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Improving Sustainability Concept in Developing Countries

Suitability of Renewable Energy Technologies in the Public Realm

Analytical Framework

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Abstract

Renewable Energy Technologies (RETs) are considered as one of the main solutions for energy efficiency in face of the climate change issue. Urban areas should contribute to the reduction in consumption of non-renewable energy sources by emphasizing on energy efficient solutions, which can play a vital role in the field of urban design and the nature of the public realm in cities, communities and neighbourhoods.
This paper is concerned with the installation of RETs in the public realm. It aims to analyse the potentiality of installing RETs within the public spaces in addition to its effects and limitations. The paper sheds light on the physical aspects of the public realm, types of RETs and presents a framework identifying the RETs suitability to be used in the public spaces.

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Keywords: Climate change; Renewable energy; RETs; Public realm; Physical aspects.

1. Introduction

Climate change is certainly one of the greatest environmental threats the world is facing. Since the 1800s, scientists have realized the significant change in the earth temperature. The 1970s witnessed the beginning of the period of atmospheric warming known as "global warming" (1) [2]. 1992 witnesses the Earth Summit in Rio de Janeiro where Governments agree on the UN Framework Convention on Climate Change (UNFCCC), which commits them to preventing 'dangerous climate change'. In 2010:

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international climate policy picks up a push at the well-organized 16th Conference of the Parties in Cancun, Mexico which set a number of policies and strategies to reduce CO2 emissions [1].

The main problem in the case of climate change is an energy system based on fossil fuels that is no longer efficient and is mainly responsible for the rise in CO2 emissions [3]. However, renewable energy provides one of the leading solutions to the climate change issue. By providing a low CO2 emissions source of power, heat, cooling and transport fuels, renewable energy options such as wind, solar, biomass, hydro, wave and tidal energy offer a safe transition to a low emissions impact (Bank, 2011). Nowadays, many countries have considered a climate change program, including responsibility sharing of CO2 emissions reductions and renewable energy targets. Such energy offers safe, reliable and increasingly cost effective alternatives for all the energy needs- mainly heating, cooling, electricity and motive power for transport [3].

Urban areas contribute to the consumption of energy due to industrialization and urbanization activities. Yet, by considering energy-efficient solutions, urban areas can play a vital role in reducing per capita consumption through changes in the physical configuration of space. These solutions should consider the urban forms and patterns that revolve around the public spaces, because it involves and affects the city and its citizens. Renewable Energy Technologies (RETs) are considered as one of these solutions for energy generation.

The objective of this paper is to install the RETs in the public realm to make the space more energy efficient. Therefore, the paper aims to analyze the potentiality of installing RETs within the public spaces as well as its effect and limitations.

To achieve this aim the following methodology is adopted; first a definition of the public realm physical aspects, identifying its main criteria forming the initial axis of the framework (part A). Secondly, a definition of RETs and their classification, identifying different types used across the literature forming the horizontal axis of the framework (Part B). Finally, through a discussion of the required inputs and outputs of RETs, a refined framework is reached that consists of the physical aspects and the suitable RETs in the public realm.

2. **The Public Realm and Its Physical Aspects**

Public realm is defined as space that is shared communally by the public. As successful public spaces respond to societal changes, they encourage human growth and contribute to the survival of a culture. They are usually situated in a central location often near main circulation paths or the crossing of such routes and are well used by pedestrians [4]. Public spaces include parks, plazas, pedestrian pathways, streets, streetscape and building interfaces. The main three elements that influence the public realm are: the buildings that enclose and define the space, the space itself and the people that inhabit the public realm and the way they use the space [5]. Those elements indicate the integration between the physical and social aspects of the public realm [6].

Notwithstanding the social aspects of public realm, the research focuses on physical interventions to the public realm in so far as they pertain to the implementation of RETs. Hence, physical aspects can be defined through three main elements: the Enclosure (the space itself), Enclosing elements (defining the space), and elements within enclosure (enhancing the use of space).

2.1 Enclosure

Enclosure measures the degree to which streets and other public spaces are visually defined by buildings, walls, trees, and other vertical elements. Spaces where the height of vertical elements is proportionally related to the width of the space between them have a proper quality [7]. A cross-sectional design ratio of approximately one height to two width, or less, creates a proper scaled image along the street

[8]. Enclosure is formed by lining the street or plaza with unbroken building fronts of approximately equal height. The buildings become the walls of the outdoor room, the street and sidewalks become the floor, and if the buildings are approximately equal height, the sky line looks like an invisible ceiling [9]. Figure (1), shows the difference between a well-enclosed street and a poorly enclosed one. A pedestrian on the well-enclosed street is reached by a continuous row of pedestrian-scale storefronts, while a pedestrian on the poorly enclosed street is met by an excess of empty space, mostly parking lots, and is lacked by the vast distances between interesting elements [8].

Defining the space within the enclosure can be fulfilled by building mass, street trees, visual termination points and street network. Street trees can define the space both horizontally and vertically. Horizontally, by visually enclosing or completing an area of open space. Vertically, by creating an airy ceiling of branches and leaves. Rows of trees on both sides of a street can humanize the height–to-width proportions [10].

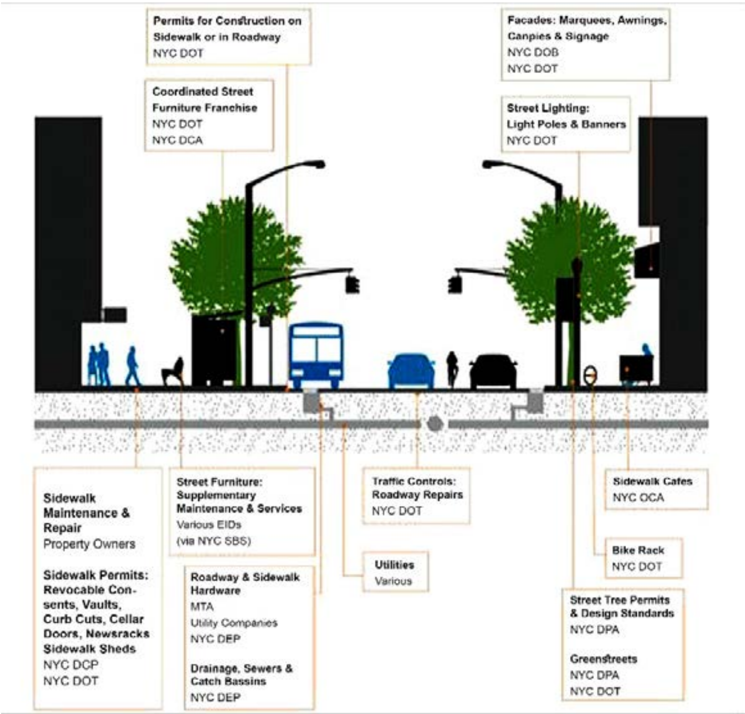

Figure :(1) Enclosure Types, Source: (Jaskiewicz, 2000)

2.2 Enclosing Elements

Enclosing elements are the way the surfaces a) form the horizontal planes of the public realm, b) form vertical and inclined planes that bound the place, and c) are penetrated by entrances or ports, largely defines the overall visual potential of particular places and links (Lang, 1994). They consist of specific materials of specific colors and other qualities, such as degree of opacity, hardness and durability. Natural elements can be used to define the limitations of behavior settings as much as artificial elements. Trees, hedges, and even air movement can be space enclosing elements as much as walls [11].

2.3 Elements within Enclosure

Outdoor open spaces for varying functions such as sidewalks, pedestrian ways, bikeways, bridges, plazas , nodes, squares, transportation hubs, gateways, parks, water fronts, natural features, view corridors, landmarks and building interfaces and articulations are considered as the public realm enclosing elements. With their multi-potential functions, they could make high quality public places which are vital for creating pleasant, socially inclusive communities (Lim, 2001). Figure (2) shows the main elements within a street section which are:

- Streetscape.
- Surfacing.
- Landscape.

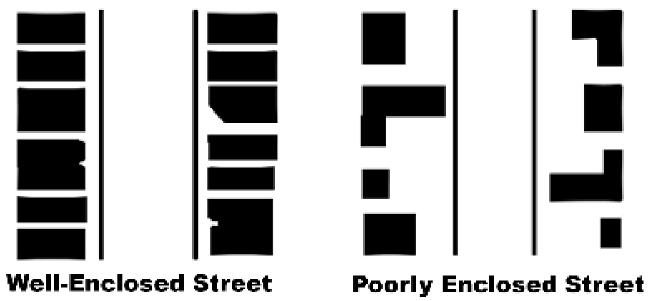

Figure (2) Enclosing elements & elements within the enclosure in the street section
source: (http://www.planetizen.com/node/39815)

3. RETs Classification and Types

Renewable Energy (RE) is a term for any useable energy that is harnessed from natural resources that is either basically unlimited (such as sunlight, or thermal energy generated and stored in the Earth) or naturally replaced in a suitable manner on a human timescale (such as energy derived from wood). A commonly cited definition is that provided by the International Energy Agency (IEA 2008): “Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly or indirectly from the sun, or from heat generated deep within the earth. Included in the definition is energy generated from solar, wind, biomass, geothermal, hydropower and ocean resources, and biofuels and hydrogen derived from renewable resources”. This definition is used by the United Nations Environment Program [12].

3.1 RETs Classification:

While there is no single agreed on categorization to classify the RETs, in reference to several authors a general classification can be based on the following technologies:

RETs that harness the RE sources which are: Thermal energy technology, Kinetic/mechanical Energy technology, chemical energy technology and electrical energy technology. This classification is based on the primary technique of extracting the energy from renewable source e.g. solar energy thermal power plant, solar heaters, geothermal power plant, Ocean thermal energy. Another example is kinetic energy: wind turbine, hydro-turbine, footsteps tiles ... etc. [12]. Regarding to the scope of this research in studying the impact of the RETs implementation within the public realm, thermal energy technology, kinetic energy technology and electrical energy technology will be three considered in classifying the RETs used. Chemical energy is not included within this classification because of its specialties in intertwined with chemistry and environmental studies which concerns more with burners and chemical engines of all kinds, grates and incinerators along with their energy efficiency, pollution and operational safety [13]. This kind of energy has less relevance in studying the impact of applying the RETs within the public realm. The systems mentioned below under each technology have been selected according to the potential of their implementation in an urban area in its wider capacity and scale.

Thermal energy technology:

- Solar water heating system.
- Roads energy system.

Kinetic/ Mechanical energy technology:

- Grid connected wind turbines.
- Stand alone wind turbines.
- Footsteps energy.

Electrical energy technology:

- Building integrated PV.
- PV lighting.

The framework which follows (Table 1) will include all the physical aspects in the public realm (Part A) and the RETs different systems that can be implemented in an urban area (Part B). RETs will be further analyzed in the next section in accordance to their suitability to the public realm in particular in order to reach the refined framework (Table 2) which will include the suitable RETs as they match the physical aspects of the public realm.

Table 1Physical aspects and RETs (Part A & Part B)

Public Realm Aspects Part A				Renewable Energy Technology Part B						
				Thermal Energy Technology		Kinetic Energy Technology			Electrical Energy Technology	
				Solar water heating	Roads energy system	Grid-connected wind turbines	Stand-alone wind turbines	Footsteps energy	BIPV	PV Lighting
Physical Aspects	A) Enclosure	1) Scale/ratio	Building Mass							
			Street trees							
			Visual terminate points							
			Street network							
	B) Enclosing Elements	1) Formatting the surface	Horizontal planes							
			Vertical & Inclined							
			Penetrated by entrances							
	C) Elements within enclosure	Streetspace								
		Surfacing								
		Landscape								

4. RETs Suitability to the Public Realm

Any system interacts with the environment by means of input and output. Input, is what enters the system from outside, and output, is what leaves the system to the environment [14] [15]. In order to analyze the RETs different systems, inputs and outputs shall be determined.

The inputs that will be considered in this section are the constraints that will affect the system installation which are: the technology installation tools and the public space installation land requirement whether it relates to the enclosure that forms the space, or the enclosing elements forming the surface or elements within enclosure that details the space and the surface. However, the output will be the end uses for each system and the energy produced. By analyzing each system according to its input and output, there will be a better understanding for each technology usage whether it has the potential to be deployed/utilized/installed within the public realm or not.

Determination of the inputs and outputs will assist in choosing the suitable RETs. Moreover, the choice of RET depends on the balance of the energy demand, the opportunity to install on site and the existing supply network in the site. The criteria to choose will be included within the following points and the technical conclusion at the end of this chapter will further explain these points in terms of the RETs mentioned below [16]:

- Determine the current mix of energy used, electricity, heating or cooling or a mixture of both.
- Determine whether the energy demand is constant or fluctuate between day and night and between seasons.
- Determine the intermittent nature of certain technologies.
- Is grid reinforcement needed to transfer power in and out the site?

4.1 Thermal energy technology:
Solar water heating

The principle of the solar water heating system is to heat water, usually in a special collector and store it in a tank until required.

The inputs for this system in the technology installation tools are the Collectors that are designed to collect the heat in the most efficient way, usually into a heat transfer fluid, which then transfers its heat to the water in the storage tank. The two main types of collector are: flat plate and evacuated tube. The cheapest technology available and the simplest to install is a thermosiphon system, which uses the natural tendency of heated water to rise and cooler water to fall to perform the heat collection task. As the sun shines on the collector, water inside the collector flow-tubes is heated. As it heats, this water expands slightly and becomes lighter than the cold water in the solar storage tank mounted above the collector. Gravity then pulls the heavier, cold water down from the tank and into the collector inlet. The cold water pushes the heated water through the collector outlet and into the top of the tank, thus heating the water in the tank. An example of a thermosiphon system is shown in figure (3). The other input of this system is fundamental requirement of land for a solar system is to have a sunny location where solar collectors can function properly. Locations were the sun is blocked from the collectors by the slope or aspect of the land, trees, neighboring buildings, or other obstructions will reduce efficiency. Solar collectors need to be placed where plenty of sunshine strikes the surface of the collectors, year round [12].

The outputs are the uses and the energy produced which is shown in this example, to heat 100 liters of water through a temperature rise of 40o C with a simple flat plate solar collector requires only approximately 2.5 m2 of collector area but saves approx. 10 kg of wood fuel that would normally be required to heat this quantity of water [17].

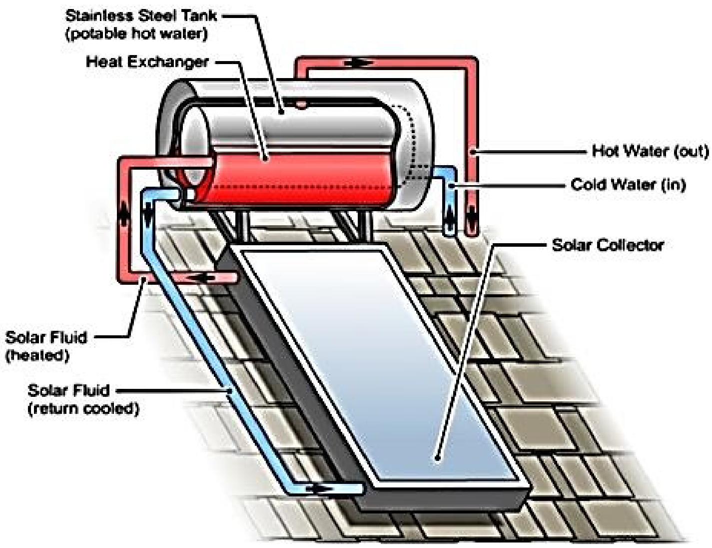

Figure: (3) , Source:(http://solarsystemindonesia.com/)

Generation and saving of energy via asphalt pavement surface

The technology uses the principle that at a certain underground level, the ground has the ability to store thermal energy for a substantial period of time. The inputs: technological inputs can be explained by

During the warm season, water from the cold store at around 7-10°C is passed through a heat exchanger providing direct cooling water to the building. The heat pump is available automatically as support in periods of peak demand. The warm store circuit water will pick up energy from the building and thus be raised in temperature to around 18-20°C (or higher for fresh air load). This water, the temperature of which is higher than the natural groundwater temperature, will be run to an underground „warm energy" store. The heat stored in the warm energy store is used for heating during the winter. Water from the store at around 20°C is passed through a heat exchanger and connected into a heat pump, which in turn provides water around 40-50°C for use in building heating. While the groundwater passes through the heat pump it cools to around 7°C. The cooled water is run to the underground „cold energy" store. The cold stored in the „cold energy" store is used for cooling, completing the annual cycle Any excess heat or cold in the system over a year is balanced using an external heat exchanger. In parallel, the road is the second major benefit, because with the movement of water through it for different seasons, it can avoid excessive temperatures [19] figure (4).. Land requirement: There is a certain classification of streets according to different levels of emphasis on motor vehicle movement versus direct access to property [20], this technology has been used in Belgium in a neighborhood street level and has a wide range of applications. In particular, it is suitable for large scale and mixed-use developments. Its benefits can also be used in commercial buildings, office buildings, and large residential estates, campus sites in educational or health sectors and for industrial cooling. The outputs: The main beneficiary uses of the this technology are buildings, houses or residencies that these will win an energy supplement as well as the streets that will be cooled therefore the outdoor environment will be better for the people who are using it [20].

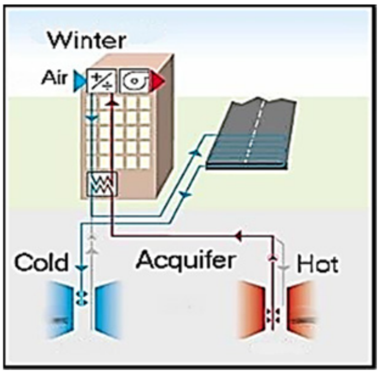

Figure (4), Source: (Pau Blaya, 2011)

4.2 Kinetic energy:
Wind turbines generating electricity

Several turbine types exist but presently the most common configuration has become the horizontal axis three bladed turbine (as shown in figure (5).

The inputs: technological inputs, The rotor may be positioned up or downwind (although the former is probably the most common). Land requirements depend on the wind turbine itself which varies in size with two market ranges: small units used mainly for rural and stand-alone power systems; and large units, from used for large-scale, grid-connected systems.

The outputs: energy produced the small units rated at just a few hundred watts up to 50-80 kW in capacity and large units, from 150 kW up to 5 MW in capacity.

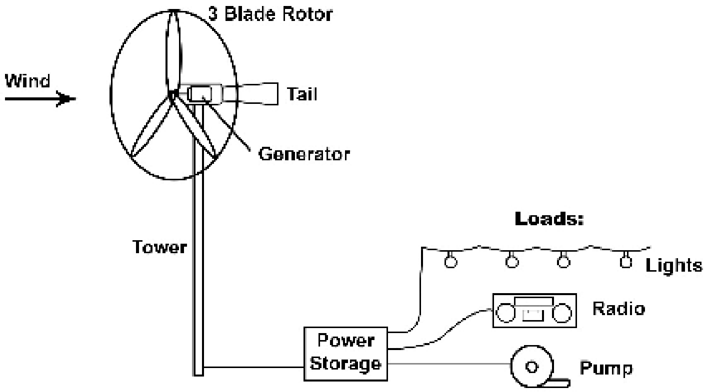

Figure: (5), Source: (http://www.intechopen.com/books/advances-in-wind-power/low-speed-wind-turbine-design)

Grid-connected wind turbines

Grid-connected wind turbines are certainly having a considerable impact in developed countries and in some developing countries, namely Argentina, China and India.

The inputs: same technological inputs like the previous system but different in land requirement. Mainly large-scale installations either on land (on-shore) or in the sea on the continental shelf (off-shore). Coastal locations, and flat rural areas without significant vegetation or buildings, offer the most laminar wind flow. Small wind systems should generally be installed only in these areas. Significant turbulence is caused by terrain such as steep hills and cliffs as well as ground clutter such as trees and nearby buildings or structures. Urban areas have a poor wind resource that is usually extremely turbulent. In addition, in developed countries, more smaller machines are now being grid-connected [21] figure (6) shows the contents of the grid- connected wind turbines.

The outputs: this system can be used in developing countries to contribute to a more decentralized grid network and/or to support a weak grid. Wind turbines do, however, generate electricity irregularly in correlation to the underlying variation of the wind. The energy comes from wind turbines do not produce power constantly and at their rated power (which is only achieved at higher wind speeds) capacity factors (i.e. actual annual energy output divided by the theoretical maximum output) are typically between 20 per cent to 30 per cent [22].

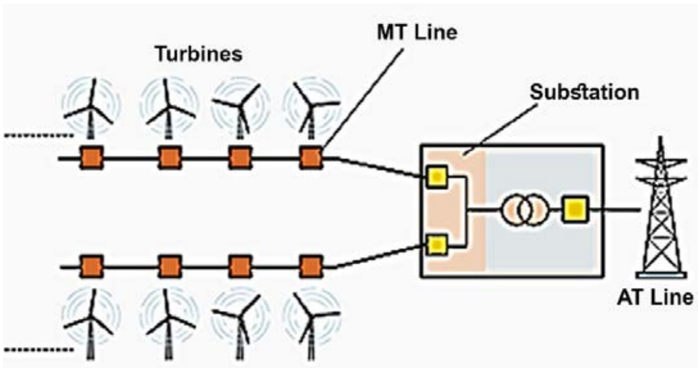

Figure: (6)
Source :(http://electrical-engineering-portal.com/download-center/books-and-guides/power-substations/wind-power-plants)

Stand-alone wind turbines

The inputs: technological inputs, the most common type of stand-alone small wind electric system involves the use of a wind generator to maintain an adequate level of charge in an electrical storage battery figure (7). The battery in turn can provide electricity on demand for electrical applications such as lights, radios, refrigeration, telecommunications, etc., irrespective of whether or not the wind is blowing. A controller is also used to ensure that the batteries are not damaged by overcharging (when extra energy is degenerate through a hole load) or excessive discharge, usually by sensing low voltage. Loads connected to the battery can either be DC or AC (via an inverter) [22]. Larger stand-alone systems, incorporating larger wind electricity generators and correspondingly larger battery banks (at an increased cost) are also available, these may include other renewable energy technologies, such as PV, as well as diesel generators to ensure that the batteries are always charged and that power availability is high. Less common is the stand-alone system which does not incorporate a battery back. This involves the use of a wind turbine with, at least, a diesel generator, which will automatically supply power when required. This has the advantage of not requiring a battery bank but the required control systems are complex. Land requirement, as a basic guide, areas on the coast or hills on exposed rural land have better wind resource, and areas in urban or heavily vegetated land, away from the coast, have less wind.

The outputs: Standalone systems are commonly used to power remote houses or remote technical applications, for example, rural telecommunication systems, and mechanical power for pumping water for the purpose of drinking and irrigation. The energy produced wind turbines used for such an applications may vary between a few watts to 50 kW. Thus, wind turbines of up to 300kW can be used for rural or village electrification systems [22].

Figure: (7) Source: (http://solarquip.com.au/off-grid-or-standalone-power-systems/)

Footsteps energy:

The inputs: technological input, when a person walks, he loses energy to the road surface in the form of impact, vibration, sound etc, due to the transfer of his weight on to the road surface, through foot falls on the ground during every step. This energy can be tapped and converted in the usable form such as in electrical form and can be temporarily stored for later use. In order to develop a technique to generate the energy from foot step one can use the pressure sensor. This can convert foot impact energy into electrical form. The working principle is simple. When a pedestrian steps on the top plate of the device, the plate will dip down slightly due to the weight of the pedestrian. The downward movement of the plate results in generation of electrical signal. The top plate reverts back to its original position due to negating springs provided in the device.

Land requirement, it is possible to implement the different device generators at different places where there is a frequent application of the pressure. This condition is fulfil by the places where large group of people wandering or where high frequency of vehicular movement takes place. The most common places for these conditions are roads, shopping malls, footpath, airport runways, railroad tracks, highways etc. Some of these are explained below.

Footpaths

Footpath in a high density spaces is the most common place where this device can be implemented to generate small amount of energy due to motion of the people. Some similar places are inside shopping malls, dance floor, subway, and outside walkways, etc. It has been used efficiently in UK in the Olympic Park. Technological inputs, The concept focuses on the large number of people moving in dense areas to step on tiles embedded in the floor which would use the device to generate electricity that could be saved and used figure (8).

The outputs: energy production, about 3 to 6 watts per step can be converted. Uses, If one consider the average energy generated per rush hour then it is possible to use that energy for powering the low power electronic devices such as display screens [23].

Figure: (8) source: (http://inhabitat.com/energy-generating-pavement/)

4.3 Electrical Energy :
PV lighting :

Photovoltaic (PV) lighting, or PV-powered lighting, is lighting that is at least partly powered by electricity generated from PV panels (often called solar panels) figure (17).

The inputs: technological input, A PV lighting system collects solar energy using one or more PV panels, stores that energy in a battery or series of batteries, and then releases the energy to power light sources at night. Typically, PV lighting system components include PV panels, batteries, electronics (including battery charge controller, inverter or ballast/driver, and timer or switch), light sources (lamps), and luminaires [24].

The outputs: Uses, a popular example of PV lighting is the solar garden or pathway light. Other examples include post-top luminaires and parking lot luminaires carrying a solar panel on top. These PV lighting systems are usually off-grid, or "stand-alone" systems, their only power source is solar energy. PV lighting technologies are intended for nighttime lighting applications [25].

Rooftop and building integrated systems:

The inputs: land requirement, rooftop PV arrays are often associated with buildings: either integrated into them, mounted on them or mounted nearby on the ground. Rooftop PV systems are most often retrofitted into existing buildings, usually mounted on top of the existing roof structure or on the existing walls. Technological input, an array can be located separately from the building but connected by cable to supply power for the building. Provided there is an open gap in which air can circulate, rooftop mounted solar panels can provide a passive cooling effect on buildings during the day and also keep accumulated heat in at night [26] figure (9).

The outputs: energy production, residential rooftop systems have small capacities of around 5–10 kW, while commercial rooftop systems often amount to several hundreds of kilowatts. Although rooftop systems are much smaller than ground-mounted utility-scale power plants, they account for most of the worldwide installed capacity.

Figure (9) Source: (http://inhabitat.com/building-integrated-photovoltaics-market-projected-to-quadruple-to-2-4-billion-by-2017/)
Source: (http://oslasolar.co.nz/pv-system.php)

5. Conclusion:

Assessing the energy mix helps determine which renewable energy technology is suitable for use in any space. For example, some renewables such as wind and photovoltaic, just produce electricity. Others such as solar water heating, just produce heat. Otherwise, the major limitations in using RETs is the intermittent nature of certain technologies. For example, wind turbines will not provide electricity when it is not windy, just as solar electricity cannot generate at night. For this reason, a grid connection is required to provide back up and power storage. Batteries are also sometimes used for storage, although this is less common.

Once appropriate renewable energy technology has been identified, their inputs and outputs shall be undertaken to determine the suitability of the technology in terms of their usage in the public spaces. Starting with the thermal energy production, the solar thermal systems should only be installed on buildings with a sufficient hot water demand to make them economically viable. Generation and savings via asphalt pavement, the main beneficiary uses of the this technology are buildings, houses or residencies that these will win an energy supplement as well as the streets that will be cooled down to help the outdoor environment to be better for the people who are using it.

Regarding the kinetic energy production that achieved by wind, urban areas present challenges for the utilization of wind energy technologies. Buildings, trees and other tall obstructions can badly impact wind direction and speed. The power generation potential of a wind turbine is determined by wind speed and consistency of the wind resource. Wind turbines are generally most effective in remote areas with proven and consistent high wind speeds and smooth airflows, where large turbines can generate significant amounts of electricity. As well as, avoid the visual and noise impact that can pollute the surrounded area. For coastal areas adjacent to urban areas, wind farms are gaining popularity. Foot pressure energy system has another technology that harness the kinetic energy. This energy can be tapped and converted in the usable form such as in electrical form and can be temporarily stored for later use. It is possible to implement the different device generators at different places where there is a frequent application of the pressure. This condition is fulfil by the places where large group of people walking or where high frequency of vehicular movement takes place. The most common places for these conditions are roads, shopping malls, footpath, airport runways, railroad tracks, highways and outdoor open spaces. About the electrical energy, many PV systems are retrofitted to buildings. However, it is becoming increasingly common for PV to be available that is integrated into building materials BIPV (for example roofing). PV arrays are connected into the building electrical system via an inverter. The visual impact of the system against the surrounding environment and the circumstances resulting in a broken roofscape- where the PV panels break the skyline are another criteria affect the PV panels installation. Sola PV lighting can work perfectly within the public spaces whenever the enclosure is a non-enclosed area which will permit great chance for unshaded areas.

According to the previous conclusion, the RETs suitability to the public realm usage framework (Table 2) concludes five out of seven systems of the RETs that have the potential to be utilized and influence the spaces of the public realm. These systems have different technology installation tools, energy production, land requirements and uses. The efficiency of the energy produced by these seven systems depends mostly on the tools that install the system and the location where it has been installed. Although, these systems have different public land requirement regarding to their usage and their installation place for example it can be used as Visual terminate points in defining the space, or mounted on the building itself, or it can be used as street furniture and other can be used as a landscape feature, but all of them can be installed within the public space. This refined framework can be applied in further studies on any example in order to check its validity or enhance it further more. After going through the examples the physical aspects can be narrowed down in terms of the relevance into the RETs and a more comprehensive framework can be achieved.

Table (2) RETs suitability to the public realm usage framework

Public Realm Aspects Part A				Renewable Energy Technology Part B						
				Thermal Energy Technology		Kinetic Energy Technology			Electrical Energy Technology	
				Solar water heating	Roads energy system	Grid-connected wind turbines	Stand-alone wind turbines	Footsteps energy	BIPV	PV Lighting
Physical Aspects	A) Enclosure	1) Scale/ratio	Building Mass							
			Street trees							
			Visual terminate points							
			Street network		✓					
	B) Enclosing Elements	1) Formatting the surface	Horizontal planes						✓	
			Vertical & Inclined							
			Penetrated by entrances							
	C) Elements within enclosure		Streetspace				✓			✓
			Surfacing					✓		
			Landscape							

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