Low Carbon Housing for `Young Cities`: Experiences from Hashtgerd New Town, Iran

1. Challenges: Contemporary Urban Iran and Climate Change

Iran is facing tremendous challenges: in the last 30 years, the country's population has doubled up to 73 million inhabitants in 2009. The median age is 23.5 years and in 2005, 25 % of Iran's population was in the age group of 15 to 24 years. Besides this natural demographic development, a massive rural-urban migration has led to an explosive urbanization since the 1960s, which is expected to continue in the next years (Roudi-Fahimi, 2007). These processes have placed immense pressure on the cities to deliver infrastructure, services, jobs and - at top priority - housing facilities. The Ministry of Housing and Urban Development estimates an ascertained need of about 1.5 million new accommodation units per year for at least the next five years on the formal housing market alone. The main arena of these drastic challenges is the Tehran Metropolitan Region being one of the most rapidly growing agglomerations in West Asia and the Middle East. In 2006, approximately 13.4 million inhabitants were residing in the Metropolitan Region (i.e. Tehran Province; Statistical Center of Iran, 2006), converting Tehran into the political, economic, cultural and social centre of the country.

The urbanization processes and its aftermaths are increasingly overlapping with the climate change and its local consequences. In this regard Tehran is subject to and driver of climate change. Firstly, impacts of climate change will be dramatic for a country characterized by its arid and semi-arid climate, which will be aggravated by climate change. It is estimated that if the CO2 concentration doubled by the year 2100, the average temperature in Iran will increase by 1.5 - 4.5ºC, which will cause more extreme weather events, droughts and significant water scarcity (National Climate Change Office of Islamic Republic of Iran, 2007). It is clear that especially in a megacity like Tehran the impacts of climate change will be increasingly felt. For example rising mean temperatures will boost energy demand for cooling due to the urban heat island effect: This will increase electricity demand by about 20,000 MW in the next 50 years (National Climate Change Office of Islamic Republic of Iran, 2003). Therefore, it must be a major task to adapt the newly constructed urban fabric to changing conditions but to also mitigate Green House Gas (GHG) emissions.

As the capital of the country and the fastest growing urban agglomeration, the Tehran Metropolitan Region is a crucial area for energy use and thus GHG production: Despite the fact that the city only occupies 1.2 % of Iran's total landmass, it houses 20 % of its population and about 35 % of the country's industries (Atlas of Tehran City, 2004). Hence Tehran is responsible for a large share of the country's emissions, since most emissions relate to transportation and power plants and most energy consumption relates to industries, transport and residential sectors (see figure 1 and 2).

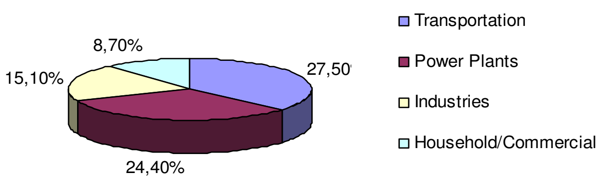

Fig. 1: Emission of CO_2 by main pollutants in 2003, Source: Sabetghadam, 2006

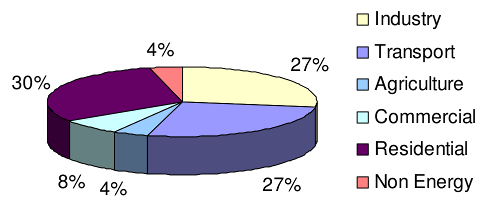

Fig. 2: Energy Consumption by Sector in 2005, Source: World Resources Institute2009)

A closer look into contemporary trends and practices in the built environment reveals the reasons behind these figures and the main drivers of climate change in Iran (not examining user behavior and political framework conditions):

1. Inefficient Building Structures as well as Urban Planning and Design Approaches
The building related energy consumption holds the highest share in the country (World Resources Institute, 2009). Reasons are fast and cheap construction, including the application of singe-glazing, inefficient HVAC systems and lack of building insulations. On urban scale, insufficient urban planning aggravates the problems. Since the 1950s, traditional urban patterns, which were adapted to the country's climatic conditions, are increasingly abandoned. Rapid modernization and application of Western urban planning schemes have lead to homogenized urban forms. These patterns do not only increase building related energy consumption but also change local climate due to the urban heat-island-effect in return increasing the cooling demand additionally.

2. High GHG Emissions through Transport Sector
With a share of 26.8 %, the transport sector is one of the major energy consumers in Iran as well as the largest emitter of CO_2. This is caused by an increasing motorization especially in the urban centers, which again is fostered by the lack of integrated planning and the absence of well-functioning public transport systems. Moreover the widespread use of inefficient vehicles has added to the significant levels of pollution in Iran's urban areas: It accounts for more than 70 % of pollutions in Tehran. This has lead to major problems concerning air pollution, putting Tehran's air on the top list of the most polluted on earth (Muir, 2007).

3. Inefficient Urban Energy and Water Infrastructure Systems
The energy infrastructure system currently in operation in Iran has large deficiencies since individual solutions by users in terms of heating and cooling connected with an electricity supply by highly inefficient central oil driven power plants often represent the status quo. Energy efficient supply systems (cogeneration or tri-generation plants) and local distribution grids are not essential elements of current practice and the use of renewable energies is marginal/. This results in high levels of GHG emissions. The water sector is characterized by a growing discrepancy between water supply and water demand. The effects of global warming have significantly exacerbated this problem. Moreover, existing water resources in the Tehran region are seriously jeopardized due to above-average water consumption, insufficient wastewater treatment and extensive leakages in overstrained systems.

2. Approach: The Young Cities Project

Observing the drastic impacts of climate change to be expected on the one hand and examining the huge regional potentials of mitigation on the other hand, the German-Iranian research project „Young Cities - urban energy efficiency" (www.youngcities.org) aims at developing solutions for low carbon urban fabric as a counter-proposition to the currently developed highly unsustainable solutions in contemporary mass housing in the Tehran region. Since 2005, the project is funded within the program on "Research for Sustainable Development of the Megacities of Tomorrow: Energy- and climate-efficient structures in urban growth centres" (www.future-megacities.org) by the German Federal Ministry of Education and Research.

The project's scientific approach is based on the principle of research *for* instead of *on* low carbon housing. This means that a combination of research activities and realization processes in the form of pilot projects is intended. The solution-oriented thinking aims at capacity building and qualification of actors in Iran. More technical and procedural innovations are expected through the following guiding principles:

- Design of tailor-made solutions adapted to climatic and cultural conditions,
- Application of sectorally integrated planning and management concepts,
- Integration of spatial scales from the single object to the city scale,
- Adaption and application of available low technological solutions,
- Reference to local and regional knowledge and resources, as well as
- Support of planning measures with participation and awareness raising measures.

The project is lead by the Technische Universität Berlin (TU Berlin) and the Building and Housing Research Centre of Iran (BHRC) affiliated to the Ministry of Housing and Urban Development. The German partners include thirteen departments of TU Berlin and two other Berlin universities as well as Berlin-based companies and consultancies. The Iranian New Towns Development Corporation (NTDC), the Housing Investment Company (HIC), a range of consulting companies as well as academic institutions and NGOs complete the Iranian consortium.
According to the broadly based objectives, the project structure encompasses a large set of disciplines and actors, representing the complexity of the built environment and the specific requirements for climate change solutions. The three German-Iranian Teams encompass:

1. Urban Development and Design: including Urban and Regional Planning, Urban Design and Architecture, Transport Planning, Landscape Planning, and Climatology,
2. Urban Infrastructure Systems: including Water and Waste Water Management as well as Energy Management,
3. Buildings and Objects: including Structural Design, Building Services Engineering, Architecture and Engineering.

A "Supportive Dimension" being responsible for cross-section tasks and objectives including environmental assessment, project management, participation, awareness raising and capacity building tasks backs these three Strategic Dimensions.

This solution-oriented approach requires a local case study, which is the focal point of all activities: This is Hashtgerd New Town situated 65 kilometers west of Tehran. Hashtgerd is part of a nation-wide new town program aiming at constructing 25 new towns. By 2009, 22 of these towns are under construction with a cumulated target population of over 4.65 million inhabitants.

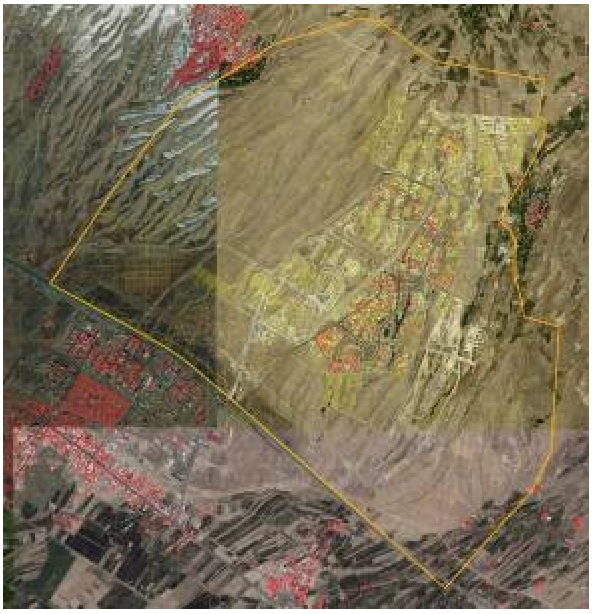

Fig. 3: Hashtgerd New Town Aerial Picture 2009, Source: Cartography Unit TU Berlin, Google Earth

Fig. 4: Hashtgerd New Town in 2005, Source: TU Berlin

With a target population of 500,000 inhabitants, Hashtgerd New Town is the largest of the Iranian New Towns. The town is organized in a grid pattern following the significant topography of the site. 25 neighborhood units of 20,000 residents each separated by large green spaces shall be developed and supplemented with large-scale facilities like shopping centers or leisure facilities. Standardized four to five-floor freestanding apartment blocks mainly erected in low construction quality dominate the car-based layout of the city. Besides massive problems in infrastructure (lack of public transport and water supply), environment (waste water disposal), planning control (slow development speed), the town lacks employment possibilities and today only houses approximately 45,000 inhabitants (see figures 3 and 4). The local conditions foster a situation regarding energy consumption very comparable to the national situation described above and makes it a very suitable case study.

The following chapter will concentrate on the first results in the field of urban development and urban design. Both aspects are major part of the central pilot project of the Young Cities project, the 35 ha area pilot project in the south of Hashtgerd New Town. This is the central demonstration ground of the project and shall be developed as a showcase for innovative design schemes and methodologies for low carbon, sustainable housing in Iran. The area is developed interdisciplinary tying together urban planning, urban design, architecture, landscape planning, transport and mobility, urban climatology, water and wastewater and energy management. Accompanying measures are conducted through participation and environmental assessment. Thus the specific quality of this pilot project is the possibility of bringing together single measures at different scales and exploring especially their synergetic effects.

3. First Results: Designing a Low Carbon Quarter

In the Young Cities project the term “Low Carbon” can be defined as the goal to minimize carbon dioxide emissions from the built environment. In this case, this is mainly based on energy-efficiency, namely the minimization of energy consumption and the efficient use of the consumed energy. This approach also includes the use of renewable energies; nonetheless the project concentrates on design measures for energy-efficiency and upgrading of existing and available technologies suited to be implemented fast and at low cost.

In order to open up a broad discussion between the partners involved from the start, three different urban design scenarios have been developed for the site. The scenarios follow different design principles but were all based on the existing Hashtgerd New Town master plan: development of a dense housing scheme for 8,000 residents including local amenities such as schools, kindergartens, shops, offices and a mosque. After intense discussions at several workshops taking place in Berlin, Tehran and Hashtgerd New Town, the consortium chose one urban design scenario for further elaboration as basis for a legally binding land use plan. This scheme will be presented in the following.

The guiding principle of the scenario is to develop a sustainable and energy-efficient urban quarter derived from the logic of the traditional Islamic city, leading to a dense and clearly readable urban pattern with a clear hierarchy of public, semi-private and private spaces and access systems. The high capacities of the Islamic city in special regard to energy-efficiency are combined with contemporary and innovative planning and infrastructure approaches, as the main features of the design illustrate:

High Densities for Reduced Sealing of Soil and Energy Savings

An adequate urban density is a precondition for achieving low carbon housing, since there is a strong link between density and energy consumption. This is mainly related to mobility needs and demands. By increasing density, the average distance between loci of activity decreases, the need for travels outside the area is reduced and the potential for public transit increases. Another argument supporting the traffic-reducing effect of density comes from increased cost efficiency in the provision of public transport options, an argument that has been strengthened by traffic-related research (Forschungsinformationssystem, 2009).

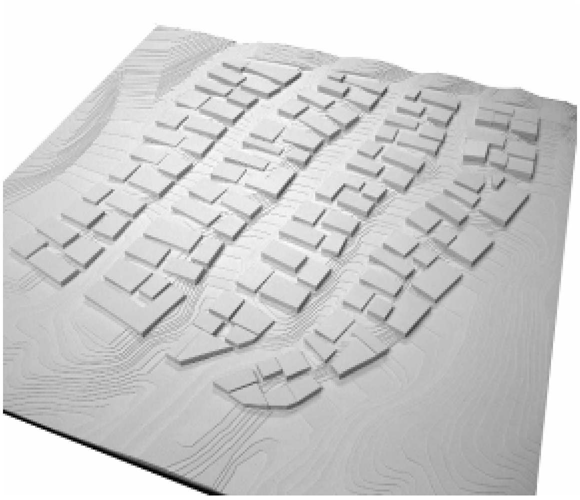

Fig. 5: 35 ha Area Massing, Source: TU Berlin

Fig. 6: 35 ha Area Concept, Source: TU Berlin

The density approach chosen for the 35 ha area can be described as “low-rise – high-density” – the preeminent approach of the traditional Islamic city. A high density with a floor area ration (FAR) of 1.6 is combined with a low elevation of maximum three floors. 8,000 residential units give space for 2,000 residents, which is equivalent to 228 persons per hectare. This means that the density demanded from the Hashtgerd New Town master plan can be achieved with much more compact urban form and reduced built-up areas. The proposed building masses are organized in four rows stretching from north to south located on the ridges in 28 compact urban clusters that allow the main (and hot) winds from west and northwest to channel through the site. The building structure supports the north-south winds that are bringing cooler air at nighttimes into the proposed central open space. The latter is linked to the quarters by east-west corridors, which alternate between being public and semi-private (for private use). The low skyline follows the topography of the site allowing for free movement of air above the city and minimizing excavation (see figures 5 and 6). The Freie Universität of Berlin conducted the microclimatic simulations und modulations with the help of the software tool “Envi-met”. The low-rise high-density approach also entails a maximum shading of all open spaces and thus enhances the sojourn quality. The team conducted shadow analyses with the simulation software ECOTECT. The high density is combined with a public and non-motorized traffic-oriented mobility concept on the 35 ha area based on a flexible minibus system and a permeable walking and cycling system.

Compact Urban Form for Reduced Energy Consumption and Good Microclimate

On the urban scale, a correlation of density and compact urban form is a major need for achieving the low carbon city. Compact urban form can be characterized by an above-average density, a below-average surface area and by inter-connected building patterns (Forschungsinformationssystem, 2009). Compact urban form leads to a lower amount of sealed ground per capita within the total settlement and traffic area. Moreover, compact urban forms allow for an efficient supply with technical infrastructure systems since compact building structures have a higher heat density and are thus more sufficient for energy-efficient grid-bound supply systems (BBR, 2001). On the building level, the compactness is one of the crucial factors for energy-efficiency since it directly influences the cooling and heating demand.

Fig. 7: 35 ha Area Cluster, Source: TU Berlin

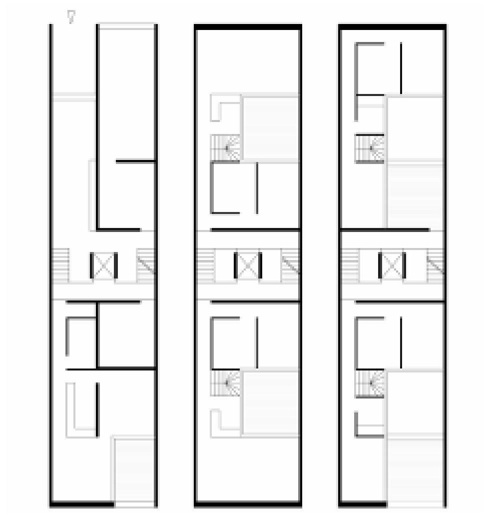

Fig. 8: 35 ha Area 7.5 m Housing Typology, Ground Floor to Third Floor, Source: TU Berlin

The urban design of the 35 ha area is based on the master plan FAR of 1.6 but does organize the urban structures in a more compact way: 56 % of the area is built-up area compared to 72 % of the master plan. Consequently, the share of public and semi-public open areas is higher than in the master plan. This improves the microclimate since the unsealed soil absorbs the heat and thus reduces the heat island effect. Very compact clusters characterize the urban form. Every cluster (approximately 100 m by 60 m) is defined by a central court (10 by 15 m) and four buildings groups situated around the courtyard. The clusters are accessible by foot and bike via a narrow, six-meter wide path in north-south direction. All clusters are connected through these paths, allowing for a good access by foot and bike - cars are not intended to be present. This introverted access system allows for a compact urban fabric and a reduction of traffic areas. The organization of each housing group and each building supports the compact form since the single plots are narrow and deep (see figure 7).

Building Typologies and Orientation for Reduced Heating and Cooling

The orientation of a building is another major aspect for energy-efficiency. In dry and hot regions, buildings should offer a minimum of exposed surfaces and adequate internal shading. This has a large impact on the design of buildings. Manzoor proposes to design the building deeper than wide and orient them according to the sun paths. Thereby, sun exposure can be minimized. At the same time, a maximum exposure to sun is important in order to make use of renewable energies. Traditional buildings and housing typologies in semi-arid regions such as Iran correspond to both of these requirements by compact building volumes and by openings facing the cooler breezes from southeast and northwest (Manzoor, 1989). The living rooms are oriented towards south since in dry regions a south-orientation offers the advantage that in summer the sun stands high during daytime and thus shading can be provided easily. In the evening, the sun is low and provides natural light for the whole house (Hassan, 1986). In addition, the typology of a house has a large impact on the energy-efficiency. A typology very suitable for semi-arid and arid regions is the courtyard house. The courtyard building is the main typology of the regional Islamic cities since it satisfies the need for privacy and is suitable to the hot climate (Wirth, 2002). The inner courtyard allows for the principle of convection, a basic element for natural cooling: During nighttimes, the hot air rises and is replaced by the cooler night air. The cooler air of the night is sinking into the rooms surrounding the yard and thus cools down the building (Hassan, 1986). Moreover, the courtyard is not exposed to sunlight directly. By introducing a contemporary interpretation of the courtyard house with a predominant south orientation, the housing design for the 35 ha area takes up these advantages. The modern two to three storey stacked courtyard house starts with a 6 m axis, developing in steps of 1.5 m to a maximum width of 15 m (for one example see figure 8). The plots are 20 to 35 m deep, predominantly orientated in north-south direction. The building volumes are elaborated with courtyards and niches in order to increase the amount of surfaces facing south. The strong vertical organization of the volume provides sun for every unit.

Mixed Land Uses for Reduced Energy Consumption

Besides the well-known qualities such as increasing vitality and urban quality, mixed land uses in compact urban environments offer high potentials for the reduction of energy consumption such as:

- Shorter travel distances and increased use of non-motorized and public transport, especially for local destinations such as shops and social amenities (BBR, 2000),
- Reduction of primary energy use through the use of waste heat e.g. from the service sector (Bundesministerium für Verkehr, Innovation und Technologie, 2002),
- Enhanced economic value as a result of the stabilizing effect of combining diverse uses and due to reduced operating costs from energy savings (BBR, 2000),
- Increased flexibility to changing user needs, enabling saving of resources through easy adaptation of existing structures.

Fig. 9: 35 ha Area, Mixed Land Use Scheme, Source: TU Berlin

Analyzing the principles of the traditional Islamic city and its specific spatial and functional hierarchies one can observe that the traditional Islamic city at the city level follows a vertical mixed-use scheme (larger uses are separated, but nearby), but that a mix of living and other functions at the quarter level is typical (e.g. bazaar). The individual housing units in a neighborhood are merely mono-functional (Wirth, 2002, Bianca, 1991).

These findings translate into a concept for the 35 ha area proposing an additive arrangement of functions for the larger functions. These are separated from residential uses but are located in spatial proximity. The social amenities among these larger "anchor uses" are located in the centre of the 35 ha area creating the focal point of the quarter consisting of a mosque, cultural facilities, a kindergarten and schools. A catchment area of 300 m guarantees the accessibility by foot from all the 35 ha area. Larger commercial uses with a multi-quarter catchment area are located at the fringe of the 35 ha area, keeping car traffic out of the area and creating a lively edge. This vertical mix is supplemented with a finer, horizontal mix on the neighborhood level (see figure 9). The ground floor of each building facing the court is potentially dedicated to social and commercial uses (stores for the daily needs, service units for the supply of the neighborhood and small scale social amenities). The upper floors are designated for residential uses. Grouping the mixed use zones around the court define them as the lively centers of every cluster and adds a high sojourn quality due to the shaded spaces.

Innovative Traffic, Energy, Water and Wastewater Concepts

The urban design and urban planning features are linked with a range of innovative infrastructure measures in the field of transport planning, energy supply and management and water and wastewater management. They cannot be explored in this paper but should be outlined briefly. A major element is a pedestrian friendly environment supporting the "slow modes", such as biking and walking. This is achieved through a high permeability on all levels. The shift from cars to public transport is supported by an integration of public transport systems on the local and regional level such as a minibus system on the 35 ha area as a

flexible, rather cheap and adaptable transport system. Another approach is car-reduced housing, offering only a reduced number of 0.2 to 0.4 parking spaces per unit.
The infrastructure planning is complemented by an energy concept. Currently, different technologies and energy components are being elaborated, based on the locally available resources of non-renewable (natural gas, oil, electrical power) and regenerative (solar radiation, potential of biomass from wastewater treatment) energy sources. Starting with technologies marked as promising, different concepts of thermal energy supply are developed, of central, semi-central or de-central characteristics. One option discussed consists of a central power-heat-cold-coupling, in which both the heating water and the cooling water will be distributed via separate networks in the residential area. The energy center with warm and cold water production is situated in the center of the 35 ha area to minimize the distances of energy distribution. Another option currently explored is a central heat supply and decentralized solar cold production, containing only one central thermal distribution network and, instead of the second one, many separate decentralized absorption chilling devices and solar thermal collectors.

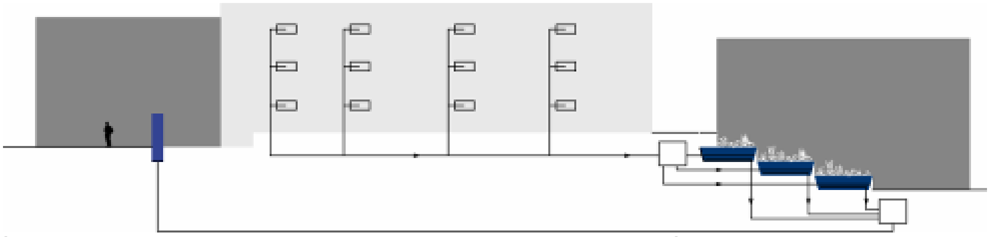

Fig. 10: Grey water reuse in decentralized constructed wetlands, Source: inter 3, Berlin

Another major innovation introduced in the area is the waste water system, which is based on the local conditions and the basic principle of reducing energy and fresh water demand without a loss of comfort. To meet the special needs for new towns the concept must be adaptive and flexible. The concept is based on separate collection, treatment and reuse of grey water in decentralized constructed wetlands as well as co-fermentation of black water and organics for biogas production (see figure 10). The black water is collected and transported by semi-centralized pumping stations and should be treated in a central wastewater treatment plant. After the treatment in the constructed wetlands, the grey water is of a quality, which is sufficient for the irrigation of green spaces, as feed water for an artificial water body, as service water in the courtyards and for the irrigation of the central green open areaspace.
The design of the central open space completes the concept of the low carbon quarter: The chosen extensive landscaping with irrigation-saving vegetation will create a landscape adapted to the consequences of regional climatic forecasts yet comfortable in use.

4. Conclusion

The Young Cities project proofs that there are new approaches for contemporary low carbon (or energy-efficient) quarters in hot and dry regions and that reference to traditional planning approaches can be suitable in this regard. It is obvious that traditional buildings are not in line with most inhabitants' requirements from today's point of view - but solutions for low carbon housing can resort to these traditional forms since they offer valuable solutions for the configuration of urban form, the organization of density and compactness and for orientation of buildings as well as for typologies. This approach can also contribute to developing a specific identity in new settlements, which often vanishes in western-influenced planning and building solutions. Large projects predominately in the United Arab Emirates currently on the way already refer to this idea of referencing traditional city models in order to achieve low carbon urban form: the two most prominent are the MASDAR CITY development in Abu Dhabi (urban planners: Foster and Partners), heavily referring to the traditional Arab townscape and the XERITOWN-Project by SMAQ and x-architects in Dubai. Especially the latter project also focuses on cost-efficient design-based measures for energy-efficiency – a major element of the Young Cities project as well.

However, innovation is not mainly to be found in referencing traditional form or applying tested and well-known design principles. The real innovation for energy-efficiency is to be found in merging the traditional approaches with modern technologies, in involving all disciplines needed and in integrating the scales from the single objects to the city or region. To solve these requirements facing the complex and reciprocal challenges of climate change increasingly requires the use of modeling and simulation software in order to test and evaluate the climatic, energetic and ecologic cross effects of certain measures.

This also holds true for the Young Cities project: After having elaborated a first draft of the design for the 35 ha area, the project team is now concerned with the computer based evaluation of the measures, especially regarding the quantitative assessment and its comparison to existing structures in Hashtgerd New Town. The results might require a certain redesign or refinement of the 35 ha area design. The elaboration of the legally binding land use plan is then planned for late 2009 and early 2010, the first infrastructure measures shall be realized in the course of 2010. By implementing the 35 ha area scheme and its accompanying measures, the German-Iranian team will help to overcome the tremendous challenges of contemporary urban Iran.

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