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Applicable Smart City Strategies to Ensure Energy Efficiency and Renewable Energy Integration in Poor Cities: Kabul Case Study

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Abstract: A smart city is fundamentally intended to reduce the consumption of resources and optimize efficiencies. In almost any area, efficiency results in energy saving, reduced energy intensity, sustainable economic development, enhanced productivity, a protected environment, and most importantly, cooperation with the climate change battle. Although budget, technology, and the required infrastructure are major constraints for poor cities to achieve smart and sustainable city goals, the benefits of smart cities are multiple for poor cities compared to developing and developed cities. Poor cities achieve improved living environments, security, safety, economic development, governance, and quality of life in addition to achieving sustainable energy goals, and this study seeks to identify those smart renewable energy and energy efficiency strategies that are economically feasible and technically applicable in poor cities. The findings of this research would help poor and low-income, developing cities take the initial steps towards becoming smart cities by applying smart, innovative, and economically feasible sustainable energy projects and initiatives. As a result, these cities will be able to enhance their environment, economy, and employment by transitioning to smart ones.

Keywords: smart city; ICT; renewable energy; sustainability; energy efficiency

1. Introduction

Cities host 55% of the world's population and are projected to reach 70% by 2050. Currently, they consume 75% of all natural resources and emit around 70% of the total greenhouse gases [1,2]. Globally, the transportation sector uses 28% of the world's energy demands and contributes 23% to global CO₂ emissions. The building sector share is 30% of the total global energy consumption and 55% of the total electricity demand. It is also forecasted that two-thirds of the buildings needed by 2060 will be built by 2035 [3]. According to an International Energy Agency (IEA) analysis published in the Energy Technology Perspectives 2016, by 2050, more than USD 20 trillion could be saved by improving urban transport systems by encouraging walking, cycling, and public transit, as well as achieving a major reduction in greenhouse gas (GHG) emissions [4]. According to the EV30@30 policy scenario, electric vehicle (EV) market share will reach 30% by 2030.

Consequently, the demand for oil products will reduce to 4.3 million barrels per day [5] and, therefore, cities will soon face many social and economic problems if these trends are not timely and wisely managed. These issues could be generalized for almost all

cities, but poor and low-income, developing cities will suffer the most and face most of the unfortunate consequences caused by these booms [6]. The challenges associated with energy, sustainability and climate change are among the problems that will arise from the rapid growth of urbanization and urban sprawl in the coming years. Therefore, efforts should be geared towards creating an intelligent environment that can conserve resources through technology, improved sustainability, solving urban problems, and improving the quality of life for people [7].

From the global urban planning perspective, smart cities can be an excellent answer to urban challenges. These challenges could be best confronted by increasing employment for citizens, using information technology, and building vital city infrastructure. The smart city is a comprehensive concept related to various domains, but the primary purpose and goal of making cities smarter is to enhance people's quality of life. Therefore, the smart city regulates and organizes all infrastructures such as roads, subways, railways, airports, bridges, piers, communication infrastructures, and all other infrastructures so that the least resources are consumed, and services are provided with the best possible quality and security. In other words, a smart city integrates physical, human, and digital structures and uses the forces that result from this integration to lead the city towards sustainability and prepare a livable environment for its citizens [6].

One of the main strategies to promote sustainability in cities is to control whatever affects the environment. So far, the undue consumption of fossil fuel energy has been proven to be one of the most destructive elements to the environment. Therefore, it is expected that smart cities would control and minimize the effects of energy consumption and prevent further damage to the environment [8]. Smart energy systems use automated algorithms to analyze, manage, predict, and optimize the historical data of energy consumption in the demand and supply sides of energy systems [9].

Now, for making a city smart, the promotion of specific technologies in cities is required. The more favorable the efficiency of these technologies, the more successful the smart city would be. There are different examples of new technologies used in smart cities of different countries, such as GPS, GSM, and wi-fi, all of which make communication easier and affect quality of life. Failing to manage the technologies within smart cities successfully would result in a waste of resources [10].

Making cities smart is one of the strategies for fighting the challenges of urbanism, but a poor economy is a challenge itself against implementing most of the required smart city features. The main purpose of this research is to specify smart city goals related to sustainable energy, to identify sustainable energy related challenges common to poor cities, to find out those features of smart cities relevant to energy efficiency (EE) and renewable energy (RE), and to introduce technically and financially practical smart strategies for integrating renewable energy and enhancing energy efficiency in poor and low-income, developing cities such as Kabul.

This study has five sections. Section one, the introduction, provides a high-level description of urban energy system concepts in general, discussed both in the global and local contexts. Section two, a literature review, provides a detailed description of smart cities; their characteristics; action areas and associated elements for each action area; the relevance of each element to renewable energy and energy efficiency; smart energy indicators for smart cities in well-known standards; the interconnection between smart and safe cities; and Kabul City challenges related to smart and sustainable energy. Section three, the methodology, provides how the research was inceptioned, formulated and conducted. Section four, results and discussion, proposes applicable smart strategies for Kabul City for each of the six areas of smart cities, and in the second part of this section, the authors present some short term and medium term recommendations for key stakeholders of the urban and energy sectors of Kabul City. The last section, the conclusion, further explains the importance and benefits of integrating smart strategies for integrating renewable energy initiatives and ensuring energy efficiency in poor cities.

2. Literature Review

2.1. Smart City Concept

The term “smart city” is a relatively new concept that emerged in the last decades of the twentieth century. Following the smart growth movement, the smart city concept emerged in the late 1980s [11]. The smart city can be considered a vision for the future of cities. According to the Smart City Council, smart cities use information and communication technologies for improved livability, workability, and sustainability. Information and data are collected through sensors and other devices, communicated by wireless or wired networks, and finally analyzed for instant and future use [12]. These cities are built with a high degree of environmental compatibility to provide security and comfort for people in every way.

Furthermore, the efficiency of these cities is much higher because all infrastructures are built based on new technologies, supported by sensors and computer systems [13]. Issues such as sustainable development and sustainable energy delivery in cities have become some of the key concerns of smart cities [14]. Future smart cities will be highly served to realize reliable, efficient, and low carbon energy supplies [15]. The sustainability measures in smart cities are rarely achieved by ICTs and the smart city agendas are entirely linked to technology and innovations. Although the smart city is not always meant to ensure sustainability, smart cities would definitely help to achieve sustainable energy targets [16].

2.2. Smart City Characteristics

Certain features distinguish smart cities from other cities. These features and factors are used to evaluate and compare the degree of intelligence of cities and specify the degree of efficiency and adaptability of cities. In other words, the smart city is a forward-looking vision that, with six characteristics in mind, copes well with urban problems and is built for smart, independent, and informed citizens [17]. These six action fields of smart cities are specifically focused on: 1. Smart Governance; 2. Smart Economy; 3. Smart Mobility; 4. Smart Environment; 5. Smart People; and 6. Smart Living (Figure 1) [17].

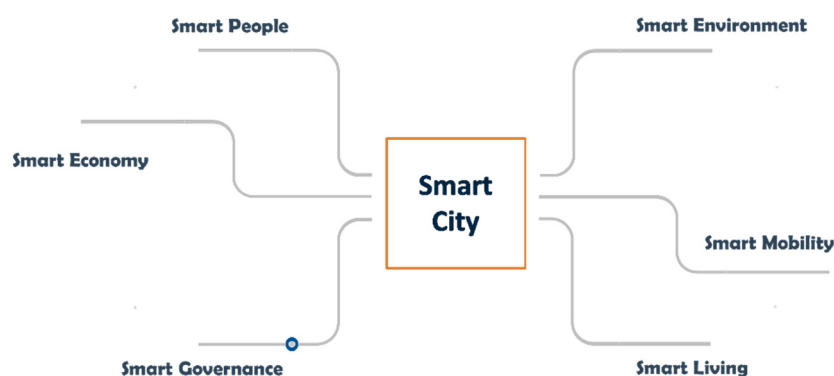


Figure 1. Action Areas of Smart Cities.

There are certain elements associated with each of the six smart city features; however, only a few have either direct or indirect relevance to RE and EE. Figure 2 specifies the relationship between Smart city elements and their relevance to RE and EE.

All six action fields of the smart cities revolve around economic growth, quality of life, and sustainability that directly relate to RE and EE. Therefore, RE and EE can contribute to cities achieving the smart city goals [18]. Transforming today’s cities into fully networked smart cities will require careful planning and investment. Governments that decide to move towards smartness will certainly find that their cities are more sustainable and livable [19].

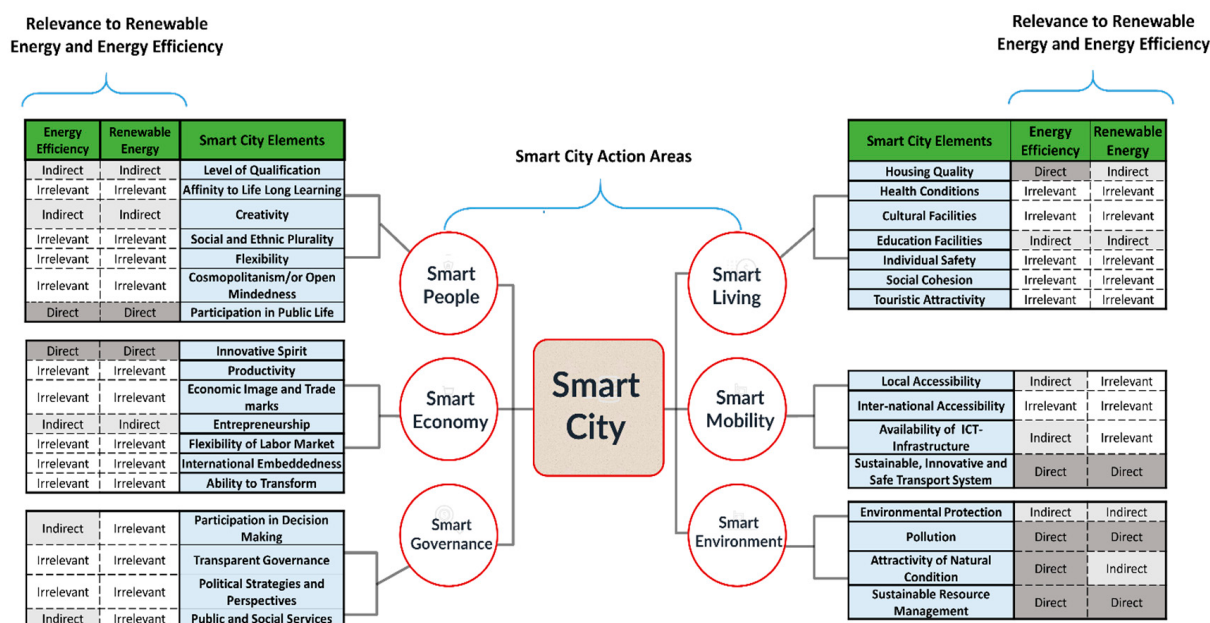


Figure 2. Relationship between Smart city elements and their relevance to RE and EE.

Figure 3 describes the relationship between sustainable energy and smart cities goals, namely, economic growth, quality of life, and sustainability, with additional details included [18].

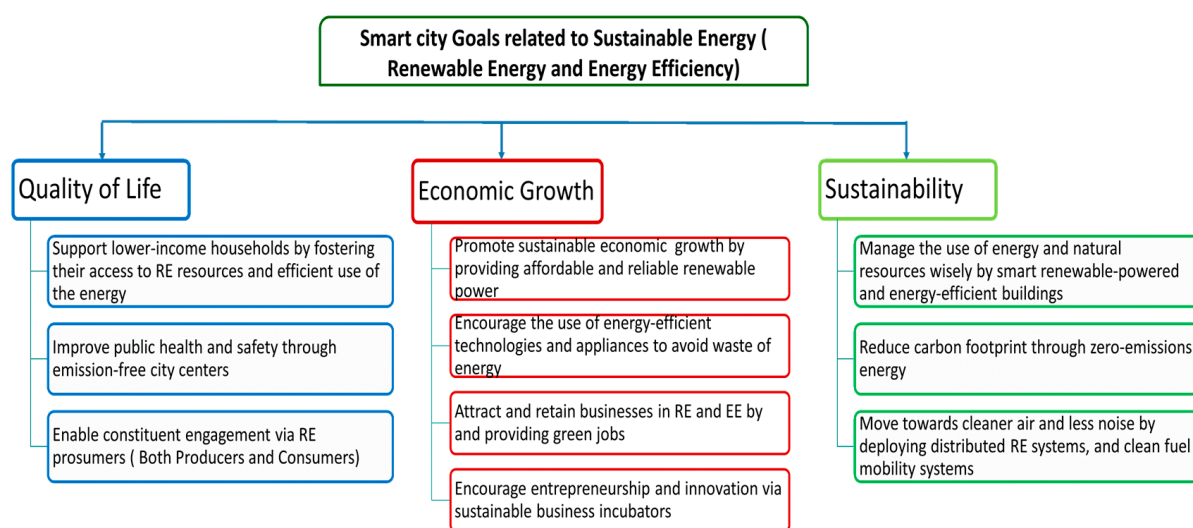


Figure 3. Relationship between sustainable energy and smart cities goals. Source: [18].

Additionally, there are several international standards for smart cities introducing indicators for energy in smart cities. The summary of the smart energy indicators from four well-known standards (ISO-37120, ISO-37122, ITU-4901, and ITU-4903) are presented in Table 1 [20–24].

Table 1. Smart Energy indicators for smart cities. Source: [20–24].

Standard	Indicator Related to Smart Energy
ISO-37120, ISO-37122, ITU-4901, ITU-4903	Electrical and thermal energy (kWh) produced from wastewater treatment, solid waste treatment, and other waste heat resources, as part of the city's energy mix (%)
	Percentage of the city's energy that is produced using decentralized energy production systems
	Storage capacity of the city's energy grid per capita (GJ/person)
	Percentage of street lighting remotely managed by a light management system
	Percentage of buildings in the city with smart electricity meters
	Percentage of households with smart electricity meters
	Automatic energy management in buildings
	Electricity system outage frequency
	Electricity system outage time

There is a strong interconnection between smart and safe cities. Essentially, smartness helps cities to be safe places for their inhabitants by providing them with a healthy environment, physical safety, reduced crime, a secure environment for business, protected privacy, and more. On the other hand, a safe city will ensure a smart city is nurtured smoothly to expand and function reliably and sustainably. Ristvej et al. (2020) describe smart and safe city concepts with further details [25]. Poor cities, where safety and security are a common challenge for every aspect of the city, ideally would willingly embrace smart city initiatives, where energy is a critical component to most of the other smart city areas. Energy security is also an extended topic closely related to the smart city; however, at this stage it could not be focused on in further detail.

2.3. Kabul City Challenges Related to the Smart City and Sustainable Energy

Rapid urbanization, demographic pressure, and climate change are common issues that almost all cities in developing countries have experienced. The development trend in these cities is much slower and falls behind compared to their population growth and urbanization rates [26]. According to an ASCIMER study, challenges relevant to smart cities that are commonly associated with this category of city, are described in Figure 4 [27].

Kabul City is one of the fastest-growing cities in the world. It has been transforming vertically and horizontally in the last two decades, and a considerable amount of money has been spent on installing infrastructures for transportation, water, energy, and ICT, without aligning them to urban smart and sustainable goals and agendas. In addition to the challenges described in Figure 4, Kabul City also suffers from high crime rates, security threats, a high rate of unemployment, corruption, a lack of citizens' awareness, insufficient electric energy, a low quality of fossil energy, a lack of national vision or targets for sustainability and city smartness, and increasing informal settlements [28].

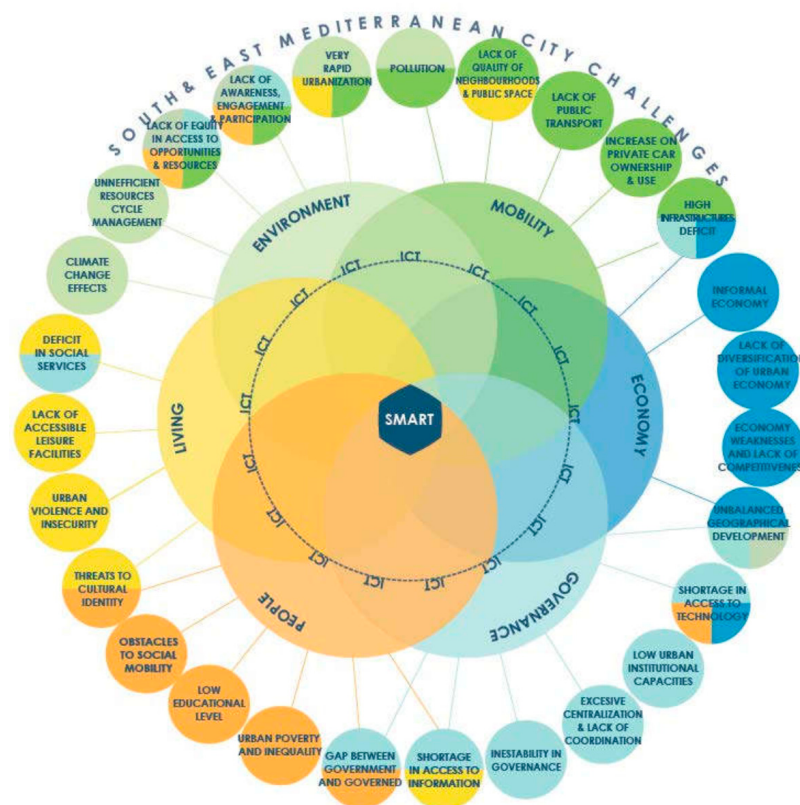


Figure 4. Challenges correlated to smart city dimensions in developing countries. Source: [27].

3. Methodology

This research is based on the data collected by desk research, field observations, and interviews with experts and urban sector authorities. A qualitative method of data analysis was applied.

First, the general features and elements of smart cities from different resources have been listed and summarized. This information and data provide a base to initiate the study. The data is mainly extracted from a number of relevant journal papers and international agencies' reports.

Next, the features and elements of smart cities have been highlighted that are relevant to RE and EE. Identification of the relevance is based on the authors' intuition, knowledge and judgments.

The key findings of this research are presented in the results and discussions section, where applicable strategies for poor cities like Kabul are proposed and discussed. The critical focus on presenting the results of the research is to present only those strategies that are quick and easily applicable in poor cities considering their economic conditions. The analysis and results are based on qualitative data analysis from the literature provided in previous sections and the authors' own expert views and judgments. Some of the strategies are proposed based on their success in similar contexts. Another group of strategies is specific to the Kabul context.

Finally, specific recommendations are provided for the stakeholders of the urban sector in order to transform their cities into smart ones with less financial burden.

4. Results and Discussion

4.1. Proposed Applicable Smart Strategies for Kabul City

Urban sprawl, energy consumption, and the population in cities are interrelated (Figure 5). It can be said that the increase in population in cities causes urban problems, and that the most important of which is the energy crisis [29].

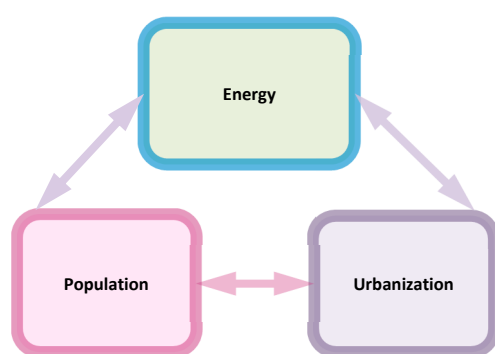


Figure 5. Energy, population and urbanization interrelation.

Urbanization, however, is an inevitable phenomenon, and one cannot avoid its problems, but there are different alternative solutions to these problems, and one is by making cities smarter [30]. To solve the energy problems of cities by making them “smart”, equipping cities with smart features is necessary. Given the economic constraints and existing infrastructure, the following applicable smart city strategies are proposed for Kabul

4.1.1. Smart Environment, Energy and Living Sustainable Resource Management

According to the national power utility company, DABS, around 90% of Kabul’s electric energy is used in buildings. On the other hand, access to reliable and sufficient electricity is another issue. The available electric power capacity can barely satisfy two-thirds of the existing city demand [31] and due to the low reliability of the Kabul City electricity grid, it is suggested that the hegemony of the centralized grid is broken by making it more local. Smart micro-grids and mini-grids would increase local RE generation and reduce power losses (both technical and commercial losses). It would certainly be a challenge for utilities providers, but micro-grid projects and distributed energy systems would bring an improved system resilience. Smart grids and micro-grids would help the distribution systems to integrate intermittent renewable power, and also enable a local market for the community to sell their excess rooftop PV and wind power back to the grid and neighbors.

Elsewhere, EE enhancement from the management of the demand side in smart cities has proven to be effective. Smart buildings and smart lighting can be named as examples that most agree with this argument, thus, the transformation of buildings to smarter ones that use less energy and utilize RE sources generated locally, is justified. Transforming residential and commercial buildings into more energy efficient ones might take longer, but should prove easier for public buildings if the government were to support such a policy.

There are many smart strategies that could ensure the increase of EE and integration of RE. Some strategies are proposed and listed below:

- I. Develop a free web or mobile app platform, where consumers can view their electricity consumption pattern, compare consumption with previous days and weeks, and provide advice on managing households’ electricity usage. This platform could educate the public by proposing smart and sustainable strategies for reduced fossil fuel consumption and enhanced energy efficiency.
- II. Replace inefficient lighting fixtures with more efficient and smart ones (lights equipped with remote control, automatic or manual dimming capability, and motion sensors).
- III. Install smart meters that can sell surplus electricity to neighbors and transmit consumption and generation data virtually.
- IV. Replace water boilers with ones with adjustable heat control, or only retrofit an adjustable heat control device instead of changing the whole boiler.
- V. Smart meters to be installed in the city power grid, so the power consumption data is collected and analyzed for future planning purposes [32].

VI. City power grid to be transformed to a smart grid [32].

The concept of decentralized heating and cooling would be another solution to make cities smarter, cleaner and more energy efficient. Currently, coal-powered small heating systems largely pollute Kabul City's air. Similarly, blackouts in summer increase the use of diesel generators and create air and sound pollution all over the city [33].

Environmental Protection

Pollution sensing smart sensors need to be installed in different locations of the city. This would enable the sharing of real-time air quality information with the authorities and the public. It would create the capability to take protective measures to reduce the adverse health effects of air pollution.

4.1.2. Smart Mobility

Sustainable, Innovative, and Safe Transport System

Another area that contributes largely to air pollution is the transportation system [34]. Smart mobility can help transportation systems to be safe, secure, cost-efficient, time-efficient and environmentally friendly. Here are some smart city strategies suggested for Kabul City:

- I. Solar powered street and traffic lights with surveillance cameras and wi-fi routers could control and monitor the traffic, traffic violations, traffic flow and count, and even weather conditions. The wi-fi routers could be used for other smart systems that would emerge in the future [33].
- II. Create a mobile app for the Kabul City transportation system to show drivers' congested routes and alternative routes. This app could be owned by the municipality or through a PPP (Public–Private Partnership) initiative. This app would need an IoT infrastructure and network which should be jointly designed and operated by the KM, Ministry of Communication and Information Technology, and the Ministry of Interior Affairs.
- III. Public transport/buses should be changed to smart and electric ones. It does not seem wise to continue the use of fossil-fueled and inefficient buses inside the city. Although this would be a relatively costly option, since there is no functioning public bus network, no existing set-up, and no regulation for any public transport developed, it would be a good opportunity to begin regulating this sector by considering smart and sustainable goals [35].

Availability of ICT Infrastructure

The existing ICT infrastructure is relatively in good condition. The fiber-optic network has been extended all around the city. At the same time, there are a number of communication towers of the four mobile companies available to support smart city initiatives; however, the speed and cost of internet access is still an issue. Integrating Internet of Things (IoT) technologies, such as sensors, with the existing infrastructure to create actionable data and specifying the type of data to be gathered is a pre-requisite for this action [18].

Local Accessibility

Nearly all residents of Kabul City have access to some sort of local transportation within their walking distance; however, the distribution of that local transport is not necessarily applicable to the demand. Mobile applications for public transport might make access much easier and reduce the waiting time for both drivers and service users. Car sharing through a mobile app is another strategy that can save resources. Crimes could also be tracked and controlled.

4.1.3. Smart Economy

The economy is the backbone of smart cities. There are a lot of economic opportunities that smart cities could create. The vision should come from the authorities, but innovative

strategies and solutions could only be made possible through entrepreneurship, research, and innovation centers. Therefore, for cities that are very new to the smart city concept, the creation of such centers is the first major step to move toward a successful smart city experience. Facilitating training in innovation and entrepreneurship is also essential for poor cities. By having new and innovative business models, they could reduce the use of fossil fuel energy and increase EE. For example, since we do not have reliable electricity and grid electricity is expensive, we could use RE for businesses and save money by applying EE strategies.

4.1.4. Smart Governance

Since the governance scope is broad, smart strategies for this area are also extensive. Reducing the bureaucracies and managing part of or the whole task through online platforms would save considerable energy in cities. For example, if online participation tools existed, the public would not need to use vehicles to physically participate in events, gatherings and meetings. Instead, they could use a computer at home to participate in events where their physical appearance is unnecessary and also save much energy. Here are some strategies that poor cities could embrace:

- I. Online platform for decision making at the city or local level.
- II. An electronic voting system would save significant resources, especially those resources used for ensuring the security of voting centers.
- III. Online systems for receiving complaints or processing claims could also save considerable energy and time.
- IV. Online platforms for city councils could be safe and resource-efficient.
- V. Smart card/ e-ID could be used to manage the distribution of aids to needy citizens. This would also avoid duplications in distribution and corruption.
- VI. Kabul Municipality (KM) could develop a web-based application, E-MUNICIPALITY, so that citizens could have access to the KM without traveling long distances or spending a lot of time, resources, and energy. This platform should be available by different means, such as via chat, call, or email to citizens.

4.1.5. Smart People

Creativity is closely linked to smart cities and EE. Smart and creative people can achieve the goals of smart cities by proposing initiatives, cost-efficient solutions to city issues, initiate business ideas and businesses, and create employment opportunities. Below are smart city strategies proposed for achieving the smart people goal:

- I. Co-working centers.
- II. Cultural activities organized by citizens through the internet.
- III. Internet platforms to disseminate information about urban events on different topics.
- IV. Centre for creating apps.
- V. Integrated platforms for media services.
- VI. Partnerships between creative industries and universities.

4.2. Recommendations for Key Stakeholders

Due to its unique nature, RE and EE integration and utilization require both the government's vision for sustainable energy provision in cities and the active participation and cooperation of the people in the energy planning process. Therefore, it can be said that municipalities have a valuable role in the process of energy planning and the use of renewable resources for the self-sufficiency of cities in terms of energy production [36].

In order to increase RE share and smartly attain EE in Kabul City, specific recommendations and strategies are proposed both for urban sector authorities and its citizens. These recommendations are grouped into short and medium-term stages (Table 2).

Table 2. Recommendation for urban stakeholders.

Recommendations for Urban Stakeholders	
Short Term	A national entity responsible for upgrading the city to a smart and sustainable one to be created.
	A clear legal and regulatory framework is needed to facilitate the transformation of the existing city to a smart and sustainable one [37].
	Develop national target for a smart city.
	Develop the capacity of policymakers on smart and sustainable urban concepts [38].
	Develop plans on how to make the city smart and to ensure higher efficiencies.
	Kabul City power, communication, transportation, and water networks should be re-designed and aligned with smart and sustainable cities goals.
	The national housing policy should follow smart and sustainable cities criteria.
	Making the city smart to increase RE utilization and EE would require close coordination between stakeholders of ICT, Energy and all relevant urban sectors. This means the traditional urban planning approaches would need to be changed to more integrated ones.
	Develop the net-metering regulation for swift utilization of RE.
	Enact mandatory codes and standards for the use of ENERGY STAR electric equipment.
	Develop optimization and demand forecast models and technologies to optimize the use of generators and reduce power dumping.
	A data center for monitoring and analysis of energy consumption in the city is to be developed. This would allow urban authorities, utilities, and researchers to manipulate and analyze data for further optimization of energy system.
	Select and implement some smart energy pilot projects around the city and consolidate experiences from these pilots for more significant steps [18].
	Incentivize the use of electric bikes and electric rickshaw (3-Wheelers) [35].
Medium Term	Design and develop the required infrastructures required for a smart and sustainable city.
	Develop codes and standards for the support of a smart city and RE and EE utilization.
	As a low-income developing country, focus should be on gaining access to long-term and climate-related finance [38].
	Develop a grid code applicable for big cities to absorb RE power.
	Housing strategies should be aligned with smart and sustainability agendas.
	Electricity regulatory institutions and utility companies should work in close coordination with citizens to find ways to integrate RE and ensure EE in the city [18].
	Prepare solar PV, solar thermal and wind energy integration into the grid plan for the city at micro to macro levels.
	Combine land-use practices with transportation and energy systems.

ASCIMER has proposed a governance framework and stages for smart city project development for better planning and implementation of smart city projects. It starts with developing project concepts and design, then financing, implementing, and managing the projects. Stakeholder involvement in each stage of the project planning and implementation has been described as a crucial aspect. There are also nine guidelines proposed for better development and implementation of the projects, listed below [27]:

- I. Stakeholders' involvement and tasks definition.
- II. Multilevel governance.
- III. Citizenship involvement and social inclusion.
- IV. Monitoring and adaptive management.
- V. Innovation and technology.
- VI. Externalities and mediation
- VII. Capacity building and knowledge transferability.
- VIII. Image, credibility and positioning of Smart city Projects.
- IX. Sustainability and efficiency.

5. Conclusions

Many Smart city features could be quickly and economically realized in Kabul City to ensure RE utilization and EE improvement in many different urban sectors. Transportation, energy, water, environment, economy, and housing sectors have the potential to adapt smart and sustainable energy features and strategies.

Poor cities like Kabul would benefit more than any other developing or developed cities by applying a smart energy system. Poor cities would be able to enhance the physical security of citizens, improve their economies by using smart and innovative strategies, and reduce corruption in different layers of the governance, in addition to achieving sustainable energy targets of the United Nations' Sustainable Developing Goals (SDGs).

Considering the collaborative nature of smart energy systems, coordination and collaboration of the key stakeholders of the urban and energy sector of cities is critical. Without having a shared vision for smart energy in cities, the energy sector on its own will not be able to achieve these goals.

It is not only the environment and the economy that is damaged, but corruption, weak governance, and a low level of transparency and accountability are also issues common to poor and low-income, developing economies. Smart technologies in cities where ICT plays a key role could be effective tools to overcome these challenges.

Considering the existing ICT infrastructure and the level of citizens' knowledge and skill for using state-of-the-art and modern technologies, the transformation of Kabul City into a smart and sustainable city seems promising and practical. However, the political uncertainty, other urban priorities, corruption, poor security, and cultural barriers are clearly visible and undeniable challenges towards this transformation.

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