EXECUTIVE SUMMARY

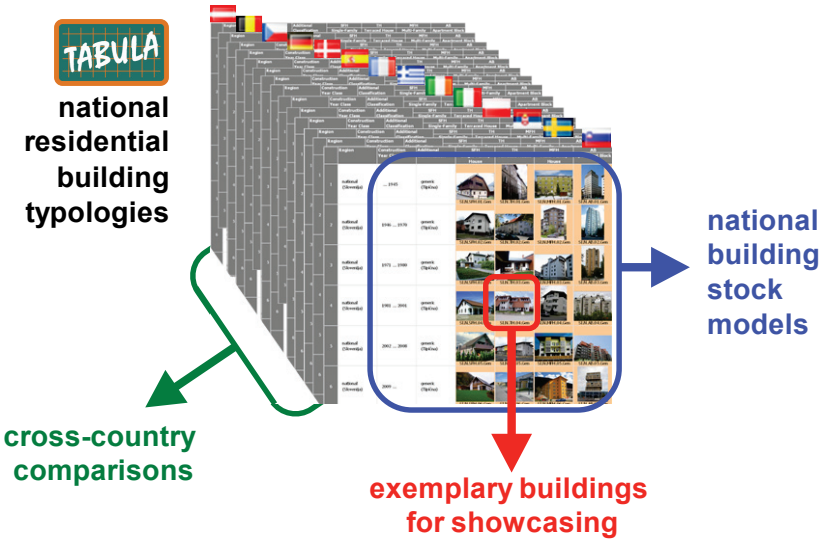
1 IEE Project TABULA – in a Nutshell

During the IEE project TABULA residential building typologies have been developed for 13 European countries. Each national typology consists of a classification scheme grouping buildings according to their size, age and further parameters and a set of exemplary buildings representing the building types. They have been published by the project partners in national "Building Typology Brochures", written in their respective languages. As a common element all brochures contain double page "Building Display Sheets" for all example buildings on which energy related features and the effects of refurbishment measures are illustrated graphically.

To exchange information on the European level the "TABULA WebTool" provides an online calculation of the exemplary buildings from all countries, displaying their energy related features and the possible energy savings by implementing refurbishment measures. Basis of the TABULA WebTool is a simple and transparent reference procedure for calculating the energy need, the energy use by energyware and the energyware assessment (primary energy, carbon dioxide, costs). Apart from the reference calculation used for cross-country comparison a calibration of the calculated energy use to the typical levels of actual consumption is foreseen – with the intention to enable a realistic assessment of energyware and heating costs savings.

Based on the residential building typologies building stock models have been created for seven countries which enable a projection of the actual national building stock consumption and the energy saving potentials.

Figure 1: General idea of TABULA Building Typologies



TABULA Project Partners

at	Austria	AEA
be	Belgium	VITO
bg	Bulgaria	SOFENA
cz	Czech Rep.	STU-K
de	Germany	IWU
dk	Denmark	SBi
fr	France	ADEME
gr	Greece	NOA
ie	Ireland	Energy Action
it	Italy	POLITO
pl	Poland	NAPE
se	Sweden	MDH
si	Slovenia	ZRMK

Associated Partners[1]

rs	Serbia	University Belgrade
es	Spain	IVE

www.building-typology.eu

[1] The associated partners elaborated basic typology elements for their country on a voluntary basis without funding by the IEE programme.

Supported by INTELLIGENT ENERGY EUROPE

Contract N°: IEE/08/495
Project duration: June 2009 … May 2012

2 Building Typologies in the Context of Energy Saving Strategies

The energy performance of buildings correlates with a number of parameters including the year of construction, the building size and the neighbour situation, the type and age of the supply system and the question of already implemented energy saving measures. If these features are known for a given building it will be possible to quickly give an estimation of its energy performance. This principle can also reduce the effort for the energy assessment of a total building portfolio (municipalities, housing companies) or a national building stock, as far as typological criteria are known.

The term "building typology" refers to a systematic description of the criteria for the definition of typical buildings as well as to a set of exemplary buildings representing the building types.

In the past few decades different experiences with building typologies have been made in European countries. The idea of the IEE project TABULA was to examine them and to come to a concerted approach for the field of residential buildings. A focus was placed on the energy consumption for space heating and hot water. The overall objective was to enable an understanding of the structure and of the modernisation processes of the building sector in different countries and – in the long run – to learn from each other about successful energy saving strategies.

The residential building typologies elaborated during TABULA form a data pool of the countries' residential building stocks. They offer different opportunities of application: Single exemplary buildings can be used as showcase examples to give a first estimation of energy saving potentials of real buildings. The set of exemplary buildings – complemented with statistical data about the national building stocks – can be applied for modelling the energy demand of the coun-

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

Figure 2: "Building Type Matrix"

Example from the Slovenian Typology

"Building Type Matrices" are available for 15 countries, see <CountryPages>.

tries' residential building sectors and form a basis for further scenario analyses. From a European point of view the harmonised approach of the TABULA project provides a framework for cross-country comparisons of residential building stocks against the background of energy efficiency.

3 The TABULA Typology Concept

Classification of the National Residential Building Stock

An overview of the national building typology is given by the "Building Type Matrix" (Figure 2). The columns of the matrix represent four building size classes (single-family houses, terraced houses, multi-family houses, apartment blocks), the rows a certain number of construction year classes. The start year and end year of the construction year classes are individually defined for each country. The single cells of the matrix form the "Building Types" of a country.

Exemplary Buildings

To each building type of a country (cell of the classification grid) an exemplary building is assigned which is represented by a photo and the data of the thermal envelope. This building is supposed to be a typical representative of the building type, meaning that it has features which can commonly be found in houses of the respective age and size class. The envelope area and the heat transfer coefficients of the exemplary building are not necessarily representative in a statistical sense.

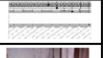
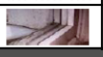
Figure 3: Characteristics of an exemplary building

Example from the Polish Typology

Kod budynku : PL.N.SFH.02.gen

Dane ogólne

typ budynku	jednorodzinny (SFH)
okres budowy	1946 - 1966
Ilość pięter	1
Ilość mieszkań	1
Kubatura ogrzewana:	245,5 m^3
Powierzchnia ogrzewana	98,2 m^2

STAN WYJŚCIOWY (przed modernizacją)				
PRZEGRODY ZEWNĘTRZNE				
			wartość U	
ściany		1,5 cegły	1,95	W/m²K
dach		dach skośny, nie wentylowany	0,9	W/m²K
podłoga		podłoga na gruncie	1,8	W/m²K
okna		drewniane, typu szwedzkiego	3,4	W/m²K

SYSTEMY		
OGRZEWANIE		
wytwarzanie	zasobnik	przesył
piece węglowy	brak	brak
η=0,59		
		
CIEPŁA WODA		
wytwarzanie	zasobnik	przesył
podgrzewacz przepływowy	brak	pobór miejscowy
η=0,59		η=1,0
		

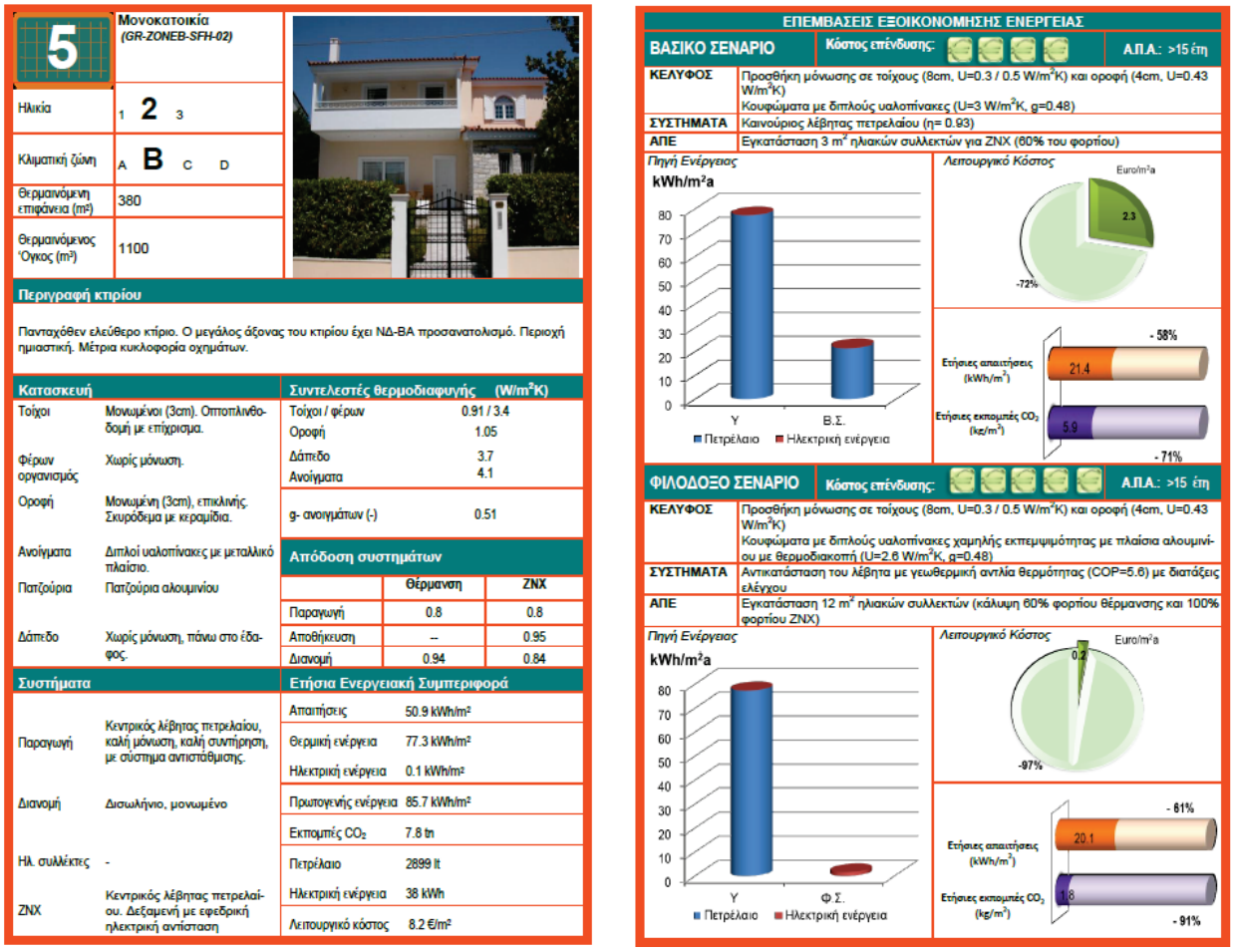
Descriptions of exemplary buildings are available for 11 countries (see <NatTypBrochures>)

4 Refurbishment Measures

The collected sets of real buildings serve as showcase examples to demonstrate the effect of refurbishment measures. For each building three stages of refurbishment were considered:

1. **"Existing State":** Typical state of a non-refurbished building.
2. **"Standard Measures"** (usual refurbishment): Package of measures for upgrading the thermal envelope and the heat supply system which are commonly realised during refurbishment; typically reflecting the national requirements in case of renovations.
3. **"Advanced Measures"** (ambitious refurbishment): Package of measures for upgrading the thermal envelope and the heat supply system which are usually only realised in very ambitious renovations or research projects; typically reflecting the level of passive house components.

Figure 4: "Building Display Sheets" as part of a national "Typology Brochure"
Example from Greece



Left side: Description of existing state / Right side: Energy savings achieved by two different packages of modernisation measures

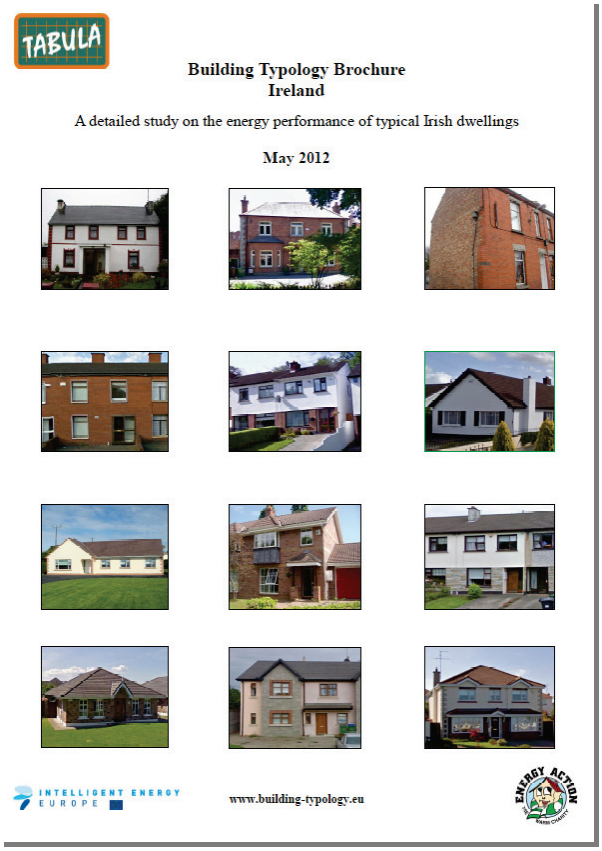
5 National Typology Brochures

For each country a brochure has been elaborated which contains the different elements of a residential building typology (Figure 5):

- the classification of the national building stock / display of the building type matrix (see above, section 2);
- frequencies of the building types (see below, section 9);
- typical energy consumption values of exemplary buildings (see below, section 6);
- definition and description of refurbishment measures (see section 4) and the energy saving potential;
- "Building Display Sheets:
  A double page showing the existing state of the building and the possible energy savings by distinct measures (see example in Figure 4);

Each national brochure addresses key actors of the respective country and supplies them with information and material for energy advice activities. In some cases, the "Building Display Sheets" are also disseminated separately. The brochures are written in national languages.

Figure 5: Cover of a "National Building Typology Brochure"
Example from Ireland



"National Building Typology Brochures" are available in 11 countries, see <NatTypBrochures>

6 TABULA Calculation Method

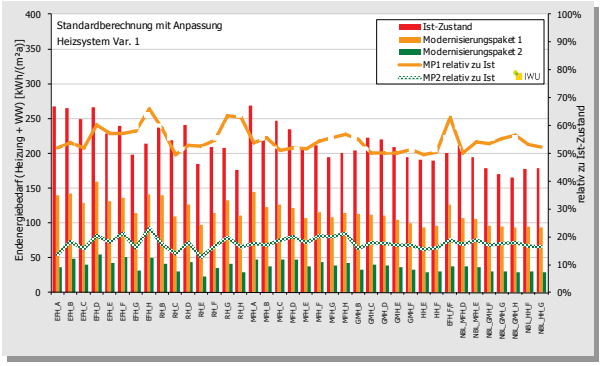
Data Structure

Since a comparable energy balance calculation for the exemplary buildings is needed the respective datasets of construction elements, envelope areas and different supply systems were collected in a common database for all countries. In case national definitions differ from this concerted data structure a data transformation had to be applied by the respective partner.

In consequence, always two versions of the example building and supply system data were produced:

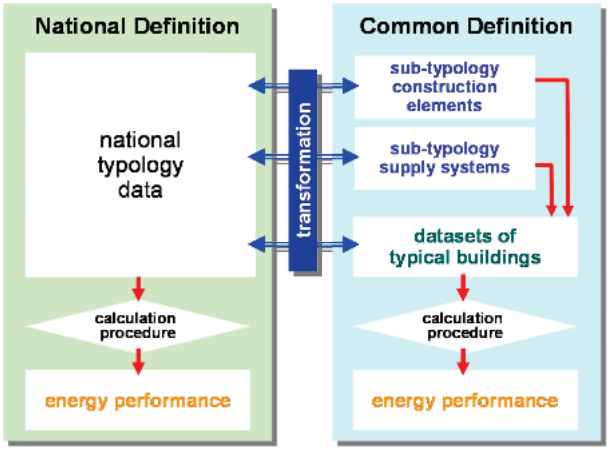
- **Data according to the relevant national energy balance procedure** (usually the national procedure for issuing energy performance certificates EPC)**,** used in the national context for analyses, typology brochures (see section 5), default datasets in energy advice and EPC software, ...
- **Data according to the TABULA data structure,** used to understand and compare the energy performance and refurbishment measures of buildings from different countries, e.g. for showcase analyses (TABULA WebTool, see section 7) or cross-border building stock models.

Figure 6: Calculation of the energy use for all exemplary buildings
Example from the German typology brochure



Delivered energy per m² reference area (calibrated to the typical level of measured consumption) for three variants: (1) existing state = red, (2) standard measures = yellow; (3) advanced measures = green)

Figure 7: Two-track approach for definition of exemplary buildings and heat supply systems



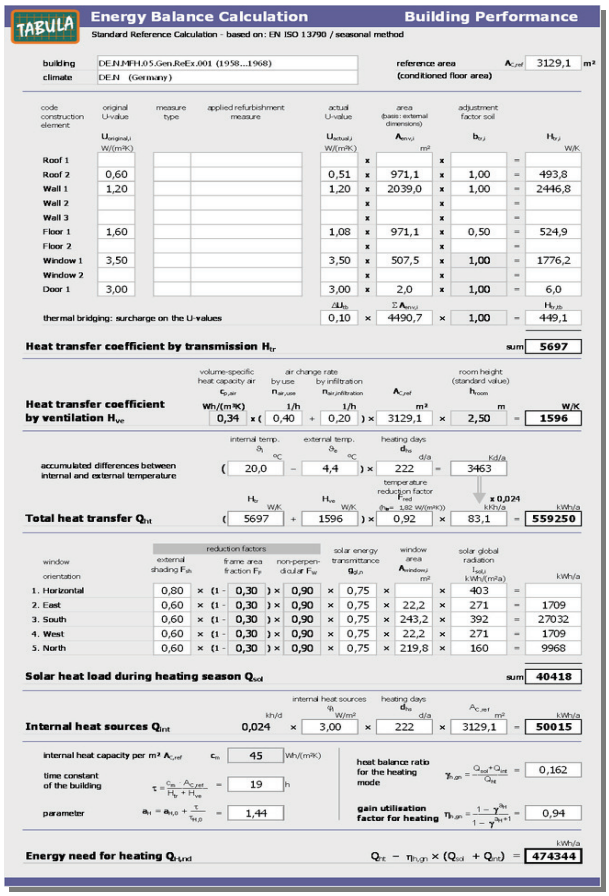
Common Calculation Procedure

The energy demand of the exemplary buildings is determined by use of a simple energy performance calculation procedure based on the respective CEN standards. The basics of the procedure are described in the first TABULA Synthesis Report <SR1>. The formulas and standard values are documented in a special report <CalcProc>.

Calculation sheets to show the formulas and interim values and thus to enable a tracking of the calculation for a given building and system have been elaborated (Figure 8).

Figure 8: Standardised Calculation sheet

Example: Calculation of the energy need for heating



Energy Balance Calculation — Building Performance

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

building: DE.NMFH.05.Gen.ReEx.001 (1958...1968) — reference area (conditioned floor area) $A_{C,ref}$: 3129,1 m²

climate: DE.N (Germany)

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

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

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

	internal temp. ϑ_i °C		external temp. ϑ_e °C		heating days d_{He} d/a		kd/a
accumulated differences between internal and external temperature	(20,0	-	4,4	) x	222	=	3463

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

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

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

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

internal heat capacity per m² $A_{C,ref}$	c_m	45	Wh/(m²K)
time constant of the building	$\tau = \frac{c_m \cdot A_{C,ref}}{H_{tr} + H_{ve}}$ =	19	h
parameter	$a_H = a_{H,0} + \frac{\tau}{\tau_{H,0}}$ =	1,44	
heat balance ratio for the heating mode	$\gamma_{h,gn} = \frac{Q_{gn} + Q_{int}}{Q_{ht}}$ =	0,162	
gain utilisation factor for heating	$\eta_{h,gn} = \frac{1 - \gamma_h^{a_H}}{1 - \gamma_h^{a_H+1}}$ =	0,94	

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

These calculation sheets form part of <TABULA.xls>, <tabula-calculator.xls> and <WebTool> (see clauses below).

Due to the low number of calculation formulas an implementation in form of a simple spreadsheet for buildings and for systems was also possible (1 row per dataset). In consequence, a large number of building and system variants can be calculated in a fast and transparent way.

Heating System Typology and Assessment of Energywares

Basis of the heat supply calculation procedure are tabled values for heat generation, storage, distribution and auxiliary energy – each for space heating and domestic hot water. The respective values for these system components have been determined for each country by use of the relevant national EPC methods, converted and entered into the TABULA database.

As a further step an assessment of the energywares used is performed by multiplying the delivered energy per energy carrier with the respective national or European factors. It includes the determination of the quantities:

- total primary energy demand,
- non-renewable primary energy demand,
- carbon dioxide emissions,
- energy costs.

Calibration to the Typical Level of Measured Consumption

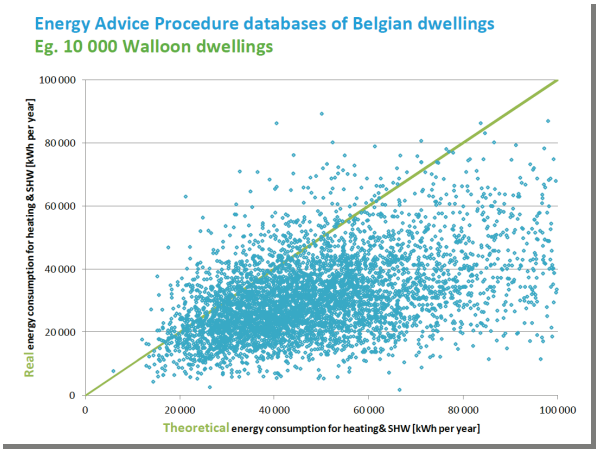
In order to enable realistic statements about the energy use and the possible energy savings, the TABULA concept includes the option of calibrating the calculated results to the typical level of measured consumption.

A precondition for such an adaptation is the knowledge about the average energy consumption of buildings for different levels of their theoretical energy performance. Some of the TABULA partners already performed respective correlation analyses (see example in Figure 9), in other cases only estimations are available. In case of estimations the calibration to the typical level of consumption is deemed preliminary – up to the time when more detailed information is available and reliable statistical analysis have been performed.

The TABULA WebTool (see section 7) takes account of this calibration. It offers an option to change all displayed results from "standard calculation, not adapted" to the status "adapted to typical level of measured consumption" (menu item "settings").

Figure 9: Measured vs. calculated energy consumption for space heating and DHW

Example from Belgium: Analysis for 10 000 dwellings

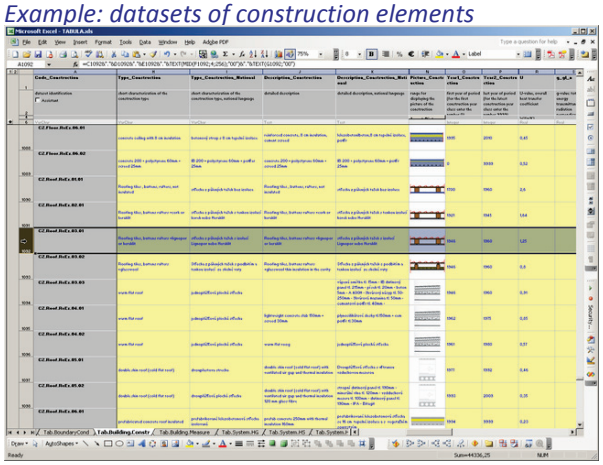


TABULA Database and Calculation Workbook

An MS Excel workbook <TABULA.xls> has been designed containing the example building datasets of all countries and enabling own calculations, modifications and variations of refurbishment measures and supply systems. The idea of this workbook is to perform the following tasks:

Figure 10: Data Sheet of "TABULA.xls"

Example: datasets of construction elements



A. **"Data Base":**
Frame for collecting and merging typology data from different countries;

B. **"Programming Template":**
Structure template and data source for the TABULA WebTool (see section 7);

C. **"Showcase Calculation":**
Display of the common energy performance procedure / check of input data;

D. **"Operative Analyses":**
Energy performance calculation of sets of buildings/systems (row by row calculation sheets).

A simplified version of the workbook has been extracted from "TABULA.xls" for easy use by third parties. This workbook "tabula-calculator.xls" provides an easy access to the data of exemplary buildings and systems, offers own calculations and variations on a row by row spreadsheet basis (<tabula-calculator.xls>).

7 Building Typology WebTool

The mentioned Excel workbooks are working tools offering many possibilities to calculate energy balances and saving potentials for a set of buildings. Of course, before an expert can use it, he/she has to spend some time to understand the structure of the workbook itself and the different calculation sheets.

With the intention to enable an intuitive easy access to the TABULA concept and its possible benefits an online application has been created. The TABULA <WebTool> is addressing energy experts in all European countries. It offers them to interactively explore the different aspects of residential building typologies and to easily track and understand the common calculation procedure.

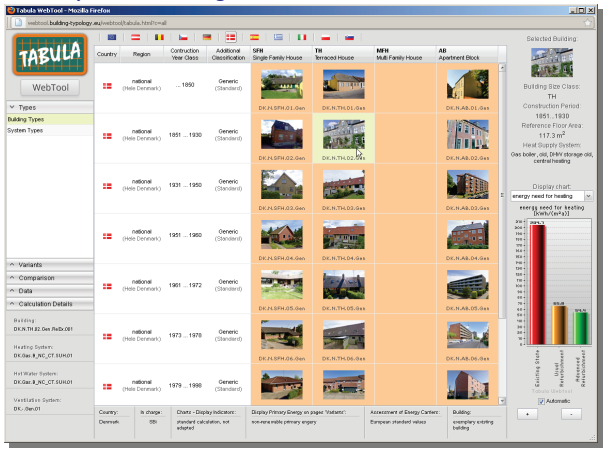
For a typical building of a selected country the energy related features, the energy consumption in the existing state and the effect of energy saving measures on the two levels "Standard" and "Advanced" can be viewed. The data structure and calculation formulas are identical with the above mentioned Excel workbooks <TABULA.xls> and <tabula-calculator.xls>.

In addition, an expert version provides an online access to all datasets including those of synthetical average buildings (if available for

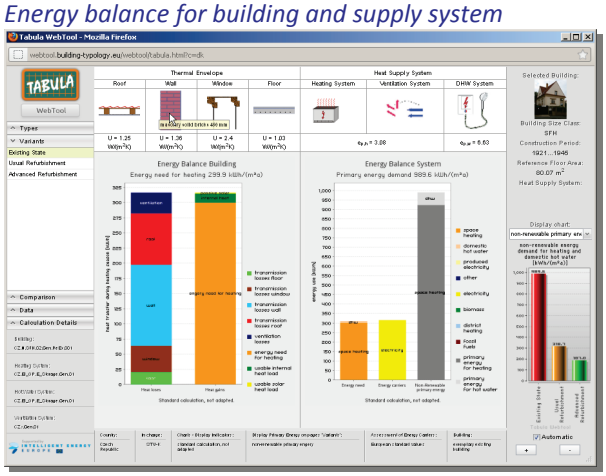
a country, see section 10) and enables a calculation of arbitrary combinations of buildings and systems <WebToolExpertVersion>.

Figure 11: Screenshots of the TABULA Building Typology WebTool <WebTool>

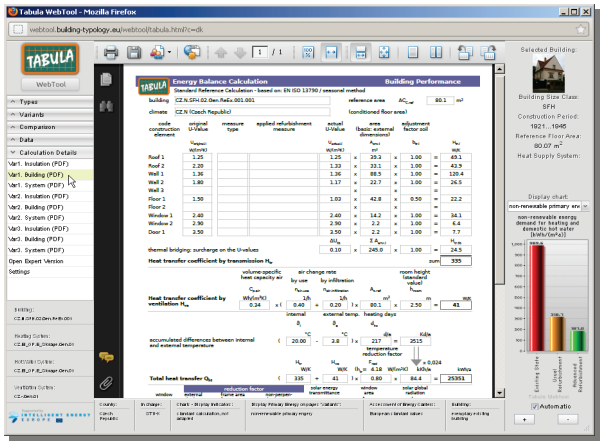
Country and building selection



Energy balance for building and supply system



Transparent and traceable online calculation



8 Cross-Country Comparison of Typical Buildings and Supply Systems

To compare the energy related properties of buildings between the different countries an analysis of typological data included in the TABULA database (MS Excel workbook <TABULA.xls>) has been performed <DataEval>. Depending on the type of data the evaluations can in the future be useful for different aspects mentioned in the following clauses.

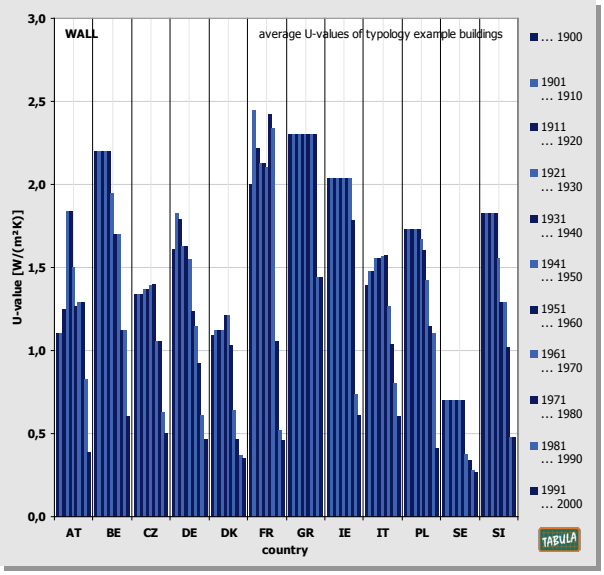
Construction Elements and Insulation Measures

An evaluation of the U-values of roofs, walls, windows and floors of the exemplary buildings provides indications about the development of thermal quality standards in the participating countries during the last century (Figure 12). Of course, since the transfer coefficients by transmission were not exactly measured the comparison is not reflecting the actual but the assumed performance relying on individual national assessment methods.

The evaluation of the refurbishment measures on the levels "Standard" and "Advanced", as proposed in different the typology brochures (see section 5), disclosed rather large differences – even between countries in similar climatic zones (Figure 13). Thus, the confrontation and discussion of energy upgrade qualities remains an important task for the future.

Figure 12: Analysis of "TABULA.xls" data – Comparison of features of exemplary buildings <DataEval>

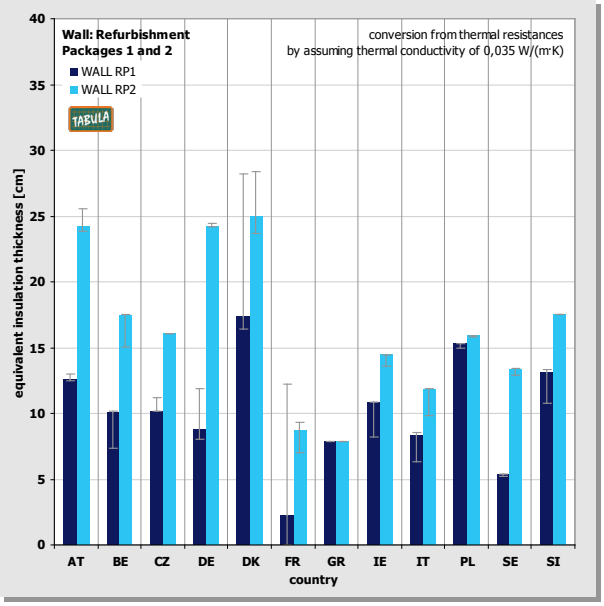
Example: U-values of walls per country and decade



Evaluations of further envelope types ("roof", "window", "floor") are available at <DataEval>.

Figure 13: Analysis of "TABULA.xls" data – Comparison of insulation measures proposed in the national typology brochures (section 5) <DataEval>

Example: insulation thickness of wall refurbishment per country; "standard" (RP1) and "advanced" (RP2) measures



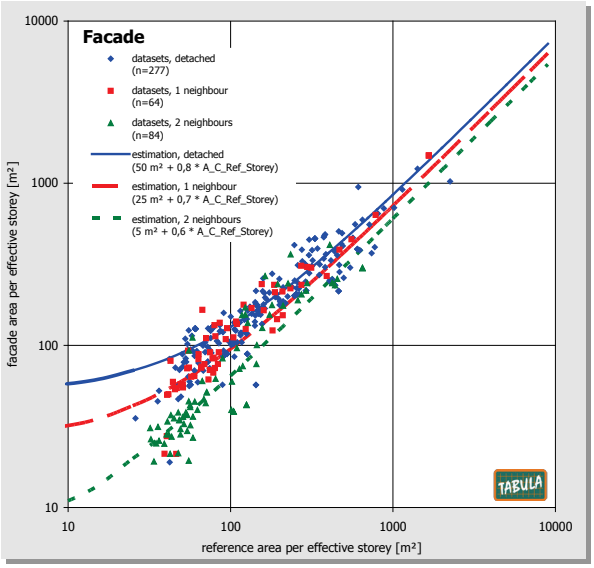
Evaluations of further envelope types ("roof", "window", "floor") are available at <DataEval>.

Thermal envelope areas

The analysis of the thermal envelope areas of exemplary buildings has resulted in typical values for the ratio of the surface area to the reference floor area per envelope type (roof, wall, window, and floor). The averages and the spreads may in the future support plausibility checks of data input. In addition, the mean envelope areas of the exemplary buildings are a possible basis for building stock models (see section 10) in case that more representative information about building stock surface areas is not available.

Figure 14: Analysis of "TABULA.xls" data – Dependency of the thermal envelope from basic parameters <DataEval>

Example: Correlation of the facade area with the TABULA reference area per storey, differentiated by the number of directly attached neighbour buildings



Further in-depth analyses revealed a systematic correlation of the envelope areas with basic geometrical parameters like number of storeys, number of directly attached neighbour buildings, etc. (Figure 14). In the future, these functional dependencies may be useful to estimate the size of the thermal envelope of a given building in the context of housing stock surveys and portfolio assessments. Also a further development of the TABULA WebTool using model buildings which can be adapted to the basic geometrical features of a given real building seems possible.

Heat Supply Systems

Since commonly defined data are available for heat generators, storages and distribution systems a comparison of the energy performance of these components between the participating countries was possible (Figure 15). Generally the values turned out to be rather similar for a given component. In some cases larger deviations were found which may either reflect differences in technologies or in methods for the determination of standard values. In any case such comparisons can also in the future be useful for a quality check of the typology input data.

Figure 15: Analysis of "TABULA.xls" data – Comparison of system data between different countries <DataEval>

Examples: energy expenditure factors of a) boilers B_NC, B_C, B_WP (non-condensing, condensing and wood pellets) and b) electrical heat pumps HP_Air, HP_Ground, HP_ExhAir (heat source: external air, ground, exhaust air)

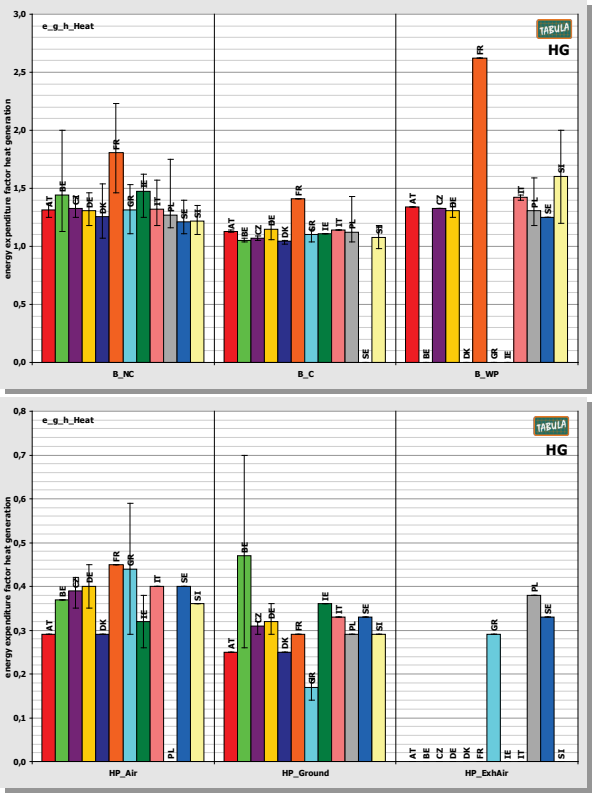


Table 1: Result of the comparative analyses of heating system data – derived default values (simplified common values) <DataEval>

Example: energy expenditure factors of heat generators

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

Furthermore, the averages of the available energy performance values of supply system components can be helpful in case that national values do not exist. In consequence, tables listing such default values have been determined for each supply system component (Table 1). The default values can also be utilised for the elaboration of transnational building stock models.

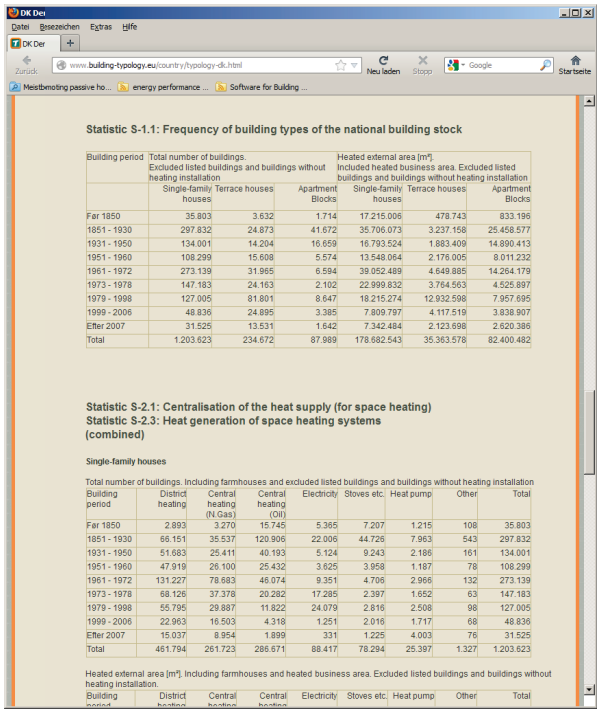
9 National Statistics of Buildings and Heat Supply Systems

In order to assess the relevance of the building types and as a pre-requisite for the design of building stock models the available statistics have been reported for each country. Basic statistics are the frequencies of building types and of supply system types. Further information about the energy related properties have been added – as far as available. It can be stated that there is a general lack of sufficiently detailed data about the energy performance of buildings in the participating countries, especially as regards the current refurbishment grades and annual refurbish-

ment rates. More details about the concept and the structure of the statistical tables can be found in the TABULA Synthesis Report SR1 chapter 6 <SR1>.

Figure 16: National housing stock statistics at the "Country Pages" of the TABULA website <CountryPages>

Example: housing stock statistics of Denmark



Statistic S-1.1: Frequency of building types of the national building stock

Building period	Total number of buildings. Excluded listed buildings and buildings without heating installation			Heated external area [m²]. Included heated business area. Excluded listed buildings and buildings without heating installation		
	Single-family houses	Terrace houses	Apartment Blocks	Single-family houses	Terrace houses	Apartment Blocks
Før 1850	35.803	3.632	1.714	17.215.006	478.743	833.196
1851 - 1930	297.832	24.873	41.672	35.706.073	3.237.158	25.458.577
1931 - 1950	134.001	14.204	16.659	16.793.524	1.883.409	14.890.413
1951 - 1960	108.299	15.608	5.574	13.548.064	2.176.905	8.011.232
1961 - 1972	273.139	31.955	6.594	39.052.489	4.649.885	14.264.179
1973 - 1978	147.183	24.163	2.102	22.999.832	3.764.563	4.525.897
1979 - 1998	127.005	81.801	8.647	18.215.274	12.932.598	7.957.695
1999 - 2006	48.836	24.895	3.385	7.809.797	4.117.519	3.838.907
Efter 2007	31.525	13.531	1.642	7.342.484	2.123.698	2.620.386
Total	1.203.623	234.672	87.989	178.682.543	35.363.578	82.400.482

Statistic S-2.1: Centralisation of the heat supply (for space heating)
Statistic S-2.3: Heat generation of space heating systems (combined)

Single-family houses

Total number of buildings. Including farmhouses and excluded listed buildings and buildings without heating installation

Building period	District heating	Central heating (N.Gas)	Central heating (Oil)	Electricity	Stoves etc.	Heat pump	Other	Total
Før 1850	2.893	3.270	15.745	5.365	7.207	1.215	108	35.803
1851 - 1930	66.151	35.537	120.906	22.006	44.726	7.963	543	297.832
1931 - 1950	51.683	25.411	40.193	5.124	9.243	2.186	161	134.001
1951 - 1960	47.919	26.100	25.432	3.625	3.958	1.187	78	108.299
1961 - 1972	131.227	78.683	46.074	9.351	4.706	2.966	132	273.139
1973 - 1978	68.126	37.378	20.282	17.285	2.397	1.652	63	147.183
1979 - 1998	55.795	29.887	11.822	24.079	2.816	2.508	98	127.005
1999 - 2006	22.963	16.503	4.318	1.251	2.016	1.717	68	48.836
Efter 2007	15.037	8.954	1.899	331	1.225	4.003	76	31.525
Total	461.794	261.723	286.671	88.417	78.294	25.397	1.327	1.203.623

Heated external area [m²]. Including farmhouses and heated business area. Excluded listed buildings and buildings without heating installation.

Building	District	Central	Central	Electricity	Stoves etc.	Heat pump	Other	Total

Available for 14 countries at the respective TABULA "Country Page" <NatStat>

10 Models of the National Housing Stock

One important objective of the set-up of national building typologies is the elaboration of bottom-up models which enable a calculation of the energy consumption of the respective building stocks. A typical application field is the investigation of energy saving potentials for a national or regional building stock as well as the design and evaluation of instruments and political strategies.

The elaborated set of exemplary buildings, as shown above, can be directly used as a building stock balance model – as far as statistics are available for the frequencies of building and system types and for the refurbishment state. The example buildings are in this case considered as a small sample of the stock. It is also possible to merge several classes and derive a small number of "average buildings". As a consequence the implementation of scenario analyses – which implicates the variation of a large number of parameter combinations (e.g. different insulation measures, supply system changes and upgrades) – will be much easier.

Table 2: Result of a housing stock energy balance

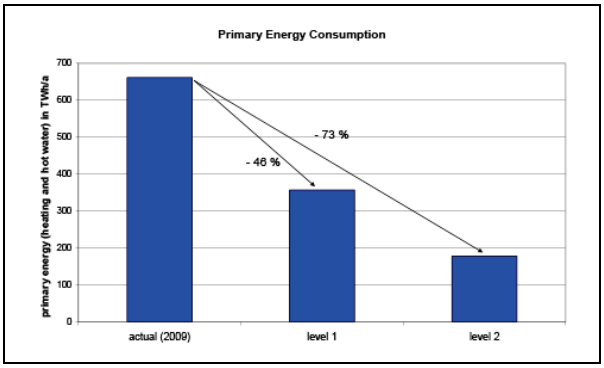
Example: Belgian housing stock model – comparison of model results with national Energy balance <NatMod>

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

National Energy balance Belgium 2006 / final energy consumption in TJ

Figure 17: Energy saving potentials determined by use of a national building stock model

Example: German housing stock model – calculation of potential energy savings <NatMod>



Calculated primary energy consumption of non-renewable energy sources in the German residential building stock: actual value (2009) and reduced consumption after application of energy saving measures (in TWh/a)

If respective statistical information is available an elaboration of "average buildings" is possible. Such synthetical buildings are usually based on random samples (or a census in the best case) collected by surveys or from EPC databases. For some countries such average buildings have been derived in the framework of the TABULA project. An access

to these datasets is possible by means of the Expert Version of the TABULA WebTool[2].

National building stock models have been elaborated by seven TABULA partners on the basis of the typology data. The results are available in a special report <NatModels>.

11 Consideration of Non-Residential Buildings

Because of the broad variety of uses and associated characteristics, setting up a typology for the non-residential sector is presumably a rather complex task. It is therefore important to consider both, practicability of and data availability for such a structure. During the TABULA project a review of existing national approaches and statistical data has been elaborated for five countries <NonRes>.

In general, the analysis shows that the current states of the non-residential building stocks and on-going retrofit processes are not very well known. For this reason, further knowledge is currently generated through national and European projects, energy audits and studies, e.g. in the framework of consulting activities. In Austria and Poland databases to collect benchmarks or data from energy certificates have been set up in the more recent past. In Germany studies analysing the possible structure of a non-residential building typology, benchmarks, and end energy uses in the tertiary sector have been carried out. Apart from these running activities in the different countries, the need for setting up representative surveys to continuously monitor the refurbishment rates was emphasized.

On the basis of the existing national information draft classification schemes were proposed by the concerned partners referring to the different uses of non-residential buildings and their construction year classes as main parameters to differentiate building categories. For the distinction of further subtypes various suggestions are made concerning climate conditions, building size, building cubature, surface-to-volume ratio, supply systems, and the state of refurbishment. Some partners suggest working with a limited number of building categories to begin with.

Table 3: National statistics of the non-residential building stock

Example: number of non-residential buildings and gross floor areas in Austria, differentiated by building category and construction year class <NonRes>

Number of buildings	Trade/ office	Factory/ operational	Tourism	Public
- 1880	8.404	4.967	3.500	5.025
1880-1918	7.927	6.291	2.141	3.440
1919-1944	4.454	5.751	1.468	1.764
1945-1960	7.005	9.396	2.373	3.096
1961-1970	8.366	11.443	3.992	3.945
1971-1980	9.920	13.138	4.941	4.531
1981 -	10.455	12.404	3.559	4.260
total	56.531	63.390	21.974	26.061
Gross floor area (m²)	**Trade/ office**	**Factory/ operational**	**Tourism**	**Public**
- 1880	13.930.724	7.144.596	4.259.481	5.678.504
1880-1918	18.942.421	11.110.819	2.158.258	7.096.492
1919-1944	6.047.604	7.939.765	1.277.937	2.371.890
1945-1960	8.310.161	11.257.905	2.112.512	4.322.751
1961-1970	14.385.015	17.358.723	3.845.046	7.212.950
1971-1980	21.134.553	23.718.989	5.477.169	10.499.270
1981 -	22.146.521	22.681.378	5.368.772	8.926.927
total	104.896.999	101.212.175	24.499.175	46.108.784
% of the total building stock	13,5%	13,0%	3,2%	5,9%

12 Recommendations and Outlook

Building typologies have proved to be a good means to combine communication about refurbishment measures and their benefit for single buildings with the overall perspective on the building stock. The TABULA partners are determined to preserve and disseminate the elaborated national typologies and to further develop certain aspects. In their role as „Caretaker“ of the typologies of their countries the partners will also in the future be responsible for the maintenance and update of typology data as defined during the project[3]. They understand the TABULA approach as a public concept open for attaching additional themes and research items –

[2] <WebToolExpertVersion>: The identification code contains "SyAv" for "Synthetical Average" in contrast to "ReEx" for real existing building).

[3] building type matrix, exemplary buildings, building stock statistics; if applicable: average buildings and building stock model

elaborated by themselves but also by third parties.

In the following a number of recommendations for the future development are given and options for the extension towards possible fields of application are discussed.

- **Inclusion of further countries:** An extension towards further countries or regions is desirable. Interested institutions are invited to become national caretaker and to commit themselves to the elaboration of a building type matrix, a typology brochure, datasets of exemplary buildings and statistics according to the common TABULA concept. This may be possible within the framework of individual national projects or – in a joint approach of several countries – on the basis of projects funded by the European Union.
- **Downscaling:** The set-up of similarly structured building typologies for regional and local housing stocks or portfolios of housing companies is a further option including tasks similar to those of the national level and providing benefits in an analogue way.
- **Inclusion of newly built homes and NZEB:** The current TABULA concept is focusing on refurbishments. An extension towards new buildings is in principle desirable but needs some further development, because the thermal envelope standards are in many countries depending on the type of heating system. Nevertheless, an inclusion of new constructions in the TABULA WebTool would result in the possibility to directly compare the requirements for new buildings between different countries. Such an extension should also include future standards, especially that of "Nearly Zero-Energy Buildings" (NZEBs).
- **"Adaptable model buildings":** The potentials of the showcase concept could be enlarged if model buildings were used that offer a flexible adaptation to the features of a given real building. Such "adaptable model buildings" could take advantage of the statistical analyses of thermal envelope areas of the exemplary buildings (section 8). They would offer a modification of the envelope depending on the number of storeys, the number of directly attached neighbour buildings as well as the attic and cellar type. Also the flexible consideration of earlier implemented energy upgrades of envelope and supply systems should be possible. Implementing these typological adaptations as features in the TABULA WebTool would enlarge the application fields and would provide a blueprint for quick online energy advice applications.
- **Simplified assessment of building portfolios:** The utilisation of adaptable model buildings as mentioned above can also be valuable for a rough assessment and continuous monitoring of building portfolios and for the data acquisition in the context of representative surveys. A precondition is a standardised questionnaire for elevating typological data.
- **Demonstration buildings ("best practice examples"):** Already refurbished buildings could be assigned as sizable examples to the different national building types. The measure description would include photographs from the renovation phase and – after a period of utilisation – values for the measured consumption.
- **Non-residential buildings:** The next steps towards a national typology for non-residential buildings are the fixing of classification criteria, the determination of exemplary buildings, the definition of a set of refurbishment measures for envelope and supply system, the elaboration of building display sheets and the collection and processing of consistent statistical information. On the international level the task would be to prepare a common building database on the basis of a concerted calculation procedure.
- **Summer performance of buildings:** The current TABULA systematic is focusing on the energy use for space heating and domestic hot water. A simplified classification of the summer performance and the determination of the energy use for cooling / air-conditioning would provide benefits for the application in southern countries and in the field of non-residential buildings.

- **Building stock monitoring:** Typology based building stock models are a good basis to proceed towards comprehensive building stock monitoring activities. This comprises the elaboration and the testing of mechanisms for a continuous update of the relevant input quantities, scenario calculations identifying refurbishment targets, necessary annual refurbishment rates, the trend development and the gap to be overcome. Moreover, the development of models for the statistical correlation of the calculated and the real energy consumption can be enabled by surveying the relevant physical indicators (thermal insulation, heat supply systems) and the actual energy consumption (heating bills) in the same process.

13 References (TABULA Publications)

Reference Shortcut	Short Title and Link
<CalcProc>	TABULA Calculation Method – Energy Use for Heating and Domestic Hot Water. Reference Calculation and Adaptation to the Typical Level of Measured Consumption; TABULA documentation; IWU, Darmstadt 2012 http://www.building-typology.eu/tabulapublications.html#Download_Data_Tool
<CountryPages>	"Country Pages" of the TABULA Website http://www.building-typology.eu/country.html
<DataEval>	Evaluation of the TABULA Database – Comparison of Typical Buildings and Heat Supply Systems from 12 European Countries; TABULA Work Report; IWU, Darmstadt 2012 http://www.building-typology.eu/tabulapublications.html#Download_Data_Tool
<EPCdatabases>	Use of Energy Certificate Databases for National Building Typologies; with contributions by: AEA / Austria; VITO / Belgium; IWU / Germany; ADEME / France; Energy Action / Ireland; POLITO / Italy; NAPE / Poland; TABULA Thematic Report N° 1; IWU, Darmstadt 2012 http://www.building-typology.eu/tabulapublications.html
<NatModels>	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
<NatScieRep>	http://www.building-typology.eu/tabulapublications.html#Download_ScientificReports
<NatStat>	National Statistics at the respective "Country Pages" http://www.building-typology.eu/country.html
<NatTypBrochures>	"National Typology Brochures" at the respective "Country Pages" http://www.building-typology.eu/tabulapublications.html
<NonRes>	Typology Approaches for Non-Residential Buildings in Four European Countries. Existing Information, Concepts and Outlook; with contributions by AEA / Austria, IWU / Germany, NOA / Greece, NAPE / Poland; TABULA Thematic Report N° 3; IWU, Darmstadt 2012 http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR3_D9_NonResidentialBuildings.pdf
<SR1>	Use of Building Typologies for Energy Performance Assessment of National Building Stocks. Existent Experiences in European Countries and Common Approach; First TABULA Synthesis Report; with contributions by NOA / Greece, ZRMK / Slovenia, POLITO / Italy, ADEME / France, Energy Action / Ireland, VITO / Belgium, NAPE / Poland, AEA / Austria, SOFENA / Bulgaria, STU-K / Czech Republic, SBi / Denmark; IWU, Darmstadt 2010 http://www.building-typology.eu/downloads/public/docs/report/TABULA_SR1.pdf
<TABULA.xls>	Excel workbook "TABULA.xls", master file containing all building, construction and system data and used as a template for programming the TABULA WebTool http://www.building-typology.eu/tabulapublications.html#Download_Data_Tool
<tabula-calculator.xls>	Excel workbook "tabula-calculator.xls", extract from the master file "TABULA.xls" http://www.building-typology.eu/downloads/public/calc/tabula-calculator.xls
<WebTool>	Building Typology WebTool / Standard Version http://webtool.building-typology.eu/
<WebToolExpertVersion>	Expert version of the TABULA WebTool; gives access to the underlying data http://webtool.building-typology.eu/

Impressum

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published by:

IWU — **Institut Wohnen und Umwelt**
Annastraße 15
D-64285 Darmstadt
Germany

October 2012

Contract N°: Contract N°: IEE/08/495

Coordinator: IWU Institut Wohnen und Umwelt GmbH Darmstadt / Germany – www.iwu.de

Project duration: June 2009 … May 2012

TABULA Project Partners

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