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Analysis of the Costs and Benefits of Green Architecture

I. Environmental Issues from the Built Environment

According to data collected in 2020, urban industrial and residential buildings make up the largest sector of energy usage in the United States, using 73% of electricity, 40% of raw materials, and 13.6% of drinkable water. These structures also make up 30% of the US's CO2 emissions (Neupane et. al., 2020), one of the most harmful greenhouse gasses (GHG) that accumulates in the atmosphere and traps in heat from the sun, warming our planet. The authors of this study as well as other authors state that GHG emissions from buildings are linked to increasing urban temperatures (Neupane et. al., 2020) and heat accumulation due to construction and human activity, also known as the Urban Heat Island effect (Yang et. al., 2016). Therefore, these buildings create a large cost to society financially via energy bills, as well as health-wise through contributing to climate change, which could result in further financial depletion via hospital bills. These statistics were accurate as of 2020, but the study also mentions how energy usage is predicted to double by 2050 as the population grows and people make lifestyle changes that could potentially use more energy (Neupane et. al., 2020).

The urban heat island effect (UHI) is an occurrence of heat accumulation in an urban environment such as a city due to construction and human activity where temperatures in the city center are distinguishably higher than temperatures in the outskirts or suburbs (Yang et. al., 2016). This effect was first measured and discussed by Lake Howard, a London scholar, in the early 1800s during his studies on urban climate. Dark surfaces like asphalt attract the sunlight and emit it back into the atmosphere where it is trapped by GHGs due to the concentrated air pollution from urban activities (Yang et. al., 2016). Therefore, UHI speeds up the effects of climate change in urban areas by the increased heat of the built environment's cycle of solar radiation reflectance being trapped in the atmosphere. Additionally, urban areas that are covered by impermeable surfaces of the built environment do not allow water to percolate into the ground as easily, so water stays on the concrete and asphalt, heats up, and adds to the humidity and general increased temperatures in a city (DNR LA). However, if these areas were covered in vegetation, solar radiation would be much more easily absorbed, as just one tree can absorb up to 600,000 Btu of solar radiation in a single day (DNR LA). Therefore, the more vegetation there is covering an urban area, the larger the latent heat storage capacity of that area will be (Yang et. al., 2016). Additionally, plants evaporate water into the air through evapotranspiration, which creates a cooling effect lower to the ground and moves warmer temperatures higher into the atmosphere, taking the heat away from communities of people (DNR LA).

UHI becomes more intense in modern cities that are continuously expanding their infrastructure, such as New York City, where the city center experiences temperature differences that range from 1.20 – 3.02 ºC higher than the outskirts of the city, and can be especially extreme in the summer (Rosenthal, 2004). Temperature is vital for controlling urban ecological processes, which affects the health of city-dwellers and can result in medical issues like extreme dehydration, heat stroke, and heat exhaustion (NYLCV, 2018). Due to these heat-related issues, city-dwellers might be generally more irritable, which reduces quality of life. Additionally, these issues also reduce people's productivity at work, especially for jobs that take place outside or involve manual labor, which can be harmful to the urban economy (Yang et. al., 2016). The same 2016 study by Yang et. al. describes how "research has found that citizens living in urban areas with UHI effect suffer digestive system disease, typically performing less appetite and indigestion with high reoccurrence rate. In addition, citizens in UHI areas are suffering from nervous system disease with insomnia, irritability, depression and memory decline." UHI will continue to increase temperatures in city centers, resulting in these problematic health issues, unless urban authorities begin to encourage ways to reduce heat reflectance and pollution and promote sustainability, such as encouraging the practice of green architecture.

II. A Potential Solution: Green Architecture

In the face of this impending harm to both city-dwellers and the environment, incorporating green architecture, or sustainable design, into new or existing buildings in urban areas is a promising way to begin to reduce the deleterious effects of the existing built environment. According to a 2008 study by Roy Madhumita, "Green, or sustainable, building is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition." Economically, this can also help reduce the amount of money spent to run a building as not as many resources are being used, including electricity, water, heating and cooling, land (through more efficient use of space), and even building materials (through recycling and reuse of building materials) (Ragheb et. al., 2016).

In order to reduce the negative environmental and economic effects of urban buildings, architects can orient buildings in order to take advantage of an architectural concept known as passive solar. The architect will analyze the path of the sun at different times of the year, analyze wind patterns in the area, and conduct a hill-shade analysis to determine if/how sunlight will be blocked by the surrounding landscape (Ragheb et. al., 2016). Then, using this information, they will design the building in such a way that it will allow as much natural sunlight as possible to enter the space during desired times of the day/year. As a result, the building will require less electricity for lighting and less heating in the winter (Ragheb et. al., 2016). Ideally, the architect will also design to promote strong building ventilation and include window techniques like double-glazing or gable overhangs outside that are long enough to block out summer sun at the hottest parts of the day, but still let in enough light/heat during winter. Techniques like these keep the building cooler in the summer and therefore the building requires less air conditioning. Designers will also use insulative building materials in the walls and roof to retain heat or air conditioning (Ragheb et. al., 2016). This building practice preserves resources and can help to reduce pollution and further destruction of the environment.

Landscaping can also be incorporated into passive solar and green building, as designers can plant evergreen trees on the north side of buildings to act as wind breaks against the north winds in winter since the leaves will not fall. Designers will also plant deciduous trees on the south side of a building to shade in the summer only when temperatures are hotter (Ragheb et. al., 2016). Adding a courtyard with landscaping into the center of a building can also be a helpful form of green building, as it draws fresh air down into the building, provides more light to the central parts of the building, helps with rainwater retention, can promote plant life and act as a place to garden, and is also aesthetically pleasing (Ragheb et. al., 2016).

There are also many ways that water is conserved and through green architecture. First, rainwater that falls on top of the building can be harvested from the building gutters or by open-basin collection and stored in rain barrels or a cistern. This water can then be used for things like irrigation of plants in and around the building, or as water to flush the toilets in the building.

Additionally, technology like low-flush toilets or low-flow showerheads can be installed in order to further reduce water usage (Ragheb et. al., 2016).

Green architecture can also improve hydrology through incorporating technology such as pervious concrete, which acts as a paving material but has no sand in its makeup in order to allow water to pass through into the ground below instead of accumulating and contributing to the UHI effect or collecting pollutants and running off into nearby streams and rivers. Pervious concrete can be used for paving things such as a parking lot or the area around the base of the building and allows water to pass through at a rate of 3 – 5 gallons per minute per square foot of surface area, which is fast enough to prevent harmful runoff events from stormwater. The pavement can also act as a sort of filtration system to remove some larger pollutants from the water entering the ground (Concrete Network, 2021).

Perhaps what most people think about when they think of green architecture would be green roofs, which are certainly a sustainable installation to any building. Green roofs that are covered in plant life absorb rainwater to help reduce harmful stormwater runoff and reduce solar radiation reflection into the atmosphere, helping to lessen the effects of UHI. These roofs also help with insulation, keeping heat or air conditioning from escaping and therefore cutting energy costs (Ragheb et. al., 2016). They can also help to promote new ecosystems and foster biodiversity in an urban environment. Finally, green roofs can improve the mental health of those who work or live within the building as they can enjoy the greenery or wildlife. There are two different types of green roofs. Intensive roofs are thicker, with a minimum depth of 12.8cm, and can support more plant life; however, they are also heavier and require a more intensive care process. Extensive roofs are thinner, their thickness ranging from 2 - 12.7cm, and they are lighter and need less care (Ragheb et. al., 2016). The term green roof could also apply to roofs equipped with green technologies such as PV solar panels or small wind turbines, as renewable energy technologies are also incorporated into green architecture as much as is feasibly and realistically possible (Ragheb et. al., 2016).

III. Cost Benefit Analysis

In many cases, buildings can be retrofitted (altered instead of being completely rebuilt) to reduce energy consumption by 30-40%, and it's one of the easiest ways to reduce energy and water usage (Neupane et. al., 2020). In the 2020 study by Neupane et. al., the authors describe how "The U.S. General Services Administration found that green buildings have 19% lower average maintenance costs, 25% of lower energy costs, and 34% lower CO2 emissions" than conventional buildings. Operation and maintenance costs make up almost 55% of the total cost of a traditional building project after 40 years, so building green significantly reduces overall project costs from the maintenance standpoint alone. The authors also continue to estimate that by 2030, new and retrofitted buildings fostering principles of green architecture will be 23% more energy efficient than traditional buildings, and that by 2050, these green structures will reduce the GHGs emitted by traditional buildings by 55%. These changes will total to an energy savings sum of about $20 billion (Neupane et. al., 2020).

Building sustainably or retrofitting buildings seems to be quite the economic choice in the long run, however, the primary reason that developers do not build more sustainable structures stems from the higher initial costs of construction vs the lower cost of conventional buildings. Often times, the public's perception of the costs of building sustainably or sustainably is higher than the actual costs (Neupane et. al., 2020). Even though the buildings' lifetime costs will be less due to lower energy and water bills and less maintenance, many remain hesitant and hold an unwillingness to pay for green features.

In order to encourage more green building, there exists a need to reduce initial costs, which could be assisted by incentives from global governments who have certain sustainability goals to meet. The Paris Agreement of 2015 emphasizes the need to reduce global emissions to as close to zero as possible by the end of the century, so many urban areas are trying to reduce emissions to contribute to this goal (Neupane et. al., 2020). Green architecture is a perfectly viable option that is already available and does not necessarily require the creation of new technology. Therefore, global governments have a currently attainable solution that could be used to work towards global sustainable development goals, significantly reduce the amount of GHGs in the atmosphere, and mitigate the effects of UHI and climate change (Neupane et. al., 2020). The only real barrier is the cost of constructing new buildings or retrofitting existing structures, but perhaps there are measures that could be taken by global governments to attempt to reduce costs or incentivize green design.

Although most research on green architecture has been conducted in global powers of the world like the US, it is also extremely important to focus on green architecture and retrofitting in developing countries and conduct cost-benefit analyses there as well. In these countries, green architecture is not popular, but there is still a need to become more sustainable and meet both national and global sustainability goals, so small changes can result in a large positive environmental impact and significant monetary savings (Neupane et. al., 2020).

There is a case study of conducting a cost-benefit analysis on an office building in New Town Dumre-Bhansar, Nepal that was retrofitted in 2020 to now include green components like rooftop PV solar panels to reduce nonrenewable energy usage, and rainwater-harvesting tanks to improve building water efficiency (Neupane et. al., 2020). The building is not very large, as it is only four stories tall with a total floor area of 1,100 m^2. There is also a flat rooftop that has an area of 275 m^2. Each year, the building has previously used an average of 47,872 kWh of electricity and 505,450 liters of water. This study accounts for the capital costs of the initial installation costs of PV solar panels (40 kW worth) and rainwater harvesting equipment (8 units of harvesting storage tanks). It also provides a caveat that the costs would likely be greater if a more in-depth remodeling was conducted, but also that these costs are incurred in Nepal, where it might be harder and therefore more costly to obtain or transport materials like PV solar panels (Neupane et. al., 2020).

The capital costs were determined to be \$1,728.70 / kW for a subtotal of \$69,148 in solar panel acquirement and installation, and \$625.60 / unit was estimated for rainwater harvesting, for a subtotal of \$5,004.80, creating a grand capital cost total of a little over \$74,000. There will also be some maintenance required for upkeep of the solar panels and rainwater harvesting infrastructure, but routine and periodic maintenance costs have been included in the capital costs. The only other cost will be that the battery of the PV solar panels will need to be replaced every 5 years (Neupane et. al., 2020).

Table-1: Monetization of Costs and Benefits

Cost Item	Value ($)	References
Capital Cost		
Solar PV Panel with Accessories (40 kW) @ 1728.70/kW	69148	MPID
Rainwater Harvesting (8 Unit) @ 625.6/unit	5004.8	Detailed Cost Estimate
Operating Cost		
Annual Energy (Electricity) Consumption (36050 KWh) @ $ 0.1/ KWh	4787.20	Building Inventory & Tariff Rate of NEA
Annual Water Consumption (505450 liters) @ $0.00054/liter	274.55	Local Water Distribution Tariff Rate
Battery Replacement every five years (24 Nos)	4000	Market Price
Benefit Items		
Annual Power Saving (73867.2 KWh) @ $ 0.1/ KWh	7386.72	MPID & NEA
Annual water saving (334125 liters) @ $0.00054/liter	181.49	Rational Equation & Local Tariff
Reduction in CO_2 Emission (21.75) @ $10/ton	523.40	World Bank Carbon Pricing

Above is a table of all costs and benefits of this case study. The benefits of this project come from the usage of renewable solar energy to cut energy costs, selling excess energy back to the grid, and using recycled rainwater to operate functions like toilets and reduce water bills. Additionally, the social cost of the CO_2 that is now not emitted as a result of these improvements is also factored in. As you can see, it will take a few years for the benefits to outweigh the costs, but according to the authors, the NPV of the project at the base year 2020 is already positive, and the internal rate of return is 7.48%, which is higher than the project discount rate of ~5%, making the project viable economically. The payback period has been calculated at 11.5 years, the length of time before the project is profitable, making the project a reasonable investment. Finally, the study furthers its findings and says that not only will this project be beneficial, but that more like it should be retrofitted or built new to further positive change (Neupane et. al., 2020).

The results of the study continue to detail how the benefits outweigh the costs if the project is not delayed, but instead is carried out efficiently and effectively. Over a span of 20 years, the Nepalese project office will decrease its project life cycle building costs by almost $15,000 as a result of using recycled rainwater and reducing energy costs by using in-house solar panels (Neupane et. al., 2020). However, the authors include how any extensive delay of the project will increase financial strain on the Nepalese taxpayers and government through continued expenditures. Despite this, upon the project's completion, the government will be a step closer to achieving its sustainable development goals.

IV. The Property Rights of Green Architecture

As the world learns more about the benefits of green architecture, environmentally, socially, and economically, it becomes increasingly important to create and enforce property rights for architectural thoughts and designs. As of December 1990, architectural designs and works are covered under copyright protection as intellectual property just like any book or song (PSMJ Resources, 2019). One can copyright buildings, drawings, and plans that are all designed for humans, but each individual item must be copyrighted separately (PSMJ Resources, 2019). These rights are defined by the type of design it is (structure, drawing, plan). They are defended by the legal power of a copyright as it prohibits others from taking the design for their own personal gain. Finally, these property rights can be delegated, as rights to plans can be sold by the creator to another person, and buildings can also be sold by one party to another.

There are exclusions to what designs can be copyrighted, including “designs like bridges, cloverleafs, mobile homes, walkways, boats, dams, and recreational vehicles. They also exclude designs for configurations of spaces and designs for fixtures like windows, doors, and staple building components” (PSMJ Resources, 2019). Finally, these intellectual copyrights are not permanent. Copyrights for work made for hire can last either 95 years from publication or 120 years after the work was created, whichever is the shorter period. Structures or plans created by individual architects, not for hire, is protected under copyright 70 years after the architect’s death (PSMJ Resources, 2019). Therefore, property rights can be extended to green architecture in the form of copyrights that are able to be defined, defended, and delegated, but there are many limitations to what can be protected and for how long that could be improved to further protect the ideas of architects building sustainably.

V. External Costs and the Future

For the most part, green architecture relieves the external costs of buildings, such as emitting CO_2, excessive power and water usage, contributing to the UHI effect, damaging nearby hydrology, and contributing to the overall degradation of the environment (Ragheb et. al., 2016). There are a few external costs, however, that could arise from an increase in green architecture prevalence. The first being potentially increased costs to taxpayers if governments decide to invest more funding in green architecture, for example through building municipal buildings or incorporating pervious concrete into more surfaces. Another external cost to civilians could be that some people might not like the way that new and retrofitted green buildings look, such as how it might be built from recycled materials or that some do not like how solar panels or wind turbines look on a roof. However, buildings that are more sustainable often follow more of a modernist, clean style that many people do appreciate. While there could be a few external costs that could arise from the prevalence of green buildings, these structures are minimizing other external costs that would otherwise harm society more than the external costs associated with green architecture projects.

Therefore, the future is bright for the success of green architecture and sustainable design. It has been a long time coming, as, for example, the US Energy Policy Act of 2005 required buildings to be designed to be 30% more efficient than the current energy code (Kampschroer, 2009). Nowadays, in places like California, architects are required to make sure all structures they design meet certain Energy Star efficiency requirements in order to be constructed (Energy Star, 2020). Hopefully more governments globally will follow this lead in order to improve the environment and the economy in a way that bears few barriers to significant positive change. After all, there are plenty of incentives for governments to do so, including the improvement of the green economy (and the economy in general) through the creation of countless jobs in over 50 different professions that will be involved with green building projects as identified by the U.S. General Services Administration. These include careers in design, engineering, manufacturing, construction, and operations industries (Kampschroer, 2009). In conclusion, world governments should all begin to shift in order to promote green architecture. The direct and indirect benefits will improve the economy as the benefits of most projects outweigh the costs, help the environment by reducing emissions and the effects of both climate change and UHI, and help society to stay healthy and inspire further sustainable technological innovation through architecture and design.

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