

# Evaluation of Cities in the Context of Energy Efficient Urban Planning Approach

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**Abstract.** Due to the increase in energy need with urbanization as a result of industrialization and rapid population growth, preservation of natural resources has become impossible. As the energy generated particularly from non-renewable natural resources that are in danger of depletion such as coal, natural gas, petroleum is limited, and as environmental issues caused by energy resources increase, means of safe and continuous access to energy are searched in the world. Owing to the limited energy resources and energy dependence on foreign sources in the world, particularly in European Union countries, efforts of increasing the share of renewable energy sources in energy consumption increased in all industries, including urban planning as well. Concordantly, it is necessary to develop policies and approaches that enable utilization of domestic resources complying with the country's conditions, and monitor developments in energy. Such policies and approaches, which must be implemented in urban planning as well, have great importance in terms of not deteriorating habitable environments of future generations while utilizing present-day energy resources, prevalence of utilization of renewable energy sources, and utilization of energy effectively. For that purpose, this paper puts forward a conceptual framework covering the principles, strategies, and methods on energy efficient urban planning approach, and discusses the energy efficient urban area examples within the scope of the suggested framework.

## 1. Introduction

Increased migration from rural to urban areas associated with industrialization and developments in knowledge and technology in the 19th century caused rapid urbanization. Consequently, utilization of non-renewable natural resources with limited reserves increased. Therefore, the entire world is finding the means of safe and continuous access to energy. The risk of depletion of non-renewable energy resources and their damage on environment at high levels on one hand, and the need to develop alternative and renewable energy sources and to expand their domains of application, on the other hand, led to emergence of new approaches in planning of cities as part of sustainability, environmental consciousness, and energy efficiency approaches [1].

With the environmental awareness that started to awaken in the world as of 1970s, and adverse effects of environmental problems on all living creatures including humans, which were revealed in 1980s, discussions started on utilization of renewable energy sources, and the notion of energy efficiency attracted great interest. Due to the limited energy resources and the 55% dependence on foreign sources for energy in the world, and particularly, in European Union (EU) countries, efforts of increasing the share of renewable energy sources in energy consumptions increased in all industries, including urban planning as well [2]. Concordantly, it is very crucial to develop policies and approaches that enable utilization of domestic resources complying with the conditions of the countries, and to monitor studies



pertaining to energy in the world. Such policies and approaches, which must be implemented in urban planning as well, are important in terms of not deteriorating habitable environments of future generations while utilizing present-day energy resources, prevalence of use of renewable energy sources, and effective use of energy. In this context, the objective of this paper is to form a conceptual framework containing the principles, strategies, and methods pertaining to energy efficient urban planning, and evaluate exemplary energy efficient urban areas in the world in the scope of this framework.

## **2. Energy efficient urban planning**

World's energy need increases 4-5% every year because of reasons such as industrialization, rapid population growth and advancement in the standards of living [3]. The issue of efficient utilization of energy gradually became crucial due to reasons such as rapid depletion of fossil fuel reserves like coal, petroleum and natural gas in order to provide the energy need of the world; thinning of ozone layer as a consequence of increasing energy consumption; raising air pollution associated with the impact of greenhouse gases; climatic change, and increasing environmental pollution [4]. Because of ever-increasing energy demand and fluctuations in energy prices, energy became a strategic issue for countries, and efficient utilization of energy became one of the most important aims. In this context, new approaches emerged in recent years, taking energy efficiency in urban planning into consideration.

### *2.1. Energy efficiency*

Energy efficiency is the transformation of each unit of energy consumed to more service and product without any compromise on quality and comfort requirements [5]. The most important element in energy efficiency is energy saving, and one of the most important indicators is energy density [5, 6]. Energy saving is ensured by minimizing the amount of consumed energy without losing quality and performance by means of utilization of energy wastes and prevention of existing energy losses. The lowest-cost energy is the energy saved by efficient utilization. Energy efficiency may be increased by decreasing energy density, which is explained as the energy consumed per unit output [7].

The most important factor triggering energy efficiency policies in the world was the energy and petroleum crisis encountered in 1970s. With environmental protection coming into prominence in 1980s, the concept of energy efficiency became the essential part of energy and development policies. Energy efficiency is one of the parameters affecting sustainable growth, which allows relaying present-day necessities to future generations without perishing natural resources. According to Brundtland Report in 1987, published by United Nations World Commission on Environment and Development, it has become necessary to take urgent, unyielding, and grave measures for more efficient energy utilization [8]. There are various measures and proposed solutions in each country in regards to energy efficiency, which is to minimize the amount of consumed energy without reducing quantity and quality in its generation and without hindering economic growth and social welfare [7].

As the first country recognizing the importance of energy efficiency, United States of America (USA) has conducted studies on this issue since 1970s. Finding the achievements from such studies insufficient, USA prepared a national action plan on energy efficiency in 2008, named Vision 2025, for reasons such as increasing security of energy supply and mitigating potential risks in carbon policies. Likewise, since early 1970s when the petroleum crisis was faced, EU countries started studies and set certain targets in order to minimize dependence on petroleum, increase supply security, reduce energy costs, encourage competition, reduce unemployment, preserve the environment, and reduce greenhouse gases. With the concern that defined targets may not be reached, Energy Efficiency Directive was prepared in late 2012 [5]. Having experienced adverse impacts from 1970s petroleum crisis, Japan renewed Law on Energy Saving in 1999. In Japan, the studies on energy efficiency are supported by the state by various financial models, such as tax incentive, long-term loans, and industrial organizations. Besides, people support such studies voluntarily, and urban managements apply various efficiency programs occasionally within their boundaries [9].

## 2.2. *Energy efficient urban planning approach*

Owing to increased energy needs in cities, urban planners recently started to attach importance to the studies manifesting the energy & city relation in the process of urban planning, and the studies on new planning approaches for liveable cities increased. It became obvious that urban planning is not just to arrange and improve any physical domain but also a development that must be taken together with economic, social, communal, environmental, and physical dimensions, and it is necessary to evaluate their interactions with each other and to develop policies [10]. In urban planning, spatial structure is generated by variables such as land use, location selection, urban macro-form, urban grandness, density, communication, and transportation facilities. Any change in any of these variables has substantial impact on energy source requirements [11]. It is therefore necessary to take the variables into account by the principles of energy efficient urban planning in order to ensure energy efficiency.

Starting in early 1990s, urban planning and design approaches were developed under the names, such as Sustainable Cities, Ecological Cities, Green Cities, Smart Growth, Smart Cities, Slow Cities, Low Carbon Cities, Liveable Cities, Digital Cities, and Smart City Initiatives in various cities and regions throughout the world. Energy Efficiency in Settlements is the most important subject that urban planning discipline must deal with primarily [12]. In other words, energy efficiency, being defined as efficient utilization of energy, must start with urban planning. Energy saved as result of efficient utilization is the least-cost energy, and the means to utilize the energy much efficiently by adopting certain habits, applying improvement methodology or making use of new technologies by making no concessions on generation and quality, and maintaining standard of social life [13]. Urban plans, which are sensitive to environmental issues, preserve ecologic balance and fulfil the requirements of comfort and health necessary for human life come into prominence for provision of energy efficiency.

Energy conservation, land conservation, water conservation, waste reduction, and accessibility ensuring are the principles necessary to be taken into consideration for energy efficient urban planning. These principles will contribute to energy efficient urban planning in terms of economic, social and environmental dimensions. In this paper, considering the classifications both in the Urbanization Council Commission Report and those presented in the papers of Arzuhan Burcu Gültekin and Seda Yavaşbatmaz [14], Arzuhan Burcu Gültekin and Bengü Alparslan Ersöz [15], Mustafa Yılmaz and Serkan Yıldız [16], Aslı Atıl, Bahriye Gülgün and İsmail Yörük [17], Mehmet Karaca and Çiğdem Varol [18] and Serkan Sınmaz [12], the principles, strategies and methods proposed regarding energy efficient urban planning intended for residential areas and liveability of the natural environment in H. Handan Yücel Yıldırım, Arzuhan Burcu Gültekin and Harun Tanrıvermiş's paper [19] are presented in Table 1.

## 3. **Evaluation of exemplary urban areas in the world within the scope of energy efficient urban planning**






For a better liveable future, there are exemplary cities of urban planning approach in the world where energy is utilized efficiently and productively, renewable energy resources are produced and used, projects to reduce water consumption are put into practice, waste and environmental problems are taken into account. While some of these cities are built according to energy efficient urban planning approach, some are transformed to the cities utilizing energy efficiently. In this paper, Dongtan Eco City, Fujisawa Smart City, City of Masdar and Songdo Smart City were evaluated in the scope of newly-built energy efficient cities. Furthermore City of Copenhagen, City of Gothenburg, and City of Portland were evaluated under transformed cities. Practices of energy efficient urban planning performed in these exemplary cities are presented in Table 2, 3 and Table 4 according to the principles, strategies and methods of energy-efficient urban planning approach presented in Table 1.

There was not enough information available in the literature regarding to exemplary urban areas throughout the world in the scope of energy efficient urban planning approach. It may be argued that constructed energy efficient cities evaluated in the light of limited information in Table 2 are not sustainable economically.

**Table 1.** A conceptual framework for energy efficient urban planning approach

Energy Efficient Urban Planning Approach		
Principles	Strategies	Methods
Energy Conservation (EC)	Reducing utilization of non-renewable energy resources	Reduction in energy consumption
		Integration of energy technologies to city, elimination of the deficiency of renewable energy systems
		Considering local climates at building design
	Generation and utilization of renewable energy resources	Issuance and enforcement of the regulations of implementation for renewable energy generation in settlements
		Creation of aids and incentives for utilization of renewable energy sources
		Arrangement of spatial areas containing renewable energy utilization
		Development of social awareness and training on renewable energy
	Determination of policies and basic principles for compliance and preventive actions for climate change	Legislating and enforcement of the law on climate change
		Regulations for increase of energy efficiency and savings for controlling and mitigating greenhouse gas emissions
		Preparation of climate maps of settlements, and keeping them updated
	Reduction of pollution	Balanced distribution, preservation, and enhancement of green spaces within settlements
		Connection of existing outdoor and green spaces to each other and to pasture area
		Utilization of local vegetation suitable for climate
		Development of urban forestry
		Implementation of green wall and green roof systems
Land Conservation (LC)	Conservation of topographic structure of land	Provision of harmony between land usage and topographic structure
	Conservation of habitat	Formation of inventory for natural resources, using values as basis of spatial planning
		Preservation and growth of agricultural areas
	Development of settlement plans by energy efficient development form and structure	Selection of right location for upper-scale decisions based on climatic properties
		Mitigation of heat island impact
		Minimization of infrastructure and superstructure problems arising from land
Water Conservation (WC)	Increasing utilization efficiency of water resources	Utilization of systems allowing efficient usage of water
		Taking legal measures for efficient utilization and management of water resources and enforcement of the law on water management
		Reduction in water consumption
		Unpolluted utilization of water resources
Waste Reduction (WR)	Formation of waste and recycling systems	Promotions to local administrations for waste systems and recycling
		Increasing public sector supervision in waste management
		Sorting of wastes on site, use of recycling technologies
Accessibility Ensuring (AE)	Generation of environment-friendly urban transportation policies and plans	Encouraging public transport usage through transportation and land use planning
		Developing energy-efficient transportation means and systems
		Minimization of private vehicle ownership




**Table 2** Evaluation of the cities built according to energy efficient urban planning approach (a)

Cities		Principles	
<b>Dongtan Eco City</b> [1, 20, 21]	  <b>Location:</b> People's Republic of China, Chongming Island <b>Intended Population:</b> 500,000 people <b>Project Date:</b> 2008-2050 <b>Area:</b> 3000 ha	<b>EC</b>	Renewable energy resources shall be used. While energy efficiency increases by minimizing the impact of energy on climate change wherever it is used, energy consumption and its costs shall be reduced. Zero-energy buildings with zero greenhouse gas emissions shall be built. Energy shall be generated from wind, sun, and biologic domestic wastes. There shall be green roof practices on buildings.
		<b>LC</b>	No high structuring shall be allowed in consideration of climatic properties. Housings shall not exceed 40% ratio, and 60% of land shall be natural bird habitat. Organic agriculture shall be utilized.
		<b>WC</b>	Agricultural irrigation shall be with rain waters. Waste waters shall be treated and reused.
		<b>WR</b>	By treating and reusing 90% of wastes, a zero-waste city shall be created.
		<b>AE</b>	Transportation shall be provided with vehicles running on hydrogen-based clean fuel. A pedestrian-based transportation system shall be promoted.
<b>Fujisawa Smart City</b> [20, 23-28]	   <b>Location:</b> Japan, Kanagawa <b>Intended Population:</b> 3,000 people <b>Project Date:</b> 2008-2018 <b>Area:</b> 19 ha	<b>EC</b>	For utilization of solar energy, roofs of buildings shall be covered by solar panels. Renewable energy sources shall be increased minimum by 30%. Greenhouse gas emissions shall be reduced by 70%. City lighting shall be provided by using smart grid systems (self-sustained energy supply). The most advanced systems shall be employed in buildings for generation, storage, and management of energy.
		<b>LC</b>	Smart infrastructure systems shall be utilized. City shall be in harmony with the nature and shall not pollute environment. An organic city shall be built where solar battery placements are to be in harmony with the soil layer. An optimal smart infrastructure system shall be created.
		<b>WC</b>	Domestic water consumption shall be reduced by 30%.
		<b>WR</b>	No available data on this subject.
		<b>AE</b>	Particularly transportation to health and public institutions shall be kept short and in walking distance. Electric bicycle, electric vehicle, and pedestrian transportation shall be promoted.









For this reason, completion dates of urban area projects implemented by both public and private sectors are postponed continuously. It may be stated that transformation of existing cities according to energy efficient urban planning approach, as presented in Table 3, is much better than building energy efficient new cities. It was determined that principles, strategies and methods proposed for energy efficient urban planning approach in Table 1 were partly applied in exemplary cities examined, but no information was available particularly on regulations, supports, and incentives for utilization of energy efficiently. In the exemplary urban areas examined, it is observed that such strategies and methods as utilization of energy generated from renewable energy sources and solid waste, integration of energy technologies into cities, reduction of greenhouse gas emissions, promoting pedestrian and bicycle transportations, reduction of private vehicle ownership by increasing electric vehicles and public transportation systems, and reusing rain water and waste water were prominent.



**Table 3** Evaluation of the cities built according to energy efficient urban planning approach (b)

Cities		Principles	
City of Masdar [1, 20, 22]	  <b>Location:</b> The United Arab Emirates (being built in desert nearby Abu Dhabi) <b>Intended Population:</b> 50.000 people <b>Project Date:</b> 2006-2025 <b>Area:</b> 600 ha	EC	Energy consumption shall be minimized in order to maximize energy efficiency. The aim shall be zero-carbon emission. Carbon dioxide generated by the city shall be buried underground. 80% of buildings shall fully have solar collectors, while solar panels shall be placed on rooftops. 99% of waste shall be used for energy generation.
		LC	Buildings shall be limited to 5 floors in order to effectively benefit from shadows and the sun.
		WC	Sea water shall be treated and utilized for meeting water needs in order to reduce water consumption; all the waste water and rain waters shall be utilized for irrigation. Solar energy shall be utilized for treatment process. Materials such as Efficient fixtures, household appliances, and smart counters shall be used in order to increase water efficiency.
		WR	All the waste shall be recycled in order to generate zero waste. A portion of wastes shall be utilized in generating energy, while another portion shall be used as fertilizer for landscaping.
		AE	Electric bus and electric rail system shall be installed throughout the city, and vehicles shall not be allowed to enter the city. Transportation shall be mainly pedestrians and bicycles. Electric taxis with one-person cabin and no drivers (Personal Rapid Transit) running on clean energy shall be utilized.
Songdo Smart City [20, 29-33]	   <b>Location:</b> South Korea <b>Intended Population:</b> 252.000 people <b>Project Date:</b> 2003-2020 <b>Area:</b> 610 ha (replenished area)	EC	Wastes shall be used in energy generation. Energy consumption shall be reduced by utilization of LED lighting, air conditioning systems with water cooling, and wind and solar energy. Green roof systems shall be applied using local vegetation. Greenhouse gas emission shall be reduced. Natural building materials shall be used. Green and smart growth has been aimed for the city with LEED certificates in 120 of its buildings. Traffic, public transportation system, energy consumption, heating, and air conditioning of the city shall be managed from one center by means of sensors controlled by computers connected through a grid.
		LC	40% of the land shall be comprised of green areas and golf courses. Environment-friendly design shall be implemented.
		WC	Water consumption shall be reduced. Rain water shall be collected, and waste water shall be treated and reused.
		WR	A waste collection system eliminating garbage trucks shall be implemented. Domestic waste shall be transported directly from the buildings to waste processing centers and sorted.
		AE	Pedestrian and bicycle transportation shall be promoted. Public transportation shall be popularized. Electric vehicles shall be in use, and private vehicle ownership shall be reduced.

**Table 4.** Evaluation of the cities transformed according to energy efficient urban planning approach

Cities		Principles	
City of Copenhagen [34]	   <b>Location:</b> Denmark <b>Population:</b> 1.213.822 people (2012)	<b>EC</b>	By the year 2020, 50% of electricity shall be generated by wind farms. The city's climate plan slogan for the year 2025 is a green and smart city with zero-carbon emission, and it is anticipated to quit utilization of fossil fuels and nuclear energy completely. By the year 2050, 100% of energy need shall be met from renewable energy resources. The heating has been almost solved by utilization of geothermal energy. There shall be green roof practices on buildings.
		<b>LC</b>	No available data on this subject.
		<b>WC</b>	Rain water shall be recycled and used.
		<b>WR</b>	94% of wastes shall be recycled.
		<b>AE</b>	Bicycling is popularized, and the subway network and bicycling are combined optimally. Emphasize is given to public transportation.
City of Gothenburg [1, 20, 35-37]	   <b>Location:</b> Sweden <b>Population:</b> 485.000 (2015)	<b>EC</b>	Solar panels and wind turbines shall be installed on roofs to save energy and to provide heating and cooling for buildings. Green roof systems shall be utilized. Greenhouse gas emissions shall be reduced by reducing energy consumption. Energy generation shall be supported by wave-power and bio-gas generated by remnants of large-scale transportation sector. Green areas shall be preserved and enhanced.
		<b>LC</b>	Traditional materials (yellow bricks) shall be used in construction of buildings, and local architecture shall be maintained. A high-density decision shall apply.
		<b>WC</b>	Rain water shall be collected and reused. The sewer system shall be re-built. Waste water shall be treated and used.
		<b>WR</b>	No available data on this subject.
		<b>AE</b>	Zero-carbon emission transportation shall be provided by Personal Rapid System. Bicycling shall be promoted using bicycle roads covered with roofing. Emphasize shall be given to hindering the gas and oil consumption. Pedestrian and public transportation shall be promoted. Use of private vehicles shall be reduced. Transportation to housing, working, and plant locations shall be provided by consuming the least energy.
City of Portland [20, 38-40]	  <b>Location:</b> USA <b>Population:</b> 609.456 people (2013)	<b>EC</b>	The city shall utilize hydroelectric plant, solar, and wind energy at 70%. There are 175 buildings with LEED certificates. It is anticipated in the climate action plan to reduce carbon emissions by 80%.
		<b>LC</b>	No available data on this subject.
		<b>WC</b>	Water consumption shall be reduced. Rain water shall be collected and waste water shall be treated for reuse.
		<b>WR</b>	60% of waste is recycled.
		<b>AE</b>	Coordination shall be established between institutions related to transportation planning; the actors involved in transportation, meaning employers, transportation companies and city people shall take part in the planning process. Bicycling shall be promoted. Public transportation shall be popularized. Investments shall be made for light rail system and tramway lines.

#### 4. Conclusions

In today's world, where most of the world population lives in cities, it is a rather expensive method to provide all of the increasing energy need from renewable energy sources with today's technology and conditions. It is therefore necessary to utilize existing energy efficiently and productively, which is a much affordable practice for fulfilling the increasing energy need.

The conceptual framework suggested in this paper may be adopted as a guideline in energy efficient urban planning, and consequently, may be used as a guide for different disciplines. Since constructing new cities according to energy efficient urban planning approach is not economically sustainable; for sustainable developments of existing cities, transformations must be performed, renewable energy sources must be utilized, wastes must be recycled, greenhouse gas emissions must be reduced, transportation must be pedestrian-based, and utilization of bicycles and public transport must be increased. Efficient and productive utilization of energy and renewable energy resources must be adopted as a government policy, and the public awareness must be increased. People shall be more selective as public awareness increases on efficient and productive utilization of energy, and investments of lesser energy consumption for less money shall be taken into consideration. In today's world, where economic growth and social welfare lead to more energy consumption, decrease in energy consumption, preservation of the environment, and reducing the burden of energy costs on the economy shall be provided with the enforcement of laws and regulations prepared for efficient and productive use of energy.

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