Integ System Design Project M (2022-23)

Group Number: Group 49

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Executive Summary

To help the University of Glasgow decarbonize, our team of six has decided to approach the issue from the following four perspectives, which have led to six different methods. Everyone in our group is responsible for collecting information on just one method:

1. Energy conservation by IOT(Internet of Things): improving energy efficiency and upgrading the power grid
2. Developing renewable energy: wind power, solar power
3. Carbon accounting
4. Green buildings

Ultimately, we have decided to adopt the first, second, and third perspectives to assist the University of Glasgow in decarbonizing. The order of implementation should be to first conduct carbon emissions accounting, then take measures to conserve energy, and finally develop sustainable energy. Due to their high cost and potential for damaging historic buildings, we have abandoned green buildings as a solution.

Improve Energy Efficiency

Improve the efficiency of electric energy utilization by IOT

How To Do

On university campuses, lighting systems are one of the important energy-consuming units. Therefore, installing energy-efficient lighting is one of the effective measures to improve the efficiency of electricity consumption on university campuses. Traditional incandescent bulbs have been replaced by LED bulbs and energy-saving bulbs because of their high energy consumption and short lifespan. According to research, LED bulbs and energy-saving bulbs can save up to 80% of energy consumption compared to traditional incandescent bulbs and can also last longer. Therefore, university campuses can achieve a reduction in energy consumption and an improvement in environmental performance by replacing light fittings.

In addition to replacing luminaires, university campuses can also optimise the efficiency of their lighting systems through The Internet of Things (IoT). In detail, we can design a solution for a hierarchical model of power saving management system with the joint application of ZigBee technology and WiFi technology, based on the original network solution of the University of Glasgow, instead of adding a wired approach, a wireless approach is adopted. The wireless sensor network gram overcomes the shortcomings of the wired network, and its easy deployment of nodes, no wiring, simple network maintenance and greatly reduces the cost of the solution. The convergence point (gateway) on each layer transmits data to the server via wireless WiFi, so that mobile phones can also be connected to the server via WiFI, allowing for real-time control. According to this design, we can develop an app on a mobile phone, so that all the electrical appliances in the school can be switched on and off through the mobile phone app after the wiring modification. Furthermore, we can monitor the electricity consumption of all appliances in real time directly through this app. With these, we can remotely switch off useless appliances or set up timer switches to turn appliances on and off in batches to save unnecessary power.

Renewable energy sources, such as solar and wind power, can also be used to improve the efficiency of electric energy utilization. By harnessing natural sources of energy, we can reduce our reliance on fossil fuels and minimize our environmental impact. Additionally, some renewable energy sources, such as solar panels, can be installed in homes and businesses to generate electricity locally, reducing the need for energy to be transported over long distances. Depending on the local climate in Glasgow, wind power may be a more suitable option. Since The largest wind farm in Europe is near Glasgow, and renewables produced the equivalent of 97.4% of Scotland's electricity consumption in 2020, mostly from wind.

So, how can the University of Glasgow incorporate wind power into its energy mix? To effectively use the wind energy resources of the campus, combined with the innate conditions of the school's grid electricity, the wind power system adopts the wind grid intelligent switching off-grid power supply system, that is, under normal circumstances the wind power system as an off-grid system to supply power to the campus lights, if the battery is under-voltage due to insufficient wind power generation, the intelligent power switching system carried on the inverter will automatically switch to the city grid to supply power to the light loads, in addition, when the battery In addition, when the battery is seriously under-voltage, the mains power will supply the load and at the same time replenish the battery in time to avoid damage to the battery due to long time under-voltage. At the same time, the whole system must ensure the stable operation of the load, no matter how the wind conditions change, without affecting the daily work of the light load.

Advantages

In summary, the use of IoT for campus grid renovation has many advantages. IoT can achieve efficient use of energy and improve the efficiency and quality of power supply, thus providing a reliable energy guarantee for the development of the campus. At the same time, the use of the system can also reduce operating costs and improve the safety and stability of the grid.
By incorporating wind power into its energy mix, the university can reduce its dependence on the grid, save money on energy costs, and demonstrate its commitment to sustainability. The university has several options for implementing wind power, such as installing wind turbines on its campus or implementing a community wind power scheme. With careful planning and execution, the University of Glasgow can successfully harness the power of the wind and become a leader in sustainable energy.

Improve the cross-sectional area of conductors and the power factor of the grid

How to do

Using renewable energy is an effective way to reduce carbon footprint. However, because of the fluctuating characteristics of wind and solar power (Chen et al., 2020), reducing the carbon footprint through grid modification is also an idea.

The transmission of electricity in the power system is achieved through the burning of fossil fuels and nuclear energy processes to generate a large amount of electricity, and then the transmission of electricity to the user over a long distance, which will generate a large number of carbon emissions (Karimi-Ghartemani, 2022).

At the University of Glasgow, all kinds of teaching activities and experimental research are inseparable from the consumption of electric energy, resulting in a large amount of carbon dioxide emissions. Therefore, reducing the carbon emissions of the university can be achieved by reducing the consumption of electric energy.

In the transmission process of electric energy, there will be losses in various links such as power transmission and transformation in the power grid (Wu & Ni, 2016). Some losses are inevitable, but some losses can be reduced by improving the power grid. When the cross-sectional area of the grid wire is set unreasonably, the loss of the circuit will become larger, so the most appropriate wire diameter should be determined by a load of electricity. Each building of the school needs different electricity consumption, so to make the power grid operator a more economical state, the wire of different diameters is determined according to the electricity load of different buildings.

Figure 1

Half hourly electricity data for the main HV incomers to the Gilmore hill site

Sum of Total	Column Labels					
Row Labels	<01/01/2016	2016	2017	2018	2019	Grand Total
Main campus		13423575.1	13912621.3	17093488	9301480.4	53731164.8
Maths and Stats			278725.4	474468.5	521597.9	1274791.8
North campus		17454043.6	17327332.1	16755894.1	16234718.1	67771987.9
St Andrews		794093.4	847061	843278.6	853747.2	3338180.2
Western Infirmary				456128.7	0	456128.7
Wolfson Medical School		5442790.2	5585779.3	5301940.6	5227338.6	21557848.7
(blank)						
Grand Total		**37114502**	**37951519**	**40925199**	**32138882**	**148130102**

Note. From the Energy Team at the university of Glasgow.

As can be seen from Figure 1, different buildings on campus have different demands for electric energy. For buildings with large electricity consumption, such as the main campus and the north campus, the required wires have high requirements for carrying current. Therefore, the wires with a large cross-sectional area are selected, while the wires with a small wire diameter can be connected to buildings with less electricity load.

For the University of Glasgow to carry out various activities normally, the active power required by the campus grid is limited. Therefore, the operation efficiency of the grid can be improved by reducing unnecessary reactive power (Ciucur et al., 2016). In other words, the natural power factor of the grid can be properly improved. On the other hand, manual compensation can also be performed to improve the power factor. For example, install some reactive power compensation equipment, such as the installation of shunt capacitors in the grid.

Advantages

At the University of Glasgow, electricity consumption accounts for a large proportion of carbon emissions, so improving the power grid to operate in a more energy-efficient state is an effective way to reduce the carbon footprint. It does require material resources and manpower to re-design and lay the wires of the power grid. However, in the long run, the new wires can not only reduce the risk of impedance increase caused by line ageing but also avoid more safety problems such as electric leakage while reducing the loss. As a result, maintenance costs are reduced.

The reconstruction of the power grid of the University of Glasgow can reduce the line loss rate of the power grid, effectively reduce the electrical energy loss of the university, and improve the efficiency of electric energy use, thus reducing the energy consumption of the university and reducing environmental pollution. The re-laying of grid wires and adding reactive compensation devices to reduce power loss can be maintained for a long time, and the maintenance cost is low.

Promote Renewable Energy

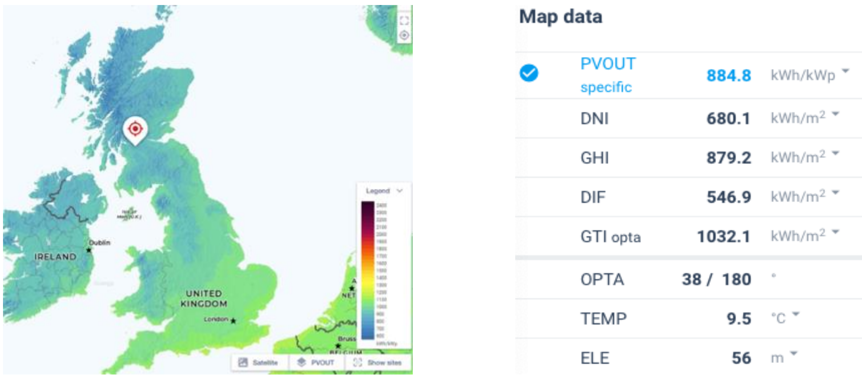
Solar Power

Investigation of Solar Power

Solar energy is a world-recognized high-quality clean energy. Li et al., (2022) pointed out the prospect and development of solar energy in the article. Today's solar systems generate roughly 255 times more electricity than they did in the early 2000s. If you want to reduce the carbon emissions of the University of Glasgow and improve the energy structure of the university campus, solar energy is one of them.

Figure 2

Global Insolation Radiation Map



Note. From the World Bank and the International Finance Corporation

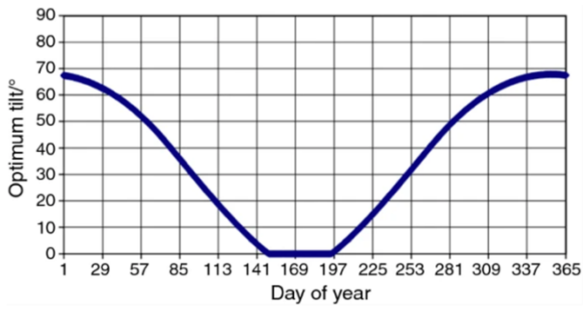
It can be seen from Figure 1 that the solar radiation level on the campus of the University of Glasgow is relatively poor. It is very difficult to install a solar system on the University of Glasgow campus to extract traditional fossil energy. Therefore, the solar system on the campus of the University of Glasgow is feasible as a clean energy alternative to traditional fossil energy. But this is only a partial replacement, not a complete improvement. The article by Ahshan et al. (2019) strongly supports this idea. The article presents a possible solution: adding facilities to a small portion of the campus. This can reduce the loss when the photovoltaic grid fails due to weather.

How to do

There are very limited places where photovoltaic systems can be installed on the campus of the University of Glasgow, and the ideal place is on the roof of each teaching building, so that better solar radiation intensity can be obtained, so that the photovoltaic system can achieve optimal power generation efficiency. The findings of Radosevic et al., (2022) also support this point of view, and it is also proposed that to improve the efficiency of solar energy, the roof photovoltaic panels can be tilted to a certain angle. Gunerhan & Hepbasli, (2007) also researched the inclination angle of solar photovoltaic panels, and the research results are shown in Table 2 below.

Figure 3

Optimal tilt angle for photovoltaic panels



Note. From Gunerhan & Hepbasli, 2007

Some solar systems are very simple to install while being undemanding to the terrain and location. Solar energy systems are almost all modular installations. Each photovoltaic panel is a photovoltaic panel that integrates various required devices. When installing, it can be simply spliced directly, plug and play. If you want to install a solar system on the roof of the building, you must also pay attention to the evaluation of various indicators (load bearing, angle, stability, etc.) of the teaching building structure on the campus. To obtain maximum power generation efficiency, it is necessary to pay attention to the angle of installation when installing solar panels on the roof to maximize the use of solar energy. At the same time, a stable control system is required to ensure that the solar system can produce stable and high-quality electricity.

Advantage

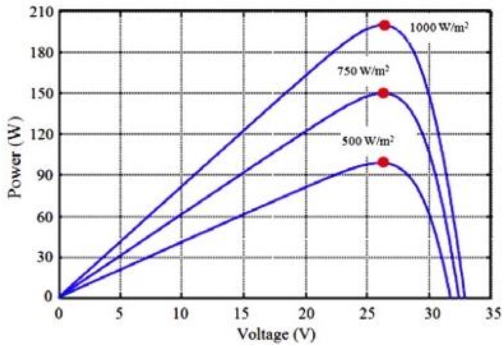
Usually, small solar systems can be installed in a few days, which is very fast. This is a very important advantage. At the same time, once solar energy is installed, except for some simple daily maintenance, the life of the solar energy system can generally reach 25 years. Now due to the development of technology and breakthroughs in various fields, the installation cost of solar energy is gradually reduced. The operating cost is also very low, with only some daily maintenance costs such as inverters, cables, connectors, etc. in the system hardware. However, as time goes by, due to factors such as solar system hardware ageing and wear and tear, the power generation efficiency of the solar system will decrease. Therefore, it is necessary to have a clear estimate of efficiency and cost before deciding to install a solar system.

Challenge

Low-cost maintenance of solar energy is a very important challenge facing the solar industry. Majdi et al., (2021) also clearly pointed out in the article that solar panel maintenance usually adheres to the concept of replacing when it breaks, which will cause a lot of money loss and a lot of electronic waste and carbon emissions.

Figure 4

Photovoltaic power curves for different sunlight intensities



Note. Eltawil & Zhao, 2013

Maximum power point tracking (MPPT) is also one of the important challenges. Since the energy conversion rate of photovoltaic panels is very low, the power of photovoltaic power generation is closely related to the intensity of sunlight radiation. The photovoltaic power curve is also non-linear. Therefore, MPPT is very important for a solar photovoltaic system. It can maximize the power production capacity of photovoltaic panels, ensure that the photovoltaic system operates at maximum capacity, improve the quality of output power, and make the photovoltaic system much more stable. However, changes in the intensity of sunlight and changes in the temperature of the photovoltaic panel will seriously affect the MPPT algorithm to track the maximum power point. Rezk & Eltamaly, (2015) focused on the response and accuracy of various MPPT algorithms under rapidly changing climatic conditions. So how to track the maximum power point more accurately has become another important challenge for photovoltaic power generation.

Wind Power

What is Wind power

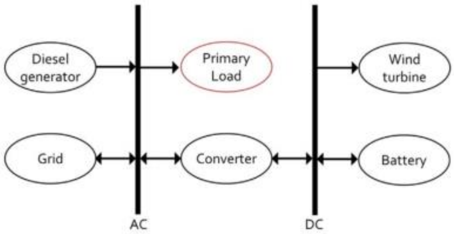
Wind energy is a clean, pollution-free renewable energy source that has long been treasured and used by humans. Since using wind energy to produce electricity is extremely environmentally friendly and has a large wind energy reserve, nations all over the world are placing a growing value on it. The fundamental idea behind wind energy production is to use the wind to propel the windmill blades to spin, then accelerate the generator to produce electricity by speeding up the rotation. Electricity can be produced using windmill technology today at a breeze pace of about three metres per second. For the University of Glasgow, this is not a problem at all. At the University of Glasgow, the wind speed at ground level is approximately 5.6 m/s, and the annual average wind speed at 25 m above the earth is approximately 6.4 m/s (Editor, 2012). The largest onshore wind power station in Europe, the Whitelee Wind Power Station, is located near Glasgow (Khan,2006).

How to do

Some of the tall and wide buildings at the University of Glasgow may have advantages when it comes to using turbines. The whole system consists of five components: wind turbine, battery, diesel generator and grid, and converter, as shown in the conceptual diagram.

Figure 5

Wind Power-Diesel Generator-Battery Power Generation System

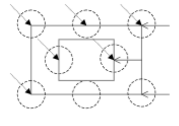
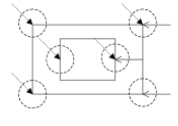
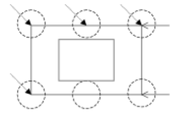
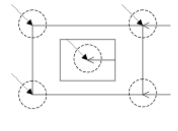


Note: Adapted from Effects of minute-to-minute variations in wind power on power system functioning by Banakar,2008

How the turbines are installed is a question to be solved. Turbines are generally used relatively infrequently in urban areas due to difficulties such as wind weakening, turbulence, and environmental issues such as noise. However, the use of turbines on the Gera campus has some important advantages: the resulting electricity is used directly locally, with no transmission losses; the form of the building concentrates the airflow, increasing output; teachers and students on the Gera campus can directly participate in the energy use in its buildings and address issues as they are identified.

Figure 6

Turbine installation configuration

No.	Configuration	Max. No.	Min No.	No.	Configuration	Max. No.	Min No.
8		6	3	6		5	3
6		4	2	5		4	3

Note: Adapted from The Potential for Urban Turbine use on Multi-Storey Housing in Glasgow by Sharpe,2003

This image is a schematic illustration of the construction of turbines on different buildings. The constructed turbine's calculated swept area is 5.6 metres. Theoretically, this would permit the installation of up to 8 turbines—6 at the parapet level and 2 in the motor room—on the available roof surface. However, prior studies have shown that installing 4 turbines at the parapet level and 1 turbine at the machine house's roof is the most economical course of action.

Figure 7

Comparison of energy demand and turbine capacity

	Existing tower block (before)			Proposed tower block (after)		
Space Htg.	Q^{htg}	Wind capacity	Residual demand	Q^{htg}	Wind capacity	Residual demand
Winter (Dec.- May)	214,957	63,333	151,624	52,887	63,333	-10,446
Annual Totals	311,390	95,000	216,390	74,307	95,000	-20,693
Annual Water Htg.	49,770			18,470		
Total	361,160	95,000	266,160	92,777	95,000	-2,223

Note: Adapted from Multistory housing complexes in Glasgow's 1998 Environmentally Friendly Cities have integrated solar thermal upgrades by Sharpe,1998

Advantages

The city of Gera near the Gera campus also has wind turbines built to generate electricity. According to the energy comparison above, wind turbines can supply more than 25% of the yearly water and heating load in established neighbourhoods and about 30% of the winter space heating load. In actuality, the low thermal efficiency of the blocks and an expensive heating system resulted in low real fuel use. If people switched to wind power, it would be cheaper and people would use it more for a reasonable level of comfort. The contribution that can be made by the wind component will thus increase proportionally. Therefore, the University of Glasgow, which is also deep in the centre of Glasgow, will also be able to solve energy problems to a great extent and reduce carbon emissions by building wind turbines.

Engineering Challenge

The challenge of improving the grid Electricity

It must be taken into account that the re-construction of the University of Glasgow campus power grid will produce certain noise, which will cause some obstacles to the teaching activities of the university and affect the daily activities of staff and students. Therefore, according to the arrangement of daily teaching activities on campus, the construction can be carried out at a time that has as little impact on daily teaching and research activities as possible.

To replay the campus power grid, it is necessary to first know the electricity load required by the buildings in each area of the campus, and at the same time to consider how to lay the lines to save more human and material costs, which requires a lot of statistics and calculation, as well as a certain time cost. It would be a priority to keep the power lines between the power plant and the areas of the University of Glasgow that use the most electricity as short as possible, because the longer the transmission lines, the more energy is lost in the transmission process. On the other hand, we should also consider making the total length of the transmission line in the school as short as possible, to save the manpower and material resources required for laying the line. At the same time, the shorter the transmission line, the less manpower and material resources required for the maintenance of the power system will be.

For large-capacity power supply, the hourly load demand is variable. At the same time, there are different load demands for winter and summer. Therefore, the algorithm is more complex when considering the optimization of the power grid (Das, 2012). In general, customers need more electricity in the summer and less in the winter. The demand for electricity in each area of the campus is also different. Therefore, it can be considered to set up an electric energy storage device in the campus grid to store the excess electric energy and transmit it to areas with high electricity demand. In this way, the waste of electric energy is avoided to some extent. At the same time, we can also consider generating electricity through clean energy. For example, we can install solar panels in areas with sufficient solar irradiation on campus to reduce the dependence on fossil fuels through clean energy generation.

If the power grid in the University of Glasgow is re-constructed, such as laying power lines and installing compensation equipment, vegetation damage and soil erosion may be caused to some extent, which may have some impact on the ecological environment in the university. In addition, if the grid is to be rebuilt, recycling discarded wires and other materials should be considered to reduce the environmental burden.

The challenge of using IoT to Transform University Power Grid

The campus grid is a complex system that provides energy to university campuses. Transforming it into a more sustainable and resilient system is an important challenge that many universities are facing.
As for IoT transformation, there are several issues that universities may face：

Data Security: With an increased number of IoT devices, there is a risk of cyberattacks and data breaches. Ensuring data security and privacy is crucial for successful IoT implementation.

Data Management: With a large number of IoT devices generating vast amounts of data, effective data management is critical to making sense of the data and identifying areas for optimization.

Compatibility: IoT devices and platforms may have compatibility issues with existing systems and infrastructure. It may be necessary to upgrade or replace current systems to accommodate new IoT technology.

At the same time, the introduction of wind power systems will also face some challenges as follows:

Ageing infrastructure: Many campuses have outdated infrastructure that requires repair or replacement. Upgrading the grid to a more sustainable system requires significant investment and can be costly.

Lack of funding: Transforming the campus grid requires significant funding, and many universities may not have the necessary resources to undertake such a project.

Complex ownership and governance structure: Many universities have complex ownership and governance structures that can make it difficult to make decisions and implement changes. This can slow down the transformation process.

Regulatory and policy barriers: There may be regulatory and policy barriers that make it difficult to implement changes to the campus grid. For example, some policies may favour traditional energy sources over renewable energy sources.

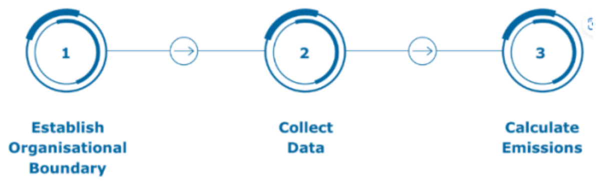
Carbon Accounting

There is a simple definition for carbon accounting: carbon accounting is a method of calculating how much greenhouse gases an organization emits (Farbstein et al., 2023). Although carbon accounting is a relatively new field, it plays a significant role in our efforts to combat global warming.

How to do

Figure 8

The steps of Carbon Accounting



Note. Adapted from How to calculate a carbon footprint for your business, by Tarleton, 2023.

Establishing Organisational Boundary is the easiest part of these three parts. It is generally recommended to have professionals handle all steps of carbon emissions, which raises the question of whether we need to pay high commissions to these professionals.

Figure 9

These are some authoritative institutions that can help us carry out carbon emissions

Advantages

Calculating carbon emissions can urge us to accelerate our pace towards carbon neutrality and thus improve the greenhouse effect (Mills, 2023). Now the whole world is demanding energy conservation and emission reduction. So what can we use to measure our achievements in energy conservation and emission reduction? I think a carbon emissions report is the best measure.

More and more countries are moving towards carbon neutrality in their regulations. Enterprises should be prepared for carbon accounting to avoid violating the laws of these countries, thereby avoiding unnecessary trouble. Due to the intensification of the global greenhouse effect, the European Union has formulated relevant regulations on carbon emissions and plans to achieve carbon neutrality by 2050 (Council of the European Union, 2023).

Carbon accounting has made it clear to us which energy sources emit the most greenhouse gases and urged people to vigorously develop new and sustainable clean energy sources

Challenges

In most parts of the world, disclosing carbon emissions data is still a voluntary action (He et al., 2021). If the disclosed carbon emissions data is too high, it will bring social pressure on companies and harm their interests. Moreover, the process of measuring carbon emissions itself requires a significant amount of funds and manpower. Researchers are now very concerned about the accuracy of the carbon emissions data that is disclosed in society.

The calculation of carbon emissions is related to the proportion of operational rights (Benn & Milliband, 2009), which is a quite tedious statistical model. Therefore, many companies have difficulty implementing carbon emission calculations and choose not to perform carbon emission calculations.

Carbon accounting requires a large amount of capital and human resources to be invested. For some small or medium-sized enterprises, it may be difficult to bear these costs.

What is a Green Building

Green building is sometimes known as "sustainable building" or "green construction." While there are multiple definitions, green building refers to the structure, i.e., the physical building, and the methods used to develop that structure that is considerate of the environment and conserves resources throughout a building's entire cycle. (*U.S. Green Building Council)*

How to do

Figure 10

Principles of a green building

Note. *Adapted from 'GSB.T, 2021'(7)*

Energy efficiency

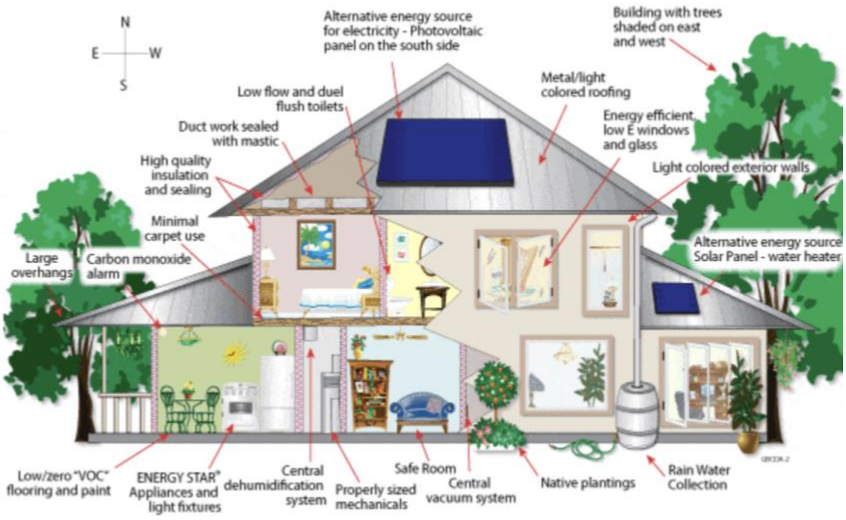
Minimizing the heat energy wasted during a building's day-to-day operations can have a huge influence on lowering its GHG emissions. Using a high-performance building envelope to decrease the transmission of heat across the interior and exterior of the structure is one of the best strategies to reduce heat energy loss. The building envelope is the building's exterior ‘shell,' which consists of its walls, roof, windows, and doors. Another significant element of green buildings is the conservation of fresh water.

Sustainable materials

A life-cycle assessment assesses the building as a whole, taking into account the building processes. All building supplies should be sourced from a sustainable form to minimize the adverse environmental impacts of construction. Purchasing the commodities from a local provider is suggested because it benefits local businesses.

Figure 11

Features of a green building



Note. Adapted from ‘The Constructor’ (8)

Advantages of Green Building

Green buildings dramatically reduce energy use. Global savings are considerable, as businesses and homes contribute to a large share of this utilization. Another benefit of green architecture is that important resources that include building supplies, water and power are used more responsibly. Sustainable building materials include wool, recycled steel, bamboo and recycled concrete. (Rosenkranz, E, 2023).

Tenants benefit from a greater level of living thanks to green development as well. The improved lighting, atmosphere, and temperature provide various health advantages including Improved cognitive ability and sleep.

Some more advantages are summarised in the table below.

Environmental benefits:	Economic benefits:	Social benefits:
• Emissions reduction • Water conservation • Stormwater management • Temperature moderation • Waste reduction • Improved air and water quality • Reduced solid waste • Conserve natural resources • Enhance and protect ecosystems and biodiversity	• Energy and water savings • Increased property values and profits • Decreased infrastructure strain • Improved employee attendance • Increased employee productivity • Sales improvements • Development of local talent pool • Reduced operating costs • Optimize life cycle performance • Qualifying for various tax rebates, zoning allowances, and other incentives in many cities	• Improved health • Improved schools • Healthier lifestyles and recreation • Improved employee satisfaction • Improve air, thermal, and acoustic environments • Enhance occupant comfort and health • Possibly limiting growth of mold and other airborne contaminants that can affect workers' productivity and/or health

Figure 12

Challenges

The main disadvantage appears to relate to the cost—that sustainable structures are more expensive than conventional buildings *(Rosenkranz, E, 2023).* Another point is that when green building renovations are carried out, the original buildings may be damaged, which may cause damage to the ancient buildings of Glasgow.

Conclusion

The University of Glasgow is a research-intensive university that requires a significant amount of energy consumption. To reduce energy consumption and emissions, we propose the following suggestions for the University of Glasgow:

1. Conduct carbon emission calculations and release emission reports promptly. This measure will inform people of the efforts made by the University of Glasgow in energy conservation and emission reduction. Through the emission reports, we can also learn how to take more effective measures to save energy and reduce emissions.

2. Improve energy utilization efficiency. After the line transformation, all electrical appliances in the school can be controlled by a mobile app, and the power consumption of all electrical appliances in the school can be viewed in real-time on the mobile phone. We can remotely turn off unused electrical appliances through this app, and also set scheduled switches to turn on and off electrical appliances in batches to save unnecessary energy consumption.

3. Electrical grid transformation. This mainly involves increasing the cross-sectional area of the wires to reduce energy loss during transportation. However, this transformation involves building destruction, and circuit redesign and requires significant human and material resources. Therefore, we will prioritize this option last.

4. Green building. Reasonable transformations of building materials and structures can achieve sufficient daylight and comfortable temperatures. This may save energy, but it may not be cost-effective compared to the high cost of

transformation. At the same time, our team members believe that transforming the historic buildings in Glasgow is a destructive act towards cultural heritage. Therefore, we do not adopt this option.

Therefore, we ultimately decide to help the University of Glasgow reduce energy consumption and emissions, and achieve decarbonization through carbon emission calculations, electrical grid transformation, and improving energy utilization efficiency through a mobile app.

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