City of York

SOLAR PV ASSESSMENT

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Revisions in this document are noted by the use of sidebars.

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EXECUTIVE SUMMARY

Figure 1 - Solar column lighting

The City of York (CoY) council has declared a Climate Emergency[1] and has an ambition to become a city with net-zero carbon emissions by 2030. We have been commissioned to investigate the viability of alternative power supplies for public lighting and how if viable they can reduce carbon emissions within CoY.

This report aims to detail alternative energy supplies and explore the viability of available solutions on the market. The lighting inventory and structure of York has been analysed to classify the viability of such technologies in York and the potential for returns in investment. The main alternative energy supply form identified as having the potential to be appropriate for use in CoY is solar PV panels. Photovoltaics (PV) converts light into electricity. Solar PV panels are panels used for the conversion of sunlight into electricity are increasingly becoming ubiquitous with onsite renewable energy generation.

The system would need to work as a hybrid system which has the potential to draw power from the grid if there is not enough sunlight available for areas in which availability of supply is critical. The report analyses the requirements, and street lighting assets available on different areas in York; and considers the feasibility of installing solar PV panels on them. The report concludes that based on the analysis provided, the primary agenda driving the switch to alternative power supplies needs to be climate and not fiscal, since there may not exist a lot of potential for economic savings through switching to solar supplies. Further feasibility studies in areas with a higher economic return potential may be required, and structural testing of all lighting columns would be necessary. A solar trial to explore real world performance and provide assurance around availability of supply may be required.

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[1] https://www.york.gov.uk/ClimateChange

1

INTRODUCTION

1 INTRODUCTION

According to UN-Habitat, cities consume nearly three-quarters of the world's energy and produce more than 60% of their greenhouse gas emissions.[2] Currently, cities need to lower their energy demand and consumption whilst supporting larger, wealthier populations and meeting citizens' expectations for local environmental quality. In 2019, the City of York (CoY) announced a Climate Emergency and have since set an ambition for York to be a net-zero carbon city by 2030.[3]

Throughout this investigation, the 'energy trilemma' is observed within the urban landscape and street lighting. The energy trilemma is used to describe the balance between the following three areas[4]:

- The maintenance of secure energy supplies,
- The social impact of using different energy supplies such as ensuring the long-term affordability of the system, and
- Their environmental impact.

Street lighting is one of the biggest energy consumers for local authorities including CoY. Past investment policies of smart lighting and LED upgrades have looked at how the electrical load can be reduced and managed. This has been one of the proven solutions that most local authorities have utilised to help meet carbon reduction targets. As per CoY's May 2022 inventory, approximately 60% of the city's lighting assets are LED (see section 5 for more details). More updates could prove beneficial for meeting the city's energy consumption and reduction targets, and for making alternative power supplies more efficient for further reductions.

The reduction targets are not only related to local Net Zero targets. They are also influenced by rising UK road lighting energy costs. These have risen due to the word's political situation and the increasing demand for electricity at night. The introduction of EV charging points, energy storage systems, and the new requirement for housing heating to be electric only have risen the total overnight energy use. The energy cost profiles shown on figure 1-1 are expected to increase more due to the current energy crisis. The cost of street lighting is currently around 35 to 40 p/kWh – seeing an increase of approximately 32% compared to the original costs of running it (11 to 13p/kWh); the current inflation, particularly on energy prices, will only further increase these costs.

One of the main alternative power supply methods for reducing the use of power from the grid is solar PV panels. Photovoltaics (PV) converts light into electricity. Solar PV panels are panels used

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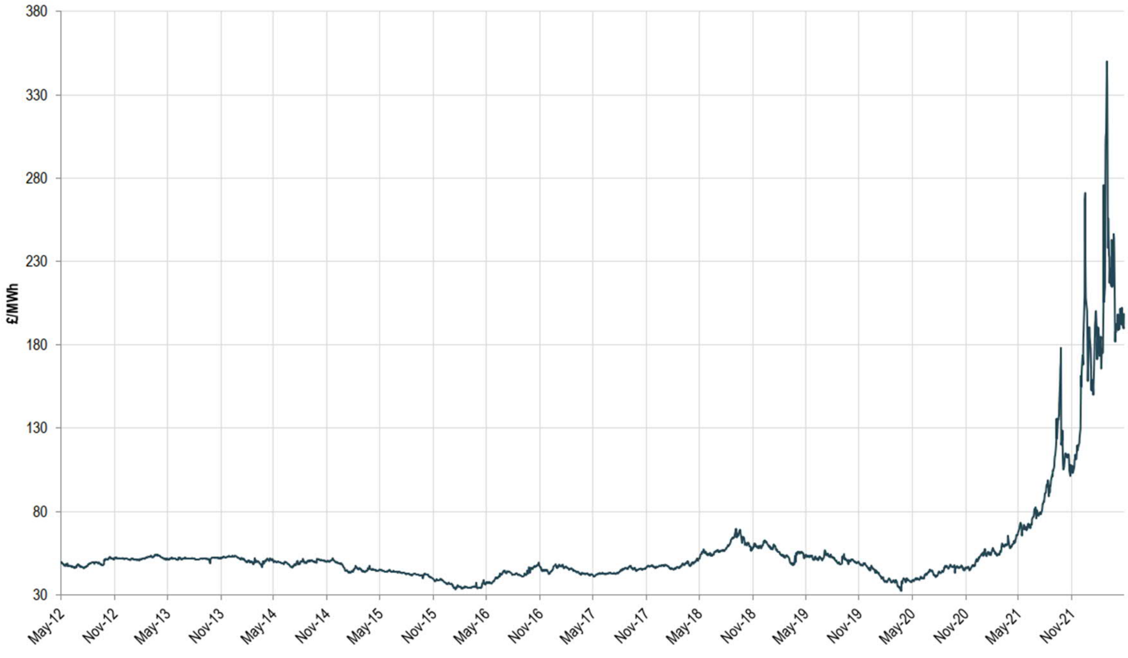
[2] https://www.un.org/en/climatechange/climate-solutions/cities-pollution#:~:text=Cities%20and%20Pollution&text=According%20to%20UN%20Habitat%2C%20cities,cent%20of%20greenhouse%20gas%20emissions
[3] https://www.york.gov.uk/ClimateChange
[4] https://www.carbonbrief.org/climate-rhetoric-whats-an-energy-trilemma/

for the conversion of sunlight into electricity and are increasingly becoming ubiquitous with onsite renewable energy generation.

Figure 1-1 - Lighting energy cost profiles from 2012 to present



Through this document, we investigate the viability of alternative power supplies and where these may be viable, we report how alternative power supplies to public lighting can reduce the consumption of electricity and carbon within CoY. The report is structured as follows:

Background considerations on alternative power solutions and streetlighting columns will be followed by a technology review of alternative power products. Then a high-level analysis of the CoY's existing assets will be conducted. Based on these sections an analysis of the viability of this technology in York will be considered followed by a summary of the investment potential on solar technologies.

2

UNDERSTANDING SOLAR AND WIND CONSIDERATIONS

2 UNDERSTANDING SOLAR AND WIND CONSIDERATIONS

When we are considering solar energy, we are talking about the available solar power from the sun falling on solar photovoltaic (PV) panels and thus generating electricity. Solar PV panels and their availability of the market will be defined and analysed in section 4. Solar energy is measured in terms of Kilowatt Hours per square metres $kWhr/m^2$. This unit indicates the amount of hourly power (kWh) produced per squared metre on an area of interest. For the purpose of this report, the area of interest is the solar PV panel located on street lighting and other highway electrical street furniture. Power is the rate of delivery of energy, and therefore how much energy is derived per second.

Wind energy is referring to the kinetic energy of air in motion. This energy can be converted by wind turbines into electrical energy. Wind energy can be measured in Kilojoules per square metre kJ/m^2. This indicates the amount of available energy kJ per squared metre.

2.1 AVAILABILITY OF SUNLIGHT

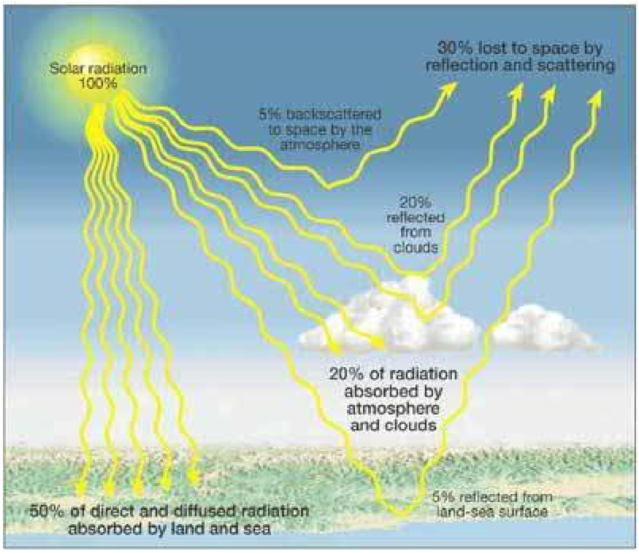
The availability of sun light is affected by a range of considerations:

2.1.1 CLIMATIC AND GEOGRAPHICAL CONDITIONS

Solar radiation is reduced through climatic influences, and geographical conditions. Climatic influences are the effect of atmosphere (reflection off and absorption by the atmosphere), reflection / blockage by clouds.

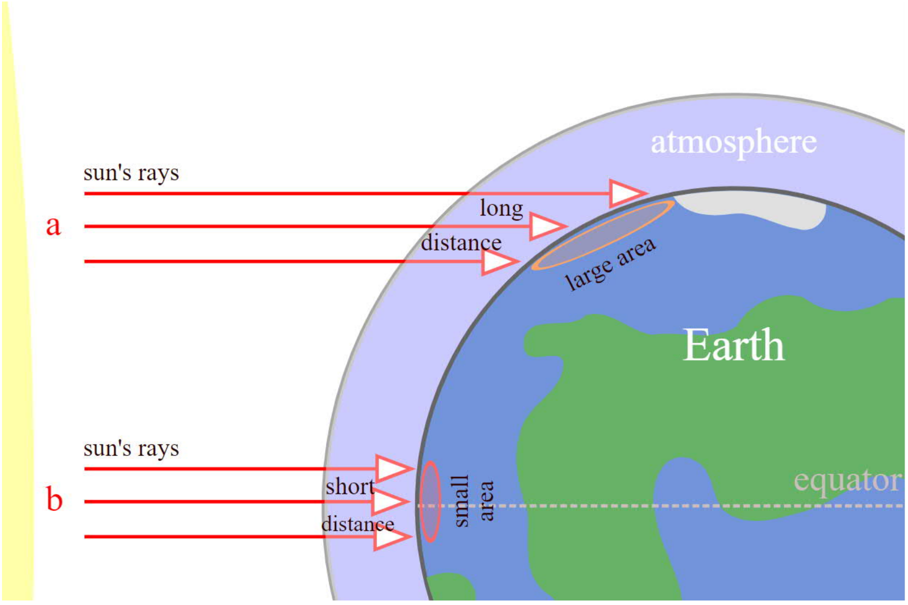
Geographical influences consist of the shadowing caused by buildings, trees, and other ground features. Neighbouring buildings, trees or natural features can shade part or the whole of an area of interest, affecting overall energy generation.

Figure 2-1 - Solar radiation reductions from atmosphere and clouds



The location of an area in relation to the equator is a geographical condition that influences the sunlight availability. This is also highly influenced depending on the time of year.

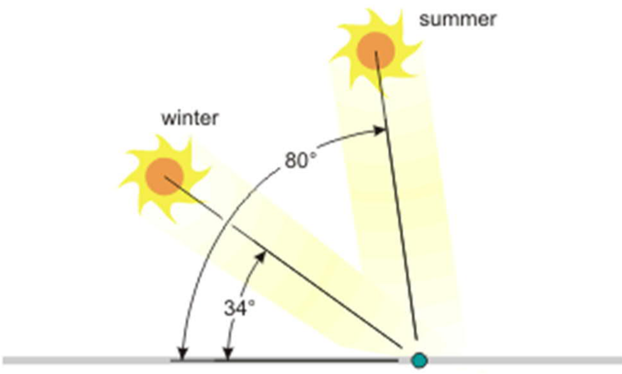
Figure 2-2 - Sunlight availability on different areas



2.1.2 TIME OF YEAR

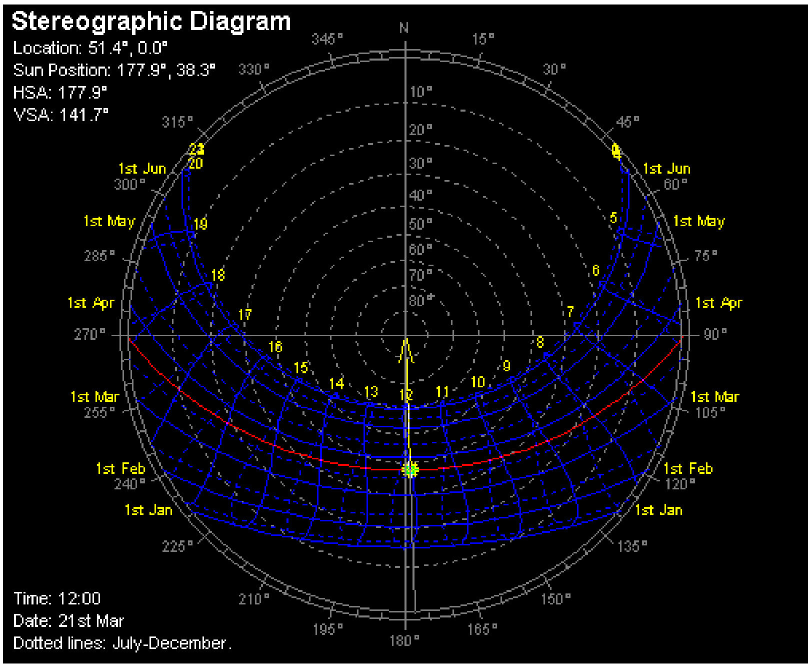
The azimuth of the sun (height above the horizon) varies over the year with the sun being more overhead during the summer and lower down over the winter. The angle of the sun in summer and winter an important step to determine the optimal orientation is review the site of solar PV panels used.

Figure 2-3 - Angle of sun in summer and winter



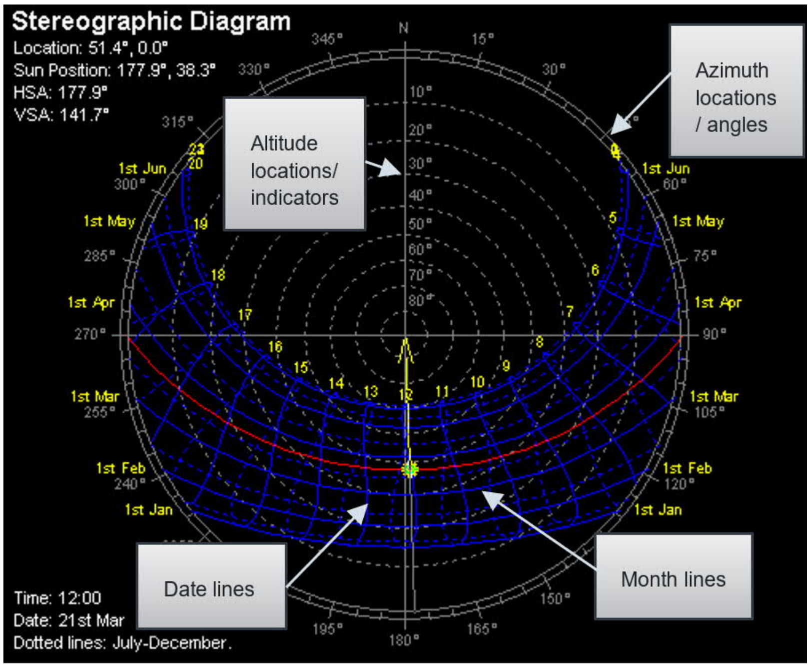
Sun path diagrams or sun charts are projections of the sky dome onto a surface. The stereographic projection is most commonly used and an example is shown in figure 2-4 below and provides an indication of sun availability over the year.

Figure 2-4 - Stereographic projection



The blue lines on the diagram indicate the month and time of year. The straight lines are used to indicate January – June, and the doted lines show July-December. In order to find the location of the sun at a specific day and time, the intersection between a specific time and month needs to be determined. Dotted lines need to be intersected with dotted lines, and straight lines with straight. Then the location of the sun can be found through the location of the intersection on the diagram. The azimuth location of the sun is indicated as an angle going clockwise from the north- the values are indicated around the circle of the sun diagram. The altitude lines are indicated by the concentric cycles in the diagram.

Figure 2-5 - Marked-up stereographic projection



2.2 AVAILABILITY OF WIND

The availability of wind gets influenced by different forces which can relate to climatic and geographical conditions and the earth's movement. Wind gets influenced by the changes of the pressure gradient which is a change of pressure over distance. This is mostly influenced by the geology of an area and characteristics such as the presence of mountains.

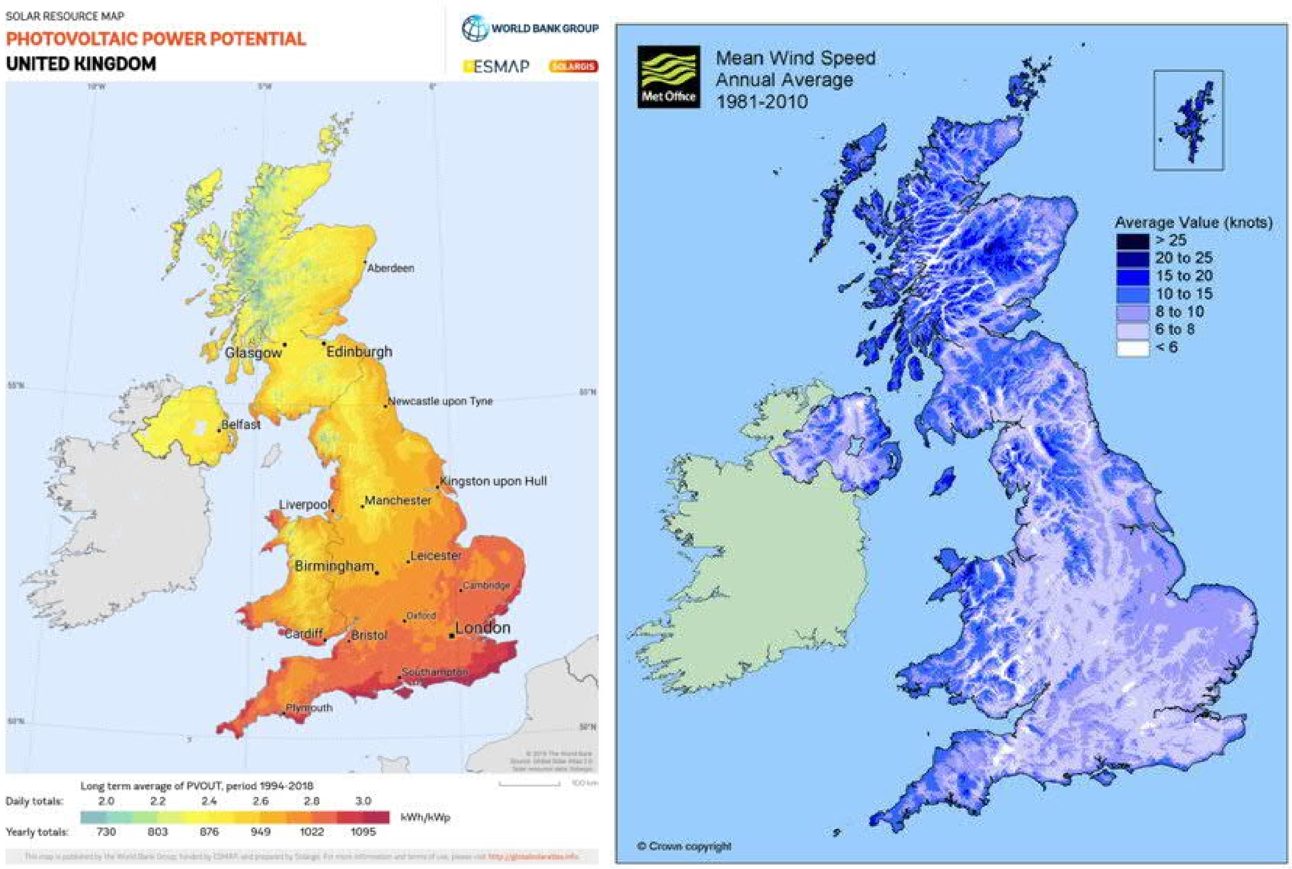
Another big influence to the wind's power is turbulent drag, which is caused when the earth's surface of objects such as buildings and trees cause resistance to airflow and reduce the wind speed. Based on this, the wind speed in an urban environment such as CoY is expected to be less than a nearby rural environment, if there are not any other prevalent forces influencing wind.

There are also different forces such as the centrifugal force which make winds move across curved paths. These have multiple influences including the movement of the earth and the location of an area of interest.

2.3 WIND AND SUN DISTRIBUTION IN UK

Wind availability tends to balance out solar availability across the UK as can be seen in the solar and wind resource maps shown in figure 2-6.

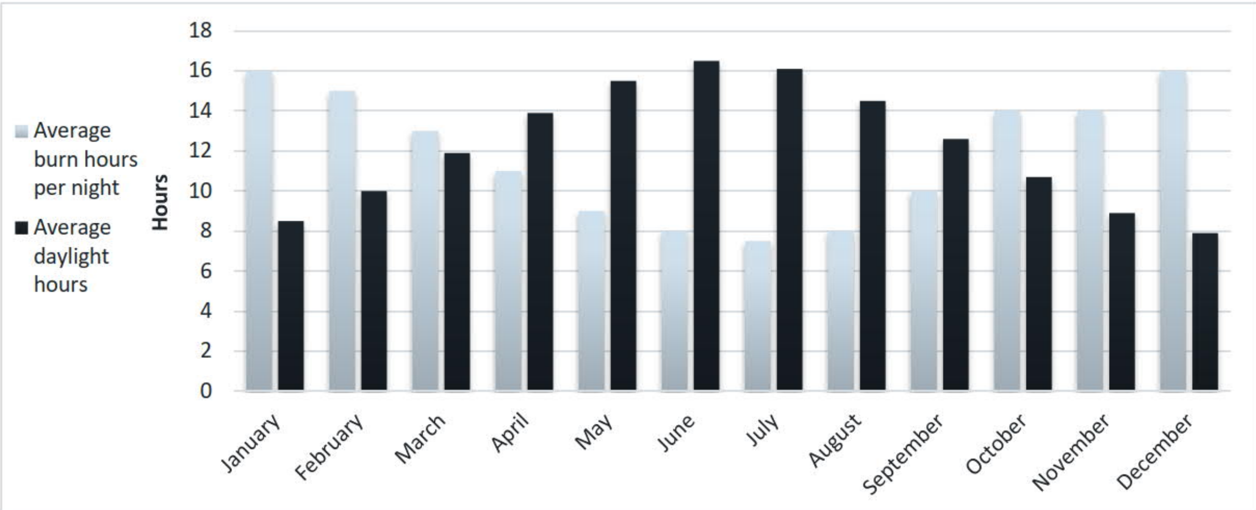
Figure 2-6 - Solar and wind resource maps



2.4 SOLAR AVAILABILITY AND STREET LIGHTING

Unlike wind availability, the provision of solar availability is unevenly distributed over the year, and this is clearly indicated in figure 2-7 which shows the average solar hour viability by day compared to the average night-time hours.

Figure 2-7 - Uneven distributed solar energy



This is an important consideration when looking at the provision of solar power for highway lighting. The following two demand profile tables are provided by Kight off grid solutions and show the ability of a column mounted solar array in an open landscape to charge a battery source and then power a 24W luminaire for each month of the year. Table 2-1 shows the results estimated if the luminaire is on full power at night, and table 2-2 shows how the system would perform if dimming is applied halfway through the night.

Table 2-1 - The luminaire is powered at 100% all night

Demand Profile 1

Solar PV demand profile 1 (100% lighting during twilight hours)

Month	Generation (Wh)	Available Energy	Demand	Gen < Demand	Days - Gen < Demand	Average SOC	Days - Storage < Demand
Jan	2,428.03	2,283.56	4,776.00	-2,492.44	29	2%	28
Feb	2,356.23	2,216.03	3,924.00	-1,707.97	24	5%	21
Mar	4,942.30	4,648.23	3,588.00	1,060.23	8	85%	2
Apr	6,719.45	6,319.65	2,688.00	3,631.65	0	100%	0
May	6,859.90	6,451.74	1,788.00	4,663.74	2	99%	0
Jun	7,441.19	6,998.43	1,080.00	5,918.43	0	100%	0
Jul	7,104.92	6,682.18	1,464.00	5,218.18	0	100%	0
Aug	5,666.89	5,329.71	2,364.00	2,965.71	3	99%	0
Sep	5,359.24	5,040.36	3,156.00	1,884.36	8	93%	0
Oct	3,450.03	3,244.75	4,080.00	-835.25	21	40%	11
Nov	2,456.41	2,310.25	4,560.00	-2,249.75	27	3%	24
Dec	2,124.73	1,998.30	4,836.00	-2,837.70	31	0%	31
					153		117

KIGHT

Table 2-2 - The luminaire is dimmed to 50% between 00.00 and 05.00 each night

Demand Profile 2

KIGHT

4 - Solar PV demand profile 2 (100% lighting except between 12-5am where is it 50%)

Month	Generation (Wh)	Available Energy	Demand	Gen < Demand	Days - Gen < Demand	Average SOC	Days - Storage < Demand
Jan	2,428.03	2,283.56	3,846.00	- 1,562.44	25	7%	20
Feb	2,356.23	2,216.03	3,084.00	- 867.97	21	15%	16
Mar	4,942.30	4,648.23	2,658.00	1,990.23	5	95%	0
Apr	6,719.45	6,319.65	1,788.00	4,531.65	0	100%	0
May	6,859.90	6,451.74	1,044.00	5,407.74	1	100%	0
Jun	7,441.19	6,998.43	540.00	6,458.43	0	100%	0
Jul	7,104.92	6,682.18	792.00	5,890.18	0	100%	0
Aug	5,666.89	5,329.71	1,470.00	3,859.71	2	100%	0
Sep	5,359.24	5,040.36	2,256.00	2,784.36	4	98%	0
Oct	3,450.03	3,244.75	3,150.00	94.75	15	60%	4
Nov	2,456.41	2,310.25	3,660.00	- 1,349.75	23	10%	17
Dec	2,124.73	1,998.30	3,906.00	- 1,907.70	29	2%	24
					125		81

As can be seen from the two tables for certain months even with the luminaire run at 50% for five hours a night the battery has insufficient charge to maintain the luminaire in operation. It should also be noted that the State of Charge (SoC) of the battery is extremely low for these months. This has a knock-on effect as a solar / battery installation has a requirement for two days of self-autonomy and three days of supported nights which clearly can't be achieved. The SoC of a battery is the level of its charge in relation to its capacity- maximum amount of energy it can store. SoC is a ratio between these two values and is therefore expressed as a percentage.

Products utilising both solar PV panels and wind turbines could provide more efficient results when dimming occurs and improve the SoC levels.

Figure 2-8 - Solar PV panel and wind turbine hybrid

3

UNDERSTANDING LIGHTING COLUMNS

3 UNDERSTANDING LIGHTING COLUMNS

Lighting columns are a core asset within CoY that has an even and widespread distribution across the city's urban areas. Over recent years, lighting columns across CoY have been utilised increasingly for purposes other than just supporting the luminaire. Third-party attachments and support have been mounted onto the lighting column, increasing electrical and structural load. These attachments include but are not limited to:

- Data collections sensors and cameras
- Festive decorations
- Wi-Fi, telecommunication enabling equipment
- CCTV equipment
- Digital signage and public communication
- Electric vehicle charging
- Transport optimisation (traffic management and parking)

3.1 STRUCTURAL AND AESTHETIC CONSIDERATIONS

Lighting columns are minor structures and need to be considered as such. They are designed to comply to BS EN 40 Lighting Columns; and are specified by the designer using PD 6547 Guidance on the use of BS EN 40. They must be considered as such when looking to mount any attachment to them. Hence, the inclusion of an energy source and storage onto a lighting column will also be subject to specific structural considerations as per the manufacturer's and CoY's specification. Structural tests may need to be conducted on existing assets as per ILP's GN22, and the column's manufacturer would need to be advised before further attachments are added. This assessment should always be undertaken by a structural engineer. The Institution of Lighting Professionals (ILP) Guidance Note (GN) 12 Smart columns provides guidance on the considerations to be made when looking to any attachment to any column.

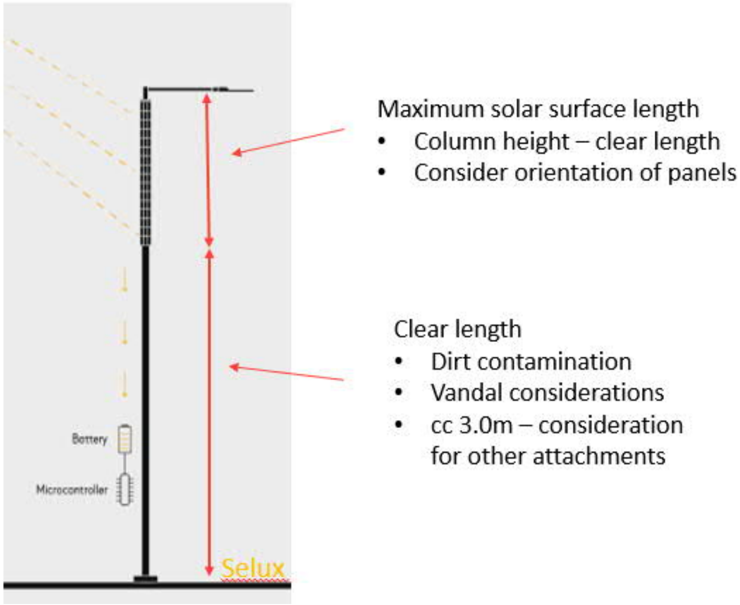
When attachments such as solar PV panels and wind turbines are considered, then due consideration should be given to the daytime aesthetic appearance. For instance, wind turbines may not look aesthetically pleasing on columns located at city centres. Further analysis on the different forms of solar PV panel attachments and wind turbines, and basic definitions of what these assets are, can be seen in section 4.

3.2 MOUNTING HEIGHT CONSIDERATIONS

Due consideration must also be given to where solar PV panel and wind turbine attachments are located on the column. They should always be mounted such that the distance from ground level to base of the array ensures minimal dirt contamination of the array from vehicle spray; and they should be located at a height that reduces vandalism.

Further care needs to be given for any other attachments the column is required to accommodate. The height of the column and these considerations will then dictate the possible size and area of the PV panel and/ or the wind turbine that may be accommodated. Figure 3-1 shows a schematic with further considerations for different mounting heights.

Figure 3-1 - Considerations for mounting height



3.3 ELECTRICAL CONSIDERATIONS

When considering electrical provision to lighting columns with assets that utilise alternative power resources two different types of column connections exist:

- Standalone columns, and
- Hybrid columns.

3.3.1 STANDALONE COLUMNS

A standalone off-grid column can operate as an isolated micro-generation renewable energy and battery storage system. This can be implemented such that the renewable energy system can power both the luminaire and any additional attachments if the environment is suitable.

Operationally, standalone off-grid solutions can have faster deployment and commissioning times than traditional DNO connected solutions.

3.3.2 HYBRID COLUMNS

A hybrid column can offer the flexibility to maintain a reliable and secure energy supply. It can be a solution coupling the DNO supply and renewable energy sources via a changeover interface. Another implementation can be that the renewable energy system can only power additional attachments while the luminaire is powered from the mains thorough DNO supply.

There will be additional space required on the column for controllers and power electronics systems, depending on the preferred implementation. For example, if the hybrid micro-generation supply agreement permits electricity exporting, space for metering equipment will be required, introducing regular asset maintenance.

In the UK, the use of hybrid columns for street lighting installations is recommended, due to the uneven light distribution through the year. Due to UK climate conditions grid export is not a feasibility, and the design would need to be made in such a way so that the excess energy is not exported to the grid.

4

TECHNOLOGY REVIEW OF ALTERNATIVE POWER PRODUCTS

4 TECHNOLOGY REVIEW OF ALTERNATIVE POWER PRODUCTS

4.1 ALTERNATIVE POWER TECHNOLOGIES

4.1.1 ENERGY GENERATION TECHNOLOGIES

Renewable energy sources such as solar PV panel and small-wind turbines can be integrated into a street lighting column. Including an onboard energy storage solution to a unit which is fed by the grid will add redundancy and flexibility to the installation and resolve the matching 'supply and demand' challenge. This means that the system would have more energy security, since the battery could act as a back-up energy source if there are power cuts, and the grid could supply the power needed if not enough energy is produced by the chosen alternative power technology.

Energy generation technologies include:

- Solar PV panels
- Micro wind
- Small hydro
- Active footways

4.1.1.1 Solar PV panels

Solar PV panels can be implemented as part of a microgrid system or a standalone lighting column system. The two primary semi-conducting materials most widely adopted are crystalline silicon and thin film.

The main types of crystalline silicon panels are monocrystalline and multi-crystalline. Mono-crystalline panels are more efficient and the most expensive on the market compared. Multi-crystalline panels are less efficient, however, they have recently improved. The manufacturing process for crystalline silicon involves extracting silicon from quartz sand at high temperatures. This is the most energy-intensive phase of solar PV panel production, accounting for 60% of the total energy requirement.

Thin-film solar panels are made by placing thin layers of semiconductor material onto various surfaces, usually on glass. They have lower manufacturing costs and are becoming more prevalent as they offer reductions in the carbon footprint. The main types of thin-film technologies used are:

- Cadmium Telluride (CdTe)
  - Solar panels are manufactured on glass.
  - Most cost-effective to manufacture.
  - Panels perform significantly better in high temperatures and low-light conditions.

- Amorphous Silicon
  - Non-crystalline form of silicon
  - Can be deposited in thin layers onto a variety of surfaces
  - Offers lower costs than traditional crystalline silicon; however, it's less efficient at converting sunlight into electricity.

There is a variety of different solar PV panel attachments available for columns which have different forms, and aesthetic properties that may be more suitable for different areas. There are wrap around solar PV panel arrays on the column shaft, circular off-set mounted arrays or horizontal arrays as indicated in figure 4-1.

Figure 4-1 - Off-set array, wrap around array & horizontal array

This characteristic also influences the type of solar PV panel utilised, which can be flexible and ridged. Ridged solar PV panels are rigid, and non-bendable, whereas flexible solar PV panel units can wrap around the column and assume different shapes.

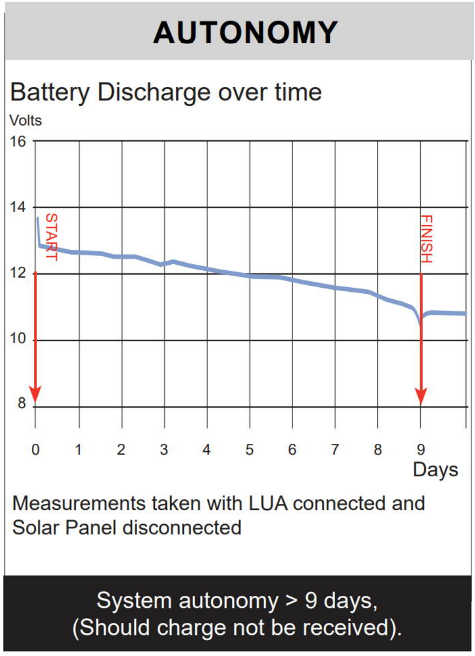
Apart from attachments to columns, lighting units with integrated solar PV panels, and batteries exist, such as Phillips SunStay (figure 4-2). Due consideration to the application of appropriate optics for the road needs to be taken into account. This is a further parameter that will need to be assessed to consider the suitability of the street-lighting asset.

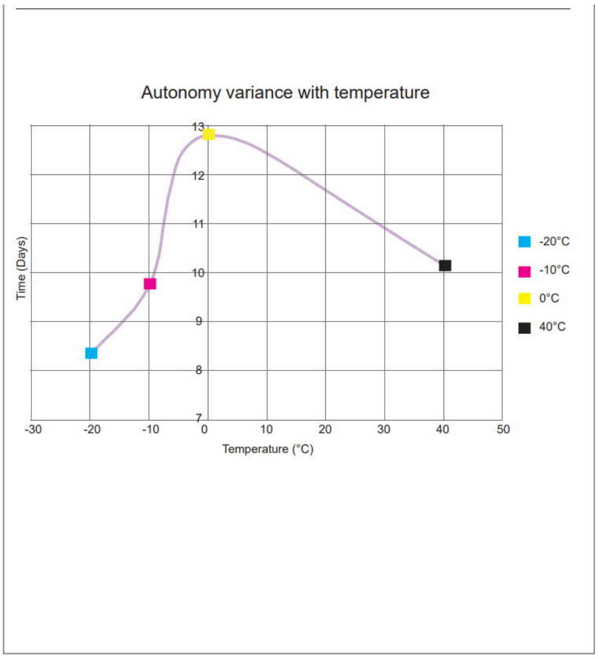
Figure 4-2 – Lighting unit with integrated panels (Philips Sunstay)

There are also other products with integrated solar PV panels such as solar illuminated traffic signs, Bellisa Beacons and school flasher units. Based on the manufacturer's data these products can have autonomy for up to nine days without charging. The following graph (4-3) is taken from

Simmonsigns and shows the autonomy of such a product. It should be noted that care should be taken on the product performance, which may vary based on operating temperature as shown on figure 4-4 provided by Simmonsigns.

Figure 4-3 System autonomy Figure 4-4 - Autonomy variance with temperature





The power generated from solar PV panels can be predicted. However, it is intermittent as the performance of a solar PV panel installation is influenced by the time of day and weather at a specific location, as discussed in section 2.

The power generated is also influenced by the system's effectiveness in converting solar energy to electrical energy. Modules currently in operation typically have an efficiency of between 9% and 22%; however, module performance deteriorates over time. This module degradation can occur at a rate of approximately 0.3% to 1%/year, depending on the module type and local conditions.

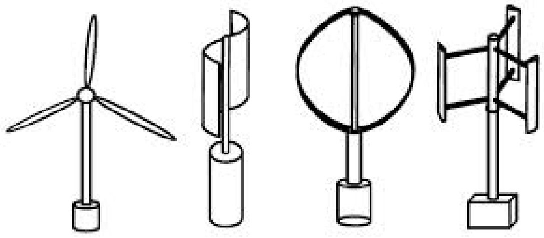
4.1.1.2 Micro-Wind

A micro-wind generation system consists of a small wind turbine, inverter, cabling and distribution equipment. The rotating blades generate electricity, which turns a shaft connected to an electrical generator. Electrical energy is generated as direct current (DC), converted to useable alternating current (AC) by an inverter. Small wind turbines are defined as those that can deliver energy up to 50kW. This definition covers different turbine sizes: horizontal axis (HAVW), and vertical axis (VAWT). Figure 4-5 shows a HAWT turbine and three different types of VAWT turbines.

Small turbines can be installed on or near windy sites to provide an additional source of electrical energy. It can be implemented as a standalone street lighting or grid-connected. A possible implementation might be as part of a renewable hybrid system along with solar PV panel and adequately sized battery storage to cover the issue of intermittency.

Before installing micro wind energy solutions, the additional loading on the lighting column needs to be considered, and the suitability of such a product may be influenced.

Figure 4-5 - Wind turbine types



The electricity generated from wind energy has one of the lowest carbon footprints. Nearly all the emissions occur during the manufacturing and construction phases, arising from the production of steel for the tower/column, concrete for the foundations, and epoxy/fibreglass for the rotor blades Emissions generated during the operation of wind turbines arise from routine maintenance inspection trips which include the use of lubricants and transport.

As has been analysed in section 2, the production of energy with wind turbines is greatly influenced by local geography. Buildings may impact wind flow and can in turn make turbines less efficient.

Wind turbines can also be a source discomfort to people in the local vicinity. They may be considered unaesthetically pleasing and they also produce noise pollution and vibrations nearby.

There's a health and safety concern due to the moving parts of the installation. This would also carry across during maintenance in contrast to static installations such as solar PV panels where there are no moving parts. CoY are rightly proud of their Peregrine Falcons that reside next to the minister building. Turbines would pose a risk to the welfare and wellbeing of these animals should one of them come into contact with a wind turbine.

4.1.1.3 Small-Hydro

Hydroelectric power is generated when hydro turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator. Small hydro generation can be classified as:

- Micro-hydro - Power generation of under 100kW or
- Pico hydro - Power generation of under 5kW

The UK Government describes the following three main types of hydroelectric schemes in use in the country:

- **Storage schemes:** A dam impounds water in a reservoir that feeds the turbine and generator, usually located within the dam itself.
- **Run-of-river schemes**; Use the natural flow of a river, where a weir can enhance the continuity of the flow. Both storage and run-of-river schemes can be diversion schemes, where water is channelled from a river, lake or dammed reservoir to a remote powerhouse containing the turbine and generator.
- **Pumped storage**; incorporates two reservoirs. At low demand, generally at night, electricity pumps water from the lower to the upper reservoirs. The water is then released to create power when demand is high. (Not considered renewable energy; however, pumped storage is very good for improving overall energy efficiency.

Small hydro schemes can be very efficient and convenient and can form an excellent long-term investment in a suitable site; however, the upfront cost of hydropower can be high. However, this scheme will be onerous to implement within City of York due to lower flowing water resources. Utilising the River Ouse is regulated and will be subject to the Environmental Agency licensing.

4.1.1.4 Active footways (Kinetic pavements and roads)

Active footways generate electricity by absorbing kinetic energy induced on specialised pavements and roads through walking, and vehicular movement. The absorbed energy is stored in batteries or utilised to supply street lighting or electrical items within the urban environment. This technology can be used as an off-grid solution. Currently, the technology is developing and is not as powerful as conventional electricity sources.

As of now this technology has been used to supply electricity to local illuminated art works, with products such as Pavegen available in the market for interactive applications.

4.1.1.5 Energy generation technologies summary

The following table provides a summary of the technologies discussed above.

Table 4-1 - Energy generation technology

Technology	Advantages	Disadvantage
Solar PV panels	• Predictable power generation (long term). • Low initial capital investment • Low maintenance- self-cleaning. (However batteries would still require cyclical maintenance) • Broad PV supply chain	• Intermittency (short term)- Due to UK climate and duration limits to diurnal generation of night the system will not be able to regularly produce enough energy. • Carbon intensive crystalline silicon manufacturing process.
Micro-Wind	• Predictable power generation (long term). • Low overall carbon footprint. • Electricity production possible overnight.	• Structural limitations on columns. • Routine maintenance and inspections due to moving parts. • Noise. • Safety.
Small-Hydro	• Predictable power generation (long term). • Electricity production at all times of the day.	• Flow may be seasonal. • High capital cost. • Must be near a river with a good head/ source. • Periodic maintenance is required.
Kinetic footways and roads	• Predictable power generation (long term). • Potential for interactive applications which can raise CoY's profile and raise awareness on Carbon issues	• High costs. • The technology is developing and is not as powerful as conventional electricity sources.

4.1.2 ENERGY STORAGE TECHNOLOGIES

The most common type of energy storage that can be used is batteries. Battery technologies have rapidly evolved over the past ten years, and a variation of solutions exist with different advantages and disadvantages. The lighting industry currently use in commercial volumes two basic types of battery: Pb Gel-mat and Lithium-Ion batteries.

Pb Gel-mat batteries have a low initial cost, can offer wide operating parameters, are highly recyclable and can trickle charge at all temperatures. However, they have a lower cycle capacity compared to Lithium-Ion batteries and weight more than Lithium-Ion batteries.

On the contrary, Lithium-Ion batteries have a high initial cost, a poor charge rate at lower temperatures, and they are not highly recyclable. They have a higher cycle capacity compared to Pb Gel-mat batteries and weight less than Gel-mat batteries.

Other types of batteries that exist are Lead Acid batteries, AGM (Absorbent Glass Mat), and Ni-cad. Figure 4-6 shows a comparison of battery technologies conducted by Simmonsigns.

Figure 4-6 - Comparison of battery types

BATTERY	Lead Acid	Gel	AGM 	Lithium	Ni-cad
Product Life span (Years)	2 - 3	2 - 4	8 - 12	5 - 6	4 - 5
Temperature Range	-18°C to 45°C	-18°C to 50°C	-40°C to 65°C	-20°C to 65°C	-20°C to 65°C
No. Discharge Cycles @80%	450	500	1500	1300	1100
Transportation Safety	Medium Risk	Low risk	No Risk	High Risk	Medium Risk

Further consideration on energy storage technologies, and alternative technologies to batteries is summarised in table 4-2.

Table 4-2 - Energy storage technology

Technology	Advantages	Disadvantage
Battery Energy Storage	• Scalable and can be installed either at point of generation or end-use. • Batteries could be used individually in micro-grids to balance variable decentralised energy sources or within individual lighting columns.	• Cooling, batteries have a tight environmental tolerance in relation to heat. • Environment, embedded carbon and green credentials. – not environmentally friendly manufacturing processes • Potential for issues associated with overheating. • Negative effects of overcharging/over-discharging.
Pumped Hydro Energy Storage (A pump stores water from the head of a river to a water reserve when there is low demand for energy. When electricity is more expensive, or there is a peak of demand, energy is released back by releasing water back to the river again)	• Its utility-scale technology can be used to balance variable large scale renewable resources (e.g. wind). • Rapid response time can help meet peak loads or sudden changes in demand. • Large power and energy capacity.	• They are geographically constrained away from demand centres.
Hydrogen Energy Storage (Energy is stored by electrolysing water to produce hydrogen and oxygen)	• Only emissions at the point of use are water vapours. • Stored hydrogen can be used any time without self-discharge. • Can be transported from the point of production to the point of demand if required.	• Fuel cell technologies are currently expensive. • There are potential safety concerns over the storage of hydrogen.
Super Capacitors Energy Storage (Energy is stored as an electric charge between two plates within the capacitor)	• Suitable for high current loads. • Extremely rapid cycle times.	• Currently expensive. • Unsuitable for long term storage solutions due to self-discharge.

4.2 AVAILABLE PRODUCTS IN THE MARKET

We conducted a review of available street lighting products which was issued in May 2022. Through the review, a product register was compiled from manufacturers' datasheets. The following observations were summarised from the product register:

- LiFePO4 Lithium batteries are the most common technology utilised by manufacturers.
- There exist some column mounted solutions having a luminaire with integrated generation and storage components.

- The market and product research concluded that solar PV panels and Wind/ PV panel hybrids with battery storage dominate the current market.

We also produced a questionnaire and sent it out to a shortlist of manufacturers to compare alternative power supply solutions. This helped us gather further information on the viability of products and technical implementations of solutions currently available on the market. The following points can be summarised from the survey:

- Most products and components are manufactured in mainland Europe and China. Some companies, such as Knight Off grid solutions, have product assembly factories in the UK, while key components are sourced and manufactured in China.
- Typical lead times are between 4 and 8 weeks, depending on the product. However, due to global material shortages and pandemic induced supply chain issues, most manufacturers advise lead times at the point of making enquiries. The increases in energy costs coupled with increasing inflation have also influenced the cost of manufacturing, delivery, installation and maintenance of electronic and electrical components and equipment.
- Though installation is typically not in the scope for most manufacturers, some responded that no special or extra equipment is required. Benefits for installation include no trenching associated costs for standalone off-grid column solutions. Pre-assembled solutions stated fewer installation times onsite.
- Concerning maintenance, a lesser unit maintenance regime is required, since rain can be utilised to wash/self-clean the solar PV panel holder. The batteries would require a cyclical replacement.
- The longevity of the products tends to consist of 20 to 25 years of designed life expectancy with 5 years of the manufacturer's warranty. The installations can be suitably specified for most external environments.
- Manufacturers seemed to be pushing for carbon neutral materials and were aiming on utilising locally sourced materials
- WEEE certified recycling company can recycle the assemblies at the end of life. Lithium batteries cannot be recycled that way.

5

SUMMARY OF ASSET EQUIPMENT INVENTORIES

5 SUMMARY OF ASSET EQUIPMENT INVENTORIES

5.1 CITY OF YORK LIGHTING INVENTORY

A high-level analysis of the lighting inventory for City of York dated May 2022 was initially carried out. The study revealed that most of the lighting assets are Street Lighting (Figure 5-1). A table with assumed meanings of the column unit type acronyms can be seen in Appendix A.

Figure 5-1 - Unit Type

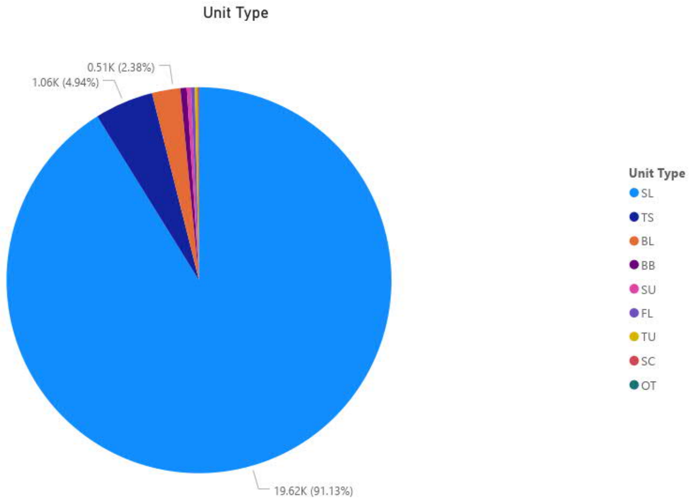


Figure 5-2 illustrates that approximately 60% of all unit types are LEDs. The analysis on the distribution of lamp types on street lighting units produces similar results for LEDs, with approximately 65% of the streetlighting assets utilising this technology.

Figure 5-2 - Lamp Type

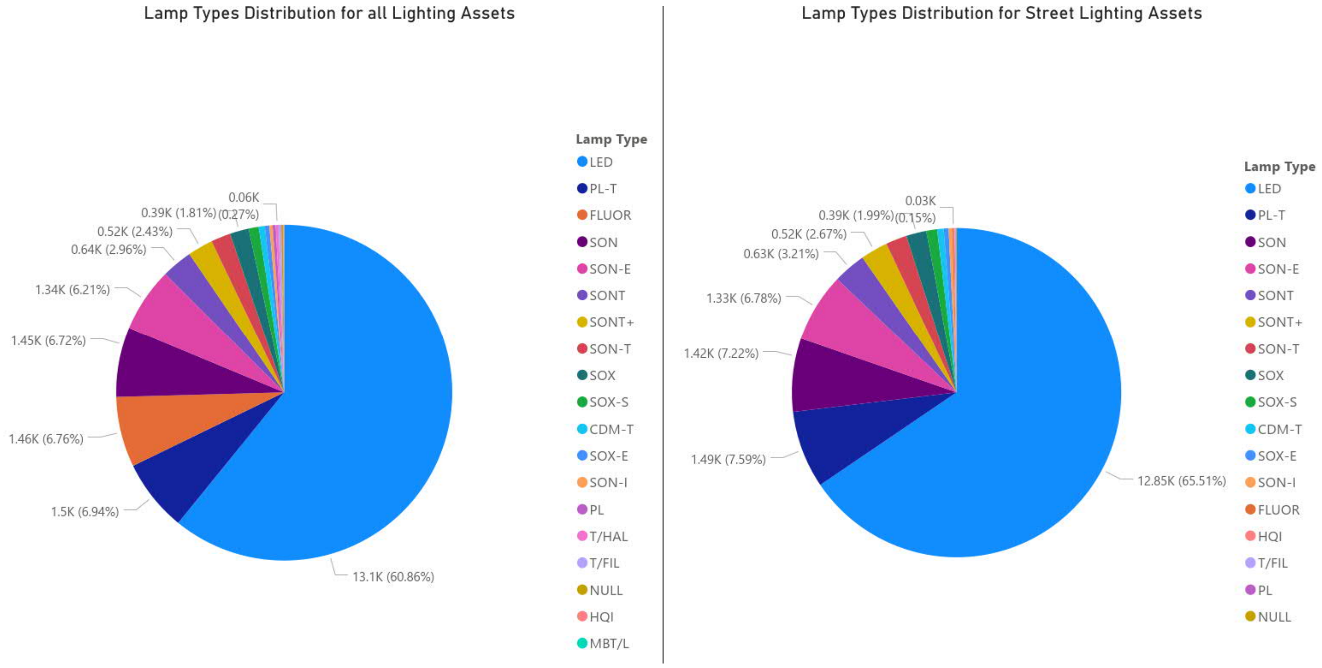


Figure 5-3 shows the percentage split of LED street lighting units by height. It indicates that most of the mounting heights are five to eight metres high. Approximately 80% of the columns are galvanised steel. Some street lighting assets are wall-mounted, meaning that their column material appears as null. 3.61% of all the SL assets are wall mounted. Out of these, 1.65% LED streetlighting units are wall mounted. A table with assumed meanings of the column material acronyms can be seen in Appendix A.

Figure 5-3 - Street Lighting by Height and Material

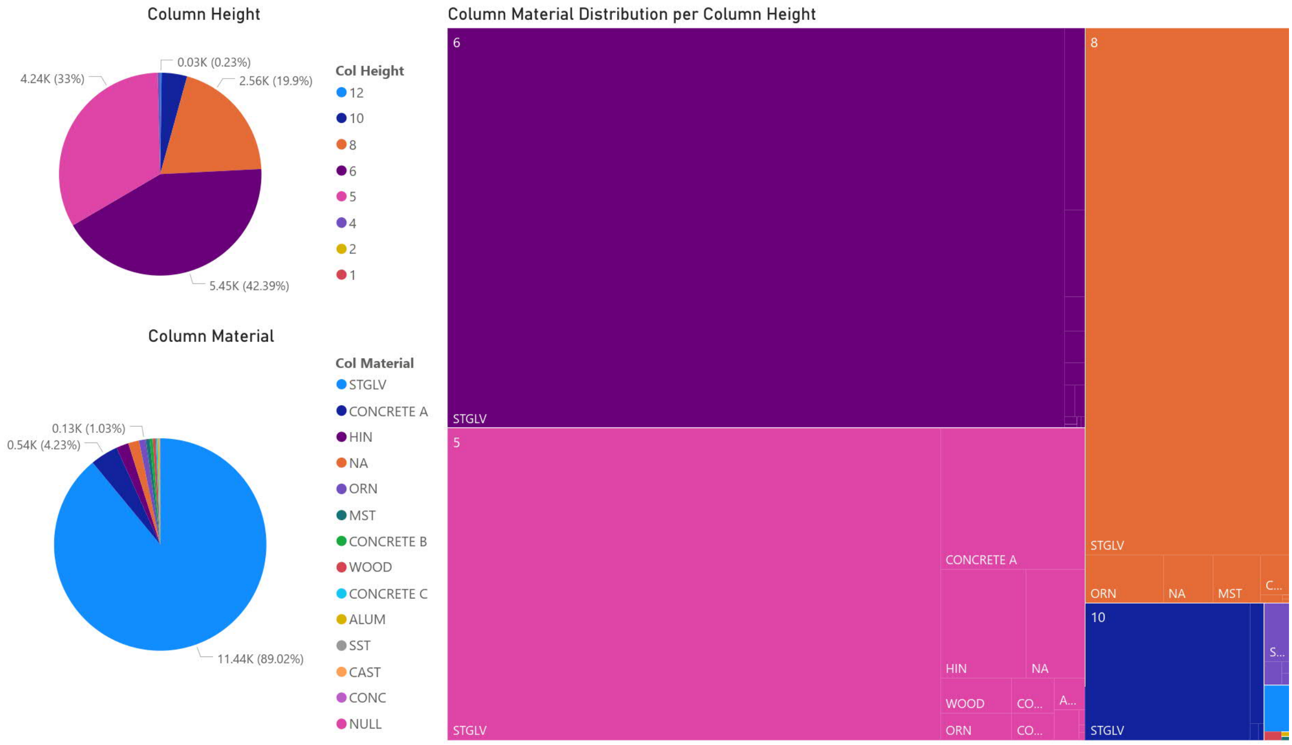
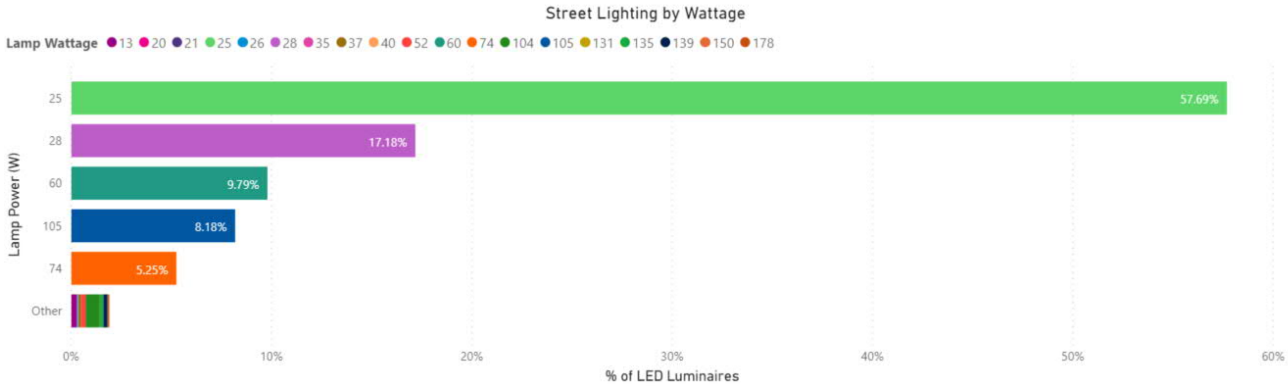


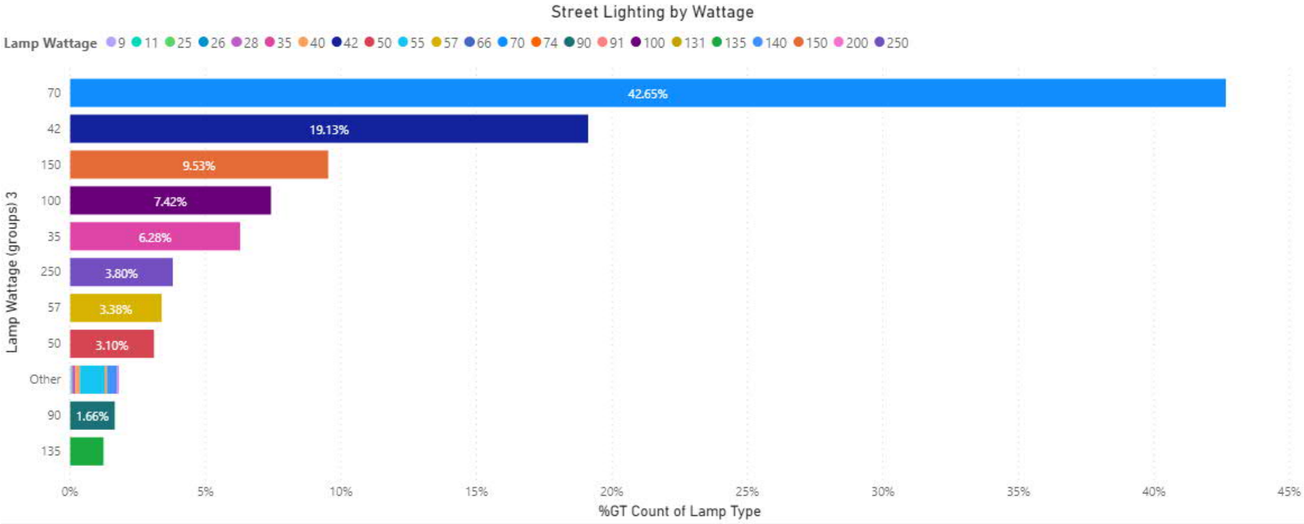
Figure 5-4. shows the percentage split of LED street lighting by wattage. It indicates that almost 60% of the units installed are 25W. Almost 20% of the units are 28W, and approximately 20% of the units are 60W or 105W. A few lamp wattage groups were below 1% of the assets available and were grouped together to aid the visual acuity of the graph provided. These highly vary in Wattage.

Figure 5-4 – LED Street Lighting by Wattage



The following figure highlights that most non-LED Street Lighting units use more power than the LED units. Approximately 40% of the units are 70W, and almost 20% of the units are 42W.

Figure 5-5 - Other Street Lighting by Wattage



The analysis indicates that the most significant opportunity for any impact lies within LED street lighting units, although solutions investigated in this report can be adopted for other lighting functions. Power supply solutions will need to cater to a streetlamp wattage of at least 25W to be viable as an alternative to what currently exists within the City of York.

Some concerns with the analysis lie on the fact that a lot of units are not converted to LED, and some of the required wattages of the units are relatively high. Further considerations for updating the lighting assets to LED units may need to be undertaken.

Some further concerns can be raised due to the height of the majority of the street lighting columns. Most of them are five and six metres high. Solar PV panel solutions installed on five metre columns are unlikely to be able to provide sufficient clearance from the ground and be large enough to produce sufficient energy for the lighting units. Separate horizontal arrays could be considered for these assets, but the added weight and windage would make these solutions hard to be adapted to these kinds of assets. Alternatively, units with integrated solar panels can be considered for 5m columns if the optics and flux levels of the units can be utilised to produce appropriate lighting designs.

6

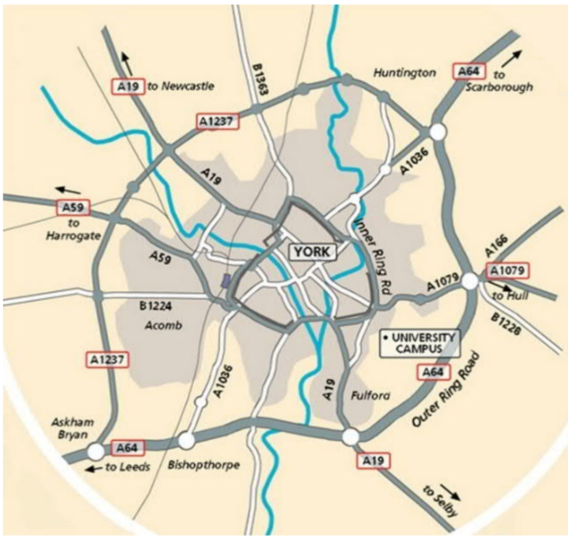
VIABILITY OF THIS TECHNOLOGY IN CITY OF YORK

6 VIABILITY OF THIS TECHNOLOGY IN CITY OF YORK

6.1 DAYLIGHT CONSIDERATIONS IN CITY OF YORK

York is a medieval walled city located in northeast England. The city has got a historic conservation core, and spreads outwards towards further residential areas.

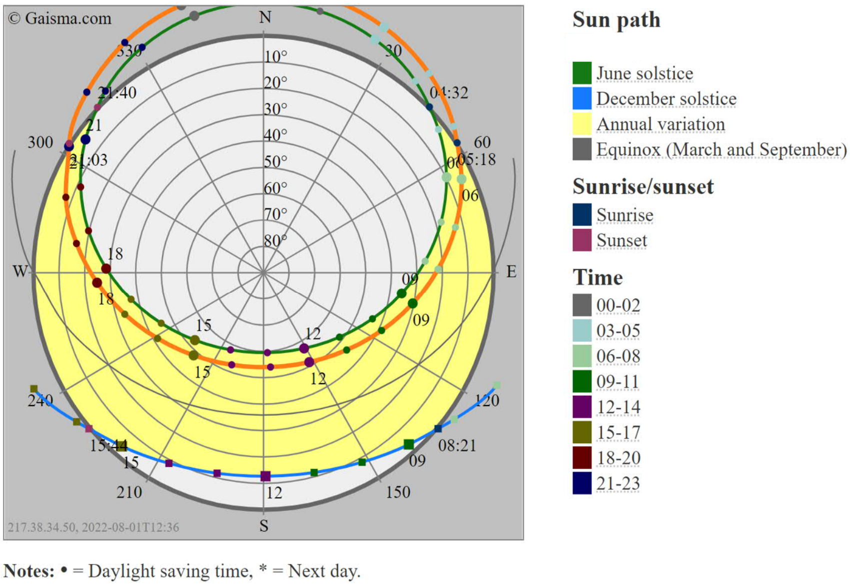
Figure 6-1 - York



The historic core of the city is surrounded by an internal ring road which is connected to A-roads. The river Ouse crosses the city, and various parks exist in the centre and on further locations.

The areas within most of the city's vicinity are urban, and therefore direct sunlight to potential solar panel locations can be blocked by shade from surrounding buildings. This means that the amount of energy produced on solar PV panels will be typically less than expected based on the sun-availability in York through the year.

Figure 6-2 - Sun path diagram for York



Based on the morphology of the city, we have recognised four types of areas which can be found within the city's vicinity. The viability of Solar Lighting will be considered for each of the defined sections. These are:

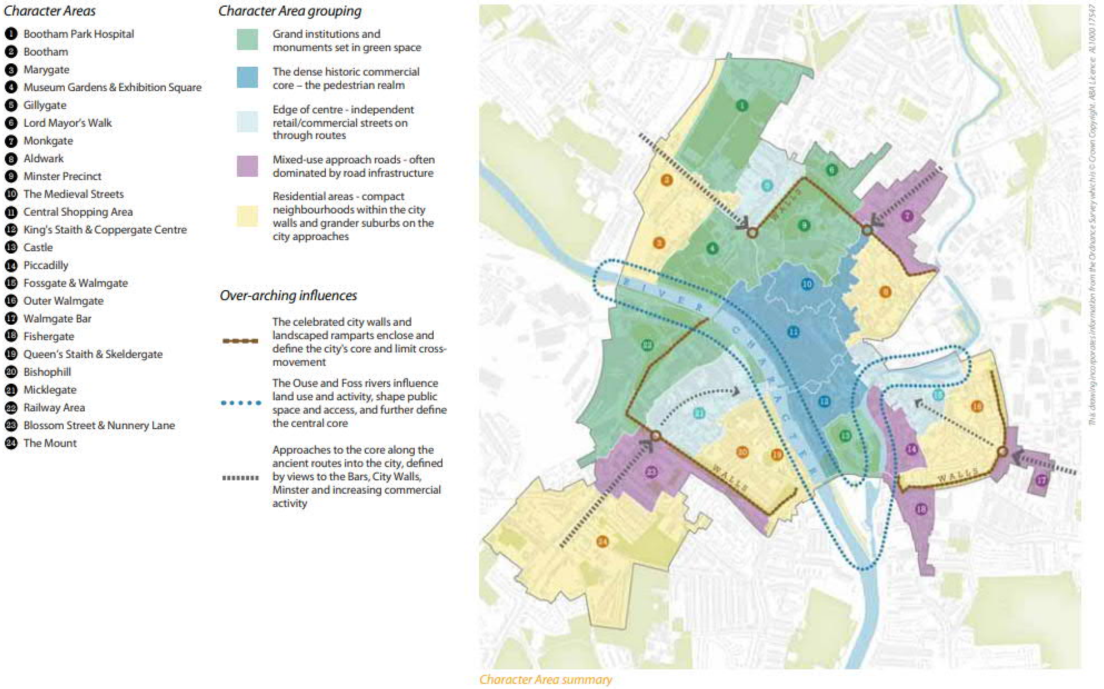
1. Historic core of the city
2. Network of larger roads
3. Surrounding residential areas
4. Parks

6.1.1 HISTORIC CORE OF THE CITY

Morphology of the area and lighting requirements

The centre of York is a listed historic area and an area of archaeological importance. Figure 6-3[5] shows an annotated map with areas of historic importance.

Figure 6-3 - Map of York's Areas of Archeological Importance



According to the Streetscape Strategy and Guidance of CoY[6], the lighting needs to play a prominent role in enhancing local distinctiveness and make a positive contribution to the city's character. Luminaires on historic streets need to be wall mounted and be of an appropriate heritage lanterns style. Figure 6-4[2] shows a proposal of historic lantern areas.

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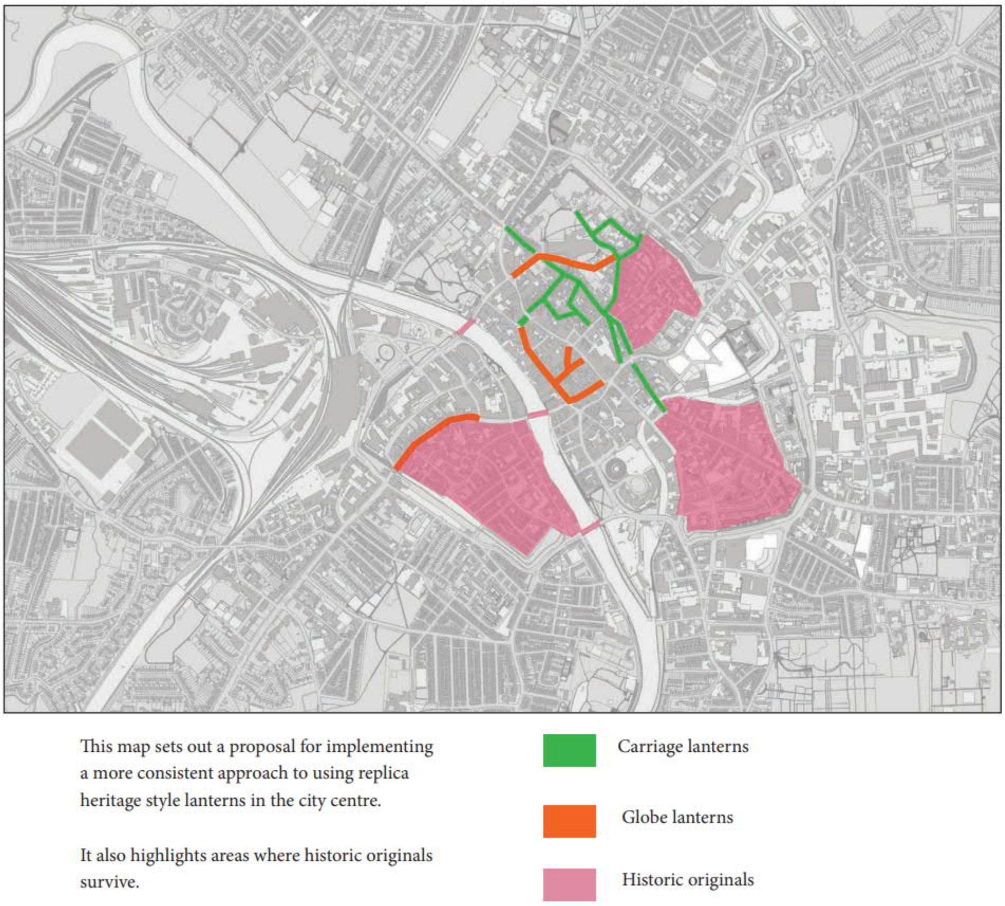
[5] https://www.york.gov.uk/downloads/file/1732/sd104-york-central-historic-core-conservation-area-appraisal-2011-

[6] sd109-city-of-york-streetscape-strategy-and-guidance-2014-

Figure 6-4 - Historic lantern areas



Viability of solar lighting in the area

Due to the mounting position of the street lighting units at the centre of York, the conservation area rules, and the high amount of shading on narrow roads related to the size of surrounding buildings; it would not be viable to convert these areas to solar lighting, unless alternatives for producing heritage lanterns with integrated solar PV panels is explored with the products' manufacturers.

6.1.2 LARGER ROADS NETWORK

Morphology of the area and lighting requirements

For the purpose of this report, the "Larger roads network" is defined as the city's inner ring road, and A-roads. These would be expected to be classified as Principle- M-type roads for lighting assessments, as defined in BS EN 13202-2 Road Lighting Part 2: Performance Requirements, and tend to be faster roads with the potential of having multiple lanes. Taller columns tend to be used on this type of road, with eight and ten metre columns being quite common in lighting designs. In CoY's inventory it is advised that there are a few 12m columns, some 10m columns and then more 8m columns in the city's vicinity, and a big percentage of these would be expected to be in the "Larger roads network" area. The luminaires used in York on this network tend to be different from the ones used in the historic core, with functional luminaires being the preference over heritage style lanterns.

Due to the width, location of these roads, and the height of the columns used, shading from adjacent buildings would have a smaller impact on the columns.

Figure 6-5 - Google maps caption of York and larger roads network

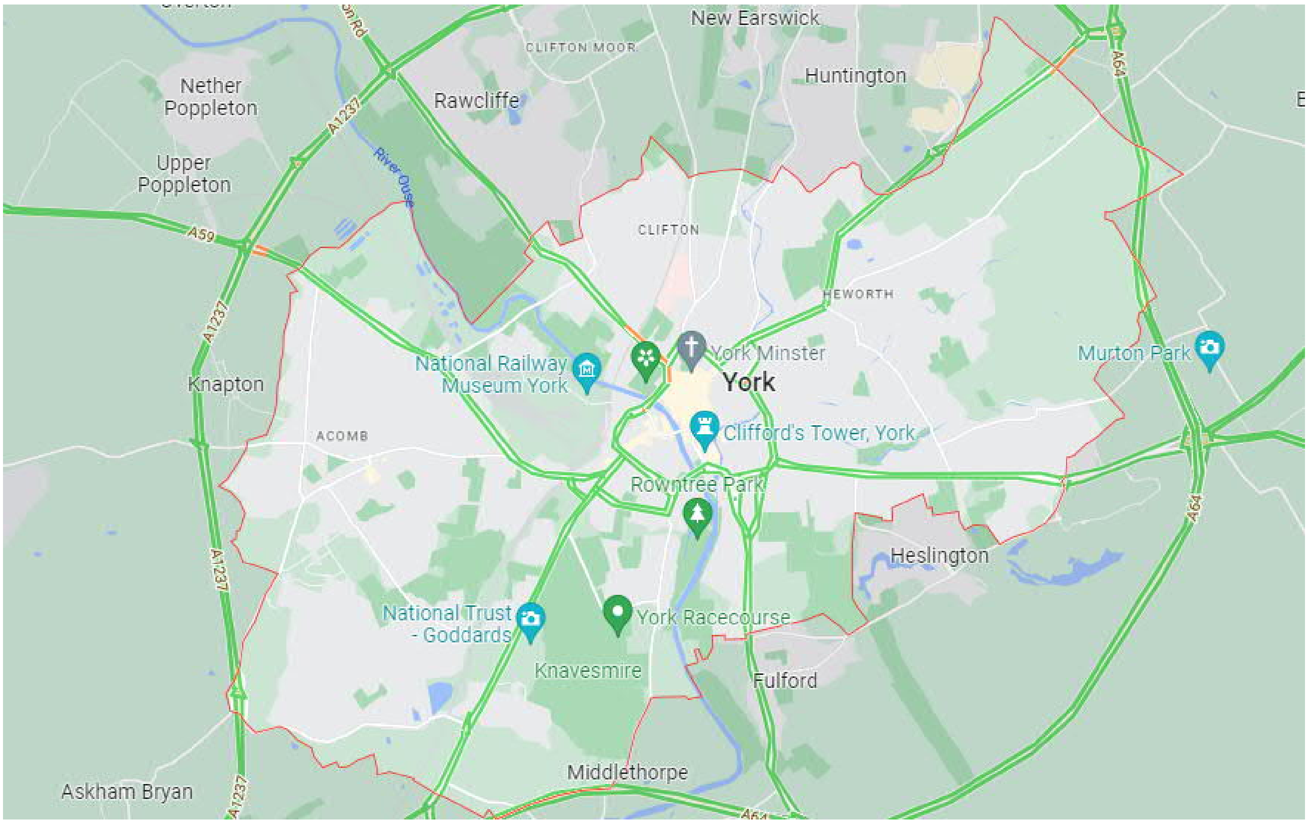
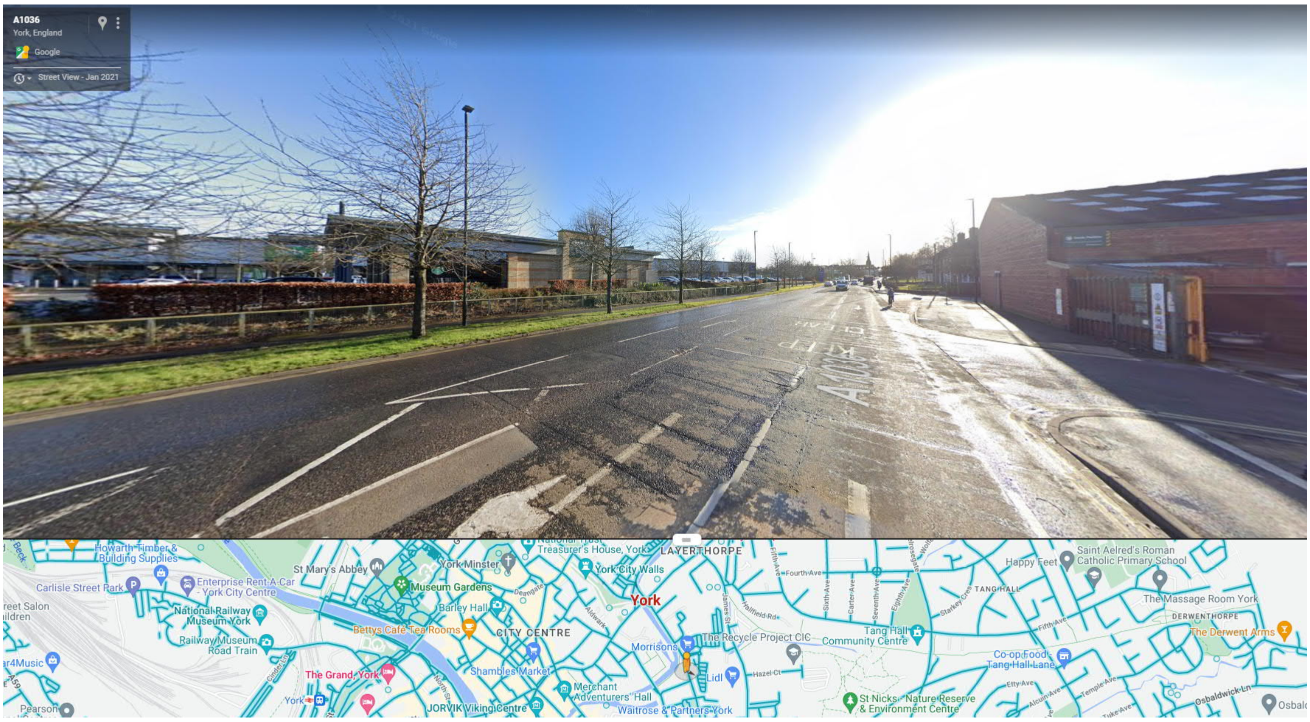


Figure 6-6 - Snapshot of street-view on an A-Road in York



Viability of solar lighting in the area

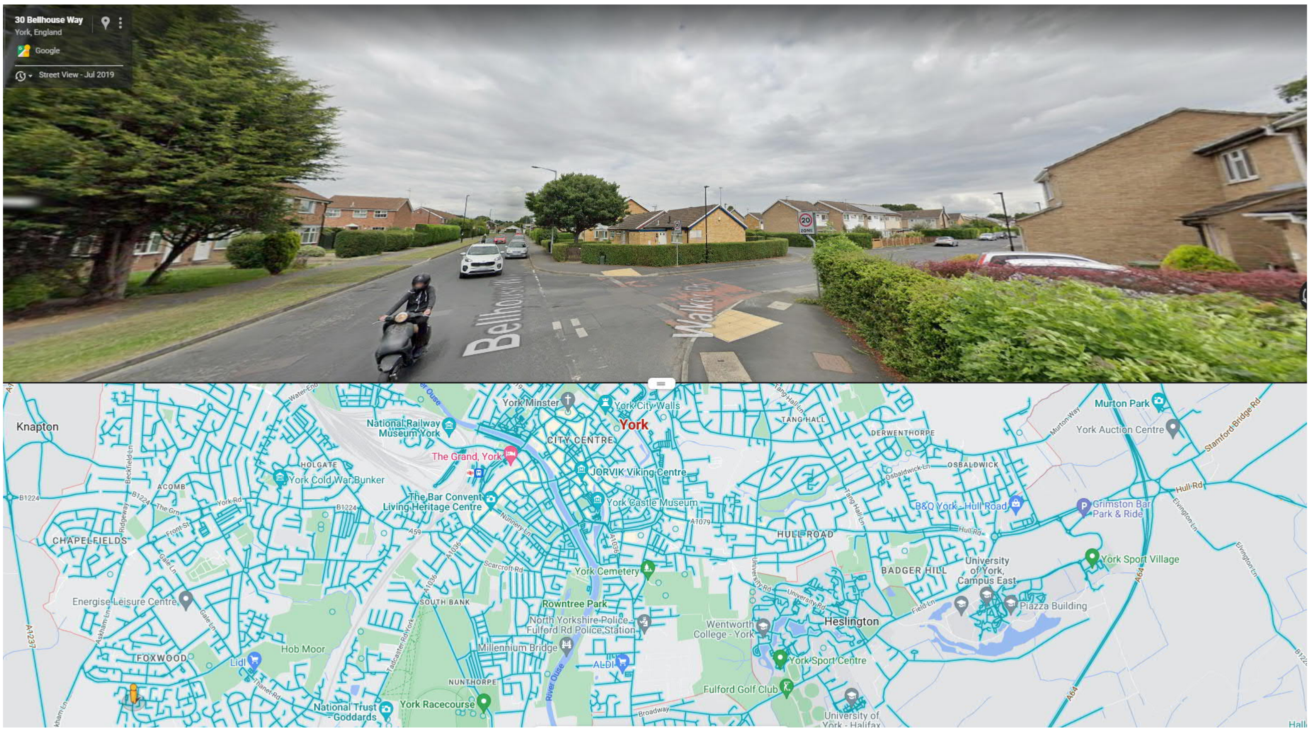
Due to the type of units used and the column heights, offset or wrap-around solar PV panel arrays would be aesthetically appropriate. The column heights would allow a sufficient safety distance from the ground. However, a drawback of these units is that the luminaires on Principle- M-type roads are of a higher wattage to provide sufficient levels of illumination. Solar PV panel units would not be able to produce and store sufficient power for these assets, and therefore a standalone solution would not be appropriate. A hybrid solution should therefore be considered.

6.1.3 SURROUNDING RESIDENTIAL AREAS

Morphology of the area and lighting requirements

The surrounding residential areas consist of wider roads than the ones seen in similar areas of the historic core of the city. The lighting columns tend to be five to six metres tall in minor roads, and six to eight metres tall in circulatory roads. Modern-looking units are used in these areas.

Figure 6-7 - Snapshot of a residential area outside York's centre



Viability of solar lighting in the area

These areas are not subject to historic or heritage status, and the lighting units used tend to require less power to operate compared to the units on the larger roads network. What's more, the buildings in these areas are not very tall, meaning that less shadowing is likely to occur.

However, due to the height of the columns, there would be less energy generation potential since there would be less solar PV panel material as discussed in section 3 to implement wrap-around and offset columns. Utilising horizontal array solar panels on top of the columns would cause aesthetic concerns with residents, and structural issues with the columns due to increased weight and windage. An alternative solution would be to consider lighting units with an included solar panel on them as discussed in section 4.

6.1.4 PARKS

Morphology of the area and lighting requirements

York has parks scattered across its centre and outer areas. Through a desktop survey, it was classified that the green areas within the centre of York appear to be lit with historic units of low height (less than six metres); whereas the park areas on the outskirts of the city tend to be unlit.

Viability of solar lighting in the area

Due to the heritage nature of the parks in central York, and the low heights of the columns, it would not be appropriate to instal solar PV panels on lighting columns. There may exist the possibility to include heritage fittings with integral solar PV panels. The manufacturer of the heritage fittings used would need to be contacted to explore the feasibility of producing such a fitting.

6.2 COLUMN MATERIAL LIMITATIONS

Further limitations on the installation of Solar PV panels on street lighting assets may occur due to the material of the lighting column. Steel and aluminium columns may be appropriate for installation of further attachments, but materials such as concrete and cast iron would not be appropriate for consideration. Steel and Aluminium columns would need to get structurally tested as per ILP's GN22 and the windage and weight allowance of the columns would need to be revised before installation of further assets is considered.

7

SUMMARY OF RETURN OF INVESTMENT POTENTIAL AND ECOLOGICAL IMPACT OF INSTALATIONS

7 SUMMARY OF RETURN OF INVESTMENT POTENTIAL AND ECOLOGICAL IMPACT OF INSTALATIONS

The analysis conducted on sections 5 and 6 highlight that solar energy is not likely to provide high investment returns in most areas of York. The street lighting assets of historic areas of the city cannot be easily adapted to include solar PV panels due to their mounting and restrictions related to conservation of the historic character of the city. This means that if the drive for updating units is fiscal, then the option may be limited depending upon the column height and luminaire wattage.

However, it should be important to note that when it comes to the NetZero / Carbon agenda that economic justification will be more difficult to show. The primary agenda driving this switch is climate and not fiscal.

In order to consider an appropriate way for reviewing the investment potential of the installations and their carbon savings, the main investigative approach of this report needs to be analysed first.

7.1 MAIN INVESTIGATIVE APPROACH OF THE REPORT

7.1.1 ELECTRICAL CONNECTIONS

Given the fact that the survey results provided by Kight Off Grid show that the proposed system cannot provide sufficient energy for a 24W luminaire (figures 2-4 and 2-5), it can be concluded that the potential energy generation for the majority of street lighting assets within York would not be sufficient, since most units require more than 24W to operate (as illustrated in figures 5-4 and 5-5). Significant levels of grid electricity may be required during the darker months of the year for the units illuminating larger roads with higher lighting class requirements and taller lighting columns.

Based on the above, the main investigative approach of the report has been the use of hybrid solar and DNO supplies. A hybrid solution for street lighting assets would be the recommended solution for most residential and larger roads to ensure sufficient power will be available in winter months to ensure roads are continued to be lit to the required level.

Where the guarantee of lighting levels are not critical, and a strict dimming regime can be used during the times of low/no occupancy - for example footpaths and park lighting - then a standalone solar/wind solution could be viable pending a more extensive evaluation. Such installations would involve a small percentage of the lighting assets for CoY and may include:

- Alternative installations like the solar illuminated traffic signs, Bellisa Beacons and school flasher units shown in section 4.1.1.1 which can be used as a political statement and an aid for fulfilling CoY’s 2030 Net Zero goal.
- Stand-alone lighting columns for parks and smaller cul-de-sac areas in which availability of lighting supply is not critical.

7.1.2 TYPE OF SOLAR PANEL AND WIND TURBINES RECOMMENDED

The main focus of the proposals has been on vertical solar panels due to their aesthetic appearance. Additionally, retrofitted columns are more likely to be able to structurally support vertical rather than horizontal panels since less stress and windage is added on the assets.

The use of micro wind turbines would not be recommended in York due to move parts creating a hazard to both human and avian wildlife and further technical concerns of the use of these assets. Our initial conclusions are that for wind to be viable a clean path of un-turbulent wind is usually required. Typically, city centres and build up areas disrupt the wind to a degree where it is not viable.

Residential areas are more likely to achieve a viable wind solution. However, a strong chance of objections from residents citing a noise nuisance may exist.

Wind options would be best suited to unpopulated and open environments, for example parks.

7.1.3 COLUMN HEIGHT

Columns which are as tall or taller than eight metres are deemed as sufficiently sized for the use of vertical/ wrap-around solar panels. The amount of solar array on the column less than eight metres is very small as it needs to start from around 2.5 to 3m above ground level which only then provides circa 2m of panel length. According to different manufacturers who were contacted during the 2022 Light + Building exhibition, an 8m column with 5m of array could run a 30W luminaire for 8 months in the year, the remaining four months would require a DNO supply to keep it operating, even if a dimming profile was applied during hours when there is little activity. Typically however, Eight metre columns tend to be too tall for residential areas so are rarely specified in these locations. For a stand-off array or an array integrated into a luminaire itself the column height does not impact viability other than ensuring it is structurally suitable and tall enough as that a solar PV array does not introduce other risks/hazards e.g. vandalism.

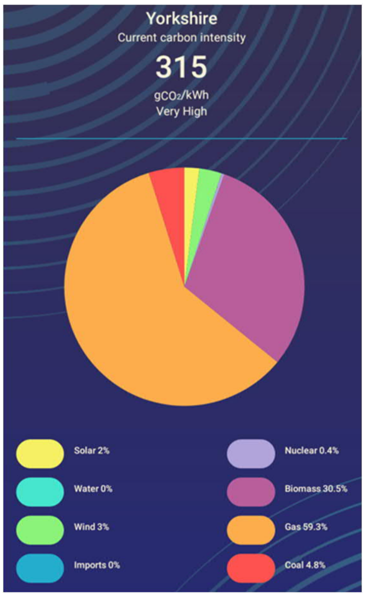
7.2 CLIMATE CONSIDERATIONS AND CO_2 SAVINGS

Its important to acknowledge that energy from the DNO does not always mean ‘dirty’ energy with a large CO_2 footprint. The UK at a national level is increasingly improving the amount of energy from green or renewable sources which should not be ignored.

The national grid provides almost live figures in terms of grams of CO_2 released for every kWh generated - this is variable depending on climatic and economic factors. For 11/10/2022 at 11:00 this was for a national average 264gCO_2/kWh but for the Yorkshire region itself this was higher at 315gCO_2/kWh seemingly due to very low contributions from solar (2%) and wind (3%) and a high contribution from gas (60%) (figure 7-1).

Therefore, a CO_2 saving could be calculated based on an average gCO_2/kWh figure and using the historical data for energy demand for CoY Street lighting and then assuming % generation from renewable sources.

Figure 7-1 - Carbon intensity in Yorkshire on 11/10/2022 at 11:00

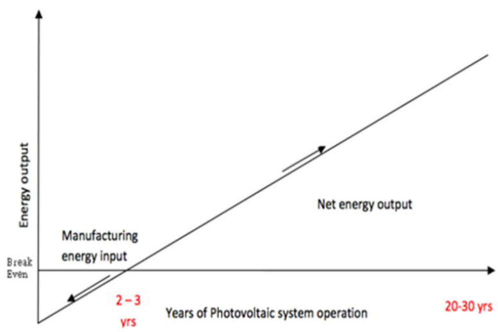


When considering the carbon cost of a solution the energy savings are not the only thing that needs to be considered. Factors such as the production of materials, manufacturing of the product, transport, installation, maintenance and decommission will incur additional carbon impacts. Hence the energy savings and their impact on overall carbon intensity would need to reach a break-even point with all the carbon costs described above before any CO_2 gains occur.

The returns of energy and carbon costs for solar panels vary depending on where the panels are produced and used. A study has shown that the payback period of crystalline solar PV panels was about 2.5 years. Saying that, the climate and production area could influence this figure drastically. - in northern UK, a typical solar panel is expected to take around 6 years to pay back its energy cost.[7]

Figure 7-2 is an indicative plan on how we would expect this to work.

Figure 7-2 - Break-even point for CO2 costs of solar panels



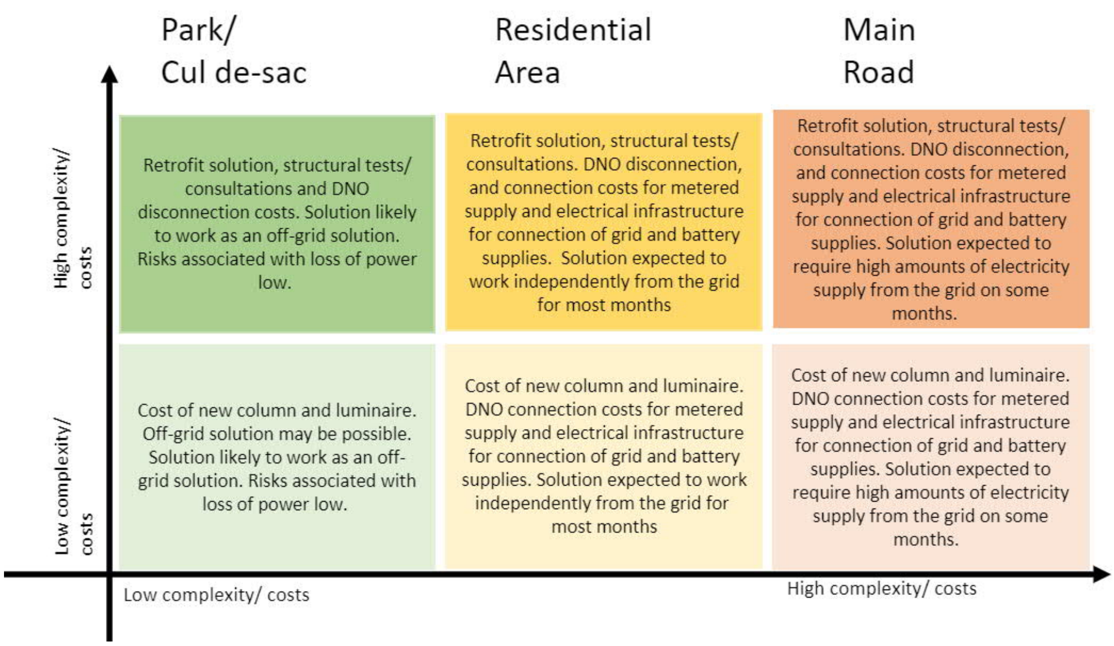
[7] https://www.renewableenergyhub.co.uk/main/solar-panels/solar-panels-carbon-analysis/

7.3 FISCAL RETURN OF INVESTMENT POTENTIAL

A fiscal analysis is hard to be conducted due to the number of parameters that need to be considered and the constant flux of price changes at the current economic climate.

The return of investment potentials can be influenced by the type of area and whether a new or existing installation will be assessed. The complexity of using alternative power solutions is higher on main roads and residential roads than on parks and areas where hybrid solutions are not necessary. New installations may incur less challenges and less fiscal risks and costs in comparison with converting existing installations. Figure 7-3 highlights a non-exhaustive list of influencing factors for a fiscal analysis for different types of installations.

Figure 7-3 - Risks and costs parameters associated with different types of streetlighting installations



A full economic analysis of different solutions and scenarios like the ones described above is not feasible due to the variation of factors which need to be considered and current financial and political instability and constant rate of inflation. A basic analysis on some solutions provided has been conducted to help estimate approximate costs and compare them with installing a normal streetlighting column (Appendix B). This analysis covers a span of 25 years which is the expected lifetime of a street lighting installation. Multiple assumptions are associated with the pricings provided. These have been listed in Appendix B.

8

CONCLUSIONS AND RECOMMENDATIONS

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSION

The adoption and uptake of alternative energy technologies for public lighting within CoY will be influenced by:

- Increasing grid-supplied electricity prices,
- Decreasing technology costs,
- Achieving economies of scale,
- Carbon emission reduction targets,
- Air pollution concerns; and energy security concerns, and
- Additional powered attachments using light column power such as Wi-Fi and EV charging.

The general rise of energy costs, and the increasing demand of electricity at night due to the uptake of electric vehicles and growing telecommunications infrastructure is increasing off-peak electricity costs.

Having a more significant share of street lighting supplied by low carbon sources can reduce greenhouse gas emissions associated with energy supply. Within the street lighting environment, the 'energy trilemma' may be solved by adopting renewable energy sources that are more flexible, responsive, and decentralised. However, this may also increase the complexity of the energy supply systems and their cost.

8.1.1 CURRENT LIMITATIONS ON TECHNOLOGIES

Even though alternative power sources to street lighting within CoY have the potential to reduce the overall carbon footprint of the installation, most standalone street lighting column solutions have a lower lamp rating compared to the bulk of York's Street lighting assets. What's more if these are used as off-grid solar only solutions, they highly depend on dimming regimes and sensors to maintain enough power resources to work on the winter months in UK. These solutions come in with additional costs and risks of not working, and making pedestrians perceive the environment as unsafe.

Currently, the popular and different variations of lithium-Ion batteries come with environmental concerns and embedded carbon issues. Recent innovations and improvements in battery technologies with increased energy density haven't filtered through to the street lighting products assessed.

A further risk related to compliance is that not all the complete solutions including luminaires are photometrically tested meaning that compliance with standards on lighting levels for safety and environmental concerns cannot be reached.

8.1.2 LEGAL CONSIDERATIONS

It should be stressed that councils are not legally bound to provide lighting on roads. A Highway Authority has a power and not a duty to provide lighting as per the Highways Act 1980. However, Section 17 of the Crime and Disorder Act 1988 requires that safety dimension of all work is considered. Should any death occur, then the incident will be investigated by the police under the Road Death Investigation Manual. This requires an investigation of the road infrastructure and its compliance with relevant standards. Failure to do so could lead the local authority being legally challenged. Hence it is important to consider the lighting standards and relevant guidance documents and provide sufficient lighting levels, or risk assess properly before lighting is removed or dimmed down. Uniformity levels are considered of higher importance than illuminance levels on a road based on current research from Professor Steve Fotios at Sheffield University.

8.1.3 FINAL CONCLUSIONS

It should be noted that based on our findings that these technologies are not yet ready for anything other than footway and park lighting. In these types of installations there needs to be a control system that dims the lighting down when people are not about and then brings it back up in section when people wish to use the path – for other applications where the availability of supply is important it is just not ready for application and economically viable.

It should be noted that technologies related to alternative power solutions are rapidly evolving, and it is highly probable that future product designs and research will make the solutions discussed viable in UK within the next few years.

8.2 RECOMMENDATIONS

As shown on section 5, SL assets are the bulk of the managed assets in York. Only 60% of these are LED units. Converting the rest of the units to LED will have the potential for further energy savings and may make the installation of hybrid solar systems more viable once technologies advance in the future.

Even though illuminated traffic signs, Bellisa Beacons and school flasher units account for less than 1% of the lighting assets, the available technologies in the market seem to be able to provide viable solutions for these systems, which could be used as an aid in helping York achieving its net zero carbon goals.

It is also recommended that CoY should consider commencing a solar trial to explore real world performance and provide assurance around availability of supply. As suggested in section 8.1, a park in a low-crime area would be an appropriate scenario to test the solution and its feasibility and performance in York.

Further future appraisals of the market may be necessary to stay informed about market development and appraise when technologies become suitable for UK use.

Appendix A

UNIT TYPE AND MATERIAL ACRONYMS

UNIT TYPE ACRONYMS

Table 8-1 – Unit Type Acronyms

Acronym	Unit type
BB	Belisha Beacon
BL	Traffic Bollard
FL	TBC
OT	TBC
SC	School Flasher Unit
SL	Street Lighting
SU	Subway
TS	Traffic Sign
TU	TBC

MATERIAL ACRONYMS

Table 8-2 – Material Acronyms

Acronym	Material
ALUM	Aluminium
CAST	Cast Iron
CONC	Concrete
CONCRETE A	Concrete type A
CONCRETE B	Concrete type B
CONCRETE C	Concrete type C
HIN	Hinged
MST	Mild Steel
N/A	Not Applicable/ Assumed to be wall mounted
NULL	Not known
ORN	Ornate
SST	Stainless steel
STGLV	Galvanised Steel
WOOD	Wood

Appendix B

COST ANALYSIS

COST ANALYSIS

ASSUMPTIONS

The following list of assumptions was made during the fiscal analysis of different solutions:

1. The luminaire wattage and therefore energy usage has been uniformly applied at 30W. This is roughly what could be expected within a residential street or park environment. It should be noted that some suppliers offer a slight variation in this figure, but the values have been assumed negligible for the purpose of this exercise. No photometry data has been assessed to confirm manufacturers proposed solution is compliant and this shall require confirmation.

2. The annual 'burn' hours whereby the luminaire will be operational as also been universally applied as 4100 hours which roughly aligns to a 35lux switch regime.

3. The cost of a new column was provided by City of York at £1,100 and this includes and column & luminaire. It was assumed that under all options the existing column will be life expired and shall require replacement at the start of the 25-year period. For renewable options a cost of £300 for just a column has been applied which is additional to the capital cost of the manufacturer luminaire. The likelihood to the column being damaged, failing or requiring replacement does not change for the various options so therefore no allowance has been made for accidental damage or emergency call outs.

4. Northern Power Grid's website advises the current disconnection cost of an unmetered connection is £650. This value has been applied for all off-grid solutions.

5. Each manufacturer has advised periodic replacement of batteries will be required. This varies in cost as shown. Snapfast did not provide this information, so the cost as been assumed as per Kight's costs. The period between battery replacement is also manufacturer specific and varies between 5 – 8 years. Therefore, the battery replacement exercise has been assumed to be carried out every 6yrs at the same time the 6 yearly period inspection and test is carried out.
6. SolarVision advise a yearly inspection to confirm correct operation and that vegetation growth is not impacting system. Manufacturer offer this service at a cost dependant on number of columns with an example of 10 columns costing £125 per year per column. Cost not allowed for in breakdown as assumed CoY maintenance provider will carry out this inspection for all lighting assets.

7. An average assumed rate of inflation 1% has been applied year on year throughout the 25-year period.

ANALYSIS

Please see next page for analysis table.

Equipment Type	Supplier	N/A	Kight	Snapfast	Snapfast	Solar Vision	Solar Vision
	Technical Solution	N/A	Solar & Wind	Solar & Wind	Solar Only	Solar Only	Solar Only
	Retrofit / New column	DNO Supplied column & luminaire	New column only	Retrofitted Solution	New column only	Retrofitted Solution	New column only
	Wattage of Luminaire	30	30	30	30	30	30
	Estimated Annual Burn Hours	4100	4100	4100	4100	4100	4100
Installation	Luminaire / Solar PV Costs	£0.00	£3,217.50	£2,500.00	£1,600.00	£2,170.00	£2,738.00
	Labour & Commissioning	£0.00	£250.00	£250.00	£250.00	£250.00	£250.00
	New 6m Column (Fully Installed)	£1,100.00	£300.00	£300.00	£300.00	£300.00	£300.00
Cost of Disconnection	Standard NPG UMS Disconnection Fee	£0.00	£650.00	£650.00	£650.00	£650.00	£650.00
Cost of Battery Replacement	As advised by supplier		£300.00	£300.00	£300.00	£175.00	£175.00
Average Rate of Inflation for next 25 years (Assumed)		1.00%	1.00%	1.00%	1.00%	1.00%	1.00%
1st Year Rate of Return	Cost of Energy (£/kWh)	0.31	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£38.13	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£38.13	£0.00	£0.00	£0.00	£0.00	£0.00
2nd Year Rate of Return	Cost of Energy (£/kWh)	0.31	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£38.51	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£76.64	£0.00	£0.00	£0.00	£0.00	£0.00
3rd Year Rate of Return	Cost of Energy (£/kWh)	0.32	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£38.90	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£115.54	£0.00	£0.00	£0.00	£0.00	£0.00
4th Year Rate of Return	Cost of Energy (£/kWh)	0.32	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£39.29	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£154.82	£0.00	£0.00	£0.00	£0.00	£0.00
5th Year Rate of Return	Cost of Energy (£/kWh)	0.32	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£39.68	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£194.50	£0.00	£0.00	£0.00	£0.00	£0.00
6th Year Rate of Return	Cost of Energy (£/kWh)	0.33	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£40.08	N/A	N/A	N/A	N/A	N/A

	Periodic Inspection	£100.00	£100.00	£100.00	£100.00	£100.00	£100.00
	Assumed battery replacement	N/A	£318.46	£318.46	£318.46	£185.77	£185.77
	Lifetime Energy Cost	£334.58	£418.46	£418.46	£418.46	£285.77	£285.77
7th Year Rate of Return	Cost of Energy (£/kWh)	0.33	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£40.48	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£375.05	£0.00	£0.00	£0.00	£0.00	£0.00
8th Year Rate of Return	Cost of Energy (£/kWh)	0.33	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£40.88	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£415.93	£0.00	£0.00	£0.00	£0.00	£0.00
9th Year Rate of Return	Cost of Energy (£/kWh)	0.34	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£41.29	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£457.22	£0.00	£0.00	£0.00	£0.00	£0.00
10th Year Rate of Return	Cost of Energy (£/kWh)	0.34	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£41.70	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£498.92	£0.00	£0.00	£0.00	£0.00	£0.00
11th Year Rate of Return	Cost of Energy (£/kWh)	0.34	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£42.12	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£541.04	£0.00	£0.00	£0.00	£0.00	£0.00
12th Year Rate of Return	Cost of Energy (£/kWh)	0.35	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£42.54	N/A	N/A	N/A	N/A	N/A
	Periodic Inspection	£115.00	£115.00	£115.00	£115.00	£115.00	£115.00
	Assumed battery replacement	N/A	£338.05	£338.05	£338.05	£197.19	£197.19
	Lifetime Energy Cost	£698.58	£871.50	£871.50	£871.50	£597.96	£597.96
13th Year Rate of Return	Cost of Energy (£/kWh)	0.35	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£42.97	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£741.55	£0.00	£0.00	£0.00	£0.00	£0.00
14th Year Rate of Return	Cost of Energy (£/kWh)	0.35	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£43.40	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£784.95	£0.00	£0.00	£0.00	£0.00	£0.00
15th Year Rate of Return	Cost of Energy (£/kWh)	0.36	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£43.83	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£828.77	£0.00	£0.00	£0.00	£0.00	£0.00
16th Year Rate of Return	Cost of Energy (£/kWh)	0.36	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£44.27	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£873.04	£0.00	£0.00	£0.00	£0.00	£0.00
17th Year Rate of Return	Cost of Energy (£/kWh)	0.36	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£44.71	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£917.75	£0.00	£0.00	£0.00	£0.00	£0.00

18th Year Rate of Return	Cost of Energy (£/kWh)	0.37	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£45.16	N/A	N/A	N/A	N/A	N/A
	Periodic Inspection	£130.00	£130.00	£130.00	£130.00	£130.00	£130.00
	Assumed battery replacement	N/A	£358.84	£358.84	£358.84	£209.33	£209.33
	Lifetime Energy Cost	£1,092.91	£1,360.35	£1,360.35	£1,360.35	£937.29	£937.29
19th Year Rate of Return	Cost of Energy (p/kWh)	0.37	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£45.61	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£1,138.52	£0.00	£0.00	£0.00	£0.00	£0.00
20th Year Rate of Return	Cost of Energy (£/kWh)	0.37	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£46.07	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£1,184.58	£0.00	£0.00	£0.00	£0.00	£0.00
21st Year Rate of Return	Cost of Energy (£/kWh)	0.38	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£46.53	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£1,231.11	£0.00	£0.00	£0.00	£0.00	£0.00
22nd Year Rate of Return	Cost of Energy (£/kWh)	0.38	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£46.99	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£1,278.10	£0.00	£0.00	£0.00	£0.00	£0.00
23rd Year Rate of Return	Cost of Energy (£/kWh)	0.39	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£47.46	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£1,325.56	£0.00	£0.00	£0.00	£0.00	£0.00
24th Year Rate of Return	Cost of Energy (£/kWh)	0.39	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£47.94	N/A	N/A	N/A	N/A	N/A
	Periodic Inspection	£145.00	£145.00	£145.00	£145.00	£145.00	£145.00
	Assumed battery replacement	N/A	£380.92	£380.92	£380.92	£222.20	£222.20
	Lifetime Energy Cost	£1,518.50	£1,886.27	£1,886.27	£1,886.27	£1,304.49	£1,304.49
25th Year Rate of Return	Cost of Energy (£/kWh)	0.39	N/A	N/A	N/A	N/A	N/A
	Annual Cost	£48.41	N/A	N/A	N/A	N/A	N/A
	Lifetime Energy Cost	£1,566.91	£0.00	£0.00	£0.00	£0.00	£0.00
Total Capital Cost		£1,100.00	£4,717.50	£4,000.00	£3,100.00	£3,545.00	£4,113.00
Total Operational Cost		£1,566.91	£1,886.27	£1,886.27	£1,886.27	£1,304.49	£1,304.49
Total Cost of Ownership (Estimated over 25yr period)		£2,666.91	£6,603.77	£5,886.27	£4,986.27	£4,849.49	£5,417.49
Operational Restrictions		All year-round operation: 12 Months	Manufacturer advises lighting estimated to only be operational from: March - September Estimated 7 Months per Annum (Manufacturer advises with 50% dimming regine between 00:00 - 05:00 the operational period would be 8 months (March – October)	Manufacturer advises that this can work as an off-grid solution. Estimated 7 Months per Annum	Manufacturer claims that solar solutions cannot work as off-grid solutions in UK. Unable to provide further detail at this point.	Manufacturer claims that solar solution would struggle over winter months for roads lit to P04 with a dimming regime to P05. Estimated 7 Months per Annum	Manufacturer claims that solar solution would struggle over winter months for roads lit to P04 with a dimming regime to P05. Estimated 7 Months per Annum

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