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Energy saving potential by retrofitting residential buildings in Europe

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The national *building typologies* can be used as data sources for forecasting and evaluating the energy saving potential and the carbon dioxide emission reductions for each European country. Thereby the main objective of the IEE TABULA project has been to create a harmonized structure of the European building typologies and to identify representative building types. Two levels of building retrofit have been considered: a *standard refurbishment*, applying measures which are commonly used in the country; an *advanced refurbishment*, applying measures which reflect the best available technologies. The evaluation of each reference building type has been performed in each country by using the national EPBD asset rating method and by showing the energy performance before and after the refurbishment. Statistical information of construction methods and of heating systems has made possible the use of the reference building types as models for the assessment of the energy performance of the whole national building stock.

The present paper reports the first outcomes of the application of the above described methodology to the national residential building stocks of four countries representative of the North, Middle, South and East European Countries. It summarizes the results presented in the TABULA report "*Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock*".

Introduction

Building typologies developed during the TABULA project can be exploited as a basis for analysing the national housing sector. Specifically, as shown in **Figure 1**, starting from global statistics at national and regional level and from the corresponding available residential building samples divided in classes, some reference building types have been selected in order to obtain a relevant characterization of the analyzed buildings. They have been chosen as representative of a large portion of the national residential building stock. Different modelling approaches were chosen by the partners depending on the available statistical data. Some defined a set of synthetic buildings reflecting building stock averages; others applied a set of generic example buildings from the national TABULA typologies.

For each reference building type two refurbishment measures have been considered: a *standard refurbishment* through the application of measures commonly applied within the country; an *advanced refurbishment* through the introduction of measures that reflect the use of the best available technologies. Finally additional information about the number and the frequency of each specific building type has made possible the application of statistical models in order to estimate the overall energy performance, energy saving potentialities, carbon dioxide emissions reductions of the building stock at national/regional level.

This paper shows the first outcomes of the application of the above described Energy Balance Method at the national residential building stock of four countries:

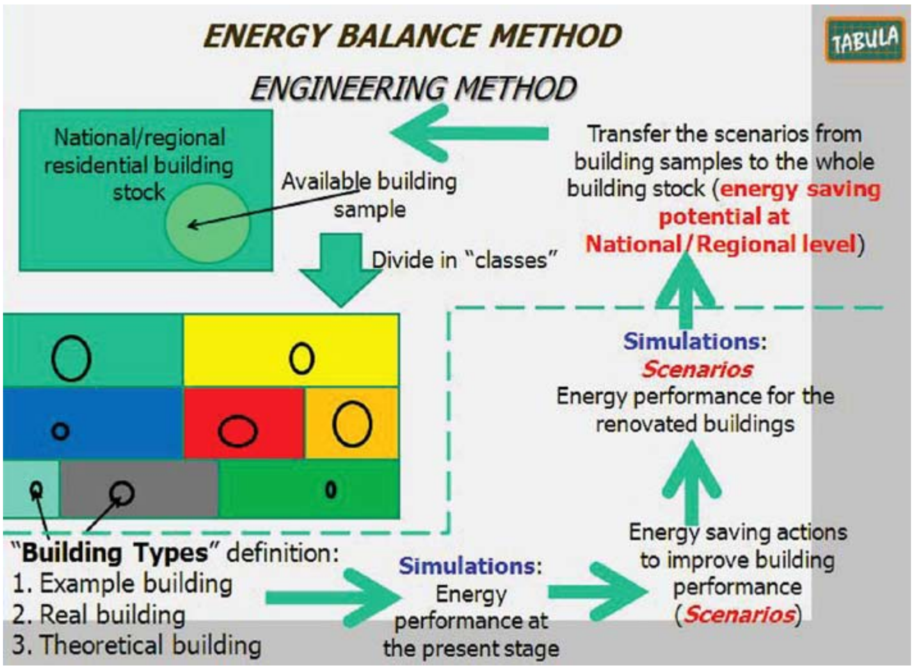


Figure 1. Procedure for Energy Balance Method used in the TABULA project to predict the potential impact of energy efficiency measures on national housing sector.

- Denmark, as a representative of the North European countries;
- Germany, as a representative of the Middle European countries;
- Italy, as a representative of the South European countries;
- Czech Republic, as a representative of the East European countries.

The data presented in this paper have been extrapolated from the TABULA report "Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock" and from the "National Scientific Report" on the TABULA project of the four analysed countries.

Denmark

The energy balance of the Danish residential buildings was calculated using synthetical average buildings. These were split within nine different construction periods and three building types (single family houses SFH, terraced houses TH, block of flats AB).

In order to estimate energy saving potentials the national Energy Balance method was used.

Refurbishment measures were applied only to the envelope and consisted in two different levels of thermal insulation: details about retrofit actions are reported on the full length version of this paper on the web site. Consequently, the energy saving potential was calculated only in term of net energy demand for heating and DHW. The results of the analysis are presented in term of energy saving and CO_2 emission reduction in **Table 1**.

Germany

The analysis of the German building stock was conducted on a set of six synthetical average buildings. Two building size classes (single family houses with one or two dwellings and multifamily houses with three or more dwellings) and three construction periods according to different levels of energy saving national regulations were considered (see full length version of this paper on the web site).

The energy balance model was developed on basis of the available statistical input data. The energy demand for space heating of the considered six building types was calculated according to a seasonal energy balance approach. In this way an estimation of energy saving potentials in the German building stock for heating and hot water supply was carried out. Details about retrofit actions are reported on the full length version of this paper on the web site.

Energy saving potential obtained by retrofitting the German residential building stock is reported in **Table 2**.

Table 1. Annual energy saving potential (in terms of net energy demand for space heating and DHW) and CO_2 emissions reductions by standard and advanced refurbishment of Danish residential building stock.

Reference building type	Original State		Standard Refurbishment			Advanced Refurbishment		
	$Q_{H,W,p}$	t_{CO2}	$\Delta Q_{H,W,p}$	Δ% savings	Δt_{CO2}	$\Delta Q_{H,W,p}$	Δ% savings	Δt_{CO2}
	[10^3GWh]	[10^6t]	[10^3GWh]	[-]	[10^6t]	[10^3GWh]	[-]	[10^6t]
SFH and TH	31.5	---	14.6	-46%	---	15.6	-50%	---
AB	12.1	---	5.3	-44%	---	5.9	-49%	---
	43.6	---	19.9	-46%	3.1	21.5	-49%	3.4

Table 2. Annual energy saving potential (in terms of primary energy for space heating and DHW) and CO_2 emissions reductions by standard and advanced refurbishment of German residential building stock.

Original State		Standard Refurbishment			Advanced Refurbishment		
$Q_{H,W,p}$	t_{CO2}	$\Delta Q_{H,W,p}$	Δ% savings	Δt_{CO2}	$\Delta Q_{H,W,p}$	Δ% savings	Δt_{CO2}
[10^3GWh]	[10^6t]	[10^3GWh]	[-]	[10^6t]	[10^3GWh]	[-]	[10^6t]
661	136	304	-46%	63	512	-77%	100

Table 3. Annual energy saving potentialities (in terms of primary energy for space heating and DHW) and CO_2 emissions reductions by standard and advanced refurbishment for Italian residential building stock.

Reference building type	Original State		Standard Refurbishment			Advanced Refurbishment		
	$Q_{H,W,p}$	t_{CO2}	$\Delta Q_{H,W,p}$	Δ% savings	Δt_{CO2}	$\Delta Q_{H,W,p}$	Δ% savings	Δt_{CO2}
	[10^3GWh]	[10^6t]	[10^3GWh]	[-]	[10^6t]	[10^3GWh]	[-]	[10^6t]
SFH (until 1900)	50.6	10.3	38.8	-77%	7.9	42.8	-85%	8.7
SFH (1921-1945)	22.1	4.5	17.8	-81%	3.6	19.4	-88%	3.9
MFH (1946-1960)	127.2	25.8	98.2	-77%	19.9	105.5	-83%	21.4
AB (1961-1975)	419.5	85.2	301.2	-72%	61.2	349.9	-83%	71
AB (1976-1990)	364.3	74	204.4	-56%	41.5	255.4	-70%	51.9
AB (1991-2005)	76.6	15.6	32	-42%	6.5	42.3	-65%	8.6
	1060.5	215.3	692.5	-65%	140.6	815.4	-77%	165.5

Table 4. Annual energy saving potentialities (in terms of primary energy for space heating and DHW) and CO_2 emissions reductions by standard and advanced refurbishment for Czech Republic residential building stock.

Reference building type	Original State		Refurbishment		
	$Q_{H,W,p}$	t_{CO2}	$\Delta Q_{H,W,p}$	Δ% savings	Δt_{CO2}
	[10^3GWh]	[10^6t]	[10^3GWh]	[-]	[10^6t]
SFH (until 1979)	11.9	5.5	7.7	-65%	3.6
SFH (1980-2001)	12.7	5.9	4.8	-38%	2.2
SFH (2002-2010)	5.5	2.6	1.1	-20%	0.5
APT (until 1979)	6.1	2.9	3.2	-52%	1.5
APT (1980-2001)	15.2	6.5	5.3	-35%	2.3
APT (2002-2010)	5.4	2.6	1	-19%	0.5
	56.8	26	23.1	-41%	10.6

Italy

In Italy, six reference building types were created to represent the housing stock for the purpose of Energy Balance analysis (single family house SFH, multi-family house MFH, apartment block AB; see full length version of this paper on the web site).

These reference buildings were chosen according to statistical analysis: they are representative of a suitable significant portion of the entire national building stock considering both the construction age and the building size (i.e. number of apartments, floor area) and they belong to the "Middle Climatic Zone" (from 2100 to 3000 heating degree days), which is the most representative of the Italian climate (about 4250 municipalities on a total number of 8100).

The official national calculation method (Technical Specification UNI/TS 11300 - National Annex to CEN Standards) for energy certificates was applied for the evaluation of the energy demand of the selected reference buildings and to assess the energy saving potential due to energy retrofit actions according to two different scenarios (standard and advanced refurbishment). Details about retrofit actions are reported on the full length version of this paper on the web site.

Energy saving potentialities obtained applying the mentioned retrofit measures at the Italian residential building stock are reported in **Table 3**.

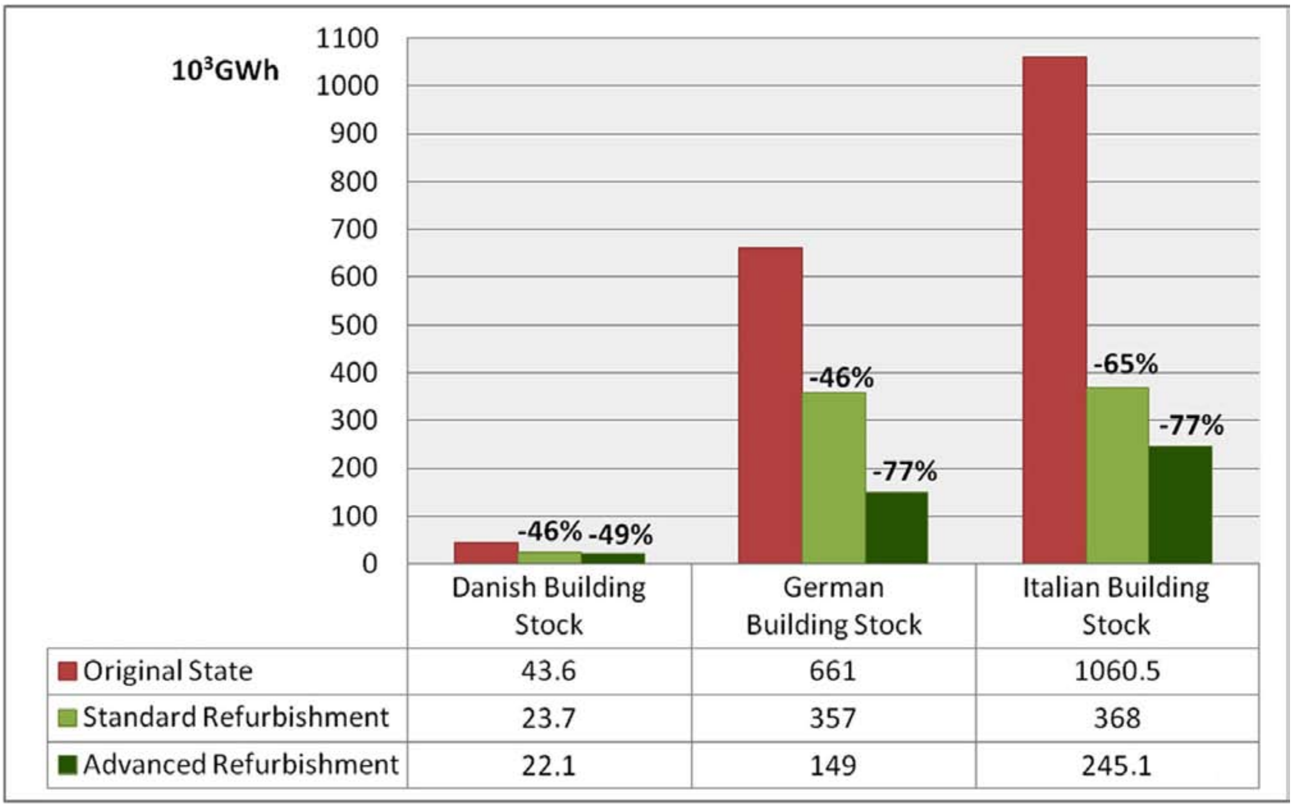
Czech Republic

Six reference building types were created to represent the Czech Republic housing stock for the purpose of Energy Balance analysis. This set of buildings was categorized by size (single family house SFH, multi-family house and apartment block APT) and age (see full length version of this paper on the web site).

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

The energy balance model was created on basis of the statistical data. The delivered energy and the energy demand for space heating of the considered six groups of buildings was calculated using national calculation method.

In this case the refurbishment measures were fixed on the basis of recent studies. Details about retrofit actions are reported on the full length version of this paper on the web site. The results of the analyses are shown in **Table 4**.



	Danish Building Stock	German Building Stock	Italian Building Stock
Original State	43.6	661	1060.5
Standard Refurbishment	23.7	357	368
Advanced Refurbishment	22.1	149	245.1

Figure 2. Comparison between annual energy saving potential by applying a standard refurbishment and an advanced one to the Danish, German and Italian building stock.

Conclusion

The analysis shows that building typologies can be a helpful tool for modelling the energy consumption of national building stocks and for carrying out scenario analyses beyond the TABULA project. The consideration of a set of representative buildings, which reflect the current state of the building national stock, makes it possible to have a detailed view on various packages of refurbishment measures for the complete buildings stock or for its sub-categories. The effects of different insulation measures at the respective construction elements as well as different system supply measures including renewable energies can be considered in detail with fast analysis.

As general rule, when two different level of retrofit were considered it is noted that the standard refurbishment is associated with high relative percentage of energy saving (**Figure 2**): the energy saving due to a standard refurbishment is bigger than the saving variation between a standard refurbishment and an advanced refurbishment. In fact, national building stock is often characterized by low energy performance and even the application of basic energy renovations may provide significant increases in energy performance and consequent reduction of CO_2 emission (the case of Italy is exemplificative of this trend). Thereby from an economic point of view it is more convenient to apply standard refurbishment measures at the national building stock than advanced ones that are the most expensive.

It was highlighted that, even with standard refurbishments, energy saving over 45% can be achieved. As a consequence of this big saving potential, suitable policies to address energy retrofit actions of existing buildings are crucial.

Finally, the quality of future model calculations will depend very much on the availability of statistical data. For reliable scenario analyses, information about the current state of the building stock and about the current trends is needed. The availability and regular update of the relevant statistical data will be an important basis for the development of energy strategies in the building sector.