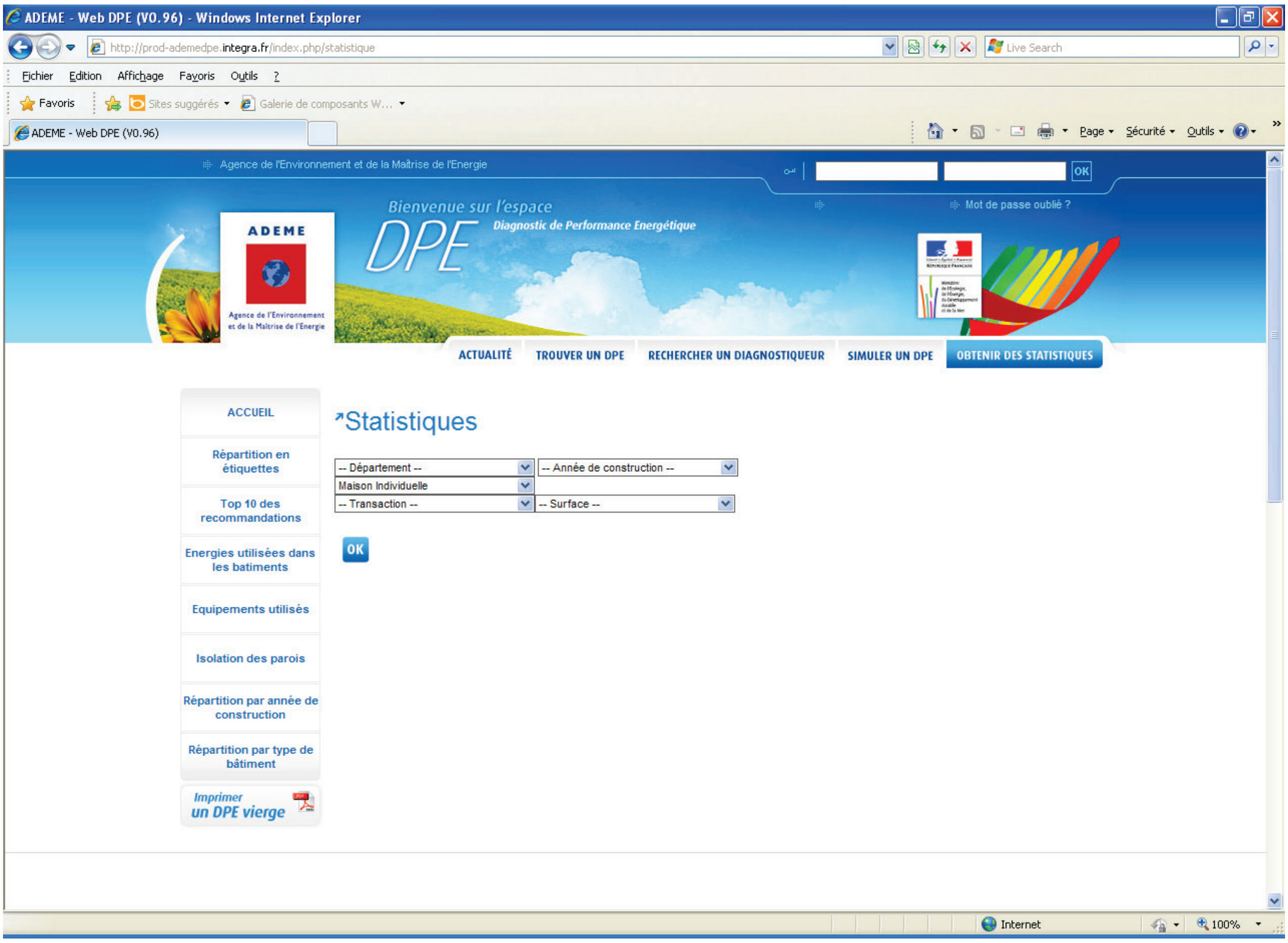
Give an improved knowledge on the national building stock

Allow continuous improvement of the calculation methodologies through on line feed back

Additional to this, it is planned to use the data base as a mean for controlling the experts in order to be able to improve the global quality of the scheme.

The data base is technically ready for use as can be seen on the pictures hereafter.





Number of buildings (theoretically) concerned by the data base

Table 15: Analysis of annual estate transactions breakdown according to the DPE structure

Transaction	Building type	Annual flow estimates	Total stock
sale	Individual housing	300 000	12 300 000
	Apartment / indiv heating	200 000	3 300 000
	Apartment / coll heating	100 000	
	Non residential	20 000	600 000
Rental	Individual housing	400 000	2 970 000
	Apartment / indiv heating	500 000	8 400 000
	Apartment / coll heating	500 000	
	Non residential	30 000	300 000
New construction	Individual housing simplified solutions	30 000	
	Other residential	250 000	
	Non residential	7000	
Display in Public buildings (>1000 m2)	Offices, administration, education		45 000
	permanent occupation		25 000
	Other		13 000

<u>For the time being, the data base is empty</u>, its opening being postponed to July 2012.

When running, the data sets should be fairly good samples of the French building stock. It will need nevertheless to be checked in terms of representativeness through comparison with the National Census data because it is highly probable that some building types might be over represented (because they are often bought or rented) whereas other types do not experience the same rate of transactions.

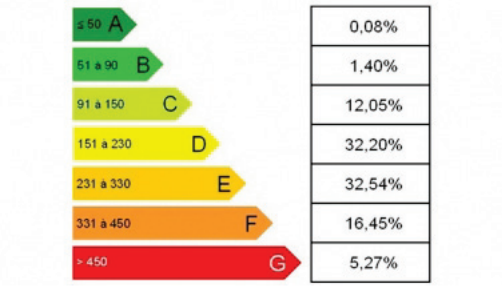
A further concerns lies within the calculation methodology (see Table 14) which may be different within a cluster (for example for individual houses built before 1948, it is not compulsory to use the 3CL calculation method, the EPC can also be prepared based on the energy bills) and this might lead to the necessity of sub dividing the samples, resulting in size which would not be statistically meaningful.

6.2 Analysis of the EPC Datasets

Not available, see above.

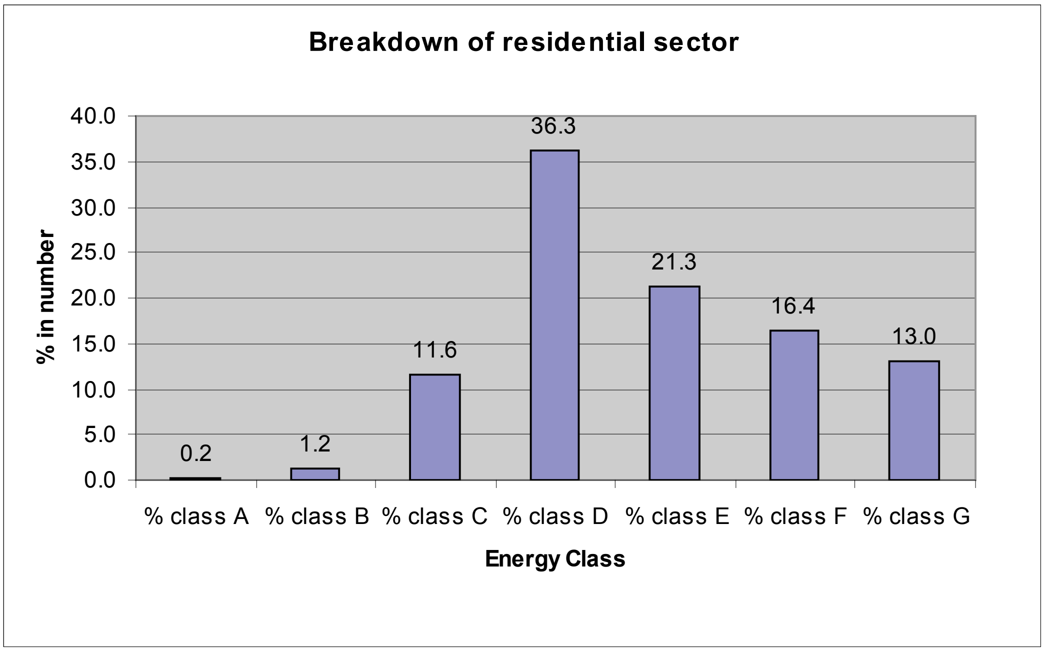
The following figure shows the result of a survey on 100 000 DPEs conducted by a group of auditors [2] since the beginning of the scheme. It seems to show that the label and its various energy classes are relatively well set up.

Figure 15 - Result of the Ex'im survey on 100 000 DPEs



This survey shows a good consistency with the statistical analysis based on global data for the whole residential stock that was conducted in 2008, the main difference being in the G category where the auditors seem to be more "understanding" towards their clients than the strict application of mathematical laws is….

Figure 16: Theoretical breakdown of the residential building stock through mathematical analysis



6.3 Conclusions

The data base will contain both the results of the DPE (energy performance index, energy class, CO2 emission index, energy conservation recommendations) and all the data that are collected to elaborate it.

The expected quantities of data should provide sufficient sample sizes to allow for a good representativeness.

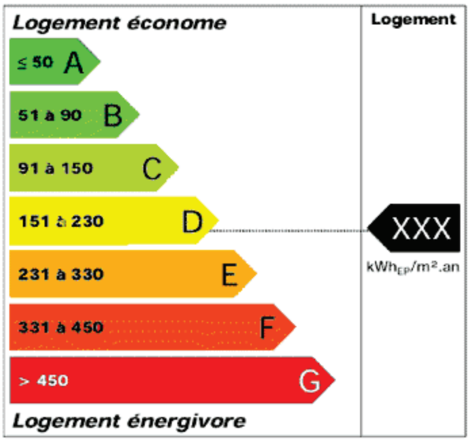
The main concern lies with the quality of data which is totally depending on the qualification of auditors. Present feed back seems to show that a large number of these professionals do not meet the expected quality requirements.

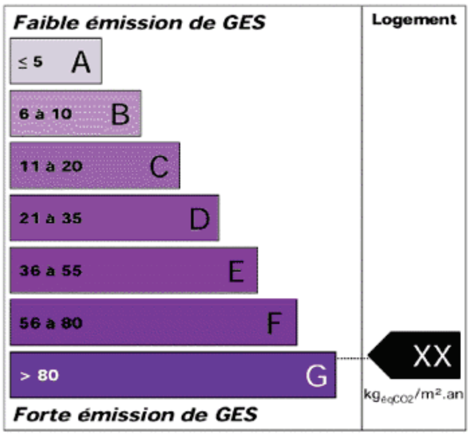
Table 16: Sources / References France

Reference shortcut	Short description (in English)	Concrete reference (in respective language)
[1]	Decree 2011-807 of July 2011	Décret no 2011-807 du 5 juillet 2011 relatif à la transmission des diagnostics de performance énergétique à l'Agence de l'environnement et de la maîtrise de l'énergie
[2]	Article in "Le Moniteur" entitled: "can the DPE auditor do anything ?" (18/07/2011)	http://www.lemoniteur.fr/201-management/article/actualite/858014-le-diagnostiqueur-peut-il-encore-se-tromper

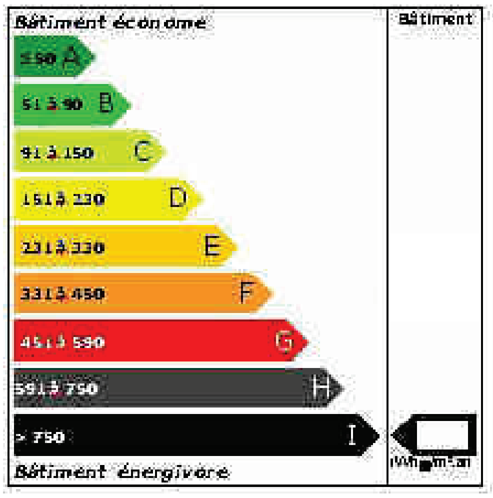
6.4 Appendix – Models of labels for EPC

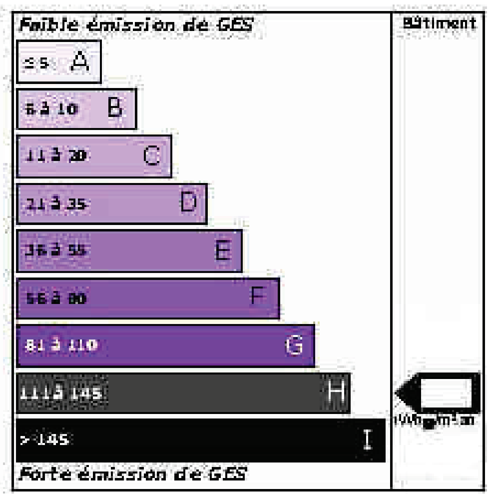
Type A





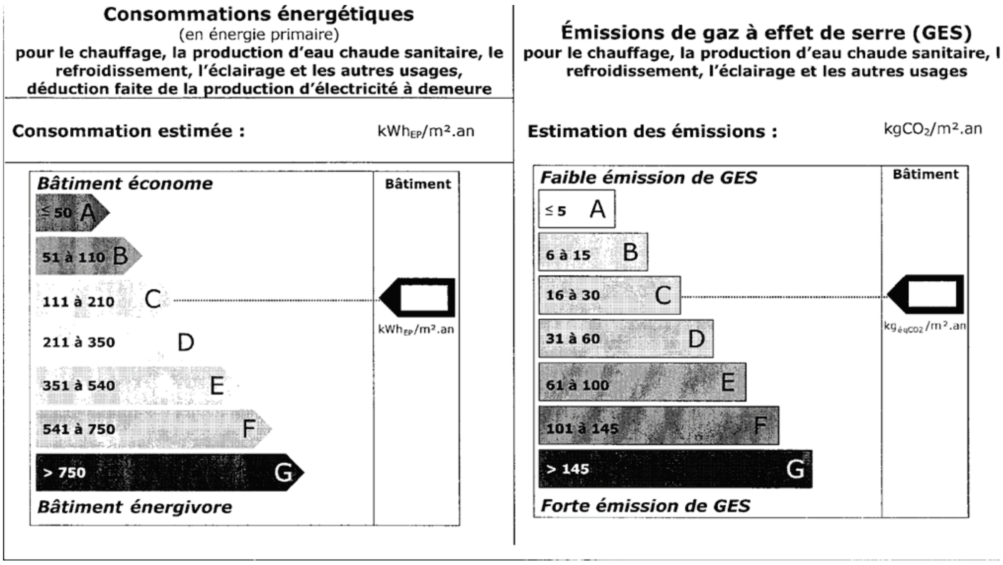
Type B





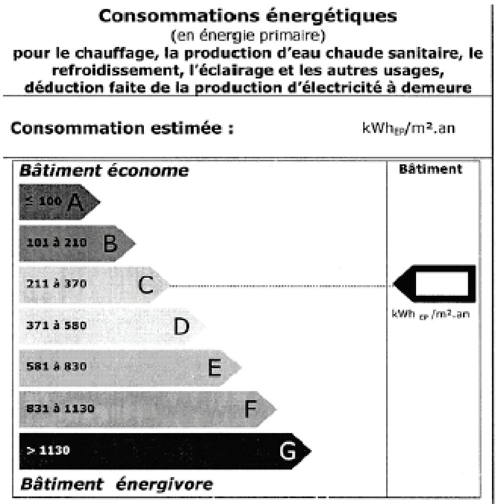
Type C1

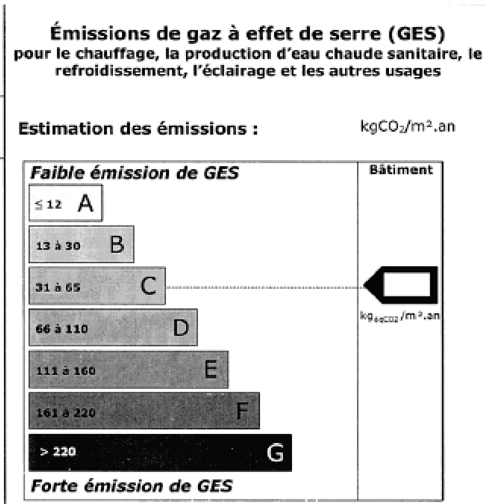
Offices, education



Type C2

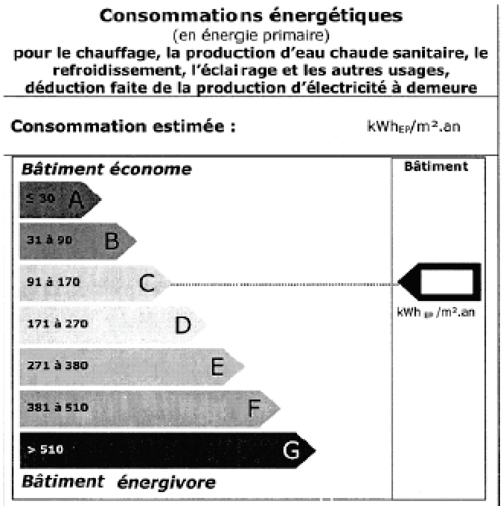
Public buildings with permanent occupation (health care,..)

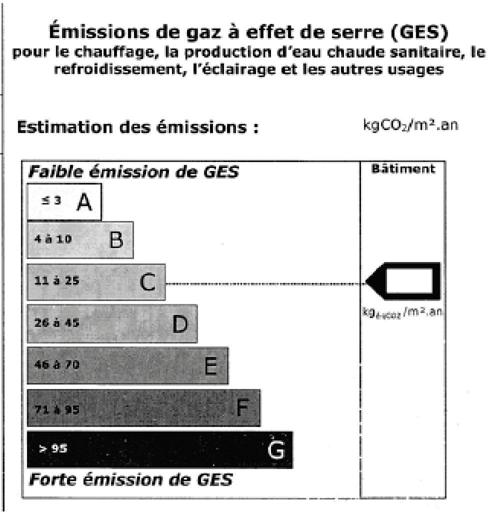




Type C3

Other non residential





Types C use the same colour palette as the other types but are only available in black and white in the implementation text.

7 <IE> Ireland

(by TABULA Partner N° 6: Energy Action / Ireland)

7.1 Description of the EPC Database

EPC certification scheme – role of the EPC database

Ireland has one national EPC methodology for residential buildings (Dwelling Energy Assessment Procedure or DEAP) and one national EPC methodology for non-residential buildings (Non-Domestic Energy Assessment Procedure).

All of the EPCs (known as Building Energy Rating certificates or BERs in Ireland) for the residential and non-residential buildings are registered and stored on the National Administration System (NAS). The NAS is managed by the Sustainable Energy Authority of Ireland (SEAI) which is Ireland's energy authority.

BER assessors must be registered with SEAI in order to conduct surveys and issue EPCs. All EPCs are generated via the DEAP software on the web-based NAS system.

Current number of buildings (new/existing; residential/non-residential) / annual growth rates

Ireland has approximately 1.6 million dwellings.

As SEAI has full management control of the EPC database, it holds accurate data on the numbers of EPCs generated. SEAI produces monthly reports on the status of the public register.

At the beginning of September 2011, the summary of residential EPCs published was as follows:

Table 17: Total Residential EPCs (September 2011)[1]

Residential EPCs	existing buildings	new buildings	total
2007		50	50
2008		3,042	3,042
2009	69,547	14,546	84,093
2010	72,196	6,862	79,058
2011*	65,491	2,198	67,689
Total (* to 06.09.11)	**207,234**	**26,698**	**233,932**

Thus, EPCs had been published for about 15% of the national housing stock by September 2011. (Note that multiple EPCs have been produced for the same building in some instances so the actual percentage may be fractionally lower).

In the non-domestic sector, at the end of September 2011, there were 7,385 EPCs on the public register. There is no accurate record of the number of non-domestic buildings.

For public sector buildings, where Display Energy Certificates (DECs) are required, 333 valid DECs had been produced by the end of September 2011.

Representativeness of the datasets

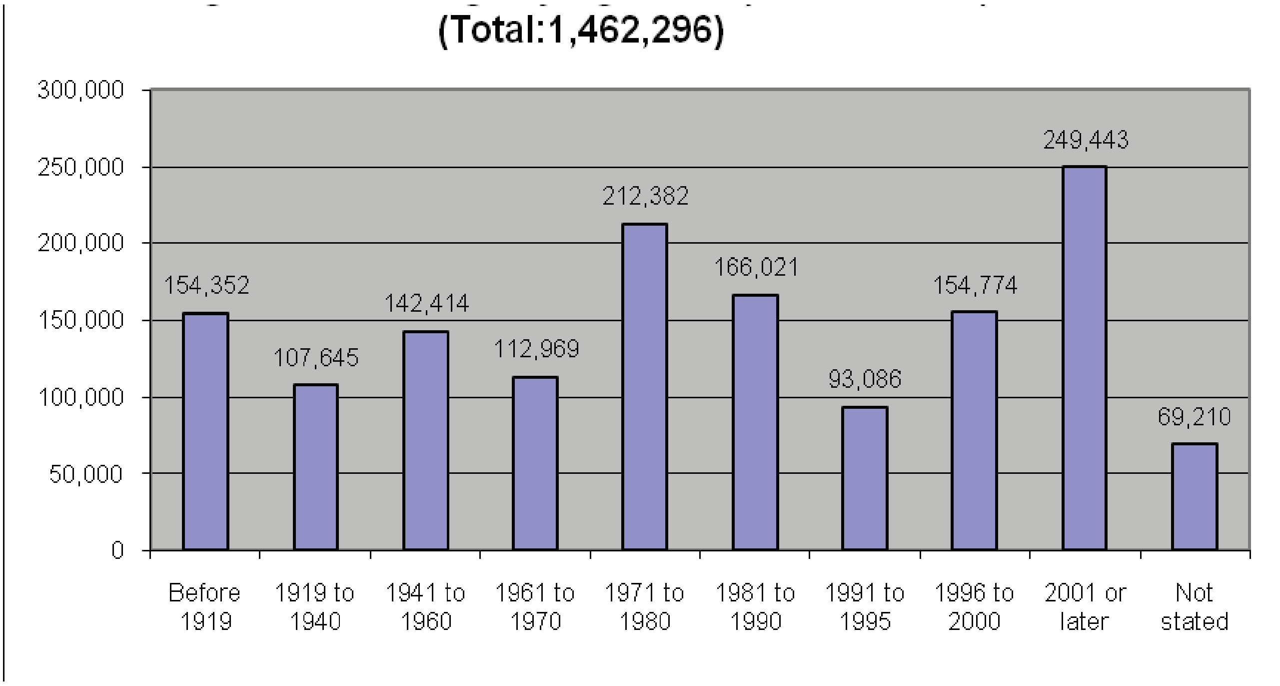
In this section, we examine if the EPC Database in Ireland is representative of the whole Irish building stock.

As Ireland has one national EPC database (rather than several regional databases as in other countries), the Irish EPC database gathers EPC data on the whole Irish residential building stock.

Outside of the EPC database, the best alternative source of data on the building stock is provided by the Census data.

The Irish census[2] (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 150,000 further dwellings were built in the period 2007-2011.

Figure 17: Dwellings by Age Built (Census 2006)



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 most of Europe, where the apartment building is given a rating rather than individual apartments or flats.

Table 18 below shows the breakdown by dwelling type of Irish residential buildings for different age bands provided in the 2006 census[2].

Table 18: 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 a 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**

The Irish Census data does not provide specific building typology data. Also the Census age bands are different from those defined within the EPC database.

In creating the Irish Building Typology for TABULA, the EPC age bands have been used to define the construction age bands. The Irish dwelling type age bands have been selected based on step changes to the building regulations that impacted significantly on energy performance, namely changes in U values. Five distinct building construction age bands have been selected to cover Irish dwelling types and indicated in Table 19 below. 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 19: Irish Construction Year Classes3

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

Thus, the EPC database will gather any EPCs produced within the Irish housing stock and the Irish building typology has been designed around the EPC methodology and categorisation structure.

7.2 Analysis of the EPC Datasets

Methodology

The Irish TABULA project team has been working in partnership with the SEAI management team responsible for the National EPC database (NAS) to examine how the EPC database resource can enhance the Irish building typology created within TABULA.
As a result of information requests placed by the Irish TABULA project, SEAI undertook a redesign of its NAS database query tool in mid 2011 to meet these requests. This redesigned query function produced some interesting results in October 2011 that allowed TABULA results and analysis to be cross-referenced with the national EPC database.

Quantities used for the definition of "average buildings"

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.

With the data provided from the National EPC database in October 2011, it is now possible to compare the research-based primary energy values (in kWh/m2/year) for each of the 29 house types within the Irish building typology to average primary energy values for those house types extracted from EPC database[4]. (See Table 20 below).

Table 20 shows the primary energy values for the 29 Irish house types created for TABULA along with the average primary energy value for each of these 29 house types derived from the EPC database in October 2011.

These differences arising are 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 fuel type. The EPC average includes all fuel types.

Table 20: TABULA & EPC Primary Energy Comparisons

TABULA House type	TABULA Typical Primary Energy Value (kWh/m2/a)	EPC Average 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%

Possible use for national energy balance calculations

As indicated above, data became available from the National EPC database in October 2011. This EPC data can be used either separately or with the Irish building typology (and other data sources) to develop a national energy balance calculation.

In fact, the data provided from the EPC database in October 2011 for the 239,000 dwellings was classified on a wider basis than the 29 TABULA typical buildings, as indicated below.

The EPC database has been categorised for 39 dwelling types defined by:

- age band and wall type
- energy value (kWh/m^2/year)
- floor area (m^2)
- number of storeys
- dwelling type (apt, detached house, mid-terrace house etc)

By conducting further and ongoing analysis of results from the EPC database and cross-referencing these results with the Irish TABULA building typology and other data sources such as the Irish Census, national energy balance calculations can be created and refined.

7.3 Conclusions

Topics

- Recommendations for the improvement of the data collection, database structure, database management, evaluation with respect to the needs of the building typology

  - 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.

- Perspectives for continuous database evaluation
  - The Irish EPC database is managed by SEAI and will be evaluated on a continuous basis into the future. Further discussions and agreements 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.
  - 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.
  - 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.

Table 21: Sources / References Ireland

Reference shortcut	Short description	Concrete reference
1	EPC database summary (06.09.2011), SEAI	
2	Irish Census 2006, Table 32A, Central Statistics Office	
3	TABULA age bands, Irish TABULA Scientific Report (2012)	
4	EPC database statistics, (October 2011), SEAI	

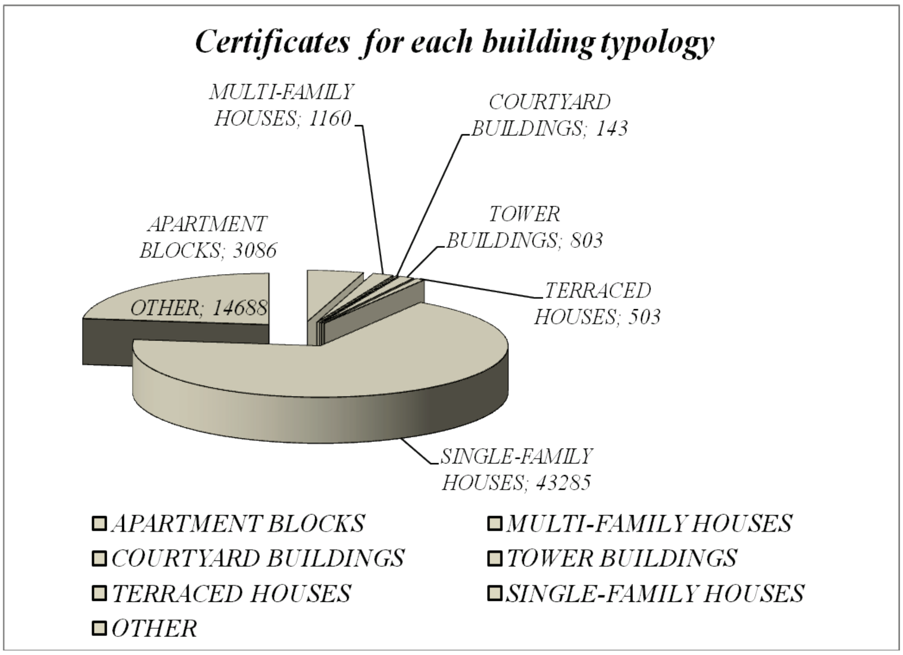
8 <IT> Italy

(by TABULA Partner N° 3: POLITO / Italy)

8.1 Description of the EPC Database

The database contains records for more than 66000 houses rated across Piedmont.
The 66000 house records represent the result of the information collected by EP certificates of Piedmont Region.

Figure 18: Split of Energy Performance Certificates for each building typology (66063 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 are included:

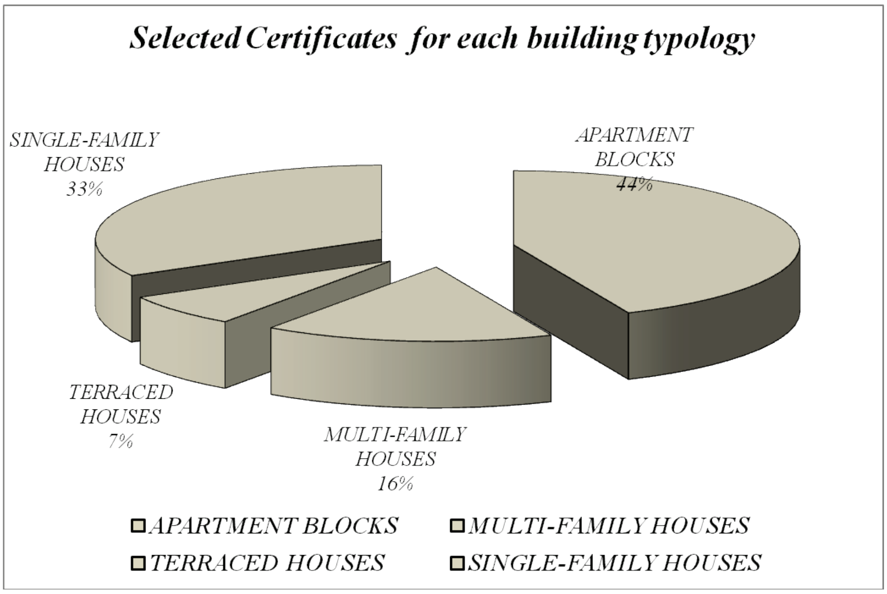
- location;
- construction period;
- compactness factor;
- heated gross volume;
- net floor area;
- average thermal transmittance of windows;
- results of the energy performance calculations.

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 amount of energy actually consumed or estimated to meet the different needs associated with a standardized use of the building) is evaluated by means of software tools based on the EPBD CEN Standard and Italian technical specifications UNI/TS 11300.

8.2 Analysis of the EPC Datasets

In order to keep the quality of the data high, the global amount of data is restricted to only 7104 certificates. Moreover, to harmonize the analysis, the EPCs have been grouped in apartment blocks, multi-family houses, terraced houses and single-family houses.

Figure 19: Split of the selected Energy Performance Certificates for each building typology (7104 certificates)



The Piedmont Regional Database of Energy Performance Certificates (EPCs) has been used to define the building typologies within the following categories:

- single family houses
- terraced houses.

In particular, three approaches are investigated to define reference buildings:

- the first approach identifies the real building with geometrical and thermo-physical characteristics similar 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.

Method 1

According to the first approach, based on the available data, representative parameters of geometric and thermal features have been selected. These parameters are:

- volume;
- net floor area;
- envelope area to volume ratio (compactness factor);
- number of floors;
- number of apartments;
- opaque envelope average thermal transmittance;
- window average thermal transmittance.

For each parameter, statistical functions are calculated such as mean, median, 25th percentile, 75th percentile.

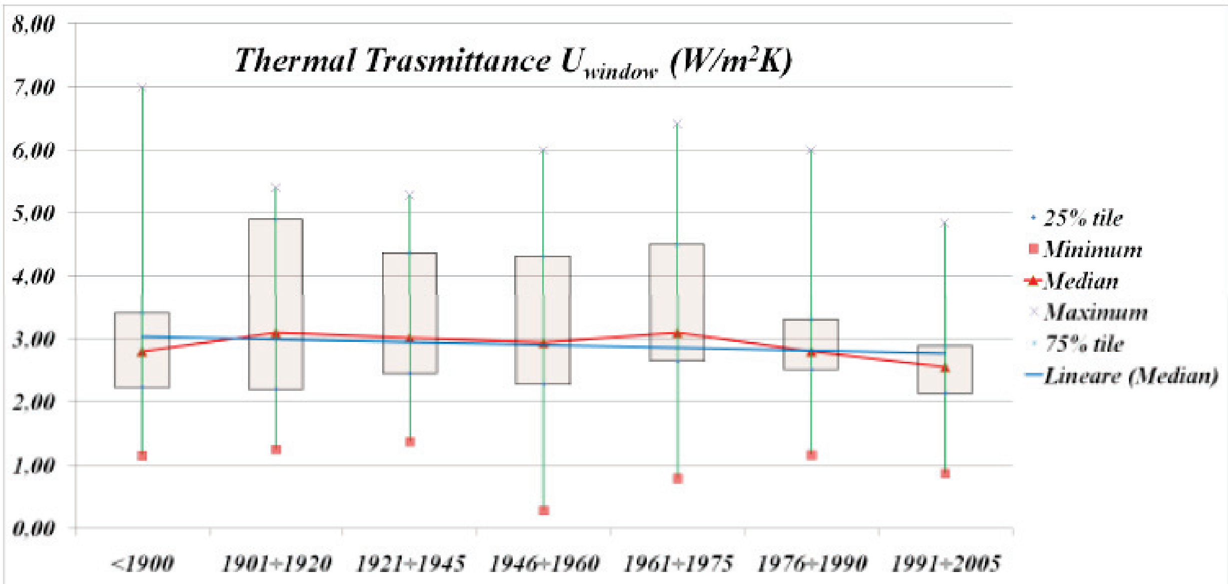
An example is shown in Table 22 for the "Middle climatic Zone".

Table 22: Analysis of window average thermal transmittance for single-family houses

Thermal Trasmittance U_{window} (expressed in W/m^2K)							
	<1900	1901÷1920	1921÷1945	1946÷1960	1961÷1975	1976÷1990	1991÷2005
Sample size	84	29	77	193	434	267	298
Mean	**3,01**	**3,38**	**9,60**	**3,56**	**5,13**	**4,70**	**6,45**
25% tile	2,23	2,20	2,45	2,28	2,64	2,51	2,14
Minimum	1,15	1,25	1,37	0,28	0,79	1,16	0,87
Median	2,80	3,10	3,02	2,94	3,10	2,80	2,55
Maximum	7,00	5,41	5,29	6,00	6,42	6,00	4,85
75% tile	3,41	4,90	4,37	4,31	4,50	3,31	2,88

Figure 20 shows the thermal transmittance values for transparent surfaces of Piedmont housing. As shown, there have been only slight improvements in the thermal insulation levels over time.

Figure 20: Window thermal transmittance characteristics for the single-family houses



Moreover, interquartile ranges (IQRs) are evaluated for all the parameters. The intersection of all IQRs permits to select the single real building whose parameters are the closest to the median values.

If this procedure gives more than one or no real building, IQRs can be tuned by means of suitable criteria in order to pick out only one real building.

Method 2

The second method begins with the identification of primary independent variables (X_i) for describing the parameters (P_j) of a specific house (B_k) in the stock. The following parameters (P_j) that characterize the building can be considered: building external shape, internal layout, window to wall ratio, thermal insulation…

On the other hand, among the independent variables (X_i) it is possible to consider: floor area, construction year, location, main heating source…

The determination of the trend of each parameter based on independent variables by means of several engineering hypotheses, analysis or rule of thumb permits to figure out the most significant independent variables X_i for each parameter.

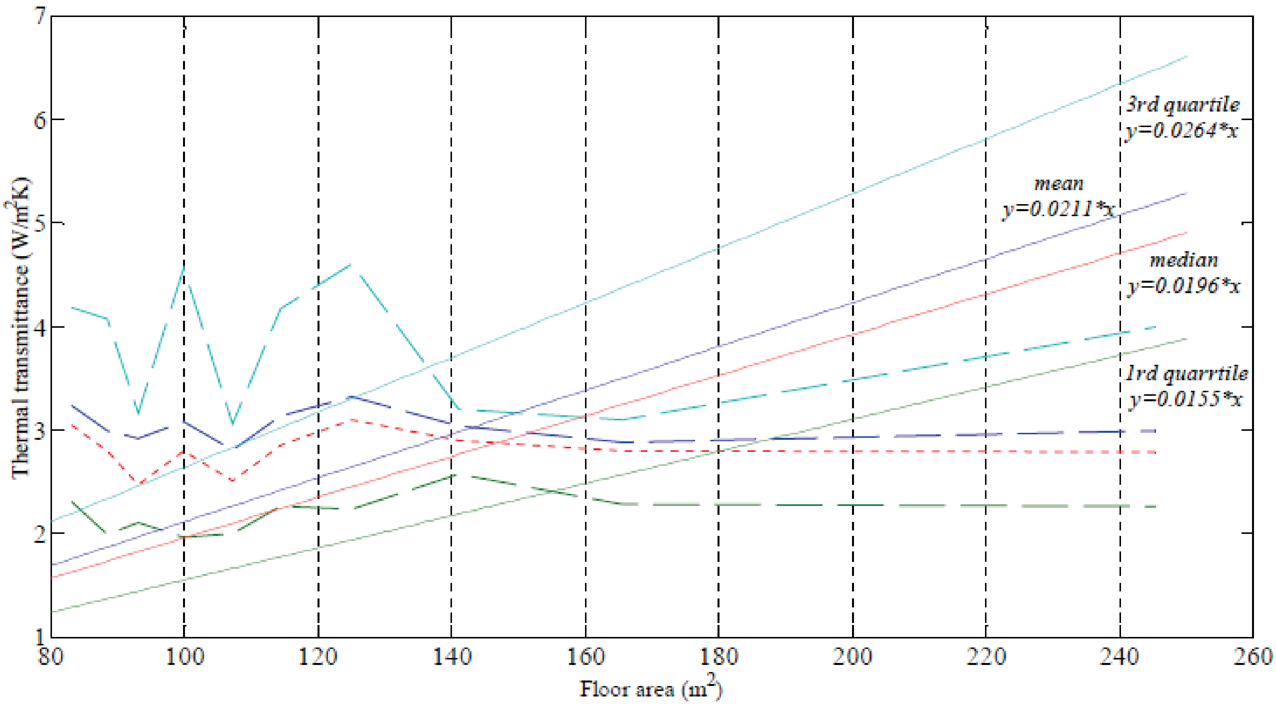
Finally, the analytical relation between the j-th parameter and its significant independent variables using statistical analysis is determined.

This approach is applied for the window average thermal transmittance (WTT).

This specific parameter presents a significant relation with the floor area. A sampling of 339 buildings was selected from the Piedmont Regional Database of Energy Performance Certificates. The WTT values associated with the 1st quartile, mean, median and 3rd quartile are evaluated for each of the 10 groups defined by the deciles of the population in terms of floor area.

Figure 21 presents the four dispersion values for each central value of these 10 groups. Regression curves and their analytical expression (STEP3) for the 1st quartile, mean, median and 3rd quartile are reported.

Figure 21: Thermal transmittance analysis.



Method 3

The third method performs cluster analysis on each building age class of terraced houses. The following variables are used:

- energy needs for space heating (Q_H);
- primary energy for space heating (EP_i);
- net floor area (A);
- opaque envelope average thermal transmittance (U_{op});
- window average thermal transmittance (U_w).

The values in the data set are normalized before calculating the distance information because variables are measured against different scales.

Such analysis is based on the calculation of the distance between every pair of objects in the data set. There exist five metrics to calculate the distance. The result of this computation is commonly known as a similarity matrix (or dissimilarity matrix).

Once the proximity between objects in the data set has been computed, the objects in the data set are separated into clusters.

Using several algorithms, pairs of objects that are close are linked together into binary clusters (clusters made up of two objects) then these newly formed clusters are linked to other objects to create bigger clusters until all the objects in the original data set are linked together in a hierarchical tree.

The hierarchical cluster tree is most easily understood when viewed graphically. The dendrogram represents this hierarchical tree information as a graph, as shown in Figure 22 and in Figure 23.

In particular, Figure 22 presents the data of the building age class VII organized in 30 clusters. A reduced number of cluster is shown in Figure 23. Such clusters correspond to the intersection of the dendrogram in Figure 22 with an orizontal line such that only five intersections take place.

This procedure allows to identify the cluster containing the representative house for the entire building age class. The reference building of the class is chosen as median value with regard the Q_H.

8.3 Conclusions

The database contains information on each house with regard to the energy-related features. One way to improve the database consists to collect additional physical and operational characteristics.

It would also be important to verify the completeness of the information by means of preliminary check of the data contained into the certificates in order to pick out field data errors.

Figure 22: Terraced houses dataset of the building built from 1990 to 2005 organized in 30 clusters.

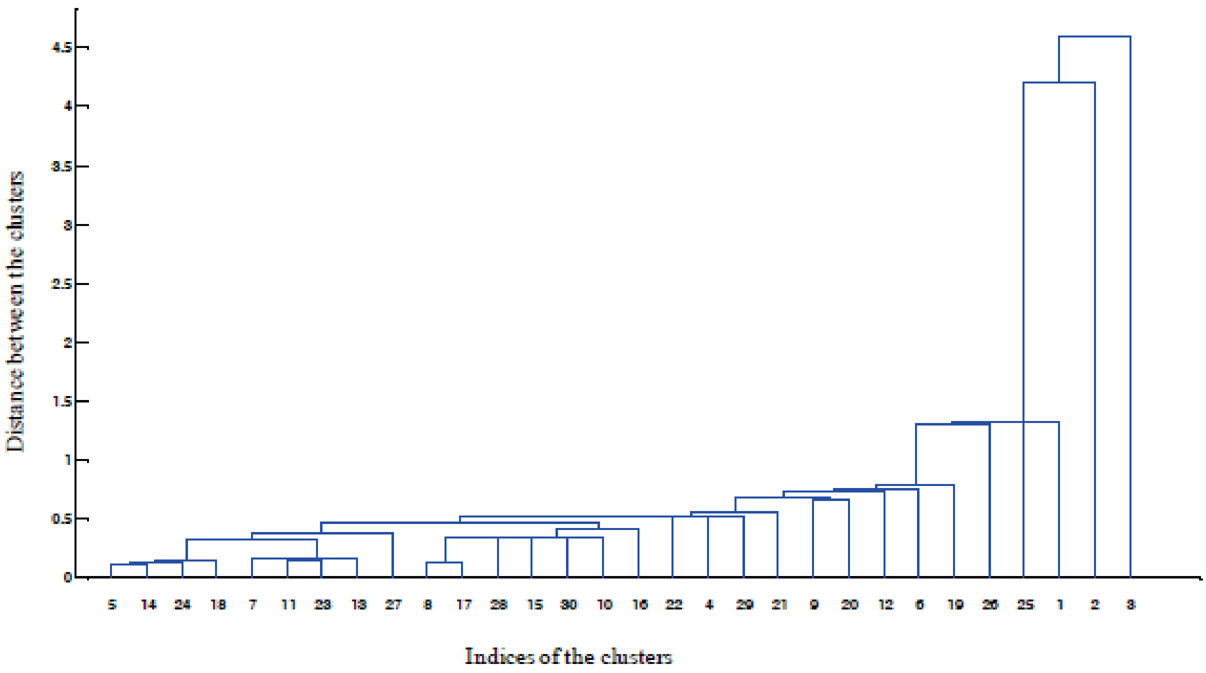


Figure 23: Terraced houses dataset of the building built from 1990 to 2005 organized in 5 clusters.

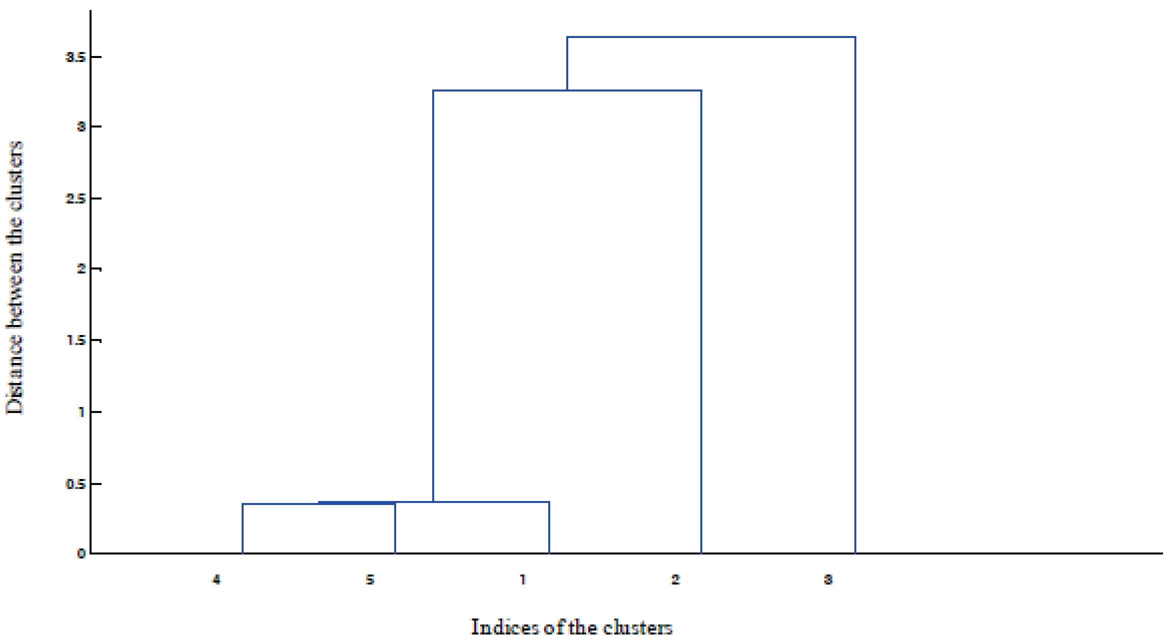


Table 23: Sources / References Italy

Reference shortcut	Short description (in English)	Concrete reference (in respective language)
LR.. 13/2007	Regional regulation (Piedmont Region) on the energy performance of buildings (framework law).	Legge regionale 28 maggio 2007, n. 13 "Disposizioni in materia di rendimento energetico nell'edilizia".
D.G.R. 43-11965 (2009)	Regional regulation (Piedmont Region) on the energy performance of buildings (implementing regulation).	Legge regionale 28 maggio 2007, n. 13 "Disposizioni in materia di rendimento energetico nell'edilizia". Disposizioni attuative in materia di certificazione energetica degli edifici ai sensi dell'articolo 21, comma 1, lettere d), e) ed f).
EN ISO 13790:2008	Energy performance of buildings - Calculation of energy use for space heating and cooling.	Prestazione energetica degli edifici - Calcolo del fabbisogno di energia per il riscaldamento e il raffrescamento.
UNI/TS 11300-1:2008	Energy performance of buildings. Part 1: Evaluation of energy need for space heating and cooling. National Annex to CEN Standard EN ISO 13790.	Prestazioni energetiche degli edifici. Parte 1: Determinazione del fabbisogno di energia termica dell'edificio per la climatizzazione estiva ed invernale.
UNI/TS 11300-2:2008	Energy performance of buildings. Part 2: Evaluation of primary energy need and of system efficiencies for space heating and domestic hot water production.	Prestazioni energetiche degli edifici. Parte 2: Determinazione del fabbisogno di energia primaria e dei rendimenti per la climatizzazione invernale e per la produzione di acqua calda sanitaria.
ROOMVENT 2011	Paper in an international conference.	**I. Ballarini, S. P. Corgnati, V. Corrado, N. Talà, Definition of building typologies for energy investigations on residential sector by TABULA IEE-project: application to Italian case studies, in Proceedings of "The 12th International Conference on Air Distribution in Rooms" (Roomvent), Trondheim, Norway, 19-22 June 2011**
BS 2011	Paper in an international conference.	**I. Ballarini, S. P. Corgnati, V. Corrado, N. Talà, Improving energy modeling of large building stock through the development of archetype buildings, in Proceedings of IBPSA Australasia and AIRAH (AUS), Building Simulation 2011 "Driving better design through simulation", Sydney, Australia, 14-16 November 2011**

9 <PL> Poland

(by TABULA Partner N° 8: NAPE / Poland)

9.1 Description of the EPC Database

This report was elaborated on the base of BuildDesk Certificate system – since in Poland official database of certificates do not exists.
Professional software **ProC** allows to carry out analysis in different section – new, old, residential and non residential buildings.

At the moment the database contains 28 000 buildings providing such a data as:

- year of construction;
- total area, heating area, cubature;
- envelopes (construction, area, u-values);
- technical systems (heating, hot water, ventilation, cooling, lighting);
- energy demand calculated according to Polish EPBD requirements (EK – final energy, EP – primary energy).

Table 24

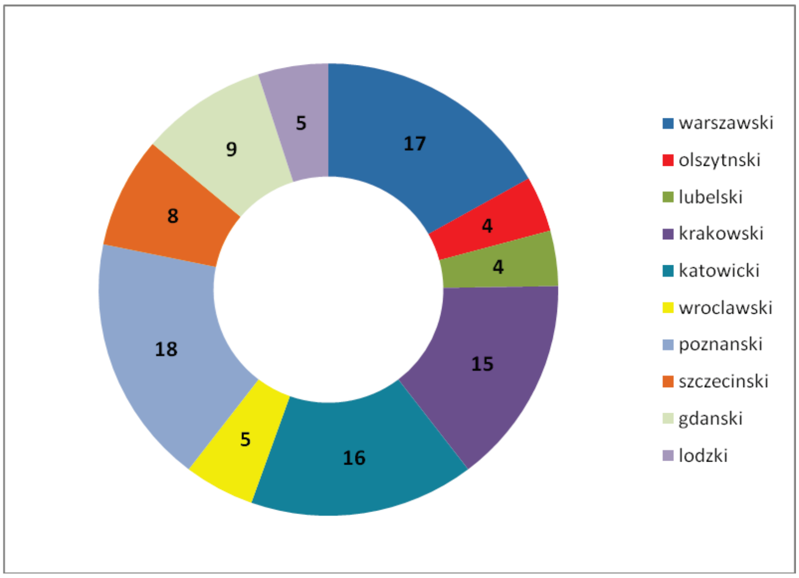
1	2	3	4	5	6	7	8	8	9	10	11	12	13	14	15	16	17
building use	certifiate for	address	year of constructio n	building type	number of floors	number of appartmen ts	number of habitants	heatinh area	usage area	cubature	A/V index	building constructio n	heating system	energy carriers for heating	hot water system	energy acrriers for hot water	HVAC
					no	no	no	m^2	m^2	m^3							
prediﬁned	predefined			predefiniowany, lista rozwijana								predefined	predefined	predefined	predefined	predefined	predefined

18	19	20	21	22	23	24	25	26	27
Ek	EP	EP for reference builing	U values			end-use energy for heating\	end use energy for hot watre	end use energy for HVAC	end use energy for lighing
kWh/m^2	kWh/m^2	kWh/m^2	walls	roof	windows				

These data are not liable to Polish requirements about confidence of personal data and therefore can be publish and used for the purpose of TABULA project. Only one confidential information is address of the building.

Regional representation

Figure 24: Percentage of issued certificates in the regions

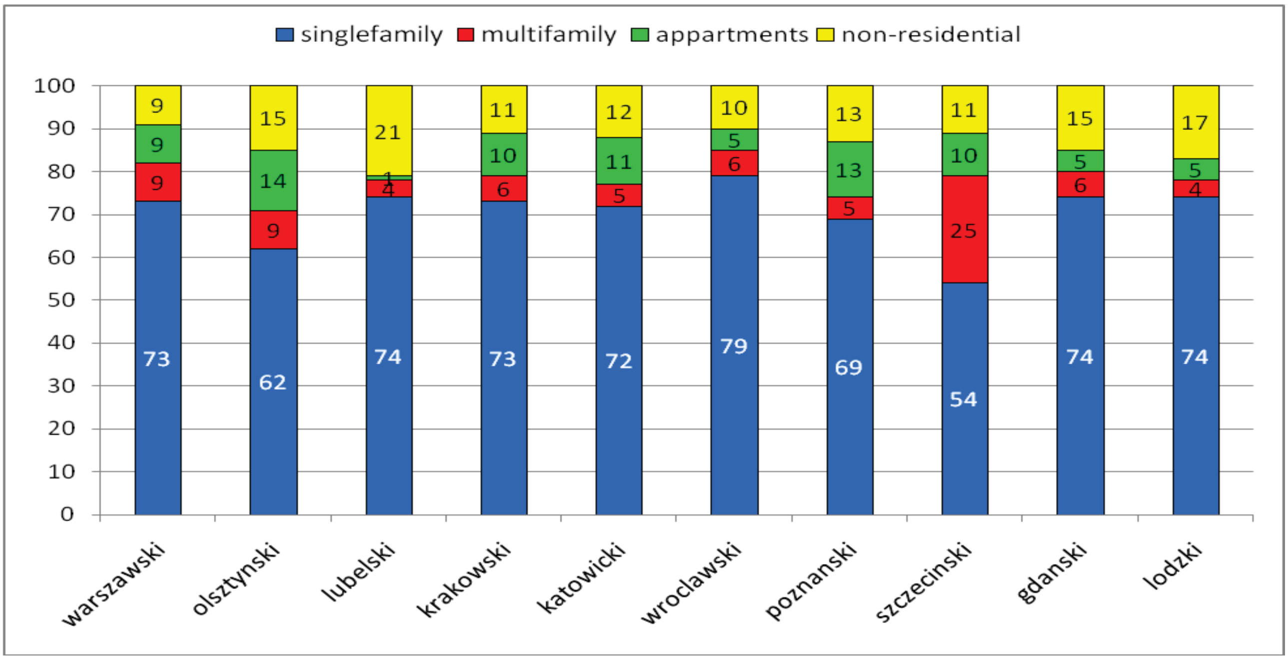


The share of issued certificates in 10 Polish region reflected the development of the housing sector in Poland.

Buildings' typology

Most of the certified buildings are single family houses – average 72 %, 8% represents multifamily houses, 8 % apartments and 13% non-residential.

Figure 25: Percentage of issued certificates according the region and building types



9.2 Analysis of the EPC Datasets

According to the Polish regulation on the certificate two indexes are presented:

EK – (final energy index) – represents amount of energy delivered to the building taken into account efficiency of the heating and hot water system (for non-residential building also electricity for lighting).

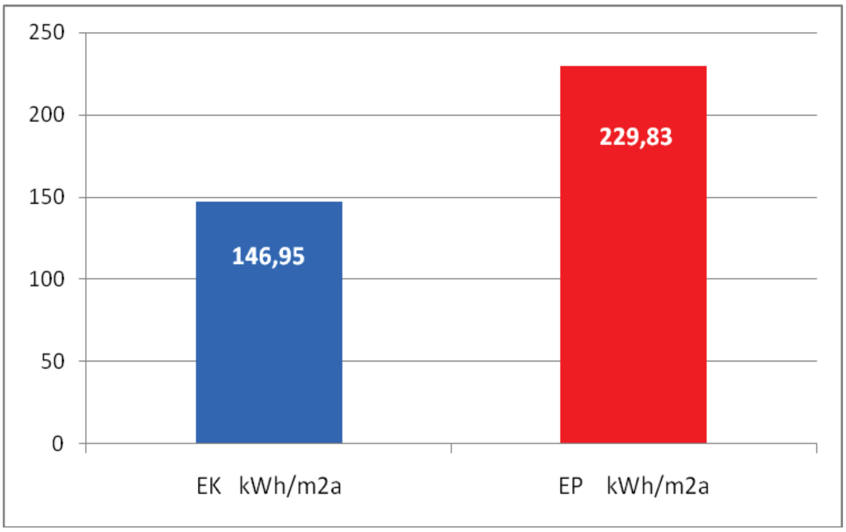
EP – (primary energy index) – is a result of multiplication of EK index times of primary energy index (defined in methodology). It represents energy demand and energy source used for the production on that energy.

Average values of EK and EP

Average EK value for 28 000 buildings registered in the database is 146,95 kWh/m2*a

Average EP value for 28 000 buildings registered in the database is 229,83 kWh/m2*a

Figure 26: Average EK and EP values for Poland



Since the primary energy indexes are lower than 1 only for renewable energy sources this results show clearly that renewable energy doesn't play significant role in the energy supply system in Polish buildings.

Of course some differences are observed in the EK and EP values in the regions. The picture below shows the Ek and EP values for 10 regions.

Figure 27: EK and EP average value in division by regions

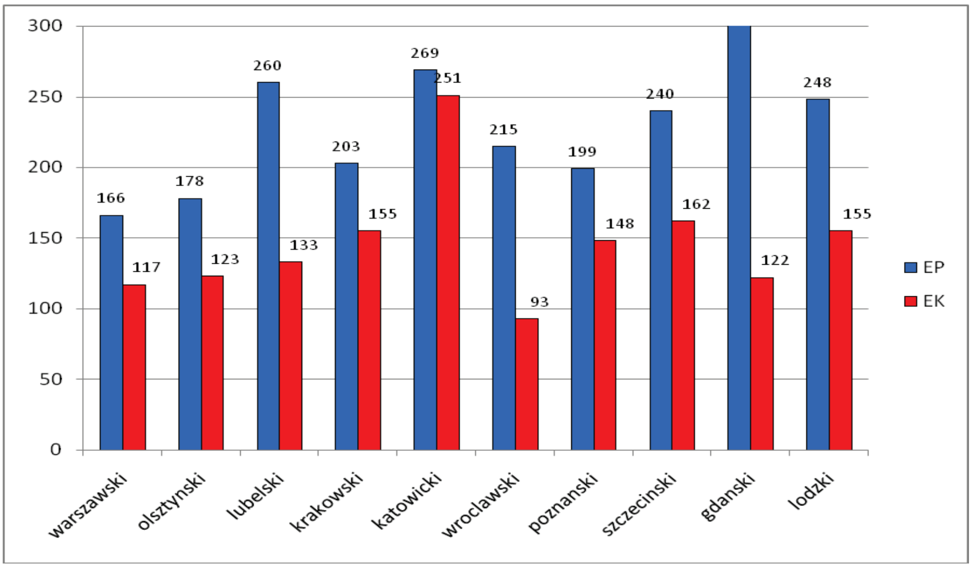
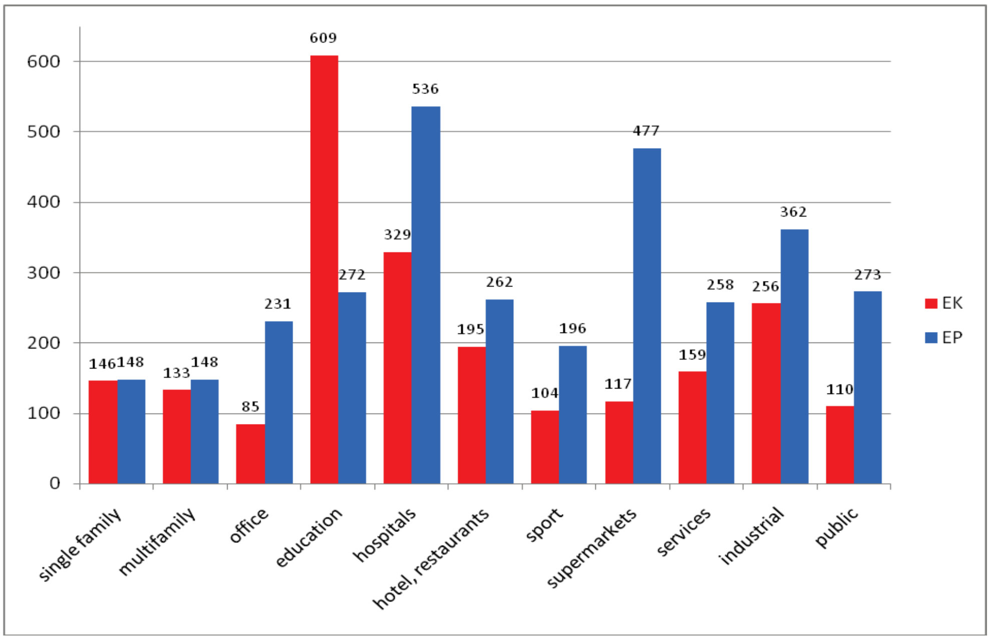


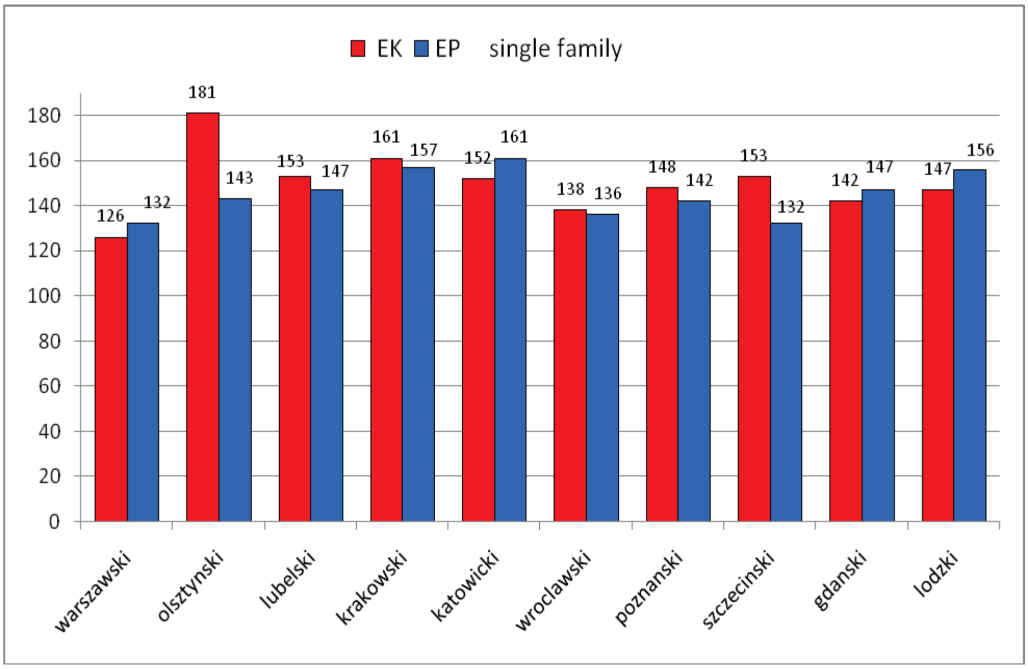
Figure 28: EK and EP average value in division by building types

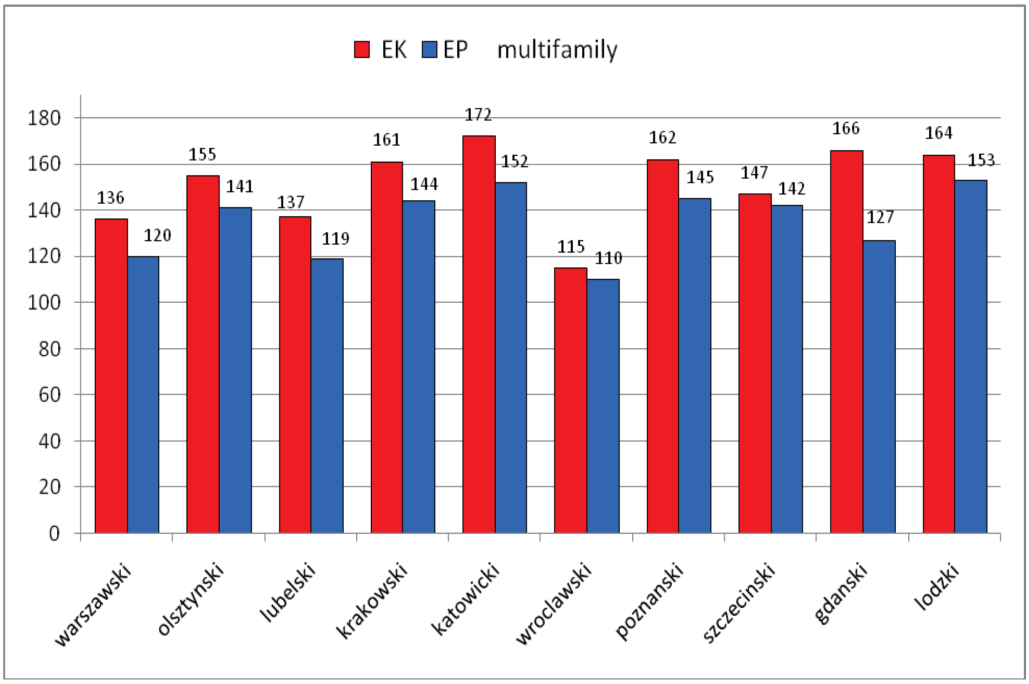


Highest value in gdanski, katowicki, szczecinski and lodzki region in comparision to the average value pointed out stronger development of non-residential buildings in that regions (this kind of constructions in Poland are less efficient that residential buildings).

The picture shows that the biggest challenge is still before public buildings (schools, hospitals) – their EP and EK values are much higher than for other buildings. Interesting situation is noticed in education buildings. Since EK is very high (i.e. low efficiency) EP for these buildings is very low (i.e. most of these buildings are located in rural area and used biomass for heating).

Figure 29: EK and EP average value for single and multifamily houses divided by regions



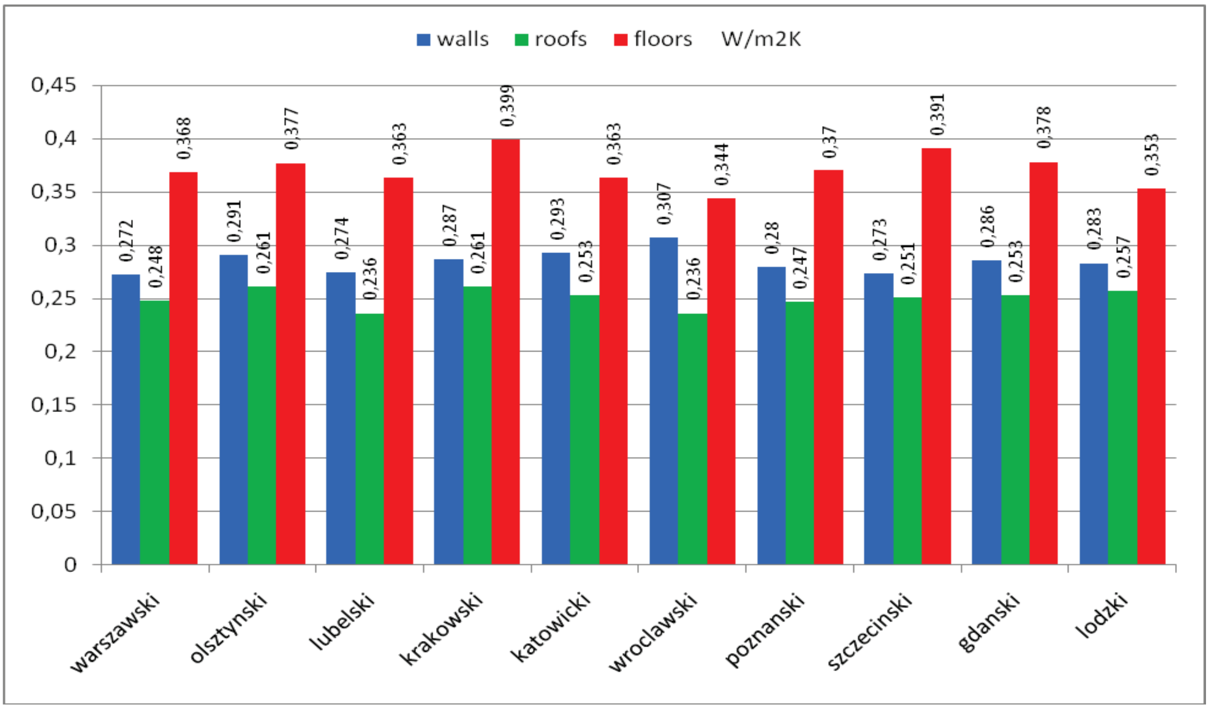


Small difference between EK and EP values for single family and multifamily houses shows, that taking into account requirement of the building users most of the building developers and building managers tried to improve the energy quality of the buildings – not only private bout also those for sale.

Average U-values

Relatively low average U values (0,284 W/m2K for walls, 0,250 W/m2K for roofs and 0,370 W/m2K for floors) do not reflect fully situation of the building sector, since the most certificates are issuing for new buildings or buildings after thermomodernisation (in this two situation the certificate is obligatory.

Figure 30: Average U-values



9.3 Conclusions

Significant improvement in the Polish data base can be reach by.... creation an official database of certified buildings. It is expected that the adaptation of EPBD RECAST requirements into Polish law will forced decision makers to improve existing law also in the field of certificates database.

Table 25: Sources / References Poland

Reference shortcut	Short description (in English)	Concrete reference (in respective language)
BuildDesk	Report about energy condition of Polish buildings	Raport. Stan energetyczny budynków w Polsce
Ordinance	Ordinance about methodology of building certification	Rozporządzenie w sprawie metodyki sporządzania świadectw charakterystyki energetycznej budynków
Energy Law		Prawo energetyczne
Building Code	Introduction of energy certificates	Prawo budowlane
EN ISO 13790:2008	Energy performance of buildings - Calculation of energy use for space heating and cooling.	Cieplne właściwości użytkowe budynków. Obliczanie zapotrzebowania na energię do ogrzania i chłodzenia.