ADAPTING URBAN SPACES TO URBAN SPACES TO URBAN HEAT ISLANDS THROUGH ARTIFICIAL PHOTOSYNTHESIS AND ROOFTOP GARDENING INTEGRATED WITH ARTIFICIAL INTELLIGENCE (AI).

Problem Statement

Rising global temperatures due to climate change is leading to extreme weather events, shifting seasonal cycles, and health risks. Urban areas are particularly vulnerable, experiencing heat waves, climate change, and seasonal shifts.

The Urban Heat Island (UHI) refers to the phenomenon where urban areas experience significantly higher temperatures than their surrounding rural areas. This temperature difference is primarily due to human activities and features characteristic of urban environments, such as:

- The prevalence of concrete, asphalt, and buildings that absorb and retain heat during the day and release it slowly at night.
- Urban areas often have fewer trees and green spaces, reducing natural cooling through shade and evapotranspiration.
- Increased energy use, vehicle emissions, combustion, and industrial activities contribute additional heat and greenhouse gases. These emissions release carbon dioxide (CO_2), carbon monoxide (CO), and methane (CH_4) gases into the atmosphere, exacerbating the Urban Heat Island effect and climate issues.

By 2050, urban areas may experience rising temperatures, contributing to climate change and seasonal shifts. Human activities such as transportation, industrial processes, and energy use are key contributors.

Impact of Urban Heat Island Effects

1. **Seasonal Shifts and Extreme Weather:** Seasonal shifts globally are altering ecosystems, with effects such as:
   - Earlier springs
   - Longer, hotter summers
   - Later autumns
   - Changes in monsoon patterns
   - Shifts in animal migration patterns
2. **Increased Energy Consumption:** UHI increases energy demand for cooling, placing strain on energy infrastructure and escalating utility costs. It can also lead to power outages during peak periods.
3. **Worsened Air Quality:** Higher temperatures exacerbate the formation of ground-level ozone, leading to poor air quality and health risks like asthma and respiratory diseases.
4. **Health Risks:** Vulnerable populations, including the elderly, children, and individuals with pre-existing conditions, face greater risks from heatwaves and heat-related illnesses.
5. **Disruption of Local Ecosystems:** UHI alters habitats, potentially causing biodiversity loss, species migration, and ecological imbalances.
6. **Acceleration of Global Warming:** Carbon emissions from urban activities disrupt the ozone layer, intensifying global temperature increases.

Innovative Solutions

To combat the UHI effect, we propose two innovative solutions: **Artificial Photosynthesis and Rooftop Gardening, enhanced with Artificial Intelligence (AI) for maximum impact.**

Artificial Photosynthesis

Artificial photosynthesis aims to mimic the natural process of photosynthesis, in which plants, algae, and some bacteria use sunlight to convert carbon dioxide (CO_2) and water (H_2O) into glucose ($C_6H_{12}O_6$) and oxygen (O_2). However, instead of glucose, artificial photosynthesis aims to produce useful renewable fuels and chemicals, such as hydrogen, oxygen, or even carbon-based fuels like methanol or ethanol. This process has the potential to provide a sustainable and clean way to generate energy and reduce CO_2 emissions thereby reducing greenhouse gas levels in the atmosphere.

How Artificial Photosynthesis Works

Artificial photosynthesis works by converting sunlight, water, and CO_2 into useful energy or chemical products, much like natural photosynthesis. The process involves three key steps:

1. Light Absorption

Just like in natural photosynthesis, artificial photosynthesis systems require a material that can absorb sunlight. In nature, chlorophyll absorbs light energy to start the process. In artificial systems, photocatalysts (light-sensitive materials) perform this role.

Materials used:

- Photovoltaic cells (like solar panels) or semiconductor photocatalysts (e.g., titanium dioxide (TiO_2) or copper oxide (CuO)) are used to capture sunlight and convert it into electrical energy.

2. Water Splitting

- In this step, light energy is used to split water molecules (H_2O) into hydrogen (H_2) and oxygen (O_2). This occurs through the oxygen evolution reaction (OER), where the energy from sunlight is used to break the bonds in water molecules.

Key catalysts for water splitting: Iridium oxide (IrO_2) and Nickel-Iron (NiFe) catalysts can be used in artificial systems to promote the OER. These catalysts are crucial in the efficient production of oxygen from water.

3. Carbon Dioxide (CO_2) Reduction

The main goal of artificial photosynthesis is to reduce CO_2 into useful chemicals or fuels, such as methane (CH_4), methanol (CH_3OH), or even liquid hydrocarbons that can be used as fuels or in chemical manufacturing. Photocatalysts in the system use the energy from sunlight (converted into electricity) to drive the reduction of CO_2, which involves adding electrons (reducing CO_2) and converting it into products.

End Products of Artificial Photosynthesis and Their Uses:

1. **Hydrogen (H_2):** Hydrogen can be used in fuel cells to generate electricity. When hydrogen reacts with oxygen in a fuel cell, it produces electricity, with water as the only byproduct, making it an ideal clean energy source, industrial processes and storage.
2. **Carbon-Based Fuels** (Methanol, Ethanol, Methane): The synthetic fuels produced (like methanol or ethanol) can be used in internal combustion engines, offering a **carbon-neutral option** if the CO_2 used for their production comes from renewable sources. These fuels can be used to generate electricity in power plants, heat in industrial processes, and even as raw materials for the chemical industry.
3. **Carbon Monoxide (CO)**: used to produce synthetic fuels. Syngas is a mixture of carbon monoxide and hydrogen, which can be converted into **liquid fuels** (e.g., diesel, gasoline). CO is also used in the production of chemicals such as formaldehyde, acetic acid and methanol. It can also be used in the production of plastics and other materials.
4. **Oxygen (O_2)**: Oxygen can be used for respiration and life support especially in medical settings (e.g., in hospitals for patients with respiratory issues or in Space exploration). It is also used in the chemical industry for various reactions that require an oxidizing agent.
5. **Formic Acid (HCOOH)**: It is used as a preservative, antiseptic and solvent in various industrial processes. It is also used in the production of textiles, leather and rubber.

AI Integration with Artificial Photosynthesis

Artificial Photosynthesis merged with AI has immense potential to revolutionize efforts in combating harmful gas emissions. By integrating predictive AI models, companies that heavily produce harmful gases can receive tailored recommendations on procedures to adopt for mitigating emissions. These models can analyze historical data, monitor ongoing production processes, and suggest optimized strategies that reduce carbon footprints without compromising productivity.

Additionally, advanced sensors will be employed to monitor artificial photosynthesis processes in real-time. These sensors will gather critical data, such as gas levels, environmental conditions, and chemical interactions, to determine the most effective catalysts for the artificial photosynthesis reaction. This real-time monitoring ensures that the process operates at peak efficiency, converting harmful gases into useful compounds like oxygen and biofuels while adapting to changing conditions.

The AI system, integrated with artificial photosynthesis, will utilize machine learning algorithms to analyze patterns and predict future trends in emissions and catalyst performance. This integration creates a self-sustaining loop, where AI continuously improves the artificial photosynthesis process and the mitigation strategies provided to industries. This innovative approach not only addresses environmental concerns but also promotes sustainable industrial practices, making it a transformative solution for reducing global carbon emissions.

Rooftop Gardening

Rooftop gardening also known as Green rooftops is the use of the top parts of buildings and infrastructures such as the rooftops for gardening. Rooftop gardens can benefit from a variety of plants that are well-suited for the unique environment of elevated, often dry and windy locations. It includes Flowers, Herbs, vegetables, ornamental grasses, and creeping phlox. Rooftop Gardening does not only transform unused urban space into green areas but also helps reduce ambient temperatures by providing natural insulation and cooling through the process of evapotranspiration. Evapotranspiration releases water vapor into the atmosphere which results in cooling. Carbon dioxide, which is a contributing factor to rising temperatures, is absorbed by these plants and oxygen is released. These gardens will contribute to urban biodiversity, serve as a green wall to filter air pollutants to improve air quality and mitigate the impacts of heat by absorbing carbon dioxide and releasing oxygen.

Green roofs decrease the total amount of runoff and slow the rate of runoff from the roof. It has been found that they can retain up to 75% of rainwater, gradually releasing it back into the atmosphere via condensation and transpiration while retaining pollutants in their soil. (Reference 2)

Examples include :

- Singapore's Green Roofs: The city is known for integrating green roofs into urban planning, contributing to both environmental sustainability and aesthetic value.
- New York City's Rooftop Farms: Rooftop farming initiatives are growing food locally, reducing carbon footprints associated with food transportation.

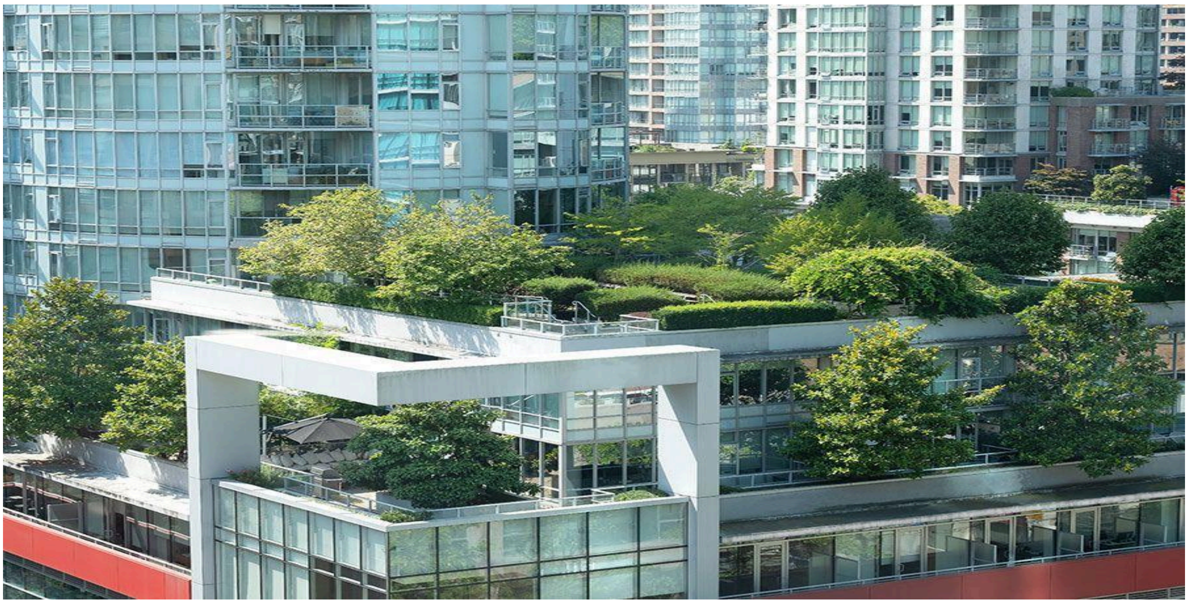
A modeling study found that adding green roofs to 50 percent of the available surfaces in downtown Toronto would cool the entire city by 0.1 to 0.8 °C (0.2 to 1.4 °F). (Reference 1).
Therefore, if most houses and infrastructures are built with green rooftops from now to 2050, it will reduce the rising temperatures in the urban areas.

AI Integration with Rooftop Gardening

The system will work hand in hand with AI, utilizing geopolitical data to identify areas with high production of harmful gases. This will enable the mapping of regions and companies that fail to adhere to environmental procedures. Rooftop gardening, coupled with AI, will also analyze urban heat data to recommend optimal plant species for specific areas. This monitoring system will suggest schedules and efficient gardening techniques to enhance natural photosynthesis processes.
In areas where rooftop gardening cannot be adopted due to financial constraints or settlement styles, the system will provide tailored gardening solutions designed for slum-populated areas. These solutions will focus on a five-year plan to help reduce harmful gases in these regions. The AI system will also recommend specific green crops suited for areas with high levels of harmful gas production.

The integration of AI will enable periodic monitoring and evaluation of pollution reduction efforts in targeted homes and areas. This approach will aid in the development of resilient urban ecosystems by promoting sustainable and environmentally friendly practices. By incorporating these tailored strategies, the system aims to significantly contribute to reducing greenhouse gas emissions while fostering greener and more sustainable communities.

The images below illustrate Rooftop Gardening.



Conclusion

Together, rooftop gardening and artificial photosynthesis integrated with AI can significantly alleviate the Urban Heat Island effect, creating cooler, healthier city environments and promoting sustainability as well as useful renewable products for energy production. Implementing these strategies would be crucial for designing resilient urban spaces that prioritize public health, climate, weather and environmental conservation by 2050..

References

1.Reducing Urban Heat Islands: Compendium of Strategies, Green Roofs. Available from:https://www.epa.gov/heat-islands.

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Team members/Participants

Kingsley Osei Danquah

Email: kingsleyosei675@gmail.com

Education background: BSc in Biochemistry and Plant Biology.

Phone number: 0544675465

Bryan Opoku Mawunyo Kofi

Email: officialmawunyokofi@gmail.com

Education background: HND in Computer Science

Phone Number: 0508567564