D2.1c Simulation Results of Reference Buildings

Development of Systemic Packages for Deep Energy Renovation of Residential and Tertiary Buildings including Envelope and Systems

iNSPiRe

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iNSPiRe
Systemic energy renovation of buildings

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1 Executive Summary

This report is the third part of the deliverable D2.1, where the other two parts report on the energy consumption in the building stock in Europe based on the available energy statistics (D2.1a) and the energy policies related to buildings (D2.1b).

The aim of this report is to give complementary information about the heating and cooling demands of residential and office buildings based on simulations, so that the many gaps in the energy statistics can be filled. The methodology results in a **complete and consistent overview of the heating and cooling demands in residential and office buildings** for seven different climate regions **covering the whole of the EU** and six different periods of construction covering pre-1945 to post 2000. In addition the data for the residential building stock is split into single family houses, small and large multifamily houses, while for offices the results are given for low and high rise offices with 6 or 12 office units per floor.

The simulation models have been benchmarked (calibrated) against the energy statistics for each of the seven climate regions based on the aggregated data for the whole residential building stock and then for the office building stock in that climate region. The methodology derives the aggregated average using weighted averages of data split into periods of construction and typology for both energy statistics and simulation results. The weighting is done based on heated and cooled floor area. As nearly all of the energy statistics are given in terms of consumption, while simulation results were calculated as demand, the consumption data were converted to demand data. One fixed conversion factor was used for heating (0.8) and one for cooling (2.5). One simulation parameter, the heating or cooling set temperature, was varied so that the aggregated simulation result was the same as that for the demand derived from the energy statistics. The calibrated models were then used to derive the average heating and cooling demands of the building stock in the seven climate regions.

The methodology has a number of uncertainties, both in terms of the energy statistics as well as in terms of the simplifications and assumptions in the simulation models. During the calibration process a number of inconsistencies have been detected for individual countries and climate regions in terms of energy use statistic data. The resulting diagrams showing heating and cooling demand across the whole EU are thus consistent with the energy statistics for the climate regions. However, they show average values and large variations can be found between individual buildings of the same age and size within a given climate zone.

Beside the building stock survey completion and statistic data quality assessment, the work is also the basis for the definition of suitable Energy Renovation Packages and Products within the iNSPiRe project. The simulation results will be used to identify which building typologies, periods of construction and climate region have the largest potential for impact on the European scenario. Such information will be used within the iNSPiRe project to define reference Target buildings, as virtual demonstration cases to prove the potential improvements and impacts following the renovation process of a given share of the European building stock.

2 Introduction

The D2.1a report, *Survey on the energy needs and architectural features of the EU building stock*, presents information about the residential and office building stock in the EU-27 countries, both separately and at EU-27 level. The information presented in D2.1a is based solely on statistics and other information collected during the literature survey. Not all the desired information related to the building stock was gathered from literature, mainly because the data was missing or unreliable. These "gaps" are being filled in using simulation work, which is covered in this report (D2.1c).

Two different types of simulation of buildings are accounted for within the project:

- Target buildings
- Reference buildings

Figure 1 summarises the difference between the uses of target and reference buildings within the project.

Target buildings are meant as Virtual-Demo buildings, whose purpose is to allow calculating the effect of a number of renovation actions (Renovation Packages) that cannot be verified otherwise on the three real demo buildings. As such, the target buildings are selected as "big fish" within the actual building stock. Target buildings are not described within this report.

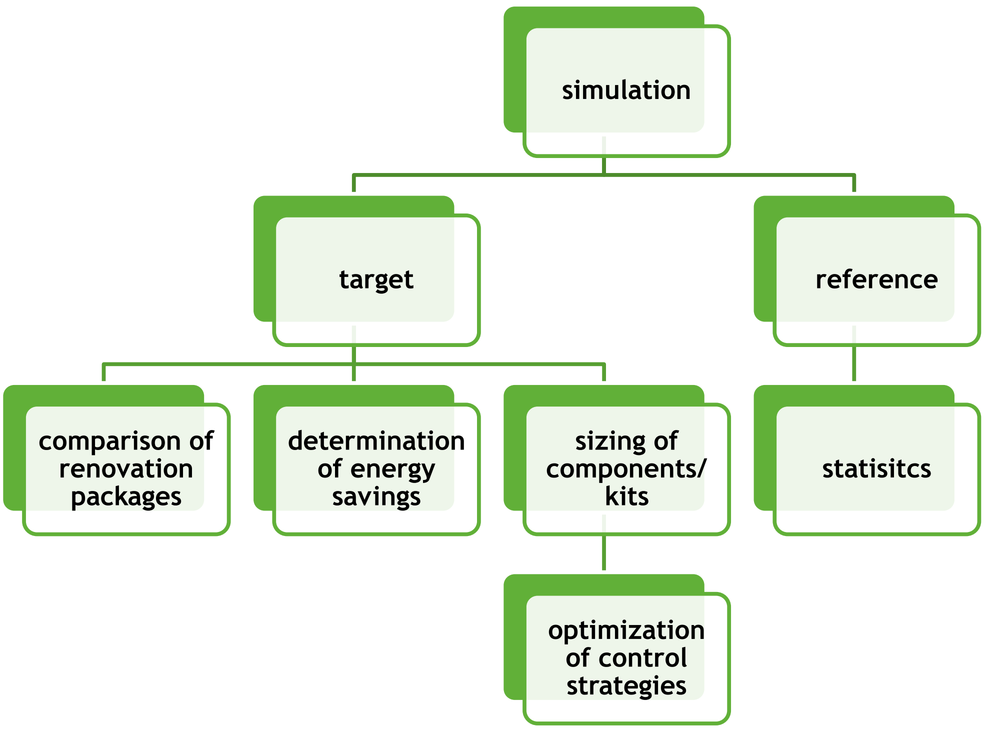


Figure 1 – Uses of target and reference buildings.

Reference buildings represent "average" buildings and are modelled/simulated to compliment the gaps in the database, specifically for heating and cooling energy demand. Chapter 6 of the D2.1a report summarises the reference buildings, for both residential and office sectors. The reference and target buildings have primarily been derived from looking at the statistics and identifying the constructions types which are typical:

- In the key years: 1945-1970 for residential and 1945-1980 in the office sector
- In the six most populated countries
- For the key typologies

Section 6.1 in D2.1a presents the three residential constructions selected (one single family house and two multi-family houses) as a starting point to elaborate the reference buildings used in this study, and section 6.2 covers the three for the office sector. For each buildings, the reasons for selection and details of the construction, materials and geometry are included.

The reference building models have been used to derive “average” heating and cooling consumption for the seven climate areas and six periods of construction defined within the project. This report defines these models and the methodology with which the results were derived (chapters 3), as well as the results themselves (chapter 4).

3 Reference building models and average demand assessment based on simulations

The reference building models are based on the representative building models in terms of building construction type and geometry. However, the construction has been modified so that the heat transmission coefficients U-values are those average values for the seven climates and six periods of construction defined in the project, according to the procedure reported in section 3.1 (see also D2.1a for more details).

The definition of the zones used as well as overall geometry are given in section 3.2.

The methodology to derive the average heating and cooling demands based on simulation work is reported in section 3.3.

Boundary conditions for the simulations (infiltrations and/or natural ventilation, shadings and occupancy profiles) are defined as in chapter 7. Simulations have been carried out in TRNSYS 17.

3.1 Derivation of construction for climates and periods of construction

External surfaces in the reference buildings models have been defined according to U-values derived from statistics (section 7.4). For each climate and each period of construction (from pre 1945 to post 2000) a U-value for roofs, walls, windows and floors has been calculated for both main categories, residential and office buildings. Limited information on the variation of U-values dependent on the typology has been found, therefore one value has been assumed for all types of residential buildings (SFH, s-MFH, l-MFH) and one value for the office buildings.

Consequently, “typical” wall constructions have been defined for each climate and building typology, according to literature and partners’ expertise, so as to obtain the needed U-value.

Figure 2 shows a part of the database that was created with all the construction details used in the reference building models. Afterwards, based on the TRNSYS material library and indication on wall construction, a stratigraphy for each climate and period has been defined; the layer thickness has been defined in order to achieve the U-value derived from the statistics.

For the windows, it has been necessary to create some fictive windows in order to reproduce the hypothetical common window for that climate and period. A frame ratio of 20% has been considered for the calculation of the U-frame. Window statistical values account for the whole window transmittance, while the material list provides only glass U-values. A frame resistance has been therefore calculated and inserted in the building models.

SFH_STU_1980-1990

	Material	λ [W/m]	l [m]	r [m²K/W]	REF value
EXTERNAL WALL	Resistance int surface			0.13	
	Lime cement mortar	0.87	0.015	0.000	
	Hollow block 3K 5	0.55	0.230	0.000	
	Polystyrene 040	0.04	0.040	0.000	
	Lime cement mortar	0.87	0.010	0.000	
	-	1.00		0.000	
	Resistance ext surface			0.04	
	Total U-value [W/m²K]		0.295	0.61	0.65
FLOORS	Resistance int surface			0.17	
	Timberfloor	0.14	0.015	0.000	
	Lw concrete 11	1.60	0.070	0.000	
	Polystyrene 040	0.04	0.035	0.000	
	Sand gravel	0.70	0.050	0.000	
	Concrete slab	1.13	0.180	0.000	
	Resistance ext surface			0.04	
	Total U-value [W/m²K]		0.35	0.67	0.69
ROOFS	Resistance int surface			0.10	
	Spruce/Pine	0.13	0.020	0.000	
	Mineral wool 040	0.04	0.080	0.000	
	Spruce/Pine	0.13	0.020	0.000	
	Roofdeck	0.14	0.010	0.000	
	-	1.00		0.000	
	Resistance ext surface			0.04	
	Total U-value [W/m²K]		0.13	0.39	0.42
WINDOW			g_{value}	U_{value} [W/m²K]	
	2-insulating glazing		0.755	2.83	2.92
		Rframe w	0.134	[(m².K)/W]	
		1/Rframe	26.8298	[kJ/(m2K)]	

s-MFH_STU_1980-1990

	Material	λ [W/m]	l [m]	r [m²K/W]	REF value
EXTERNAL WALL	Resistance int surface			0.13	
	Lime cement mortar	0.87	0.015	0.000	
	Hollow block 3K 5	0.55	0.230	0.000	
	Polystyrene 040	0.04	0.040	0.000	
	Lime cement mortar	0.87	0.010	0.000	
	-	1.00		0.000	
	Resistance ext surface			0.04	
	Total U-value [W/m²K]		0.295	0.61	0.65
FLOORS	Resistance int surface			0.17	
	Timberfloor	0.14	0.015	0.000	
	Lw concrete 11	1.60	0.070	0.000	
	Polystyrene 040	0.04	0.035	0.000	
	Sand gravel	0.70	0.050	0.000	
	Concrete slab	1.13	0.180	0.000	
	Resistance ext surface			0.04	
	Total U-value [W/m²K]		0.35	0.67	0.69
ROOFS	Resistance int surface			0.10	
	Spruce/Pine	0.13	0.020	0.000	
	Mineral wool 040	0.04	0.080	0.000	
	Spruce/Pine	0.13	0.020	0.000	
	Roofdeck	0.14	0.010	0.000	
	-	1.00		0.000	
	Resistance ext surface			0.04	
	Total U-value [W/m²K]		0.13	0.39	0.42
WINDOW			g_{value}	U_{value} [W/m²K]	
	2-insulating glazing		0.755	2.83	2.92
		Rframe w	0.134	[(m².K)/W]	
		1/Rframe	26.8298	[kJ/(m2K)]	

l-MFH_STU_1980-1990

	Material	λ [W/m]	l [m]	r [m²K/W]	REF value
EXTERNAL WALL	Resistance int surface			0.13	
	Lime cement mortar	0.87	0.015	0.000	
	Lw concrete 11	1.60	0.200	0.000	
	Polystyrene 040	0.04	0.050	0.000	
	Lime cement mortar	0.87	0.010	0.000	
	- (dropdown: -, Perpendicular Air layer 10-20, Perpendicular Air layer 20-500, Horizontal Air layer 10-500, Concrete block, Concrete slab, Fibreglass, Foam insulation)	1.00		0.000	
	[illegible]			0.04	
	[illegible]		0.275	0.62	0.65
FLOORS	[illegible]			0.17	
	[illegible]	0.14	0.015	0.000	
	[illegible]	1.60	0.070	0.000	
	Polystyrene 040	0.04	0.035	0.000	
	Sand gravel	0.70	0.050	0.000	
	Concrete slab	1.13	0.180	0.000	
	Resistance ext surface			0.04	
	Total U-value [W/m²K]		0.35	0.67	0.69
ROOFS	Resistance int surface			0.10	
	Lime cement mortar	0.87	0.015	0.000	
	Concrete slab	1.13	0.250	0.000	
	Mineral wool 040	0.04	0.080	0.000	
	Bitumenroof	0.17	0.010	0.000	
	-	1.00		0.000	
	Resistance ext surface			0.04	
	Total U-value [W/m²K]		0.355	0.40	0.42
WINDOW			g_{value}	U_{value} [W/m²K]	
	2-insulating glazing		0.755	2.83	2.92
		Rframe w	0.134	[(m².K)/W]	
		1/Rframe	26.8298	[kJ/(m2K)]	

Office_STU_1980-1990

	Material	λ [W/m]	l [m]	r [m²K/W]	REF value
EXTERNAL WALL	Resistance int surface			0.13	
	Lime cement mortar	0.87	0.015	0.000	
	Lw concrete 11	1.60	0.230	0.000	
	Polystyrene 040	0.04	0.035	0.000	
	Lime cement mortar	0.87	0.010	0.000	
	-	1.00		0.000	
	Resistance ext surface			0.04	
	Total U-value [W/m²K]		0.29	0.80	0.80
FLOORS	Resistance int surface			0.17	
	Timberfloor	0.14	0.015	0.000	
	Lw concrete 11	1.60	0.070	0.000	
	Polystyrene 040	0.04	0.055	0.000	
	Sand gravel	0.70	0.050	0.000	
	Concrete slab	1.13	0.180	0.000	
	Resistance ext surface			0.00	
	Total U-value [W/m²K]		0.37	0.51	0.51
ROOFS	Resistance int surface			0.10	
	Lime cement mortar	0.87	0.015	0.000	
	Concrete slab	1.13	0.250	0.000	
	Mineral wool 040	0.04	0.060	0.000	
	Bitumenroof	0.17	0.010	0.000	
	-	1.00		0.000	
	Resistance ext surface			0.04	
	Total U-value [W/m²K]		0.335	0.50	0.48
WINDOW			g_{value}	U_{value} [W/m²K]	
	Sunguard Clear+		0.295	2.30	2.14
		Rframe w	0.501	[(m².K)/W]	
		1/Rframe	7.18757	[kJ/(m2K)]	

Figure 2 Example of a part of the database defining construction based on statistical U_{values} for climate and age. The section shown is for the climate of Stuttgart.

3.2 Models of Reference Buildings

3.2.1 Residential building - SFH

The SFH model has a fixed geometry for all the climates and periods of construction. It has been defined following the common characteristics for a European SFH. The building model is composed of two storeys with a total of 100 m² (therefore 2 zones are simulated); no balcony has been taken into account, only an overhang due to the roof has been modelled. The glazing ratio changes according to the façade orientation: in the south side it amounts to 20%, in the north side around 10% and in the east and west side around 12%.

Main geometrical features are reported in Table 1. Models for semi-detached and row houses have also been created by defining the wall in between dwellings as adiabatic.

3.2.2 Residential building - s-MFH

The second reference building typology represents multi-family houses with a small size base area (S/V= 0.61 to 0.46 assuming number of floors from 3 to 10, see Table 2). This reference building has two dwellings per floor and an individual staircase located inside the building envelope. The dwelling size is 50 m^2 and the number of floors varies from 3 to 7.

The building model includes two zones per dwelling, plus the staircase zone. Three floors have been simulated, and for buildings with more than 3 floors, the consumption of all intermediate floors is assumed to be the same as the mid-floor.

A glazing ratio of 20% in the north and south facades has been defined according to the most common s-MFHs.

3.2.3 Residential building - l-MFH

The third reference building represents larger multi-family houses with at least three floors and several dwellings per floor (therefore S/V= 0.42 to 0.26 assuming number of floors from 3 to 10, see Table 3). The dwellings are slightly larger than those in s-MFH: 65 m^2.

A seven zone building model was developed in TRNSYS. The building is simulated with three floors. Each floor has two zones and each zone includes three dwellings. The staircase is modelled as a separate zone.

The total specific heating and cooling demand of the building are varied in a post processing step by increasing the number of floors. The heating and cooling demand of every extra floor are taken to be equal to the simulated demands of the mid-floor.

3.2.4 Office building

In the office building model, six zones are considered: two mid-row office cells with one external wall and one cell in each corner of the building with two external walls. All internal walls are assumed to be adiabatic. The mid-row cells were multiplied in post-processing to obtain results for the whole building, and the number of floors was varied by multiplying results for the entire floor. All office cells are of the same size and shape. The main geometrical features of the model are reported in Table 4. The zone air capacity was incremented 10 times, to account for furniture inside the room.

Table 1 – SFH main geometrical features

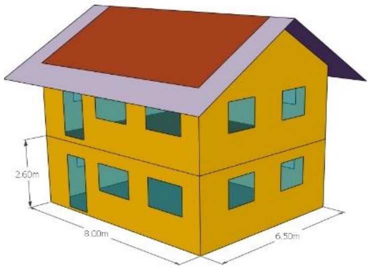
SFH	
Sketch and picture	-  
Number of floors	2
Living area per floor	50 m^2
Ceiling/floor height	2.5 / 3.0 m
Building width /depth	6.5 / 8.0 m
Roof type and materials	Tilted (30°) saddle roof
Glazing ratio	20 %

Table 2 – s-MFH main geometrical features

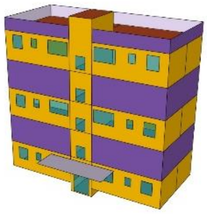
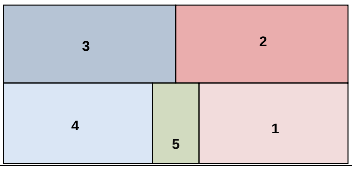
s-MFH	
Sketch and picture	 
Zones / floor	
Number of floors	3 to 7
Living area per dwelling	50 m^2
Number of dwellings per floor	2
Ceiling/floor height	2.5 / 3.0 m
Building width / depth	16.3 / 7.6 m
Roof type and materials	Flat concrete roof
Glazing ratio	20 %

Table 3 – I-MFH main geometrical features

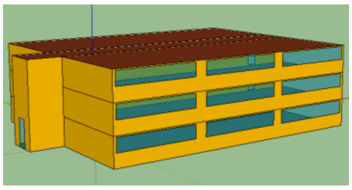
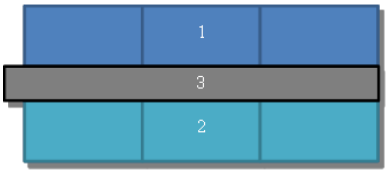
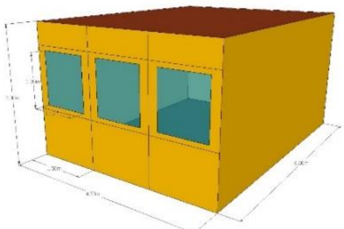
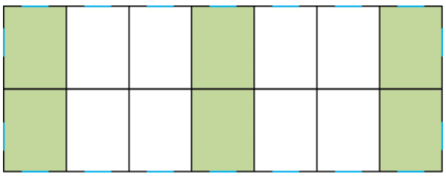
I-MFH	
Sketch and picture	 
Zones / floor	
Number of floors	3 to 7
Living area per dwelling	65 m^2
Number of dwellings per floor	6
Ceiling/floor height	2.5 / 3.0 m
Building width / depth	19.25 / 24 m
Roof type	Flat concrete roof
Glazing ratio	20 %

Table 4 – OFF main geometrical features

OFF	
Sketch and picture	 
Zoning	
Zone height/width/depth	3.0 / 4.5 / 6.0 m Ceiling height 2.8 m
Zone floor area / volume	27 m² / 81 m³
Office area per floor	6 to 12 offices per floor
Number of floors	3 to 7
Roof type	Flat concrete roof
Glazing ratio	30 % to 60%

3.3 Methodology to derive average energy demand based on simulations

The overall methodology used to derive simulation results calibrated (benchmarked) to the energy statistics followed the following steps:

1. Definition of typologies to be considered for residential and for office buildings and thereafter detailed building descriptions for these typologies (described in report D2.1a)
2. Definition of periods of construction (described in report D2.1a).
3. Definition of climate regions and which countries belong to these regions (described in report D2.1a but also summarised in section 7.3.3 of this report)
4. Derivation of average U-values for walls, floors, roofs and windows for each climate region and period of construction (described in report D2.1a and summarised in section 7.4 of this report).
5. Definition of boundary conditions for building simulations including infiltration, ventilation, shading and internal gains for both residential and office buildings and how these vary with climate region (see chapter 7).
6. Elaboration of a methodology to define detailed building constructions to match the average U-value for the climate regions and periods of construction (see section 3.1).
7. Implementation into the simulation tool (TRNSYS) of all variations of building typologies, periods of construction and climate with the relevant boundary conditions.
8. Sensitivity analysis of a number of parameters for which limited statistical data were available, such as ventilation, glazing ratio, number of occupants, number of floors (and in the case of offices, number of office units), orientation and set temperatures.
9. Choice of parameters to vary in order to calibrate simulation results to energy statistics.
10. Calculation of the weighted average simulated demand for heating and cooling at various set temperatures, using the statistical floor areas for the different typologies and periods of construction (see Figure 6)
11. Calculation of the weighted average consumption based on the statistics.
12. Calculation of the average demand derived from statistics by multiplying consumption with a conversion factor.
13. Calibration of simulated average demand for whole building stock by identifying the set temperatures for cooling and heating so that the simulated demands match those derived from statistics.
14. Analysis of the derived set temperatures and comparison with literature, and through this, identification of inconsistencies.
15. Simulation of the range of building typologies, periods of construction and climates to derive average heating cooling demands for this complete

range.

3.3.1 Detailed description of the steps followed

The methodology used to derive the heating and cooling consumption for residential buildings was based on the available statistics for the different types of buildings and the heated/cooled area of that type. For residential buildings there was sufficient data for most countries to derive a share of single family houses (SFH) and two sizes of multi-family houses (s-MFH and l-MFH) and thus all these three building types were used. For all of these there are additional variations for which information was available and that have been considered. For the SFH there are three variations: detached houses, where the building model has all outer walls connected to ambient; semi-detached, where one of the outer end walls is assumed connected to another identical building at the same temperature, and thus there is no heat transfer through the wall; and row houses, where the two end walls have no heat transfer to the assumed identical buildings either side. In addition statistics on the average heights of the buildings were retrieved along with the survey reported in D2.1a. Table 5 and Table 6 show the share of buildings by typology and age respectively.

Table 5 Share of m² for residential sector between category (SFH, s-MFH and l-MFH), typology within SFH (detached, semi-detached and row houses) and MFH (number of floors)

	Categories			SFH typology			MFH typology	
	SFH	**s-MFH**	**l-MFH**	**Detached**	**Semi-Detached**	**Row houses**	**low rise (<4 floors)**	**high rise (>4 floors)**
Southern Dry	38%	43%	19%	47%	36%	17%	47%	53%
Mediterranean	33%	46%	21%	54%	31%	15%	69%	31%
Southern Continental	67%	21%	12%	71%	20%	10%	64%	36%
Oceanic	85%	13%	2%	27%	48%	24%	86%	14%
Continental	63%	30%	7%	65%	22%	14%	81%	19%
Northern Continental	61%	16%	22%	84%	8%	8%	42%	58%
Nordic	55%	22%	23%	82%	12%	6%	49%	51%

Table 6 Share of m² for residential sector for construction period – SFH on the left and MFH on the right

	Period SFH						Period MFH					
	pre 1945	**1945-1970**	**1970-1980**	**1980-1990**	**1990-2000**	**post 2000**	**pre 1945**	**1945-1970**	**1970-1980**	**1980-1990**	**1990-2000**	**post 2000**
Southern Dry	1%	33%	20%	14%	17%	15%	0%	34%	21%	13%	16%	15%
Mediterranean	17%	39%	19%	13%	8%	4%	19%	40%	19%	12%	7%	4%
Southern Continental	27%	27%	14%	12%	12%	8%	27%	35%	14%	9%	9%	7%
Oceanic	30%	35%	13%	8%	7%	6%	31%	29%	17%	10%	8%	6%
Continental	24%	24%	15%	14%	17%	6%	26%	27%	16%	13%	14%	5%
Northern Continental	16%	39%	16%	12%	9%	8%	19%	35%	19%	14%	8%	5%
Nordic	18%	29%	20%	15%	8%	9%	22%	33%	18%	14%	7%	7%

As can be seen in Table 5, apart for Southern dry and Mediterranean countries, the residential building stock in EU-27 is largely dominated by SFHs. Again the majority are detached units, with exception to the Oceanic climate (mainly UK), where semi-detached and row houses come out. The typology share is to some extent mirrored in the average height of the residential constructions: the bulk is lower than 3 floors, whilst, in general, less than 30% of the buildings have more than 4 floors.

Within the simulation work, SFHs have been modelled with 2 floors; MFHs with 3, 5 and 7 floors have been considered. As a simplifying hypothesis, a direct relation has been stated between share of buildings with lower than 4 floors and the simulation results for 3 floors MFH, between 4-5 floors category and simulation results for 5 floors MFH, and between >5 floors category and simulation results for 7 floors MFH.

Additionally to this hypothesis a number of assumptions on simulations boundary conditions influence the outcome of the study. Among other, orientation of the building, number of persons occupying the dwelling, glazing ratio and set temperatures (in winter and summer operation) and infiltration rate.

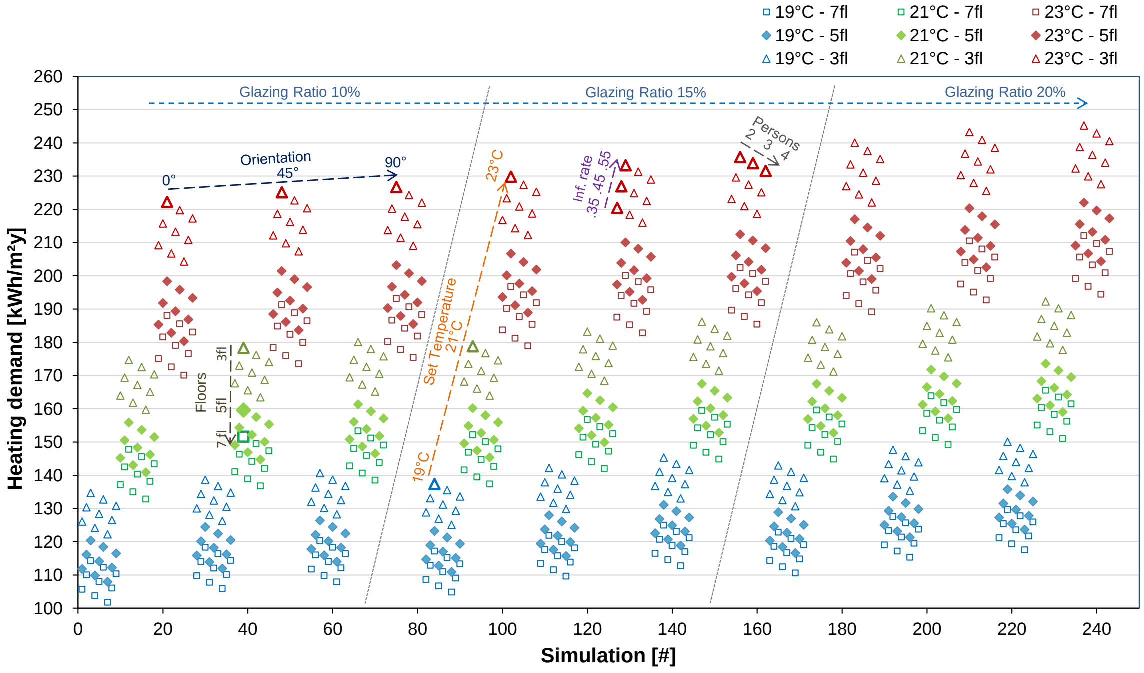


Figure 3 – Heating Demand variation depending on different parameters (orientation, number of floors, Infiltration rate, set temperature and persons).

As can be seen in Figure 3 (reported as an example of a vast parametric analysis), heating demand moves in a huge range depending on the combination of the above parameters. However, having set within reasonable intervals orientation, occupation (2 to 4 people per dwelling) and infiltration + natural ventilation rate (0.35 to 0.55 1/h), heating demand is changing only slightly (± 5 kWh/(m^{2}y)) when varying one parameter at a time. Therefore it was decided to use the mid-value of each parameter as a boundary to the simulations. Glazing ratio has also little effect on heating demand; in this case however, it was decided to use the 20% value, since it is believed to be representing of the actual average construction typology in Europe. A larger influence is due to set temperatures and number of floors (i.e. S/V ratio).

The charts in Figure 4 show the relative deviations of heating and cooling demands as functions of the mentioned parameters for a s-MFH of the period 1945-1970 located in Madrid. The set temperature is the most influencing variable also in terms of calculated cooling demand. In the latter case, also orientation plays a role, however there is no evidence that buildings are preferably oriented in one direction rather than another. A full parametric analysis was carried out to prove that the same results are obtained for all residential buildings typologies.

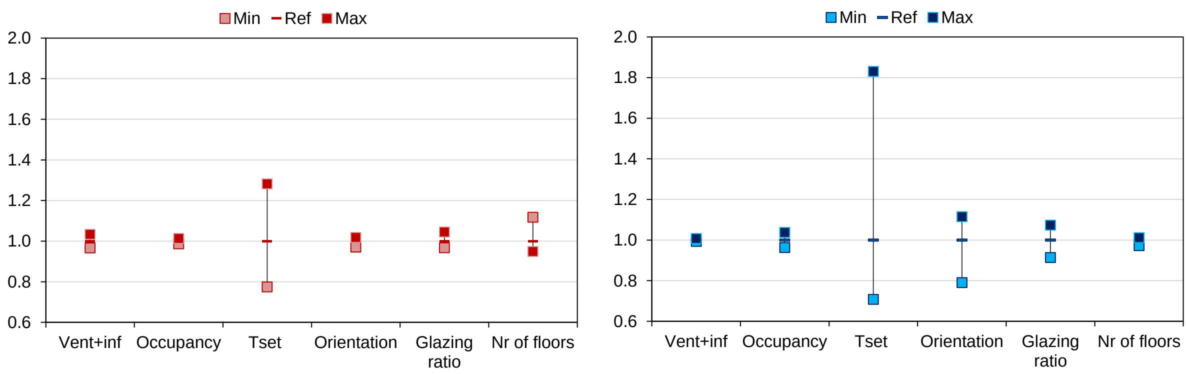


Figure 4 – Relative variation of Heating Demand (left) and Cooling Demand (right) for s-MFH (period 1945-1970 located in Madrid) as a function of the investigated parameters. Infiltration + natural ventilation 0.35-0.45 1/h, occupancy 2-4 people, set temperature heating 19-23°C, set temperature cooling 24-26°C, Orientation 0-90°, Glazing ratio 10-20%, number of floors 3-7.

For offices, a slightly different approach was used. A standard office unit (cell) was defined and then used in different numbers in an office floor. As well as for MFH, also offices were simulated with three floors: bottom, middle and top. For the bottom floor, heat transfer to the ground below was simulated, while for the ceiling it was assumed that there was no heat transfer to an identical floor above. For the top floor, heat transfer to the ambient was simulated through the ceiling while it was assumed that there was no heat transfer to the identical floor below. For the middle floor, there was no heat transfer to the identical floors above and below. Post processing was used to derive data for buildings with two or more floors by multiplying the results for the middle floor with the number of such floors. A similar approach was used to calculate the demand for offices with more than six office units in one floor, the results for the middle units was multiplied by the number of such units.

Table 7 reports on the share of office buildings ages and number of floors. **Low-rise** buildings with 2 or 3 floors mainly influence the results, while **high-rise** buildings, with more than 5 floors, account for only small percentages and are mainly located in large cities. Information on the share of low and high rise buildings has been found although for only few countries though. Buildings with 3 floors identify the category 2-3 floors in Table 7, 4 stories buildings represent the category 4-5 floors and 6 floors buildings characterize the last group.

The parametric analysis, performed by varying relevant boundary conditions within suitable ranges, gives the results reported in Figure 5. Heating demand is significantly influenced by set temperatures used, number of floors and offices per floor (S/V factor again), while glazing ratio plays a role for cooling. The shape of the building has a lower relevance on the cooling demand, while again set temperature, glazing ratio and therefore shading elements management, control the physics of the problem.

Table 7 Share of m² for office sector for construction period and number of floors

	OFFICES - Period						OFFICE - nr floors		
	pre 1945	1945-1970	1970-1980	1980-1990	1990-2000	post 2000	2-3	4-5	>5
Southern Dry	32%	21%	11%	11%	12%	12%	76%	13%	11%
Mediterranean	25%	20%	9%	14%	16%	16%	76%	13%	11%
Southern Continental	5%	53%	11%	10%	10%	12%	58%	38%	3%
Oceanic	24%	22%	13%	19%	9%	12%	93%	7%	0%
Continental	20%	16%	15%	12%	20%	17%	60%	20%	20%
Northern Continental	20%	22%	14%	15%	11%	19%	78%	20%	2%
Nordic	19%	30%	20%	16%	6%	9%	80%	10%	10%

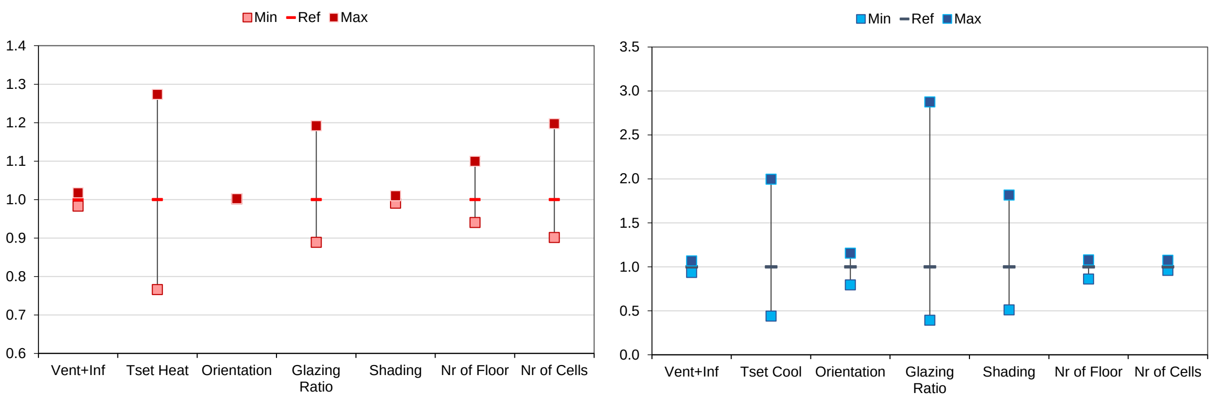


Figure 5 - Relative variation of Heating Demand (left) and Cooling Demand (right) for an Office building (period 1945-1970 located in London) within the investigated parameters ranges. Infiltration + natural ventilation 1.4-1.8 m³/h/person, set temperature heating 19-23°C, set temperature cooling 24-26°C, Glazing ratio 10-60%, number of floors 3-5, number of cells per floor 6, 12, 24.

As the reliability of the statistics is variable, depending on the country and the degree of detail of splitting the building stock into different categories, it was decided to avoid the comparison of the results by single building category and country. As an alternative, aggregated values were compared based on the idea that the uncertainty in such data should be lower than the uncertainty for individual data items.

To do that, the shares reported in Table 5 to Table 7 are used as weighing factors to express the relevance of the one typology, age and height on the others. In the residential sector, for a given climate and set temperature, the average specific demand is obtained as:

$$Dem_{avg} = \frac{\sum_{type}\left(\sum_{age}\left(\sum_{floors}(Dem_i)\cdot f_{floors}\right)\cdot f_{age}\right)\cdot f_{type}}{\sum Dem_i}$$

where Dem_{avg} is the average heating or cooling demand, *type* refers to the subdivision into SFH, s-MFH and l-MFH, and *f* factors represents the percentage shares. f_{floors} for single family houses refers to subdivision into detached, semi-detached and row houses.

In the office sector, since a subdivision into building typologies was not available, the calculation simplifies to:

$$Dem_{avg} = \frac{\sum_{age}\left(\sum_{floors}\left(\sum_{cells}(Dem_i) \cdot f_{floors}\right) \cdot f_{cells}\right) \cdot f_{age}}{\sum Dem_i}$$

The average demands can thus be compared to the averages obtained in D2.1a for each climate region (see also chapter 8.3). The simplest comparison is among simulated demands and demands found in the literature. However the latter is not always available and in many cases it was believed to be untrustworthy. Therefore additional/alternative terms of comparison were obtained by extrapolating demand values from consumptions, through conversion factors accounting for average boilers efficiencies (in case of heating consumption data = 0.8) and chillers energy efficiency ratios (in case of cooling consumption = 2.5 [9]).

Figure 6 shows the flow chart summarizing the methodology for deriving the figures later in this chapter showing the simulated heating and cooling consumption of the residential and the office building stock for the seven climates defined within the project.

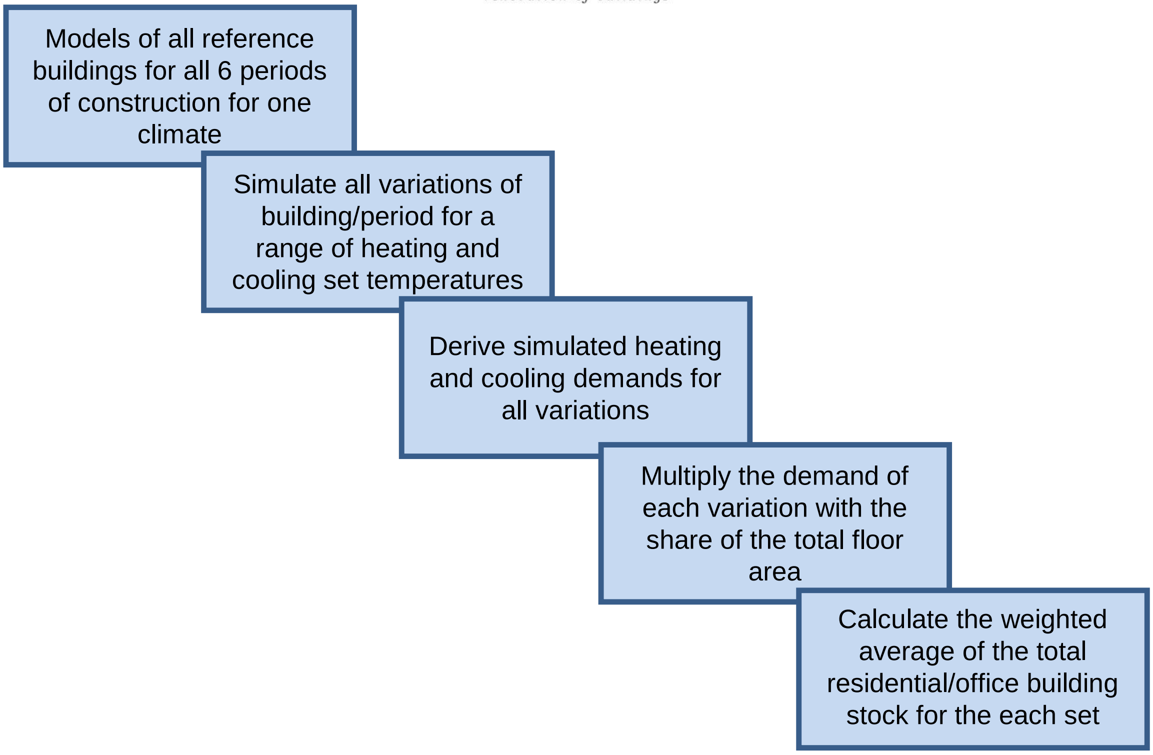


Figure 6 – Methodology to provide figures of simulated heating and cooling demand for a range of set temperatures for all the reference buildings and comparison with values derived from statistical values for heating and cooling consumption.

4 Simulation results for reference buildings

The entire set of data derived using the methodology described in the previous chapter is reported in Annex II. The figures in this chapter represent a concise view of the complete dataset, allowing a fast and direct comparison among literature statistics and simulation results for the seven climate regions.

The first set of figures shows the weighted average demands of heating/cooling for a range of set temperatures (see Figure 7 as an example). The yellow squares represent the weighted average of the simulated cases for given set temperature, typology of building and age of construction. The equivalent average demand derived from statistics is represented with the red squares. The range of demands found from simulations as well in the statistics is also shown by the green dots.

In the second set of figures (see Figure 10 as an example), the simulation results for each building typology and period of construction simulated are shown for the set temperature for which the simulated weighted average demand best matches the equivalent value based on energy statistics. This set temperature varies from climate to climate and is discussed in the following sections.

The diagrams shown in Annex II provide more details with one diagram for each climate for heating and one for cooling. More information about the energy statistics is given: on a country by country basis as well as the average for the climate region. In addition, the simulated heating and cooling demand is shown for a range of set temperatures for each of the building typologies.

4.1 Residential Buildings – Heating demand

Figure 7 shows a summary of the simulation results for heating demand in the residential sector. As can be seen, the statistic averages of the heating demand across Europe do not vary significantly, moving from around 100 kWh/(m^{2}y) to 140 kWh/(m^{2}y). Despite more severe climatic conditions moving from south to north, more demanding building regulations avoid that heating demands grow as fast. For all climates, the range of energy statistics is quite low except for the Mediterranean and Continental regions.

The simulated averages (yellow dots) vary strongly as a function of the set temperature imposed; the same holds for the spread in the simulated demands: the higher the set temperature the larger the data variation, as a consequence of enhanced transmission losses for given building envelope.

The most evident result out of Figure 7 is that, for the given range of set temperatures within comfort boundaries (18 °C to 24 °C), an average simulated demand matching the average statistic demand (named Identified temperature from here onwards) can be identified only in some climate regions: Southern Dry, Mediterranean, Southern continental, Continental and Nordic. At the other climates, the statistical average is lower than all the simulated averages.

The single cases will be discussed next into this section, however some common understanding can be reported already here.

According to the World Health Organisation, the optimum indoor temperature for health is between 18 ºC and 24 ºC [7], the range of temperatures shown in the figures. Previous studies have shown that the indoor temperature does vary dependent on a number of factors. A study by Wilkinsson et al. from 2001 [6], based on long-term measurements of indoor residential temperatures in the UK, showed that the indoor temperature was 17-18 ºC in older buildings. For more modern buildings it was 19-20 ºC. A report on the European heat market [8] states that the indoor temperatures are 20 ºC in Ireland, 21-22 ºC in Sweden and that in South-East Europe, substantially reduced indoor temperatures have been a reality during the recent years for the poorest part of the population with respect to affordability. Generally speaking, set temperatures are not fixed values (regardless the standards obligations); on the contrary, comfort conditions might usually not be met for the entire building for 24 hours/day, as a consequence of high energy prices, country economic conditions and severity of the climate.

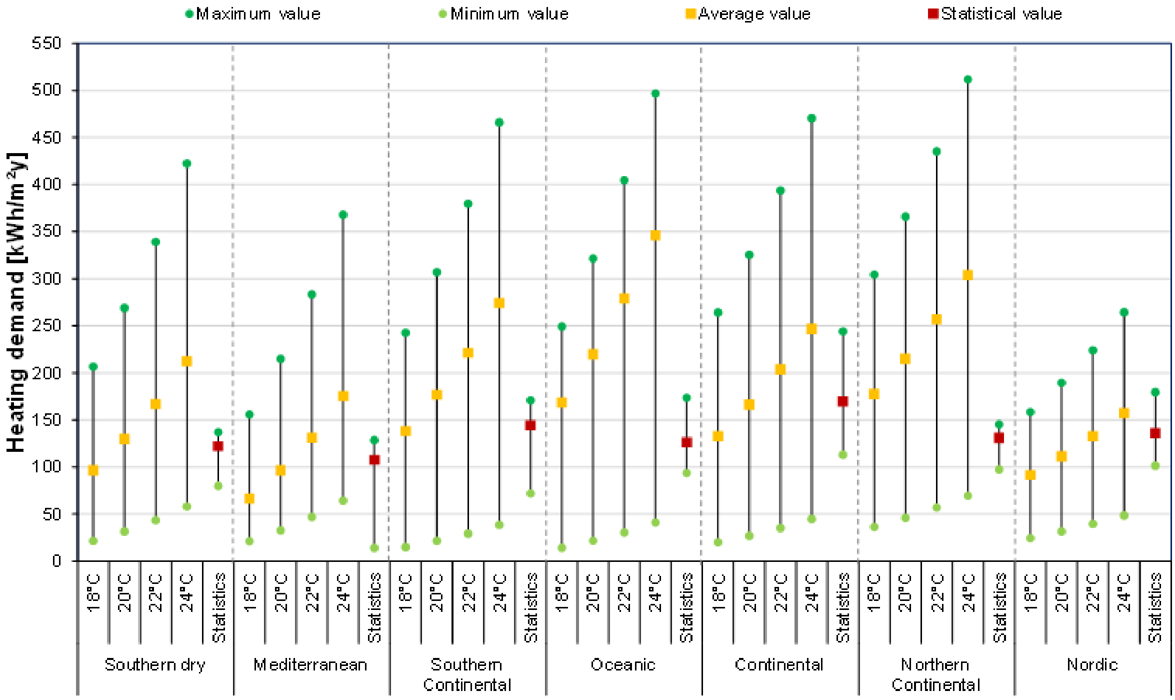


Figure 7 Yearly heating energy demand for residential buildings – range of variations for simulation results and statistical values. For Southern Dry and Continental, the red square and the range of variation correspond to the demand value in the statistics rather than demand calculated based on consumption statistics

Additionally to this, there are many uncertainties in the methodology that has been used, split here into ones related to the energy statistics and ones related to the simulation results.

Uncertainties in simulations' boundary conditions:

- The data for the original U-values at period of construction is not very accurate for the investigate climates. However, it was possible to find good data for all climates, so this is judged less likely to be a significant factor.
- There has been a significant amount of renovation in the building stock of the investigated countries. Improved windows, roof insulation etc. would lead to lower average U-values in practice compared to those when the buildings were constructed and thus lower identified set temperature for heating. Given that less than 1% of the building stock is renovated every year, this is also a factor with lower relevance.
- The climate used for the simulations is colder than the representative climate for the building stock. The Heating Degree Days (HDD) vary in a range of around ± 250 (Kd) in

countries within a given climate region.

- The simulations work assumes that the entire dwelling is heated so as to maintain the given set temperature 24/7. In reality, mostly in less efficient houses, some rooms (sleeping rooms for example) are maintained at a lower temperature level in order to save money. In addition many householders turn down the set point temperature when they are not in the building. Both these effects lead to lower demand in real buildings compared to that calculated by the simulations and as a consequence a lower identified set temperature.

Uncertainties in energy statistics:

- The distributions of buildings typologies in terms of single-, semidetached- and row houses, as well average number of floors and S/V values of the constructions simulated are not well representing the built environment.
- The conversion factors used to move from consumption data to demand (see section 3.3) are not in line with actual status. Different sources for the space heating have different conversion factors (efficiencies). Electrical heating has 100% conversion factor whereas coal based heating will have a lower conversion factor. Most extreme is the heat pump with a conversion factor of over 2. The share of different sources for space heat varies from country to country, and thus an average conversion factor will vary from country to country. This has not been taken into account, rather the same value has been applied for all countries. A parametric analysis shows that, by varying heating conversion factor from 0.8 to 0.9, calculated average heating demand increases by 10 to 20 kWh/(m^2y) depending on climate severity. By varying cooling conversion factor between 1.8 and 3.1, calculated cooling demand changes by -3 to -15 kWh/(m^2y). Again, this variable seems to play a minor role.
- There can be a large variation in GDP/inhabitant and cost of energy between countries within a climate and thus the investment in good quality HVAC equipment with high conversion factors will vary from country to country.
- There are many uncertainties in the energy statistics. Some countries use gross area whereas others use different definitions of “living areas”. Specific values are calculated by dividing the absolute values by an area, which might be different in different publications/countries (treated area, net area, gross area, useful area to name just a few). Between gross and treated area there can be up to a factor 1.5 difference. Hence, published specific values could theoretically vary in the same range. However, the data analysis and quality assessment procedure reported in D2.1a (chapter 3) aimed to exclude unreliable high/low values and to average the remaining data. In addition data from national as well as international sources were compared in order to check consistency and identify unrealistic (or at least inconsistent) data. As a consequence a good agreement between averages and single literature data values was retrieved in most cases (See Annex II) and the uncertainty in the values used in this report are judged to be relatively small.
- The statistics for heating and cooling demand are not consistent for many countries. Table 22, at the end of the report, compares the demand with the consumption data giving resulting in conversion efficiencies for heating and cooling. In most cases these are very different from the fixed values used to convert from consumption to demand in this study. Some conversion factor are even unreliable (see conversion factor for heating

Spain: demand/consumption=155%). On the one had this is due to the fact that the terms "demand" and "consumption" are used as equivalent in many documents and often they are confused with heating loads. On the other hand a wide range of statistical assessment methods have been found when surveying the literature:

a. Consumption values out of monitoring studies of single buildings and large scale monitoring projects

b. Consumption values from Energy Agencies, European-wide energy efficiency databases and research projects and other professional bodies

c. Consumption values obtained by energy bills analysis of a relevant set of buildings

d. Top-down consumption calculations based on the national consumption and building stock

e. Demand calculations out of simulation elaborations

The data treatment is tricky and not always single figures easily reveal to be untrustworthy, therefore are not eliminated by the database.

In the following section, the results for each climate are discussed. The countries are listed in order of heated floor area, therefore relevance on the average demands calculated. "Identified" set temperature in this context means the set temperature that leads to a match between average demand from the statistics and average demand from the simulations.

4.1.1 **Southern Dry** (Spain, Portugal).

The specific consumption for Spain (80 kWh/m^2.a) is much lower than that for Portugal (128 kWh/m^2.a) and even other southern countries in other climate regions such as Greece and Italy. It is also inconsistent with the Spanish demand statistics that give 124 kWh/(m^{2}y) (see Table 22). This latter value on the contrary is consistent with the demand data for Portugal (111 kWh/(m^{2}y)). Thus the simulation results were matched with demand data rather than consumption data, resulting an **identified indoor temperature of around 20 ºC** (Figure 22), which is more realistic. The variation of simulated data for typology and age at 20°C is in the range between 30 kWh/(m^{2}y) and 270 kWh/(m^{2}y). The average is a consequence of a building stock characterized mostly by SFHs and s-MFHs built for the majority between 1945 and 1980.

4.1.2 **Mediterranean** (Italy, Greece, Cyprus, Malta).

There is reasonable agreement between data for the two largest climates, Greece and Italy. Average statistic demand and demand derived from consumption data are also in good agreement (see Figure 23). Therefore this information is believed to be reliable. The identified set temperature is **around 20 - 21 °C** again. As well, the average comes from a building stock characterized mostly by SFHs and s-MFHs built for the majority between 1945 and 1980 as in the Southern dry climate.

4.1.3 **Southern Continental** (France, Bulgaria, Slovenia).

The weighted average from energy statistics is completely dominated by the data for France, which has reasonable agreement between demand and consumption statistics. The identified set temperature is relatively low (**18 - 20 ºC,** Figure 24), indication that maybe the dwellings are not completely warmed up. It is unlikely that the climate assumed as a reference (Lyon) is too rigid for the climate region.

4.1.4 **Oceanic** (UK, Belgium, Ireland).

The identified set temperature found in the literature for UK, which has over 75% of the heated floor area in the climate region. The statistical data for consumption and demand are reasonably consistent. The **identified set temperature is lower than comfort, around 17 °C** (Figure 25). Again this is consistent with Wilkinsson et al [6] that indicate indoor temperatures of 17-18ºC in older buildings in UK. Again, comfort conditions might usually not be met for the entire building for 24 hours/day.

4.1.5 **Continental** (Germany, Netherlands, Austria, Czech R., Hungary, Luxemburg).

Germany dominates the heated floor area with 67%, and the demand and consumption statistics are not very consistent, with the reported demand being greater than the consumption. As a result the average statistic demand is 170 kWh/(m^2y), while the demand out of consumption data is 125 kWh/(m^2y): quite a large span is identified. The latter value seems to be underestimated since the resulting identified set temperature is around 18°C (Figure 26). Thus the specific energy demand from the statistics were used to match with the simulation results, resulting in an **identified set temperature of around 20 – 21 °C**.

The consumption data for the different countries is very similar apart from for Netherlands (much lower) and Luxemburg (much higher). An explanation for this could be that Germany has a relevant share of renovated buildings, which would result in lower calculated heating demands for given set temperature.

4.1.6 **Northern Continental** (Poland, Romania, Denmark, Slovakia, Lithuania).

The identified set temperature is very low, around 16 ºC . There was very little data available for specific energy consumption or demand. Thus the derived specific heating demand was calculated by dividing the total heat demand by the heated floor area, assuming that 99% of the total floor area is heated. The value derived for specific energy consumption was then compared with values derived from other data in literature, such as energy consumption per dwelling, and found to be very similar.

The statistics are well in line both country-wise and from the calculation point of view. It must be highlighted here that also U-values information was quite lacking for this region. Moreover, being the results mostly dominated by Poland, the statistics might trace the economic conditions of the country (the statistic data are not always updated to the last few years).

A lower assumption than 99%, which can be justified if not all the building is heated at the same level, leads to higher specific heating demand and thus a higher identified set temperature for the simulations. More detailed data would be required to identify the cause(s) for this extremely low identified set temperature in this region.

4.1.7 **Nordic** (Sweden, Finland, Latvia, Estonia).

The consumption statistics for the different countries are similar, apart from for Sweden that has lower consumption for heating than the others. However, Sweden has lower U-values than the other countries. Consumption and demand data are consistent. The **identified set temperature agrees with the literature (around 20 - 22 ºC,** Figure 28).

4.1.8 Conclusions

It is common practice in many countries to not heat all areas of the building all the time, rather to reduce the set point temperature in certain parts of the building for all or part of the time. There is little information in the literature on which to quantify this, and thus a constant set point temperature for the whole building has been used in the simulations. This results in higher heating demand than in a building that has some areas at lower set temperatures for parts of the building. Thus it is to be expected that the identified set point temperatures could lower here than that used in practice for the areas of the house during occupancy. The Building Performance Institute Europe have reported that fuel poverty is a big problem in certain countries in EU [10] and that many cannot afford to heat their homes to acceptable levels. This is consistent with some of the findings presented here.

The approach has led to the identification of statistical data that is not consistent with the simulation results through the detection of very low identified set point temperatures. For these climate regions, other data than the weighted average consumption data for the climate region have been used for matching with simulation results. In particular, the consumption data for Germany and Spain, both dominating for their climate regions, are inconsistent with the simulation results and with the national demand statistics. In both cases the specific demand statistics seem to be more realistic.

In future, surveys on heating and cooling energy use in buildings should clearly identify if they refer to consumption or demand, and which is the area assumed as a reference (treated area, net area, gross area, useful area to name just a few).

4.2 Residential buildings – Cooling demand

Figure 8 shows a summary for the cooling demand in the residential building stock. The identified residential cooling set temperatures for the seven climates lie within a three degree band from 22 – 25 ºC, which is consistent with comfort criteria mentioned previously. Most of the climates are seated around 24°C (identified set temperature), whilst only Southern dry countries seem to accept higher set temperature and Oceanic ones require lower (22 °C).

The simulation results are thus consistent with the energy statistics, as a consequence of the fact that cooling demands are affected by transmission losses to a low extent, while glazing ratio (quite fixed around Europe) and shape factor (S/V) mostly influence the physics.

Cooling demand in the most northern countries range between 10 kWh/(m^{2}y) and 20 kWh/(m^{2}y). It increases in the Southern dry climate to 40 kWh/(m^{2}y) (i.e. France, identified set temperature 24 - 25 °C) and in the Mediterranean one (55 kWh/(m^{2}y), again identified set temperature 24 - 25 °C). Interestingly, with respect to the latter, the result is driven by Greece, which has both a very high specific energy demand and a significant share of the stock that is actually setup with cooling units. Cooling demand drops to 35 kWh/(m^{2}y) in the Southern dry countries, apparently as a result of lower comfort requirements (identified set temperature higher than 25°C). It is to be noticed however, that only one data source was retrieved with respect to Spain cooling consumption (see section 8.1.2). With this regard, if the demand value is used for the Southern dry climate, again values around 55 kWh/(m^{2}y) are retrieved and an identified set temperature of about 24°C. As for the heating case, probably the consumption is lower than foreseen since not all rooms are cooled.

Remarkable here is that the above extrapolations are based on consumption data and conversion factor of 2.5. Direct cooling demand data are extremely rare around Europe. Basically, the only source of information with this respect is the project EcoHeatCool [8], which calculated specific cooling demands of European countries based on the European Cooling Index (elaboration of the Cooling Degree Days concept). The demand data derived from consumption equal EcoHeatCool ones only for Mediterranean and Southern dry climates. In the other the EcoHeatCool demand tends to be higher. The methodology used within iNSPiRe is more detailed, with a better basis for chosen parameters, and thus likely to give more reliable results for cooling demand than those produced by the EcoHeatCool study.

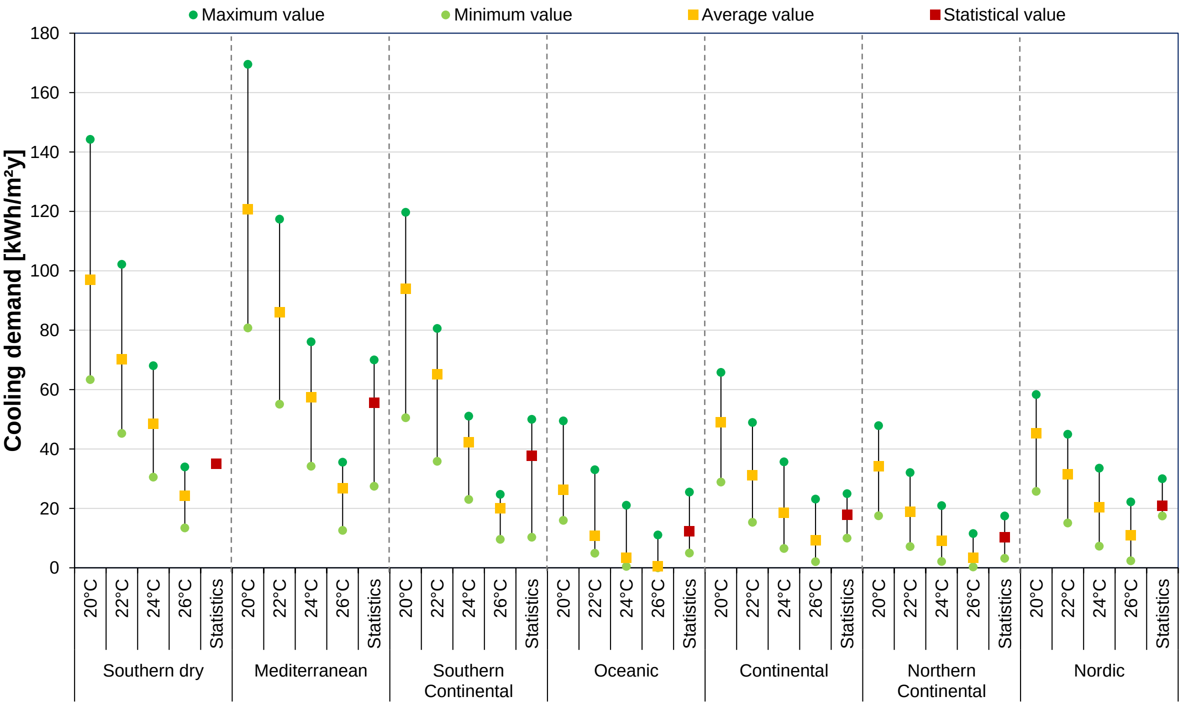


Figure 8 Yearly cooling energy demand for residential buildings – range of variations for simulation results and statistical values

It is obvious from the data shown in section 8.1.2 that only a small fraction of the residential building stock is actually cooled. For the southern dry climate, ~50% of the floor area of the residential building stock while in the Mediterranean climate it is ~20% and ~7% in Southern Continental. In the other four climates, very small areas are cooled. If cooling of residential buildings becomes more popular, then the results show how much energy will be required for the various climates.

4.2.1 Conclusions

There is a lack of information available about the residential cooling demands in buildings across Europe. The simulation results are, despite this, quite consistent with the limited energy statistics' data in the literature. The methodology described and tested here thus provides a reasonable way of evaluating these demands. However, more information about the glazing ratios and S/V values would enhance the reliability.

The cooling demands in residential buildings (see Figure 10) are much smaller than those for heating (see Figure 9). This is the case for all climate regions, even Southern Dry and Mediterranean regions. Cooling demands can be reduced in practice in many cases by improving shading and using night ventilation (the latter in northern countries).

4.3 Results for calibrated residential building models

Using the identified set temperatures from the calibration process, shown in sections 4.1 and 4.2, the heating and cooling demand for the three typologies and six periods of construction was calculated for each of the seven climates based on the simulation results. These results are shown in Figure 9 and Figure 10. The results show that the average specific heating demand based on energy statistics is in all cases (with exception of Southern dry and Mediterranean) the same or higher than the demand for the worst small multifamily house (s-MFH). As the weighted average of the simulation results is the same as that from the statistics, this shows how the single family houses dominate in terms of floor area in the most northern countries (60-70% on average) and thus make the average specific heating demand relatively high, despite the better U-values. On the contrary southern regions "profit" of more favourable shape factors, on average.

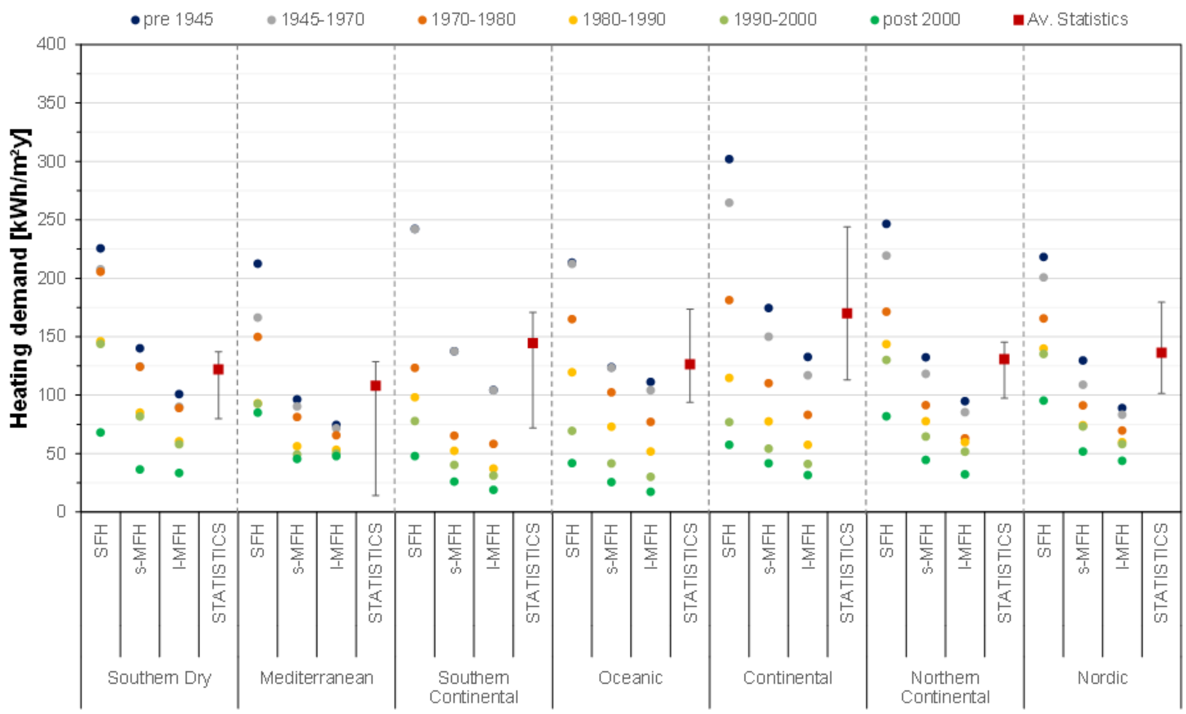


Figure 9 Simulated yearly heating demand for residential buildings for three typologies and six periods of construction. Simulated demand for whole building stock calibrated to value from statistics.

As already noticed, the variability of cooling demand with respect to building typology is much lower than for the heating demand. Moreover, cooling demand is almost independent of period of construction. The larger variability goes with the countries where buildings' insulation levels increased significantly over the years: a more efficient building in terms of reduced transmission losses in winter tends to be less sensitive to night cooling in summer.

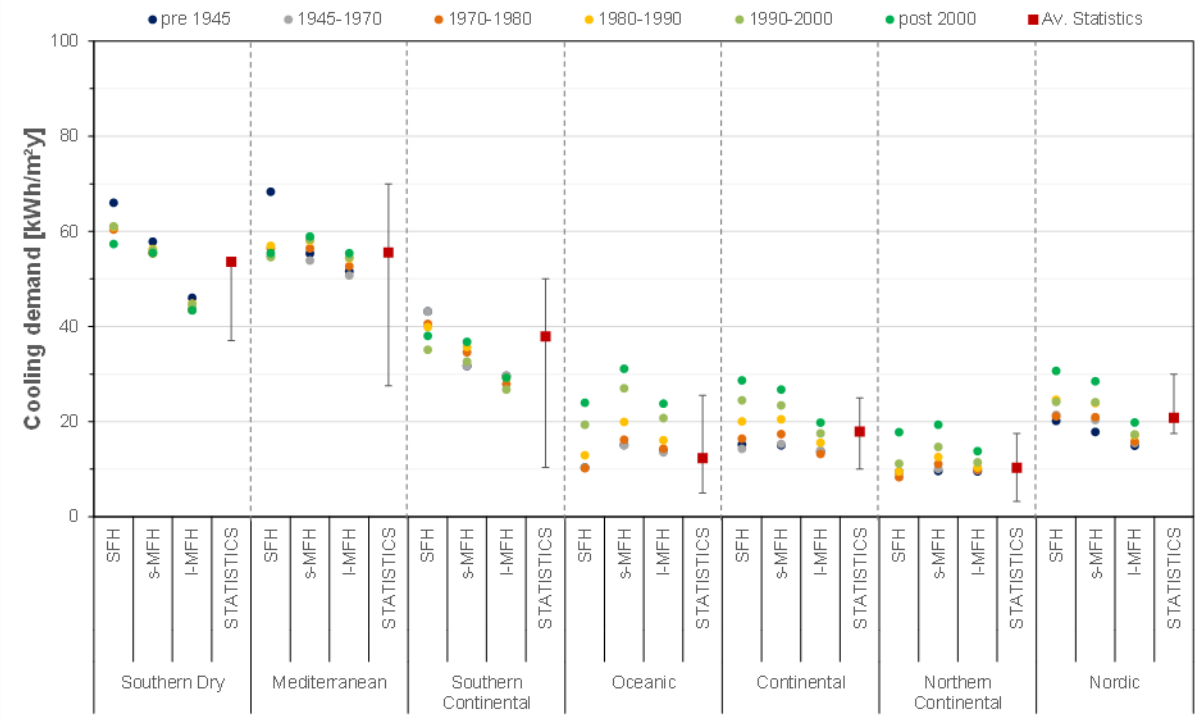


Figure 10 Simulated yearly cooling demand for residential buildings for three typologies and six periods of construction. Simulated demand for whole building stock calibrated to value from statistics.

4.4 Office Buildings

The share of m² for climates and construction periods for office buildings has been derived from statistics. For some countries (i.e. Greece, France, Slovenia, Belgium) data for pre 1970 are not broken down by age. Age splits for Belgium, United Kingdom, Hungary, Estonia and Sweden data post 1990 or 2000 are also not available. For these cases, a split based on other countries of the same climate has been used. The weighted average of the share of m² on heated/cooled area for each climate has been therefore calculated.

As specified in section 3.2.4, the office building model consists of a number of cells with different orientations. In particular on the east/west sides there are only two corner modules, while on the north/south side an intermediate module accounts for the all in-between cells. Based on this, the intermediate modules have been multiplied up to obtain from 6 to 12 cells per floor. Using these proportions, the building shape has an S/V ratio within 0.34 and 0.54 (for the range of 12 cells and 6 floors to 6 cells with 3 floors).

Based on these values, the specific heating and cooling demands of offices in the seven climates was derived from simulation results, as shown in Figure 11 and Figure 12 respectively. As with the residential buildings, an “identified” set temperature was computed such that the weighted average of the simulation results matched that from the energy statistics. There are very little data in the literature for heating and cooling demands, and thus nothing is given in the summary table (Table 23 at the end of the report). Only demand data extrapolated by consumptions (with a factor 2.5) are reported next in this section.

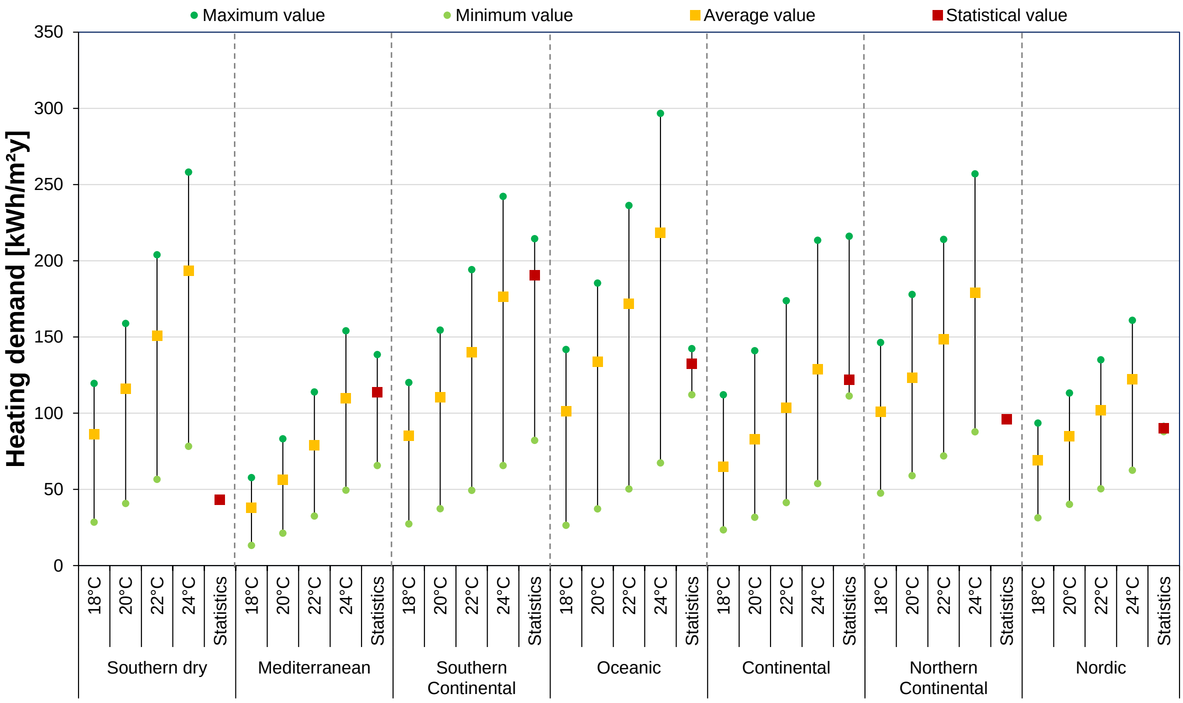


Figure 11 Yearly heating energy demand for office buildings – range of variations for simulation results and statistical values

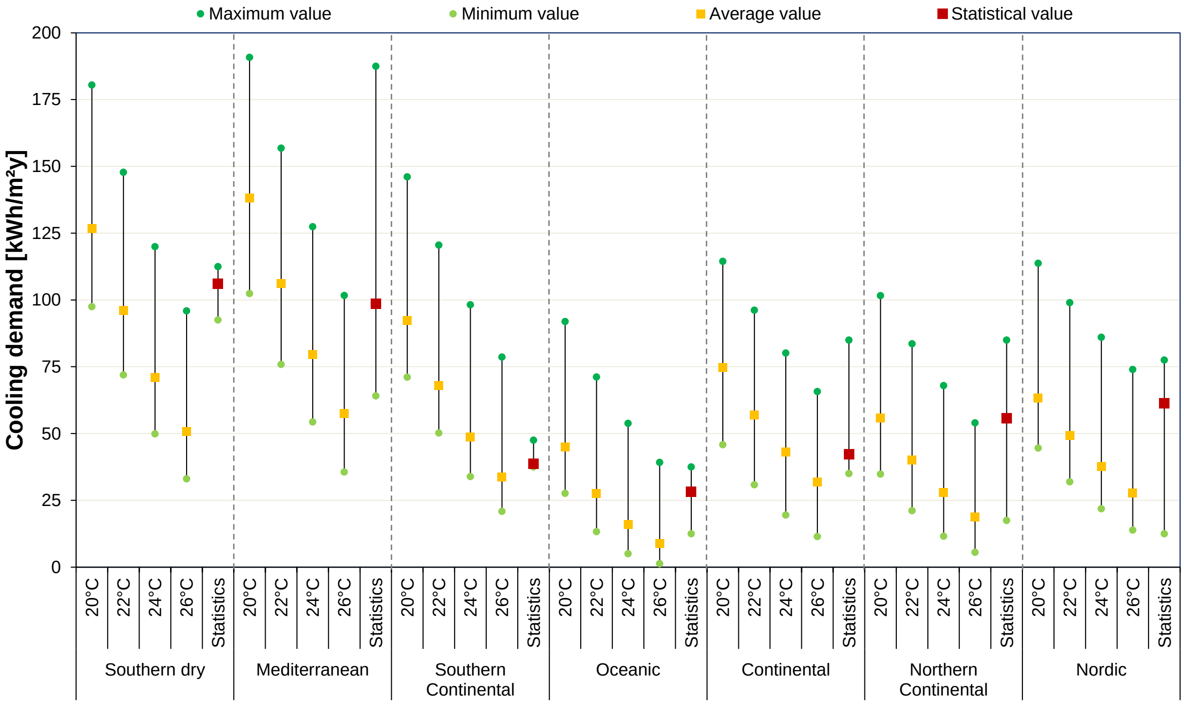


Figure 12 Yearly cooling energy demand for office buildings – range of variations for simulation results and statistical values

Figure 13 and Figure 14 show a summary of the simulation results for cooling demand in the office building stock and the identified set temperatures for cooling. All identified set temperatures are consistent with recommended indoor temperatures for working.

The following are possible explanations for the variation of identified set temperatures, split again into ones related to the energy statistics and ones related to the simulation results.

Simulation uncertainties:

- The data for the original U-values at time of construction is not very accurate for these climates. For many countries it was not possible to find reliable data for U-values, and the values derived have been set to those of the residential buildings. This was principally for the most southerly countries and affected the Southern Dry climate most.
- The weighting use to derive the average demand, based on number of offices per floor and number of floors is not representative of the building stock. There is not much literature available with respect to the shape of office buildings; however the few available shows that the mentioned values might be representative [11]. The shape has no influence on cooling demand.

Uncertainties in energy statistics:

- Limited data were found for heating and cooling energy use in offices. Thus energy statistics are rather uncertain for many countries and therefore climate zones, resulting in a large uncertainty in the identified set temperatures. In Figure 11 the range for certain climates is not shown as there was not sufficient data.

- The (relatively few) offices that have cooling are those naturally with high cooling demand/need – this leads to a higher average cooling demand in energy statistics than the average for the whole building stock, and thus low identified set temperatures.
- There can be a large variation in GDP/inhabitant between countries within a climate and thus the investment in good quality HVAC equipment with high conversion factors.

The following section discusses the results for both heating and cooling for the seven climate regions. The countries are listed in order of heated floor area.

4.4.1 **Southern Dry** (Spain, Portugal).

There is no data for heating consumption in offices for Portugal, but the values for both Italy and Greece are much higher than those for Spain, suggesting that the limited statistical data for consumption in Spain is too low (identified set temperature 16 °C), as is the case for residential heating. In addition, there is only limited data for Spain, with some variation. Thus the simulation results for heating were matched with consumption data for Italy that has a similar number of degree days, resulting in an identified set temperature in winter of around 20 °C (Figure 36).

The consumption statistics for Spain and Portugal are similar, but higher than for Italy that has roughly the same cooling degree days as Spain. Identified set temperature is about 22°C (Figure 43).

4.4.2 **Mediterranean** (Italy, Greece, Cyprus, Malta).

The identified set temperature for heating is slightly high at roughly 24 ºC, as far as cooling set temperature. There are large differences in both heating and cooling consumption between Italy and Greece.

As regards to the cooling demand, the cooling degree days are almost double in the southern countries with respect to Italy (see Figure 44). In this case, however, the result is driven by Italy that has a much larger cooled floor area.

4.4.3 **Southern Continental** (France, Bulgaria, Slovenia).

There are two main sources of heating consumption data for France, giving two very different values. The higher value is the one believed to be more realistic from the statistics analysis, resulting in a identified set temperature for heating slightly high at roughly 24 ºC (as in the previous case, Figure 38).

The cooling consumption is consistent within the climate region as well as with that for Germany that has a similar number of cooling degree days. Identified set temperature in this case is 24 – 25 °C (Figure 45).

4.4.4 **Oceanic** (UK, Belgium, Ireland).

The identified set temperatures are roughly 20 ºC and 21 ºC for heating and cooling respectively. The heating consumption is relatively consistent within the climate region and is quite similar to that in the Netherlands and Germany.

The cooling consumption is significantly lower than for the Continental climate, which is consistent with significantly lower number for degree days for the climate and therefore the inclination of people to require lower ambient temperatures. However, a large variability of data is noticed with respect to UK, where most of the cooled area concentrates (Figure 46).

4.4.5 **Continental** (Germany, Netherlands, Austria, Czech R., Hungary, Luxembourg).

The identified set temperatures are roughly 24 ºC for both heating and cooling. The heating consumption for Germany and the Netherlands is similar, whereas those for Czech Republic and Austria are much higher.

The cooling consumption is very similar for the three countries with the largest areas that are cooled (Germany, Czech Republic and the Netherlands), whereas it is much larger for the other countries.

4.4.6 **Northern Continental** (Poland, Denmark, Lithuania, Romania, Slovakia).

The identified set temperatures are very low both for heating (< 18 °C) and cooling (< 20 °C). The weighted average heating demand is based only on energy statistics for Denmark (no other data found in the literature), which has a lower number of heating degree days than Gdansk, the climate used for simulations. Using Copenhagen as the climate, a higher heating set temperature would be identified.

There is a large range of specific cooling consumptions over the countries in the climate region. The climate of Gdansk has much lower cooling degree days than the majority of the climate region, leading to lower cooling demand in the simulations and thus lower identified set temperature.

Statistics in this climate region, both in terms of energy use and U-values, are believed to be unreliable.

4.4.7 **Nordic** (Sweden, Finland, Latvia, Estonia).

The identified set temperatures are roughly 20 ºC for both heating and cooling. Both cooling consumption is much higher in Sweden than in Finland but the heating consumption is very similar. This is consistent with the fact that the majority of the cooled floor area is in southern Sweden, which has a higher number of cooling degree days than Finland.

4.5 Results for calibrated office building models

Using the identified set temperatures from the calibration process the heating and cooling demand for 6 and 12 cells for low and high rise offices, for each of the six periods of construction was calculated for each of the seven climates based on the simulation results. These results are shown in Figure 13 and Figure 14. The results show that for the Oceanic and Southern Continental climates, that the heating demand based on statistics is higher than all simulated values apart from for the oldest and smallest buildings, showing the large share of these buildings in the two regions. In all other cases it is more in the middle.

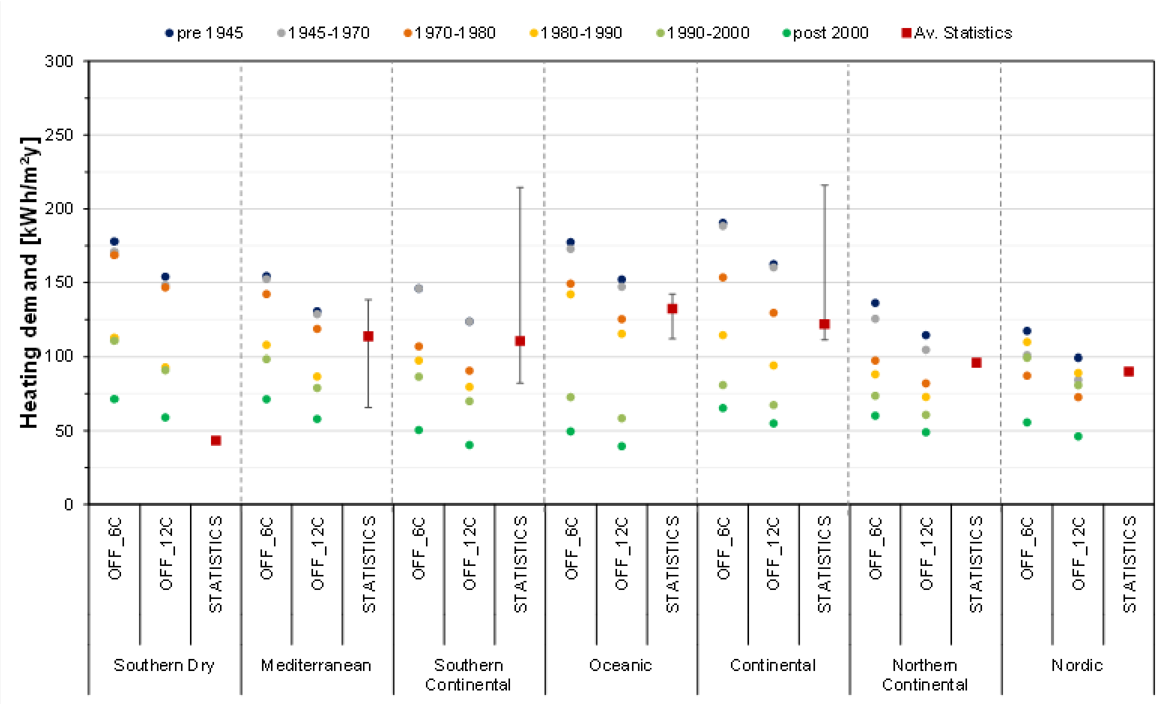


Figure 13 Simulated yearly heating demand for offices for two numbers of cells per floor and six periods of construction. Simulated demand for whole building stock calibrated to value from statistics

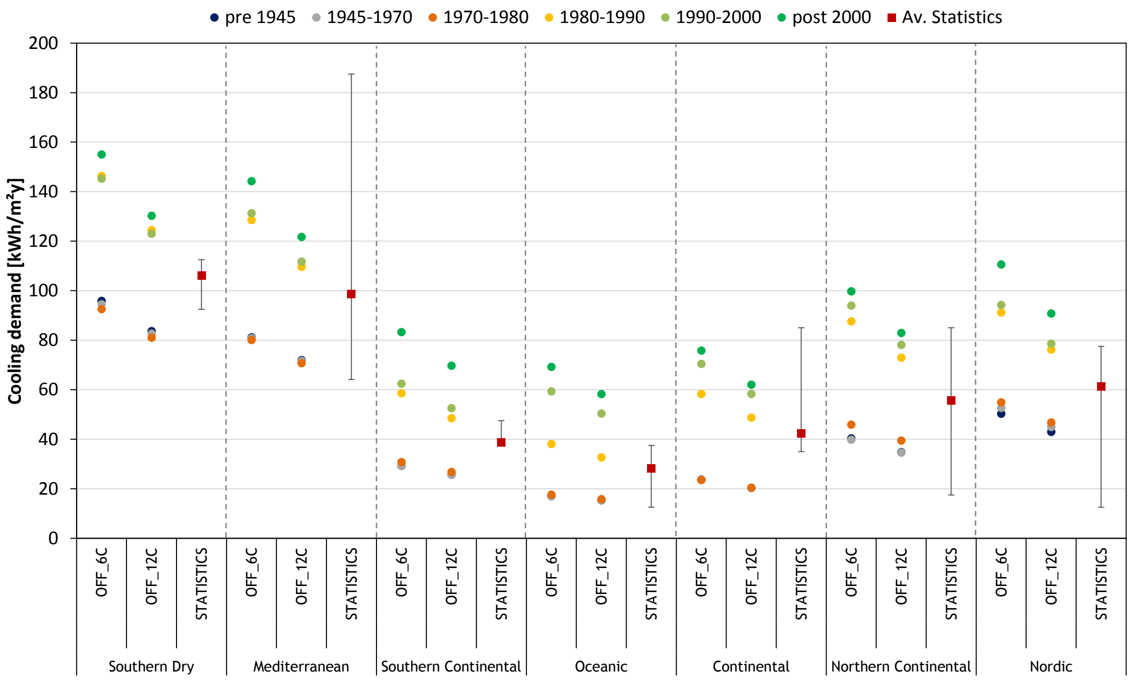


Figure 14 Simulated yearly cooling demand for offices for two numbers of cells per floor and six periods of construction. Simulated demand for whole building stock calibrated to value from statistics.

4.5.1 Conclusions

There is a limited amount of data in the literature for heating and cooling consumption for office buildings. Thus the approach used in this report can be used to estimate the heating and cooling demand in office buildings of different periods of construction, location and typology.

Inconsistent statistical data have been identified and, e.g. for Southern Dry, data for Italy were used to calibrate the simulation model instead of those for Spain and Portugal. This required more care and greater analysis than for the residential building stock.

Statistical data are believed to be unreliable also with respect to the northern continental climate.

The heating demand is quite uniform all over Europe. The cooling demand is higher (almost double) in offices in the southern climates, and it is significant in all climates. The lowest cooling demands are in the Oceanic and Southern Continental climates regions. There is a larger range of heating demand (often over 100 kWh/m^2.a) over the range of periods of construction than for cooling (mostly around 60 kWh/m^2.a).

5 Conclusions

As with any extensive study like this, there is always going to be gaps in literature. The purpose of the work and results presented in this report is to complement the iNSPiRe database so the energy demands for residential and office buildings across Europe are better understood.

The approach of matching the simulation results with the energy statistics by varying the set temperature, resulted in several inconsistencies being found and suitable adaptations were chosen. These inconsistencies would need to be further investigated in order to find their causes. It is a far more detailed and comprehensive approach than has been previously applied, and the derived results are believed to be more reliable than those previously published for the whole of EU. The approach itself, ensures that the simulation results are consistent with the energy statistics.

The methodology developed as part of this WP is a novel approach has a number of uncertainties, from both a statistical and simulation perspective. However, it has provided further information about the energy demands for building typology, age at regional and European level. These can be found in chapter 8, where a comparison of heated and cooled floor areas across EU can also be found. Future work to improve the methodology is needed to make sure that the specific energy consumption used for the calibration process is based on the same definition of area and that consistent terminology (i.e. demand/consumption) is used when addressing energy use in buildings.

The results suggest that lower set point temperatures in winter are often used in practice at least in the residential sector compared to those used in simulation studies. Barely the identified set temperature exceeds 20 °C (except for the Nordic climate). This seem to indicate that not all the living area is equally warmed up 24hours a day. Literature shows that a better building standard is correlated with higher indoor temperature, and thus real energy savings when improving the insulation level of residential buildings is likely to be somewhat lower than expected. However, comfort would be significantly improved. Heating demand in office buildings in Europe is quite uniform.

The method gives consistent results in term of cooling demand estimation both for residential and office sectors, where few statistical data are available. Therefore it could be used to complement energy statistics where data is missing. While 24 – 25°C seem to be accepted in residential buildings (with exception to the Oceanic climate, around 22 °C), lower temperatures are required in offices (20 -23 °C), with exception of Continental and Southern continental regions (about 25 °C). In this case however, the cooled floor area showed to be relevant only in the most southern countries.

The work reported here used TRNSYS as the simulation as this degree of detail will be necessary in other parts of the iNSPiRe project. However, the methodology would be equally applicable using a much simpler building simulation tool.

6 References

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7 Annex I – Boundary conditions defined for simulations

Common boundary conditions are defined for all categories in the residential sector and all in the office sector. The conditions for heating and cooling as well as for ground coupling were also the same for both residential and office buildings.

7.1 Residential sector

For residential buildings, assumptions on shading and internal gains were mainly based on boundary conditions from Task 44 [1]. All of these assumptions are listed and further explained below.

7.1.1 Internal gains

Internal gains are divided into occupational gains and gains from electrical appliances. No separate gains from lighting are defined. Each of these can be described by some periodic profile, possibly with variations depending on season and day of the week. For single family houses, profiles from Task 44 were applied and specific value from statistics has been used (see D2.1a).

The profiles for multi-family houses were generated for a number of inhabitants of the building using a stochastic model developed by researchers at Uppsala University [2]. Once the profiles were generated, they were implemented in all building simulations where applicable, thus not varying from one simulation to another. These profiles have a day-to-day variation over the whole year, whereas the Task 44 profile is a repeated 24 hour cycle. The aggregate profile from the stochastic model is also smoother and more realistic than an aggregate of one and the same profile, e.g. the one from Task 44. Both this and the Task 44 profiles have a 1 hour resolution.

Table 8 – Summary of internal gains for residential buildings

INTERNAL GAINS		Unit
Occupancy		
Schedule	see Figure 15 and Figure 17	
Activity level (ISO 7730)	Seated, very light writing	
Sensible heat	65	[W]
Latent heat	55	[W]
Appliances		
Schedule	see Figure 16 and Figure 18	
Sensible heat	10	[W/m²]

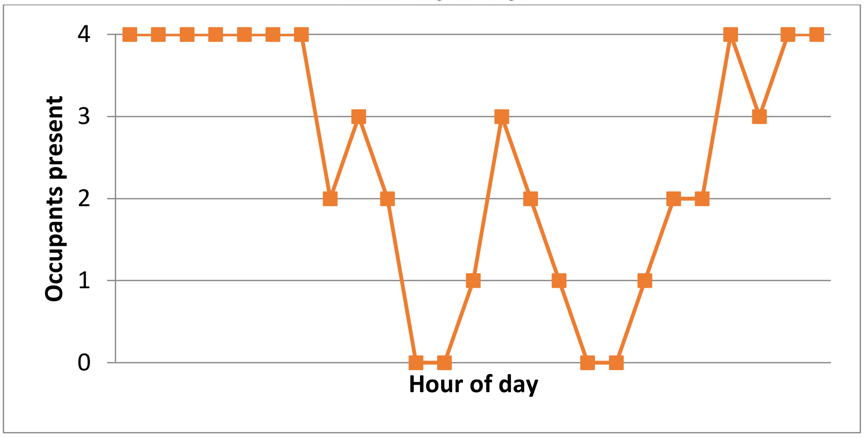


Figure 15 – Task 44 presence profile for single family house with four occupants

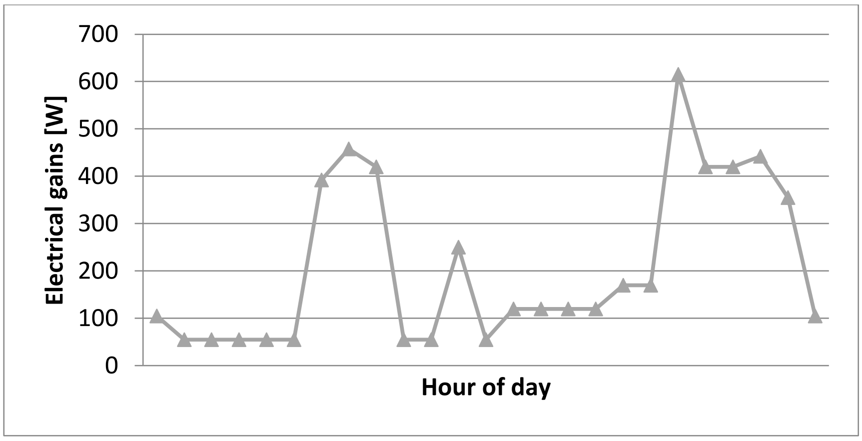


Figure 16 – Task 44 profile for internal electrical gains in a single family house of 140 m² with four occupants

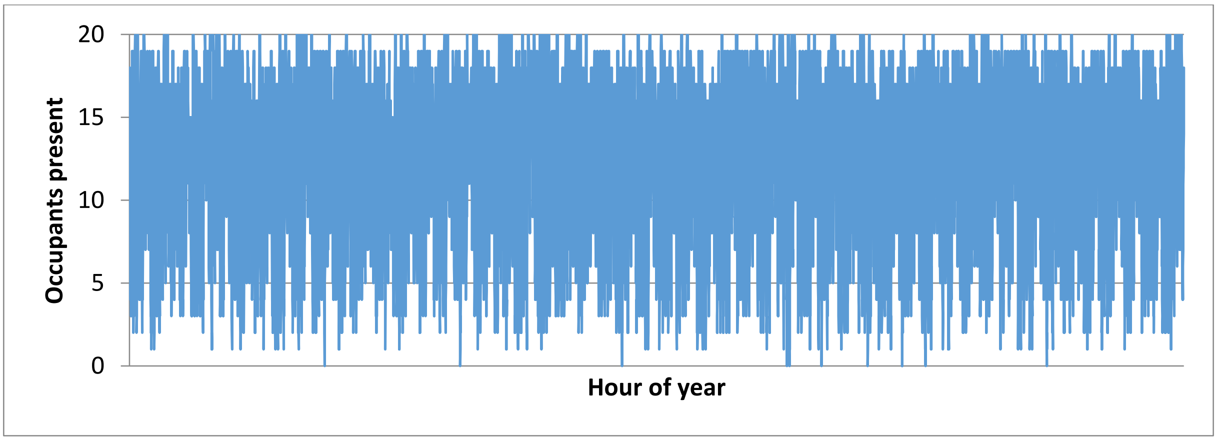


Figure 17 – Stochastically generated presence profile for a multi-family house with 20 occupants

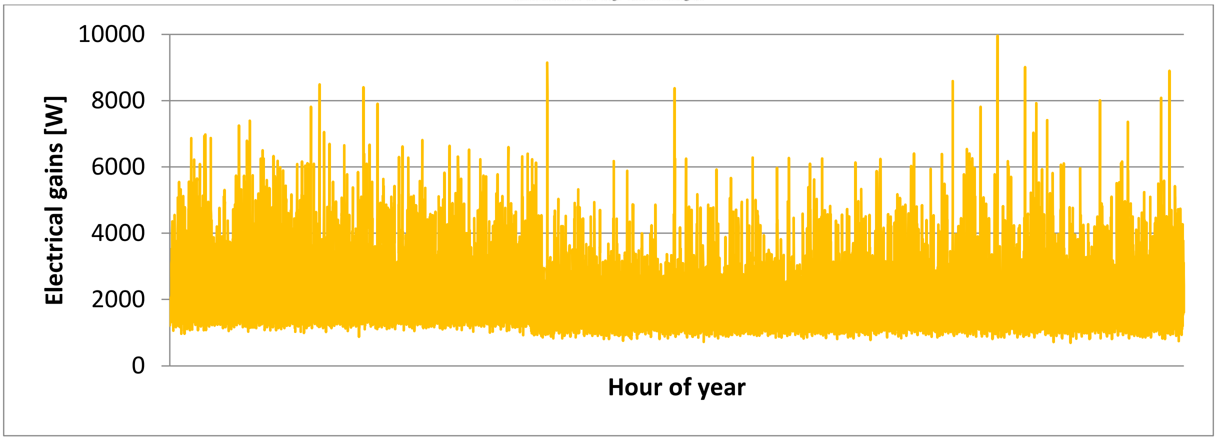


Figure 18 – Stochastically generated internal gains profile for a multi-family house with 20 occupants

7.1.2 Shadings

Shading on windows has been assumed to be activated if three conditions are met:

- Horizontal, global irradiation greater than 300 W/m^2 (shades removed if < 250 W/m^2)
- Room temperature greater than 24 °C (shades removed if < 23 °C)
- 24 hour moving average ambient temperature greater than 12 °C

In Southern Europe, external shading is commonly used also for multi-family houses, either in the form of jalousies or marquises, while buildings in Northern and Central Europe rarely are equipped with external shading. Therefore, external shading was assumed for the climates of Lyon, Madrid and Rome and internal shading for the climates of London, Stuttgart, Gdansk and Stockholm (see Table 9).

Table 9 – Summary of shading for residential buildings

SHADING		Unit	Note
Climates			
Internal	Stockholm, Gdansk, Stuttgart, London		
External	Lyon, Rome, Madrid		
Solar heat gain coefficients			
Internal	0.28		
External	0.10		
Conditions for shading activation			
Solar irradiance on horizontal	> 300	[W/m^2]	Deactivate if < 250
Room temperature	> 24	[°C]	Deactivate if < 23
Last 24 hours average temperature	> 12	[°C]	

7.1.3 Infiltration and ventilation

There are essentially two parts of natural ventilation: leakage through the building envelope (infiltration) and ventilation activated by the occupants by opening windows.

Infiltration rate is strongly connected to the building airtightness and occupants' behaviour and it varies during the year. For the sake of simplicity, a fixed value through the day and the year has been defined. For existing buildings the blower door test value has been assumed to be around 3 vol/h, which means an infiltration due to building airtightness around 0.15 vol/h. Moreover, assuming an average of 2.5 persons per dwelling and an air-change due to opening windows around 15 m^3/h per person, and additional ventilation rate around 0.30 vol/h is added to the infiltration rate.

Table 10 – Summary of ventilation for residential buildings

VENTILATION		Unit
Infiltration		
Living zone	0.15	[vol/h]
Staircase	0.45	[vol/h]
Ventilation		
Airflow	0.30	[m^3/h·person]
Temperature	outside	[°C]
Relative Humidity	outside	[%]

7.2 Office sector

The boundary conditions for office buildings were based on data from the Cost Effective project [3] and the technical standard UNI/TS 11300 [4]. All assumptions are listed below.

7.2.1 Internal gains

Internal gains are divided into three main categories: occupancy, appliances and lighting gains. The level of occupancy is estimated to be 3 persons per cell. The presence of persons in the office varies during the day and the year according to schedules defined in Table 11. While during the weekend the occupancy is set to zero. Holidays are taken also into account by setting 1+1 weeks off during the summer (mid-August holiday) and winter (Christmas) time. According to typical office activity level, a total internal gain of 100 W is considered. This value takes into account sensible (72 W) and latent gains (0.059 kg/h/person). Sensible gains are further divided into convective (40 %) and radiative (60 %) contributions.

In order to evaluate indoor comfort conditions during the year, a clothing factor of 0.6 and 1.0 is considered for summer and winter time, respectively. This value is varied through the year accordingly to the local weather conditions. The presence of typical office appliances is considered, adding 12.5 W/m^2 of internal gains. The convective fraction is fixed to 73 %, while the remaining part is radiative. During the working days, these internal gains are assumed to be continuously on.

As well as internal gains from occupancy and appliances, the activation of lighting during the day is controlled by a presence schedule. According to the fact that the study is conducted on existing building, it is assumed that the total electrical gains from lighting amount to around 16 W/m^2, in agreement with statistical data.

Table 11 – Schedule profile during working days

From	Until	People & lighting	Electric appliances
00:00	07:30	0	0
07:30	08:30	0	1
08:30	12:30	1	1
12:30	13:30	0	1
13:30	17:30	1	1
17:30	00:00	0	0

Table 12 – Summary of internal gains for office buildings

INTERNAL GAINS		Unit	Notes
Occupancy			
Radiative power	43	[W/pers]	
Convective power	29	[W/pers]	
Absolute Humidity	0.059	[kg/h·person]	
Schedule	See Figure 19		
Comfort			
Clothing factor	0.6/1.0	[clo]	summer/winter
Metabolic rate	1.2	[met]	
External work	0	[met]	
Relative air velocity	0.1	[m/s]	
Appliances			
Radiative power	3.5	[W/m^2]	
Convective power	9	[W/m^2]	
Absolute Humidity	0	[kg/h]	
Schedule	See Figure 19		
Lighting			
Radiative power	6	[W/m^2]	
Convective power	10	[W/m^2]	
Absolute Humidity	0	[kg/h]	
Schedule	See Figure 19		

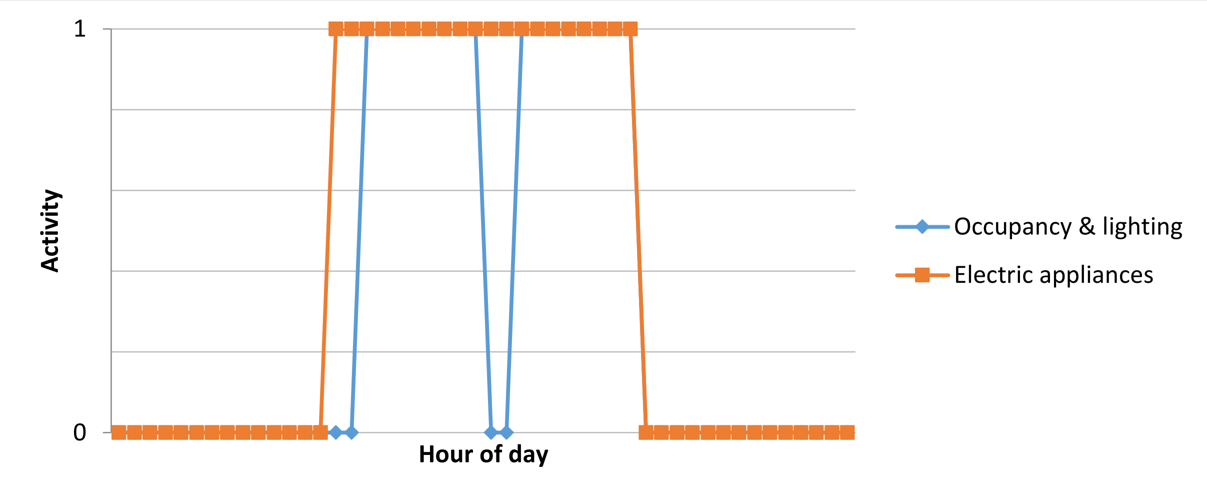


Figure 19 - Internal gains profiles for office buildings

7.2.2 Shading

For office buildings, the assumptions on shading are similar to those for residential buildings. The threshold for room temperature was set to vary depending on the set temperature for cooling. All boundary conditions for shading are given in Table 13.

Table 13 – Summary of shading for office buildings

SHADING		Unit	Note
Climates			
Internal	Stockholm, Gdansk, Stuttgart, London		
External	Lyon, Rome, Madrid		
Solar heat gain coefficients			
Internal	0.50		
External	0.50		
Conditions for shading activation			
Solar irradiance on horizontal	> 300	[W/m²]	Deactivate if < 50
Room temperature	> Tset,cool - 1	[°C]	Deactivate if < Tset,cool - 2
Last 24 hours average temperature	> 12	[°C]	

7.2.3 Ventilation

As the study is conducted on existing buildings, a value of n50 around 3 vol/h has been used. As a consequence, a natural air change rate of 0.15 vol/h is assumed due to leakages in the façade. This value is taken as constant throughout the year. A fresh-air supply of 40 m³/h per person is further included when occupant's presence is scheduled.

Table 14 – Summary of infiltration and ventilation for office buildings

INFILTRATION AND VENTILATION		Unit
Infiltration		
Zone	0.15	[vol/h]
Stairs	0.15	[vol/h]
Ventilation		
Airflow	40	[m^3/h·person]
Temperature	outside or from mechanical ventilation	[°C]
Relative Humidity	outside or from mechanical ventilation	[%]

7.3 Common settings

7.3.1 Heating and cooling

In order to assess the heating and cooling demands of the buildings before renovation, ideal heating and cooling were applied. The set point for heating varied from 18 °C to 24 °C, while the cooling set point varied from 20 °C to 26 °C, both with a 2 °C step. When varying the cooling set point, the heating set point was kept at 18 °C, and the cooling set point was kept at 26 °C when the heating set point was varied.

Table 15 – Summary of heating and cooling for residential and office buildings

HEATING AND COOLING	Default	Min	Max	Step	Unit
Heating					
Set temperature	18	18	24	2	[°C]
Heating Power		Infinite / ideal			[W]
Humidification	Off				
Cooling					
Set temperature	26	20	26	2	[°C]
Cooling Power		Infinite / ideal			[W]
Dehumidification	On				

7.3.2 Ground coupling

The ground coupling has been modelled applying indications from ISO/DID 13370 standard [5] on thermal losses through the ground. A non-ventilated air gap of 1.5 m below the ground floor has been considered in order to take into account slab-on-ground houses and buildings with cellars. For each climate, a ground profile temperature has been therefore calculated and used as external file.

7.3.3 Climates

The simulation climates were taken from Meteonorm data, with statistical data for the period 1986-2005 for global radiation and 2000-2009 for temperature, humidity, precipitation and wind speed. The locations for these are given in Table 16.

The climates were chosen to have a representative number of degree days for the climate region that they represent. Figure 20 and Figure 21 show maps of the heating and cooling degree days respectively, with the locations of the climates used in the simulations shown as rings. It is clear from these that the heating and cooling degree days show different trends for the different climate regions. From France across to Poland, the lines of equal heating degree days are nearly north-south whereas they are more or less east-west for cooling degree days.

Table 16 - Locations for simulation and related climatic zones

LOCATION	Climatic zone	Countries within climatic zone
Madrid	Southern Dry	Portugal, Spain
Rome	Mediterranean	Cyprus, Greece, Italy, Malta
Lyon	South-Continental	Bulgaria, France, Slovenia
London	Oceanic	Belgium, Ireland, Netherlands, UK
Stuttgart	Continental	Austria, Czech Republic, Germany, Hungary, Luxembourg, Romania, Slovakia
Gdansk	North-Continental	Denmark, Lithuania, Poland
Stockholm	Nordic	Estonia, Finland, Latvia, Sweden

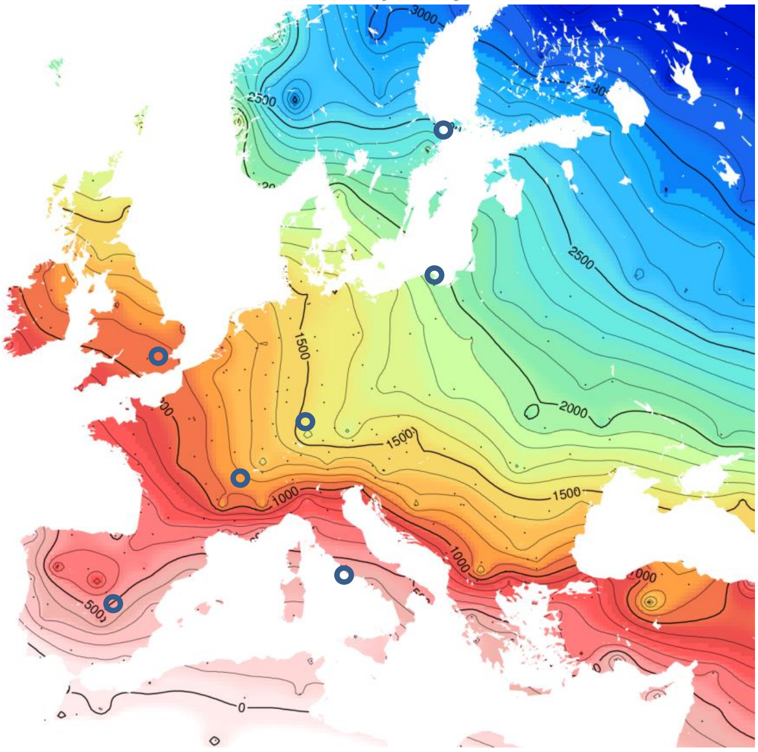


*Figure 20 – Heating degree day base 12 in Europe (Source: zafh.net, based on **Meteonorm** Data).*

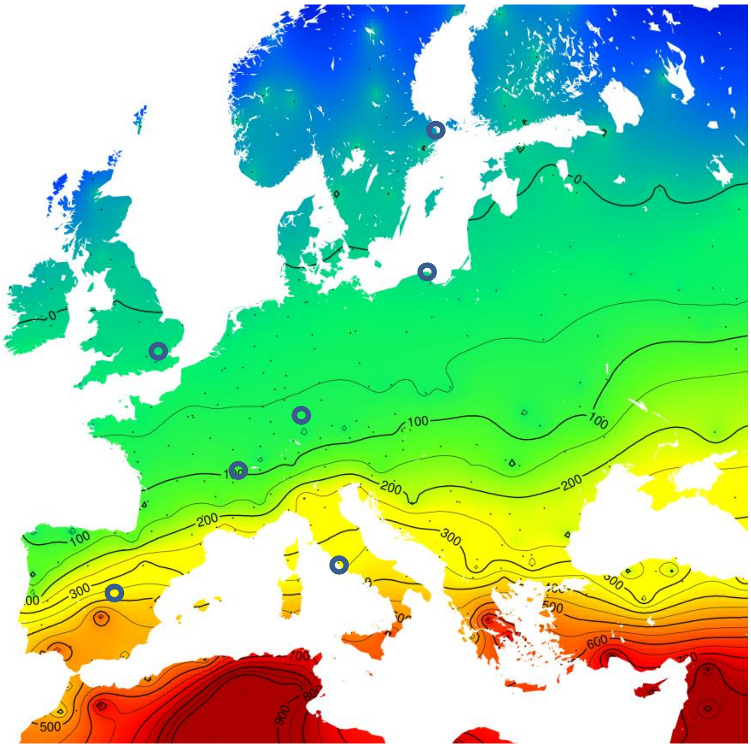


*Figure 21 – Cooling degree day base 21 in Europe (Source: zafh.net, based on **Meteonorm** Data).*

7.3.4 Other general settings

Common settings for simulation of t reference buildings are listed in Table 17:

Table 17 - Common settings for simulation of target buildings and reference buildings

GENERAL		**Units**	**Note**
Simulation START TIME	0	[h]	1 month of pre-conditioning
Simulation STOP TIME	9504	[h]	
Simulation TIME STEP	15/60	[h]	
Radiation mode			
Detailed or Standard	Standard		Target buildings
Geometry mode			
3D data or Manual	Manual		Target buildings
Geometry	Centerline		
Cold bridges	Not considered		
Boundary temperatures			
Adjacent floors	Adiabatic		

7.4Tables of U-values for the 7 climates and 6 building period categories

The tables in this section show the derived statistical average U-values for the six periods of construction seven climates for: walls, roofs, ceilings, ground and windows. Tables are given for both residential and offices. The figures highlighted for each period of construction are the average values for the climate weighted by the heated/cooled areas in the different countries that form that climate region.

Table 18 - Summary of residential u-values by country and climate region. Walls and windows. Weighted averages over total floor area

			RESIDENTIAL WEIGHTED AVERAGES - WALL							ESIDENTIAL WEIGHTED AVERAGES - WINDOW						
			uvalues W/m²/K							uvalues W/m²/K						Calcu
Climatic region	Total floor space in EU (Mm2)	Country	Pre 1945	1945-1970	1970-1980	1980-1990	1990-2000	Post 2000	Average	Pre 1945	1945-1970	1970-1980	1980-1990	1990-2000	Post 2000	Average
Southern dry																
	410	Portugal	2.0	1.5	1.5	1.4	1.2	0.8	1.4	4.3	4.2	4.2	4.2	4.2	3.2	4.0
	1,568	Spain	2.5	2.1	2.1	1.6	1.6	0.8	1.8	5.7	5.7	5.7	3.3	3.3	3.1	4.5
		WEIGHTED avg	2.4	2.0	2.0	1.6	1.5	0.8	1.7	5.4	5.4	5.4	3.5	3.5	3.1	4.4
Mediterranean																
	39	Cyprus	2.1		1.4	1.4	1.4	1.4	1.5	5.8		5.8	5.8		2.7	5.0
	323	Greece	1.6	1.6	1.6	0.9	0.9	0.7	1.2	4.1	4.1	4.1	3.2	3.2	3.1	3.6
	2,577	Italy	1.8	1.6	1.6	1.0	0.9	0.9	1.3	5.4	5.4	4.6	4.1	4.0	4.0	4.6
	14	Malta	2.0	2.0	1.5	1.5	1.5	1.5	1.6	5.8	5.8	5.8	5.8	5.8	5.8	5.8
		WEIGHTED avg	1.8	1.6	1.6	1.0	0.9	0.8	1.3	5.3	5.2	4.5	4.0	3.9	3.9	4.5
Southern Continental																
	197	Bulgaria	1.6	1.6	1.5	1.2	1.0	0.5	1.2	2.7	2.7	2.7	2.7	1.8		2.5
	2,480	France	2.4	2.4	1.0	0.7	0.5	0.4	1.2	4.2	4.2	3.6	3.0	2.1	1.8	3.1
	61	Slovenia	1.5	1.5	1.4	0.8	0.6	0.2	1.0	2.4	2.3	2.1	1.9	1.7	1.5	2.0
		WEIGHTED avg	2.4	2.3	1.1	0.8	0.5	0.4	1.2	4.0	4.0	3.5	2.9	2.0	1.8	3.1
Oceanic																
	379	Belgium	1.9	1.9	1.7	1.6	1.2	0.8	1.5	4.5	4.5	3.9	3.8	3.8	2.5	3.8
	185	Ireland	1.9	1.9	1.7	0.7	0.7	0.3	1.2	4.7	4.7	4.5	3.3	2.9	2.5	3.8
	1,924	United Kingdom	1.8	1.8	1.3	0.6	0.4	0.4	1.0	4.8	4.8	4.6	4.6	2.7	2.0	3.9
		WEIGHTED avg	1.8	1.8	1.4	0.8	0.6	0.4	1.1	4.8	4.7	4.5	4.4	2.9	2.1	3.9
Continental																
	341	Austria	1.6	1.3	0.9	0.7	0.5	0.5	0.9	3.3	3.3	2.3	2.1	1.5	1.5	2.3
	310	Czech Republic	1.1	1.0	0.9	0.8	0.4	0.4	0.8	3.5	3.1	2.7	2.7	2.2	1.7	2.7
	3,230	Germany	1.7	1.3	0.8	0.6	0.4	0.4	0.9	3.5	3.2	3.2	3.0	2.0	1.6	2.7
	303	Hungary	1.6	1.6	1.5	0.8	0.8	0.5	1.1	2.5	2.5	2.5	2.5	2.5	1.5	2.3
	16	Luxembourg	1.6	1.6	1.6	0.6	0.5	0.4	1.0	4.5	3.8	3.0	2.0	1.6	1.3	2.7
	631	Netherlands	1.8	1.7	1.6	0.5	0.5	0.4	1.1	3.8	3.4	3.4	3.4	2.9	2.0	3.2
		WEIGHTED avg	1.7	1.3	1.0	0.6	0.4	0.4	0.9	3.5	3.2	3.1	2.9	2.1	1.6	2.7
Northern Continental																
	298	Denmark	0.9	0.9	0.5	0.4	0.4	0.3	0.5	2.6	2.6	2.5	2.4	2.4	1.7	2.4
	104	Lithuania	1.0	1.0	0.5	0.5	0.5	0.2	0.6	2.2	2.2	1.8	1.8	1.8	1.6	1.9
	942	Poland	1.7	1.4	0.9	0.9	0.6	0.4	1.0	4.6	3.6	2.6	2.6	2.1	2.1	2.9
	456	Romania	1.9	1.7	1.7	1.3	1.3	0.9	1.5	2.6	2.5	2.5	2.4	2.4	1.4	2.3
	133	Slovakia	1.5	1.2	1.1	0.8	0.8	0.5	1.0	3.7	3.7	3.3	2.9	2.9	1.7	3.0
		WEIGHTED avg	1.6	1.4	1.0	0.9	0.7	0.5	1.0	3.6	3.1	2.6	2.5	2.3	1.8	2.6
Nordic																
	37	Estonia	0.5	0.5	0.3	0.3	0.2	0.2	0.3	1.7	1.7	1.7	1.1	1.1	1.1	1.4
	200	Finland	0.6	0.6	0.4	0.3	0.3	0.2	0.4	2.2	2.2	1.9	1.7	1.7	1.5	1.9
	61	Latvia	1.0	1.0	1.0	0.9	0.9	0.5	0.9	2.7	2.6	2.6	2.5	2.5	1.8	2.5
	386	Sweden	0.6	0.4	0.3	0.3	0.2	0.2	0.3	3.2	3.0	2.8	2.5	2.5	1.0	2.5
		WEIGHTED avg	0.6	0.5	0.4	0.3	0.3	0.2	0.4	2.8	2.7	2.5	2.2	2.2	1.2	2.3

Table 19 - Summary of residential u-values by country and climate region. Floors and Roofs. Weighted averages over total floor area

			RESIDENTIAL WEIGHTED AVERAGES - FLOOR							RESIDENTIAL WEIGHTED AVERAGES - ROOF						
			uvalues $W/m^2/K$						Calcu	uvalues $W/m^2/K$						Calcu
Climatic region	Total floor space in EU (Mm2)	Country	Pre 1945	1945-1970	1970-1980	1980-1990	1990-2000	Post 2000	Average	Pre 1945	1945-1970	1970-1980	1980-1990	1990-2000	Post 2000	Average
Southern dry																
	410	Portugal	2.1	2.1	2.1	2.1	2.0	1.3	1.9	3.1	3.0	2.7	2.6	2.4	1.3	2.5
	1,568	Spain	2.5	2.5	2.5	0.8	0.8	0.7	1.6	1.8	1.4	1.4	1.0	1.0	0.5	1.2
		WEIGHTED avg	2.4	2.4	2.4	1.1	1.0	0.8	1.7	2.0	1.7	1.6	1.3	1.3	0.7	1.4
Mediterranean																
	39	Cyprus										3.3	3.3	0.6	0.6	1.9
	323	Greece	2.4	2.4	2.4	2.4	2.3	0.7	2.1	2.5	2.5	2.5	1.1	1.1	0.5	1.7
	2,577	Italy	1.9	1.8	1.6	1.4	1.4	1.3	1.6	2.2	2.0	1.7	1.2	1.0	0.9	1.5
	14	Malta	3.0	3.0	3.0	2.0	2.0	2.0	2.5	1.9	1.9	1.9	1.9	1.8	1.8	1.9
		WEIGHTED avg	1.9	1.9	1.7	1.5	1.5	1.2	1.6	2.2	2.1	1.8	1.2	1.0	0.9	1.5
Southern Continental																
	197	Bulgaria	1.0	1.0	1.0	0.6	0.5	0.5	0.8	1.3	1.3	1.2	1.1	0.5	0.3	0.9
	2,480	France	1.9	1.9	0.8	0.7	0.5	0.4	1.0	2.5	2.4	1.1	0.7	0.6	0.2	1.3
	61	Slovenia	1.3	1.2	0.9	0.8	0.6	0.2	0.8	1.3	1.2	1.0	0.7	0.4	0.2	0.8
		WEIGHTED avg	1.9	1.8	0.9	0.7	0.5	0.4	1.0	2.4	2.3	1.1	0.8	0.6	0.2	1.2
Oceanic																
	379	Belgium	1.0	1.0	1.0	0.9	0.8	0.6	0.9	2.3	2.3	2.3	1.1	0.9	0.6	1.6
	185	Ireland	1.4	1.4	1.4	0.8	0.7	0.3	1.0	1.0	1.0	0.8	0.4	0.4	0.3	0.7
	1,924	United Kingdom	2.0	1.7	1.4	1.1	0.5	0.3	1.2	2.4	2.0	0.9	0.5	0.3	0.2	1.1
		WEIGHTED avg	1.8	1.6	1.3	1.1	0.5	0.3	1.1	2.3	2.0	1.1	0.6	0.4	0.2	1.1
Continental																
	341	Austria	1.7	1.7	1.0	0.7	0.5	0.4	1.0	1.3	0.8	0.6	0.4	0.3	0.2	0.6
	310	Czech Republic	1.5	1.1	1.0	0.9	0.6	0.4	0.9	1.1	0.9	0.6	0.5	0.4	0.2	0.6
	3,230	Germany	1.4	1.4	1.0	0.6	0.4	0.3	0.8	1.5	1.5	0.6	0.4	0.3	0.2	0.7
	303	Hungary	1.0	1.0	1.0	0.8	0.8	0.5	0.9	1.2	1.2	0.9	0.6	0.6	0.3	0.8
	16	Luxembourg	1.8	1.4	0.6	0.6	0.5	0.4	0.9							
	631	Netherlands	2.0	1.7	1.5	1.0	0.9	0.4	1.3	2.6	1.8	1.1	0.6	0.6	0.4	1.2
		WEIGHTED avg	1.5	1.4	1.0	0.7	0.5	0.4	0.9	1.6	1.4	0.7	0.4	0.4	0.2	0.8
Northern Continental																
	298	Denmark	0.9	0.7	0.3	0.3	0.3	0.2	0.4	0.6	0.4	0.3	0.2	0.2	0.1	0.3
	104	Lithuania	1.0	1.0	0.6	0.6	0.6	0.4	0.7	0.8	0.8	0.5	0.5	0.5	0.2	0.5
	942	Poland	1.9	1.4	1.2	1.1	0.9	0.6	1.2	0.8	0.7	0.6	0.6	0.6		0.7
	456	Romania	1.6	1.4	1.3	1.1	1.0	1.0	1.2	1.4	1.3	1.3	1.2	1.2		1.3
	133	Slovakia	2.0	1.7	1.6	1.6	1.5	1.0	1.6	2.0	1.5	1.1	0.7	0.6		1.2
		WEIGHTED avg	1.6	1.3	1.1	1.0	0.9	0.6	1.1	1.0	0.9	0.7	0.7	0.7	0.2	0.8
Nordic																
	37	Estonia	0.5	0.5	0.4	0.3	0.2	0.2	0.3	0.5	0.5	0.4	0.2	0.2	0.2	0.3
	200	Finland	0.6	0.5	0.4	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.3
	61	Latvia	0.9	0.9	0.9	0.6	0.6	0.3	0.7	1.2	1.2	1.1	0.9	0.9	0.5	1.0
	386	Sweden	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.2	0.2	0.1	0.1	0.2
		WEIGHTED avg	0.4	0.4	0.3	0.3	0.3	0.2	0.3	0.5	0.5	0.3	0.3	0.2	0.2	0.3

Table 20 - Summary of office building u-values by country and climate region. Walls and windows

			OFFICE WEIGHTED AVERAGES - WALL							OFFICE WEIGHTED AVERAGES - WINDOWS						
			uvalues W/m²/K						Calcu	uvalues W/m²/K						Calcu
Climatic region	Total floor space in EU (Mm2)	Country	Pre 1945	1945-1970	1970-1980	1980-1990	1990-2000	Post 2000	Average	Pre 1945	1945-1970	1970-1980	1980-1990	1990-2000	Post 2000	Average
Southern dry																
	21	Portugal	2.0	2.0	1.6	1.5	1.3	0.8	1.5	4.5	4.5	4.5	4.4	1.6	3.8	3.9
	84	Spain	2.5	2.2	2.2	1.8	1.7	0.9	1.9	5.8	5.8	6.1	3.3	3.3	2.8	4.5
		WEIGHTED avg	2.4	2.2	2.1	1.7	1.6	0.8	1.8	5.5	5.6	5.8	3.6	2.9	3.0	4.4
Mediterranean																
	2	Cyprus	2.1	1.9	1.5	1.5	1.5	1.5	1.7	6.2	6.2	6.2	5.9	2.5	1.6	4.8
	26	Greece	2.5	2.4	2.1	0.8	0.7		1.7	5.1	5.0	5.3	3.7	3.5		4.5
	52	Italy	1.2	1.2	0.8	0.8	0.8		0.9	5.5	5.5	4.9	4.2	3.6	3.6	4.5
	1	Malta	2.0	1.9	1.6	1.6	1.6	1.7	1.7	6.1	6.1	5.9	5.8	5.7	5.3	5.8
		WEIGHTED avg	1.6	1.6	1.2	0.8	0.8	1.6	1.2	5.4	5.4	5.0	4.1	3.5	3.6	4.5
Southern Continental																
	28	Bulgaria	1.6	1.5	1.4	1.3	1.0	0.4	1.2	3.1	3.1	3.1	3.1	2.7	1.9	2.8
	199	France	2.1	2.1	1.2	1.2	1.0	0.4	1.3	5.0	5.0	4.4	3.4	3.3	2.7	3.9
	7	Slovenia	1.4	1.4	1.4	0.9	0.9	0.6	1.1	2.4	2.4	2.1	1.6	1.6	1.6	2.0
		WEIGHTED avg	2.0	2.0	1.2	1.2	1.0	0.4	1.3	4.7	4.7	4.2	3.3	3.1	2.5	3.7
Oceanic																
	25	Belgium	1.9	1.8	1.8	1.7	1.3	0.8	1.5	4.5	4.6	4.2	3.8	3.7	2.3	3.8
	10	Ireland	1.9	1.8	1.8	0.8	0.7	0.3	1.2	4.8	4.8	4.8	3.3	2.9	2.3	3.8
	122	United Kingdom	1.8	1.7	1.3	0.7	0.5	0.4	1.1	4.9	4.9	4.9	4.6	2.7	1.8	4.0
		WEIGHTED avg	1.8	1.7	1.4	0.8	0.6	0.4	1.1	4.8	4.9	4.8	4.4	2.9	1.9	4.0
Continental																
	21	Austria	0.7	0.7	0.6	0.6	0.4	0.3	0.6	3.2	3.4	2.4	2.1	1.4	1.3	2.3
	36	Czech Republic	0.8	0.8	0.7	0.7	0.5	0.4	0.6	2.8	2.8	2.8	2.8	2.0	1.5	2.5
	360	Germany	1.5	1.5	1.2	0.9	0.4	0.4	1.0	2.9	2.9	2.9	1.9	1.6	1.3	2.3
	5	Hungary	1.4	1.2	1.2	0.7	0.7	0.5	0.9	3.0	3.0	3.0	2.7	2.7	2.2	2.8
	1	Luxembourg	1.5	1.5	1.7	0.6	0.5	0.4	1.0	4.5	3.9	3.2	2.0	1.6	1.2	2.7
	47	Netherlands	1.8	1.6	1.6	0.6	0.5	0.4	1.1	3.8	3.7	3.7	3.4	2.9	1.8	3.2
		WEIGHTED avg	1.4	1.4	1.2	0.8	0.4	0.4	0.9	3.0	3.0	2.9	2.1	1.8	1.4	2.4
Northern Continental																
	45	Denmark	1.2	1.0	0.6	0.4	0.4	0.3	0.6	2.6	2.5	2.5	1.4	1.4	1.7	2.0
	8	Lithuania	1.0	0.9	0.6	0.6	0.4	0.3	0.6	2.4	2.4	2.3	2.3	1.9	1.9	2.2
	89	Poland	1.3	1.3	1.3	0.8	0.6		1.1	4.7	3.7	2.6	2.6	2.3	2.1	3.0
	8	Romania	1.9	1.6	1.6	1.4	1.4	1.0	1.5	2.6	2.7	2.7	2.4	2.4	1.3	2.4
	7	Slovakia	1.5	1.0	1.0	0.7	1.1	0.5	1.0	3.2	3.2	2.9	2.9			3.1
		WEIGHTED avg	1.3	1.2	1.0	0.7	0.6	0.4	0.9	3.8	3.2	2.6	2.2	2.0	1.9	2.6
Nordic																
	2	Estonia	0.5	0.5	0.3	0.3	0.2	0.2	0.3	1.8	1.8	1.8	1.1	1.0	1.0	1.4
	16	Finland	0.8	0.6	0.5	0.3	0.3	0.3	0.5	2.4	2.3	2.2	2.0	1.7	1.5	2.0
	4	Latvia	1.0	1.0	1.0	1.0	0.8	0.5	0.9	2.7	2.7	2.5	2.5	2.5	1.8	2.5
	27	Sweden	0.6	0.4	0.3	0.3	0.2	0.2	0.3	3.2	3.1	3.0	2.5	2.5	0.9	2.5
		WEIGHTED avg	0.7	0.5	0.4	0.4	0.3	0.2	0.4	2.8	2.7	2.6	2.3	2.2	1.2	2.3

Table 21 - Summary of office building u-values by country and climate region. Roofs and Floors

			OFFICE WEIGHTED AVERAGES - FLOOR							OFFICE WEIGHTED AVERAGES - ROOF						
			uvalues W/m²/K						Calcu	uvalues W/m²/K						Calcu
Climatic region	Total floor space in EU (Mm2)	Country	Pre 1945	1945-1970	1970-1980	1980-1990	1990-2000	Post 2000	Average	Pre 1945	1945-1970	1970-1980	1980-1990	1990-2000	Post 2000	Average
Southern dry																
	21	Portugal					1.9	0.8	1.4	2.5	2.8	2.8	2.7	1.5	1.2	2.2
	84	Spain	2.5	2.5	2.5	0.8	0.8	0.8	1.7	1.4	1.4	1.4	1.0	0.9	0.6	1.1
		WEIGHTED avg	2.5	2.5	2.5	0.8	1.1	0.8	1.6	1.6	1.7	1.7	1.4	1.0	0.8	1.4
Mediterranean																
	2	Cyprus										3.4	3.5	0.5	0.7	2.0
	26	Greece	0.7	0.7	0.7	0.7	0.7	0.8	0.7	3.2	3.0	2.7	0.7	0.5	0.6	1.8
	52	Italy	0.8	0.8	0.5	0.5	0.5	1.4	0.8	1.3	1.3	0.8	0.8	0.8		1.0
	1	Malta	2.6	2.6	2.4	2.0	2.1	2.3	2.3	1.7	1.7	2.0	2.0	1.7	2.1	1.9
		WEIGHTED avg	0.8	0.8	0.6	0.6	0.6	1.2	0.8	1.9	1.9	1.5	0.9	0.7	0.6	1.3
Southern Continental																
	28	Bulgaria	1.0	1.0	1.0	0.8	0.6	0.5	0.8	1.0	1.2	1.1	1.1	0.6	0.3	0.9
	199	France	1.8	1.8	1.8	1.0	0.8	0.4	1.2	1.8	1.8	1.0	0.8	0.6	0.3	1.0
	7	Slovenia	1.1	1.1	0.9	0.8	0.8	0.5	0.9	1.2	1.2	0.9	0.8	0.8	0.5	0.9
		WEIGHTED avg	1.6	1.6	1.6	0.9	0.8	0.4	1.2	1.6	1.7	1.0	0.8	0.6	0.3	1.0
Oceanic																
	25	Belgium	0.8	0.8	1.0	0.9	0.8	0.7	0.8	2.0	2.0	2.2	1.2	0.9	0.7	1.5
	10	Ireland								0.8	0.9	0.8	0.4	0.4	0.4	0.6
	122	United Kingdom	2.0	1.7	1.4	1.1	0.5	0.3	1.2	1.9	1.8	0.9	0.5	0.3	0.2	1.0
		WEIGHTED avg	1.8	1.5	1.3	1.1	0.5	0.3	1.0	1.9	1.8	1.1	0.6	0.4	0.3	1.0
Continental																
	21	Austria	1.2	1.5	1.0	0.6	0.5	0.5	0.9	1.1	0.7	0.6	0.4	0.3	0.2	
	36	Czech Republic	1.5	1.0	0.8	0.8	0.6	0.4	0.9	0.8	0.6	0.5	0.5	0.4	0.2	0.5
	360	Germany	1.2	1.2	0.9	0.4	0.4	0.4	0.7	1.0	1.0	0.8	0.5	0.3	0.3	0.6
	5	Hungary	1.0	1.0	1.0	0.8	0.8	0.5	0.9	1.4	1.4	1.0	0.7	0.7	0.3	0.9
	1	Luxembourg	1.5	1.2	0.6	0.6	0.5	0.5	0.8							
	47	Netherlands	2.0	1.7	1.5	1.0	0.9	0.5	1.3	2.1	1.7	1.2	0.7	0.5	0.5	1.1
		WEIGHTED avg	1.3	1.2	0.9	0.5	0.5	0.4	0.8	1.1	1.0	0.8	0.5	0.3	0.3	0.7
Northern Continental																
	45	Denmark	0.8	0.6	0.6	0.5	0.5	0.3	0.5	0.5	0.5	0.3	0.2	0.2	0.2	0.3
	8	Lithuania				0.4	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.3	0.2	0.5
	89	Poland	1.6	1.2	1.2	1.1	1.0	0.7	1.1	1.0	0.9	0.7	0.5	0.3		0.7
	8	Romania	1.4	1.4	1.4	1.1	1.0	1.0	1.2	1.1	1.2	1.2	1.2	1.1	0.0	1.0
	7	Slovakia	1.5	1.5	1.5	1.5	1.4	1.1	1.4	1.6	0.7	0.7	0.5	0.5	0.0	0.6
		WEIGHTED avg	1.3	1.0	1.0	0.9	0.8	0.6	0.9	0.9	0.8	0.6	0.4	0.3	0.1	0.6
Nordic																
	2	Estonia	0.4	0.4	0.4	0.3	0.2	0.2	0.3	0.4	0.4	0.4	0.2	0.2	0.2	0.3
	16	Finland	0.6	0.5	0.4	0.3	0.3	0.3	0.4	0.5	0.4	0.3	0.2	0.2	0.2	0.3
	4	Latvia	1.0	1.0	1.0	1.0	1.0	0.3	0.9	1.0	1.2	1.2	1.2	1.0	0.5	1.0
	27	Sweden	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.2	0.2	0.1	0.0	0.2
		WEIGHTED avg	0.4	0.4	0.4	0.3	0.3	0.2	0.3	0.4	0.4	0.3	0.3	0.2	0.1	0.3

8 Annex II - Graphs of simulation results vs statistical values

8.1 Residential buildings

In this section, the figures shown are simulation results from the reference buildings as compared to statistical data. These are shown for the six periods of construction.

The coloured dots on the left hand side section represent demands for a range of heating and cooling set point temperatures (from 18°C to 24°C). These are shown for the six periods of construction. Values are shown for three variations of the SFH - detached, semi-detached and row – (S/V = 0.90), an average small-MFH with 5 floors (S/V = 0.53) and an average large-MFH with five floors again (S/V = 0.33).

For simulation results the red squares represent the weighted average result based on the floor areas of the typologies simulated.

In the right hand area, the bars represent heated/cooled areas (orange/light blue part) and total floor areas for the whole climate region, as well as for the relevant countries.

The blue dots represent statistical demand data out of the survey reported in D2.1a. This values are calculated by consumptions converted with a coefficient of 0.8 for heating (bolier efficiency) and 2.5 for cooling (chiller EER).

For statistical values, the red square represents the weighted average (on heated/cooled areas) of the latter calculated demands. The yellow square is the weighted average (on heated/cooled areas) of direct demand values retrieved in the literature (where available).

8.1.1 Residential heating demand

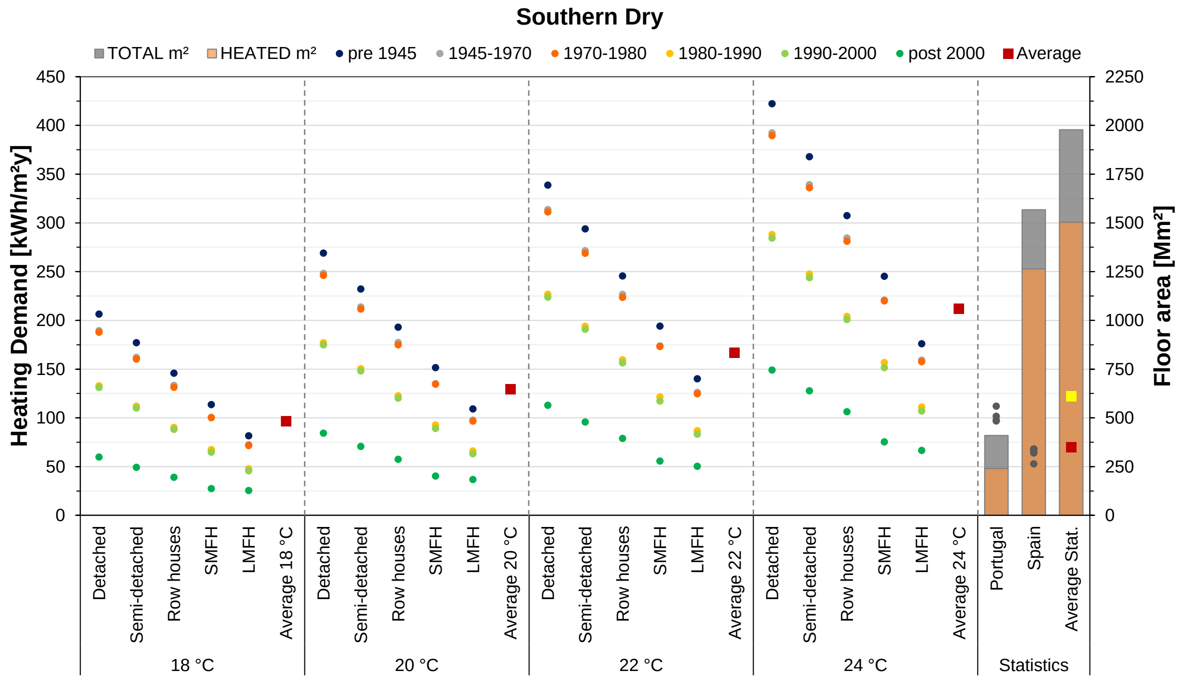


Figure 22

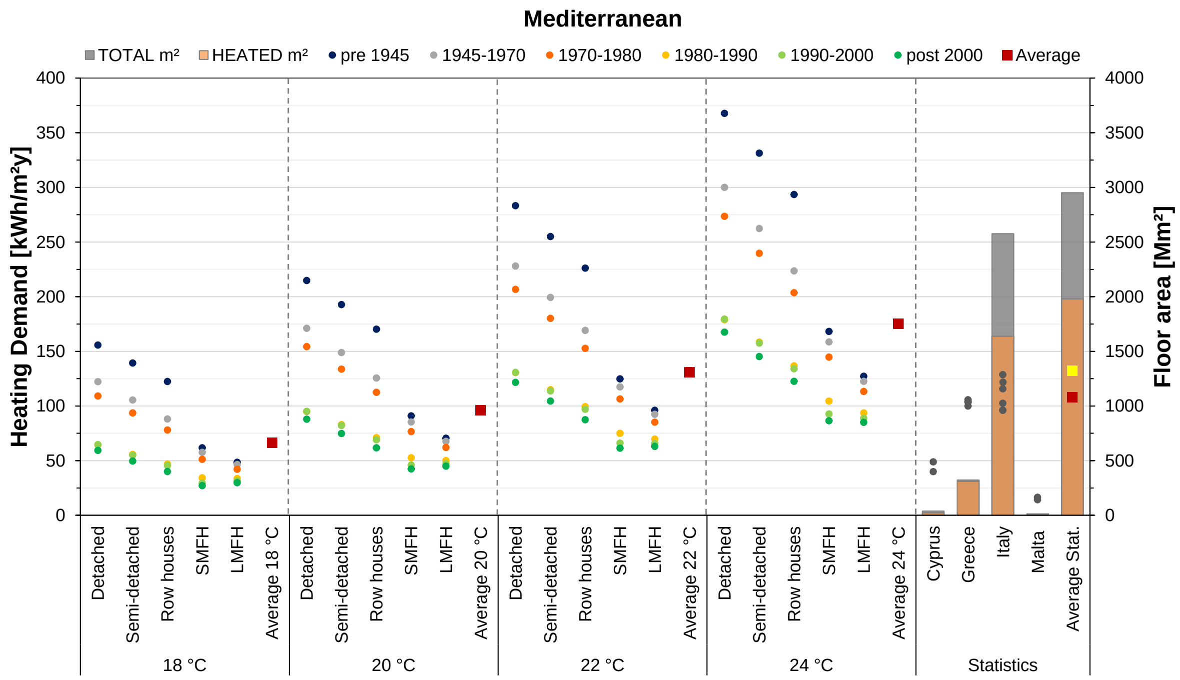


Figure 23

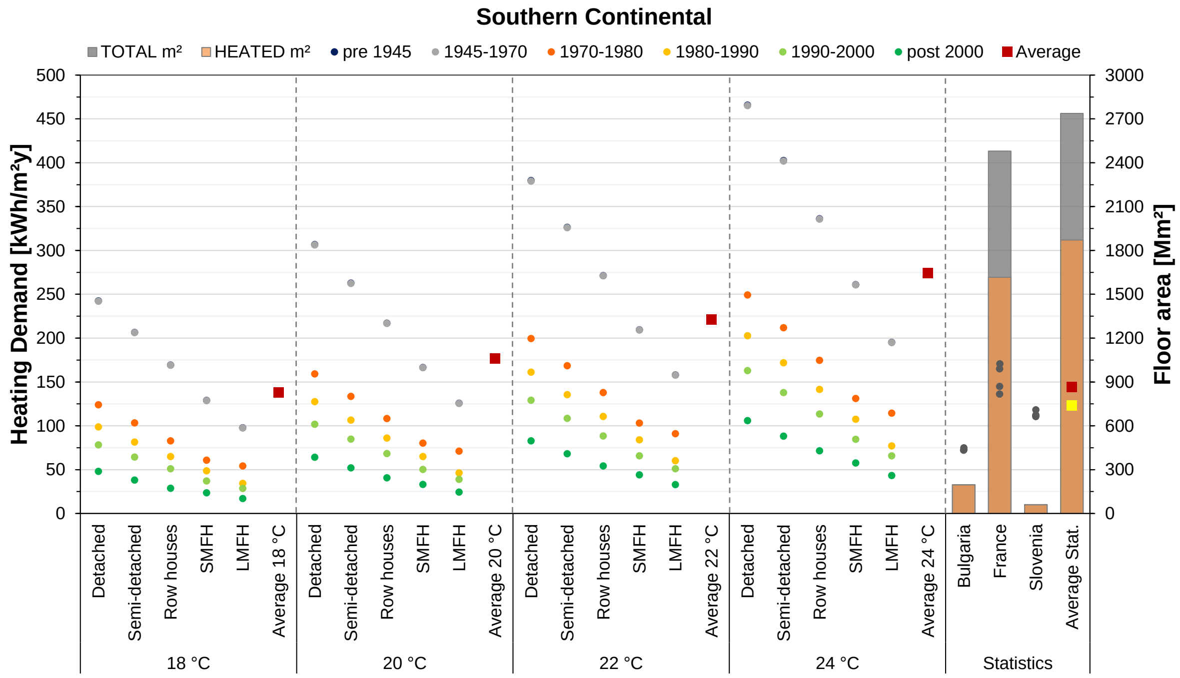


Figure 24

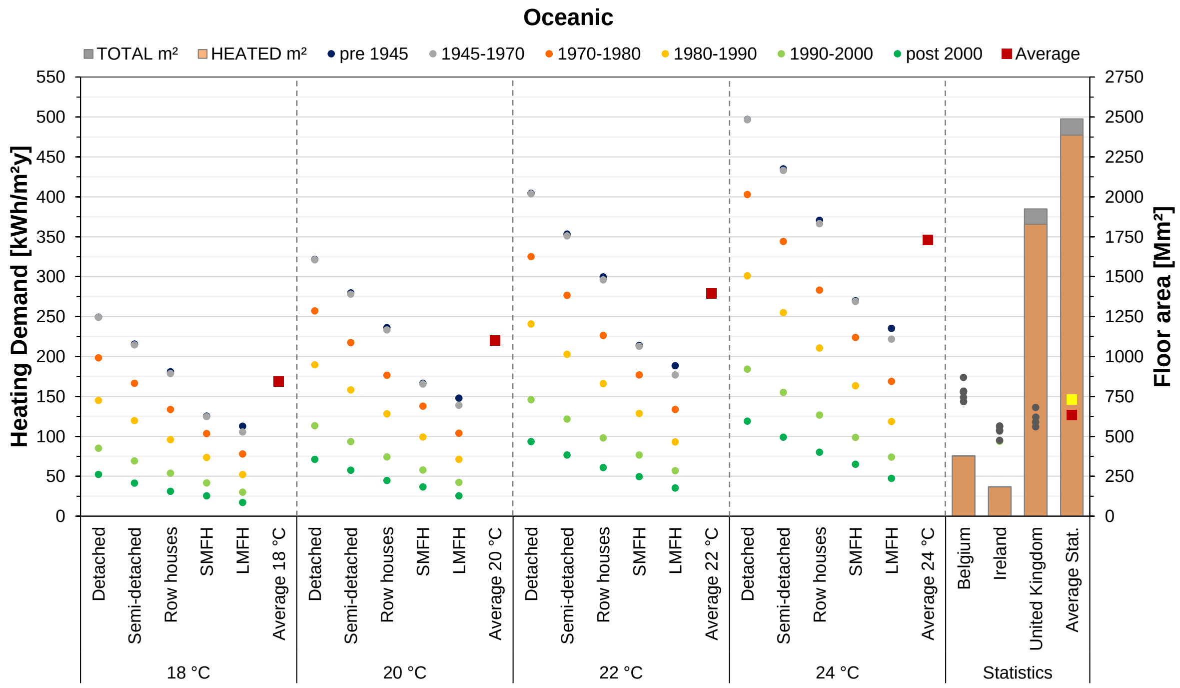


Figure 25

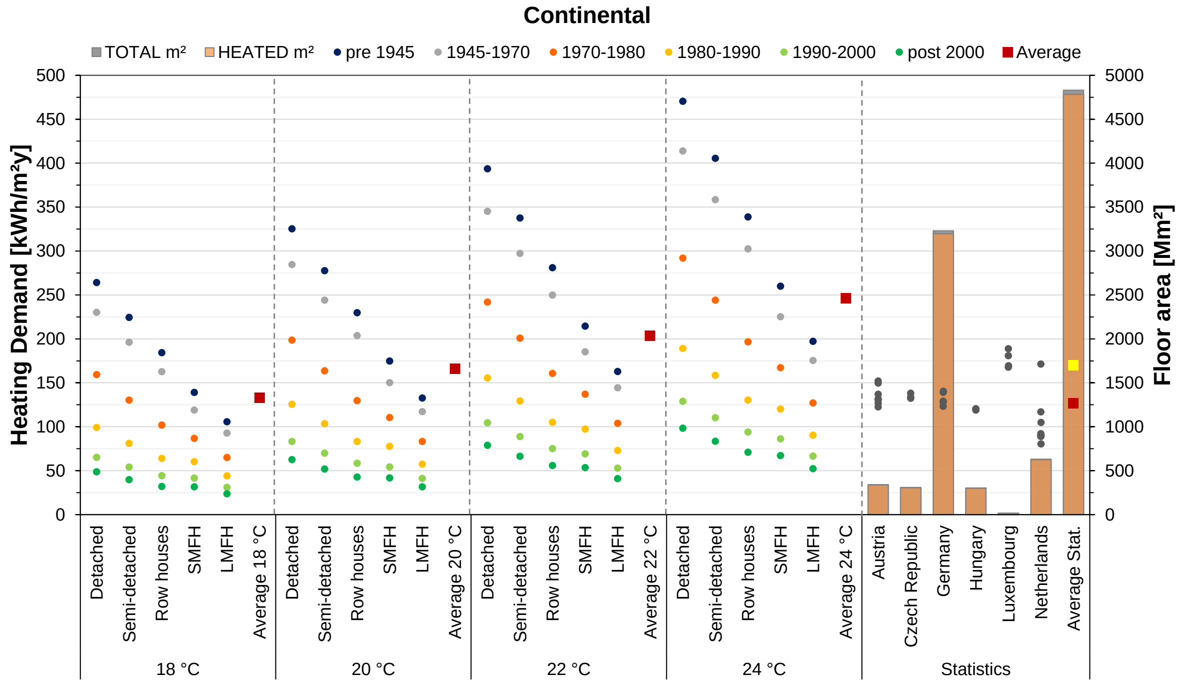


Figure 26

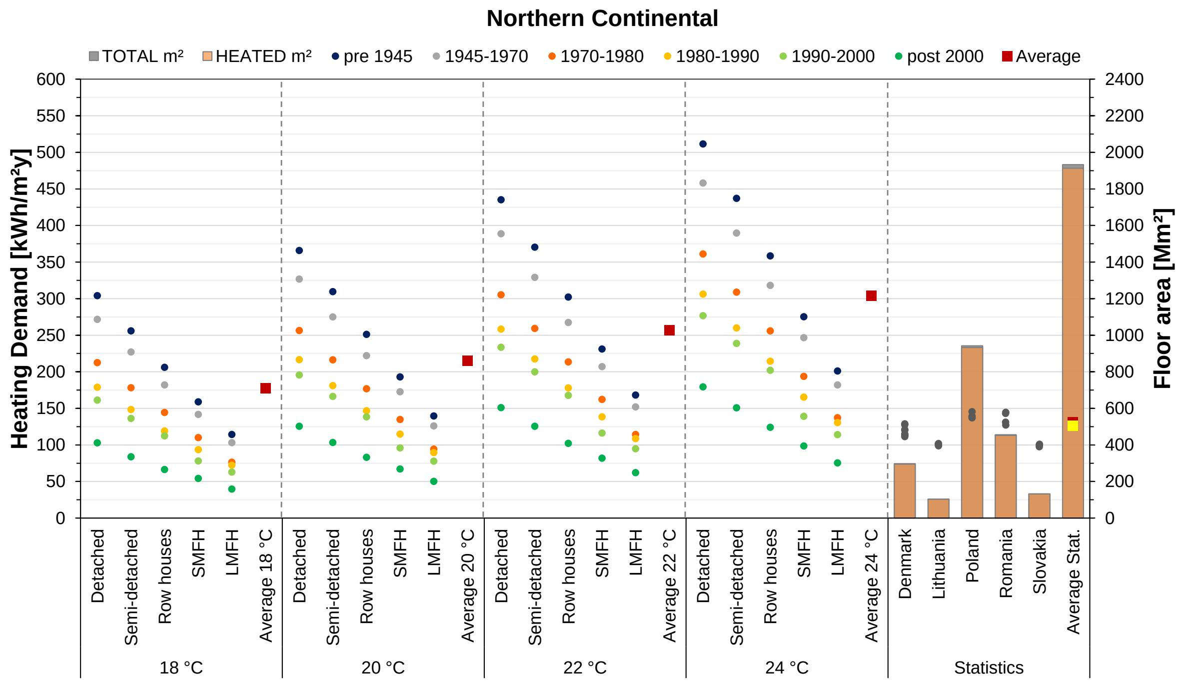


Figure 27

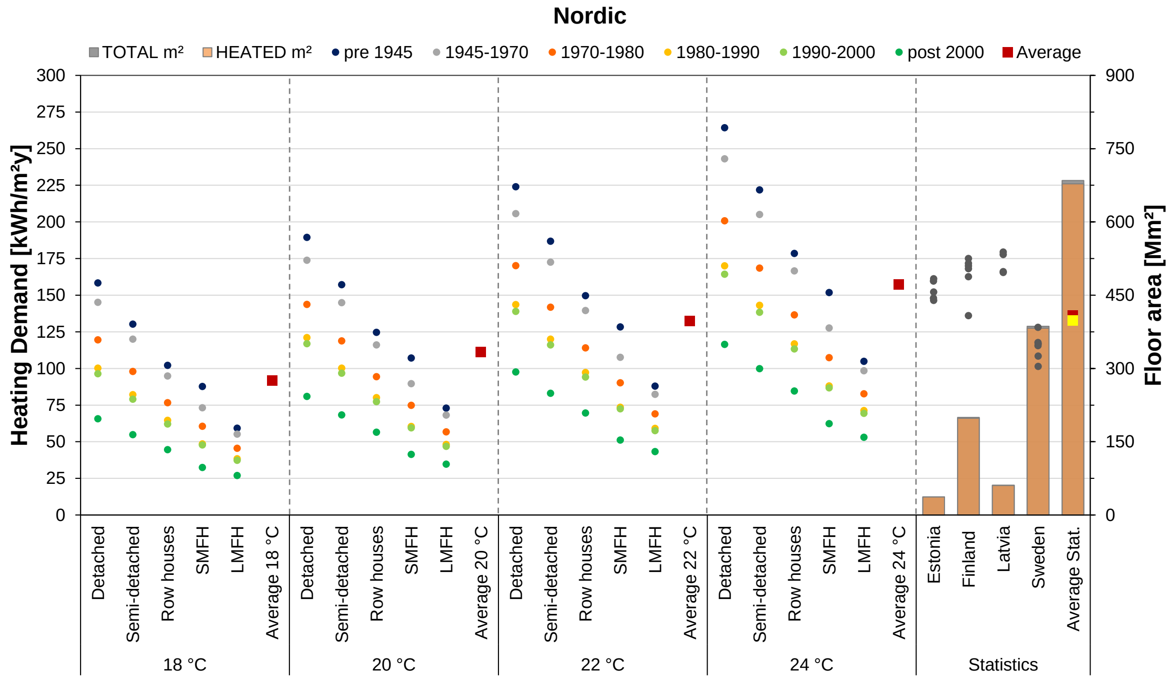

Nordic
TOTAL m²
HEATED m²
pre 1945
1945-1970
1970-1980
1980-1990
1990-2000
post 2000
Average
Heating Demand [kWh/m²y]
Floor area [Mm²]
300
275
250
225
200
175
150
125
100
75
50
25
0
900
750
600
450
300
150
0
Detached
Semi-detached
Row houses
SMFH
LMFH
Average 18 °C
Average 20 °C
Average 22 °C
Average 24 °C
Estonia
Finland
Latvia
Sweden
Average Stat.
18 °C
20 °C
22 °C
24 °C
Statistics

Figure 28

8.1.2 Residential cooling demands

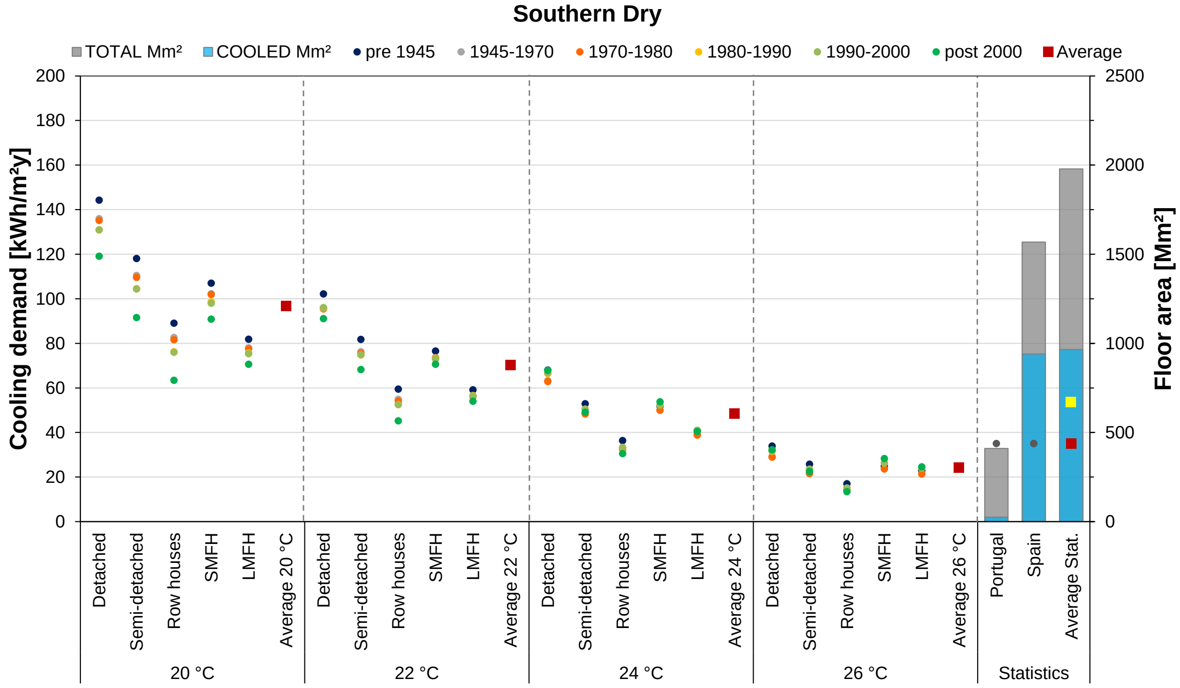


Figure 29

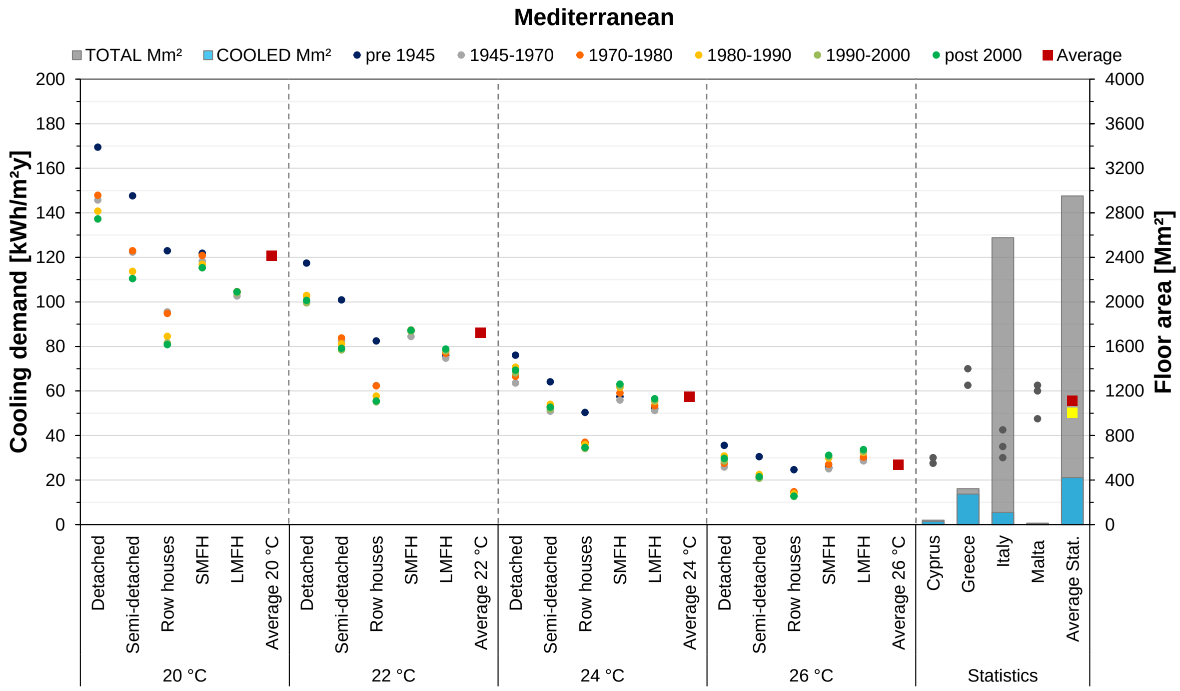


Figure 30

Southern Continental

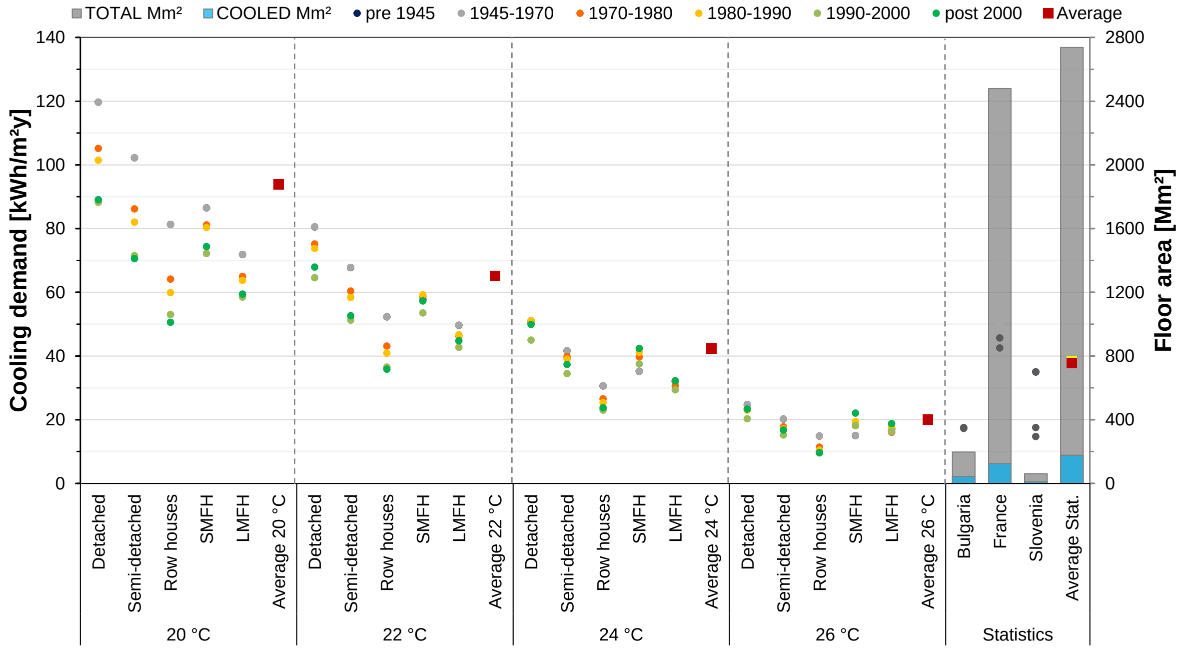


Figure 31

Oceanic

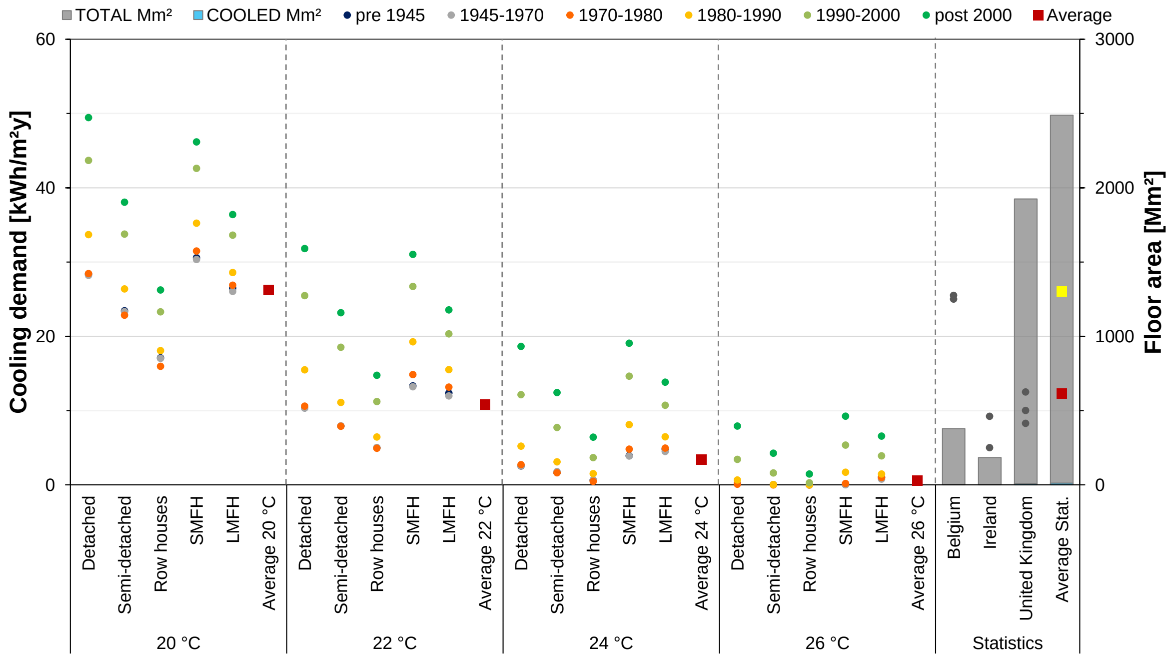


Figure 32

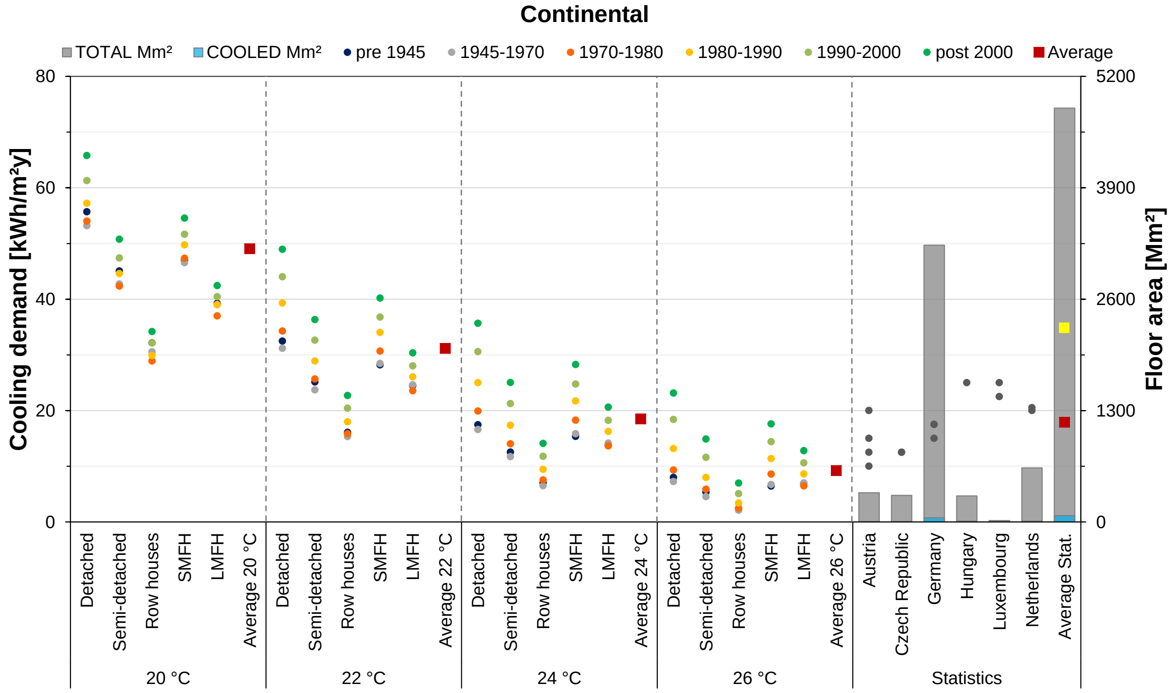


Figure 33

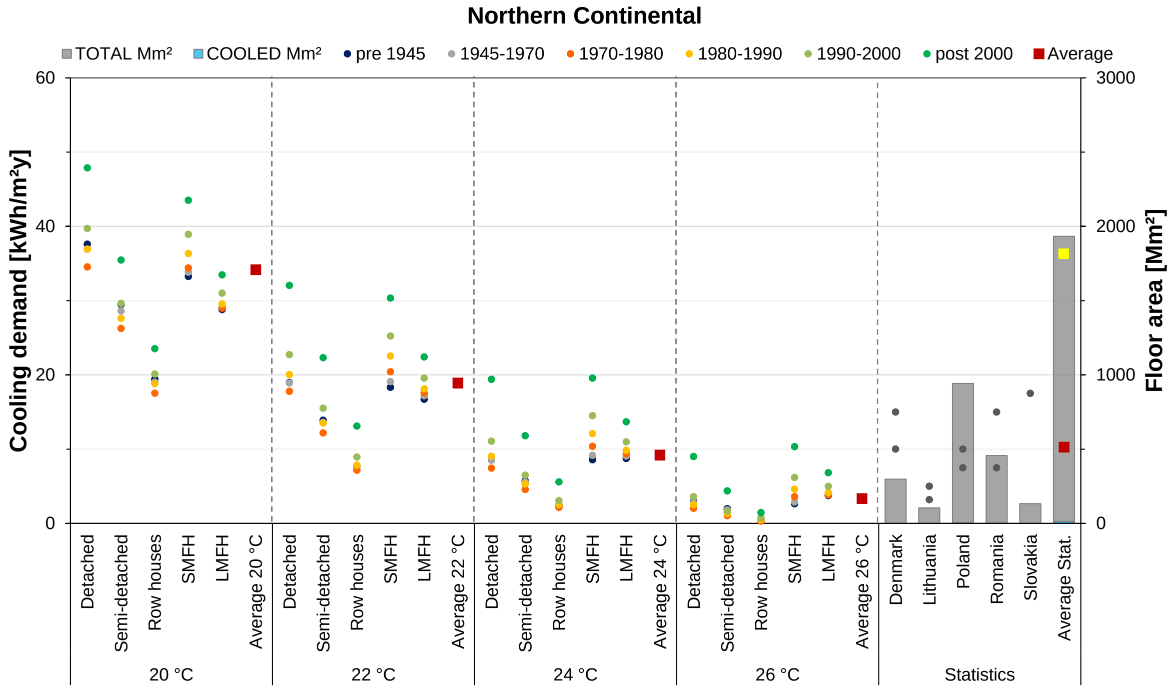


Figure 34

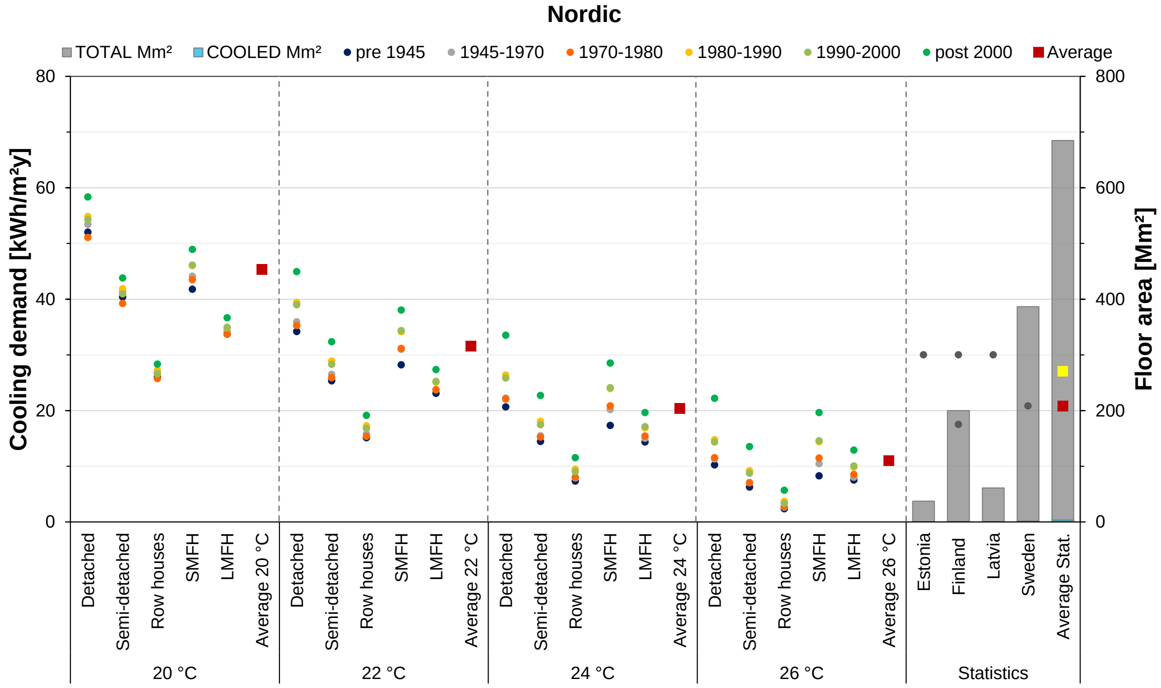

Nordic
TOTAL Mm²
COOLED Mm²
pre 1945
1945-1970
1970-1980
1980-1990
1990-2000
post 2000
Average
Cooling demand [kWh/m²y]
Floor area [Mm²]
80
60
40
20
0
800
600
400
200
0
Detached
Semi-detached
Row houses
SMFH
LMFH
Average 20 °C
Average 22 °C
Average 24 °C
Average 26 °C
Estonia
Finland
Latvia
Sweden
Average Stat.
20 °C
22 °C
24 °C
26 °C
Statistics

Figure 35

8.2Office Buildings

In this section, the figures shown are simulation results from the reference buildings as compared to statistical data. These are shown for the six periods of construction.

As in the previous paragraph, the coloured dots on the left hand side section represent demands for a range of heating and cooling set point temperatures (from 18°C to 24°C). These are shown for the six periods of construction. Values are shown for low-rise building (<4 floors) with 6 cells per floor (S/V = 0.54), high-rise building (>4 floors) with 6 cells per floor (S/V = 0.43), low-rise building with 12 cells per floor (S/V = 0.46) and high-rise building with 12 cells per floor (S/V = 0.35).

For simulation results the red squares represent the weighted average result based on the floor areas of the typologies simulated.

In the right hand area, the bars represent heated/cooled areas (orange/light blue part) and total floor areas for the whole climate region, as well as for the relevant countries.

The blue dots represent statistical demand data out of the survey reported in D2.1a. This values are calculated by consumptions converted with a coefficient of 0.8 for heating (bolier efficiency) and 2.5 for cooling (chiller EER).

For statistical values, the red square represents the weighted average (on heated/cooled areas) of the latter calculated demands. For office buildings, the weighted average (on heated/cooled areas) of direct demand values retrieved in the literature has been not calculated because of the lack of statistics.

8.2.1 Office heating demands

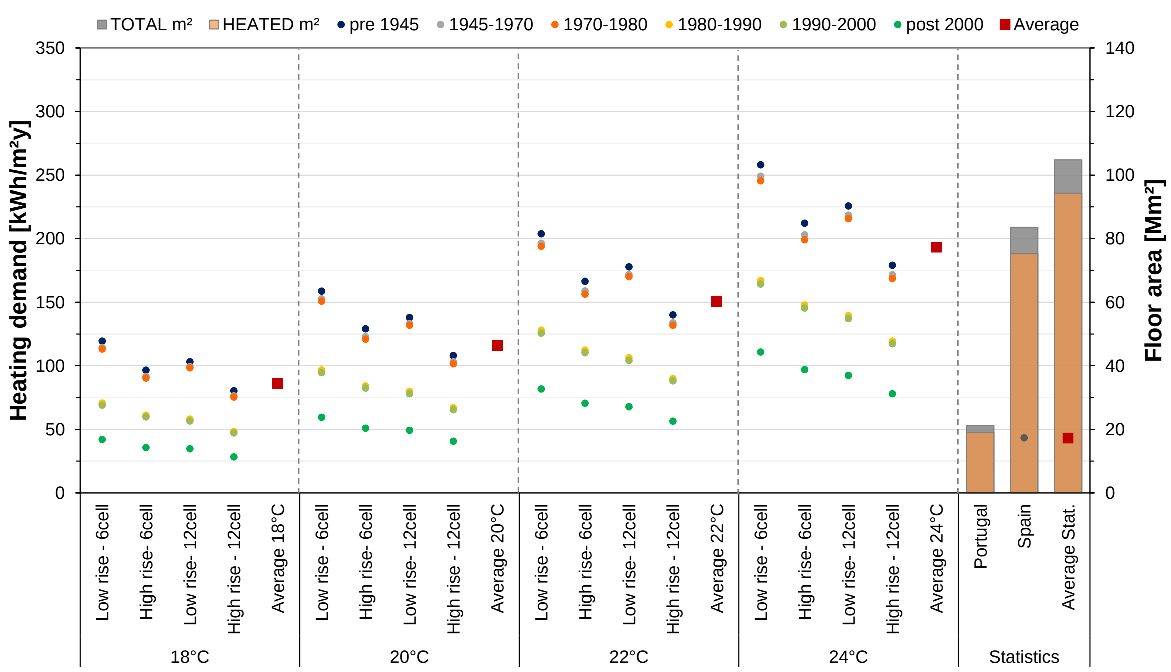


Figure 36

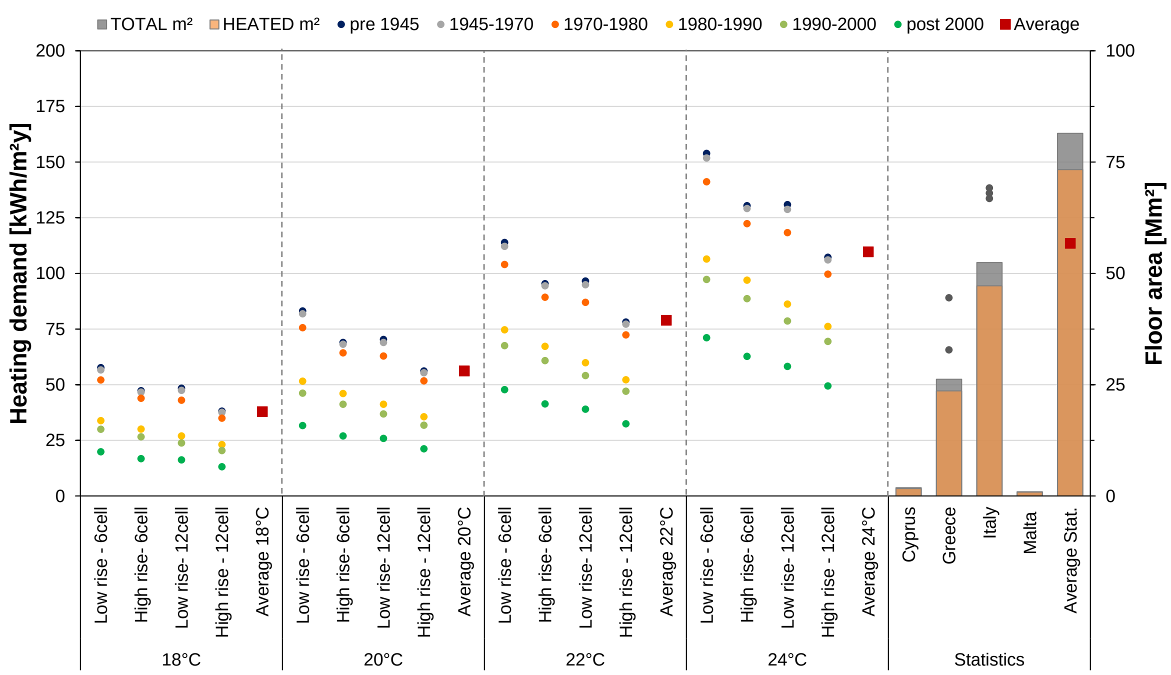


Figure 37

Southern Continental

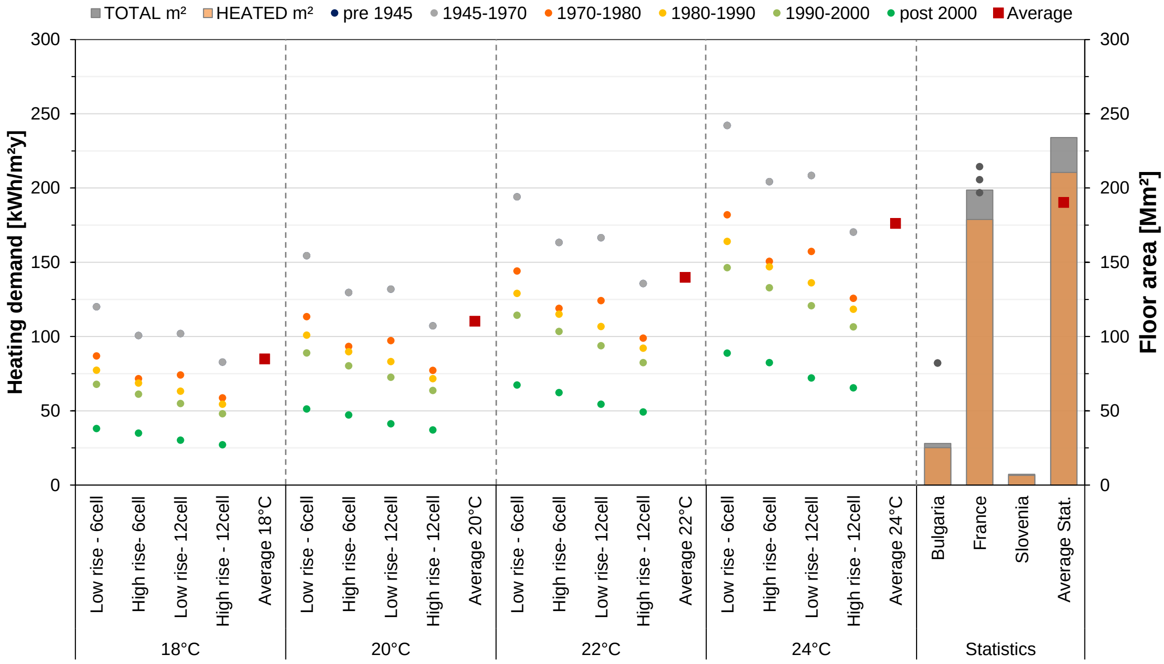


Figure 38

Oceanic

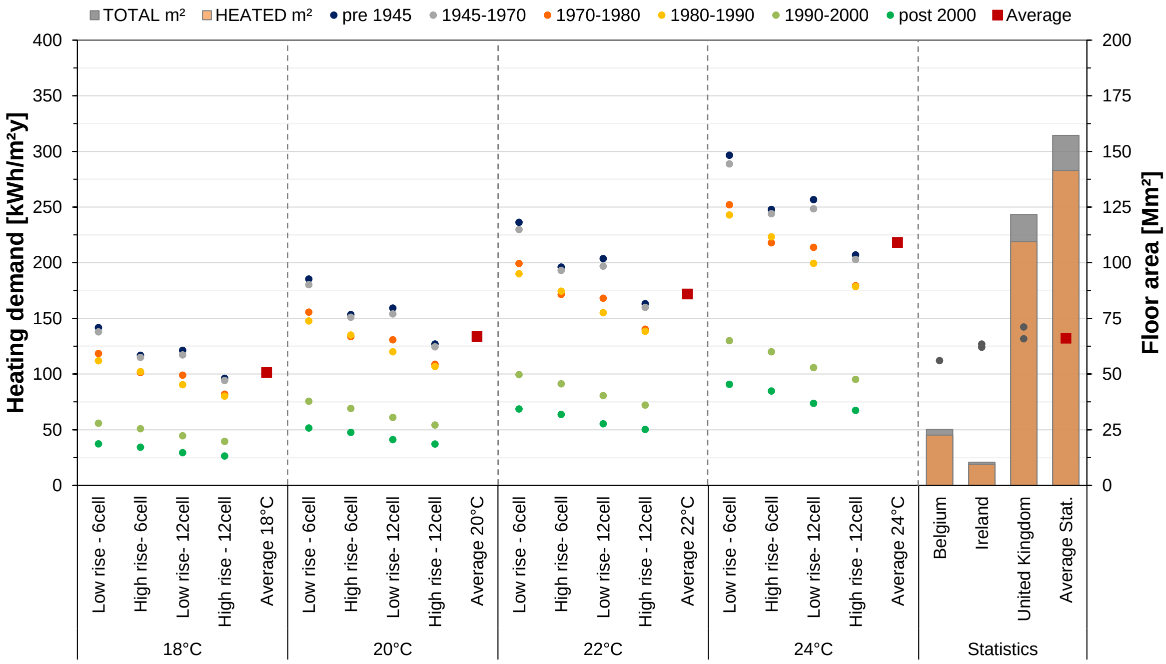


Figure 39

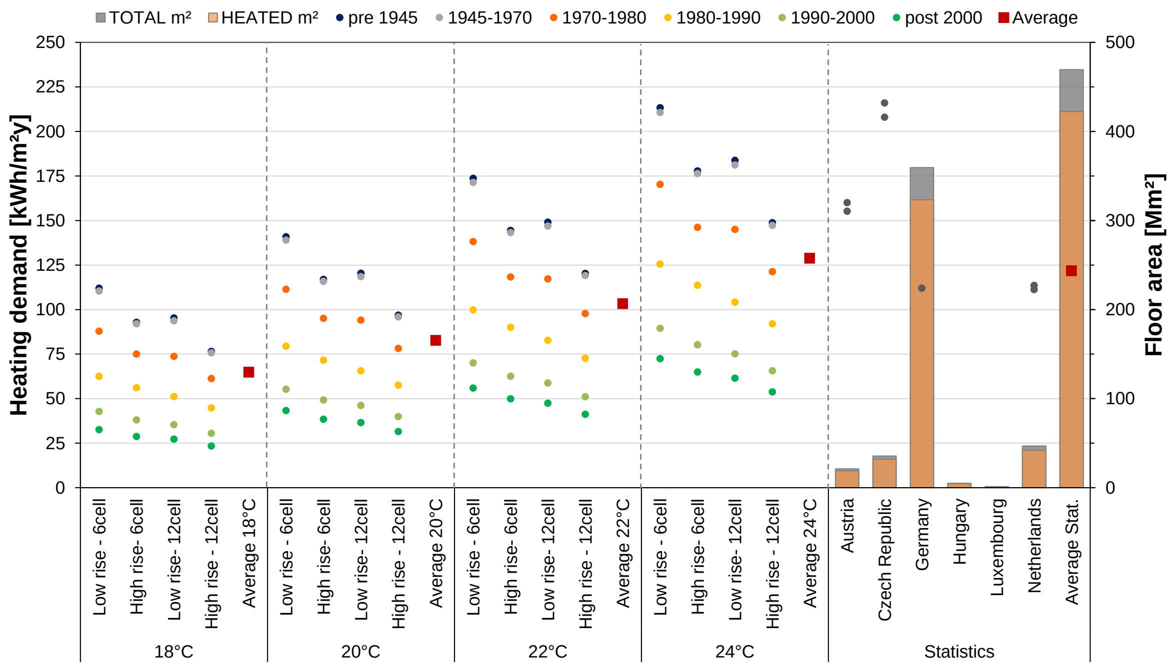


Figure 40

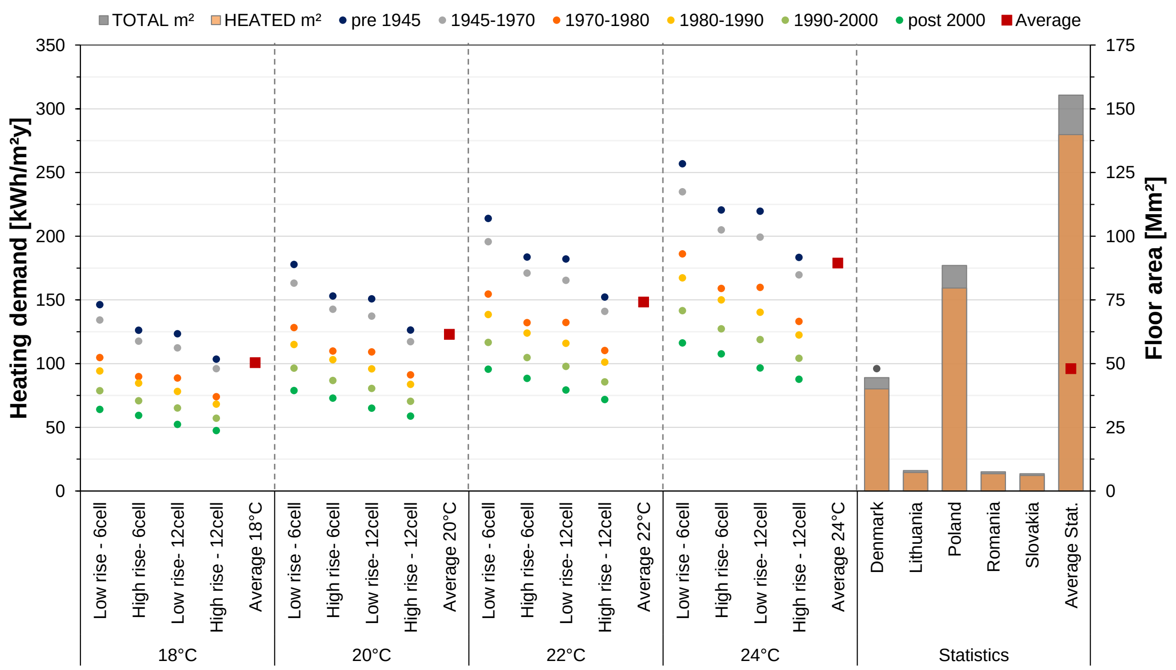
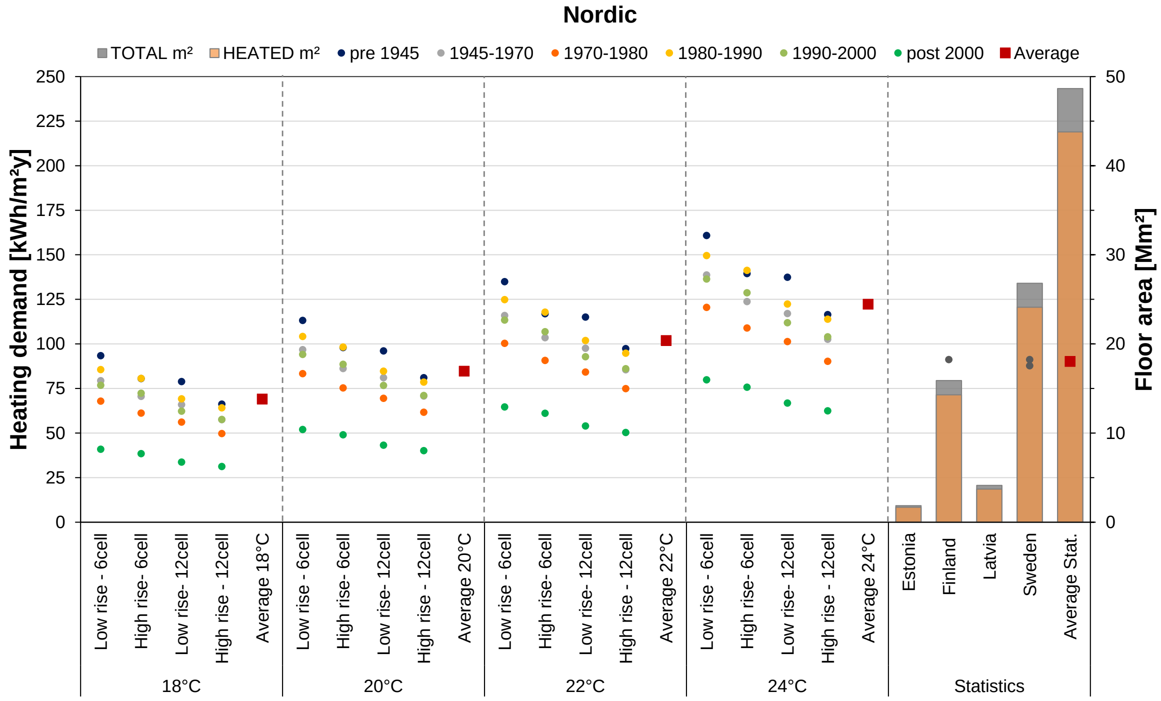


Figure 41



Nordic
TOTAL m²
HEATED m²
pre 1945
1945-1970
1970-1980
1980-1990
1990-2000
post 2000
Average
Heating demand [kWh/m²y]
Floor area [Mm²]
250
225
200
175
150
125
100
75
50
25
0
50
40
30
20
10
0
Low rise - 6cell
High rise- 6cell
Low rise- 12cell
High rise - 12cell
Average 18°C
Average 20°C
Average 22°C
Average 24°C
Estonia
Finland
Latvia
Sweden
Average Stat.
18°C
20°C
22°C
24°C
Statistics

Figure 42

8.2.2 Office cooling demands

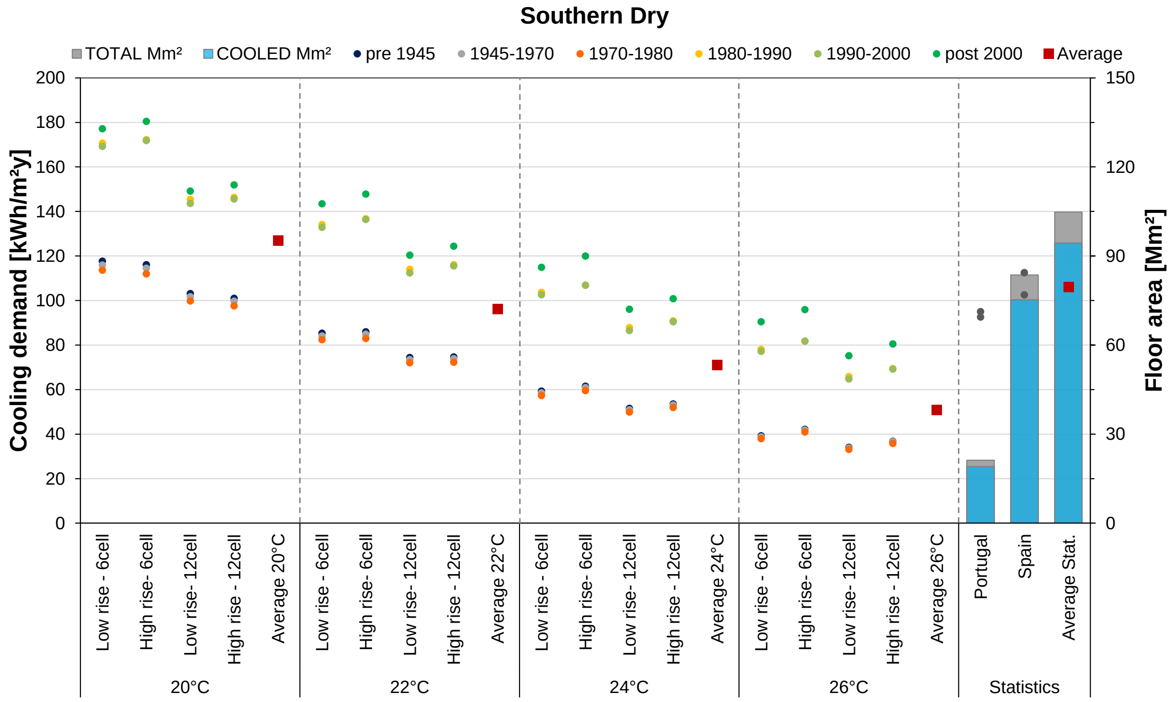


Figure 43

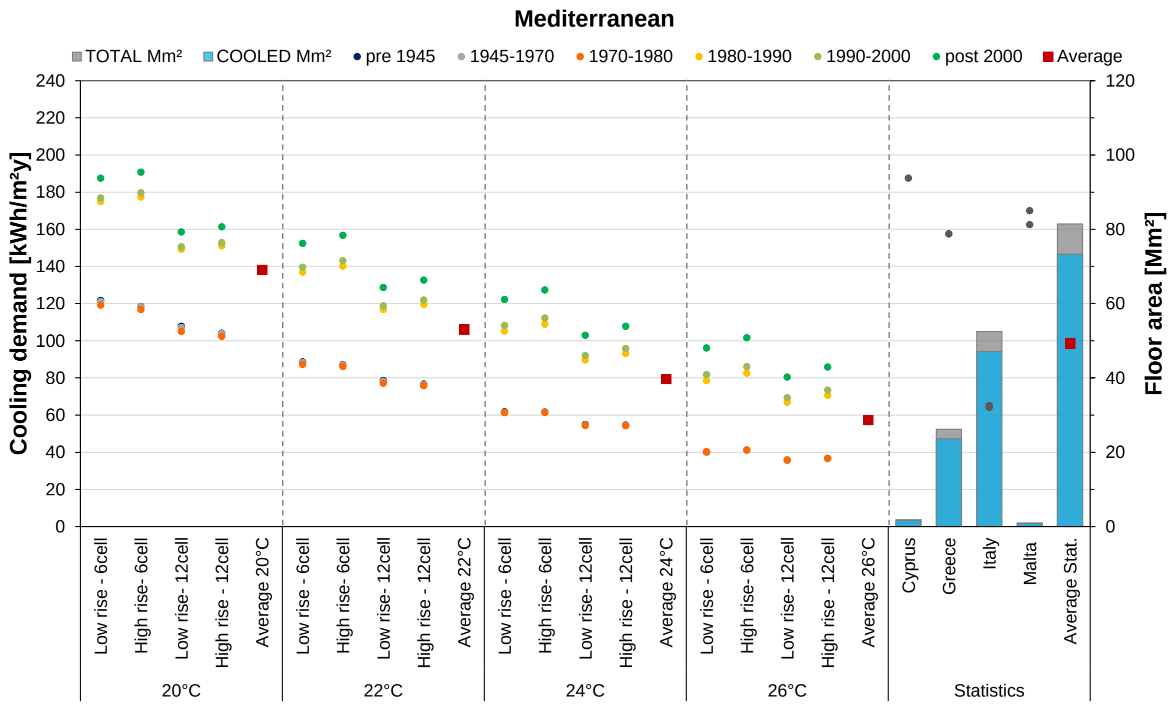


Figure 44

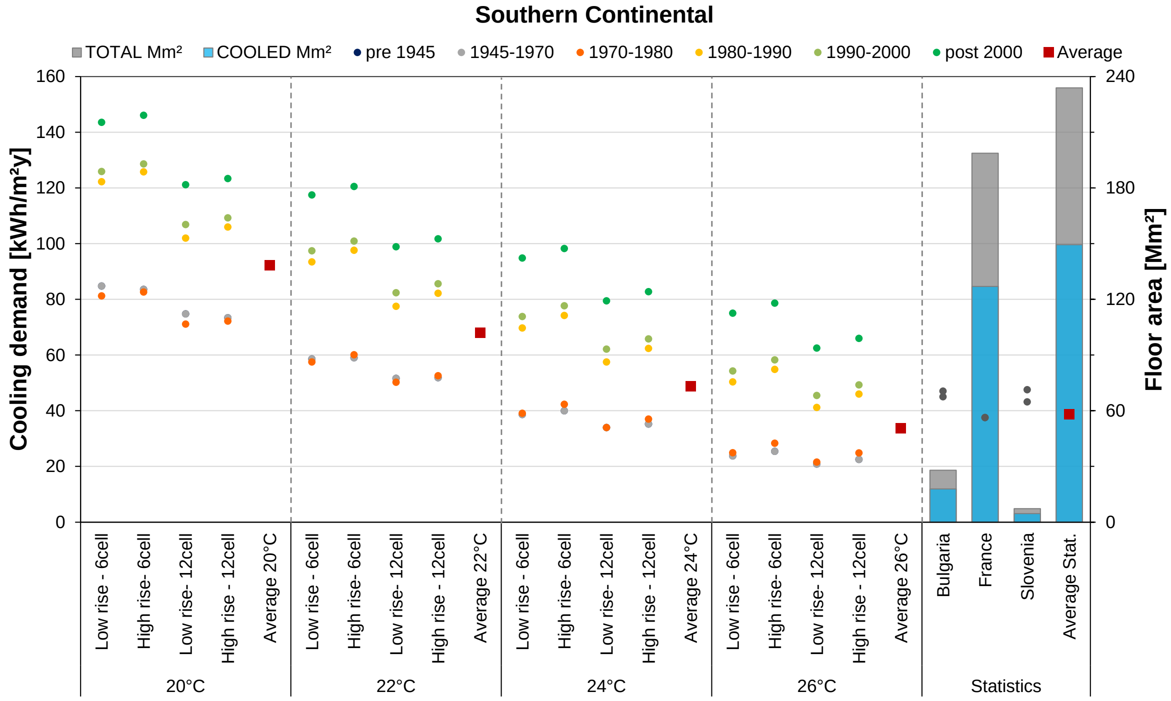


Figure 45

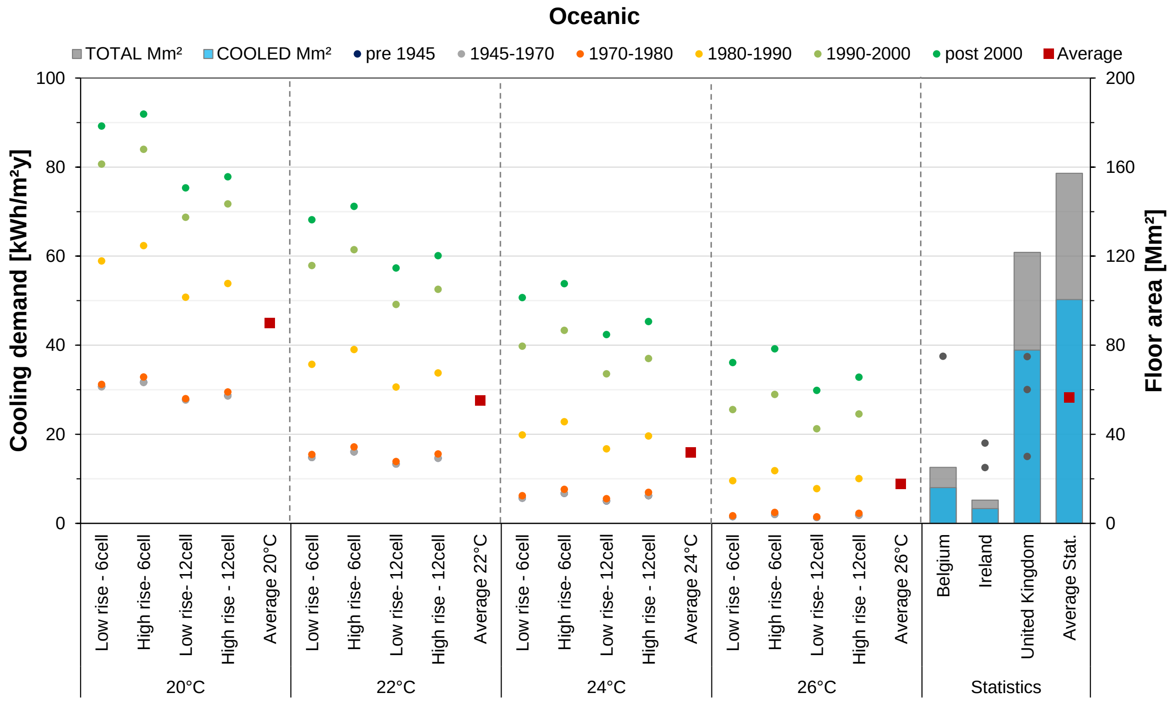


Figure 46

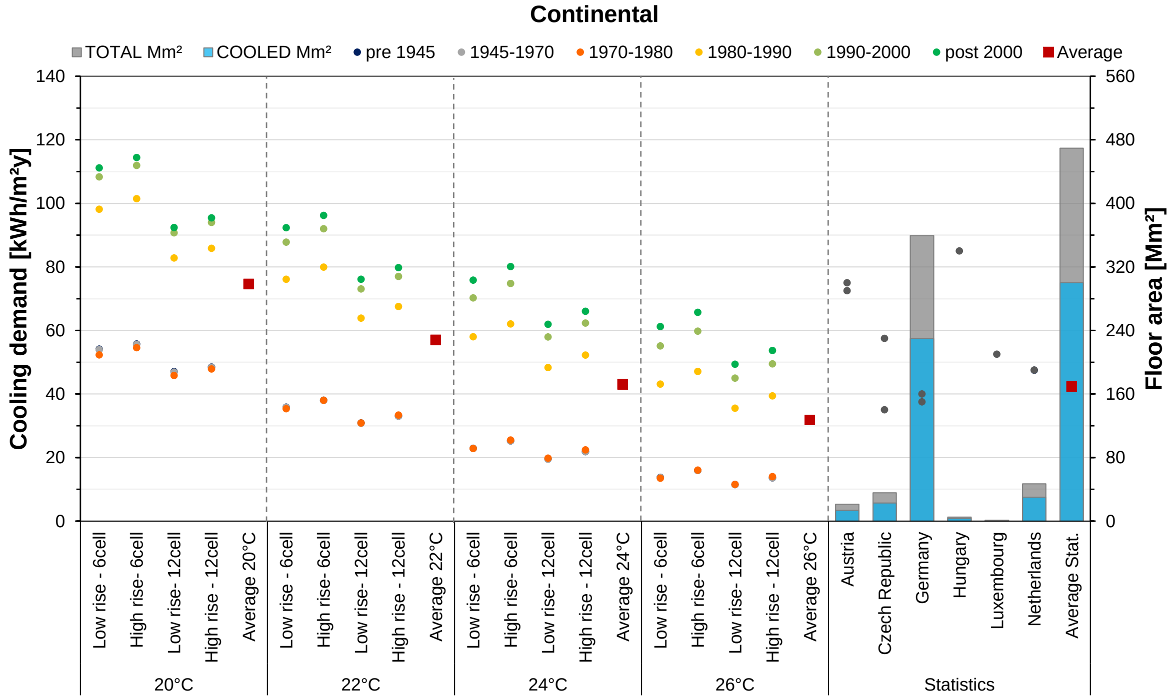


Figure 47

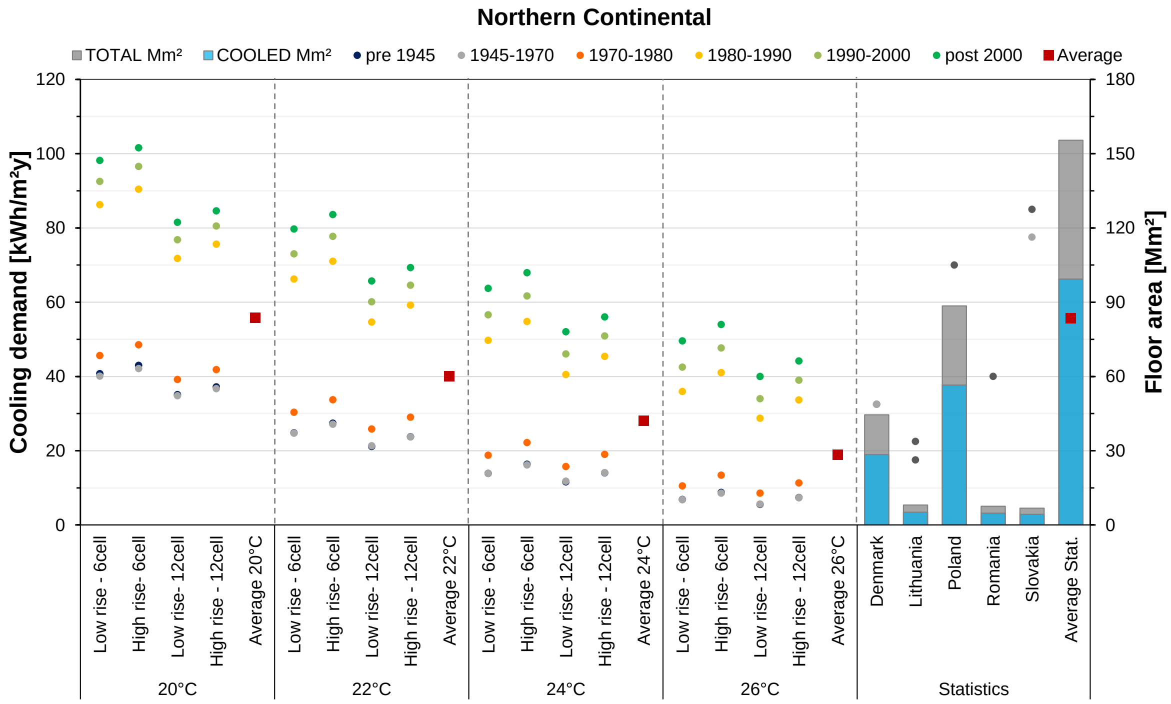


Figure 48

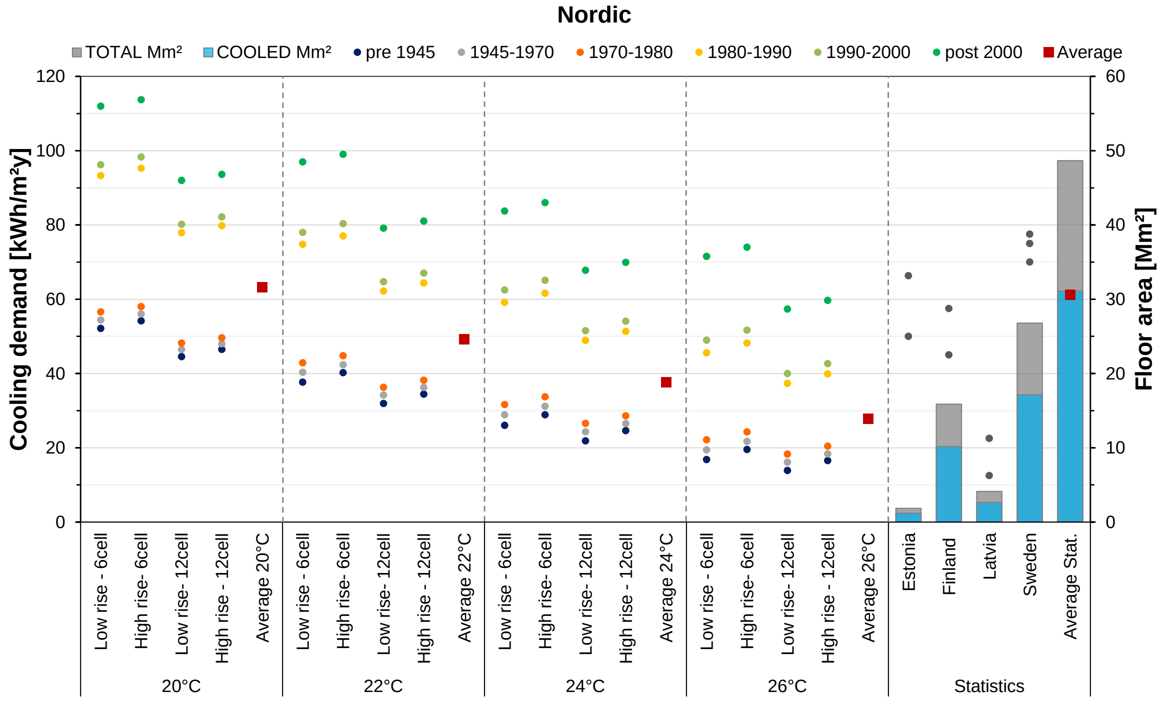

Nordic
TOTAL Mm²
COOLED Mm²
pre 1945
1945-1970
1970-1980
1980-1990
1990-2000
post 2000
Average
Cooling demand [kWh/m²y]
Floor area [Mm²]
Low rise - 6cell
High rise- 6cell
Low rise- 12cell
High rise - 12cell
Average 20°C
Average 22°C
Average 24°C
Average 26°C
20°C
22°C
24°C
26°C
Estonia
Finland
Latvia
Sweden
Average Stat.
Statistics

Figure 49

8.3 Tables of heating and cooling consumption derived from statistics

Table 22 and Table 23 show a summary of the consumption and demand for space heating and cooling in residential and office buildings in the EU based on the available statistics (see D2.1a for more details about the data and Inspire database). The climate average values have been calculated by averaging the statistical values within the standard deviation, weighted by the total floor area. For the office buildings no reliable data for heating and cooling demand have been found, and thus no data for this is given in Table 23.

The data used to derive the figures shown below have come from a range of sources. Some data came from simulation results from other projects, but most came from European studies, online research and energy efficiency databases and reports from Energy Agencies in the relevant countries.

Table 22 - Average **demand** and **consumption** for space heating and cooling in residential buildings.

	Countries	Total floor area (Mm2)	Heated floor area (Mm²)	Cooled floor area (Mm²)	Specific heat demand (kWh/m².a)	Specific heat consumption (kWh/m².a)	Demand / Consumption	Specific cold demand (kWh/m².a)	Specific cold consumption (kWh/m².a)	Demand / Consumption
Southern Dry	Portugal	410	240	25	111	128	87%	37	14	2.6
	Spain	1568	1263	941	124	80	155%	54	14	3.9
Average/Total		**1978**	**1504**	**965**	**122**	**87**	**140%**	**54**	**14**	**3.9**
Mediterranean	Cyprus	39	23	29	82	55	149%	53	12	4.4
	Greece	323	31	274	91	129	71%	51	27	1.9
	Italy	2577	1638	109	142	138	103%	47	14	3.4
	Malta	13	8	10	21	19	111%	53	23	2.3
Average/Total		**2952**	**1980**	**423**	**132**	**135**	**98%**	**50**	**22**	**2.3**
Southern Continental	Bulgaria	197	195	43	56	91	62%	46	7	6.6
	France	2479	1616	124	132	193	68%	35	18	1.9
	Slovenia	61	60	10		142	0%	47	10	4.7
Average/Total		**2738**	**1871**	**178**	**123**	**180**	**68%**	**38**	**15**	**2.5**
Oceanic	Belgium	379	375	1.9	179	194	92%	28	10	2.8
	Ireland	185	183	0.9	106	131	81%	12	3	4.0
	UK	1925	1828	9.6	144	153	94%	27	4	6.8
Average/Total		**2488**	**2387**	**12**	**146**	**158**	**92%**	**26**	**5**	**5.2**
Continental	Austria	341	338	3.4	149	169	88%	38	6	6.3
	Czech R.	310	306	3.1		168	0%	33	5	6.6
	Germany	3230	3197	48.4	182	165	110%	35	7	5.0
	Hungary	303	300	9.1		149	0%	45	10	4.5
	Luxemb.	16	16	0.2	203	221	92%	30	10	3.0
	Netherl.	631	624	9.5	117	117	100%	24	8	3.0
Average/Total		**4831**	**4783**	**74**	**170**	**158**	**108%**	**35**	**7**	**5.0**
Northern Continental	Denmark	298	295	2.1	133	148	90%	19	5	3.8
	Lithuania	104	103	0.7		126	0%	31	2	15.5
	Poland	942	933	6.6		175	0%	35	4	8.8
	Romania	456	452	3.2	122	170	72%	50	5	10.0
	Slovakia	133	131	0.9		124	0%	43	7	6.1
Average/Total		**1933**	**1914**	**14**	**126**	**164**	**77%**	**36**	**4**	**9.0**
Nordic	Estonia	37	37	0.2		192	0%	24	12	2.0
	Finland	200	198	1.0	169	205	82%	27	10	2.7
	Latvia	61.1	60.5	0.3		215	0%	29	12	2.4
	Sweden	386.5	382.6	1.9	114	143	80%	27	8	3.4
Average/Total		**685**	**678**	**3**	**133**	**170**	**78%**	**27**	**9**	**3.0**

Table 23 - Average **consumption** for space heating and cooling in office buildings. No demand data available.

	Countries	Total floor space in EU (Mm2)	Heated floor area (Mm²)	Cooled floor area (Mm²)	Average space heating demand (kWh/m².a)	Average space heating consumption (kWh/m².a)	Average space cooling demand (kWh/m2.a)	Average space cooling consumption (kWh/m2.a)
Southern Dry	Portugal	21.2	19.1	19.1		-		38
	Spain	83.6	75.2	75.2		54		44
Average/Total		**105**	**94**	**94**		**54**		**42**
Mediterranean	Cyprus	1.9	1.7	1.7		-		75
	Greece	26.2	23.6	23.6		86		63
	Italy	52.4	47.2	47.2		170		26
	Malta	1.0	0.9	0.9		-		67
Average/Total		**81**	**73**	**73**		**142**		**39**
Southern Continental	Bulgaria	28.0	25.2	17.9		103		18
	France	198.7	178.8	126.9		257		15
	Slovenia	7.3	6.5	4.6		-		18
Average/Total		**234**	**211**	**149**		**238**		**16**
Oceanic	Belgium	25.1	22.6	16.0		140		15
	Ireland	10.4	9.4	6.6		157		6
	UK	121.7	109.6	77.8		171		11
Average/Total		**157**	**142**	**100**		**165**		**11**
Continental	Austria	21.2	19.1	13.5		197		30
	Czech R.	35.6	32.0	22.8		265		19
	Germany	359.5	323.6	229.7		140		16
	Hungary	5	4.5	3.2		-		34
	Luxemb.	1.2	1.0	0.7		-		21
	Netherl.	46.9	42.2	30.0		141		19
Average/Total		**469**	**422**	**300**		**152**		**17**
Northern Continental	Denmark	44.5	40.1	28.4		120		13
	Lithuania	8.1	7.3	5.1		-		8
	Poland	88.5	79.7	56.6		-		28
	Romania	7.6	6.8	4.8		-		16
	Slovakia	6.8	6.1	4.3		-		33
Average/Total		**155**	**140**	**99**		**120**		**22**
Nordic	Estonia	1.9	1.7	1.2		-		23
	Finland	15.9	14.3	10.2		114		21
	Latvia	4.1	3.7	2.6		-		7
	Sweden	26.8	24.1	17.1		112		30
Average/Total		**49**	**44**	**31**		**113**		**25**