young cities
Developing Urban Energy Efficiency
Tehrān-Karaj

04

Young Cities Research Paper Series, Volume 04

Energy Efficient Housing for Iran

Pilot Buildings in Hashtgerd New Town

Farshad Nasrollahi, Philipp Wehage, Effatolsadat Shahriari, Abbas Tarkashvand

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BHRC

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List of Volumes
01 **Accomplishments and Objectives (in Farsi)**
Rudolf Schäfer, Tayebeh Parhizkar, Farshad Nasrollahi, Holger Ohlenburg, Ghazal Raheb, Florian Stellmacher (Eds.)

02 **Accomplishments and Objectives (in English)**
Rudolf Schäfer, Farshad Nasrollahi, Holger Ohlenburg, Florian Stellmacher (Eds.)

03 **The Shahre Javan Community Detailed Plan**
Elke Pahl-Weber, Sebastian Seelig, Holger Ohlenburg (Eds.)

04 **Energy Efficient Housing for Iran**
Farshad Nasrollahi, Philipp Wehage, Effatolsadat Shahriari, Abbas Tarkashvand

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Farshad Nasrollahi
TU Berlin

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Table of Contents and Authors

Foreword

The fourth volume of the “Young Cities Research Paper Series” presents the research and design activities performed within the German-Iranian research project “Young Cities”, which has a focus on residential buildings. Young Cities: Urban Energy Efficiency – Developing Energy-Efficient Urban Fabric in the Tehran-Karaj Region is part of the funding programme “Research for the Sustainable Development of Megacities of Tomorrow” sponsored by the “German Federal Ministry of Education and Research” (BMBF). The programme, which includes nine research projects in different countries of Asia, Africa and Latin America, focuses on “Energy and Climate-Efficient Structures in Urban Growth Centers”. Following the objectives of the Future Megacities Programme, the main objective of the Young Cities project is to create energy efficiency in urban environments. As the building sector is the biggest energy consumer in Iran and community housing is generally, and especially in new towns, responsible for the high density, this volume focuses on the Young Cities’ activities regarding energy efficiency in residential buildings.

This fourth volume introduces a cost-neutral method to reduce the energy demand of residential buildings in the climatic conditions of the Tehran region. “Architectural Energy Efficiency” describes how the energy demand of residential buildings can be lowered through a conscious and intelligent design. It indicates the high energy saving potential that can be achieved through architectural design and introduces different measures to minimize energy consumption in dwellings in this particular climate region. Furthermore, it presents the designs of three different housing estates called “New Generation Residential Pilot Projects”. The main objective of these pilot projects is energy efficiency; however, the aim is to achieve further benefits including high quality architecture, flexibility, low-carbon emissions, affordability, cultural and social adaptation as well as earthquake resistance. Energy efficiency as the main objective is effected within these pilot building complexes through a conscious design. Due to the fact that these schemes are developed by different groups and each has its own specific targets, the results present different approaches to achieve the high quality, energy and cost-efficient architecture.

The research on how to reach energy efficiency through architectural measures, as well as the design of different energy-efficient residential complexes, is intended to raise awareness among responsible institutions, decision makers, investors as well as the general public for energy-efficient architecture, especially in cases where efficiency is simply achieved through climate-responsive design. When the pilot projects are implemented in Tehran’s research area, the buildings created according to the Young Cities’ research and design activities will certainly arouse public interest and quickly become everyday practice within the region.

Farshad Nasrollahi
TU Berlin

I
Introduction

1 The Shahre Javan Community in Hashtgerd New Town – concept and design for an energy-efficient and sustainable urban quarter

Philipp Wehage | Elke Pahl-Weber, TU Berlin

The "Shahre Javan Community" pilot area is the central laboratory for developing energy-efficient urban fabric in the Young Cities project – one of the projects with an applied research approach in the "Future Megacities" research programme funded by BMBF. It covers a nearly 35 ha-large planning area in the southern part of Hashtgerd New Town, situated near the future megacity Karaj in the Tehran region. Pilot projects are a central methodological part of an applied research approach; this particular one is being developed with a "research by design", approach. The aim is to develop a neighbourhood with 2,000 housing units for 8,000 inhabitants, including a social and cultural centre, retail units and office space. In comparison to the existing quarters in Hashtgerd New Town, which are characterized by mono-functional linear building arrangements, the "Shahre Javan Community" concept incorporates a lively urban quarter composed of compact and mixed-use urban clusters, which benefit from the synergies of integrated disciplines on an urban level: the "low rise – high density" urban design concept integrates the climate–adapted, environmental aims of resource-efficient water treatment, the sustainable design of open space, innovative mobility concepts and the energy-related demands of the built settlement. Synergy effects for resource efficiency are achieved through the holistic approach of the integrated design. For example, grey water collected in the housing areas is treated in constructed wetlands and then used for the irrigation of the planted open spaces as a measure to counteract the heat island effect.

The urban layout is characterized by the arrangement of 29 compact urban clusters on north-south oriented ridges. The low-rise, but dense composition of the built areas produces large-scale open spaces for recreation and an optimized micro-climate through cultivation and air circulation. The eastern and western valleys provide the infrastructure for the main access to the quarter and natural ventilation axes for the fresh mountain winds from the north. The valley position and the distance to the ridge from the estate keeps the main roads free as escape routes in case of seismic hazards.

A central walkway in east-west direction connects the quarter with the new parkland in the east, which serves as a compensation area for the new estate and strengthens the prevailing ecological value. The central green in the valley line of the quarter forms the public recreation area. The social centre of the quarter with a mosque, education and cultural facilities is located at the crossing point of the central green and main walkway. As a suitable example for Iranian traditions, the urban units bordering the pilot area are occupied by superordinate functions, such as office areas and educational institutions, such as the LIFE Centre, with direct access from the adjoining main roads.

The spatial arrangement with clearly defined urban units allows for the application of innovative energy systems, including decentralized power plants.

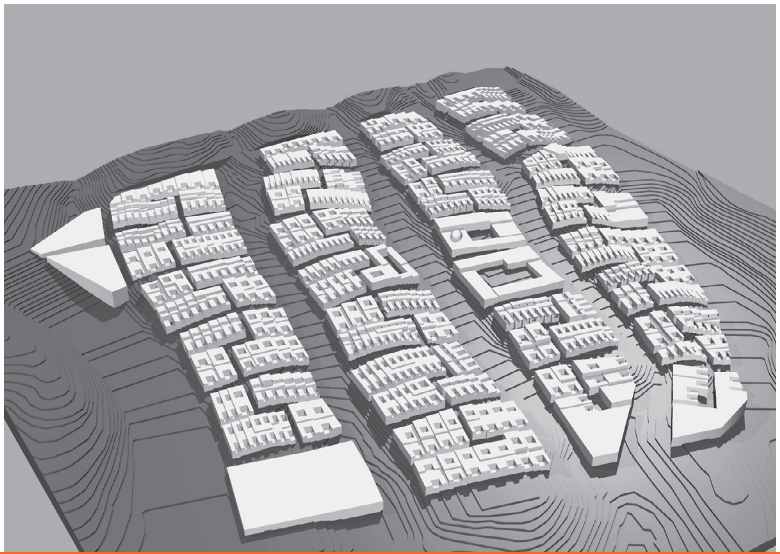


Fig. 1: Urban layout of the "Shahre Javan Community" (YC Research Paper Series, Vol. 3, 2012)

Following the vernacular approach of an oriental city, the urban housing clusters are designed according to the introverted courtyard house principle on a neighbourhood level, providing accommodation for about 250 to 300 inhabitants each. Accessed by a path from the valley road, a small square inside each unit defines the neighbourhood centre with everyday facilities in a mixed-use arrangement. The access spaces are dimensioned for pedestrians. Motorized traffic is permitted only for service and emergency vehicles. The private cars can be parked in the garage below the developed area and, by exploiting the topographical situation, direct access is provided from the collecting roads in the valley. The provision with parking is designed to reduce the amount of sealed surfaces. Furthermore, the presence of less private cars, due to future developments concerning private mobility, will not have such a great impact on the urban appearance.

The consideration of major morphological aspects, to exploit passive solar energy through building orientation and minimize energy loss through compactness, determine the low-cost design measures for energy efficiency derived from the urban form. Restrictions established in the binding detailed plan (Tarh-e-Tafsili), which was developed in a German-Iranian cooperation, including regulations for building lines, building heights and mass, define the framework for the architecture and secure the energy efficiency objectives strived for in the Young Cities project.

Fig. 2: District plan of the "Shahre Javan Community" (YC Research Paper Series, Vol. 3, 2012)

2 Architectural design for energy-efficient pilot buildings in Hashtgerd New Town

Farshad Nasrollahi | Philipp Wehage, TU Berlin

The New Generation Pilot Buildings represent the final applications in the “Young Cities” project. Integrated in the “Shahre Javan Community” pilot area, the five exemplary designs are developed as prototypes for energy-efficient buildings in the Iranian New Towns’ context. The New Generation Pilot Projects show a spectrum of buildings with different functions including residential, office and educational buildings. The housing design, as the most numerous in the Iranian New Towns’ Programme, is represented in three different designs: one by the dimension “Urban Design and Architecture”[1], one by the dimension “Design, Structure and Materials”[2] and the third by the Iranian partners of BHRC[3]. Besides the residential pilot projects, two pilot buildings with other occupancy profiles are being designed within the Young Cities Project to include all occupancy types required in a city quarter. The New Generation Office Building[4] designed by the dimension “Architecture and Energy” and an educational building, the LIFE Centre, by the dimension “Architecture and Engineering”[5] complete the architectural programme within the New Generation Pilot Projects’ scheme.

Although the main objective of all New Generation Pilot Projects is energy efficiency, each pilot project has its own methodology and interpretation of innovative architectural design solutions. Aspects of economy and the socio-cultural context are the most important objectives alongside the energy-related aims set for all projects.

During the course of the development and execution of the first pilot project, the “New Quality Building” in 2010, the typical design for a housing complex in Hashtgerd New Town was revised by taking structural, technical, physical and procedural optimization measures. All improvements in the New Quality Building were based on the application of Iranian National Building Codes or enhancement (improvements) of their criteria in the building design and construction. The energy saving measures applied in the building brought about a significant reduction of energy consumption in comparison to conventional constructions in Iran. For example, energy demand was reduced by almost 55% for heating by insulating the thermal envelope and by about 25% for cooling (according to the simulations of K. Naeiji in the team “Design, Structure and Materials” in 2012). The most important energy saving measure in this building was the application of insulation material. The findings made in the development of the “Shahre Javan Community” highlighted further potential for energy efficiency, which could be achieved through spatial configuration.

Based on the findings of the “New Quality Building” and the findings of the urban processes for the “Shahre Javan Community”, the development of the New Generation Pilot Buildings extends the focus on energy efficiency by the phenomenon of spatial design on a building scale. In the New Generation Pilot Buildings, the architectural design plays the most significant role in energy saving. Building orientation, façade design according to the cardinal directions, building elongation, building height and compactness are the most important aspects of the passive energy-related design. The high demand for affordable mass housing emphasizes the challenges for the discipline of architecture to create integrated, energy-efficient spatial solutions. The use of innovative energy systems in the spatial arrangement allows for further enhancement of energy efficiency according to different economic approaches. The presented designs highlight the prospects of energy-efficient buildings as integrative solutions that are derived from design processes and supported by simulations.

The locations of the pilot buildings inside and next to the “Shahre Javan Community” are determined in the approved detailed plan of the pilot area. The representative public buildings, New Generation Office and LIFE Centre, are situated on the boundary of the quarter, which can be accessed from the surrounding main roads without disturbing the interior housing areas. The housing designs represent a complete scenario of an urban unit for about 250–300 inhabitants inside the quarter with different typologies, including everyday facilities in a mixed-use arrangement.

The site specifications derived from the urban layout, topography and climate context, determine the physical pre-conditions for the design process. The topography and the urban context have an impact on the energy-relevant design approach concerning building compactness and orientation. The local semi-arid climate influences the strategies for passive energy impact as well as the performance of energy systems. Due to the wide range of seasonal and even daily outside temperatures at the site, with cold winters and warm summers, energy is required to reach a comfortable indoor climate, both in the heating and the cooling period. Thus, measures and strategies for energy efficiency in buildings and systems must consider both cases.

Besides the climate and topographical conditions, the building designs also consider the socio-cultural context. The New Generation Buildings represent socio-cultural adapted solutions for energy-efficient building designs using different approaches. As exemplary scenarios, they stand for the broadness of individual design solutions. In a scientific context, they offer prospects for the design strategies of energy-efficient and sustainable buildings in Iran with mitigation potential for the MENA region. The choice of design measures and components is related to the context on all levels: economic, ecological and socio-cultural.

[1] Architects: Arch. Philipp Wehage, Arch. Annette Wolpert and Prof. Elke Pahl-Weber.
[2] Architects: Dipl.-Ing. Effat Shahriari and Prof. Dr.-Ing. Klaus Rückert.
[3] Architects: Dr. Abbas Tarkashvand and Dr. Ghazal Raheb, under supervision of Dr. Tayebeh Parhizkar.
[4] Architects: Dr.-Ing. Farshad Nasrollahi and Prof. Dipl.-Ing. Claus Steffan.
[5] Architects: Prof. Dipl.-Ing. Ute Frank and Dipl.-Ing. Andrea Böhm.

II

Energy-Efficient Architecture for Residential Buildings

A New Approach to the Energy Efficiency of Buildings in Tehran

Farshad Nasrollahi, TU Berlin

Abstract

Architectural design can act as a very effective, but cost-neutral measure for energy efficiency in buildings. This study investigates the effect of architectural design on the heating, cooling and primary energy demand of residential buildings in the climatic conditions of Tehran. It is based on the simulation of different building typologies and the analyses of results to determine which architectural factors most reduce the energy consumption of buildings in the capital city of Iran. The implementation of these factors in the urban and architectural design of residential buildings will lower the energy consumption of buildings without increasing buildings costs or requiring any additional technologies. The results show that architectural features have a great impact on the heating and cooling energy demand in residential buildings. Among all simulated buildings, the energy demand of the most efficient building is 48% less than a comparable building without any particular energy efficiency features and 55% less than the least efficient building in similar conditions and by only varying the architectural design. These findings highlight the high potential of architectural energy saving in the climatic conditions of Tehran.

1 Introduction

Although the energy consumption was rising in Iran and an increase of 5.86% was detected between 2000 and 2009 (according to data issued by IEA, 2012 and Iran's Ministry of Energy, 2007–2011), energy consumption decreased from 2009 to 2010. The share of renewables in Iran's energy mix is negligible, and was less than 0.5% in 2010 (according to data issued by Iran's Ministry of Energy, 2011).

On the other hand, some of Iran's larger cities, such as Tehran and Isfahan, produce high levels of air pollution, much higher than the standards set by the World Health Organization. According to the Air Quality Index (AQI), Tehran had only 3 days with a "Good" and 144 days with a "Moderate" Air Quality Index in 2011; the number of "Unhealthy" and "Very Unhealthy" days was 215 and 3 respectively the following year (Ahadi et al., 2012).

The number of unhealthy days between 20 March 2011 and 20 February 2012 was twice that of the year before. The number of unhealthy days increased from 95 days to 208 days. The city had only 126 "Moderate" and only 2 "Good" days during the respective period (according to the Iranian daily Hamshahri, 2013). The energy sector is the biggest producer of air pollution. The sector emitted 532,324.8, 52.2 and 11.9 thousand tons of CO_2, CH_4 and N_2O respectively in 2010. The preservation and reduction of energy consumption is therefore of utmost importance in Iran.

This year, the residential and commercial building sector has been responsible for 25.06% of greenhouse gas emissions (Iran's Ministry of Energy, 2011).

The energy consumption of buildings in Iran is very high compared to other countries and the worldwide average. Therefore, the introduction and realization of energy-efficient buildings is crucial for Iran in order to decrease the total energy demand of the country.

In recognizing the importance of reducing the worldwide primary energy consumption, Iran founded various governmental organizations to research energy conservation methods and renewable energies in 1995, the most notable of which are the "Iranian Fuel Conservation Company" (IFCO), the "Iran Energy Efficiency Organization" (IEEO), and the "Renewable Energy Organization of Iran" (SUNA) (Nasrollahi, 2009). Following the introduction of these establishments, Iran defined some strategies and plans to reduce the country's energy consumption including that of buildings. The measures include the introduction of national building regulations for energy saving in buildings (Code 19), the increase of energy prices, etc. Even though the implementation of building energy regulations and especially the higher energy prices have led to some energy savings in the building sector in the last years, these improvements were not sufficient compared to global levels as well as the importance of reducing energy consumption worldwide. The potential for energy saving in Iran's building sector is very high due to the fact that many building envelopes are not insulated; furthermore, the potential of the climate as an energy source is significant in large parts of Iran. Improvements in energy consumption can therefore be achieved more easily in the building sector and require comparably little investment.

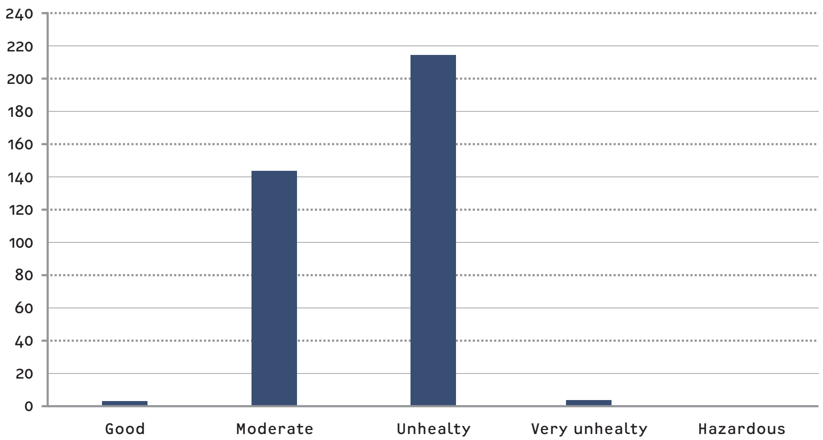


Fig. 1: Air Quality Index in Tehran in 2011, according to data from Ahadi et al., 2012

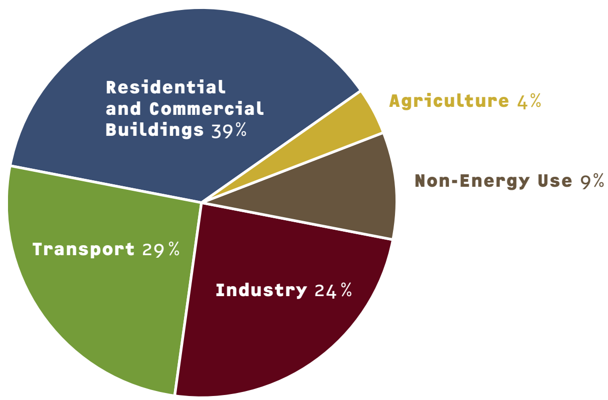


Fig. 2: Iran's energy consumption by sectors in 2010, according to data issued by Iran's Ministry of Energy, 2011

The share of energy consumed by the building sector in Iran's final energy consumption has been decreasing every year in the last 5 years and has shrunk from 45.8% in 2006 to 40.6% in 2010 (according to data issued by Iran's Ministry of Energy, 2007–2011). The share of energy consumed by buildings in the total energy consumption in Iran (including non-energy use) was 37% in 2010, which makes the building sector the biggest energy consumer in Iran (according to data issued by Iran's Ministry of Energy, 2011).

Iran's high demand for new buildings indicates the great potential and importance of energy conservation in the building sector. Only the construction of new energy-efficient buildings can lead to a higher degree of energy saving.

As the following diagram shows, decreasing the energy demand of buildings by applying cost-intensive measures (such as the addition of insulation material, energy-efficient heating and cooling systems, renewable energy systems, etc.) leads to an increase of building investment costs. Investment costs, including user costs and governmental subsidies, for very low energy buildings, zero or plus-energy buildings are generally too high, and construction is not economically viable in consideration of the national capital in the present economic conditions of most countries.

Because of the subsidized and very low energy costs in Iran, there was little interest for energy-efficient buildings in the last decades. The buildings completed in Iran have been inefficient in terms of energy, and most designs for energy-efficient buildings never left the drawing board. However, since the reduction of energy subsidies in 2010, social interest in low energy buildings has increased significantly and investors are more willing to consider energy-efficient designs. The result is that in 2013, two zero-energy office buildings are being developed in Iran.

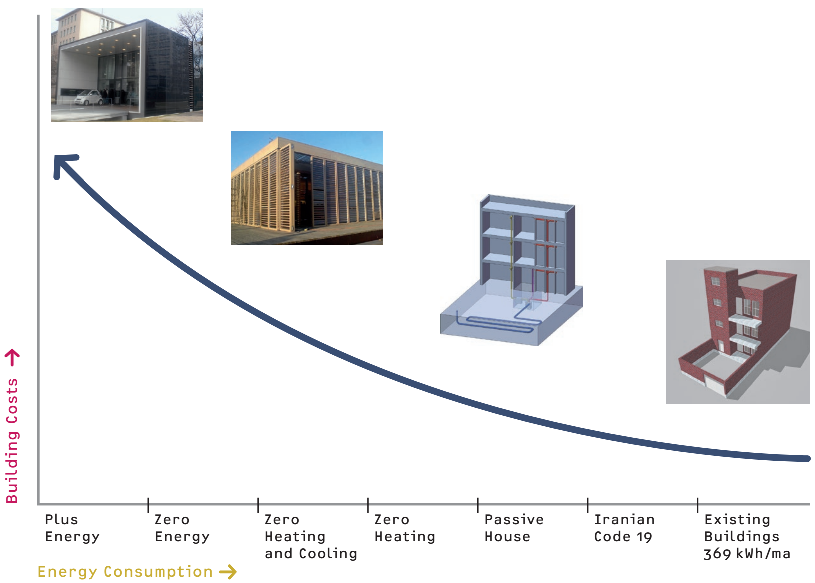


Fig. 3: Relationship between energy consumption and building investment costs

2 Architectural Energy Efficiency

One of the main reasons for the high energy consumption in buildings is the poor designs without taking into consideration the climatic circumstances of the location.

The reduction of energy subsidies and the increase of energy costs have made energy saving in buildings using cost-intensive methods more economically viable. But because of the high building material costs required to save energy, such as insulation materials and renewable energy systems, there is little interest in energy saving measures that increase the building costs. For this reason, the use of cost-neutral energy saving methods is very important. Architectural methods to reduce energy consumption rarely increase the building costs and are purely achieved through an intelligent design.

Due to Iran's climate conditions, the potential of architectural energy efficiency is very high in large parts of the country. Research, which has been performed in regard of a reduced energy consumption in buildings through architectural design for the climate of the Tehran region, has shown that the potential for energy saving in buildings through architectural design is very high.

No building materials or technologies are required to save energy through architectural design. It is, therefore, not only a cost-neutral method, but also an economically viable, emission-free and simple one in its application. Thus, this means of energy saving is very suitable not only for Iran, but for all regions with similar climate conditions.

3 Research methodology

This research investigates the effects of the architectural design by performing simulations of buildings in the climate conditions of Tehran. 30 different buildings are examined with a dynamic energy modelling program and compared to identify which architectural features most reduce the energy consumption of buildings in Tehran.

The city of Tehran is located in a “warm and dry” climate zone in Iran. The city has a “cold” winter climate and a “warm and dry” summer climate (according to weather data provided by the US Department of Energy, 2008). The annual heating degree days and the annual cooling degree days in Tehran are 1,708.4 and 965.4 respectively (IMO, 2009).

The following figures show the psychrometric chart and the (recorded, design and mean) monthly maximum and minimum temperatures as well as the monthly average air temperature in Tehran in relation to the comfort zone[1].

annual time share and hours using different ways to generate comfortable conditions in Tehran’s buildings are listed in the Table 2.

The research area of the Young Cities Research Project, which includes this study, is the Tehran-Karaj region or, more precisely, Hashtgerd New Town. Unfortunately, there is no weather station in Hashtgerd New Town and the weather data available for Hashtgerd had to be interpolated from other nearby locations, which means that the data is not quite as accurate as measured data. The simulations within this study were therefore carried out with the hourly weather data of Tehran, which was derived from statistics (long-term averages) and is more accurate.

The aim of this study is to identify architectural features, which reduce the energy consumption of residential buildings in the Tehran region. The implementation of these features in urban planning, urban design and the architectural design of buildings will lower the energy consumption of buildings without increasing the building costs or needing any additional technologies. This method of energy saving is suitable

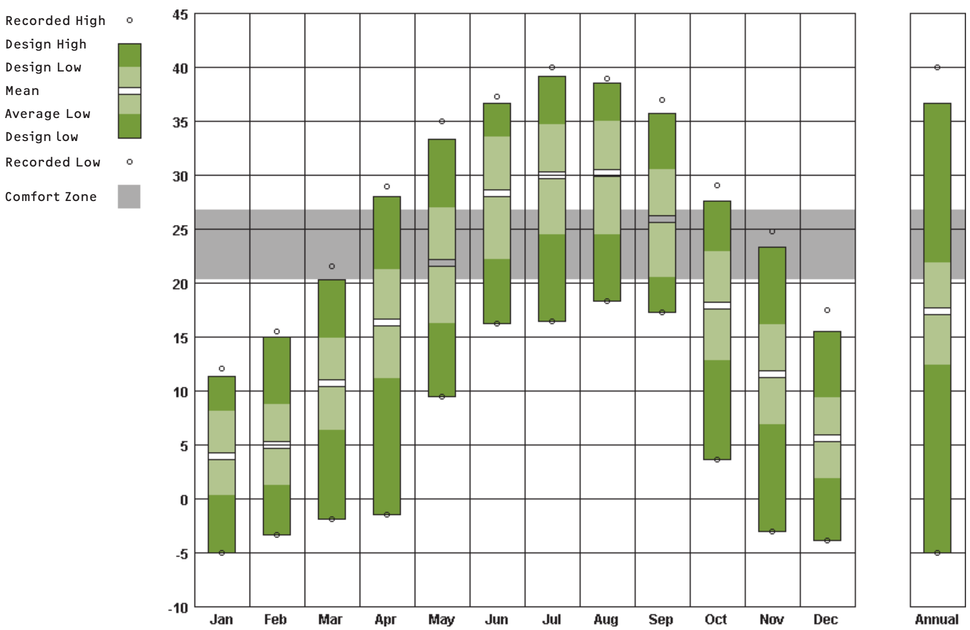


Fig. 4: Temperature range in Tehran, source of weather data: ITMY

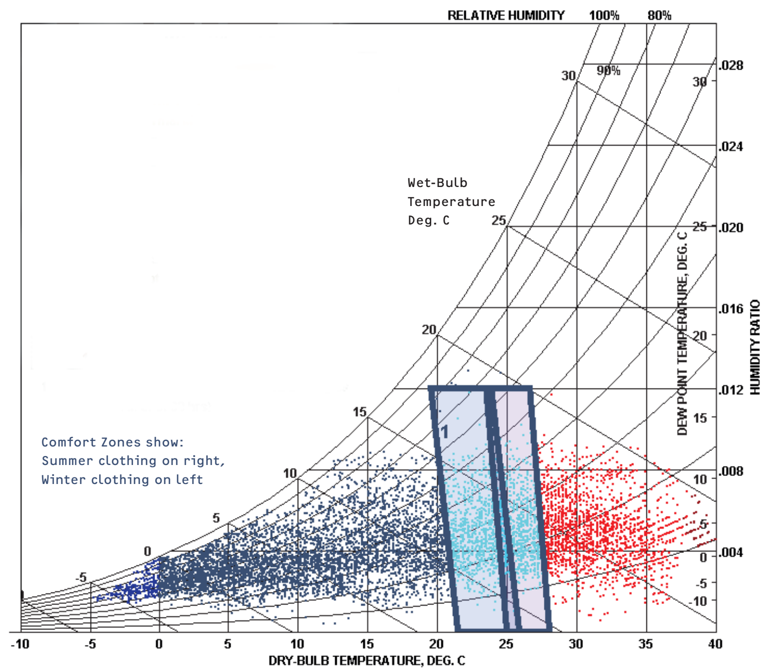


Fig. 5: Psychrometric chart of Tehran, source of weather data: ITMY

The psychrometric chart of Tehran, based on the dry-bulb temperature, detects that both heating and cooling will be necessary to achieve comfortable room conditions, however, that the need for heating is greater than the need for cooling. It also shows that the city’s relative humidity is very low, especially in warm periods.

According to the psychrometric chart of Tehran, the annual time percentages of different air temperatures are as presented in the Table 1. The for all climates, which have the potential for energy saving through adaptation of the architectural design. It is especially suitable for countries with a relatively low energy price and high construction costs, such as Iran. In these countries, investments for energy saving in buildings using expensive methods are not economically viable, despite interest in measures to save energy. Cost-neutral measures will be more successful in these economic conditions.

To estimate the effect of the architectural design on the energy consumption of buildings in Tehran, a typical average building[2] is selected and its heating and cooling energy demand is calculated using energy modelling with the DesignBuilder simulation software tool. The building is then simulated with an insulated thermal envelope. Finally, other buildings, under the same conditions, but with different architectural design features, are developed and simulated. In each case, the new building is designed so that it is similar to the previous building with only a single variation. Then, in order to neutralise the effect of control variables on the results, similar buildings, differing only in one factor, are compared with each other. Therefore, the change in energy demand is affected only by the one different factor.

In this research, both the heating and cooling energy demands of buildings are calculated. The results address the reduction of the total heating and cooling energy demand as well as the primary[3] energy demand. Most of the analyses and conclusions refer to the total energy[4] consumed for heating and cooling. The energy consumption for heating and cooling is also used separately in some analyses.

Temperature	< 0°C	0–22°C	22–24°C.	24–38°C
Relative occurrence	3%	54%	19%	23%

Strategy		Time/Year
Comfort	19.4%	1,698 h
Sun shading of windows	18.9%	1,656 h
High thermal mass	9.7%	853 h
High thermal mass/night flushing	9.8%	861 h
Direct evaporative cooling	21.6%	1,890 h
Two-stage evaporative cooling	21.7%	1,897 h
Natural ventilation cooling	5.9%	516 h
Fan-forced ventilation cooling	7.1%	623 h
Internal heat gain	21.3%	1,867 h
Passive solar direct gain (low mass)	11.9%	1,039 h
Passive solar direct gain (high mass)	14.1%	1,234 h
Wind protection	0.5%	45 h
Heating, add humidification if needed	28.9%	2, 534 h

Tab. 1: Annual time percentages of different air temperature ranges in Tehran
Tab. 2: Annual time periods using different design strategies in Tehran, source of weather data: ITMY

4 Architectural design and energy efficiency

Table 3 presents the simulated buildings and their heating, cooling, total and primary energy demand. Except Building No. 1 (typical building), all these buildings have similar constructions and differ only in one architectural design feature.

4.1 Total energy demand of simulated buildings

The heating, cooling and total energy demand of all buildings with similar building materials are presented in the following chart. According to the diagram, the energy demand differs significantly between the buildings. It also illustrates the impact architectural features have on the cooling and heating energy demand.

The total energy demand of the most efficient building is 55% less than the least efficient one in similar testing conditions and with the architectural design as the only variable factor. The best case with a minimum total heating and cooling energy demand is the architecturally upgraded building (Building No. 8); the worst case is the building with an attic unit and a large skylight (Building No. 5). The main reason for the bad results of Building No. 5 is the fact that buildings with big skylights have excessive solar heat gains in summer. The building therefore has a high cooling energy demand in summer.

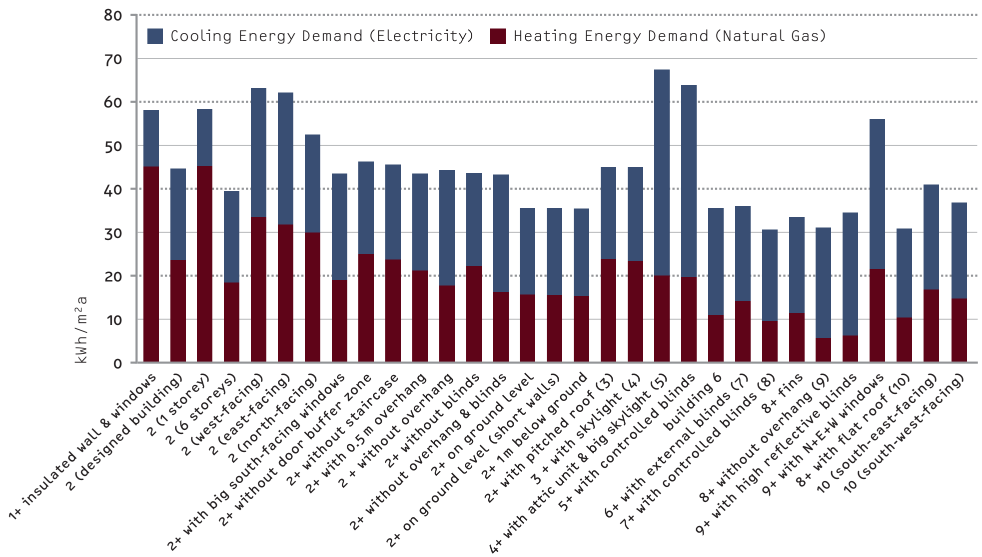
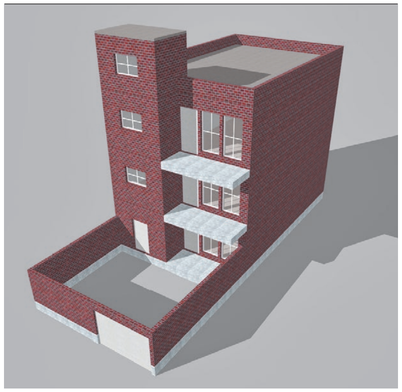
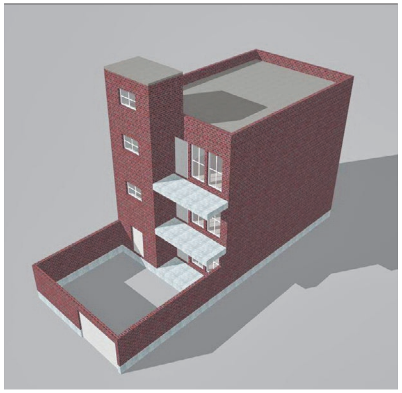
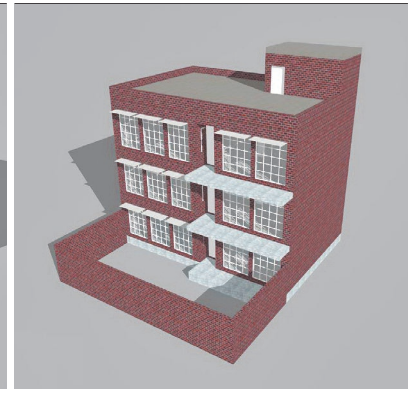
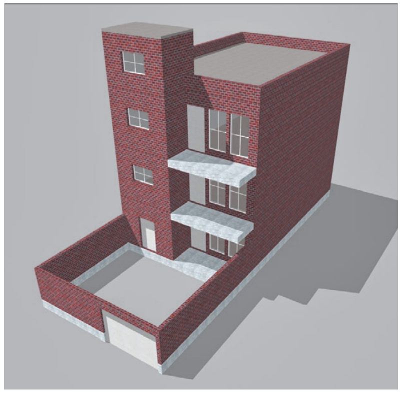
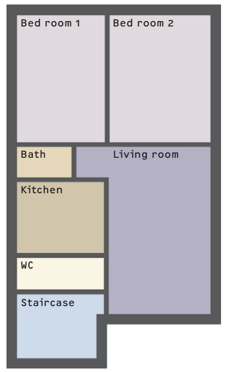
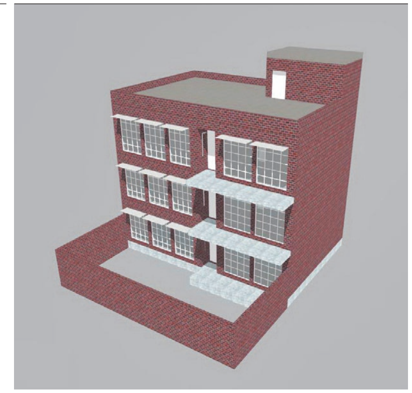


Fig. 6: Comparison of heating and cooling energy demand in buildings examined with the same construction materials

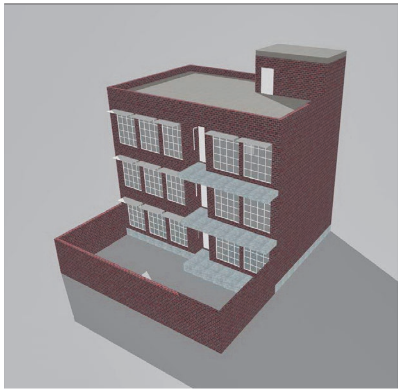
	1 (typical building)	1+ insulated wall & windows	2 (designed building)	2 (west-facing)
Perspective — Winter 15 Jan – 2:00 p.m.				
Perspective — Summer 15 Jul – 2:00 p.m.				
Architectural features (characteristics)	•• uninsulated thermal envelope •• single glazing •• south-facing orientation •• north-south elongation •• small south-facing windows internal blinds •• unconditioned space in the south •• not compact volume	•• insulated thermal envelope •• triple glazing •• south-facing orientation •• north-south elongation •• small south-facing windows •• internal blinds •• unconditioned space in the south •• not compact volume	•• south-facing orientation •• big south-facing windows •• 1 m overhang •• unconditioned space in the north •• compact volume •• internal blinds	•• west-facing orientation •• big west-facing windows •• without south-facing windows •• 1 m overhang on west façade •• internal blinds
Energy Demand kWh/m^2a — **Heating**	127.13	45.32	23.55	33.55
Cooling	39.95	12.98	21.07	29.68
Total	167.08	58.30	44.61	63.22
Primary	283.66	96.57	101.75	143.74

Tab. 3: Energy consumption of typical and newly designed buildings

Perspective

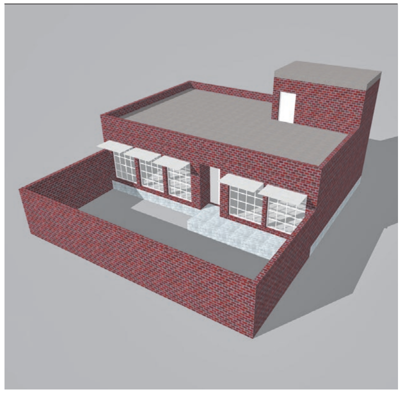
Winter 15 Jan – 2:00 p.m. / Summer 15 Jul – 2:00 p.m.

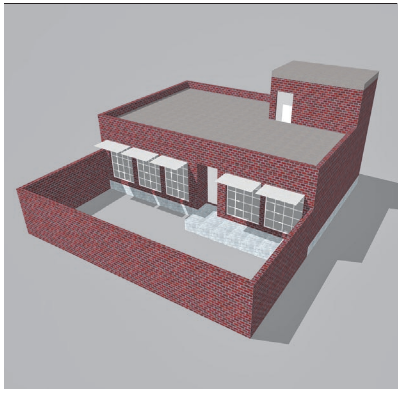
2 (east-facing)



- east-facing orientation
- big east-facing windows
- without south-facing windows
- 1 m overhang on east façade
- internal blinds

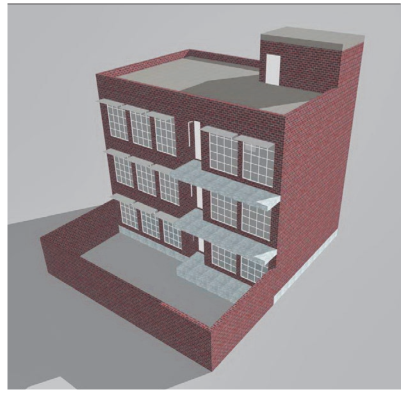
2 (1 storey)

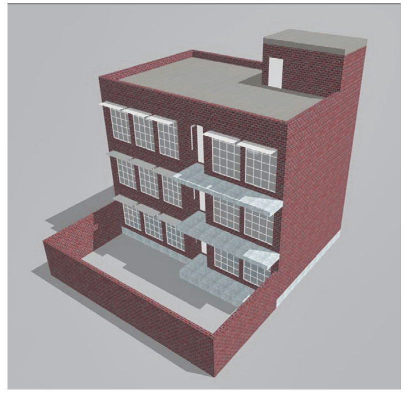




- 1 storey
- south-facing orientation
- big south-facing windows
- 1 m overhang
- internal blinds

2 (north-facing)





- north-facing orientation
- big north-facing windows
- small south-facing windows
- 1 m overhang on north façade
- internal blinds

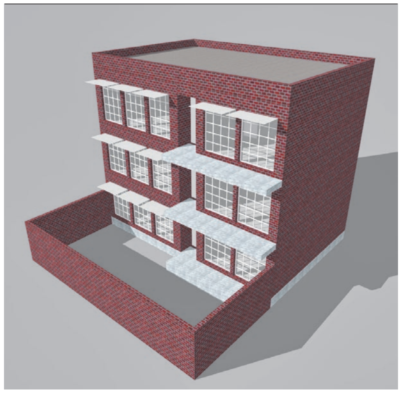
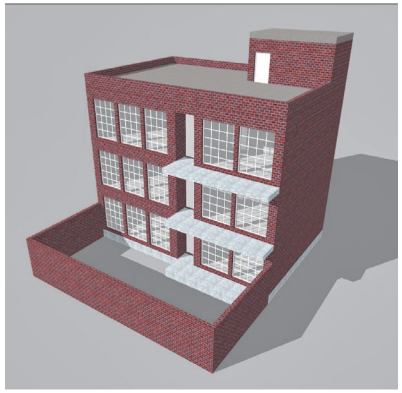
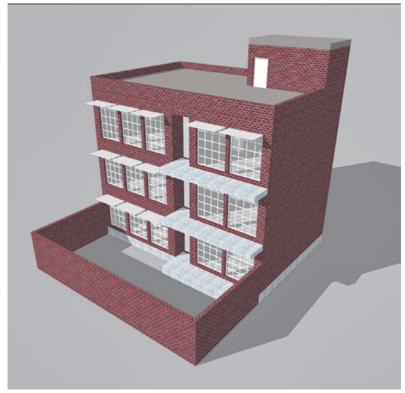
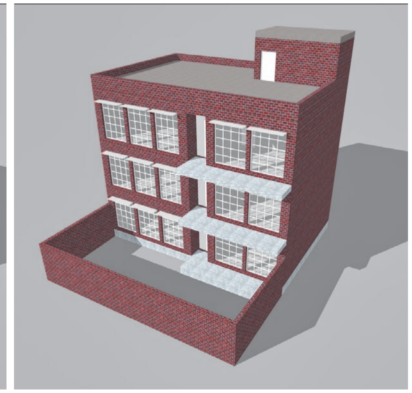
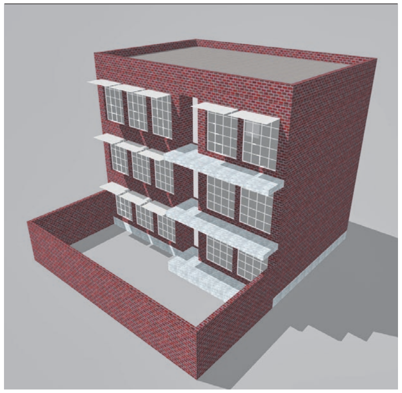
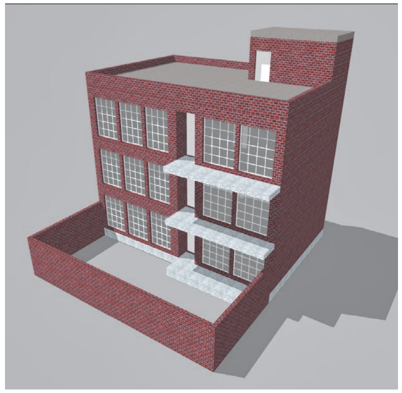
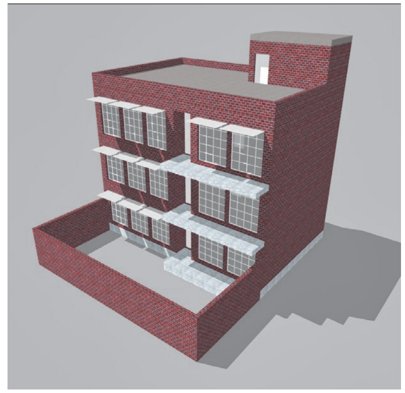
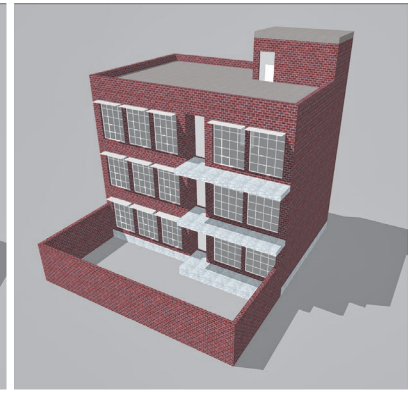
2 + without front door buffer zone

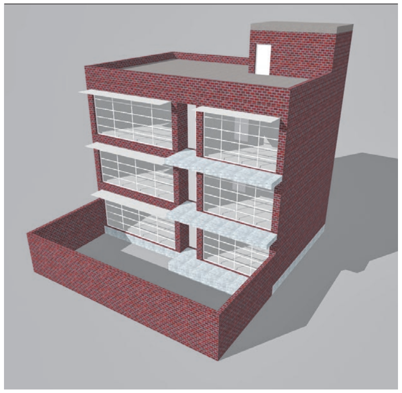
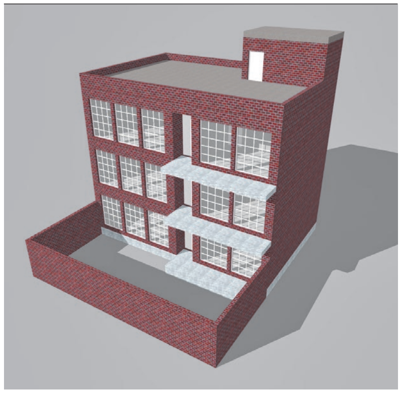
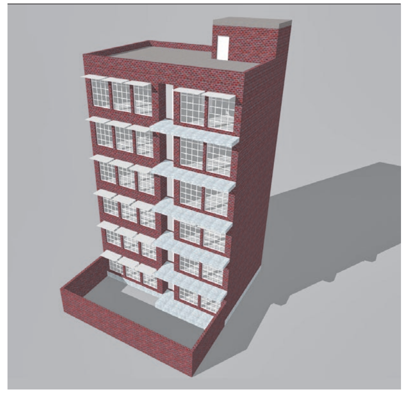
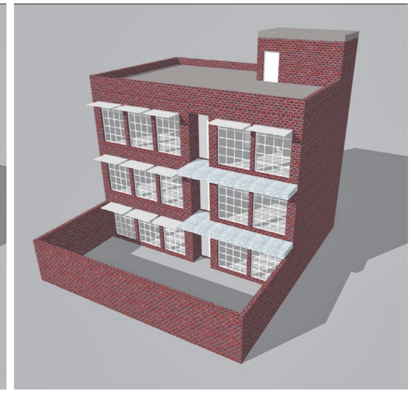
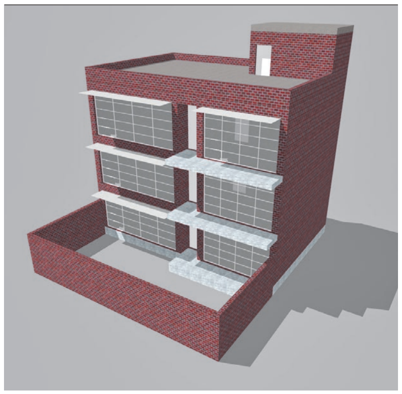
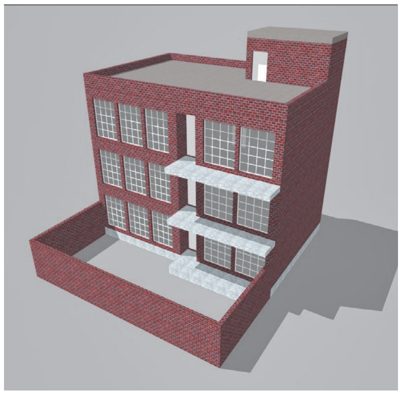
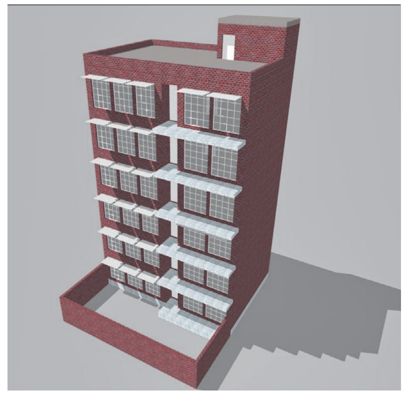
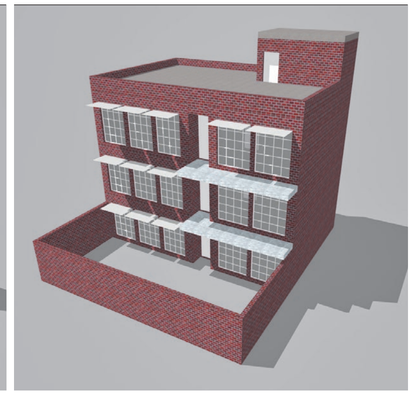
- without front door buffer zone
- south-facing orientation
- big south-facing windows
- 1 m overhang
- internal blinds

Architectural features (characteristics)

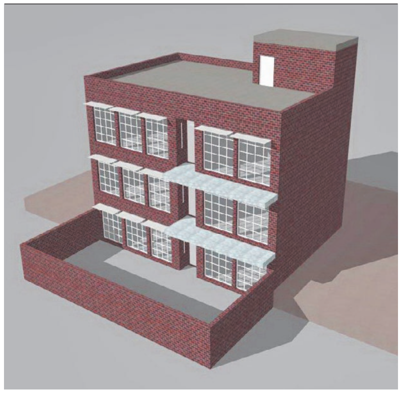
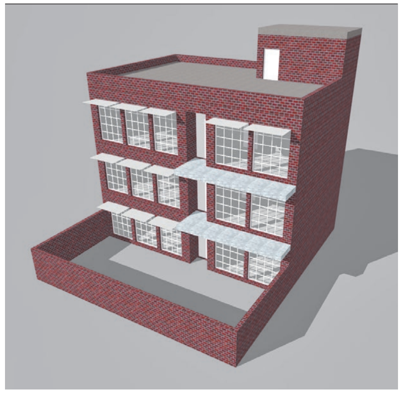
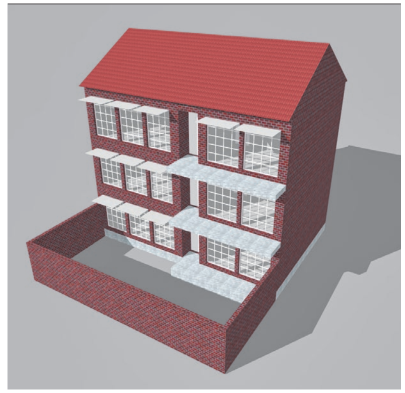
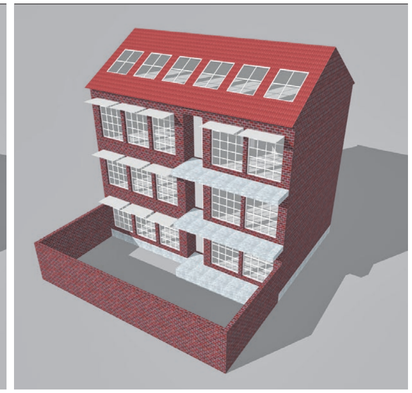
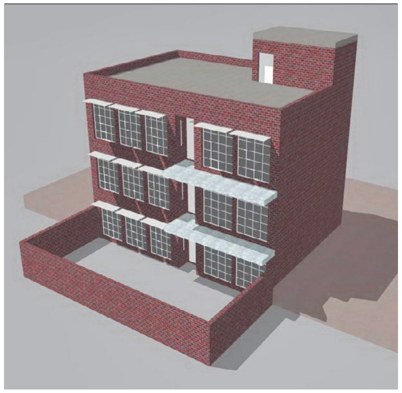
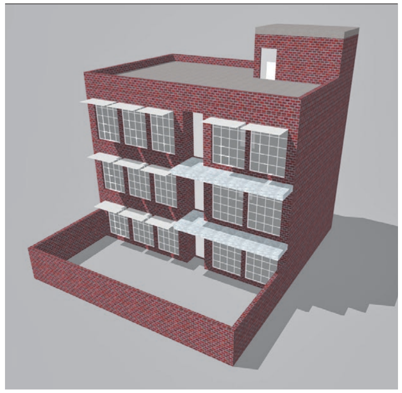
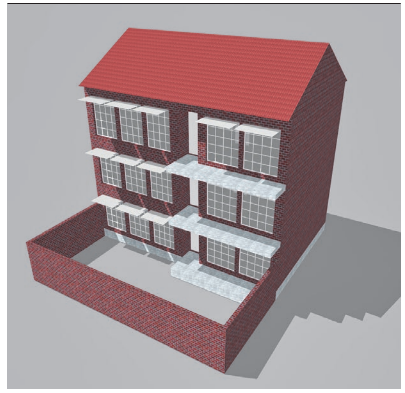
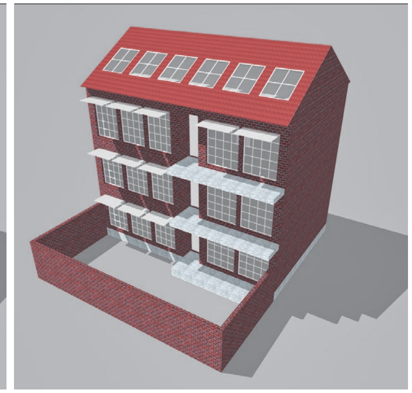
Energy Demand kWh/m²a

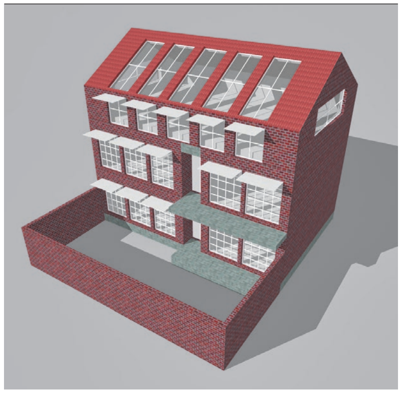
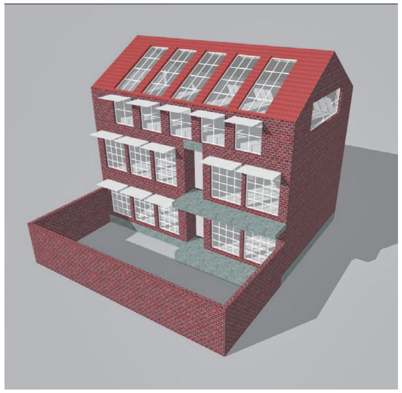
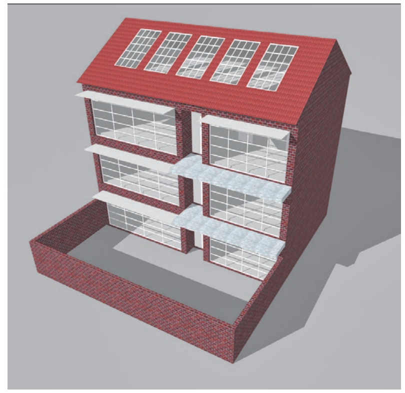
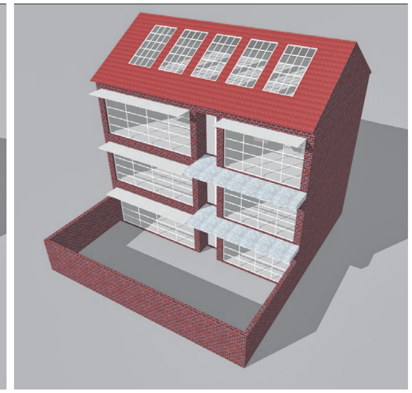
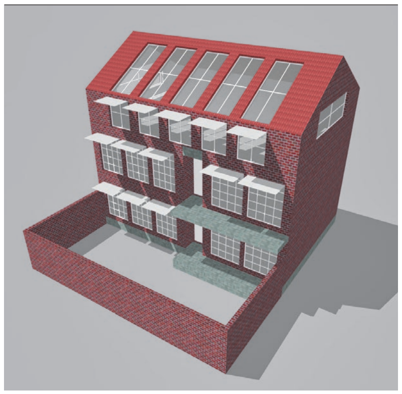
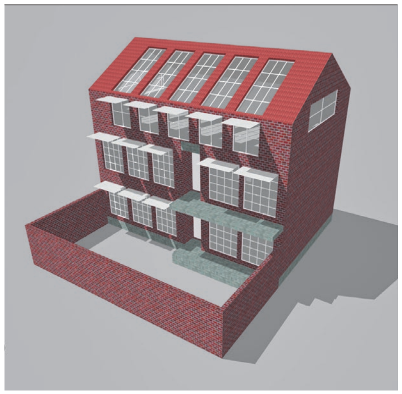
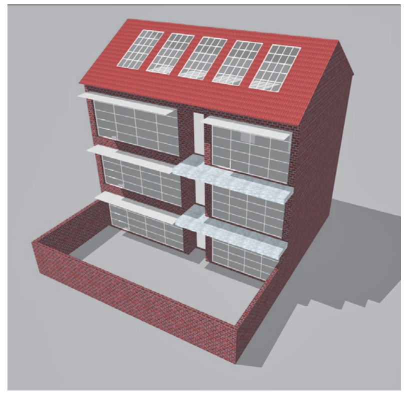
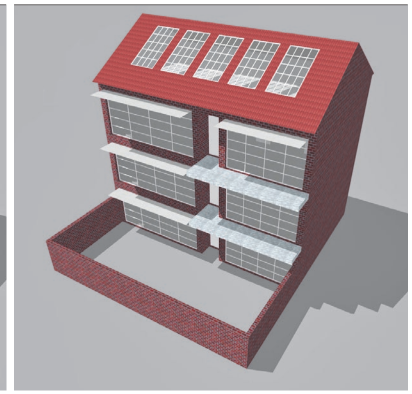
	2 (east-facing)	2 (1 storey)	2 (north-facing)	2 + without front door buffer zone
Heating	31.80	45.32	29.80	24.98
Cooling	30.49	12.98	22.72	21.26
Total	62.29	58.30	52.52	46.24
Primary	144.75	96.57	114.58	104.03

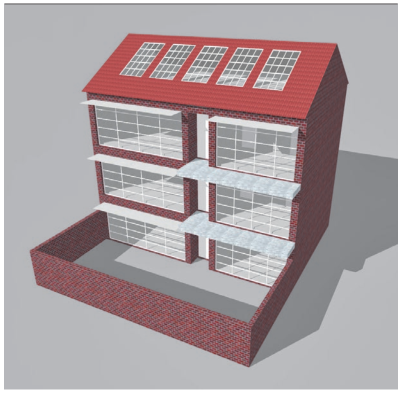
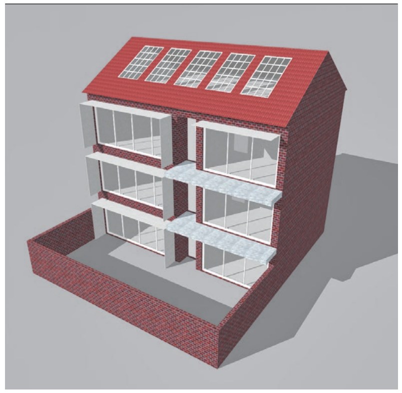
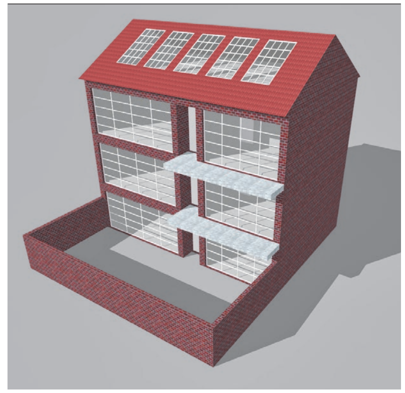
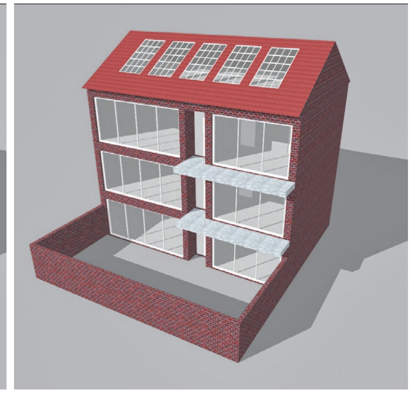
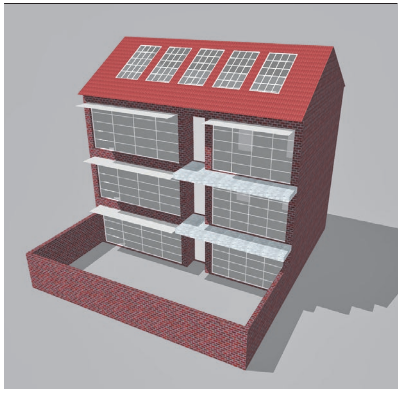
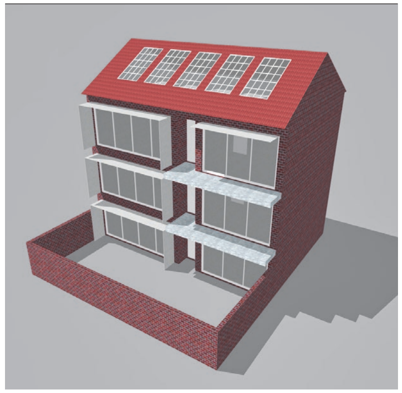
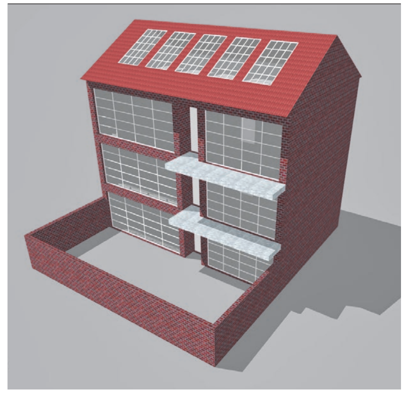
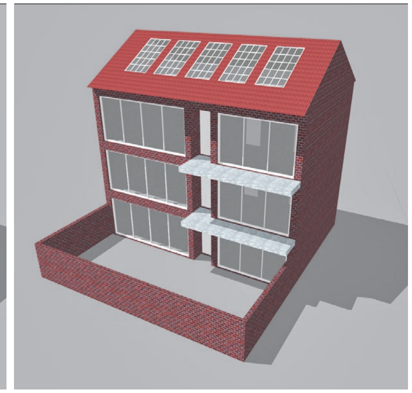
		2 + without full staircase	2 + without overhang	2 + without blinds	2 + with 0.5 m overhang
Perspective	Winter 15 Jan – 2:00 p.m.				
	Summer 15 Jul – 2:00 p.m.				
Architectural features (characteristics)		•• without staircase •• south-facing orientation •• big south-facing windows •• 1 m overhang •• internal blinds	•• without overhang •• internal blinds •• south-facing orientation •• big south-facing windows	•• without blinds •• 1 m overhang •• south-facing orientation •• big south-facing windows	•• 0.5 m overhang •• internal blinds •• south-facing orientation •• big south-facing windows
Energy Demand kWh/m²a	Heating	23.75	17.63	22.22	21.15
	Cooling	21.79	26.68	21.40	22.38
	Total	45.54	44.31	43.62	43.53
	Primary	104.58	115.44	101.48	103.84

2 + with big south-facing windows	2 + without overhang & blinds	2 (6 storeys)	2 + on ground level	
				Winter 15 Jan – 2:00 p.m.
				Summer 15 Jul – 2:00 p.m. **Perspective**
•• south-facing orientation •• very big south-facing windows •• 1 m overhang •• internal blinds	•• south-facing orientation •• big south-facing windows •• without overhang •• without blinds	•• south-facing orientation •• big south-facing windows •• 6 storeys •• 1 m overhang •• internal blinds	•• south-facing orientation •• big south-facing windows •• on ground level •• 1 m overhang •• internal blinds	**Architectural features** (characteristics)
18.91	16.10	18.34	15.71	Heating
24.54	27.15	21.02	19.77	Cooling
43.45	43.25	39.36	35.48	Total
144.75	96.57	114.58	104.03	Primary

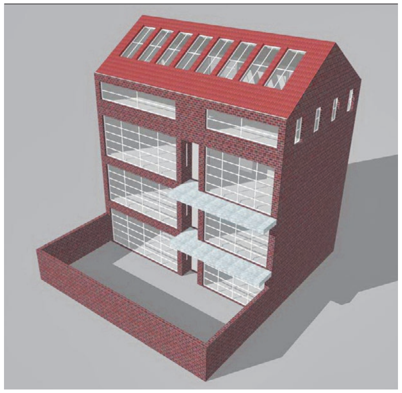
Energy Demand kWh/m²a

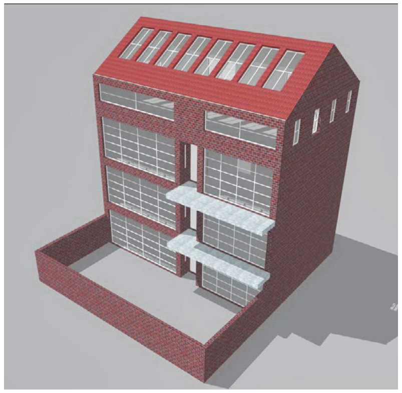
	2 + 1 m below ground	2 + on ground level (short walls)	2 + with pitched roof (3)	3 + with skylight (4)
Perspective Winter 15 Jan – 2:00 p.m.				
Perspective Summer 15 Jul – 2:00 p.m.				
Architectural features (characteristics)	•• south-facing orientation •• big south-facing windows •• 1 m below ground •• 1 m overhang •• internal blinds	•• south-facing orientation •• big south-facing windows •• on ground level •• low courtyard walls •• 1 m overhang •• internal blinds	•• south-facing orientation •• big south-facing windows •• pitched roof •• uninhabited attic •• 1 m overhang •• internal blinds	•• south-facing orientation •• big south-facing windows •• pitched roof •• uninhabited attic •• skylights •• 1 m overhang •• internal blinds
Energy Demand kWh/m²a — **Heating**	**15.16**	**15.46**	**23.79**	**23.43**
Cooling	**20.27**	**19.96**	**21.22**	**21.60**
Total	**35.43**	**35.42**	**45.01**	**45.02**
Primary	**89.65**	**88.86**	**102.56**	**103.52**

	4 + with attic unit & big skylight (5)	5 + with controlled blinds	building 6	6 + with external blinds (7)
Perspective – Winter 15 Jan – 2:00 p.m.				
Perspective – Summer 15 Jul – 2:00 p.m.				
Architectural features (characteristics)	·· south-facing orientation ·· big south-facing windows ·· third floor attic apartment ·· inhabited attic ·· big skylight ·· 1 m overhang ·· internal blinds	·· south-facing orientation ·· big south-facing windows ·· third floor attic apartment ·· inhabited attic ·· big skylight ·· 1 m overhang ·· external, highly reflective, sensor controlled blinds	·· south-facing orientation ·· very big south-facing windows ·· on ground level ·· pitched roof ·· uninhabited attic ·· skylight ·· 1 m overhang ·· internal blinds	·· south-facing orientation ·· very big south-facing windows ·· on ground level ·· pitched roof ·· uninhabited attic ·· skylight ·· 1 m overhang ·· external blinds
Energy Demand kWh/m^2a – Heating	20.05	19.76	10.84	14.19
Cooling	47.55	44.23	24.65	21.91
Total	67.59	63.99	35.49	36.10
Primary	193.22	180.98	100.66	94.49

		7 + with controlled blinds (8)	8 + fins	8 + without overhang (9)	9 + with high reflective blinds
Perspective	Winter 15 Jan – 2:00 p.m.				
	Summer 15 Jul – 2:00 p.m.				
Architectural features (characteristics)		•• south-facing orientation •• very big south-facing windows •• on ground level •• pitched roof •• uninhabited attic •• skylight •• 1 m overhang •• external sensor controlled blinds	•• south-facing orientation •• very big south-facing windows •• on ground level •• pitched roof •• uninhabited attic •• skylight •• 1 m overhang •• external sensor controlled blinds •• 1 m side fins (south-facing windows)	•• south-facing orientation •• very big south-facing windows •• on ground level •• pitched roof •• uninhabited attic •• skylight •• without overhang •• external sensor controlled blinds	•• south-facing orientation •• very big south-facing windows •• on ground level •• pitched roof •• uninhabited attic •• skylight •• without overhang •• external, highly reflective, sensor controlled blinds
Energy Demand kWh/m²a	Heating	9.49	11.35	5.51	6.15
	Cooling	20.96	22.06	25.40	28.39
	Total	30.45	33.41	30.91	34.54
	Primary	85.88	91.90	97.51	108.96

9 + with N+E+W windows (4 storeys)

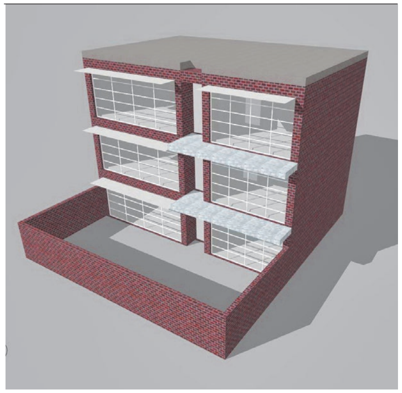


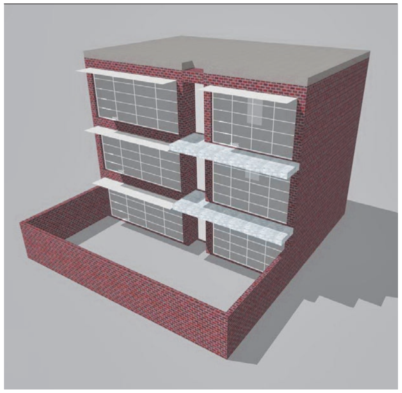


- south-facing orientation
- very big south-facing windows
- on ground level
- fourth floor attic apartment
- inhabited attic
- 4 storeys
- east and west-facing windows
- skylight
- external sensor controlled blinds
- without overhang

21.59
34.55
56.14
148.12

8 + with flat roof (10)





- south-facing orientation
- very big south-facing windows
- flat roof
- on ground level
- 1m overhang
- external sensor controlled blinds

21.59
34.55
56.14
148.12

4.2. Primary energy demand of simulated buildings

Natural gas and electricity is predominantly consumed in Iran for heating and cooling respectively. The same energy carriers have been applied for the heating and cooling of the tested buildings. As in 2009, 97.6% of electricity in Iran was generated from fossil fuels (56.8% from gas and 40.8% from oil (Iran Daily, 2011)) and the efficiency of power plants is less than 40% (Press TV, 2011), electricity must take on a more important role than gas in the analyses. For the same reason, electricity is more expensive and emits more greenhouse gases than natural gas. Therefore, from an ecological and economic point of view, the primary energy demand is a more meaningful criterion in the analyses. Primary energy consumption refers to the direct use of energy at the source, or supplying users with crude energy which has not been subjected to any conversion or transformation process (IEA, 2013).

In Iran, the primary energy factor for natural gas is 1.1; for electricity it is 3.6. The primary energy for heating and cooling the simulated buildings is presented in the following diagram. It shows that the primary energy demand differs according to the building and that the most efficient building's primary energy demand is 55.9% lower than that of the least efficient building. The most efficient building with the lowest primary energy demand is the upgraded building (Building No. 10); the least efficient building is Building No. 5. It has large skylights and therefore a large amount of solar heat gain in summer. To reduce the significant heat loads, the cooling energy demand is increased, which is multiplied by the high primary energy factor of electricity (see Fig. 7).

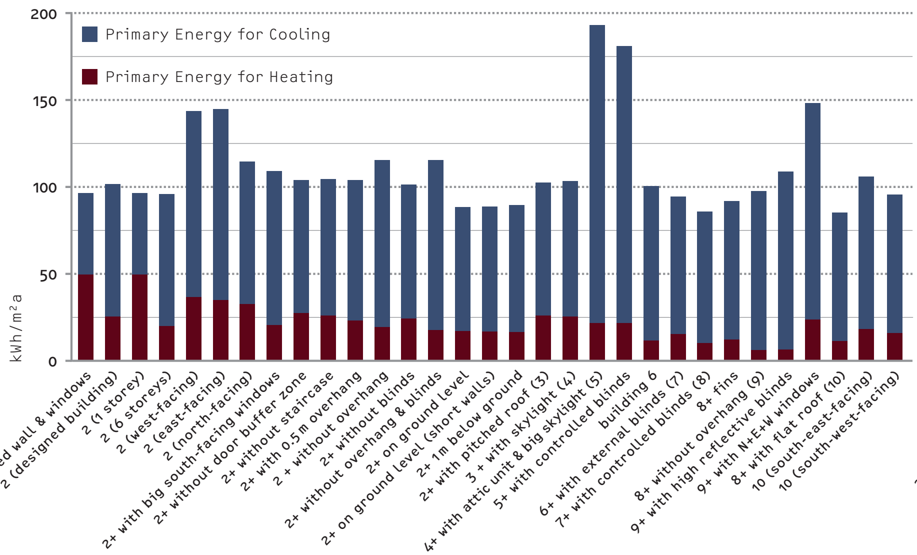


Fig. 7: Comparison of the primary energy demand for heating and cooling in buildings examined with the same construction materials

4.3. Comparison of Building No. 2 and similar buildings

The following diagram compares Building No. 2 with similar ones in their heating, cooling and total energy demand (see Fig. 8). It shows that:

- By increasing the number of storeys, the amount of energy expenditure is reduced
- The orientation of the building, the elongation and the surface area of windows facing in every direction affect the energy consumption significantly. Of the four cardinal directions, south is the most appropriate for buildings in Tehran.
- By increasing the amount of south-facing window area, the cooling energy demand increases. However, the heating energy demand is reduced in winter and therefore the total energy consumption.
- Thermal buffer zones at exterior doors reduce energy consumption.
- Locating the building on the ground, i.e. not raised, or even part of the building below the ground reduces energy consumption.

4.4. Comparison of Buildings No. 3-10

Figure 9 compares the heating, cooling and total energy demand of buildings 3-10 with the same construction materials, but different architectural designs.

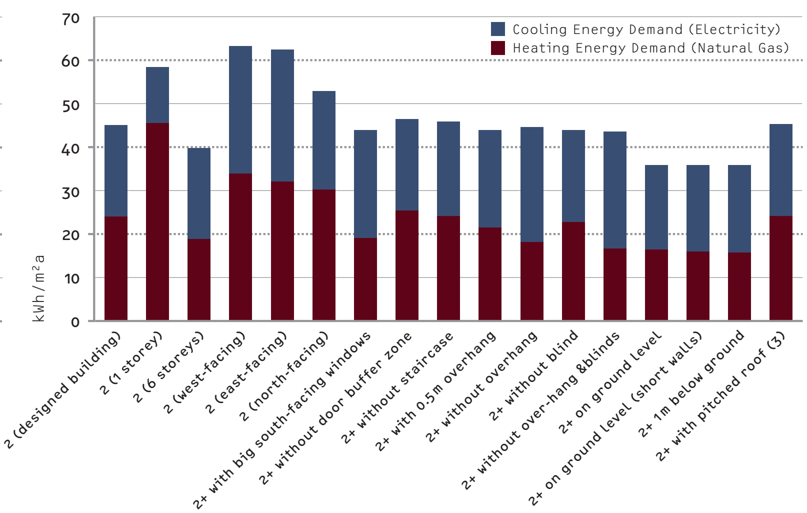


Fig. 8: Comparison of the heating and cooling energy demand between Building No. 2 and similar buildings

The diagram illustrates that:

- *Building 3 and 4:* The building with skylights and internal blinds incorporated in the pitched roof with uninhabited attic space, has approximately the same energy demand as the same building without skylights. Therefore, skylights with internal blinds have little effect on the energy consumption.

- *Building 4 and 5:* Large skylights (without shading devices) in pitched roofs with attic apartments lead to a smaller heating energy demand, but greater cooling energy demand and thus increase the total energy demand of the building significantly.
- *Building 5 and similar:* External blinds (controlled according to cooling and heating requirements) reduce both the heating and cooling energy consumption of the building. Controlled external blinds lower the cooling energy demand since they decrease the solar heat gain in cooling periods and decrease the heating energy demand in winter. This is achieved by closing the blinds and preventing the radiation of heat (long-wave energy) to cold exterior zones during winter nights.
- *Building 6 and 7:* Despite the fact that closed external blinds (or blinds which are not controlled according to the heating and cooling requirements) reduce the cooling energy demand, they simultaneously increase (to a greater degree) the heating energy demand and thus the total energy consumption. In comparison to internal shading devices, external shading devices are more effective in reducing the cooling energy demand.
- *Building 7 and 8:* By controlling the blinds according to the cooling and heating requirements, energy consumption is reduced significantly (especially heating energy). The opening and closing of blinds according to the requirements during different seasons, day and night, is a crucial factor in lowering the energy consumption of buildings.
- *Building 8 and similar one with side fins:* The use of side fins at south-facing windows with external blinds increases the energy consumption.
- *Building 8 and similar one without window overhangs:* By using 1 m deep window overhangs at south-facing windows, which are also equipped with external blinds, the cooling energy demand is reduced, but the heating energy consumption is increased. The total energy consumption is lowered slightly. Because the cooling of buildings is more difficult and more expensive than heating, the use of overhangs above south-facing windows is recommended, even if the windows are equipped with external blinds. Since overhangs do not need to be adjusted by the inhabitants, they are even beneficial without being controlled. The dimensions of overhangs must be calculated with regard to the window dimensions.
- *Building 8 and 10:* By developing a pitched roof over a flat roof, the heating energy decreases slightly and the cooling energy increases. The total energy consumed for heating and cooling is lowered slightly. Because the effect of the pitched roof in decreasing the energy consumption is so slight, it is, for economic reasons, recommended to use a flat roof.
- *Building 9 and similar ones:* North, east and west-facing windows in buildings with a large proportion of south-facing windows and highly reflective blinds increase the energy consumption of the building.

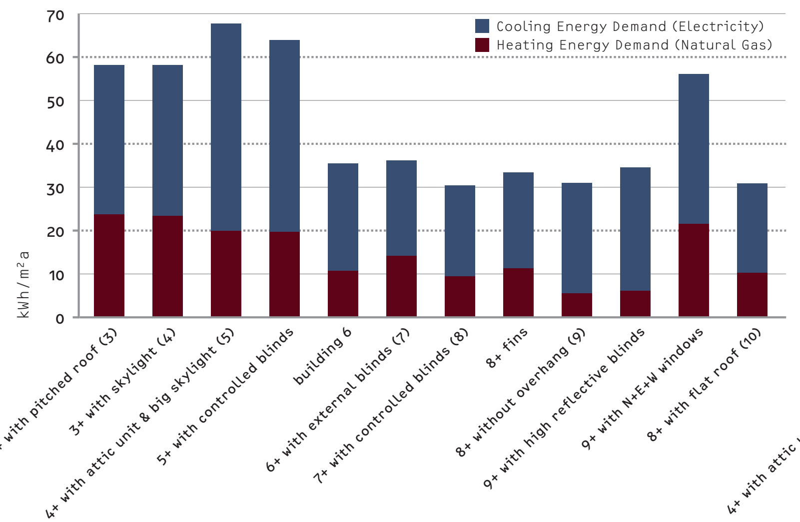


Fig. 9: Comparison of the heating and cooling energy demand of buildings No. 3–10

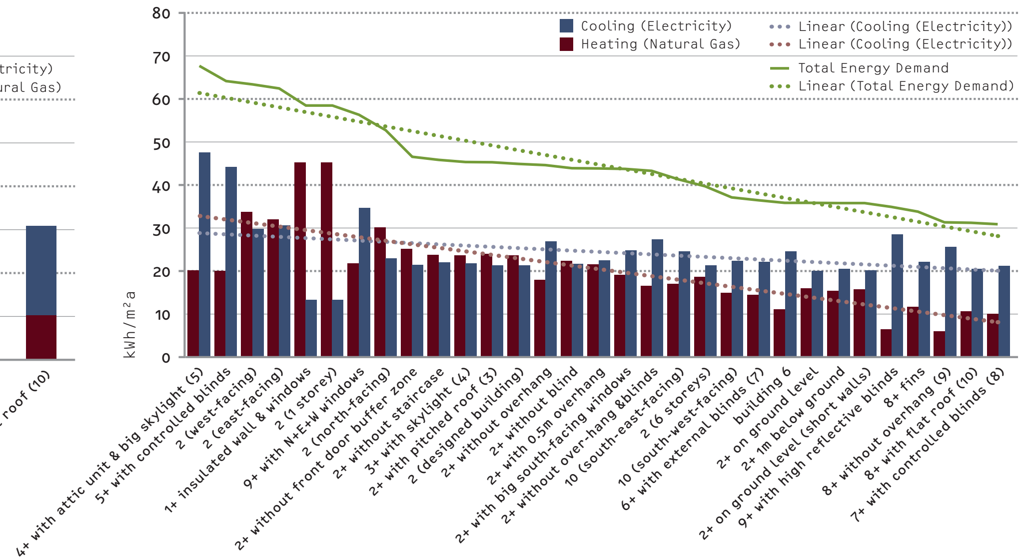
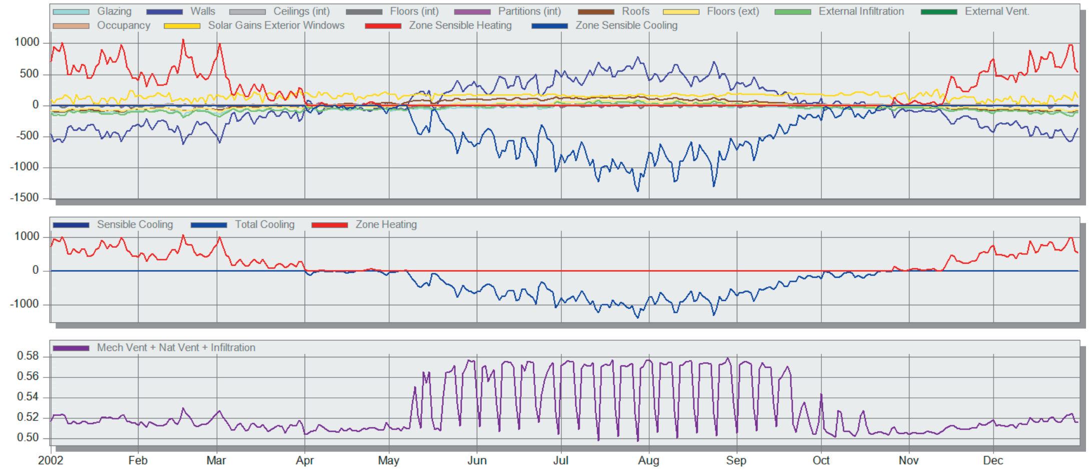


Fig. 10: Behaviour of heating and cooling energy demand for reducing the total energy demand of buildings

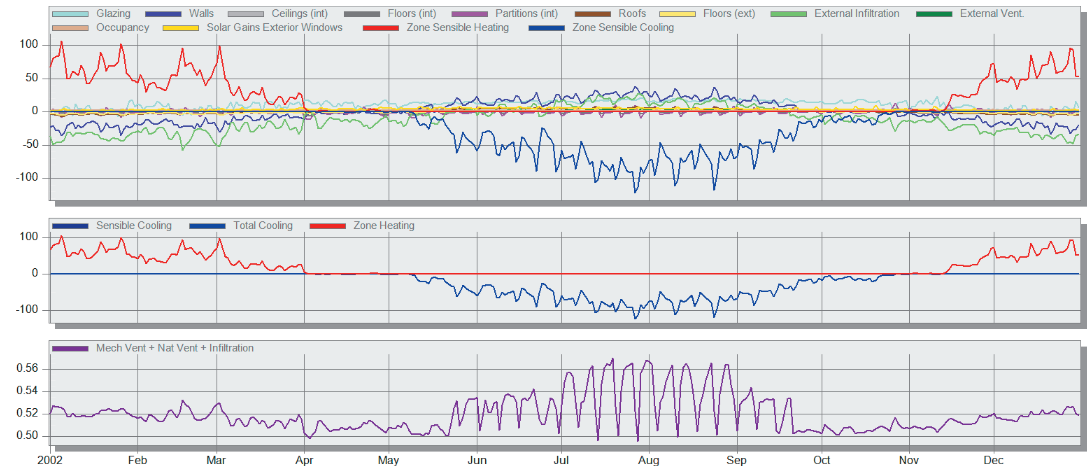
4.5 Comparison of the heating and cooling energy demand in buildings

Figure 10 shows that, when the total energy demand is reduced in the simulated buildings, the amount of heating energy decreases more than the cooling energy, which means that the difference between the heating and cooling energy is also decreased. By decreasing the heating energy, the total energy demand is also decreased. If the cooling energy demand of these buildings were reduced in the same way, the energy demand would

Typical Building with Uninsulated Thermal Envelope



Typical Building with Insulated Thermal Envelope



Energy-Efficient Building (Building No. 8)

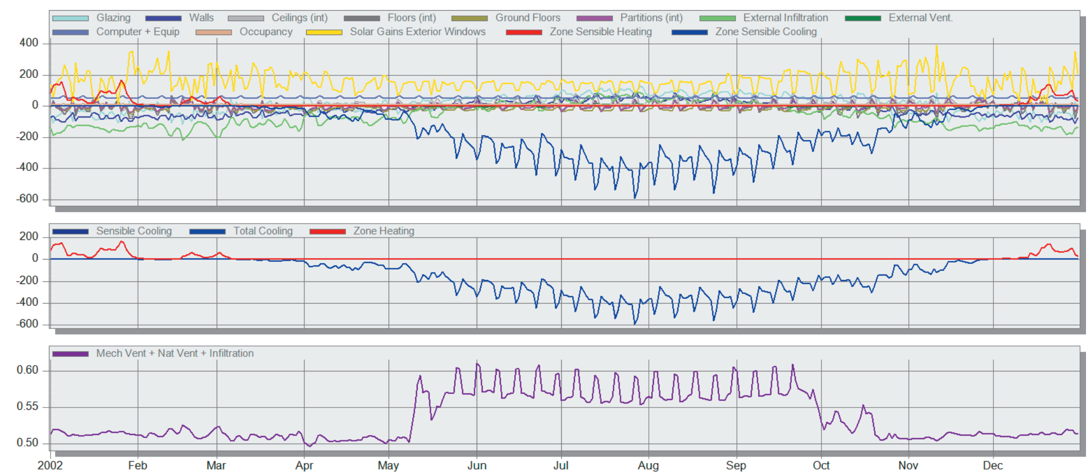


Fig. 11: Daily graphs of the heat gains, energy consumption (Wh/m²) and total fresh air (ac/h) in the typical building with and without insulated thermal envelope and the energy-efficient building

decrease even more effectively. Typical uninsulated buildings in Tehran consume 3.2 times more heating energy annually than cooling energy. On the other hand, the amount of cooling energy in insulated buildings is 1.2 times more than the energy required for heating. Possibilities to make passive use of solar energy for heating purposes have made it easier to decrease the heating energy demand than the cooling energy demand. Moreover, cooling is more expensive and more complicated than heating. It is therefore extremely important to consider cooling issues, especially in continental climates like Tehran, more thoroughly in energy-efficient buildings (see Fig. 12).

4.6. Comparison of the least and the most efficient buildings

The comparison of heat gains and energy requirements in the typical building without insulation (Building No. 1), the typical building with an insulated thermal envelope and the recommended energy-efficient building (Building No.8) shows that the heat losses and gains through glazing and walls are very high in comparison to other components. This highlights the importance of these factors for energy efficiency. The graphs on page 30 (see Fig. 11) show the daily heat gains and energy consumption of the typical building with an insulated thermal envelope and the energy-efficient design (Building No. 8).

Figure 13 compares the annual heat gains and losses through different architectural components of the typical house with an insulated thermal envelope and the well-designed building (Building No. 8) constructed using the same materials.

It indicates that air infiltration causes a high degree of heat loss in the insulated building. This finding underlines the importance of developing an airtight thermal envelope. The comparison shows that two factors, in particular, namely the heat loss and solar gain through windows, demonstrate the most significant differences. This suggests that, from the point of view of (both constructional and architectural) energy efficiency, the windows (and shading devices) are the most important building elements. In the recommended energy-efficient building, the solar heat gain through windows (50.33 kWh/m²a) is 5.3 times more than the natural gas consumption for heating (9.49 kWh/m²a), which highlights the importance of using the solar heat gain through windows for architectural energy efficiency.

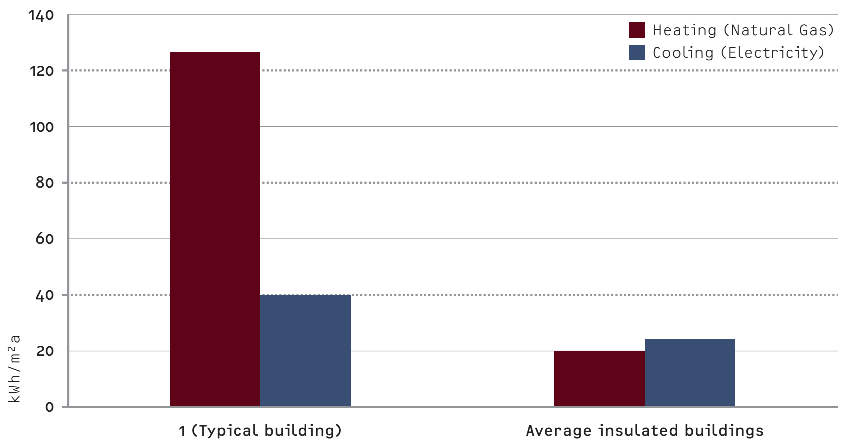


Fig. 12: Comparison of the heating and cooling energy demand in uninsulated and insulated buildings

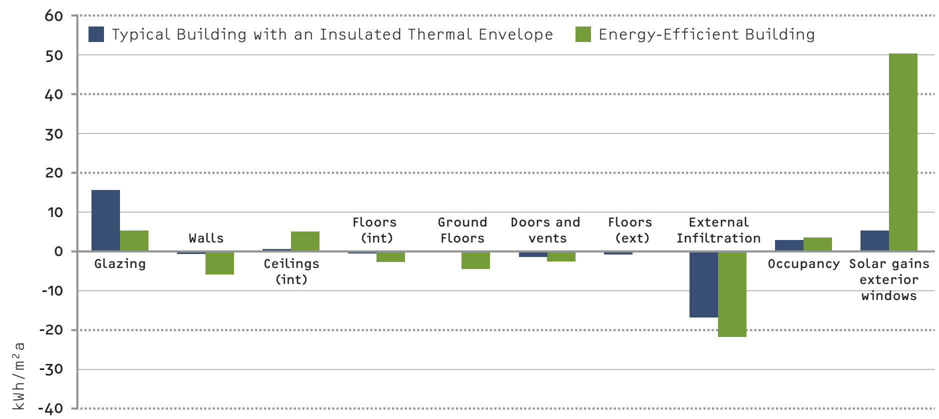
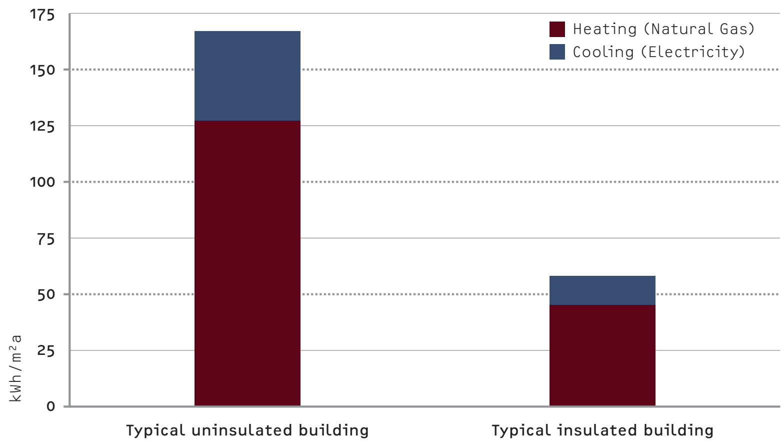
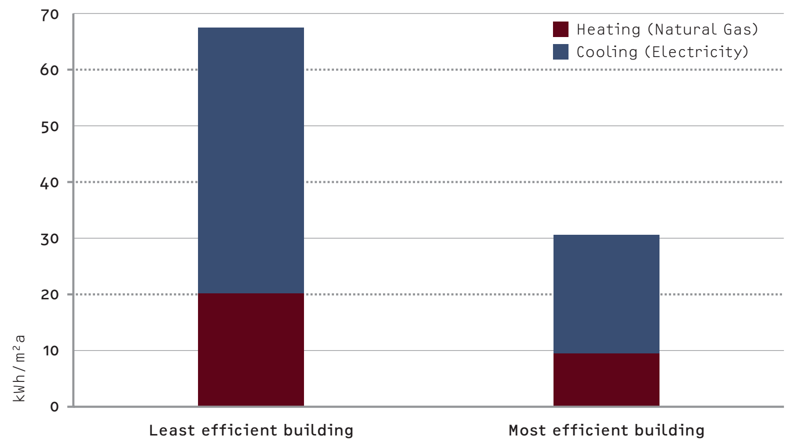


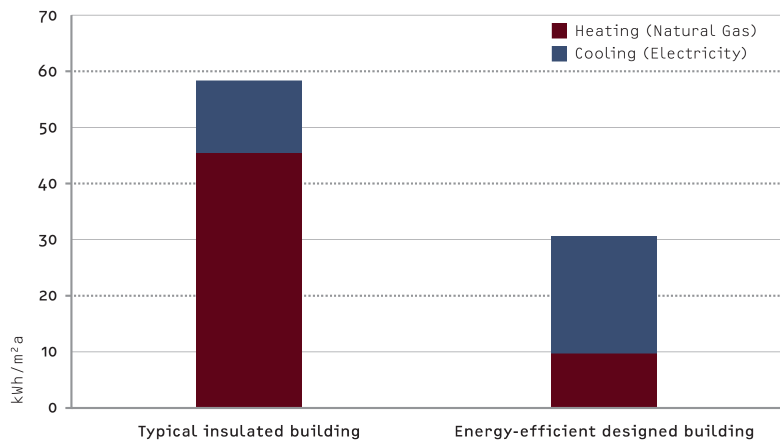
Fig. 13: Comparison of heat gain and heat loss in the typical and the energy-efficient well-designed building with the same construction materials

5 Conclusion

The difference between the energy demand of the typical building (Building No. 1) and the same building with an insulated thermal envelope is presented in the following chart. The energy consumption of this residential building in Tehran is decreased significantly[5] through the application of insulation material in the exterior walls[6] and the use of insulated windows[7]. The reduction of both the heating and cooling energy demand was in this case achieved by decreasing the U-value of the thermal envelope (see Fig. 14).







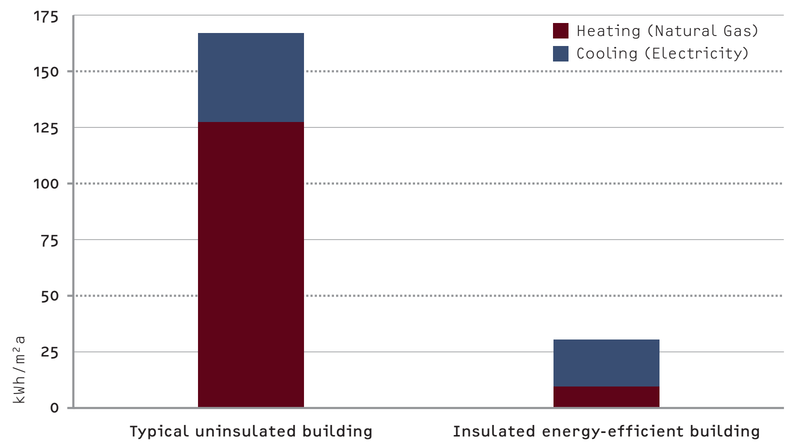


Fig. 14: Comparison of the heating and cooling energy demand in Building No. 1 with and without insulation | Fig. 16: Heating and cooling energy demand of the typical building (Building No. 1) and the most efficient building

Fig. 15: Heating and cooling energy demand of the least and the most efficient buildings | Fig. 17: Heating and cooling energy demand of the uninsulated Building No. 1 and the insulated upgraded Building No. 8

Simulations and analyses of the results show that architectural features have a great impact on the heating and cooling energy demand of residential buildings in the climate conditions of the Tehran region. Among all simulated buildings, the energy demand of the most efficient building is 48% less than the typical building (Building No. 1) and 55% less than the least efficient building in similar testing conditions and with the architectural design as the only variable factor. In the simulated buildings, the architectural design has reduced the energy demand of the building from 58.30 to 30.45 kWh/m²a. These results indicate the high potential of architectural energy saving in Tehran (see Fig. 15 and 16).

Figure 17 compares the energy demand of the typical building (Building No. 1) and the upgraded building with an insulated thermal envelope. The reduction of the energy demand is very high, particularly for the insulated, upgraded building. The energy consumption of our selected building in Tehran is reduced by about 81.8% due to the good architectural design and the insulation of the thermal envelope.

5.1 Results

Based on the simulations and the analyses, the following factors reduce the energy demand of buildings in Tehran:

- south orientation and east-west elongation
- increased amount of south-facing windows
- increased number of floors
- thermal buffer zones at front door
- avoiding the position of ancillary space (staircase, bathroom, WC, garage, etc.) in the south
- location of living rooms, which are used during the day, to the south
- setting the building on the ground or even a part of the building belowground level
- use of external rather than internal shading devices, especially adjustable shading devices
- control over the adjustable shading devices according to cooling and heating requirements
- use of overhangs with adequate dimensions for south-facing windows, including windows which have external blinds

The following factors increase the energy demand of buildings in Tehran:

- north, east and west-facing windows in buildings with large south-facing window areas
- skylights with internal blinds in pitched roofs with uninhabited attic space
- skylights without shading devices in pitched roofs with inhabited attic space
- large skylights in the pitched roofs with inhabited attic space, especially with shading devices that are not controlled according to heating and cooling requirements
- use of side fins at south-facing windows
- closed exterior blinds, or blinds which are not controlled according to heating and cooling requirements

5.1.1 Different architectural features and energy efficiency

In order to provide a brief overview of the study results, the findings are presented in tables. The following one presents the positive and negative effects of different architectural features in reducing the energy demand of residential buildings (see Tab. 4).

Feature			Effect
Orientation	south		++
	north		––
	east		––
	west		––
	south-east		+
	south-west		–
	north-east		––
	north-west		––
Elongation	east-west		++
	north-south		––
Increase of window area	south-facing windows		++
	north-facing windows	in buildings with a large area of south-facing windows	–
		in buildings with a small area of south-facing windows	––
	east-facing windows	in buildings with a large area of south-facing windows	–
		in buildings with a small area of south-facing windows	+
	west-facing windows	in buildings with a large area of south-facing windows	–
		in buildings with a small area of south-facing windows	+
	skylights	without shading device	–
		with internal shading device	–
		with external shading device	+–
Distance to ground	location of the ground floor level above the ground (raised)		–
	location of the ground floor level on the ground		+
	location of the ground floor level below the ground		++
Increase in the number of storeys			+
Thermal buffer zone at the front door			++
Shading devices	external	fixed	+
		adjustable	++
	internal	adjustable	+–
Compactness	decrease in the external envelope		+
	increased length of south-facing façade		+

Tab. 4: Effect of architectural features on the energy demand of residential buildings (++: very positive, +: positive, ––: very negative, –: negative)

5.1.2 Shading devices

Due to the importance of shading devices and the large variety available, the effects of different shading devices on reducing the energy demand of residential buildings in the climate zone of Tehran and similar are presented in Table 5.

Type of shading device			Window orientation	Effect
External	fixed[8]	horizontal	south	++
			north	–
			east	+
			west	+
		vertical	south	–
			north	+
			east	++
			west	++
	adjustable[9]		south	++
			north	+
			east	++
			west	++
			skylight	++
Internal	adjustable		south	+
			north	+
			east	+
			west	+
			skylight	+

Tab. 5: Effect of shading devices on the energy demand of residential buildings (++: very positive, +: positive, ––: very negative, –: negative)

5.1.3 Space arrangement

The space arrangement and the location of different rooms in a residential building is a key factor for architectural energy efficiency. However, space arrangement in residential buildings is also dependent on other factors, including the number and area of rooms, the size of the building (or the floor area of a building), etc. A precise suggestion for the arrangement of space from an energy efficiency point of view is not possible. Nevertheless, the space in a residential building can be arranged according to Table 6.

Orientation	Occupancy	Space
South	space occupied during the day	**living room**
		daily working area
	spaces used for long periods during the whole day and night	**kitchen and dining room** (only if they are used frequently (during the day))
North	unconditioned and buffer spaces	**garage**
		storage room
		staircase
	ancillary space, only used for short periods	**WC**
		kitchen
	space that is not used during the day	**bedrooms**
East	space that is not used during the day	**bedrooms**
	ancillary space and rooms which are only used during short periods	**kitchen**
		WC
		bathroom
West	ancillary space and rooms which are only used during short periods	**WC**
		kitchen
		bathroom

Tab. 6: Space arrangement for energy efficiency in residential buildings

1 The comfort zone is based on the ASHRAE Standard 55-2004 using a PMV model.
2 The floor area of the average and newly designed house is 91.69 m² per level and 275.07 m² in total.
3 In this study, the primary energy demand refers to the primary energy demand for heating (natural gas) and cooling (electricity).
4 The total energy demand in this study refers to the total heating and cooling energy demand.
5 65% for this example building
6 U-value $_{\text{Wall}}$: 0.25 W/m²K; U-value $_{\text{Roof \& Floor}}$: 0.15 W/m²K
7 U-value $_{\text{Glass}}$: 0.781 W/m²K, SHGC: 0.471; U-value $_{\text{Frame}}$: 3.633 W/m²K
8 The dimensions and projections of shading devices affect the energy demands of buildings.
9 The control of adjustable shading devices and being able to open and close them at the right time is the most important factor for reducing the energy demand of buildings. Adjustable shading devices which do not open and close according to heating and cooling requirements can sometimes even increase the energy demand of buildings.

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Figures

Tables

III

Energy-Efficient-Homes for the Shahre Javan Community

Designing energy-efficient architecture in an urban context

Philipp Wehage | Annette Wolpert | Elke Pahl-Weber, TU Berlin

Abstract

The concept for the Energy- Efficient- Homes is part of a holistic approach to develop urban structures with energy-saving features, high quality, low carbon emissions and affordable costs for middle and lower income classes.

The process of developing this concept includes a design for energy-efficient housing in an Iranian new town project with potential for mitigation in the region and climate adaptation. The method of developing a spatial concept according to the energy-relevant aspects of urban and architectural morphology and integrating it into the socio-cultural context of the "Shahre Javan Community" is designed to provide an economic strategy for a practical basic energy standard that has been adapted to the region. The courtyard housing scheme of the Energy-Efficient-Homes shows a new development derived from the vernacular approach of spatial hierarchy considering the major morphological aspects of orientation and compactness.

With the use of new technologies for energy efficiency, this basic standard of spatial organization and design can also be upgraded to meet higher standards.

Housing is the central, if not the original objective of architecture. The human need for a climate adapted envelope and the areal formulation of the smallest social unit has always followed specific social and spatial visions. In a fast growing society like Iran, the demand for mass produced housing requires efficient strategies for the planning and construction processes. These challenges in mind, a typological approach for the design of an energy-efficient housing architecture, that derives from the planning process directly, has been chosen as the appropriate method. This "research by design" method provides the opportunity to apply a typological approach to the development of an energy-efficient estate. The pilot area selected is the "Shahre Javan Community". Here, the "research by design" approach serves as a tool to develop design solutions that incorporate the urban context of the pilot area. Respecting the aims of the urban design and its relevance concerning the spatial arrangements for energy efficiency, the housing typologies follow the needs of the local culture, which means creating places for privacy in a compact urban context. The design of residential architecture is therefore the outcome of simultaneous aims, those for energy efficiency and those concerning the spatial need for privacy.

1.1 Goals and strategies

Supposing the general scientific principles for energy efficiency as well as the need for privacy applied in the pilot project are comparable to regional demands, then the design resulting in the "Shahre Javan Community" project does not just stand for this specific location. Despite the fact that design solutions are always connected with the "genius loci", these are in fact transferable to other regions in the Middle East as they respect the general climate conditions and the socio-cultural demand in the region. Geological (e.g. earthquake resistance) and geographical (e.g. topography) aspects that are specific to each site need to be reflected and adapted to local demands. Therefore, the aim of this typological work is not to give fixed answers for mass housing in the whole region, but to give a catalogue of planning measures and processes that can be adapted to specific applications and standards.

The research process involved in developing the energy-efficient architecture for the "Shahre Javan Community" pilot project is characterized by the relation between the general scientific principles (physical and technical) and the local and regional conditions (climate and site). The housing for Iran's new towns demands an analysis of the country's present situation in regard of urban design and architecture and the potentials of vernacular architecture for future developments in semi-arid regions. By analysing the spatial formulations of architecture and urban design regarding energy efficiency, it was possible to categorize suitable organizational forms. The energy efficiency value of the general architectural and urban findings on the site with its specific features concerning climate and topography has been adjusted to the socio-cultural context. The result of this research is formulated in a catalogue of architectural criteria as an approach for further design solutions.

1.2 Housing in the orient and Iran

1.2.1 Housing in the orient – tradition and today

In the architectural traditions of Iran and the Orient, a home is characterized by the demand for absolute privacy. Following the hierarchy of public and private space in urban designs, the following consequences can be outlined:

Integrated in the hierarchical definition of space, the house represents the final step into the private realm (Wirth, 2000, p. 325 ff). The introversion of the traditional courtyard house is one spatial expression of the need for tranquillity and intimacy. This hierarchical system of space in urban designs is accepted and also pursued in the organization of the house. Areas for access, guests, services and family-life are integrated in a well-defined floor plan around one or several central courtyards which form the centre of the house (Edwards et al., 2006, p. 21ff). The layout illustrates the hierarchical system from public to private areas inside the dwelling (Bianca, 1991, p. 196ff). The open spaces attached to the courtyard houses, such as access paths, are minimized as the focus is on the spatial quality of private space inside the house. The introverted housing scheme allows for a climate-sensitive urban arrangement, which is characterized by compactness through the attachment of units in closed coverage. Elements for ventilation, such as wind towers, optimize the climate conditions, especially in hot arid regions (Edwards et al., 2006, p. 155 ff.).

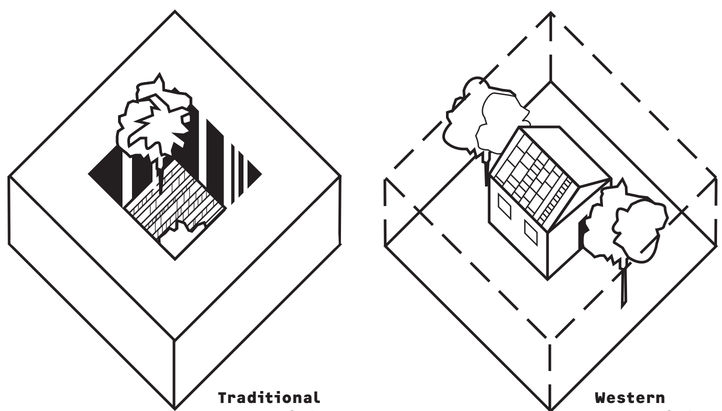


Fig. 1: The sense of place according to S. Manzoor

The adaptations of modern housing typologies in the 20th century have transformed the dwelling into an extroverted volume in a Western style. The definition of space, as known in the introverted traditional style, has been turned inside out. This break in tradition has made available the advantage of exposition to light and air on the outside by opening up the façades, and therefore the possibility of creating multi-storey buildings.

The former organizational scheme of the neighbourhood has been transformed – from a horizontal to a vertical arrangement. The consequence is that the inhabitants have to react by defining a new spatial organization or by changing their habits. The stairway, for example, has been transformed into a vertical "dead end" and defined as a semi-private space according to Islamic tradition (Wirth, 2000, p. 398ff).

But the separation between private indoor and public exterior space was disturbed by opening up the façades. The informal result of this spatial turn-around is that the apertures are now covered up with curtains. The private open areas attached to the façades and facing onto the streets, such as gardens, balconies and loggias, are not frequented due to their visibility from the public space and have therefore developed a backyard character. They are often used for storage or technical supplies (e.g. air conditioning equipment). On an urban design level, this relation of the façade to the exterior creates relic open spaces in the Islamic regions of the Orient (Diba, 2002).

The extroverted housing schemes in new towns often apply linear building arrangements, comparable to housing developments in the Western world. The broad and wide linear urban space between the building volumes appears as a relic negative space with a lack of quality, because there has been no cultural adaptation.

Fig. 2: Housing blocks in Hashtgerd NT – view from the south

Fig. 3: Housing blocks in Hashtgerd NT – site plan

The contradiction between privacy according to a traditional Islamic understanding and the Western-style vertical housing typology has not yet been addressed, neither the urban principles of developments in new towns nor in the renovations of existing structures in the large cities like Tehran or Karaj.

1.2.2 Housing in Hashtgerd New Town

The common housing typology for the medium density of Hashtgerd New Town is based on the orthogonal layout of the urban masterplan (Wehage et al., 2012, p. 39ff). This system orients buildings in a north-south direction, such that access to the buildings is either from the north or the south. The plots are arranged in a rectangular layout without regard to topography. The common plot width is 15 to 18 m. The common plot area is about 600 m². The position of the building volume on the plot is defined by regulations on distance, which are based on light exposure, privacy aspects and regulatory plot coverage. Ignoring light orientation, the staircases are often positioned in the street-side façades. This type of attached building ("closed coverage type") leads to a linear structure of building volumes. The linear arrangement of buildings leads to uniform linear open spaces oriented towards the public and private sides of the houses (Fig. 2-3). The only spatial measure for defining the private open space is the enclosure of the plots with walls. Thus the spatial boundaries of the north-south oriented open spaces, e.g. streets and parks following the topography, are not properly defined. Furthermore, the ends of the linear building structures are simply cut off with a closed shear wall, lacking any architectural corner design.

1.3 Energy-efficient urban design and architecture

The position and configuration of the building volume and its orientation to the sun is an important factor for energy-efficient architecture. Because of its relevance concerning the spatial organization on an urban scale, defined for example by access situations and morphological settings, the position in the urban fabric must be considered.

The main aspects of the urban context are determined by the orientation, as a factor for passive energy gain, and the compactness, as a factor for minimizing energy loss through the thermal envelope (Hegger et al., 2008, p. 62ff).

The ideal volume for the use of solar incidence, as the main passive energy yield, is characterized by a glazed façade for all main rooms oriented to the south and a more closed façade to the north enclosing secondary rooms. The north-south orientation leads to large areas with an east-west direction and small depths in the north-south direction. It is for this reason that this layout is not practical for compact urban schemes.

The courtyard houses in Iran are traditionally located in arid and semi-arid regions. The compact urban form of courtyard houses guarantees good climate conditions inside the buildings. Only selected rooms and spaces are oriented to the sun. The use of these areas depends on the heat impact of the sun. Special (often temporary) functions make use of the solar heat input in winter. The compact, almost closed volumes, ensure a more constant micro-climate in contrast to the considerable daily and seasonal fluctuations on the macro-level outside.

To improve the micro-climate in high density areas, traditional elements, such as air circulation by making use of vertical shafts or shady courtyards with plants or water basins, can be used as vernacular low tech devices for better energy efficiency.

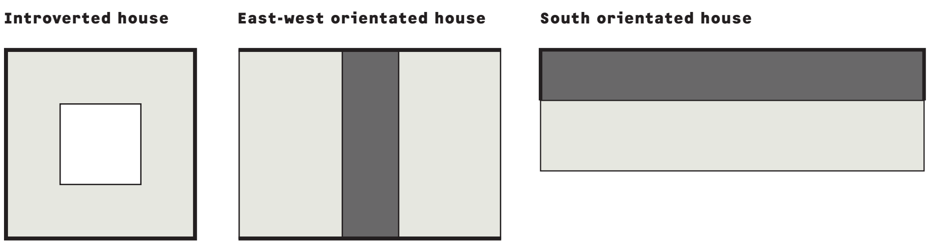


Fig. 4: Housing typologies and energy efficiency

1.4 The climate context

The semi-arid climate in the region of the pilot project is characterized by warm and dry summer periods, with extreme temperatures of more than 35°C during the day and colder and more humid winters with occasional frost periods (FU Berlin, 2010). Because of the extreme seasonal temperature range, energy for cooling as well as heating is required to provide thermal comfort in the building. The significant difference between the day and night-time temperatures of up to about 16°C is also characteristic of the local climate. In the context of the urban configuration and climate of the "Shahre Javan Community" site, the following findings regarding energy-efficient aspects are outlined:

The linear arrangement of the existing housing typologies in Hashtgerd New Town and the maximization of south-oriented façades is a good approach for the use of passive solar energy. The need for privacy however contradicts the need for opening up the façades, and the greater consumption of land demanded by such typologies conflicts with energy objectives on an urban scale. Furthermore, the high demand for cooling energy in summer needs to be considered in the architectural design.

The compactness of traditional courtyard housing schemes in dense urban layouts avoids energy loss for heating and cooling via the thermal envelope. The shaded courtyards and their micro-climates produce thermal comfort and air circulation according to the building morphology. The solar heat gain in winter periods is restricted to south oriented subzones. The introversion of this typology respects the demand for privacy.

The chosen research methodology for the Energy-Efficient-Homes is performed for a residential pilot project in the “Shahre Javan Community” area in Hashtgerd New Town. To ensure the appropriateness to the pilot project, the methods of research are integrated in a planning process. The method suitable for combining scientific and planning results is the research by design process. In a systematic work process, the findings of a general approach and specific design allow for the evaluation and definition of further steps. By applying this scenario-specific methodology for architectural and urban design suppositions, that have been obtained from a general approach, to real planning situations, the assessment can be performed on different scales. Finally, the results gathered in the design process are used to revise the formulation of the initial approach.

The data collection process and the analysis of preconditions for the task “energy-efficient housing” is characterized by general dimensions (e.g. general aspects for energy efficiency and volumetric matters) and specific dimensions (e.g. site and socio-cultural context). The influence of general and specific aspects enables the transferability of the results to a general dimension (e.g. energy efficiency through spatial design) and a specific dimension (e.g. climate and social adaptation). The graphic shows the research by design process with the design and examination steps in a linear arrangement. The final step shows the conceptual design for one urban unit in the pilot area as a standard definition and design solution for application in the “Shahre Javan Community” context (see Fig. 5).

2.1 Energy-Efficient-Homes in the “Shahre Javan Community” – parameters of influence

The development of housing design solutions is affected by several groups of parameters: spatial, social, economic and technical.

The different groups of parameters function as tools for the assessment. The influential degree of each parameter group on the final design solution is the result of their consideration, discussion and integration in the design process. Several parameters can influence different groups (for example orientation as an aspect of urban design as well as energy efficiency). This highlights the complex relations and influences amongst the groups. They should never be seen isolated. Thus, the design for the architecture of housing typologies is the result of an integrated planning process.

Following the approach that every architectural design is part of an urban configuration, the influences of general dimensions on the architectural design solutions has to be proved by specific site characteristics and conditions. The discussed requirements for the Energy-Efficient-Homes in the “Shahre Javan Community” have led to the following parameter groups:

Urban design

The first group of parameters describes the influence of the urban design:

In continuation of the urban design criteria established in the project pre-phase, the typologies must follow the urban morphology. The architecture of housing typologies is directly influenced by the determination of urban design features with a technological and socio-cultural background. The “hard facts”, such as the access system, the technical infrastructure, the plot orientation and the design requirements to avoid earthquake hazards are preconditions for the site.

The so called “soft facts”, such as identity, flexibility or the implementation of mixed-use schemes, should be integrated in the development of housing typologies and are defined by the spatial measures of architectural and urban design. They establish the ‘sensuous’ dimension of architecture.

Users and codes

The second group is characterized by the analysis of users and stakeholders. It determines the requirements in a technical and spatial dimension. Building codes, technical principles, materials, the demand for energy efficiency, as well as local and regional specifications and urban design preconditions are analysed in an integrative process with the project partners.

The analysis of users, in the sense of a target group, helps to define the technical requirements in a socio-economic context and encourages the image and marketing strategies of the design.

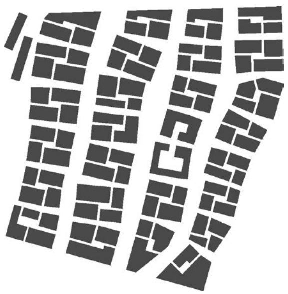
Energy efficiency

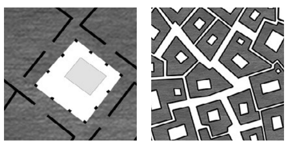
The third group defines aspects of energy efficiency. Several aspects can be derived from the urban design, like the orientation of volumes or technical basics, which again define the strategy on a building scale. Following the need for energy efficiency, aspects such as the surface-to-volume ratio and the floor-organization influence the building design directly. The technical standard of energy efficiency (‘high tech standard’ or ‘low cost standard’ as possible benchmarks) depends on the preconditions of the local and regional situation.

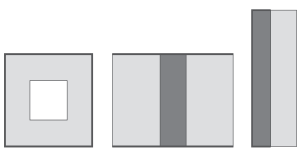
Sense of place and vernacular architecture

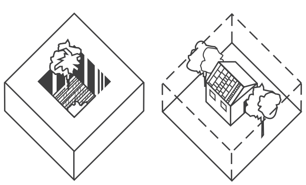
The fourth dimension is developed according to the research on vernacular architecture and urban design. It shows the socio-cultural dimension of architecture. Traditional Iranian urban and housing designs support the building typology following energy-efficient urban design criteria. The understanding and use of space from public to private areas and vice versa influences traditional Iranian cities. The compact form is one approach for the creation of energy-efficient housing typologies and an identity of space.

Input from analysis









Parameter

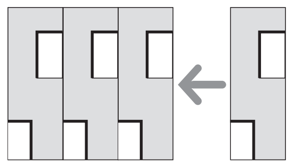
Urban design

Users and codes

Energy efficiency

Sense of place

Design approach



Criteria

Definition
of access system and urban morphology

Adaption
to site and topography

Ground Floor
with mixed-use potential

Spatial hierarchy
from public to private

Potentials
multi-floor courtyard house

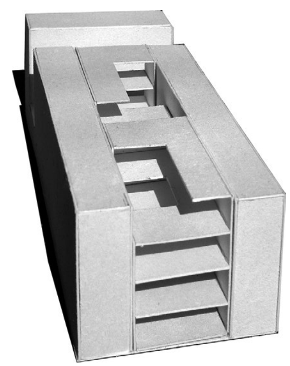
Orientation
Of volumes and surfaces

Application
Of simple constructions

Energy Efficiency
as a result the architectural design

Architectural concept
as an expression of identity

Design concept



Design measures

Orientation + dimension
- Optimize sun orientation through sculptural modelling
- Possible vertical organization of units in building volumes
- Closed coverage in an east/west direction
- Façade openings to exterior space in N and S

Organization + structure
- Modular space system as structural pre-condition for functional and constructive organization
- Vertical continuity for provision of economic and simple construction methods

Access + vertical connection
- Entrance from path
- Provision of additional entrance from garage
- Provision of central stairway inside the volume

From public to private
- Potential commercial unit and entrance hall on ground level accessed from path
- Semi private stairway
- Graduation of privacy inside unit through organization around courtyard

Variety + flexibility
- Horizontal organization for small units
- Vertical organization for big units
- Morphological variety through sculptural modelling of upper floors

Design study sub-neighbourhood

Adaptive measures

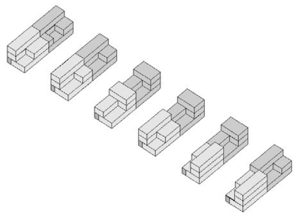
Site adaptation
- Choice of type
- Morphological variety through plot layout and dimension
- Morphological variety through sculptural modelling of building volume based on modular space structure

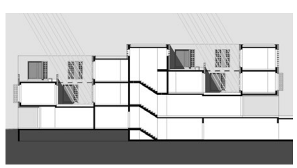
Functional adaptation
- Choice of type
- Access system
- Use (mixed use/housing)
- Vertical or horizontal floor organization
- Variety of floor plan layout

Standard adaptation
- Choice of type
- Construction and materials
- Facade structure and design
- Energy efficiency
- Supporting systems
- Interior arrangement and equipment

Energetic adaptation
- Choice of energy system
- Supportive, energy-efficient measures on an urban scale
- Supportive, energy-efficient measures on a building scale
- Construction and materials
- Technological input

Typological catalogue and design scenarios





Innovations

Basic principle

Courtyard house
Resource protection through building configuration

Modular space
Cost and energy – efficiency through planning process

Upgrades

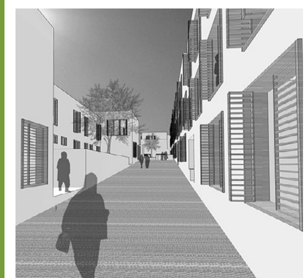
Sun shutters
Energy impact regulation through facade elements

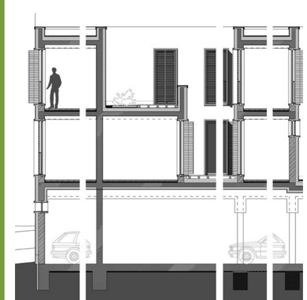
Light shelves
Energy gain through individual natural light and heat control

Photovoltaic fabric
Energy gain through individual control of natural light and heat

Geothermal energy and heat exchangers
Energy reduction through air-driven, combined heating-cooling-ventilation system

Design for urban unit





Conceptual design

Urban unit

Architectural plans
- Site adaptation to technological, functional and economical context
- Spatial organization of urban unit according to basic principle
- Spatial integration of innovative upgrades
- Spatial organization of floor plans and apartment layouts
- Preliminary plans concerning construction and materials
- Preliminary plans concerning construction and materials
- Visualization of spatial and physical qualities
- Integration of energy efficiency concept on an urban and building scale

Perspectives
- Basis for tendering and execution planning
- Basis for construction and detail research
- Basis for adaptation to other sites in the Shahre Javan community
- Basis for mitigation in a regional context

Fig. 5: Design process of Energy-Efficient-Homes

The analysis of preconditions and the definition of requirements determine the influential framework of architecture. A certain vagueness in the formulation (e.g. target group) can be replaced by assumptions or as a safeguard for flexibility. Because this development of housing typologies is bound to the application on the ”Shahre Javan Community” site in Hashtgerd New Town, a “research by design” strategy was chosen for this specific scheme. In a first step, the morphological and functional demands, as a result of the research on energy efficiency and the urban design framework, were analysed and transferred into a design strategy.

The strategy represents the aim of combining the advantages of two main topics relevant for the energy efficiency in architecture and urban design: orientation and compactness. In a second step, strategies and measures for energy-efficient housing typologies specific to the site conditions were determined by adjusting the morphological study with the gathered groups of parameters. The identified criteria were put into a catalogue as a tool for the evaluation, adaptation and transferability of the site-specific design.

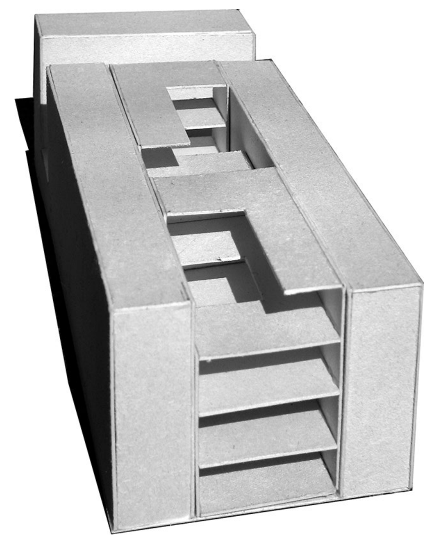


Fig. 6: Model study of energy-efficient housing in a compact urban form

3.1 Energy-efficient housing for a compact urban form

In order to ensure the ideal amount of sunlight in a horizontally organized apartment building, the distance between the urban volumes has to be enlarged. This however limits the density in a low-rise area.

Compactness, as the second most important factor for energy-efficient architecture and urban design, provides thermal comfort inside the building, but limits the use of passive solar energy due to the orientation of the volumes (Schramm, 2005, p. 79ff).

The volumes in the compact urban design scheme have to take advantage of their individual positions. The orientation is defined by access systems and plot design – parameters which are determined by the urban layout. A plot design with a north-south direction offers south-oriented buildings attached at the western and eastern sides of the plot. This volumetric organization guarantees south orientation for every plot, in particular if the compactness is maintained and the façade surfaces facing east and west are reduced.

To gain greater width in the south façade, “supplementary south-facing surfaces” can be produced by shaping the volume with courtyards and niches.

In addition, due to the vertical organization of dwellings with duplex or maisonette typologies, the floor organization can follow the demand of sunlight exposure. Rooms in need of direct sunlight, like major living areas, can be organized on the upper level and behind the “supplementary south-facing surfaces” in rear zones of the building volume. Sleeping or service areas need less direct sunlight and can therefore be arranged in darker zones.

This strategy makes use of both advantages, the energy savings achieved by reducing the cooling and heating loads through the compact form and the energy gains through solar energy input achieved by the supplementary south-oriented façades (Brunner et al., 2009, p. 42ff). Seen economically, the façade surface can be reduced by up to 30% by attaching

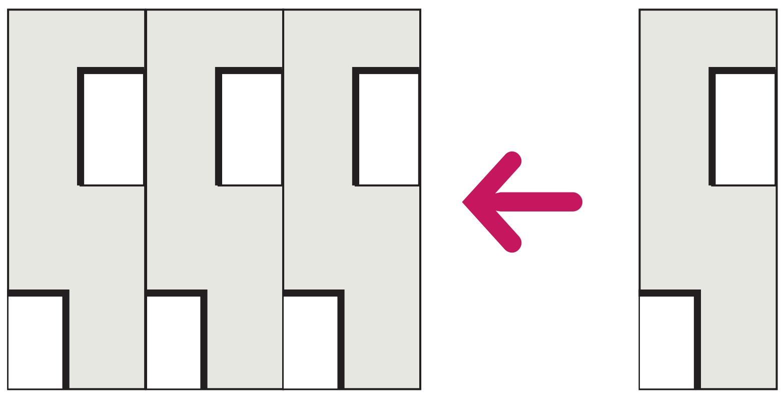


Fig. 7: Approach for energy-efficient housing in a compact urban form

compact building forms as described above. The result of this study can be seen as a contemporary and economic approach to vertically organized courtyard housing.

3.2 Criteria for energy-efficient architecture in the region

A criteria catalogue was compiled by analysing the parameter groups with regard to their morphological consequences. This catalogue helps to identify planning aspects for future evaluation, transferability and adaptation of the typological study. The criteria function as important indicators (tools) and, in total, as a task catalogue for design solutions.

3.2.1 Building criteria – strategy for designing housing typologies in the "Shahre Javan Community"

The combination and discussion of the aspects formulated by the parameter groups define the task of designing housing typologies for the "Shahre Javan Community". The result is a catalogue of 'building criteria' that describes a design strategy for energy-efficient architecture and the urban design of mass housing in a regional context. The criteria are named as follows:

Definition of access system and urban morphology
The typology must follow the urban design criteria. The process of designing the typology perpetuates the findings of the urban design and raises it to a more detailed level in terms of functionality and identity.

Adaptation to site and topography
The typology is adaptable regarding plot layout and topographical specifications.

Ground floor with mixed-use potential
As a provision for flexible use, the ground floor offers potential for different commercial functions with housing on the levels above.

Spatial hierarchy from public to private
This is the definition of a functional spatial design in a socio-cultural context. Design quality and its local acceptance is achieved through the adaptation of regional customs and traditions.

Potentials of multi-floor courtyard houses
Introversion as an expression of privacy and climate-friendly organization of volumes with regard to light exposure and quality of life.

Orientation of volumes and surfaces
Climate adaptation/optimization by adjusting building surfaces through architectural design (e.g. supplementary south-facing elements).

Application of simple constructions
Economic and ecological building constructions in consideration of the regional technological conditions. Design as a step towards efficiency.

Energy efficiency as result of the architectural design
Design as a strategy for energy efficiency. An integrated design approach instead of isolated technological optimization.

Architectural concept as an expression of identity
The architectural design in the urban context of the 'low rise – high density' scheme creates a spatial identity for energy efficiency in the region.

Reflecting the criteria for energy-efficient housing in the context of its application in the "Shahre Javan Community" led to different design scenarios for a specific site in a variety of stages and scales. The conceptual scale allowed for a study within a specific framework. The basis for the study was the development of a typological approach using the criteria catalogue. Through a modular space concept, typological characteristics of the approach were defined in terms of access, floor organization, constructive principles and urban implementation. The outcome of the modular space concept describes three basic types with a range and variety of dwelling sizes and different housing styles as a first adaptive measure. The results of the concept were monitored in models and sketches; studies and simulations were carried out to determine the energy efficiency achieved using systems specifically chosen to suit the local climate. The application to a specific site on an urban scale in the pilot area gave a first impression of the concept's potential to vary the typology. The conceptual design of one urban unit in the "Shahre Javan Community" is used to refine the design scenario in several revisionary steps and serves as a planning basis for a specific application with the prospect of dissemination through energy-relevant elements.

Fig. 8: Private courtyard in an Energy-Efficient-Home

4.1 The classification of types

The typological approach in architecture is characterized by the classification of a hierarchical system of basic modules, their variations in arrangement and adaptation to the site. The development of the building typology starts with the adjustment of the gathered building criteria as the scientific, theoretical and urban framework for the site specifications of the pilot area, which is then used as a practical and physical basis.

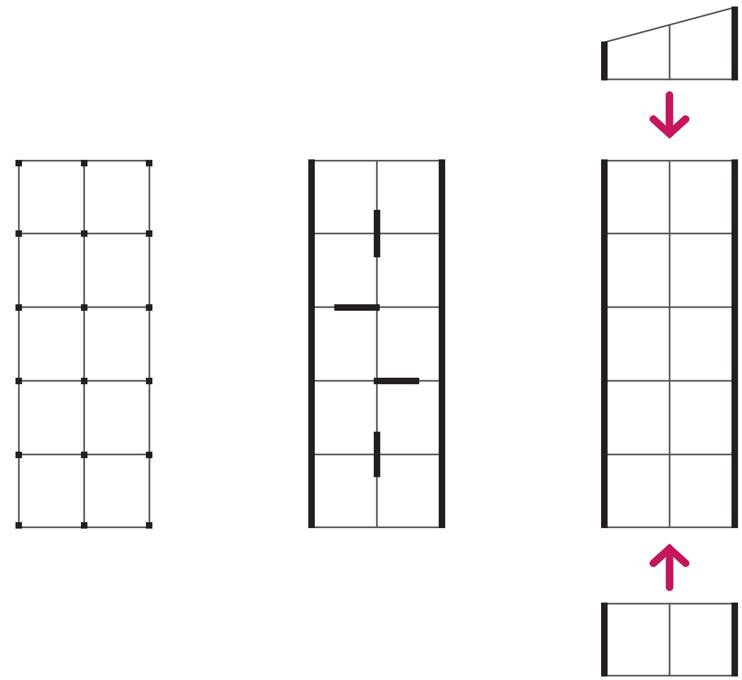


Fig. 9: Modular space concept of the Energy-Efficient-Homes

The chosen scenario allows for the classification using a work process. Integrated in the urban design concept, the first step of the typological approach is carried out as a parallel process with an analytical (top down) and synthetic (bottom up) classification.

Beginning with the definition of types in an urban context, the analytical framework is provided by the site specifications and the demands for the "energy-efficient housing in a compact urban form" (see 3.1). The developed structure in the first draft of three housing types expresses the typological approach. Due to the fact that the typology is adaptable to the length of the site as a consequence of the urban design and the method of construction, the classification is characterized by the width of the plot (7.5, 9 and 15 m types). A modular space system, developed for introverted housing schemes in a compact format, is the tool used for this adaptation process. By organizing and arranging spatial modules according to the depth of the site and maintaining standardized widths, various floor layouts, sizes and designs are possible.

The transfer of the carved-out types to the “Shahre Javan Community” project on an urban scale and in a defined urban unit of the sub-neighbourhood highlights the potentials for adaptation of this typology, as is shown exemplarily in the second step of the typological development. The results gathered from this design scenario are then used to establish a typological classification. In order to evaluate the potentials of modifications and variations of the building types within the typological concept and according to the site conditions, the functional aspects, technical standards and adaptive characteristics must be filtered out. In a third step, the characteristics are defined and depicted in design studies and different scales. A catalogue of possible variations of these basic types shows the morphological variations and their urban relevance. The variety offered in the typological catalogue can be regarded as a tool to create identity on a building and urban scale and is an expression for the correlation between architecture and urban design. The display of exemplarily variations on a building scale, in terms of floor plans, sections and elevations, is therefore designed to evaluate the architectural qualities. By illustrating the strategies and measures of constructional concepts and elements for upgrading the energy efficiency through additive technical equipment, a categorisation of standards can be achieved for the identification of basic principles and additive upgrades. Thanks to this categorisation, measures and strategies for energy as well as economic alterations are easily identified.

The main components of the typological design process are as follows:

Orientation and dimension

The urban design led to plots on the site of the “Shahre Javan Community” with lengths of around 25–35 m, mostly with north-south orientations. Cut-outs and courtyards are applied to the volume to increase the length of south-oriented façade to generate greater solar yield. These structural incisions create private locations and improve the climate conditions. A vertical arrangement of setbacks produces further differentiation and enables direct sunlight to reach into every dwelling unit.

Organization and structure

A structural system forms the basis of the layout strategy. A modular space system with room axes for different room sizes is the structural basis for construction and use. With its vertical continuity and the low building height, with a maximum of three storeys, the structure can be organized with a simple system of walls and ceiling slabs or as a frame structure. The vertical continuity even offers the opportunity to provide underground parking. The structured volume facilitates a high variety of floor layouts.

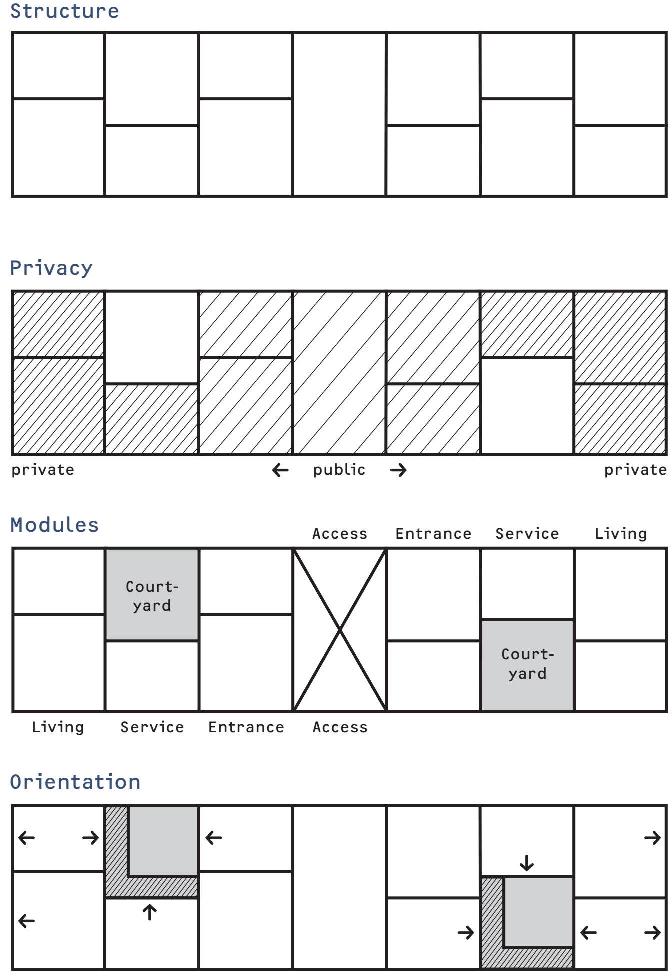


Fig. 10: Structure of the Energy-Efficient-Homes

Access and vertical connection

The house is accessed at street level and, in addition, by an entrance from the underground parking. A hallway leads to the central stairway. Besides its purpose of access and level connection, the stairway can also function as a vertical air shaft. In smaller types with up to two dwelling units, the central stairway can be replaced by interior private stairs.

From public to private

On the ground floor, the area facing onto the street is a potential commercial unit. Together with the apartment above, it is possible to establish a mixed-use scheme. The ground level functions as the first threshold from the public area of the urban space into the private housing zone, with the commercial unit and the entrance hallway as a semi-private entity. The stairway marks the transition point from the semi-privacy of the interior access zone to the privacy of each apartment. The vertical organization of apartments around a central courtyard again creates different degrees of privacy affecting the interior space. Areas for guests, service zones (kitchen, bathrooms, inner stairways, etc.) and private family space can be organized individually due to the flexibility of the structure.

Variety and flexibility

The structural system and the morphological concept permit a variety of layouts; the morphological adaptation allows for different size dwelling units. The vertical continuity of structural and technical elements also enables a vertical connection of space (e.g. duplex units). The inner organization of the units is regulated by a few structural elements (e.g. party walls on the long sides of the building and staircases). The distribution and use of rooms is therefore very flexible. A sloped location can offer greater dwelling areas due to additional façades.

4.2 Scenario and transfer – the adaptive typology

The scenario work for the "Shahre Javan" site reviews and evaluates the project aims and design results. The evaluation of the planning results for a specific application helps to revise the developed concept. The detail planning for the "Shahre Javan" site ('Tarh-e-Tafsili' – see also Young Cities Research Paper Series, Vol. 3) ascertains the potential for changes and improvements of the housing typologies as a necessary part of each planning process. The conceptual design, as a basis for the execution planning, defines the final design solution for one urban unit in the "Shahre Javan Community".

Re-transferring the first scenario to the general typological concept shows the potential of the architectural design approach and enables a morphological study of all basic types. Moreover, it highlights that the large number of variations can function as an adaptive tool. This large variety on a conceptual scale illustrates the potential for flexibility, especially in regard of functional and technical adaptations, as well as the integration of identity aspects. The consequences of a step-up in scale and an exemplary adaptation of a specific type are revealed in floor plans and sections. The identification of characteristics and the definition of measures for possible alterations are the result of this work process.

4.2.1 Fixed and flexible elements

Elements and components with their technical, constructional and sensuous characteristics ensure structure and functionality and are the basis of the Energy-Efficient-Homes. They can be termed as flexible or fixed elements.

Modifications or adjustments to the volume and floor layout allow for adaptation and transferability and are necessary to achieve variety and identity. While modifications and adjustments to meet the demands of specific sites and functions are an adaption to the so-called "fixed" characteristics, flexibility in the typology is required in the planning process. Concerning the typology in the "Shahre Javan Community" area, the following characteristics are representative and significant:

The modular space system serves as a framework for the construction and organization of the dwelling units (fixed). On the other hand, the modular framework enables the organization of private zones and service zones in different floor layouts (flexible). The vertical continuity of the structure offers constructional and technical functionalities (fixed). The arrangement of space modules to form different building morphologies on different plot sizes is necessary to meet the functionality, privacy and energy efficiency in a specific urban context (flexible).

Flexibility, meaning temporarily adaptable, is only provided by measures for façade design. For example, a certain combination of fixed and flexible construction elements has a direct impact on light and energy efficiency as well as the degree of privacy. It is achieved by the fixed structures in the façade and the flexible regulation of mechanical shading elements. Due to the fact that flexible elements have higher requirements in terms of technical details, they also have a direct impact on building costs. Thus their application should be considered carefully.

Identifying fixed and flexible elements allows the formulation of adaptive strategies for the transfer of research and planning results as well as the specification of elements to create architectural and urban identity and variety. The strategies for adaptation are classified according to different aspects of the architectural design:

- *Morphology* – as a volumetric feature to perform adaptations in an urban context
- *Floor layout* – for a functional and spatial adaptation within a single building
- *Passive and active energy measures* – spatial and technical design features for the adaptation of energy consumption
- *Appearance and construction* – design and structural measures for the adaptation of social and economic standards

4.2.1.1 Morphology – strategy for site adaptation

The design approach of the housing typology respects the urban design concept as a spatial denominator for the insertion of a building. Thus every building is a specific element in a larger spatial arrangement.

Due to this commitment, the design concept of the building must offer suitable adaptive tools. Regarding the site, the developed modular space scheme is adaptable by performing morphological measures.

The length of the building is the first adaptive measure. In a sequence of modules, the length of the building can always respond to the plot size.

Depending on the length of the plot, in smaller vertical-organized housing types (7.5–9 m), the private courtyard is enclosed on three sides by private rooms (in longer units) or only on two sides (in shorter units – north, east or west), simply by adding or removing a space module.

For bigger housing types (12–15 m or more) and on longer plots, a second courtyard is integrated in the building volume; on smaller plots, it is only one courtyard.

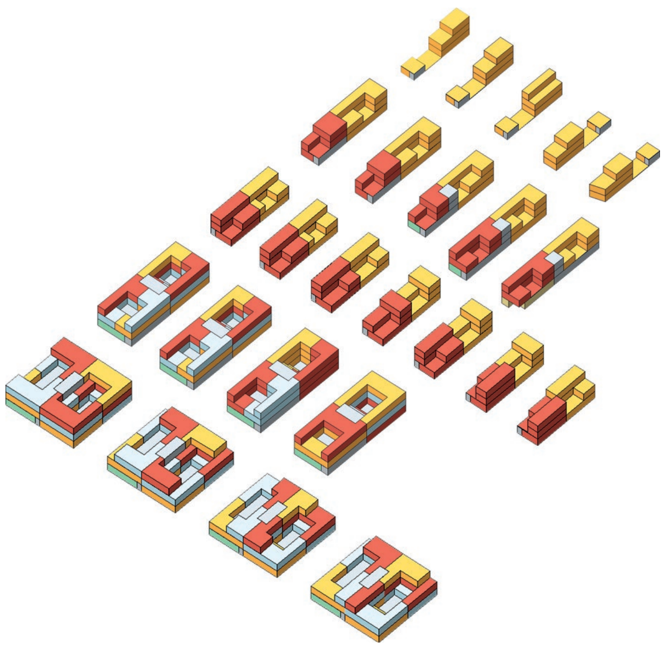


Fig. 11: Typological catalogue

The second measure is the orientation of the volume. In order to achieve variations in the orientation, improve energy efficiency and/or the degree of privacy, the upper storeys in vertically-organized units can be modified. By arranging the volumes, adding terraces or varying the layouts of the upper levels, it is possible to regulate the incidence of sunlight and privacy. These measures have a direct influence on the urban appearance and can also be seen as a tool for creating identity.

4.2.1.2 Floor layouts – strategy for functional adaptation

For functional reasons, the housing typology must offer flexibility in its use. On the one hand, this flexibility is necessary to meet the different needs of users, on the other hand, the changing requirements in terms of target groups or the insertion of commercial units for a mixed-use scheme demand flexible floor layouts. A graduation of flexibility must therefore be defined. It is not the aim of the architectural concept to create a fully flexible space, which is only fixed by the building envelope, even if the modular space system were able to fulfil such a demand. The structural requirements to achieve such a high degree of flexibility are more suitable for frequently changing floor layouts as is the case in office buildings. It is more important, in this case, to keep open the choice of construction method (from traditional solid construction to pre-fabricated building elements) with space module dimensions, which allow for a certain number of variations. In order to maintain this flexibility, the arrangement of the spatial modules offer different room as well as unit layouts and various fittings. Experience has shown that most of the layout determinations are made in the planning phases before construction. Thus, the focus on flexibility is determined by the following measures:

The smaller types (7.5–9 m) provide two vertically organized dwelling units with separate access at ground floor level. The staircases can be set inside the private units with a first emergency exit via the entrance hall and a second one via the apertures in the façades. As the demand for privacy is not easy to fulfil at ground floor level, because of the visibility from the public streets, a mixed-use scheme with a commercial unit might be the right the solution. Here a joint staircase for the units above is necessary as part of the modular space scheme. The maximum number of dwellings in these types could be four. The commercial unit can be planned as part of the apartment above or as an independent space.

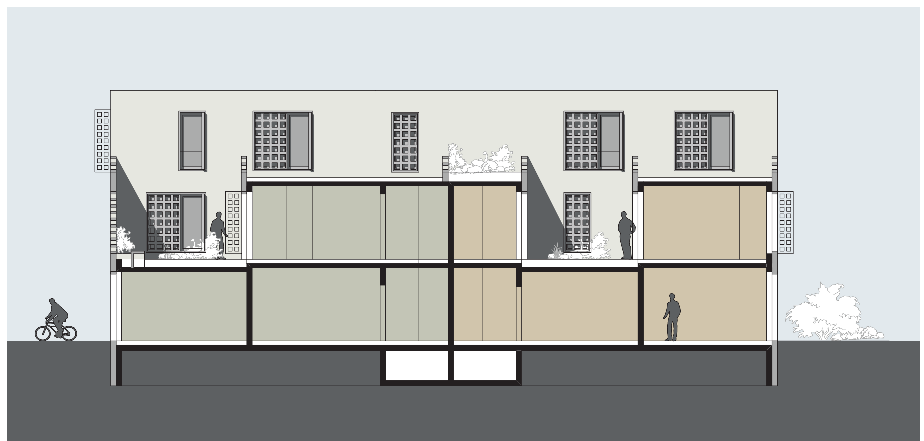


Fig. 12: Section through a 9 m-type building with two dwelling units, each with its own private courtyard

Fig. 13: Floor plans of a two and three-storey dwelling in a 9m-type with a private courtyard and zoning inside the dwelling

For the bigger types (12–15m or more), the size and number of dwelling units depend on the chosen floor layout. The combination of levels to form vertical units is also possible within this typology. In buildings with single-floor apartments, the number of units that can be arranged around one courtyard ranges from one to two, and a maximum of eleven units in total in one building. A joint staircase is always necessary in this case. In all types, the size of the staircase must allow for the incorporation of an elevator to provide barrier-free access. Depending on the position of water and energy supplies, different room layouts, such as closed or open kitchens, are possible.

All in all, the organization of floor layouts is flexible enough to accommodate individual needs in terms of a unit. Furthermore, the flexibility of unit sizes and layouts is a suitable tool to meet demands on the housing market.

4.2.1.3 Passive and active energy measures – strategy for energy-related adaptation

Besides achieving energy efficiency through the building's configuration, further improvements can be made by performing additional measures. Renewable resources, such as sunlight and ground temperature, can be used by carrying out simple constructions.

Sunlight incidence and its effect on the energy demand

The amount of daylight use influences directly the demand for electricity to provide artificial lighting. In the case of unfavourable light incidence or angles, daylight can be redirected by using reflecting devices. The light diversion can be used as a protection against too much light exposure or for increasing daylight incidence, for example in deep rooms. In both cases, the light diversion reduces energy consumption. On the one hand, it reduces the cooling energy demand as it prevents overheating in summer; on the other hand, the reduction of artificial lighting reduces energy consumption directly. The provision of daylight depends on various factors, for example the degree of sun exposure, the angle of incidence, the general layout, the number and dimension of transparent openings, the glass type and factor of light transmission as well as the position of openings.

Light-diverting devices are available for internal and external use. External devices are the most effective. Daylight is redirected into the room by using, for example, external reflectors, mirrors or prism plates, which are normally used for sun shading, but are very effective for diverting light. The downside of external devices can be, depending on the form and position, the dirt accumulation on devices, which reduces the efficiency and results in higher maintenance than that required for internal light diverting devices.

In the "Shahre Javan Community" project, the configuration and compactness of the buildings is responsible for reducing heat loss in winter and avoiding overheating in summer. Furthermore, the north-south orientation captures the intense radiation from the south and avoids the more critical east and west sun in summer, which is more complicated to control.

Duplex units, which are positioned back to back, form a deep north-south oriented housing complex. Inner courtyards with large south-oriented openings help to provide an even amount of light throughout the apartment. The ratio of street width to building height and the dimensions of the inner courtyards optimize the relation between maximum illumination of the rooms and negative impact of heat during summer (Nytsch-Geusen et al., 2012).

In winter, the same light shelves in a vertical position receive approximately 50% of the sun and divert it into the north-facing rooms adjoining the courtyard. This means that the rooms opening up towards the courtyard are all lit and preheated by the sun. The above-mentioned downside of higher maintenance is negligible due to the overall dimensions of the courtyards and the reachable position of the shelves, which means that the maintenance can be carried out by the inhabitants.

As an alternative to the large rotatable shelves stretching across the courtyard, a sun screen made of photovoltaic fabric can cover the courtyard in summer. It prevents the inner courtyard and adjacent rooms from overheating and produces energy. In the evening, this energy can be used to partially illuminate the same area. In winter, the fabric is pushed aside and the sun can warm and lighten up the inner courtyard and adjoining rooms.

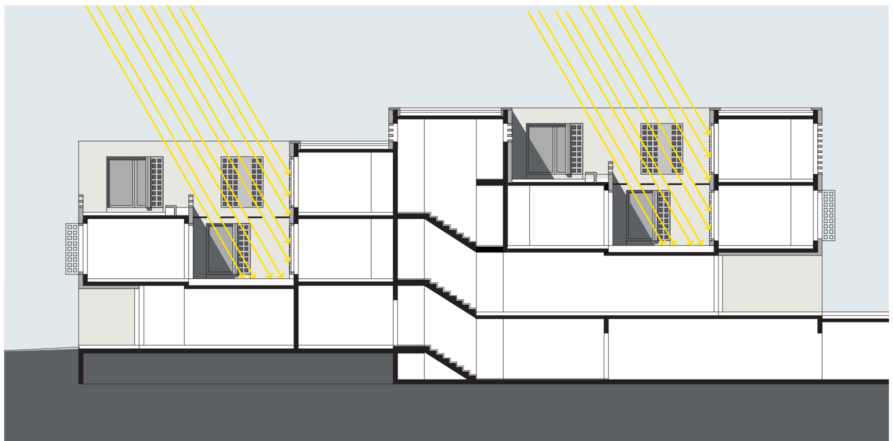


Fig. 14: Light shelves (louvres) – summer position

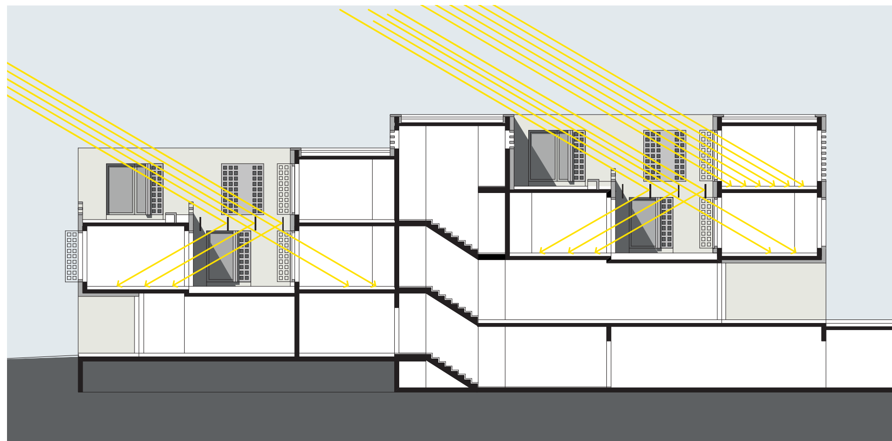


Fig. 15: Light shelves (louvres) – winter position

Heat-exchange to reduce the energy demand for heating/cooling

Currently most Iranian households use evaporative cooling systems in summer. For an apartment of 120 m² with a room height of 2.8 m, an air-exchange rate of 25 l/h is required to keep the temperature within a comfortable range. This leads to an energy demand of 2.920 kWh of electricity and 63.5 m³ of water per cooling season (Nytsch-Geusen et al., 2012).

Considering the high air exchange rate and the fact that the exhaust

Fig. 16: Earth tube system in an urban unit

air is still much cooler than the supply/outside air, it is obvious that the temperature difference between the exhaust air and supply air should be used to precondition the supply air. Preconditioning the supply air with exhaust air works both in summer and winter. In summer warm/hot supply air is cooled with the cooler exhaust air and in winter, when the exhaust air is much warmer than the supply air, it is used to preheat the outside air and reduce the energy demand for heating.

This preconditioning of supply air can be achieved by installing a heat exchanger. A heat exchanger relies on the fact that energy media want to be in balance, which means that heat will dissipate and move to cooler materials. A heat exchanger simply transfers heat (energy) from one medium to another. The use of a heat exchanger enables the recovery of otherwise "lost" energy contained in the exhaust air.

The described heat exchanger for use in a building/apartment can be integrated into the ground as an earth tube to supply a whole neighbourhood with preconditioned air. The constant ground temperature at a depth of approximately 1.5–4 m below the surface is used to precondition the supply/outside air.

A central supply air intake can be installed for several buildings and dwelling units. The fresh air is drawn in through earth tubes that run in loops and is either heated or cooled by geothermal energy through direct contact with the soil. At a length of 50 m and a depth of 2 m the supply air can be heated or cooled by at least 5°C. This is a rough estimation for the Hashtgerd region and its climate conditions, as no simulations were carried out during the project. However, the assumption is based on detailed studies for different regions and climate data, which has shown that the air temperature can be lowered or raised by up to 10–11°C depending on the specific climate conditions (Blümel et al., 2001).

The combination of several dwelling units allows for a more economic installation and use of earth tubes. For a sub-neighbourhood area, this could involve a division into four zones. While the supply air intake is centralized, the exhaust air system would be decentralized and work with a heat exchanger on a building scale as described above.

tural design of the apertures characterize a building's façades. The aperture typology is influenced by role as energy impact element. Due to the fact that the south orientation is important for the use of solar heat gain, the design of the apertures within the façades is a very important tool for energy efficiency. Considering the morphological arrangement of closed coverage and compactness, the surface of the façades is initially reduced to a minimum. The south façades of the single units, facing onto paths, courtyards and open areas, have to provide most of the sunlight for the living rooms. Therefore, the proportion of apertures in south-facing exterior walls should be as high as possible.

Due to the high density of the "Shahre Javan Community" urban concept, the positioning and dimensioning of openings must balance the need for low energy consumption and privacy. The strategy used for balancing and planning the façade design for the housing typology chosen is performed on two levels. On the first level, the design of the façade is characterized by the fixed elements of the building`s structural system, the construction of the exterior walls and the zoning of closed and open elements. On the second level, flexible elements to control light and sun incidence structure the façade.

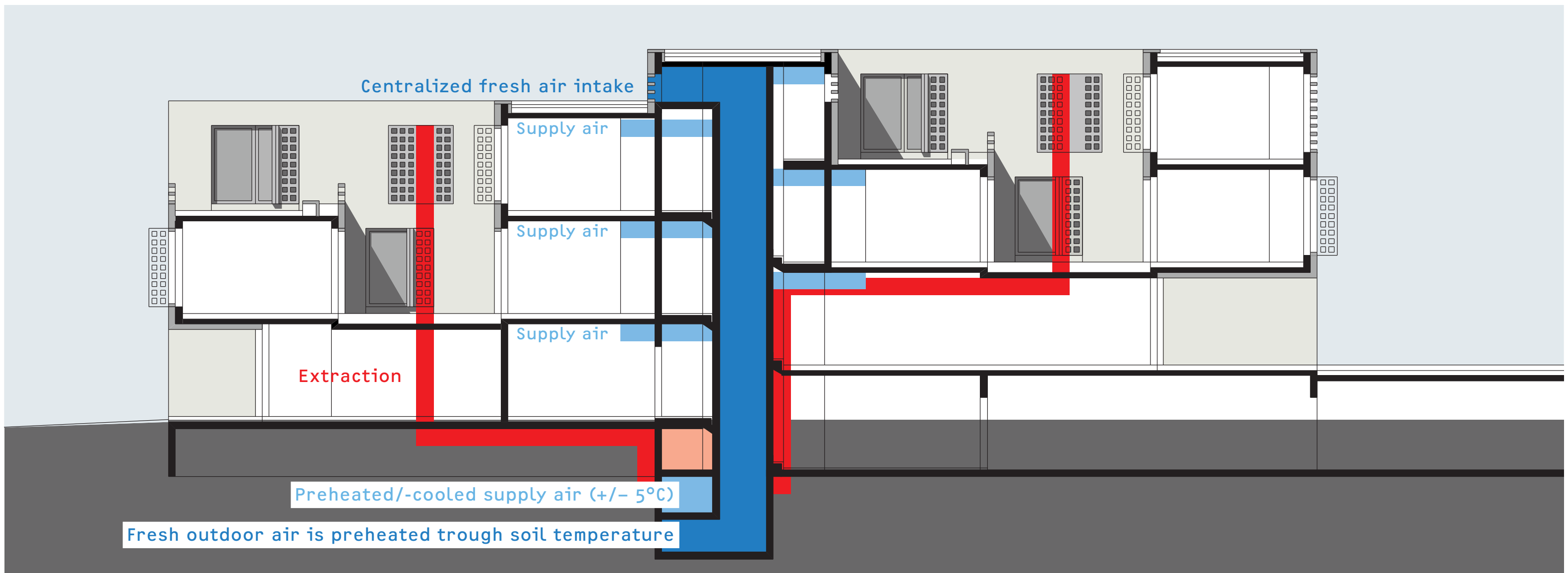


Fig. 17: Building section with heat recovery system

4.2.1.4 Appearance and construction - strategy for standard adaptation and identity

Façade as a relevant element for energy impact and identity

Alongside the morphological arrangement (see above) as a strategy for creating an energy-efficient structure on an urban scale, the design of the façades also has an influence on the appearance of a building. The structural method, the floor layouts and shapes as well as the architec-

The dense configuration of the "Shahre Javan Community" pilot project requires measures for privacy. As a first measure, the width of standard apertures with a higher privacy factor is reduced, but the proportion of glass is maintained by choosing vertical, room-high apertures. A staggered arrangement of apertures on opposite façades avoids direct views and is a second measure to achieve privacy. From an economic point of view too, high, narrow openings with a simple mechanism are more reasonable than horizontal ones.

Alongside the demand for good technical standards as a means to increase the quality of the windows' thermal insulation, the design of the apertures is a tool for regulating sun incidence and a first opportunity to achieve variety within the exterior appearance. Size, number and location of apertures, however, depend on the façades structure. In order to maximize the aperture surface, the window is no longer only an opening in a closed wall, but a constructive element of the building envelope. A frame structure means that façades are classified as non-load-bearing walls and there are greater possibilities in regard of the arrangement and construction of elements. The appearance of the façade is thus characterized by the layout of load-bearing and non-load-bearing elements and by the design and positioning of the apertures within the closed walls (e.g. thermal insulation composite system). Windows can, for example, be aligned with the outer or inner surface of the external wall. Set into the wall, a small overhang is formed which already reduces the heat load of the high sun in summer. This structural shading of the frame is a "fixed" measure. On a second level, the individual control of view and energy input is achieved with "flexible" measures. By installing sun shutters or blinds on the outside of the façade, individual control is made possible. Flexible, mechanical control of the elements regulates the energy input during daytime, but also provides a means of controlling the amount of privacy in the living areas.

Construction method – application of simple constructions
The modular space system of the building typology allows for a variety of construction methods. The terrace ends with façades facing the open areas are set on the boundary lines. The chosen modular system is based on an economic construction grid. With its vertical continuity and the low building heights, featuring a maximum of three storeys, the structural system is kept simple and a frame mode of construction is possible. Pre-fabrication, in-situ construction methods or a combined solution with semi-precast elements are all possible and depend on site conditions, traditional building methods/ education of workmanship, availability of material and budget. The same applies to the range of possible construction materials. A frame construction made of concrete can be combined with light wall materials or bricks. The difference in thermal behaviour at the interface of the materials is evened out by installing a thermal insulation composite system. A monolithic system without exterior insulation in combination with a concrete frame structure must be assessed regarding its thermal properties. A system for a monolithic structure could involve shear walls and concrete ceilings. The shear walls must be placed inside the unit as the façade, in this case, only functions as a non-load-bearing thermal envelope, for example using perlite or mineral wool-filled bricks or light concrete blocks. Due to the special demands concerning earthquake resistance in the region, the choice of the construction system and materials is very much dependent on the site conditions. A concrete framework with concrete bracing walls inside the units and ETICS as the thermal envelope was chosen as the structural system for the Energy-Efficient-Homes in the Hashtgerd New Town pilot project area. The choice of the remaining façade materials (e.g. bricks) can be made according to ecological as well as economic aspects.

Fig. 18: Study of different south façades for 7.5 m building type

The room axes are the basis for construction and use, and define the modular space system. As described earlier, the different plot types start with a 6 meter axis-centre distance and can reach a width of 15m in 1.5m steps in an east-west direction. This modular system offers a great variety of floor layouts with the most economic structural span being of 7.5 m. The depth of the building structure can be adapted according to the plot layout by adding spatial modules in north and south direction.

4.3 "Basic Principle" and "Upgrades"

The result of the design process for adaptive measures and the identification of urban, architectural and technical elements for developing the Energy-Efficient-Homes led to a distinction between a basic principle and possible upgrades. This categorisation helps to define different standards as well as a scientific basis for the planning process of energy-efficient housing in the region.

The basic principle is the design strategy for energy-efficient architecture and urban design from a spatial approach without any additional technical demands. It contains all planning and design measures to increase energy efficiency through spatial configuration, such as building orientation and compactness, site suitability and cultural context. It can be seen as a low-cost approach and defines a minimum standard for energy efficiency in the Middle East.

The upgrading measures include possibilities to raise the standard of the basic principle. Supplementary technologies can be integrated into the spatial approach. (see 4.2.1.3 and figures 14–17)

Possible upgrades include simple mechanical elements for light and energy guidance, such as sun-shutters, furthermore the use of the ground temperature by means of earth tubes and a concept of heat exchangers, and finally the application of higher technological materials, such as photovoltaic fabrics to generate supplementary energy. The measures are characterized by a planning dimension as well as a technological and economic dimension. The choice of upgrading measure is dependent on the economic and technological context. The upgrade defines the standard for maximum energy efficiency in the region.

4.4 The conceptual design

The findings of the design and research process for the Energy-Efficient-Homes are transferred to a final design proposal for an urban unit in the “Shahre Javan Community” pilot project. By transforming the design and adaptation measures from the typological approach into a specific design scenario, the challenges for the practical application of such a general approach can be weighted and evaluated. Furthermore, the realistic scenario serves as a basis for cost estimations, energy simulations and constructional detailing. Architectural models and drawings of the architecture in the “Shahre Javan Community” to a scale of 1:100 to 1:20 are used to define a standard for materials and energy objectives.

The chosen site in the centre of the pilot area (sub-neighbourhood 3.3) is located on a ridge with access from the collecting road coming from the eastern valley and bordered by the central public green of the western valley.

Following the determinations of the “Tarh-e-Tafsili” (Detailed Plan), developed by the Strategic Dimension Urban Development and Design at TU Berlin, the urban outline as well as the inner access routes are fixed by building lines. Parking is provided below the building development with access from the collection road. The inner access paths are for pedestrians as well as for supply and emergency traffic. The paths structure the urban unit into four building sections. A small urban square, positioned at the crossing of the access paths, is the social and spatial centre of the urban unit.

The density on the building plots was estimated using a floor area ratio of about 1.7–2.0. The range in apartment sizes was set at 75-200 m² for at least 75% of the dwelling units. A possible replacement of different housing types creates flexibility. For example, to gain greater variety, the seven 7.5 m types in the south-western section can be replaced by six 9 m types still staying within the building lines.

4.4.1 The architectural design solution in an urban context

The conceptual design shows a specific design scenario for one urban unit from the typological approach with adaptations to the site specifications using the described morphological strategies, the floor layouts, the energy-related measures and the choice of construction method.

The design of the urban unit should offer a large variety of dwelling types. Alongside the single-floor apartments on broader plots, single family housing is also provided. The suitable basic types determined in the topological approach are the 15 m type for single-floor apartments and the 7.5m and 9m types for duplex units. For an effective infrastructure and a clear urban identity, all buildings are accessed from the inner paths of the sub-neighbourhood. By placing the parking level underneath the southern plots, the site`s slope is exploited. A main exit from the parking level with stairs and a lift is placed on the central square of each sub-neighbourhood.

The distribution of building types is aimed at maximizing direct sunlight. The south orientation of the plots and the sloped topography ensure maximum passive solar heat gain in winter. The overheating of open spaces, such as paths and courtyards, is avoided in summer by installing suitable shading devices. Positioning three-storey apartment buildings on the northern plots of each sub-neighbourhood and two-storey duplex units on the southern ones enhances the use of passive solar energy in the northern buildings, which are separated by narrow paths. The north-south directed green areas between the sub-neighbourhoods are wider than the 6m-wide paths within the sub-neighbourhoods. Thanks to the

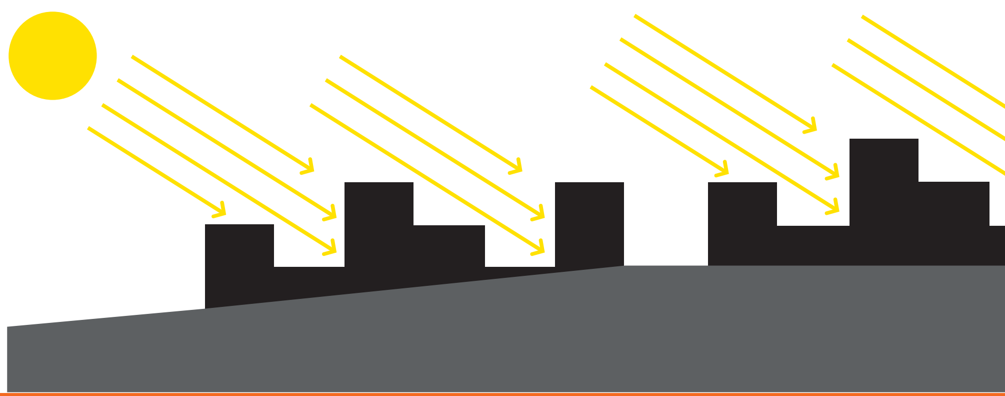


Fig. 19: Basic principle of Energy-Efficient-Homes

Fig. 20: Areal view of urban unit from the southeast

natural slope of the site, sunlight is never an issue for the southern plots in the sub-neighbourhood. Terraces on the third floors of the apartment buildings are designed to provide supplementary light to the rear zones of the buildings as well as more differentiation in the façades.

The second measure to enhance light input is a partial set-back of some of the duplex units on the southern plots. This has more than one advantage. First of all, the partially enlarged paths can function as semi-public entrance zones for the duplex units, secondly it allows the parking level to be naturally ventilated and lit through apertures in the ground. Last but not least, it improves the lighting conditions of the northern buildings. Thus the morphological measures for greater efficiency ensure, at the same time, spatial quality and low energy consumption.

4.4.2 Design solution for the residential buildings

The multi-storey apartment buildings are organized around a large central courtyard. The central stairway with lift separates every floor into two units. Setbacks on each level are used to generate at least one private terrace for each dwelling unit. Every apartment has façades facing private zones (courtyard) and public areas (path or open space). The main openings are always oriented south. This solution considers the desired use of passive energy and maximizes privacy by avoiding direct views between two opposite units.

Due to setbacks in the upper floors of the spatial modules, the courtyard is enlarged and the apartment size changes. The apartment layout is divided into private and public zones. The private bathroom and bedroom zone is separated from the more public living and kitchen zone. Depending on the size of the apartment, the distinction between private and public zones within the apartment is solved differently. In large apartments, the public zone includes a large entrance hall and a flexible space either for office use or as a guest bedroom including a small bathroom. The kitchen block separates the public zone from the private living zone with bedrooms and bathrooms set in the rear of the apartment.

The units on the ground floor, facing the central square, are used as commercial units and are therefore part of a mixed-use scheme.

The buildings with two duplex units, each facing south, are more introverted. The two storeys of each unit are organized around a private courtyard. Morphological measures in the courtyard arrangement, as described earlier, enhance the use of passive energy. Due to setbacks on the upper level within the modular space system, the incidence of sunlight is maximized. The north façade facing the private courtyard is also set back on the upper level allowing more direct light to penetrate the south-facing façades. Like in the multi-storey apartment buildings, the roof created by the set-back can be used as a private terrace on the upper level, in the case of duplex units, this is within the same unit. Thanks to this arrangement, even the rear zones within the deep building volumes receive natural daylight. This has the effect that the façades visible to the public require very few openings. The two units in every building are organized in a back-to-back arrangement.

Following the hierarchy from public to private space, the semi-private entrance courtyard (widening of path as described earlier) provides the first step into privacy, at the interface of the urban and building design. The two-unit building type is accessed from this zone. The subsequent hall and corridor are a “dead end” in the sense of the traditional spatial hierarchy (see 1.1.1). Within the private unit, the hall, with a central internal stairway, is part of the vertical and horizontal arrangement. In apartments with two levels, it is easy to make a distinction between private and guest/public floor areas (as shown in the floor plans of the dwelling units). With the public zones on the lower level, the upper level ensures absolute privacy. If the private zones are accommodated on the ground floor, guests are immediately guided up the stairs without passing the private zones.

The floor plan layouts illustrate the relation between energy efficiency and privacy. Although the arrangement of private zones at ground floor level does not comply with Iranian traditions and culture, advantages in terms of energy efficiency and privacy can be achieved.

Private bedrooms do not require as much light and heat as living zones. The façades of private zones can be designed with a smaller proportion of window surface. Transom windows deliver sufficient light at the same time as avoiding views into the private rooms from the street.

The parking level is dependent on the construction of the buildings above. Placed in an earthquake-prone area, the load-bearing elements have to be continued down to the foundations. Shear walls and columns are organized in the modular space arrangement. The main exit, with staircase and lift in the urban square, guarantees central accessibility even for disabled persons. Further stairs and the entrance/exit ramps serve as emergency exits. The main lane is positioned beneath the access path. General facilities used by the whole sub-neighbourhood, such as the grey water supply system and the energy plant, are located beneath the central square.

With the help of the typological approach, the conceptual design for the Energy-Efficient-Homes illustrates the strategies for adaption on different levels and scales.

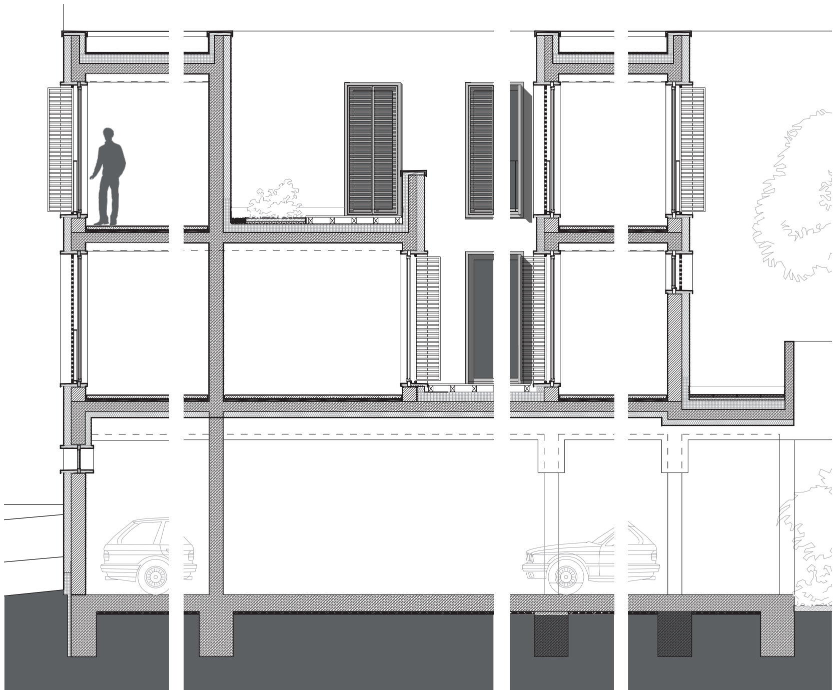


Fig. 21: Detail section of the conceptual design

4.4.3 Conclusion of the conceptual design

In accordance with the provisions of the detailed plan (Tarh-e-Tafsili) of the "Shahre Javan Community", adaption of the typological approach on an urban scale is achieved in the conceptual design of the Energy-Efficient-Homes by:

- the choice of type and its position as a functional adaptation measure
- shape and organization of the volumes, e.g. by implementing entrance courtyards and setting back volumes, as a morphological adaptation measure.

Adaption on a building scale is achieved by:

- the floor layout, such as the arrangement of private and public zones, the cut-outs in upper levels for better light conditions in the courtyards, as a morphological and functional adaptation measure.

The energy efficiency is enhanced on a detail scale by:

- adapting the façade design to suit the site, e.g. by integrating sun shutters
- provision of system-relevant elements, such as the technical plant beneath the central square and the earth tubes at parking level
- choice of materials with respect to site conditions, availability, required standards, energy-related objectives and economic aspects, e.g. choice of materials for the thermal envelope and construction system.

5 Perspectives

The research process in this design concept is aimed at providing a planning concept for energy-efficient housing in the Iranian New Town programme with a potential for dissemination and adaptation.

The spatial strategy, which considers the energy-relevant aspects of urban and architectural morphology within a specific social context, has led to a concept of basic practical energy standards that are adapted to the region. The courtyard housing scheme of the Energy-Efficient-Homes shows a new development based on the origins of vernacular architecture.

By adding technical supply systems (e.g. light and sun directing elements or earth pipes to make use of geothermal energy), it is possible to upgrade the energy efficiency already achieved by the basic standard through spatial organization and design.

The volumetric arrangement incorporates socio-cultural references to Iranian vernacular architecture. The urban and architectural design combines the aims for energy efficiency and a regionally adapted identity by integrating spatial aspects into the socio-cultural context.

5.1 Potential for realization

The developed design solution for the Energy-Efficient-Homes is a conceptual guideline for the detailed planning of the "Shahre Javan Community" pilot project. The typology needs to be examined carefully regarding the chosen construction method (especially the earthquake resistance), site topography and building quality standards (target groups). The gathered adaptive measures describe a future work process. These include, among others, the choice of typology as a tool for controlling the size and number of units as well as the choice of construction method and façade appearance as a tool for economic issues and identity within the estate.

5.2 Potential for transferability in the region

Because of its high degree of variability concerning unit size and morphological adaptation, the typology can serve as a basis for transferability to other sites in the region. The developed housing scheme, based on traditional spatial arrangements, offers culturally adapted energy-efficient housing for the Middle East. The energy-relevant advantages of the compact urban form and its building configurations could change to provide higher spatial quality for new towns as the concentrated building volumes create clear defined open spaces with public relevance. The simple basic layout and structure of the introverted, individually controlled dwelling units also accounts for the specific technical and economic conditions in the region.

Fig. 22: Urban path in sub-neighbourhood

Fig. 23: Urban square in sub-neighbourhood

Urban Design and Architecture

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Date
1 November 2011

Fig. 24 Siteplan of the "Shahre Javan Community" with the urban unit marked magenta (Sub-Neighbourhood 3.3)

Fig. 25: Ground level floor plan

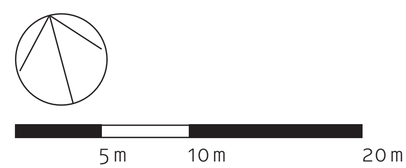

Fig. 26: First level floor plan

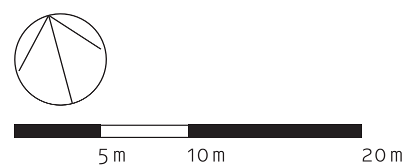

Fig. 27: Second level floor plan

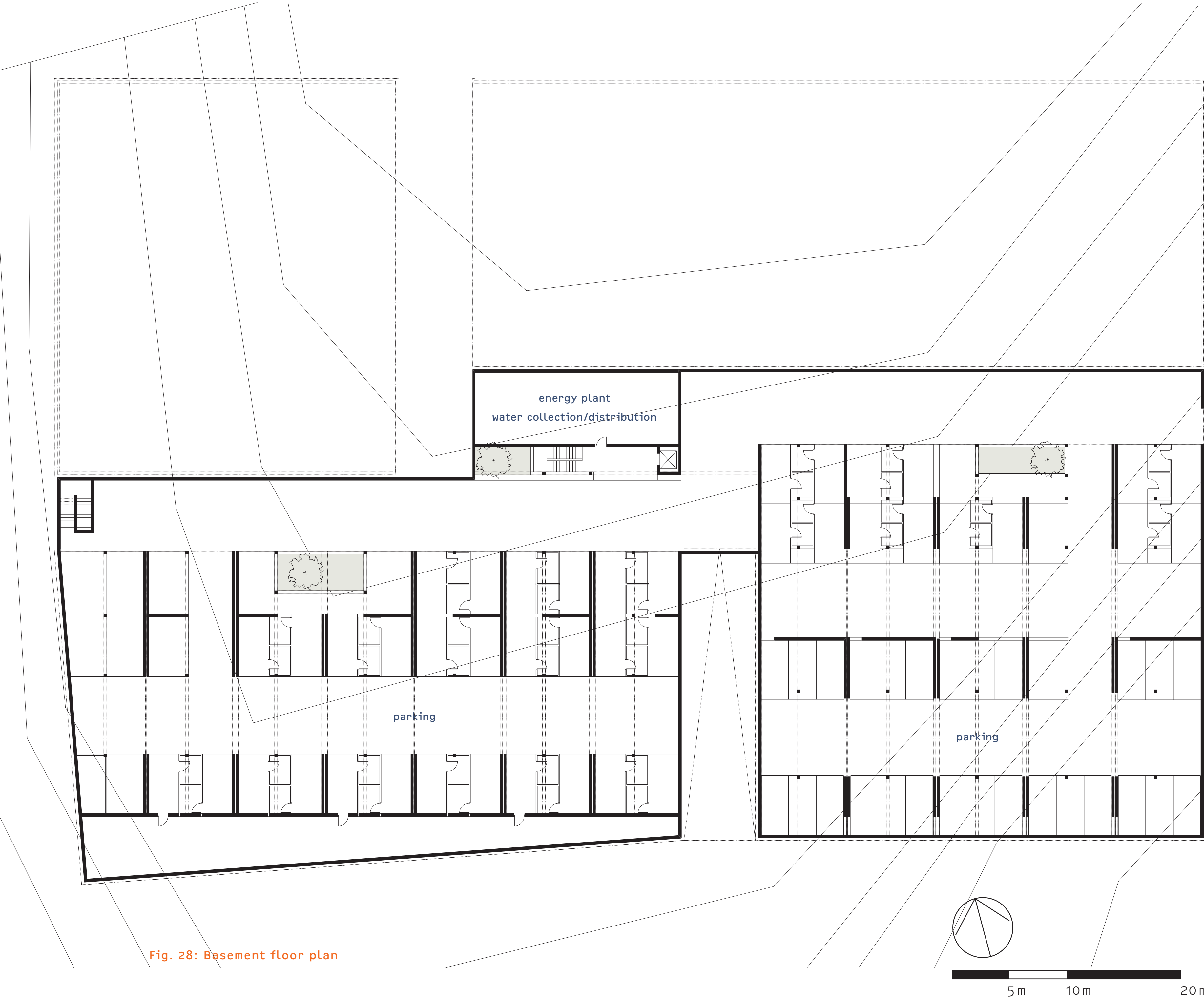

Fig. 28: Basement floor plan

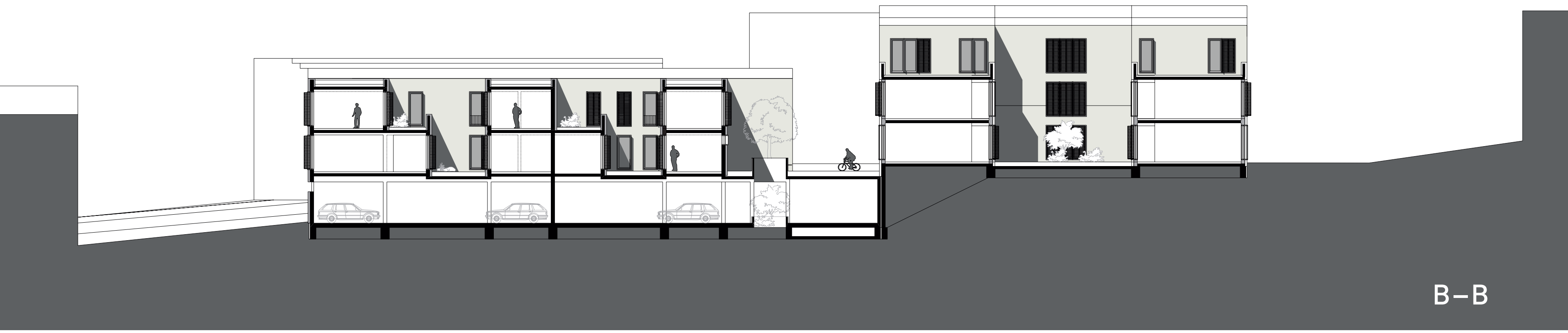

Fig. 29: Section and east elevation

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Figures

IV
Pilot project: New Generation Residential Buildings; Learning from the past, designing for the future

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Abstract

The ever growing dimensions and problems of Iranian cities, especially Tehran, reveal the necessity for comprehensive solutions. Newtown with well-defined plans and a reasonable distance from the mother city could be a logical response to these issues.

Viewed in this light, the new generation residential buildings pilot project utilizes an appropriate methodology without jeopardizing the environment, but instead maximizing indoor comfort. At the same time the project intends to use a maximum of renewable energy, providing higher flexibility and optimal land use.

Through the development of an energy-aware design and the construction of both a modular and flexible system, the project attempts to create a multitude of unique apartment buildings as a solution to contrast the widespread anonymous residential blocks.

In consideration of important global issues, the main objectives of the project are introduction of renewable energy sources, passive architectural measures and innovative solutions to reduce energy consumption as well as the use of energy-efficient, affordable construction techniques and materials.

1 Introduction

Living in a well-defined place has always been one of the most important needs of mankind, and adequate solutions have always been strived for. The importance of the issue could be rooted in the high potential of the dwelling as a means to facilitate and improve the abilities and capabilities of the resident.

The dwelling itself is a matter of indoors versus outdoors, action versus interaction and finally security versus different threatening factors outside the territory of the residence.

Traditional architecture in general, and traditional Iranian architecture in particular, include all of the above-mentioned characteristics; they have been formed, established and developed in a harmonic way. At a city level, on a big scale, the different elements have been formed as a part of nature where the city is positioned in a natural environment and less damage is caused to the context. At a house level, on a smaller scale, a courtyard is a miniature of nature. Here, all aesthetical, cultural and functional aspects are gathered to generate a microclimate in each house to moderate the harsh climate conditions of the context.

Nevertheless, Iranian architecture has experienced vast changes during the last century that have caused a historical break from the traditional roots. Following western styles, despite all cultural, local and technological differences, an urban and architectural culture has developed which is hardly recognizable compared to the traditional principles of architecture. In new developments, the essential connections to nature, the environment as well as local and geographical characteristics of the land have disintegrated.

This development highlights the need to reveal the essential principles of traditional architecture and prove that they are compatible with the new lifestyles of Iranian society. The principles also concern the importance of energy efficiency, the climate and context awareness for architecture. These are the very basic principles of the traditional architecture in most cultures.

2 Goals and strategies

Considering the home as a residence and a place of comfort, with sustainability, energy efficiency and cost efficiency as the main characteristics, is one of the most basic principles of this pilot project: the home as a place to meet various cultural, social, environmental, economic and political needs that are part of the concept of habitation.

Architecture in general, and residential architecture in particular, has always consisted of different dimensions, which can be classified both in terms of quantity and quality.

From a quality point of view, (conceptual) architecture considers cultural, social, environmental and ecological aspects. Therefore, despite the improper definition of habitation within the contemporary Iranian society, the main objectives of the pilot project have been determined as follows:

- achieving an all-encompassing definition of residential architecture based on Iranian ideals and values; in other words cultural-responsive architecture that is applicable to the contemporary lifestyles of Iranian society

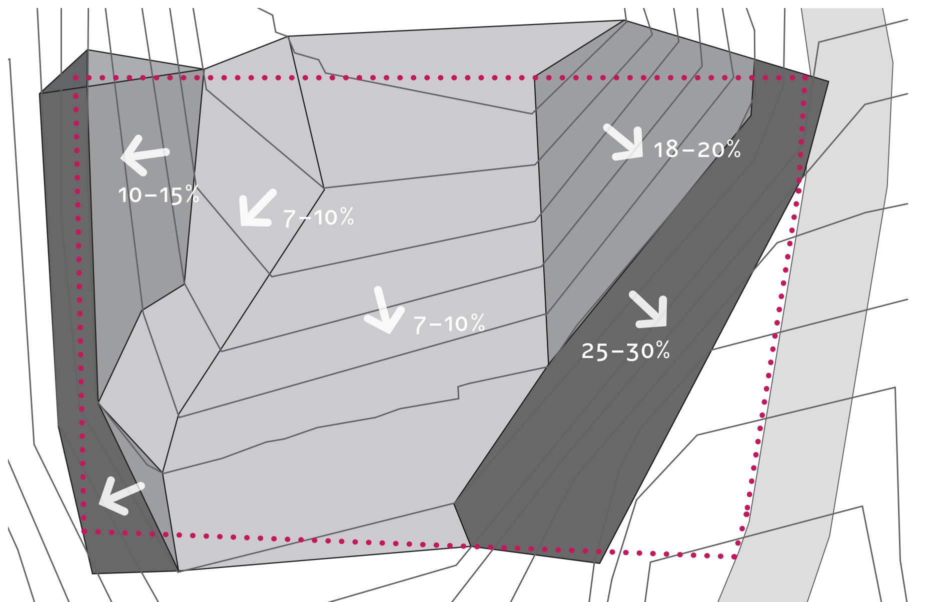


Fig. 1: Inclination analysis of the sub-neighbourhood

- climate-responsive architecture, where urban, architectural and constructional principles are coordinated with the regional climate, and special attention is paid to the climate not as a factor to be controlled, but as a tool with precious potential
- resource-saving and climate-responsive architecture
- prototype architecture applicable to different locations with minor changes

These factors together portray the state of nature, architecture, mankind and his primary needs concerning habitation as an integral part of nature, where its ecological background has a significant impact.

From a quantity point of view, while keeping in mind the cultural, social, ecological and especially economic particularities of Iran, the crucial factors can be determined as:

- social environmental potential and limitations considering target groups
- topographical background of the 35 ha project site
- technical possibilities, potentials and limitations in consideration of the Iranian state of technology and present requirements
- construction material alternatives; potentials and limitations
- construction detail alternatives; potentials and limitations
- implementation of alternatives, possibilities, potentials, requirements and limitations

Harmony with nature, ecology, the environment and the incorporation of the main principles and local characteristics of traditional architecture as well as maximum benefits by using natural energy resources to ensure less environmental damage are the most important features of this pilot project. It is for this reason that it may function as a rich source for green or sustainable architecture and urbanism.

3 Research Methodology

In consideration of the fact that no one research methodology is intrinsically better than the other, some authors pledge for a combination of research methods in order to improve the overall quality of results (Kapan and Duchan, 1988).

Due to the broad theoretical structure and potential of research in the project, different methodologies have been adopted for the identification of new knowledge and ideas. During the planning process, it was identified that investigations should be conducted in a variety of sub-disciplines, including the built environment, environmental behaviour, the history of traditional and endemic architecture, the status of Iranian contemporary architecture, building and materials technology and computing methods. Therefore, the architectural research for this project actually required different methodologies, depending on the subject of study.

Accordingly, the methods applied range from experimental to descriptive, depending on the nature of the research problem and question.

The adopted methods can be classified as:

- theoretical analyses and studies referring to available references and viewpoints with findings concerning the principles of traditional Iranian architecture and urbanism
- comparative studies and practical analyses based on the experiences made by different new cities at an urban, sub-neighbourhood and residential building level. With the help of field studies, different case studies from traditional and contemporary housing were examined and analysed which led to a set of guidelines for the "new generation residential building pilot project"
- simulation methods using software suitable for the addressed issues, such as ideal structure and size of a sub-neighbourhood, good orientation, ideal heights, adequate size and location of windows, suitable heating and cooling systems, appropriate structural systems and construction materials. The findings were applied to the design through the process of planning at various levels. At the design level, the improvements that were made to the sub-neighbourhood and building plans are based on the simulations. On a structural and technical level, the simulations improved and formed the technical details in consideration of the building's construction.

Finally, based on the comparison of findings made at different levels, a range of theoretical principles and practical solutions were compiled as a "Theoretical Guideline" and a "Catalogue of Solutions".

4 Concepts of the project

The main project concept is the development of energy-efficient, low-density residential buildings with a reduced building height, which reflects the regulations determined by the master plan for the “Shahre Javan community” including energy efficiency and earthquake resistance by using a maximum of three storeys and maintaining the natural profile of the area.

Through the development of energy-aware designs and constructions, the project offers solutions to problems that are widespread in mass building construction. These large-scale projects are characterized by huge anonymous residential blocks which do not pay sufficient attention to globally important issues, such as reducing energy consumption, innovative solutions for saving energy, efficient construction techniques and affordable technologies.

The utilization of a modular system that allows a flexible configuration to create a multitude of unique apartment buildings together with cost and time-efficient construction is one of the most fundamental measures towards energy efficiency.

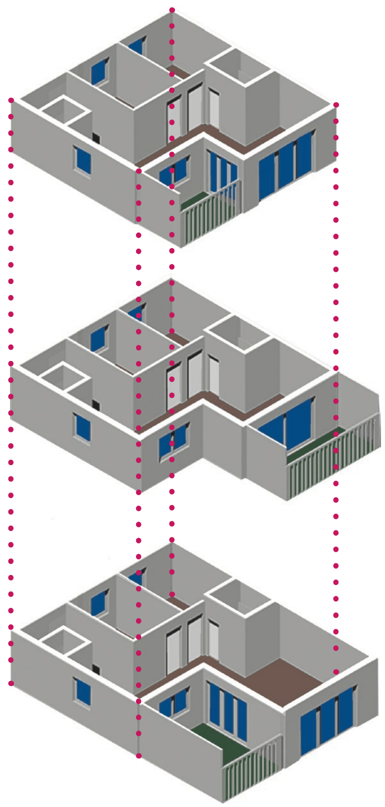


Fig. 2: Hierarchy and space diversity; two governing concepts of the project

4.1 Identification and site concept

The main concept supporting the design of the sub-neighbourhood is a combination of the most important issues governing traditional and modern Iranian architecture and urban design.

As Ardalan mentioned “the special form and structure of a traditional Iranian city is, on the one hand, a cultural-historical response to the natural environment, on the other hand, a reflection of Islamic principles …” (Ardalan. Nader, Sense of Unity, 1971)

Following these principles, the special form and design of the sub-neighbourhood corresponds to the climate requirements, the long-lasting cultural and traditional values of Iranian architecture and urbanism and, at the same time, modern Iranian lifestyles.

Considering the mixed-use concept within the Shahre Javan Community and the diverse activities in the neighbourhood, the project pays special attention to the spatial hierarchy, which guarantees a certain level of privacy for the residents of the sub-neighbourhood.

Following this concept, the new generation sub-neighbourhood and the new generation residential buildings are designed as a series of proportional spaces for a variety of activities. The scheme includes a strip, which has been adjusted to the grid of pedestrian passages, as a tool to not only access the upper levels of open space, but also the commercial, recreational facilities at ground level.

Gathering places are located at the intersections of the pedestrian grids where a variety of residential, social and commercial functions take place around a green space with fountains. The social activities that take place in the common areas between blocks are of a different nature. The frequent use of this space by family members during different times of the day and night give this area the impression of being a living space. By extending the comfort of these open garden spaces and water surfaces into the residential blocks and units, the social effect of the central sub-neighbourhood open space is reinforced. (Ardalan, Nader, Structure of Traditional Concepts of Iranian Architecture and Urbanism, Iranian Art and Architecture magazine, 1987).

The spatial details of the project are based on the Islamic tradition of an open space. These were always encircled by, for example, walls, buildings, trees. Grids of green, water gathering places and movement in general function as channels in the project and are part of the fabric of the “Shahre Javan Community” in line with a traditional Iranian city.

The main concept governing the New Generation sub-neighbourhood and the New Generation residential buildings are as follow:

- *Culture:*
  Cultural aspects have been observed and considered by paying attention to the most important cultural and traditional characteristics of Iranian society, such as social and family values.

- *Sense of Place (Location):*
  This aspect has been considered by paying attention to the relationship between every space, such as its function, its visual effect and the way it is perceived by residents and passer-bys.
- *Spatial Hierarchy:*
  Spatial hierarchy can be seen at different levels of the sub-neighbourhood: open space in the sub-neighbourhood, communication networks, nodes and crossing points of pedestrian pathways, public open space inside the residential blocks and finally the same rhythms in every single residential unit (same reference)
- *Spatial Continuity:*
  Spatial continuity is ensured at every level of the sub-neighbourhood, in the blocks and residential units by using smooth and fluid movements in the different spaces at every level and also between levels (same reference)
- *Climate and Comfort:*
  Throughout the process of designing the sub-neighbourhood and the residential units, the climate and local characteristics of the project were observed as crucial factors that should be worked with, not against. The consideration and response to these factors has brought greater quality and comfort to the whole project. As an example, the south-oriented courtyards are a crucial element of the residential units. They are a physical response to the high degree of radiation as well as the large number of cold months.
- *Light:*
  The concept of light is a cultural and religious feature as well as a very important physical element. It therefore has an important effect on the different parts of the project. Designing units with the greatest possible access to light and the best transparency in south-facing façades is the physical response to this issue.
- *Green space:*
  Green space is most appropriate for social activities in the neighbourhood. Planted areas between the blocks can generate more social interactivity and motivate residents to establish better contacts and social connections with their neighbours.
- *Courtyards:*
  Courtyards are utilized on a family level. These exterior spaces are neither completely covered, nor completely open. In fact, they can be considered as an extension of the living space outside
- *Surface, Volume:*
  By placing the courtyards at different levels and in different positions on each level, there is greater diversity in the façade and the volumes of the buildings. The semi-open space has important functions in family life and can be regarded as a valuable opportunity for owners to present their own identity.

4.2. Development concept

The initial building design concept included a large circulation zone at the centre of each building (designed by the urban planning, urban design and architecture team) and configurations with a north-south elongation. Whilst still respecting the original project concept, this design has been altered dramatically to minimize the circulation area and maximize natural light and heat gain through large south-facing openings by the designers of the architecture, structure and materials department/group—Team 3). Thanks to the new design, heat loss has been minimized through a smaller proportion of north-facing windows. The adopted alterations provide good natural light and ventilation conditions to all apartments. The new circulation zones are designed to break up the large building bulk and communicate a clear sense of orientation. The new layouts provide a flexible entry to each sub-neighbourhood, to the buildings and common green areas due to their special shapes and the materials used (application of traditional shapes and patterns combined with semi-transparent and opaque glass).

Fig. 3: Building concept; flexiable combination of open and closed space

4.3 Building design concept

The internal layouts of the buildings include mainly one and two-bedroom apartments featuring generous living areas and bedrooms with an integrated private area, a separate bathroom and toilet and multi-functional courtyards on all levels to provide both a flexible use in summer and winter. Most apartments have the potential for an additional bedroom or home office close to the entrance.

The common green area is an open space bordered by buildings and stairways. The size and shape allows for it to be used as a meeting area for residents including a semi-private area with a playground or a gathering place. Each building incorporates a fairly large entrance zone that can accommodate a bicycle parking area and/or a secure storage space for each apartment on every floor.

In addition, all apartments can utilize the roof space. The south side of the building projects 1.50 m beyond the ground level to provide a visual "base" to the building and minimize the potential damage to the natural profile of the land.

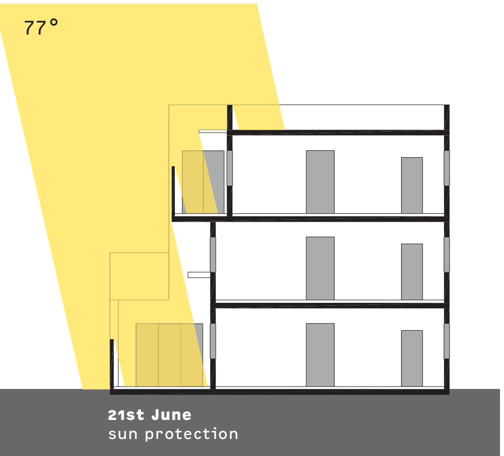
4.4 Energy concept

In consideration of the high number of sunlight hours in Iran, in particular in the Hashtgerd region, one of the most important energy sources for the development is the natural heat provided by the sun. Passive and active use of solar energy is employed by incorporating large glazed areas in the south, and solar collectors and photovoltaic panels on the flat roofs.

The layouts of each building and the associated apartments position the living and dining areas and courtyards in the south; the sleeping areas and the kitchen in the north. The openings are provided accordingly, with larger glazed areas facing south to maximize solar heat gain and smaller vertical windows facing north to mitigate heat loss in winter. Glass-enclosed balconies allow a flexible use of the outdoor space: in summer, it is used for cooling; in winter, it is used as a conservatory. Due to the significant amount of glazing in the staircases, these circulation zones are treated as "unconditioned" space and will be neither heated, nor cooled.

The specification of Gisoton blocks is a central feature of the project's energy concept. Since Gisoton blocks are prefabricated, material wastage is minimized and the construction time and therefore cost is reduced. Due to the possibility of establishing a local production centre, the environmental impact of material transportation can also be mitigated. The proposed Gisoton blocks have an exceptional U-value of between 0.29 and 0.13 W/m²K (for exterior walls, the blocks are between 32 and 42.5 cm thick) and will therefore reduce the energy demand significantly in comparison to more commonly used materials, such as normal brick, concrete or masonry blocks. Additional thermal insulation installed in front of the structural elements will lead to better U-values of the load-bearing elements and improve the overall U-value of the building.

The apartments are heated with a geothermal ground source heat pump system, which is shared between groups of buildings. The hot water is generated by roof-mounted solar hot water systems, which are supplemented by a gas or electric heater to cover peak loads, if necessary.



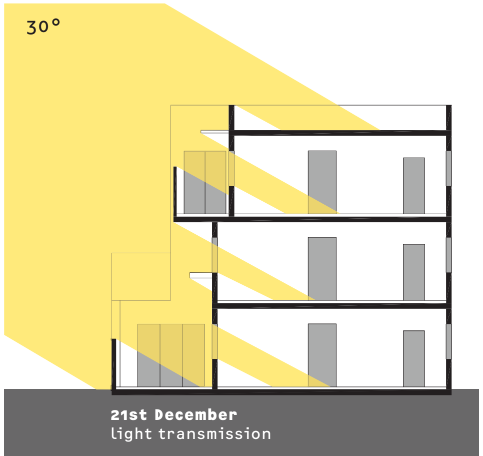


Fig. 4: Sun protection and light transmission

4.5. Shading concept

Effective shading is provided by natural landscaping or by architectural elements, such as awnings, overhangs, trellises, screens and fins, which are designed in a way that allows winter sun to penetrate into the buildings for heating purposes.

A wide range of adjustable shading products is commercially available, ranging from canvas awnings to solar screens, roll-down blinds, shutters and vertical louvers. While they usually perform well, their practicality is often limited by the fact that either manual or mechanical control is required. Durability and maintenance issues are also a concern.

Fixed exterior shading devices, such as overhangs, are generally most practical for small private buildings. The ideal depth of an overhang depends on the size of the window and requirements concerning heating and cooling in the building.

4.6 Waste management concept

Rainwater is harvested in each building for further use in the "Shahre Javan Community". Grey water is directed into the specially constructed wetlands in the exterior landscape areas for treatment and irrigation purposes. Black water is directed to an anaerobic treatment facility; the resultant biogas is stored on site for potential reuse.

Surplus biogas or waste from the anaerobic treatment process (fertilizer) could be used and sold to farmers who live in the villages around Hashtgerd New Town.

5 Findings and governing principles

Traditional Iranian architecture, whilst always in harmony with nature, has been using locally available, eco-friendly energy and low-energy consumption constructions. Following this principle and by paying attention to the location and specific climate zone, the new generation residential pilot project is striving to utilize an appropriate methodology for designing and constructing contemporary architecture suitable for Iran. The aim is to maximize indoor comfort without jeopardizing the environment at the same time as utilizing a maximum of renewable energy, providing a high degree of flexibility and making good use of the land.

The project has concentrated not only on the apartments, but also on the blocks and the sub-neighbourhood. From a typology point of view, the focus has been on apartments in blocks, rather than single-family houses. However, most of the dwellings are accommodated in two or three-storey houses and all units are provided with a courtyard, which is designed as a roofless outdoor space, and a roof terrace, which could become part of a room or an extension of the interior space.

Some of the most important methods and concepts governing the project, either on the sub-neighbourhood or house level, are as follows:

5.1 Sub-Neighbourhood

A range of cultural, social, geographical and climate-responsive rules and regulations have been used as measures to modify the current urban patterns in an appropriate way, especially on a neighbourhood level, such as:

- east-west elongation of the blocks as one of the most important factors in a sustainable and climate-responsive urban environment
- new and innovative utilization of green spaces and vegetation as a multi-functional element to create better ecologically and environmentally-sound solutions
- compactness and high density despite providing adequate exterior space on different levels of the neighbourhood and sub-neighbourhood
- provision of various combinations of public, semi-public and private space
- orientation in consideration of the wind direction, sunlight, etc.
- the general structure and its effects on geographical and climate aspects, such as the consideration of wind, sunlight, etc.
- proportion of open to closed space
- east-west elongation of the residential units as one of the most important factors in sustainable and climate-responsive architecture
- north-south orientation of the blocks and apartments for better climate conditions and to obtain greater heat gain in winter and less in summer
- introduction of a modular system in the residential architecture as a basic approach to facilitate mass construction as well as pre-fabrication
- utilization of flexibility concept with both traditional and modern features
- utilization of various roof concepts: walk-able roofs, shade-generating roofs, combined roofs (masonry and green)
- development of traditional courtyards, ranging from a large open space at ground floor level to a flexible open space in the centre of an apartment, which could function as an extension of the living room
- flexible façade solutions with double façades to create a functional and flexible space between the layers, which can be used as an extension of the main space or simply as a buffer zone to control the heat transfer

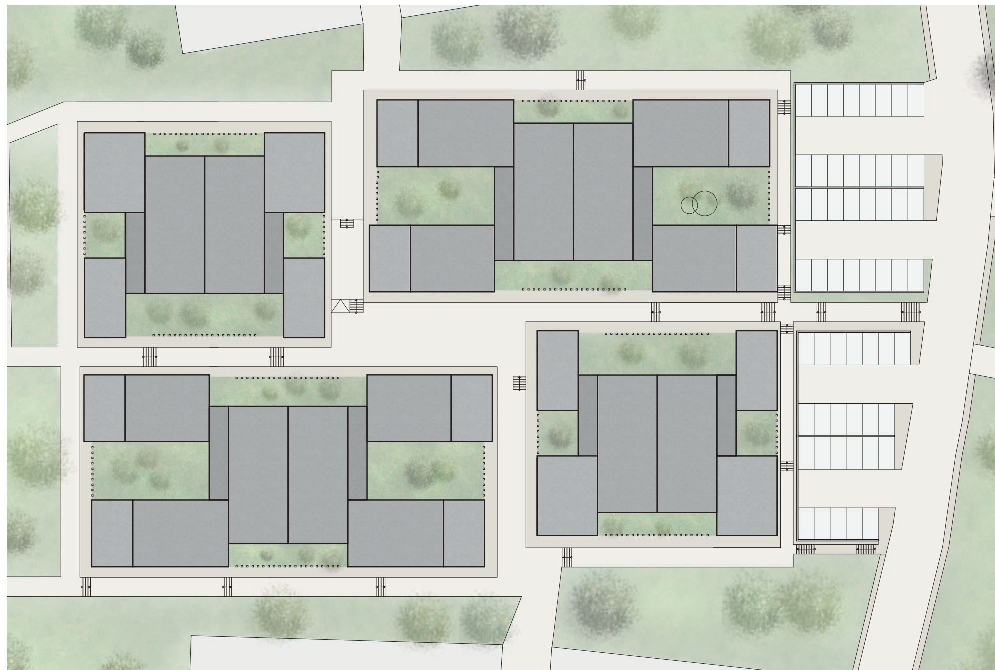


Fig. 5: Site plan of the sub-neighbourhood

5.2 House

On a house level, there are various measures that have been adopted from modern, traditional and climate-responsive architecture, but are nevertheless compatible with traditional Iranian architecture. The adopted measures are able to modify existing Iranian residential patterns in terms of cultural, economic, social and technical aspects. These are as follows:

- dimensions of the exterior surfaces (those in direct contact with sunlight)
- combination and ratio of closed to open spaces
- parallel to the hierarchy of space, an introduction of a green space hierarchy with green areas in the neighbourhood, sub-neighbourhood and residential unit

- proposed forms, materials and structures to improve the current housing industry and energy consumption patterns
- dimensions, heights and thicknesses of walls according to adopted standards and codes to increase safety and earthquake protection and decrease energy consumption
- form, dimensions and types of windows and doors as the basic elements of a climate-responsive architecture and measures for passive architecture
- utilization of sunray inhibitors, shading devices, etc. as the most important items of passive and climate-responsive architecture

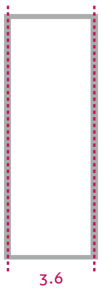
6 Architectural Typology

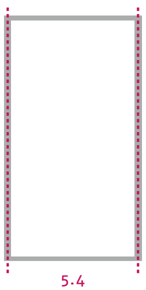
According to the "Detailed Plan" (Tarhe Tafsili), the concentration in the Shahre Javan Community is supposed to be average, which means groups of two to three-storey blocks, not high-rise buildings or single-family housing.

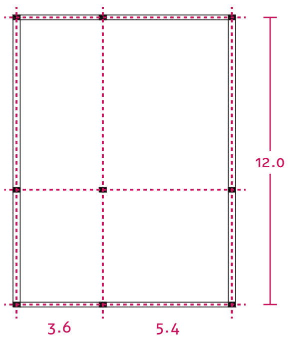
In the process of the project, the sub-neighbourhood was developed according to a concept of combining a courtyard typology and an apartment typology where each apartment has one open space, which, at ground floor level, is better described as a functional courtyard.

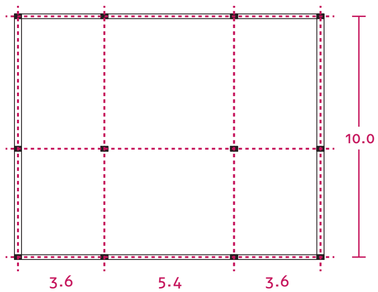
Basic modules:

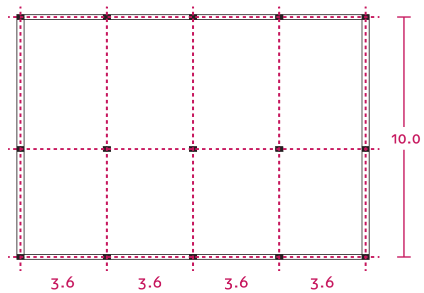
There are six apartment typologies using the 3.6 and 5.4 metre module with the following dimensions:

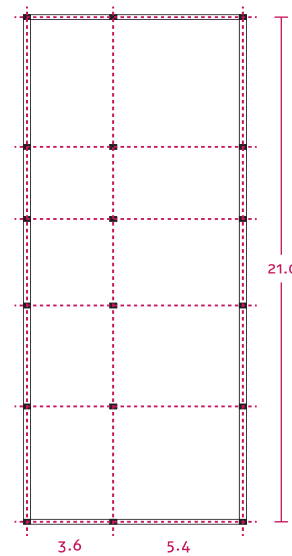


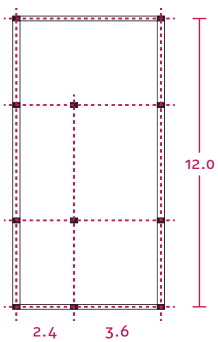












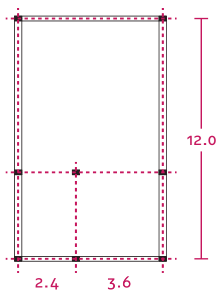


Fig. 6: Basic module
Fig. 7: Extended basic module
Fig. 8: Module Type A
Fig. 12: Module Type E
Fig. 9: Module Type B
Fig. 13: Module Type F
Fig. 10: Module Type C
Fig. 11: Module Type D

The issue of the modularity and flexibility in the project has been driven by a cultural-structural concept where the most common dimensions of an Iranian carpet (3 × 4 m) have been adopted as the module for the apartments and, consequently, the residential blocks as well.

Due to the importance of spatial hierarchy in Iranian architecture and urban design, a hierarchical approach has also been adopted for green and open spaces to communicate better quality, liveliness and vitality in the various levels of the project, from a sub-neighbourhood level to every single apartment.

According to the possible social structure of the potential inhabitants of the Shahre Javan Community, different residential typologies have been provided to cater for the different family structures in Iran, ranging from couples with or without children to extended families, which are provided for by incorporating a multi-functional room close to the entrance of larger apartments.

The basic modules are 3.6 and 5.4 meter. (see Fig. 06 and Fig. 07). There are six apartment typologies using the 3.6 and 5.4 meter modules with various combinations (see Fig. 08 to Fig. 13).

There are two types for each width: 10 m depth and 12 m depth. The 12m-deep apartment has been designed using an innovative concept with a double façade as a functional space adjoining the living room or bedroom.

The 2-module type is designed for small families without children or just one child.

The 3-module type is intended for families with two children or more.

The 4-module type is designed for extended families, families with more than two children and grandparents.

Apartment plan of Type B:

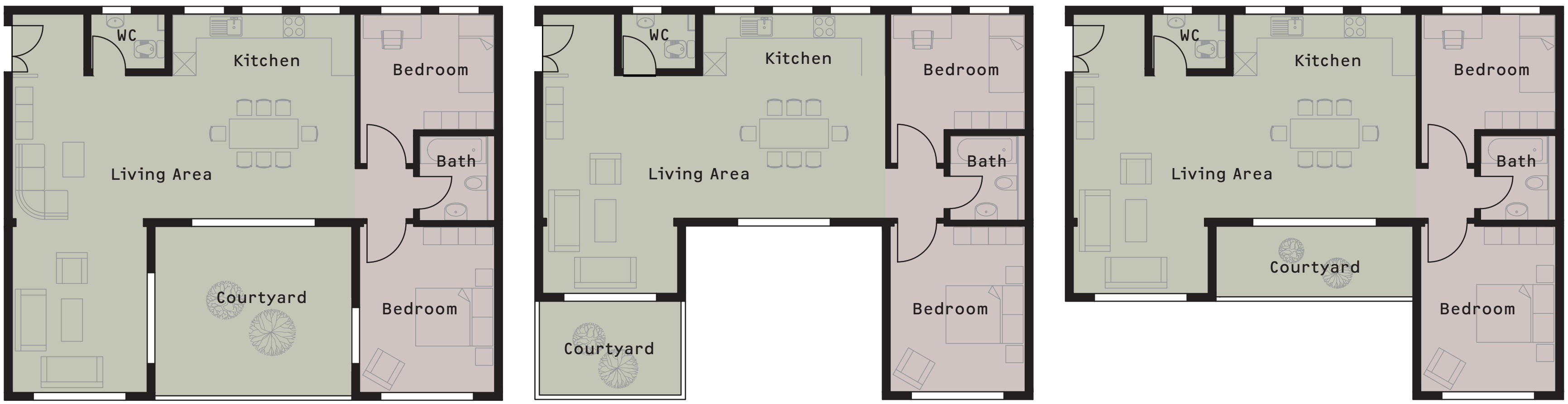


Fig. 14: Scheme of Type B

7 Characteristics of the sub-neighbourhood and residential blocks

The design of the sub-neighbourhood was developed according to the above-mentioned concept. The scheme has a central open space and two perpendicular axes which form the pedestrian network of the Shahre Javan Community:

1. a north-south axis which connects the different sub-neighbourhoods
2. an east-west axis which connects the sub-neighbourhoods to the main north-south direction roads

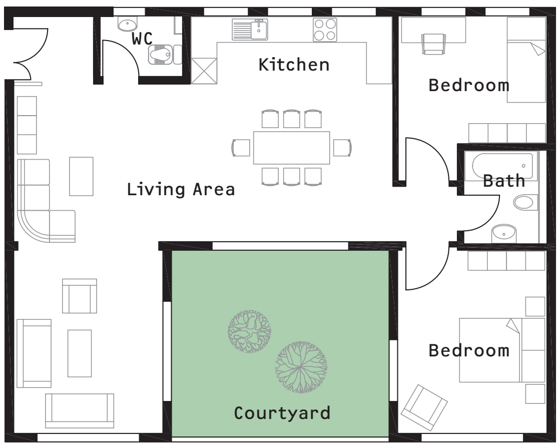
The open green spaces are located at the intersections of these two grids, at the centre of each sub-neighbourhood. Thus, all public open spaces are connected by these grids. Each central open space of a sub-neighbourhood is equipped with outdoor furniture to create an adequate and motivating context for:

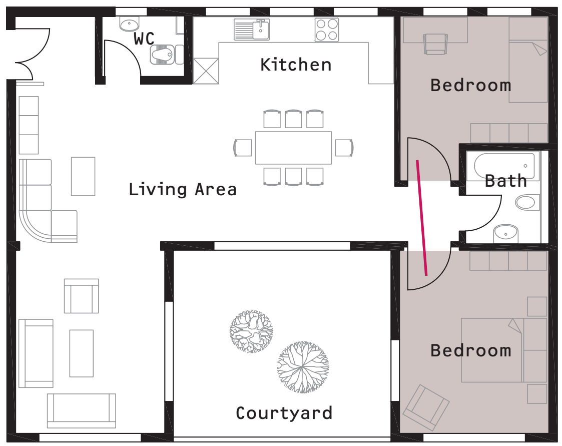
- social interaction between residents
- playground for children
- symbolic elements to generate identity in the sub-neighbourhood

Every four blocks share two more open green spaces , areas similar to a cul-de-sac, for closer social interaction between parents and children under six years, who still need to be looked after. This includes planted areas and water features to motivate greater contact between neighbours.

The ecological-cultural rules observed in the blocks and apartments are as follows:

- most of the apartments have a private open space (courtyard) for family enjoyment only (see Fig. 15)
- flexible and undisturbed movement between the different parts of the communal space in each apartment as a unit of space
- separation of the public and private parts of the apartment to create more privacy in the home as a cultural-responsive solution (see Fig. 16)
- provision of semi-private and private living rooms in the context of a living and sitting room (guest room), and the possibility to connect them in order to provide a deeper understanding of space and culture
- in the bigger apartments, the private rooms are designed in a way that provides better opportunities for families with grown-up children or grandparents, who will prefer more independence and greater privacy
- courtyards and balconies adjoin the living rooms and bedrooms to create a different quality of open space inside each apartment





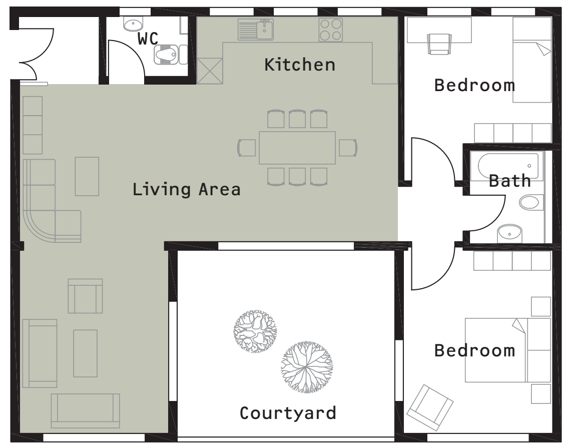


Fig. 15: Apartment courtyard as an extension of the living area

Fig. 16: Bedrooms/private apartment zone

Fig. 17: Courtyard as part of the living/public apartment zone

- since the living and sitting rooms are considered the heart of the apartment, they are provided with the best lighting conditions and positioned on the south side of the apartment (see Fig. 17)
- in consideration of the different lifestyles and social backgrounds, the kitchen is flexible and can either be designed as an open, semi-open or closed kitchen
- in consideration of cultural aspects, the bathroom and toilet have been incorporated as separate rooms in order to respect the belief of the toilet being a polluted and unclean area (see Fig. 18)

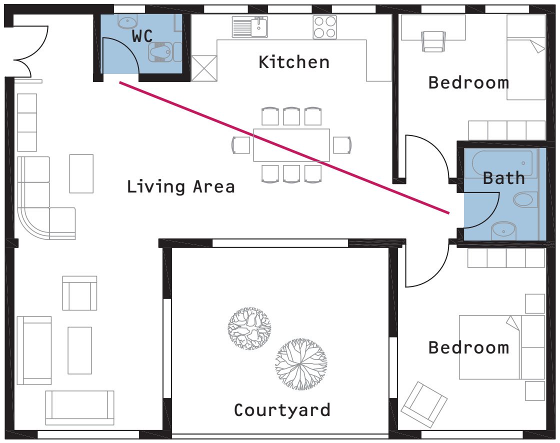


Fig. 18: Toilet and bathroom as separate rooms

8 Analysis of structural and material choices

The advanced technologies and progress of engineering standards have created lot of advanced and innovative solutions in recent years when it comes to building materials and structures. In order to select the best solution, it is necessary to study, analyse and consider the different economic, ecological, social and technological factors as well as the mutual relations between these.

Based on these considerations and the availability of materials, the following structural system and materials are being proposed:

8.1 Structural design

Based on the experiences of residential buildings in Germany and concerning the above-mentioned aspects to consider the best technology suitable for the Iranian housing industry, from an ecological, economic and social viewpoint, the following structural system has been selected.

8.2 Structural materials

A sustainable approach, which will make a lasting impact on society in terms of environmental, social, economic and technical aspects, calls for an accurate selection of materials.

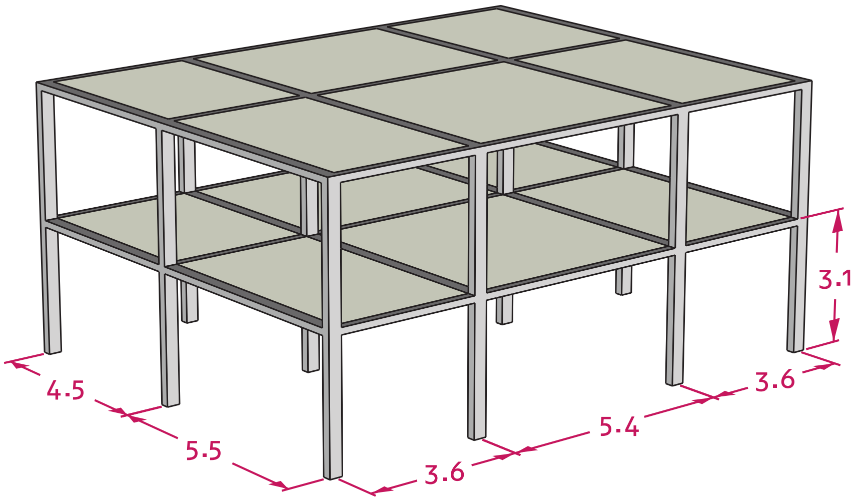


Fig. 19: Modular structure to create architectural flexibility

8.2.1 Structural materials: reinforced concrete

Concrete has valuable inherent properties that can significantly contribute to the three pillars of sustainable construction for the benefit of people and society. Globally, the efficient use of energy is a key factor to limit the impact on climate change. When the whole life cycle of a building is assessed, concrete performs better than all other primary construction materials in terms of energy efficiency.

The thermal inertia of concrete allows it to absorb and store surplus heat or cold, and release these back to the air (heat in winter and cold in summer) as part of a designed thermal strategy. The main benefits of concrete construction are as follows: (http://www.europeanconcrete.eu)
- reduce the heating energy consumption by 2 to 15%
- reduce energy use for cooling when combined with natural ventilation
- unique properties to provide a comfortable and safe environment to live and work in
- high thermal mass to provide a stable indoor climate
- excellent sound suppression and vibration dampening properties
- fire resistant, it therefore provides comprehensive fire protection including life safety
- resistant to explosions, break-ins and break-outs, high temperatures and extreme natural disasters, furthermore, it is not affected by fungal or insect attacks
- concrete-framed structures suffer less damage from leaks or water ingress
- long lifespan and recyclability
- full re-use of precast concrete elements

8.2.2. Materials for external walls

In consideration of the possibility to establish a Gisotone construction line, two innovative materials have been identified suitable for the project:
- Gisotone blocks
- H+H Thermosteine

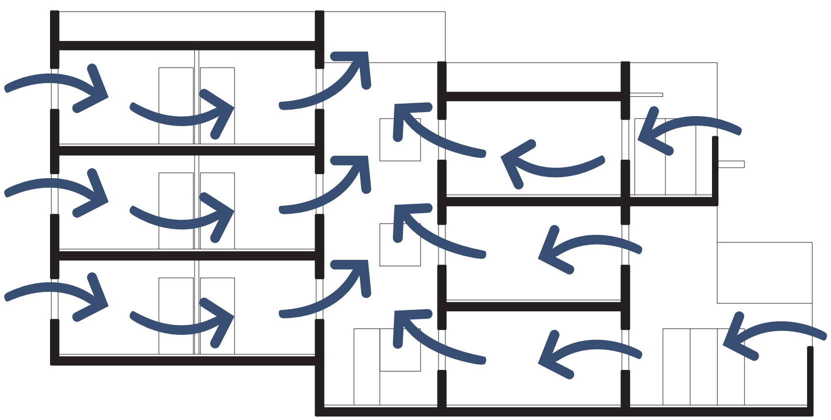


Fig. 20: Type D: natural ventilation

Autoclaved aerated concrete (AAC) is well-known as an environmentally-friendly construction material. The main qualities of the products are as follows:
- manufacture using common and abundant natural raw materials
- energy consumed in the production process emits no pollutants and creates no by-products or toxic waste
- new generation of products eliminates the need for many different layers of material
- workability of the products helps to eliminate waste on the construction site
- the use of these blocks can reduce indoor air pollutants
- material is extremely resource-efficient and environmentally-friendly

8.2.3 Façade materials

The key factors for the façade materials are: availability, cultural acceptance, cost and energy efficiency. Possible options are as follows:
- facing stone
- facing bricks
- ETICS system;

The External Thermal Insulation Composite System (ETICS) is a viable solution to upgrade existing buildings. The effects of the ETICS installation are not limited to energy saving and comfort, but include protection of the building structure from stress caused by temperature fluctuations.

By using ETICS components, the following environmental qualities can be achieved:
- significant improvements to the U-value, for example the U-value of a house with normal external walls can be improved from 1.76 W/m²K to 0.28 W/m²K using ETICS
- reduction of air pollution
- reduction of CO_2 emissions

According to the above-mentioned aspects, an ETICS system is a good choice, especially if the new system, where solar wall heating is integrated in the external wall insulation system, or a prefabricated ETICS system is used.

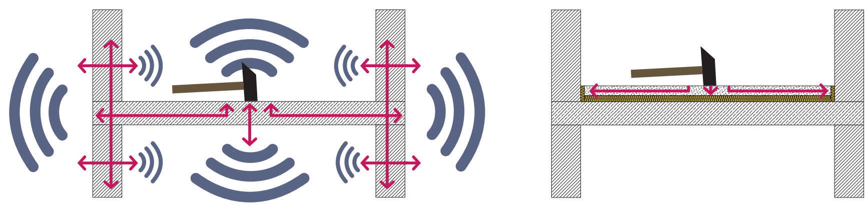


Fig. 21: Function of floating floor; left without insulation, right with insulation

8.2.4 Window materials

An efficient way of reducing energy loss through windows is to select suitable low-e or solar control glass suitable for the climate and utilize new materials for the frames, such as U-PVC or aluminium thermal break profiles.

By using high thermal resistant materials for the frames and special glazing, such as double low-e glass, the total U-value of windows decreases by 30% or more. In consideration of the availability, double low-e glass with a krypton gas fill between the panes could be a good choice. Moreover, these windows are more air and water tight. The advantages of these windows are as follows:

- decrease of heat loss
- decrease of unwanted infiltrations, i.e. water and air
- better thermal comfort by creating a more uniform temperature profile in the rooms
- decreased risk of condensation on windows

8.2.5 Insulation materials

The main insulation issues in the residential units concern thermal breaks to provide protection against thermal bridges and floating floors to provide protection against the impact of noise.

- thermal breaks
  Different technical solutions have been developed to provide thermal breaks in exterior and interior components. The most important solutions are as follows:
  - thermal breaks in exterior building components
  - thermal break elements for basement joints
  - products for mounting insulation materials to walls with reduced thermal bridge effect
  - thermal bridge solutions for windows and wall joints
  - warm-edge spaces for double and triple-glazed windows
- floating floor

The impact of noise on the surface of a floor can be transmitted through the structure and ceiling to the rooms below. This effect can be minimized by using a floating floor system. By installing 25 mm of glass wool, the impact of noise can be reduced to 34 dB.

8.2.6 Shading devices

Two innovative shading devices are as follows:

Metal mesh

Metal mesh is a material with visual versatility, in terms of reflectivity, transparency and opaqueness, and has numerous functional advantages, such as flexibility combined with robustness, permeability to light and air, use as a discretionary screen or sunscreen, safety balustrades and for climate regulation, its practically unlimited service life and ease of maintenance.

It can be wrapped flexibly around objects, in waves or circular shapes, or laid flat on them as though it were a second skin with fixed or sliding panels. Backlit, the mesh becomes invisible; in natural lighting, it reflects the colours of its surroundings.

Roller shutters and sunshades

The new generation of roller shutters and sunshades does not allow any direct sunlight into the rooms once the angle of the sun exceeds 20° (Sun shutters made of stainless steel, a product made by CM, Clauss markisen project GmbH).

8.2.7 Materials for earthquake resistance (shear wall)

As mentioned before, analyses have been performed to define the behaviour of structures during earthquakes. As a result, shear walls, 20 to 22 cm-thick walls made of reinforced concrete, have been recommended. Principally, shear walls are constructed throughout the building, from the bottom to the top to avoid so-called soft storeys. Shear walls ensure the horizontal stiffening of the construction (Grunwald, Jan, New quality paper; Khaligh, Solmaz; New generation structural analysis).

Fig. 22: Shading; combination of various types of shadings to create indoor comfort

Fig. 23: Perspective from sub-neighbourhood

Design, Structure and Materials

Authors
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Date
09 April 2013

Fig. 24: Site plan, sub-neighbourhood

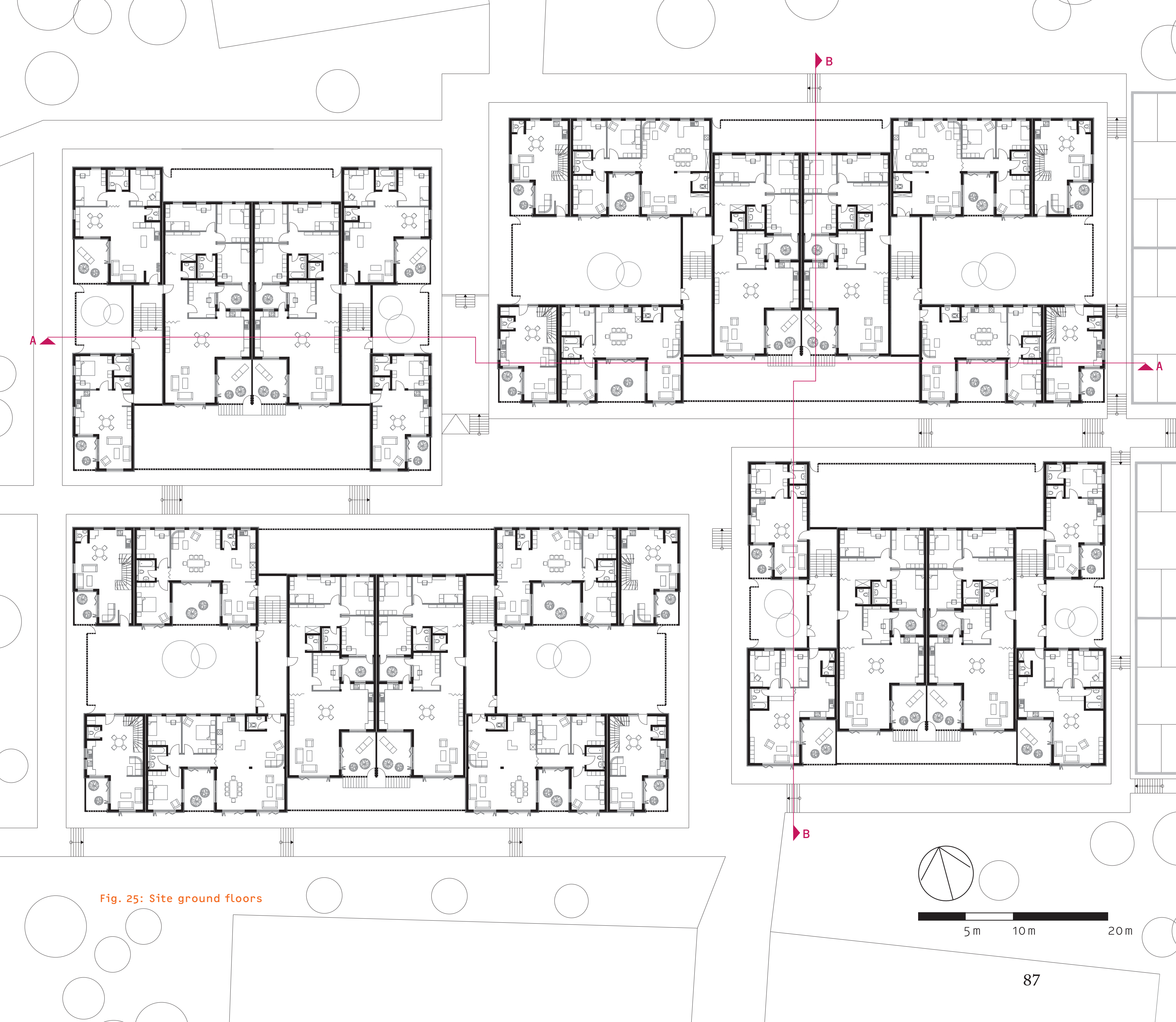

Fig. 25: Site ground floors

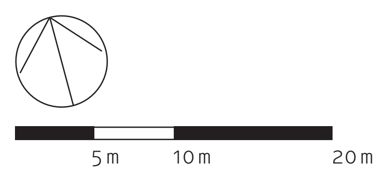

Fig. 26: Site first floors

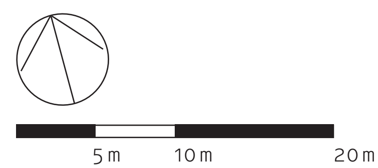

Fig. 27: Site second floors

Fig. 28: Site section A–A and B–B

Fig. 29: Site southern façade Types F, C and D

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Figures

V

Architectural design process for Hashtgerd New Town

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Abstract

The project objective is to design an urban fabric in coordination with a traditional Islamic city and the energy-saving principles to provide a sustainable environment. Accordingly, the design strategies are presented in two main parts: general architectural requirements and energy-efficiency requirements. The general architectural principles are determined according to national codes, particular features of the project, but also social, economic and environmental issues related to the project. The reduction of energy consumption on a building scale is pursued through ideas of architectural design and integrating specific elements, such as planted roofs and window shutters, which are effective in lowering the energy demand. Because the urban design includes different neighbourhood layouts with variable sizes and shapes, the main idea concerning the architectural design process was to provide a modular approach, which decreases the complexity of architectural design. Therefore, this project includes north-south and east-west oriented block patterns that are extremely flexible in the way they can be combined. Accordingly, different shapes in the neighbourhood layout can be covered by using various combinations of the above-mentioned blocks. Finally, a conceptual design of the sub-neighbourhood is presented.

1 Introduction

Architecture is the last step in the process of planning a sustainable and high quality neighbourhood. Therefore, the major objectives envisaged in the site plan, which are expressed in the context of urban design, landscape planning, traffic, environmental issues, infrastructure, etc., should also be incorporated in the architectural design process. In fact, the main approach to the architectural design of a project should be based on the overall anticipated goal. It is therefore necessary to review the objectives of the site plan before considering the overall target of the scheme. As architecture is a process in line with the development of urban configurations as well as neighbourhood areas, it is necessary that the objectives are reflected in terms of the above-mentioned aspects and that the goals are defined in relation to the architecture. In this essay, the objectives of the site plan are firstly defined ON a large scale for the whole project, the urban development and the neighbourhood and finally reviewed in the context of a residential unit.

2 Theoretical approach

Iran's contemporary architecture is, in good approximation, the result of the country's economic, social and cultural conditions. Despite recent styles of Iranian residential architecture containing valuable aspects reflecting current aesthetic values, characteristics of Iranian families and their lifestyles, there are shortcomings regarding the quality of construction and energy matters. Although Iranian traditional architecture has made valuable experiences regarding its high adaptability to the environment and dwellers, few traces are apparent in current residential architecture. A great deal of architectural experience has been gained through long periods and adaptation processes in the environment; another significant aspect to be considered is the mentality of the people living and associated with that socio-cultural background. Thus, traditional architecture includes an accumulation of experiences related to successive generations finding solutions to unique problems leading to gradual optimization processes. Hence, architecture bears collective memories and symbolic features formed in correspondence to these responses. In other words, tradition is a two faceted issue. On the one hand, it involves the old process of solving past design issues; on the other hand, it contains symbolic forms and features that encompass the collective memoires of a nation due to the gradual evolution.

Fact is therefore that both current and traditional architecture in Iran have their qualities. Modernity adds new life values to architecture, such as the application of new construction technologies, optimized building materials, suitable installations, the ease of accessibility, adaptation to current visions and values as well as new lifestyles, including personal and social aspects. In addition, tradition holds numerous values: the materialistic values used to solve design challenges and the spiritual values which are a symbolic manifestation of those solutions and have, over time, transformed into collective aesthetic values. These values cannot be found in modernity. Consequently, it is difficult to live in a new atmosphere without the integration of the symbolic elements from the collective past.

Changing our perspective to obtain a more comprehensive approach could integrate high qualities of both contemporary and traditional architecture. New values added to contemporary architecture through a desire for modernity are today's life essentials. On the other hand, tradition encompasses the inherited values which, if added to the share of today's generation, have the capability of transforming values into wealth. If we succeed, the share of today's generation will be added to that of our ancestors and a full evolution of tradition will be inevitable. This comprehensive approach should contain the following aspects:

- Integration of traditional features, such as acoustic and visual privacy (especially in open spaces), separation of private, semi-private and public spaces inside apartments (hierarchy of space), traditional climate solutions
- Integration of current construction and architectural features, such as advanced infrastructure, materials, construction techniques and energy-efficient approaches with an emphasis on current Iranian lifestyles (especially in related spaces)

3 Strategies and goals

The project objective is to design and create an urban fabric in coordination with a traditional Islamic city and the energy-saving principles to provide a sustainable environment for the next generation of inhabitants. Ideally it should be a systematic and coordinated pattern suitable for conditions and characteristics of Iran and applicable in other Iranian new towns. The main project approach is to optimize the energy consumption in new towns, especially in Hashtgerd New Town, and reduce the negative impact of greenhouse gases (GHG) by developing and implementing innovative infrastructure, planning and design methods, models and plans to provide sustainable housing. Furthermore, the project is designed to look into new trends concerning technical and scientific matters and integrate them in all specialized areas by applying a multi-level approach (from the city to a building) regarding the values of a traditional Islamic city.

The approach of this project is characterized by an optimization of energy consumption and has, in this context, tried to apply vernacular Iranian architectural models as much as possible. According to this trend, the Iranian hierarchal space structure, which refers to an organization of space from public to private, is analysed and adapted to the contemporary urban setting, from a neighbourhood area to a building unit. Furthermore, the aim has been to use some general physical patterns most common in the central parts of Iran featuring very good energy-efficient records. The most significant principles which function as a basis for the urban design and may influence the architectural plan are as follows:

- use of a dense urban pattern to reduce soil erosion, save energy consumption and ensure optimized installation conditions,
- proposal of a mixed-use concept to reduce travel distance, lower energy consumption and increase the quality of urban life,
- provision of open space within the estate with maximum climate comfort thanks to adiabatic cooling,
- suitable building configurations (orientation, surface-to-volume ratio, elongation, shading, etc.) according to sun, wind and vegetation in order to provide indoor and outdoor thermal comfort.

4 Design strategies

The design strategies are divided into the two main parts: general architectural requirements and energy-efficiency requirements.

4.1 General architectural requirements

The general architectural principles are determined according to national codes, particular features of the project, but also social, economic and environmental issues related to the project. Although the project does not necessarily have to observe local regulations, rules and guidelines which provide a universal, secure and safe architecture are considered in the design process as follows:

- Iranian National Building Code, Vol. 4 is considered as a reference for general architectural requirements.
- The principles regarding safety and security have been considered in the design process. The applied regulations are in accordance with the Iranian National Building Code, Vol. 3 and other credible international codes. Moreover, regulations regarding safety and security defined by BRE have been considered.
- As Iran is a seismic prone area, it is of utmost importance to construct buildings to be earthquake resistant. The regulations regarding earthquake resistance, which are related to the architectural design, are in accordance with the Building Code No. 2800 (Iranian Code of Practice for the Seismic Resistant Design of Buildings).
- The architecture must suit the occupants and the scale of the city, neighbourhood and residential units; the occupants include disabled persons and senior citizens. Public and semi-public spaces have been adapted to the needs of these target groups, in accordance with the Iranian Code for disabled persons. Furthermore, 10 per cent of the residential buildings must be designed suitable for disabled residents.
- Solutions should be applied to reduce the noise pollution in buildings and apartments. However, the majority of such solutions are related to building materials and construction techniques, such as sound insulation and the application of floating floor systems, which are not discussed in the present paper. Nevertheless, relevant solutions have been applied in accordance to the BRE codes (BRE housing design handbook, 2003).

The principles of architecture and spatial design have been considered in accordance with the inhabitants' needs and culture. The required standards have been observed with a priority on saving energy. Accordingly, the principles are defined as follows:

- hierarchy of space, from public to semi-private to private
- perfect arrangement of space meeting functional needs
- provision of accurate space per capita according to Iranian lifestyles

- appropriate proportions of open and enclosed areas
- appropriate proportion of interior space

The present plan is a pilot project. Its aim is to provide a model which is capable of being transformed into a pattern. The success of this model depends on the acceptance BY the inhabitants. The main aim has therefore been to provide a model with multiplication capability which makes use of local potentials and has economic advantages. Furthermore, it has specific characteristics which support public acceptance. These features include the following aspects:

- In design, it is necessary to apply features that can be transformed into symbols. If the features weigh strong in the society's culture, there will be greater acceptance and the influence on the "construction culture" will be more significant.
- The architectural design must be innovative and arouse desire among the inhabitants. In terms of the interior space, these features should include good light conditions, a creative relationship between open, closed and semi-closed areas with attention to the privacy of the inhabitants as the most important issue. Therefore, all interior space has direct access to exterior space and there is a good variety of open, closed and semi closed areas in the design.
- Each apartment has a courtyard and a terrace. Natural daylight and views are provided by these courtyards and terraces. The exterior areas are located at the opposite ends of each dwelling unit, which means there are views in both directions. The kitchen and living room also have direct access to the courtyard and at least one of the rooms opens out onto the balcony.
- The site layout facilitates social relationships and supports interaction between the inhabitants. As privacy has been a major consideration for each of the dwelling units, conflicts between occupants can be largely eliminated. The architectural design helps residents to create a healthy social life and take part in collective activities. The development of private, semi-private open and semi-open spaces has been considered on a local and on a neighbourhood scale, respectively, this helps to establish closer bonds between neighbours. In other words, according to the hierarchy of accessibility, people enter the

Fig. 1: Apartments around the public area

The site layout should facilitate social relationships and support interaction between the inhabitants. Apartments located on the north face incorporate courtyards at ground floor level and terraces on the upper levels. Because the apartments face south, residents have a good view of the public area and also receive direct sunlight. The open areas are equipped with movable vertical grills reaching up to 2.1 m. The grills can be adjusted according to the need for more sunlight or greater privacy.

Fig. 2: View into semi-public area from a terrace

The terraces are also equipped with adjustable vertical grills which can provide different degrees of privacy and light conditions.

estate from a public open space on a local scale and move into a semi-public space in the blocks and sub-blocks on a neighbourhood scale. Finally, the last open space, a semi-private open space, is located in the residential units as a courtyard or terrace.

The present design should be able to create an appropriate link between the inhabitants and their environment and help to return the daily dialogue between man and nature to city dwellers. It should also reintroduce the natural environment into people's everyday lives. The design tries to remind people of the sky above, invite sunlight and wind into the estate as desirable phenomena and allow residents to appreciate rain as a positive attribute in a dry climate like Iran. The provision of courtyards, green roofs and open spaces in public and private areas supports this approach.

It is important that the floor plans provide a healthy and safe environment for children; a place for their mental and spiritual growth. The incorporation of a secure place for the interaction of children in a nurturing environment, with parent supervision, has a beneficial impact on this issue.

A house must form a stable and sustainable centre for a family to live together and be a place that sustains human values and emotions. A house must be like a shelter, removed from the hassles of city life, so that parents can bring up their children in peace and stability. Furthermore, it must ensure the residents privacy and enable them to cater for different family occasions. It is for this reason that it must include open, semi-open and closed spaces suitable for different family gatherings, such as birthday or anniversary celebrations, games and other activities. The private courtyards and the possibility of linking the exterior space with the living room, this is the case in most apartments, provide the facilities to meet these requirements.

The site plan must be able to create a link between the occupants and traditions, which exist in the subconscious minds of the inhabitants. The traditions are occasionally expressed in the physical format of the building and should remind inhabitants of the context they originate from. Sometimes these form a basis to revitalize the habits of traditional persons. On the other hand, the link is seen as a privilege for more contemporary persons, who benefit from their ancestors' experience. Tradition is the response to human needs in interaction with the environment, some of which still remain today. Hence, the application of traditional patterns

Fig. 3: View out of the window

Even from the highest level, nothing inside the terraces and courtyards can be seen.

Fig. 4: Courtyard

Rigid walls, reaching up to a height of 2.1 m, adjustable vertical grills and vertical shutters in combination with horizontal shields beneath windows are used to produce private family courtyards.

is important for the following two aspects:

- vernacular architecture as a symbol of identity and a link between inhabitants and their environmental and vernacular background
- reintroduction of traditional lifestyle values

It is for these reasons that the local vernacular elements are reflected in the site plan and improvements are made by combining new methods and technologies.

The site plan must meet the real needs of Iranian families. Often Iranians believe in the Islam faith and its values frequently dominate their lives. Moreover, the lifestyle and general customs are a model for family life. It is important however to mention that the religious behaviour of the occupants does not necessarily follow a fixed pattern and cannot simply be defined as a contemporary lifestyle. The site plan must also cater for different eventualities and be sufficiently flexible. The following aspects must therefore be considered:

- definition of multi-purpose, multi-functional space in different areas to allow for various activities
- distinction between private and public space
- clear relation between kitchen, living room and outside areas (these three zones are the main elements of an Iranian family house; a good link between them will guarantee good suitability for Iranian lifestyles)
- links between interior and exterior space; in particular the avoidance of shared areas, such as light wells, since this distorts independence and privacy of the units and causes problems with, for example, acoustics or odour nuisance

It is important to understand which target group will be living in the apartment blocks. The social composition of the target group determines the necessities and requirements. Thus the income groups, lifestyles, number of family members and social aspects of the resident families must already be considered in the design. The aim is to design a large variety of apartment types that range in size and layout.

Fig. 5: Adjustable vertical grills

Adjustable vertical grills facilitate a variable degree of light as well as privacy.

Fig. 6: Main entrance to the sub-neighbourhood

The residential blocks located on the southern side are setback to provide a wider entrance into the sub-neighbourhood, which is enriched with plants. The setbacks also generate more space between the north and south façades. Accordingly, the lower levels have a greater chance of receiving direct sunlight. Furthermore, direct views between opposite apartments are more easily prevented.

4.2 Energy efficiency requirements

As mentioned before, one of the main objectives of the project is to present an environmental design pattern to reduce energy consumption. The solutions that have been selected to provide greater energy-efficiency on a building scale include:

- reducing the energy consumption through architectural design
- integrating specific elements that are effective in reducing energy consumption
- using materials efficiently
- installing highly efficient infrastructure

Since this paper focuses mainly on architecture, only the first and second issue from above are considered. In other words, although the building materials, construction details and infrastructure play a very important role in reducing the energy consumption of buildings, the purpose of this paper is to focus on energy saving achieved through the architectural design. The design is based on LEED guidelines that are standard practice in the development of a sustainable building. Reducing the energy consumption in a building through the architectural design can be affected by, for example, the subdivision of land, the shape of the building, the relation of dimensions and sizes, openings and the allocation of space. The following paragraphs illustrate the aspects in greater detail:

4.2.1 Orientation of buildings

The orientation of the blocks was determined in the urban plan. This project is based on the results. By proposing a subdivision of land inside the sub-neighbourhood areas, maximum use has been made of direct sunlight from the south. Yet, this factor, in interaction with others, among these the use of a dense layout as the initial principle on the urban planning scale, has resulted in two unit types: the north-south elongation and the east-west elongation type. In the units with a north-south elongation, the volumetric fracturing and stepped terraces ensure that sunlight is admitted into the houses.

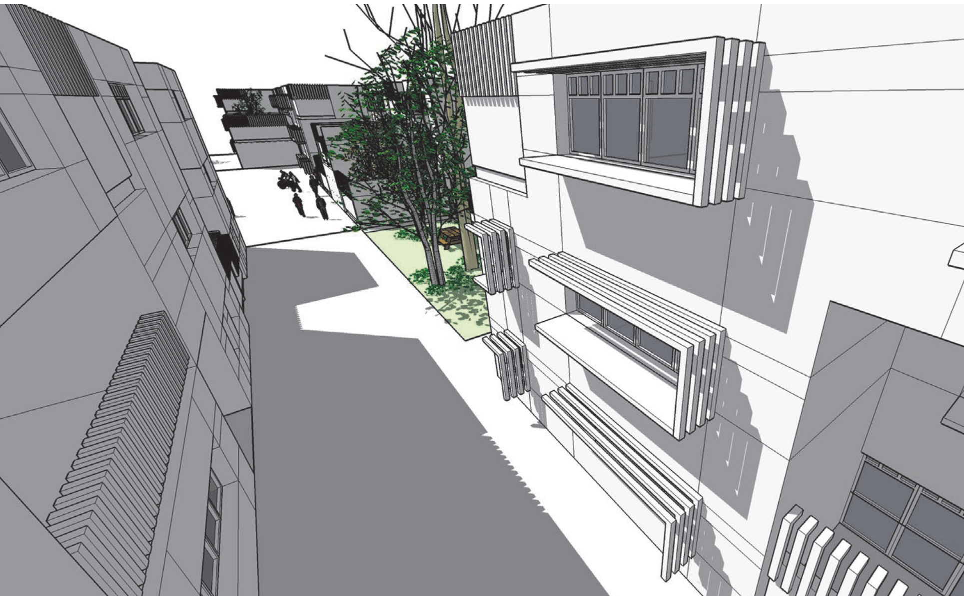


Fig. 7: West entrance to sub-neighbourhood

This entrance is very narrow, which means that the distance between the apartments is fairly small. To reduce problems concerning privacy, which normally occur in these situations, the street is classified as a semi-public area. The solid façades are broken up and structured with a number of small terraces.

Fig. 8: Semi-public area

This area is shared by the surrounding apartments. It is a safe place for children, adults and families to linger play and rest. The apartments facing this area are designed accordingly using special features to prevent disturbance in terms of visibility and acoustics.

4.2.2 Space between blocks
The small distances between the blocks, as defined in the development plan (Tarh-e-Tafsili), and the narrow gaps have led to the buildings casting shadows on each other. To resolve this problem through architectural design, the open spaces between the blocks are increased by designing consecutive setbacks in the buildings.

8.2.3 Green spaces in semi-private and private spaces
Storeys and corners are staggered to create stairways and private courtyards on each level; this is beneficial in terms of directing more light into the units.

8.2.4 Series of stepped volumes
In order to create a space between the blocks with better views and natural lighting, this especially applies to blocks that are immediately next to each other and have a shared corridor for access, courtyards that face each other have been introduced on the south-face of the northern blocks and on the north-face of the southern blocks. These courtyards are terraced so that the distance between the walls of opposite blocks increases gradually (see Fig. 20 and 21).

8.2.5 Reduction of wind speed
Long corridors between blocks can turn into wind channels. If the corridor width to length ratio is less than 0.05, the wind speed increases (Gander, 1994). If the corridor width at the entrance and exit are different, the so-called Venturi phenomenon occurs and wind speed rises even further. High wind speed is responsible for tremendous heat loss from the corridor walls and a threat to the comfort conditions in the blocks facing the corridor in winter. This is a very important aspect in the case of Hashtgerd New Town due to its cold climate, especially in winter.

In order to reduce or even resolve this problem at the design stage, the lengths of the corridors are reduced by dividing the terraces into blocks. A further increase of wind speed is avoided by terracing or setting back the blocks accordingly. Furthermore, care is taken to avoid positioning long building faces perpendicular to the wind direction and aligning the longer building elements with the dominant wind direction.

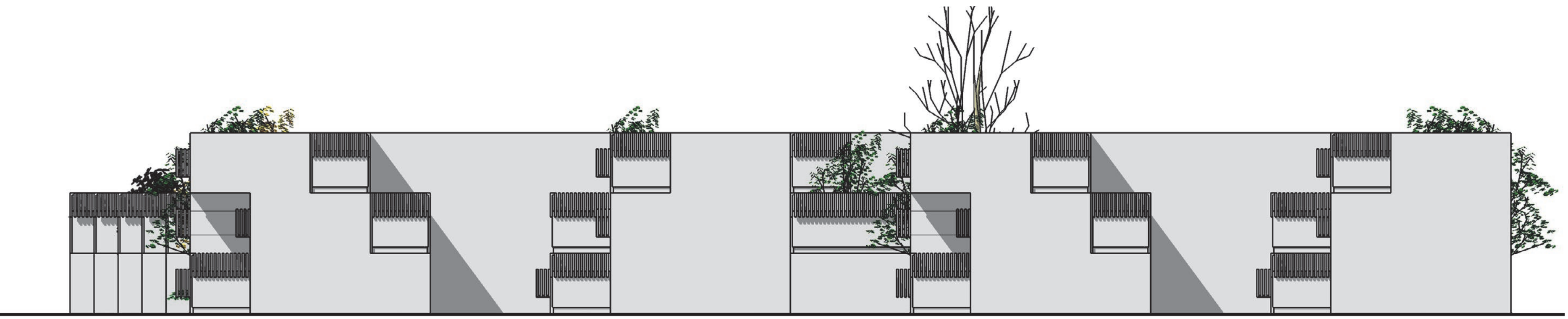


Fig. 9: Series of stepped volumes

The stepped volumes help to provide more space between opposite blocks, affecting more privacy, better natural light and views.

8.2.6 Combined commercial and residential use

The intention of a mixed-use scheme is to reduce trips into the surrounding urban environments and increase social activities in the estate. This principle has been applied to this project (see Fig. 11).

8.2.7 Compact form

The compact form is one of the main principles of the urban design as a solution to reduce energy consumption - one of the main intentions of this project.

8.2.8 Corridors as buffer zones

To avoid energy loss from the east and west-facing exterior walls, access corridors to the different storeys have been used to create buffer zones.

8.2.9 Spatial distribution

The space in residential units can be classified as: 1) space that needs natural daylight and is used throughout the day, 2) space mainly used during the night, 3) service zones, such as storage, entrance, bathrooms, etc., that are used throughout the day, but do not necessarily require daylight. The kitchen needs daylight and ventilation, but not actually direct sunlight. The kitchen is a space which distributes energy because activities producing heat,such as cooking and a number of related devices, e.g. oven, take place there. The arrangement of space should be made accordingly:

- Units with an east-west orientation divide the residential area into a northern and southern zone, in which the best location for the living room, dining room and bedrooms is to the south. But because the bedroom is not used during the day, it is more important to use the southern location for the living rooms. Service areas are usually located in the north. Since it distributes energy, the kitchen can be located on the north side, too. The best location for the entrance is in the centre, between the north and south side, which ensures better access to the interior space. However, from an energy point of view, the south side is the preferred location. To provide better lighting conditions in the bedrooms, the bathrooms are located in the centre of the apartments (see Fig. 12 and 13).
- Units with a north-south orientation divide the residential area into three zones, a northern, southern and centre zone. The middle zone

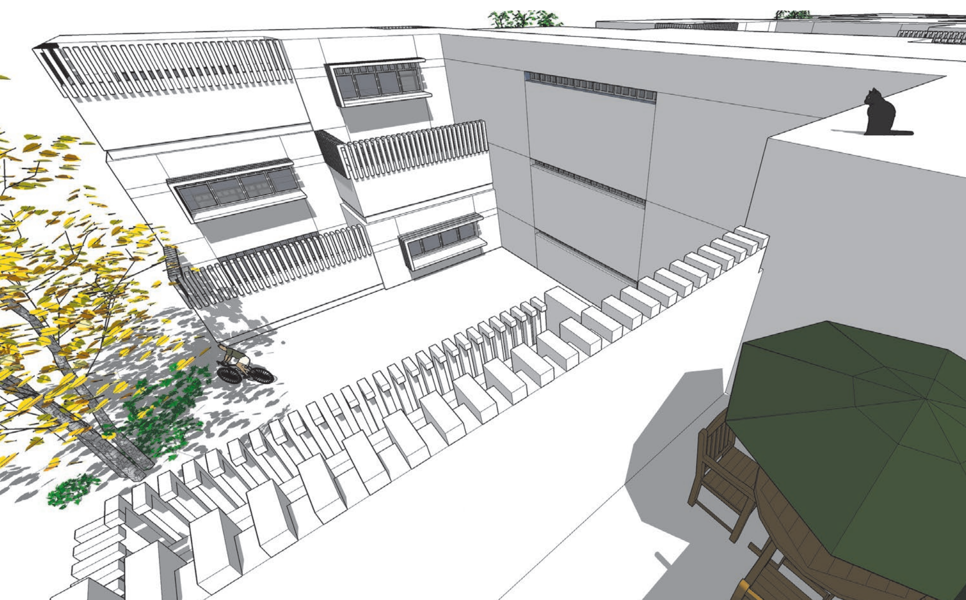


Fig. 10: Private terraces

Creating terraces with as much privacy as possible, yet not isolated from views and sunlight, is regarded as a key design strategy.

Fig. 11: Public area

The public area is surrounded by the apartment types A and B. This space is suited to incorporate commercial units and provide facilities for social resident activities.

is allocated to spaces which distribute energy (like the kitchen) and spaces that do not necessarily need natural daylight (like bathrooms and storage space). The living and dining rooms are best located in the southern zone. Because bedrooms are not used during the day, they are predominately located in northern zone; the southern zone accommodates the living and dining rooms. The entrance is positioned in the middle of the east or west side of the apartment (see Fig. 14).

- All areas must be organized so that warm and cold air can flow freely within the interior space.

8.2.10 Maximum use of sunlight

The use of natural light in the interior space does not only create a more desirable atmosphere, but also reduces electricity consumption in the buildings. Therefore, space used throughout the day should be located in the south. Other important aspects of natural lighting are: the type of glass, sufficient room depth and the size of openings, each of which is reviewed as follows (BRE housing design handbook, 2003):

- If houses are too close to each other, the amount of daylight entering the building is reduced severely. As a rule of thumb, the obstruction angle to the horizontal, measured in a cross section at a point 2m above floor level, should be less than 25°.
- Windows should be large enough: the amount of daylight in a room is measured using the average daylight factor DF. It is determined as:

$$DF = \frac{W \Theta T}{A\,(1\text{-}R^2)}\,\%$$

W is the total area of glass; A is the total area of all room surfaces (ceiling, floor, walls and windows); R their area-weighted average reflectance. Typically R=0.5 is used for light coloured surfaces, 0.3 for rooms with dark finishes. T is the glass transmission factor (0.85 for single glazing, 0.7 for double glazing); Θ is the angle of visible sky. The recommended average daylight factors DF are 2% for a kitchen, 1.5% for a living room and 1% for bedrooms (see BS 8206: part 2). If there are windows in more than one wall, facing different obstructions, the average daylight factors should be calculated separately and then added together.

- Reduce the amount of dark areas: If a room is too deep, the back of the room always appears gloomy compared to the areas close to the window, no matter how large the windows are. In residential buildings, this usually occurs in rooms with openings in one wall only. The room is too deep if:

$$l/w + l/h > \frac{2}{(1\text{-}R_B)}$$

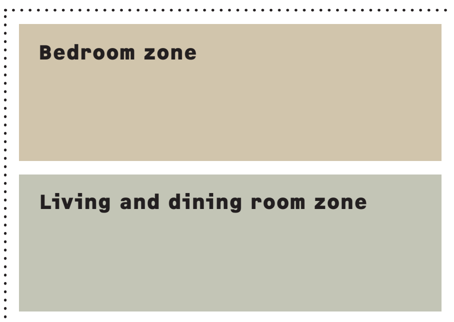


Fig. 12: Pattern of spatial distribution in east-west oriented unit

Fig. 13: Pattern of spatial distribution in square-shaped unit. Square-shaped units provide a better air flow in the living and dining room zone.

Fig. 14: Pattern of spatial distribution in north-south oriented unit

- Windows near projecting components or the internal corners of courtyards are also affected. The 45° approach can be used as a guideline. The elevation of the window can be used to apply an angle of 45° from the closest corner of the protruding element. If the centre of a window lies on the 45° line, the protruding element can cause a significant reduction of the daylight that could be received by the window.

Here, l is the depth of the room from the wall with the window; w is the room width and h the height of the lintel above the floor. R_B is the average reflectance of the back half of the room, typically 0.5 for light finishes, 0.3 for darker finishes.

- Daylight distribution: The daylight distribution in a room may also be poor if there are too many obstructions. The worst problems occur when some parts of the room receive no direct light from the sky.

The *no sky line* marks out these areas. Its position is determined by connecting the top of the obstruction and the window lintel. It is usually plotted at tabletop height (0.85 m). Areas beyond this *no sky line* will look gloomy and should be kept to a minimum by increasing the lintel height, improving the room layout or increasing the space between the window and the obstruction.

8.2.11 Reflectors for north faces

The north-facing areas of a building lack direct light due to their position. The problem may be resolved somewhat by installing reflectors on the south-facing walls opposite to reflect more light onto the north face. Flexible control of the reflectors should be considered.

8.2.12 Conservatory and double façade

Semi-open space that can be changed into closed space, in particular in south-facing façades, has several advantages. The flexible zones increase the interior area when needed. They can be used as a conservatory (greenhouse) in winter and a balcony in summer. The greenhouse effect is avoided by being able to change the space into a semi-open zone.

8.2.13 Green space on a neighbourhood scale

The development of green exterior space improves the environmental conditions in an estate. Most plants produce shade and a fresh appearance around buildings. Four-season plants can be used to control wind speed in winter as well as provide greater privacy throughout the year.

8.2.14 Planted roofs

Terraces and private courtyards are an opportunity in any unit to create planted areas such as green roofs. They do not only improve the environment and appearance, but also attract birds and generate pleasant conditions for residents during their leisure time. Furthermore, the roof, in this context, acts as a heat insulator and has an important impact on temperature fluctuations. Often green spaces are developed in the large courtyards in front of buildings. In Hashtgerd New Town, because of its climate, extensive or semi-extensive green roofs in combination with pots are recommended. Considering the water shortage in this area and in order to nevertheless provide water for plants, water tanks are mounted on the roofs. Seasonal rainfall and wastewater can be used for the irrigation of plants. In order to prevent views into the apartments, plants are best placed at the outside corners of terraces, at least 70 cm deep.

8.2.15 Adjustable canopy roofs

The possibility to adjust light according to the different seasons and hours of the day is an important issue concerning the management of energy consumption and the profitable use of sunlight. Regarding the issue mentioned above, adjustable canopy roofs, louvre blinds and shutters are an important consideration in the design.

8.2.16 Solar collectors (PV panels)

There are on average 300 sunny days a year in most regions of Iran (90%) and approximately 5.5 kWh of solar energy can be absorbed per day and square meter (Renewable Energy Organization of Iran, 2005), which is remarkable in comparison with other countries. This in mind, it is better to install solar collectors on the roof; façade-mounted applications are however also worthwhile. By installing the PV panels near plants and, for example, in combination with a green roof, the efficiency is increased further. All solar water heaters work as a pre-heating system and support the conventional water heater, which now becomes a back-up unit. A variety of solar water heaters are available on the market. They are divided into three categories: active, thermosiphon and batch. Active and thermosiphon water heaters use solar panels or collectors to capture the sun's heat. The water running through the collectors absorbs heat and increases in temperature. The warm water then flows to a storage tank. Batch water heaters, also called bread boxes, are simpler and combine the collector and storage tank in one box. (Govenor's Division of Energy, 1988). The selection and application of appropriate solar collectors (including PV panels and solar water heaters) should be the next step. Currently, investigations are being made into providing the appropriate conditions on roofs and in courtyards for the application of solar collectors.

8.2.17 Passive cooling

In arid areas with hot days and cold nights, cooling systems, such as evaporative cooling, earth tubes and solar chimneys, are well suited. An earth tube is a pipe buried a few feet below the ground, which draws outside air into the house. A solar chimney is an air collector on the roof that is used to ventilate a house in summer. According to architectural features of the design, some of the above-mentioned solutions are applicable.

5. Architectural design

The urban design includes different neighbourhood layouts with variable sizes and shapes. If each neighbourhood layout were designed individually, the complexity of the design process would increase inexorably. To overcome this problem, the main idea has been to provide a modular approach and simplify the architectural design. The scheme therefore includes north-south oriented and east-west oriented block patterns that are extremely flexible in the way they can be combined. North-south oriented blocks, which are 9 m wide, have the required flexibility by being able to differ in length in the north-south direction. East-west oriented blocks are constrained in their length, but the widths of these blocks can range from 6, 9 to 12 m and include a combination of different models. According to the type of neighbourhood layout, different combinations are possible. For example, north-south oriented blocks with their flexible lengths in north-south direction can be combined with different size blocks with an east-west direction, in accordance with the special shape of each neighbourhood layout in the urban design. Accordingly, different shapes in the neighbourhood layout can be handled by using different combinations of north-south oriented and east-west oriented blocks.

In a north-south oriented layout, the subdivision of land is based on a compact scheme with north-south oriented 9 m-wide blocks that are located side by side, sometimes with a slight shift in the north-south direction. The lengths of the blocks allow for setbacks or protrusions in the north-south axis. It is therefore possible to develop open space on a neighbourhood scale in front of the blocks. The access to the units is from a central corridor; the entrance to the blocks is in the middle of the boundary line. The blocks have three storeys; each has one residential unit with a private courtyard and a terrace. The floor areas therefore reduce gradually towards the top of the building. The following plans illustrate proposals for the units and their communication schemes (see Fig. 16, 17, 18).

East-west oriented layouts include three different types with widths of 6, 9 and 12 m. In order to maximize the use of the south orientation in the subdivision of land in an east-west direction, the length is reduced and there is the possibility of constructing two separate blocks with a middle passageway (see Fig. 20 and 21). The width of the passageway is designed in such a way that daylight can be used to illuminate the apartments down to the lowest level. Because of the short length, the passageway appears as an open space in the peripheral neighbourhood rather than a corridor to access the units. There are three storeys to this residential unit at both sides of the space. The terraces of the northern units are located in the south; the terraces of the southern units in the north. The terraces have been designed with a stepped configuration and in reverse to the opposite units. The space between the apartments is like a wedge. This arrange-

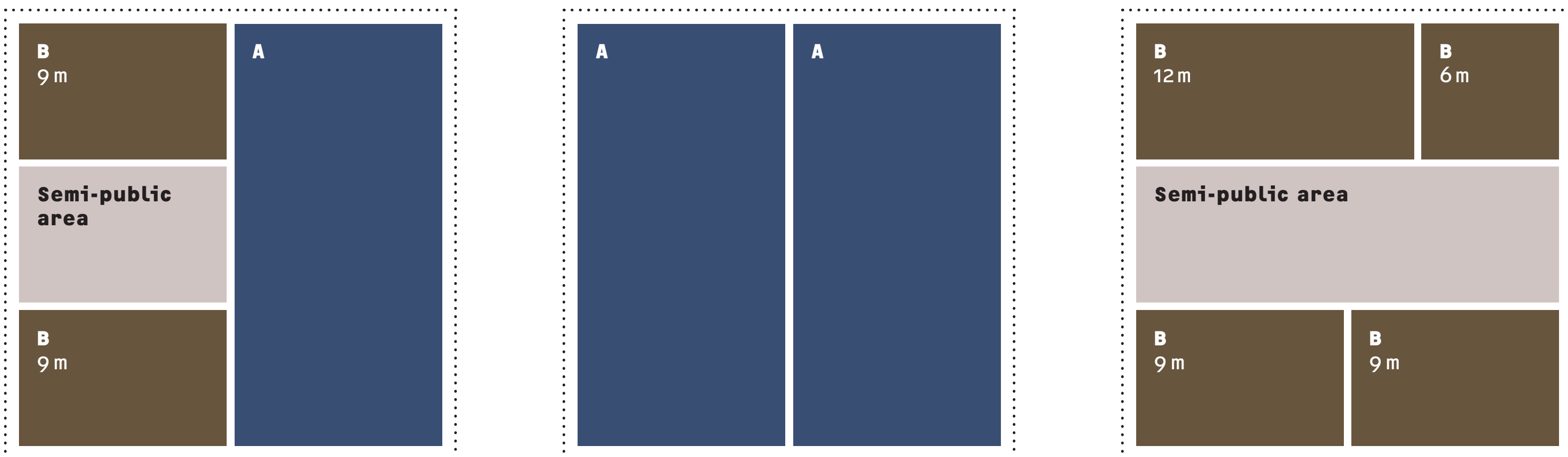


Fig. 15: Possible combinations of different block patterns

North-south (here called A) and east-west (here called B) block patterns can generate a number of different arrangements in a certain plot ment does not only supply more light to the lower apartments, it also reduces overshadowing. Furthermore, the configuration generates favourable space in the semi-private areas of the peripheral units and is beneficial to all terraces. Reflectors may nevertheless be installed on the south-facing façades of the opposite units to provide even better light conditions in the north-facing units.

Rhythmic and semi-symmetric setbacks in types D1 and D2 create a V-shaped space between the two sets of apartments. Due to this arrangement, direct sunlight can even reach the lowest levels on the north-facing side. In addition, the V-shaped space generates a sufficient distance between the opposite apartments for the residents to enjoy total privacy on their terraces.

The access to the 6 m-wide unit (B3) is practical. In this case, residents on the ground floor access their unit from the middle courtyard; residents on the upper floors must access their dwellings from the south using stairs that are shared with the north-south elongated blocks. The first and second floor in this block incorporate duplex units, which means that only one flight of stairs is required. The diagram below shows the different types of access and the floor plans of the units.

The proposal to combine type A and B affects both the shape and the length of the blocks. Nevertheless, there are some very interesting aspects:

- the length of the corridors and the open space providing access to the units is reduced
- open space is created, which provides suitable light conditions in the units, but does not affect the semi-private atmosphere of the open space.

Apartments located on the north face incorporate courtyards at ground floor level and terraces on the upper levels. Because the apartments face south, there is a good opportunity for them to receive direct sunlight. The open areas are equipped with movable vertical grills reaching up to 2.1 m. The grills can be adjusted according to the need for more sunlight or greater privacy.

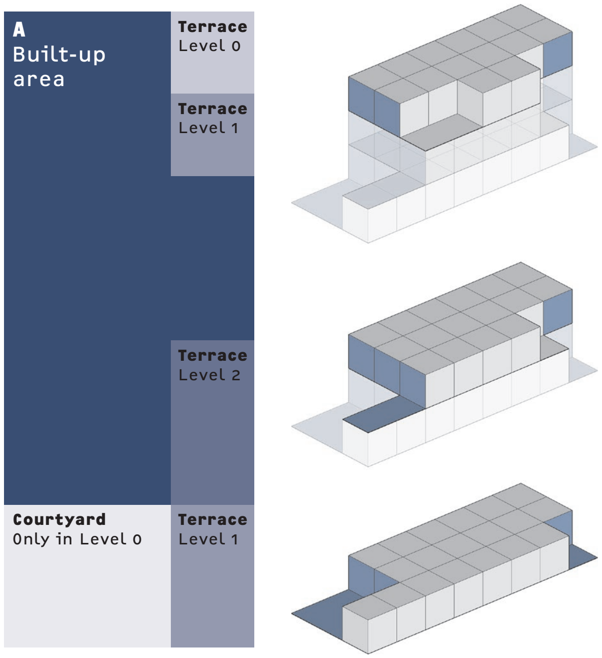


Fig. 16: Diagram type A

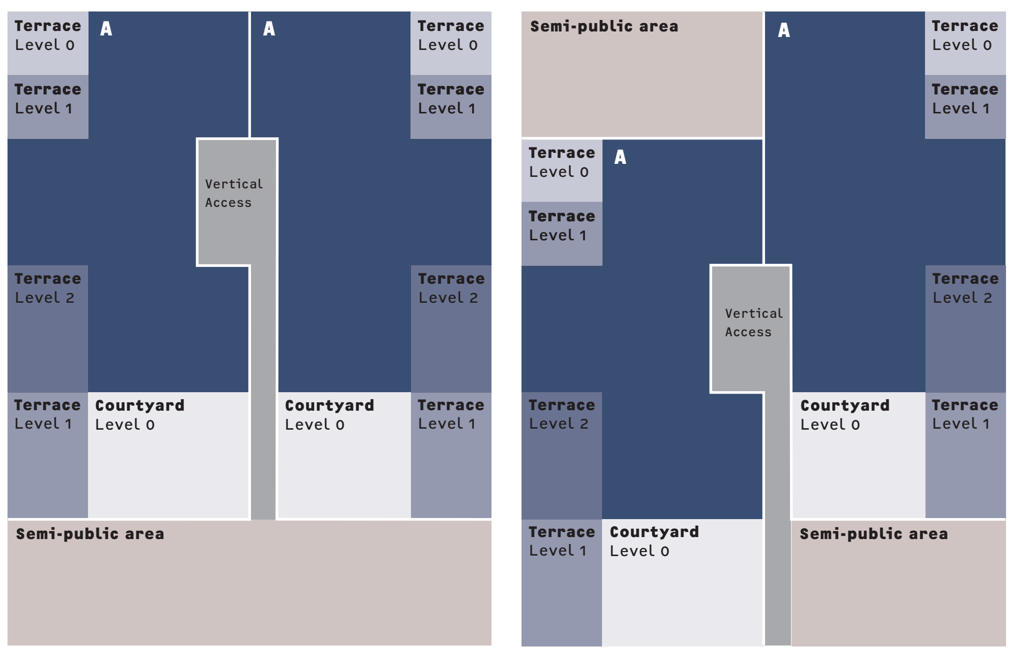
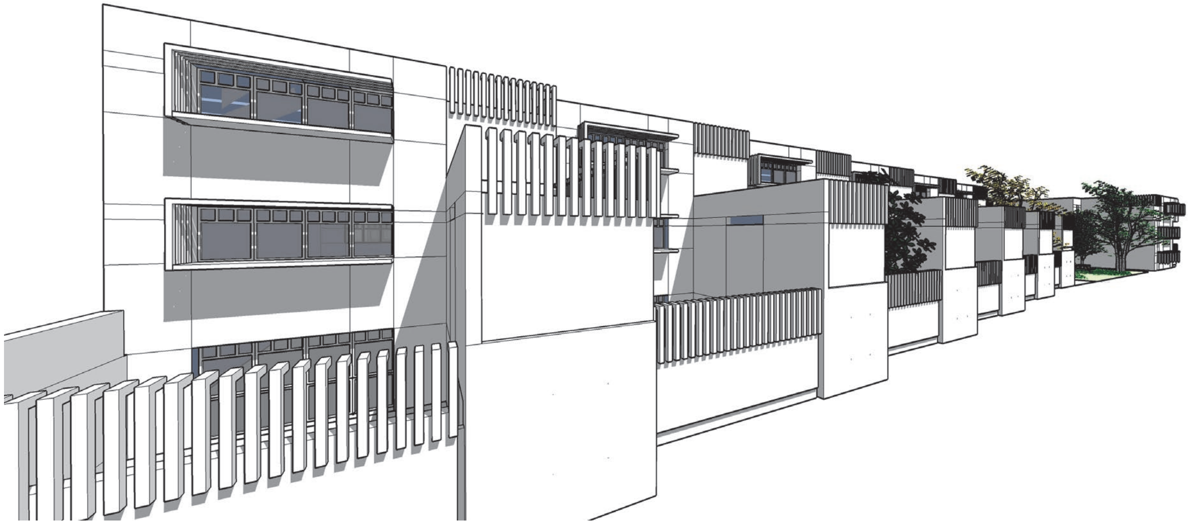


Fig. 17: Access diagram type A



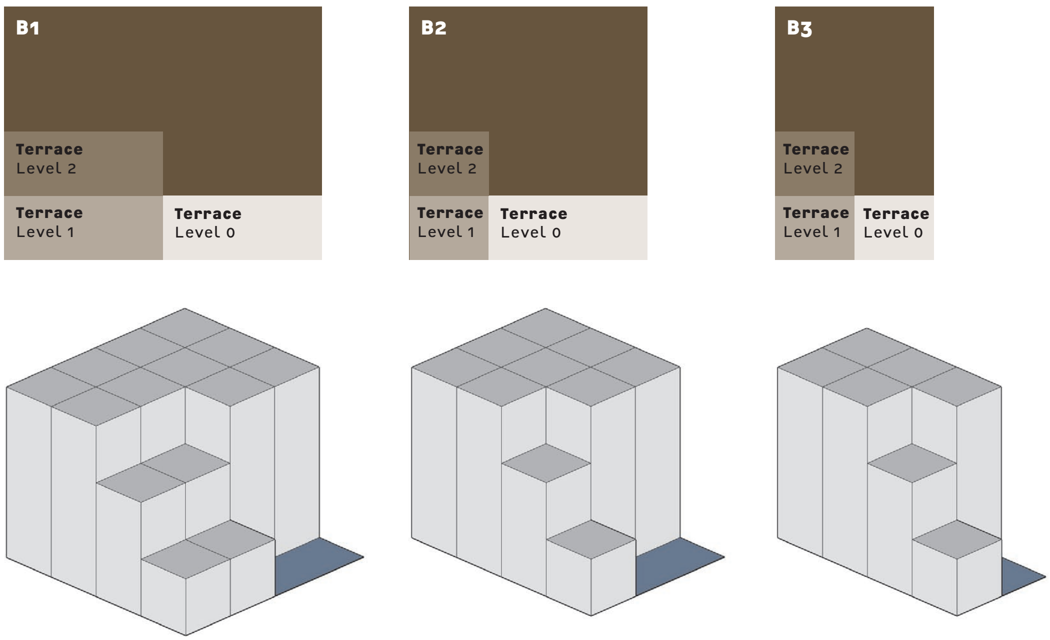


Fig. 18: Arrangement of type A
Fig. 19: Diagram type B

Fig. 20: Mirror arrangement of type B

Type B includes three different sizes with the following widths: B1 with 12 m, B2 with 9 m and B3 with 6 m.

When two type B blocks are combined in a mirror arrangement, the open space between them can be used as a semi-public area (see fig. 21).

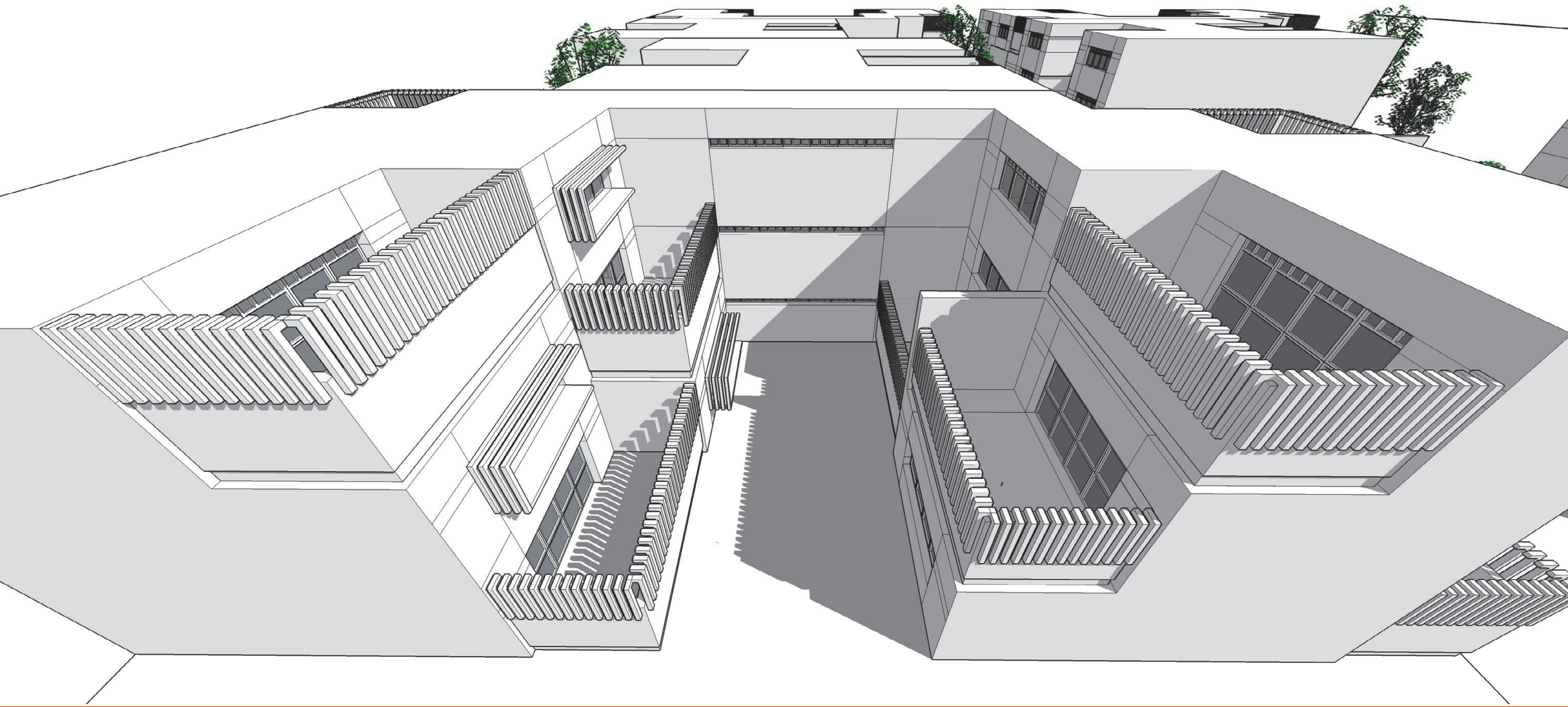


Fig. 21: V-shaped space with type B1

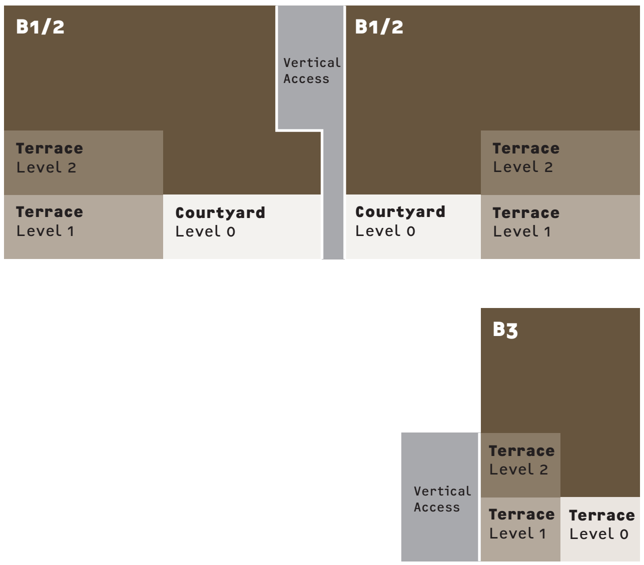


Fig. 22: Access diagram type B

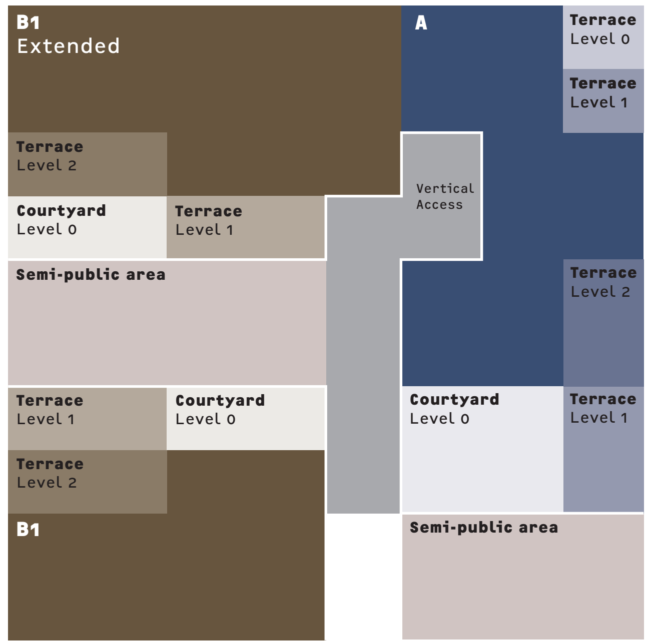


Fig. 23: Combination of type A and B

Type B1 and B2 can use a common vertical access, but block B3 requires a separate access.

The combination of two types provides better opportunities for access, the hierarchy of space (from public to private) and adaptation to the urban plot.

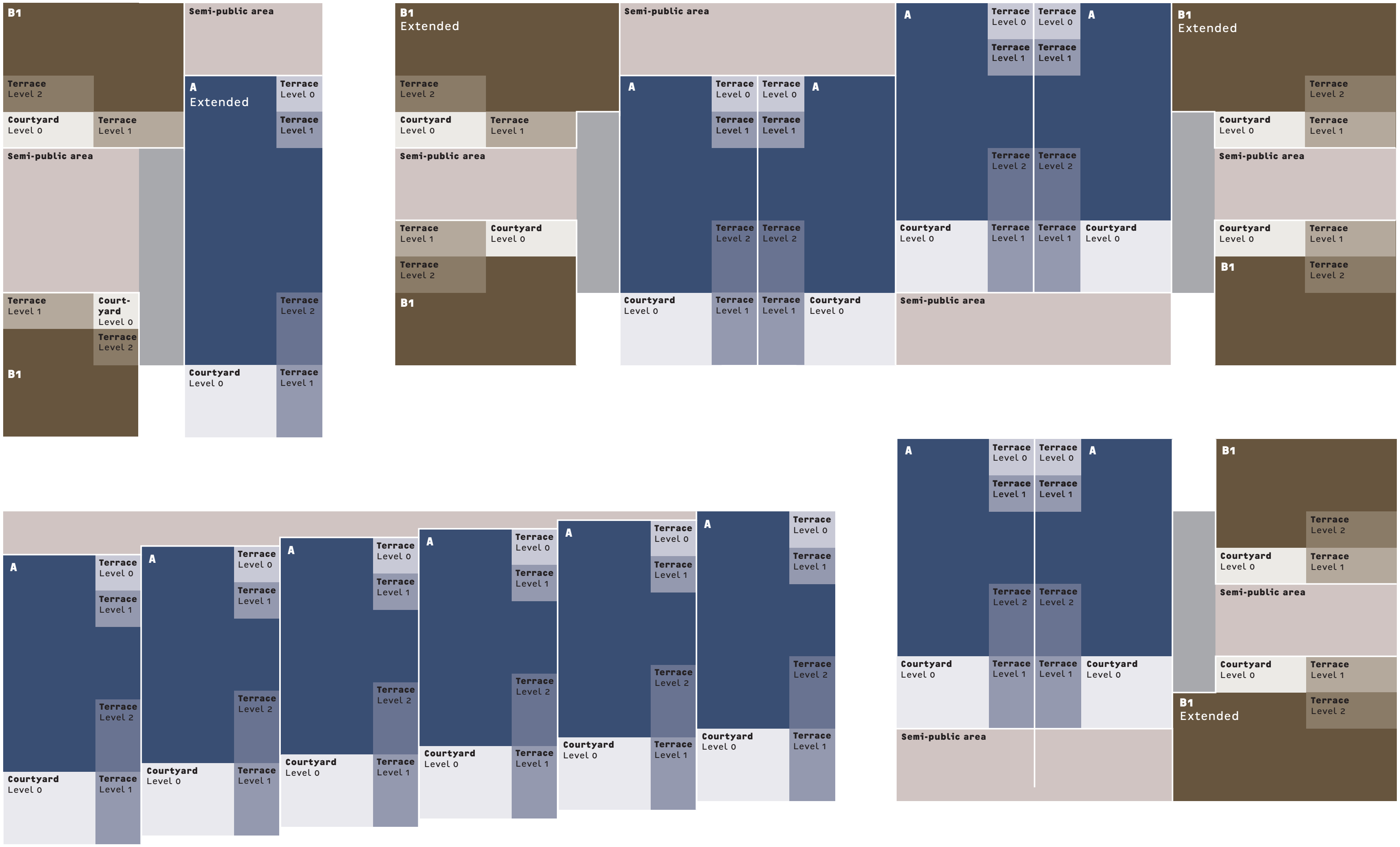


Fig. 24: Neighbourhood layout, combination of type A, B1 and B2

This neighbourhood layout is arranged with a combination of type A, B1 and B2. A number of different combinations are available thanks to the flexibility of the blocks.

Fig. 25: Apartments around the public area

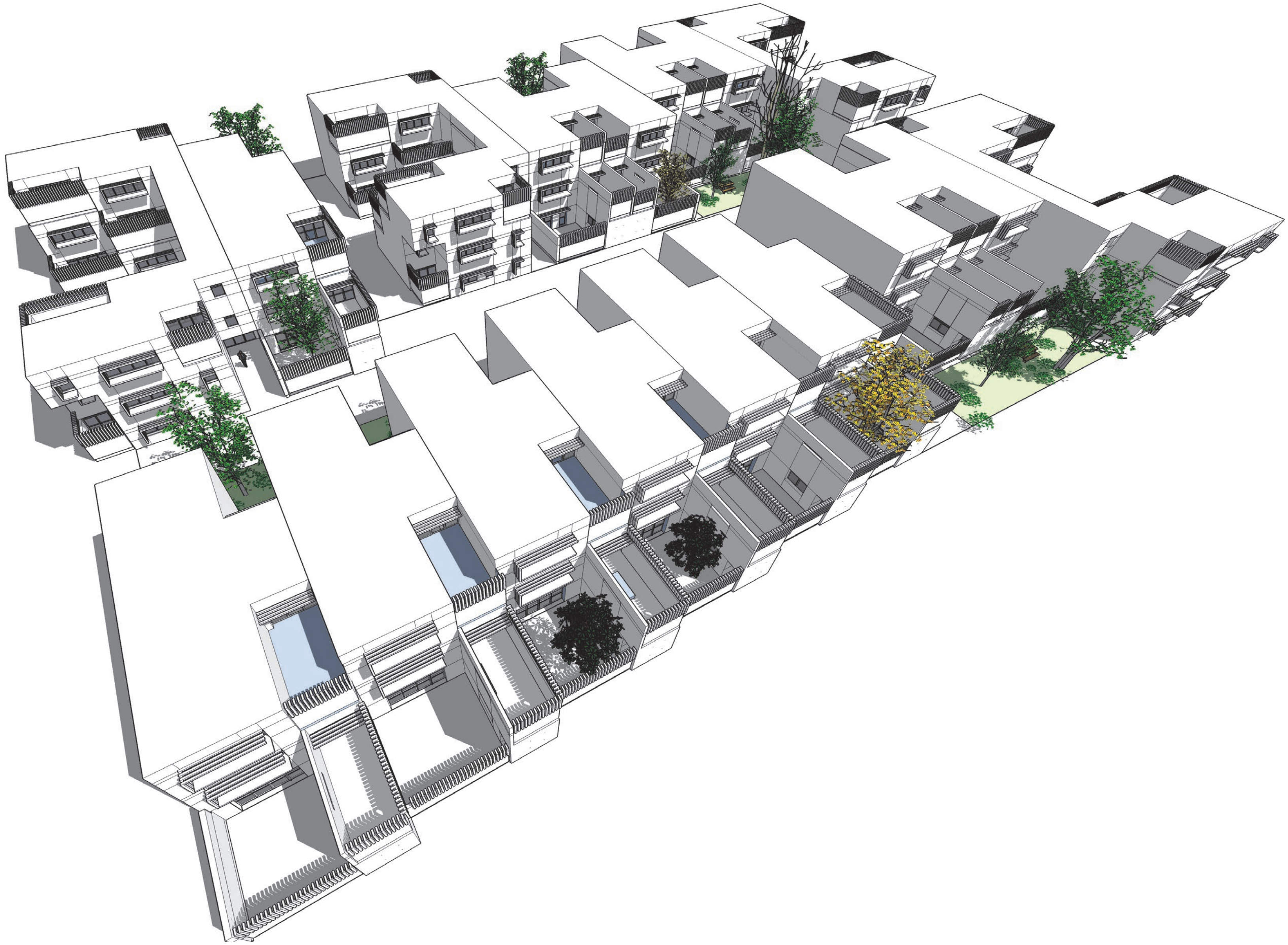


Fig. 26: Bird-eye perspective of the neighbourhood

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Date
09 April 2013

Fig. 27: Site plan

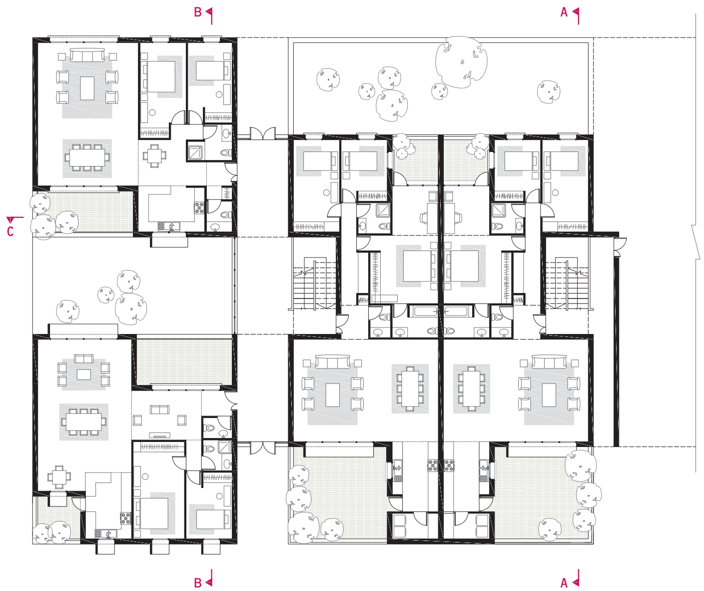


Fig. 28: Combination of layout type A and B, Level 0

Fig. 29: Combination of layout layout type A and B, Level 1

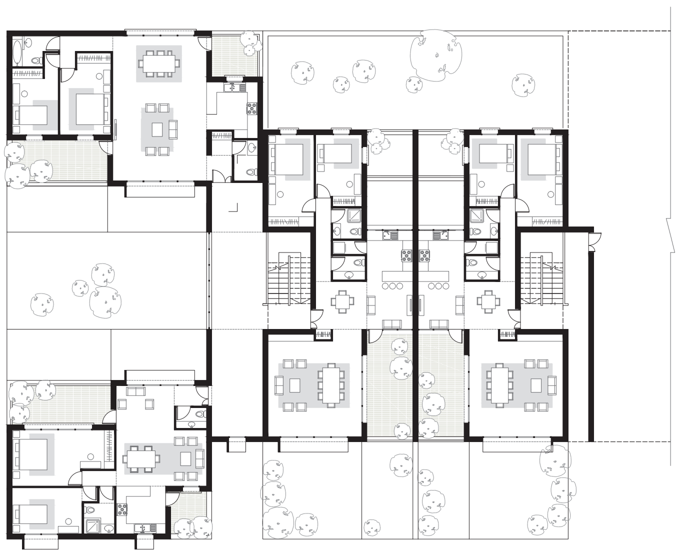
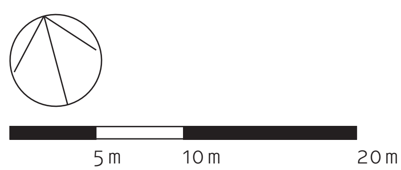


Fig. 30: Combination of layout type A and B, Level 2



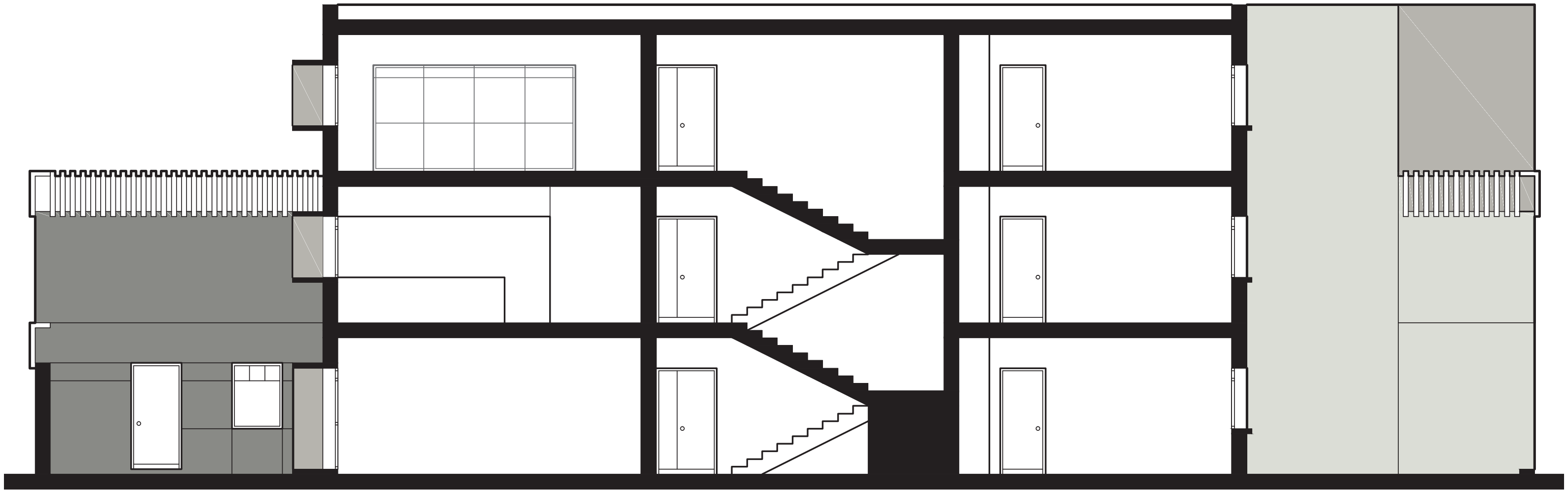


Fig. 31: Cross section, A–A

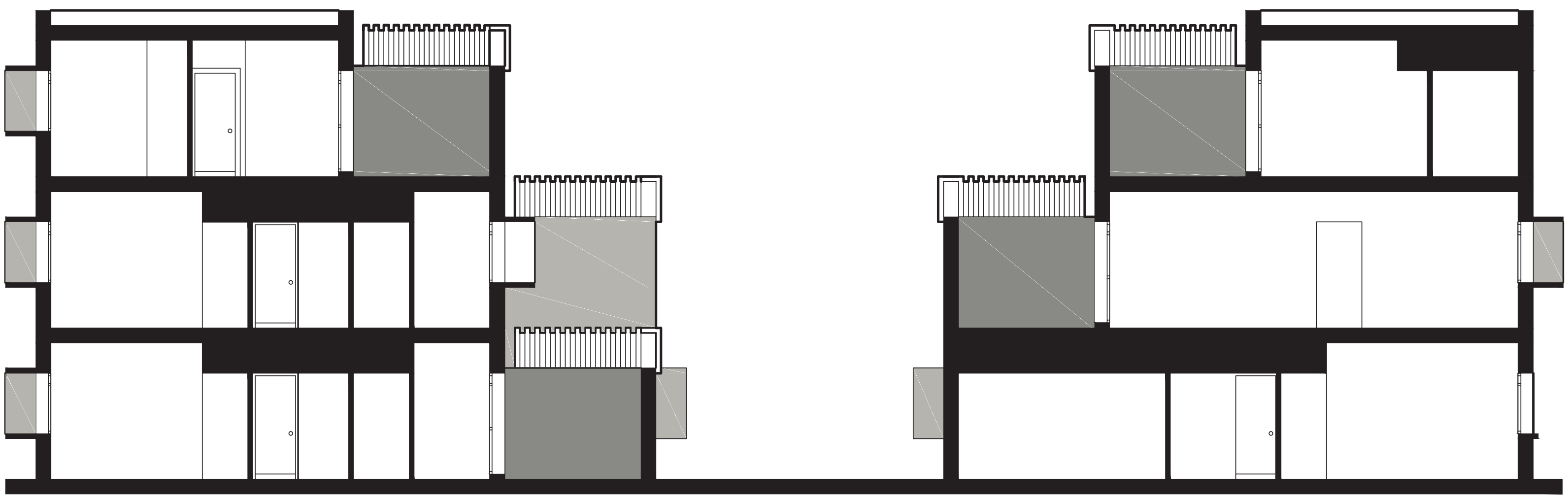


Fig. 32: Cross section, B–B

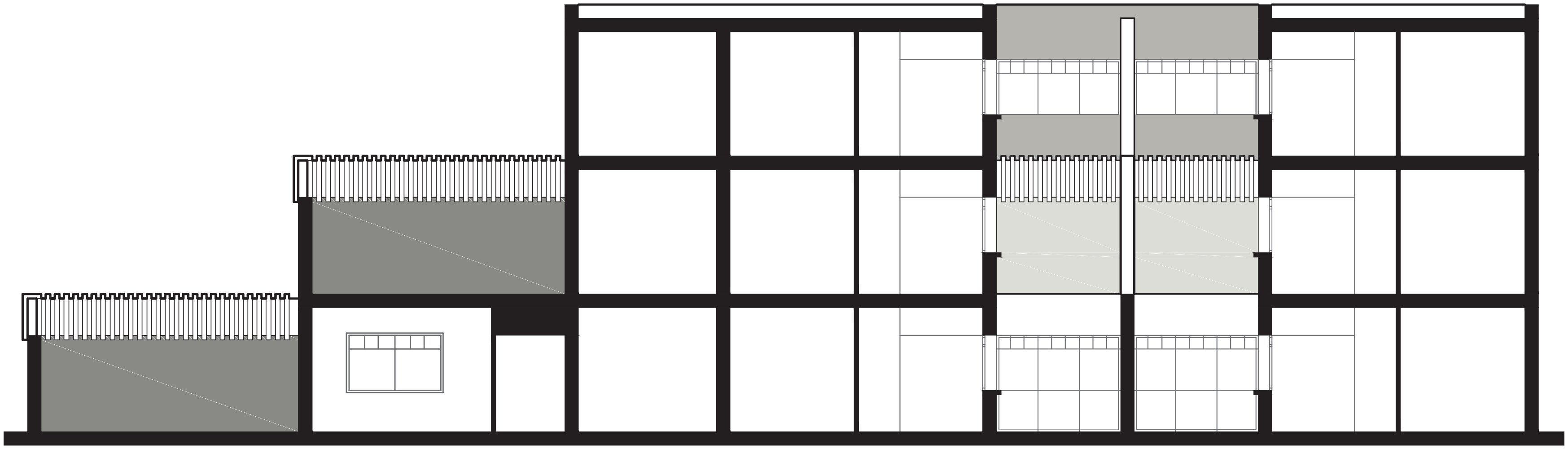


Fig. 33: Cross section, C-C

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Figures

VI
Appendix

Young Cities Project Consortium

young cities
Developing Urban Energy Efficiency
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Technische Universität Berlin
Berlin, Germany

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New Towns Development Corporation
Tehran, Islamic Republic of Iran

Iranian Ministry of Roads & Urban Development (MRUD)
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