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Developing Urban Energy Efficiency
Tehrān-Karaj

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New Town versus Old Town

A Study on Urban Pattern and Energy Efficiency

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1 Introduction

The idea of creating New Towns, in its modern form, was emerged in Iran for the first time in the early 20th century, when the process of industrialization and modernization began in the country (Shirazi, 2013). This idea got its crucial importance when the urban population increased suddenly. While in 1900, only 20.6 percent of people were residents of the cities, in 1976, approximately half of the entire population resided in the cities. And since 1996 the urban population exceeded half of the population (ibid.). This matter caused emerging big, highly populated cities over the country with various urban problems such as pollution, poverty and traffic (Figure 1).

Fig. 1: Traffic, Tehran (by author)

New Town concept nowadays is considered as a strategic response to emerging Megacities by governments in countries that face fast population growth in these cities (FMER, n.a.). However, building new towns and settlements in Iran is not a new phenomenon; during the history different new towns for both military as well as agricultural purposes have been extensively built and developed (Habibi 2007). After the Arab conquest of the 7th century, a new wave of establishment of new towns started where new settlements were erected besides the existing Iranian towns (Madanipour, 2006).

At the beginning of 20th century, new towns were constructed either for military (Zahedan) or economic purposes (Noshahr), followed by a series of settlements which were established as a response to the rapid process of industrialization, particularly oil industry after the Second World War (Naftesefid, Abadan, and Mahshahr).

Due to high oil revenue industrial and economic activities boomed, resulted in the major flux of immigrants to the cities which raised the demand for new housing. Consequently, some new towns such as Pulad-shahr and Shushtar-No were planned and constructed (Ziari 2009).

Following the Islamic Revolution in 1979, the last generation of new towns emerged after a pause caused by the Iran-Iraq war and its consequences. Urban population changed drastically so that by 1996 it exceeded half of the population, reaching 61.3 percent (Zanjani 2003). This rapid change forced Iranian government to plan a new generation of new towns: in 1986, construction of 12, later growing to 28, new towns around major cities was approved by the government to provide affordable accommodation for low-income families. New Towns Development Corporation (NTDC) was responsible for design and planning. About the goals of new towns NTDC states that "To achieve a balanced economic and social growth and to control [big cities'] planless development, the best solution is establishing new satellite towns in a proper distance from them. This not only rectifies big cities and decreases their attractiveness, but also changes them to a suitable center for regional economic, social, and spatial development" (Sherkate Omran 1989: 20).

Despite the convincing reasons behind establishment of new towns and their theoretical justification, realities on the ground show that they have not been able to meet the planned expectations to the extent that they have been, in many cases, a new problem rather than a solution. As Shirazi (2013: 52) states, "In reality, the new towns of Iran suffer from a variety of problems. From the vantage point of policy making and management, the quantitative approach to housing overwhelmed the qualitative approach, a situation escalated by the mass housing production system. The novelty of this topic, and the lack of both relevant experience and practical background, led to crucial problems for the managers as well as for the consulting offices. Moreover, the break in and inconsistency of national policies and strategies, as well as regional priorities, made realization of the initial goals in the given period impossible." Statistics show that new towns are mainly dormitory towns and have not attracted the expected population because of the lack of standard

	Population of country (thousands)	Urban population (thousands)	Percentage of Urban Population (%)
1900	9,860 (estimated)	2,033	20
1956	18,954	5,997	31.4
1966	25,078	9,790	38.7
1976	33,708	15,855	47
1986	49,445	26,845	54.3
1996	60,055	36,700	61.3
2006	70,495	48,259	68.5

Tab. 1: Population growth of Iran from 1900 to 2006 (Shirazi, 2013)

urban services provided for the inhabitants (Eetemad 2004). To this one can add the lack of new employment possibilities around the new towns, and the lack of livable socio-cultural atmosphere.

Hashtgerd New Town was originally planned to accommodate 500,000 inhabitants by 2010. Located 65 km to the west of Tehran, 25 km from Karaj and 75 km from Qazvin, it is 1,300 to 1,550 meters above sea level with hot in summers and cold winters. It is now connected to Tehran through highway, Metro line is now under construction and supposed to reach the new town by the end of 2013.

The first Comprehensive Plan was prepared by Tarh-va-Me'mari Consultation (Figure 2). Two population predictions (probable and desired) were calculated for three periods, 1996, 2006, and 2016. The initial plan intended to accommodate 350,000 inhabitants (desired assumption) or 230,000 (probable assumption).

	1996	2006	2016
probable assumption	30,000	102,000	230,000
desired assumption	38,000	143,000	350,000

Tab. 2: Population prediction in Hashtgerd New Town (Hashtgerd NTDC, 1993)

Physically, Hashtgerd New Town is comprised of industrial (350 ha, south of the highway), and residential (4,000 ha, to the north) sections, with an average density of 140 pph. The initial plan was connecting the new town to the old Hashtgerd and unifying them into a larger city in the future. In terms of urban pattern, it has a grid-like atonement based on a hierarchy of streets and surrounded by a green belt. All the urban facilities, including commercial, religious, and administrative are distributed through the city, local services are available at the neighborhood scale. The New Town is divided into 23 urban zones (nahie) with 20,000 inhabitants each.

Fig. 2: Hashtgerd New Town, first comprehensive plan (Tarh va Memari Consultation)

The construction of the new town began in 1990s. By 2006, the built area reached 521 ha, 123 ha of which was residential, 76 ha was green area, 330 ha was public access (streets), and 319 ha was other urban services (Peykadeh 2008). In 2009, about 37 percent of phase 1, 2, and 3 was developed, 56 percent of which was dedicated to streets, 27 percent to residential uses, 17 percent to other uses (Azizi and Arbab 2010).In 2008, Peykadeh Consulting Engineers was commissioned to provide a revised version of the original Comprehensive Plan to adapt it to social, economic, and demographic chang-

Fig. 3: Hashtgerd New Town, revised comprehensive plan (Peykadeh Consulting Engineers, 2008)

es in the region (Figure 3). Some revisions were considered. “To achieve optimal distribution of urban facilities, a mediatory scale of “district” (mantageh) was added; the city was divided into 5 districts and 19 zones (nahie). A flexible mixed use area was to provide room for later necessary land uses. The green belt was converted to major urban services such as sport facilities, a hospital, and a university, justified by the idea that this amount of green belt is too large to be maintained carefully. To enhance the quality of the urban landscape, establishment of a controlling office was proposed to approve

Fig. 4: Hashtgerd New Town (by author)

all the plans and designs and to permanently monitor their complete realization" (Shirazi 2013: 56).

Hashtgerd New Town has been studied from different perspectives which give an overview to the existing urban life. In general, the inhabitants are mainly young families, with a high rate of literacy and average level of education, generally employed in either industrial or public service sectors. The majority of the inhabitants have their original residency in Tehran, or other neighbor cities like Karaj. Cheap housing is a main reason for moving to this town. The lack of sufficient urban facilities is observable, such as medical centers, educational facilities, and public transportation. This convinces the inhabitants to leave the town whenever affordable. From the point of view of identity, inhabitants of phases 1 and 2 offer a better sense of identity since they were the first parts constructed and established. In terms of safety, the town is enough safe for the inhabitants.

The developments in the new towns are in fact building the city from the very first step, so it gives a proper opportunity whereas make it decisive that the concept of sustainability in all its terms and dimensions—social, physical and economical—is followed in the designs and planning strategies in the city. The current condition in the Hashtgerd New Town shows this is not

Fig. 5: Hashtgerd New Town (by author)

the case and the conventional concept for designing and realization is being pursued in this city as well. These matters show that formulating planning solutions based on the research in different disciplines is very urgent at this point of time. The Young Cities Project and single researches attached to that can be the responses to this need.

The physical part of the built environment is the main focus of this research. The researches in the field of environmental sustainability, in general, and the few researches on the sustainability of built environment in the Hashtgerd New Town, in particular, mainly focus on either the scale and dimension of architecture or the scale of the city. Although in achieving energy efficiency, the architecture of the complex plays an important role, the urban configurations at the lower resolutions of scale impact the efficiency of architectural designs by filtering the synoptic climates too. So, this text, as a part of the results driven from the author's postdoctoral research done within Young Cities Project, emphasizes on the role of the urban geometry as a parameter which influences the sustainability in the city and tries to figure out how efficiently the conventional urban pattern in Hashtgerd New Town act in comparison to the other patterns. The dimension of sustainability which has been focused is the *building energy consumption*.

2 Energy Consumption and Urban Pattern

Cities, as the recent main living environments, consume space, air, water, energy, and other resources in their areas and are responsible for the majority of global energy consumption (Bonhomme et al., 2011; Apel & Henckel, 1998). Energy use in living environments occurs in different ways ranging from transportation, the sector of industry and buildings (Williams et al., 2000; Dempsey et al., 2010; Jones et al., 2010). The urban energy use can be studied by investigating the living environments named as the urban form which is made up of five elements that have been claimed to be influential in achieving urban sustainability: density, layout, transport infrastructure, land use and housing/building type (Dempsey et al. 2010). This text concentrates on the sector of building among the categories of the energy use origins. The physical and spatial characteristics of built urban fabric—such as urban form, spatial principles, components, relations, structure, shape, configuration—and the people affect the building energy consumption. According to Baker & Steemers (2000) building energy consumption is highly dependent upon four parameters: building design, system efficiency, occupant behavior and urban geometry. Generally, it has been proved that the user life style and the dynamic effects of occupant behavior are likely to obscure static physical influences (Keith et al., 2010: 131). However, the nature of the built form is also a determinant of energy use which can be investigated in the form of architecture (housing/building type) and urban geometry. The focus will be on the urban layout or urban geometry, as one of the elements of the urban form which has direct impact on the energy use in the building sector. The urban layout has been supposed as a three dimensional pattern according to which the physical elements of the urban form including the buildings, streets, courtyards are being combined with each other and made a particular urban configuration. It determines the framework and the relationships of the juxtaposed urban physical elements at different levels from a single building up to the whole city. It constitutes the physical compositions.

As mentioned, similar to other elements, the layout of the city plays a role in the energy consumption of the city in the building sector (Adolphe, 2009; Ratti et al., 2005; Adolphe, 2001a). The morphology of cities has effects on the outdoor climates, as well as indoor climates and the buildings should not be considered 'as self-defined entities', neglecting their configurative contexts at the urban scale (Adolphe, 2001a, 2001b, 2009). The re-

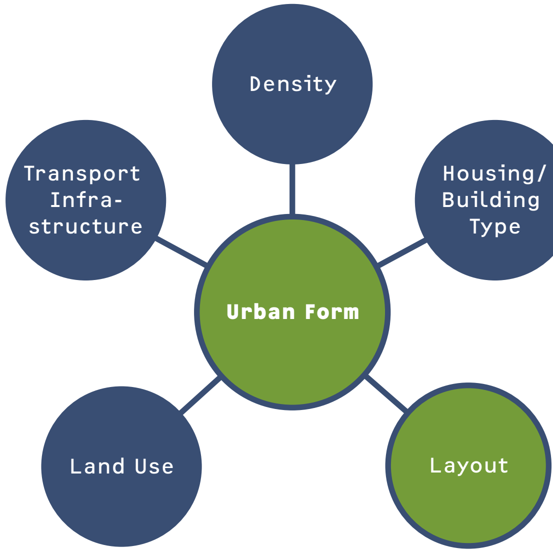


Fig. 6: Factors of urban form (by author)

gional 'synoptic' climate becomes modified by the 'structure' of the city and the neighborhood and more efficient overall configurations for urban areas can result in long term improvements in the energy efficiency of buildings (Rickaby, 1987).

Ratti et al. (2005) prove that the variation of energy consumption on urban geometry is 10%, which is though small in comparison to system efficiency or occupant behavior, it could have a tremendous impact on the energy budget of cities and would justify careful thought in urban planning. This gets important considering the fact that "A high proportion of the energy consumption of cities is linked to buildings" (Jones et al. 2010: 246).

In Iran, the energy use in the building sector with 41.92 percent of all energy use in 2008 is the largest consuming sector in the country (Energy Planning Office, 2010; Seelig et al., 2012). To control and reduce the building energy consumption, the Iranian government took some policies and improvements in technologies and practices over the past three decades in building systems as well as whole-building design and construction. The positive impact of these policies can be seen in the slight decrease from 44.5% to 41.9% in the energy consumption of the building sector between 2007 and 2008 (Riazi & Hosseyni, 2011). However, the solutions for reducing energy consumption in construction and building sector in Iran have been mainly limited to the architectural scale in regard to the physical built environment and the possibility of decreasing energy use in building sector by cautious design and planning at the urban scale is still understudied.

3 The Scale

In studying, analyzing and measuring the urban form as well as the urban layout the issue of scale constitutes an underlying dimension and plays a determining role (Dempsey et al. 2010). According to Kropf (2005) and Moudon (1997), the structure of urban form is a hierarchy of levels related part to whole and it can be understood at different levels of resolution. That is to say, the urban form divides into distinct levels. The patterns found at different levels such as street/block, plot series, plot, building, cell and structure are not interchangeable but are interdependent. Commonly, four levels are recognized, corresponding to "the building/lot, the street/block, the city, and the region" (Moudon, 1997: 7).

At each scale the urban geometry is defined in differently depending on the relevant specific elements and their relationships. For instance, "At the broad city or regional scale, urban form has been defined as the spatial con-

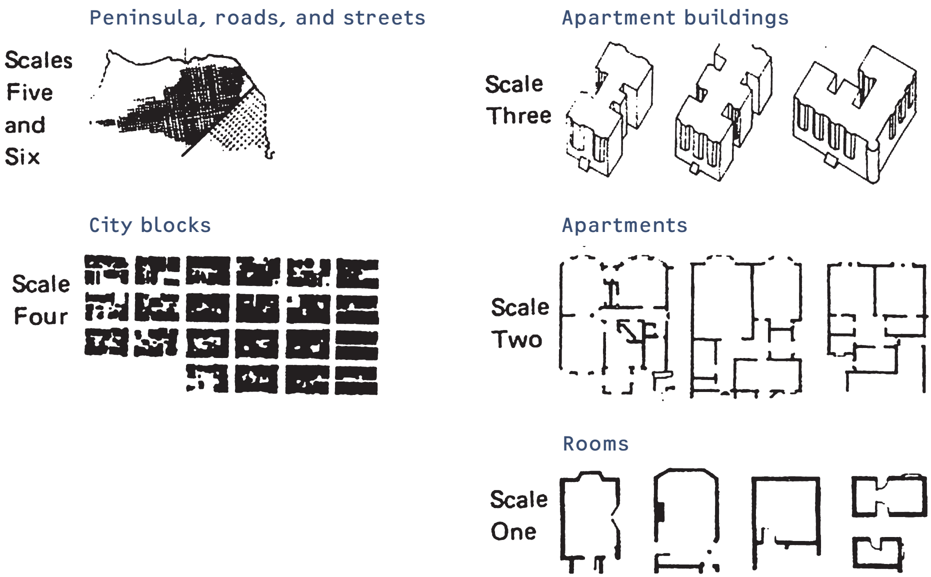


Fig. 7: Typology at different scales (Moudon, 1994)

figuration of fixed elements. Features of urban form at this scale would include urban settlement type… Characteristics therefore range from, at a very localized scale, features such as building materials, facades and fenestration, to, at a broader scale, housing type, street type and their spatial arrangement, or layout" (Dempsey et al. 2010: 21). Besides, the role of the urban geometry in the building energy consumption is highly dependent on the scale at which we are considering the layout. According to Adolphe (2009) characterization of the relationship between urban morphology, climate and energy is heavily dependent on the geographical scale of the observation (not the phenomenon) and varies between the scale of a public space, the scale of a neighborhood and the scale of a metropolitan area which are highly interacting (Adolphe, 2009).

The interrelation between the urban layout and building energy efficiency at the scale of neighborhood has not been adequately studied and still remains understudied and controversial (Bonhomme et al. 2011; Ratti et al., 2005; Adolphe, 2009). Adolphe puts forth, "it seems attractive to work at a macroscopic level, allowing to get away from local heterogeneity, and to consider large enough volumes and mean effects of the interaction between urban shape and microclimate" (Adolphe, 2001b: 679).

At the neighborhood scale, also called micro-urban scale or inter-mediate scale, the urban unit consists of an ensemble of buildings and open spaces, namely, "the buildings and their close environments" (Adolphe, 2001a: 183). This scale connects the building scale to the macro scale (the whole city) and, as the context of buildings, it contains the buildings. So the characteristics of the forms of the development at this scale delimit the architectural designs and may necessitate particular solutions for energy efficiency at the building scale. So, the design at the micro-scale is an important parameter in controlling building energy consumption.

4 Urban Configuration at Intermediate Scale

The urban geometry has two fundamental components: form or configuration; and the resolution. The elements that constitute the form are: buildings, streets and plots.

The urban units, in general, are the areas with a distinct combination of three basic urban physical elements: buildings and their related open spaces, plots or lots, and streets (Moudon, 1997). At the micro-urban scale an ensemble of a distinct number of buildings which are located beside each other within a boundary of streets constitutes this combination. In fact, the composition of the two elements: the individual parcel of land, together with its buildings or buildings and open spaces constitute the smallest cell of the city. That means, the volumetric characteristics of built structures are linked to their related open spaces by parcels and generate *'built landscape types'*. The characteristics of the cell influence the urban form's shape and density, as well as its actual and potential use over time. "As a cell, the lot establishes the pattern of the grain of the city and determines its scale" (Moudon, 1986: 144).

On the other hand, in various cases the groups of buildings, open spaces, lots, and streets form a cohesive whole either because they were all built at the same time or within the same constraints, or because they underwent a common process of transformation. These textures are called the Plan units or 'tissues' (Moudon,1997).

It is useful to think of the typical textures as the basic unit of the study. When a number of the urban textures share particular characteristics, they can be represented by one single urban texture chosen from among them as the 'representative urban type'. These representative types, called urban structural unit (USU), reference unit and character area, reduce the multiplicity of studying the micro-urban form one more level and using them as bases for the studies provides a common frame of reference for dealing with different areas (Kropf, 2011). They can be investigated as samples of the urban texture and as a basis for assessing the environmental and cultural performance of different types of urban form. The character areas point to the most common forms of morphological analysis, which is characterization. The general aim of characterization is to identify areas of distinct character within a settlement (Kropf, 2011). Identifying character areas, reference unit or USUs provides an explicit definition of the area and "a sound and objective basis for going on to make further judgments about the value and significance of the different areas…characterization sets out in detail the particular characteristics of each area or sub-area-its component parts, structure, function and origins" (Kropf, 2011: 395).

Ünlü (2011) categorizes the characteristics of built environment into 6 groups: spatial, morphological, functional, visual, contextual and constructional (Table 04). Each of these aspects reveals a part of the characteristics of the urban layout and urban form by defining a number of indicators (constituents). In this categorization, the morphological category is the one that describes the physical form of the ensemble of the buildings and their open spaces at micro-urban scale. The mentioned constituents are: building heights, building type, plot coverage, plot size, block size, block form, setbacks and density which, as will be seen in the following, are influential in building energy consumption.

Characteristic of the Built Environment	Constituents
spatial	Settlement pattern, hierarchy of roads, public space system, borders, etc.
morphological	Building heights, building type, plot coverage, plot size, block size, block form, setbacks, density, etc.
functional	Land use, zoning, infrastructure, parking, lighting, etc.
visual	Landscaping, local style, material, environmental quality, scale, harmony, rhythm, etc.
contextual	Morphological and visual characteristics of an area and distinct surrounding areas: environmental quality, landscaping, vista, character, local style, etc.
constructional	Building strength, use of material, prevention against fire, story height.

Tab. 4: Built Environment Factors (Ünlü, 2011)

5 Energy Consumption-Related Parameters

The goal of an energy efficient design is gaining the thermal comfort in indoor spaces with a decreased demand for mechanical energy suppliers by enhancing the natural energies, namely, the solar radiation and the wind flow. So the parameters such as the heat gain, solar gain, day lighting and natural ventilation are parametric variants.

Urban layout impacts the building energy consumption of a group of buildings in two ways: a direct influence, by filtering the sun (solar radiation) or wind; and an indirect influence by defining a particular microclimate in the local area. Simply to say, sun provides the building with heat gain, daylighting which reduce the heating loading of building and also may cause overheating which can increase the cooling loads of a building. Urban geometry relates to the availability of solar radiation, sunlight and daylight on building facades and "highly-obstructed urban areas are deprived of useful daylight and solar gains, thus necessitating generally higher energy inputs" (Ratti et al. 2005: 763). Similar thing happen in the case of wind: by letting the good wind in summer to enter the urban block, the chance for designing a building with decreased demand for mechanical ventilation increases.

According to March (1972), the ratio of surface area to volume or measures of compactness are not determinant in thermal performance of a building in terms of heat loss while she believes the exposure to the outside should be reduced because it causes heat loss. Contrasting March's approach, Ratti et.al. (Ratti et al. 2005) suggest that the main energy distinction to be drawn within buildings is a function of the exposure to the outside environment and argues that the heat loss is not the main concern in energy consumption but in reverse to be more energy-efficient a building should have high outside exposure (ibid.). They believe: "The surface-to-volume ratio is an interesting descriptor of urban texture. It defines the amount of exposed building envelope per unit volume, and can be used in a number of different applications (possibly, estimating the quantity of façade paint necessary per unit built urban fabric). Its relevance to the energy consumption of buildings, however, must be considered carefully. Minimizing heat losses during the winter requires minimization of the surface-to-volume ratio; but this implies a reduction of the building envelope exposed to the outside environment, this reducing the availability of daylight and sunlight and increasing energy consumption for artificial lighting, natural ventilation, etc." (Ratti et al. 2005: 767).

So, the simple ratio of floor space to surface area "provides some indication of the spatial efficiency of the enclosure, but it takes no account of variations in the thermal characteristics of building fabric, nor of the effects and directionality of solar gains… When orientation and insolation are also taken into account, then the form that will minimize net heat loss (after solar gain) is the one whose net thermal image is a cube, and this form will change constantly with the movement of the sun" (Rickaby, 1987: 48). It seems there is a contradiction in the ways of performance of building to respond the above-mentioned factors. For instance, "reducing the building envelope, which is beneficial to heat losses, and increasing it, which is favorable to the availability of daylight and natural ventilation. Which of the two phenomena prevails in the global budget of buildings?" (Ratti et al. 2005: 768)

Not having an absolute answer, the above question is highly dependent on the climate. The climatic zones that have scarce solar gains and low temperatures, heat conservation strategies might be prevalent over the collection of daylight and natural ventilation. In these cases energy efficient buildings should probably minimize the external envelope, while at other climates they might try to maximize them (Ratti et al. 2005). However, "It has been demonstrated that solar exposure by itself is not a good index of the efficiency of a building form in hot climate and that other building features can nullify the effect of solar exposure. In view of the fact that massive building elements such as brick walls and concrete roofs moderate solar heat gains even in cold climates, the applicability of solar exposure as a measure of building efficiency is doubtful even here. However, if one could have two building forms equal or nearly equal in all respects except for solar exposure, the choice between them could be based upon solar exposure" (Gupta, 1987: 144, 145). Olgyay (1963) emphasizes on the ratio of summer insolation to winter insolation in built forms, since while the building can benefit from solar gains in winter by reducing its heating loads, in summer the solar gains may lead to overheating. However, the issue of climate has a crucial role. For example, "The principles of good thermal design for temperate climates require: 1) a building that promotes solar heat gain; 2) a low surface to volume ratio to reduce conductive heat flow, and 3) a tight building envelope to reduce infiltration" (Gupta, 1987: 133). And for hot arid climates: "a building form that intercepts least possible solar radiation; a low surface area to volume ratio, and a building design that promotes ventilation when needed" (Gupta, 1987: 134).

At the urban scale, to discuss the capacity of an urban block in having the least shading and maximum solar gain, Ralph Knowles (1981) developed the technique of 'solar envelope'. "The solar envelope defines the greatest volume of development that can be placed on a given site without shading neighboring sites, and it must be calculated by convention at some appropriate time such as noon on the winter solstice" (Rickaby, 1987: 46). Its form of the solar envelope is determined by the pattern and width of the surrounding streets, and by the orientation and slope of the site (Rickaby, 1987). "A principle that might be adopted in determining efficient urban block forms is that during the heating season the shading of any block by its neighbours should be minimized or eliminated in order to maximize the opportunity for the exploration of direct solar gains (though in some cases shading may be desirable in order to reduce gains)" (Rickaby, 1987: 46).

Gupta (1984) indicates that the nature of inter-block shading is determined by the form of the blocks and the width and pattern of streets. According to Rickaby, "Overall plot ratio, the mix and density of uses (and resultant fuel-demand densities), the relationship with the solar envelope, the ratio of surface area to floorspace, and the ratio of summer to winter solar exposure per unit surface area" are energy-related characteristics of urban form at micro-urban scale (Rickaby, 1987: 60).

So if we return to the categorization of Ünlü (2011) (Table 04), among the constitutes that he named for each characteristic the following are the energy efficiency-related elements in the physical built environment at the micro-urban scale: building heights, building type, plot coverage, plot size, block size, block form, setbacks, density, etc.

By the way, "Buildings are hardly finished without their inhabitants and the activities that they pursue inside or around them" (Steane & Steemers, 2004: 3). There are marked differences in thermal characteristics—energy density, heat loss and heat gain, and heating demand—between different types of floor space. To what extent this is due to the location of these uses within the urban block, rather than the nature of uses, is unclear, "but it is reasonable to assume that different uses are associated with different heat gains and demands" (Rickaby, 1987: 58).

6 New Town Pattern versus Traditional Configuration

The aim is to compare the energy efficiency of the typical conventional urban pattern with the typical traditional one. Such discussion revolves around the physical form of buildings, their locations, their effects on energy use patterns and on resultant disaggregated and aggregated fuel consumptions.

Fig. 8: Examples from historical urban textures of a number of Iranian cities (Bonine, 1979)

To this end, two basic sample study units as the representative of urban geometries in two categories: traditional and conventional, should be defined. To define the basic sample types we need to study a number of case study urban textures from both pattern categories. For that, different examples from urban patterns over Hashtgerd New Town should be studied in order to define a 'typical' configuration for Hashtgerd New Town as the 'conventional' category. The 'typical' traditional urban form has been studied and can be concluded based on former investigations. Then, different variants derived from these 'typical' examples will be evaluated against building energy consumption, for instance, as mentioned above, building height, building distance, street widths, plot pattern, plot width.

6.1. Urban Configuration of Typical Traditional Town

In the texts, there are similar opinions on the typical form of the traditional Middle Eastern North African cities. According to Stefano Bianca, two kinds

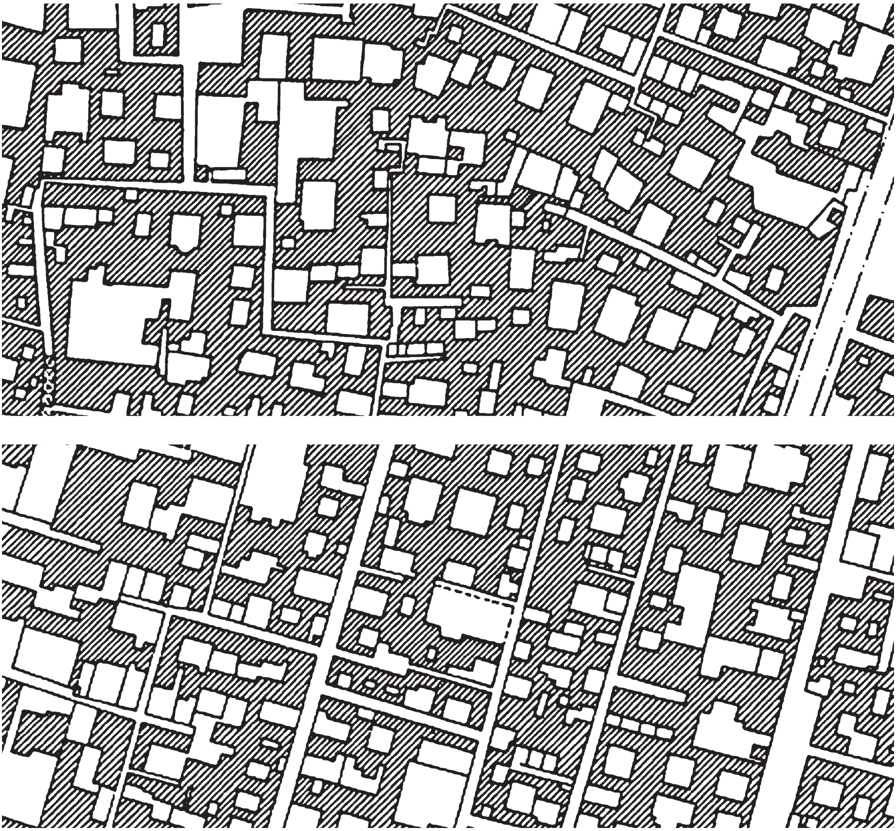


Fig. 9: Urban Form of Oudlajan (above) and Baharestan (below) historic neighborhoods, Tehran (Madanipour, 1998)

of urban pattern have been attributed to typical traditional cities in the region, so called 'Islamic cities': spontaneous or planned. He relates the 'spontaneous' pattern to the pattern of cities with vernacular urban configurations, some of which have a rural origin, and the 'planned' one to the formal layouts of palace cities. Having stated that such palace cities were constructed with military aims and based on a representation of princely needs, he noted that such cities were not typical of the Muslim world. According to him, this "prevalent 'spontaneous' urbanization mode" is often reflected by "tortuous residential access lanes and cul-de-sacs [sic]" (Bianca, 2000: 142) and its urban structures were influenced by principles and attitudes firmly rooted in the rules of Islam, the traditional community life of Muslims, and the tribal customs of the Arabs. Moreover, according to Bianca, most traditional 'Islamic cities' followed an organic pattern of growth, in which a certain group of archetypes of built form act as architectural 'seeds'. A wide range of related physical shapes are created from such archetypes whose combination, due to their common origin, generates a structure "in an unforced and quite natural manner" (Bianca, 2000: 31). Similarly, Alsayyad (1991) believes the following description represents the common picture of traditional Muslim urban settlements, and names it as the model commonly used to theorize, teach and discuss the Muslim city: Housing was mainly made up of inward oriented core residential quarters, each allocated to a particular group of residents and each is served by a single dead-end street. As for its spatial structure, the Muslim city had no large open public spaces serving its movement and traffic network were narrow, irregular and disorganized paths that do not seem to represent any specific spatial conception" (6).

Figure-ground studies (Figures 10, 11) can help in identifying and comparing the general characteristics such as orientation, dimensions, solid-void ratios, geometry of plots, street network geometry and subdivision of blocks. The traditional tissues refer to the compact texture in which the courtyards and alleys are the open areas and are manifestations of a typical 'Islamic city'. There is a network of interconnected streets and a number of disconnected blind alleys (culs-de-sac). The building pattern is introverted with courtyard and includes a number of formal typologies: courtyard with four, three, two or one built area around it. Since the houses are introverted, the built area boundary of houses follows generally the plot pattern. So, the plot pattern is in fact the external boundary of houses and, thus, irregular. To drive a character area from the sample tissues of this age the arguments are premised on two presuppositions. Firstly, at the micro-scale, namely, an ensemble of a group of buildings and their open spaces, the orientation of buildings are almost the same. Secondly, since the chosen area belongs to micro scale, it is located normally between the networks of roads and includes only culs-de-sac which according to Adolphe (2009) should be ignored in energy performance evaluation at this scale.

Fig. 10: Design for future developments in Hashtgerd New Town (Peykadeh, 2008)

6.2. Hashtgerd New Town

This study chooses the urban form of Hashtgerd New Town (population: approximately 60,000) as its case study.[1] This city, locating 80 kilometers west of Tehran and 25 kilometers east of Karaj, is planned as an overspill city for the fast emerging megacities of Tehran and Karaj. It was founded by the approval of the High Council of Architecture and Urban Planning of Iran in 1993. The concept of its foundation follows one of the strategic answers to emerging Megacities by governments in countries that face fast population

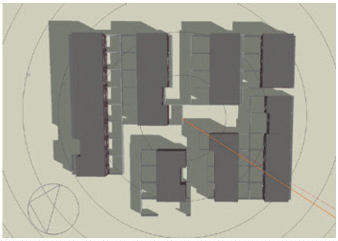
Fig. 11: Construction pattern in Hashtgerd New Town (by author)

growth in these cities (FMER, n.a.). Hashtgerd belongs to the climatic zone which overall has cold winters and hot summers (Kasmaee, 2002).[2]

Analyzing the existent patterns in Hashtgerd New Town, in order to isolate those parameters which allow us to reduce the multiplicity of urban tissues, the variety of building, street and plot types already existing in the city or are planned for the future of the city are categorized. The results show that the street pattern in almost all parts follows a regular ordered pattern, the plots and the buildings are rectangular, and in the volumetric dimension the urban form consists of rows of buildings lined besides each other (Figures 10, 11). This is the conventional modern urban configuration of Iranian cities since the emergence of the '40%–60% construction regulations'.

6.3. Analyzing the Textures

The characteristics of the different textures seen in the modern developments or traditional neighborhoods can be summarized or simplified in two 'typical typologies'. These typologies have been characterized in tables 5 and 6. By relating the performance characteristics to the parameter variations of the forms, it is possible to identify forms which offer satisfactory performance in energy efficiency terms. Also, for studying the environmental quality of urban space, various configurations can been generated made up from different combinations of the parameters.

	Textures	Pattern	
1	New, residential area, medium density, 2–3 floors height, large courtyards, small back/foreyard, urban green space, culs-de-sac, regular geometry		conventional
2	New, residential, high density, 4–5 floors, regular geometry.		conventional
3	Old, residential, medium density, 1–2 floors, irregular geometry, compact		traditional

Tab. 5: Features of the existing urban textures in Iran and some patterns as the representatives of these textures (by author)

Characteristics		Street pattern	Building pattern	Plot pattern
	traditional	There is a network of interconnected streets and a number of disconnected culs-de-sac	it is introversion with courtyard; a number of formal typologies: courtyard with four built area around it, courtyard with three built area around it, courtyard with two built area in two sides	Since the houses are introversive, the built area boundary of houses follows the plot pattern. So, the plot pattern is in fact the external boundary of houses.
	New Town	Regular, geometric	Extroversion, the buildings stand beside each other in rows	rectangular

Tab. 6: characteristics of sample representative patterns

1 Although so far a small part of the Hashtgerd New Town has been built, the designs for future constructions in the city help in making an overview to the general urban form of the city.

2 In the closest climatic station (Karaj/Payam, IR) celsius-based 2-year-average (2011 to 2012) cooling degree days for a base temperature of 15.5°C is 16.57 and heating degree days is 1,899 (Degree days, 2013).

7 Conclusion: A Method for Studying the Link between Urban Form and Energy Consumption

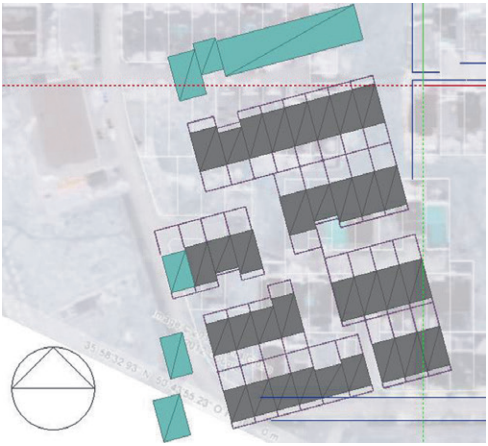
To be able to draw conclusions answering the question: which kind of the pattern or urban texture provides more energy efficiency; the energy performance of the sample urban patterns should be assessed. To this end, a number of targeted alternatives and variations should be created from the representative urban patterns. The alternatives should be created according to the urban elements which impact the building energy consumption. Then, these alternatives should be assessed by some 'Evaluation Techniques'. Determining the alternatives is based on the fact that the urban geometry at micro-urban scale relates to the availability of solar radiation, sunlight and daylight on building facades. For instance, 'highly-obstructed urban areas are deprived of useful daylight and solar gains, thus necessitating generally higher energy inputs' (Ratti et al., 2005: 763). Similarly, by letting the appropriate wind in summer enter the urban block, the chance of decreasing demand for mechanical ventilation in building design increases. The plot ratio, the relationship with the solar envelope, the ratio of surface area to floorspace, and the ratio of summer to winter solar exposure per unit surface area, the pattern and width of the surrounding streets, the orientation and slope of the site are among the energy-related characteristics of urban form at this scale (Rickaby, 1987).

Based on these characteristics, each of the patterns of urban textures (conventional or traditional) constitutes a number of variations by changing the parameters such as different courtyard sizes, number of floors (height of buildings). By calculating the relative performance of these module micro-urban types, it is possible to isolate certain correlations which allow the reclassification of types in energy and environmental terms. Then, it is possible to identify forms which offer efficient building energy performance which fulfill the efficient energy performance of buildings at the micro-urban scale.

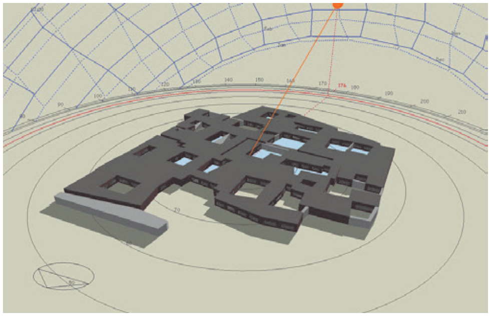
Among the evaluation techniques, the Design Builder software has been chosen as the simulation tool, due to its numerical results and simple way of application.

The study analyses some example textures (100 m × 100 m) from each mentioned character area. The following are two examples of the simulations of variants of the categories of urban patterns in Iranian cities.

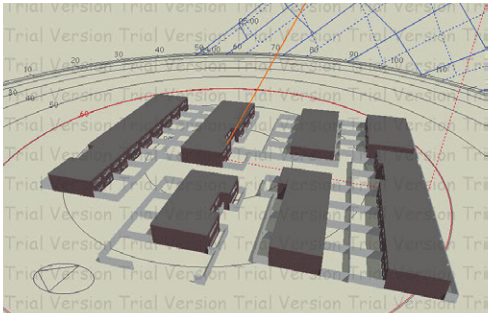
Texture



Winter Shading



Summer Shading



Energy Consumption

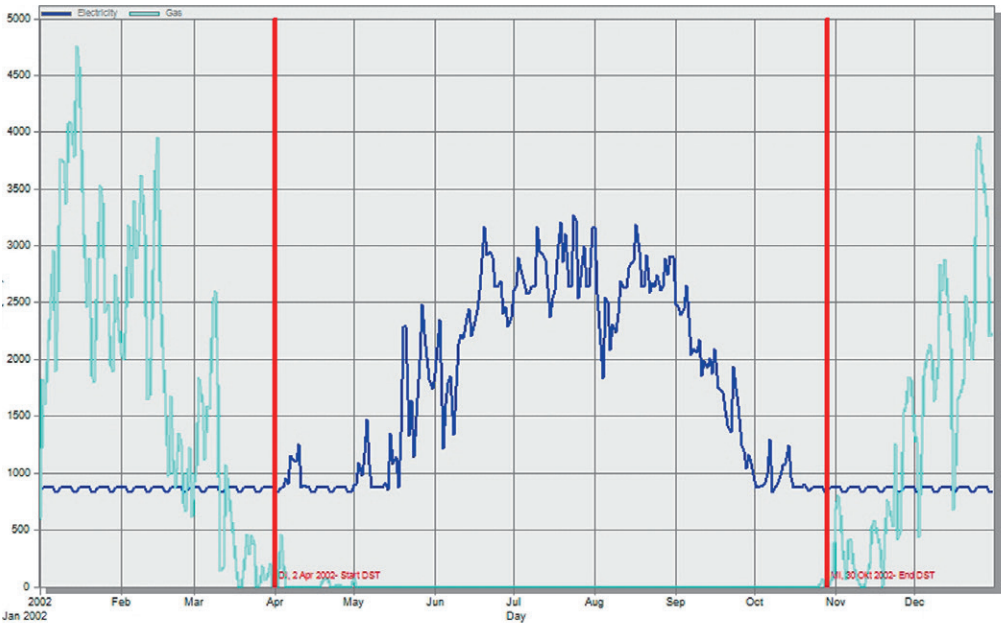
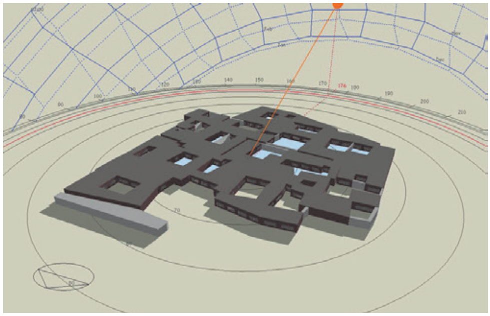


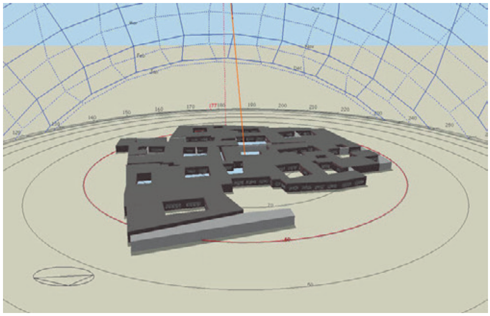
Fig. 12

Texture

Winter Shading



Summer Shading



Energy Consumption

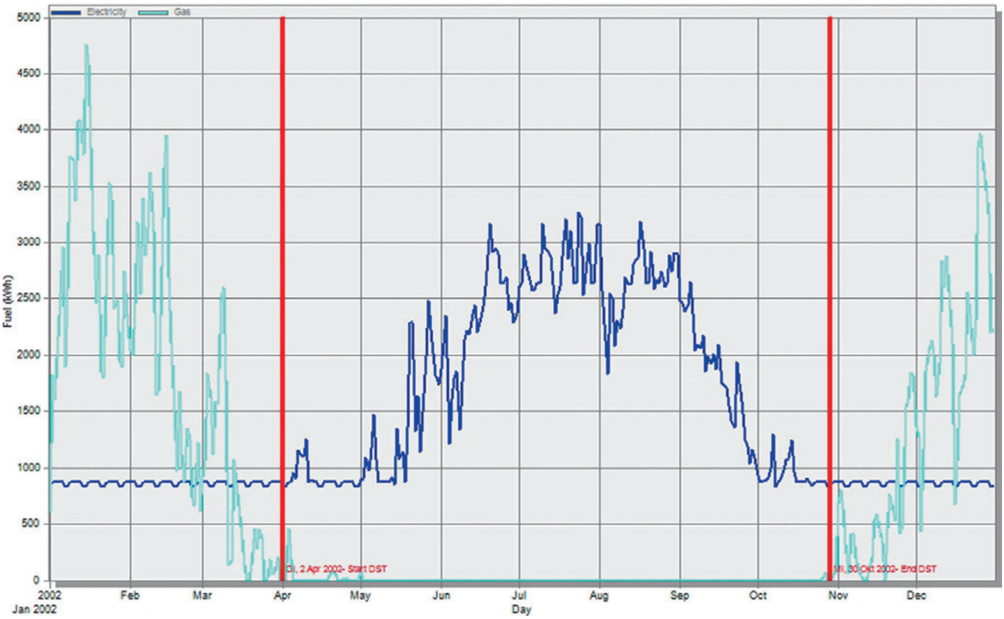


Fig. 12

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