BUILD_ME

MENA BUILDING TYPOLOGY AND ENERGY BENCHMARKS

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Guidehouse Germany GmbH
Albrechtstr. 10 c
10117 Berlin
T +49 30 7262 1410
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Authors:

Sven Schimschar, Riadh Bhar, Eslam Mahdy, Ahmed Ibrahim Amr (Guidehouse)
Dr Sorina Mortada, Ghada Rahal, Mohammad Hammad (LCEC)
Dr Ashraf Kamal (HBRC, Egypt)
Dr Mohamed Salheen, Mai Adel, Nada Hossam, Rana Abouzeid (IDG, Egypt)
Ali AlMarzouq, Sawsan Bawaresh (Royal Scientific Society, Jordan)

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List of acronyms and abbreviations

AC	**Air Conditioning**
BAU	Business as Usual
BEP	Building Energy Performance
CAPMAS	Central Agency for Public Mobilization and Statistics
DHW	Domestic Hot Water
EEBC	Energy Efficiency Building Code
GAEB	General Authority for Education Buildings
GHG	Greenhouse Gas
HVAC	Heating, Ventilation, and Air Conditioning
ISO	International Organization for Standardization
LED	Light-Emitting Diode
MENA	Middle East and North Africa
MFH	Multi-Family House
NEEREA	National Energy Efficiency and Renewable Energy Action
NUCA	New Urban Communities Authority
PSZ	Package Single Zone
PV	Photovoltaics
RSS	Royal Scientific Society
SFH	Single-Family House
SHGC	Solar Heat Gain Coefficient
SWH	Solar Water Heater
TPFC	Two Pipe Fan Coil

1 Introduction

The findings from the first phase of BUILD_ME show that there are several challenges linked to enforcing and implementing energy efficiency building codes (EEBCs) and to their success in promoting efficiency in the target countries' building sectors. The incomplete enforcement and implementation of EEBCs has resulted in the lack of reference values for overall building energy performance (BEP). This situation makes it difficult to develop and implement suitable funding programmes and national strategies.

Various financing institutions in the Middle East and North Africa (MENA) region aim to provide special financing for eligible building energy efficiency measures. A new building with a higher energy efficiency is usually considered eligible to receive financial incentives or support. This eligibility can be proven by providing a valid energy certificate or if a comparable audit that demonstrates better energy efficiency than the national baseline has been issued. If there are no national minimum requirements (e.g. defined in a building code or sufficiently enforced and implemented), another reference value must be specified. As a principle, this reference value should reflect the business-as-usual (BAU) situation in the building and construction sector (i.e. the average real energy performance of typical new and existing buildings). The reduction should then be compared with the representative energetic reference values of the buildings using a robust methodology and calculated using a suitable BEP tool.

To calculate the representative energetic reference values of the buildings, a compilation of reference buildings must be developed. Reference buildings are those that represent a certain type of building, such as a detached single-family house (SFH), and its characteristics, such as geometries, location and urban context, age class and typical system parameters. A complete collection of such reference buildings, which adequately depicts the entire building stock, is called a building typology. Such a building typology that comprises a set of typical building constructions in the MENA region has been developed within BUILD_ME. For each of these reference buildings, the Guidehouse BEP tool has been used to calculate their energy performance. These energetic reference values can later be used to facilitate the eligibility verification for building projects to receive financial support.

Apart from the work in Working Package WP1, the reference buildings and building typology were also required and used for work in other project activities, such as the comparison of the proposed measures in WP2 (pilot projects), various activities in WP3 (e.g. work on the building codes, conceptual design of certification systems, and potential assessments for national strategies), and the training and dissemination activities in WP4. This report presents the methodology and working steps toward the development of the building typology and reference buildings in the BUILD_ME target countries and the results.

2 Building typology

This buildings typology database depicts representative reference buildings in Egypt, Jordan and Lebanon. These buildings in the building stock (new and existing buildings) represent a specific building type (e.g. free-standing SFH) and reflect the region's typical architecture and technical building systems. The building typology covers all project-relevant building categories. The MENA building typology developed within BUILD_ME includes different categories of non-residential buildings in addition to residential buildings. An individual building typology is developed for each main targeted country. The following figure shows the key aspects considered in the building typology, which include the building type, age group, region, building envelope and technical system.

Figure 1. Key characteristics considered in the building typology

2.1 General approach

To calculate and identify market representative new construction specifications as the basis to calculate energetic reference values, a database with relevant technical specifications of recently completed new building constructions (or buildings currently being erected) in the three target countries was first created. The aim of the database is to define typical new building configurations that are as representative as possible for the national markets.

The technical specifications include all relevant input parameters of the software tool to calculate the BEP developed in Activity 1.4. Relevant parameters comprise information on the façade, roof, ground plate, windows, heating system (including hot water), cooling system and combinations of these systems. The database provides information for all reference buildings covered in the building typology (Activity 1.5). As the information should be as current as possible, the focus was on constructions younger than 3 years. For this purpose, the project team has prepared the following working steps:

a) Prepare a template to collect all relevant data and information: This template includes, but is not limited to, general information on the building, building geometries, technical specifications of the building envelope, and specifications of technical building systems. Figure 3 depicts the key categories of the template.

b) Data collection: Literature research was conducted considering different kinds of sources, such as scientific publications, available databases (if existing) and case study data from other research projects or subsidy programmes, such as the National Energy Efficiency and Renewable Energy Action (NEEREA) in Lebanon, as far as accessible and useful. The aim was to estimate the market penetration of different technologies in the new construction market and to identify the most common characteristics. As part of the data collection, the project team has approached different stakeholder groups, such as project developers, consultants, architects and construction companies, for each of the covered building types to obtain average technical specifications (qualitative and quantitative) and data from concrete case studies.

c) Real case studies: In addition to the collected information from literature research and the qualitative assessment of market players, the aim was to collect relevant data from two or three real building projects (case studies) per covered building type. This information was collected from the project owners, energy audits and field visits, when necessary. The gathered information was analysed in detail and, if there were gaps, discussed with the responsible persons to get a complete set of data.

d) Data validation: During interviews with relevant stakeholders, typical u-values, insulation thicknesses, window types, HVAC systems etc. were discussed. This discussion helped to obtain typical average ranges that could be used as data validation sources.

e) Reporting and uploading to the website: The collected data and information have been prepared and organised to visually be presented in the project website. For more information, check the building typology database using this link.

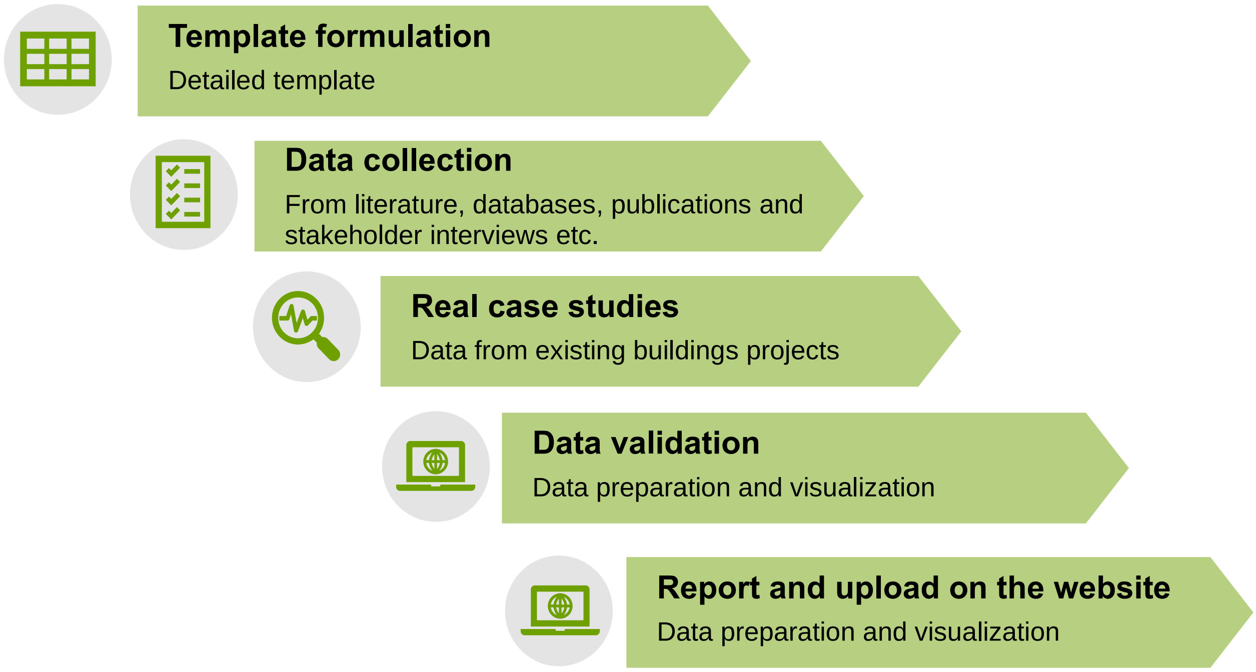


Figure 2. Working steps to develop the building typology

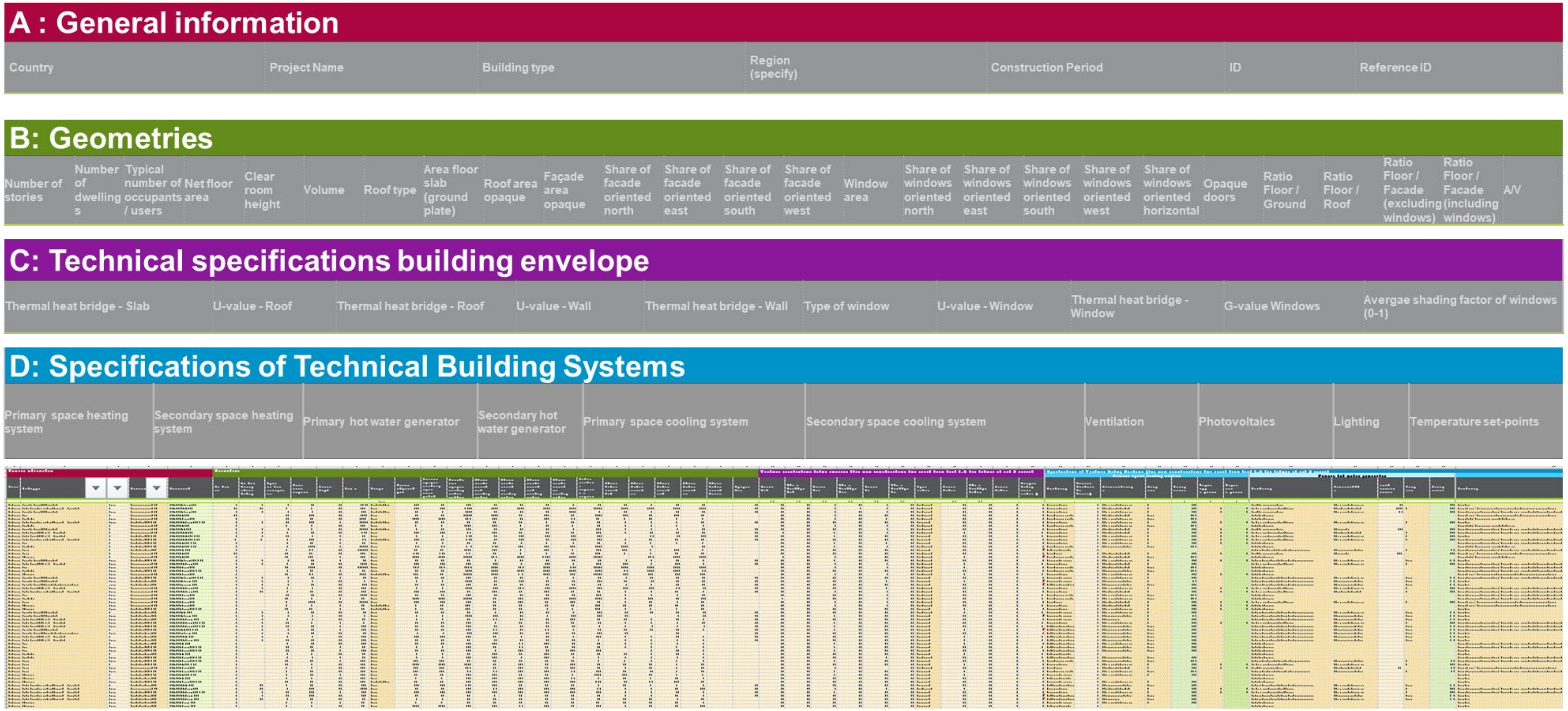


Figure 3. Key sections of the template for data collection

2.2 Country approaches and background information

To best understand the building sector and to define the building types considered and included in the building typology, the project team has prepared a literature review to understand the characteristics of the building stock in each country. This review has mainly been prepared based on official statistics, the status of building laws and codes, publications and recent studies. This approach also explains the partly significant differences in lengths of country chapters (2.2.1, 2.2.2 and 2.2.3) since more information is available for some countries than for others. The climate, market and legal characteristics also require a different depth of descriptions and explanations for each country.

2.2.1 Background information for the building typology in Egypt

2.2.1.1 Overview on building stock and building practices in Egypt

This section illustrates that there are no major differences in the building practices and building materials that are used across different regions in Egypt, which is also proven by the cases gathered in the Reference Building sheet in the two construction periods: New Construction (built after 2015) and Existing Buildings (1980-2015). While existing and new buildings have similar architectural styles and construction characteristics, older buildings (built before 1980) illustrate the major difference, which is the architectural style specifically. Therefore, the building typology was not divided by region but rather created as a national depiction of the country's common building practices. The similarity of construction methods across different regions and in different constructions periods can be attributed to the unified building regulations across the regions of Egypt and the mega-scale housing projects constructed by the government. The following points explain these arguments.

a) The Unified Building Law does not mandate any differentiation in the construction among the different regions of Egypt.

Law no.119 for 2008, also known as the Unified Building Law, was issued by a presidential decree and ratified by Egypt's parliament on the May 11, 2008 to systemise and regulate the building process in the country. The executive appendix for the Unified Building Law (Ministerial Decree no.114 for 2009) was published in *National Gazette* no.11-A in April 2009. The executive appendix describes the detailed regulations of the articles in the main law. As a general note, the regulations inscribed in the appendix do not differentiate between the different regions and their respective climates and natural settings (Karim M Ayyad, 2020). All building and occupancy permits nationwide are bound to abiding by this law and its executive appendix; therefore, there is no obligation for changing the construction practices across the different climatic regions.

b) The large-scale governmental construction projects use the similar prototypes and construction methods.

The government constructs large-scale projects across the country. For example, Egypt is constructing more than 40 new cities. New Urban Communities Authority (NUCA) has the mandate to supervise, construct and manage all new cities in Egypt. NUCA utilises the same building prototypes, building materials and construction methods across all new cities in Egypt. The following table shows different residential and administrative building projects constructed following the typical prototypes and located in different climatic conditions and regions.

There are 2.2 million residential units constructed in the new cities in Egypt. The typologies of these housing projects are replicated despite the variation in geographical locations and corresponding climate. The idea of using fixed prototypes for public housing projects is not a new practice, and it extends back to the first projects in the 1950s. One example of this kind of project is the youth housing project, which began construction in the 1990s and is still ongoing. The first phase of this project began in 1996 and was completed in 1998. More than 20,000 housing units were constructed in six new cities. The second phase of the project started immediately after the first phase, and more than 34,000 housing units were constructed throughout nine new cities in different regions in Egypt. The government continues to use the same prototype in other new and existing cities, four of them around Cairo (Ahmed, 2012).

	
Building type: Administrative buildings (Public buildings) Location: New Administrative Capital Region: Greater Cairo and Delta Region	Building type: Administrative buildings (Public buildings) Location: New Alamein (Next to Alexandria) Region: North Coast Region

Table 1. Administrative buildings with the same characteristics in different locations

	
Building type: Residential buildings Location: New Administrative Capital Region: Greater Cairo and Delta Region	Building type: Residential buildings (Social Housing) Location: New Alamein (Next to Alexandria) Region: North Coast Region

	
Building type: Social housing Location: New Asyiut Region: Upper Egypt	Building type: Housing Location: 10th of Ramadan city Region: Greater Cairo and Delta Region

Table 2. Residential buildings with the same characteristics in different locations, Egypt

c) This similarity is further confirmed by the case studies included in the reference buildings.

The project team conducted field visits and detailed case studies. The data and energetic characteristics of the case studies showed no difference across the different cities and regions in Egypt. The following figure shows snapshots of some of these reference cases and their identified typical characteristics. In addition, most of the added literature baselines in the Reference Buildings sheet were streamlined for different regions in Egypt.

General information								
Country	Building type	Region (specify)	Construction Period	Ratio Floor / Ground	Ratio Floor / Roof	Ratio Floor / Facade (excluding windows)	Ratio Floor / Facade (including windows)	A/V
Egypt	Education	Alexandria	New construction (after 2015)	2.5	2.1	1.9	1.5	0.2
Egypt	Education	Alexandria	New construction (after 2015)	3.0	2.3	1.8	1.5	0.1
Egypt	Education	Cairo	New construction (after 2015)	4.0	3.3	1.6	1.4	0.2
Egypt	Education	Minia (Upper Egy	Existing building: 1980-2015	4.7	5.2	1.1	1.0	0.3

General information				Technical specifications building envelope (For new constructions final result from				
Country	Building type	Region (specify)	Construction Period	U-value - Slab	U-value - Roof	U-value - Wall	U-value - Window	G-value Windows
				W/(m²*K)	W/(m²*K)	W/(m²*K)	W/(m²*K)	
Egypt	Education	Alexandria	New construction (after 2015)	2.6	0.9	2.4	3.5	0.5
Egypt	Education	Alexandria	New construction (after 2015)	2.6	0.9	2.4	3.5	0.5
Egypt	Education	Cairo	New construction (after 2015)	2.6	1.1	2.3	3.5	0.5
Egypt	Education	Minia (Upper Egy	Existing building: 1980-2015	2.1	2.1	2.0	5.6	

Figure 4. Snapshots of reference buildings showing similar characteristics of case studies across different regions

2.2.1.2 Definition and selection of building types considered in the Building Typology

The Central Agency for Public Mobilization and Statistics (CAPMAS) is the governmental official statistical agency of Egypt that collects, processes, analyses and disseminates statistical data and conducts the census. CAPMAS publishes a *Statistical Yearbook* for the housing sector in which several statistics relevant to the building sector are covered. Based on this *Statistical Yearbook*, the buildings in urban areas are categorised under the main categories of housing buildings, mixed-use buildings, administration buildings and commercial buildings. The following chart illustrates the percentages of main building uses in urban areas in Egypt.

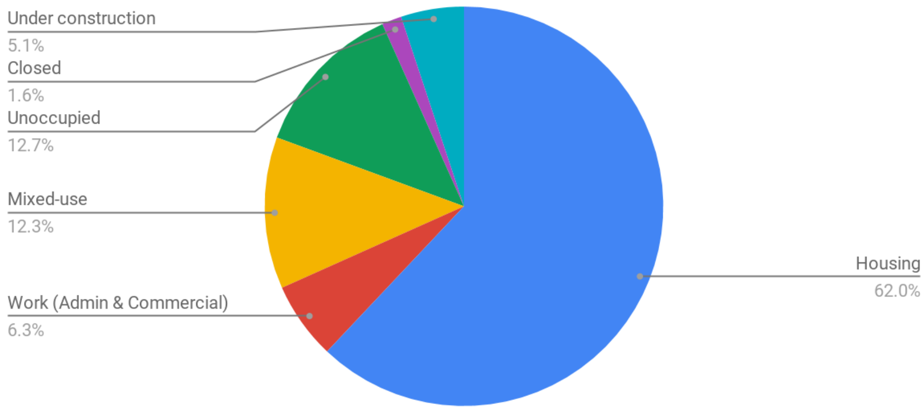


Figure 5. Current use of buildings in urban areas in Egypt based on the Statistical Yearbook for Housing Sector (Source: CAPMAS, 2019)

The following figure shows the distribution of non-residential buildings by building types according to 2017 census data.

Unit: No

	Governorates		Types of Buildings مباني عادية للعمل Regular Buildings for Work Purposes					
			الجملة Total	دكان أو أكثر Shop / more	عوامة Boat House	مول Mall	مبنى عمل به وحدة أو أكثر Work Building with one Unit or more	مسكن عام بالكامل Public Building
1	Total	Urban	285 998	86 798	207	1 710	184 152	13 131
2		Rural	546039	137 905	169	296	385 375	22 294
3		Total	832 037	224 703	376	2 006	569 527	35 425
4		%	5.8	1.6	0.0	0.0	4.0	0.2

Figure 6. Numbers of non-residential buildings by type in urban and rural areas (CAPMAS, 2020)

Next to those main categories, the building typology also covers other building types. Therefore, the building typology in Egypt covers the following:

a) residential buildings;

b) educational buildings;

c) retail/trade: commercial buildings;

d) offices: administrative buildings;

e) mixed-use buildings;

f) hospitals and medical buildings;

g) hospitality buildings

To profoundly prepare the building typology, this section includes information about the geometries and specifications of each building type according to various sources from literature, case studies and field visits. The information mainly covers all aspects that are required to prepare the building typology, including the following:

- Building Type Overview: general characteristics of the typology, geometry characteristics, how it differed over the time, etc.;
- Building Design Description: building orientation, building envelope, construction materials, and passive aspects (covered when applicable);
- Building Systems Description: HVAC, lighting, water heating, and active design aspects

2.2.1.3 Residential buildings

The building sector in Egypt is responsible for 60% of electricity consumption and more than 70% of the resultant CO_2 emissions. The residential sector consumes around 50% of the country's total produced electricity (Egyptian Electricity Holding Company, 2017). There has been a significant increase in the number of residential units constructed every year by both the public and private sectors, as shown in the following figures. Residential buildings, therefore, have the highest priority for energy efficiency actions and measures in Egypt's building sector.

Unit : No.

	Sectors	18/17	17/16	16/15	15/14	14/13	13/12
1	**Total**	**326 263**	**276 600**	**254 083**	**352 629**	**145 783**	**135 630**
2	**Total Public Sector**	**105 076**	**59 964**	**86 340**	**221 547**	**42 500**	**30 573**
3	Economic level	89 395	57 502	84 821	219 839	35 961	23 218
4	Middle level	15 023	2 137	1 089	1 065	1 488	6 889
5	Upper-middle level	508	275	284	-	-	-
6	Luxury level	8	50	30	175	314	-
7	Low cost level	0	0	116	468	4 737	466
8	**Private Sector (1)**	**221 187**	**216 636**	**167 743**	**131 082**	**103 283**	**105 057**
9	**Percentage Distribution%**						
10	Public Sector	32.2	21.7	34.0	62.8	29.2	22.5
11	Private Sector	67.8	78.3	66.0	37.2	70.8	77.5

7-3 HOUSING INVESTMENTS , BY SECTOR (05/06 - 17/2018)

Unit : Mil. L.E.

	Sectors	18/17	17/16	16/15	15/14	14/13	13/12
12	**Total**	**106 876**	**85 052**	**43 503**	**40 086**	**20 716**	**8 056**
13	Public Sector	29 499	34 206	7 334	20 424	5 224	1 753
14	Private Sector	77 377	50 846	36 169	19 662	15 492	6 303
15	**Percentage distribution%**						
16	Public Sector	27.6	40.2	16.9	51.0	25.2	21.8
17	Private Sector	72.4	59.8	83.1	49.0	74.8	78.2

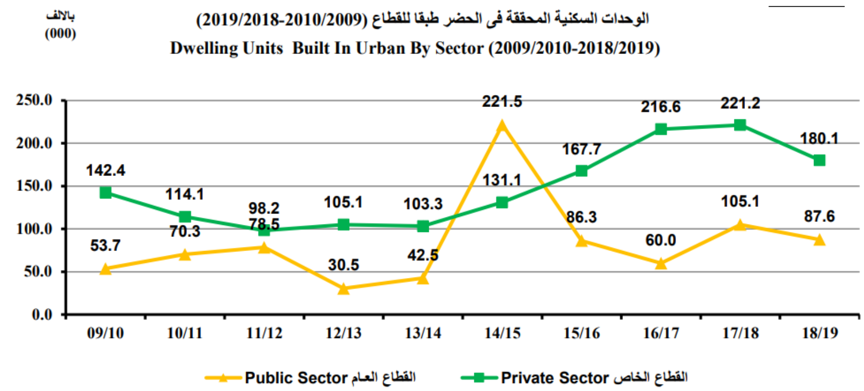


Figure 7. Dwelling units built in urban areas by sector and level (06/07-17/18) (CAPMAS, 2019)

Based on the data published by CAPMAS, there are several different residential building types, such as SFHs, multi-family houses (MFHs), skyrises, chalets, country houses and makeshift buildings, as shown in the following figure. SFHs and MFHs represent the vast majority of these residential building types; therefore, SFHs and MFHs have been considered when preparing the building typology for Egypt.

الكتاب الاحصــائى السنــوى ـ الاسكــان

7- 5 توزيع المبانى(1) بالمحافظات طبقاً لنوع المبنى وفقا للنتائج النهائية للتعداد العام للسكان والإسكان والمنشآت 2017

الوحده : بالعدد

أنواع المباني / مباني عادية للسكن Regular Buildings for Housing Purposes						عدد المبانى	المحـافـظات		
الجملة Total	بيت ريفي به وحدة أو أكثر Country House with or more Unit	شاليه Chalet	فيلا بها وحدة أو أكثر Villa with one or more Unit	برج Skyrise Apartment Building	منزل / عمارة House/ Building	No. of Buildings			
4 075 399	118 542	45 322	151 902	11 824	3 747 809	4 361 397	حضر	إجمالى الجمهورية	1
9 391 934	977 296	19 958	40 315	19	8 354 346	9 937 973	ريف		2
13 467 333	1 095 838	65 280	192 217	11 843	12 102 155	14 299 370	إجمالى		3
94.2	7.7	0.5	1.3	0.1	84.6	100	%		4

Figure 8. Numbers of residential buildings by type in urban and rural areas (CAPMAS, 2020)

The characteristics of the different residential buildings in terms of design layouts, window areas and construction methods remain comparable across different locations and types of residential buildings. Figure 9 shows different case studies of these buildings, based on the study “Developing a National Stock Model to Support Building Energy Efficiency Research and Policy in Egypt” (Raslan & Mavrogianni, 2013) .

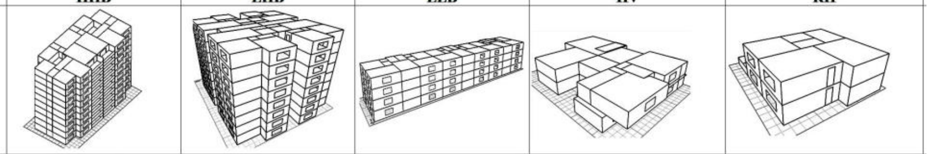
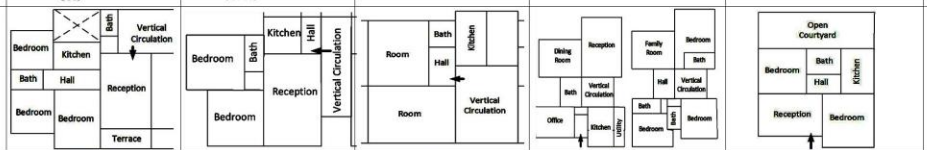
Variant	High Income High Rise Block	Low Income High Rise Block	Low Income Low Rise Block	High Income Villa	Rural House
Code	HHB	LHB	LLB	HV	RH
Unit Layout					
Unit Layout Plan					
Income Group	High	Low	Low	High	Low
Location	Urban	Urban	Urban	Suburban	Rural
Occupants	Multi-Family	Multi-Family	Multi-Family	Single Family	Multi-Family
Floor Area	150m^2	90m^2	60m^2	450m^2	100m^2
No of Floors	12 floors	8 floors	4 floors	2 floors	1 or 2 floors
No of Units	2 to 3 per floor	4 per floor	6 per floor	N/A	1 per floor
Tenure	Owner-Occupied	Rented (New Law)	Owner-Occupied	Owner-Occupied	Owner-Occupied
Age band	1980-1989	Post 1999	1960-1969	Post 1999	1950-1959
Construction	Reinforced Concrete	Cement Brick	Cement Brick	Cement Brick	Silt Brick
WindowArea	>15m^2	<15m^2	<15m^2	>15m^2	<15m^2
Installed Air-Conditioning	Yes	No	No	Yes	No
Appliance Ownership	High	Low	Low	High	Low

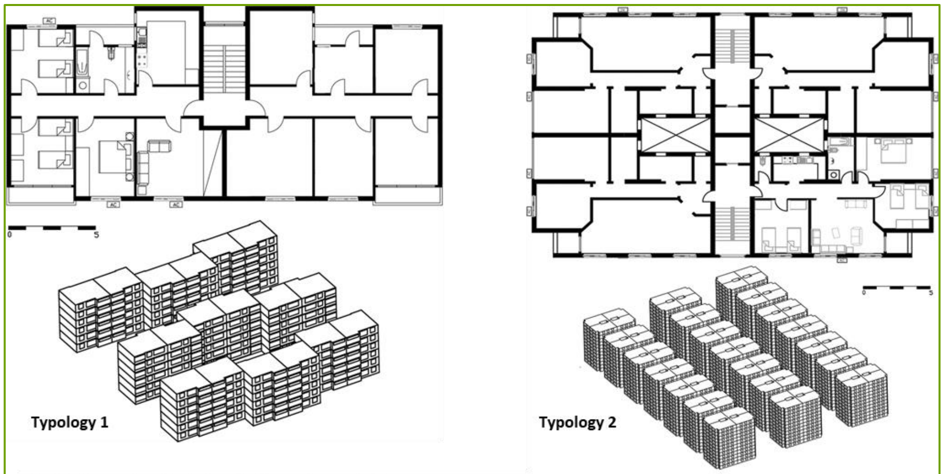
Figure 9. Design characteristics of residential buildings Egypt (Raslan & Mavrogianni, 2013)

MFHs

Egypt has more than 13 million buildings for housing purposes. Most of these buildings (around 12 million) are MFHs (Egypt Data Portal, 2015), which means that most Egyptians live in MFHs. Studies and research have been prepared to highlight the physical building characteristics of the MFH in Egypt. Among those studies, a study titled "Development of benchmark models for the Egyptian residential buildings sector" (Attia, Evrard, & Gratia, 2012), published in *Applied Energy*, highlighted the energy profiles of different MFHs. These profiles were based on the data collected from surveying 1,500 flats from different cities that represent different regions in Egypt, including Alexandria (Northern Coast region), Cairo (Greater Cairo region), and Asyut (southern upper Egypt region). The study defined two main common typologies in the three cities. Those two MFH typologies are shown in Figure 10 and have comparable characteristics, with one difference relevant to average annual energy use.

Typical geometries and building envelope of MFH typologies

The following figures show the result of a study prepared by Egypt (Attia, Evrard, & Gratia, 2012) that depicts the differences between two typical building blocks of MFH in Egypt. Typology 1 is a block base that includes a typical apartment with the size of 122 m^2, a net conditioned area of 60 m^2, and three rooms in each apartment. The basic building construction is a reinforced concrete structure with 0.15 m thick brick walls without insulation, as this is the typical construction practice in Egypt. Windows are single glazed. The total amount of glass is around 45% and 35% of the total wall area in both in the north and south facades with shade devices and solar protection. Typology 2 represents a 12-story building with a gross floor area of around 7,200 m^2 and a net conditioned area of 60 m^2, representing three-room apartments. In terms of the construction characteristics, Typology 2 has comparable characteristics to Typology 1.



Both typologies' building description.

Building description	Typology 1	Typology 2
Shape	Rectangular (25 m × 11 m)	Rectangular (30 m × 20 m)
No. floors and height	6 and 2.8 m height per floor	12 and 2.7 m height per floor
Aspect ratio	2.3/1	1.5/1
Apartment description		
volume	366 m^3	337.5 m^3
External wall area	110 m^2	68 m^2
Roof area	122 m^2	125 m^2
Floor area	122 m^2	125 m^2
Windows area	60 m^2	13 m^2
Glazing *U*-Value	6.25 W/m^2 K	6.25 W/m^2 K
Exterior wall *U*-Value	2.5 W/m^2 K	2.5 W/m^2 K
Roof *U*-value	1.39 W/m^2 K	1.39 W/m^2 K
Floor *U*-value	1.58 W/m^2 K	1.58 W/m^2 K
Single clear glazing	$T_v = 0.88$	$T_v = 0.88$
SHGC	0.75	0.75

Figure 10. Characteristics of the two typical typologies of MFH identified in Egypt (Attia, Evrard, & Gratia, 2012)

Typical technical building systems in MFH

The following table shows the status of the different building systems in the two building typologies.

Building system	Status
Lighting	Incandescent lamps and fluorescent tubes are the leading type of lamp used. The average lighting power intensity is: - in living rooms: 17 W/m^2 - in bedrooms: 13 W/m^2 - other spaces: 9 W/m^2
Domestic Hot Water (DHW)	Most of the surveyed apartments in the three cities had: - gas stoves for cooking; - gas water heaters for DHW; many electric water heaters found in the surveyed apartments - The average DHW was estimated to be: - 0.35 l/m^2/day from October to April; - 0.05 l/m^2/day from May to September
Electric Fans	The average home in Alexandria, Cairo and Asyut has an average of 2.8, 3.5 and 4.3 ceiling fan units, respectively, with a power of 60 W. The average annual operation time of the fan units is 1,400 hours in Alexandria, 1,800 hours in Cairo, and 2,300 hours in Asyut.
Air Conditioning (AC)	80% of the apartments in the sample had AC (split or window units).
Operating Schedules	Regarding occupant behaviour, no significant difference was found in the three cities, which could mainly be attributed to the similarity of AC units' penetration values, reflecting similar economic and lifestyle status.

Table 3. Typical building systems in a typical apartment of MFH in Egypt (Attia, Evrard, & Gratia, 2012)

SFHs

In Egypt, most SFHs are concentrated in new cities. Egypt is constructing more than 40 new cities on the outskirts of existing cities (NUCA, 2021). These new urban communities are home to MFHs and SFHs with similar characteristics. No baseline was created in literature for this building type. A few studies were reviewed to highlight the main common characteristics of SFHs (Mourad, H. Ali, & Abdel-Rahman, 2013).

Typical geometries of SFH

According to some estimates and statistics, there are more than 1.5 million SFHs in Egypt (CAPMAS, 2019) (Egypt Data Portal, 2015). While the SFHs in Egypt vary in terms of built-up area, size and other characteristics, the SFHs are still similar in many aspects. Figure 11 shows a typical prototype house design for a detached SFH in new Egyptian cities, which is considered a key for future habitation in these new towns. The prototype house has an area of 240 m^2 over two floors (each floor 120 m^2), as shown in the following figure (Mourad, H. Ali, & Abdel-Rahman, 2013). Such a prototype is being repeated and constructed across the different regions in Egypt. Another prototypical design is that used in Al Rehab City (as an example of the gated communities in Egypt). Al Rehab City was the first city built by the private sector in Egypt, offering comprehensive services to its residents. It was built in New Cairo, the new urban community at the outskirts of Cairo. The design prototypes shown in Figure 12 are similar to the characteristics of SFHs in other compounds in different new urban communities. The area of SFHs in this case ranges from 170 m^2 in the semi-detached villas to 520 m^2 in the luxurious units (Mourad, Hamza, Ookawara, & Abdel-Rahman, 2015).

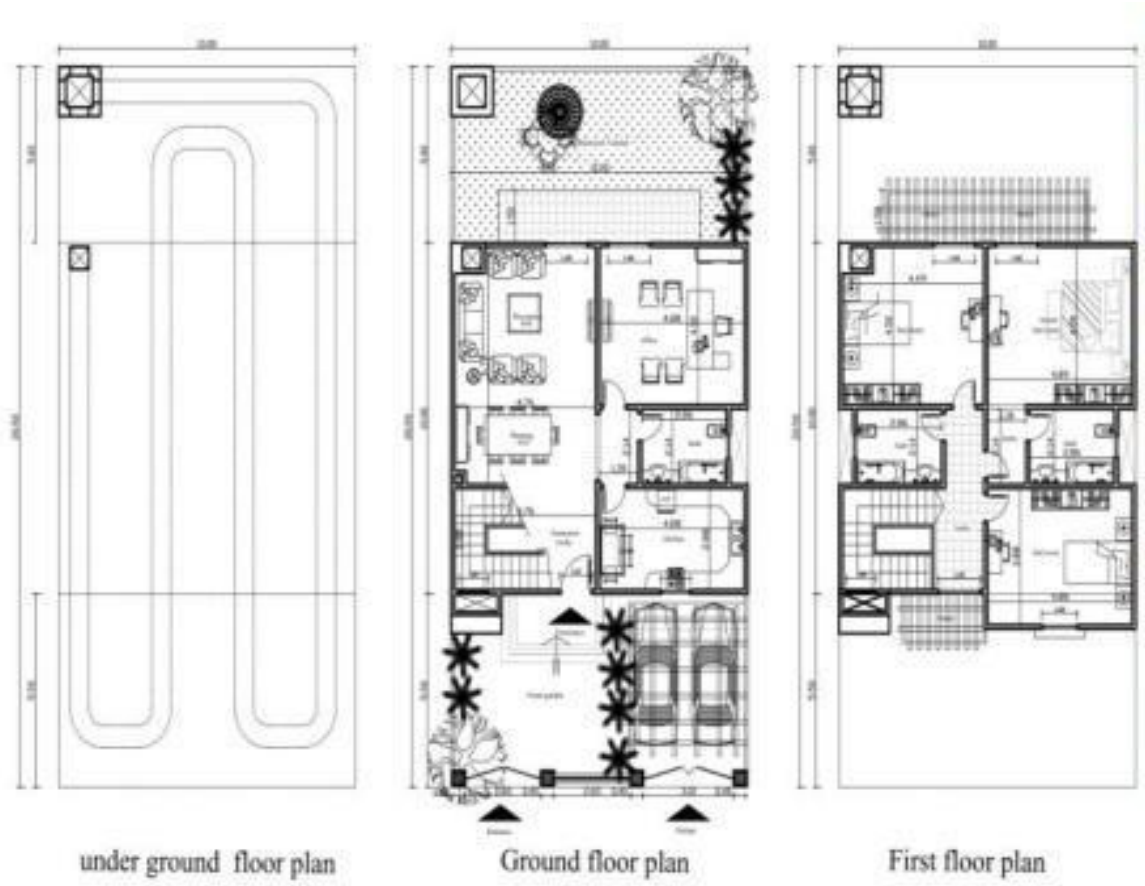


Figure 11. A prototype of SFH in Egypt (Mourad, H. Ali, & Abdel-Rahman, 2013)

Figure 12. Examples of SFH in Al Rehab City, Egypt (Mourad, Hamza, Ookawara, & Abdel-Rahman, 2015)

Typical wall construction and building envelope in SFH

The specifications of SFH wall constructions in Egypt, as common practice, are presented in the following table. The thermal properties for the construction materials were concluded from the EEBCs for residential buildings in Egypt, as published by the Housing and Building National Research Center. Furthermore, literature reviews and the Egyptian Specifications for

Thermal Insulation Work items have also been reviewed (Fahmy, Mahdy, Rizk, & F. Abdelaleem, 2018).

External walls main characteristics.

External walls	ABBRV.	Thick (mm)	U-value (W/m^2 K)
Full red-brick wall	*RB*	30	1.898
GRC wall (2 cm GRC + 11 cm thermal insulation + 2 cm GRC)	*GRC*	15	0.257

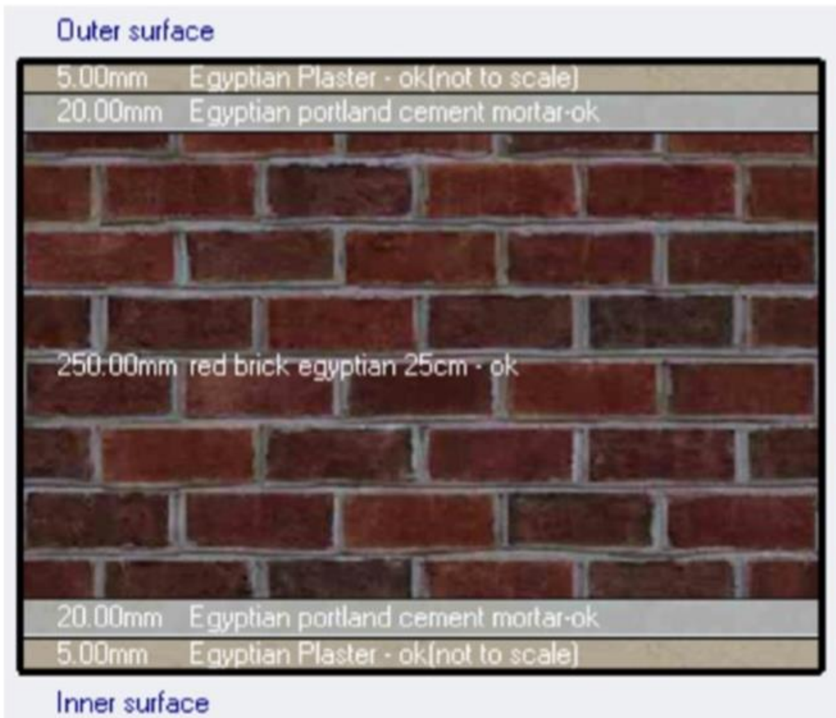


Figure 13. External walls main characteristics and U-values in residential buildings in Egypt (Fahmy, Mahdy, Rizk, & F. Abdelaleem, 2018)

The outer walls are typically constructed with 25 cm-wide red brick. All walls have 2 cm-thick cement plaster internally and externally. Such a typical wall construction method results in an average u-value between 1.74 W/(m^{2}K) and 2.55 W/(m^{2}K) (Sameh, El Zafrany, & Attiya, 2019). SFH roofs in Egypt are constructed using different materials and layers. The typical roof layers include concrete tiles, cement and sand. In some cases, the roof includes a layer of polystyrene as a moisture insulation material. In other cases, the roofs are not insulated. Table 4 shows the different roof materials alternatives in SFH in Egypt.

Name	Materials	Thickness (m)	Conductivity (W/mK)	U-value [W/(m^{2}K)]
Isolated concrete roof	Concrete tiles (roofing)	0.02	1.5	0.280
	Cement/plaster	0.02	0.72	
	Sand	0.06	0.25	

	Expended polystyrene	0.10	0.04	
	Bitumen	0.002	0.17	
	Concrete/cast-dense reinforced	0.12	1.9	
	Cement/plaster	0.02	0.72	
	Plaster (light weight)	0.02	0.16	
Non-isolated concrete roof	Concrete tiles (roofing)	0.02	1.5	1.014
	Cement/plaster	0.02	0.72	
	Sand	0.06	0.25	
	Bitumen	0.002	0.17	
	Concrete/cast-dense reinforced	0.12	1.9	
	Cement/plaster	0.02	0.72	
	Plaster (light weight)	0.02	0.16	
U-Value calculated by DesignBuilder				

Table 4. Roof layer variables in SFH in Egypt (Sameh, El Zafrany, & Attiya, 2019)

Floor materials (including slab and floor finishes) are constructed in different ways in Egypt. Two alternatives of the floor materials have been identified as typical and common floor construction methods in Egypt. The following table shows these four variables.

Name	Materials	Thickness (m)	Conductivity (W/m.K)	U-value ($Wm^{2-}K$)
Floor 1	Ceramic	0.02	1.3	0.831
	Plaster	0.02	0.72	
	Sand	0.10	0.25	
	Expended polystyrene	0.02	0.04	
	Sand and gravel	0.10	2	
Floor 2	Ceramic	0.02	1.3	0.884
	Plaster	0.02	0.72	
	Concrete roofing slab	0.12	0.25	
	Plaster	0.02	0.04	
	Acrylic	0.02	2	

Name	Materials	Thickness (m)	Conductivity (W/m.K)	U-value ($Wm^{2-}K$)
U-Value calculated by DesignBuilder				

Table 5. Floor material layer variables in SFH in Egypt (Sameh, El Zafrany, & Attiya, 2019)

Typical glazing material

The commonly used glass in Egypt is the clear, 6.4-mm, single glass that is mentioned and specified in the code. In some new constructions, such as the new offices in New Capital and some specific building types (e.g. hospitals), double glazing is also utilised. However, single glazing remains the typical and common glazing used in Egypt.

Name	Category	SHGC[a]	LT[b]	U-value (W/m^2 K)
Clear 6.4 mm	Single	0.71	0.65	5.76

[a] SHGC: Solar Heat Gain Coefficient.
[b] LT: Light Transmission.

Figure 14. Specification of the glass used in windows in Egypt (Fahmy, Mahdy, Rizk, & F. Abdelaleem, 2018)

Some more characteristics of the windows used in Egypt are included in the following table.

	Identification	W1	W2	W3
Specifications	Windows	2.0 x 1.3m^2	1.0 x 1.0m^2	No window
Window layout	Glaze martial	Clear 3mm	Clear 3mm	-
	Glazing (%)	26%	11.1%	-
	Window width	2.0	1.0	-
	Window height	1.3	1.0	-
	Sill height	1.0	1.0	-
	Window spacing	0.1	1.0	-
	Vent spacing	0.1	0.1	-
	Frame width	0.040	0.040	-
	Divider width	0.020	0.020	-
	frame	Painted wooden	Painted wooden	-

Table 6. Window variables in Egypt (Sameh, El Zafrany, & Attiya, 2019)

2.2.1.4 Educational buildings

Schools

Egypt has more than 52,000 schools, and more than 80% of them are public schools. The public schools are constructed by the General Authority for Education Buildings (GAEB). GAEB constructs similar prototypes across all regions and governorates in Egypt. The following aspects represent the key characteristics of the schools constructed by GAEB (Abdin & Mahmoud, 2017):

- The structures of the schools' buildings consist of sand-brick walls and reinforced concrete column and beam structures.
- The walls are constructed of white concrete frames infilled with brick. The walls typically do not have thermal insulation.
- There is no energy efficiency code for school design, and the EEBC is not implemented.
- Public school buildings commissioned by the GAEB are single-loaded, allowing daylight to penetrate.
- The prototype design can be a single linear four classrooms per floor, or an eight classrooms per floor L-shaped building. For most of the schools, the building is four stories.
- In 2014, the average density of classroom ranges from 57.3 pupils per class for primary education, 52.2 pupils per class for preparatory education, and 50.2 pupils per class for secondary education. The occupancy levels in Egypt are often below 0.8 m^2/person.

Typical geometries and building envelope of school buildings

The typical classroom's window-wall ratio WWR is 30%. The fenestration is simple sliding aluminium section frames around the glass. The glazing type is typically single, 6-mm clear glass. The following figures show examples of school building prototypes.

Figure 15. An example of public schools building prototypes (Egypt SIS, 2016)

Table 1 Building Dimensions

1.	Classroom Dimensions		
	Shape	Rectangular	
	Volume	143.13m3	
	Floor Area	40.89 m2(W 5.01m x L 8.16m x H 3.5m)	
	External Wall Area	28.15 m m22	
	Partition Area	17.54 m2	
	Window Area	8 m2 ((W 2.50m x H 1.6m) x 2)	
	Window Wall Ratio (WWR)	28.42% ≈ 30%	
2.	Building Envelope		
	Exterior Wall	Rose Brick 250mm Mortar 20mm	
	Roof Materials	50mm Cement Tile & Mortar 50mm Sand 70mm Cement Mortar 50mm Expanded Polystyrene (Heavyweight) 200mm Reinforced Concrete (2% Steel) 20mm Gypsum Plastering	
	Glazing	Single clear 6mm	
3.	Thermal Properties		
		U-Value	R-Value
	Exterior Wall	2.866 W/m²K	0.349 m²K/W
	Roof	0.497 W/m²K	2.012 m²K/W
	Glazing Frame	5.881 W/m²K	0.17 m²K/W
	Glazing	6.121 W/m²K	0.16 m²K/W
		Solar heat gain coefficient (SHGC)	0.81

Figure 16. An example of a school building dimensions (Abdin & Mahmoud, 2017)

Typical building systems of school buildings

Typically, most public school buildings do not have space heating and cooling systems. In some cases, particularly for private schools, air conditioning (AC) units are installed. The AC units' technologies vary from school to school. However, there are usually separated AC units installed for each room. The temperature set points of the AC unit is 26°C for cooling and 19°C for heating. Since Fridays and Saturdays are the weekend in Egypt, they are set as days off. The scheduled week means that the AC unit works throughout the school calendar year and is set from Sunday to Thursday from 8:00 to 15:00.

University buildings

Due to general population growth in Egypt and the significant increase in annual rates of student enrolment in universities, the number of university buildings and the number of universities in general is increasing. Most the university campuses and higher education buildings are built without meeting the minimum thermal requirements described in the EEBCs. At the same time, when active systems are used, high rates of energy are consumed for AC and artificial lighting (Samaan, Farag, & Khalil, 2018). The following figures show some examples of the university buildings in Egypt's different regions.

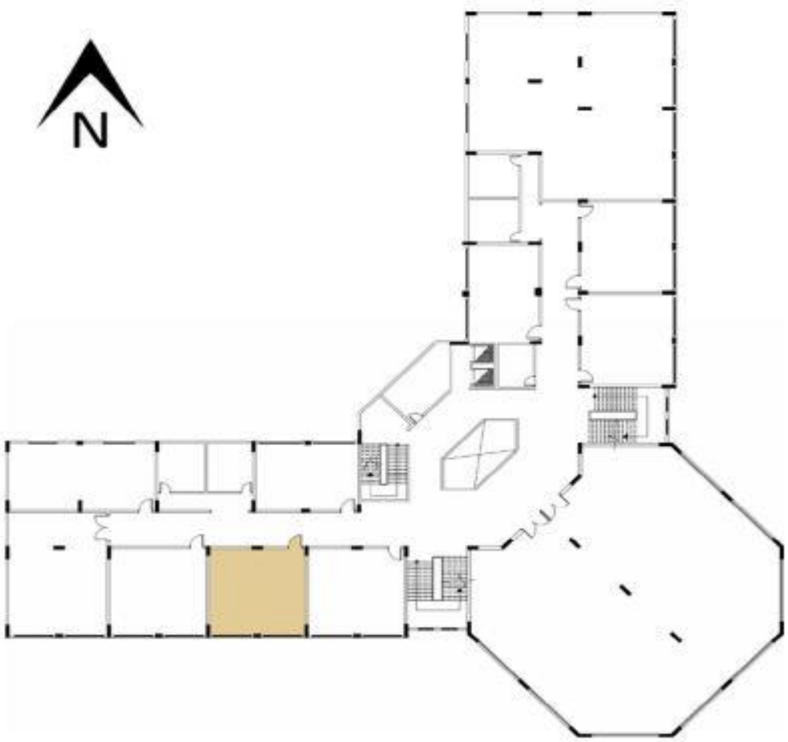


Figure 17. Standard floor plan indicating the study area at the Higher Institute of Science and Technology, Beheira Governorate (Samaan, Farag, & Khalil, 2018)

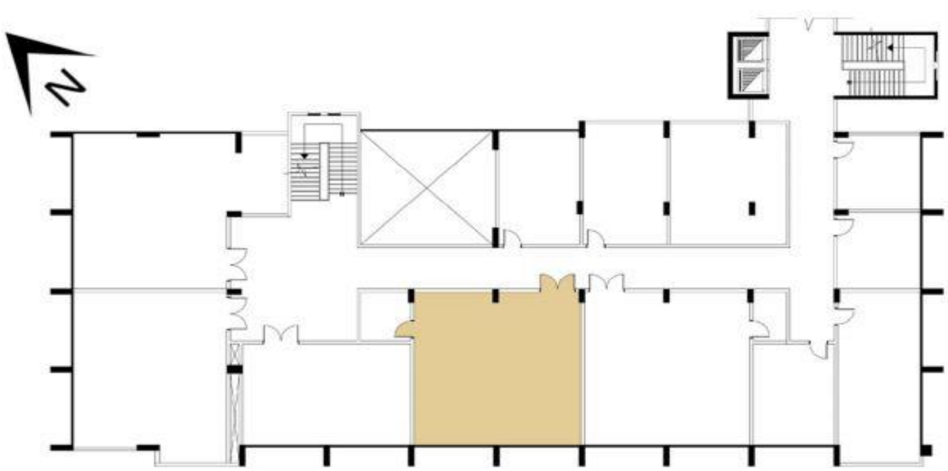


Figure 18. Typical floor plan showing a study area at the Arab Academy for Science and Technology, Alexandria Governorate (Samaan, Farag, & Khalil, 2018)

The typical characteristics of university buildings are not different from one region to another. The following figure shows three examples of the baseline conditions of study rooms in different universities that are located in different regions. The rooms are similar in terms of most of the design geometries, such as the depth, width and height of the room. The building systems, in terms of HVAC, lighting systems, and fan ventilation, are also similar (El-Darwish

& Gomaa, 2017) (Aboulnaga & Moustafa, Sustainability of higher educational buildings: Retrofitting approach to improve energy performance and mitigate CO 2 emissions in hot climates, 2016).

Table 5 Baseline condition of the selected study areas.

Classroom description		TU	BHI	AAST
Shape				
Orientation		North	South	South-West
Depth (m)		7.8	7.9	10.25
Width (m)		6.7	7.3	8.8
Height (m)		3.3	3.4	3.3
Material & Finishing	Floor	Granite Tiles	Granite Tiles	Granite Tiles
	Wall	Plaster (Dense)	Plaster (Dense)	Plaster (Dense)
	Ceiling	Rendering	Rendering	Rendering
WWR		46%	48%	55%
Window/Frame Description		Aluminum	Aluminum	Aluminum
Shading Devices		N/A	N/A	N/A
HVAC		Cooling Only	Cooling Only	Cooling Only
Lighting System		Surface Mounted (Fluorescent)	Surface Mounted (Fluorescent)	Surface Mounted (Fluorescent)
Fan Ventilation		Yes, Suspended	Yes, Suspended	Yes, Suspended
Occupation Density		0.4	0.35	0.35

Figure 19. Bassline conditions of different study areas located in different regions (El-Darwish & Gomaa, 2017)

2.2.1.5 Hospitals and medical buildings

In Egypt, there are more than 2,000 hospitals with more than 130,000 hospital beds (Colliers, 2017). The public or parastatal sector is the largest in terms if the number of beds and hospitals in Egypt. Parastatal organisations are governmental establishments operated through the Egyptian Ministry of Health and Population MOHP or other ministries, including the Teaching Hospitals and Institutes Organization, the Health Insurance Organization, and the Curative Care Organization (DHS Program, 2020). The private sector provides more than 33,000 beds in 1,400 hospitals. The overall average number of beds per hospital is around 105 beds in government sector, 212 beds in the public or parastatal sector, and only 24 beds in the private sector (Colliers, 2017). Across the region and in Egypt specifically, there is a new trend in developing healthcare and medical-driven mixed-use buildings, known as Healthcare Cities/Parks or Medical Cities/Parks, with retail, residential, commercial, and hospitality developments (Colliers, 2017).

Hospitals building design description

In terms of building regulation for hospital buildings in Egypt, limited obligatory measures are in place. For example, and according to the Executive Appendix of the Unified Building Law, Ministerial decree no.144 of 2009, the clear height from the floor finishing surface to the bottom of the ceiling must not be less than 2.7 m. It can also be down to 2.3 m in entrances, toilets, corridors, laundry rooms and guardrooms. If there are rooms or service areas where it is impossible to open windows that overlook courtyards or streets, recessions (pocket courts) can be made to allow an opening. The depth of the recession must not exceed half of its width, and the window must be directly in the face of the recession. Balconies can also be built in the recessions with a maximum width equal to half of the recession's width. Figure 20 shows an example of the building envelope characteristics of a hospital building in Egypt based on the provisions provided by building regulations (William, El-Haridi, Hanafy, & El-Sayed, 2019).

Furthermore, the figure also shows some recommendations for a modified and enhanced energy efficiency model.

AC systems in hospital buildings consume more than the 50% of total energy consumed. For example, a hospital in Alexandria is considered a huge energy consumption building due to 24-hour, seven-day availability, medical equipment, and requirements for clean air and disease control (Radwan, Hanafy, Elhelw, & El-Sayed , 2016). The installed HVAC and AC systems are different, depending on the size of the hospital. Small hospitals install separate AC units that operate room by room while mid-size and large hospitals typically have central HVAC systems.

Model	Initial & Baseline	Modified Energy Model
Exterior walls		
Construction	200 mm Common Brick + 50 mm Cement Plaster	200 mm Common Brick + 50 mm Cement Plaster + 25 mm Polyurethane
U-factor (W/ m^2 °C)	1.924	0.708
Roof		
Construction	20 mm Cement Plaster + 180 mm Hurdy Block + 20 mm Moisture Insulation + 50 mm Sand Layer + 25 mm Mortar Layer + 30 mm Tiles	20 mm Cement Plaster + 180 mm Hurdy Block + 20 mm Moisture Insulation + 50 mm Sand Layer + 25 mm Polyurethane + 25 mm Mortar Layer + 30 mm Tiles
U-factor (W/ m^2 °C)	2.27	0.75

Figure 20. Building envelope characteristics of the baseline and modified energy model of a hospital building in Egypt

Zone	Area (m^2)	Area %
Trauma	46	0.54%
Triage	16	0.19%
Examination/ Treatment	301	3.55%
Staff Lounge	131	1.54%
Offices	243	2.86%
Imaging Diagnosing Rooms	228	2.68%
IT Room	50	0.60%
Corridor/ Waiting Area	3,774	44.30%
Pharmacy	68	0.80%
Shop	27	0.32%
Clinics	331	3.89%
Conference room	130	1.53%
Sampling/ Laboratories	48	0.57%
Physical Therapy	133	1.56%
Operating Rooms	351	4.12%
Delivery Rooms	32	0.38%
Recovery Rooms	83	0.98%
Post-Surgery Rooms	37	0.44%
NICU	129	1.52%
ICU	226	2.66%
Bedwards	1,728	20.20%
Living Rooms	248	2.92%
Isolation Rooms	58	0.69%
Doctors Rooms	99	1.18%
Total Conditioned Area	8,517	100%

Figure 21. Conditioned area percentages in a hospital example in Egypt

2.2.1.6 Hospitality buildings

In Egypt, recreational and hospitality buildings have grown speedily over the last 30 years, particularly in locations such as Sharm Elsheikh, Hurghada, Safaga, Taba, Marsa Alam and the Sinai Peninsula and Red Sea areas. Over the last 30 years, the number of hospitality hotels and their rooms has increased from around 20,000 rooms to around 200,000 rooms. The tourism sector is also expected to grow, which will require more hospitality buildings to be built over the coming years (Aladassy, Mosaad, & Tarabieh, 2016).

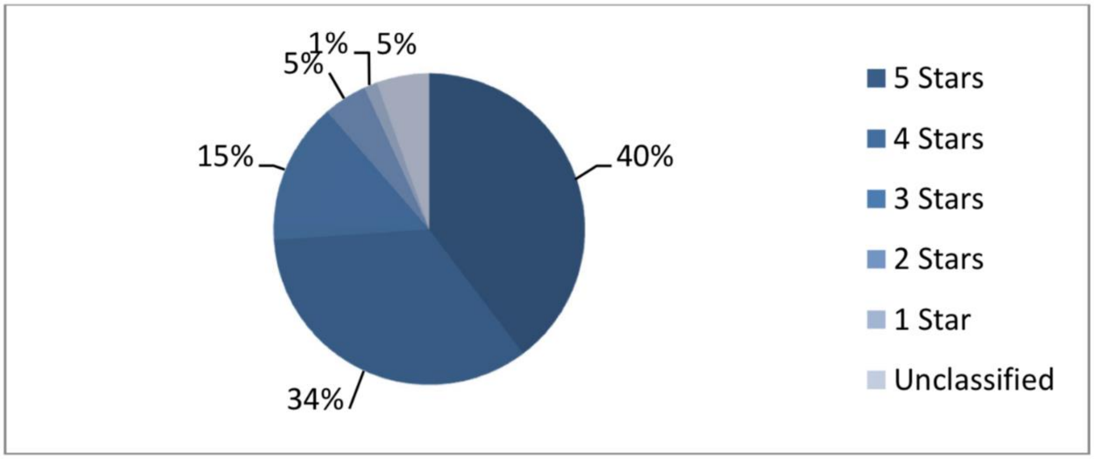


Figure 22. Egypt's hospitality room capacity over the past 30 years (Aladassy, Mosaad, & Tarabieh, 2016)

Hospitality buildings design description

As shown in the following figure, the baseline and BAU construction of hotels in Egypt are different from what the EEBCs require. For example, external walls are not insulated. The baseline for large hotels also uses a single pane glass with a solar heat gain coefficient (SHGC) of 0.61, 1P_SHGC_61 (Hanna & Farouh, Energy Analysis for New Hotel Buildings in Egypt, 2014).

Measure		Current Practice	Energy Code
WALL	WALL INSULATION	None	25mm Polystyrene out
	CONSTRUCTION	- Curtain Wall – 12 cm brick	12 cm Brick
	WALL ABSORPTANCE	0.5 - 0.7	0.3
ROOF	ROOF INSULATION	50 mm Polystyrene	25mm Polystyrene or 150 celton
	ROOF ABSORPTANCE	0.7	0.3
WINDOW	GLASS TYPE	1P_Grn (SHGC_6	2P_Hpt-Std-ClrSue (SHGC 35)
	WWR	Above 0.6	0.3
	FINS & OVERHANG	- No fins - No overhang	- Fins 0.25m - Overhang 0.5m
LOADS	LIGHTING POWER DENSITY	Medium	Low
	EQUIPMENT POWER DENSITY	Medium	Low
HVAC SYSTEM	CHILLER EIR	.22	.22
	COOLING_SPT	23	25
	OUT AIR PER PERSON	10	7.5

Figure 23. Comparison between the hotel buildings current construction practice and the energy code requirements

Building systems and HVAC

Due to the cheap prices of electricity until July 2014, Solar water heaters SWH was not in high demand. Solar heating for hotels was required at the beginning of the 1980s, but the maintenance difficulties and the high initial investments needed for SWH made it difficult for most hotel operators to install them. With the gradual cutting of electricity subsides and the improvement of SWH technologies, SWH installations gained momentum in hotels by the end of 2014 (Aboulnaga & CES-MED, Recommended National Sustainable Urban and Energy Savings Actions for Egypt , 2016). In Egypt, the two most common HVAC systems are the package single zone (PSZ) and two-pipe fan coil (TPFC). For example, hotels and resorts in the Red Sea region are cooled using central AC with large chillers. Guest rooms can use either central or split systems. Most of the systems have a cooling set point of 23°C during occupied periods (Hanna & Farouh, Energy Analysis for New Hotel Buildings in Egypt, 2014).

2.2.1.7 Administrative and office buildings

In a paper prepared by an EEBC author, the results of the energy analysis are summarised and used to determine the effectiveness of building characteristics in reducing electrical energy consumption for office buildings in Egypt. The design characteristics of a typical office building in Egypt are shown in the following figure. For example, the current method to construct walls uses 12-cm brick, the window-to-wall area ratio is around 0.40, and most of the office buildings in Egypt use single glass (Hanna, Energy Analysis for New Office Buildings in Egypt, 2015).

Parameter Studied	*Current Practice*	*Energy Code*	*Energy Saving*
Orientation	-	N-S	2%
WALL_CONSTRUCTION	12cm_Brick	25cm_HClay	2%
WALL_SURFACES	Mortar Both	Mortar Both	-
WALL_INSULATION	None	25mm_Out	2.5%
WINDOW_TYPE	1P_SHGC_61	1P_SHGC_37	6%
ROOF_INSULATION (Top Floor)	None	Poly_75mm	30%
WINDOW-TO-WALL-RATIO(WWR)	0.4	0.2	20%
SHADING USING OVERHANGS (OH) AND FINS (FINS)	-	N-S	10% 4%
OFFICE_LPD	15	15	-
OFFICE_EQPD	5	5	-
Set-Point Temperatures	22	24	2%
CHILLER_EIR	0.253	0.182	8%

Figure 24. Design characteristics of a typical office building in Egypt, in comparison with requirements of the EEBCs

Office building systems in Egypt

Most offices in Egypt use lighting power density with an intensity of around 15 W/m^2 for lighting systems. The two most common HVAC systems are the PSZ and TPFC. Large office buildings have an average AC chiller efficiency of 0.25 (Hanna & Farouh, Energy Analysis for New Hotel Buildings in Egypt, 2014) (Hanna, Energy Analysis for New Office Buildings in Egypt, 2015).

2.2.1.8 Commercial (retail and trade) buildings

Commercial (retail and trade) buildings vary in specs and systems according to scale. As there was no sufficient literature available on retail and trade buildings, the inputs were derived from real projects and common practice inquiries.

Building Systems of commercial buildings

The following table is filled by an engineering sector head at a reputable design consultancy in Egypt with over 15 years of experience in different projects, including commercial buildings.

Aspect	Commonly used values/technologies
Clear room height	4.5-5
WWR	Not less than 18%
Type of window	Double glazing
Technology	- Centralized chiller in malls - Centralized multi-split system in small scale commercial buildings
Energy Carrier	Electricity
Technology	Air-conditioning system (reversible for heating; air-air heat pump)
Energy Carrier	Electricity
Technology	- Dedicated gas or electric heater (dedicated = just hot water generation) - Solar Thermal collector on the roof
Energy Carrier	Gas or Electricity
Type of Lighting technology	LED (Light emitting diode lamps)

Figure 25. Commonly used technologies in office buildings in Egypt

The following table depicts information obtained from specialised consultants working in commercial and mixed-use building design in Egypt.

Space cooling system	- up to 100-tonne AC capacity, direct expansion system (semi-central system) used; - more than 100-tonne AC capacity, chilled water central system used
Ventilation system	- part of the space cooling system
Lighting	- LED lamps
Hot water generator	- mix between solar thermal collector on the roof, dedicated gas heater (just hot water generation) and dedicated electric heater (just hot water generation)
Temperature set points	- cooling 22°C design wise but is advised to be 24°C in real use
Building envelope	- most of the facades of the building are opaque with few windows; - walls are constructed from cement hollow blocks in a single wall; - curtain walls are installed on the entrance façade and are double glazed, laminated and tempered; - skylights are used in a limited manner, are double glazed and are laminated and tempered; - roofs are insulated with a thermal and water insulation material

Table 7. Design characteristics of typical office building in Egypt

2.2.1.9 Mixed-use buildings

Mixed-use buildings in Egypt are generally classified into the following typologies:

- First Typology: A typical MFH building that hosts more than one use. The most common combination is residential-commercial, where the first one or two floors are commercial and the rest is residential. In some cases, the MFH is totally changed from residential into one or more other uses (commercial administrative, medical administrative, hospitality commercial, etc.)
- Second typology: The other prominent mixed-use building typology is mainly in new construction, such as mixed development projects, including business parks and complexes with administrative, commercial and residential buildings or only administrative and commercial buildings.

In terms of building and construction characteristics, the first typology is similar to residential buildings and MFHs. The characteristics of second typology are closer to commercial and administrative buildings.

2.2.2 Background information of the building typology in Jordan

The Royal Scientific Society (RSS) has established a database for building typologies in Jordan as a part of BUILD_ME project. It includes a sample of reference buildings that are available in the building market (new and existing buildings), which conveys certain building types and shows Jordan's technical building systems and typical architecture. This part of the report includes background information about building typology in Jordan and features of new constructions (Activities 1.5 and 1.6).

2.2.2.1 Building sector in Jordan

Architecture in Jordan went through wide development phases, especially in the final years of the twentieth century. Jordan is considered a small country in the Middle East. The Jordanian culture was shaped by its architecture, which had a central role and was connected to many factors. These factors included the character of inhabitants of the land and the land's morphology, which is composed of the River Valley, the Dead Sea and the Jordanian Highlands. The arid climate of Jordan had a strong influence as well. Because of the increase in urbanisation, a neutralisation effect took place over the traditional architecture that dominated the region (Rajoub, 2016). The change in social and economic conditions after independence in 1946 had a strong influence on modern Jordanian architecture as it was more exposed to the Western world's influence. International styles took over the vernacular styles. One of the affecting factors was that many architects continued their education in foreign countries and were affiliated with the Department of Lands & Survey. Most of the new buildings had a mixture of past and new building styles, an effort to keep the Jordanian identity in the nation's architecture. The obvious development was in materials, including concrete, marble, glass, metal and roof tiles, depending on their functions (Rajoub, 2016).

During the last 40 years, with dominant changes in the Jordanian socioeconomic environment, the architecture of Jordan also changed. The change included the wide spectrum of buildings, from large-scale projects to small-scale houses. These changes follow different schools, varying between modern and traditional styles. Until 1040, the traditional styles were the dominant styles. The modernistic style was introduced with the rise of other types of buildings, including schools, governmental buildings and entertainment buildings. As mentioned previously, the return of architects who had continued their educations abroad (e.g. Europe, Egypt, and Lebanon) had a strong influence. By the 1960s, the international style was fully introduced to the Jordanian context, including hotels, public facilities and university buildings. The increase in oil prices between the 1970s and 1980s had a strong influence on the construction industry. Many countries, including Jordan, started depending on local and international architects (Dahabreh & Al-Shami, 2016).

Figure 26. Amman, Jordan (AmmanJo, 2021)

By the end of the 1980s, there was an interest in expressing the local and cultural values in the architectural field, which created an impact on practitioners and university educators. That movement was apparent in several public and touristic projects that followed the same approach. Globalisation and geo-political changes had a strong impact on the society and the culture between the 1990s and the mid-2000s. Globalisation was incentivised by the digital world and international neo-liberal values. These factors facilitated the movement of capital, the spread of consumption culture, and the rise of the characteristics of contemporary living. The effect stretched from small-scale production to entire urban development plans. The Gulf War and the September 11 attacks lead to an increased flow of immigrants, which had a strong impact on the need for housing, boosting construction in the housing sector at all of its levels (Dahabreh & Al-Shami, 2016).

Because of the strong socioeconomic changes in Jordan within the last 40 years, the building sector was affected from small-scale projects to complex and large-scale projects and urban developments. These changes led to the diversity of styles between traditional and modernistic architecture. Even in terms of aesthetic measures, projects varied between pleasing and displeasing, traditional and modernistic. With the world changing toward digital media, there was a breaking effect in the Jordanian architecture and its original cultural and regional identity (Dahabreh & Al-Shami, 2016).

2.2.2.2 Buildings in numbers in Jordan

In 2015, the Jordan Department of Statistics conducted the latest population and housing census, which indicated that the total population is 9.5 million. This census is run every 10 years, as indicated by Law No. 12 of 2012 and as per the recommendation of the competent bodies. Based on the last census, the distribution of housing buildings in Table 8 included three types of housing buildings: MFHs, SFHs, and villas (Jordan Department of Statistics , 2016).

Building Type	Residential Only	Residential & Business	Business Only	Under Construction	Others	**Total**
MFH	211,496	53,610	18,222	2,252	2,911	288,491
SFH	458,005	9,311	6	7,416	14,626	489,364
Villa	15,217	59	0	666	1,152	17,094
Total	684,718	62,980	18,228	10,334	18,689	794,949

Table 8. Distribution of housing buildings by type of occupancy (2015), villa (Jordan Department of Statistics , 2016).

As shown in Table 9, most of the building sector in Jordan is for SFHs while MFHs are common for the mixture of residential and business buildings. Multi-storey buildings that accommodate residential and offices or commercial uses are common.

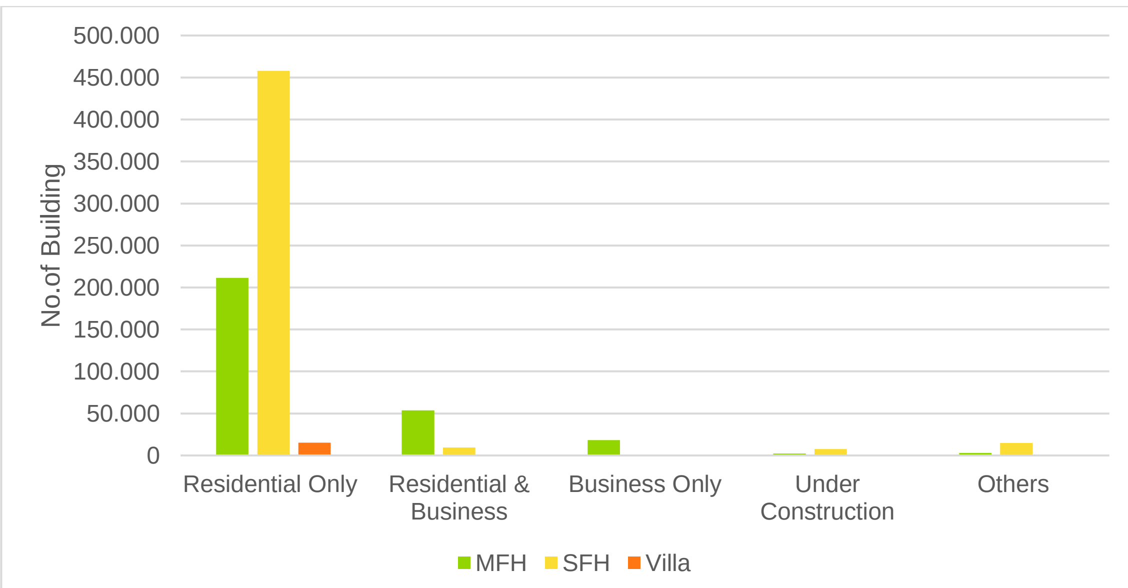


Figure 27. Distribution of housing buildings by type of occupancy in Jordan (2015)

Based on Figure 28, which shows the distribution of all housing buildings in Jordan by the type of occupancy for 2015, SFHs are the leading type of residential use buildings.

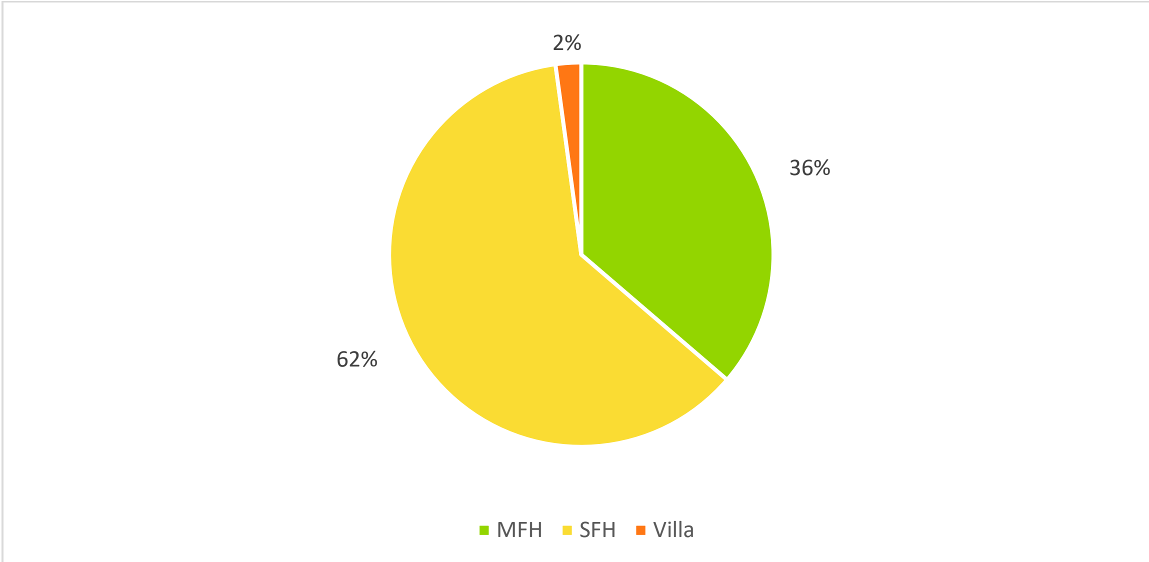


Figure 28 Share of building types in Jordan (2015)

Based on the census, Table 9 shows the distribution of different types of housing buildings according to the year that construction started from the period before 1950 until 2015. The tables include three types of housing buildings: MFHs, SFHs, and villas.

Year of Construction	Unspecified	Before 1950	1950-1959	1960-1969	1970-1979	1980-1984	1985-1989	1990-1994	1995-1999
MFH	56,119	1,855	3,979	11,839	28,391	30,372	20,070	28,320	21,425
SFH	89,121	1,840	4,151	12,136	34,853	36,897	29,808	40,114	35,718
Villa	2,902	14	44	71	443	665	777	1,296	1,178
Total	148,142	3,709	8,174	24,046	63,687	67,934	50,655	69,730	58,321

Year of Construction	2000-2004	2005-2009	2010	2011	2012	2013	2014	2015	**Total**
MFH	25,425	18,377	6,788	2,752	3,741	6,858	9,614	12,566	288,491
SFH	48,170	47,903	17,736	7,640	9,681	17,515	25,207	30,874	489,364
Villa	2,014	2,642	792	393	603	791	980	1,489	17,094
Total	75,609	68,922	25,316	10,785	14,025	25,164	35,801	44,929	794,949

Table 9. Distribution of Housing Buildings by year of laying fundaments before 1950 to 2015

The following figure shows the distribution of housing buildings based on the start date of construction (before 1950 to 2015) for each type of building. Fluctuations can be deduced from the graph, and they are related to the geo-political conflicts occurring in the region. First, there is an increase after independence until the second half of 1980s due to the Gulf War, which affected oil prices and, accordingly, the building sector. Therefore, the number of new buildings decreased until 1990. After that period, there was an increase in the number of buildings until the economic crisis of 2008, and the increase was due to the increase of immigrants from after the Gulf War in 1990 until the American-Iraqi war in 2003. This increase in immigration led to the high demand for residential buildings, specifically MFHs. The improvement of Jordan's economic situation led to the demand for more commercial, trade, office, hotel and education buildings, which contributed to that development.

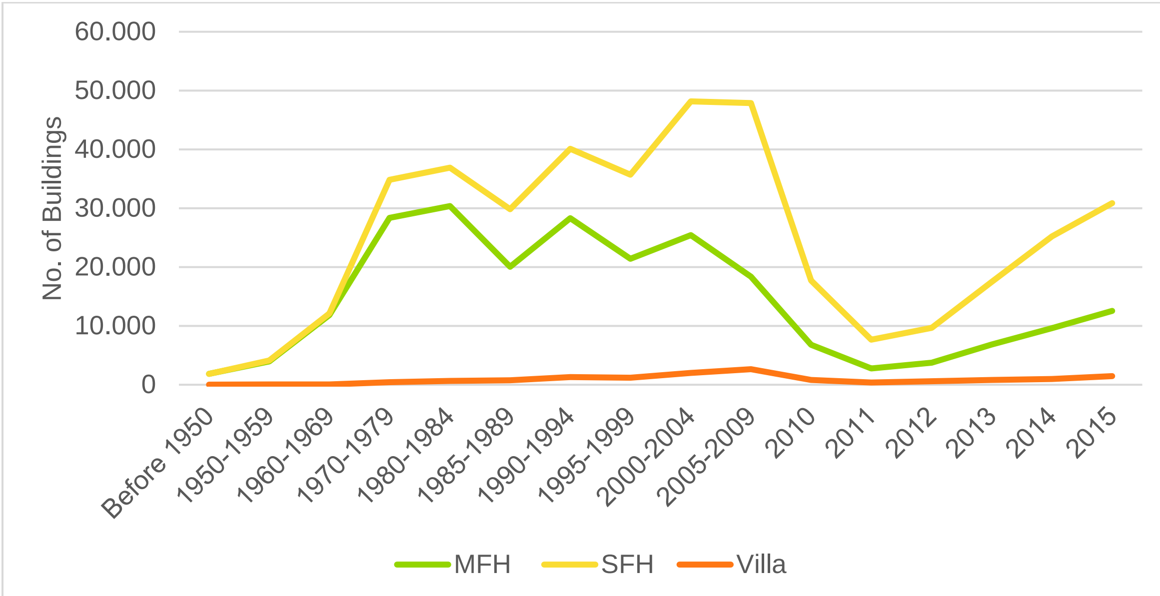


Figure 29. Distribution of housing buildings by year of laying fundaments (before 1950 to 2015)

There was an increase in the number of new buildings from 2010. The main cause of this increase was the increase of Jordan's population and the increase of refugees, especially after the Syrian crisis in 2011. The following figure shows the total of housing buildings according to the date of construction start (before 1950 to 2015).

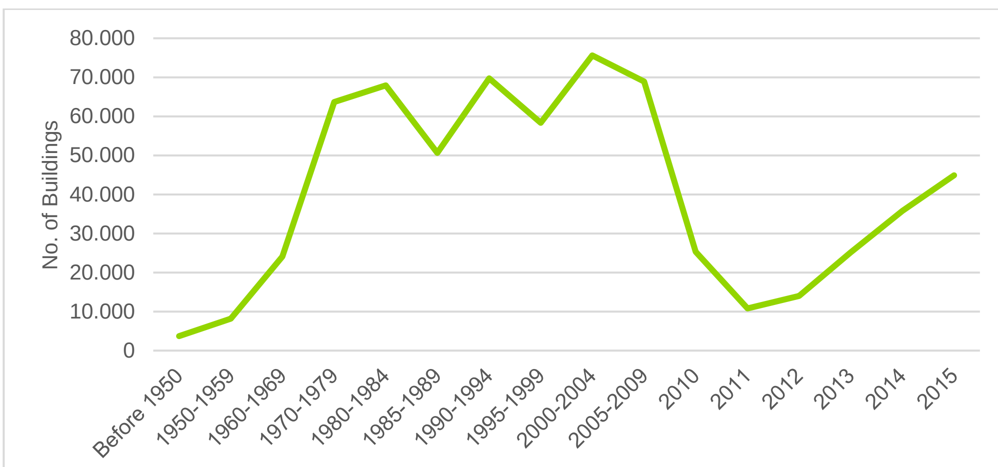


Figure 30. Total housing buildings by year of laying fundaments (before 1950 to 2015)

2.2.2.3 Building typology: sources

The selection of building categories, different regions and construction intervals was performed based on the following sources.

A. Building statistics

The representation of apparent changes in the building sector, as shown in the previous section, was based on the data from the Jordan Department of Statistics. The major change occurred by the end of 1980s and the start of 1990s. The other major change occurred at the end of 2010s. The three periods investigated include before 1990, from 1990 to 2010 and after 2010. Literature review findings and expert consultation supported the same time frame definitions.

B. Literature review

The construction periods have been selected based on several factors:

- The change in architectural trends that occurred in Jordan over the span of the last 100 years;
- The major political changes, including the large number of Palestinian refugees in 1948 and 1967 and the refugees of the Gulf War in 1990;
- The improvement of the Jordanian quality of life and educational opportunities, which gave a wider chance for modern architecture with various concepts of different types of buildings

C. Experts consultation

Three experts were consulted for the selection of criteria for building categories through a meeting held by RSS. This meeting included Dr Adnan Khasawneh, former director of Constructions and Sustainable Buildings Centre at RSS; Eng. Tala Awadalleh, a consultant in the building sector in Jordan and architecture lecturer in German-Jordan University; and Eng. Naela Daoud Manager of Buildings Codes at RSS. The decision was made to focus on the regions east of Amman and west of Amman. The decision was made because most of Jordan's cities have the same building architecture as Amman. Because there are some differences between architectural elements (such as areas, designs, materials used and installed systems) of the country's east and west regions, both were considered as two separate regions. All the selections were made according to building statistics and literature reviews, and the selection of building categories made by RSS were approved and acknowledged during the meeting.

D. RSS assessment

The RSS team conducted a quick assessment for the main building categories in Amman to accurately choose the buildings categories to be investigated. Based on the assessment, six building categories were selected:

- SFH;
- small (≤ 1500 m²) detached MFH;
- large (>1500 m²) detached MFH;
- detached, combined buildings (trade and office);
- combined buildings (trade and MFH);
- schools

The building category selection has been approved and acknowledged by the experts' consultation meeting.

2.2.3 Background information of the building typology in Lebanon

2.2.3.1 Building sector in Lebanon

The history of modern construction in Beirut is divided into three phases:

- Phase 1, between 1840 and 1975;
- Phase 2, from 1975 to 1990;
- Phase 3, post 1990

Phase 1 is highlighted by the active years of urban construction was influenced by the Ottomans rule, the French mandate in parallel and the rise of Lebanese governments after the independence of 1943. Cities kept growing and were influenced by European architecture. The main available typology was a detached building composed of large apartments and limited to three floors (Chedid, 2012).

Figure 31. Lebanese Ministry of Foreign Affairs building, dating back to the Phase 1 (Middle East in 24, 2021).

During Phase 2, from 1975 to 1990, the Lebanese Civil War froze and construction activities were focused on cities. At the same time, the development of rural and suburban areas increased, reaching agricultural lands with unregulated construction activities. The increase in rural density led to horizontal and vertical extensions of existing buildings (Fawaz & Peillen, 2004).

Phase 3 started after 1990 and included the reconstruction movements in Lebanon. The built environment changed immensely, including introducing new typologies, such as high rise buildings, huge commercial areas and offices. Also, this phase included the emergence of technology and manpower (al-Asad, Musa, & Saliba, 2001).

Figure 32. High rise building after 2010 (Elkhoury, 2021)

As per a survey conducted by the Central Administration of Statistics to assess Lebanon's construction state and building trends over the six governorates between 1996 and 1998, 518,858 buildings were found, distributed into residential, non-residential and mixed-use buildings. The residential sector makes up 65% of the buildings, the non-residential sector makes up 11% and mixed-use buildings make up 20% (The Central Administration of Statistics, Lebanon, 1996-1998).

Mohafaza	*Total Buildings*	*Residential*	*Non-Residential*	*Mixed*	*Other*
Beirut	18,810	6,257	2,320	8,616	1,617
Mount Lebanon	168,475	104,963	18,813	37,873	6,826
North Lebanon	107,268	65,388	13,434	23,285	5,161
South Lebanon	69,873	48,389	7,578	10,714	3,192
Nabatiyeh	56,705	42,172	4,405	7,531	2,597
Bekaa	97,727	64,357	11,977	18,049	3,344
TOTAL	518,858	331,526	58,527	106,068	22,737

Table 10. Distribution of buildings per governorate and use (The Central Administration of Statistics, Lebanon, 1996-1998)

Of 1.45 million dwelling units, 73% are dedicated for residential use. Non-residential buildings have diverse uses that include, but are not limited to, services, shops, hotels, restaurants, health care and insurance. The classification of non-residential area per use is displayed in Figure 33.

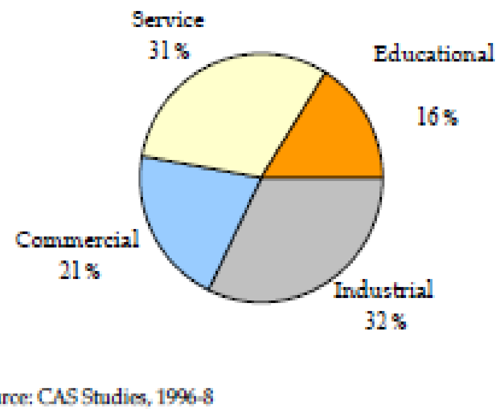


Figure 33. Total floor area by type of establishment (The Central Administration of Statistics, Lebanon, 1996-1998)

After 1996, the commercial sector experienced wide development. The change in construction permits between 2008 and 2012 had an impact on the new building spirit in the country. The leading residential sector had a downward slope while the commercial and economic sector had an increase. This change was the result of development in the building typology with other factors, such as economic situation.

Construction Permits by Use					
(in ,000 sqm)	2008	2009	2010	2011	2012
Residential Buildings	10,264	6,441	8,203	7,401	6,714
% Change		*-37%*	*27%*	*-10%*	*-9%*
Commercial Buildings	1,066	338	598	616	845
% Change		*-68%*	*77%*	*3%*	*37%*
Public Buildings	547	486	381	236	425
% Change		*-11%*	*-22%*	*-38%*	*80%*
Economic Sector Buildings	252	284	520	425	397
% Change		*13%*	*83%*	*-18%*	*-6%*
Hotel & Tourism Services Buildings	296	122	156	232	104
% Change		*-59%*	*28%*	*49%*	*-55%*

Source: Order of Engineers

Table 11. Construction permit per use variation between 2008 and 2012 (The Central Administration of Statistics, Lebanon, 1996-1998)

The variation was also obvious in the residential buildings themselves. SFHs were replaced by more rewarding investment. Compound residential projects were increasing at a higher pace than standard residential buildings due to the saturation of areas within the city, the cheaper investment within city suburbs, and the development of connecting infrastructure.

More focus is directed toward compact apartments between 100 m^2 and 150 m^2, and more units that are larger than 150 m^2 were built before 1980. The compact units are more affordable. In addition to the size shift, there was also a locational shift. Total property sales transactions shifted from 31% to 28% in Beirut, due to the affordability of other regions (BankMed, 2014).

New Residential Units by Size				
Units	2009	2010	2011	2012
Below 100 sqm	2,712	1,695	1,853	1,504
% Change		*-37.5%*	*9.3%*	*-18.8%*
101 - 150 sqm	5,729	10,053	11,573	9,938
% Change		*75.5%*	*15.1%*	*-14.1%*
151 - 200 sqm	6,178	7,201	5,735	5,401
% Change		*16.6%*	*-20.4%*	*-5.8%*
201 - 300 sqm	3,581	4,046	2,771	2,386
% Change		*13.0%*	*-31.5%*	*-13.9%*
301 - 400 sqm	850	503	505	345
% Change		*-40.8%*	*0.4%*	*-31.7%*
Above 400 sqm	609	543	279	151
% Change		*-10.8%*	*-48.6%*	*-45.9%*
Houses	999	1,426	1,583	1,464
% Change		*42.7%*	*11.0%*	*-7.5%*
Villas	1,108	1,036	863	914
% Change		*-6.5%*	*-16.7%*	*5.9%*
Palaces	8	1	6	5
% Change		*-87.5%*	*500.0%*	*-16.7%*
Total	21,774	26,504	25,168	22,108

Source: Order of Engineers

Table 12. Variation of new residential unit's size between 2009 and 2012 (BankMed, 2014)

New Residential Units by Type				
Units	2009	2010	2011	2012
Standard Residential Building	17,409	20,287	17,890	15,750
% Change		*16.5%*	*-11.8%*	*-12.0%*
Standard Residential Compounds	480	2,135	3,310	2,215
% Change		*344.8%*	*55.0%*	*-33.1%*
Luxurious Residential Building	1,418	1,086	932	1,100
% Change		*-23.4%*	*-14.2%*	*18.0%*
Individual Houses	999	1,426	1,583	1,464
% Change		*42.7%*	*11.0%*	*-7.5%*
Luxurious Residential Compounds	352	533	584	660
% Change		*51.4%*	*9.6%*	*13.0%*
Villas	1,108	1,036	863	914
% Change		*-6.5%*	*-16.7%*	*5.9%*
Palaces	8	1	6	5
% Change		*-87.5%*	*500.0%*	*-16.7%*
Total	21,774	26,504	25,168	22,108

Source: Order of Engineers

Table 13. New residential buildings development between 2009 and 2012 (BankMed, 2014)

In the past few years, all building examples prove the diversity within the typology of Lebanese construction. Still, the differences between the typology within cities and the typology in villages are distinguishable. Cities are characterised by more coherent groups with urban homogeneity while villages present a unique architectural heritage.

Sustainability in the construction sector:

Lebanon's environment is experiencing obvious deterioration due to the abuse of natural resources and the government's preoccupation with political, financial and economic fields. Due to fires, cutting of trees and urbanisation, the surface area covered by forests decreased from 13% to 5%. From another perspective, the Lebanese building code does not provide sufficient guidance for incentives to achieve sustainable construction. Sustainable construction is voluntary, and the environmental impact of design and construction in buildings is not considered by the existing construction laws. Sustainable construction is threatened by the lack of proper legislative systems to enforce and monitor green construction practices. The importance of sustainable development and the preservation of nature's resources are elements that lack public awareness. As real estate buyers or end users, the public can impact construction practices and, accordingly, developers and contractors (Awwad & Khoury, 2012).

2.2.3.2 Sources and information of the building typology in Lebanon.

The categorisation of building typology in Lebanon was based on the following sources:

a) NEEREA database

For the private sector, NEEREA is considered the mechanism that facilitates energy efficiency and renewable energy financing for projects. The database includes over 1,000 existing and new buildings, focusing on the technological side. The categorisation of new building typology was mainly based on the NEEREA database, which covers different sectors (e.g. residential, commercial, industrial and educational). The database covers the different regions of Lebanon, the relevant energy and the economic savings for each project. Geometrics, technical specifications, and the type of HVAC system used were provided by the database that serves the categorisation of the existing building typology.

b) Market study

Two surveys were disseminated and collected to give a clearer image of the building typology and complement the data from NEEREA database:

- The first survey was for experienced engineers (consultants and contractors in the building sector) who are tackling construction practices. Data from project execution plans, construction materials, relevant specifications, heating and cooling technologies for every project and region and ventilation calculations were collected for the projects.
- The other survey tackles the different types of heating systems that are available in different Lebanese regions, the efficiency of these systems throughout the year, and their correspondence to the building type. The data was collected from heating system suppliers.

c) Literature review and research

A literature review was used as a source for reliable data to understand the knowledge about building types, geometries and most mechanical systems applied in Lebanon. In addition to this review, construction permits from the Order of Engineers and Architects were used to classify building typologies in Lebanon.

d) Expert consultation

To collect data about building typologies from different construction periods and regions, consultants and contractors were contacted as experts. The data that was collected from experts acted as a method to exchange and accumulate data sources. It also highlighted the common approaches, methods and different indicators for building typologies.

2.3 Building typologies

The building typologies have been prepared based on the country background information, literature review, data collection and the country-specific approach, as explained in the previous sections of this report. Furthermore, the project team considered information from partners and experiences from other building sector-related projects in the MENA region. The full information on building characteristics is provided in the Annex of this report. The categorisation of building types and building typologies for each country has been prepared.

This building typology database depicts representative reference buildings in Egypt, Jordan and Lebanon. The building typology reflects the region's typical architecture and technical building systems. The photos shown are generic photos for each category, and the technical specifications can be found in the Annex of this report. Alternatively, the technical specifications can also be shown when clicking on some of the photos on the BUILD_ME Project website.

2.3.1 Building typology in Egypt

As concluded in Section 2.2.1, there are no major differences in building practices and building materials that are used across different regions in Egypt. This lack of differences is mainly because the Unified Building Law does not mandate any differentiation in construction among Egypt's different regions. This lack of differences has also been confirmed by the case studies included in the reference buildings. The buildings have been classified into two main construction periods: New Construction (built after 2015) and Existing Buildings (1980-2015). Based also on the background information, the building typology in Egypt covers the following types:

a) residential buildings;
b) educational buildings;
c) retail/trade: commercial buildings;
d) offices: administrative buildings;
e) mixed-use buildings;
f) hospitals and medical buildings;
g) hospitality buildings

In the building typology of Egypt, there are two available energy related options. The first option is national, which represents the typology as concluded in BUILD_ME project. The second option is the national improved baseline (Egypt), which has parameters that are set in accordance with Egypt's EEBC. The following figure shows screenshots of the building typology database as uploaded in the BUILD_ME Project website.

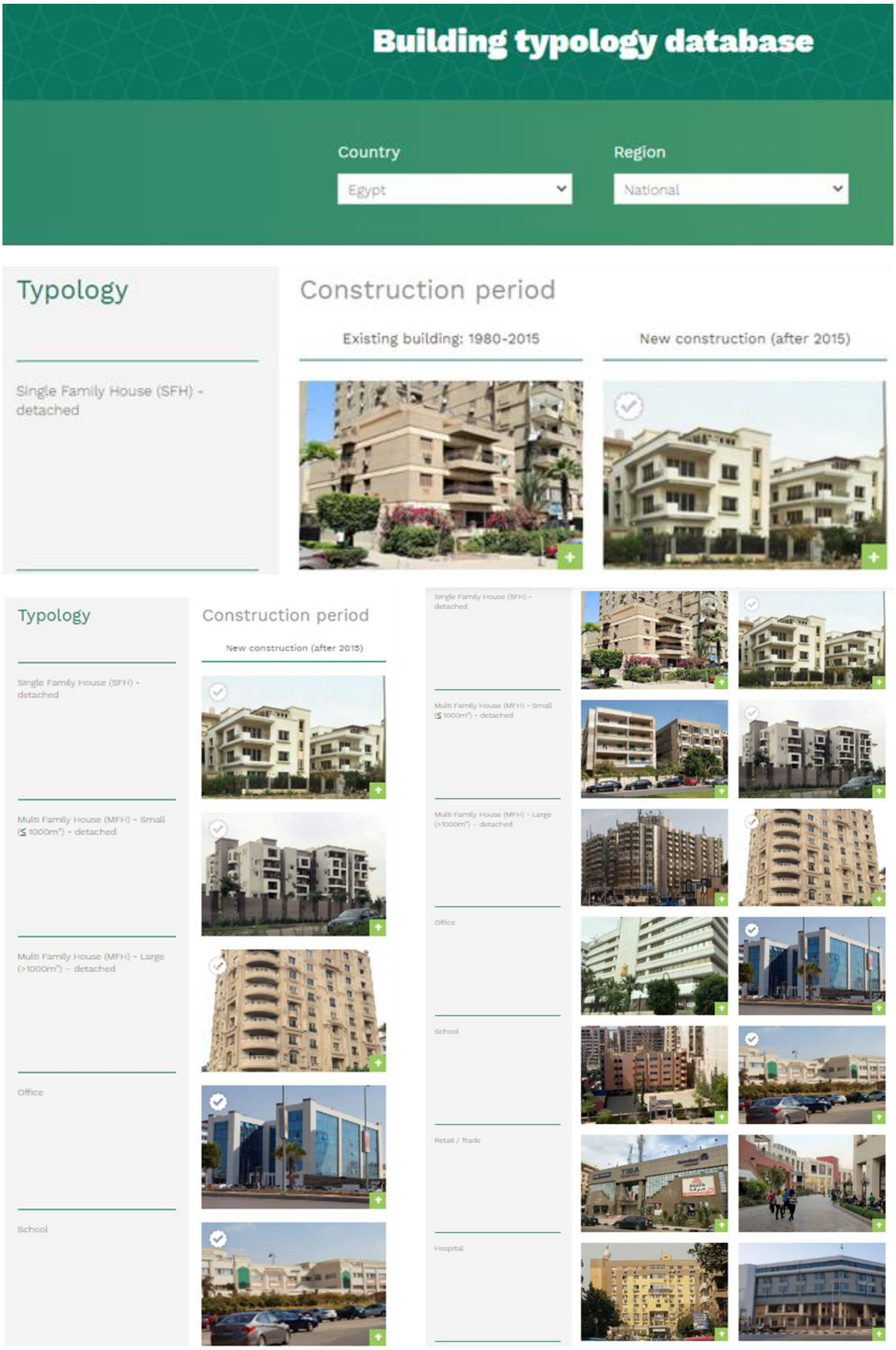


Figure 34. Screenshots of the building typology in Egypt, from the [BUILD_ME Project website]

2.3.2 Building typology Jordan

The building typology in Jordan has been prepared based on the background information as shown in Section 2.2.2. The typology covers the main building types in Jordan that were investigated, including the following:

- detached SFH;
- small (≤ 1500 m²) detached MFH;
- large (>1500 m²) detached MFH;
- school;
- combined buildings (trade and office);
- combined buildings (trade and MFH)

The two regions defined as representative to show the full variance of buildings in Jordan are east of Amman and west of Amman. The typology also covers the following three construction periods:

- before 1990;
- between 1990 and 2010;
- after 2010

As a result, 36 reference buildings were defined to represent Jordan's building stock. The detailed information of those buildings is provided in the Annex of this report.

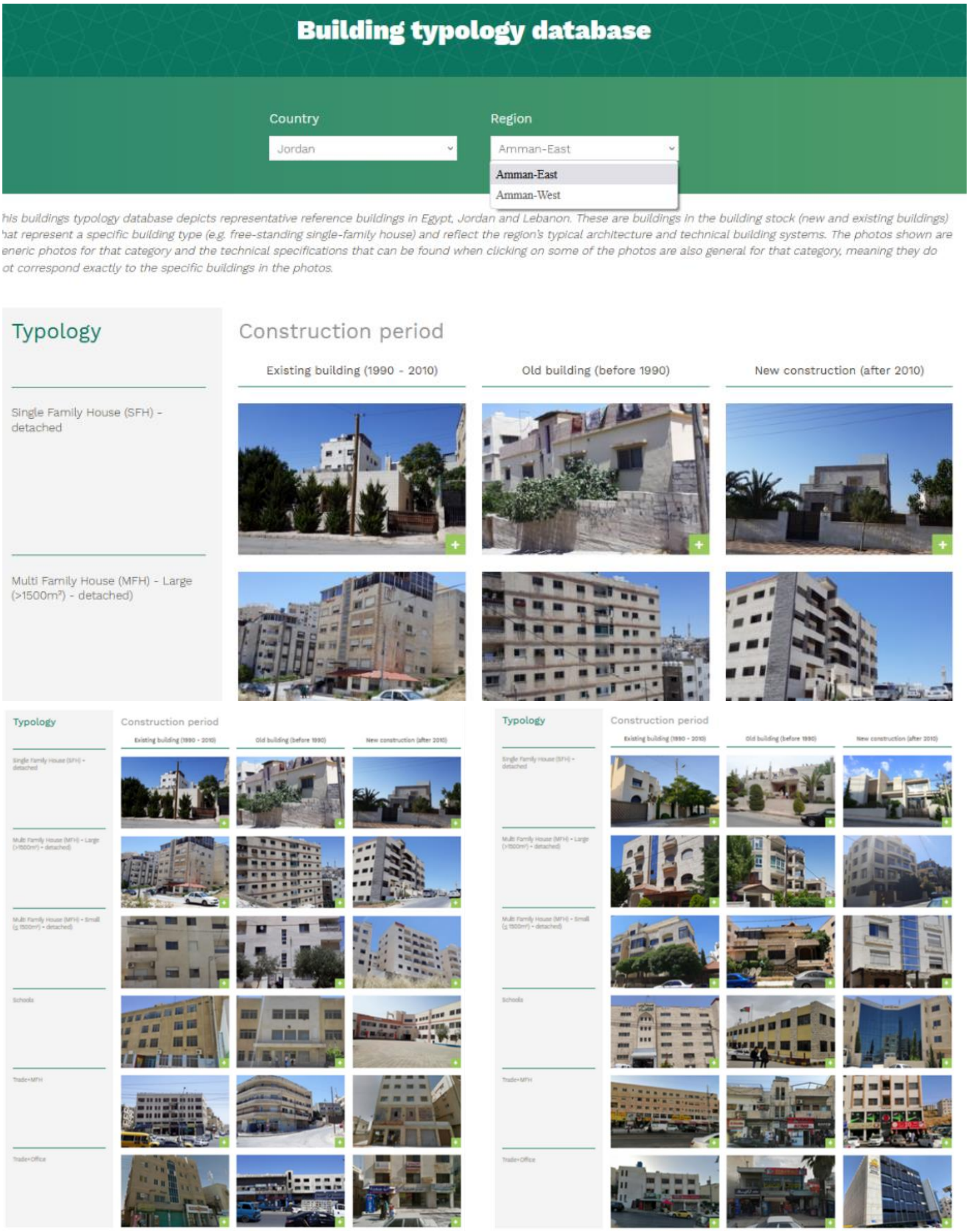


Figure 35. Screenshots of the building typology in Jordan, from the [BUILD_ME Project website]

2.3.3 Building typology Lebanon

Based on the analysis of the collected data and the analysis of the building stock in Lebanon, several building types have been considered and analysed in the country, including the following building types:

- detached SFH;
- small (less than or equal to 1000 m²) detached MFH;
- large (greater than 1000 m²) detached MFH;
- offices;
- schools;
- retail or trade;
- hospital

Thermal standards for buildings in Lebanon differentiate between four climatic zones, but the standards are not enforced. Therefore, due to the judgement of the project team's partner LCEC and based on several experts' interviews, the project team decided not to consider these climate regions but instead differentiate between size of urban and rural agglomerations. As presented in Section 2.2.3, the construction sector in Lebanon can be divided into three phases: Phase 1 covers before 1980 until the construction was stopped by the civil war; Phase 2 covers the period between 1980 and 2015, where the reconstruction took place at fast rates; Phase 3 covers the period after 2015, where construction practices have changed and improved in terms of integrating sustainable design elements. In addition, the country's building typology differentiates between three main regions:

- City: more than 40,000 inhabitants representing a dense and large urban environment;
- Town: a population ranging between 4,000 and 40,000—larger than a village and smaller than a city;
- Village: a population smaller than 4,000 inhabitants in rural areas

As a result, 59 reference buildings were designed that represent the Lebanese building stock. The detailed information of those buildings is provided in the Annex of this report.

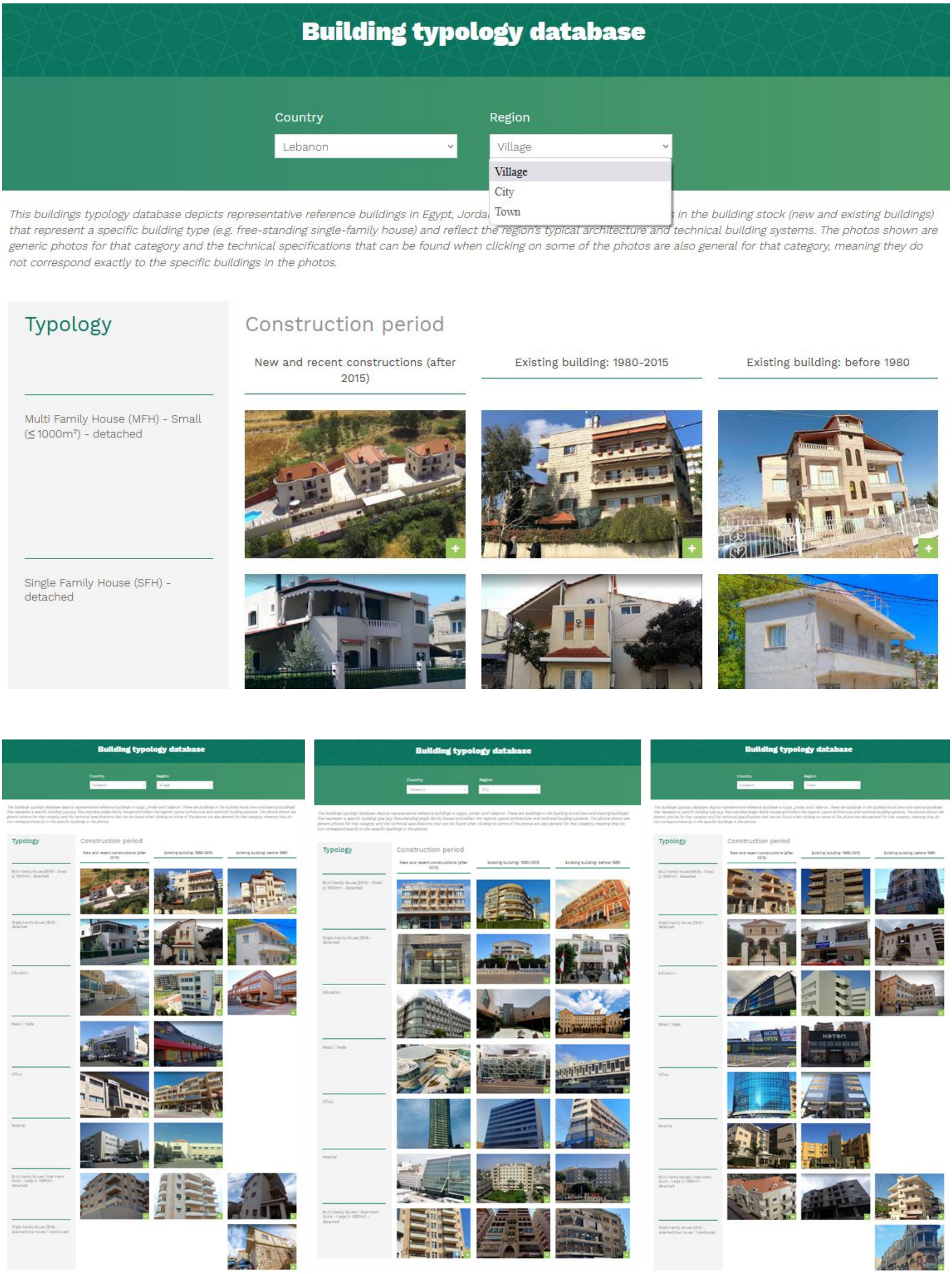


Figure 36. Screenshots of the building typology in Lebanon, from the [BUILD_ME Project website]

3 Energy reference benchmarks

The identified representative baseline parameters (geometry, building envelope and technical building systems) have been used to calculate building-specific baselines for the three building types. The baseline energy benchmarks express representative final and primary energy demands and CO_2 emissions. For the calculations, Guidehouse's BEP tool has been used. This report presents the CO_2 emissions and final energy results.

3.1 Guidehouse's Building Energy Performance (BEP) tool

The tool allows the energy demand (useful, final and primary energy), the greenhouse gas (GHG) emissions and the global costs for several energy efficiency measures for buildings to be calculated. These calculations include the investments for HVAC systems, PV and solar thermal, insulation and shading measures. Maintenance of these systems and the resulting energy costs over the calculation period are also included. The potential residual values of investments and earnings through PV feed-in are considered in the costs. Figure 37 shows the inputs, calculation steps and the relevant results in the present case.

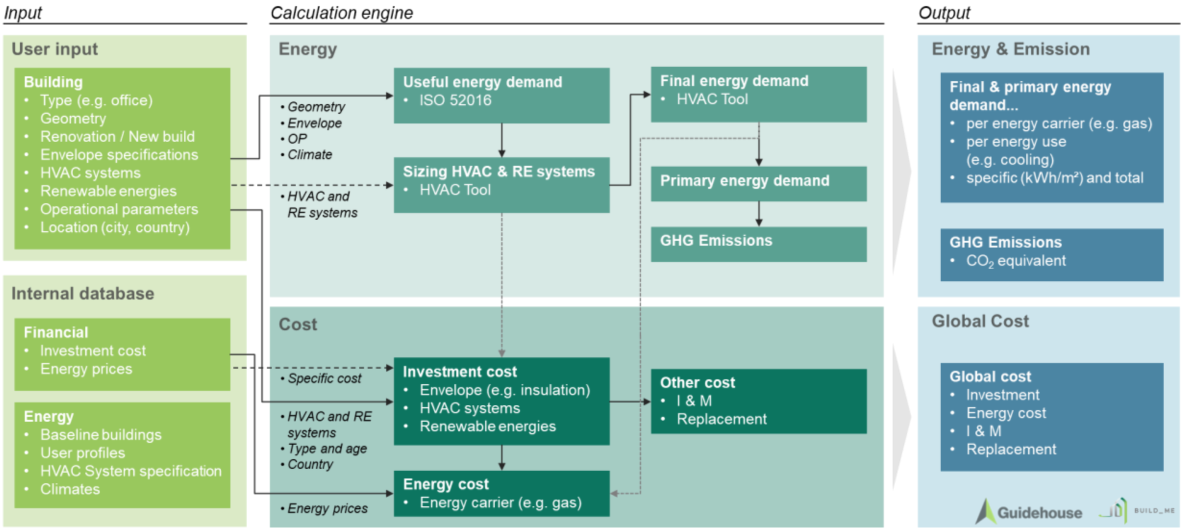


Figure 37. BEP tool calculation procedure

Relevant inputs for the energy performance of the building are the geometries of the envelope, the number of inhabitants, the assumed operational parameters and the HVAC systems to consider. The climate data is, as with the entire energy calculation, hourly and extracted from Meteonorm. Furthermore, the country's primary energy factors and a reality factor are mandatory input parameters. As consumption does not equal the calculated energy demand of a building (which is normal), the reality factor considers typical user behaviour to avoid high energy costs, including a conditioning factor that represents the average share of the building unit that is being conditioned (heated and cooled). Many low income households are living in cold parts of the country with limited financial means to heat up their houses. In those cases, all parts of the building are often not heated in the same way, and people do not heat their building during the entire heating period (e.g. to 20°C). Often, sleeping rooms, kitchens, bathrooms and other rooms are not heated or cooled. Therefore, a significant discrepancy between theoretical demand and real consumption can occur.

The subsequent cost calculation is based on system investment cost and energy prices—collected from local country experts—and assumptions for price increases, the country's inflation rate and the country's interest rate. The first step of the energy calculation is determining the useful energy demand, which depends on the envelope of the building, internal heat gains and operational parameters and the climate conditions. This step is calculated according to the international standard for building calculation norm, International Organization for Standardization (ISO) 52016. Consequently, the final energy demand is determined based on the defined HVAC system. The systems' dimensioning is calculated by the tool, considering the useful energy demand and the building's size. The reality factor considers that non- or partly refurbished buildings often have less real energy consumption than calculated by the ISO norm, since they adapt their heating and cooling behaviour.

3.2 Reference climate

3.2.1 Egypt's climate

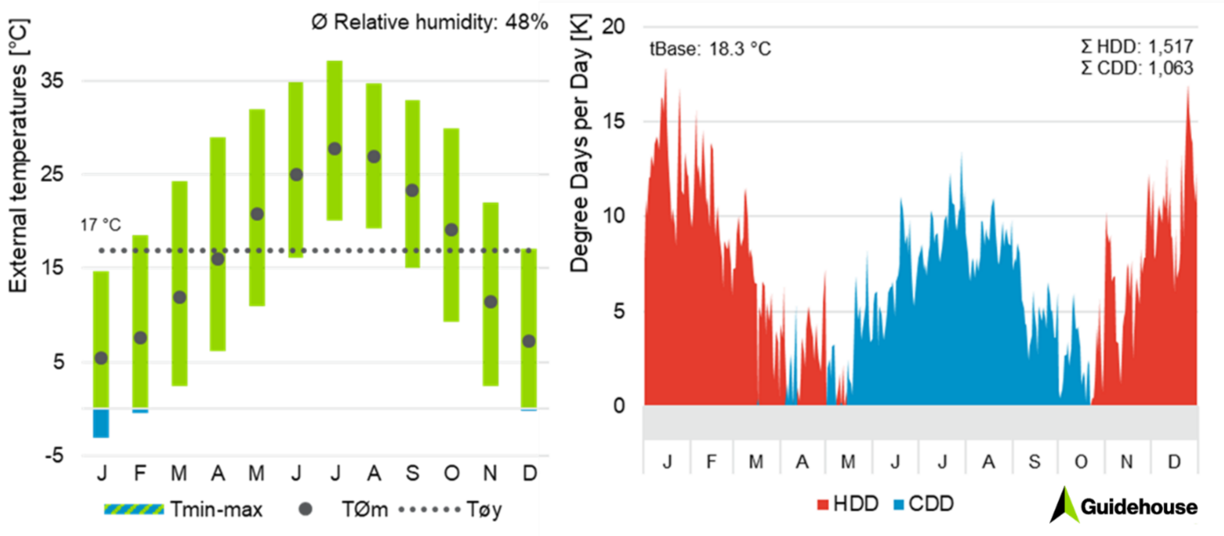


Figure 38. Reference climate: Cairo (Source: Guidehouse, based on Meteonorm data)

Temperatures in Cairo historically range from above 5°C to about 40°C with a mean temperature of about 22°C. Also, high cooling degree days, more than 1,800 days compared to only 290 heating degree days, indicate high cooling loads and low need for heating. The average relative humidity of 56% implies dry climate.

3.2.2 Jordan's climate

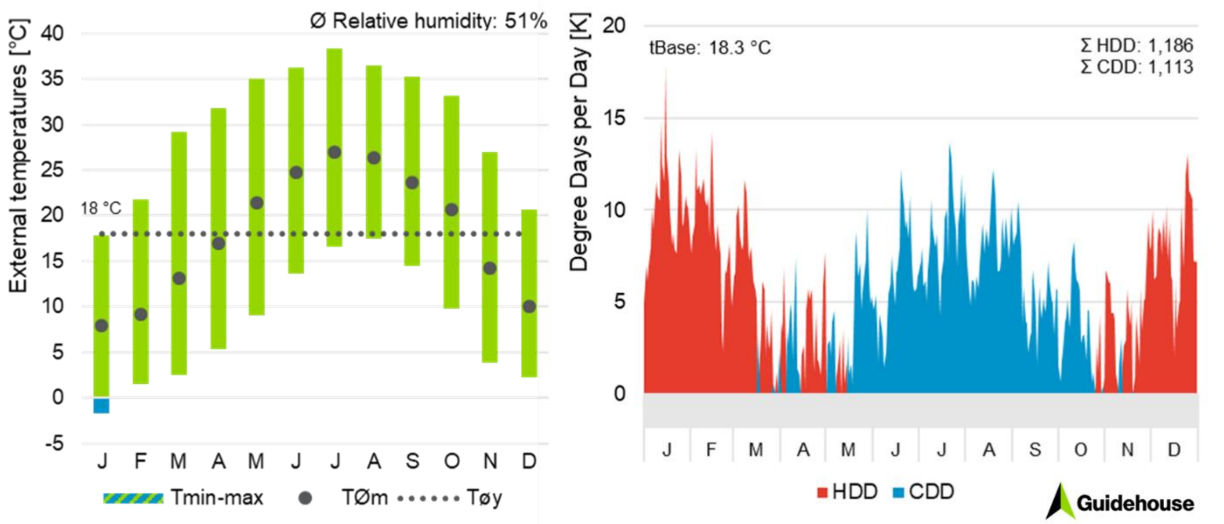


Figure 39. Reference climate: Amman (Source: Guidehouse, based on Meteonorm data)

Temperatures in Amman historically range from about 0°C to about 40”C with a mean temperature of about 18°C. Similar cooling degree days and heating degree days of about 1,100 degree days indicate moderate cooling and heating loads. The average relative humidity of 51% implies dry climate.

3.2.3 Lebanon’s climate

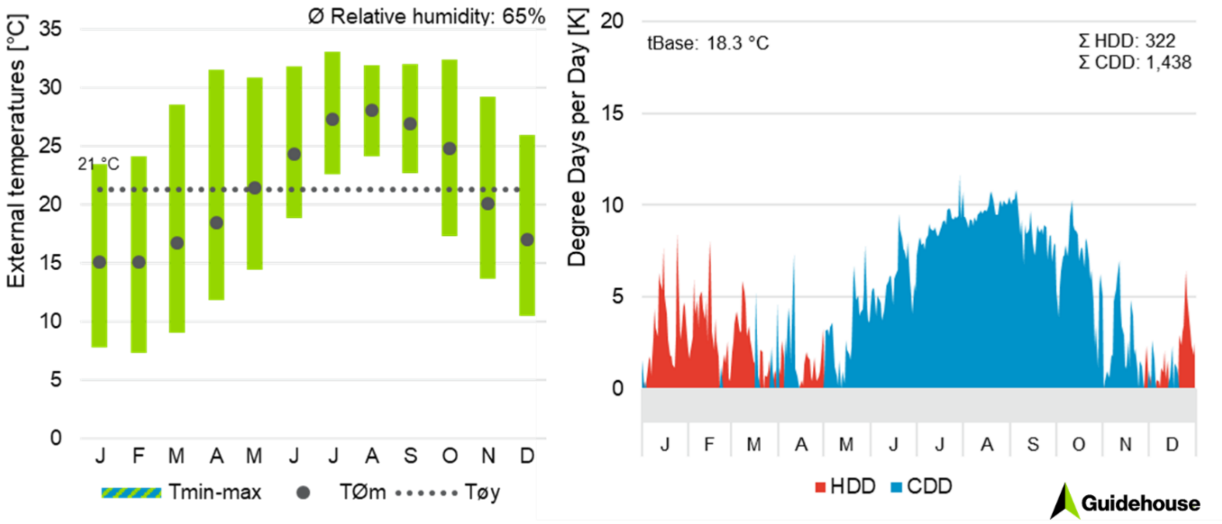


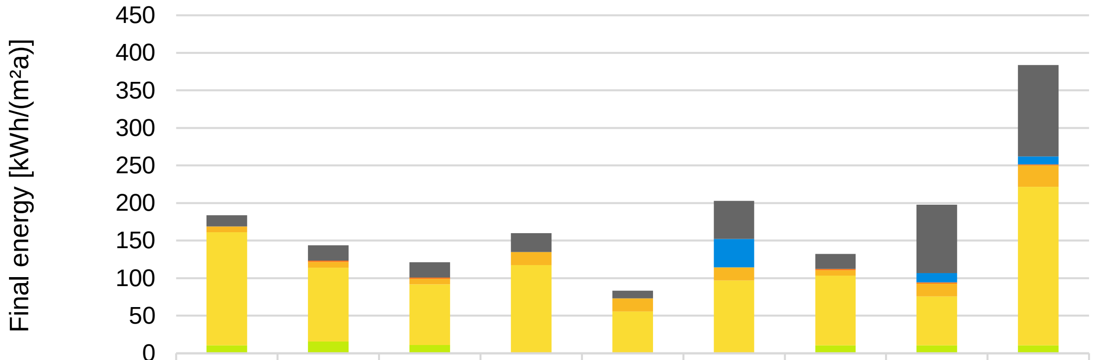
Figure 40. Reference climate: Beirut (Source: Guidehouse, based on Meteonorm data)

Temperatures in Beirut historically range from above 5°C to about 35°C with a mean temperature of about 21°C. Compared to only 320 heating degree days, the country’s 1,400 cooling degree days indicate high cooling loads and low need for heating. With dry summers and rainy winters, the average relative humidity is about 65%.

3.3 Energy benchmarks: Egypt

3.3.1 Final energy demand of reference buildings

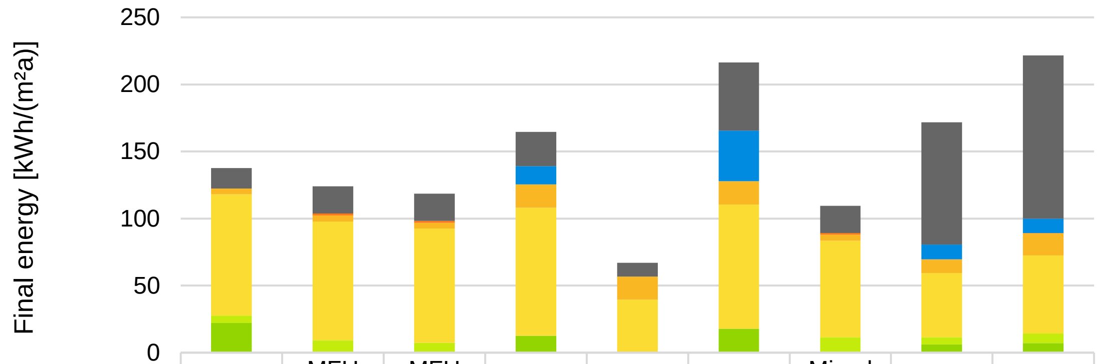
Among the energy demands of different reference buildings in the existing building stock, as shown in Figure 41, hotels are considered the most energy consuming. Hospitals and retail buildings have the second highest energy demand. Space cooling and other electricity applications are the main sources for the high energy demand among all cases. The difference between the highest and the second highest energy demand is approximately 187 kWh/(m²a).



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Mixed use	Hospital	Hotel
Other electricity	15	20	20	25	10	51	20	91	122
Ventilation	0	0	0	0	0	38	0	12	11
Auxiliary energy	0	2	2	0	0	0	1	1	1
Lighting	7	7	7	17	17	17	7	17	28
Space cooling	151	98	81	117	56	97	93	65	211
DHW	11	16	11	0	0	0	11	11	11
Space heating	0	0	0	0	0	0	0	0	0

Figure 41. Final energy demand of reference buildings in the existing building stock in Egypt

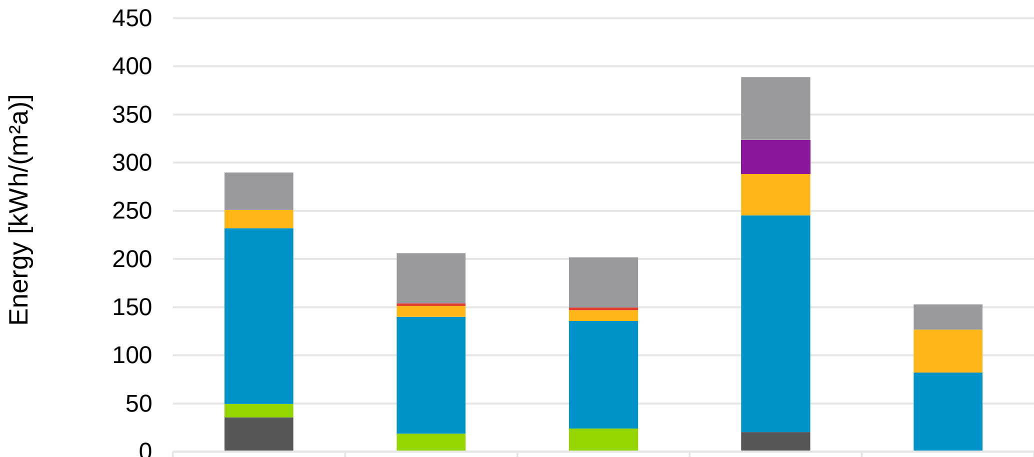
For new buildings, as shown in Figure 42, hotels have the highest energy demand. For most reference buildings, cooling loads have the highest energy consumption. The high electricity demand of hotels can especially be explained by the fact that they also include several other high energy consuming uses. Retail buildings have the highest energy consumption for ventilation purposes compared to other categories. The difference between the highest energy demand and the lowest energy demand is approximately 84 kWh/(m²a).



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Mixed use	Hospital	Hotel
Other electricity	15	20	20	25	10	51	20	91	122
Ventilation	0	0	0	14	0	38	0	11	11
Auxiliary energy	0	2	1	0	0	0	1	0	0
Lighting	4	4	4	17	17	17	4	10	16
Space cooling	91	89	85	95	40	93	72	48	58
DHW	5	9	7	0	0	0	11	5	7
Space heating	22	0	0	13	0	18	0	6	7

Figure 42 Final energy demand of reference for new buildings in Egypt

For improved baseline reference buildings, as shown in Figure 43, the highest energy demand is for office buildings, while SFHs are ranked as second. Space cooling is the highest energy consumer among all the included reference buildings. Household electricity is ranked second among all reference buildings in terms of energy demand.

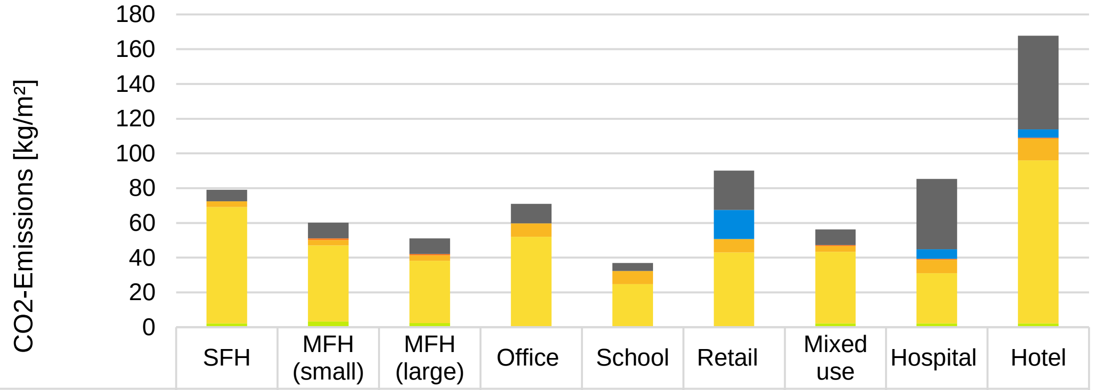


	SFH	MFH (large)	MFH (small)	Office	School
Household electricity	39	52	52	65	26
Ventilation	0	0	0	35	0
Auxiliary energy	0	3	3	0	0
Lighting	19	11	11	43	44
Space cooling	182	121	112	225	82
DHW	14	19	24	0	0
Space heating	36	0	0	20	0

Figure 43. Final energy demand of improved baseline for buildings

3.3.2 CO_2 emissions of reference buildings

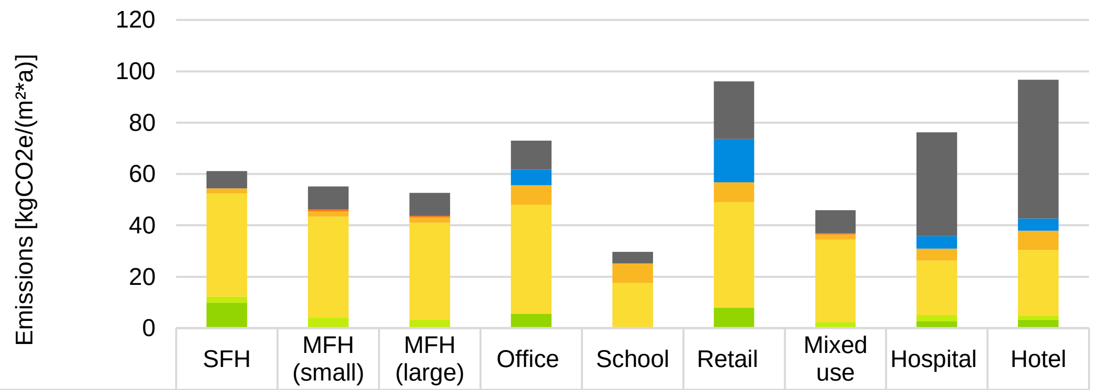
Figure 44 shows carbon emissions of reference for existing buildings in Egypt. Hotels have the highest carbon emissions while schools have the lowest. The difference between both is 131 kgCO2e/(m²*a). Space cooling is the highest generator of carbon emissions, while ventilation is the lowest.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Mixed use	Hospital	Hotel
Other electricity	7	9	9	11	5	23	9	41	54
Ventilation	0	0	0	0	0	17	0	5	5
Auxiliary energy	0	1	1	0	0	0	1	1	1
Lighting	3	3	3	8	8	8	3	8	13
Space cooling	67	44	36	52	25	43	41	29	94
DHW	2	3	2	0	0	0	2	2	2
Space heating	0	0	0	0	0	0	0	0	0

Figure 44 Carbon emissions of reference for existing buildings in Egypt

Carbon emissions of reference for new buildings in Egypt are shown in Figure 45. Hotels and retail buildings have the highest generation of carbon emissions while schools have the lowest generation of carbon emissions. The difference between them is 65 kgCO_2e/(m²a). Among all cases, space cooling and other electricity uses have the highest contribution to carbon emissions while auxiliary energy has the least contribution.



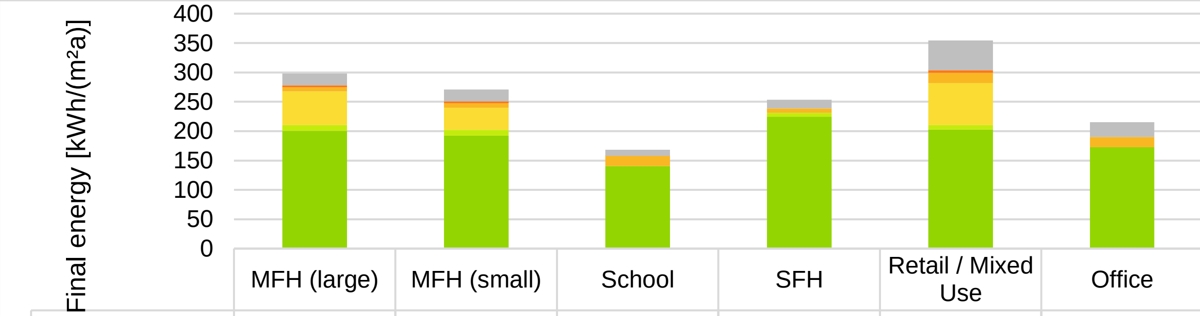
	SFH	MFH (small)	MFH (large)	Office	School	Retail	Mixed use	Hospital	Hotel
Other electricity	7	9	9	11	5	23	9	41	54
Ventilation	0	0	0	6	0	17	0	5	5
Auxiliary energy	0	1	1	0	0	0	1	0	0
Lighting	2	2	2	8	8	8	2	4	7
Space cooling	40	39	38	42	18	41	32	21	26
DHW	2	4	3	0	0	0	2	2	1
Space heating	10	0	0	6	0	8	0	3	3

Figure 45. Carbon emissions of reference for new buildings in Egypt

3.4 Energy benchmarks Jordan

3.4.1 Final energy demand of reference buildings

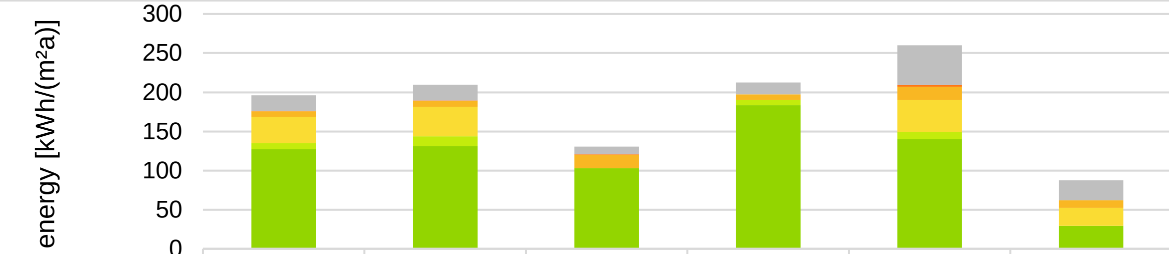
According to an analysis of the reference for old buildings in east Amman, shown in Figure 46, retail and mixed-use buildings have the highest energy demand. Large MFHs and small MFHs are ranked as second and third, respectively, in terms of energy demand. Space heating is the highest energy consumer among all the reference buildings. The difference between the highest and the lowest energy demand is approximately 186.4 kWh/(m^2a).



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	20,3	20,3	10,1	15,2	50,7	25,3
Ventilation	-	-	-	-	-	-
Auxiliary energy	3,2	3,2	0,1	-	4,6	-
Lighting	7,6	7,6	17,3	7,3	17,3	17,3
Space cooling	56,9	37,9	-	-	71,8	-
DHW	10,2	9,6	-	6,6	7,3	-
Space heating	200,3	192,5	140,7	224,6	202,9	172,6

Figure 46 Final energy of reference for old buildings in east Amman

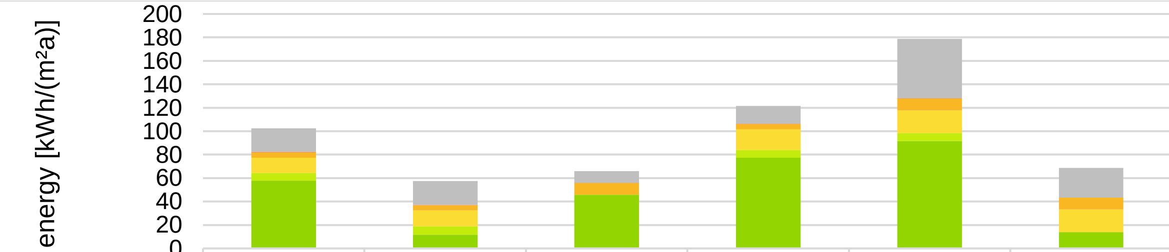
According to the reference buildings in the existing stock of east Amman, shown in Figure 47, retail and mixed-use buildings have the highest energy demand and office buildings the lowest energy demand among all cases. Heating is the leading energy use among all reference buildings. The difference in final energy demand between the highest energy demand and the lowest energy demand is approximately 172.3 kWh/(m^2a).



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	20,3	20,3	10,1	15,2	50,7	25,3
Ventilation	-	-	-	-	-	-
Auxiliary energy	0,4	0,8	0,1	-	2,0	-
Lighting	7,3	7,3	17,3	7,6	17,3	10,0
Space cooling	32,9	37,5	-	-	40,5	22,9
DHW	7,9	12,7	-	6,6	8,8	-
Space heating	127,4	131,2	103,1	183,3	140,5	29,3

Figure 47. Final energy of reference for existing buildings in east Amman

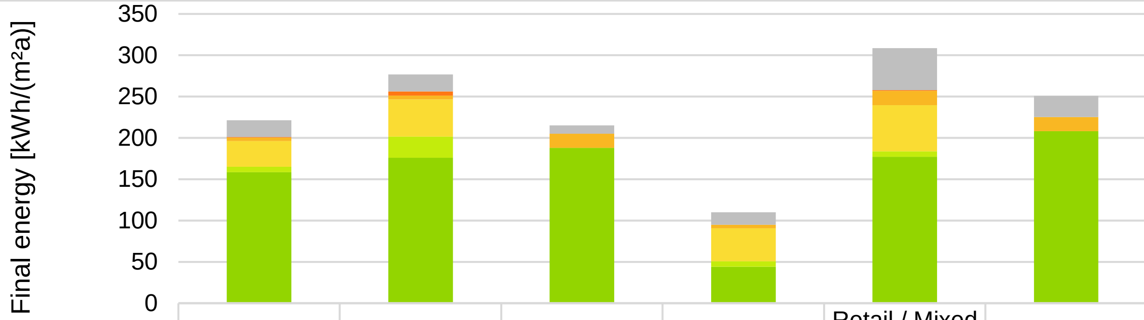
According to Figure 48, which shows reference cases of newly constructed buildings in east Amman, retail and mixed-use buildings have the highest energy demand while MFHs have the lowest energy demand. Auxiliary energy has the lowest contribution to energy demand while space heating has the highest for most cases. The final energy demand difference between the highest and the lowest energy consumer is approximately 121.4 kWh/(m^{2}a).



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	20,3	20,3	10,1	15,2	50,7	25,3
Ventilation	-	-	-	-	-	-
Auxiliary energy	0,4	0,4	0,0	0,3	0,4	-
Lighting	4,4	4,4	10,0	4,4	10,0	10,0
Space cooling	13,1	13,6	-	17,6	19,2	19,4
DHW	6,6	7,0	-	6,6	6,9	-
Space heating	57,8	11,7	45,7	77,5	91,6	14,0

Figure 48. Final energy of reference for newly constructed buildings in east Amman

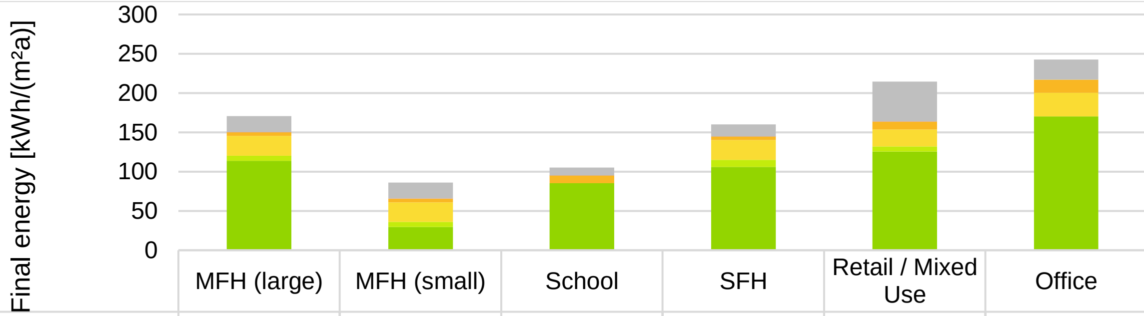
Based on Figure 49 showing the energy demand of reference for old buildings in west Amman, retail/mixed use buildings have the highest energy demand while single family houses have the lowest. Space heating is the highest in terms of contribution to energy demands among all reference cases while ventilation has no contribution. The difference between the highest and the lowest energy demands is approximately 198.4 kWh/(m^{2}a).



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	20,3	20,3	10,1	15,2	50,7	25,3
Ventilation	-	-	-	-	-	-
Auxiliary energy	0,6	5,3	-	-	0,8	-
Lighting	4,4	4,4	17,3	4,4	17,3	17,3
Space cooling	31,2	45,0	-	39,9	56,1	-
DHW	6,6	25,9	-	6,6	6,6	-
Space heating	158,4	175,8	187,9	44,1	177,1	208,0

Figure 49 Final energy of reference for old buildings in west Amman

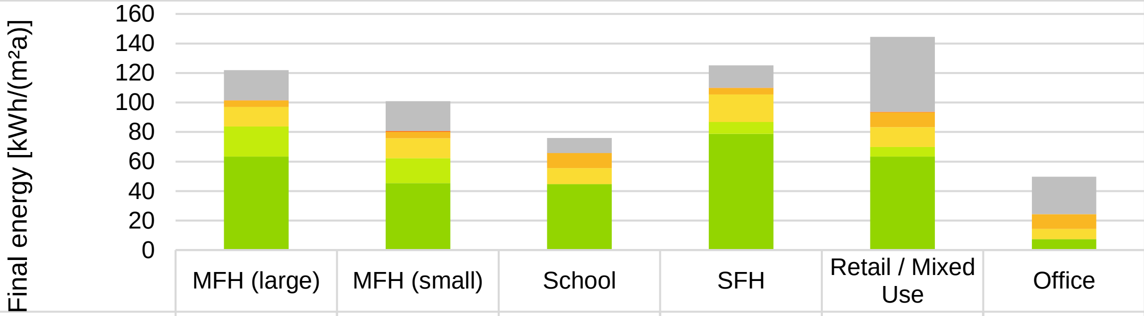
Figure 50 shows the reference energy demand of existing buildings in west Amman, where office buildings have the highest energy demand while MFHs have the lowest. Space heating applications are the highest contributor to energy demand while auxiliary energy has the lowest energy demand. The difference between the highest and the lowest energy demands is approximately 156.3 kWh/(m^2a).



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	20,3	20,3	10,1	15,2	50,7	25,3
Ventilation	-	-	-	-	-	-
Auxiliary energy	0,4	0,5	0,0	0,3	0,4	-
Lighting	4,4	4,4	10,0	4,4	10,0	16,7
Space cooling	25,2	24,7	-	25,3	21,3	29,9
DHW	6,6	6,6	-	8,8	6,6	-
Space heating	113,7	29,6	85,2	106,0	125,5	170,5

Figure 50 Final energy of reference for existing buildings in west Amman

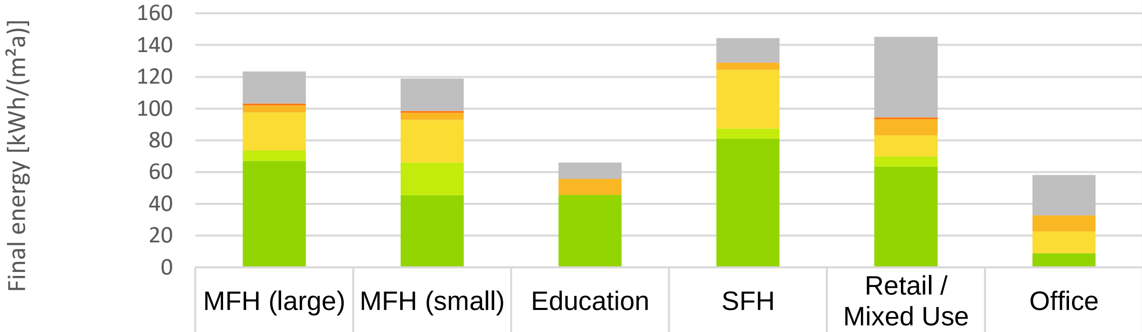
The reference values for newly constructed buildings in west Amman are shown in Figure 51. Retail and mixed-use buildings have the highest energy demand while office buildings have the lowest. In most cases, space heating is the main contributor to the energy demand while auxiliary energy is considered the lowest contributor. The approximate difference between highest and lowest energy demand is 94.8 kWh/(m^2a).



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	20,3	20,3	10,1	15,2	50,7	25,3
Ventilation	-	-	-	-	-	-
Auxiliary energy	0,3	0,5	0,0	0,3	0,4	-
Lighting	4,4	4,4	10,0	4,4	10,0	10,0
Space cooling	13,2	13,5	10,8	18,5	13,4	6,8
DHW	20,2	16,7	-	8,1	6,6	-
Space heating	63,5	45,5	44,8	78,8	63,3	7,5

Figure 51 Final energy of reference for newly constructed buildings in west Amman

Figure 52 shows the reference values for newly constructed buildings in Amman. Office buildings have the lowest energy demand while retail and mixed-use buildings and SFHs have the highest. Space heating is the highest contributor to energy demand while auxiliary energy is the lowest, and ventilation does not have an effect. The difference between the highest and the lowest energy demands is 87.1 kWh/(m2a).

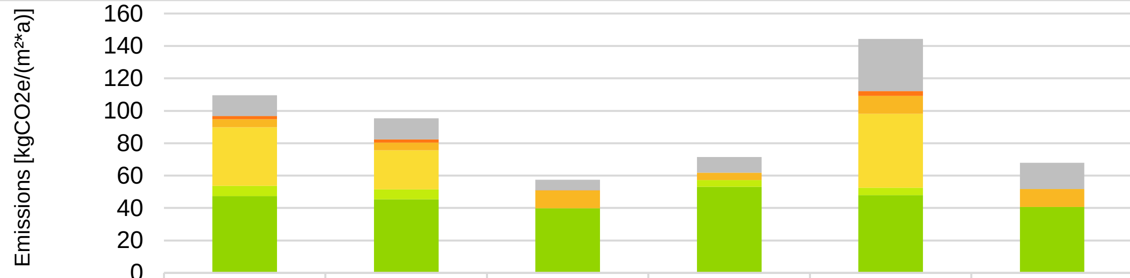


	MFH (large)	MFH (small)	Education	SFH	Retail / Mixed Use	Office
Other electricity	20,3	20,3	10,1	15,2	50,7	25,3
Ventilation	-	-	-	-	-	-
Auxiliary energy	1,2	1,3	0,0	0,3	1,1	-
Lighting	4,4	4,4	10,0	4,4	10,0	10,0
Space cooling	23,9	27,0	-	36,9	13,4	13,8
DHW	6,6	20,5	-	6,6	6,6	-
Space heating	67,1	45,5	45,7	80,9	63,3	8,9

Figure 52 final energy of reference for newly constructed buildings generally in Jordan

3.4.2 CO_2 emissions of reference buildings

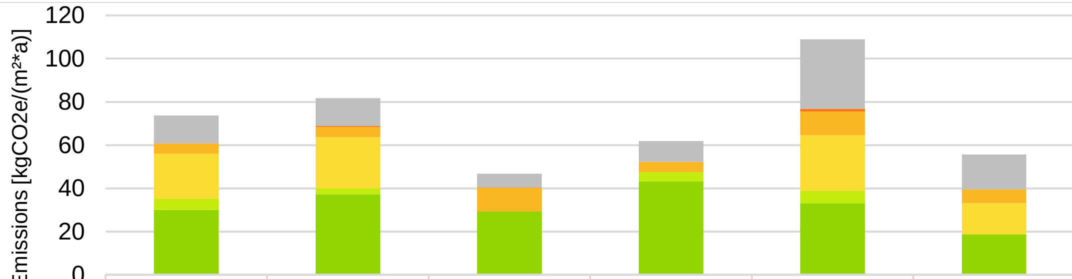
Figure 53 shows carbon emissions of reference for old buildings in east Amman. Retail/Mixed use buildings have the highest carbon emission while schools have the lowest. The difference between both is 88 kgCO2e/(m²*a).. For all reference cases, space heating contributes most to the GHG-emissions, while ventilation doesn't contribute at all.



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	13	13	6	10	32	16
Ventilation	0	0	0	0	0	0
Auxiliary energy	2	2	0	0	3	0
Lighting	5	5	11	5	11	11
Space cooling	36	24	0	0	46	0
DHW	7	6	0	4	5	0
Space heating	47	45	40	53	48	41

Figure 53. Carbon emissions of reference for old buildings in east Amman

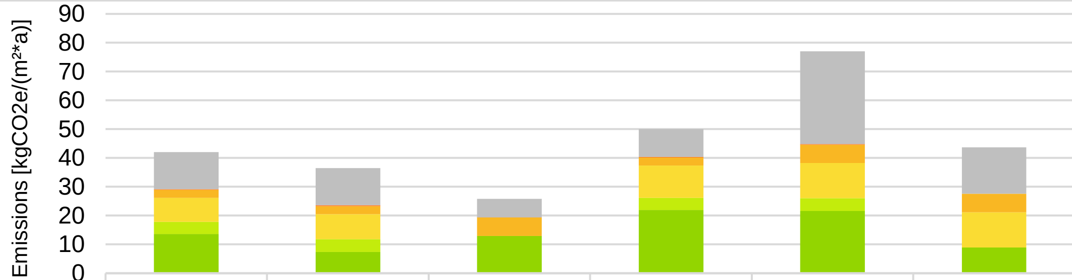
Carbon emissions of reference for existing buildings in east Amman are shown in Figure 54. For all cases, space heating contributes most to the carbon emissions. Auxiliary energy has the lowest contribution, and ventilation does not contribute at all. Retail and mixed-use buildings have the highest carbon emissions while schools have the lowest. The difference between them is 63 kgCO_2e/(m²a).



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	13	13	6	10	32	16
Ventilation	0	0	0	0	0	0
Auxiliary energy	0	1	0	0	1	0
Lighting	5	5	11	5	11	6
Space cooling	21	24	0	0	26	15
DHW	5	3	0	4	6	0
Space heating	30	37	29	43	33	19

Figure 54. Carbon emissions of reference for existing buildings in east Amman

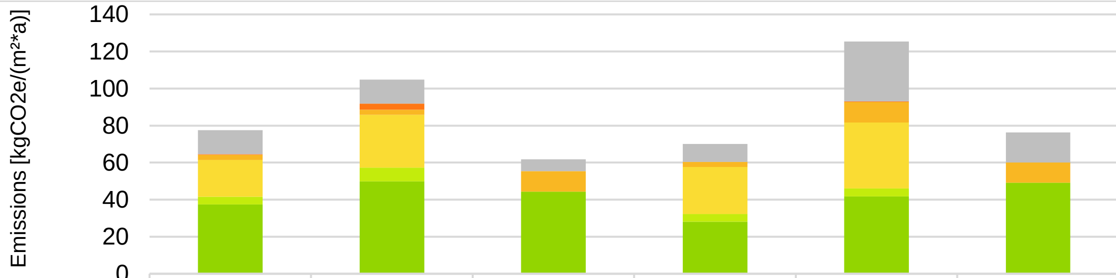
Figure 55 shows carbon emissions of reference for newly constructed buildings in east Amman. The lowest relative carbon emissions have school buildings while the highest have retail/mixed use buildings. The difference between them is 51 kgCO2e/(m²*a). Space heating and other electricity uses have the highest contribution to carbon emissions, while ventilation has no contribution at all.



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	13	13	6	10	32	16
Ventilation	0	0	0	0	0	0
Auxiliary energy	0	0	0	0	0	0
Lighting	3	3	6	3	6	6
Space cooling	8	9	0	11	12	12
DHW	4	4	0	4	4	0
Space heating	14	7	13	22	22	9

Figure 55. Carbon emissions of reference for newly constructed buildings in east Amman

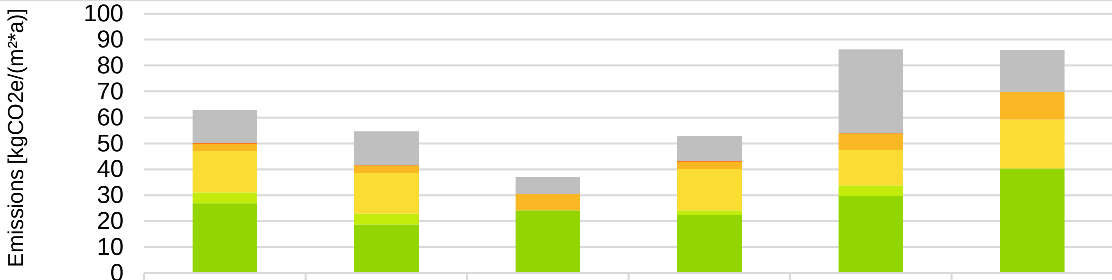
Carbon emissions of reference for old buildings in west Amman are shown in Figure 56. Retail and mixed-use buildings have the highest carbon emissions, while schools have the lowest. The difference between both is 65 $kgCO_2e/(m^2a)$. Space heating has the highest contribution to carbon emissions while auxiliary energy has the lowest.



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	13	13	6	10	32	16
Ventilation	0	0	0	0	0	0
Auxiliary energy	0	3	0	0	1	0
Lighting	3	3	11	3	11	11
Space cooling	20	29	0	25	36	0
DHW	4	7	0	4	4	0
Space heating	37	50	44	28	42	49

Figure 56. Carbon emissions of reference for old buildings in west Amman

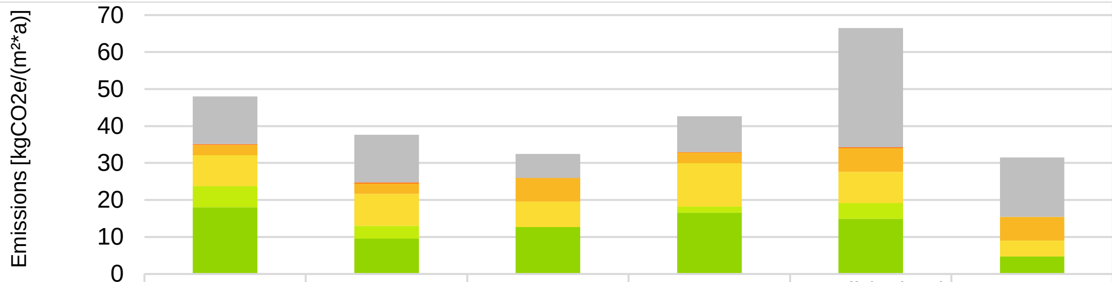
Figure 57 shows carbon emissions of reference for existing buildings in west Amman. Both offices and retail and mixed-use buildings have the highest carbon emissions while schools have the lowest emissions. The difference between the highest and the lowest is 50 $kgCO_2e/(m^2a)$. Space heating, space cooling and other electricity uses have the highest contribution to carbon emissions. Both auxiliary electricity and other electricity have no contribution.



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	13	13	6	10	32	16
Ventilation	0	0	0	0	0	0
Auxiliary energy	0	0	0	0	0	0
Lighting	3	3	6	3	6	11
Space cooling	16	16	0	16	14	19
DHW	4	4	0	2	4	0
Space heating	27	19	24	22	30	40

Figure 57. Carbon emissions of reference for existing buildings in west Amman

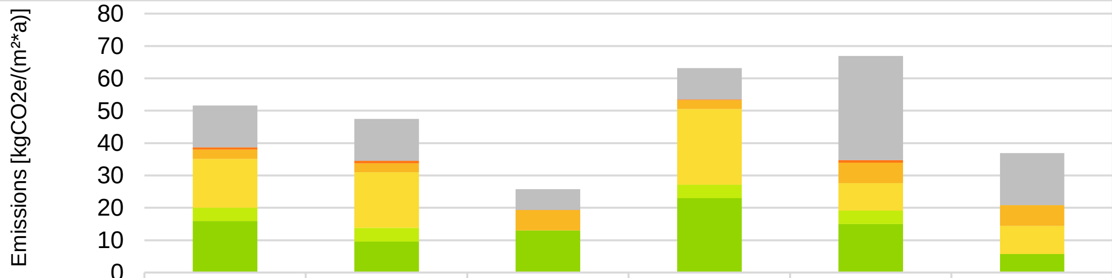
Carbon emissions of reference for newly constructed buildings in west Amman are shown in Figure 58. Retail and mixed-use buildings generate the highest carbon emissions while offices generate the lowest. For all cases, space heating and other electricity uses have the highest contribution to carbon emissions while ventilation and auxiliary energy have no emissions generation.



	MFH (large)	MFH (small)	School	SFH	Retail / Mixed Use	Office
Other electricity	13	13	6	10	32	16
Ventilation	0	0	0	0	0	0
Auxiliary energy	0	0	0	0	0	0
Lighting	3	3	6	3	6	6
Space cooling	8	9	7	12	8	4
DHW	6	4	0	2	4	0
Space heating	18	10	13	17	15	5

Figure 58. Carbon emissions of reference for newly constructed buildings in west Amman

Figure 59 shows carbon emissions of reference for newly constructed buildings in west Amman. Retail and mixed-use buildings and SFHs have the highest contribution to carbon emissions while educational facilities have the lowest contribution. For all cases, space heating and other electricity uses have the highest contribution to carbon emissions while educational facilities have the lowest contribution to carbon emissions.



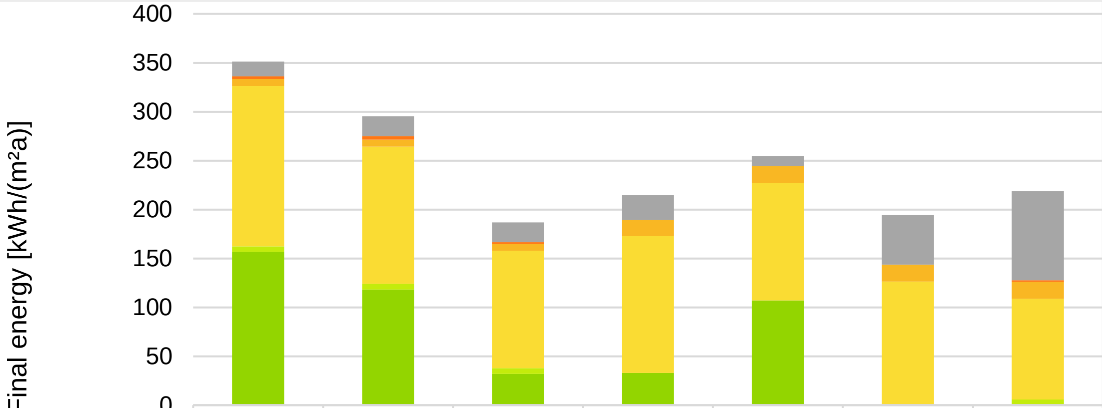
	MFH (large)	MFH (small)	Education	SFH	Retail / Mixed Use	Office
Other electricity	13	13	6	10	32	16
Ventilation	0	0	0	0	0	0
Auxiliary energy	1	1	0	0	1	0
Lighting	3	3	6	3	6	6
Space cooling	15	17	0	23	8	9
DHW	4	4	0	4	4	0
Space heating	16	10	13	23	15	6

Figure 59. Carbon emissions of reference for newly constructed buildings in Amman

3.5 Energy benchmarks Lebanon

3.5.1 Final energy demand of reference buildings

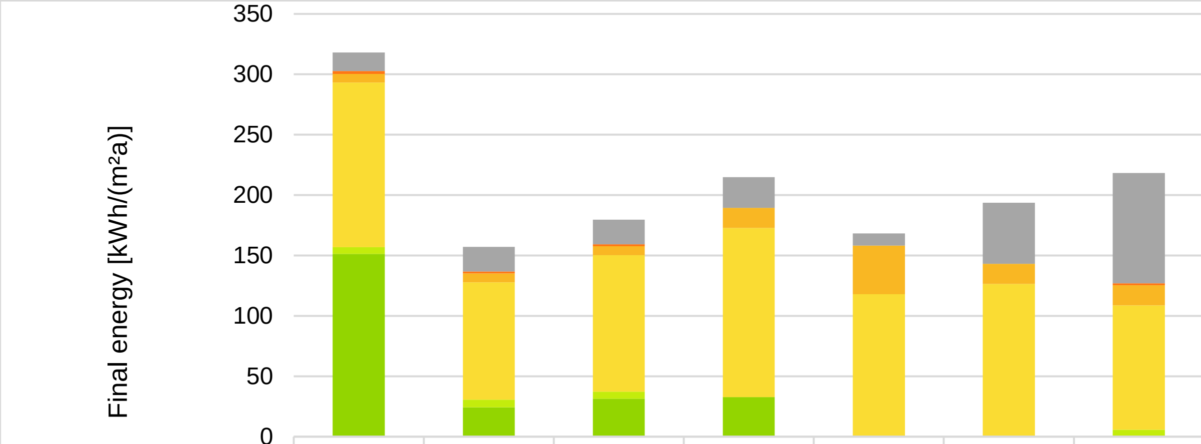
Figure 60 shows the energy demand of reference for existing buildings that were built before 1980 in a village. SFHs have the highest energy demand while large MFHs have the lowest. The difference in energy demand between the highest and the lowest cases is approximately 164.4 kWh/(m^{2}a). The highest contributor to the energy demand for all cases is space cooling while the lowest is auxiliary energy.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	15,2	20,3	20,3	25,3	10,1	50,7	91,2
Ventilation	-	-	-	-	-	-	-
Auxiliary energy	2,4	3,5	1,5	-	0,1	-	1,7
Lighting	7,3	7,3	7,3	16,7	17,3	17,3	17,3
Space cooling	164,0	140,3	120,1	139,9	120,2	126,3	102,9
DHW	5,7	5,7	5,7	-	-	-	5,7
Total space heating	156,6	118,2	31,9	32,7	107,0	-	-

Figure 60 Final energy demand of reference for existing buildings before 1980 in a village

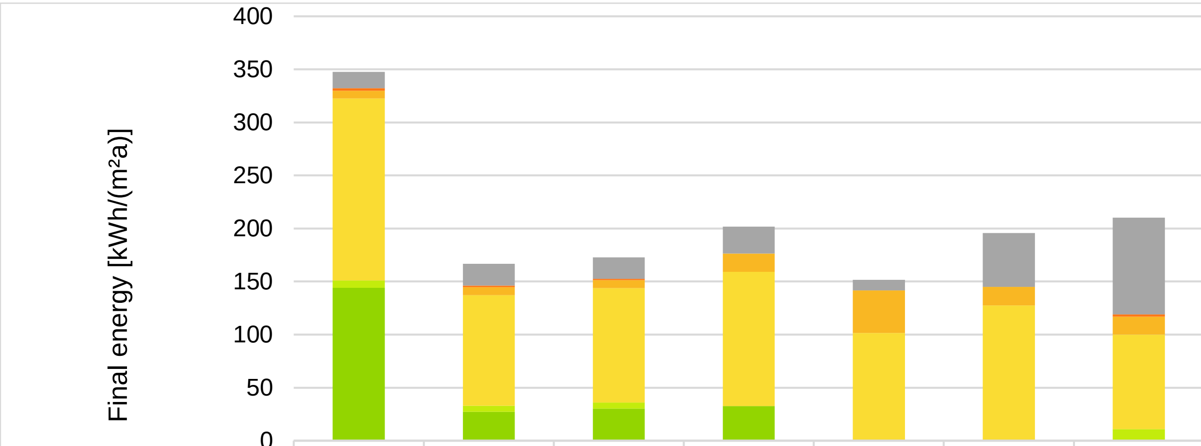
Final energy of reference for existing buildings that were built before 1980 in a town is shown in Figure 61. SFHs have the highest energy demand while small MFHs have the lowest energy demand. The difference between the highest and the lowest energy demand is approximately 160.8 kWh/(m^{2}a). Space cooling is the highest contributor to energy demand for all cases while auxiliary energy is the lowest.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	15,2	20,3	20,3	25,3	10,1	50,7	91,2
Ventilation	-	-	-	-	-	-	-
Auxiliary energy	2,4	1,7	1,8	-	-	-	1,7
Lighting	7,3	7,3	7,3	16,7	40,2	16,7	16,7
Space cooling	136,1	97,3	113,0	139,9	118,0	126,3	102,9
DHW	5,7	6,3	5,7	-	-	-	5,7
Total space heating	151,3	24,3	31,5	32,7	-	-	-

Figure 61 Final energy demand of reference for existing buildings before 1980 in a town

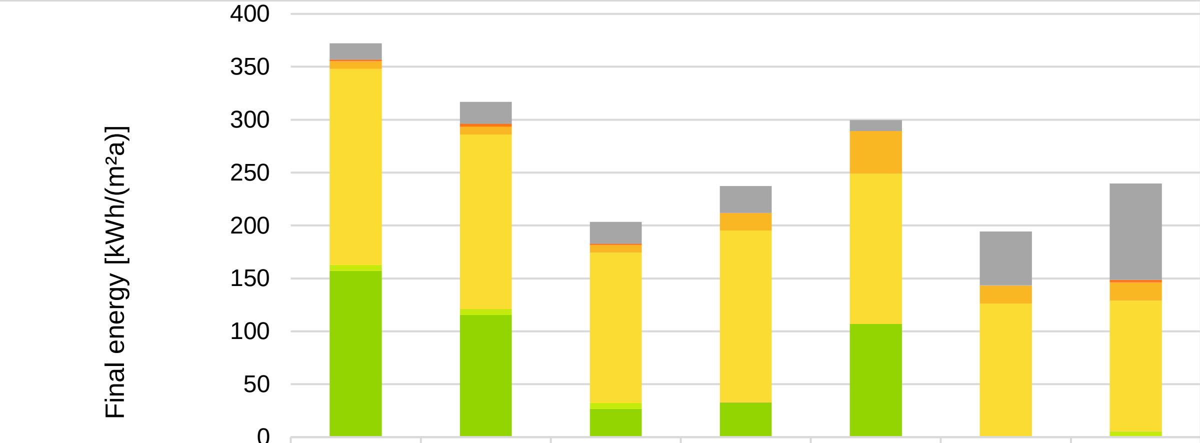
Figure 62 shows the energy demand of reference for existing buildings that were built before 1980 in a city. Space cooling has the highest contribution to energy demand while auxiliary energy has the lowest. SFHs have the highest energy demand while schools have the lowest. The difference between both is approximately 196 kWh/(m^{2}a).



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	15,2	20,3	20,3	25,3	10,1	50,7	91,2
Ventilation	-	-	-	-	-	-	-
Auxiliary energy	2,4	1,8	1,3	-	-	-	2,3
Lighting	7,3	7,3	7,3	17,3	40,2	17,3	16,7
Space cooling	171,7	104,4	107,8	126,6	101,5	127,6	89,1
DHW	6,9	5,7	5,7	-	-	-	11,0
Total space heating	144,0	27,1	30,3	32,5	-	-	-

Figure 62 Final energy demand of reference for existing buildings before 1980 in a city

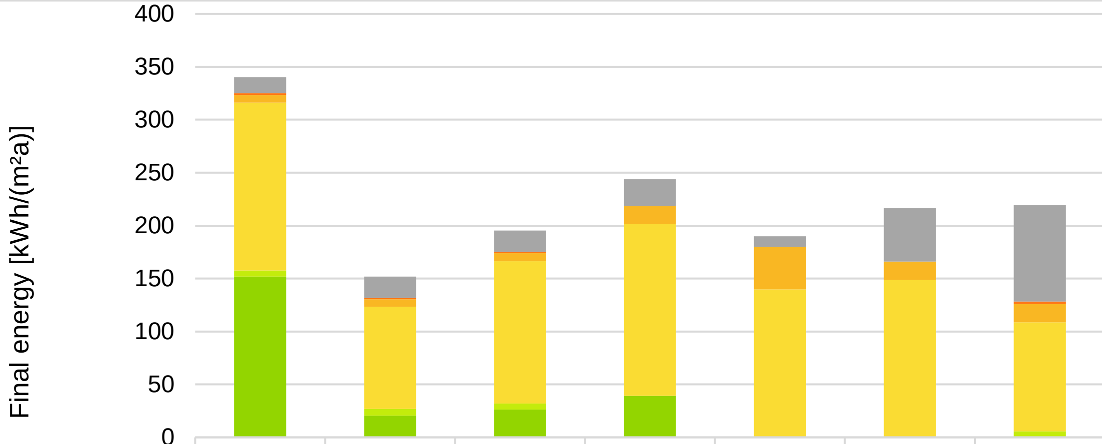
Primary and final energy demand of reference for existing buildings that were built from 1980-2015 in a village is shown in Figure 63. SFHs have the highest energy demand while retail buildings have the lowest. The difference between both is approximately 178 kWh/(m²a). Space cooling is the highest contributor to energy demand while auxiliary energy is the lowest.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	15,2	20,3	20,3	25,3	10,1	50,7	91,2
Ventilation	-	-	-	-	-	-	-
Auxiliary energy	1,7	3,3	1,5	-	0,1	-	2,3
Lighting	7,3	7,3	7,3	16,7	40,2	17,3	17,3
Space cooling	185,2	164,6	142,0	162,5	142,1	126,3	123,2
DHW	5,7	5,7	5,7	-	-	-	5,7
Total space heating	157,2	115,6	26,7	32,7	107,0	-	-

Figure 63 Final energy demand of reference for existing buildings from 1980-2015 in a village

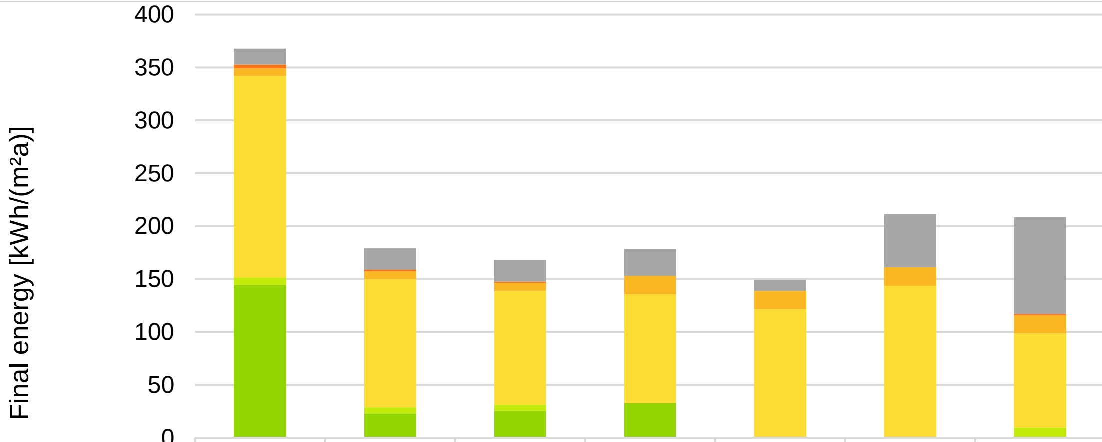
Figure 64 shows final energy demand of reference for existing buildings that were built from 1980-2015 in a town. SFHs have the highest energy demand while small MFHs have the lowest. The difference in energy demand between both is approximately 188.5 kWh/(m²a). Space cooling has the highest contribution in energy consumption for all cases.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	15,2	20,3	20,3	25,3	10,1	50,7	91,2
Ventilation	-	-	-	-	-	-	-
Auxiliary energy	1,7	1,3	1,4	-	-	-	2,3
Lighting	7,3	7,3	7,3	16,7	40,2	17,3	17,3
Space cooling	158,6	96,2	134,4	162,5	139,8	148,6	102,9
DHW	5,7	6,3	5,7	-	-	-	5,7
Total space heating	151,9	20,5	26,4	39,3	-	-	-

Figure 64 Final energy demand of reference for existing buildings from 1980-2015 in a town

Final energy demand of reference for existing buildings that were built from 1980-2015 in a city are shown in Figure 65. SFHs have the highest energy demand while schools have the lowest. The difference between both is 218.8 kWh/(m^{2}a). Space cooling has the highest impact in energy demand while ventilation has none.

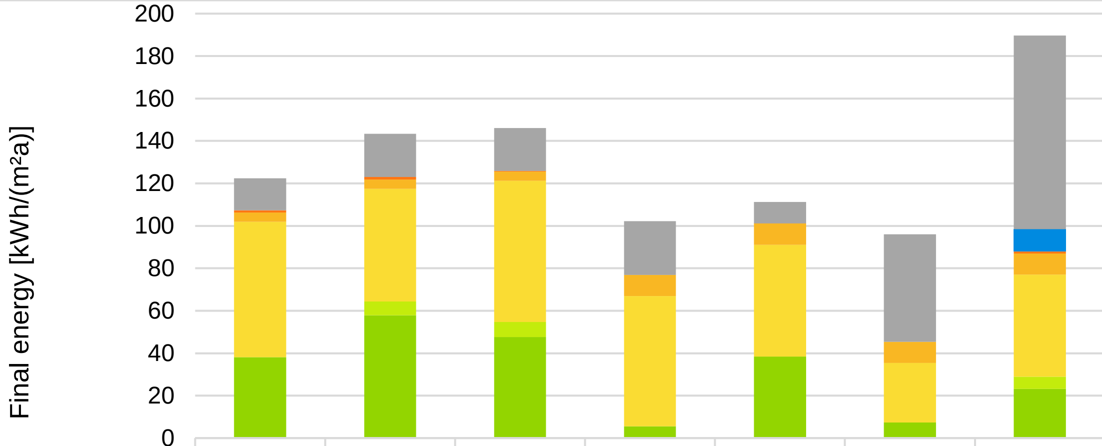


	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	15,2	20,3	20,3	25,3	10,1	50,7	91,2
Ventilation	-	-	-	-	-	-	-
Auxiliary energy	3,5	1,3	1,3	-	-	-	1,7
Lighting	7,3	7,3	7,3	17,3	17,3	17,3	16,7
Space cooling	190,6	121,3	107,8	102,9	121,6	143,8	89,0
DHW	6,9	5,7	5,7	-	-	-	9,7
Total space heating	144,3	23,0	25,4	32,7	-	-	-

Figure 65 Final energy demand of reference for existing buildings from 1980-2015 in a city

Figure 66 shows Final energy demand of reference for new buildings that were built after 2015 in a village. Hospitals have the highest energy demand while retail buildings have the lowest.

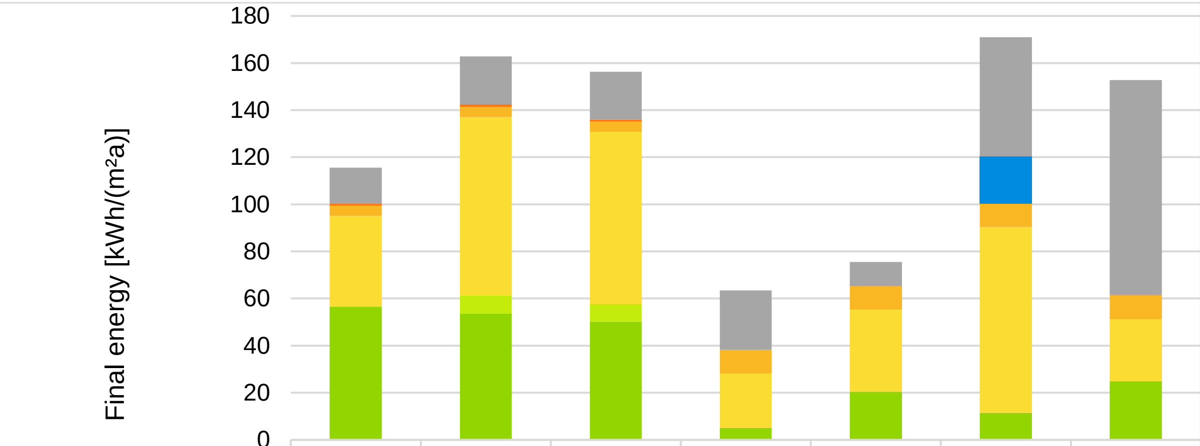
The difference between both is 93.5 kWh/(m²a). Other electricity uses have the highest portion of energy demand in hospitals and retail while space cooling has the highest impact for the other reference buildings.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	15,2	20,3	20,3	25,3	10,1	50,7	91,2
Ventilation	-	-	-	-	-	-	10,6
Auxiliary energy	1,0	1,3	0,3	-	0,0	-	0,8
Lighting	4,4	4,4	4,4	10,0	10,0	10,0	10,0
Space cooling	63,8	53,0	66,5	61,3	52,7	28,0	48,1
DHW	-	6,6	7,1	-	-	-	5,7
Total space heating	38,1	57,8	47,6	5,6	38,4	7,3	23,1

Figure 66 Final energy demand of reference for new buildings after 2015 in a village

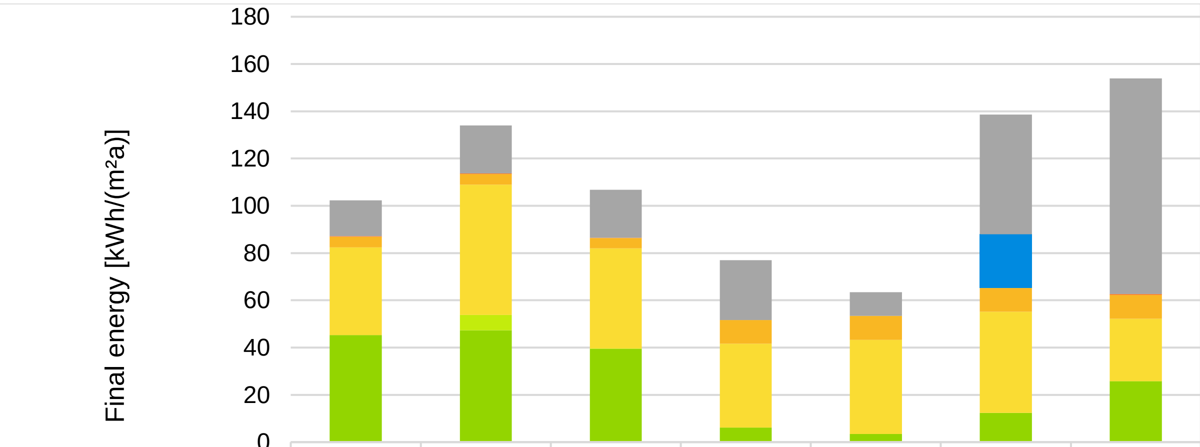
Final energy demand of reference for new buildings that were built after 2015 in a town is shown in Figure 67. Retail has the highest energy demand while offices have the lowest. The difference between both is 107.5 kWh/(m²a). Other electricity uses have the highest portion of energy demand in hospitals and retail while space cooling has the highest impact for the other reference buildings. Energy demand for mechanical ventilation is only relevant in retail buildings.



	SFH	MFH (small)	MFH (large)	Office	Education	Retail	Hospital
Other electricity	15,2	20,3	20,3	25,3	10,1	50,7	91,2
Ventilation	-	-	-	-	-	19,9	-
Auxiliary energy	1,0	1,1	0,9	-	0,0	-	0,2
Lighting	4,4	4,4	4,4	10,0	10,0	10,0	10,0
Space cooling	38,6	75,6	73,1	23,1	34,9	78,9	26,4
DHW	-	7,7	7,5	-	-	-	0,0
Total space heating	56,5	53,6	50,2	5,0	20,4	11,4	24,9

Figure 67 Final energy demand of reference for new buildings after 2015 in a town

Figure 68 shows Final energy demand of reference for new buildings that were built after 2015 in a city. Hospitals have the highest energy demand, and educational facilities have the lowest. The difference between both is 90.4 kWh/(m^{2}a). Energy demand for mechanical ventilation is only relevant in retail buildings. Other electricity uses have the highest portion of energy demand in hospitals and retail buildings while space cooling has the highest impact for the other reference buildings.

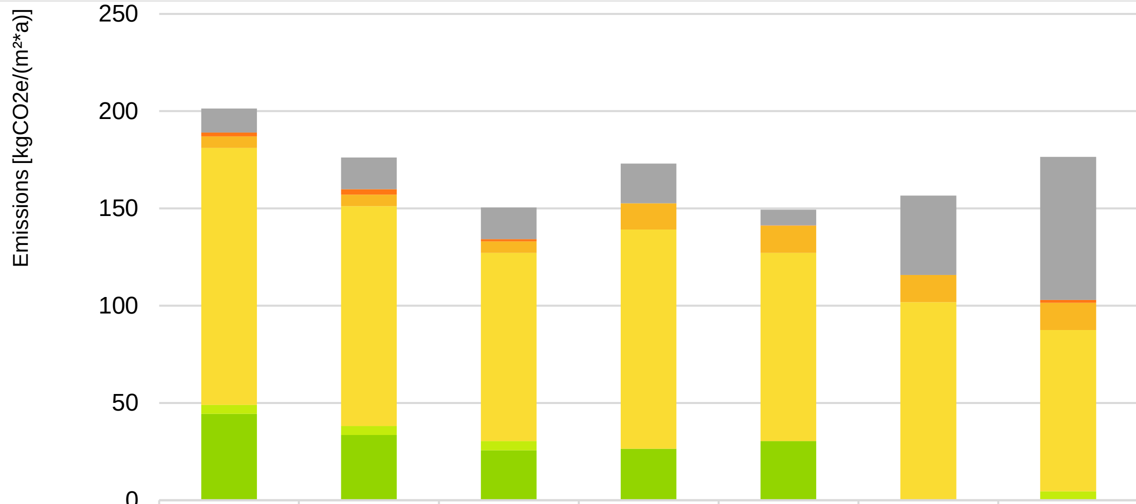


	SFH	MFH (small)	MFH (large)	Office	Education	Retail	Hospital
Other electricity	15,2	20,3	20,3	25,3	10,1	50,7	91,2
Ventilation	-	-	-	-	-	22,7	-
Auxiliary energy	0,3	0,3	0,1	-	-	-	0,4
Lighting	4,4	4,4	4,4	10,0	10,0	10,0	10,0
Space cooling	37,1	55,1	42,4	35,5	39,9	42,8	26,4
DHW	-	6,5	0,1	-	-	-	0,0
Total space heating	45,3	47,4	39,5	6,2	3,4	12,4	25,8

Figure 68 Primary and final energy demand of reference for new buildings after 2015 in a city

3.5.2 CO_2 emissions of reference buildings

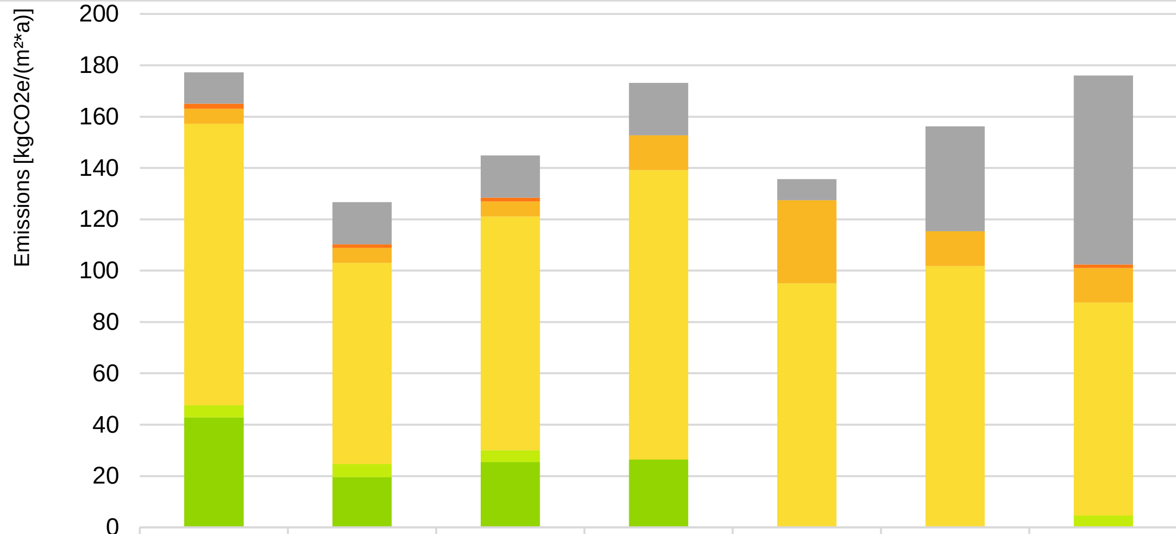
Carbon emissions of reference for existing buildings that were built from 1980-2015 in a village are shown in Figure 69. SFHs emit the highest amounts of carbon while schools emit the least. The difference between both is 52 kgCO_2e/(m²a). Space cooling has the highest contribution to carbon emissions while auxiliary energy has the lowest contribution. Ventilation does not contribute to carbon emissions.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	12	16	16	20	8	41	74
Ventilation	0	0	0	0	0	0	0
Auxiliary energy	2	3	1	0	0	0	1
Lighting	6	6	6	13	14	14	14
Space cooling	132	113	97	113	97	102	83
DHW	5	5	5	0	0	0	5
Total space heating	44	34	26	26	30	0	0

Figure 69 Carbon emissions of reference for existing buildings from 1980-2015 in a village

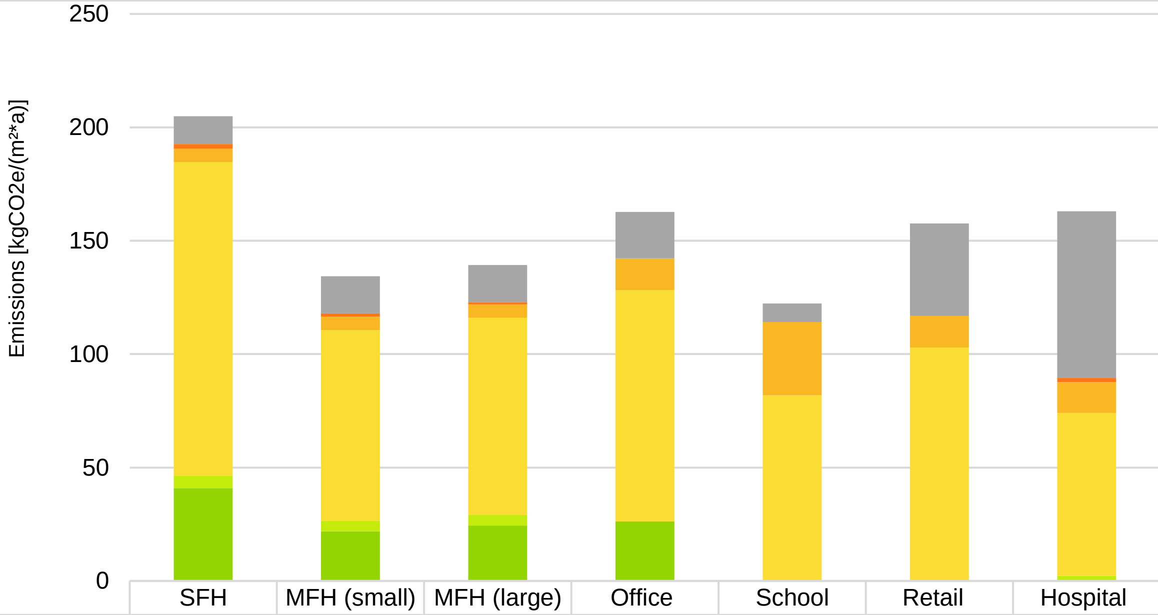
Figure 70 shows carbon emissions of reference for existing buildings that were built before 1980 in a town. SFHs and hospitals emit the highest emissions while MFHs emit the least. The difference between them is 52 kgCO_2e/(m²a). Space cooling has the highest portion of carbon emissions while auxiliary energy has the lowest.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	12	16	16	20	8	41	74
Ventilation	0	0	0	0	0	0	0
Auxiliary energy	2	1	1	0	0	0	1
Lighting	6	6	6	13	32	13	13
Space cooling	110	78	91	113	95	102	83
DHW	5	5	5	0	0	0	5
Total space heating	43	20	25	26	0	0	0

Figure 70 Carbon emission of reference for existing buildings before 1980 in a town

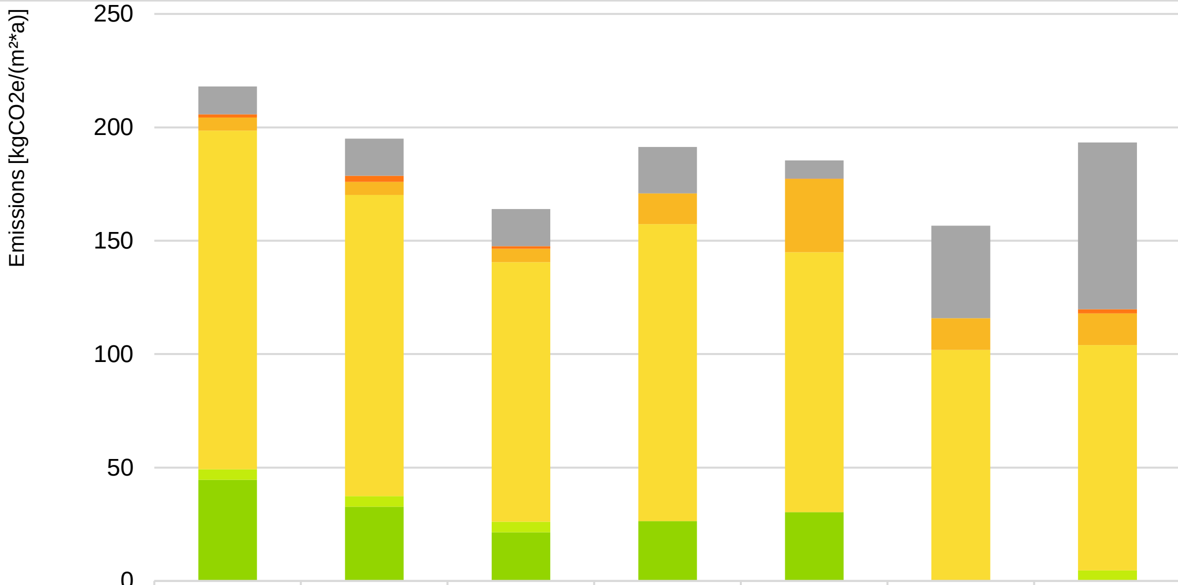
Figure 71 shows the carbon emissions of reference for existing buildings that were built before 1980 in a city. SFHs produce the highest carbon emissions while schools produce the lowest. The difference between the highest and the lowest is 83 $kgCO_2e/(m^2a)$. Space cooling has the highest contribution to carbon emissions while auxiliary energy has the lowest.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	12	16	16	20	8	41	74
Ventilation	0	0	0	0	0	0	0
Auxiliary energy	2	1	1	0	0	0	2
Lighting	6	6	6	14	32	14	13
Space cooling	138	84	87	102	82	103	72
DHW	6	5	5	0	0	0	2
Total space heating	41	22	24	26	0	0	0

Figure 71 Carbon emissions of reference for existing buildings before 1980 in a city

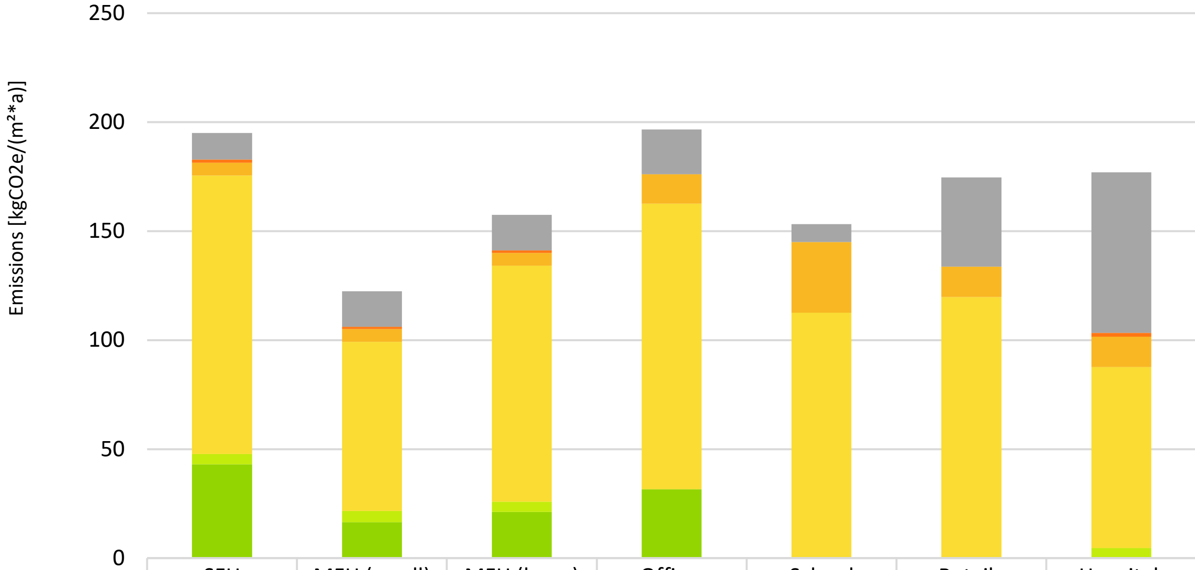
Figure 72 shows carbon emissions of reference for existing buildings that were built from 1980-2015 in a village. Space cooling creates the highest range of carbon emissions while auxiliary energy and lighting create the least. SFHs are the highest contributors to carbon emissions while retail buildings are the lowest contributors. The difference between them is 61 $kgCO_2e/(m^2a)$.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	12	16	16	20	8	41	74
Ventilation	0	0	0	0	0	0	0
Auxiliary energy	1	3	1	0	0	0	2
Lighting	6	6	6	13	32	14	14
Space cooling	149	133	114	131	115	102	99
DHW	5	5	5	0	0	0	5
Total space heating	45	33	21	26	30	0	0

Figure 72 Carbon emissions of reference for existing buildings from 1980-2015 in a village

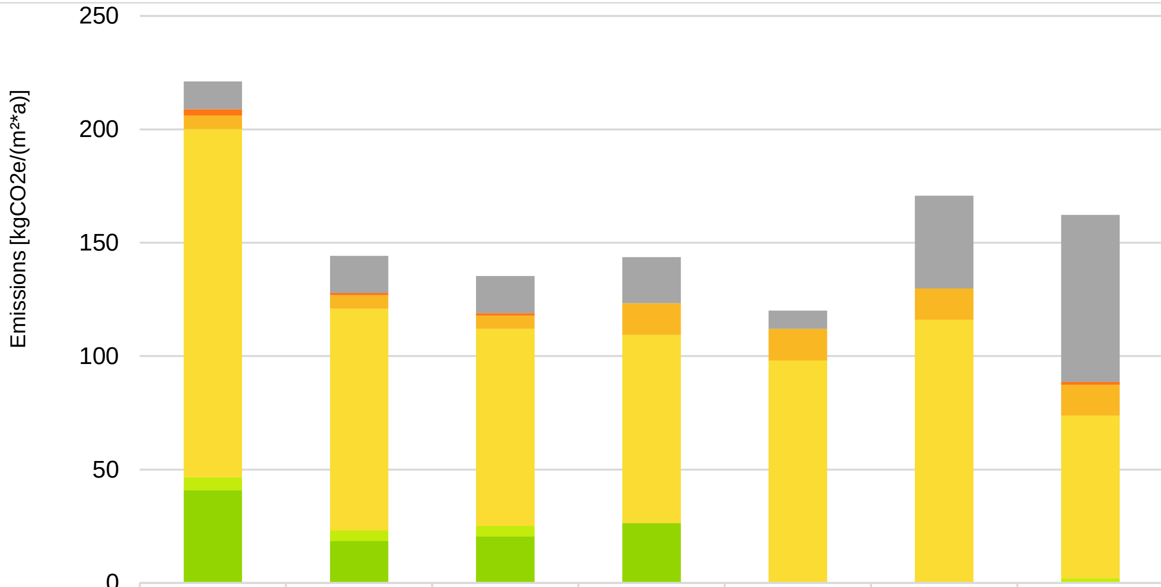
Carbon emissions of reference for existing buildings that were built from 1980-2015 in a town are shown in Figure 73. Both office buildings and SFHs are the sources of the highest carbon emissions (relatively) while MFHs are the source of the lowest carbon emissions. The difference between the highest and the lowest values is 73 $kgCO_2e/(m^2a)$. Space cooling contributes the most to carbon emissions while auxiliary energy contributes the least. Ventilation has no effect on carbon emissions.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	12	16	16	20	8	41	74
Ventilation	0	0	0	0	0	0	0
Auxiliary energy	1	1	1	0	0	0	2
Lighting	6	6	6	13	32	14	14
Space cooling	128	78	108	131	113	120	83
DHW	5	5	5	0	0	0	5
Total space heating	43	17	21	32	0	0	0

Figure 73 Carbon emissions of reference for existing buildings from 1980-2015 in a town

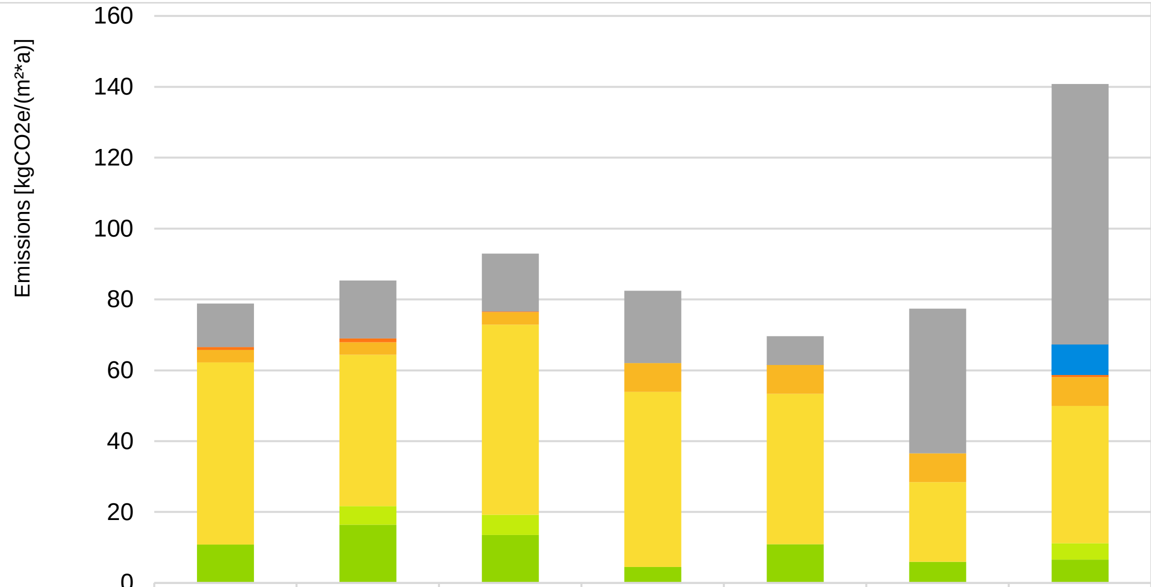
Figure 74 shows carbon emissions of reference for existing buildings that were built from 1980-2015 in a city. SFHs are the highest contributors to carbon emissions while schools are the lowest contributors. The difference between both is 102 $kgCO_2e/(m^2a)$. Space cooling has the highest contribution to carbon emissions while auxiliary energy has the lowest. Ventilation has no effect on carbon emissions.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	12	16	16	20	8	41	74
Ventilation	0	0	0	0	0	0	0
Auxiliary energy	3	1	1	0	0	0	1
Lighting	6	6	6	14	14	14	13
Space cooling	154	98	87	83	98	116	72
DHW	6	5	5	0	0	0	2
Total space heating	41	19	20	26	0	0	0

Figure 74 Carbon emissions of reference for existing buildings from 1980-2015 in a city

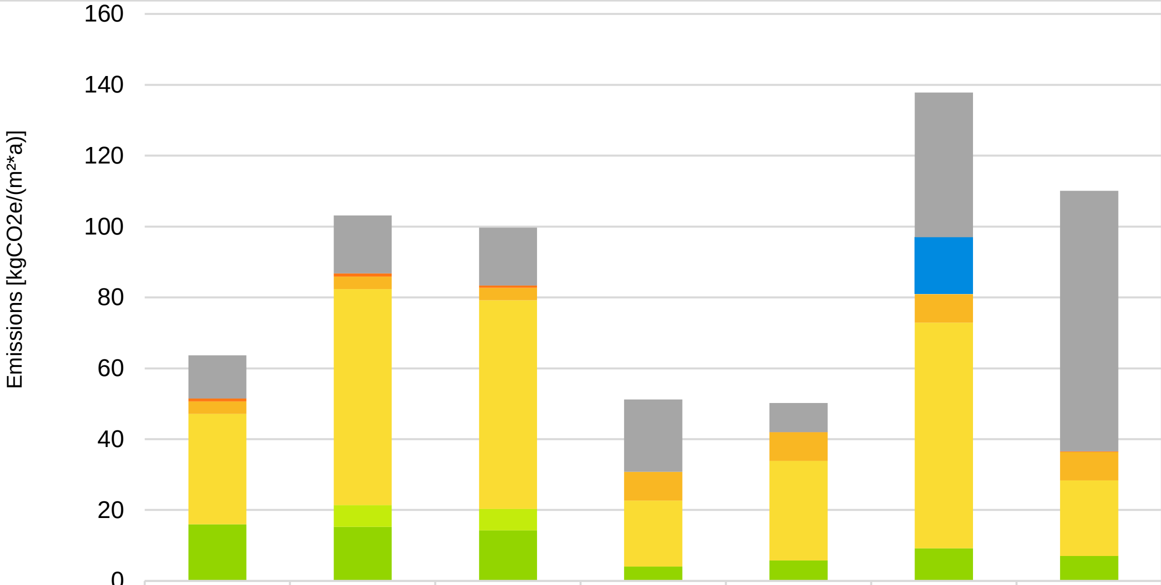
Carbon emissions of reference for new buildings that were built after 2015 in a village are shown in Figure 75. Hospitals generate the highest amounts of carbon emissions while schools generate the least. The difference between both is 73 $kgCO_2e/(m^2a)$. Space cooling contributes the most to carbon emissions while auxiliary energy contributes the least. Ventilation has no effect on carbon emissions.



	SFH	MFH (small)	MFH (large)	Office	School	Retail	Hospital
Other electricity	12	16	16	20	8	41	74
Ventilation	0	0	0	0	0	0	9
Auxiliary energy	1	1	0	0	0	0	1
Lighting	4	4	4	8	8	8	8
Space cooling	51	43	54	49	43	23	39
DHW	0	5	6	0	0	0	5
Total space heating	11	16	14	4	11	6	7

Figure 75 Carbon emissions of reference for new buildings after 2015 in a village

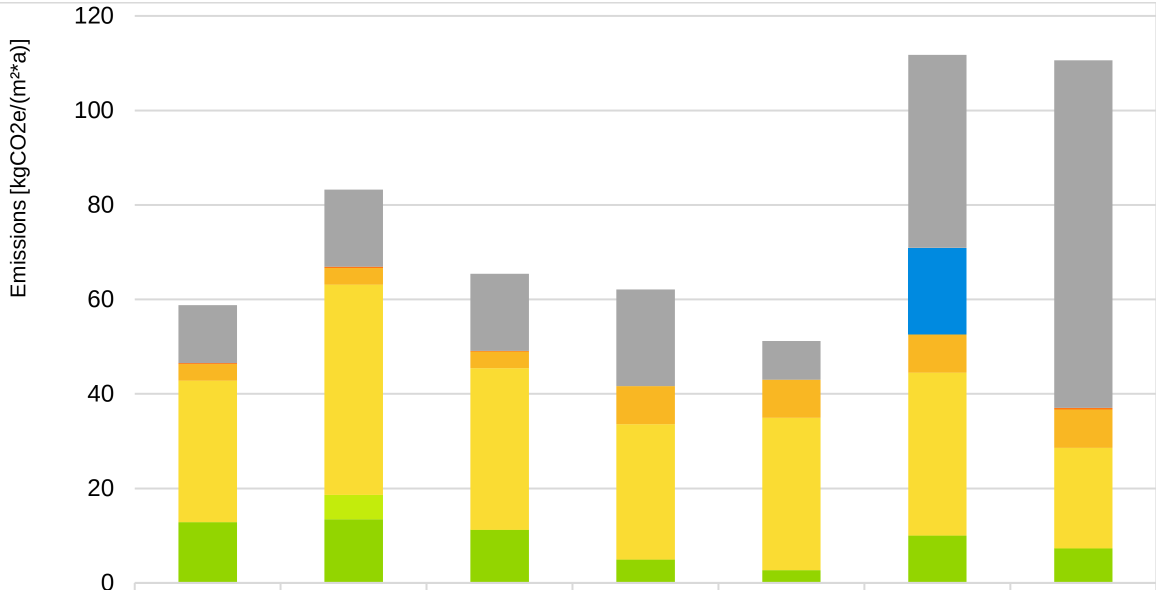
Figure 76 shows carbon emissions of reference for new buildings that were built after 2015 in a town. Retail buildings emit the highest amounts of carbon while educational buildings emit the lowest. The difference between both is 88 $kgCO_2e/(m^2a)$. For most cases, with hospitals being the only exception, space cooling has the highest contribution to carbon emissions while auxiliary energy has the least. Ventilation has no effect on carbon emissions.



	SFH	MFH (small)	MFH (large)	Office	Education	Retail	Hospital
Other electricity	12	16	16	20	8	41	74
Ventilation	0	0	0	0	0	16	0
Auxiliary energy	1	1	1	0	0	0	0
Lighting	4	4	4	8	8	8	8
Space cooling	31	61	59	19	28	64	21
DHW	0	6	6	0	0	0	0
Total space heating	16	15	14	4	6	9	7

Figure 76 Carbon emissions of reference for new buildings after 2015 in a town

Carbon emissions of reference for new buildings that were built after 2015 in a city are shown in Figure 77. Retail and hospital buildings have the highest contribution to carbon emissions while educational buildings have the lowest. For most cases, space cooling has the highest contribution to carbon emissions while auxiliary energy has the lowest. Retail and hospital buildings are the exceptional cases where other electricity uses have the highest contribution to carbon emissions. Ventilation has no effect on carbon emissions.



	SFH	MFH (small)	MFH (large)	Office	Education	Retail	Hospital
Other electricity	12	16	16	20	8	41	74
Ventilation	0	0	0	0	0	18	0
Auxiliary energy	0	0	0	0	0	0	0
Lighting	4	4	4	8	8	8	8
Space cooling	30	44	34	29	32	35	21
DHW	0	5	0	0	0	0	0
Total space heating	13	13	11	5	3	10	7

Figure 77. Reference carbon emissions for new buildings after 2015 in a city

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Annex – Detailed Reference Building fact sheets

Annex including tables of all reference buildings in the three BUILD_ME target countries.

BUILD_ME

_Get in contact with us

Guidehouse Germany GmbH
Albrechtstr. 10C
10117 Berlin
+49 (0)30 297735790
www.guidehouse.com

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