Green IoT Applications in Agriculture

Eva Cipi; Eljona Zanaj
Department of Computer Science
University "Ismail Qemali" Vlore
Vlore, Albania
{ eva.cipi;eljona.zanaj }@univlora.edu.al

Redi Capoj
Department of Computer Science
University "Ismail Qemali" Vlore
Vlore, Albania
redi.capoj@univlora.edu.al

Arlind Ago
University "Ismail Qemali" Vlore
Vlore, Albania
arlind.ago @univlora.edu.al

Abstract—**Green IoT (Internet of Things) refers to the integration of environmentally friendly practices and technologies in the development and implementation of IoT systems. The main goal of Green IoT is to minimize the environmental impact of IoT devices and networks, both during their production and throughout their lifecycle. This includes reducing energy consumption, minimizing electronic waste, and optimizing resource usage.**

The technical aspects of Green IoT involve the integration of IoT devices and sensors with renewable energy systems, energy storage systems, and energy management systems. These systems are connected to the internet, allowing for real-time monitoring, analysis, and control of energy usage.

Green IoT also known as sustainable IoT, it is the marriage of internet of things technology and environmentally friendly practices. It aims to minimize the ecological impact of technology while enhancing resource management and efficiency.

Keywords-Green IoT, Smart Buildings, Agriculture, Smart Grids, Smart Cities

I. Introduction

The Internet of Things (IoT) paradigm was introduced over two decades ago, in the late 1990s and early 2000s, and its deployment has been ongoing for almost one. In its most general definition, IoT is a network of devices, that is, focussing on connecting everyday objects to the internet, which gather and exchange data possibly over the Internet in order to improve said data gathering and efficiency. The ultimate goal of IoT is to enhance existing services and applications or deliver new ones to users, with little to no human intervention [1,2].

The extreme heterogeneity of application domains and involved devices has led to different requirements and expectations. Therefore, a large variety of wireless communication technologies has gradually emerged for enabling IoT, and is expected to connect up to 75 billion devices by the end of 2025, with an economic impact of around \$11.1 trillion per year [3,4]. However, the deployments of early IoT systems, despite their advantages also raised concerns related to energy consumption and sustainability, as the millions of devices connected together required more power and resource use [5].

Manuscript received May 6, 2025; revised September 11, 2025; accepted September 11, 2025. Published October 14, 2025.
Issue category: Regular
Paper category: Regular
DOI: doi.org/10.64552/wipiec.v11i2.84

IoT-based environmental monitoring, one of the main fields of IoT, leverages Internet of Things (IoT) technology to gather data on various environmental factors, such as air quality, temperature, and humidity levels. This data can be analyzed to gain a deeper understanding of both indoor and outdoor conditions, enabling businesses to make informed decisions on how to mitigate negative environmental impacts. It can also guide companies in adjusting their operations to support sustainability and protect the local community or the planet.

These IoT systems help identify environmental issues that are often overlooked, normalized, or unnoticed. By detecting these challenges, businesses can take proactive measures to reduce their environmental footprint while safeguarding the well-being of employees, visitors, and the wider community.

In the field of environmental monitoring, IOT technologies have been heavily felt. The governments and industries can identify harmful substances, chemical spills and dangerous pollutants through using connected devices as well as sensors [6]. This way, we are able to purify and protect and save our air, land and water resources using these IOT solutions. In addition, IOT sensors assist in perfecting operations thus aiding positive ecological impact leading to a sustainable future.

As the awareness of the climate change and also the energy consumption continued to grow, Green ICT, technologies that are able to reduce impact of environmental technologies through the usage of energy efficient hardware, software, and networks, began to gain more and more traction. This laid the groundwork for the concept of Green IoT [7]. The term Green IoT started to gain traction around the early 2010s, being referred as IoT systems that were designed to minimize environmental impact by reducing energy consumption, optimizing resource use, and supporting sustainable practices (e.g., smart grids, smart agriculture, waste management). Key aspects of Green IoT include: energy-efficient sensors, low-power communication protocols (like ZigBee, BLE), renewable energy-powered devices [8]. By the mid-2010s, Green IoT expanded beyond concept to applications like:

- Smart cities reducing carbon footprint through optimized lighting and waste systems.
- Smart agriculture using IoT to reduce water and fertilizer usage.
- Industrial IoT optimizing manufacturing to reduce emissions.

This led to energy harvesting techniques and low-power IoT became research hotspots [9]. At the same time there was a need for the standardization [10] of Green IoT technologies, with the efforts intensifying to achieve this, including:

- Development of energy-efficient communication protocols (6LoWPAN, NB-IoT).
- Integration with renewable energy sources.
- Emphasis on circular economy principles for IoT device lifecycle.

Today, Green IoT is a critical part of global sustainability agendas, aligned with the UN Sustainable Development Goals (SDGs). Focus areas of Green IoT include:

- Edge computing to reduce data transmission energy.
- AI-driven optimization to improve energy use.
- Blockchain for transparent, sustainable supply chains.
- Circular economy in IoT manufacturing and disposal.

Governments and industries are investing heavily in Green IoT for smart grids, transportation, and environmental monitoring [11].

II. Green IoT

The carbon footprint of electronic gadgets, the internet, and the systems supporting them account for approximately 3.7% of global greenhouse emissions, according to the studies [12]. In the greenhouse effect, the concentrated gases absorb the energy, thereby increasing the global temperature.

The continuous escalation of the usage of IoT enabled devices, equipped with additional sensors and communication add-ons, consumes huge amounts of energy and results in carbon emissions. The most pressing issue is a methodology that prioritizes resource conservation and environmental governance and intensifies efforts to decarbonize the atmosphere. The future challenge of IoT is to develop processes and policies that make sustainable use of IoT to reduce the greenhouse effect and further optimize IoT greenhouse footprint.

Green IoT (GIoT) represents the energy efficient procedures (hardware and software) adopted by IoT to facilitate reducing energy consumption and carbon emission of the existing applications and services, as well as IoT devices to achieve a sustainable smart world. This is also known as sustainable IoT, better described as the marriage of internet of things technology and environmentally friendly practices. It aims to minimize the ecological impact of technology while enhancing resource management and efficiency.

Several green technologies like green RFID tags [13], green sensor networks, and green cloud computing networks have become an essential part of Green IoT research. Organizations and companies these days are being motivated to use more natural or renewable energy sources like solar and wind energy.

Green IoT in agriculture [14], [15] refers to the use of Internet of Things (IoT) technologies to promote sustainable farming practices that are environmentally friendly and at the same time resource-efficient. The aim of Green IoT in agriculture is to improve agricultural productivity by optimizing the use of water, energy, fertilizers, and other resources, which is also able to minimize the environmental footprint.

Green IoT has an architecture that follows a layered structure which is very similar to the traditional IoT systems, but with enhancements that allow energy efficiency and sustainability. The standard layers of Green IoT architecture include:

1. Perception Layer (Sensing Layer)

- Contains sensors and actuators that interact with the physical environment.
- Designed with energy-efficient or energy-harvesting devices (e.g., solar-powered sensors).
- Utilizes green materials or recyclable hardware.

Technologies that also have the same layer are **:** RFID, ZigBee sensors, MEMS-based devices [16].

2. Network Layer

- Transmits data collected by sensors to processing units.
- Uses low-power wide-area networks (LPWAN) or energy-aware routing protocols.
- Green networking principles: reduced redundancy, optimized data transmission, minimal interference.

Protocols that also have this layer include [17, 18]: 6LoWPAN, ZigBee, NB-IoT, LoRaWAN

3. Middleware Layer
   - Manages services and communication between hardware and applications.
   - Supports context-awareness and energy optimization algorithms to reduce unnecessary processing and transmission.
   - Can incorporate AI for smart decision-making at the edge (reducing cloud reliance).

4. Application Layer
   - Includes green applications like smart grids, smart agriculture, smart homes, and environmental monitoring.

- Focuses on sustainable outcomes such as reducing water/energy usage, optimizing traffic flows, and reducing waste [9].

5. Business and Management Layer (Extended Layer)
   - Manages the lifecycle of IoT devices: manufacturing, deployment, maintenance, disposal, and recycling.
   - Emphasizes eco-friendly production, reusability, and circular economy practices.

The main components of Green IoT include:

1. Green Sensors – are Low-power, energy-harvesting (solar, kinetic, thermal) and made from recyclable or biodegradable materials.
2. Green Communication Protocols – are designed to reduce energy consumption during transmission.
3. Energy-Efficient Processing Units - Use ultra-low power microcontrollers (e.g., ARM Cortex-M) and are able to perform edge computing to reduce cloud dependency.
4. Power Management Systems - Include batteries, supercapacitors, and power harvesting units. And are able to optimize usage via dynamic power scaling.
5. Green Cloud and Edge Computing - Use of green data centers with renewable power while edge computing reduces transmission energy costs.

Key Components of Green IoT in Agriculture are :

- *Precision Farming:* IoT devices such as soil moisture sensors, weather stations, and drones are used to collect real-time data on various environmental conditions. This data helps farmers make informed decisions about when and where to irrigate, fertilize, or apply pesticides, thereby reducing resource wastage and environmental impact.
- *Smart Irrigation [16]*: Automated irrigation systems, controlled by IoT sensors, deliver the right amount of water to crops based on soil moisture levels and weather forecasts. This prevents over-irrigation and reduces water consumption, making farming more sustainable.
- *Energy-Efficient Operations*: IoT technologies help optimize the energy usage of farm equipment and facilities. For example, smart lighting and HVAC systems in greenhouses can be adjusted based on real-time data, reducing energy consumption and costs.
- *Waste Reduction [17]*: IoT systems can monitor and optimize the use of fertilizers and pesticides, ensuring they are applied only when needed and in precise amounts. This reduces chemical runoff into the environment and minimizes waste.

Benefits of Green IoT in Agriculture include:

- *Resource Efficiency*: Better management of water, energy, and fertilizers leads to reduced wastage and lower environmental impact.
- *Increased Yields*: Precision farming and real-time monitoring improve crop yields while minimizing the use of harmful chemicals.
- *Sustainability*: By reducing the environmental footprint of farming, Green IoT supports long-term sustainability and helps mitigate the effects of climate change.
- *Cost Savings*: Efficient use of resources and energy can lead to significant cost savings for farmers, making sustainable practices more economically viable.
- *Improved Food Security*: Enhanced productivity and reduced waste contribute to a more stable and reliable food supply.

III. Green IoT in Albania

In this section we will present the usage of Green IoT in Albania and also show a real-life project that uses IoT combined with Arduino [14] to create an Automatic Watering and Water Reuse system.

Green IoT has made significant steps in transforming Albanian agriculture, while enhancing sustainability, efficiency, and resilience across the agriculture sector. The key initiatives and projects that have incorporated Green IoT in Albania:

1. UKA Farm: a model of smart agriculture

UKA farm is located near Tirana, and has integrated IoT technologize in order to optimize its operations. The farm employs energy-efficient sensors that are connected together via a mobile network, making use of a Vodafone pilot project [15]. These sensors help provide real-time data related to soil moisture, temperature, and weather conditions. The usage of this system has led to :

- 30% reduction in water usage;
- 15% improvement in fertilizer efficiency;
- Enhanced disease prevention through early detection.

These advancements have improved crop yields and also have helped to reduce the environmental impact [16].

2. Digital Agriculture and Rural Transformation (DART) Program.

The DART program was first launched in November 2024, and is a joint initiative by the United Nations and Albania's government. This project aims to digitally transform the agriculture sector. The program has a budget of USD 3.3 million, and focuses on [17]:

- The development of a national digital agriculture strategy;
- The enhancement of digital public services through the usage of platforms such as the Albanian Farmer's Portal;
- Building digital capacities among small-scale farmers and public sector employees.

This initiative aligns with EU standards and supports the process of Albania's EU accession.

3. Farmonaut's Precision Farming Platform.

Farmonaut's satellite analytics platform [16], using advanced satellite imagery and sophisticated algorithms, is being utilized by Albanian apple growers to enhance orchard management. This technology has helped apple cultivation in the following ways:

- Precision crop monitoring;
- Early disease and pest detection;
- Optimized resource management;
- Climate adaptation strategies
- Yield prediction and quality enhancement.

In regions like Korçë and Dibër, farmers have reported:

- 20% increase in yield;
- 30% reduction in pesticide use;
- 25% decrease in water consumption.

These improvements are achieved through optimized irrigation and early disease detection, leading to cost savings and better-quality produce.

4. NiuBol's Soil and Agro-Meteorological Sensors.

Chinese company NiuBoL has exported high-precision soil sensors and agro-meteorological stations to Albania. These IoT devices enable farmers to monitor soil conditions and environmental parameters remotely, facilitating:

- Informed irrigations and fertilizations decisions;
- Early warning for adverse weather conditions;
- Improved crop planning and disaster prevention.

5. SMART4ALL Project

This project [18] is a regional initiative that helps promote digitized agriculture through funding and collaboration, with a special session held in Tirana to showcase IoT applications.

6. IoT-ECO Project

This is an Erasmus+ initiative [19] aiming to build capacity and foster innovation in IoT solutions for agriculture in the Western Balkans, including Albania.

IV. GREEN IOT: REAL SCENARIO

A it was mentioned in th above sector, Green IoT in agriculture refers to the use of Internet of Things (IoT) technologies to promote sustainable farming practices that are environmentally friendly and resource-efficient. The goal is to enhance agricultural productivity while minimizing the environmental footprint by optimizing the use of water, energy, fertilizers, and other resources. The proposed scenario was carried out by the Local Action Group VJONA, with members being students of the University of Vlora. The main activities included:

- The creation of an automated irrigations and water reuse system using electronic devices;
- Real time data collection from sensors monitoring soil moisture and water levels;
- Automation of the irrigation process;
- Reuse of excess water to minimize waste and increase efficiency.

This is an Arduino-based project [20] which involves the use of electronic components like Arduino, sensors, breadboards, relays, etc. The system is designed to handle the watering of a plant by measuring the moisture of the soil in different time periods of the day, at the same time reusing the water that is being collected at the plate of the plant. The function of the system is based on the checking of the moisture of the soil of the plant. The moment the sensors gather the necessary data that the moisture of the soil is below a threshold esteablished at the beginning , it hydrates the plant in the right moment and with the right amount of water by improving the growth of the plant, also it reuses the water that is leaked at the plate, uses this water to water the plant again by pumping the water to the initial reservoir. The functioning of the Arduino scheme, first studied in the laboratory, is shown in the Fig.1.

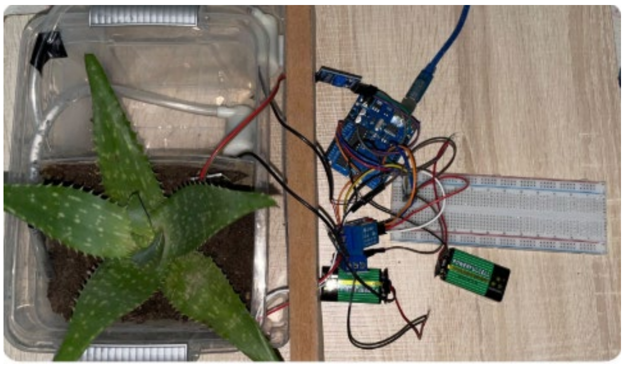

Figure 1. The model of the plant and the Arduino circuit

This project includes the usage of an Aloe Vera plant, which is placed in a container with water, and s connected via different tubes to an Arduino circuit. This is an example of Green IoT in Agriculture in which it contributes in: Precise Farming, Waste Reduction and Smart Irrigation.

Key Components of the System include: Arduino Uno, Soil Moisture Sensor, Water Pump, Water Level Sensor, Relay Module, Fig. 2., Fig.3.

The system operates through an Arduino Uno which receives signals from a sensor that constantly checks the dryness/moisture of the soil. If the sensor detects that the soil is dry, it sends a signal to the Arduino to activate the water pump. Once the Arduino gets the signal, it turns on the water pump. Water flows from the reservoir to the plant, hydrating the soil. After watering, any extra water drains into a tray beneath the plant. The water level sensor detects if the water in the tray is too high.

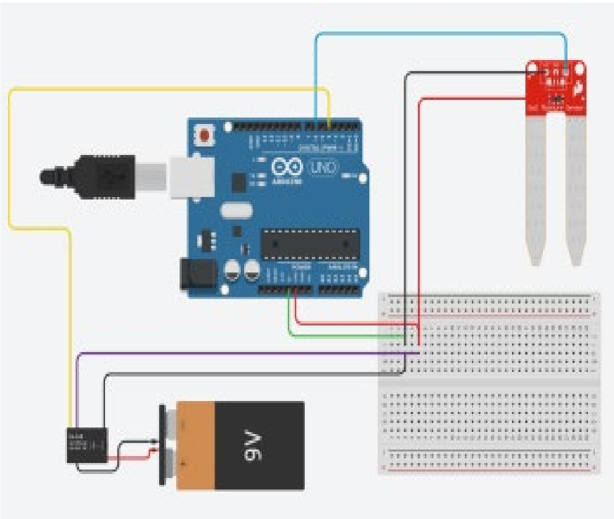

Figure 2. Circuit view

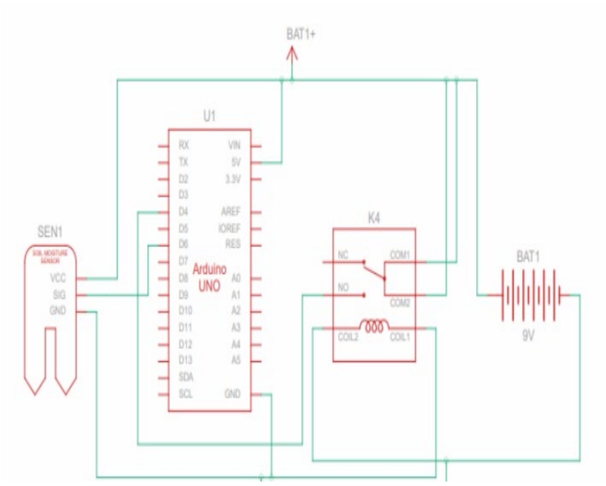

Figure 3. Schematic view

If too much water is collected, the sensor signals the Arduino to pump the water back to the main reservoir, saving water and keeping the tray from overflowing.

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Except for the hardware part it requires a code to operate, Arduino code is written in C++ with an addition of special methods and functions. The Arduino Integrated Development Environment (IDE) is the main text editing program used for Arduino programming.

The code that was used to program the above circuit is given below:

```
void setup() {
 pinMode(3, OUTPUT); // output pin for relay board, this will send signal to the relay
pinMode(6, INPUT); // input pin coming from soil sensor
pinMode(4, OUTPUT); //output pin for relay board
pinMode(5, INPUT); //input pin from water level sensor
}
 void loop() {
 int moistureLevel = digitalRead(6); // reading the signal coming from the soil sensor
 int waterLevel = digitalRead(5); //reading the signal coming from the water sensor

if (moistureLevel == LOW) { // if water level is low (i.e., soil is dry) then turn on the relay
 digitalWrite(3, HIGH); // high is to turn on the relay
}
 else { // if water level is high (i.e., soil is wet) then turn off the relay
 digitalWrite(3, LOW); // low is to turn off the relay
}

if (waterLevel == HIGH) { // if water level on the plate is high, turn on the relay
 digitalWrite(4, HIGH);
 }
else { digitalWrite(4, LOW); // if it is low, turn off the relay
}
delay(400);
 }
```

After the experiment was successful in the laboratory, the next step was to recreate the system for the campus green areas and garden plots near the University of Vlora, surrounding the building A, C and Rectorat. The project included the campus maintenance team and the students of the computer science department. The setting for the study included:

1. Time-Trigered monitoring

- The system uses the RTC (Real-Time Clock) module to take moisture readings at 5 specific intervals during the day (e.g., 6 AM, 10 AM, 2 PM, 6 PM, 10 PM).

- Each zone of the campus has its own moisture sensor for localized monitoring.

2. Decision Making

- If the moisture level in any zone drops below a predefined threshold, the Arduino activates the corresponding relay to turn on the water pump or valve.
- Watering is limited to a maximum duration (e.g., 5 minutes) to avoid overwatering.

3. IoT Integration

- Moisture data and watering times are sent to a cloud dashboard via Wi-Fi.
- University staff and students can access a live interface to monitor the health of the grounds.

4. Feedback and Alerts

- The system sends alerts if:
  - A sensor fails or disconnects.
  - A zone remains dry despite watering (suggesting pump or valve failure).
- Historical data is logged for sustainability reporting.

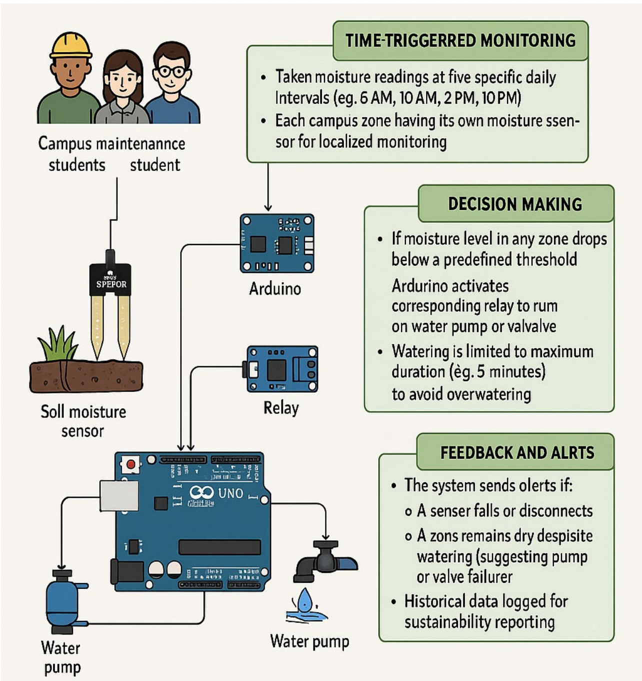

Figure 4. General view of the system and tasks

Relay module & water pump, RTC Module, Wi-Fi Module and IoT cloud. The created system monitors the ground surrounding the university and at the same time gather data.

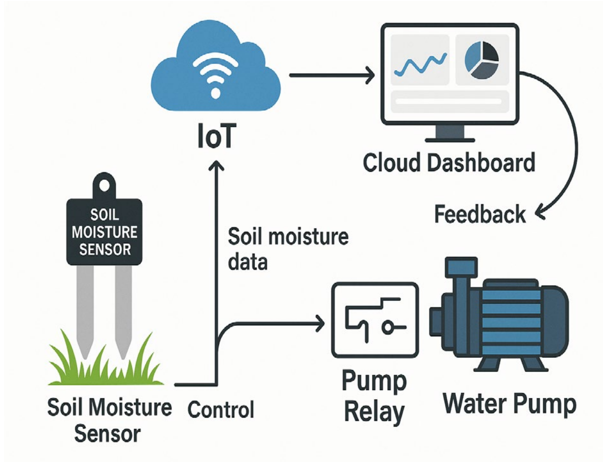

Figure 5. System Schematic

The key results of the experiment showed:

- A reduction in water consumption by 40-60%
- Prevention of water waste achieved through real-time moisture sensing and time-based irrigation scheduling, while at the same time having an automatic shut -off once the moisture levels reaches the desired valed.
- Reduction of energy efficiency in the range of 20-30%, related to controlled activation of the pump and the optimization of pump usage (only when it is necessary).
- Improvement of plant health as a result of stable moisture levels that are maintained throughout the day, while at the same time avoiding problems such as over-watering or under-watering.
- Real-time monitoring and remote access – achieved by the use of live dashboards that help provide soil moisture levels, watering activity logs and alerts in the cases of low moisture or a failure of the sensors that are placed on the grounds.
- Cost savings – this helps to reduce operational costs considering the water bill will be lower and there will be less manual labor for irrigation.

V. CONCLUSIONS

Green IoT is transforming industries by using smart technology to reduce energy consumption and environmental impact. In agriculture, it offers a sustainable solution to resource management, ensuring efficient water use, reducing waste, and promoting eco-friendly practice.

This project demonstrates how smart systems can automate plant care, recycle water, and optimize water usage, contributing to more sustainable farming and gardening practices. With further improvements like IoT integration, solar power, and machine learning, this project can be scaled up for larger farms or urban environments, contributing to more efficient and eco-friendly food production. It can be used by houses to better efficiently water their gardens, or by farmers to better monitor and water their crops. In this way they will be able to water the crops when they need to be watered and not risk the possibility of ruining their crops by overwatering or not giving them the necessary water the crops need.

REFERENCES

[1] Atzori, L.; Iera, A.; Morabito, G. The internet of things: A survey. Comput. Netw. 2010, 54, 2787–2805.

[2] ITU. Internet of Things Global Standards Initiative. 2015. Available online: https://www.itu.int/en/ITU-T/gsi/iot/Pages/default.aspx (accessed on 18 March 2021).

[3] Statistica. Internet of Things (IoT) Connected Devices Installed Base Worldwide from 2015 to 2025 (in Billions). 2015. Available online: https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/ (accessed on 18 March 2021).

[4] Gillis, A.; Rosencrance, L.; Shea, S.; Wigmore, I. Internet of things (IoT). 2016. Available online: https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT (accessed on 18 March 2021).

[5] Ashton, K., 2009. That 'internet of things' thing. RFID journal, 22(7), pp.97-114.

[6] Nizetic, S., Soli, P., González-de, D.L.D.I. and Patrono, L., 2020. Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future. Journal of cleaner production, 274, pp.1-32.

[7] Murugesan, S., 2008. Harnessing green IT: Principles and practices. IT professional, 10(1), pp.24-33.

[8] Albreem, M.A., El-Saleh, A.A., Isa, M., Salah, W., Jusoh, M., Azizan, M.M. and Ali, A., 2017, November. Green internet of things (IoT): An overview. In 2017 IEEE 4th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA) (pp. 1-6). IEEE.

[9] Gubbi, J., Buyya, R., Marusic, S. and Palaniswami, M., 2013. Internet of Things (IoT): A vision, architectural elements, and future directions. Future generation computer systems, 29(7), pp.1645-1660.

[10] Lu, Y., 2017. Industry 4.0: A survey on technologies, applications and open research issues. Journal of industrial information integration, 6, pp.1-10.

[11] Albreem, M.A., Sheikh, A.M., Alsharif, M.H., Jusoh, M. and Yasin, M.N.M., 2021. Green Internet of Things (GIoT): applications, practices, awareness, and challenges. IEEE Access, 9, pp.38833-38858.

[12] https://caburntelecom.com/iot-environmental-monitoring/

[13] Khan, M.A., Sharma, M. and Prabhu, B.R., 2009. A survey of RFID tags. International Journal of Recent Trends in Engineering, 1(4), p.68.

[14] Ruan, J., Wang, Y., Chan, F.T.S., Hu, X., Zhao, M., Zhu, F., Shi, B., Shi, Y. and Lin, F., 2019. A life cycle framework of green IoT-based agriculture and its finance, operation, and management issues. IEEE communications magazine, 57(3), pp.90-96.

[15] https://www.vodafone.com/news/digital-society/stories/spotlight-stories-digitalising-uka-farm-iot?.com

[16] https://farmonaut.com/precision-farming/smart-precision-farming-in-albania-boost-apple-orchard-yields?.com

[17] https://albania.un.org/en/283080-united-nations-launches-ambitious-programme-sustainable-digital-transformation-albania's?.com

[18] https://smart4all-project.eu/news/smart4all-digitized-environment-digitized-agriculture-special-session-in-tirana-23rd-of-february-2024/?.com

[19] https://iot-eco.eu/?.com

[20] Majumdar, P., Bhattacharya, D., Mitra, S. and Bhushan, B., 2023. Application of green IoT in agriculture 4.0 and beyond: Requirements, challenges and research trends in the era of 5G, LPWANs and Internet of UAV Things. Wireless Personal Communications, 131(3), pp.1767-1816.

[21] Perera, C., Zaslavsky, A., Christen, P. and Georgakopoulos, D., 2013. Context aware computing for the internet of things: A survey. IEEE communications surveys & tutorials, 16(1), pp.414-454.

[22] Sanchez-Iborra, R. and Cano, M.D., 2016. State of the art in LP-WAN solutions for industrial IoT services. Sensors, 16(5), p.708.

[23] Zanaj, E., Caso, G., De Nardis, L., Mohammadpour, A., Alay, Ö. and Di Benedetto, M.G., 2021. Energy efficiency in short and wide-area IoT technologies—A survey. Technologies, 9(1), p.22.

[24] Obaideen, K., Yousef, B.A., AlMallahi, M.N., Tan, Y.C., Mahmoud, M., Jaber, H. and Ramadan, M., 2022. An overview of smart irrigation systems using IoT. Energy Nexus, 7, p.100124.

[25] Shyam, G.K., Manvi, S.S. and Bharti, P., 2017, February. Smart waste management using Internet-of-Things (IoT). In 2017 2nd international conference on computing and communications technologies (ICCCT) (pp. 199-203). IEEE.

[26] https://docs.arduino.cc/learn/starting-guide/whats-arduino/, consulted 3 September 6, 2024.

[27] https://projecthub.arduino.cc/Aswinth/soil-moisture-sensor-with-arduino-91c818, consulted 3 September 2024.