TABULA

Typology Approach for Building Stock Energy Assessment
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1 Introduction

1.1 Objectives of the TABULA project

The TABULA project focused on the creation and applicability of European building typologies with emphasis on the residential sector. The overall objective of the project was to enable an understanding of the structure and modernisation processes of the building sector in different European countries and share experiences on successful energy saving strategies.

The term “building typology” in TABULA describes a classification of buildings according to some specific characteristics which are related to the building energy performance. The energy consumption in buildings depends on a number of factors among which the envelope construction, age distribution of the existing building stock, outdoor weather conditions, size of buildings, type, age and efficiency of equipment. The year of building construction provides useful insight information with regard to the type of envelope construction, in accordance to the national building standards in force at that time. In particular, this is related to the use of thermal insulation and materials used for the building envelope or even the type of electromechanical installations.

In order to overcome the restrictions in the generalisation of the typology concept imposed by the diversity of construction trends in the various European countries, a harmonised structure was set up and used for the creation of the national typologies, facilitating a cross country comparison of building stocks. Based on the TABULA harmonised structure, a total of 13 national building typologies were created, each representing the corresponding residential building stock. Each national typology consists of different building types with energy related characteristics that are representative of the corresponding country, classified on the basis of two critical parameters, i.e. age and size. This classification results in a group of building categories (“classes”) corresponding to distinct, nationally defined construction periods and up to four general building sizes in the national residential building stock, namely: single family house, terraced house, multi-family house and apartment block. The building size categories were carefully selected to cover the diversity of building structures in the participating countries in a representative, yet not too detailed manner. Each national typology is supplemented by two sub-typologies describing the most common building construction types and system installations in the participating countries, namely, the “building elements” and the “systems” sub-typology. The first one includes descriptions of building construction types (walls, roofs, floors, windows) and their respective heat loss coefficients before and after refurbishment (U-values for opaque and transparent elements) and g-values for glazing. The second one includes descriptions of heat generation, storage and distribution system types for space heating and domestic hot water (DHW) production along with the respective expenditure coefficients for the generation systems and the average heat loss for the distribution systems. Additional information about the frequencies of building element and system types in the residential building stock make it possible to use the typology as a model for estimating the share of the residential building sector in the national energy balance and assess the saving potential of partial or general application of well targeted energy conservation strategies.

TABULA project focuses on the energy consumption for space heating and hot water production, which constitute the main energy consuming end-uses in the residential sector. The harmonized structure supports energy performance calculations for the typical buildings, including heating energy demand, primary energy and CO_2 emissions as well as energy consumption per energy carrier. The energy demand for space heating is calculated by applying the seasonal method according to EN ISO 13790 on the basis of a one-zone model. The external boundary conditions (air temperature, external temperature / solar radiation) are defined on a national basis for a standard base temperature. In case of significant climatic differences between regions of a country several climate datasets are provided. Standard values are used for the utilisation conditions (room temperature, air exchange rate, internal heat sources) as well as for the solar radiation reduction factors (shading).

The structure and features of a national building typology can be displayed in two ways:

- “Building Matrix” providing an overview of all building types according to the classification.
- “Single Building Overview” for each building type providing information on the thermal properties of the envelope and the installed heating system along with an assessment of energy savings from the application of suitable ECMs.

The main result of the project is a webtool designed to offer experts from all European countries the possibility to use the TABULA data to make an assessment of national building stocks, perform cross-country comparisons or even scenario calculations for energy saving policies, programmes or projects. It will also serve as a demonstration tool providing on-line calculations for each typical building to show the possible energy savings achieved by standard and ambitious refurbishment scenarios.

1.2 Status of introduction of energy performance certificates in Greece

EPBD transposition was enacted in Greece by the national law N.3661/2008 on “Measures for the reduction of energy consumption in buildings and other provisions” that was published in May 2008 (FEK 89/A 19.5.2008). The law is basically a translation of EPBD, providing the general framework, with all major provisions mandated by the directive. Two years later, the “Regulation on Energy Performance in the Building Sector – KENAK” was issued by the Ministry of Environment, Energy and Climatic Change (YPEKA) by a Ministerial Decision MD6/B/5825 (FEK 407/B/9.4.2010). KENAK outlines the general calculation method in compliance with the European standards and EN ISO 13790 (2008) and overall approach towards issuing an energy performance certificate (EPC). It is supplemented by four technical guidelines (TOTEE 20701-4/2010) that were developed by the Technical Chamber of Greece (TEE) and approved by YPEKA (MD 17178 FEK 1387/B/2.9.2010).

Transposition of the European Directive 2006/32/EC took effect in June 2010 by the national law N.3855/2010 (FEK 95/A 23.6.2010), introducing various energy efficiency improvement measures, energy service companies (ESCOs) and third party financing (TPF) arrangements, in order to achieve by 2016 an overall national indicative target of 9% energy conservation.

Several revisions have been integrated in satellite legislative efforts and are directly related to the contents of N.3661/2008. The national law on RES (N.3851/2010) extends the obligation to perform an energy design study to all new buildings, regardless of their size, and allows audits in individual units (properties) of a building (e.g. an apartment). The national law N.3889/2010 on the Green Fund (FEK 182/A/14.10.2010) mandates that residences with an annual use of less than four months (e.g. summer residences) should also comply with N.3661/2008.

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

1.3 The TABULA project in Greece

The aim of the TABULA project in Greece was to elaborate and improve the existing knowledge on the Hellenic building stock, providing a powerful means for the assessment of the energy performance of individual buildings, groups of buildings and even for the evaluation of the impact of energy conservation scenarios on the entire residential building stock. Accordingly, the main objectives of the Hellenic TABULA project were to:

- Contribute to the development of and provide input for the TABULA harmonized structure
- Create the Hellenic residential building typology in line with the TABULA harmonised structure and feed it with up-to-date input data on buildings, structures and electromechanical (E/M) systems
- Use the typology for the assessment of the energy performance of residential buildings and for the evaluation of the impact of energy conservation measures (ECMs)
- Use the typology concept to create a model for the estimation of the national energy balance of the Hellenic residential building stock
- Investigate the possibility of extending the typology concept to non-residential buildings.

The work and outcome of the TABULA project is addressed to:

- architects, engineers and consultants

Energy advisors can use it in counselling sessions to give their clients a quick overview of the energy performance of a building similar to their own and demonstrate the effect of possible measures. Energy consultants may use it as a set of example buildings for demonstrating and testing their software.

- building owners / building’s technical and maintenance staff

House owners may use it on their own to assess the energy performance of their buildings as well as the cost effectiveness of measures to improve it.

- national and international energy and policy experts

On a national level, the building typology can be used as a model for imaging the energy consumption of the residential building stock.

2 The TABULA typology for the Hellenic Residential Buildings

2.1 Hellenic Building types

The first Hellenic Building Thermal Insulation Regulation (HBTIR) (OHJ 362/4-7-79) took effect in 1980 setting the minimum requirements for thermal conductivity of the building envelope for different climatic zones. Buildings constructed before 1980 (pre-1980) correspond to 75% of the total building stock. During the first decade of the HBTIR implementation (1980s), the majority of buildings were not properly insulated and only recently new buildings have thermal insulation on the load bearing structure. Consequently, the great majority of the Hellenic building stock is not thermally insulated, despite the fact that the heating degree days (HDDs) in the northern parts of the country range over 2600 HDD due to the severe cold and rainy weather conditions affecting Greece during the cold period of the year between late October and early April [1]. As discussed in section 1.2, EPBD transposition was enacted by the national law N.3661/2008 that was published in May 2008 and HBTIR was replaced by the new "Regulation on the Energy Assessment of Buildings – KENAK" in April 2010. KENAK outlines the general calculation approach in accordance to European standards, the use of a reference building for benchmarking, the requirements for EPCs based on an asset rating accounting for heating, cooling, ventilation, sanitary hot water and lighting, the minimum energy performance requirements and thermal envelope heat loss constraints.

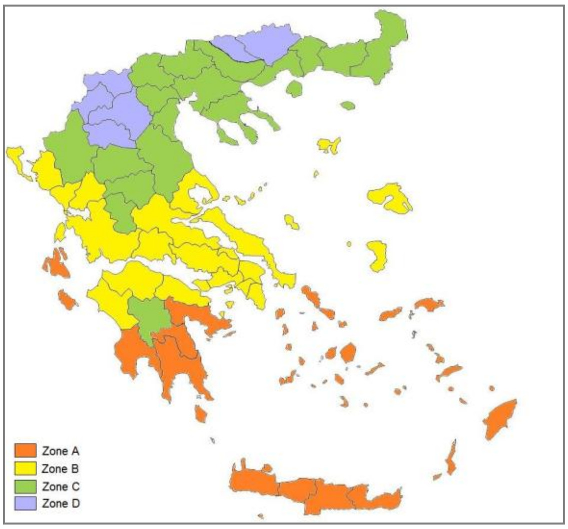
According to the records of the Hellenic National Statistical Service, residential buildings account for about 75% of the total building stock. The great majority of buildings have been constructed before 1980 and, therefore, they are either not thermally insulated or poorly insulated; over 60% of exterior walls and 80% of windows of the existing building stock do not meet current minimum code requirements [2]. Based on 1996 data [1], there has been some limited improvement, with 12% of households having cavity-wall insulation and 8% are double-glazed.

The harmonised structure developed within the TABULA project was used in order to derive a typology for the Hellenic residential building sector. The classification of buildings was based on three main parameters: the building age, size and climatic zone. According to the year of building construction three categories were defined:

- Buildings constructed before 1980 (pre-1980), which is considered the border line for buildings without thermal insulation since they were constructed before the implementation of the national thermal insulation regulation.
- Buildings constructed during the period 1981–2000, which are considered to be partially or fully insulated. Despite the introduction of the HBTIR since 1980, the integration of thermal insulation was problematic during the first decade of its implementation. For example, only recently the new buildings have thermal insulation on the load bearing structure to eliminate thermal bridges. Ordinary double glazing is also common practice in all new buildings and the most frequent refurbishment activity in existing buildings.
- Buildings constructed after the year 2000.

As mentioned above, the harmonized TABULA structure allows for input in four size related building categories. According to the building size, two more categories were defined: single family houses-SFH (low-rise buildings with one or two floors) and multifamily houses-MFH.

The climate plays an important role in the typical building construction techniques of a region. Climatic variability in Greece affects the regional construction trends regarding the energy performance of buildings. The energy-related characteristics of buildings differ according to the prevailing conditions in their geographic location, which has a significant impact on the relative effectiveness of ECMs.



The new regulation on the energy performance assessment of buildings (KENAK), defines four climatic zones on the basis of the heating degree days, namely: Zone A (601–1100 HDD), Zone B (1101–1600 HDD), Zone C (1601–2200 HDD) and Zone D (2201–2620 HDD).

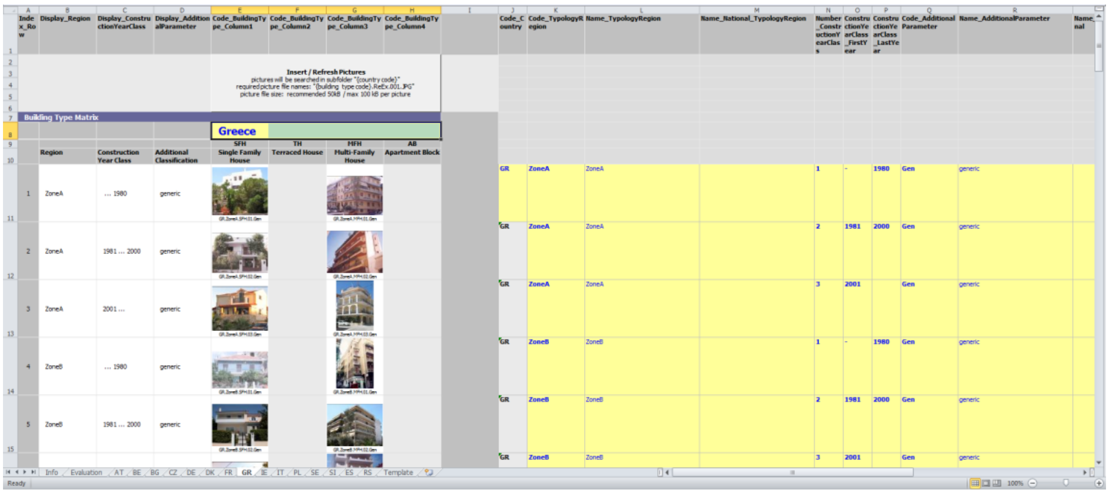
Table 2.1 summarizes the different classification parameters that were used for the creation of the Hellenic residential building typology. The Hellenic typology consists of **24 building classes**, resulting from the combination of the classification parameters (2 sizes X 3 construction periods X 4 climatic zones). Each class was assigned an **example building**, carefully selected to be representative of all buildings that belong to the particular class.

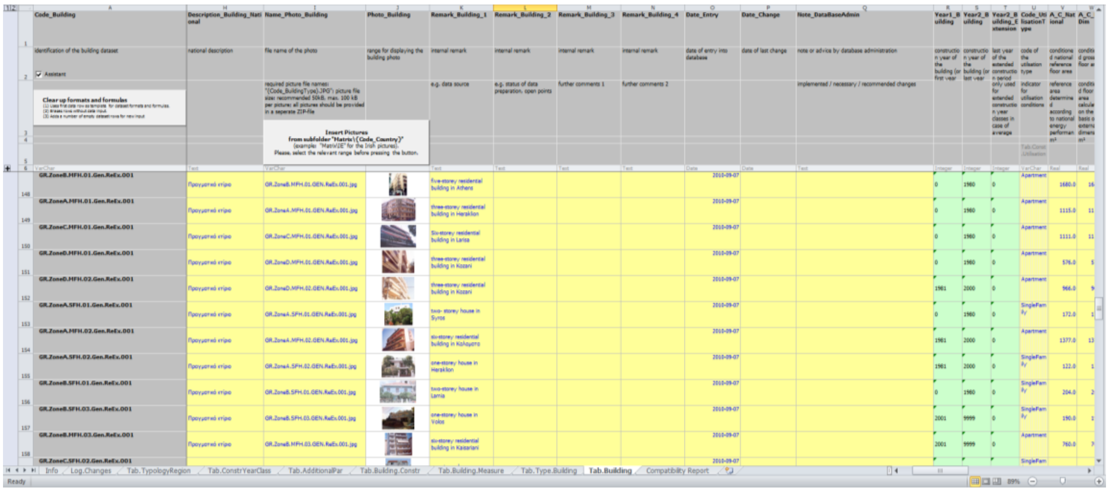
Table 2.1: Classification parameters

Size	2 sizes	Single Family Houses (*) – Multi Family Houses
Year of construction	3 periods	1: pre 1980 2: 1980-2000 3: 2001-2010
Climatic zone	4 climatic zones	A, B, C, D (according to KENAK)

(*) low rise, one or two floors

The available information for the 24 example buildings along with all relevant data were incorporated in the TABULA matrix, as the national database.





The thermal characteristics of the envelope, as well as the performance coefficients of the heating systems installed in the example buildings of the Hellenic typology, are summarized in Table 2.2 together with the corresponding minimum requirements imposed by the national regulation (KENAK).

Supplementary sub-typologies regarding building elements and systems were prepared in accordance to the construction and system installation trends in the Hellenic residential building sector throughout the three age classes.

Table 2.2: Energy related characteristics of the envelope and installed systems of the buildings used as real examples for the 24 classes of the Hellenic residential building typology.

SIZE CLASS	ZONE/ AGE	HEAT TRANSFER COEFFICIENTS OF BUILDING ELEMENTS (W/m^2K)						PERFORMANCE COEFFICIENTS OF HEATING INSTALLATIONS (-)			
		Walls	Load Bearing	Roof	Floor		Windows	Space Heating		DHW	
					On ground	Pilotis		Generation	Distribution	Generation	Distribution
SFH	A/1	0.95	3.40	3.10	2.00		3.10	0.80	0.86	1.00	1.00
	A/2	0.85	3.40	3.10		2.75	6.10	0.72	0.86	1.00	1.00
	A/3	0.59	0.67	0.70	3.10		4.10	0.84	0.94	0.80	0.98
	B/1	2.20	3.40	3.70	0.95		4.70	0.72	0.86	1.00	1.00
	B/2	0.60	3.40	0.70	3.70		4.10	0.80	0.94	0.80	0.98
	B/3	0.61	0.67	0.63		0.63	3.50	0.84	0.92	1.00	1.00
	C/1	2.20	3.40	0.63	3.10		4.10	0.75	0.86	1.00	1.00
	C/2	0.64	0.67	0.63 / 0.69		0.63	3.60	0.84	0.89	1.00	1.00
	C/3	0.59	0.67	0.69	3.10		3.20	0.84	0.94	1.00	1.00
	D/1	2.2 /0.59	3.40	0.78		2.75	6.00	0.90	1.00	1.00	1.00
	D/2	0.59	3.40	0.63		0.63	4.10	0.84	0.89	1.00	1.00
	D/3	0.59	0.67	0.69	0.65		3.70	0.84	0.94	1.00	1.00
MFH	A/1	2.20	3.40	3.10	3.10		4.70	0.80	0.93	1.00	1.00
	A/2	2.51	3.40	3.10	3.10		6.10	0.72	0.88	1.00	1.00
	A/3	0.59	0.67	0.63		0.90	4.10	0.84	0.95	1.00	1.00
	B/1	2.20	3.40	3.10	3.60		5.00	0.72	0.88	1.00	1.00
	B/2	2.20	3.40	3.10		2.75	6.10	0.80	0.88	1.00	1.00
	B/3	0.64	0.67	0.63		0.63	3.20	0.84	0.94	1.00	1.00
	C/1	2.20	3.40	3.10	3.10		5.00	0.71	0.90	1.00	1.00
	C/2	2.51	3.40	3.10		2.75	6.00	0.84	0.89	1.00	1.00
	C/3	0.59	0.67	0.63		0.63	4.10	0.84	0.94	1.00	1.00
	D/1	2.20	3.40	3.10	3.10		3.20	0.95	0.86	1.00	1.00
	D/2	2.20	3.40	3.10	2.00		4.10	0.95	0.86	1.00	1.00
	D/3	0.59	0.67	0.63		0.63	3.20	0.84	0.94	1.00	1.00
SFH MFH	MINIMUM REQUIREMENTS BY NATIONAL REGULATION (KENAK)										
	A	0.60	0.60	0.50	1.20	0.50	3.20	0.92-0.94	0.92-0.98	0.92-0.94 (boiler)	0.87-0.93 (central distribution)
	B	0.50	0.50	0.45	0.90	0.45	3.00				
	C	0.45	0.45	0.40	0.75	0.40	2.80				
	D	0.40	0.40	0.35	0.70	0.35	2.60				

2.2 "Building Element" sub-typology

The Hellenic "building element" sub-typology consists of **107 types** of roof, floor, wall and window elements reflecting the most common construction types in the residential building stock. For each element type, the thermal transmission coefficient (U-value) is specified along with the corresponding period of application to the residential building sector. The U-values of the opaque elements are specified for three levels of thermal insulation (no insulation, partial and full) in accordance to the national technical guideline (TOTEE-20701-1/2010). Tables 2.3 and 2.4 summarize the contents of the building element sub-typology.

Table 2.3: Building element sub-typology – opaque element types. U-values (W/m²K) for three levels of insulation degree.

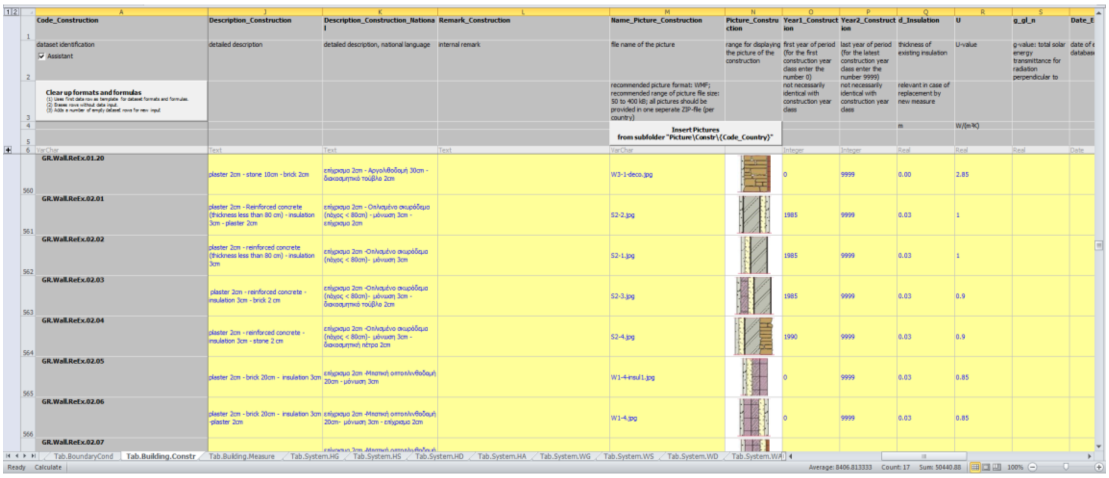
WALLS	**None**	**3 cm**	**5 cm**
Brickwork 10cm - Unplastered on one or both sides	3.25	0.95	0.65
Brickwork 10cm - Plastered on both sides	3.05	0.95	0.64
Brickwork 10cm - With brick finishing	2.50	0.85	0.61
Brickwork 10cm - With stone finishing	2.80	0.90	0.63
Double Brickwork 10cm - Unplastered on one or both sides	2.30	0.85	0.60
Double Brickwork 10cm - Plastered on both sides	2.20	0.85	0.59
Double Brickwork 10cm - With brick finishing	1.90	0.80	0.57
Double Brickwork 10cm - With stone finishing	2.10	0.80	0.59
Double Brickwork 10cm with slightly ventilated air layer	2.51	0.85	0.61
Brickwork 20cm - Unplastered on one or both sides	2.30	0.85	0.60
Brickwork 20cm - Plastered on both sides	2.20	0.85	0.59
Brickwork 20cm - With brick finishing	1.90	0.80	0.57
Brickwork 20cm - With stone finishing	2.10	0.80	0.59
Stone wall 30cm - Unplastered on one or both sides	4.25	1.05	0.68
Stone wall 30cm - Plastered on both sides	3.85	1.00	0.67
Stone wall 30cm - With brick finishing	2.85	0.90	0.63
LOAD BEARING STRUCTURE	**None**	**3 cm**	**5 cm**
Reinforced concrete - Unplastered on one or both sides	3.65	1.00	0.67
Reinforced concrete - Plastered on both sides	3.40	1.00	0.66
Reinforced concrete - With brick finishing	2.45	0.90	0.61
Reinforced concrete - With stone finishing	2.90	0.90	0.64
ROOFS	**None**	**3 cm**	**7 cm**
Conventional flat roof	3.05	0.95	0.50
Flat roof under not insulated pitched roof	3.70	1.00	0.50
Tilted reinforced concrete slab with ceramic tiles	4.70	1.05	0.50
Wooden beams with ceramic tiles	4.25	1.00	0.50
Green roof	1.20	0.70	0.49
FLOORS	**None**	**3 cm**	**5 cm**
Pilotis	2.75	0.90	0.63
Slab on grade	3.10	0.95	0.65
Slab over unheated space	2.00	0.80	0.58

Table 2.4: Building element sub-typology – transparent element types. U-values (W/m²K) and g-values (-)

WINDOWS	**U_value**	**g_value**
Single glazed, metal frame	6.1	0.58

Single glazed, wooden or synthetic frame	4.7	0.58
Double window, wooden frame	2.3	0.51
Double glazed (6mm), metal frame	4.5	0.51
Double glazed (6mm), metal frame, thermal break 12mm	3.5	0.51
Double glazed (6mm), metal frame, thermal break 24mm	3.3	0.51
Double glazed (6mm), synthetic frame	3.3	0.51
Double glazed (6mm), wooden frame	3.1	0.51
Double glazed (12mm), metal frame	4.1	0.51
Double glazed (12mm), metal frame, thermal break 12mm	3.2	0.51
Double glazed (12mm), metal frame, thermal break 24mm	3.0	0.51
Double glazed (12mm), synthetic frame	2.9	0.51
Double glazed (12mm), wooden frame	2.8	0.51
Double glazed (6mm) low -e, metal frame	4.0	0.45
Double glazed (6mm) low -e, metal frame, thermal break 12mm	3.1	0.45
Double glazed (6mm) low -e, metal frame, thermal break 24mm	2.9	0.45
Double glazed (6mm) low -e, synthetic frame	2.9	0.45
Double glazed (6mm) low -e, wooden frame	2.6	0.45
Double glazed (12mm) low -e, metal frame	3.5	0.45
Double glazed (12mm) low -e, metal frame, thermal break 12mm	2.7	0.45
Double glazed (12mm) low -e, metal frame, thermal break 24mm	2.4	0.45
Double glazed (12mm) low -e, synthetic frame	2.3	0.45
Double glazed (12mm) low -e, wooden frame	2.1	0.45

The available information for the 107 building elements was processed and the corresponding data along with the supporting pictures were incorporated in the TABULA matrix, as the national database.



2.3 “System” sub-typology

The Hellenic system sub-typology consists of generation and distribution systems as well as auxiliary systems for space and DHW heating. Expenditure coefficients are specified for a total of **67 heat generation systems for space heating** and **50 for DHW production**. The heat generation systems include boilers (condensing/non condensing, constant/low temperature), heat pumps, electric heaters, stoves, district heating and cogeneration systems. Boilers are differentiated according to the type of fuel (oil/natural gas), maintenance level and insulation degree. Heat losses (kWh/m^2

reference area) are specified for **32 space heating** and **25 DHW heat distribution systems**. Typical values of auxiliary energy demand are supplied for the heating systems. For each of the above system the period of application to the residential building sector is also specified. Table 2.5 summarizes the average expenditure coefficients of the heat production systems of the system sub-typology. The tabulated average values are the result of grouping the systems in categories and using weighting factors to express the frequency of occurrence of each system in the three age bands. The weighting factors are best estimates derived in collaboration with experts participating in the National Advisory Group.

Table 2.5: "System" sub-typology: average expenditure coefficients per age band for space and DHW heating systems (based on High Calorific Value)

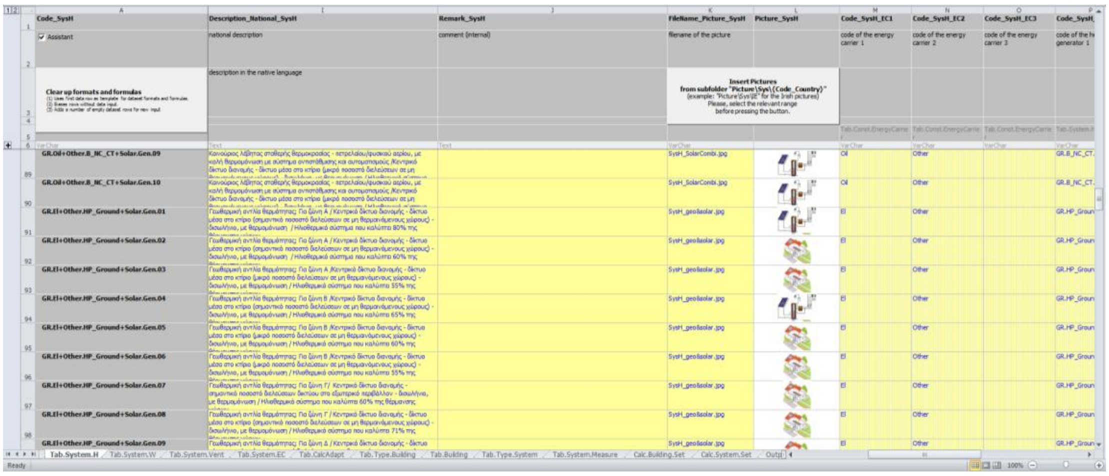
SPACE HEATING	**pre 1980**	**1981-2000**	**2001-2010**
Oil boiler, well maintained	0.79	0.83	0.86
Oil Boiler, poorly maintained	0.70	0.76	0.81
Natural gas boiler, well maintained		0.86	0.87
Natural gas boiler, poorly maintained		0.81	0.80
Stoves_gas/oil fuel	0.80	0.80	0.80
Open fire	0.20	0.20	0.35
District heating		0.88	0.88
Heat pumps	1.70	1.95	4.00
Electrical space heaters	0.98	0.98	0.98
DHW HEATING	**pre 1980**	**1981-2000**	**2001-2010**
Oil boiler, well maintained	0.83	0.82	0.86
Oil Boiler, poorly maintained/poorly insulated	0.66	0.76	0.79
Oil boiler, well maintained + electric immersion resistance	0.83	0.82	0.86
Oil boiler, poorly maintained + electric immersion resistance	0.66	0.76	0.79
Natural gas boiler, well maintained		0.86	0.87
Natural gas boiler, poorly maintained/poorly insulated		0.77	0.80
Instantaneous water heaters	0.95	0.98	0.98
Instantaneous water heaters fired by gas		0.80	0.83
Electric water heaters	0.95	0.97	0.97

Similarly, the average heat losses of the distribution system per age band are summarized in Table 2.6.

Table 2.6: "System" sub-typology: average heat losses per age band (kWh / m^2 reference area)

DISTRIBUTION LOSSES (kWh/m^2a)	**pre 1980**	**1981-2000**	**2001-2010**
Pipelines mainly in heated spaces (non/partly insulated)	5.8	3.7	3.7
Pipelines mainly in unheated spaces (non/partly insulated)	11	5.4	5.4
Pipelines well insulated	1.8	1.8	1.8

The available information, including the 67 heat generation systems for space heating and 50 for DHW production, along with the 32 space heating and 25 DHW distribution systems, were processed and the corresponding data along with the supporting pictures were incorporated in the TABULA matrix, as the national database.



3 Application of the typology concept in the Hellenic residential building sector

3.1 The Hellenic Energy Performance method: TEE-KENAK

The TEE-KENAK software[1] is the official national tool developed by NOA for the Technical Chamber of Greece (TEE) that is used for the energy performance assessment of buildings in Greece. Its calculation engine is based on the EPA-NR tool, which was developed within the framework of a European project (www.epa-nr.org). The tool was upgraded by NOA to meet national requirements and the final European standards, incorporating the relevant national technical guidelines prepared by TEE (TOTEE 20701-(1-4)/2010), the concept of the reference building for benchmarking, the relevant national technical libraries, weather data, user's guide etc. The TEE-KENAK software is used as a stand-alone tool for energy audits and benchmarking. It is also adapted by all commercial software companies that develop building design tools for engineers.

The energy performance assessment takes into account the following aspects, covering the most common uses in a building:

- Space heating
- Space cooling
- Ventilation
- Humidification
- Domestic hot water
- Electrical energy for
  - Lighting
  - Pumps and fans

Calculations of space heating / cooling demand and consumption are performed using the quasi-steady monthly method in line with to EN ISO 13790 (2009) [3]. For the calculations of DHW demand and consumption, the monthly method is used in line with EN 15316.03.01 (2008) [4], EN 15316.03.02 (2008)[5] and EN 15316.03.03 (2008) [6].

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

3.1.1 Assumptions and simplifications

Calculations for the heating / cooling and DHW demand are taking into account several assumptions in order to minimize the judgment of the software user. Typical values for residential buildings are summarized in Table 3.1.

[1] http://portal.tee.gr/portal/page/portal/SCIENTIFIC_WORK/GR_ENERGEIAS/kenak

Table 3.1: Assumptions and simplifications of the TEE-KENAK software for assessing the energy performance of residential buildings

Parameters	Default values
OPERATING TIME	18 hrs, 360 days / year
HEATING CALCULATIONS	
Heating period Climatic zones A, B Climatic zones C, D	 1/11 – 15/4 15/10 – 30/4
Set-point temperature, heating mode (^oC)	20
Relative Humidity, heating mode (%)	40
COOLING CALCULATIONS	
Cooling period Climatic zones A, B Climatic zones C, D	 15/5 – 15/9 1/6 – 31/8
Set-point temperature, cooling mode (^oC)	26
Relative Humidity, cooling mode (%)	45
VENTILATION	
Required fresh air [$m^3/h/m^2$]	0.75
Annual domestic hot water consumption (m^3/bedroom)	27.38
INTERNAL GAINS	
Internal heat gains from lights, W/m^2	0.64
Internal heat gains from persons, W/m^2	4
Internal heat gains from equipment, W/m^2	2
LIGHTING	
Lighting in the case of residential buildings is only considered as a fixed value and it only affects the energy demand without being included in the energy consumption breakdown report for the building.	0.1W/m^2 heated space
SHADING (internal / external movable)	NA
DHW	
Mean hot water temperature (^oC)	45

The infiltration load is added to the ventilation load and there is no compensation with fresh air due to natural ventilation. Typical values for windows, doors, chimneys and exhaust grilles are summarized in Table 3.2.

Table 3.2: Assumptions of typical values for infiltration rates in residential buildings.

INFILTRATION RATE ($m^3/h/m^2$ opening area)	Door	Window
Wooden frame, single pane	11,8	15,1
Wooden frame, double pane	9,8	12,5

Wooden frame, double pane with ISO	7,9	10,0
Metal or synthetic frame, single pane	7,4	8,7
Metal or synthetic frame, double pane	5,3	6,8
Metal or synthetic frame, double pane with ISO	4,8	6,2
INFILTRATION RATE (m³/h)		
Chimney	20	
Exhaust grilles	10	

3.2 Assessment of the energy performance of buildings

The energy performance of all 24 buildings included in the Hellenic typology was assessed using the TEE-KENAK software. Results are illustrated in Figure 3.1. Overall, the SFH present higher energy demand for space and DHW heating than MFH of the same age in the same climate zone. This could be attributed to the fact that the majority of SFH are free standing buildings, while the majority of MFH are more sheltered as one or two of their facades are in contact with neighbouring buildings. Comparing buildings of the same age class it is obvious that, as expected, the colder the climate the higher the energy demand regardless their size.

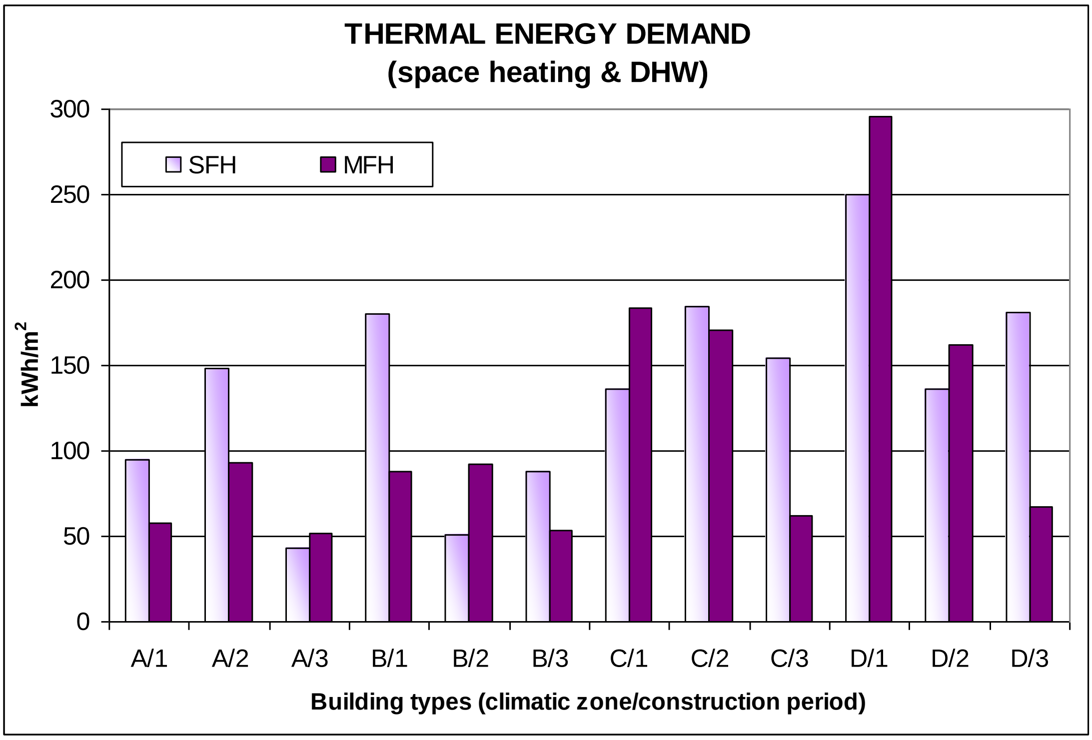


Figure 3.1: Calculated thermal energy demand for space and domestic water heating for Single Family Houses (SFH) and Multi Family Houses (MFH)

The corresponding energy demand data were normalized by multiplying with the ratio of the climate zone's HDD to the HDD of climate zone B (Figure 3.2). Accordingly, excluding the weather impact from the data, normalization reveals that the construction year class plays an important role as more recently constructed buildings (age class: 3) have better thermal insulation and, therefore, they exhibit lower energy demand.

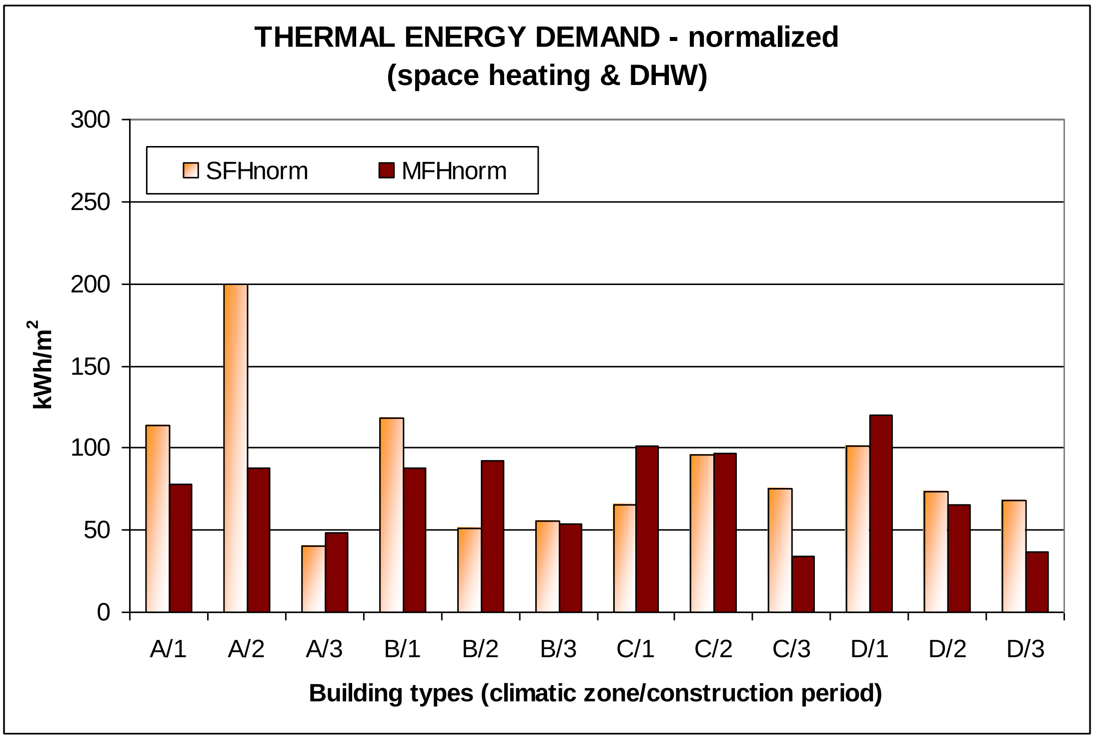


Figure 3.2: Normalized thermal energy demand for space and domestic water heating for Single Family Houses (SFHnorm) and Multi Family Houses (MFHnorm).

It is a fact that the majority of buildings before 1980 are non-insulated while most of the buildings of the period 1980-2000 are partly or insufficiently insulated. The load bearing structure is not insulated for the buildings before 2000. Buildings of the period after 2000 are mostly insulated according to HBTIR, the old Thermal Insulation Regulation of 1980, yet the standards imposed by the new regulation (KENAK) are stricter. Thus, there is room for improvement regarding the energy related characteristics of the envelope in all classes of the residential building stock, which is reflected by the selection of buildings in the Hellenic typology. In many cases, buildings of the first two construction year classes (built before 2000) have already undergone partial refurbishment in the course of time and therefore, their energy related features deviate from the standard characteristics of their construction period. Indeed the most common retrofit intervention in old buildings is the addition of roof insulation, the replacement of single glazing with double ones and the introduction of higher efficiency boilers.

Two levels of refurbishment scenarios were defined for each building type; standard and ambitious. As of October 2010, all new buildings and existing buildings that undergo major renovations must be at least class-B in order to obtain a building permit. Both scenarios include a combination of interventions on the building envelope and the installed systems. The “**Standard**” **scenario** includes interventions on each building component in order to comply with the minimum requirements of KENAK foreseen in the case of major renovation. In the case of buildings constructed after 2000, major renovation is rather unlikely; therefore, the standard scenario in this case includes a set of interventions upgrading the building to rate class B. Additionally, solar collectors are introduced to cover at least 70% of the DHW demand. The “**Ambitious**” **scenario** involves all the standard scenario interventions combined with an incorporation of high performance technologies such as geothermal heat pumps and advanced building components (e.g. use of low-e windows with thermal breaks instead of common double glazing). The solar collectors are sized to cover 100% of the DHW demand as well as part of the space heating demand ranging from 10% to 80% in some cases. The detailed contents of the "Standard" and "Advanced" interventions on each of the 24 typology buildings are summarized in Tables 3.3 and 3.4, respectively.

Figures 3.3 and 3.4 illustrate the impact of the two energy saving scenarios on the primary energy consumed by the Hellenic typology buildings for space and DHW heating along with the corresponding simple payback period (SPBP), estimated using fuel costs reported for the year 2010. As expected, in both cases, the highest energy savings are achieved for the buildings of the first age band that are older and have a poor initial energy performance. Interventions on these buildings exhibit the lowest SPBP. The lowest energy savings are achieved for buildings of the third age band, with energy related features close to the requirements of the new regulation. This fact combined with the high investment cost make these interventions less attractive for these buildings, as the corresponding estimated simple payback periods often exceed 20 years. Therefore, individual measures could prove more cost effective for this building category. The CO_2 emission reduction ranges from 17% to 80% for the Standard scenario and from 62% to 98% for the ambitious scenario.

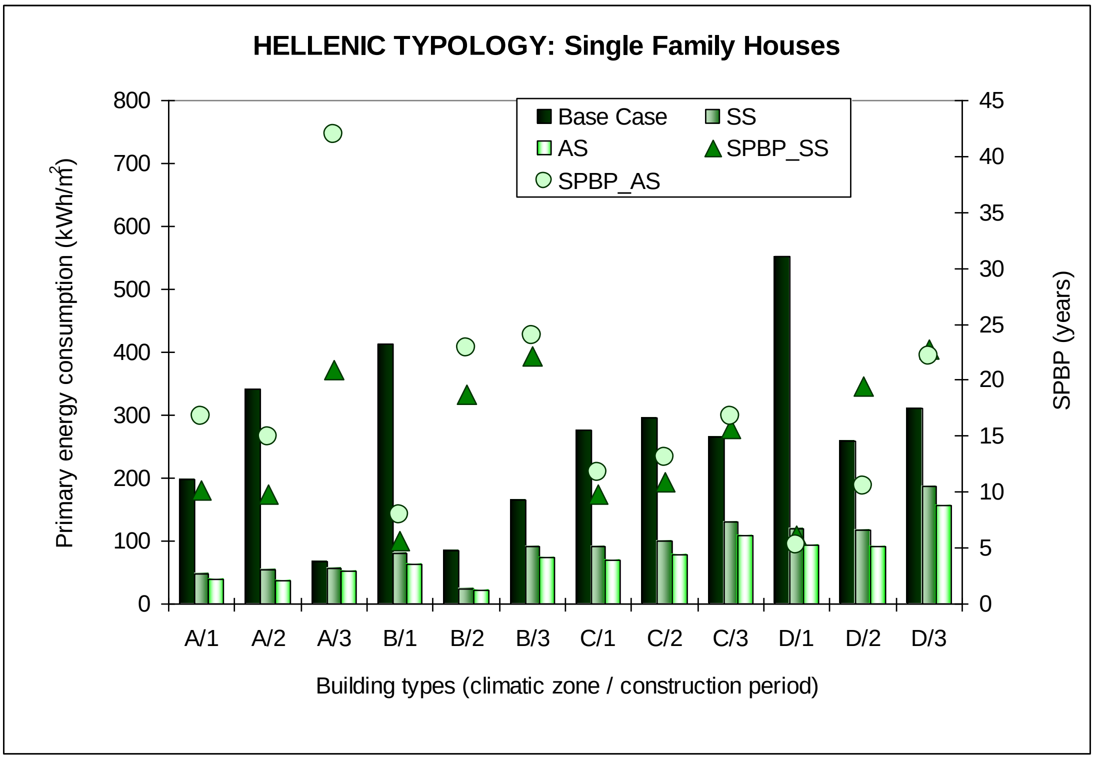


Figure 3.3: Impact of the Standard and Ambitious Scenarios on the Single Family Houses of the Hellenic typology.

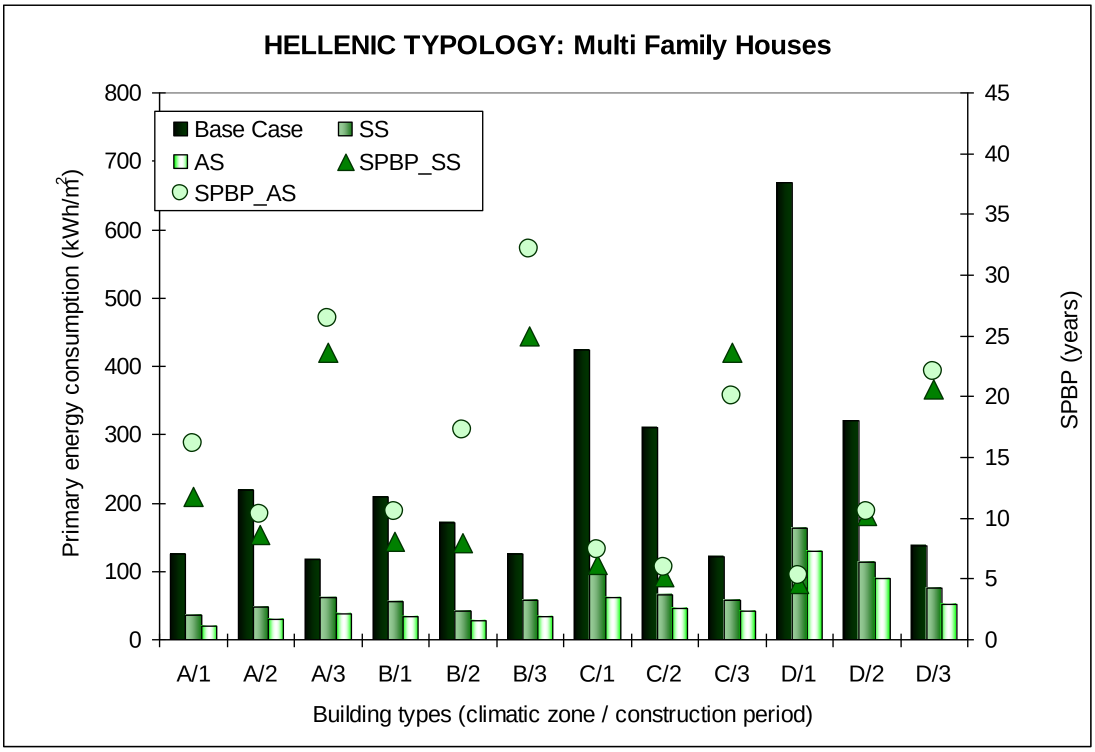


Figure 3.4: Impact of the Standard and Ambitious Scenarios on the Multi Family Houses of the Hellenic typology.

3.3 TABULA vs Hellenic Calculation Method (TEE-KENAK)

The TABULA calculation tool was used to assess the energy performance of all 24 buildings included in the Hellenic typology as well as the impact of the Standard and Ambitious scenarios on their performance. Results are illustrated in Figure 3.5 in comparison with the corresponding results from the Hellenic EPC using the official national software (TEE-KENAK). As illustrated, there are differences in the calculation results given by the two tools (TABULA and TEE-KENAK). These are attributed to the differences in the assumptions of each of the tools, which are summarized in Table 3.5. In order to overcome the problem of diversity in the national calculation methods that would not allow for a harmonized approach, the TABULA method has adopted constant values in some of the variables used in the calculation tool that apparently influence the results.

Table 3.5: Basic differences between TABULA calculation method and the Hellenic calculation method and software (TEE-KENAK).

	TABULA method	TEE-KENAK method
Climatic data	local weather data is calculated from average values for each of the four climatic zones	local weather data is available for different locations
Operational time	24 hours/day for all heating days	18 hours/day for the heating period
Floor area	heated floor area calculated using “internal” dimensions	heated floor area calculated using “external” dimensions
Orientation	four fixed orientations for transparent surfaces (E, S, W and N)	actual orientation of transparent surfaces
Thermal	adding a standard value in all	adding a standard value only in

bridges	elements of the building envelope	opaque elements of the building envelope
Infiltration	choice from four fixed values; too low for Hellenic buildings	input value, depending on the type and area of openings and the number of chimneys
Natural ventilation	fixed value in air changes per hour (ach)	fixed value calculated as a function of the floor area (in $m^3/h/m^2$ of floor area)
Losses to the ground	reduction of transmission losses to the ground by a factor of 0.5	estimation of a new U-value for the surface in contact to the ground, depending on the depth, the area and – in case of floor - the perimeter of the slab; reduction exceeds 50%
U-value and g-value of openings	average values for openings of specific type	different values depending on the frame factor
Indirect solar gains on opaque surfaces of building envelope	not taken into account	taken into account
Intermittent heating	not taken into account	taken into account
Terminal units	not taken into account	input the efficiency
Auxiliary systems for heating	fixed value depending on the floor area	different value for each building
Auxiliary systems for DHW	fixed value depending on the floor area	not taken into account
Controls	not taken into account	taken into account for different controls resulting in a reduction of the final energy consumption for heating
DHW demand	typical values for single family and multi-family units	values depending on the number of bedrooms

A very important issue to take into account when comparing the results is the input related to climate. TABULA uses average values per climatic zone, whereas TEE-KENAK uses national climatic data that are based on meteorological measurements in the locations of the buildings. Thus, higher differences between the two methods are observed in the cases where the local climate significantly deviates from the average climate of the respective climatic zone.

A striking difference is observed in the case of the SFH building D1. This is a non-insulated building in the coldest climatic region of Greece. The building is located in a city which exhibits an average temperature in winter 4°C higher than the corresponding zone average. Further investigation has revealed that the difference between the two methods is reduced when the actual climatic data of the building location are fed in to TABULA. Thus, the differences between the two methods that are attributed to the climate input are accentuated in the cases of non-insulated buildings, as they are more sensitive to the impact of the weather.

Figure 3.5 illustrates comparatively the energy demand of the Hellenic typology buildings as reported by TABULA and TEE-KENAK in kWh per m^2 heated floor area. In TABULA the floor area is input as measured in internal dimensions whereas in TEE-KENAK external dimensions are used. If TABULA results are corrected using the external dimensions for the heated floor area calculation (green bars in Fig.3.5), the differences from TEE-KENAK are reduced. In any case, TABULA predicts higher energy demand in 63% of the cases.

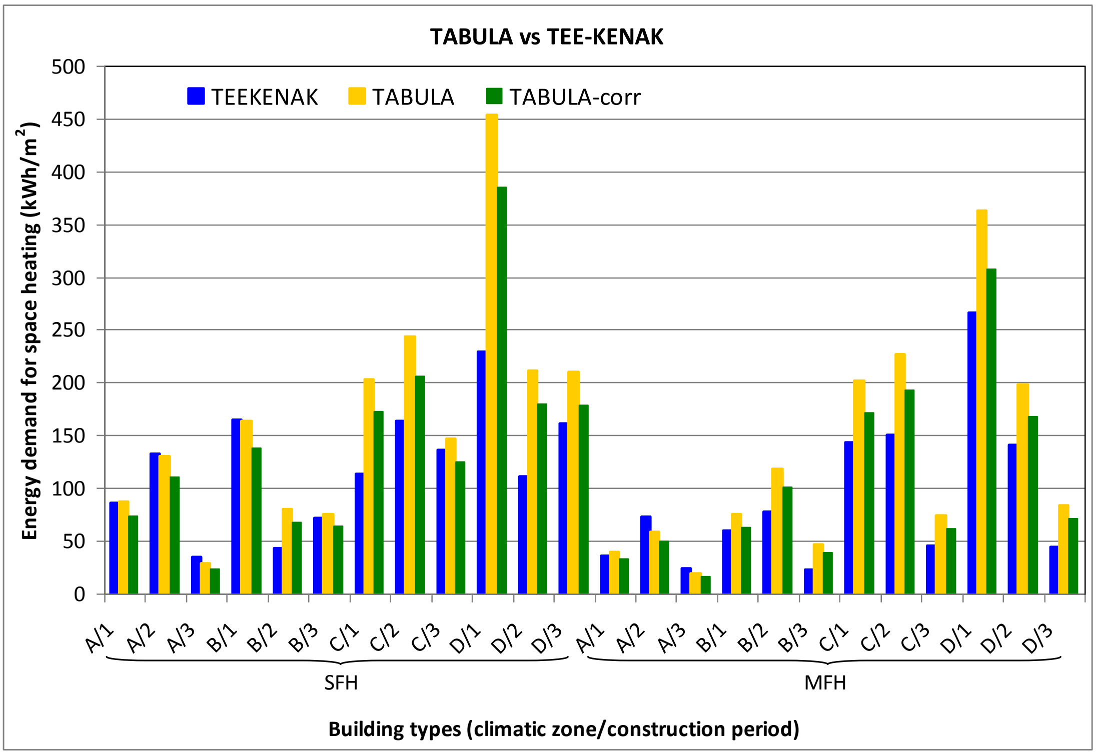
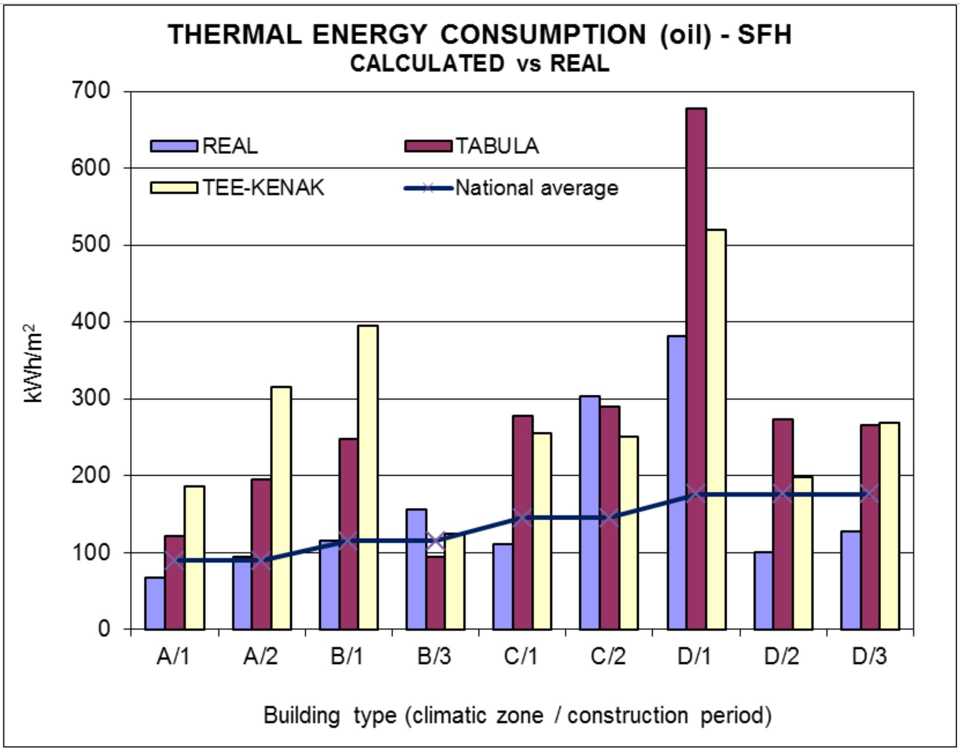


Figure 3.5: Comparison of TABULA with the Hellenic calculation method and software (TEE-KENAK). The green bars correspond to the TABULA results corrected for the TEE-KENAK reference area (heated floor area in external dimensions)

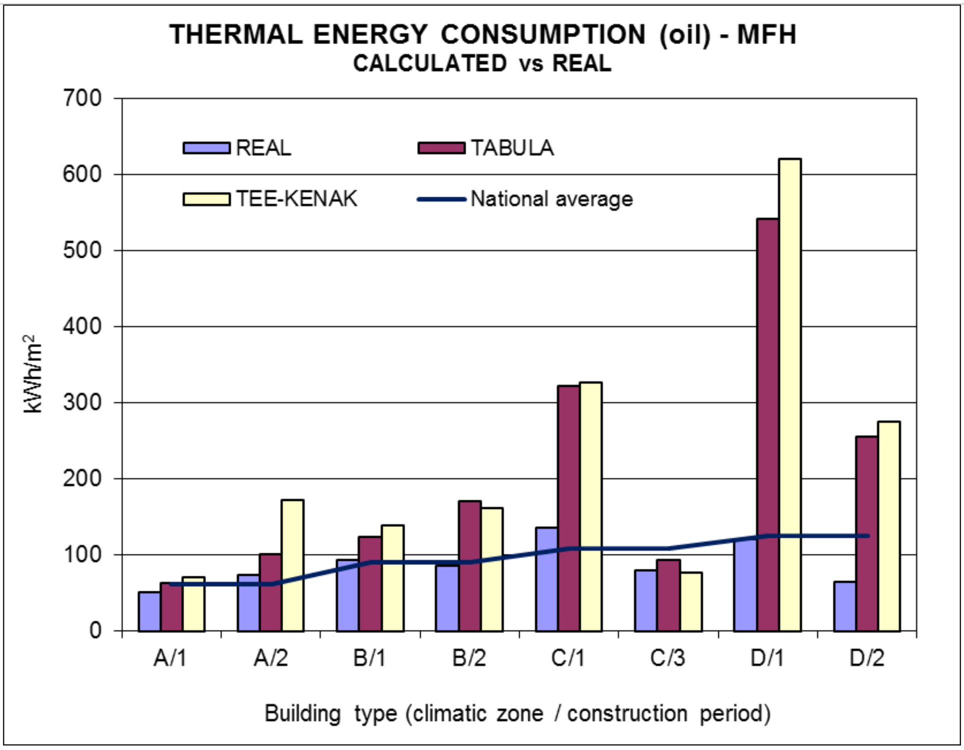
3.3.1 Comparison with actual energy consumption

Data on the actual energy consumption was available for 17 out of the 24 buildings of the Hellenic typology, specifically, for 9 single family and 8 multifamily houses. Figure 3.6 illustrates the comparison of the results produced by TABULA and TEE-KENAK with the actual energy consumption of oil available by the building owners.

Figure 3.6 illustrates the comparison of the two methods with actual oil consumption data. Calculated results are expressed in kWh/m^2 reference area (internal dimensions). In most cases the differences between the calculated and the actual data are rather large. This may be attributed to the number of operating hours, which, in both methods is set very high. TABULA considers a 24hr operation for residential buildings, whereas TEE-KENAK considers an 18hr operation. In reality, the daily operating period of the heating system in Hellenic residential buildings is much shorter. As expected, the calculated results are significantly higher than the actual oil consumption. Furthermore, the actual energy consumption in the Hellenic residential buildings is often affected by the social and economic status of the owner. Households of lower income tend to spend less energy at the expense of their living standards, while high income households tend to overspend it, as a result of carelessness. Therefore, an in-depth comparison of the calculated and actual energy consumption would not be possible in the context of this study.



(a)



(b)

Figure 3.6: Comparison of the estimated thermal energy consumption using TABULA and TEE-KENAK, with actual energy consumption for (a) SFH and (b) MFH of the 17 Hellenic typology buildings

The solid blue line in figures 3.6a and 3.6b represents the national standards for the energy consumption for heating for SFH and MFH buildings respectively in the four climatic zones. Currently, there are no official national averages for the Hellenic residential building stock. The values presented in this graph come from a recent study [7] and they are based on the analysis of the available information on actual oil consumption from 6550 residential buildings located throughout the country [8].

Table 3.3: Synoptic presentation of the "Standard" Scenario interventions on the buildings of the Hellenic typology

'STANDARD' SCENARIO				**ENVELOPE**				**SYSTEMS**		**RES**
				ADD INSULATION			REPLACE WINDOWS			
Bldg No		Clim. Zone	Age Band	Roof	Walls	Floor (pilotis)		REPLACE BOILER	INSULATE PIPES	SOLAR COLLECTORS (60% DHW coverage)
1	SINGLE FAMILY HOUSES	A	1	✓	✓		✓	✓	✓	✓
2		A	2	✓	✓	✓	✓	✓	✓	✓
3		A	3					✓		✓
4		B	1	✓	✓		✓	✓	✓	✓
5		B	2	✓	✓		✓	✓		✓
6		B	3	✓	✓			✓	✓	✓
7		C	1	✓	✓		✓ (low-e)	✓	✓	✓
8		C	2	✓	✓	✓	✓ (low-e)	✓	✓	✓
9		C	3	✓	✓			✓		✓
10		D	1	✓	✓	✓	✓ (low-e)	✓	✓	✓
11		D	2	✓	✓	✓	✓ (low-e)	✓	✓	✓
12		D	3	✓	✓		✓ (low-e)	✓		✓
13	MULTI FAMILY HOUSES	A	1	✓	✓		✓	✓	✓	✓
14		A	2	✓	✓		✓	✓	✓	✓
15		A	3	✓	✓	✓		✓		✓
16		B	1	✓	✓		✓	✓	✓	✓
17		B	2	✓	✓	✓	✓	✓	✓	
18		B	3		✓			✓	✓	✓
19		C	1	✓	✓		✓ (low-e)	✓	✓	✓
20		C	2	✓	✓	✓	✓ (low-e)	✓	✓	✓
21		C	3	✓	✓	✓	✓ (low-e)	✓	✓	✓
22		D	1	✓	✓		✓ (low-e)	✓	✓	✓
23		D	2	✓	✓	✓	✓ (low-e)	✓	✓	✓
24		D	3	✓	✓	✓		✓		✓

Table 3.4: Synoptic presentation of the "Ambitious" Scenario interventions on the buildings of the Hellenic typology

'AMBITIOUS' SCENARIO				**ENVELOPE**				**SYSTEMS**			**RES**
				ADD INSULATION			REPLACE WINDOWS				
Bldg No		Clim. Zone	Age Band	Roof	Walls	Floor (pilotis)		REPLACE BOILER	INSULATE PIPES	GHP	SOLAR COLLECTORS (100% DHW coverage, partial space heating)
1	SINGLE FAMILY HOUSES	A	1	✓	✓		✓ (low-e)		✓	✓	✓
2		A	2	✓	✓	✓	✓ (low-e)		✓	✓	✓
3		A	3	✓	✓		✓ (low-e)	✓			✓
4		B	1	✓	✓		✓ (low-e)		✓	✓	✓
5		B	2	✓	✓		✓ (low-e)			✓	✓
6		B	3	✓	✓		✓ (low-e)	✓	✓		✓
7		C	1	✓	✓		✓ (low-e)		✓	✓	✓
8		C	2	✓	✓	✓	✓ (low-e)	✓	✓		✓
9		C	3	✓	✓		✓ (low-e)	✓			✓
10		D	1	✓	✓	✓	✓ (low-e)		✓	✓	✓
11		D	2	✓	✓	✓	✓ (low-e)	✓	✓		✓
12		D	3	✓	✓		✓ (low-e)	✓			✓
13	MULTI FAMILY HOUSES	A	1	✓	✓		✓ (low-e)		✓	✓	✓
14		A	2	✓	✓		✓ (low-e)		✓	✓	✓
15		A	3	✓	✓	✓	✓ (low-e)	✓			✓
16		B	1	✓	✓		✓ (low-e)		✓	✓	✓
17		B	2	✓	✓	✓	✓ (low-e)	✓	✓		✓
18		B	3	✓	✓	✓	✓ (low-e)	✓	✓		✓
19		C	1	✓	✓		✓ (low-e)		✓	✓	✓
20		C	2	✓	✓	✓	✓ (low-e)	✓	✓		✓
21		C	3	✓	✓	✓	✓ (low-e)	✓	✓		✓
22		D	1	✓	✓		✓ (low-e)	✓	✓		✓
23		D	2	✓	✓	✓	✓ (low-e)	✓	✓		✓
24		D	3	✓	✓	✓	✓ (low-e)	✓	✓		✓

4 Modeling the energy balance of the Hellenic building stock

4.1 Building Typology Approach

The buildings included in the Hellenic typology are real examples that can be considered as representative of the corresponding classes. However, due to peculiarities in their initial construction or refurbishment actions taken on their envelope and/or system installations over the years, they may not reflect the typical buildings of their class. Thus, the set of buildings included in the TABULA typology has to be elaborated before it is used in the building stock balance model.

The derivation of the national energy balance was based on "**typical**" **buildings** defined for each of the 24 typology classes. In order to define the characteristics of the "typical" buildings in all the building classes of the Hellenic typology, it would be necessary to have detailed statistical data regarding the construction and system installations in the building stock. Due to the lack of official national data in the required level of detail, it was decided that the "typical" buildings used in this study would have the same architectural features as the "real examples". In collaboration with experts active in the field of building construction from the TABULA National Advisory Group (NAG), percentages were assigned to each type in the "Building Element" sub-typology. Similarly, each system type in the "Systems" sub-typology was assigned a percentage. In both cases the percentages reflect the frequency of occurrence of the types in the different parts of the building stock depending on the building size, age band and climatic zone.

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

4.2 Available Data

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

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

Table 4.1 outlines the data that could be retrieved from the above sources regarding the Hellenic residential building sector. The available data is analytically presented in Appendix I.

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

Table 4.1: Available frequencies regarding the Hellenic residential building stock.

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

The gaps in the availability of frequencies are attributed to the absence of systematic collection of relevant information. Most of the statistical data on the residential building sector come from the latest Censuses carried out in 1990 [9] and 2000 [10]. These data include number and size of buildings as well as floor area per building age band and geographic region. Further analysis based on this data [1] resulted in frequency distributions of buildings according to their level of thermal insulation, the installed systems for heat generation and the presence of solar systems for hot water heating.

In the absence of sufficient official data for the derivation of the national energy balance model it was decided to use “typical buildings”, as mentioned in the previous section. The thermo-physical properties of the envelope, as well as the expenditure coefficients per “typical” building, were derived as weighted averages per building class. The weighting factors for each category were well educated guesses derived in collaboration with NAG experts active in the field of construction and currently constitute a realistic estimate of the evolution of the construction and renovation trends over the years (Appendix II). Table 4.2 summarizes the resulting “typical” values of the thermal transmission coefficient for the main components of the building envelope for each of the 24 building classes of the Hellenic residential building typology.

Table 4.2: “Typical” values (weighted averages) of the thermal transmission coefficient (kWh/m^{2}K) for the main components of the building envelope

	Single **F**amily **H**ouses (SFH)			**M**ulti **F**amily **H**ouses (MFH)		
	-1980	***1980-2000***	***2000-***	***-1980***	***1980-2000***	***2000-2001***
Climatic Zone ***A***						
Wall	2.36	1.28	1.01	2.13	1.11	0.81
Roof	3.12	1.68	0.91	2.96	1.33	0.72
Floor	3.07	2.95	2.94	3.07	2.21	2.08

Window -U	4.89	4.82	3.33	5.14	4.88	4.40
- g	0.60	0.57	0.54	0.62	0.58	0.55
Climatic Zone ***B***						
Wall	2.02	0.96	0.86	2.06	1.09	0.75
Roof	2.72	1.09	0.70	2.85	1.28	0.62
Floor	2.60	2.02	1.93	2.13	1.52	1.00
Window -U	4.71	4.51	3.33	4.99	4.25	3.55
- g	0.59	0.56	0.54	0.61	0.51	0.55
Climatic Zone ***C***						
Wall	2.02	0.96	0.86	2.06	1.09	0.75
Roof	2.72	1.09	0.70	2.85	1.28	0.62
Floor	2.28	1.01	0.79	2.68	1.21	0.74
Window -U	4.71	4.51	3.33	4.99	4.25	3.55
- g	0.59	0.56	0.54	0.61	0.51	0.55
Climatic Zone ***D***						
Wall	2.61	1.02	0.86	2.00	1.02	0.75
Roof	3.06	1.15	0.71	2.76	1.20	0.62
Floor	2.47	1.00	0.79	2.10	1.06	0.66
Window -U	4.63	4.33	3.33	4.92	4.52	3.53
- g	0.60	0.56	0.54	0.61	0.56	0.55

Similarly, Table 4.3 summarizes the “typical” expenditure coefficients (using the Higher Calorific Value) for the systems installed in the 24 buildings of the Hellenic typology, based on their size and time construction period. In this case, no distinction is made for different climatic zones, since they are applicable for the entire country.

Table 4.3: “Typical” values (weighted averages) of the expenditure coefficient (higher calorific value) for the space and water heating systems

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

Finally, Table 4.4 summarizes the “typical” performance coefficients for the distribution system. In this case, no distinction is made for different building sizes or energy end use, so they are applicable for the entire building stock based on the time construction period.

Table 4.4: “Typical” values (weighted averages) of the performance coefficient for the distribution systems of single and multi family houses, according to the insulation level of the system

Level of insulation	***S**ingle / **M**ulti **F**amily **H**ouses*		
	- 1980	***1980-2000***	***2000-2010***
Pipelines non/partly insulated	0.89	0.93	0.93
Pipelines well insulated	0.97	0.97	0.97

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Further assumptions that were made for some parameters affecting the performance of the “typical” buildings are summarized in Table 4.5.

Table 4.5: Parameters affecting the energy performance of the “typical” buildings

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

4.3 Energy Balance Method

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

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

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

4.4 Energy Balance of the Residential Building Stock

The buildings considered in this study are permanent dwellings, with continuous occupancy throughout the year and do not include summer (vacation) dwellings. The permanent dwellings average about 68% of the total dwellings stock throughout the country [10]. The floor area of permanent dwellings for each of 24 residential buildings categories is given in Table 4.6. This data has been published in [9] and it is based on available information from:

- a detailed register of 6550 dwellings, which was performed during the period 1987–1988 [8]
- results of the 1990 census [10]
- the construction activities after 1990 [11]

The corresponding data for the period 2000-2010 was estimated based on the assumption that the annual growth rate of the number of dwellings during 2002–2010 is equal to the average of the two previous decades. During the 1980s, the average annual growth rate of the number dwellings was 1.65%, while during the 1990s it dropped to 1.46% [1].

The TEE-KENAK calculation results regarding the heating energy consumption of the 24 “typical” buildings representing each of the classes included in the Hellenic typology are summarized in Table 4.6.

In order to derive the thermal energy consumption for the entire residential building stock it was necessary to transform the total floor area into heated floor area. For this purpose, the heated floor area was calculated as a percentage of the total floor area given in Table 4.6. Specifically, it was assumed that the percentages of the total floor area that is actually heated are 70% and 80% for SFH and MFH buildings, respectively. This assumption is necessary in order to account for unheated areas, e.g. corridors, stairwells, cellars as well as basements that are usually unheated spaces.

Table 4.6: Total floor area per building class in the Hellenic permanent residential building stock and calculation results for "typical" buildings using the TEE-KENAK software.

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

(*):space heating only (auxiliary systems included), (**):space and DHW heating
The (+) sign indicates that SFH buildings of the class use an oil boiler for both space and DHW heating.

Using the TEE-KENAK software with the data from Tables 4.1-4.5 and taking into account the above assumptions, the energy balance for the residential building stock was derived. Results are summarized in Table 4.7. The "thermal" part of the energy consumption includes mainly space heating and only in three cases (buildings marked with the (+) sign in Table 4.6) where oil boilers are used for DHW preparation, it also includes water heating. The "electrical" part includes mainly DHW heating and the consumption of the auxiliary heating systems (e.g. pumps).

Table 4.7: Calculation results for different quantities of energy balance for permanent residential building stock (year 2010).

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

4.4.1 Comparison to National Statistical Data of the Residential Building Stock

The following analysis is based on national energy consumption data as reported by the Hellenic Ministry of Environment and Climatic Change – YPEKA [12] for the years 2000-2008 and CO_2 emissions taken from official reports of the European Union [13] for the years 2000-2007. Table 4.8 summarizes the official energy consumption and CO_2 balance reported for the Hellenic residential building sector.

Table 4.8: The official energy consumption and CO_2 emission balance reported for the Hellenic residential building sector [12, 13].

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

(*) calculated values

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

The CO_2 emissions from households reported in [13] refer to space and DHW heating excluding the related electricity consumption [1]; therefore, they refer to the thermal part of the energy consumption. Based on the energy consumption and CO_2 emission data reported in Table 4.8, the average annual growth rate (AAGR) was derived. Specifically:

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

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

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

A comparison of the initial energy balance results presented in section 4.4 with the corresponding official national balance reveals an overestimation of about 63% in the thermal energy balance. As mentioned in section 3.3 (Table 3.5), the TEE-KENAK software performs the calculations based on a default 18hr per day operation of residential buildings throughout the year. In order to adapt the results so that they better reflect the actual operating hours of residential buildings, the initial consumption and CO_2 emission results (Table 4.8) were adjusted on the basis of the following assumptions. These were derived in collaboration with experts from NAG, who are active in the field of building construction and maintenance, without providing them any access to the original figures in order to minimize any predisposition or bias. At present, as there is no official reference on this issue, the following assumptions are considered to be a realistic approximation of the Hellenic residential building stock operating patterns:
- SFH buildings: 10% have an 18 hr and 90% have a 12 hr operation per day
- MFH buildings: 10% have a 12 hr and 90% have a 9 hr operation per day

The resulting adapted energy balance to reflect the actual operating hours is summarized in Table 4.9.

Table 4.9: Adapted calculation results for different quantities of energy balance for the permanent residential building stock (year 2010).

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

Comparison of the adapted calculated thermal energy balance (Table 4.9) with the officially reported value reveals that the adjustment improved the predictions significantly, as the overestimation dropped down to 4.2%. The CO_2 emissions were found to be underestimated by approximately 5%. These deviations are considered to be acceptable for the level of detail of the present study.

4.4.2 Calculation of Energy Saving Potentials

Transposition of the European Directive 2006/32/EC took effect in June 2010 by the national law N.3855/2010, introducing various energy efficiency improvement measures, energy service companies - ESCOs, third party financing - TPF and other instruments, in order to achieve by 2016 an overall national indicative target of 9% energy conservation. Applying this target to the thermal energy consumption of residential buildings it is found that it should reach 2.44 Mtoe in 2016. As discussed in section 4.4.1, the average annual growth rate over the period 2000-2008 is about 1.46%. Using this rate for the business as usual (BaU) scenario, the thermal energy consumption for 2010 and 2016 is estimated to reach 2.66 and 2.90 Mtoe, respectively.

Figure 4.1 illustrates the evolution of the annual thermal energy consumption for the Hellenic permanent residential building stock, with 2008 being the year with the most recent published data. Accordingly, the national indicative target of 9% for 2016 applied to the thermal energy consumption of permanent residential buildings requires savings of 0.54 MToe from 2005 data. Savings can be achieved through energy efficient measures and scenarios. As discussed in section 3.2, in the framework of TABULA two different scenarios have been studied: the Standard and the Ambitious scenario, which target different levels of interventions in the buildings' thermal envelope and E/M installations with the exploitation of renewable energy sources (RES), which are summarized in Table 4.10.

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

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

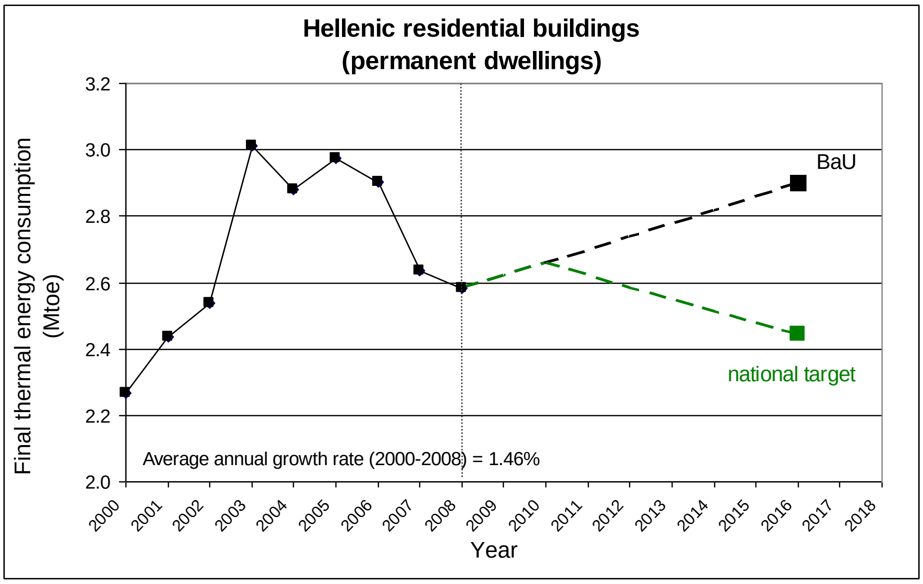

Figure 4.1: Evolution of the thermal energy consumption in permanent dwellings since 2000 and estimated for 2016 to reach the national indicative energy savings target of 9% in Greece.

Table 4.10: General description of Standard and Ambitious scenario.

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

The TEE-KENAK software was used in order to calculate the energy savings achieved by applying the two scenarios to the typical buildings. Results are summarized in Table 4.11. Note that in some cases the estimated thermal energy savings correspond to a fuel switch, for example, from oil to electricity (i.e. replacing an oil boiler with a geothermal heat pump). The data in Table 4.11 refer to final thermal energy consumption and do not reflect the resulting increase of electrical energy consumption or the increased primary energy consumption for power generation. This is also elaborated in the following discussion.

Table 4.11: Calculated savings in the thermal energy consumption and in the total primary energy from the application of the Standard and Ambitious scenario in the typical buildings.

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

The (+) sign indicates that SFH buildings of the class use an oil boiler for both space and DHW heating.

The potential energy conservation achieved as a result of the two scenarios is very high, as they represent a holistic approach towards energy efficiency, affecting both the envelope and the installed systems and including RES for covering part of the demand. As expected, the savings resulting from the Ambitious scenario are higher than those of the Standard scenario. The use of geothermal heat pumps (GHPs) minimizes the thermal energy consumption leading to savings close to 100%. However, the operation of the GHPs introduces an increase in the total electrical energy consumption. This will have to be added to the electrical energy balance (i.e. primary energy for power generation), thus the overall impact of the Ambitious scenario on the total energy balance will be smaller. Based on estimates regarding the COP and electricity consumption of GHPs given by NAG experts, it was calculated that the resulting increase in the total primary energy consumption would not exceed 1%. However, further analysis of the energy balance is not possible since there is no official data reported on the breakdown of primary energy use of power generation for the different end-uses.

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

Taking into account the calculated energy savings reported in Table 4.11 and the target value of thermal energy consumption for 2016, the energy balance model was used in order to derive the percentage of the building stock that will have to adopt the Standard or the Ambitious scenarios to achieve the target savings. Indicatively, it was found that the national target could be reached by applying the Standard scenario in 15% of the residential buildings of the first age band (built prior to 1980) and 30% of the buildings of the second age band (built between 1980 and 2000). The same could be achieved by applying the Ambitious scenario in 10% and 25% of the buildings in the corresponding age bands.

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

4.5 Conclusion

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

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

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

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

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

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

5 Extension of the typology concept to the non-residential building sector

5.1 Existing typology concepts

In Greece, there is no elaborate monitoring of the building stock. The process of the Energy Performance Certification of buildings was launched in January 2011 when selling and renting entire buildings. The certification of renting building units (e.g. apartments) has been postponed, for the time being, until January 2012. So far, very limited efforts have been carried out to successfully collect and analyze detailed data on the building sector and emphasis has been given to the residential sector. Therefore, comprehensive information and official data for the non-residential (NR) building stock is rather limited, although it is the fastest growing energy demand sector.

Knowledge on the energy-related aspects of the NR building sector can be derived from treating scattered data coming from various sources, mainly the building construction activities, statistical reports periodically issued by the National Hellenic Statistical Service (NHSS) and various publications usually focussing on the energy retrofitting of representative examples in the tertiary sector.

NOA's knowledge on the NR building sector comes from:

- involvement in European projects related to this subject over the past 15 years (TOBUS [14], XENIOS [15], EPA-NR [16] and DATAMINE [2])
- involvement in national projects to assess the building stock, the potential for energy conservation and the abatement of environmental pollution
- involvement in short energy audits and energy studies in the framework of consulting activities.

In the framework of TOBUS and XENIOS projects dealing with the retrofitting of office and hotel buildings respectively, various representative buildings were thoroughly investigated in order to assess the potential of retrofit measures for upgrading the indoor environmental quality and energy performance of the buildings. Relevant information were also collected thus revealing any national data. In the framework of EPA-NR project dealing with the energy performance assessment of NR buildings, a total of six buildings (an office, a hospital and four schools) were also audited regarding the energy-related characteristics of their envelope and the installed systems. Data from a total of 84 NR buildings have been included in DATAMINE structure in a preliminary test of its applicability in extracting results regarding the Hellenic building stock based on data coming from the national EPCs. In the absence of EPCs at the time of the DATAMINE project, the data came from previous energy audits in buildings and energy studies in the framework of NOA's consulting activities.

The most relevant source of information and experience for extending the concept of TABULA to the NR building sector is a national project assigned to NOA by the Ministry of Environment (2001-2002) on the: "Investigation of supporting policies for the advancement of the Ministry's policies in relation to the abatement of CO_2 emissions in the residential and tertiary sectors" [7]. In the framework of this project, data on the NR building stock were collected from various sources (NHSS - census of construction activities 1990-2000 and published literature). The effort resulted in mapping the number and size (floor area) of NR buildings classified according to the building use, date of construction and climate. Similarly, a mapping of the annual operational specific electrical and thermal energy consumption was achieved for the different categories.

Non-residential buildings represent about the 25% of the total number of Hellenic buildings for 1990. A first classification is presented in [17]. Accordingly, the main categories of the Hellenic NR building stock according to their end use are: *offices/commercial* (2.74% of the total number of Hellenic buildings), *schools* (0.41%), *hotels* (0.26%) and *hospitals* (0.05%). Other uses of NR buildings include churches, factories, athletic facilities, storage areas, closed parking spaces etc, which account for 21.9% of the total stock, the majority of which have periodic use and a limited overall contribution to the total energy consumption. Therefore, from the energy consumption point of view the NR building sector would be reasonably represented by the four main categories mentioned above. Table 5.1 summarizes the number and total floor area of buildings per construction year band for each of the four categories.

Table 5.1: Number of buildings and total floor area for the main categories of the Hellenic tertiary sector.

	Offices/Commercial		**Schools**		**Hotels**		**Hospitals**	
	# bldgs	Floor area (m^2)	# bldgs	Floor area (m^2)	# bldgs	Floor area (m^2)	# bldgs	Floor area (m^2)
pre 1980	89,352	34,176,657	14,126	20,966,906	3,015	6,524,219	1,566	3,394,400
1981-2000	39,348	32,361,389	700	1,164,145	2,580	9,380,098	117	1,004,400
2001-2010	23,850	25,544,135	750	1,322,299	1,214	5,430,632	59	580,041

Figure 5.1 illustrates the distribution of NR buildings in the four climatic zones defined in KENAK. Information on the energy-related characteristics of the buildings in the NR sector can be drawn from Table 5.2 giving a distribution of the buildings in different subcategories with common characteristics.

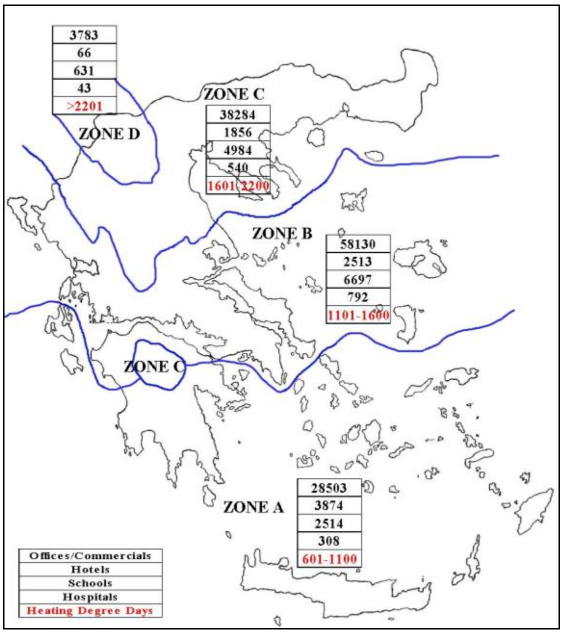

Figure 5.1: Distribution of Hellenic non-residential building stock estimated for the four climatic zones of Greece and the corresponding heating degree-days for each climatic zone. [7,17]

Figure 5.2 presents the estimated average annual specific electric (left) and thermal (right) energy consumption (kWh/m^2) for 2001. The thermal energy consumption refers to buildings with central heating systems using fossil fuels (i.e., oil, gas).

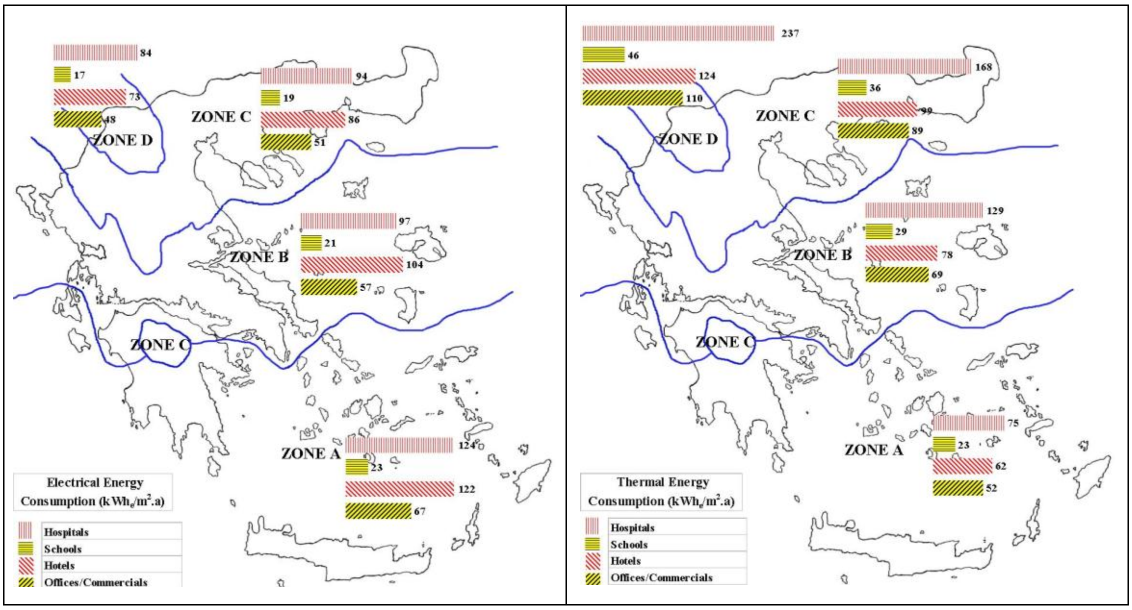

Figure 5.2: Distribution of estimated average annual specific electrical (left) and thermal (right) energy consumption in 2001 for the non-residential building stock in the four Hellenic climatic zones. [7,17]

The potential savings as a result of various energy conservation measures (ECMs) on the energy performance of NR buildings are summarized in Table 5.3 [17]. The ECMs per climatic zone are ranked according to the amount of energy savings for the different final uses (heating, cooling, sanitary hot water, lighting). The total annual energy savings are expressed as a percentage of the total thermal & electrical consumption for the different building categories that each ECM was applied to. Some ECMs are financially attractive and would not require the support of any financial instruments, while their total contribution in the reduction of CO_2 emissions is about 77%. These recommended ECMs are identified for the corresponding building category by the (✓) symbol in Table 5.3. The recommended ECMs that need some kind of support are identified for the corresponding building category by the (*) symbol.

Table 5.3: Priorities for the implementation of ECMs in Hellenic NR buildings (O/C: offices/Commercial, H: Hotels, S: Schools, HC: Health Care) [17]

Energy Conservation Measures (ECMs)	Total annual energy savings in NR buildings								Recommended ECM			
	Thermal				Electrical							
	O/C	H	S	HC	O/C	H	S	HC	O/C	H	S	HC
	Space heating – building envelope											
#1: Thermal insulation of external walls	31%	40%	31%	37%	4%	5%		4%	*	✓	*	✓
#2: Thermal insulation of roofs	5%	6%	5%	6%	2%	2%		2%		*		*
#3: Installation of double-glazing	11%	19%	18%	18%								*
	Space heating - heat production											

#4: Maintenance of central heating installations		11%							✳	✓	✳	✓
#5: Replacement of inefficient boilers with energy efficient oil-burners		17%							✓	✓	✓	✓
#6: Replacement of inefficient boilers with energy efficient natural gas - burners		21%							✓	✓		✓
#7: Temperature balance controls for central space heating		5%							✳	✓		✓
#8: Space thermostats		5%							✓	✓		✓
Cooling												
#9: External shading					14%	17%	15%	14%	✳	✳		✳
#10: Ceiling fans						60%			✓	✓	✳	✓
#11: Night ventilation					16%				✳			
Sanitary hot water												
#12: Solar collectors for SHW production					43%	76%	33%	64%		✳		✳
Lighting												
#13: Energy efficient lamps						60%			✓	✓	✓	✓
Total Energy Management												
#14: BMS - Building Management System	20%	20%		20%	30%	30%		30%	✓	✓		✓

5.2 Draft classification scheme for non-residential buildings

The NR sector presents a large variety of building uses that differ in terms of operation time and indoor environmental requirements, which has a significant effect on their energy demand and consumption. Therefore, a national typology of NR buildings should be based on three parameters, namely:

- *building utilization*, affecting the operational patterns and the indoor air requirements
- *construction year band*, characterizing the architectural features and envelope construction as well as the system installations to some extent
- *climate*, affecting the construction trends and determining the energy demand of the buildings.

Along these lines, a classification of the NR buildings is presented in [17]. According to the building use, four discrete typologies are presented, namely:

- Offices / commercial
- Hotels
- Hospitals
- Schools

Three construction year bands are defined:

- pre 1980 when the national HBTIR came into force
- 1981-2000 when implementation of the TIR was gradually adapted
- 2001-2010 full implementation of HBTIR

Despite the fact that no significant differences should be expected between residential and non-residential buildings regarding the envelope characteristics, the system installations in the tertiary sector buildings present a higher level of complexity, since a wider variety of systems must be considered in order to include cooling, ventilation and air conditioning technologies that play a very significant role in the energy consumption of these buildings.

Among the above mentioned building uses, the simplest is schools, as it includes buildings operating only a few hours a day and nine months a year. The system installations mainly include boilers (oil/ gas) and they seldom incorporate cooling technologies, due to the fact that schools remain closed during the summer period. Therefore, the overall complexity of this typology is similar to the one of residential buildings. Table 5.4 summarizes the frequencies available for the twelve classes (three construction periods x four climatic zones) of the school building typology [17].

Table 5.4: Frequencies (number of complexes, floor area) for the classes of the school building typology [17].

Climatic Zone(*)	Number of school complexes			Floor area (m^2)		
	Pre 1980	1981-2000	2002-2010	Pre 1980	1981-2000	2002-2010
Zone A	2,395	119	127	2,395,303	130,567	152,610
Zone B	6,381	316	339	10,847,369	600,770	677,560
Zone C	4,749	235	252	7,123,025	400,038	453,824
Zone D	601	30	32	601,208	32,771	38,304
Total	14, 126	700	750	20,966,906	1,164,145	1,322,299

(*) According to KENAK, four climatic zones are defined on the basis of the number of heating degree days (HDD), namely: A: 601-1100 HDD, B: 1101-1600 HDD, C: 1601-2200 HDD, D: > 2201 HDD

Table 5.2: Number of non-residential buildings for different subcategories with common characteristics [2]

	OFFICES/COMMERCIAL			**HOTELS (number of complexes)**			**SCHOOLS (number of complexes)**			**HEALTH CARE**		
Construction period	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Total	**89,352**	**39,348**	**23,850**	**3,015**	**2,580**	**1,214**	**14,126**	**700**	**750**	**1,566**	**117**	**59**
Without or inadequate wall insulation	89,352	--	--	1,543	--	--	14,126	--	--	282	282	282
Without or inadequate roof insulation	89,352	--	--	1,543	--	--	14,126	--	--	42	42	42
With central heating systems	15,539	32,465	23,850	3,015	2,580	1,214	14,126	700	750	--	--	--
With old central heating systems	10,877	9,740	--	2,279	750		9,888	210	--	783	783	783
No temperature balance control	15,539	22,726	--	1,453	586	--	14,126	490	--	59	59	59
No space thermostats	10,887	16,233	--	772	234	--	9,888	350	--	29	29	29
No solar collectors	17,870	7,870	4,770	2,279	1,875	877	2,825	140	150	1,566	1,566	1,566
No shading	5,361	9,444	--	547	1,125	--	848	63	--	--	--	--

The estimated number of school complexes and floor areas for each of the 12 building categories and the number of school complexes for each of the subcategories for the three different construction periods were estimated using data from the Organization of School Buildings (OSB) (i.e. number of classrooms, area per classroom, classrooms per school etc), the construction activity during the 1990s and relevant existing studies.

Figure 5.3 illustrates the ECMs described in Table 5.3 ranked for the school building stock according to the amount of energy savings for the different final uses (heating, cooling, sanitary hot water, lighting).

The most effective ECMs for schools are the ones dealing with the reduction of thermal energy for space heating. First is the addition of thermal insulation to reduce heat losses through exposed walls, followed by the replacement of old oil boilers and the frequent maintenance of central heating installations. The installation of energy efficient lamps, due to the high-energy consumption for artificial lighting in schools, is also an effective measure.

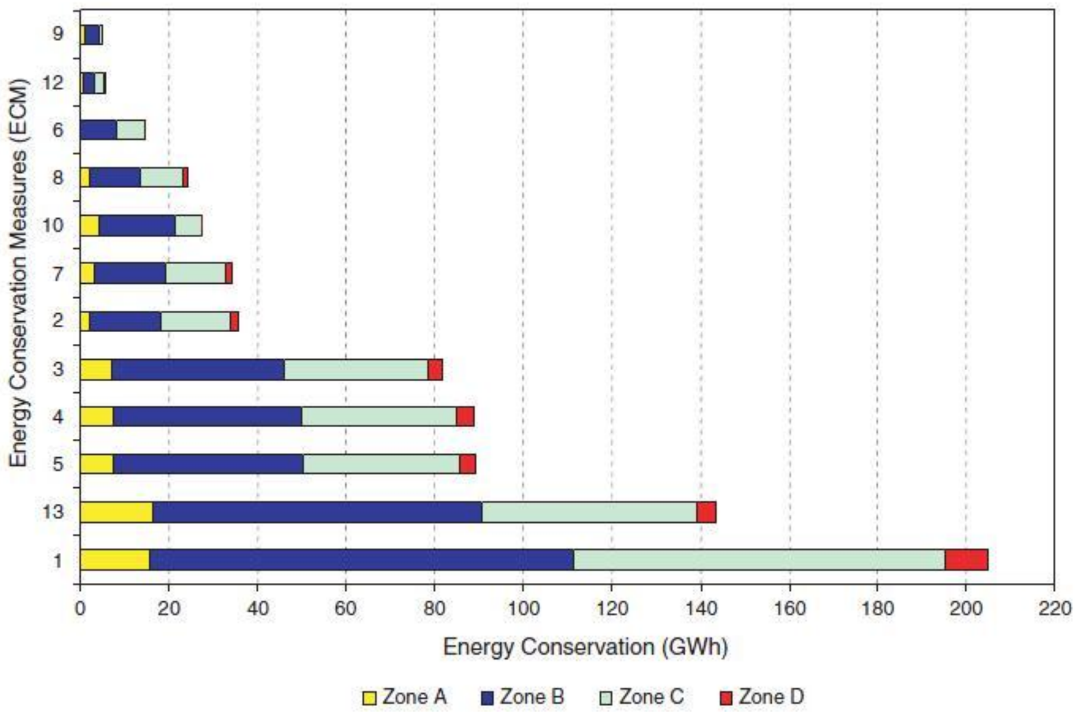

Figure 5.3: Ranking of energy conservation measures for the Hellenic school building stock in 2010 [17]

5.3 Proposed proceeding / link with current national activities

As discussed in section 5.2, a non-residential buildings typology should be based on the building end-use rather than on building size. Due to the lack of official data/information that would permit a refined representation of the different uses in a typology, a first classification of the non-residential buildings would result in a typology including a total of 48 types of buildings (4 categories of use X 3 construction periods X 4 climatic zones)

Data to feed the non-residential building typologies can be drawn from the DATAMINE platform that includes, a total of 85 NR buildings, among which, 29 airports, 3 hotels, 5 offices, 4 schools, 10 hospitals, 18 sports halls and 16 swimming pools. Additional information could also be retrieved from the following sources:

- Empirical data for the Hellenic building stock
- Existing and on-going studies
- National standards and regulations providing information on building construction types and heat supply systems
- National statistical data from recent releases of the Hellenic Statistical Service
- National EPC register; this presents an excellent opportunity to get an insight of the energy-related features that differentiate buildings according to use by analyzing the EPC data as they become available.

The TEE-KENAK software should be used as the Hellenic calculation tool for the energy assessment of the buildings as it is in-line with the provisions of the Hellenic Regulation (KENAK) and most recently updated technical guidelines for tertiary sector buildings.

5.4 Conclusions

The TABULA typology concept could be expanded to apply to non-residential buildings. As there is a large variety of building uses and operational characteristics in the tertiary sector, it is necessary to classify buildings according to their use rather than their size. Accordingly, a preliminary classification could include the following four main building end-uses:

- Schools
- Offices
- Hotels
- Hospitals

Additionally, the three construction year bands used in the residential building typology: pre-1980, 1981-2000 and 2001-2010 to reflect the different trends in the envelope construction before and after the HBTIR and an additional period after 2011 for new buildings in compliance with KENAK. Using the four climatic zones A, B, C and D defined in the national regulation - KENAK would result for each typology related to a building use that includes a total of 12 building classes (3 age bands x 4 climatic zones).

As in TABULA residential typology, the above typologies will have to be complemented by two sub-typologies, namely, the “building element” and the “systems” sub-typologies. In the case of NR buildings the “building elements” sub-typology would be more or less the same as the one prepared for the residential buildings. However, as cooling, mechanical ventilation and air conditioning are very important factors of energy consumption in the tertiary sector, the “Systems” sub-typology would have to be expanded to include the large variety of relevant technologies that are commonly met in the tertiary sector.

6 The Hellenic TABULA Brochures

In order to facilitate the national dissemination efforts of the TABULA results, two-page **brochures** were prepared for each of the 24 buildings of the Hellenic typology. The brochures were prepared in Hellenic.

- The first page includes information on the building at its present state (e.g. a description of the envelope components and their heat transfer coefficients, an overview of the installed systems and their performance coefficients as well as the calculated energy demand, consumption per energy carrier and fuel, CO_2 emissions, primary energy and operational cost).
- The second page summarizes the results of the standard and ambitious scenarios illustrating the energy savings by comparison to the actual state of the building, the respective investment costs and the corresponding SPBPs. Figure 6.1 illustrates the brochure layout and content.

Apart from the two-page brochures, dissemination material was prepared including a short presentation of the TABULA project, the existing European Directive EPBD, the National Legislation on the EPA of buildings and general information on the Hellenic building stock and its energy balance. Practical information is included on energy saving measures and tips with a discussion of the related pros and cons. Relevant information on financing schemes are also included. This material along with the 24 two-page brochures for the buildings of the Hellenic typology is available for public access (www.energycon.org/tabula.html) in the form of an **electronic booklet** (Figure 6.2).

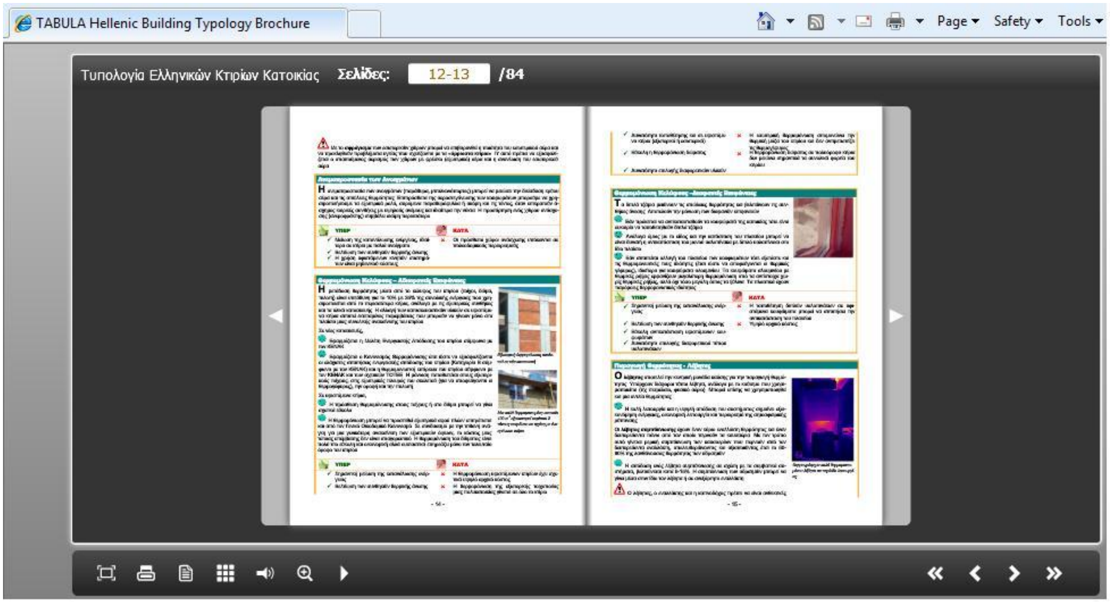

Figure 6.2: Electronic Booklet of the Hellenic Brochure report

Figure 6.1: Layout and content of the Hellenic Brochures

Building index	**Building type (SFH – MFH)** ***TABULA code***	Photo of a representative building (existing building used as an example)
Age	***Construction year band*** *1: prior to 1980* *2: 1981 – 2000* *3: 2001 – 2010*	
Climatic zone	*A B C D* *Defned in the National Regulation KENAK*	
Heated floor (m^2)	*Total heated floor area (external dimensions)*	
Heated volume(m^3)	*Total volume of heated areas in the building*	

Building description
A description of the most prominent characteristics of the building and its surroundings

Construction details	
Walls Structure Roof Windows Shutters Floor	*Description of the main structural elements of the building. Materials, energy-related features of the envelope (ie. existence and type of insulation, window and frame types)*

Thermal characteristics (W/m^2K)	
Walls / structure	*U values*
Roof	
Floor	
Windows	
g- windows (-)	*Solar heat gain coefficient per window type*

Systems - performance		
	Heating	**DHW**
Generation	*Performance coefficients (Higher Calorific Value)*	
Storage		
Distribution		

Systems - description	
Generation Distribution	*Type, age, insulation level, maintenance level of space heating systems.*
Solar collectors	*Total surface installed (m^2)*
DHW	*Type, age, insulation level, maintenance level of space heating systems.*

Annual Energy Performance	
Demand	*Total energy demand for space and DHW heating (kWh/m^2)*
Thermal energy Electrical energy	*per energy-end use (kWh/m^2)*
Primary energy	*kWh/m^2*
Emissions CO_2	*tn*
Oil	*lt*
Electricity	*kWh*
Operational cost	*€/m^2 heated floor area*

ENERGY SAVING INTERVENTIONS				
STANDARD SCENARIO	**Investment cost**		up to 10000 €	**Simple payback period (SPBP)**
			10000 – 20000 €	
			20000 – 40000 €	
			40000 – 60000 €	
			over 60000 €	

ENVELOPE	*Interventions on the building envelope (description and new U_values)*
SYSTEMS	*Interventions on the systems for space heating and DHW (description and new coefficients of performance)*
RES	*Incorporation of RES systems and techniques (solar collector area and percentage of coverage of DHW demand)*

Energy source *Comparison of energy consumption per fuel type of the building before and after the application of the Standard Scenario.*	Operation and cost (annual) *Cost (€/m^2) and savings (%)*
	Energy demand *Demand (kWh/m^2 heated floor area) and savings (%)* Emissions CO_2 *Emissions (kg/m^2 heated floor area) and reduction (%)*

AMBITIOUS SCENARIO	**Investment cost**		up to 10000 €	**Simple Payback Period (SPBP)**
			10000 – 20000 €	
			20000 – 40000 €	
			40000 – 60000 €	
			over 60000 €	

ENVELOPE	*Interventions on the building envelope (description and new U_values)*
SYSTEMS	*Interventions on the systems for space heating and DHW (description and new coefficients of performance)*
RES	*Incorporation of RES systems and techniques (solar collector area and percentage of coverage of DHW demand)*

Energy source *Comparison of energy consumption per fuel type of the building before and after the application of the Standard Scenario.*	Operation and cost (annual) *Cost (€/m^2) and savings (%)*
	Energy demand *Demand (kWh/m^2 heated floor area) and savings (%)* Emissions CO_2 *Emissions (kg/m^2 heated floor area) and reduction (%)*

All relevant material is included in the Hellenic TABULA brochure report [18]. It is intended for engineers and energy consultants in order to provide a quick overview of the available national typologies and potential energy savings through the implementation of effective ECMs. Examples (in English) for an SFH and an MFH building respectively are included in Appendix III.

7 eKIA: A web application based on the Hellenic typology concept

In an effort to facilitate dissemination of the typology concept in Greece, NOA has prepared **eKIA**, a web application <u>in Hellenic</u>, addressed mainly to home owners who wish to have a first assessment of the energy performance of a building and its potential for improvement through energy efficient measures. Exploiting the Hellenic TABULA typology, users may browse through the 24 building types to choose the one that better approximates the building under assessment (Figure 7.1). There is a possibility to choose among four different climatic zones (A, B, C, D) and the three construction periods (pre-1980, 1981-2000, 2001-2010). Typical U-values [18] and coefficients of performance for buildings of the same class in terms of size, climatic zone and time band are automatically attributed to the envelope elements and installed systems for space and DHW heating. Heat pump is the only type assumed for cooling.

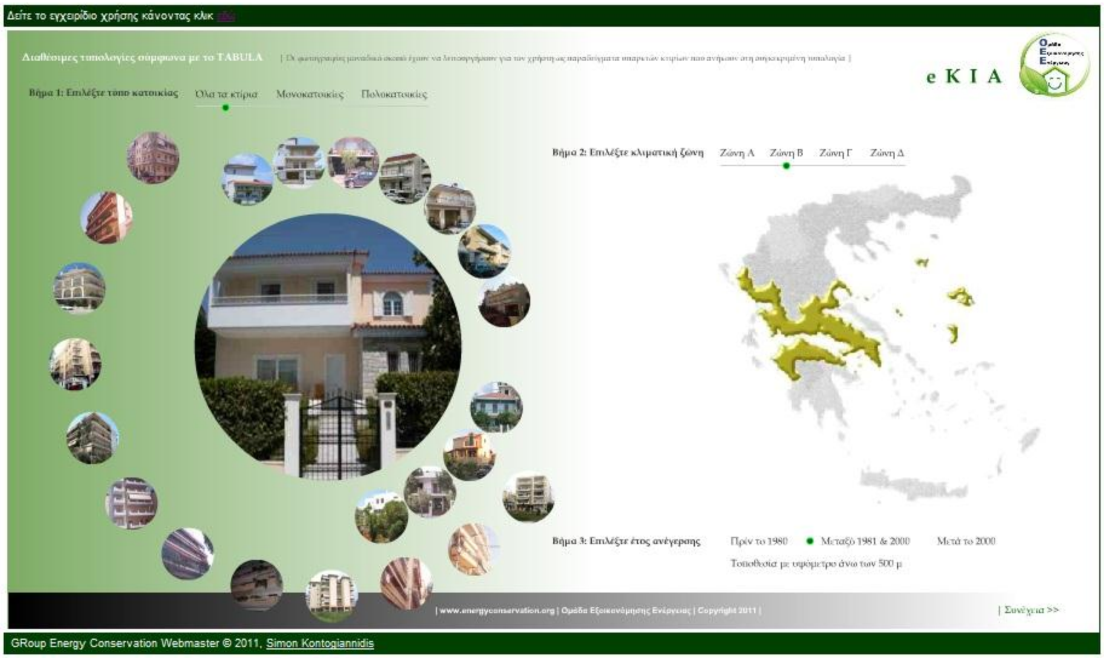

Figure 7.1: eKIA - Definition of a building using the Hellenic typology. Overview of available example buildings.

Adaptation of the initially selected building from the available 24 Hellenic typologies would be necessary for a more realistic representation of the actual building. This is possible by defining basic parameters such as the actual heated floor area and building volume, the total window area as well as the number of floors (Figure 7.2). Further refinement is possible by providing some basic information related to the:

- actual envelope construction (e.g. the use of thermal insulation for walls/roof/floor, the use of double glazing, and the use of shading)

- heating system (e.g. type, installation year and controls, maintenance level)
- cooling system (e.g. installation year, possible use of ceiling fans)
- solar collectors (e.g. use for DHW and/or space heating, collector area) and
- PVs (area)
-

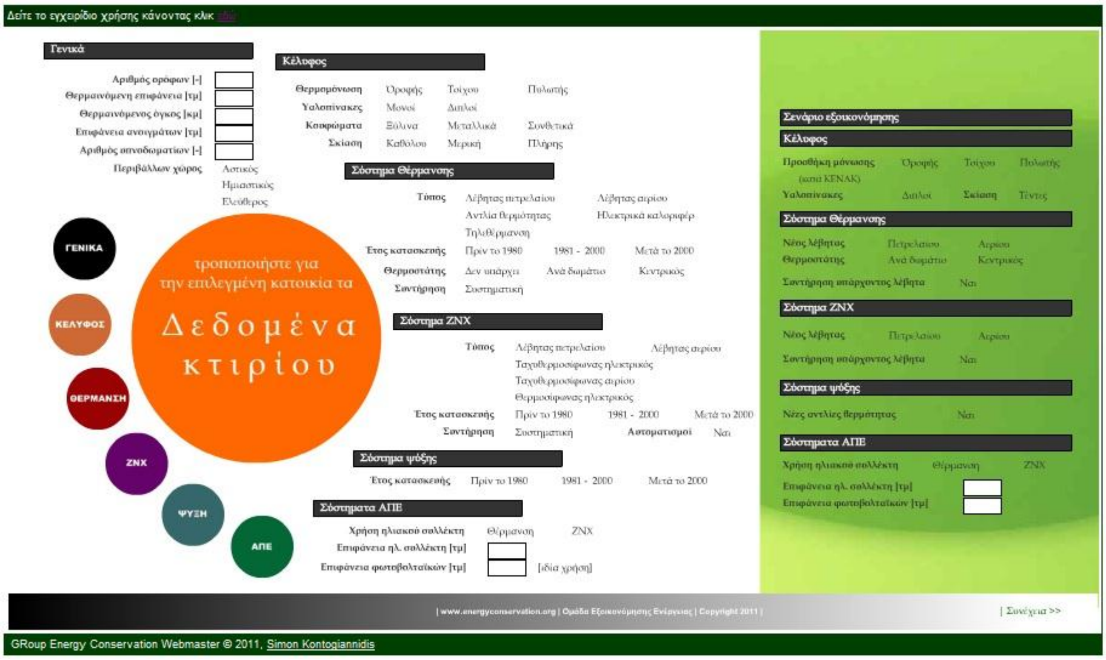

Figure 7.2: eKIA – Building input data : existing condition and energy conservation scenarios.

Calculations are performed using the official national tool (TEE-KENAK) with the corresponding inputs defined by the user. The goal was to significantly simplify the necessary input data in order to perform a first assessment of the buildings energy performance. Results include a preliminary benchmark for the investigated building at its present state, along with estimations for its primary energy consumption, site energy consumption breakdown (total, heating, cooling, DHW) and CO_2 emissions.

Furthermore, eKIA provides a means for a fast preliminary assessment of energy conservation scenarios. These include envelope and system interventions as foreseen by the new national regulation (KENAK), as well as the incorporation of RES and other technologies for space and DHW heating. Scenario results are presented in comparison with the existing condition (Figure 7.3). Three additional outputs are provided for each scenario, namely, the resulting energy savings, the investment cost (costs reflect the prices of year 2010) and the simple payback period.

This procedure, takes advantage of the Hellenic basic typology but also of the two additional sub-typologies, reducing the need for complex and time consuming data entry of all the detailed inputs required by TEE-KENAK. This simplified tool would be most appropriate in order to promote the TABULA approach and deliverables and facilitate users for a quick first assessment of the energy performance of a residential building and potential ECMs.

The software has been available for public use since November 2012 at: http://174.36.160.183/ekia.html

Figure 7.3: eKIA – Results (existing condition and scenarios).

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APPENDICES

Appendix I: Statistical tables (Frequencies)

Statistical Table	**Item**	**Availability**	**Data Source**
S-1.1	Frequency of building types of the national building stock	✓	**[1]**
S-1.2.1	Percentage of thermally refurbished envelope areas		
S-1.2.2	Information on insulation level and window types	✓	**[2]**
S-2.1	Centralisation of the heat supply (for space heating)	✓	**[2], [3]**
S-2.2	Heat distribution and storage of space heating systems		
S-2.3	Heat generation of space heating systems	✓	**[1], [2], [4]**
S-2.4	Heat distribution and storage of domestic hot water systems		
S-2.5	Heat generation of domestic hot water systems	✓	**[4]**
S-2.6	Solar thermal systems	✓	**[2]**
S-2.7	Ventilation systems		
S-2.8	Air-conditioning systems	✓	**[2]**
S-2.9	Control of central heating systems	✓	**[2]**
S-2.10	Correlation of envelope and heat supply modernisations		

Data sources

[1] Hellenic Statistical Authority (HSA), Census 2001.

[2] D. Lalas, C.A. Balaras, A. Gaglia, E. Georgakopoulou, S. Mirasgentis, I. Serafidis, S. Psomas, Evaluation of supporting policies for the advancement of the Ministry's policies in relation to the abatement of CO_2 emissions in the residential and tertiary sectors, 650 p. *in Hellenic*, IERSD, National Observatory of Athens, Ministry for the Environment, Physical Planning and Public Works, Directorate Urban Planning & Housing, November (2002).

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[4] National Advisory Group (NAG) Unpublished data – empirical data on the Hellenic building stock

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

National: living space external dimensions (reported by the National Statistical Service)
Conditioned area – SFH: National x 0.70
Conditioned area – MFH: National x 0.80
TABULA ref: conditioned area based on internal dimensions
SFH: National x 0.70 x 0.85
MFH: National x 0.80 x 0.85

CLIMATIC ZONE A	SFH			MFH		
	# bldgs	Floor area in 1000 m^2		# bldgs	Floor area in 1000 m^2	
		National	TABULA ref		National	TABULA ref
pre-1980	256,126	24,010.738	14,286.389	14,815	2,987.390	2,031.425
1980 – 2000	101,543	16,535.476	9,838.608	10,851	6,309.271	4,290.304
2000 -	76,012	13,226.145	7,869.556	55,629	6,119.221	4,161.070
TOTAL	433,681	53,772.359	31,994.553	81,295	15,415.882	10,482.800

CLIMATIC ZONE B	SFH			MFH		
	# bldgs	Floor area in 1000 m^2		# bldgs	Floor area in 1000 m^2	
		National	TABULA ref		National	TABULA ref
pre-1980	589,178	59,222.241	35,237.233	134,423	52,591.634	35,762.311
1980 – 2000	187,005	30,665.932	18,246.229	51,239	38,614.093	26,257.583
2000 -	99,873	18,726.225	11,142.104	44,862	35,037.293	23,825.359
TOTAL	876,056	108,614.398	64,625.567	230,524	126,243.020	85,845.254

CLIMATIC ZONE C	SFH			MFH		
	# bldgs	Floor area in 1000 m^2		# bldgs	Floor area in 1000 m^2	
		National	TABULA ref		National	TABULA ref
pre-1980	471,650	45,250.489	26,924.041	42,918	18,500.091	12,580.062
1980 – 2000	141,938	23,051.218	13,715.475	27,375	19,554.006	13,296.724
2000 -	88,118	16,257.744	9,673.358	25,080	18,483.636	12,568.873
TOTAL	701,706	84,559.451	50,312.873	95,373	56,537.733	38,445.658

CLIMATIC ZONE D	SFH			MFH		
	# bldgs	Floor area in 1000 m^2		# bldgs	Floor area in 1000 m^2	
		National	TABULA ref		National (*)	TABULA ref
pre-1980	54,688	5,193.004	3,089.837	2,511	527.809	358.910
1980 – 2000	20,237	3,184.299	1,894.658	1,978	1,248.487	848.971
2000 -	14,348	2,475.032	1,472.644	1,764	1,145.100	778.668
TOTAL	89,273	10,852.335	6,457.139	6,253	2,921.396	1,986.549

NOTE: Officially reported floor areas (tabulated under “National”) refer to total (gross) floor areas measured using external dimensions. These include non-heated areas (basements, corridors, stairwells etc.). In order to convert this information to the TABULA reference areas it was necessary to make an assumption of the average percentage of the total area that corresponds to the heated floor area in SFH and MFH buildings. In collaboration with the NAG the percentages 70% and 80% were adopted for SFH and MFH buildings respectively.

Statistic S-1.2.2: Information on insulation level and window types

(no common template)

S-1.2.2.1: Number of buildings with non-insulated walls [2]

Building classes	Climatic zone A	Climatic zone B	Climatic zone C	Climatic zone D	Total
SFH					
pre-1980	256,126	589,178	471,650	54,688	1,371,642
1980 – 2000	10,595	25,262	17,659	2,353	55,869
2000 - ..	0	0	0	0	0
MFH					
pre-1980	14,815	134,423	42,918	2,511	194,667
1980 – 2000	1,097	5,236	2,707	196	9,236
2000 - ..	0	0	0	0	0

S-1.2.2.1a: Percentage of buildings with non-insulated walls [2]

Building classes	Climatic zone A	Climatic zone B	Climatic zone C	Climatic zone D	Total
SFH					
pre-1980	100%	100%	100%	100%	100%
1980 – 2000	10.4%	13.5%	12.4%	11.6%	12.4%
2000 - ..	0	0	0	0	0
MFH					
pre-1980	100%	100%	100%	100%	100%
1980 – 2000	10.1%	10.2%	9.9%	9.9%	10.1%
2000 - ..	0	0	0	0	0

S-1.2.2.2: Number of buildings with non-insulated roofs [2]

Building classes	Climatic zone A	Climatic zone B	Climatic zone C	Climatic zone D	Total
SFH					
pre-1980	179,288	412,425	330,155	38,281	960,149
1980 – 2000	0	0	0	0	0
2000 - ..	0	0	0	0	0
MFH					
pre-1980	10,370	94,096	30,042	1,758	136,267
1980 – 2000	0	0	0	0	0
2000 - ..	0	0	0	0	0

S-1.2.2.2a: Percentage of buildings with non-insulated roofs [2]

Building classes	Climatic zone A	Climatic zone B	Climatic zone C	Climatic zone D	Total
SFH					
pre-1980	69.9%	70.0%	70.0%	69.9%	69.9%
1980 – 2000	0	0	0	0	0
2000 - ..	0	0	0	0	0
MFH					
pre-1980	69.9%	69.9%	69.9%	70.0%	70.0%
1980 – 2000	0	0	0	0	0
2000 - ..	0	0	0	0	0

S-1.2.2.2: Number of buildings with partly insulated walls [2]

Building classes	Climatic zone A	Climatic zone B	Climatic zone C	Climatic zone D	Total
SFH					
pre-1980	0	0	0	0	0
1980 – 2000	3,532	8,421	5,886	784	18,623
2000 - ..	0	0	0	0	0
MFH					
pre-1980	0	0	0	0	0
1980 – 2000	366	1,745	902	65	3,079
2000 - ..	0	0	0	0	0

S-1.2.2.2a: Percentage of buildings with partly insulated walls [2]

Building classes	Climatic zone A	Climatic zone B	Climatic zone C	Climatic zone D	Total
SFH					
pre-1980	0	0	0	0	0
1980 – 2000	3.4%	4.5%	4.1%	3.8%	4.1%
2000 - ..	0	0	0	0	0
MFH					
pre-1980	0	0	0	0	0
1980 – 2000	3.3%	3.4%	3.3%	3.3%	3.4%
2000 - ..	0	0	0	0	0

S-1.2.2.3: Number of buildings with partly insulated roofs [2]

Building classes	Climatic zone A	Climatic zone B	Climatic zone C	Climatic zone D	Total
SFH					
pre-1980	17,929	41,242	33,015	3,828	96,015
1980 – 2000	3,532	8,421	5,886	784	18,623
2000 - ..	0	0	0	0	0
MFH					
pre-1980	1,037	9,410	3,004	176	13,627
1980 – 2000	366	1,745	902	65	3,079
2000 - ..	0	0	0	0	0

S-1.2.2.3a: Percentage of buildings with partly insulated roofs [2]

Building classes	Climatic zone A	Climatic zone B	Climatic zone C	Climatic zone D	Total
SFH					
pre-1980	7.0%	6.9%	6.9%	6.9%	7.0%
1980 – 2000	3.5%	4.5%	4.1%	3.8%	4.1%
2000 - ..	0	0	0	0	0
MFH					
pre-1980	6.9%	7.0%	6.9%	7.0%	7.0%
1980 – 2000	3.3%	3.4%	3.3%	3.3%	3.4%
2000 - ..	0	0	0	0	0

Statistic S-2.1: Centralization of the heat supply (for space heating)

Percentages related to *<u>number of buildings</u>* *per age band / climatic zone / type [2]*

Climatic zone A	SFH			MFH		
	pre-1980	**1980-2000**	**2000-2010**	**pre-1980**	**1980-2000**	**2000-2010**
Room heating systems	84 %	14 %		90 %	14 %	
Central heating systems	16 %	86 %	100 %	10 %	86 %	100 %
District heating						
	100 %	100 %	100 %	100 %	100 %	100 %
Climatic zone B						
Room heating systems	9 %			51 %		
Central heating systems	81 %	100 %	100 %	49 %	100 %	100 %
District heating						
	100 %	100 %	100 %	100 %	100 %	100 %
Climatic zone C						
Room heating systems	57 %			36 %		
Central heating systems	43 %	100 %	100 %	64 %	100 %	100 %
District heating						
	100 %	100 %	100 %	100 %	100 %	100 %
Climatic zone D						
Room heating systems	62 %	10%		21 %	10%	
Central heating systems	38%	90 %	95 %	79 %	90 %	100 %
District heating			5 %			5 %
	100 %	100 %	100 %	100 %	100 %	100 %

Statistic S-2.3: Heat generation (for space heating)

Percentages related to *<u>number of buildings</u>* *with central heating systems [2]*

	SFH			MFH		
	pre-1980	**1980-2000**	**2000-2010**	**pre-1980**	**1980-2000**	**2000-2010**
Old boilers	70 %	10 %	0	70 %	10 %	0
New boilers	30 %	90 %	100 %	30%	90 %	100 %
	100 %	100 %	100 %	100 %	100 %	100 %

➢ *Alternatively:*
Percentages related to <u>number of buildings</u> per age band / energy carrier / type. ([4], used in the National Balance calculations)

	SFH			**MFH**		
	pre-1980	**1980-2000**	**2000-2010**	**pre-1980**	**1980-2000**	**2000-2010**
New Oil boiler	40 %	41 %	40 %	41 %	45 %	44 %
Old Oil Boiler	34 %	30 %	19 %	44 %	37 %	31 %
New Natural gas boiler		2 %	5 %	2 %	3 %	6 %
Old Natural gas boiler		1 %	4 %		1 %	2 %
Stoves_gas/oil fuel	7 %	10 %	15 %	4 %	7 %	11 %
Open fire	5 %	4 %	2 %			
Heat pumps	1 %	7 %	12 %	1 %	3 %	5 %
Electrical space heaters	13 %	5 %	3 %	8 %	4 %	1 %
	100 %	100 %	100 %	100 %	100 %	100 %

Statistic S-2.5: Heat generation (DHW)

Percentages related to <u>number of buildings</u> per age band / energy carrier / type. Main heat generation systems (solar systems are considered in S-2.6)[4]

	SFH			**MFH**		
	pre-1980	**1980-2000**	**2000-2010**	**pre-1980**	**1980-2000**	**2000-2010**
Oil boiler, well maintained	1 %	3 %	4 %	1 %	3 %	4 %
Oil Boiler, poorly maintained / poorly insulated	3 %	2 %	2 %	1 %	1 %	4 %
Oil boiler, well maintained+electric immersion resistance	5 %	11 %	18 %	1 %	4 %	8 %
Oil boiler, poorly maintained+electric immersion resistance	4 %	8 %	9 %	1 %	3 %	6 %
Instantaneous water heaters	6 %	10 %	7 %	7 %	7 %	6 %
Electric water heaters	81 %	66 %	60 %	89 %	82 %	72 %
	100 %	100 %	100 %	100 %	100 %	100 %

Statistic S-2.6: Solar thermal systems

Percentages related to <u>dwellings</u> in SFH / MFH buildings [2]

	SFH / MFH		
	pre-1980	**1980-2000**	**2000-2010**
No solar thermal systems	80%	64%	50%
Solar system for hot water	20%	36%	50%
	100 %	100 %	100 %

Statistic S-2.8: Air conditioning systems

S-2.8a: Percentage related to dwellings in SFH and MFH buildings [2]

	SFH / MFH			
Climatic Zones	**A**	**B**	**C**	**D**
Split units	50 %	55 %	40 %	20 %
No local cooling systems	50 %	45 %	60 %	80 %
	100 %	100 %	100 %	100 %

- *Alternatively:*

S-2.8b: Number of dwellings per age band / climatic zone / type [2]

	SFH			MFH		
	pre-1980	**1980-2000**	**2000-2010**	**pre-1980**	**1980-2000**	**2000-2010**
Climatic zone A						
Split units	139,695	59,377	44,087	22,980	30,495	27,815
No local cooling systems	142,784	59,378	44,087	22,980	30,495	27,814
Climatic zone B						
Split units	375,619	123,167	68,663	445,006	207,275	175,186
No local cooling systems	321,113	100,772	56,179	364,096	169,589	143,335
Climatic zone C						
Split units	209,947	66,702	43,354	113,847	75,895	67,213
No local cooling systems	322,412	100,053	65,031	170,770	113,844	100,820
Climatic zone D						
Split units	12,089	4,595	3,300	1,624	2,433	2,082
No local cooling systems	49,005	18,378	13,200	6,496	9,734	8,328

Statistic S-2.9: Control of central heating systems

S-2.9a: Percentages related to number of buildings with central heating per age band. [2]

	SFH / MFH		
	pre-1980	**1980-2000**	**2000-2010**
Outdoor temperature compensation for ON/OFF control of boiler	30 %	70 %	100 %
Indoor air temperature controller	10 %	80 %	100 %

- *Alternatively:*

S-2.9b: Percentages related to number of buildings per age band / climatic zone / type [2]

	SFH			MFH		
	pre-1980	**1980-2000**	**2000-2010**	**pre-1980**	**1980-2000**	**2000-2010**
Climatic zone A						
Outdoor temperature compensation	5 %	60 %	100 %	3 %	60 %	100 %

for ON/OFF control of boiler						
Indoor air temperature controller	2 %	69 %	100 %	1 %	69 %	100 %
Climatic zone B						
Outdoor temperature compensation for ON/OFF control of boiler	24 %	70 %	100 %	15 %	70 %	100 %
Indoor air temperature controller	8 %	80 %	100 %	5 %	80 %	100 %
Climatic zone C						
Outdoor temperature compensation for ON/OFF control of boiler	13 %	70 %	100 %	19 %	70 %	100 %
Indoor air temperature controller	4 %	80 %	100 %	6	80 %	100 %
Climatic zone D						
Outdoor temperature compensation for ON/OFF control of boiler	11 %	63 %	95 %	24 %	63 %	100 %
Indoor air temperature controller	4 %	72 %	95 %	8 %	72 %	100 %

Appendix II: Weighting factors

(energy balance model)

CLIMATIC ZONE : A (NI: non-insulated bldgs PI: partly insulated bldgs I: insulated[*] bldgs)

(%) of bldgs in the specified time band	**SINGLE FAMILY HOUSES**									**MULTI FAMILY HOUSES**								
	prior to 1980			**1981 – 2000**			**2001 - 2010**			**prior to 1980**			**1981 – 2000**			**2001 - 2010**		
	NI	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**
	82	15	3	30	50	20	10	20	70	95	5	0	20	70	10	5	20	75
Walls																		
Brickwork	50	30	0	20	25	0	10	5	0	40	5	0	20	10	0	10	5	0
Double brickwork	20	70	100	70	70	100	10	90	95	60	95	0	80	90	100	90	95	100
Stone walls	30	0	0	10	5	0	80	5	5	0	0	0	0	0	0	0	0	0
Roofs																		
Conventional flat roof	38			35			30			98			98			98		
Flat roof under not insulated pitched roof	35			40			45			2			2			2		
Tilted reinforced concrete slab with ceramic tiles	2			5			5			0			0			0		
Wooden beams with ceramic tiles	25			20			20			0			0			0		
Floors																		
Pilotis	2			5			3			5			45			40		
Slab on grade	88			60			17			30			15			10		
Slab over non-heated space	10			35			80			65			40			60		
Windows																		
Single glazed – wooden frame	50			10			2			60			10			2		
Single glazed – metal frame (aluminum)	25			30			3			34			35			10		
Double glazed – wooden frame	3			3			10			1			5			5		
Double glazed – metal frame (aluminum)	20			55			80			5			48			81		
Double glazed – synthetic frame - PVC	2			2			5			0			2			2		

(*) : according to the Hellenic Thermal Insulation Regulation (enforced in 1980, replaced by KENAK in April 2010)

CLIMATIC ZONE : B (NI: non-insulated bldgs PI: partly insulated bldgs I: insulated* bldgs)

(%) of bldgs in the specified time band	**SINGLE FAMILY HOUSES**									**MULTI FAMILY HOUSES**								
	prior to 1980			**1981 – 2000**			**2001 - 2010**			**prior to 1980**			**1981 – 2000**			**2001 - 2010**		
	NI	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**
	70	25	5	10	60	30	5	10	85	90	9	1	20	60	20	1	20	79
Walls																		
Brickwork	30	30	0	10	10	0	10	5	0	30	10	0	20	10	0	10	5	0
Double brickwork	50	60	100	80	90	100	10	90	95	70	90	100	80	90	100	90	95	100
Stone walls	20	10	0	10	0	0	80	5	5	0	0	0	0	0	0	0	0	0
Roofs																		
Conventional flat roof	60			60			50			98			98			98		
Flat roof under not insulated pitched roof	10			20			25			2			2			2		
Tilted reinforced concrete slab with ceramic tiles	5			15			22			0			0			0		
Wooden beams with ceramic tiles	25			5			3			0			0			0		
Floors																		
Pilotis	2			2			0			5			60			70		
Slab on grade	78			60			20			10			5			2		
Slab over non-heated space	20			38			80			85			35			28		
Windows																		
Single glazed – wooden frame	45			10			0			55			5			2		
Single glazed – metal frame (aluminum)	20			20			5			30			25			10		
Double glazed – wooden frame	5			10			15			5			5			5		
Double glazed – metal frame (aluminum)	25			55			70			10			53			81		
Double glazed – synthetic frame - PVC	5			5			10			0			2			2		

(*) : according to the Hellenic Thermal Insulation Regulation (enforced in 1980, replaced by KENAK in April 2010)

CLIMATIC ZONE : C (NI: non-insulated bldgs PI: partly insulated bldgs I: insulated* bldgs)

(%) of bldgs in the specified time band	**SINGLE FAMILY HOUSES**									**MULTI FAMILY HOUSES**								
	prior to 1980			**1981 – 2000**			**2001 - 2010**			**prior to 1980**			**1981 – 2000**			**2001 - 2010**		
	NI	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**
	70	25	5	10	60	30	5	10	85	90	9	1	20	60	20	1	20	79
Walls																		
Brickwork	30	30	0	10	10	0	10	5	0	30	10	0	20	10	0	10	5	0
Double brickwork	50	60	100	80	90	100	10	90	95	70	90	100	80	90	100	90	95	100
Stone walls	20	10	0	10	0	0	80	5	5	0	0	0	0	0	0	0	0	0
Roofs																		
Conventional flat roof	60			60			50			98			98			98		
Flat roof under not insulated pitched roof	10			20			25			2			2			2		
Tilted reinforced concrete slab with ceramic tiles	5			15			22			0			0			0		
Wooden beams with ceramic tiles	25			5			3			0			0			0		
Floors																		
Pilotis	2			2			0			5			60			70		
Slab on grade	78			60			20			10			5			2		
Slab over non-heated space	20			38			80			85			35			28		
Windows																		
Single glazed – wooden frame	45			10			0			55			5			2		
Single glazed – metal frame (aluminum)	20			20			5			30			25			10		
Double glazed – wooden frame	5			10			15			5			5			5		
Double glazed – metal frame (aluminum)	25			55			70			10			53			81		
Double glazed – synthetic frame - PVC	5			5			10			0			2			2		

(*) : according to the Hellenic Thermal Insulation Regulation (enforced in 1980, replaced by KENAK in April 2010)

CLIMATIC ZONE : D (NI: non-insulated bldgs PI: partly insulated bldgs I: insulated* bldgs)

(%) of bldgs in the specified time band	**SINGLE FAMILY HOUSES**									**MULTI FAMILY HOUSES**								
	prior to 1980			**1981 – 2000**			**2001 - 2010**			**prior to 1980**			**1981 – 2000**			**2001 - 2010**		
	NI	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**	**NI**	**PI**	**I**
	75	20	5	10	65	25	5	10	85	85	14	1	15	65	20	1	20	79
Walls																		
Brickwork	30	20	0	10	5	0	10	10	0	40	10	0	30	10	0	10	5	0
Double brickwork	10	30	100	60	75	95	10	70	90	60	90	100	70	90	100	90	95	100
Stone walls	60	50	0	30	20	5	80	20	10	0	0	0	0	0	0	0	0	0
Roofs																		
Conventional flat roof	28			20			20			95			85			75		
Flat roof under not insulated pitched roof	25			50			60			5			13			23		
Tilted reinforced concrete slab with ceramic tiles	2			15			10			0			2			2		
Wooden beams with ceramic tiles	45			15			10			0			0			0		
Floors																		
Pilotis	1			2			2			2			55			60		
Slab on grade	90			50			18			28			10			5		
Slab over non-heated space	9			48			80			70			35			35		
Windows																		
Single glazed – wooden frame	55			5			0			60			5			2		
Single glazed – metal frame (aluminum)	15			15			5			25			20			10		
Double glazed – wooden frame	10			15			20			5			10			10		
Double glazed – metal frame (aluminum)	18			60			70			10			63			76		
Double glazed – synthetic frame - PVC	2			5			5			0			2			2		

(*) : according to the Hellenic Thermal Insulation Regulation (enforced in 1980, replaced by KENAK in April 2010)

Appendix III: Sample Brochures

5	**Single Family House** *(GR-ZONEB-SFH-02)*	
Age class	1 **2** 3	
Climatic zone	A **B** C D	
Heated area (m2)	380	
Volume (m3)	1100	

Description

Free standing single family house, with four exposed facades. Some free surrounding space. The long axis of the building is oriented SW-NE.

Construction

Walls	Insulated (3cm), brick with concrete rendering
Load bearing	Not insulated
Roof	Insulated (3cm), tilted, concrete covered with ceramic tiles.
Windows	Double glazed with aluminium frames.
Shutters	External aluminium shutters
Floor	Non insulated, in contact with the ground

Thermal transmittance (W/m^{2}K)

Wall	0.91 / 3.4
Roof	1.05
Floor	3.7
Windows	4.1
g-windows (-)	0.51

Expenditure coefficients

	SH	DHW
Generation	1.25	1.25
Storage	--	1.05
Distribution	1.06	1.19

Systems

Generation	Central oil boiler, well thermally insulated, well maintained, with outdoor temperature compensation.
Distribution	Double pipe, insulated
Solar system	-
DHW	Central boiler. Additional electric resistance in the hot storage tank (stand-by)

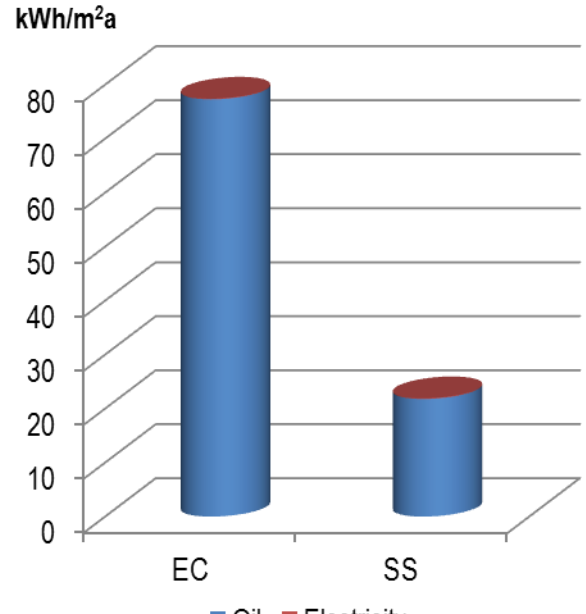
Annual Energy Performance

Demand	50.9 kWh/m^2
Thermal energy	77.3 kWh/m^2
Electricity	0.1 kWh/m^2
Primary energy	85.7 kWh/m^2
CO_2 emissions	7.8 tn
Fuel (oil)	2899 lt
Electrical	38 kWh
Operational cost	8.2 €/m^2

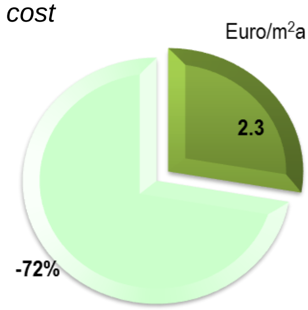
ENERGY SAVING INTERVENTIONS

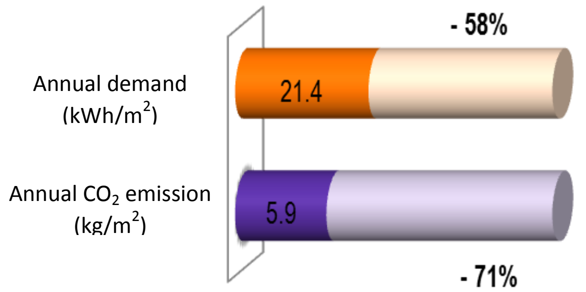
STANDARD SCENARIO	Investment cost: €€€€	SPBP : >15 years
ENVELOPE	Add insulation on walls (8cm, U=0.3 / 0.5 W/m^{2}K) and roof (4cm, U=0.43 W/m^{2}K). Replace windows with double glazed windows (U=3 W/m^{2}K, g=0.48)	
SYSTEMS	New oil boiler (η= 0.93)	
RES	Install 3 m^2 solar collectors for DHW (60% of DHW needs)	

Energy carriers



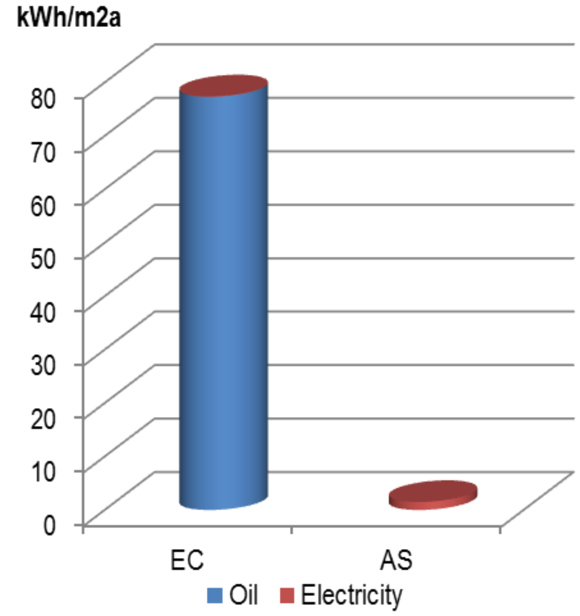
Operational cost



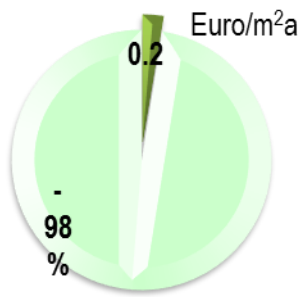


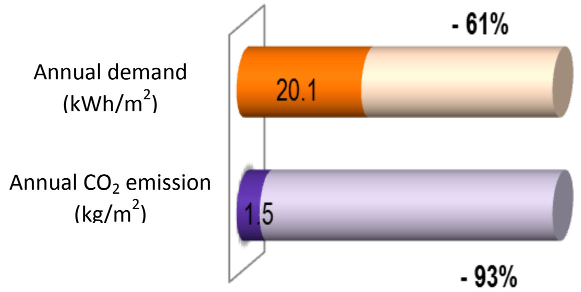
AMBITIOUS SCENARIO	Investment cost: €€€€€	SPBP : >15 years
ENVELOPE	Add insulation on walls (8cm, U=0.3 / 0.5 W/m^{2}K) and roof (4cm, U=0.43 W/m^{2}K) Replace windows with double glazed low-e windows with aluminium frames with thermal break (U=2.6 W/m^{2}K, g=0.48)	
SYSTEMS	Replace existing oil boiler with a geothermal heat pump (COP=6.2) with outdoor temperature compensation and automations	
RES	Install 12 m^2 solar collectors (60% space heating demand and 100% DHW needs)	

Energy carriers



Operational cost





17	**Multi Family House** *(GR-ZONEB-MFH-02)*	
Age class	1 **2** 3	
Climatic zone	A **B** C D	
Heated area (m2)	1356	
Volume (m3)	4610	

Description

Free standing building, with four exposed facades (4 floors). A total of 12 apartments. The long axis of the building is oriented SW-NE. Sub-urban area.

Construction

Walls	Not insulated. Brick with concrete rendering.
Load bearing	Not insulated
Roof	Not insulated, flat. Concrete.
Windows	Single glazed with metal frames
Shutters	External plastic shutters
Floor	Not insulated, pilotis.

Thermal transmittance (W/m^{2}K)

Wall	2.2 / 3.4
Roof	3.1
Floor	2.75
Windows	6.1
g-windows (-)	0.58

Expenditure coefficients

	SH	DHW
Generation	1.25	1.00
Storage	--	1.00
Distribution	1.14	1.02

Systems

Generation	Central oil boiler, well thermally insulated, well maintained.
Distribution	Single pipe, well insulated.
Solar system	21 m^2
DHW	Electric heaters

Annual Energy Performance

Demand	92.6 kWh/m^2
Thermal energy	137.6 kWh/m^2
Electricity	6.7 kWh/m^2
Primary energy	171.6 kWh/m^2
CO_2 emissions	58.2 tn
Fuel (oil)	184151lt
Electrical	9085 kWh
Operational cost	15.6 €/m^2

ENERGY SAVING INTERVENTIONS

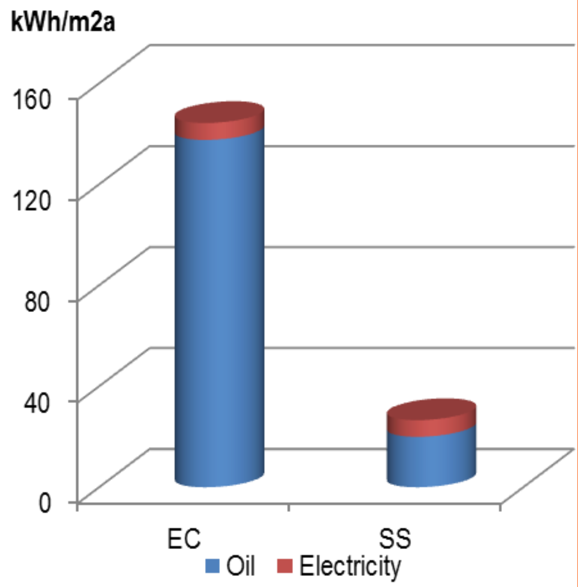
STANDARD SCENARIO

Investment cost :

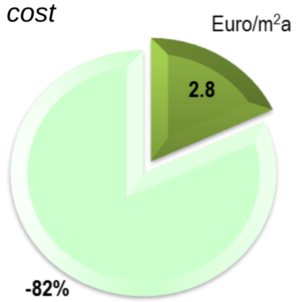
SPBP : 5-10 years

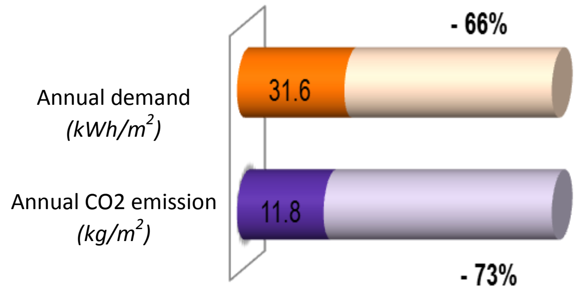
ENVELOPE	Add insulation on walls (8cm, U=0.46 / 0.5 W/m^{2}K), roof (9cm, U=0.44 W/m^{2}K) and pilotis (9cm, U=0.44 W/m^{2}K) Replace windows with double glazed windows (U=3 W/m^{2}K, g=0.54), reduced infiltration
SYSTEMS	New oil boiler (η= 0.934) with outdoor compensation system
RES	-

Energy carriers



Operational cost





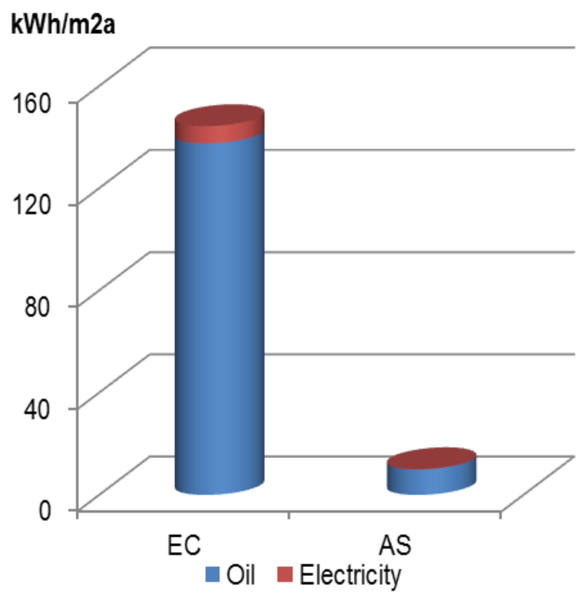
AMBITIOUS SCENARIO

Investment cost :

SPBP : 10-15 years

ENVELOPE	Add insulation on walls (8cm, U=0.46 / 0.5 W/m^{2}K), roof (9cm, U=0.44 W/m^{2}K) and pilotis (9cm, U=0.44 W/m^{2}K) Replace windows with double glazed low-e windows with aluminium frames with thermal break (U=2.6 W/m^{2}K, g=0.48), reduced infiltration
SYSTEMS	New oil boiler (η= 0.934) with outdoor compensation system and controls
RES	Install 48 m^2 solar collectors (65% space heating demand and 100% DHW needs)

Energy carriers



Operational cost