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# Modelling a Sustainable Smart City

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## Abstract

This article presents the development of a model of a sustainable smart city. The model demonstrates the use of sustainable forms of energy and incorporates Internet of Things functionalities to simulate energy efficiency, monitoring of air quality, and safety. The city was designed to raise awareness about problems people living in cities face, as well as to inspire relevant technology-based innovative solutions in the context of the Sustainable Development Goal 11 (Sustainable Cities and Communities).

## Introduction

The Sustainable Development Goals (SDG) were created by the United Nations to model a more sustainable, fitting future. To this point there are seventeen documented goals to achieve by 2030. A major theme is improving life quality, such as ending poverty and malnutrition, as well as providing good health care services and education to people of all ages. Even more vital is to ensure that everyone, across the globe has access to fresh, drinkable water and sanitation facilities, while providing sustainable forms of energy worldwide. Adding to this, the SDGs encourage the building of sustainable industries and infrastructure, reducing the number of people living in slums, using resources wisely, and taking immediate action against global warming. Similarly, the use of an eco-friendlier lifestyle is promoted so as to sustain terrestrial ecosystems. [1]

One of these Goals, The Sustainable Development Goal 11 (Sustainable Cities and Communities), aims in overcoming challenges created by the fact that over 50% of the world's population resides in cities. This is predicted to become a whopping 60% by 2030. While cities contribute the most to the world's economy, they are also responsible for the most greenhouse gas emissions (75%) and for depleting the world of resources (60%). Furthermore, due to the phenomenon of growing urbanization poverty intensifies, and the percentage of people who live in slums keeps increasing, currently being at 828 million worldwide. At the same time, the environment is impacted negatively, as air pollution worsens and infrastructure is overburdened, including sanitation

[1] https://sdgs.un.org/goals

systems, water and waste collection, transport, and roads. The Goal 11 targets propose the areas which require immediate attention and improvement by 2030. [2]

Today, technology is a bigger part of our lives than it ever was before, and technological innovations in cities and infrastructure will be vital in our future. Smart cities are expected to be using Big Data analysis and the Internet of Things (IoT) to benefit their citizens in many areas including health, safety, and energy efficiency. IoT consists of networks of devices that communicate with each other through the internet: Input devices (sensors) collect data from their environment which are analyzed by control systems and are used to instruct output devices (actuators) to act upon their environment. This conceptual process runs in real time continuously with minimum human intervention. For example, an IoT system could use data from public cameras to detect traffic congestion and modify the functionality of traffic lights accordingly to address the issue. Diaz-Sarachaga [1] states that "Smart irrigation technology can optimize water use in gardens, parks, and other public spaces by considering variables such as weather, soil conditions, plant needs, and changing sunlight patterns". Boulos & Al-Shorbaji [2] argue that cities could harness the power of IoT to improve the health and well-being of their citizens, while smart LED lighting deployed in Amsterdam can generate energy savings of up to 80% [3]. To put into perspective how big IoT is and how fast it is growing, it is worth noting that there are more than 10 billion active IoT devices in 2021, estimated to surpass 25.4 billion by 2030[3].

As we wanted to contribute to a sustainable future for the cities, we formed the Green Team in 3rd Grade while we were Elementary students at the American Community Schools (ACS) Athens. We had a vision to make the world a better place where everyone can enjoy the natural environment and use technology to build a world of minimum pollution that utilizes sustainable energy like solar, wind, biofuel, and hydrogen, as well as raise awareness and inspire young students about our vision. For that purpose, we built, among others, a model of a sustainable city (the "Smart City"). To successfully complete the project, we had to meet frequently during and after school, distribute the work according to our needs and talents, and collaborate effectively. Building the model city took three years and some external support regarding understanding and assembling the electronics of the city.

The following sections include the description of the materials, functionalities, and purpose of the components of the model sustainable city built by the team, the presentation of the outreach activities of the team, the discussion of the challenges of the overall endeavour, and the conclusions and future plans.

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[2] https://www.un.org/sustainabledevelopment/sustainable-development-goals/

[3] https://dataprot.net/statistics/iot-statistics/

## The smart city

The Smart City is a miniature representation of what an eco-friendly lifestyle and city space would look like. Our main focus was to raise awareness of what the world could be if we took care of it. The model consists of a wooden base topped by several electronics components, cardboard objects, and ABS plastic 3D prints that represent a smart, sustainable city. It demonstrates environmentally friendly use of natural resources through photovoltaic cells that are stationed all over the city to provide solar power, wind turbines to provide wind energy, and hydrogen and biofuel tanks. Furthermore, it includes planted roofs and recycling stations. Apart from the represented facilities, it also includes functionalities such as sensors that communicate with Arduino boards under the model base to trigger specific outputs in the city. For example, a light sensor detects when it is dark ("nighttime") and turns on a series of LED lamps that light the city. Similarly, a gas sensor detects carbon dioxide ($CO_2$) in the air to alarm the city with flashing LED lights when the amount of detected $CO_2$ is high. In contrast to the light and gas sensors that detect events in their environment, the LED lights act upon it (actuators).

The hollow wooden base of the model includes the electronics that power the city. Apart from the aforementioned Arduino boards - the ''brain'' of the city - and the corresponding sensors and cables, an installed ESP8266 Wi-Fi microchip and a relevant Adafruit online service provide the city with Internet of Things capabilities to control the functionality of the light and gas sensors through the internet from computers and mobile phones. For example, once connected to the city's network from anywhere in the world you can immediately access the air pollution level of the city as detected by the gas sensor and monitor its readings in real time. An annotated photograph of the Smart City is illustrated in Figure 1. Figure 2 shows screenshots of the Adafruit app used to control and display the IoT functionalities of the city. A list of the main electronics used in the city can be found in Table 1, together with a short description of their functionalities and indicative relevant applications.

A prototype of the model city was presented at the 2017 ACS Athens Science Fair. An advanced version of the city to include the aforementioned Internet of Things functionalities was presented at the 2019 Athens Re-Science Festival[4]. The city, including model hydrogen-powered cars and improved IoT functionalities, was presented at the 2020 Innovation Summit of ACS Athens[5].

[4] https://www.huffingtonpost.gr/entry/athens-re-science-festival-mathetes-foitetes-start-ups-kai-anthropoi-tes-epistemes-kai-tes-kainotomias-paroesiasan-protzekt-pteches-toe-kontinoe-mellontos-mas_gr_5cab206de4b047edf95d1c88
[5] https://issuu.com/acsathens/docs/isci_2020_final_oline


**Figure 1** Annotated photograph of the top view of the Smart City.

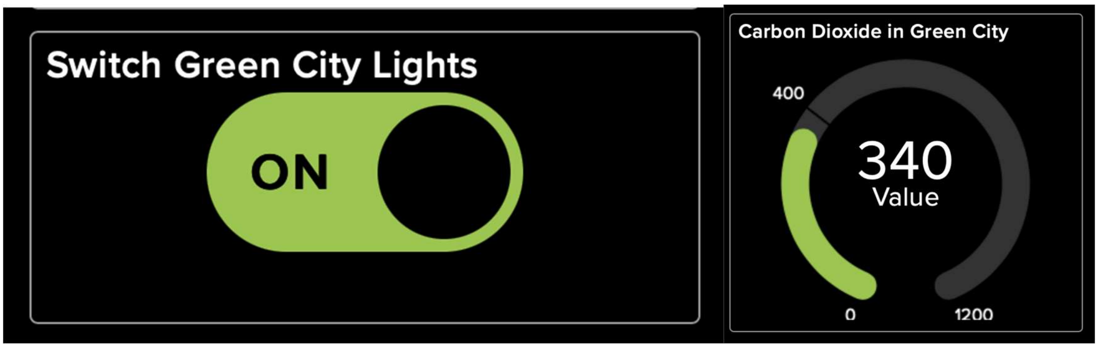


**Figure 2** Screenshots of the interface of the app used to control the IoT functionalities of the Smart City. Left: LED lights' control button. Right: $CO_2$ sensor's values.

**Table 1** List of the main electronic components of the smart city with outlined functionalities and applications.

| Electronic Component | Functionality | Indicative application |
|---|---|---|
| Gas Sensor | Detects the amount of $CO_2$ in the air | Monitoring air pollution |
| Light Sensor | Detects the ambient intensity of light | Efficient use of energy resources |
| LED lights | Light or alarm the city | Safety |
| Arduino Mini microcontroller | Controls the city's electronics | Smart "brain" of the city |
| ESP8266 WiFi microchip | Internet of Things capabilities | Wireless communication between devices |

## Challenges

Creating the Smart City was an amazing experience as we became more knowledgeable and skilled towards pursuing our vision of making the world a better place. Nevertheless, the project wasn't easy to complete as we needed to address numerous challenges along the way. For example, the ordered materials were sometimes defective. Therefore, they had to be re-ordered from the same or different supplier resulting in time loss. Also, the Smart City's components needed to fit in a relatively small panel (1 m x 1 m), and as the prototype was enriched with more components, it became crowded. The issue was eventually resolved by raising the city with wooden support. This allowed for enough space to fit the electronics beneath the city. Moreover, it was challenging for all built and 3D-printed components - people, trees, cars, houses, power plants, etc. - to be of balanced size in relation to each other. To visually improve the situation, a road was created to split the city into two areas of different scale. Furthermore, the IoT provider would frequently update the interface, resulting in the need to update the relevant libraries accordingly and check the effects on the existing code. In general, there was a constant need to test what works and what not, identify problems, brainstorm solutions and improve the prototype. Apart from the technical challenges, the team members had to work effectively both independently and collaboratively within a busy school schedule. Additionally, following safety protocols and guidelines relevant to the COVID-19 pandemic was a major constraint due to the hands-on nature of the project. However, our dedication to our vision and our passion to improve the world had us giving our best efforts into our project despite the challenges.

## 4. Conclusions and future plans

Creating the Smart City had the team realize the negative impact of humankind into the climate and our responsibility to reverse or at least minimize the damage. Being part of such a project inevitably leads to the realization of how important it is that we take action and that we do not hide behind excuses, such as “that’s not possible” or “this won’t make a significant difference”. One of the key achievements of the Smart City was the fact that it raised awareness of the problem at hand and the potential solutions that could be applied so as to bring about positive change. In the future, we intend to improve the Smart City model by adding Artificial Intelligence functionalities like traffic recognition and speech-based control, and to organize social events where the team could present their work for a sustainable world. Furthermore, we would like to collaborate with teams of students from other schools that share our vision in order to organize events that promote sustainability, like a reforestation or an ocean clean up. We are responsible for our world's future, and it is up to us on whether we make it sustainable.

## Acknowledgements

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## Keywords

Smart city; internet of things; sustainable development goals

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## Authors Biographies

A. E. Botsios:
I am Adrianos Botsios and I have a vision of making the world a better place by eliminating pollution, utilizing technology and using sustainable energy to make everyday life better. Currently in 9th grade, my horizons have expanded to include new technologies like Artificial Intelligence.

H. J. Sabbagh:
I am Hasib Sabbagh and I joined the Green Team in 4th grade as one of the co-founders. Recently I have been working a lot with the Green Team as we have seen many new opportunities to help our world.

D. Romain:
I am Denis Romain and at the time of writing this, I am a ninth grade student. I joined the Green Team later on in 2019, and I share the vision of a harmonious world between nature and technology.

A. Theodorakis:
I am Alexandros Theodorakis and I am a 9th grade student at ACS Athens. I could not be more satisfied to know that just a couple years ago we were just having fun and now we are experimenting with all different forms of new technologies.