SMART ENERGY APPLICATIONS AND INTEGRATION OF URBAN FURNITURE INTO SMART SYSTEMS IN CITIES

SUZAN NEŞE MURADOĞLU & DENİZ DENİZ
Izmir University of Economics, Faculty of Fine Arts and Design, Izmir, Turkey.

ABSTRACT

Smart cities aim to adapt the living conditions in the best way by using human and technology factors, which are among their basic components. At this point, the components of smart cities show some changes according to the economic, social and cultural values of the countries, and the investments made in these components reveal new city versions. Improving sustainable design thinking and social innovation requires collaborative studies via policy-making process and related applications. Local governments, designers and stakeholders need to focus on how to create a new way of thinking for smart and sustainable solutions for cities. This study presents an environmentally sensitive design proposal that uses smart energy technologies for integrating renewable energy alternatives into smart lighting system for promoting circular economy and increasing sustainability in public areas. Using renewable energy technologies not only adds value to the identity of these cities but also increases public awareness among users. For this purpose, a smart lighting design that generates electrical energy with kinetic flooring is designed and presented for usage in Çorlu Cumhuriyet Park. Çorlu has a strategic location and investment targets. It also has a high potential to become a smart city that can stand out on smart energy in Turkey, which is supported by the Covenant of Mayors for Climate & Energy Agreement signed in 2019. The designed smart lighting aims to integrate renewable energy into city furniture and increase environmental awareness by presenting citizens' instant contribution to the renewable energy production in their daily activity.

Keywords: design, renewable energy, smart cities, sustainability, urban furniture.

1 INTRODUCTION

Cities behave like living organisms for their residents, and the concept of 'Smartness', which has developed over time with technology, can be seen in many reflections throughout many fields. Smartness is applied in different dimensions in cities, corresponding to the concepts of improvement and restructuring. What makes one smart city different from another is the percentage of investments made on these dimensions. Investments in renewable energy have brought the needs of consumers to the forefront in line with more current demands in recent years. Information and communications technology (ICT), Internet of Things (IoT) and smart grids are also adapted to be used, and have taken their place in the chain of awareness and information collection for years. Although these smart systems are widely used in some cities, they do not always guarantee success. Target-oriented cities may lack efficiency in the long run, leading to the missing of social goals. Therefore, the integration of smart systems should go through the evaluation of human and technological dimensions that complement each other. The importance of social/cultural criteria in urban growth is achieved by a sense of place and use of space. The fact that renewable energy sources (RES) are now shown as the lowest-cost source of energy production technology and do not emit air pollutants or are low-emitting makes them a great choice proposal for climate and health, making them more attractive for its integration into the environment. Cities have the potential to actively fight against climate change at the national and global levels. Yet, sustainability has a wide spectrum and is not an issue that municipalities can address by themselves. Thus, to support the use of renewable energy resources in public areas as well as smart parks is crucial.

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The aim of this study is to encourage cities in Turkey to adopt smart energy initiatives and present a prominent proposal to develop a city into a smart city. Smart city initiatives in Turkey have not yet come to the fore with examples that have reached the desired maturity. Local cities should take their place in the competitive market effectively with the smart cities 2.0 versions and the industry 5.0 foresight. To undertake this task, Çorlu has a high potential with its strategic importance due to its location and stands out with its industry. It is also expected that the types of energy used in the city aim to be regulated in line with the Covenant of Mayors for Climate & Energy Europe agreement signed by the mayor of Çorlu in 2019. In this respect, a smart lighting system was designed for the Republic Park to increase environmental awareness of individuals by the proposed design. With this aim, a smart lighting system working with piezoelectric floor tiles, which can generate electricity from human movement, was designed to encourage citizens to partake in physical activity and to gain awareness about renewable electricity generation. The design proposal also aims to bring the human factor to the forefront and ensure that the user-oriented approach forms the central theme of the plan to be an implemented kinetic energy system.

1.1 Definitions and core components of smart cities

Although the concept of the smart city emerged in the 1990s, 'Smartness' is used in a wide variety of meanings and different interpretations, as well as projects and these visions are associated with the term smart city. Smart cities represent a conceptual model of urban development based on human, collective and technological capital to develop urban growth, which has become a wider term and brings a sustainable, greener city and increased quality of life. Being a smart city means using resources and technologies in innovative and more efficient way to develop liveable and sustainable cities and economies. By becoming more energy-efficient, cities are critical proving grounds for utilising sustainable and low carbon economies. Local governments and city planners need to re-evaluate their urban planning designs to enable growth in cities to sustainability obligations.

Smart cities are based on understanding producer and consumer behaviour to use technology for innovation and human capital development to solve problems. Smart environment addresses the efficiency and sustainability aspects of urban life, such as efficient energy use and intensive energy consumption strategies [1]. Smart living improves the quality of life by transforming the home, workplace, transportation and energy infrastructure into smart environments. Cities have different social, economic, environmental and technological infrastructures, whereby they need to find their technical and digital capabilities in the urban context to build this infrastructure to adapt complex urban scenarios. They should also provide transparency in democracy and allow citizens to participate in decision-making processes since planning smart solutions on a city scale with citizen participation accelerates activities and increases quality efficiency [2].

A large percentage of the population in developed countries lives in cities and the problems of meeting the needs of the growing population and the adequacy of energy resources have led cities to find more rational solutions. Cities rely on external resources for their resident consumers. As one of the more current interpretations of urban sustainability, a more people-centred approach is promoted, where cities must respond to people's needs with sustainable solutions for social and economic spaces. The criteria for a smart city depend on the investment in energy production matching the potential of energy use. In energy production, renewable energy consumption plays a crucial role. This situation offers a mutual gain

in two ways: by reducing global warming with the reduction of pollution generated within the country in the production of energy, and by generating affordable and sustainable energy for use in the formation of smart cities [3]. The energy identity of countries is evaluated through the economic growth of energy where there is a direct correlation between economic growth and higher energy demand due to the growing population, which causes higher economic growth [4].

This positioning goes through scenarios that countries or local communities create to prepare themselves for the future. To create broader and long-term sustainable development projects in renewable energy solutions, local governments need to break down their internal barriers with many areas such as urban planning, energy, transportation and waste management. Today, many cities and local communities have been involved in designing strategies to transform the energy supply into a renewable energy system in the future by anticipating the energy supply of their regions. Within these strategies, policies supporting a wide range of clean energy-related technologies have been adopted, including renewable energy, as well as energy flexibility. In this respect, there has been a concerted effort to define and plan for smart cities in Turkey since 2000; various municipal, government and private organisations have come together to define and draw legislations for cities. According to the World Energy Council's report, Turkey's national renewable energy action plan is setting out strategies to encourage the development of new renewable energy with the long-term objectives like contributing to technological and industrial development by reaching and using higher renewable energy in cities [5]. With all the preparations with the renewable energy policies, Turkey seeks to achieve specific goals that include reducing energy dependence by increasing electricity production from RES in Turkey.

1.2 Integration of urban furniture into smart systems in cities

Societies have been reminded that natural resources are limited and are a critical component of the system that supports the human condition. In this case, public spaces such as parks and public squares are elements that create a sense of community. Well-designed public spaces have a potential to attract more users and a wide range of activities from poor-quality areas that tend to be used for essential activities [6]. Public spaces have remarkable potential to facilitate increased diversity of functions, activities and social needs in cities. Therefore, the characteristics of the built environment and recreational facilities can be associated with social adaptation. Particularly, the level of participation in the green space may vary depending on the qualities and intended use of the green space. Due to their meaning and role, public outdoor spaces affect the city's quality and identity, which varies depending on the level of design and details [7]. Structural elements, one of the main elements that make up the identity of cities, are shaped according to social and cultural features and natural factors. Products created for and adding meaning to the spaces are as important as the natural three-dimensional perceptual environment. Urban furniture is an indispensable element of life as it comprises units that meet individuals' functional and aesthetic needs by making the space liveable and meaningful; this is created in the design process of urban reinforcement elements and reflects the identity of cities, their harmony with the architectural structure, and their imaginary features [8].

Integrating renewable energy into urban areas prevents resource depletion by preventing environmental degradation and providing energy efficiency [9]. Providing parks improvement determines the positive environmental impacts on global climate change and energy efficiency measures, thus, sources of renewable energy are important choices for the sus-

tainable development policies, which must consider these criteria to integrate renewable energy into urban areas. One of the goals of urban parks and public spaces with the use of clean and renewable energy is to install many renewable energy equipment in the park to generate renewable energy and make it a sustainable energy exhibition for future generations [10]. Smart parks should support new approaches of smart technologies in their design and during their life cycle. On behalf of these technologies, environmentally friendly and cost-reducing solutions can be offered, which can be used to maintain and improve parks by conserving energy and water resources. Smart parks, broad information sharing and high levels of connectivity can ensure human well-being by reducing costs, generating new revenue streams, improving environmental control and enhancing the visitor experience. Smart Environment, one of the fundamental dimensions of the Smart Park, aims to create a healthy and sustainable environment by reducing human impact on the environment [11]. Parks consume energy mostly for lighting and air conditioning, so parks are good places to deploy energy-efficient technologies. Therefore, energy use is an essential issue in smart parks [12].

In this case, it is crucial for 'Smart Parks' to use strategies that conserve energy resources and enable the production of clean energy. Energy savings can be achieved if they can reduce the air conditioning of park structures and surrounding areas by using green spaces for cooling and providing shaded areas for visitors. Solar panels and other renewable energy technologies can be easily integrated into open spaces in city parks and community buildings, reducing emissions by providing clean energy. Clean energy or energy-efficient technologies in parks can also be used as a tool to educate public visitors and increase their awareness about sustainability, climate change and clean energy. As cities combat climate change, public spaces are crucial places to reduce energy consumption and generate renewable energy.

2 MATERIALS AND METHODS

In addition to the literature review, Çorlu Republic Park was analysed through a systematic observation method and the amount of equipment in the park was determined and photographed. Besides, the mayor of Çorlu was interviewed, and the Covenant of Mayors for Climate & Energy Europe agreement was reached. The current plan and layout of the Republic Park were obtained by interviewing the Çorlu Parks and Gardens directorate, and the diversity of the lighting systems used in the park was determined. Trakya Development Agency reports were accessed by meeting with Çorlu Chamber of Industry officials, as well. Information was collected for the analysis of the field study by communicating with the relevant authorities.

As stated above, Çorlu Republic Park was selected for the conceptual application and design proposal. To do that, the potentials of renewable energy technologies and their possible integration in the urban furniture were assessed. At the conceptual design phase of the study, basic design requirements of the urban furniture were evaluated according to renewable energy potentials and the levels of the inclusion of smart systems are described in Fig. 1.

Although technological improvement is not the only way to solve problems in cities for sustainable future, using alternative and green energy supplies – especially for industrial cities like Çorlu – is crucial. This will not only help to meet the increasing energy consumption need, but also raise the awareness and cooperation of citizens for sustainable development. In this respect, one of the main purposes of smart lighting designed for Çorlu Cumhuriyet Park is to use the energy need arising from the city's density by converting citizens' movements such as walking, running, jumping and cycling into the city electrical

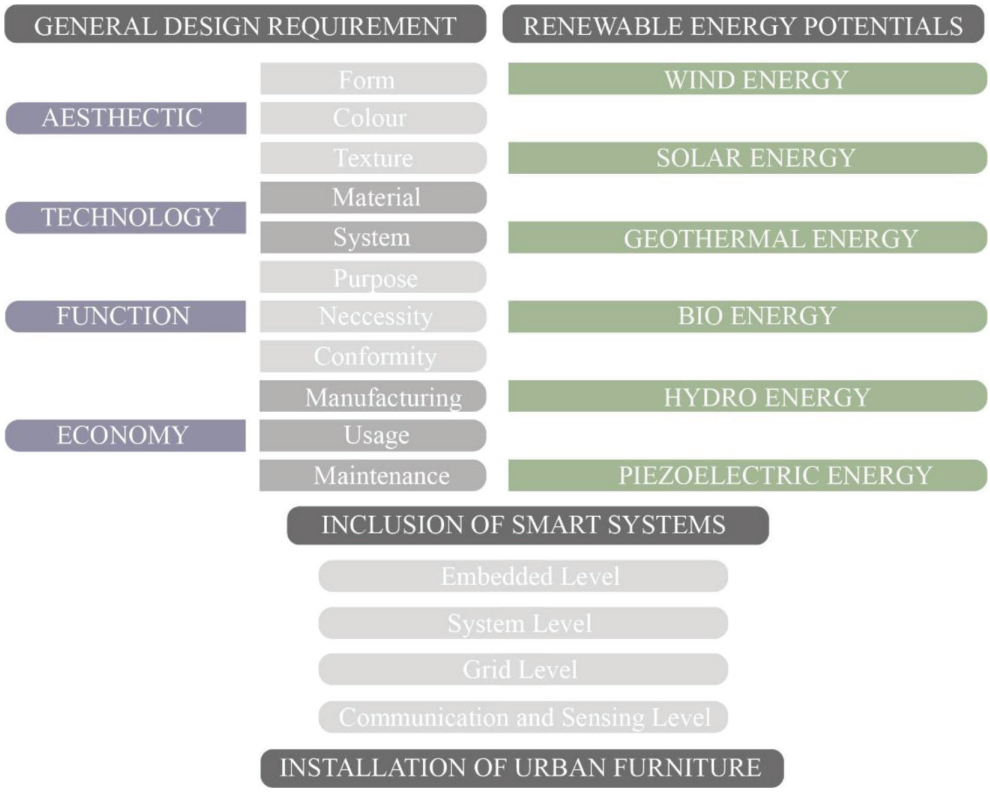

Figure 1: Stages of smart systems in the application of renewable energy sources for urban furniture.

energy in the public green areas. Another aim is to increase the citizens' environmental awareness, contribute to renewables and encourage action. Consciousness has been created to serve this purpose by the energy obtained by the piezoelectric floor tiles covering and the charging indicator on the lighting pole. The information collected by sensors and cameras is used for needs such as field analysis and information gathering. It is designed to determine the capacity of the IoT node and other smart lightings to provide energy efficiency and energy savings. BAILIFF is urban furniture that can be used as a support for common ones apart from being high-tech smart lighting. It is suitable for industrial cities with a high potential to become smart cities, such as Çorlu, and can be applied in different areas with its modular structure.

3 CASE STUDY: USING RENEWABLE ENERGY FOR DEVELOPING SUSTAINABLE CITY FURNITURE, ÇORLU REPUBLIC PARK

3.1 Definition of the case area

Çorlu has a strategic central location, being just far enough from Istanbul on the main corridor to Europe (Fig. 2). Being blessed with a mild climate and usable lands gave it a leg up in being the hub for the region [13]. Over the last 50 years, its population has grown

Figure 2: Location of Çorlu in Turkey (Source: Çorlu Belediyesi, 2017).

fivefold. It has a large industrial base because its location is ideally located for servicing and a distribution centre for Istanbul and its hinterland. Çorlu hosts a total of 629 factories and 1 free zone [14], and expectations are that the city's population will reach one million over the next 30 years. Within the next 50 years, the outer suburb of Istanbul is expected to merge with Çorlu.

Çorlu is the largest settlement centre in Thrace after Istanbul. It is the most developed district of Tekirdağ with its strong transportation connections and strategic importance. It is a large industrial centre with the potential to accommodate more industries and is a candidate for further development. This led to the construction of new residences, regular urbanisation and the continuation of physical and social infrastructure development. In 2019, the mayor of Çorlu signed the Covenant of Mayors for Climate & Energy to create a sustainable energy and climate action plan. Within this contract, the conditions for increasing the resilience to minimise the effects of climate change, achieve more use of RES and achieve improved energy efficiency to reduce carbon emissions by at least 40% by 2030 [15].

Çorlu Cumhuriyet Park was opened in 2012 and was built on an area of 162,518.12 m^2. This area comprises a running and cycling path, children's playgrounds and flower beds of 1,843.44 m^2; a grass area of 92,104.68 m^2; a pond of 882 m^2; six rectangular fountain pools, one circular pool, concert area and backstage building, three tennis courts and three grandstands, two basketball courts, picnic area, walkways, a summer cinema with 280 seats and a car park for 410 vehicles [16]. Examples of lighting poles and other urban furniture in Çorlu Republic Park is presented in Figs. 3 and 4, respectively.

3.2 Smart lighting system – product proposal

The smart lighting system designed for Çorlu Republic Park was designed to be placed at 30-m intervals on the approximately 1500-m walking path. BAILIFF and BAILIFF 2.0 are two different versions of smart lighting (Fig. 5). BAILIFF 2.0 is powered by energy derived

Figure 3: Examples of lighting poles in Çorlu Republic Park.

Figure 4: Examples of urban furniture in Çorlu Republic Park.

from human movement on piezoelectric floor tiles. According to the energy capacity of its battery, the tile transmits electrical energy to BAILIFF and another to BAILIFF 2.0. These two versions and the kinetic tile are designed to increase people's environmental awareness and encourage action.

BAILIFF is a smart lighting system with all its equipment. Air quality measurement is made with the air sensor. The camera monitors 360-degree human movement. The IoT node uses both versions of BAILIFF to analyse information gathered from energy use, savings, transmission and all other sensor-oriented technologies. BAILIFF is the semi-smart version of smart lighting. It is a supporting product for actual smart lighting. It is illuminated by the electrical energy obtained by BAILIFF 2.0 (Fig. 6). Since the equipment is modular, accessories such as camera and USB input can be added according to the place and purpose.

Piezoelectric floor tiles can also be used in the entrance/exit of the park or the children's playground. It is used along the walking path is preferred because it ensures that the citizens who use the walking path create the enthusiasm to take the walking path second tour as they contribute energy. With the microphone and loudspeaker, communication is provided with the citizens in emergencies. With the motion sensor, energy savings are made in cases where the night citizen factor is low. The charge indicator shows the capacity of the electric energy

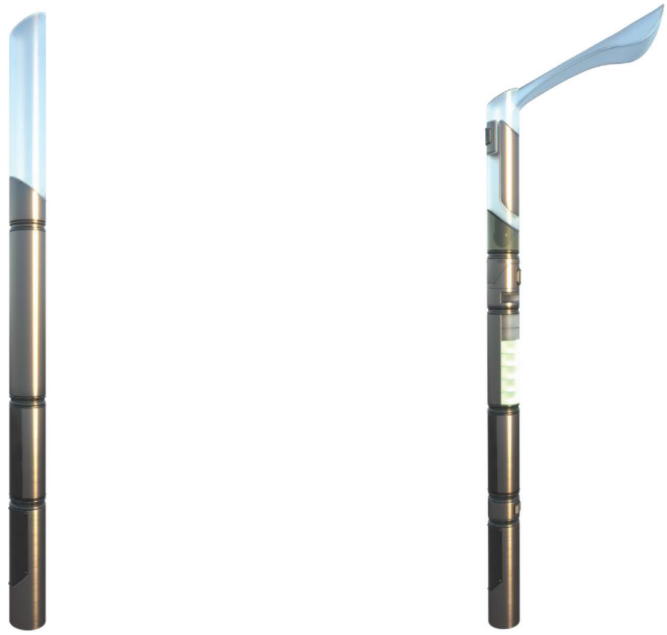

Figure 5: BAILIFF and BAILIFF 2.0.

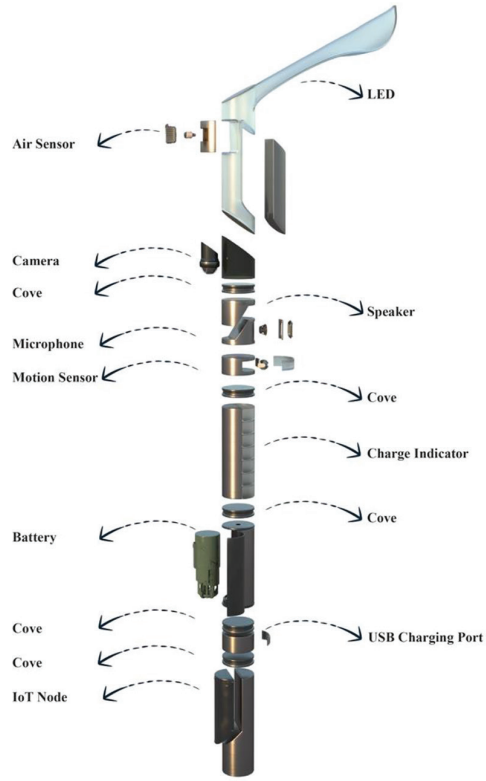

Figure 6: BAILIFF 2.0 exploded perspective view.

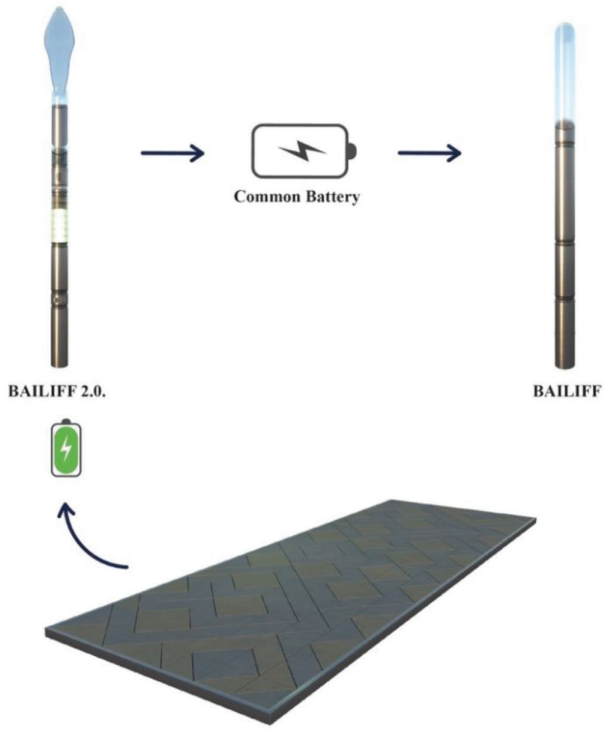

Figure 7: Demonstration of energy transfer from piezoelectric floor tile and battery.

obtained from the kinetic tile in the battery (Fig. 7). The USB port is for charging. The improved piezoelectric floor tiles support sustainable development by providing a cost-effective, green and sustainable energy transformation.

To encourage citizens to act

1. the charge indicator levels relative to the amount of energy the battery is filled with are increased and
2. the light of the kinetic tile under the step taken is on.

In total, these three methods will be a visual reflection in the design that people of all ages contribute by converting their activities such as walking, running and jumping into electrical energy with kinetic tile (Figs. 8 and 9). The embedded common battery will store the excess electrical energy obtained from the piezoelectric floor tiles coverings for the days when the human density is low. The energy obtained will be accumulated in the batteries and distributed to other lightings when the capacity is full. Thus, the energy need will be met without being connected to the municipal grid or the need for a second renewable energy (solar and wind) system.

The comparison of the energy produced by BAILIFF and other energy sources is presented in Fig. 10. In this case, one step corresponds to 5 watts of energy, the electrical energy that BAILIFF will use; 1 year is taken as an average of 300 days, and considering that it works 12 hours a day, 1 smart lighting will need 30 steps to work. It will provide illumination with a

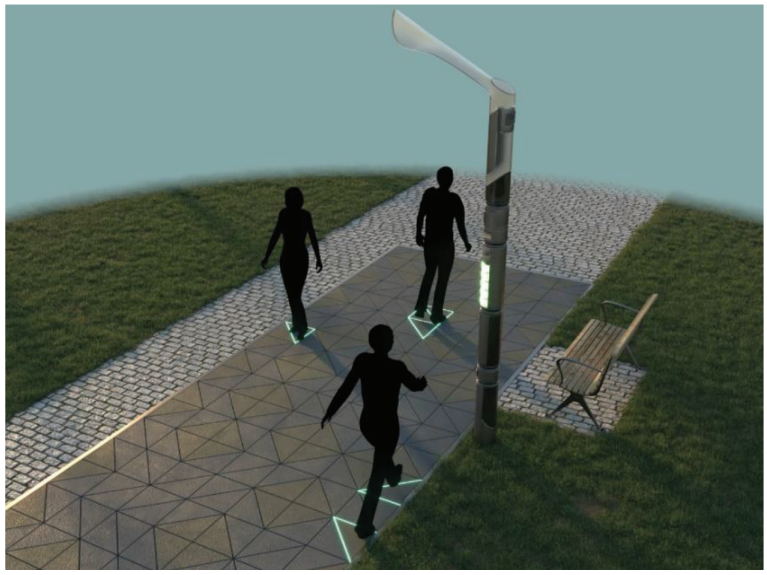

Figure 8: BAILIFF 2.0 and kinetic piezoelectric floor tile human product interaction.

Figure 9: BAILIFF 2.0 improves user's awareness through gradual power indicator located in the product body.

10-watt LED, which is equivalent to a BAILIFF 60 normal bulb. Energy will be generated from human movement with a piezoelectric floor tile covering 2.80 by 8 m in front of each smart lighting. In other words, by applying the BAILIFF Smart System to the Çorlu Republic Park, one person will provide the energy of lighting by taking three tours on the walking path alone.

Product	Product Dimension	Energy Generated	Life Span by Years
Kinetic Energy			
Sound Power	50 x 50 cm tile	0.1 watt per 2 steps	20
Sustainable Energy Floor (SEF)	75 x 75 or 50 x 50 cm	Up to 30 watt	15
Pavegen Tiles	V3 Tile 50 cm each edge	5 watts / footsteps	20
Parquet PVDF layers	Layers	2.1 mWs per pulse with loads of 70 kg	20
PZT ceramic (Lead zirconate titanate)	Manufacturing in a small size	8.4 mW	20
Drum Harvesters Piezo buzzer Piezoelectric Ceramics	Vary	Around 2.463 mW	20
Hybrid Energy Floor Which Integrate the human power with the solar energy	Manufacturing in a small size	8.4 mW	20
Bailiff	50 x 50 cm	One step 5 watt	20+
Solar Energy			
Monocrystalline	65 inches by 39 inches	350W	25+
Polycrystalline	65 inches by 39 inches	300W	25+

Figure 10: Potential electricity generation by smart methods, materials and energy types.

4 CONCLUSION

This study analyses the reflections of renewable energy and smart energy technologies on urban furniture in smart cities and presents a remedial proposal. As the most common feature of smart cities, it is necessary to have a networked infrastructure supporting social and cultural development. Such an infrastructure is used as social capital of its citizens for urban development by encouraging such development and creative activities. The natural environment, which plays a critical role in the planning of cities, is also used as a mask for countries' intentions to take their place in the technology market in the smart city strategy and participate in the competition in the world economy market. A country's energy policy and energy security do not only determine its economic power in the world. In countries aiming to be independent of energy imports or close to reaching self-sufficiency in energy supply, war, famine and disease are less likely to occur.

The changing and shaping factors in the energy sector from past to present have been examined. According to this, technology development efforts in renewable energy have led to a significant increase in the world portfolio of renewable resources. It is also seen that energy-based problems are related to changing the flexibility of traditional energy, and complex energy systems are managed by blending energy demand among different sectors. The intelligence of energy is much broader than the concept of being renewable. Based on the principles of smart electricity grids, smart storage and smart consumption, the Internet of Energy (IoE) model integrates any clean, green, sustainable, renewable and conventional energy with ICT. It is foreseen that renewable high smart grids will provide two-way information energy flow to power all system users shortly, and RES will form most future smart grids. The current state of technological development and the energy market should be considered to design the future's high renewable energy electricity system and implement the products that will contain the system. Electricity generation from RES will provide direct or indirect economic benefits, apart from environmental contributions and future energy security. Energy demand and increasing population are directly proportional to economic growth, which creates the need for higher energy technology.

When developing energy strategies, countries should know how to overcome local and global non-residential problems and position themselves in an international context through local communities. This goes through scenarios in which cities prepare themselves for the future. Smart cities all use different concepts and schemes for the transition of energy-based targets. The integration of renewable energies in urban areas prevents the depletion of resources and energy efficiency, and environmental degradation.

Public outdoor spaces, by their meaning and role, affect the identity and quality of the city. Considering this will vary depending on the level of detail and design, urban furniture should serve the region's spirit, serving the common language and not contradicting the aesthetic values of the place, rather than being a part of the system. Increasing the use of clean and renewable energy in urban open spaces will not only increase the quality of wisdom in a city. It will enable the citizen to take a step from not in my backyard to where I live. And the finding of smart urban furniture working with renewable energy in cities will also give the appearance of a sustainability fair for future generations.

The reason for considering the case study Çorlu is that it can handle such an investment in smart energy. BAILIFF is an effective solution proposal for the Covenant of Mayors for Climate & Energy Europe agreement signed by Çorlu in 2019 and the role it will assume due to its potential. It will also inspire prominent energy-based projects for smart cities in Turkey by using kinetic energy and smart energy technologies. The use of renewable energy technologies in cities will be increased against possible power cuts and energy wars in the future. BAILIFF is designed to fit the keywords of industry 5.0: sustainability, people, green technologies and digitalisation. Therefore, it should be considered how high-tech products will be adapted to live, the green technology–human relationship, and most importantly, what will replace sustainability.

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