Parametric Analysis Method for Urban Energy Transformation Projects

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ABSTR ACT

In tandem with industrialization, migration from rural to urban has caused unstructured and unplanned cities. On the other hand the needs of people in the cities have begun to change according to overpopulation, new technologies and life styles. This change results in growing energy demand at the cities and the governmental authorities and municipal services has to respond it. Urban transformation projects are given as a solution for struggling with these problems and reshaping the cities. Energy, one of the main topic on the urban transformation projects, contains the efficient resource and energy management, minimization of the energy consumption as far as possible and capacity enhancement for renewable energy sources. While developing urban transformation projects, the optimal and effective solutions should be investigated for the project area having regard to applicability, environmental impact, and economical feasibility. In this research, the energy demand profiles of generic residential urban blocks for two city locations in Germany and Turkey are simulated using EnergyPlus to identify the site density and physical properties effect moreover the significance of site design on future renewable energy integration opportunities. The research shows that 10-20% energy demand can be saved by an energy aware site planning and the urban transformation projects also have a big potential to supply more than 30% of the energy used with renewable energy sources.

INTRODUCTION

At the end of the 19th century with industrialization, many people began to live in the cities which are the centre for trade, industry and transport. Migration from rural to urban area has gained accerleration with education and business opportunity in middle of 20th century. Today half of the world population lives in cities and it is predicted to increase to more than %65 by 2050 [UnitedNations, 2008]. Nowadays, cities are the overpopulated sharing place of all networks such as transportation, services, finance, social spaces, cultural links, etc. Therefore management of all networks in cities is concerned with configuring, efficiently and equally supplying of the resources to the citizens and ensuring the continuity of the cycles for sustainability.

Especially in Europe, cities have been developed over hundreds years ago. Zonning, structure and network systems were consisted with industrialization but nowadays the European cities are transformed to management centers with head quarters of many firms so cities have to be globalized with sharing network and they need additions or refurbishment for information age [Thorns, 2002].Another point worth mentioning is that new poor citizens (not in Western Europe but rest of the World) who came to city with hope of job placement, solve their residence problem by ownself and living area capacity of the

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city has been increased many times without planning or structuring the new development areas. It is estimated that by the year 2035 half of the world poor population will live in this unplanned areas [Horwood, 2007]. It means that this population will begin to live in unstandardized building blocks with lack of infrastructure and with insufficient supply mechanism. It is big challenge to struggle with this problem for city managers.

Besides that, life style in cities and the technology has metamorphosed the demand of people. Industrial production and modern-day consumers with increasing wealth require more energy for daily needs. Basically all international and national governmental or local authorities deal with this energy management problem. On the other hand authorities have an important role on reducing green gas emissions and climate change mitigation. There is a big opportunity to make a cost effective saving in the energy demand of city building stock and provide the sustainable environment development for cities.At this juncture, sustainable urban development becomes even more important for future of urban life. Sustainable development first appeared in the literature during the 1970s and 1980s and early 1990s the issue of sustainable development gained momentum. After the United Nations' Rio Conference's Agenda 21, sustainable development is preferential as policy for every urban authority (Beatley and Manning, 1997). Many projects and programs are going on for sustainable or energy efficient cities on the world and especially European Union level (Concerto, Civitas, Urbact, Energy Cities, etc.) [http://www.eumayors.eu/about/related-initiatives_en.html]. Reconstruction, renewal or transformation projects can be the solution for urban quarters.

One of the most common sustainable urban development strategies is transformation of the city's quarters. Urban transformation projects are kind of solution for unplanned or unusable urban areas. It is physical transformation for existing building stock with new standards and also it provides better structure to public space and supply network. For developed countries like Germany, it is way to alter the unusable area with new technology integration and to mitigate the impact of climate change. For developing countries like Turkey, urban transformation projects change the physical environment and especially urban spatial structure and begin to control building standards. After having lost thousands of people in earthquake in the past, before even worse disasters hit the country, unplanned cities with buildings out of keeping standards should be transformed in Turkey.Transformation projects are significant for integrating strategies and aspects for energy management of authorities. It has big potential to integrate efficient resource and energy management principals, to minimize the urban enegy consumption and to adapt the renewable energy sources. Chief point for this energy transformation acts is that affordable and adaptable solutions should be determined for the urban sites. Sustainablity of the developing areas has to be considered for present and future users.

In urban projects, the steps and strategies are important for implement and handle the project as a result of the largeness of the area. If the project developer has an approach for different sites and it is applicable for different area, it can be used for various places. This research takes the common points for all urban transformation projects such as density, building property and possible renewable energy sources. It clarified the steps for this urban energy transformantion project and prose a practicable approach for the projects.

FACTORS AFFECTING THE URBAN ENERGY IN TRANSFORMATION PROJECTS

In the urban scale studies, to know the patterns of energy consumption is important for the management of supply. In the energy management works, it is easy to get information from supply but it is hard to define the requirement for different energy sources and the nature of users' requirements. This kind of energy information is significant for sustainable urban energy planning, for the reason that the energy supply needs to be on meeting energy users' needs in the best way possible. Urban design pattern mainly draw the city line and it shapes the inhabitant's comfort requirement or requests. On this level architecture or city planning doesn't have a comprehensive model which can be applied to every place and can take all factors on the account for developing sustainable cities or settlements. But we can define the main factors that affect the urban energy consumption and shape with urban design decision. These factors can be categorized as follows:

Urban density

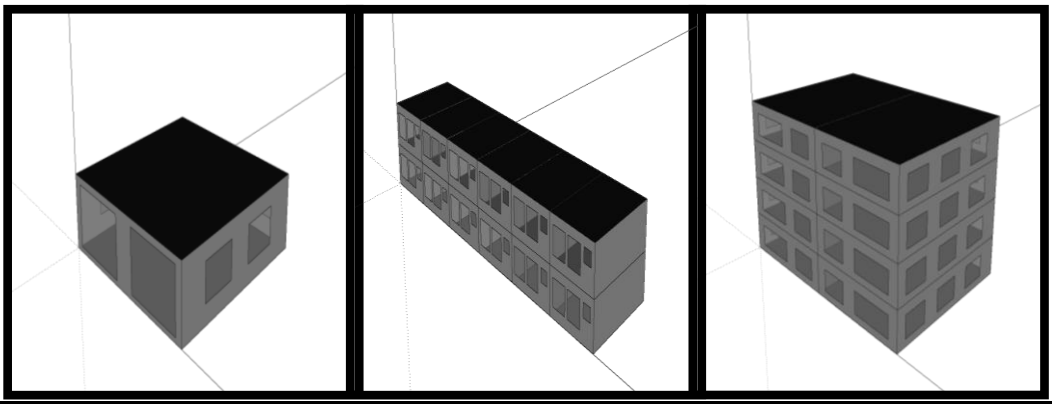
Rapid population growth brings with it, a growing need for built-up area which is one of main problems of the cities. Most of the time, this need is proved with high-rise buildings or compact settings, instead of expanding the boundaries. This brings the term of "urban density" which is used in urban planning and urban design to refer to the number of people inhabiting in a given urbanized area [Sokido and Bhaduri, 2013]. The urban density can affect the total energy demand of a city with different ways and these effects are complex and conflicting [Givoni, 1998]. Density sometimes can bring the benefits but it also creates extra loads and undesirable conditions. It affects the thermal performance, the natural lighting and ventilation possibilities of the buildings and these effects can either be positive or negative according to dominant climatic condition. On the other hand, the density supports to the district energy systems and besides that, the infrastructure facilities are shorter so it reduces also the energy requirement for pumping. Controversially, the energy requirement for pumping on the vertical direction is getting higher in the high-rise cities [Eicker et al., 2010]. The effect of density on heating, cooling and lighting energy demand of the areas is different and their influences are changing according to climatic conditions.

Characteristics of built environment

Physical properties of buildings and technologies in the building sector have a significant effect on the energy consumption. Insulation properties, windows type and area, the efficiency of technical appliances in buildings such as elevators, escalators, HVAC systems' equipments are profiled the building for evaluation of its energy. Building envelope, this is interface between outdoor environment and indoor conditions, works as a thermal barrier and serves a function in regulating a comfortable indoor temperatures. It plays a crucial role for reducing the need for heating and cooling of building. Moreover the placement of windows and doors, the size and location in the envelope has a significant role on the control of energy losses. Buildings should always be contemplated in the conjunction with their surroundings. In order to manage the use energy of the built environment in a sustainable way and to minimize harmful emissions, the performance of the city scale must be considered. Building energy condition can be characterized with urban pattern, building stock properties and also infrastructure possibilities. In the terms of shading and reflection, lighting and thermal energy loads are influenced by the architectural form of the urban structures and the neighborhood relationship.

Possible renewable energy source applications

Buildings are integrated into networks of overriding technical infrastructures which are water supply, drainage, sewerage, water disposal, electricity system, heating and cooling networks and transportation. The development of more sustainable cities critically depends on a style of urban infrastructure condition that encourages more efficient patterns of resource consumption. District heating or cooling in combination with energy efficiency measures in buildings account for approximately one third of the reduction of emissions [Särnholm et al., 2009]. Therefore, efficient supply system and integration of renewable energy technologies to the network are crucial for sustainable cities. On the other hand renewable energy integration is more meaningful solution at urban scale. Indivual building renewable energy integration is not factual answer for efficiency and feasibility. Renewable energy application on the urban area or district, which is directly connected to the grid so it eliminates transmission loss on the other hand it doesn't use any other land for application, has better energy performance than the individual applications. Solar PV or solar heating system integration on the roof has high potential with easy application. Façade integration has not easy for the underperformance of panels caused by the inequable shading. Wind tirbunes are not easy to implement to the urban district for the reason that it is affected from location of the building, wind direction, heights of surrounding buildings, other roof-top structures and so on.



Building type	One storey house	Row houses	Apartment block
Floor area	10.5mx10.5m	7m x10m	20mx14m
Height	3.5m	7m	10.8 m
Building unit	1 house-	6 houses	1 block-

Figure 1 (a) Energy plus model of one storey house (b) Row houses and (c) Apartment block

METHODOLOGY FOR PARAMETRICAL ANALYSIS

In the urban transformation projects, especially used for residential areas, highrise apartment form is used for restructuring the land in the furtherance of scalling up the recreation and green area opportunity. In order to limit the complexities related with real urban areas, the archetype was defined according to common typologies for transformation projects and this simplified type is used for energy performance simulations. There is not any survey for common building typology in Turkey but the German building stock was explored on the basis of energy demand properties and main residential building typologies defined by Institute for Housing and Environment-Germany (IWU, 2003). According to this research one storey, row houses and apartment blocks take into account for possible former building types of urban transformation area **as shown in Figure1.** According to profesionel point of view similar building forms are commonly used also in Turkey.

The apartment block with 10 storeys is chosen for possible new building form for urban transformation projects in Turkey and Germany. Floor area of the building is 24,4m*24,4m and height of it is 30m. Glazed area on the façade is 35% of the full façade area. Three dimensional urban quarter simulation was done for generic urban form **as shown in Figure 2.** The representative urban quarter constitutes of 9 generic building blocks and the distance between the buildings varies according to site density. The major orientation for the site design is the South. To see the total energy demand of the building, heating and cooling analysis including the annual electricity consumption with daylight responsive control was calculated in the Energyplus simulation program (simulation methodology has been described detailedly in the paper Kesten et al., 2011). Ankara and Stuttgart Energyplus weather data is used for the simulations.

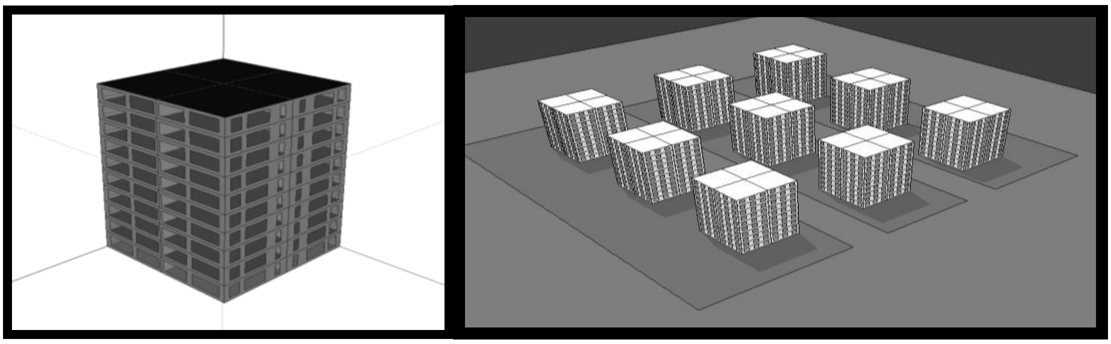


Figure 2 (a) Energy plus model of urban quarter and (b) Energy plus model of urban quarter according site density.

Table 1. U-values (W/m²K) of building envelope according to construction year and building energy standards (LE: Low energy standard, PH: Passive house standard)

Building Component	ANKARA			STUTTGART										
	1984	2000	2008	1948	1968	1978	1983	1994	2000	2007	2009	LE1	LE2	PH
Exterior walls	1.2	0.5	0.5	1.7	1.4	1.03	0.8	0.6	0.5	0.3	0.24	0.23	0.15	0.13
Floor	0.75	0.45	0.45	0.8	0.8	1	0.8	0.6	0.5	0.3	0.24	0.3	0.26	0.19
Roof	0.47	0.3	0.3	0.8	0.8	0.6	0.5	0.3	0.3	0.3	0.24	0.25	0.19	0.15
Windows	2.7	2.6	2.4	5.89	2.72	2.72	2.72	1.93	1.82	1.73	1.3	1.2	0.9	0.8

Occupation of the flats was simulated for an identical family scenario, consisting of 4 family members who are not home during the day except on weekends. The usage time of the appliances was configured according to the statistical data. Every house has television, computer, washing machine, dishwasher, oven, and fridge. The usage was determined as the average time taken from the German household statistic (Gruber and Schlomann., 2005)The EN ISO 13791 was taken as an input for internal gains from occupants. The lighting was defined as 13 W/m^2 and 40% of this is the convective gains. The heating set point was defined as 20°C and cooling set point was defined as 26°C. The heating system was shut down end of April to the end of October and while the cooling was operational for the duration of this time. The properties of building envelope are defined according to national standarts of the countries **as shown in in Table 1.** Simulation has been validated with measured data and it has been described detailedly in the paper Tereci et al., 2010. In the transformation project areas it is assumed that the former buildings in Germany can have been built before 1994 standards. Because of the unplanned development after 1980 in Turkey, the energy values of former buildings can be the worse than this results. But 1984 building standards are taken into account for building envelope which can be the best energy performance case for urban transformation project.

PARAMETRICAL ANALYSIS RESULTS

The heating, cooling, electricity and hot water useful energy demands for possible former building types were simulated without considering the effects of obstructions. These results are **presented in Table 2** and serve as a baseline for comparison. In the cold climatic condition like Stuttgart and Ankara, heating demand especially for residential houses is very important indicator for energy performance of the building.

Heating and cooling demand of the building types in different dense areas were evaluated to get an understanding of the site density effect. **Figure 3 shows** the heating and cooling demand of the former building types located in the centre of an urban block with function of site density densities which were constructed in 1984. Without any shading effect the heating consumption of one storey house is 106.5 kWh/m^2 while depending on the shading of the area the heating consumption can be 12% higher in Ankara climatic condition. The energy demand of apartment block is less by compare with one family house and row houses for both climatic conditions. Site density is affected less in Stuttgart by 8% for one family houses. Especially for cooling loads site density was highly affected in Ankara conditions and coillings loads decrease nearly 50% for all type of buildings.

Table 2. Dynamic simulation results of former reference buildings (construction year 1984) without surrounding obstructions

Reference Buildings	Ankara			Stuttgart		
	Heating	Cooling	Electricity	Heating	Cooling	Electricity
One Family House	106.53	19.44	30	101.53	6.03	33
Row Houses	98.63	15.38	18	94.01	2.82	19
Apartment Block	61.82	19.2	21	62.77	6.87	23

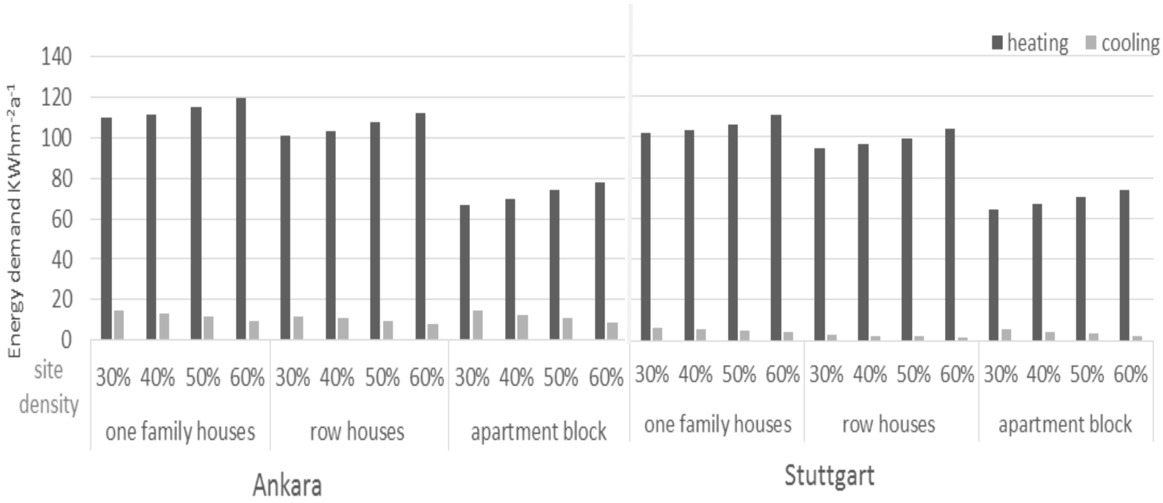


Figure 3 Heating and cooling energy demand of building types with site density

As mentioned before, physical properties of buildings have a significant effect on the energy consumption so the building envelope properties according to energy standards or codes are profiled the building for evaluation of its energy. To understand the effect of energy standards on the buildings, reference buildings are simulated according to different construction years. **Figure 4 presents** the energy demand of eleven versions of apartment block according to different energy standards in Germany since 1948. The passive standard buildings show the heating demand without heat recovery from exhausted ventilation air. Similar trend is observed for one family house and row houses. It is not possible to mention or calculate for Turkey another building envelope properties because of the lack of the energy standards. We can assumed that the buildings which were built before 1984 are in the worse than these conditions and Germany example can have an idea about the effect of thermal properties of envelope. According to results, building standards in 1994 has given a jump for the energy performance of buildings and we can say that for urban transformation project for both countries, the energy performance of the site can be enhance at least 30% for the buildings constructed in the year before 1994.

It is also important to decide for new construction area density for urban transformation project. Therefore ten storeys apartment block which is constructed with current energy standards (Turkey 2008, Germany 2009) was evaluated according to site density and the results are presented **in Figure 5**. The heating consumption of the blocks is 53 kWh/m^2 and cooling demand is 10 kWh/m^2 in Stuttgart. The heating consumption of the blocks is 55 kWh/m^2 and cooling demand is 16 kWh/m^2 in Ankara. Depending on the shading on the site, the heating demand can be 25% higher more and the cooling demand can be 40 % less than the building without shading.

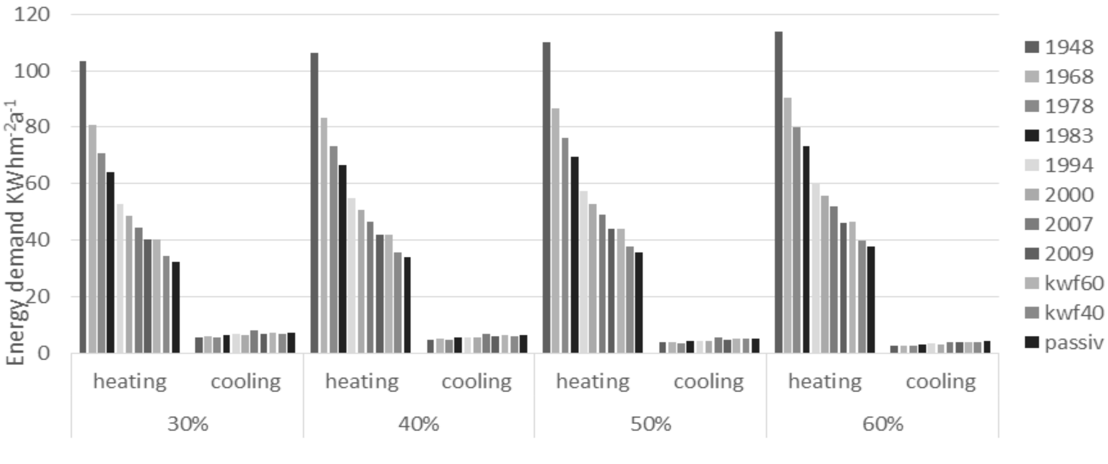


Figure 4 Heating and cooling demands of the ten storey apartment block in Germany with different site densities and envelope properties.

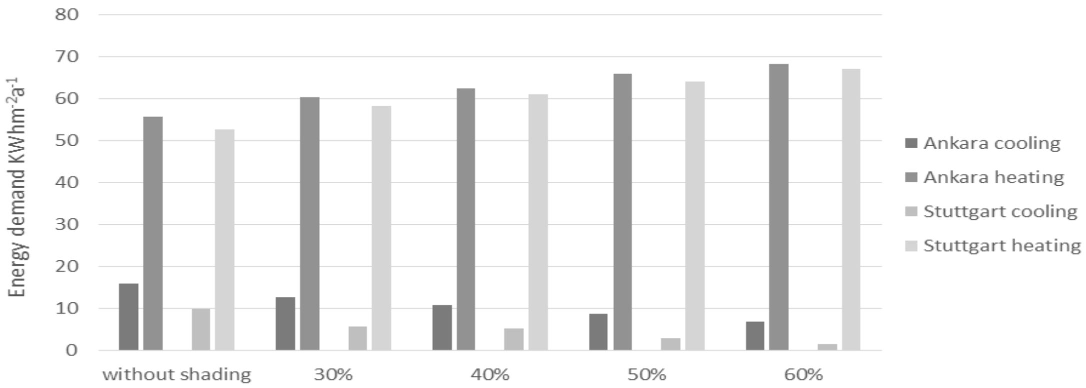


Figure 5 Heating and cooling demands of the ten storey apartment block constructed with current energy standards for Ankara and Stuttgart climatic conditions within different site density.

According to the reference building results, it is not easy to compare the site energy performance. Therefore the site performance of the new and former buildings was evaluated according to the same size urban districts and equal densities. Depending on the building typology chosen, the number of buildings, and therefore the number of housing units and their occupancy will vary. For each building type, the heating and cooling demand of the whole site was simulated at a density of 40% for Stuttgart. These figures are presented **in Table 3.** The average heating demand of ten storeys apartment block for urban transformation project is 60 kWh/m^2 while the average heating demand of one family house is 105 kWh/m^2, row houses' is 98 kWh/m^2 and apartment block with 4 storeys' is 68 kWh/m^2. The urban transformation project can reduce the heating demand up to 43% and it has the similar positive effect on the cooling demand of the site. In Ankara, the average heating demand of ten storeys apartment block for urban transformation project is 58 kWh/m^2 while the average heating demand of one family house is 114 kWh/m^2, row houses' is 105 kWh/m^2 and apartment block with 4 storeys' is 72 kWh/m^2. Reduction on the heating demand by urban transformation project can be 50% and also cooling demand reduction can be seen up to 28%.

In this study, supply scenario an electric heat pump with a COP of 4.0 was chosen as a standard heating system solution, covering 80% of the heat demand, supplemented by a gas condensing burner with 96% efficiency. Cooling was provided by an electric chiller with a COP of 3.0. Also, auxiliary electrical energy for pumping as well as delivery distribution losses of 10% of the heating and cooling demand was added. According to the CO_2 emission factor for natural gas was 0.202 t CO_2/MWh and for electricity 0.539 t CO_2/MWh, per capita CO_2 emissions is calculated. The lowest primary energy demand is ten storey apartment block for urban transformation project but lowest per capita CO_2 is the old apartment blocks.

Table 3. Heating and cooling energy demands of an urban area with 40% site density for different building types

	Number of buildings	Flats	Conditioned floor area/m^2	Total heating energy demand/ MWh	Total cooling energy demand/ MWh	Average primary energy demand (kWh/m2)	CO_2 emission /t CO_2	CO_2 emission per capita/t CO_2 cap−1
One family house	88	88	8800	926	61	115.5	176	0.5
Row houses	21	147	20580	2010	596	107.5	378	0.64
Apartment block	31	372	34720	2353	202	87	494	0.33
Apartment block (urban transformation)	14	560	83342	5034	283	79	1291	0.58

In the urban transformation project to add some renewable energy sources to the site is easier than the implemention to former buildings by reason of orientation, construction conditions, shading and etc. It is possible to add some district heating system for both cities and also this system can be combined with cogeneration plant, geothermal heating or central solar heating system in the urban transformation project. These systems can reduce high amount of carbon emissions and burning fossil fuels. For determining the performance of a PV system for the buildings in Ankara and Stuttgart, it was considered that the whole roof area of the buildings would be used for a free standing PV-installation with a tilt angle of 25°. PV-fields with for this example chosen 44 Sunpower SPR-305-WHT panels each, oriented to South. Each PV field was arranged to 4 strings of 11 PV-panels each which are connected to one inverter. The total collector fields and two inverters with a nominal power of 29.34 kW and a power ratio of 1.18. The average energy yield of the system is 34.2 MWh/a for Stuttgart and 48 MWh/a for Ankara. It is possible the produce 25% -35% of the consumed electricity with these installations.

CONCLUSION

The total energy consumption of the cities is crucially influenced by urban design decisions. This study shows that the site density and physical properties of buildings have significant effects on the site energy performance so this kind of evaluation should be made before the design of refurbishment of old settlements area. It is difficult to make the recommendations for all cities since they have unique characteristic and context but according to building standards and density decisions can provide big key for energy management of the cities. There is notable connection between energy demand and the urban site planning. Definitely instantaneous energy demand of the city is highly affected from the energy usage behavior of citizens and operation of the system but statistic mode of energy consumption may give design criteria for energy management decisions. Hovewer in addition to that, the climatic conditions and the population of the area, building typology and the density should be analysed carefully before the urban transformation projects.Detailed dynamic thermal simulations show that 10-20% heating and cooling demand may be saved by an energy aware site planning.

Beside that, renewable energy applications should be integrated in the urban planning process at the beginning in order to maximise the use so the urban transformation projects also have a big potential for integrating the renewable sources. According to this study, there is a big potential to save more than 30% of the energy used with renewable energy integration. This study covers only project site decision for urban transformation projects but better renewable energy integration can be done with district planning.

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