RAMIZ SALAMA

GREEN LEARNING ENVIRONMENT FOR SUSTAINABLE EDUCATION

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**NEAR EAST UNIVERSITY**

**INSTITUTE OF GRADUATE STUDIES**

**COMPUTER EDUCATION AND INSTRUCTIONAL TECHNOLOGY**

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**Ph.D. THESIS**

**By**

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**NICOSIA**

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## Approval

We certify that we have read the thesis submitted by RAMIZ SALAMA titled GREEN LEARNING ENVIRONMENT FOR SUSTAINABLE EDUCATION" and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy in Computer Education Instructional Technology.

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**Declaration of Ethical Principles**

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## ABSTRACT

Determining how to provide ubiquitous and durable electricity to the deployed Internet of Things (IoT) branches is crucial to ensuring the ongoing development of smart cities. IoT devices more extensively acknowledged as essential components of modern cities because they provide the foundation for enduring security measures. IoT hubs could become able to look for independent power via environmental vital sources because of to the suggested extraction of energy method. In accordance with explanations provided by researchers in the scientific literature, most of the viable municipal resources for energy were investigated in this paper. Considering the region's wealth of complimentary assets under investigation, we have also suggested that energy sources may vary depending on the application. In order to automate smart cities, this proposes identifying energy requirements that are similar to those of various IoT devices or wireless sensor networks (WSNs). Cognitive cities and communities represent some of the significant technological, sustainable, and renewable energy issues that have arisen due to the advancement of sophisticated municipal technology. Gathering and distributing Internet of Things (IoT) devices and smart apps that enhance the standard of living of individuals is the primary objective of an environmentally friendly smart city. One of the most important aspects of sustainable urban computing, energy harvesting management has challenges due to the rapid development of intelligent apps, complex demographics, and Internet of Things (IoT) detectors. Reducing the related aspects of preserving utilization of energy, and environmental waste management is one of these problems. Nevertheless because of budgetary and legal limitations, the concept of energy extraction and administration for environmentally friendly city computing is presently developing at a rapid pace and needs consideration. In order to create smart and sustainable cities, this study looks at a number of green gathering techniques as well as creative uses of edge-based intelligent urban computing. Nowadays, harvesting electricity techniques fall into four main groups: intelligent cities, smart ecological frameworks, smart transit systems, and smart power lines. Technology aspects of sustainable metropolitan computational energy extraction and administration systems, including developed algorithms, examination settings, and regulations, are the main emphasis of this review. Since energy harvesting and waste management examining existing problems and undiscovered research is essential from a technological standpoint in order to make a contribution to the rise in energy usage of intelligent programs and human existence in complicated metropolitan areas directions in these areas for sustainable smart cities

**Keywords:** Sustainable Energy, Renewable Energy, Energy Efficiency, Smart Grid, Smart Building, Smart City

**Özet**

Yaygınlaştırılmış Nesnelerin İnterneti (IoT) dallarına her yerde ve dayanıklı elektriğin nasıl sağlanacağının belirlenmesi, akıllı şehirlerin sürekli gelişimini sağlamak için hayati önem taşımaktadır. IoT cihazları, kalıcı güvenlik önlemlerinin temelini oluşturdukları için modern şehirlerin temel bileşenleri olarak giderek daha yaygın olarak kabul edilmektedir. IoT merkezleri, önerilen enerji çıkarma yöntemi sayesinde çevresel hayati kaynaklar aracılığıyla bağımsız güç arayabilecektir. Bilimsel literatürdeki araştırmacılar tarafından sağlanan açıklamalara uygun olarak, bu makalede enerji için uygun belediye kaynaklarının çoğu incelenmiştir. Bölgenin araştırılan tamamlayıcı varlıklarının zenginliğini göz önünde bulundurarak, enerji kaynaklarının uygulamaya bağlı olarak değişebileceğini de öne sürdük. Akıllı şehirleri otomatikleştirmek için bu, çeşitli IoT cihazlarının veya kablosuz sensör ağlarının (WSN'ler) gereksinimlerine benzer enerji gereksinimlerinin belirlenmesini önermektedir. Bilişsel şehirler ve topluluklar, gelişmiş belediye teknolojisinin ilerlemesi nedeniyle ortaya çıkan önemli teknolojik, sürdürülebilir ve yenilenebilir enerji sorunlarından bazılarını temsil etmektedir. Bireylerin yaşam standartlarını artıran Nesnelerin İnterneti (IoT) cihazlarının ve akıllı uygulamaların toplanması ve dağıtılması, çevre dostu bir akıllı şehrin temel amacıdır. Sürdürülebilir kentsel bilişimin en önemli unsurlarından biri olan enerji hasadı yönetimi, akıllı uygulamaların hızlı gelişimi, karmaşık demografik özellikler ve Nesnelerin İnterneti (IoT) dedektörleri nedeniyle zorluklar yaşamaktadır. Enerji kullanımının korunması ve çevresel atık yönetimi ile ilgili hususların azaltılması bu sorunlardan biridir. Bununla birlikte, bütçesel ve yasal kısıtlamalar nedeniyle, çevre dostu kentsel bilişim için enerji çıkarma ve yönetimi kavramı hızla gelişmekte ve değerlendirilmeyi gerektirmektedir. Akıllı ve sürdürülebilir şehirler yaratmak amacıyla, bu çalışma bir dizi yeşil toplama tekniğinin yanı sıra uç tabanlı akıllı kentsel bilişimin yaratıcı kullanımlarını da ele almaktadır. Günümüzde elektrik hasadı teknikleri dört ana gruba ayrılmaktadır: akıllı şehirler, akıllı ekolojik sistemler, akıllı ulaşım sistemleri ve akıllı enerji hatları. Sürdürülebilir metropol hesaplamalı enerji çıkarma ve yönetim sistemlerinin teknolojik yönleri, geliştirilen algoritmalar, inceleme ortamları ve düzenlemeler de dahil olmak üzere, bu incelemenin temel odak noktasıdır. Enerji hasadı ve atık yönetimi, karmaşık metropol alanlarında akıllı programların enerji kullanımının ve insan varlığının artmasına katkıda bulunmak için teknolojik açıdan mevcut sorunları ve keşfedilmemiş araştırmaları incelemek açısından önemlidir. Sürdürülebilir akıllı şehirler için bu alanlardaki yönelimler.

**Anahtar Kelimeler:** Sürdürülebilir Enerji, Yenilenebilir Enerji, Enerji Verimliliği, Akıllı Şebeke, Akıllı Bina, Akıllı Şehir

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| | |
|---|---|
| **IoT** | Internet of Things |
| **SDGs** | Sustainable Development Goals |
| **VEH** | Mechanical Vibration Energy Harvesting |
| **WSN** | Wireless Sensor Network |
| **EECO** | Energy-Effective Calculation Offloading |
| **ILEC** | Integrated local energy community |

# CHAPTER I

# INTRODUCTION

## 1.1 Introduction

Since sustainable development is so crucial to defining the future, it has become a fundamental aspect of all daily activities and concerns. This study examines the potential contribution of green education to the Sustainable Development Goals. To do this, this study employed a narrative/traditional literature review approach. Considering the literature, the review concluded that green education contributes to the attainment of sustainable development goals in a number of ways. The main method that green education helps achieve these aims is by encouraging social and behavioral change, which is accomplished by raising global awareness of climate change, according to a synthesis of the results from multiple studies on the subject. between green education and sustainability. Accordingly, this study comes to the conclusion that green education may be more effective in achieving sustainable development objectives. However, considering the significant climatic and environmental changes that are predicted for the future, securing this function would be challenging. This study therefore also discusses barriers that reduce the impact of education, offers suggestions for the future, and looks at the consequences for further research in this field (Smith,. 2020). Concerns regarding economic, social, and environmental resources have led the scientific community to concentrate on sustainable development in recent decades. From high school to college, the quality of education is the main focus of Sustainable Development Goal (SDG) 4. With innovative teaching strategies that support sustainable ideals, it emphasizes free, nondiscriminatory education that boosts the chances of entrepreneurship, better employment, and skill development. Blended learning strategies, which control educational resources and lower educational expenses, are closely related to the research of sustainable teaching approaches.This academic study examines the research on blended learning in accounting courses to find viable paths for long-term enhancement of the learning environment. Few published studies currently make an effort to bridge this gap (Johnson et al,. 2021).

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Several researches have addressed various facets of smart cities (Perera et al., 2017; Silva et al., 2018; Ahad et al., 2020). The topic's entire bibliometric character has not yet been examined. The goal of this study is to clearly distinguish between urban sustainability and modern cities that are sustainable cities—differences that have not been examined in previous studies. This study tackled four main research concerns to bridge the gap in corpus of existing literature:

(i) What are the most prevalent study topics and mainstream methodologies on smart cities? (ii) How much do studies on sustainable Goals align? (iii) In the chosen literature, what subjects and collaborative trends are most commonly covered? and (iv) what prospects might there be for further study in sustainable smart cities?

## 2.2. Review of the literature

### 2.2.1. Smart cities, sustainable cities, smart cities

In order to produce sustainable and environmentally friendly urban environments, sustainable cities focus on minimizing environmental consequences, protecting resources, and guaranteeing social fairness (Sodiq et al., 2019). Conversely sophisticated metropolitan region It makes use of ICT (information and communication technology) and additional tactics for efficiency, and urban services (Toh, 2022; Agboola et al., 2023).

### 2.2.2. Analysis of data

The results are divided into two sections. The descriptive analysis is covered in the first section. We used literature-derived markers to filter and classify the data. R Studio's "Biblioshiny" default package was utilized. Finding pertinent bibliometric information, including productivity, author influence, document sources, yearly publishing trends, and national scientific output, requires the use of this application. In the second section, we examined the scientific data using the VOSviewer application. Large datasets can be shown using the VOSviewer software, which also provides three analysis options: authors, publishing sources, and cited references. This makes it easier to understand large amounts of data. Bibliographic coupling are among the bibliometric mapping features that are improved by its user-friendly interface (Bhatnagar and Sharma, 2022).

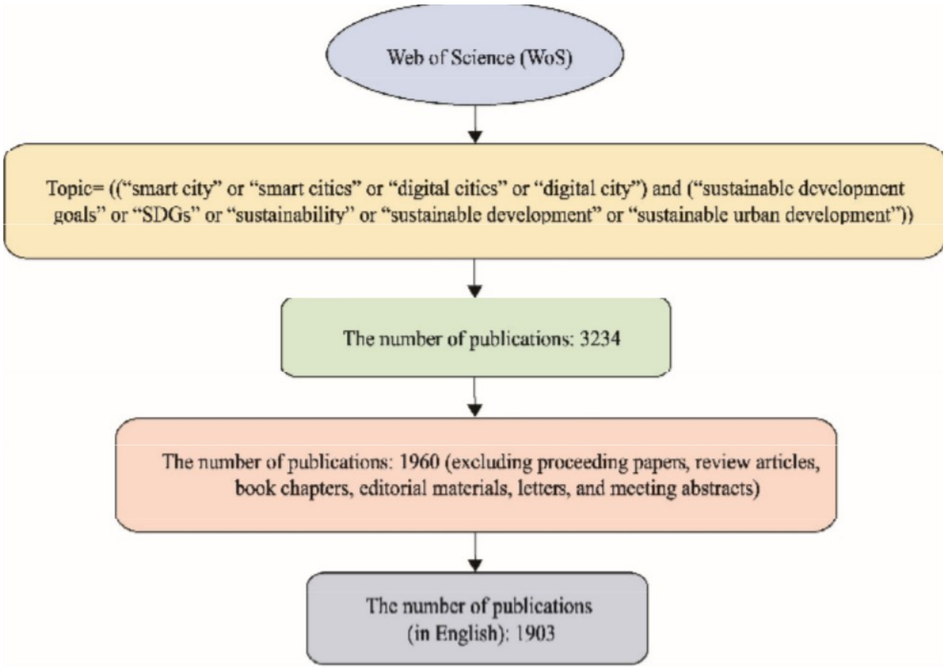


**Fig. 2.1**. Data extraction process.

## 2.3. Findings and conversation

### 2.3.1. Information identification

This study used descriptive analysis to evaluate particular subject in current status of sustainable smart cities (Donthu et al., 2021; Islam et al., 2022). Document sources, regional distribution, yearly publishing trends, and highly referenced articles were all examined in this study. Citations are a gauge of influence, whereas the number of publications shows creation.

#### 2.3.1.1. Analysis of publication trends

Figure 2 displays the publishing patterns articles on sustainable smart cities. The quantity of articles sustainability cities grew at a fairly slow rate every year until 2012. But beginning in 2013, the pace of this field's research accelerated dramatically, peaking around 2023. Even though 2024's first five months showed a drop in publishing production, this trend might turn around before the year is out, according to scholars, are responsible for the notable rise of publications (Sharifi, 2021). Smart city research started in 2010 and started to get a lot of attention in 2013, according to previous bibliometric evaluations (Guo et al., 2019; Zhao et al., 2019; Bajdor and Starostka-Patyk, 2021).

#### 2.3.1.2. How the Sustainable Development Goals (SDGs) relate to publishing

In order to accomplish the SDGs through urban transformation, scholars have emphasized the necessity of sustainable smart city efforts (Sharifi et al., 2024). As anticipated, 59.00% and 9.00% cities were related to SDGs 11 and 13, respectively. A similar percentage of materials were shared by SDGs 7 and 9 (Responsible Consumption and Production), representing 5.00% of the chosen publications (Table 2). Even if cooperation and partnerships between nations and organizations are essential to achieving the SDGs, SDG 2 (Zero Hunger) and SDG 17 (Partnerships for the Goal) have not gotten much attention cities. In a similar vein, although sustainable smart cities are crucial to reaching through technological breakthroughs, researchers have paid less attention to them. Previous research has attempted to and evaluate how the are integrated into the idea of a sustainable smart city (Blasi et al., 2022).

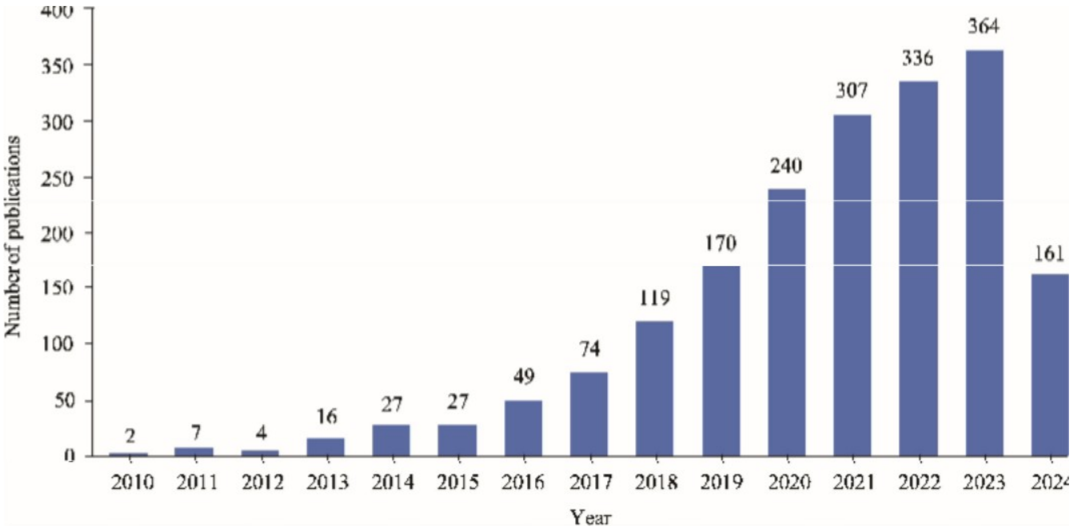


**Fig.2. 2**. Articles on sustainable smart cities between January 2010 and June 2024.

#### 2.3.1.3. Journals, highly referenced publications, and the most prolific nations

As seen in Figure 3, we classified articles according to the geographic distribution of the selected articles facilitates comprehension of the variations in regional importance and policy in the study of sustainable smart cities (Shang and Jin, 2023). With 316 articles, China is the world leader. The top 10 nations by number of articles are shown in Figure 3. In contrast, there are 147–155 publications from the US, UK, and India. European countries accounting for 50.00%. Italy boasts the smartest cities in Europe, including tiny villages, whereas China now has 290 major cities with programs (Dameri et al., 2019). Despite not making the top ten lists, Agboola and Findikgil (2023) asserted that African countries are making a contribution to the discussion on sustainable smart cities. Additionally, the study's findings showed that researchers from other countries, such as India, are also focusing on the topic of sustainable smart cities.

**Table 2.1** shows the total number of SDG-related publications in the chosen periodicals from 2010 to 2024.

| SDGs | Number of publications | Percentage (%) |
|---|---|---|
| SDG 11: Sustainable Cities and Communities | 1124 | 59.07 |
| SDG 13: Climate Action | 172 | 9.04 |
| SDG 12: Responsible Consumption and Production | 103 | 5.41 |
| SDG 7: Affordable and Clean Energy | 96 | 5.05 |
| SDG 9: Industry, Innovation and Infrastructure | 93 | 4.89 |
| SDG 15: Life on Land | 51 | 2.68 |
| SDG 3: Good Health and Well-Being | 47 | 2.47 |
| SDG 4: Quality Education | 43 | 2.26 |
| SDG 6: Clean Water and Sanitation | 24 | 1.26 |
| SDG 1: No Poverty | 12 | 0.63 |
| SDG 2: Zero Hunger | 11 | 0.58 |
| SDG 8: Decent Work and Economic Growth | 10 | 0.53 |
| SDG 14: Life below Water | 3 | 0.16 |
| SDG 10: Reduced Inequalities | 2 | 0.11 |
| SDG 16: Peace, Justice and Strong Institutions | 2 | 0.11 |
| SDG 5: Gender Equality | 1 | 0.05 |

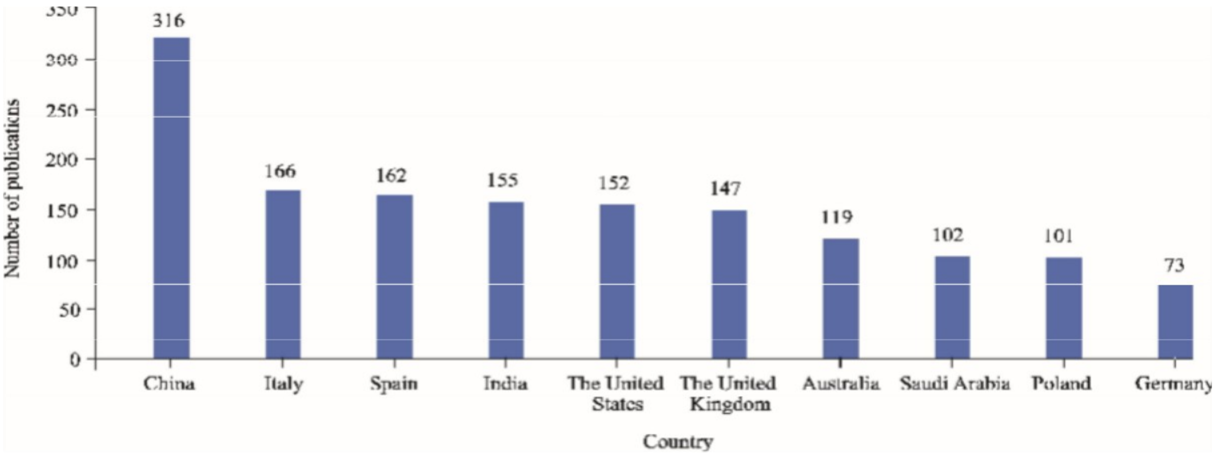


**Fig.2.3**. The top ten nations that published the most on sustainable smart cities between 2010 and 2024.

Table 3 displays the results of studies on sustainable smart cities published in the top 10 publications. The most published topic between 2010 and 2024. Remarkably, the Journal of Urban Technology received the most citations. While publishing less pieces. Additionally, while publishing fewer papers, made significant strides in the field of sustainable smart cities, with 3571 and 2218 citations, respectively. The fact that 36.0% of the papers selected for this study were from the top 10 journals shows how much of an impact they have on the research of cities. The contributions of a country and the labor of its authors, the significance of particular works must be recognized. The number of citations an article has gotten is one of the most crucial indicators of its importance and impact on the topic. Publications with many citations are sometimes seen none at all. Table 4 includes the source journals, total citations, and publication years for the top 10 referenced works. According to the findings, the Journal of Urban Technology produced the two most mentioned articles, while Urban Studies produced the third. Cities published three of the top 10 stories. The Journal of Urban Technology article "Smart cities in Europe" has received the most citations (1733), Caragliu et al. (2011) explicitly. To do this, it employed a number of metrics, such as astute individuals, astute governance, and astute economics. “Smart thinking: the smart city as a method of discipline the third most-cited piece, criticized exploit it to further their own agendas (Vanolo, 2014). In particular, they examined how cities address environmental and developmental issues and detailed the naturalization and DE politicization of the idea.

**Table 2.2** The performance of the top ten journals covering sustainable smart cities from 2010 to 2024

| Journal name | Number of publications | Percentage (%) | Total citations |
|---|---|---|---|
| Sustainability | 289 | 15.19 | 4205 |
| Sustainable Cities and Society | 86 | 4.52 | 3378 |
| Energies | 61 | 3.21 | 930 |
| Smart Cities | 60 | 3.15 | 1101 |
| Cities | 54 | 2.84 | 3571 |
| Journal of Cleaner Production | 42 | 2.21 | 2218 |
| IEEE Access | 34 | 1.79 | 731 |
| Journal of Urban Technology | 24 | 1.26 | 4385 |
| Sensors | 21 | 1.10 | 465 |
| Applied Sciences | 19 | 1.00 | 72 |

**Table 2.3** Top 10 cited articles related to sustainable smart city during 2010–2024.

| Article title | Authors and publication year | Journal name | Total citations | Average annual citations |
|---|---|---|---|---|
| Smart cities in Europe | Caragliu et al. (2011) | Journal of Urban Technology | 1733 | 124 |
| Smart cities: Definitions, dimensions, performance, and initiatives | Albino et al. (2015) | Journal of Urban Technology | 1495 | 150 |
| Smart mentality: The smart city as disciplinary strategy | Vanolo (2014) | Urban Studies | 690 | 63 |
| What are the differences between sustainable and smart cities? | Ahvenniemi et al. (2017) | Cities | 642 | 80 |
| Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco | Lee et al. (2014) | Technological Forecasting and Social Change | 458 | 42 |
| Smart cities: A conjuncture of four forces | Angelidou (2015) | Cities | 413 | 41 |
| Introducing the “15-Minute City”: sustainability, resilience and place identity in future post-pandemic cities | Moreno et al. (2021) | Smart Cities | 408 | 102 |
| Applications of big data to smart cities | Al Nuaimi et al. (2015) | Journal of Internet Services and Applications | 407 | 41 |
| On big data, artificial intelligence, and smart cities | Allam and Dhunny (2019) | Cities | 397 | 66 |
| Programming environments: Environmentality and citizen sensing in the smart city | Gabrys (2014) | Environment and Planning D: Society and Space | 374 | 34 |

Whereas smart cities often concentrate more on elements. (Ahvenniemi et al., 2017). Additionally, Lee et al. (2014) searched for smart cities using case studies California etc. Numerous aspects of the idea that have been examined in other research (Angelidou, 2015), as well as the advantages and challenges of incorporating (Al Nuaimi et al., 2015).

# CHAPTER 3

## Energy Production for Sustainability in Smart Cities

### 3.1. Introduction

Energy harvesting is the act of converting energy that would otherwise be squandered into energy that might be utilized to power autonomous devices (EH). Energy harvesting offers a solution to the current energy problem that Internet of Things (IoT) networks face by enabling the physical or chemical extraction of ambient energy from artificial or natural environmental sources, are facing. Conversely, the phrase "smart city" describes the degree of technical advancement and urbanization in a certain city. There are several definitions of intelligence. In each nation or group. Energy Harvesting (EH) is the technique of recycling otherwise lost energy into energy that might be used to drive self-sufficient gadgets. The current energy problem that Internet of Things (IoT) networks are facing can be addressed by energy harvesting, which enables the physical or chemical extraction of ambient energy from artificial or natural environmental sources are facing. Conversely, the phrase "smart city" describes the degree of urbanization and technological development in a particular metropolis. Intelligence is defined differently in each nation or area. This provides the city regularly automates complicated issues and provides planners with information on the smart city. The creation of green energy sources to fight climate change and lower carbon emissions, quicker health care delivery services, improved energy and transportation networks (despite increasing urban congestion), safekeeping security intelligence services, prompt rescue operations in the event of a fire or natural disaster, and improved daily human habitation. In smart cities, physical assets are accessed and managed through web technologies. In order to give them sentience and to facilitate communication between them —whether between machines or humans—things are connected to the internet. The smart city uses tactile data from the Internet of Things to allow the planner to complete the positive details connected to the specific demands of the city (Hoang et al., 2021; Kim et al., 2021). This is the fundamental concept of an Internet of Things-enabled smart city. To put it briefly, A network of gadgets or individuals is known as the Internet of Things, or IoT. that can communicate with cloud-hosted devices. Online or cloud-based communication between objects or between people and products is made possible by the Internet of Things (IoT), which uses the various sensors located throughout the city to transmit data between physically connected IoT devices. Therefore, both wired and wireless internet-enabled devices, such as sensors, RFID tags, telemedicine networks, phones, actuators, and so forth, are commonly included in the Internet of Things. Rapid access to data about intelligent cities for self-governing planning and their capacity to sustain daily living and human life is made possible by the Internet of Things (IoT). Figure 1 illustrates this. Smart cities, a state-of-the-art approach to urban management, will raise sustainability and inhabitants' quality of life. Furthermore, initiatives that incorporate digitization and smart cities must be worthwhile in order to enhance ecological and economic sustainability. This greater value, however, becomes clearer when the advantages are first subtracted from the efforts. Building infrastructure in smart cities is a problem that requires the use of contemporary techniques that use less energy and have a less environmental impact. The creation of "smart buildings" and an improved transit system are essential to combating environmental problems, including climate change. The balanced energy exchange of a smart city necessitates an automated system that can manage itself and transform electric energy into a final product with the least amount of human involvement. Smart cities are combining several to balance power output and demand, reduce generation capacity, and have an impact on other energy market players, energy, heat, gas, and water systems are combined into one system. Electrical power, or the transition of civilization to electricity as its main energy source, is essential to the long-term viability of the energy sector.

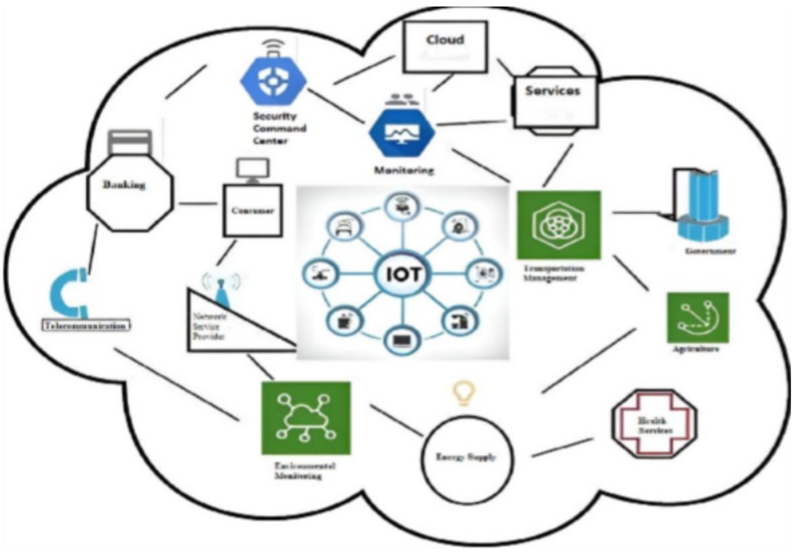

**Figure 3.1**. The Internet of Things

Many The Internet of Things (IoT) is no longer seen by some demographic groupings as unattainable. For example, modernizing the Internet of Things (IoT) paradigm has become essential because to the COVID-19 epidemic and the corresponding activity lockdowns in almost every country. In order to keep the peace during this pandemic, most nations have chosen to rely on internet and IoT innovation as a vital safety net. For linked devices to function constantly, the Internet of Things needs an energy source. How connected devices and/or IoT nodes might be fueled to continually send data to planners is the question that raises the most concerns regarding the adoption of smart cities and their sustainability. Researchers have carried out a number of studies to control and maintain the energy delivery at various times to WSNs and subsequently IoT nodes. Energy management systems can reduce the energy consumption of smart buildings, according to several worldwide research. In 2002, the European Parliament released suggestions aimed at improving the energy efficiency of buildings. By 2022, experts predict that over 500 smart devices will be connected in smart buildings. Therefore, raising awareness of the growing energy needs of Internet of Things technology is crucial. The Internet of Things, which consists of devices that require more energy than WSNs, is the most crucial node in a smart city. It is important to comprehend how problems with wireless sensor networks (WSNs) and Internet of Things devices are taking the place of problems with energy supplies. This is the result of the successful integration of cloud server (web) technologies, mobile network computing, and WSNs by the Internet of Things—all of which have found useful applications in contemporary life. This review focuses on the available urban energy sources and the different conversion techniques that can be applied. This is how connected IoT devices generate electricity in a smart city. To address the problem of battery replacement, the Internet of Things will be widely used, self-sufficient, and equipped with durable energy sources. This is due to the fact that replacing dead batteries in Internet of Things devices that are used in hazardous or difficult-to-reach locations can be extremely difficult (De Guimarães et al., 2020). We also discussed the notable decreases in maintenance expenses. Energy collection solutions offer a variety of potential benefits and unique characteristics for the near and distant future, especially with the introduction of 5G innovation in 2020 and the next 6G or beyond 5G, IoT, and remote communications innovation in general. Self-maintainable capabilities, ubiquitous energy, a reduced carbon footprint, no battery maintenance, and possibly no grid connection are some of these advantages. Current batteries and framework-worked correspondences cannot accomplish these. Additionally, they are easily transported to dangerous, toxic, and inaccessible locations. The Internet of Things (IoT) is one way that energy-harvesting techniques are being used in our study. The

Internet of Medical Things (IoMT), Internet of Mobile Things (IoMobT), Internet of Remote Things (IoRT), and Internet of Environmental Things (IoET) are a few examples of these. To collect real-time data for automated smart cities, the Internet of Things network requires a dependable energy supply from energy-collecting devices. The sources of ambient energy that can be produced in any city are examined in this analysis. Many academics have written on these sources in the literature. There has been much discussion on the benefits of energy gathering. In this analysis, our main objective is to demonstrate that Internet of Things applications may produce energy locally. As a result, we have analyzed and grouped several energy-harvesting devices that are now on the market based on the most recent studies carried out by different academics. Every energy transduction mechanism's output power and, in some situations, efficiency has been examined. The physical or chemical occurrences around the procedures performed and their merit ratings served as our primary classification criteria.

The production of our summary, which is displayed in Table 1, was the primary outcome of the review. The harvester model type, possible output power, and our information sources are shown in the table. The need to gather energy from other sources to store in batteries or refresh the batteries in IoT nodes was eliminated when we discovered that energy could be collected directly at the precise location of the application. Vibration, heat, sunlight, wind, radio frequency, water, and many more naturally occurring sources are examples of ambient energy (Neffati et al., 2021). In order to ensure that Internet of Things technology is always accessible and functional, innovative techniques such as those depicted in Figure 2 have been developed. The EH can supply the energy needed for the IoT to run consistently and everywhere.

**Table 3.1.** Types of sensors utilized in various smart city application division

| Subcategory | Sensing Parameters | Type of Sensors | Distance GW-Sensor |
|---|---|---|---|
| Agriculture | Humidity, Temperature, Luminosity, Solar radiation, Soil, Conductivity, Ph | Ultrasonic Temperatur e Humidity Soil | 30 cm–15 km |
| Healthcare | Health signs | Biosensors | 3 m |
| Energy | Light intensity Motion Voltage Temperature Humidity | Temperature Humidity Motion | 15 km |
| Traffic | Motion Occupancy | Magnetic Ultrasonic | 500 m–1 km |
| Environment | $CO_2$, $NO_2$, $O_3$ Concentration Weather | Gas Temperature | 200 cm–5 km |

**Figure 3.2.** An energy collecting framework for a smart city.

Since it enables researchers to become acquainted with the texts and determine which renowned writers who have written about the subject, and the literature survey is the foundation of scientific writing. We employed a method of systematic analysis for the literature review. The search terms the systematic review employed the terms "energy harvesting," "Internet of Things," and "sustainable smart cities" to locate papers in extensive databases. This study looks at a number of green energy-gathering methods in light of the creative applications of edge-based intelligent urban computing for smart and sustainable cities. The five categories of energy-harvesting methods include smart cities, smart ecological frameworks, smart transportation networks, and smart electrical grids that are now in use. This study examines common algorithms, evaluation standards, and evaluation settings to give a Technical description of environmentally friendly city computation energy extraction and systems for management. The following are recommendations made by the authors:

1. Learn how to power Internet of Things (IoT) nodes that are widely distributed and reliable.

2. The bulk of urban energy sources that scholars have reported in the literature were examined in this study.

3. Energy collection is one method that has been suggested that would allow IoT hubs will look for self-sufficient, ecologically varied energy sources.

This assessment concludes with the paragraph "Contemporary Energy-Harvesting Techniques in a Smart City." The vast majority of methods used by researchers and developers to convert energies from either organic or artificial events into a quantity were compiled and classified in this area sufficient to power sensors and Internet of Things nodes. A concise, easily legible table summarizing our results, listing most of the accessible energies, and, in some cases, the efficiency of the transduction system is shown in the next section. The information sources and the research year were provided. Our findings were derived on studies conducted about ten years ago. Finally, we have illustrated the importance of energy harvesting through smart city applications (Liu et al., 2019). The final section explains It encourages the collection of electrical power from Internet of Things devices in close proximity to applications.

### 3.2 The Most Recent Advances in Smart City Energy Harvesting Systems (SOA)

IoT node batteries were the subject of earlier power studies. By making the batteries smaller, the entire network was intended to demand less upkeep and extending the life of the batteries and other components. The reduced power usage of the various microprocessors, integrated sensors, and actuators utilized in Internet of Things devices was one of the primary causes of this. Following that, research was done to determine how to simultaneously decrease battery size, boost battery efficiency, and prolong battery life. Event-driven methods and duty cycling were found to be essential in a number of studies. They thought that some components might save electricity by going into an idle state while not in use. Travelling to the precise locations of IoT nodes will still incur some expenses related to maintenance despite all of these efforts and changing batteries. When IoT devices are placed in hazardous, difficult-to-reach locations in smart cities, battery replacement will become difficult. However, if they are in hazardous locations and need emergency or smart city rescue applications, it will be more challenging. Every city has a variety of ambient sources for energy scavenging, and there are a variety of techniques for doing so (Akin-Ponnle & Carvalho, 2021). The most common energy sources in cities, including radio frequency, mechanical vibration, thermal radiation, and solar radiation, are discussed in this review.

#### 3.2.1. Mechanical Vibration Energy Harvesting (VEH)

Because of the almost constant mechanical and/or human activity, mechanical ambient vibration energy can be effectively converted into electrical energy for Internet of Things devices. Studies show that vibration energy can be produced by a variety of activities, such as walking, the impact of a navy boot heel on the ground, an external transmitter, the vibration of a bridge, AC power lines, a bus or subway handrail, and more. The literature contains a large number of experimental and applied research papers on vibration energy-harvesting (VEH) transduction. Electrostatic, turbine, electromagnetic, and piezoelectric are the four primary categories of VEH mechanisms (Sun et al., 2021; Pompigna & Mauro, 2021). Occasionally, performance was enhanced by combining two or more of these strategies.

#### 3.2.2. Energy Harvesting via Electromagnetic Vibrations

An electromotive force (EMF) is generated in accordance with Faraday's Electromagnetic Induction Law. Since it enables researchers to become acquainted with the texts and identify the most renowned authors who have written on the topic, the literature review is the foundation of scientific writing. We employed a method of systematic analysis for the literature review. The search terms "energy harvesting," "Internet of Things," and "sustainable smart cities" were used in the systematic review to find publications in large databases. This study looks at a number of green energy- gathering methods in light of the creative applications of edge-based intelligent urban computing for smart and sustainable cities. Smart grids, smart environmental systems, smart transportation systems, and smart cities are the five types of energy-harvesting techniques that are now in use. Based on current algorithms, evaluation criteria, and evaluation environments, this paper presents a technical overview of energy-harvesting management systems for green urban computing. The following actions have been recommended by the authors:

1. Identify the best way to power Internet of Things (IoT) nodes that are broadly distributed and sturdy.

2. Most urban energy sources reported by researchers in the literature have been examined in this study.

3. One suggested method that would allow IoT hubs to search for environmentally diverse sources of self-sustaining energy is energy collecting.

This assessment concludes with the paragraph "Contemporary Energy-Harvesting Techniques in a Smart City." This section gathered and categorized the great majority of techniques engineers and scientists have employed to transform energy from man-made or natural events into a quantity sufficient to power sensors and Internet of Things nodes. A concise, easily legible table summarizing our results, listing most of the accessible energies, and, in some cases, the efficiency of the transduction system is shown in the next section. The information sources and the research year were provided. Our findings were derived on studies conducted about ten years ago. Finally, we have illustrated the importance of energy harvesting through smart city applications (Muscat et al., 2022; Wang et al., 2021). The final section explains and supports the need to gather energy from Internet of Things devices near applications.

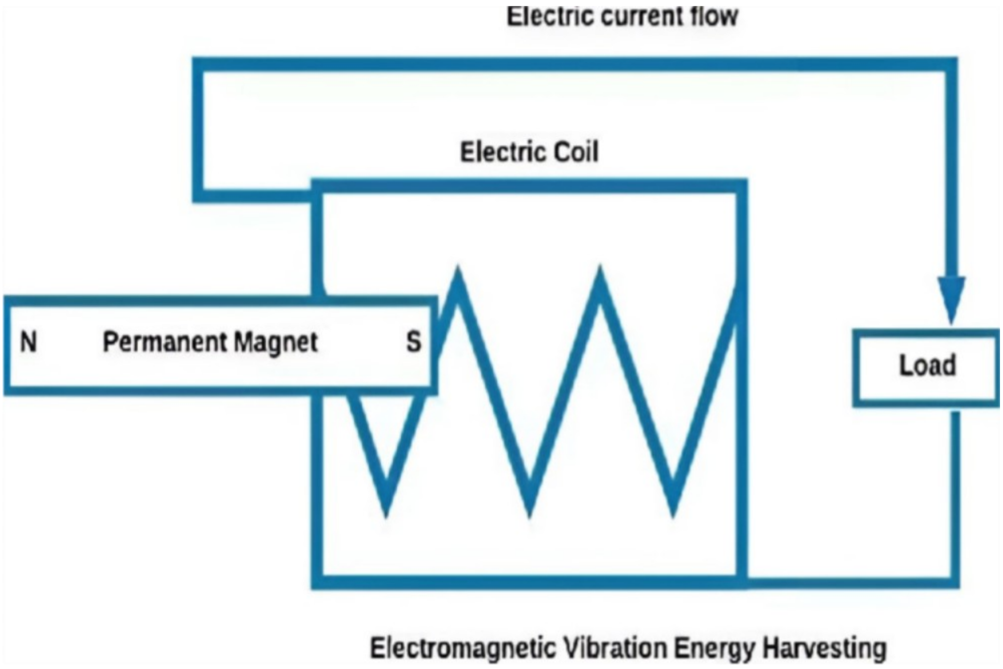


Figure 3.3. Electromagnetic Vibration Energy Harvesting.

### 3. 3 Intelligent Urban Computing and Energy Harvesting Management

Energy-harvesting techniques are coupled with the best on-time efforts and optimal solutions to reduce energy and power consumption in the IoT ecosystem and provide sophisticated and ubiquitous intelligent urban computing (Bibri, 2021). This section arranges energy-harvesting techniques on platforms for intelligent urban computing using a technological taxonomy. Figure 3 displays the taxonomy we suggested for energy-harvesting systems based on the literature review. Numerous energy-harvesting techniques are covered in this topic, including deep learning, fuzzy logic and methodology, supervised and unsupervised machine learning algorithms, and algorithms inspired by nature and evolution. Nonetheless, the intelligent urban computing platforms covered in this part can be categorized into four main groups: smart grids, smart homes, smart cities, and smart environmental systems (Lu et al., 2021; Bibri, 2021; Li et al., 2021).

#### 3.3.1. The Home with Intelligence

Energy harvesting in smart homes is one of the most prevalent problems with IoT devices. Management operations and support operations are the two types. The assistive operations function of a smart home gives consumers basic help with everyday chores. Additionally, because of their administrative duties, smart houses offer unique potential (Gordon et al., 2020). Examples of these responsibilities include keeping an eye on the energy efficiency of the house and regulating the lights and appliances to use less energy while still satisfying the needs of the residents (Deng et al., 2021). The automatic setting of various smart home components is depicted in Figure 4: A basic remote control may be used to operate every lightbulb in your house. The light can be programmed to go on or off automatically after a specified amount of time, and its brightness and intensity can be changed. Every switch in a smart home can be turned off remotely. It is possible to program timers to turn specific gadgets on and off. A pair of home security cameras is one of the most important and necessary parts of a smart home. Any activity that takes place inside the house can be tracked with the use of sophisticated sensors. With intelligent entry software, you can digitally manage who can enter your house and how your doors and entrances operate. The automated thermostat in a smart house might change the temperature by itself. Last but not least, smart homes can increase energy efficiency and lower energy usage by utilizing door lock and lighting systems. Four publications in this category classify existing energy-harvesting techniques for Internet of Things applications related to smart homes. Participants in the study emphasized a very advanced home health and patient monitoring system (Cibas & Ali, 2017). This experiment made advantage of Internet of Things technologies. Low-power data, including body temperature, heart rate, ambient and contextual information, and galvanic skin reaction, can be wirelessly transmitted to system gates by sensor nodes. Both solar and radio energy generation have been used to power the sensor nodes. There are also instances of energy production using radio frequencies, rectifier circuits, and multiband antennas. The generated and existing voltages were found to be sufficient for connecting the sensor nodes in a room sensor powered by photovoltaic (PV) solar cells.

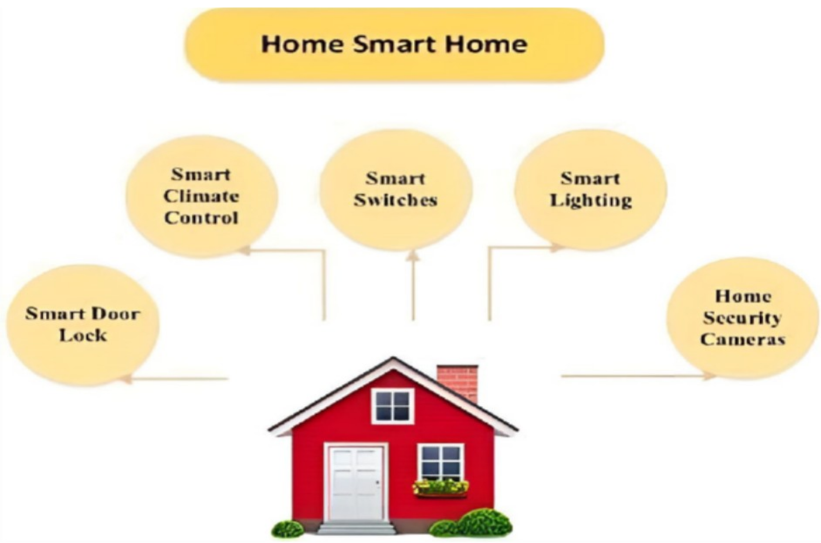


Figure3.4. Smart Home.

It was suggested that integrated, battery-free sensors aimed at smart houses use thermoelectric strength collection. Similar applications include vacuum-isolated plates for battery-free tension- feeling structures. The plates might be used to push a wireless detector to determine their strain grade because of their significant increase in heating and cooling power consumption. utilizing validated climate data, they first constructed a prototype utilizing the available strength. After that, a vacuum-isolated plate was attached to the thermoelectric generator and examined via a window to measure its extraordinary electrical strength. The authors discovered that a sensor node may be operated on the anticipated temperature slope. They demonstrated how thermoelectric power collecting could enable a new class of implanted, low-maintenance, battery-free smart home sensors. Any electrical equipment in the house can wirelessly receive data thanks to the energy produced by standing on the ground tiles made by (Kim & Asbury, 2020). The optimal output zone for power extraction is the octahedral–tetragonal step border, which offers an immediate advantage for balanced power generation. The authors also developed a portable robotic piezoelectric transducer that may be activated by a foot switch. The primary appliance's transmitter changes device and a wireless transmission scanner network work together to effectively control the feedback impedance that a person experiences from their steps. The easily modifiable tiles, according to the study, give individuals hope for a smart home in the future, with potential applications for those with mental health issues. Citation (Cappellini et al., 2020) has developed a dependable smart home switch system that combines wireless connectivity for smart outlets and ports, access to the house electrical network, and power generation and processing for complex electric modules and circuits. This article addresses safe fluorescent signals for ego energy storage in smart homes, as well as the concept and development of communication networks. The safety of electrical energy use in buildings is greatly improved by the device architecture outlined in this paper. Even better, the plan collects and stores energy that can be used by any digital device using energy buffer solar panels. In order to lower base energy use, the authors suggested a smart home that makes use of wireless ZigBee connectivity for energy management services. The message Queuing Telemetry Transport (MQTT) is used in the built-safe smart home for automation, control, and user-friendliness. Many concept testing have demonstrated improvements in the structure's safety and energy efficiency. As demonstrated in Figure 5, the emergence of smart cities is one of the most intriguing and challenging scenarios for a smart environment. These include power, lighting, education, housing, public health, and building. They cover a wide range of industries as well. This paragraph presents eleven research findings that illustrate the potential classification of various energy harvesting techniques for Internet of Things (IoT) applications.

In (Kaginalkar et al., 2021), a design that can manage high-data applications was proposed. To get over this problem, they have combined cloud computing and mobile computing technologies with the Internet of Things notion. This design's primary objective was to handle enormous volumes of data from images and videos. The benefit is that there is no need for communication between the three layers because each layer can independently gather the information needed to perform its duties. Making this idea rich and including a variety of applications is one of the author's objectives (Wood et al., 2020).


Figure 3.5. Smart City.

(Puspitawati et al., 2019) has proposed a strategy for allocating resources that splits them evenly between communication and radio. The authors' use of a time average rate to optimize computation improved the system's performance. Better bandwidth, edge job loading, and dynamic power decision-making are provided by the proposed method. When their own batteries run low, energy-harvesting gadgets may now temporarily store radio frequency signals in their bodies to power other devices, thanks to WET. By using Wireless Energy Transfer technology, which gathers signals, like radio frequencies, as energy and releases them in different states, UEs can use their maximum system computing capacity and rate without taking into account the energy sources that are necessary for UE. For massive fog computing networks, (Ullo & Sinha, 2020) suggested a ground-breaking dynamic network slicing technique.

This article focuses on fog computing systems that allow cloud data centers to expand by a large number of fog nodes spread over a large area. Each hub must obtain energy from the environment in order to offer computational services to the community. The authors describe the concept of dynamic network slicing in this section. A geographical orchestrator can theoretically distribute workloads among nearby fog nodes and deliver a specific type of service with exact quality of service assurances by carefully allocating energy and computing resources. Each component's resources can be quickly adjusted to meet service requirements and energy availability. Using actual BS location data from a system with more than 200 BSs in Dublin, the authors' concept's functionality is developed and its substructure evaluated. Scalar investigations show that once fog computing is qualified, the authors' substructure significantly increases the burden. They discussed modern scavenging techniques for independent ICT applications. When they looked at better power sources and alternatives including paper, RF signals, and energy gathering devices, they discovered the shortcomings of conventional sensor node power sources like batteries. In order to track the sensor nodes in real-time and document their concentrated, less energy-scavenging actions, the researchers used inkjet technology to produce a three-dimensional RFID cubic antenna. A wireless sensor transmitter prototype was then used to show the scavengers' inerrability, and Satao's Stairgate 64 Antenna Chamber system was used to measure the module's radiation diagram. They evaluated the efficiency of their equipment and established its frequencies for energy collecting in a variety of locations, primarily in Tokyo, including train stations, laboratories, city streets, and open spaces. The results of the experiment show that the radiation emissions from broadcasting equipment change with frequency. The possible calorie intake of a normal Tokyo worker's day is also displayed in charts. Proposed an Omnidirectional Biomechanical Energy Harvesting Block (OBEH) that might use human movement to generate electricity (Ismagilova et al., 2019). Just to move about on a daily basis, humans need a lot of mechanical electricity. The development of IoT will soon make the sparkling city's age accessible. After all, there are a number of drawbacks to chemical batteries, which are utilized in wireless sensors and related applications. To accomplish the goal of a smart city, WSNs must function more sustainably. As a safeguard, a self-generating power infrastructure should be established to lessen dependency on batteries. This article outlines a successful design approach for the OBEH walkway block. The first section discusses tracking footprints, the second discusses modeling output outcomes, and the third discusses reliability and optimizing OBEH walkway blocks. Two types of haphazardness are identified by this study: slow haphazardness and haphazardness related to step size and bearing.

The outcome energy provided by an annular piezoelectric layer affixed to the core of the primary layer was enhanced while achieving the exacting goal quality of 99.87% using the

Dependability Mindful Planning problem. For cognitive IoT networks with RF power collection, a 5G support organization model was introduced. This framework aims to increase output, convince customers of the advantages of the services, and lower the control energy consumption of each IoT sign. The results demonstrate the similarity between voracious computing and the simplex technique in the proposed structure. For its upcoming IoT projects, this group will concentrate on the NOMA-based stock management zone. To build a single public network system that would mostly incorporate aspects of any of these difficulties, the concept of merging the capabilities of a Wireless Sensor Network (WSN) with a Wi-Fi access system was proposed (2012). By extending organizational chains from the distribution of end-user products and perceived information security via the group's Wi-Fi access network to information identification at specific IoT device levels, the interdisciplinary design of the proposed device makes the end-to-end technique possible. The proposed structure can be regarded as environmentally sensitive since it employs multiple methods to regulate the energy consumption of the WSN protector's constituent parts. The WSN system uses a virtualization sensor and a green, decentralized justification design to lower overall network energy consumption. The city-scale Wi-Fi connection point content aggregation, which also incorporates user-side data consumption and automatic content distribution, enables users to access the internet from any location. Another aspect of the WSN concept is the gathering of real-time measurements related to the atmospheric properties of genuine artifacts.

### 3.3.2. The Light Grid

The project creates multipurpose smart grid gadgets that can be controlled remotely. A dynamic, bidirectional, decentralized energy generation and sharing model that is deployed at the edge and closer to the user can now take the place of the traditional passive, centralized smart grid paradigm. We must acknowledge that the administration of the smart grid requires software and its design rather than the physical principles themselves as it gets closer. Figure 6 illustrates the importance of energy optimization and renewable energy for sustainable energy collection and smart grid mitigation. The energy-conscious smart grid can leverage IoT technologies for power-electric flow management, smart metering, smart charging, and piezoelectric energy harvesting. IoT can be used by smart grids to boost energy efficiency, boost the proportion of renewable energy, and reduce the negative environmental effects of energy use. Six publications in this category classify the current smart grid energy harvesting methods used in Internet of Things applications.The creation of a smart city that makes use of piezoelectric energy harvesting has made this service accessible. Piezoelectric materials transform vibrational energy into electrical energy. Piezoelectric devices use titanium lead zirconated (PZT), a nonconductive substance. It sits between two metal plates and is fastened to a base. Despite being more costly than alternative power generation methods, piezoelectric power generation is environmentally friendly. In this work, switch bias is eliminated by using a piezoelectric vibration oscillator to produce a sine wave at the required frequency and voltage. The energy efficiency of this lossless, renewable system is better. Among the low-consumption applications of the technology are wireless sensor networks, medical body networks, and agriculture. Ref. (Hoang et al., 2020) offered a framework for an energy-saving strategy that preserves customer privacy. Determining how much energy each person requires and how much energy is lost as a result of non-suppliers' influence is the aim. By analyzing every element, including data security and energy dissipation, they assessed client security and energy efficiency (Fletcher et al., 2019). They also discovered that utilizing a device to get information uses more energy and yields the client's secret while using less energy. The advantage of this study was that it examined rechargeable batteries with limited storage capacity and found a device known as the EH that could generate discrete amounts of energy at each moment in an independent distribution that was equally distributed. These batteries efficiently prepare energy by storing extra energy for later use. By not disclosing to the manufacturer how each electrical gadget is used, they can also improve privacy. A range of ideas and resources for using body energy to power assistive devices were examined in Ref. (Lund et al., 2017) in their research led to the development of a ground-breaking system that used a range of transducers to boost power output and prolong battery life, outperforming previous methods.

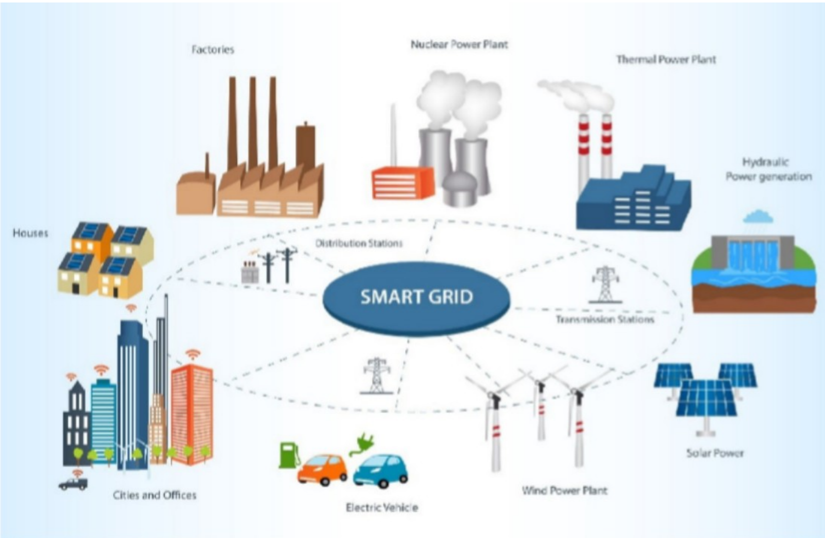


Figure 3.6. Applications of the Internet of Things smart grid for intelligent urban computing.

The authors used human-worn piezoelectric generators and DC-DC converters to assess their work. Even though the generated method is currently impractical, it might still be helpful because it offers a new concept. (Yarashynskaya & Prus, 2022) Suggested an IoT-enabled strategy to increase the smart grid's utility with the internet of things. This framework's nodes are cordless IoT widgets and internet-connected system- generating components. This architecture addresses a spectrum imbalance, enhances band performance, and reduces a band's cacophonous moods by utilizing incompatible channels and cognitive radio. The cordless widget's lifespan and supply shortage problem were among the many elements that were enhanced by the energy scavenging technology, or EH. Consequently, the authors released an energy-harvesting IoT-enabled cognitive system and an innovative networking architecture for the Internet of Things (IoT). The primary goal of future development will be to examine EH characteristics and energy consumption stability in order to achieve battery-free operation. The method forbids the devices from being recharged by connecting a dongle to them, but it does not limit the devices' use, mobility, or quantity of charged devices. To determine whether devices have this capability and are within the permitted range, this method makes advantage of device-to-device communication. Priority is determined by considering the battery's remaining capacity. The resonant coupling circuit is used to carry out the energy transfer process. According to the simulation's results, connecting to the charging system would probably take 10 to 20 seconds. Furthermore, regardless of the user's mobility, performance is greatly enhanced by using high- quality amplifiers. Its advantages include allowing users to roam around while charging, prioritizing charging according to the device's remaining battery life, utilizing the system both indoors and outdoors, and providing a premium version that allows users to prioritize charging even further. The suggested technology may be used in future mobile devices such as electric vehicles. A method for power storage and energy distribution based on radio frequency has been suggested. This method requires a large, energy-collecting antenna on the receiving device. Here, lowering energy use and increasing energy efficiency are the goals. From a programming standpoint, it is challenging to combine the subcarrier and the power consumption component to accomplish this purpose. The study's findings demonstrate that this novel power depletion process accelerates energy supply and reserve, particularly in situations when there are more users than devices interacting with one another. 3. 4. Intelligent Environment Frameworks

Poor air quality and tainted water supplies are the main causes of the real environmental issues we are currently facing. If the world is to support sustainable growth, a healthy community must be maintained. In recent years, environment monitoring has developed into a smart environment monitoring system, mostly due to improvements in sensors and Internet of Things (IoT) technologies. The term "smart environment" refers to the range of tools and solutions that modern technology provides for a number of environmental problems, such as resource waste management, air and water pollution, and other environmental indicators. Poor air quality and tainted water supplies are the main causes of the real environmental issues we are currently facing. If the world is to support sustainable growth, a healthy community must be maintained. In recent years, environment monitoring has developed into a smart environment monitoring system, mostly due to improvements in sensors and Internet of Things (IoT) technologies (Puspitawati et al., 2019; Ullo & Sinha, 2020). In order to power water measurement sensors, a study on the inline vertical cross-flow generator for future hydroelectric power harvesting within water inventory channels was given. To determine the best construction, the water-producing device's block structure shapes were computationally analyzed. The observational results showed that the computational approach used in this study to evaluate this micro-water generator's efficacy was valid. (Ismagilova et al., 2019) Created a dependable solar energy harvesting control system for managing micro grids in smart buildings. The proposed approach utilizes augmentation and control computations, as well as distributed and parallel computing. The hardware implementation of the suggested method is tested on the roof of a twelve-story building using a micro grid equipped with a power velocity array and a power velocity tracking system. Experiments have shown that the proposed design works well and achieves the required resilience and dependability. These robust, well-designed, loT-enabled control systems are energy sustainable and fully tolerant due to their fast self-recovery and ubiquitous computing capabilities. The intricate 3D stream field of the turbines has been replicated using computational fluid dynamics (CFD) simulations and artificial intelligence (AI) calculations, such as Fake Brain Organizations (ANN). While ANSYS is used for simulation, Simulink, a MATLAB application, is used to construct artificial neural networks. According to the research, RWTs will produce less noise than traditional turbines, employ more robust and recyclable materials, and improve safety for both people and animals. The turbine also outperforms other turbines in terms of Power Coefficient (Cp). It has been demonstrated how to use solar panels to prolong the life of a fog computing network. Fog nodes often rely on batteries, thus figuring out how to efficiently manage their energy can extend their lifespan. Before allocating the hubs their offloading needs, they categorized them based on cost and energy usage using the Energy-Effective Calculation Offloading (EECO) technique. Smart energy management can forecast the energy use of the nodes by contracting out computation to edge servers. The researchers' method improved network longevity by 20% and 100%, respectively, as compared to fog networks that were fueled by solar panels. Citation (Hoang et al., 2020) Recharging the WSN's battery with solar energy is one way to solve the finite vigoro layout problem. Even in earlier WSN versions, energy collecting is made possible by the ZIGBEE network, which is employed in this method.The simulations were conducted using the Net Sim simulator. The simulation results demonstrate that the proposed method mounts all parameters using a drawing technique suitable for the placement and direction of the substrates (application layers two and three), releases a more useful IoT- and vigoro-based platform for flexible farming monitoring, and optimizes the algorithm to reduce the energy required for the proposed method (Figure 3.7).

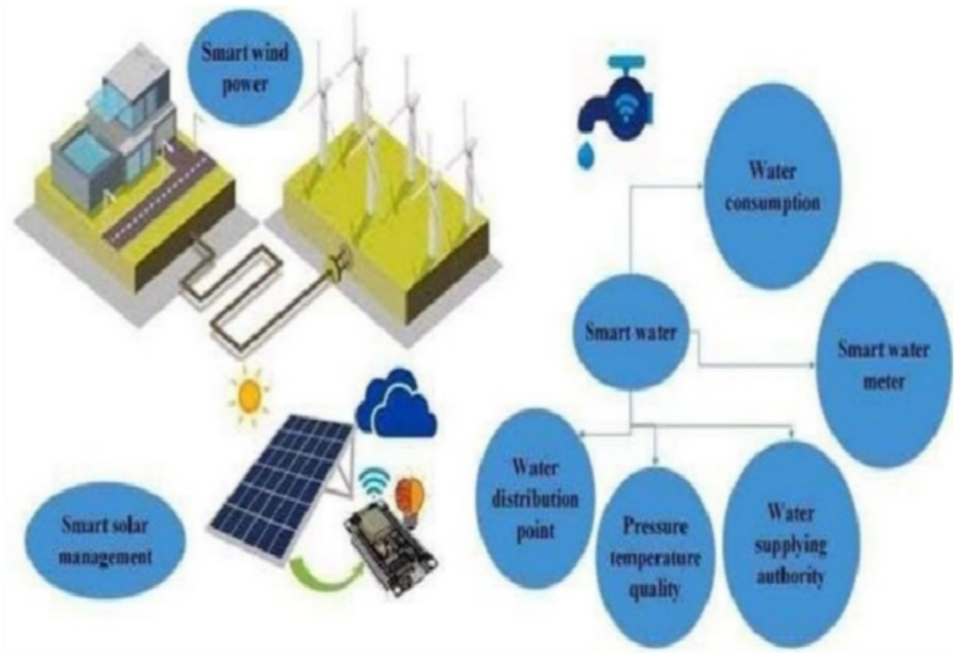


**Figure 3.7.** IoT applications of intelligent urban computing and smart environmental systems.

## 3.4 The Most Recent Publications Discuss "Smart Energy" Issues for an Effective and Efficient Energy Supply

### 3.4.1 Systems for Intelligent Energy Use and Intelligent Energy

In recent years, the terms "smart energy" and "smart energy systems" have gained popularity to refer to a strategy that goes beyond the definition of "smart grid." Unlike smart grids, which mainly concentrate on the electrical sector, smart energy systems incorporate other sectors (such as industry, buildings, transportation, heating, cooling, and power) in a more thorough and integrated manner. This makes it possible to find more practical and cheap strategies to make future transitions to sustainable and renewable energy sources.

An overview of the pertinent scientific literature opens this essay. The issues of defining, figuring out solutions, modeling, and incorporating storage are then examined in connection with the phrase "Smart Energy Systems." A scientific paradigm change away from single-sector thinking and toward an understanding of coherent energy systems that demonstrate how to benefit from the fusion of all infrastructures and sectors is reflected in the concept of a smart energy system (Lund et al., 2017).

### 3.4.2 An Examination of Urban Development Plans in Poland Analyzing Smart Cities' Smart Energy

To successfully and efficiently supply energy to meet the constantly rising energy demands of modern cities, it is essential to comprehend the condition of smart energy systems now and their future developments. A key element of the "Smart City" concept is smart energy. This study looks at how Polish concepts for smart city development incorporate the Smart Energy agenda using text analysis technologies. Stakeholder involvement, regional variables, Smart Energy principles, and Smart Energy core sectors were the most often referenced components of the Smart Energy agenda. Incorporating stakeholders into Smart Energy agendas involves essential players like public governance organizations, small businesses, and universities. The Smart Energy agenda's spatial dimension components include individual, municipal, regional (sub regional), national, and international (EU) levels; naturally, the city level is the most important. The "Smart Energy conceptions" component makes a clear distinction between the four "core" Smart Energy conceptions—energy security, energy efficiency, renewable energy, and energy-saving technology—and the "peripheral" conceptions. The only industries in the examined urban development plans that were found to be connected to the Smart Energy agenda were manufacturing, transportation, lighting, and construction. The study's conclusions suggest that Poland's energy and smart city planning environments are better understood, and that the cities' spatial planning techniques might be improved (Yarashynskaya & Prus, 2022).

### 3.4.3 Stochastic Operation: Optimizing the Smart Savona Campus as a Comprehensive

Local Energy Community while Accounting for Carbon Emissions and Energy Costs. By merging many energy sectors and leveraging the synergies that arise from the interaction of different energy carriers, sector coupling lowers carbon emissions and boosts the adoption of renewable energy sources. At the local level, sector coupling aligns nicely with the concept of an integrated local energy community (ILEC). An ILEC's active customers coordinate the use of many multicarrier energy solutions to determine the optimum strategy to meet their energy needs. Compared to the current situation, this has more positive effects on the economy and ecological. This paper investigates the economic and environmental aspects of optimizing stochastic operations on the smart Savona Campus of the University of Genoa. The campus is considered an ILEC with two electrically connected Mult Energy hubs that use combined heat and power systems, solar thermal, photovoltaic, absorption chillers, electric and geothermal heat pumps, and more. The ILEC can participate in the day-ahead market (DAM) from this position with the appropriate bidding strategies.The rapid forward selection approach reduces the computing burden of the subsequent optimization step while maintaining the most representative possibilities. The first set of solar irradiance scenarios is constructed using the roulette wheel method. Using a Multi-Objective approach, the bidding tactics of the ILECs in the DAM and the operating strategies of the different technologies in the ILEC are optimized by accounting for both energy prices and carbon emissions. MILP, or mixed-integer linear programming, is used to achieve this. The case study's findings show how the ILEC's optimal bidding strategies on the DAM can lower users' net daily expenses. The ILEC operates in self-consumption mode, which is comparable to environmental optimization (Di Somma et al., 2022).

### 3.4.4 Implementing Smart Cities with IoT Technologies

#### 3.4.4.1 Various Sensor Types for Smart Cities

Experts predict that 85% of the world's population will live in cities by 2050. Therefore, cities should be prepared to provide the best services and satisfy the needs of their citizens. One well-known example of the concept of a future metropolis is the smart city, a more efficient system that makes the most of its resources and services via the use of monitoring and communication technologies. Therefore, one of the things that cities throughout the world can do to become more sustainable is to make the transition to smart cities. Because they gather relevant data from the city, its citizens, and the related communication networks that convey it in real time, sensors are essential to this system. Despite their wide range of uses, these sensors fall into six categories: waste management, water, security, mobility, health, and energy. Based on these classifications, this study provides an overview of a number of sensors commonly used in smart city development projects. Along with a number of applications and communication technologies, the main advantages and challenges of creating a smart city are discussed. In the end, this process is about how these new developments in sensing and digitization enhance life quality, not only smart urban infrastructure. Communities that invest in, utilize, and adjust to these technologies in line with local and regional societal requirements and goals are considered smarter. Disruptions to cybersecurity and privacy remain significant flaws.

#### 3.4.4.2 A table listing the several IoT networks used in smart cities, including Bluetooth, LoRa, WSNs, and others, together with information on their advantages

**and disadvantages, energy consumption, etc.**

The benefits, drawbacks, and energy usage of IoT networks—such as LoRa, Bluetooth, Wireless Sensor Networks (WSNs), and others—used in smart cities are listed in Table 3.2.

Table 3.2 lists the advantages and disadvantages of different IoT networks, including Bluetooth, LoRa, WsNs, and others, as well as their energy consumption in smart cities.

| IoT Network | Advantages | Disadvantages | Energy Usage |
|---|---|---|---|
| LoRa | - Long-range communication<br>- Low power consumption<br>- Scalability | - Low data rate<br>- Limited bandwidth<br>- Not suitable for real-time applications | - Low power |
| WSNs | - Scalability<br>- Low power consumption<br>- Suitable for sensor data collection | - Limited range<br>- Network topology maintenance<br>- Limited processing capabilities | - Variable, depends on node activity |
| Bluetooth | Low power consumption<br>- Wide device compatibility<br>- Low cost | - Short range<br>- Interference in crowded environments | - Low power |
| Zigbee | - Low power consumption<br>- Scalability<br>- Suitable for home automation | - Limited scalability<br>- Limited range<br>- Interference from other wireless devices<br>- Limited data rate | - Low power |
| NB-IoT | - Wide-area coverage<br>- Low power consumption<br>- Suitable for large-scale deployments | - Costly infrastructure deployment<br>- Limited bandwidth<br>- Relatively higher device cost | - Low power |
| 5G | - High data rates<br>- Low latency<br>- Supports massive IoT devices | - Infrastructure deployment cost<br>- Limited range<br>- Energy-intensive for small devices | - Variable, depends on usage |

**CHAPTER 4**

## Creation of a comprehensive idea for smart cities that are both economical land environmentally sustainable

### Overview

The development of smart cities has become the most pressing global need due to the concerning patterns of pandemics and the quickening rate of climate change. In addition to incorporating artificial intelligence and the idea of "intelligent cities" involves information and communication technologies takes into account important factors including infrastructure development, the economy, society, and pandemic resilience. Elezaj et al. (2025) examined the financial metrics used to evaluate a green and sustainable city. In making their recommendation, they took into account the effects on the economy, ecology, technology, and environmental preservation. It is becoming more and more important to do research and put this all-encompassing idea of smart cities into practice. Cities' infrastructure is constantly under pressure to adapt and evolve due to the growing demand for resources, electricity, water, and transportation brought on by the world's population expansion (Valdez et al., 2018. The environment is directly impacted by these modifications and shifts, leading to adverse patterns including poor air quality and abrupt alterations in the climate and global climate change. The results of According to Jindal's review of the research and study of the environmental, social, and economic facets of the pursuit of ecological sustainability models and indicators have a direct influence on the operations of numerous sectors (Jindal, 2025).

More research is being done on the connection between economic expansion and environmental protection. Some of these new issues have been artistically and practically overcome because of the Internet of Things (IoT). One of the new projects of the century is the creation of "smart cities," (Anwar et al., 2021) which are automated, dependable, utilizing of information and communication technology (ICT) across several sectors, Mosannenzadeh et al. (2017) offers a thorough and interdisciplinary description of a smart city. These authors contend that efficiency, renewable energy, and energy conservation are the fundamental tenets of the smart city concept. Smart cities require energy management, but there are no economic, social, or environmental guiding principles. Chishti et al. (2025) has investigated how sustainable development is impacted by green ICT and its socioeconomic components in several regions of China. They examined the relationship between green ICT and human resources, urbanization, globalization, intensity of energy consumption, and carbon emissions.

They came to the conclusion that GCIT promotion can significantly boost green growth in Chinese provinces. Despite the need to improve sustainability, quality of life, safety, and health as well as transportation efficiency, many traditional urban centers are becoming insufficient and inefficient to fulfill the increasing demands of their population (Paes et al., 2023). They came to the conclusion that although social and economic issues are important, the smart city formula does not account for them. Closing this research gap is the aim of this project. For example, the Spanish electrical network is used to reproduce the Superconducting Magnetic Energy Storage (SMES) system, which has a number of benefits and drawbacks, such as the high cost of installation and maintenance (Colmenar-Santos et al., 2018). Additionally, (Fokaides et al.. 2018) offers a thorough framework for smart cities that includes a comprehensive energy model. This framework describes the fundamental components of an intelligent city and talks about numerous smart city efforts and standards. Along with contemporary developments in energy management in smart cities, such as metrics, big data processing, the role of zero energy buildings, and lifecycle evaluation in the smart city concept, technical standards and standardization initiatives are also covered. Abu-Rayash and Dincer (2021) to satisfy the needs of 5,000 families, an integrated solar system for smart city applications was developed. The system makes use of absorption refrigeration, photovoltaic thermal, and concentrated solar power. Ismagilova et al. (2019) Introduces smart cities from an information systems (IS) standpoint, emphasizing smart architecture, smart residents, smart government, smart living, smart transportation, smart environment, and associated technologies and ideas.

The connection between smart cities and the Sustainable Development Goals (SDGs) of the UN is also covered in this article. They assert that technology for smart cities has been widely studied. However, more recent research has adopted a more comprehensive approach, including sustainability, quality of life, and citizens. A more recent study Cai et al. (2023) examined 103 American towns to ascertain whether local adoption of smart cities is linked to sustainability results for municipalities. According to their research, smart city statements are available on the websites of more than 80% of the cities. Furthermore, compared to non-smart cities, smart cities typically exhibit superior sustainability results. This study's objective is to develop a conceptual model of an intelligent city and investigate how its numerous components interact with one another. The following are the study's four particular goals:

- To evaluate infrastructure and energy improvements to promote ecologically sustainable economies;
- To offer a thorough strategy that promotes the growth of smart cities across the globe.

Investigate the technological, economical, and environmental facets of smart cities; do parametric studies that assess the model's robustness and the connections across elements and fields, particularly those pertaining to facilities, energy, and the environment.

According to the current data, there is a direct and positive correlation between smart city applications and the environmental and economic sectors. The unique issues and challenges that each industry encounters can be addressed with the support of routine observation and information exchange. Additionally, intelligent programming and automation can aid in the creation of more reasonable and effective laws and regulations in general.

### 4. 2. Methodology and model development

A smart city's energy infrastructure needs to be constructed efficiently and unified so that a single system can accomplish multiple goals. These days, cogeneration power plants—also referred to as combined heat and power, or CHP—are widely used. In a similar vein, energy systems can supply numerous essential commodities and can be trigenerational, quad generational, and more.

Therefore, in order to create new and more effective technologies in a smart city, traditional energy- producing processes must be altered. Real-time data sharing on manufacturing, distribution, and consumption of energy improves the efficiency of these operations in the spirit of linking and exchanging data. Energy generation, delivery, and consumption are the three interrelated and mutually influencing parts of the energy ecosystem. Because of differences in availability, cost, and environmental effects, energy-producing technologies—whether nuclear, renewables, or fossil fuels—have a direct impact on consumption patterns. On the other hand, consumption levels generate demand for a variety of generating sources and affect the choice of energy infrastructure investments. To give customers a consistent and sustainable supply of electricity from generating sources in the interim, effective energy distribution infrastructure is required. The potential for changes to these elements to impact system-wide pricing, dependability, and environmental sustainability emphasizes the intricate relationship between energy generation, usage, and delivery. Energy savings at the transmission and consumer levels can be achieved through the use of smart meters and other Internet of Things solutions. Depending on usage patterns, Energy distribution can also be optimized through consumption control and conservation. Online access to energy statistics and data increases public knowledge and participation. The JRC and the OECD both created a thorough, detailed methodology for the smart city index. The smart city index is the model's final composite indicator, and these 10 processes ensure its high accuracy, reliability, and usefulness.

Additionally, Liu and Wen (2024) used multicriteria decision-making to do sustainability assessments for other cities by integrating their approach with deep learning capabilities. They evaluated the social, economic, and environmental conditions of sixteen Chinese cities in the province of Shandong. According to their findings, Jinan ought to concentrate on environmental metrics like wastewater treatment and green coverage. In addition, Binzhou ought to give social and environmental concerns—such as social insurance and healthcare—top priority.

### 4. 3. The factor of energy efficiency

One of the most important metrics for evaluating this topic is energy efficiency. Reduced energy expenses, reduced emissions, enhanced operational effectiveness, and enhanced asset value are characteristics of energy-efficient communities. The performance level that characterizes a process that uses the least amount of input to achieve more valuable output is called energy efficiency. Recall that the OECD (OECD.,2008) recommends that nations pursue energy efficiency in all spheres and views it as a critical indicator. Additionally, computational and thermodynamic frameworks for structures, energy systems, or other businesses can be used to quantify efficiency (Abu-Rayash, 2024). The first law of thermodynamics and energy efficiency are intimately associated. Therefore, the ratio of sound energy production to beginning energy intake is the definition of energy efficiency. According to Sharifishourabi et al. (2024), an intergenerational energy system designed for sustainable communities that uses solar and biomass power achieved overall energy and exergy efficiency of 71.25% and 36.68%, respectively.

### 4. 4. The factor of energy efficiency

Another important metric that provides a more thorough evaluation of efficiency than energy is energy efficiency. Energy efficiency emphasizes the need to assess internal irreversibility's and losses to improve performance. Although reduced energy efficiency indicate energy losses and internal irreversible reactions, higher exergy efficiencies indicate finer energy quality inside an energy system, making the system more sustainable (Hacatoglu et al., 2015).

### 4. 5. The Clean Energy Utilization metric

Keep in mind that there are numerous varieties of energy sources, including solid, gaseous, and liquid fuels, fossil fuels, and renewable energy sources. Nuclear power, and also the main sources of energy include fossil fuels like coal, oil, and natural gas as well as renewable energy sources like hydropower, geothermal, solar, and wind. Secondary energy sources are created from these fundamental sources of energy with a variety of applications, like electricity. The transportation industry uses a lot of energy. With 30% of

Ontario's overall energy consumption, after the industrial sector, the transportation sector uses the most energy. Therefore, in order to promote more sustainable growth, economic prosperity, and environmental protection, clean fuel must be used for transportation in smart cities. These days, the transportation industry uses a lot of gasoline and diesel as fuel. Sustainable energy sources benefit the economy, the environment, and eventually a more intelligent society. Because fossil fuels are readily available and reasonably priced, many municipalities increasingly rely on them to supply their base load energy demands. Nevertheless, there are disadvantages to exploiting these sources, such as political disputes, pollution, climate change, and social unhappiness. The 3S paradigm states that sources that are easily accessible, affordable, plentiful, and clean should be used in smart cities. To forecast air quality in smart city design planning, the Long Short-Term Memory (LSTM) assisted Staked Auto-Encoder (SAE) (LSTM-SAE) model was presented Liu and Zhang (2021).

## 4.6. The factor of energy storage

The technique of storing energy generated at one moment for use at a later time is known as energy storage. The concept of a smart city cannot be realized without energy storage. Storage is necessary when using renewable energy sources. Storage between the system and the source and between the system and the service is part of the 3S concept. Moreover, there are numerous ways to store energy, such as mechanical, thermal, electrochemical, and other chemical techniques. Smarter energy is typically found in cities with more options for energy storage. Using a similar criterion, Ishaq and Dincer (2024) investigates how decisions about on the impact of hydrogen and battery energy storage on a tri-renewable energy system to achieve durability in urban settings. The results show that their technology has an efficiency of 45.5% for storing hydrogen.

### The cost of energy

This area is also greatly impacted by the cost of energy. Cities with lower energy prices are thought to be more intelligent than those with higher energy costs. In this instance, this indicator [$/kWh] will be quantified using the levied cost of electricity (LCOE). Every community needs utilities because they supply and oversee vital resources like power, gas, and water. This domain is optimized and integrated with data analytics and optimization technologies to ensure the most profitable and efficient design while distributing these commodities. For instance, chemical leakage sensors are used to find factory waste and leaks in rivers and other bodies of water, and water monitoring is used to make sure the water quality is within an acceptable range, preventing contamination.

Water network control is further enhanced in a smart city concept by water outflows, liquid presence monitoring outside tanks, and pressure adjustments throughout pipelines. Grid power optimization is made possible by demand and response management, grid control and electricity use in real time. Since one-way electron flow was the original concept of the grid, the growth of renewable energy sources that feed into it requires enhancements to its operation to allow two-way communication inside the network. Similarly, gas and other fossil fuels are typically used for heating.

Demand control and improved gas line consumption and management are made possible by data monitoring of gas use across all sectors, including residential, institutional, and industrial. Furthermore, by keeping an eye on variables like temperature, pressure, and humidity, intelligent ventilation, lighting, and heating may be achieved. By modifying the HVAC systems based on the data gathered, the building's overall performance and system efficiency are enhanced. In urban settings, buildings are the main source of greenhouse gas (GHG) emissions (Morvaj et al., 2011). Thus, one of the most challenging jobs is to reduce building consumption without sacrificing occupant comfort. Actually, Moreno et al. (2014) examined building operations and energy efficiency from a municipal standpoint. Additionally, they suggested a number of energy-efficiency management systems that are connected to building automation control systems. Their strategy resulted in a 20% reduction in heating expenses, which equates to an 8% reduction in building energy use across the city. More access to data from buildings and the outside world is made possible by intelligent modeling and control technologies like Building Information Modeling (BIM). This information can subsequently be used to build Artificial Neural Network (ANN) techniques. With potential savings of roughly 30%, such models drastically cut down on energy use (O'Dwyer et al., 2019). Several processes, such as chieving energy efficiency in buildings from a city viewpoint involves a number of factors, including the building's design and structure, building envelope, energy systems and equipment, construction methods, performance management and monitoring, and end of life. To attain energy efficiency, a strategy must be implemented step-by-step. The design needs to be multi-targeted, integrated, and thorough. Other requirements for the building's structure are affordability, adaptability, and sustainability Moreno et al., 2014). Instead of being passive energy consumers, buildings can actively contribute to the power system, increasing their efficiency and environmental friendliness (Karnouskos, 2011). Real-time demand-response systems can be used to put this paradigm shift into practice. Clearly, intelligent controls and smart city concepts can influence short-term occurrences through automated decisions based on real-time data. Energy utilization will undoubtedly be decreased by gathering data from user actions and using it to suggest load control. The passive strategy and this energy-saving method are not exclusive. Since passive technology preserves and evenly distributes thermal energy throughout the structure—for instance, by preserving the integrity of the thermal insulation—it can continue to be a component of the energy strategy. Furthermore, as smart cities' energy needs must be met by nonpolluting renewable sources, it is anticipated that they will heavily utilize Near-Zergy-Energy-Buildings (NZEB) or Zero-Energy-Buildings (ZEB) (Lund et al., 2017).

### The role of technology infrastructure

The quantity of money invested demonstrates a city's readiness to address present issues and expand and improve its services. It is believed that intelligent cities are those that make constant improvements to their internal infrastructure. The money invested in infrastructure is utilized to evaluate this metric. Wang and Ma (2024) this feature was utilized to build a digital twin that mirrored a city's landscape design in order to promote urban sustainability. Their model enhances energy efficiency's demand-side management component.

### The parameter for green space

Urban planning is becoming increasingly important as cities grow and change into centers of civilizations and metropolitan areas. The percentage of green public areas in the entire city region and the number of airports in each city are used to evaluate this statistic. Greener cities are thought to be wiser than urban ones. Cheng et al. (2022) has looked into and created a lifetime estimate of how much city level bike sharing reduces greenhouse gas emissions. Green areas are preferable to the irrational urban transit system. According to their research, encouraging bike sharing can greatly lower emissions in Shanghai's transportation industry.

### The proportion of smart devices

This metric evaluates the proportion of smart device owners in each nation in the digital era. Smarter cities are believed to result from a greater uptake of smart gadgets. This is because residents now have more opportunities thanks to smart devices. This figure comes from the global cybersecurity index. It is a reliable source for assessing global cities' dedication to cybersecurity. The existence of organizational, technological, legal, capacity-building, and collaboration measures is the basis for evaluating the index. Supporting information was also gathered via an online poll. These questions were weighted to obtain an overall GCI score after consulting with experts. Using digital twins, Liu and Zoh (2024) came up with an inventive landscaping concept to make a city carbon neutral. Geographical limits are taken into consideration as they integrate storage facilities with distributed energy systems.

They intended to reduce greenhouse gas emissions, boost energy efficiency, and reduce operating expenses. Their findings show notable gains in power systems efficiency, including notable reductions in power loss, peak voltage swings, and temperature fluctuations.

### The parameter for water resources

The most precious resource on the planet is water. All living beings on this planet derive their life from it. Thus, water consumption is required. Water use is neither extravagant nor excessive in a smart city. Conversely, more intelligent civilizations make more sustainable and comfortable use of less water. Globally, the average person uses 742 m3 of water. By contrasting a city's per capita m3 consumption with the global average, this indicator is evaluated. A city's water supply needs to be self-sufficient for it to be prudent and sustainable. Water production is hence one metric used to evaluate this aspect of prudent resource management. It is always beneficial to increase a city's water production capability. However, if a city lacks self-regulated water production systems or produces its own water, it is not seen as intelligent. To be fully sustainable, a city needs a variety of factors. A comprehensive review of the built environment in the GCC by Imran Khan et al. (2024) found that 46 barriers, including social, technological, and policy ones, are impeding the implementation of building energy efficiency. Together with all of the equations and specifics in Table A1, Appendix A provides a summary of the methods by which each of these factors is assessed. This study compares the average water output of each participating city. Fig. 4.1 shows the entire model, including these three crucial indexes and additional significant features. The main objective of this article is to examine the effects of COVID-19 and these three categories on the idea of a smart city. Weighting is an essential part of data building. Each indicator is assigned a weight within its segmentation index following data normalization using the previously mentioned techniques. For more information, see Ref. Abu-Rayash and Dincer (2020) as previously mentioned, each index has four indications assigned to it for analysis and assessment.

## 4.7 Results and discussion

It is thought that both the weighting and aggregation processes are required for the construction of a composite model. Both principal component analysis and a multi-criteria decision analysis are taken into consideration in this work due to the multidisciplinary nature and diversity of indicators. Cairo, Addis Ababa, Cairo, Lima, Amman, Tunisia, and Abuja are all part of the first cluster. These cities' portfolios are probably comparable because of their close proximity to one another.

Moscow, Istanbul, and Kuala Lumpur make up the second cluster, which is located in the middle of the region. Western cities, including those in Helsinki, London, Osaka, Sydney, and Canada, make up the third cluster. Outliers like Doha and New York make up the last cluster. New York is special because of its excellent economy, transportation, and infrastructure. At 107%, the economic index value of Doha is higher than twice as high as the national average. This is due to Doha's small population and disproportionate GDP, which makes GDP per capita vital. In its most comprehensive suite, the economy index, Doha's Sustainability Triad program comes in at number four. Its score of 0.619, however, puts it in tenth place when all weights are equal. While the other methods do not account for the economic index, Doha is 0.549 and 0.546, respectively, according to the energy-focused and pandemic-focused systems. These results are further illustrated in Fig. 2. The accuracy and resilience of the model are demonstrated by the fairly surprising similarity of the average SCI across the four distinct weighting processes. The pandemic-focused plan presents the best opportunities for all cities except Lima, while the energy-focused strategy produces a more focused set of data with dire outcomes. Additionally, Fig. 4.2 illustrates how the equal weighting system affects the SCI results for each city. The construction of smart cities requires a complicated interplay between several policy aims, as evidenced by the fact that the energy-centered program created many negative consequences while the epidemic-centered one accomplished nearly all positive ones.

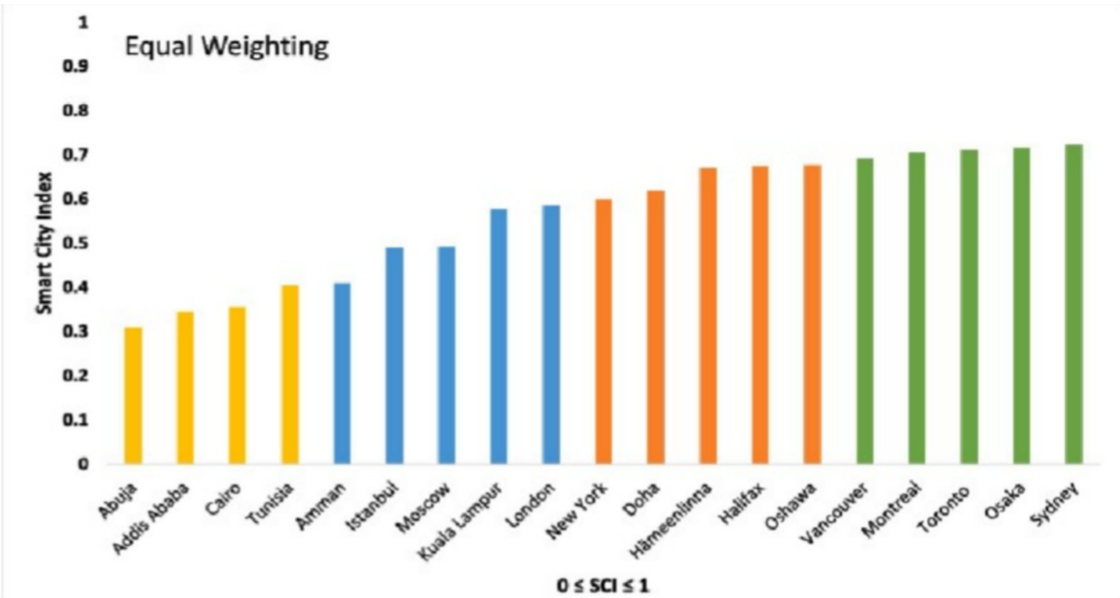


**Fig. 4.2.** The equal weighting scheme is the basis for the smart city index findings.

Although the excellent Although the results of the epidemic-centered program show that controlling and lessening the effects of epidemics like COVID-19 must be prioritized, this does not mean that policy should only concentrate on controlling infections.. Rather, it emphasizes how important it is to strike a balance between resolving public health emergencies and advancing sustainability and economic growth. If cities adopt a strategy of complete liberalization and disregard epidemic control and prevention strategies, they may become more exposed and dangerous. Therefore, in order to ensure the entire development of smart cities, the conclusion highlights the significance of implementing a complex and diversified approach that incorporates multiple policy objectives, such as economic growth, sustainability, and epidemic control. In this case, the Equal Weighting Scheme bar graph serves as the benchmark for evaluating the other systems. The scheme alterations only marginally alter the overall SCI for the majority of cities. For nearly all cities, the Energy Focused method yields lower SCI scores than the Equal Weighting strategy, as seen in Figures 4.3 and 4.4. On the other hand, the pandemic-focused strategy leads to increased SCI in places like Abuja, Addis Ababa, and Amman and lower SCI in Cairo, Lima, and New York.

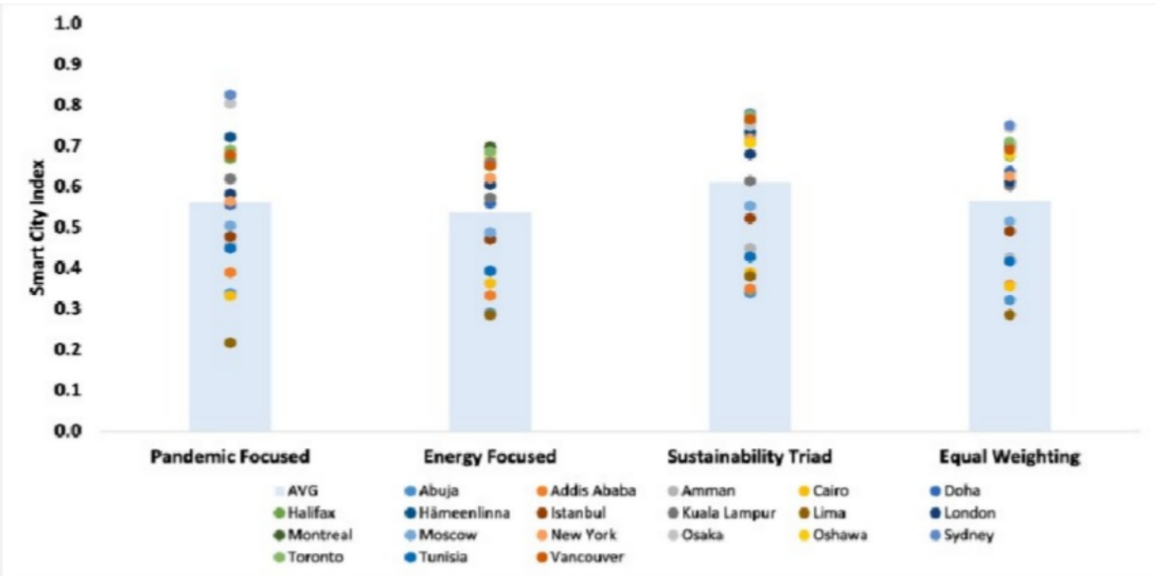


**Fig. 4.3.** The results of the smart city index are determined by the various weighting methodologies

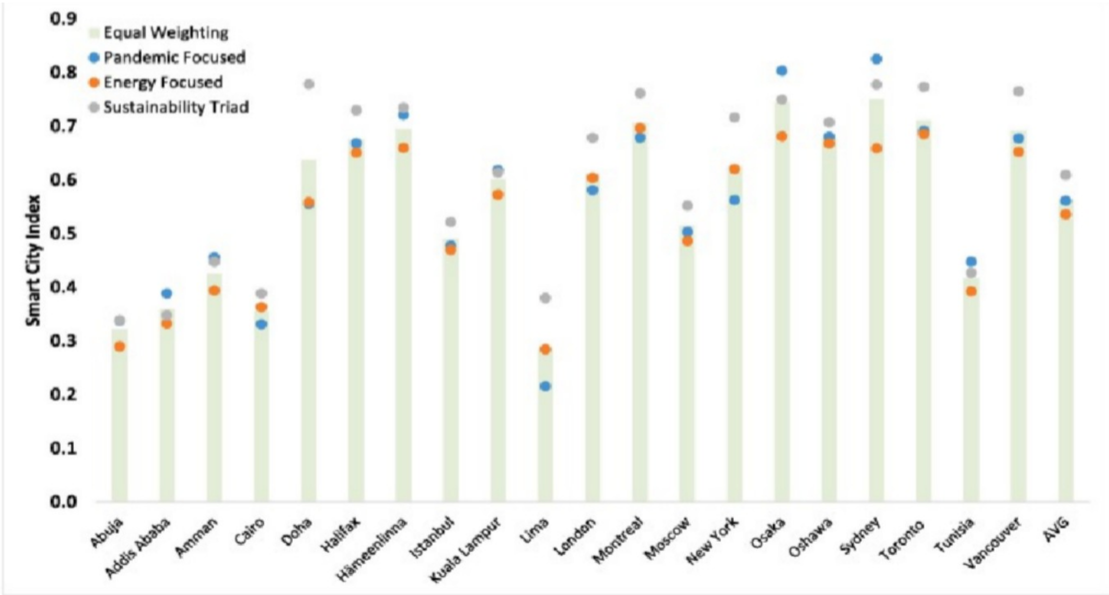


**Fig. 4.4.** The smart city index's results differ depending on the weighting scheme.

Another significant component of the energy is the economic index. Investments made to increase the energy index can have a significant positive impact on the economy. When enhancement occurs, there is an extraordinarily strong connection between the two indices, as seen by the significant R-value of 0.97. The findings also demonstrate that raising each city's smart energy index score by 25%, 50%, and 75% has an impact on the economic index that is produced. Doha was not included in this relationship because of its outlier smart economy index ratio of 172%. With greater populations and somewhat faster rates of economic growth, other cities around the world experience a similar scenario. Figure 4.5 illustrates the strong relationship between the social and economic worlds. This implies that the economic development and prosperity of the individual cities will be mostly attributable to investments in healthcare equity, education, and other social objectives. The R-value of 0.839 indicates that cities with a smarter economy index also have a wiser society index. Just as important as identifying the relationship between the social and economic field coefficients is analyzing the reasons for the link and how it contributes to the paper's model's rationality. Since social and economic challenges are entwined in the creation of smart cities, there is probably a strong correlation between them. Smart city initiatives often aim to increase economic success, diversity, and societal well-being. For example, spending on social infrastructure, healthcare, and education can result in a workforce that is more capable and productive, which will promote economic growth.

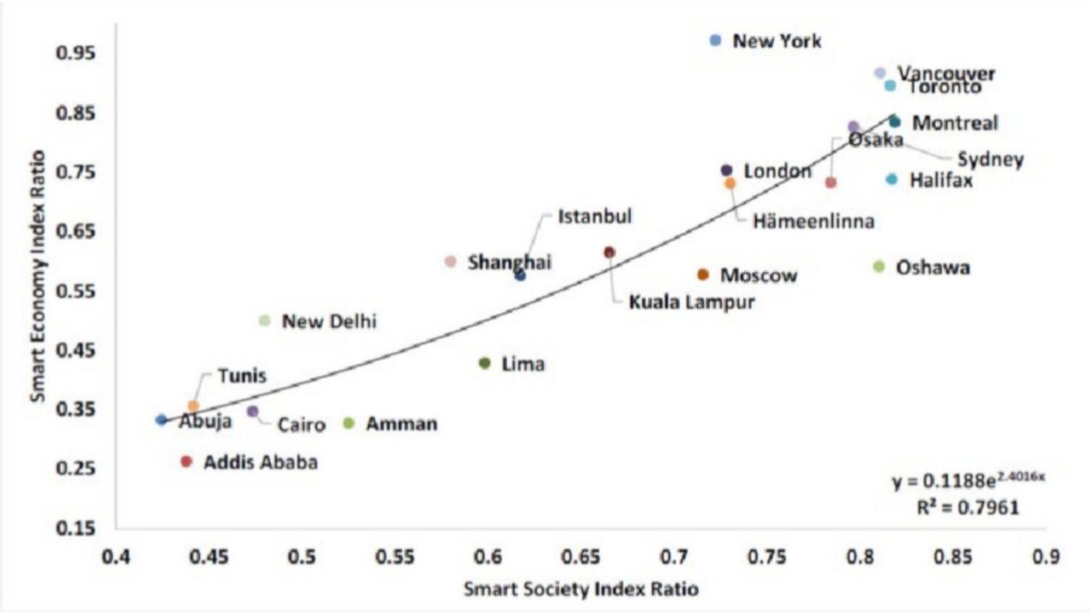


**Fig.4.5.** the connection between economic and societal indices

In a similar vein, social metrics such as access to essential services and the alleviation of poverty can benefit from economic developments like job creation and income growth. The model illustrates how social and economic elements interact to build the overall smart city landscape by showing a strong correlation between them. Because it emphasizes the necessity of comprehensive and integrated approaches to city development, this concept is essential for politicians and urban planners. When developing smart city policies, the idea urges policymakers to take into account the trade-offs and synergies between social and economic issues rather than focusing solely on one. Additionally, there is an exponential correlation between the environment and energy indices. Enhancing energy storage, increasing the usage of clean energy, and increasing energy efficiency have all been shown to reduce greenhouse gas emissions, improve waste management, and improve air quality. Additionally, this is a smarter energy index performance that ultimately preserves habitat. The relationship between these two indexes is depicted in Fig. 4.6.

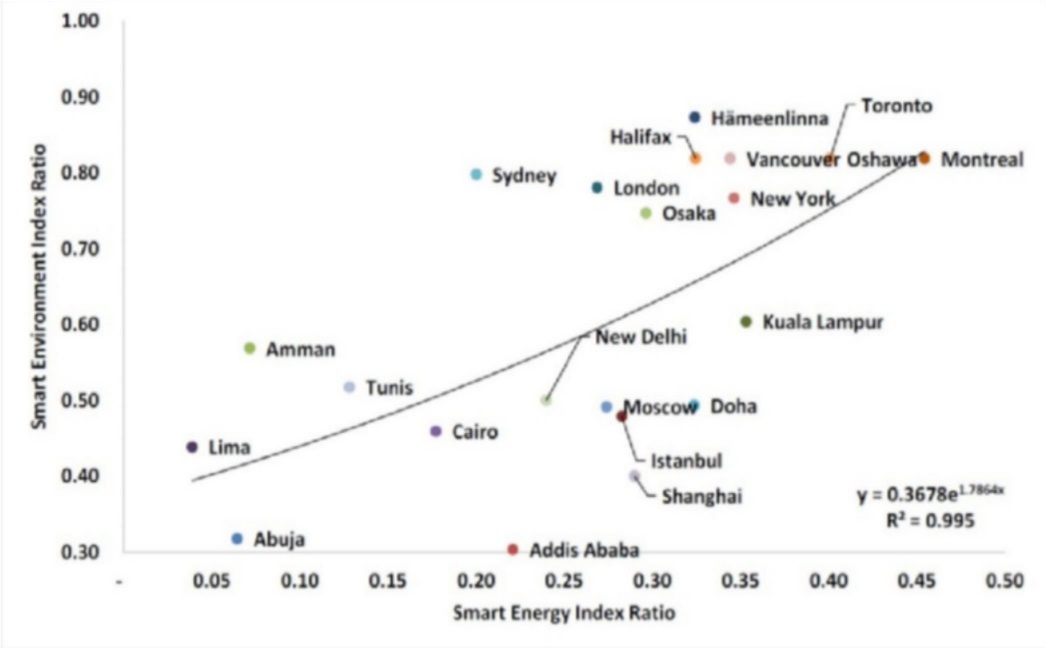


**Fig. 4.6.** The connection between environment and energy indexes

It is believed that smart cities are a new idea that needs to be measured. It is frequently qualitatively characterized and heavily promoted. This research regularly and carefully examines the effect matrix and the relationships between the several components and domains in addition to offering a quantitative assessment. However, because it uses national data points as a typical value for the city and depends on readily available local data, the approach does have limitations. Misinterpretation is an additional risk associated with using a composite indicators methodology. To expand on this study and deepen our understanding of smart cities, more research is needed. The idea of "smart cities" is a dynamic and complex phenomenon that seeks to improve the efficiency and sustainability of urban settings. Smart cities of the future should be more responsive and networked. Better decision-making and proactive city administration will result from advanced data analysis made possible by AI and machine learning advancements. 5G networks will significantly improve connectivity by facilitating more dependable communication between devices and systems. Urbanization does have several drawbacks, too, particularly in terms of security and privacy.

## 4.8 Remarks

This study presents a new paradigm for creating and defining smart cities. There are eight domains in the integrated model that creates a smart city index. The approach is applied to 20 cities globally and assessed according to their intelligent performance using four different weighted techniques.

The results show that the ecological, socioeconomic, and energy variables are strongly correlated. This implies that cities will become economically affluent as a result of social and energy growth. The corresponding dimensionless component values of 0.395, 0.336, and 0.374 for the environment, government, and society sub-indices, respectively, show strong relationships between them. The disparity between the population and the yearly GDP is the cause of Doha's 107% economic index performance. The R-value of 0.839 indicates a high link between social variables and the economy. Four types of smart city outcomes may be distinguished from this study. Helsinki, Sydney, Osaka, and London are the Canadian cities that best demonstrate the cluster's intelligent performance. The accuracy and resilience of the model are demonstrated by the fairly surprising similarity of the average SCI across the four distinct weighting processes. The pandemic-focused plan presents the best opportunities for all cities except Lima, while the energy-focused strategy produces a more focused set of data with dire outcomes.

# CHAPTER 5

## An assessment of how green education helps achieve the Sustainable Development Goals

Sustainable development is now a basic component of all daily activities and concerns because it is so important in determining the future. This study looks at how green education might help fulfill the SDG. In order to accomplish this research was conducted to employ a literature review style. The review came to the conclusion that green education helps achieve its goals based on existing research. A summary results of numerous research connections within sustainability education which show the primary way that green education advances these goals is by encouraging social and behavioral change, which is accomplished by raising global awareness of climate change. Thus, this study comes to the conclusion that green education might be more successful in accomplishing goals related to sustainable development. Securing this function would be difficult, though, given the substantial climatic and environmental changes that are anticipated in the future. As a result, the study also addresses obstacles that lessen the influence of education, makes recommendations for the future, and weighs the implications for future studies in this area.

### 5.1. Overview

The future of the world will depend on humanity's capacity to fulfill the SDGs. To accomplish the SDGs, a number of factors must be taken into account, including the environment, green education, nature-based learning, and cleaner production (Glavič & Lukman, 2007). The majority of people concur that improving health, ending the cycle of intergenerational poverty, and protecting the environment for present and future generations all depend on green education (Leal Filho et al., 2019). Since then, the idea and use of green education have grown its inception, as Agenda 21 at the 1992 Earth Summit in Brazil recognized as a way to balance human and economic well-being through educational practices (Glavič & Lukman, 2007). Integrating ecological, into the process of human lifelong learning was the main objective of ESD. Through the integration of multiple aspects of growth and development, ESD involves more than only learning and information generation (Leal Filho et al., 2019). Therefore, ESD is essential for developing the values, skills, and capacities needed to solve issues and ensure a commitment to building sustainable societies (Brundiers et al., 2021) .According to UNESCO, education for sustainable development “enable students to accept cultural variety while acting responsibly and making well-informed decisions for economic sustainability, environmental integrity, and an equitable society for current and future generations.". The three primary elements of ESD are pedagogy, learning materials, and learning outcomes. It seeks to empower kids to think independently and with confidence. Creating change agents as opposed to passive consumers has also been facilitated by ESD (UNESCO, 2017). It enables people to advocate for social and environmental issues in their private lives, businesses, and communities.

### 5.2. Green education and sustainability

Informing people about environmental issues, sustainable habits, and ecological principles (Akinsemolu, 2020). It seeks to raise public awareness issues, (Sterling, 2010). Increasing information, fostering understanding, and motivating action regarding environmental preservation, are appropriate in world are the main goals of green education. It motivates people to adopt sustainable practices, actively engage in community projects, support legislative changes, and make environmentally favorable decisions (Orr, 1992). Another crucial is creation of responsible, ecologically aware individuals who can handle. This enables people to actively participate in creating a world that is sustainable and resilient (Palmer, 1998). Consistent with its principles, objectives and in its efforts to promote cleaner production methods throughout communities, industries, and individuals (Akinsemolu, 2020). Green education is strongly related to focuses educational activities on the natural environment (Louv, 2005). Generally speaking, fostering sustainability literacy requires education (Parkin, 2010). Specifically, sustainability literacy and the SDGs—are directly advanced by green education. Therefore, subjects like The SDGs are influenced by green education. These crucial terms will be utilized throughout most of this text. This study is divided into four components. The introduction provides a summary of how green education contributes to the SDGs. The outlines the procedures used to locate relevant research on the role that education plays in achieving the SDGs. The third section compiles the findings from the literature review. The conclusion summarizes the review's results and makes recommendations for potential areas and subjects for future study.

### 5.3 Methodology

#### 5.3.1. Design of the study

The majority of this analysis is based on a review of previous research done between 2000 and the present. The following main research questions were the focus of a thorough evaluation of the publications to make sure they were peer-reviewed: What does "green" schooling mean? How sustainable development goals can be attained through green education the methods employed in green education to forward the objectives of sustainable development. Peer review was necessary to ensure that the findings came from legitimate and trustworthy research. The primary review approach for this work is the narrative/traditional literature review. Because the strategy was based on a collection of data from many sources, it was useful in determining if green education is advantageous for achieving the SDGs. A review can also highlight areas of knowledge that need further investigation and provide suggestions for how such findings could be integrated into standard procedures. Reviews' conclusions are generally regarded as more reliable than those of individual investigations. Most importantly, because it lessens bias in the conclusions reached, the review was used as the study technique (Petticrew & Roberts, 2006). The review was less costly to complete because it took less time than a new set of investigations. The conventional literature review approach was used primarily to examine the opinions and attitudes about sustainable development goals and green education, as well as their implications for sustainability. By giving a summary of the corpus of existing research on the topic, this study sought to illustrate the different ways that green education supports the Sustainable Development Goals (SDGs).

#### 5.3.2. Study selection

To make sure that the data sources mirrored the review's concerns, this study decided to look at a range of databases, including Google Scholar, JSTOR, Emerald Group Publishing, Eric, Research- Gate, Web of Science, and Emerald Insight. This was because the Sustainable Development Goals include a very broad range of topics. These databases were selected due to the paucity of research on SDGs at all levels and the relationship between SDGs and green education. A manual search on Google Scholar was also conducted to broaden the search's scope because academics evaluating green education have also found these databases to be helpful. The first search, which used the keywords "Green Education," yielded a lot of research papers that were dispersed equally among the databases that were located. However, because there was interest in both green education and its connection to the SDGs, the study used more specific terms to focus the search, integrating teaching about sustainability, nature-based learning, and the environment, as well as knowledge regarding sustainability and cleaner production. They were also checked for Qatar and Nigeria because the study was restricted to those two countries. Research papers, peer-reviewed journal articles, and books specifically used for definitions and theoretical underpinnings were all included in the study.

#### 5.3.3. Selecting and confirming

The search parameters used in the previous section resulted in the identification of 180 resources from various databases. Duplicate papers, studies that did not address the primary review questions and publications about green knowledge that had no bearing on the study because they addressed topics outside its scope were then removed from these results. This was accomplished by looking at the abstract, article names, and keywords used by the writers. After being chosen and assessed, thirty publications were forwarded for further examination. Twenty-five of the papers were retained for additional review and analysis. The 25 papers were three eligibility requirements were used to filter: the books or articles had to be original, and search terms had to be included in the abstract or title. The study's main objective was to explain or analyze green education and how it relates to the Sustainable Development Goals. Studies, papers, or reports published up until December 31, 2018, were covered using a prospective methodology. This recognizes that papers conducted before to 2000–2018 were considered outliers and that the review's study duration was limited to this time frame. To more thoroughly apply various filters, eligibility screening was conducted using two reading levels. An assessment of the articles' full text versions and an initial screening of abstracts and titles to exclude irrelevant articles were the two filters that were employed. At every stage, conservatism was used to ensure that only things that did not meet the inclusion criteria were removed. Articles that sparked debate were allowed to go to the following round for additional review. In the event that eligibility following thorough text screening is still questionable, If possible, further information was obtained so that the study may be included or removed. A synthesis of findings was produced by combining and analyzing all of the chosen publications. Findings and conversation

### 5.4.1. The green education concept

The synthesis of the selected articles indicates that many of them described green education as instruction intended values, while laying the foundation (Sterling, 2014,). It provides educators with practical learning models that connect science, technology, and social processes. Furthermore, everyone may benefit from green education by gaining the knowledge, abilities, attitudes, and values necessary to build a sustainable future (UNESCO, 2016; Varela-Candamio et al., 2018) Important subjects linked to sustainable development, including biodiversity, climate change, poverty alleviation, disaster risk reductions, and sustainable consumerism, are included in the curriculum. The reviewed literature indicates that in order to inspire and empower students to change their behavior and take action in support of sustainable development, green education requires the use of participatory teaching and learning methodologies (Ibezim, 2013). Consequently, it promotes significant changes to the existing educational system and enhances abilities such as group decision-making and critical and creative thinking (Papathanasiou et al., 2014). Green education is still necessary, and it is unquestionably crucial to creating a sustainable society (Juntunen & Aksela, 2014).

It encompasses the instruction required to maintain and improve the quality of the present and future generations (González-Gaudiano et al., 2005; Vare & Scott, 2007). Green education, as defined by sustainable development, is a means by which individuals can gain the values, information, abilities, and experience required to participate in local and global decision-making both independently and in collaboration with others (Ekwueme et al., 2016). It's crucial to remember that the selected research on green education teaching techniques claimed that there isn't a single effective teaching approach for the subject. The necessity of switching to immersive, active, and participatory learning approaches that include the learner and affect their comprehension, thought processes, and behavior is instead a spans, it may pose a threat to achieving this goal. Children's test scores can be significantly raised in green classrooms with improved acoustics, more daylighting, and healthier carpets and paints that don't emit airborne pollutants, according to a topic of significant debate. The five primary pedagogical components are some of the pedagogical approaches that are frequently utilized to incorporate the ideas of green education into the classroom (Vare & Scott, 2007). Both conventional lectures and more contemporary methods like learning notebooks, discussion boards, and reflexive narratives are included in critical reflection (Chan & Lee, 2021; Machost & Stains, 2023; Tight, 2024). However, system thinking is the term used to describe the use of important events, real-world case studies, campus and project-based learning, and engaging activities as teaching methods (Huckle & Wals, 2015). Using collaborative learning, creative thinking employs role-playing, problem-based instruction, crisis space, and future visioning (Pike et al., 2017; Yazar Soyadı, 2015; Yu & Zin, 2023).

### 5.4.2. The contribution of green education to the accomplishment environmentally friendly development objectives

The study claims that by providing instructors and students with resources and a curriculum, green education encourages critical and thorough thinking about global environmental issues and solutions (Bajaj & Chiu, 2009). Second, green schools help teachers, students, by maintaining health, improving student performance, cutting costs, lowering carbon emissions, conserving water, and offering unique educational opportunities to parents and the community at large (Schaffer & Vollmer, 2024). Green learning environments and education save health by making sure a high-quality indoor air environment for learning (Jickling & Wals, 2008). Because they are constructed with green building characteristics including non-VOC paints and carpeting, greater ventilation, and better daylighting, these schools are healthier for both staff and children (Jickling & Wals, 2008). By encouraging healthy lifestyles among students, the community, and educators, green education and green schools contribute to the achievement of SDG 3, which aims to provide universal health coverage, reduce unnecessary deaths, and minimize child mortality. Everyone should have access to inclusive, equitable, high-quality education and lifelong learning, according to SDG 4 (UNESCO, 2016). Because poor air quality shortens children's attention number of studies that were part of the analysis (Jickling & Wals, 2008). The primary goals of the unachievable Goal 4 on quality education—ensuring inclusive and egalitarian education and providing opportunity for everyone to live long lives—require this. Even while there has been progress toward high-quality education, there are still a lot of gaps. For example, if the rate of advancement continues at its current pace, it is estimated that more than 22 million children in 43 countries will not be able to obtain pre- primary education. Similarly, success or high-quality educations are not always correlated with availability. In fact, about 60% of the 103 million young people who are illiterate globally are women. Additionally, almost half of youngsters in 25% of the world's nations are unable to satisfy the minimal competency requirements (Goldman et al., 2018). Green education has become a viable substitute to increasing overall student achievement in light of these challenges. Third, several studies have demonstrated that by lowering energy expenses and consumption, green education helps achieve the SDGs. Generally speaking, green school lighting alternatives use less energy than traditional school lighting systems. Estimates suggest that energy operation costs at green schools could be reduced by 20–40%, allowing money for other important purposes (Bajaj & Chiu, 2009). Achieving SDG 7, which demands simultaneous improving access to reliable and reasonably priced energy. The achievement of these objectives can be accelerated by green education. These goals can be achieved by promoting increased infrastructure investment, fostering international collaboration to open up technology, and improving energy efficiency. The study recognized the significance of green education in accomplishing SDG 7 by lowering carbon emissions through cleaner production, in addition to expanding access to energy (Bajaj & Chiu, 2009). Cleaner production has been increasingly important since the 2002 World Conference on Sustainable Development increased. Because cleaner energy uses less energy, water, and raw materials, fewer toxic and hazardous compounds are created as byproducts of energy generation, and fewer of these compounds are bad for the air, water, and soil. Cleaner production aims to lessen the negative impacts of consumer products on the environment, human health, and safety throughout their entire life cycle, from raw material extraction to production and disposal (Kopnina, 2012). Integrating environmental issues into service design and delivery is a crucial component of greener manufacturing in service delivery.

Cleaner manufacturing is a comprehensive and integrated approach that addresses sustainable development challenges at many phases of production in order to save the environment (Fischer et al., 2022). Cleaner manufacturing has been shown to be an effective tool for increasing the efficiency of the energy sector. The study also demonstrated that cleaner manufacturing can help accomplish the sustainable development goals (Bajaj & Chiu, 2009). For instance, environmental issues must be balanced with elements like job creation and economic expansion in developing countries like South Africa. However, as demonstrated by Khalili et al., sustainable development necessitates the use of integrated techniques that may address environmental waste and sustainability while ensuring socioeconomic success at the national or international level. Because of its philosophy, which encourages the creation of varied viewpoints, policies, methodological tools, and paradigms in addition to the promotion of sustainable social patterns, Khalili et al., further highlighted the need of capacity building for sustainable development. Because it provides a framework for higher education authorities to assess the necessity and urgency of training efforts that could aid in the development of human capital required to attain SDGs, Khalili's study is particularly noteworthy. The proposed method uses expert opinion to assess the significance of cleaner production metrics and sustainable development [34]. This is in line with previous studies' conclusions that the most widely used strategy was incorporating resource management courses into the curriculum. Program development and sustainable economic growth came next. Cleaner production increases competitiveness, eco-efficiency (the best use of natural resources), and quality of life. To assist the continuous pursuit of environmental operational efficiency, cleaner production—which maximizes the use of natural resources and eliminates waste—can be positioned as a tool for corporate sustainability. Therefore, cleaner manufacturing is viewed as a "win-win" strategy that might increase profitability, competitiveness, efficiency, and production while simultaneously safeguarding the environment, employees, and customers (Fischer et al., 2022). The selected research suggests that cleaner production may be crucial to reaching Goals 12 and 13, given the previously noted link between cleaner manufacturing and access to clean energy. Achieving Goal 12, which is the worldwide transition to sustainable patterns of production and consumption, may depend on cleaner production. One of the goals of Goal 12 is to reduce waste and use ecologically friendly production methods. Global recycling rates must increase by 2030, per the reviewed research. Organizations also need to produce sustainability reports and use sustainable practices. Cleaner manufacturing is consistent with the 10-Year Framework of Programs on Sustainable Consumption and manufacturing, an international effort to accelerate the shift to sustainable production and consumption. According to Mogensen and Schnack (2010), cleaner production is also essential for reducing emissions of gases that contribute to global warming, which aids in achieving Goal 13, which is all about combating climate change. The goal urges society to take proactive steps to combat climate change and its effects by limiting emissions and promoting the expansion and development of renewable energy. Last but not least, green education helps accomplish SDG 6 by reducing water consumption, improving teacher retention, increasing daily attendance, providing special education opportunities, and creating green jobs. Green education promotes equitable access to and sustainable management of water resources with regard to water consumption (Goal 6). Progress is monitored using SDG 6's eight primary targets, several of which have 2030 as their target year. Green education, which seeks to ensure that water is used and maintained properly, is directly related to the objectives related to the drinking water supply. According to green education, 60% of people lack access to maintained sanitary facilities, and 30% of people lack access to safe water (Adomßent et al., 2014). Green education can help communities become more productive by promoting the availability of clean restrooms, safe drinking water, and water usage. Studies show that green schools use about 32% less water, which leads to immediate financial savings and significant societal benefits like less transportation, wastewater treatment, and storm water runoff. Green schools can also cut teacher turnover by nearly 5%, which is good for student learning, the school community, and the financial line of the organization (Leal Filho, 2018). Children who attend green schools generally have lower absence rates than those who attend other traditional schools, per the analyzed studies. The possibility that green education could offer a unique educational opportunity is one fascinating finding. If buildings integrate cutting-edge technology and green design aspects to teach children about the practical applications of green technologies, they might be valuable teaching tools and essential parts of science, math, and environmental curriculum. In addition to its role in attaining SDGs 3, 7, 12, 13, and 6, green education could help accomplish SDG 8 by fostering the development of green jobs that foster economic growth without posing a threat to the environment. Putting money into green jobs like building product manufacturing, green architecture, and green construction is equivalent to investing in green education. The creation of green jobs is linked to Goal 8, which seeks to guarantee that everyone has access to gainful work and promote sustainable economic growth. In essence, the objective is to give everyone access to decent, productive work in order to foster long-term, equitable, and sustainable economic growth. Green education has been very helpful in encouraging " (Goldman et al., 2018). This is a great illustration.

The Green School Bali is among the best illustrations of the advantages of green education. Its importance is closely related to the integration of families, staff, faculty, and nearby neighbors. The community's diversity, which encompasses a variety of languages, customs, and beliefs in addition to distinct identities, values, and ideals, is associated with several multicultural benefits. The varied student body at the institution promotes tolerance, widens perspectives, and develops global intelligence. More importantly, the school offers a great environment for participation, enjoyment, learning, and growth. Creating a sustainable space where people may exchange knowledge about global citizenship, innovative teaching methods, and social interactions is one of the school's objectives. (Goldman et al., 2018). Volunteers, interns, and employees gain invaluable experience in addition to job-related skills and the importance and influence of cross-cultural communication and teamwork. Additionally, the location provides a safe living environment with regular check-ins and a rigorous working strategy. As a result, they are able to keep things in balance in every aspect of campus and academic life. Because of the enthusiasm, dedication, and love that interns and volunteers have shown for the school, it is now an amazing place to learn. By sharing with the community, they help people see the possibilities of education in the future. Table 5.1 outlines the several roles of green education and their connections to the Sustainable Development Goals (SDGs).

**Table 5.1:** Green education's contributions to the attainment of sustainable development Objectives.

| Roles of Green Education | Related SDGs |
|---|---|
| Encourages holistic thinking | SDG 3 (Good Health and Well-being) [39] |
| Promotes quality education | SDG 4 (Quality Education) [40] |
| Reduces energy costs | SDG 7 (Affordable and Clean Energy) [1] |
| Reduces carbon emissions | SDG 13 (Climate Action) [41] |
| Decreases water usage | SDG 6 (Clean Water and Sanitation) [8] |
| Enhances teacher retention | SDG 8 (Decent Work and Economic Growth) [42] |
| Reduces student absenteeism | SDG 4 (Quality Education) [40] |
| Provides unique learning opportunities | SDG 4 (Quality Education) [40] |
| Creates green jobs | SDG 8 (Decent Work and Economic Growth) [42] |

### 5.4.3 Green education tactics to advance the objectives of sustainable development

The examined literature suggests that the idea of learning from the outdoors is utilized in green education to assist achieve the SDGs. Green education prioritizes fostering research excellence in the identification of nature-based strategies that foster economic expansion and innovation while concurrently addressing environmental problems and improving human welfare to increase the capacity to develop research techniques in the pursuit of sustainable development. (Sterling, 2014). The study claims that living solutions that successfully and adaptably solve societal concerns are nature- based solutions (Mogensen & Schnack, 2010). The phrase "going green" refers to actions and knowledge that may result in eco-friendly choices and ways of living, which will eventually contribute to protection has a negative impact on ecology and sustainability. Governments providing basic infrastructure, companies growing, and people trying to meet and satisfy their basic needs all contribute to the degradation of the environment. The concept offers a natural solution that recognizes the influence that education and ecological awareness have on people's daily lives. The goal of universal resource and energy conservation, recycling, waste generation, pollution reduction, and maintaining the earth's natural equilibrium are its driving forces. Furthermore, all of the program's activities revolve around enlightenment and consciousness-raising, which further solidifies its link to its goal, was to make young people more conscious of the need. GEFTY uses a variety of strategies to raise awareness, including creating comprehensive green education at the state's primary and secondary levels, securing sponsorship from both domestic and foreign sources, raising funds from a variety of sources, and promoting awareness of the need for a green revolution through various green initiatives. In order to combat the threat posed by climate change, the legislature has been entrusted with ensuring that all governmental levels adopt new legislation and update their policies to take environmental advancements into account. In order to mitigate the effects of climate change, the organizers of the two projects encouraged people to embrace planting trees. The concept was adopted by nine educational institutions throughout the state. One of the evaluation criteria was how nature-based learning affected students' attempts to protect the environment by actively encouraging greater biodiversity and cleaner water. The most successful use of nature-based learning, according to researchers who assessed it, is in conjunction with curriculum strategies and laws that include instruction on natural elements (Miller et al., 2022). A similar short-term nature-based learning program with greater concern for responsible behavior, and improved course learning outcomes (Kras, 2021).

The project's findings corroborate a broader study that found nature-based learning improves certain green learning elements, such environmental stewardship, in terms of overall learning outcomes (Jordan & Chawla, 2022). Green education has mostly depended on networking and training to boost research capacity and promote excellence in sustainable development. Enhancing skills and synthesizing knowledge about the advantages of nature is one of the primary objectives of networking and training initiatives (Müller-Christ et al., 2013). The study has looked closely at ReNature in Malta, which seeks to build strong relationships with business and policies (Tomaˇskinov ´a et al., 2021). ReNature has promoted a culture of evidence-based environmental planning and decision-making. Land use planning that would make it easier to implement nature-based solutions is highly desired in order to build green infrastructure in urban areas and greatly boost ecosystem services and biodiversity. Malta has developed into a robust innovation and research actor in the field of nature- based solutions, which have recently emerged as a significant proponent and facilitator of the SDGs, thanks to the initiative, which enables the development and testing of technical and policy solutions in an island context. By focusing exclusively on the components deemed vital, training in sustainability and green education ensures that learning is focused in a way that highlights the primary deliverables. By building capability, an organization evaluates its own and its members' performance in a complex context. The evaluation process and the implementation component are crucial for ensuring sustainability and success. Therefore, training and capacity-building are crucial strategies that have been thoroughly discussed in the literature (Karpudewan et al., 2015; Leal Filho, 2018; Tundo & Griguol, 2018). Green education also leverages ownership and consultations, advocacy and vision-building, networks and collaborations, research and innovations to attain sustainability. Table 2 lists the strategies used by green education to advance the Sustainable Development Goals (SDGs).

### 5.4.4 How green learning's effects and results have changed over the last 20 years

According to the synthesis of the selected publications, as the concept has gained popularity over the past 20 years, the effects and results of green education have changed over time. The establishment of proof of concept was the main result of Education for Sustainable Development (ESD) between 2005 and 2014, according to an assessment of the focus of green education in 18 countries (Laurie R et al.,2016). Because of this, most green education programs focused on raising awareness and grabbing stakeholders' attention. In learning environments across a variety of contexts was then initiated by these stakeholders.

In order to drive a change in perspective regarding the incorporation of assessment of its impact on sustainability, the objectives of green education shifted from proving the concept and raising consciousness to developing expertise, investigation, and the application of best practices after 2014 (Laurie R et al.,2016).

Notably, most of the selected studies that were published after 2014.

**Table 5.2** Techniques used in green education to promote sustainable development goals (SDGs).

| Strategies | Description |
|---|---|
| Nature-based learning | Incorporating natural elements into education, fostering a connection with the environment, and encouraging conscious actions for conservation [6]. |
| Promotion of research excellence | Emphasizing research excellence to find nature based solutions for economic growth, innovation, and addressing environmental challenges while improving human well-being [49]. |
| Training and capacity building | Focusing on imparting knowledge and skills aligned with SDGs, evaluating organizational capacity, and assessing members' abilities to function effectively in complex environments [1]. |
| Collaboration and networking | Collaborating with businesses, policymakers, and stakeholders to develop evidence-based environmental decision-making and planning, fostering strong collaboration and capacity-building [50]. |
| Knowledge synthesis and capacity building | Aiming to synthesize knowledge and build capacity in areas related to nature-based solutions, educating individuals and organizations about the benefits of nature, and aligning training with SDGs [51]. |
| Vision-building and advocacy | Developing a vision for sustainability, advocating for environmentally responsible practices and policies, and inspiring a shared vision for a greener and more sustainable future [51]. |
| Networks and partnerships | Valuing networks and partnerships to advance research and practical solutions, strengthening research capacity, and providing practical solutions based on scientific findings [52]. |
| Monitoring and evaluation | Utilizing monitoring and evaluation to assess the impact of sustainability initiatives, ensuring that progress aligns with SDGs and actions lead to meaningful results [39]. |
| Consultations and community involvement | Actively engaging communities and stakeholders, seeking input, and ensuring that environmental initiatives are relevant and effective, fostering a |

| | |
|---|---|
| | sense of ownership and commitment to sustainability efforts [53]. |
| Research and innovation | Encouraging research and innovation to develop and implement sustainable solutions, focusing on finding new and innovative ways to address environmental challenges and promote SDGs [1]. |
| Land use planning and green infrastructure | Emphasizing land use planning and the development of green infrastructure within urban areas, supporting ecosystem services, biodiversity, and the implementation of nature-based solutions for SDGs [54]. |

# CHAPTER 6

# CONCLUSION

There are many different ways to generate energy, including solar energy, fossil fuels, gas, electricity, and batteries. Although energy can change into a variety of forms, it cannot be created or destroyed. In recent years as substitutes for the more widely used "conventional" energy. The potential depletion of the world's usable energy supply served as the impetus for these innovative developments in the energy sector. Clean energy, also referred to as "green energy," describes energy sources that have little or no adverse effects on the environment. Renewable resources like the sun and wind are the source of green energy. Since renewable and sustainable energy may be produced more quickly than they can be used, they are both best suited for long-term use. Sustainable and renewable energy sources differ in a few small ways. While renewable energy is produced by humans, sustainable energy comes from non-human sources. One sustainable energy source derived from the creation, use, and breakdown of organic materials is biogas. Because their energy generation and consumption are equal, There is no net external utilization of energy in zero-energy technologies and infrastructures. What is intelligent energy exactly? Compared to conventional and renewable energy, smart energy encompasses a wider range of ideas one could consider Smart are all included in this strategy.

On the other hand, any traditional energy supported by modern information and communication technology is referred to as smart energy. The intelligent energy system intelligently integrates the production, delivery, and use of renewable energy. Consequently, in order to form a single system, intelligent energy needs to be carefully coordinated and communicated among its three constituent parts. With the correct ICT, smart home appliances like water heaters and dishwashers may operate as energy-efficiently as possible. HVAC (heating, ventilation, and air conditioning) transactions are made easier by ICT. Energy can be harvested from a variety of sources, including as wind turbines and solar panel systems, using information and communication technologies. The third crucial component of a smart energy system is consumption optimization. Using energy storage wisely, Page 16 of Smart Cities 2022, 5 1404, Efficient energy management and metering may be essential to optimizing energy. Another name for it is a "smart grid." The central nervous system of the system is the smart energy grid. The efficient integration of the activities and behaviors of all connected users, including (1) consumers, (2) generators, and (3) users who are both consumers and generators, is the official definition of a smart grid. Reduced loss levels, improved supply quality, fault tolerance, are just a few benefits of smart grids. Using smart grid technologies, a variety of renewable and non- renewable energy sources, including solar and wind power, can be integrated with more conventional thermal energy derived from fossil fuels. Smart grids of the future will be far more advanced than those of today. Any user could eventually produce their own sun, wind, or biofuel. To ensure that all of these power sources work together, a smart grid will provide power at the exact voltage and frequency required for each one. Demand response energy consumption management, wind and solar power generating dispatch, improved customer relations, and point-of-sale transaction services for non-physically located plug-in electric vehicles (PEVs) are being given a lot of attention. Intelligent energy metering is a key component of the smart grid. For analysis and billing purposes, the smart meter records and sends the electricity usage data to the utility provider at predetermined intervals. This makes it possible to analyze consumption numbers accurately without requiring human intervention. To ensure that all of these power sources work together, a smart grid will provide power at the exact voltage and frequency required for each one. Demand response energy consumption management, wind and solar power generating dispatch, improved customer relations, and point-of-sale transaction services for non-physically located plug-in electric vehicles (PEVs) are being given a lot of attention. Intelligent energy metering is a key component of the smart grid. For analysis and billing purposes, the smart meter records and sends the electricity usage data to the utility provider at predetermined intervals. This makes it possible to analyze consumption numbers accurately without requiring human intervention. Smart buildings will require higher demands from energy and capacity providers, such as greater production and grid capacity, to provide a steady power supply. The goal of this project is to find solutions for smart cities of the future. Advanced social and economic structures, environmental consciousness, and an expanding corpus of knowledge are characteristics of these utopian ideas. Furthermore, because of their capacity to condition and manage household energy use, Smart Energy Control Systems (SECS) have become more and more popular in the context of smart homes. To forecast electrical consumption, the Smart Cities Energy Prediction Task Force employs e-learning tools, SVM, and STLF. Electric power administration platform, smart cities can dependable deliver electricity to a variety of demands. A factor is shared by the scalar mean and the vector minimum-maximum. In urban sustainable development, the subjects of expansion, preservation, and equity were discussed. Modernizing the energy industry and integrating ICT into the grid are essential to creating a smart city. In smart cities, buildings—new and old—perform better and consume less energy.

Because of its importance and complexity issues (Page 17, Smart Cities 2022, 5 1405). The strategies outlined in this paper promote discussion about smart city energy use and, consequently, economic growth. Reducing greenhouse gas emissions is one of the numerous advantages of increasing energy efficiency. The optimal way to employ solar panels and batteries depends on a number of elements, including the controller itself, the particular design, the power requirements, and the electricity market. Additionally, smart city electricity employs a variety of strategies to control power going forward. The bundle includes modern technology, high living standards, and environmental friendliness. The energy industry has expanded primarily because it is stable and prepared for a new phase of electrification, when electricity permeates almost all systems and processes in the industrial, residential, and transportation sectors, making them easier to control and "greener." This study concluded that improving the quality of life for citizens is one of the main objectives of smart city initiatives, but it did not elaborate on what this meant or the implications for the environment and society at large. Therefore, future initiatives to build a "smart city" ought to take into account the causally enhancing  the integrating state-of-the-art technology.

## 6.1 Conclusion

The findings and recommendations of the research that were highlighted have an impact on the following methods for using green education to help achieve the Sustainable Development Goals: To attain the sustainability that the SDGs want to accomplish, education is essential [62]. Combining formal education with green education would create a population that understands sustainability and contributes to the SDGs through clean energy innovation, green entrepreneurship, appropriate waste management, and a decrease in waste from water and other natural resources. Green education results in a change in social behavior. As a result, it might cause a paradigm shift in how society views and acts in relation to sustainability. By applying the behaviorist approach that has encouraged the adoption of environmental conservation measures like the Kyoto Protocol, green education can contribute to this shift in social attitudes and behaviors [63]. Last but not least, green education equips students with the knowledge and abilities necessary to build and sustain sustainable societies by integrating the environmental, social, and economic pillars of sustainability in an interdisciplinary manner [64]. Integrating sustainability courses across a wide range of academic subjects will undoubtedly assist sustainable communities by transforming students into agents of social change.

## 6.2 Further research

Since William Snap first proposed the idea of environmental education in Ref. [65], numerous researches have examined the connection between education, environmental education, and the Sustainable Development Goals. But the idea of "green schooling"" is very recent. As a result, nothing is known about how the concept relates to other fields, such sustainability. Future research may focus on how green education connects with other domains and sectors and supports the SDGs.

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**APPENDIX 1**

**NEAR EAST UNIVERSITY**

**INSTITUTE OF GRADUATE STUDIES**

**DEPARTMENT OF EDUCATION ADMINISTRATION AND SUPERVISION**

**GREEN LEARNING ENVIRONMENT FOR SUSTAINABLE EDUCATION**

**Participant Information Sheet and Informed Consent Form**

**DEAR PARTICIPANT**

This research aims to explore how green learning environments can enhance sustainable education through the integration of digital technologies, environmental awareness, and sustainable practices in educational settings. The study seeks to identify key factors that contribute to sustainability-oriented learning and how these can be implemented effectively across educational institutions.

Please note that you are being invited to take part in this study because you are a student, educator, or academic staff member whose experience and perspective are valuable for understanding sustainable educational environments. Your participation will help contribute to the development of frameworks that promote sustainable learning practices. Participation is entirely voluntary, and you may withdraw at any point without giving a reason. There will be no penalty or loss of benefits for choosing not to participate. All information collected will be treated in strict confidence. Data will be anonymized and stored securely according to the ethical standards of Near East University. Only the researcher and supervisors will have access to the raw data. Your identity will not be revealed in any report or publication. There are no anticipated risks to participants. However, if any question makes you feel uncomfortable, you may skip it. The study's outcomes will benefit educational institutions and policymakers by supporting the creation of sustainable learning environments.

Participation in this study is voluntary. You have the right to withdraw at any stage without penalty or explanation. Withdrawing will not affect your relationship with the university or any institution involved.

In case you have any question or concern, please contact us using this information below.

Researcher:

Ramiz Salama

Email: ramiz.salama@neu.edu.tr

Near East University, Institute of Graduate Studies

Supervisor:

Prof. Dr. Fadi Al-Turjman

Email: fadi.alturjman@neu.edu.tr

For ethical concerns, you may also contact the Research Ethics Committee of Near East University.

**INFORMED CONSENT FORM**

By signing below, you agree to take part in this study.

Full Name and Sign ………………………………

Title: Green Learning Environment for Sustainable Education

Researcher: Ramiz Salama, Near East University

# APPENDIX 2

## ETHICAL APPROVAL LETTER

**TO INSTITUTE OF GRADUATE STUDIES**

**REFERENCE:** RAMIZ SALAMA (20244856)

I would like to inform you that the above candidate is one of our postgraduate students in Computer Education and Instructional Technology department he is taking thesis under my supervision and the thesis entailed: GREEN LEARNING ENVIRONMENT FOR SUSTAINABLE EDUCATION. The data used in his thesis does not require any ethical report.

Please do not hesitate to contact me if you have any further queries or questions. Thank you very much indeed.

Best Regards,

Prof. Fadi Al-Turjman

Near East University,

AI, Data Analytics, and Software Engineering Departments, AI and IoT research center, AI and Informatics Faculty, Near East University,

Mersin 10, Turkey

Email: fadi.alturjman@neu.edu.tr

# APPENDIX 3

# CURRICULUM VITAE

## CURRICULUM VITAE

**Ramiz Salama** received his BSc from Near East University (NEU) Department of Computer Engineering in 2002, he continue in the same department, in 2005 he started his MSc in Computer Engineering Department, Now days he prepare his self to complete his Phd. Lecturer Ramiz Salama started his work in Computer Engineering Department , lecturer, supervision of graduation projects, supervision of Summer Training and exams coordinator, since 2009.At [2005 -2009] Ramiz Salama was working at Innovation and Information Technologies Center for Computer Network & Hardware in Near East University. In [2003 -2005] Ramiz Salama was assistant in Engineering Faculty, Department of Computer Engineering.

Ramiz Salama is lecturer at the Engineering Faculty – Computer Engineering Department, teach courses of: Computer Networking & Data Communication, Mobile Computing, Cyber Security, and Introduction to Computer Programming, Computer Engineering Orientation, and Computer Hardware. His research and interesting areas are related to Computer Networking, Learning Management Systems, Mobile Applications Development, Cyber Security..

## PERSONAL DATA

| | |
|---|---|
| Name: | Ramiz Salama |
| Date of Birth: | 8th May,1976 |
| Nationality: | Cyprus |
| Place of Birth: | Palestine |
| State of Origin: | Palestine |
| Permanent Address: | 706 Near East University academic |

Lodgeman

Current Address: 706 Near East University academic Lodgeman

Mobile Number: 05338418142

Marital Status: Single

Email: ramiz.salama@neu.edu

**QUALIFICATIONS**

| INSTITUTIONS | QUALIFICATIONS | DATES |
|---|---|---|
| Near East University | Msc. Computer Engineering | 2008 |
| Near East University | Bsc. Computer Engineering | 2002 |

**WORKING EXPERIENCE**

- Near East University as a Research Assistant
- Near East University as a Lecturer

**ADMINISTRATIVE RESPONSIBILITIES**

- Coordinator of the Engineering Faculty's distance exams

**AWARDS**

- Near East University Young Researcher Encouragement Award in 2022

**PUBLICATIONS**

Articles Published in International Peer-Reviewed Journals (SCI,SSCI, AHCI, ESCI, Scopus)

- Salama, R., & Al-Turjman, F. (2023). Blockchain Technology, Artificial Intelligence, and Big Data in Education. In Machine Learning and the Internet of Things in Education: Models and Applications (pp. 245-253). Cham: Springer Nature Switzerland.
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# APPENDIX 4

# SIMILARITY REPORT

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