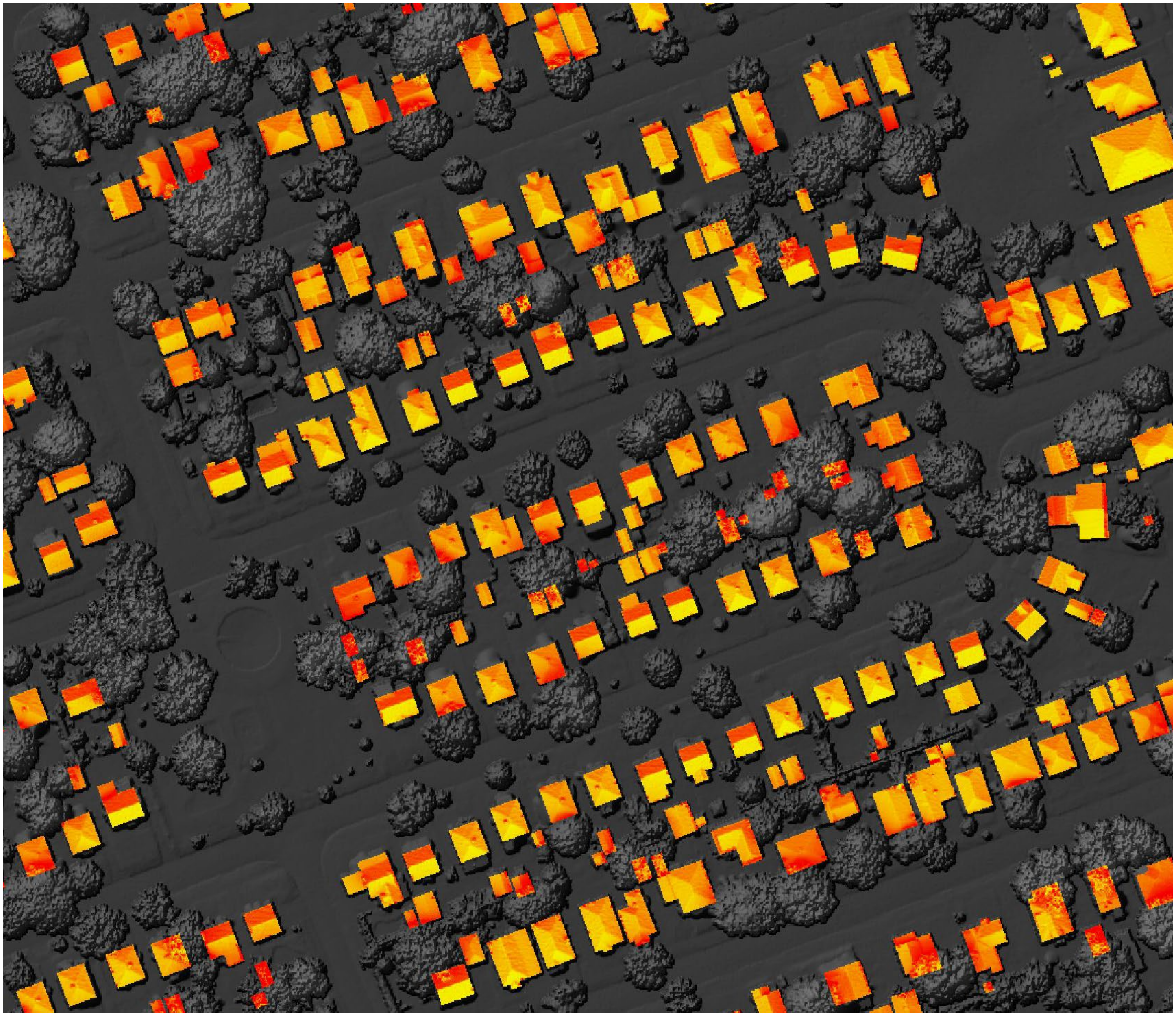

Rooftop Solar Potential in Peterborough

GIS Collaborative Project 2109 | Fleming College

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GIS Collaborative Project - Final Report

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GIS Collaborative Project Final Report

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Academic Statement*: This proposal is presented in partial fulfilment of the academic requirements for Apst 62, GIS Collaborative Project course, Fleming College.*

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1.0 Abstract

Overview: In collaboration with the City of Peterborough, we created a rooftop solar potential layer to be used in an interactive web map for property owners in Peterborough, as well as a cartographic poster to help disseminate the results of the project to policy makers and to the public. The main goal of the project was to provide easy access to information on rooftop solar potential in Peterborough thereby encouraging property owners to install solar panels. This should ultimately lead to an increase in private solar panel sales in the city.

Methods: The solar potential layer was created using Solar Radiation tools in ArcGIS Pro 2.7 and is based on a high-resolution Digital Surface Model (DSM) created from lidar point data. We developed the web application using Experience Builder - one of Esri's latest configurable apps available through ArcGIS Online - which allows users to find their building on a map and display the solar potential values in a customised pop-up display. The final poster was created in ArcGIS Pro 2.7 and highlights the relevance of the project for reaching the City's greenhouse gas emission reduction goals.

Results: The results from the final solar potential layer show that the City of Peterborough can produce 10,969.37 MWh of electricity per year from rooftop solar power. This equates to a reduction of about 439 tonnes of CO_2 per year and highlights the potential of solar power for reducing greenhouse gas emissions in the city. Moreover, even though less than 1% of buildings were responsible for a significant proportion of the city's highest solar potentials, the average building in Peterborough does in fact have the potential to meet its electricity consumption through rooftop solar power.

Conclusions: This project is a step toward a more sustainable energy sector for Peterborough. The results of the solar potential layer highlight the potential benefits of solar power in the city and the web application and poster will play important roles for disseminating this information to the public.

Keywords: climate change, solar power, solar panels, spatial analysis, data processing, web application, enterprise technology, cartographic map, poster

2.0 Introduction

Global climate change is one of the most challenging threats to ever face humanity. The Supreme court of Canada agrees with this sentiment declaring in a majority decision on the legality of a carbon tax that global climate change poses a grave threat to societies worldwide and is indeed the result of greenhouse gas emissions from human activities (Supreme Court of Canada, 2021). For this reason, governments of every level must implement policies and programs to reduce greenhouse gas emissions. The City of Peterborough has made a commitment to reduce the city's greenhouse gas emissions by 30% by 2030 and down to net zero by 2050 (Environment and sustainability, n.d.).

To reach the reduction targets listed above, the City of Peterborough will need to implement a wide variety of policies and programs that focus on high emission sectors, like residential buildings. City buildings are responsible for 32% of total emissions, with the residential sector being the highest emitter when compared to industrial, commercial, and transportation sectors (Figure 1; City of Peterborough, 2016). Reducing CO_2 emissions from residential buildings would thus be a logical approach for reaching the City's climate change targets. One program that the City of Peterborough would be interested in implementing is a web application that displays the solar potential of all buildings within the city limit. The web application will aid homeowners and business owner's decision-making to assess if solar technologies are viable for their property. The goal of this project is to encourage home and business owners to install solar panels and therefore reduce their greenhouse gas emissions.

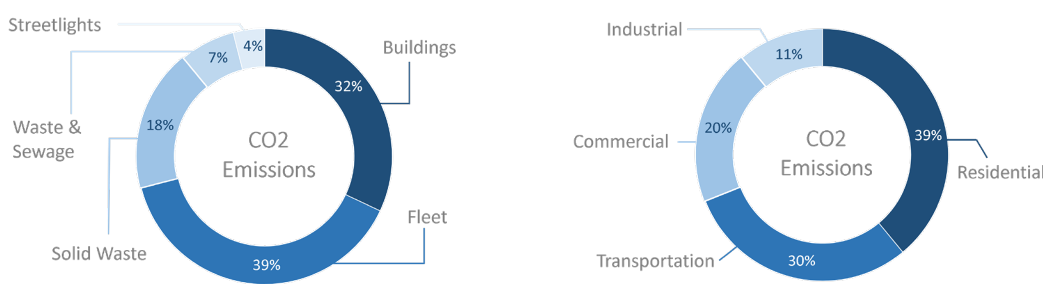

Figure 1. *Percent CO_2 emission by sector for the City of Peterborough.*

2.1 Problem Definition

The City of Peterborough perceived a need to develop a web application that shows the solar potential of rooftops, which would assist property owners in the City of Peterborough determine the feasibility of solar technologies on their properties. Due to surface features of each rooftop being unique, the web application must display the unique solar potential for each rooftop and the area on each rooftop suitable for solar panels.

2.2 Client and Study Area

The client for this project is the City of Peterborough represented by James Byrne, the Climate Change Coordinator, and Andrew Nichols, GIS Technologist. The requested web application will only include rooftops that are located within the City of Peterborough boundaries (Figure 2).

Figure 2. *Study area extent. Source: City of Peterborough GIS Open Data, https://dataptbo.opendata.arcgis.com/*

2.3 Past Work

The city of Edmonton has already developed a web application very similar to what the City of Peterborough is interested in developing. This web application for the City of Edmonton can be found at: https://solar.myheat.ca/edmonton/, and is powered by Google Project Sunroof. Importantly, the web application allows a user to search an address and then click on the rooftop resulted from the search. Clicking on a rooftop activates a pop-up window that shows the number of usable sunlight per year and area available for solar panels on the rooftop.

2.4 Objectives & Deliverables

The main goal of this project is to allow property owners within the City of Peterborough to view the solar potential of their properties by finding their property within the web application. By providing easy access to the solar potential of properties it will hopefully encourage property owners to install solar panels, which would ultimately increase private solar panels sales in the City of Peterborough. The following objectives listed below will help achieve the project goal:

1) **Provide Client with the operational layers from an analysis of solar potential for buildings in Peterborough**. The building solar potential layer and associated attributes resulting from the analysis will be provided to the Client in the form of a file geodatabase. The client would also like to retain intermediate layers resulting from the analysis to facilitate QA/QC and future reproduction of the analysis as updated Lidar datasets become available.

2) **Create a solution that allows public and private property owners to view the solar potential of their buildings**. To encourage the use of solar panels among property owners, they must first be made aware of the energy potential and capacity that their building has for installing solar panels. This solution is meant to approximate what is possible based on total solar hours that a building receives, as well as area available for panel installation. Once homeowners are made aware of their solar potential, they can get a more detailed assessment by a qualified practitioner.

3) **Allow Client to showcase the methodology and disseminate the results of the solar potential survey**. As a public organisation, the City of Peterborough would like to be able to communicate its actions on climate change mitigation to the public and disseminate the results of the solar potential analysis.

The proposed services, tangible deliverables, and academic requirements associated with each of the three objectives are summarised in Table 1. Note that some elements described in the original proposal were not included in the final product (indicated by '*' in Table 1) with approval from the Client.

Table 1. List of project deliverables and description of each deliverable adapted from Project Proposal.

OBJECTIVE	PROPOSED SERVICES	DELIVERABLES	REQUIREMENTS
O1. Provide Client with the operational layers from an analysis of solar potential for buildings in Peterborough.	O1.S1. Process provided lidar data to create a DSM. O1.S2. Acquire climatic data for Peterborough and integrate into analysis of solar potential. O1.S3. Model solar potential of rooftops using DSM, climatic data, and building footprint layer. O1.S4. Join address data* (excel file) and city-owned facilities data (excel file) to final solar potential layer. O1.S5. Provide toolbox with parameterised models that can be used to re-run analysis. (optional)*	D1. File Geodatabase (Deliverable 1)	- Data Acquisition and/or Preprocessing - Spatial and Statistical Analysis.
O2. Create a solution that allows public and private property owners to view the solar potential of their buildings.	O2.S1. Use solar potential layer to create a web application that shows solar potential of each building. O2.S2. Add page(s) detailing how the process works. O2.S3. Calculate energy savings for each building. (optional)*	D2. Web app showing solar potential of buildings in Peterborough (Deliverable 2)	- Enterprise/Web Technologies.
O3. Disseminate the results of the solar potential survey.	O3.S1. Create cartographic poster detailing methodology and results of the project.	D3. Cartographic output (Deliverable 3)	- Visualisation/ Presentation

* Note that these elements were removed from the final project deliverables.

3.0 Methodology

3.1 Deliverable 1: File Geodatabase with Solar Potential Layer

To model rooftop solar potential, we adapted an Esri workflow (Khanna 2020) which utilises the Solar Radiation toolset in ArcGIS Pro 2.7. Here, we describe those steps with particular emphasis on data preprocessing and how we selected parameter values for each of the geoprocessing tools used in the analysis. Figure 3 provides a brief overview of the process in creating the solar potential layer. A more detailed workflow is provided in Appendix A.

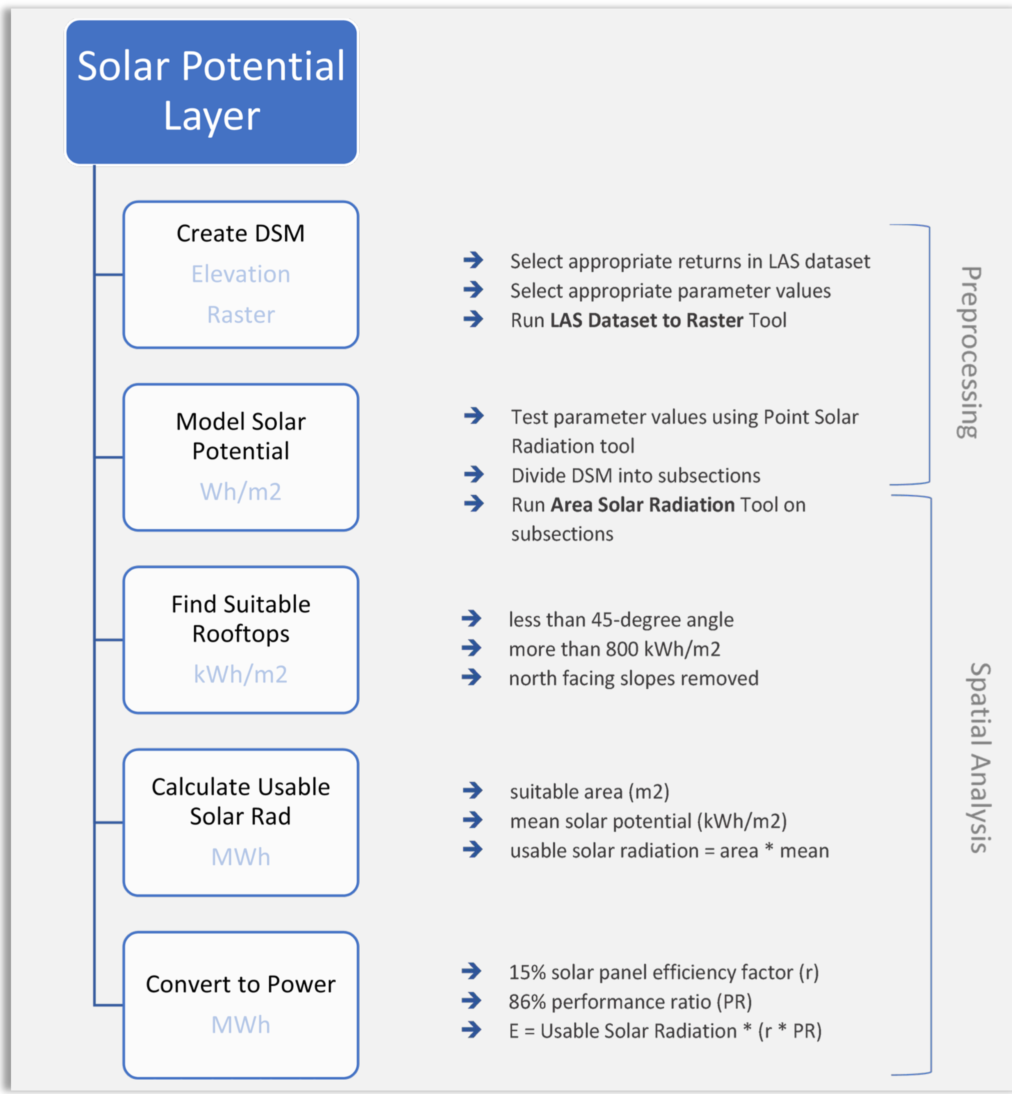

Figure 3. Flowchart for Deliverable 1 methodology.

3.1.1 Create Digital Surface Model (DSM)

We used the LAS Dataset to Raster tool to create our Digital Surface Model (DSM) from airborne lidar data acquired for the City of Peterborough in 2020. Using interpolation methods, this tool estimates elevation values based on nearby lidar points across a continuous surface at a user-determined sampling distance. Some of the key input parameters for the tool are discussed below. A step-by-step procedure can be found in Appendix A.

Selecting a cell size sampling value

The cell size sampling value is arguably one of the most important parameters to consider for this tool as it will determine the resolution of the output DSM and thus influence the rooftop solar radiation calculations. A sampling size that is too large will underutilise the lidar data and result in an unnecessarily low resolution than what is possible with the data. A sampling value that is too small will result in more artifacts from interpolation (i.e., because of an increase in 'No Data' cells) and would also unnecessarily increase processing time.

It is best practice to choose a sampling value that is close to the average point spacing of the original LAS files; however, to account for the fact that point sampling is not evenly distributed (some areas have a denser point cloud than others), it has also been suggested to choose a value that is 3 to 4 times larger than the original point spacing so that there are fewer 'empty' cells (Esri 2019). This is more important for generating DTMs, where sampling density is more variable due to a lowered penetration of the canopy to the ground. As we are creating a DSM and would like to characterise as best as possible the above ground structures (e.g., trees and buildings), we decided to go with as fine a resolution as possible without inducing too much 'noise'.

Our average point spacing in the LAS files was generally below 0.2. To test our output resolution, we created DSMs from three sampling values: 0.2, 0.3, and 0.5. The hillshades produced from the DSM created using a sampling value of 0.3 seemed to have the best resolution (very clear rooftop shape and dimension), while also reducing some of the artifacts created using a lower value of 0.2 (e.g., along the edges of buildings; refer to Figure 4). This value was selected for the analysis.

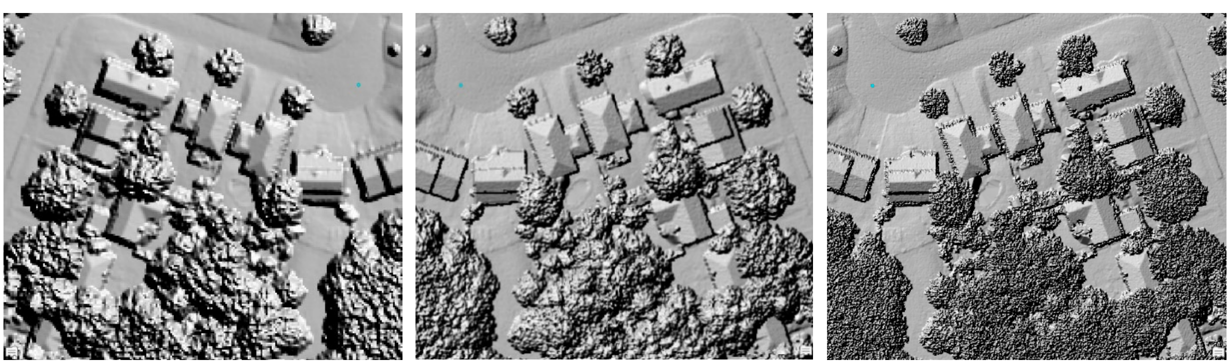

Figure 4. Hillshade produced from DSMs created using the LAS Dataset to Raster tool with a sampling value of 0.5 (left), 0.3 (middle), and 0.2 (right).

Choosing an interpolation method

In Esri's guide to lidar data (Esri 2015), it is suggested to use Binning for the interpolation algorithm when there are no constraints being used and there are few areas of sparse point coverage. We do not have any landscape constraints and have good overall lidar coverage and therefore used Binning, together with Natural Neighbour for void filling, as suggested. Moreover, we used the suggested "Maximum" option for cell aggregation as we want to create a DSM and are thus interested in the max point returns for our analysis.

3.1.2 Model Solar Potential

We used Esri's overview of the "Area Solar Radiation" tool (Esri 2016) to determine appropriate values for most parameters, as well as the advice given by Falklev (2017), especially regarding transmittivity and diffuse proportion values.

Selecting parameter values

The following is a description of the parameter values used for the Area Solar Radiation tool:

- *z-factor*: We used the default value of 1 since our data is projected in UTM and is thus in meters.
- *slope and aspect:* These rasters are calculated directly from the input DEM.
- *calculation directions*: The default value of 32 calculation directions or higher is suggested for complicated terrain. To reduce computing time, it has been recommended to use a value of 16, especially for lower resolution DEMs and/or smooth terrain. As we are using a fine resolution DEM (0.3m) that includes man-made structures, the total number of directions should be at least 32.
- *zenith and azimuth divisions*: each uses the default value of 8.
- *sky size:* A large sky size may increase calculation accuracy, but at the cost of computation time. As we are calculating a complete DEM with a large day interval (>14 days), it is sufficient to use the default value of 200. (Esri 2016)
- *diffuse proportion*: see below
- *transmittivity*: see below

Diffuse Proportion of Radiation and Transmittivity parameters

Diffuse Proportion of Radiation (D) accounts for how much of the total global solar radiation is diffuse whereas the Transmittivity (T) parameter accounts for the proportion of extraterrestrial radiation that penetrates through the atmosphere and cloud to reach the earth, or "direct" radiation. The total solar radiation is the sum of these two parameters. When choosing appropriate values for D and T, it is important to note their inverse relationship and adjust both simultaneously to accurately represent atmospheric conditions (Fu and Rich 1999).

Following a similar methodology to that used by Falklev (2017), we compared average daily solar radiation values (kWh/m^2) at a set of 12 "open" (unobstructed view) point locations across our DSM to a "real world" value (3.65 kWh/m^2 per day averaged from 1974 to 1993[1]) using different D and T value combinations for the year 1993. The goal was to select the D and T combination that most closely represents solar radiation values observed in real life. To get point measurements of solar insolation, we used the "Point Solar Radiation" tool, which takes the same input DSM and parameters as the "Area Solar Radiation" tool, but measures radiation at a specific point or set of points instead of an area. The results of the parameter test indicate that the best parameter value combination for most accurately respresenting climate in Peterborough is T = 0.6 and D = 0.2 (refer to Figure 5).

Note that the 'real world' value of 3.65 kWh/m^2 is derived primarily from Environment Canada CERES Ground Station data (Pelland et al. 2006). We would ideally use more accurately measured solar insolation data, such as that obtained from a climate station, and select parameter values based on this data.

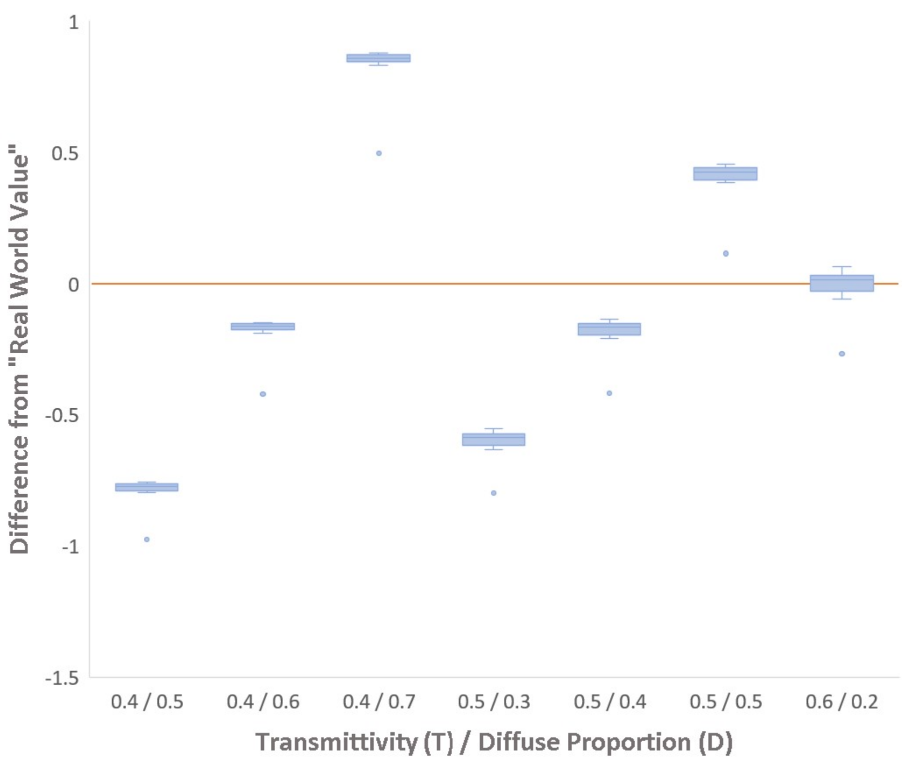

Figure 5*. Results from the parameter test showing how daily mean solar radiation (kWh/m^2) resulting from different combinations of Transmittivity (T) and Diffuse Proportion (D) differ from actual measured values in Peterborough (red line; see text for details).*

[1] The 'real world' value is based on insolation data provided by Environment and Climate Change Canada and obtained through an online web map application developed by the Federal Geospatial Platform (online at https://fgp-pgf.maps.arcgis.com/apps/webappviewer/index.html?id=c91106a7d8c446a19dd1909fd93645d3; Pelland et al. 2006)

Effect of DSM size on processing time

A major bottleneck to the workflow is the processing time needed to run the Area Solar Radiation tool in ArcGIS Pro. This was especially time consuming for our project due to the very fine resolution of the DSM (0.3m) which made analysis of the entire city impractical. Similar to Falklev (2017), we also found that the size of the DSM directly impacted our processing time (Figure 6). Here, we provide an overview of processing time for various sizes of our input DSM as well as our solution to splitting the DSM by ward and subward groupings.

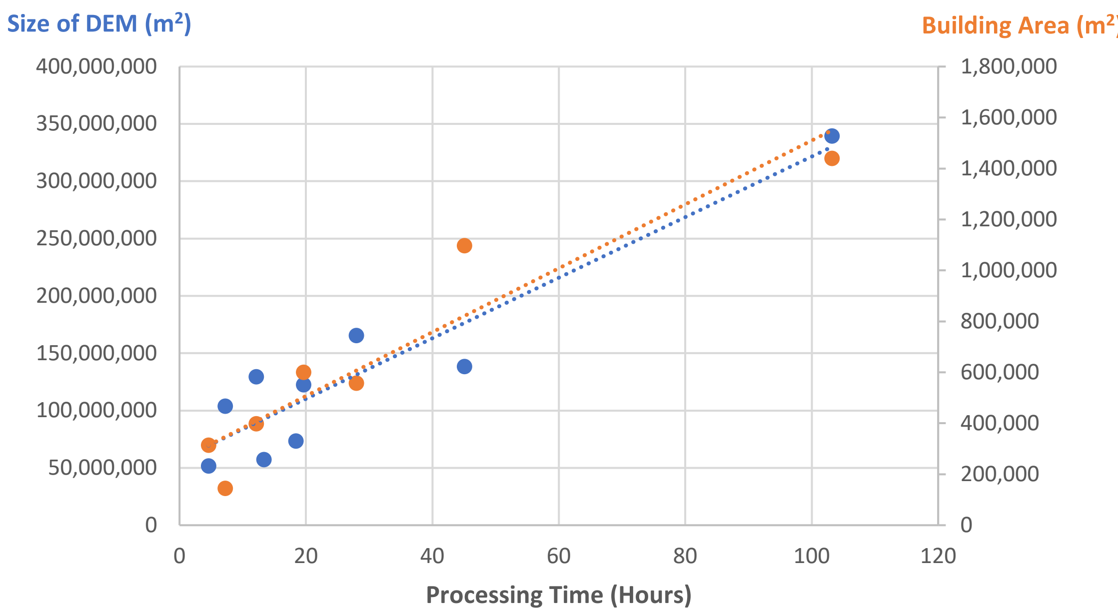

Figure 6. *Processing time in hours for Area Solar Radiation analysis in ArcGIS Pro 2.7 with different sizes of Digital Elevation Model (DEM) and Building Footprint input files.*

Adding a 100m buffer to subsections of the DSM

One problem with splitting up the input DSM is that distant cells matter for the Area Solar Radiation analysis. The shadow cast by a distant building or tree will impact the solar insolation of cells within reach of that shadow. Buildings that are removed along the edge of a clipped ward will cause an overestimate of solar insolation for cells that would normally be affected by those buildings. We overcame this issue by introducing a 100m buffer around each of the clipped DSM extents. Our justification for the 100m cut-off is that the highest building in Peterborough is about 50m high and a 100m buffer would account for a shadow 2 times the height of that building. In Peterborough, shadow length reaches a value that is approximately 2 times the height of an object when the sun's altitude (angle from the horizontal plane) is 27 degrees (Hoffmann 2021). The shadow will be much longer at smaller sun angles (i.e., close to sunrise and sunset), but the radiation intensity will be much lower (Pidwirny and Jones 2009) and the overall impact should be minimal. Figure 7 gives an overview of how solar radiation intensity changes with sun angle throughout the day and how this affects shadow length at two annual extremes: summer and winter solstice. Shadow length and sun angles were determined for Peterborough using Hoffmann's

SunCalc app (Hoffmann 2021) and the percent intensity of solar radiation is calculated as *Intensity = sin(A)*, where *A* is the angle of the sun to the horizon (Pidwirny and Jones 2009).

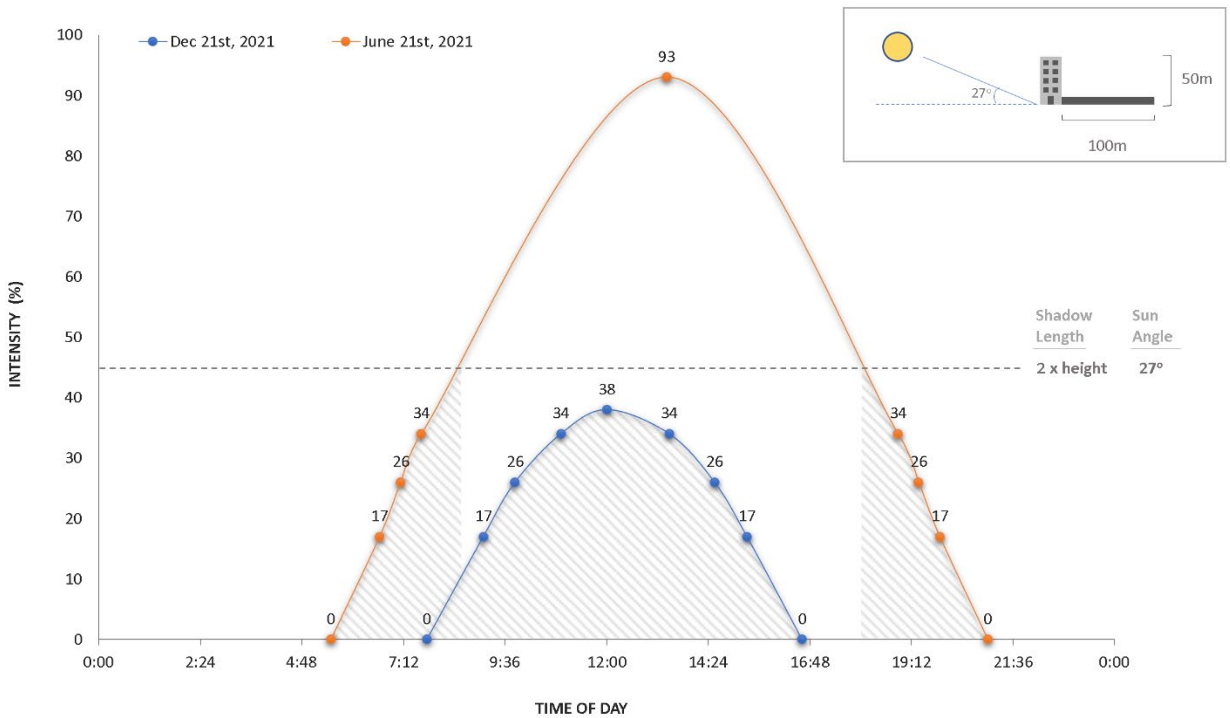

Figure 7. *Change in the percent intensity of solar radiation throughout the day at summer and winter solstice in Peterborough, where a lower intensity corresponds to a lower sun angle. Hashed areas correspond to times of the day when the sun angle is low enough that a shadow may reach lengths greater than 2 times the height of an object. The top right schematic demonstrates the effect of sun angle from the horizon on shadow length of a building that is 50m tall (i.e., the tallest building in Peterborough).*

To confirm the 100m buffer as an appropriate cut-off, we ran the Point Solar Radiation (PSR) tool on 6 points near Peterborough's tallest building (Charlotte Towers): 3 points within a 100m buffer and 3 points outside a 100m buffer. We ran the PSR analysis twice, once using the full city DSM and once using a clipped DSM which excluded the Charlotte Towers from the analysis. Figure 8 shows that solar radiation for buildings within the 100m buffer increased when the Charlotte Towers were removed from the analysis, as expected. Points outside the 100m buffer, on the other hand, had a lower solar radiation when the Charlotte Towers were absent. Since we would expect an increase in solar in the clipped DSM, we conclude that changes in solar radiation outside the 100m buffer is not a result of removing the Towers.

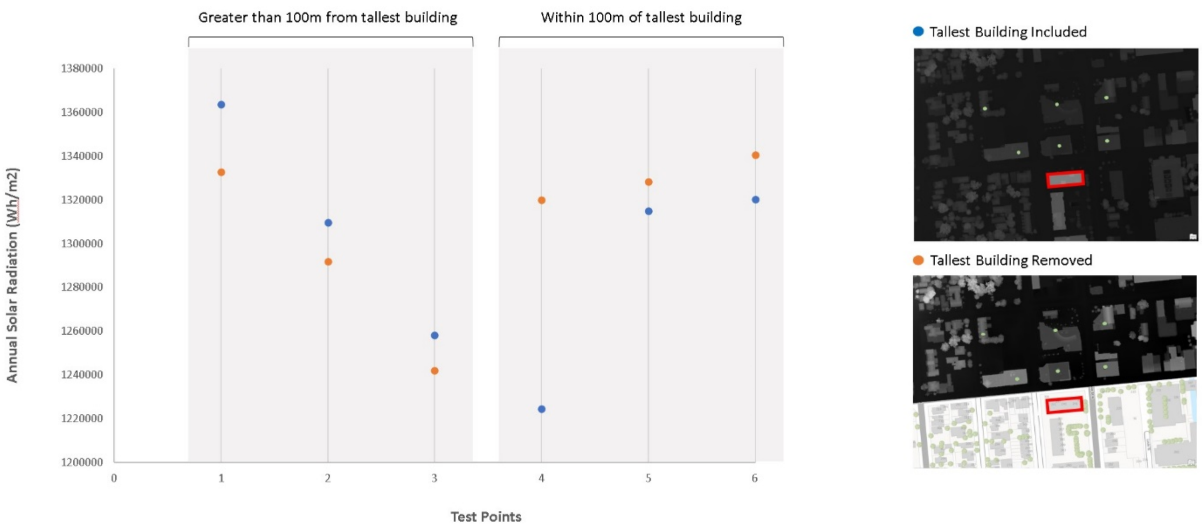

Figure 8. *Annual solar radiation (Wh/m^2) calculated with the Point Solar Radiation tool in ArcGIS Pro for 6 points located near the tallest building in Peterborough (Charlotte Towers). The analysis was run twice, once using the full city DSM (Charlotte Towers included) and once using a clipped DSM (Charlotte Towers excluded). Points 1, 2, and 3 are located more than 100m from the building, while points 4, 5, and 6 are located within 100m of the building. Right side: images of the input DSM with the towers (top) and without the towers (bottom), as well as locations of the 6 points (green) in relation to the towers (red polygon).*

3.1.3 Find suitable rooftops

Not all cells in the solar radiation output layer can be used to calculate total rooftop area suitable for solar panel installation. For instance, north facing slopes and cells with low solar radiation values (less than 800 kWh/m^2) receive minimal sunlight and do not contribute much to the overall solar potential of the roof. Moreover, practical considerations for installing solar panels, such as the slope of the roof, were also considered for the model. Areas with a slope greater than 45 degrees were removed from the analysis.

3.1.4 Calculate usable solar radiation (MWh)

After selecting suitable rooftop area, cells in the solar radiation layer were aggregated together based on their corresponding building footprint and three metrics were calculated using the Zonal Statistics tool: Count (number of pixels), Mean (average solar radiation in MWh), and Area (total suitable area per building in square meters). The AREA and MEAN were then multiplied to give a usable solar radiation value, which was further divided by 1000 to give units of MWh.

3.1.5 Convert to power (MWh)

Finally, the annual electricity output from solar radiation was estimated for each rooftop using the Area and Mean values calculated previously, as well as default energy factors recommended by the Environmental Protection Agency (EPA) for latitudes similar to Peterborough (EPA 2021). Power was then calculated with the following equation:

$$E = A * r * H * PR$$

E = *Energy (MWh)*
A = *Suitable Area (m^2)*
r = *Solar Panel Efficiency (%)*
H = *Annual Average Solar Radiation (MWh/ m^2)*
PR = *Performance Ratio*

Based on documentation provided by the EPA (EPA 2021) and the National Renewable Energy Laboratory (NREL 2020), solar panel efficiency (r) was given a default value of 15 percent and the performance ratio (PR) was set at 86% (to reflect 14% in additional system losses). Note that the usable solar radiation (MWh) described in the previous section is equal to A * H in this equation.

3.1.6 Quality Assessment and Quality Control (QAQC)

To ensure the final solar layer is accurate and complete, we assessed the following: (1) compare solar potential values to known values of rooftop solar radiation provided by the client, (2) ensure that all buildings are included in the final layer, and (3) remove buildings that are no longer present in the city.

3.2 Deliverable 2: Web Application

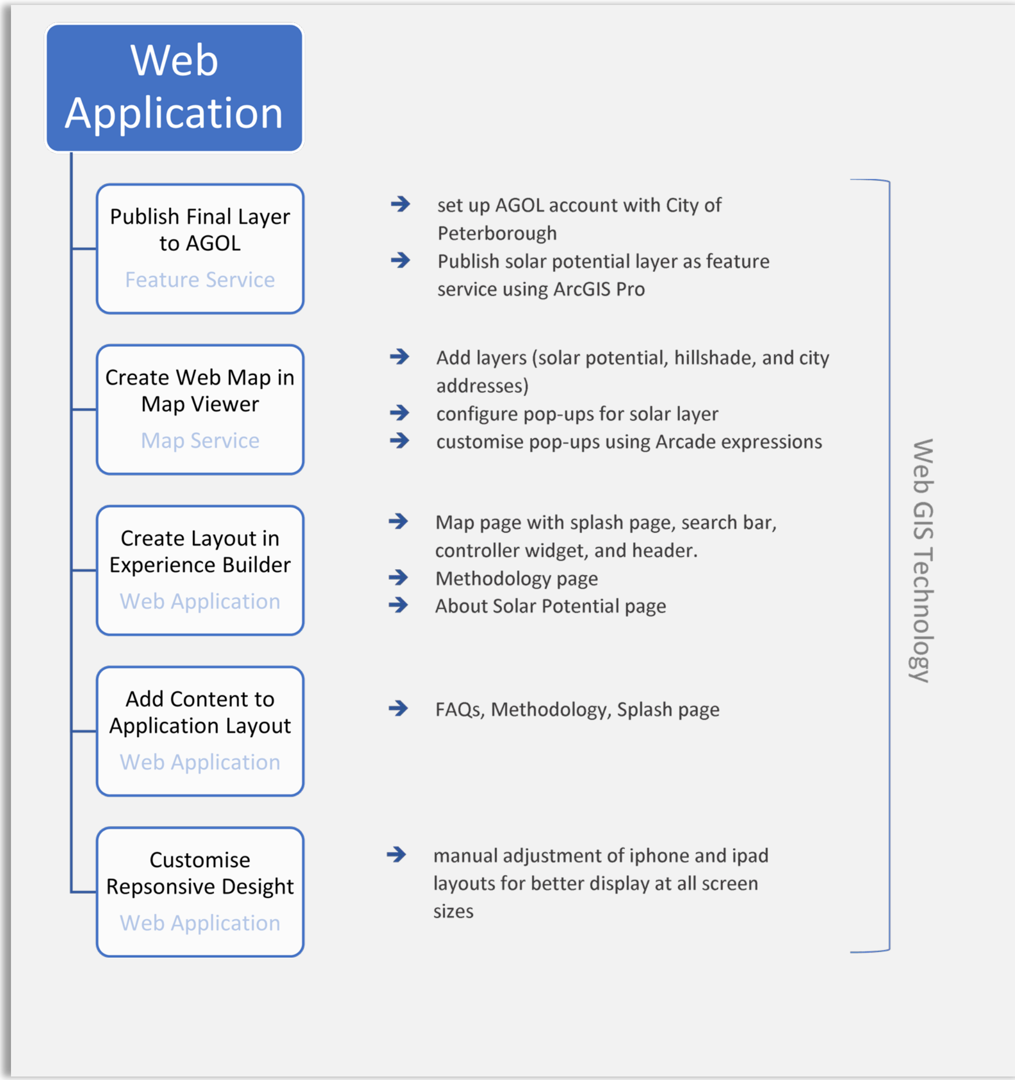

Figure 9. Flowchart for Deliverable 2 methodology.

3.2.1 Create the Web Map

The final solar radiation layer was published as a feature service from ArcGIS Pro 2.7 to ArcGIS Online (AGOL). To add visual texture to the rooftops, a hillshade layer clipped to building footprints was also published to AGOL. The web map was created in Map Viewer with three layers: the solar potential layer symbolised by Usable Solar Radiation (MWh), the hillshade layer, and an Address layer to be used for querying addresses. The Address point feature layer was added as a separate layer since many buildings have multiple addresses making it impractical to add this data as an attribute in the solar potential table. We then used an Arcade expression in the solar potential layer pop-up configuration window to allow the selected feature's address to appear in the pop-up:

```
var addressLayer = FeatureSetByName ($map,  <Address_Layer>)
var addressFeature = Intersects (addressLayer, $feature)
return First (addressFeature).ADDRESS
```

where <Address_Layer> is the name of the Address point feature layer with an ADDRESS field. The solar potential layer pop-up was further customized to display the total potential Electricity Production (MWh) for the entire city using the following expression:

```
Text (Round (Sum ($layer, <Elec_Prod_MWh>) ), '#,###' )
```

where <Elec_Prod_MWh> is the name of the field storing the potential electricity production values in MWh. A third arcade expression was used to calculate the percent usable area of the total rooftop surface:

```
Round ( ( ($feature.AREA) / (AREA ($feature) ) ) * 100)
```

where AREA($feature) is the area calculated from the feature geometry (i.e., the actual size of the roof) and $feature.AREA returns the remaining rooftop area after the removal of unsuitable areas. A final expression was included to display the amount of CO_2 emissions (in tonnes) that can be saved if solar panels were to be installed. This calculation is based on the average amount of CO_2 produced per kWh in Ontario (40g per kWh/m2; CER 2020).

```
Round ( ( ($feature.Elec_Prod_MWh) * 1000 * 40 * 0.000001), 2)
```

3.2.2 Create the Web Application

The rooftop solar potential web application was created using ESRI's ArcGIS Online newest web application builder called "Experience Builder". This online software is intended to slowly replace ESRI's ArcGIS Online other web application builder "Web AppBuilder." Like its predecessor it is a what you see is what you get software. What this means practically is you do not need to code your web application but drag and drop design features called widgets into the web application, importantly what is present in the software is what the final web application will look like.

Additionally, since "Experience Builder" is an ArcGIS Online application it behaves like any other item on ArcGIS Online, where for example you can set user roles and privileges. This means only certain users granted editing privileges can edit the web application. Also, the sharing level of the web application can be set, for example the sharing level can be set to the organization level and once the web application is completed can the sharing level be set to public, which means any one on the web can view the web application but importantly they cannot edit/change the web application.

The web application was given a map-centric layout. As mentioned above the design elements of “Experience Builder” are called widgets, and there are two types of widgets either stock or custom. This project only made use of stock widgets, and a list along with description of each stock widget used in this project can be found in Table 2.

Table 22. The stock widgets used to create the rooftop solar potential web application.

Stock Widget	Description
Map	Allows the display of spatial data from ArcGIS Online.
Header	Allows the placement of a title, logo, and navigation bar which do not interfere with the map.
Menu	A navigation bar which links to other pages. Allows easy navigation within the web application, placed inside the header.
Text	Allows the placement of text within the web application, was used to create the title.
Picture	Allows the placement of pictures within the web application, was used to place the City of Peterborough logo within the header section.
Legend	Can display the legend for data found within the map widget when a user clicks on the widget.
FAQ	Can display frequently asked questions (FAQ) along with answers when a user clicks on the widget.
Splash	A splash page is displayed when the web application is launched and before the user can view the rooftop solar potential map. Contains text widget with a disclaimer.
Button	The user must click the ok button to remove the splash page and proceeded to the rooftop solar potential map.

Another important feature of “Experience Builder” is the allowance of multiple pages within the web application. This feature was implemented within the web application and allowed the addition of a Methodology and About Solar Potential page. The methodology page explains the method used to create the rooftop solar potential map, and the About Solar Potential page contains links to websites with information about solar potential and technologies. These two additional pages made use of the stock widgets detailed in Table 2. Importantly, the menu widget allows the user to navigate between the pages and was placed within the header widget of each page.

Finally, “Experience Builder” has a responsive design feature. It allows the responsive design to be set for larger screens like laptops or desktop monitors, medium screens such as tablets, and small screens such as phones. There are two options for responsive design for each screen size, either automatic or custom. For automatic responsive design “Experience Builder” moves the layout automatically to fit the screen size. This was not used for this web application and instead custom responsive design was implemented. For custom responsive design, the layout for each screen size must be manually changed.

3.3 Deliverable 3: Cartographic Poster

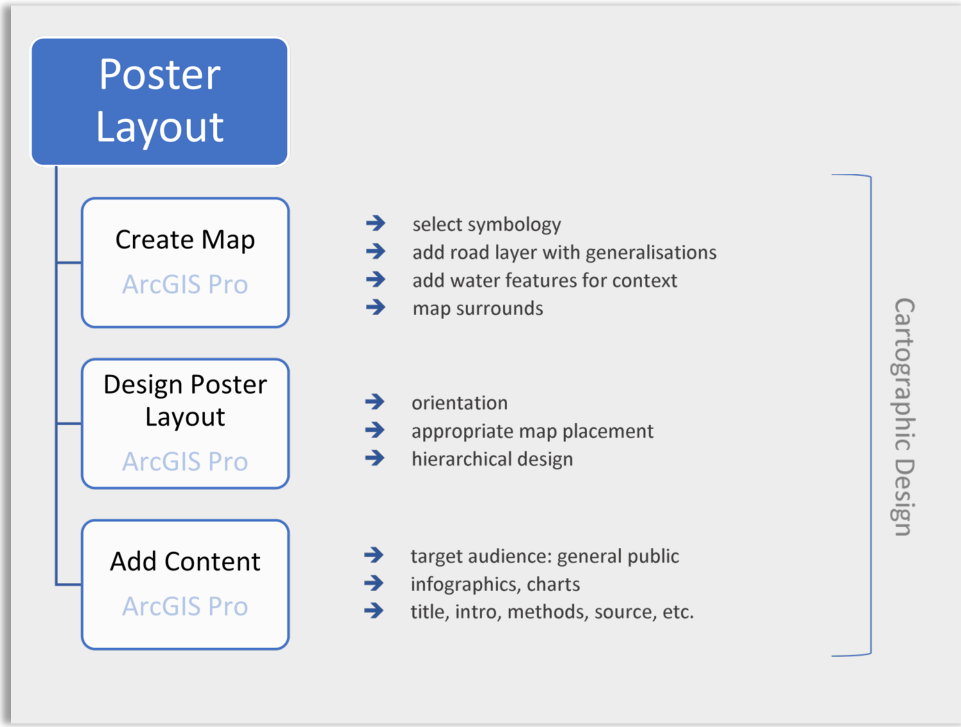

Figure 10. Flowchart for Deliverable 3 methodology.

3.3.1 Create Map

The solar potential layer created in Deliverable 1 was imported into a new map in ArcGIS Pro and symbolised to help identify buildings and their individual solar potential. An intuitive, warmth-based colour symbology was used to emphasize the level of solar potential of each building. Pale yellows represent a low solar potential, darker yellows and oranges represent a moderate potential, while shades of red represent high potential buildings.

To add context to the map, a generalized road layer and water feature layer were imported from the City of Peterborough's Open Data portal and symbolized below the solar potential layer. This will also help identify location based on existing features.

After completing the main body of the map, other map elements were added to provide addition information, such as: a legend showing the levels of solar potential, a north arrow, a scale bar, scale ratio, and a general inset map of Peterborough in relation to the surrounding area. The spatial reference and list of feature sources were moved to the bottom of the poster to reduce crowding of text.

3.3.2 Design Poster Layout

Before starting the final layout, the client was consulted to ensure that the client's requirements of the poster were met. The client was given different variations of potential layouts, which included different poster orientation, element size, and content areas. The client decided on specific elements to include and excluded, gave feedback on elements to change. These considerations were used in the final layout in ArcGIS Pro.

The final layout for both the poster and map were vertically oriented (portrait orientation) to maximize the size of the map and to allow the poster to place it on an easel for presentations. The solar potential map was placed prominently in the top-right, two-thirds of the poster. This is to attract attention to the results of the analysis, while allowing room for other content. Sequential map elements were sized appropriately, following hierarchical organization and conventions. Font types and colours were limited, such as using the font 'Futura' to comply with the City of Peterborough's branding.

3.3.3 Add Content

After finalizing the layout, additional content was added to provide background information and general statistic about the project. The text content of the poster introduces the project, the methodology of finding the solar potential, results, introduction to the web application, and conclusion. All text content was written from a generalized approach, to allow the public to understand the project. Graphics were added to highlight climate and solar statistics, the generalized process of obtaining solar radiation, and the web application. Other information related to the poster, such as addition map information, map creator information, and legal disclaimers, were placed in the footer of the poster.

3.3.4 QAQC

The final poster, and its contents, was checked for spelling and accuracy of data. The overall layout was reviewed to ensure proper cartographic principles were enforced and exported for delivery.

4.0 Results

4.1 Deliverable 1: File Geodatabase

4.1.1 The Solar Potential Layer

To help visualise the distribution of rooftop solar potential in the city, the final solar potential map layer was symbolised by "Usable Solar Radiation" in MWh (Figure 11) and "Electricity Production" in MWh (Figure 12) for all 26,396 buildings. There is a noticeably higher potential in the central downtown area of Peterborough and for large, flat-roofed buildings, as well as in peripheral neighbourhoods along the edge of the city boundary (i.e., the newer built areas). Total usable solar radiation for the entire city modeled for the year 2020 is 4,851,466.34 MWh, with an average of 183.80 MWh per rooftop. The estimated electricity production for 2020 is 625,839.16 MWh, with an average of 23.71 MWh per building. The distribution of solar potential is highly skewed. Removal of 179 building outliers with extremely high solar potential resulted in a significant decrease in skewness (from 50 MWh electricity production for all buildings to 7 MWh when outliers were removed). Additionally, removing these buildings from the dataset reduced the max electricity production from 10,969 to 342 MWh and the average electricity production per building from 24 to 18 MWh.

4.1.3 QAQC

We did not have comparable rooftop solar potential data available to us for assessing the accuracy of our solar potential values. However, the Client did have access to a non-public dataset for the city and confirmed that our values were within the range of those produced by this alternate dataset (James Byrne, personal communication). We additionally met with the Client to review the final layer and removed three buildings that had been demolished during/after the time of lidar acquisition. After accounting for the removal of these buildings, as well as all outbuildings, it was determined that no buildings were missing from the layer.

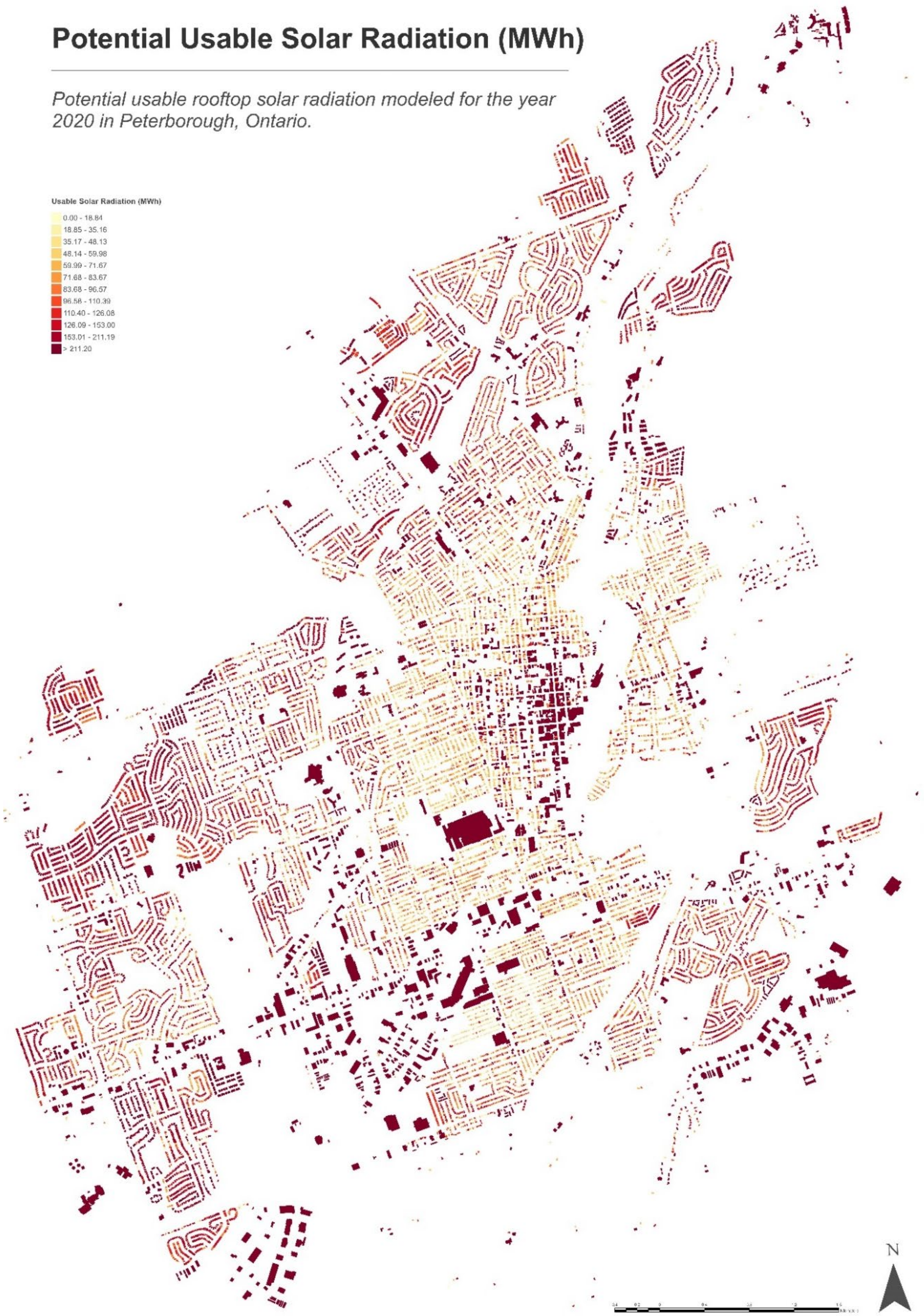

Figure 11. Solar potential layer showing usable rooftop solar radiation in MWh for the year 2020 in Peterborough.

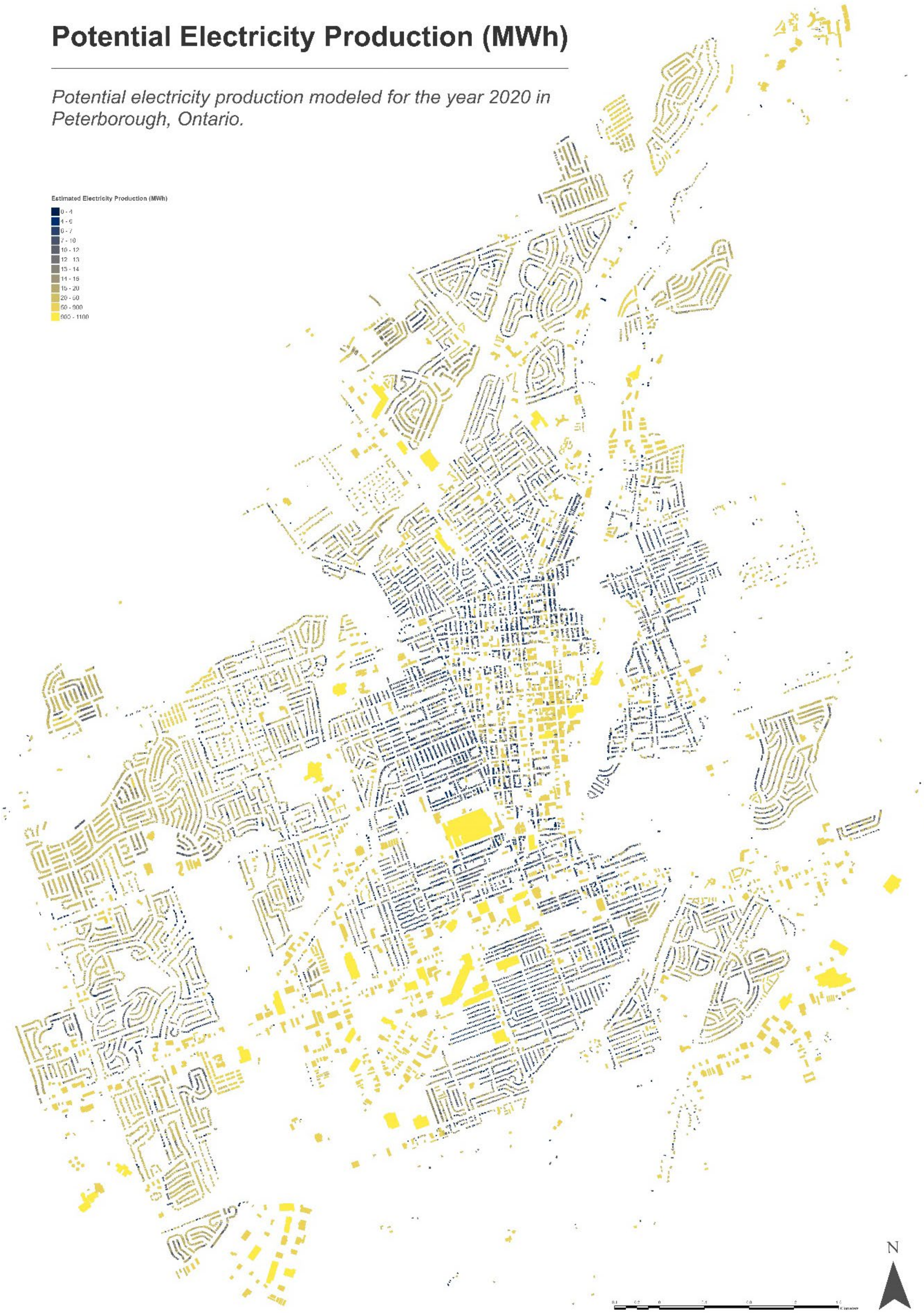

Figure 12. *Solar potential layer showing rooftop electricity production in MWh for the year 2020 in Peterborough.*

4.2 Deliverable 2: Web Application

4.2.1 Rooftop Solar Potential Web Application

When the rooftop solar potential web application is launched the first item displayed is a splash page containing information about the web application and a disclaimer. The user must also click the ok button to proceed to the rooftop solar potential map. Figure 13 shows the splash page displayed when the web application is launched.

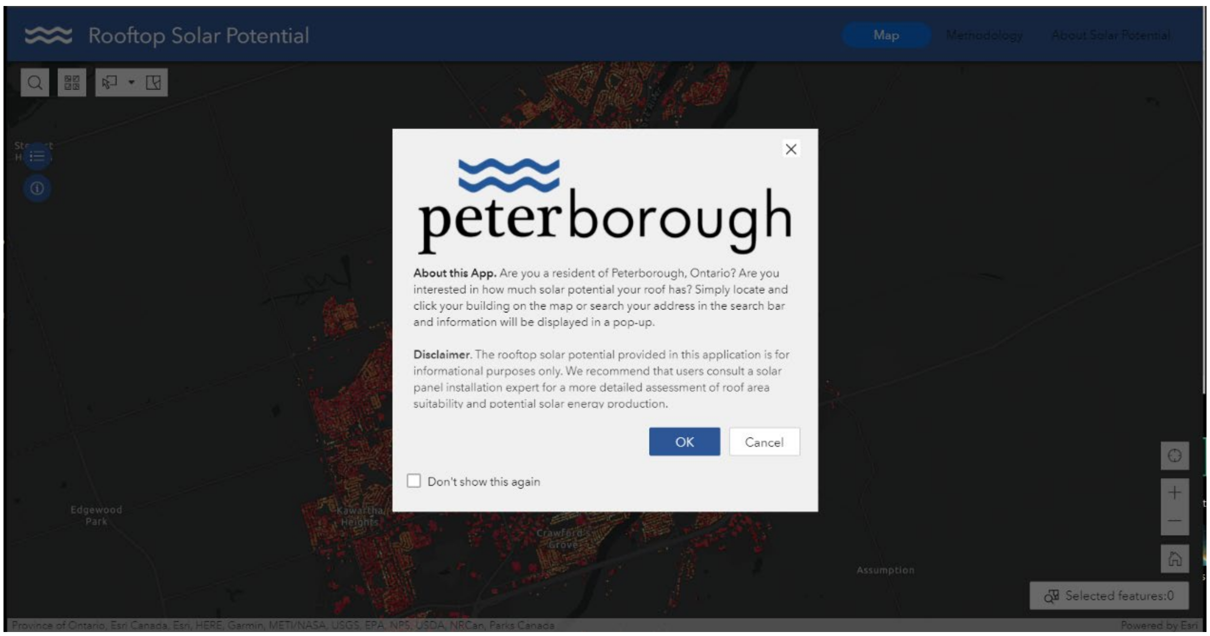

Figure 13. The splash page that displays when the rooftop solar potential application is launched. The user must click the OK button to proceed onto the rooftop solar potential map.

Figure 15 shows the main page of the web application that displays the rooftop solar potential map of the City of Peterborough. Additionally, a user can click on any rooftop located within the city of Peterborough to activate a pop-up that shows some general information about the rooftop solar potential of that certain rooftop. Figure 14 is an example of the pop-up that displays when you click on a rooftop.

Figure 14. *An example pop-up that displays when you click on rooftop located within the rooftop solar potential map on the main page of the Rooftop Solar Potential web application.*

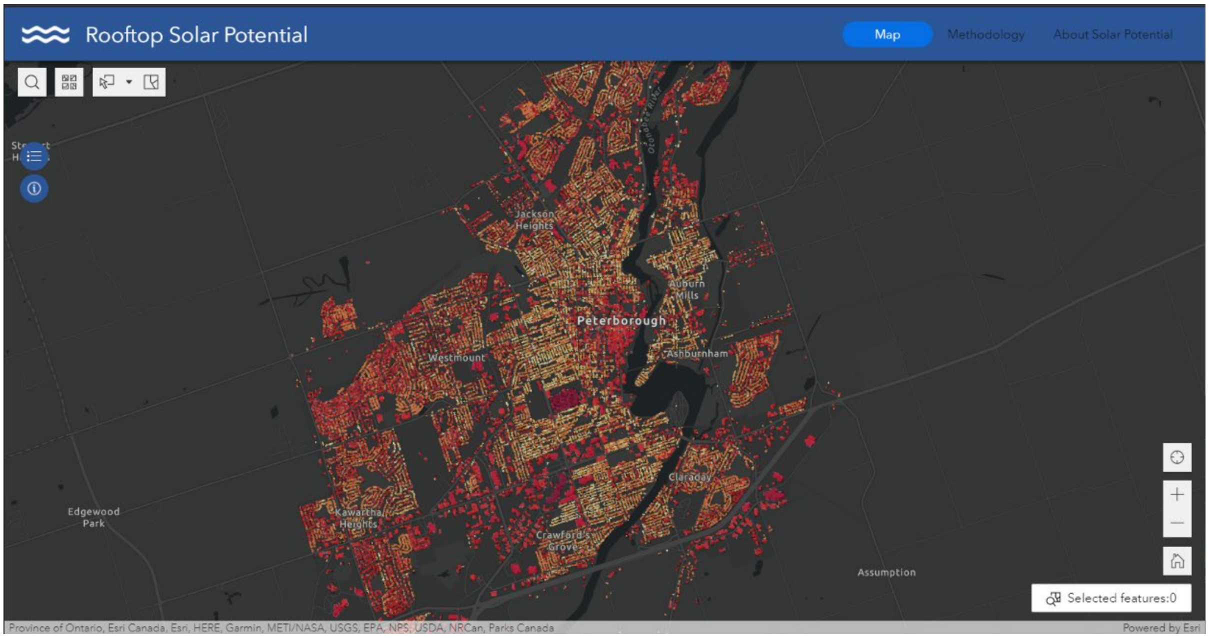

Figure 15. *The main page of the Rooftop Solar Potential web application. Displays the rooftop solar potential of every rooftop located within the City of Peterborough.*

4.2.2 Additional Pages

The Rooftop Solar Potential web application contains two additional pages for information about the methodology and solar potential. The methodology page contains information about how the solar potential was calculated within the rooftop solar potential map. Figure 16 shows what the methodology page of the web application looks like. The second page located within the web application is the About Solar Potential page (Figure 17) which contains links to external web sites with more information about solar potential.

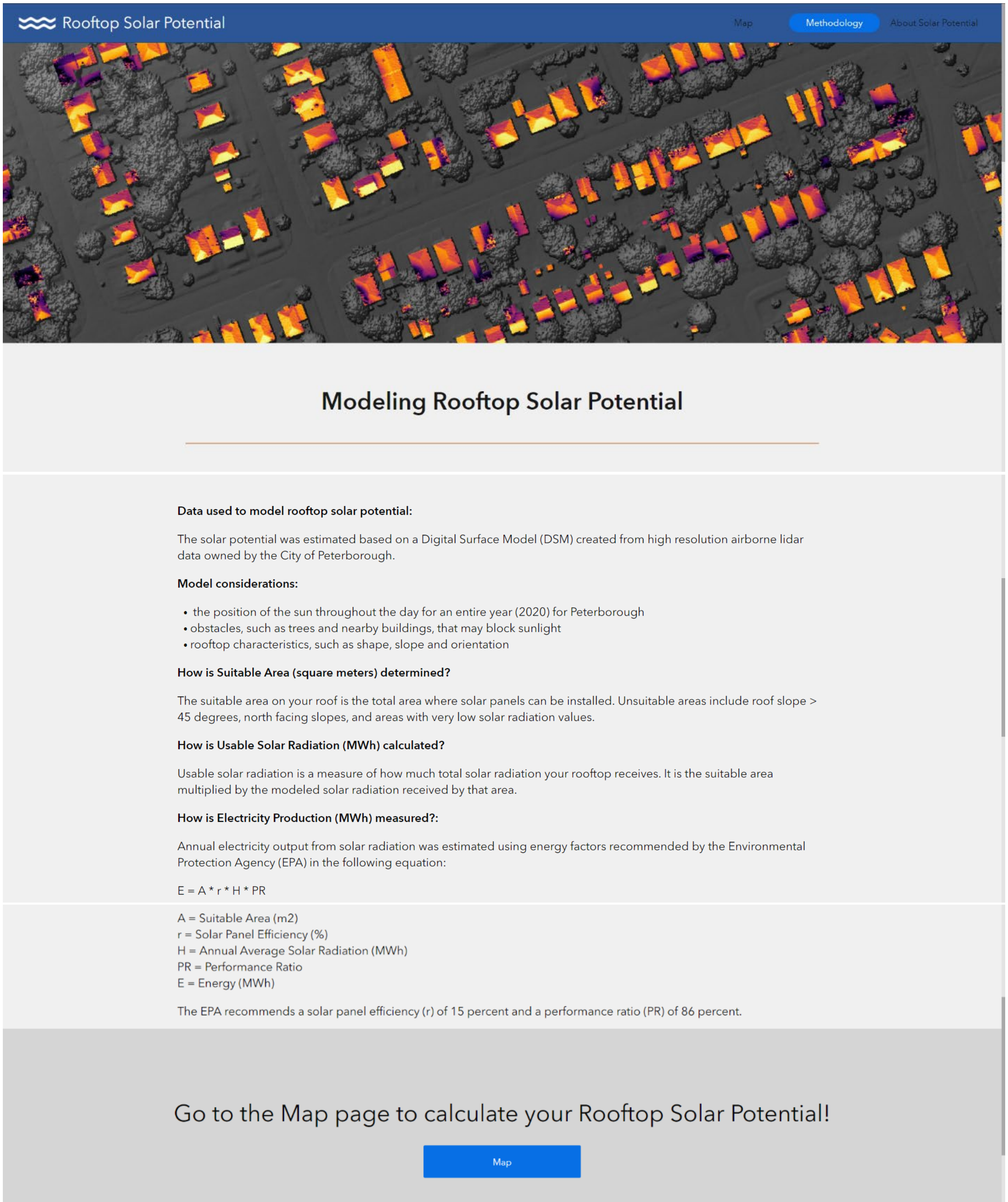

Figure 16. *The Methodology page of the Rooftop Solar Potential web application, which explains how the rooftop solar potential is calculated within the rooftop solar potential map.*

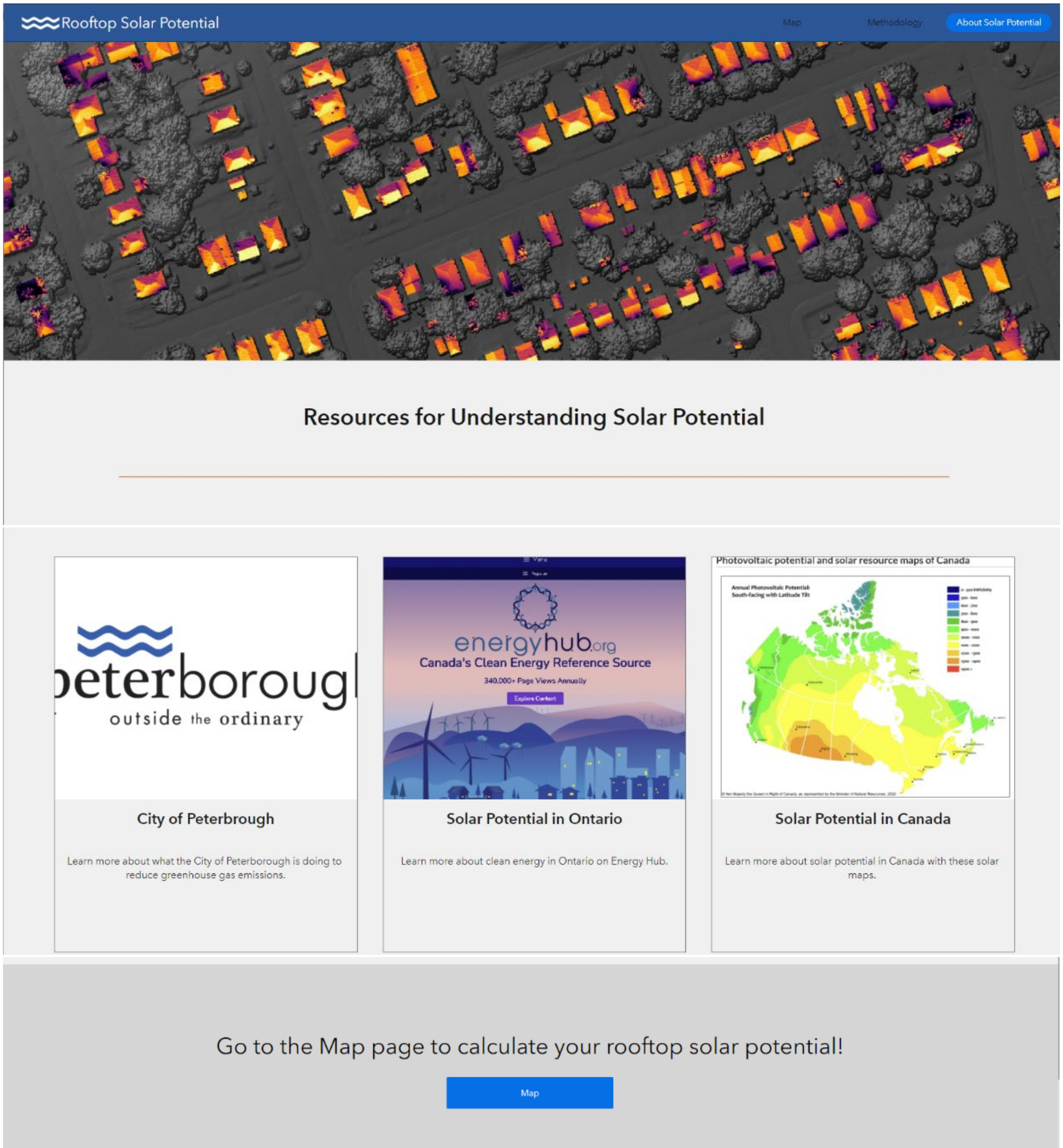

Figure 17. The About Solar Potential page of the Rooftop Solar Potential web application, which provides links to other web sites with more information about solar potential.

4.2.3 Responsive Design

The responsive design layout for medium and small screen was manually set by switching between screen size modes and rearranging/removing widgets (Figure 18).

Figure 18. The custom responsive design layout of the Rooftop Solar Potential application for medium (left side) and small (right side) screens with the rooftop solar potential map in the top row, the methodology page in the middle row, and the about solar potential page in the bottom row.

4.3 Deliverable 3: Cartographic Poster

The final cartographic solar potential map with generalised road and water features is displayed in Figure 19 and is prominently displayed in the finished poster layout (Figure 20), paired with text describing the project and the process of obtaining the results. The poster also disseminates the results of the analysis, introduces the web application, and concludes with the City of Peterborough stating its continued work to mediate climate change locally. For quality control, the text and graphic content was checked for spelling and accuracy. The overall layout was further reviewed to ensure proper cartographic principles were enforced. The poster will be available in both in physical and digital formats.

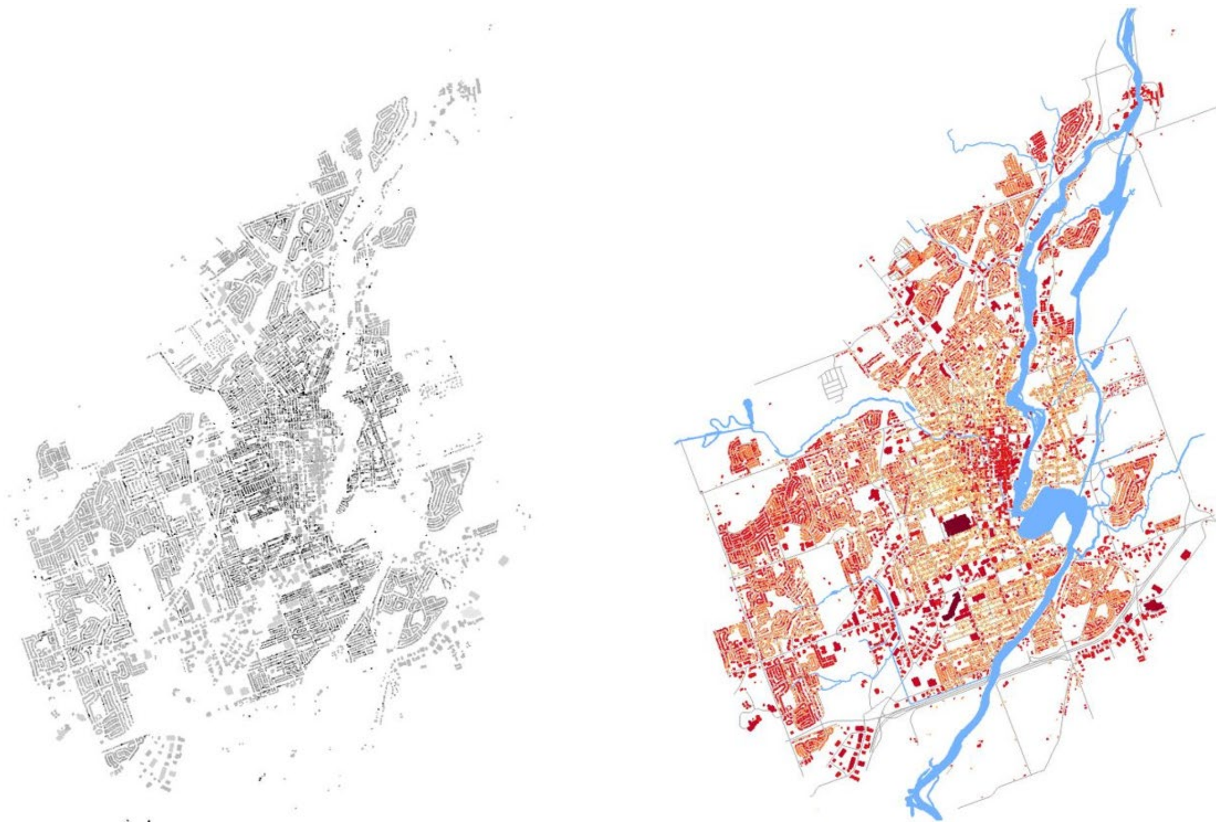

Figure 19. The solar potential layer, before and after symbology was applied.

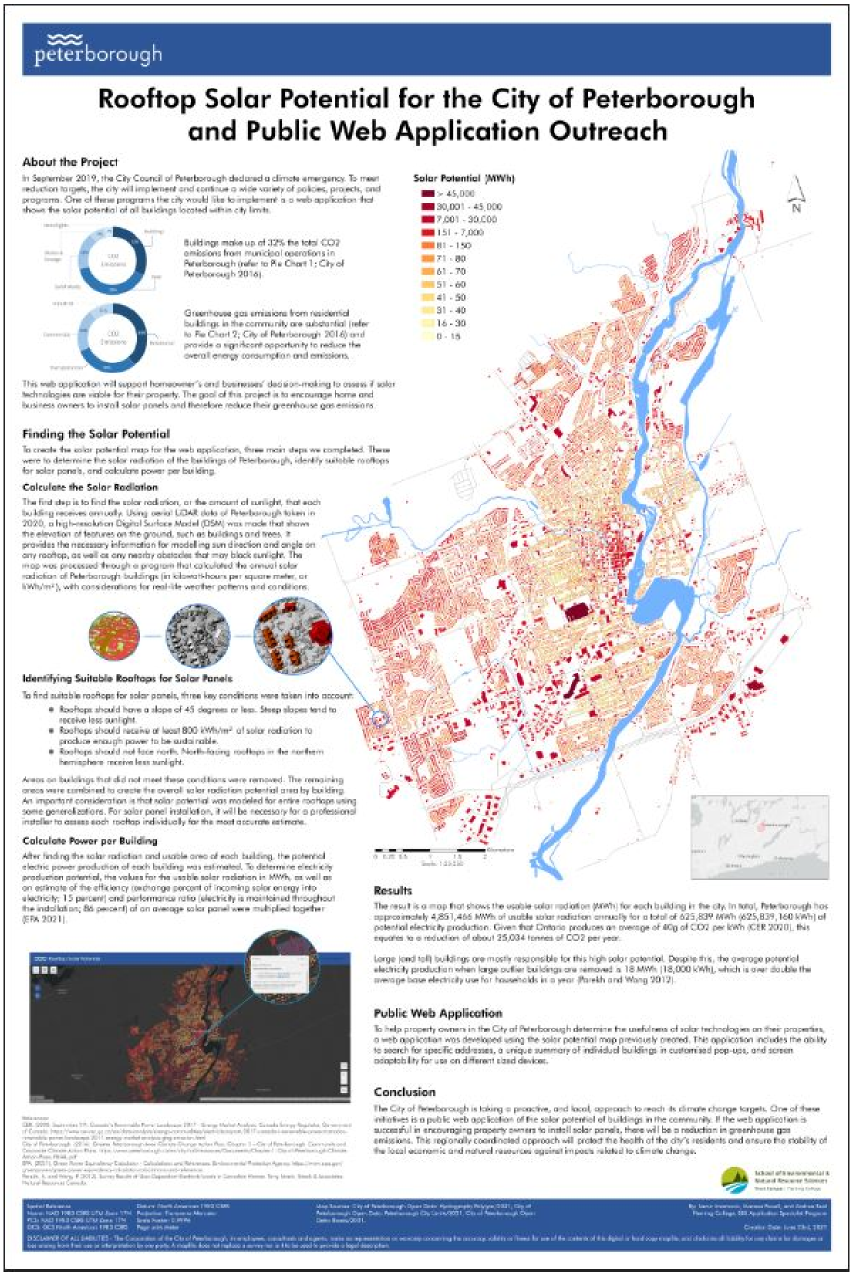

Figure 20. Final cartographic poster.

5.0 Discussion & Conclusions

5.1 Project Summary

We created a solar potential layer to be used in a web application for homeowners in Peterborough, as well as a cartographic poster to help disseminate the results of the project to policy makers and to the public. Despite encountering some limitations during the spatial analysis phase of the project (described in the Limitations section below), we successfully completed all three deliverables and achieved the objectives outlined in the Introduction of this report. A brief discussion of the results for each deliverable is given below, as well as the potential benefits, limitations, and future outlook for the project.

5.1.1 Deliverable 1: Solar Potential Layer

Modeling solar potential of city rooftops with relatively high accuracy was possible due to the availability of high resolution lidar point data provided by the City of Peterborough. The lidar data allowed us to create a detailed Digital Surface Model (DSM) for modeling the influence of rooftop structures and nearby obstructions on the total amount of solar radiation received by a building. In addition, the Solar Radiation tools in ArcGIS Pro offered an easy and effective way to model solar radiation from all angles and for every hour over the course of a year.

Figures 11 and 12 from the Results section provide an interesting overview of the distribution of rooftop solar potential across the city. As expected, the large (and often taller), flat-roofed buildings characteristic of the central downtown area show some of the highest potentials. There is also a trend toward higher solar radiation on the periphery neighbourhoods of the city. These neighbourhoods are often newer developments and likely have a reduced tree canopy that would increase the viewshed (thus increasing total sun hours) of buildings in those areas.

A key strategy listed in the City of Peterborough's "Climate Change Action Plan" is to make existing homes more energy efficient (i.e., Strategy H1: Help existing homes become more energy and water efficient and be more adaptable; refer to page 2 in City of Peterborough 2016). This could potentially reduce greenhouse gas emissions by 22,661 tonnes of CO_2e/per year. Our results show that the City of Peterborough can produce 625,839.16 MWh (625,839,160 kWh) of electricity per year from rooftop solar power. Given that Ontario produces an average of 40g of CO_2 per kWh (CER 2020)[2], this equates to a reduction of about 25,033.57 tonnes of CO_2 per year, more than enough to cover the emissions reduction target for the city's H1 Strategy described above.

As noted above, solar potential scales with size, where larger buildings tend to have a higher solar potential than smaller buildings. When large building outliers were removed from the statistical analysis, the maximum rooftop solar potential dropped significantly. This suggests that a small proportion of buildings (less than 1%) are responsible for most the city's solar potential.

[2] Note that this value is an average for the province and some buildings produce a higher or lower amount of CO_2 per kWh depending on where the electricity is sourced from.

Despite this fact, buildings in Peterborough do on average have the potential to meet their electricity consumption through rooftop solar power. The average household in Canada consumes about 6,920 kWh per year for base electricity use (Parekh and Wang 2012). The average potential electricity production modeled for rooftops in Peterborough without considering large outlier buildings is 18 MWh (18,000 kWh) per year, more than double the base electricity use for an average household.

5.1.2 Deliverable 2: Web Application

The Experience Builder web application is an effective way to showcase the published solar potential map service and provides an intuitive and user-friendly design for use by the general public. As a highly configurable application, Experience Builder provides all commonly used layouts and widgets and was sufficient for our needs. Given the main objective of the web application - to allow users to obtain solar information from an interactive web map - it made sense to have a map centric design for the app. In addition, a thoughtfully designed and informational pop-up was an important component of the application and was easy to achieve using ArcGIS Online's Map Viewer. In general, Esri's seamless connection between desktop applications and web services made it very easy to go from map layer to web application.

5.1.3 Deliverable 3: Cartographic Poster

Similar to the web application, the public-facing poster showcases the City of Peterborough's solar potential. The poster also highlights the web application, bringing awareness to the product. The poster allows our client to discuss the project to both the public and municipal figures to plan future green initiative and projects.

5.2 Benefits of Project

5.2.1 Deliverable 1: Solar Potential Layer

The City of Peterborough is taking a proactive, and local, approach to reach its climate change targets. As a public organisation, the City of Peterborough wants to communicate its actions against climate change to the public and increase community involvement in its goals. Given that a high proportion of CO_2 emissions come from residential buildings in Peterborough (refer to Figure 1 in Introduction), promoting rooftop solar power use would help the city get closer to its climate change targets. Moreover, as discussed above, the high potential for electricity production via solar energy in the city provides further support for this approach. The final solar map layer additionally highlights areas in the city where solar potential tends to be higher (refer to Figures 11 and 12 in Results section). This could be very useful for targeting certain areas, such as the downtown core, for promoting the installation of solar panels.

5.2.2 Deliverable 2: Web Application

Because of the simple and user-friendly design of the web application, we expect that many property owners in Peterborough will take advantage of this freely offered solar information, which should lead to an increased interest in private solar panel installation across the City. If the web application is successful in encouraging property owners to install solar panels, there will be a reduction in greenhouse gas emissions.

5.2.3 Deliverable 3: Cartographic Poster

The poster can be shown to policy makers to aid in decision making that is favourable to renewable energy production and reducing greenhouse gas emissions. Presenting and disseminating the results of this project will help showcase the results to policy makers and will help inform property owners of the existence of the new web app available to them. It can also help showcase the City of Peterborough's progress in finding solutions to reach its climate change targets.

5.2.4 Additional Benefits of the Project

The positive results from the solar analysis suggest that other cities in Canada may also benefit from the exploitation of solar energy, especially in areas that receive higher solar radiation. Other cities are using similar solutions to spread awareness of solar potential in their cities. Calgary and Edmonton, two populous cities in Alberta, have similar public applications in place to show their solar potential and city actions. By developing a community solution, the project could allow more communities to move towards reducing their climate impact locally.

5.3 Limitations

5.3.1 Deliverable 1: Solar Potential Layer

The creation of a rooftop solar potential layer would not be possible without a DEM and local weather data. Fortunately, for the city of Peterborough both pieces of data were present, the local weather data came from a weather station located at the Peterborough Airport and Lidar data for the city is collected every few years. The collection of Lidar data to produce a DEM is very expensive and only municipalities/organizations with sufficient funds can collect this data. Additionally, if the area of interest is in a remote area there might not be local weather data.

Even if the data is present to determine rooftop solar potential being able to choose realistic or more fine-tuned parameter values may not be possible. This is due more to practical considerations, such as processing time and power than anything else. Since the Area Solar Radiation tool makes calculations for each pixel, increasing any parameter will increase the processing time. For example, the Area Solar Radiation tool parameter Calculations Directions checks the number of directions inputted around each cell to find light-blocking obstacles. If you increase that parameter from 16 to 32 it will vastly increase the processing time because now the tool for every pixel checks 32 directions to find light-blocking obstacles. If access to a computer with high processing power was possible this it would not be an issue to choose more realistic parameters, but most municipalities/organizations do not have access to these kinds of computers. The city of Peterborough does not have access to high processing power computers and has no plans to purchase one.

Processing time is the biggest limitation for creation of the solar potential layer. The reason for this is the Area Solar Radiation tool calculates the solar potential for each pixel found within the processing mask. Figure 6 shows that increasing the building area, which is the processing mask increase the processing time, the same is seen for the size of the DEM. Where increasing the DEM size means more pixels must be processed therefore increasing processing time.

The project workaround for this limitation was to split up the DEM into smaller sections. This decreases the number of pixels that need to be processed and therefore processing time. The concern with this solution is it may influence the results since distant cells matter for calculating solar radiation. Figure 8 shows this is a concern. There is most definitely a trade off between efficiency and accuracy when it comes to the Area Solar Radiation tool. Since this project was conducted within a short time frame efficiency had to be considered.

5.3.2 Deliverable 2: Web Application

The web application for this project was created using Experience Builder, which is ESRI's ArcGIS Online newest what you see is what you get web application builder. It is meant to slowly replace ESRI's other web application builder "Web AppBuilder." Since Experience Builder is relatively new there is not as much online resources/information when compared to "Web AppBuilder." Additionally, there is many more widgets available for "Web AppBuilder" than Experience Builder, but with time this will lessen as ESRI adds more widgets to Experience Builder. Additionally, customisation of widgets is not possible in Experience Builder unless using the Developer's Edition, which takes away from Experience Builder attractiveness as a what you see is what you get web application builder.

Another limitation of Experience Builder is it does not automatically update data from ArcGIS Online. First data must be updated within ArcGIS Online and then re-set the source of the map widget data within Experience Builder. With respect to the project, the building footprints would need to be updated at least once a year and the process within Experience Builder is cumbersome.

5.3.3 Deliverable 3: Cartographic Poster

The poster is a static product, meaning it will need to be updated or completely redone as soon as a new solar analysis is completed. In addition, the static poster does not document any changes to the buildings of Peterborough, such as new developments or demolition of older buildings. Any changes will need to be done manually.

5.4 Recommendations & Concluding Remarks

5.4.1 Deliverable 1: Solar Potential Layer

Given the limitations we experienced for calculating solar potential (described above), we highly recommend that the Solar Potential layer be processed as a whole (i.e., using the complete DSM) instead of as individual subsections, as we were forced to do. This would require access to a high-functioning computer with strong processing power, or possibly the option to leave the analysis running remotely on a server. In addition, acquiring more accurate values for determining transmittivity and diffuse proportion parameters would provide a more realistic solar radiation map. This could be done by comparing highly accurate solar insolation values obtained from a local climate station to solar radiation values modeled for that same geographic location using the Point Solar Radiation tool. Unfortunately, the climate data that we had access to was located outside of our DSM boundary.

5.4.2 Deliverable 2: Web Application

For a more customisable web app development experience, it may be helpful to employ the developer's edition of Experience Builder. This would allow for the creation of more customised widgets and layouts using code. More customisation options would be particularly relevant for Experience Builder, which is a newer technology and thus not fully stocked with the lesser used widget options and other small features that might enhance functionality. For instance, we would have liked to be able to dock the pop-up window to the side by default so that the selected building is still visible. While the docking option is available to the user in the pop-up, it may not be immediately obvious and having a default docking option would allow for a better user experience.

Given the newness of Experience Builder, future improvements to the web application will be inevitable (and necessary) to maintain the highest performance. This will be completed by the City of Peterborough's GIS Technologist. Additional recommendations for the app would be the ability to calculate current energy consumption of homes in Peterborough and compare that directly to what could be saved if solar panels were installed. This would provide more incentive for looking further into solar power production.

5.4.3 Conclusion and Next steps

This project is a step toward a more sustainable energy sector for Peterborough. The results of the solar potential layer highlight the benefits of solar power in the city and the web application and poster will play important roles for disseminating this information to the public. Depending on the success of the web application, additional app features and map layers would be an excellent way to enhance the information it provides. For instance, a map displaying thermal energy in the city to monitor heat loss from buildings could easily be incorporated into the web app design and would help building owners relate their energy consumption to the potential savings from solar power.

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Appendix A

Spatial Analysis Workflow

Create DSM from Lidar Data in ArcGIS Pro

1. Create LAS dataset

Using the "Create LAS Dataset" tool, create a LAS dataset and add all LAS files that cover the extent of the City of Peterborough boundary file.

2. Select Classes & Returns

In the Contents pane, select classes 2 to 6 (includes all ground, vegetation, and building classes) and all returns from the Properties menu of the newly created LAS dataset.

3. Create DSM from LAS dataset

Using the LAS Dataset to Raster tool, add the filtered LAS dataset as the input raster. Select a cell size sampling value of 0.3 (refer to Notes on Methodology for how sampling value was determined).

Calculate Solar Potential using Area Solar Radiation Tool

1. Create a solar radiation layer

The “Area Solar Radiation” tool will be used to create the solar radiation layer. For Input raster, choose your DSM of interest. The latitude parameter is automatically populated when an input raster is chosen and helps determine the sun’s position. For Time configuration, choose Whole year. If necessary, for Year, type the year when the data for the DSM was collected. For Hour interval, type 1, this means the tool calculates the amount of solar radiation once every hour for each day sampled.

For the Topographic Parameters section, choose 32 for Calculation directions, which means the tool checks 32 directions around each cell to find light-blocking obstacles.

Under the Radiation Parameters, type 8 Zenith divisions and 8 Azimuth divisions. Ensure that the Diffuse model type is set to Uniform overcast sky is chosen. Set Diffuse Proportion and Transmittivity to 0.2 and 0.6, respectively.

For the Output Coordinate System under Environments settings, choose your desired local coordinate system. Ensure the Processing Extent is set to the DSM of interest and the Mask is set to the building footprint layer. Refer to Figure 19 for complete parameter settings of the “Area Solar Radiation” tool used for this project.

Lastly, the raster layer produced from the “Area Solar Radiation” tool is in units of watt-hours per square meter (Wh/m^2). Some cells in the raster have very large values and to make the units easier to read the whole raster layer was converted to kilowatt-hours per square meter (kWm/m^2).

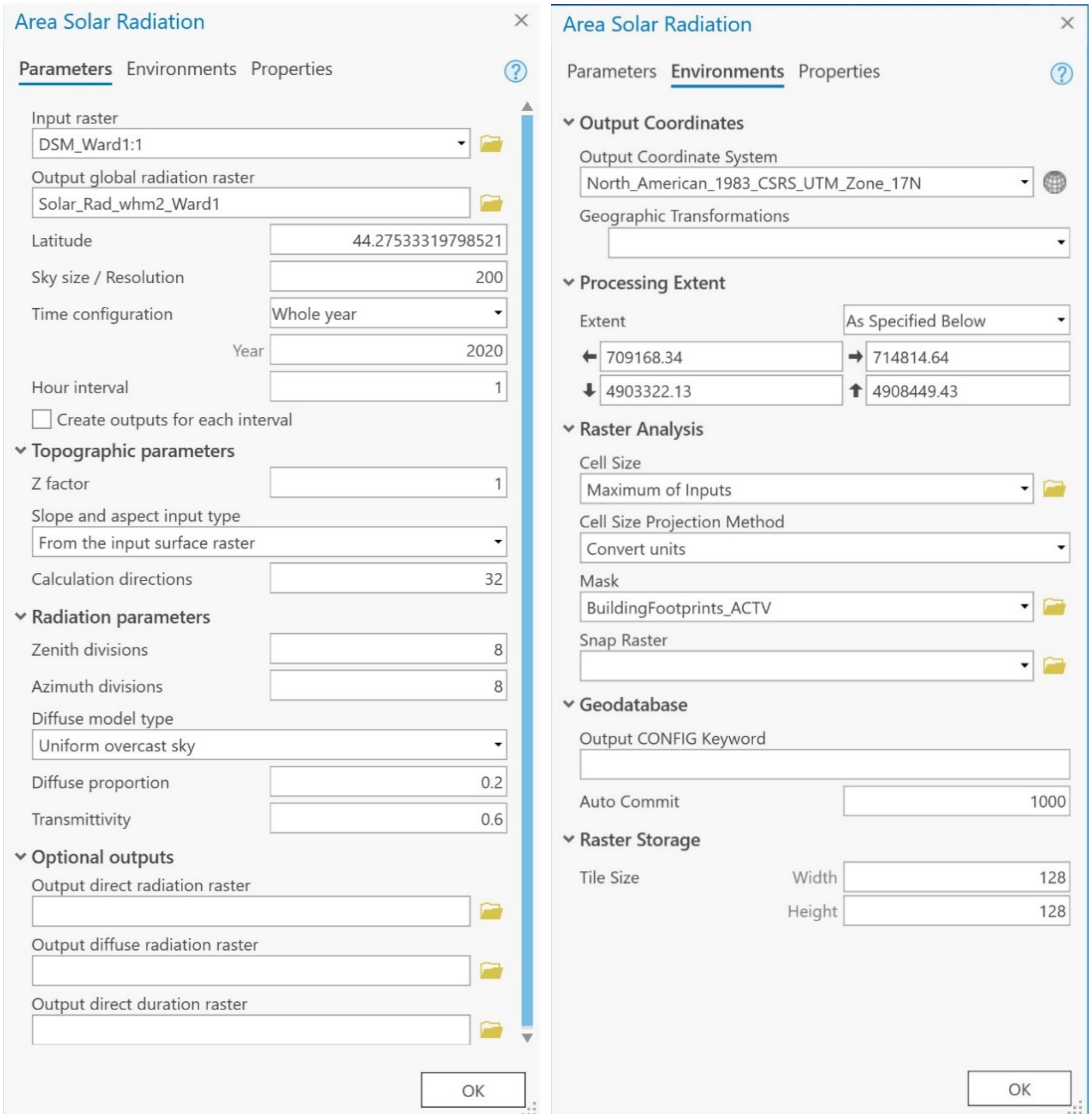

Figure 21: *Complete parameter settings of the “Area Solar Radiation” tool used for this project.*

2. Identify suitable rooftops

These three criteria were used to identify suitable rooftops for solar panels:

- have a slope of 45 degrees or less, determined from a slope raster layer.
- receive at least 800 kWh/m^2 of solar radiation, determined using the solar potential layer.
- Does not face north, determined from aspect raster layer.

First, rooftops with a slope of greater than 45 degrees were removed, because steep rooftops tend to receive less sunlight. The Slope tool was used to create a slope raster layer based on your DSM of interest (Figure 20). Then the con tool was used to create a solar radiation raster layer that does not include rooftop slopes steeper than 45 degrees (Figure 21). Where the input conditional raster is the slope raster layer created by the slope tool and the input true raster or constant value is the solar radiation layer produced in step 1 (Figure 21). Also create the expression Where Value is less than or equal to 45 (Figure 21).

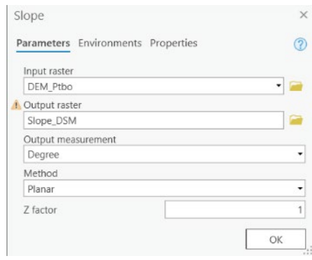

Figure 22: Parameter settings for the Slope tool.

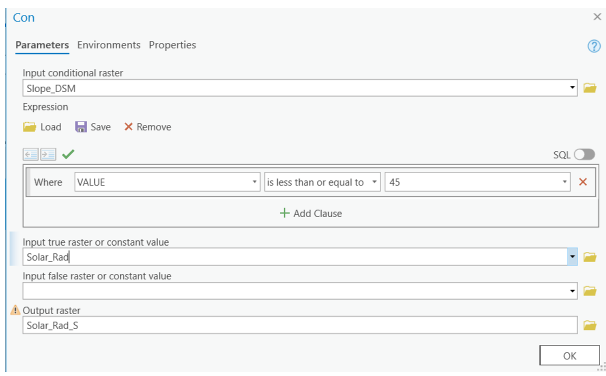

Figure 23: Con tool parameter settings to create a solar radiation layer with no rooftops with a slope steeper than 45 degrees.

Second, rooftops that receive less than 800 kWh/m^2 of solar radiation were removed. This entailed again using the Con tool (Figure 22). Where the input conditional raster is the slope raster layer with slopes steeper than 45 degrees removed, and the input true raster or constant values is that same raster (Figure 22). Also create the expression where value is greater than or equal to 800 (Figure 22).

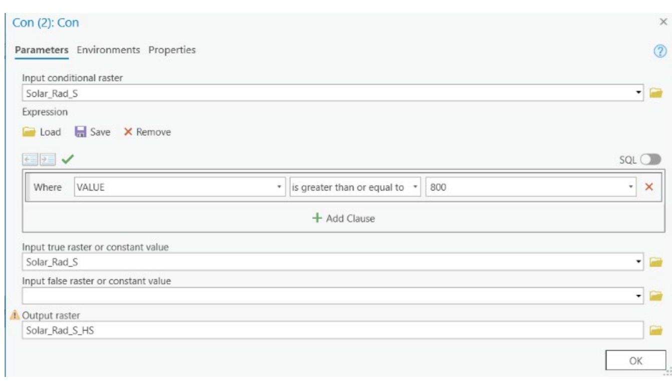

Figure 24: Con tool parameter settings to create a solar radiation layer with no rooftops that receive less than 800 kWh/m^2.

Third, rooftops that face north were removed, because in the northern hemisphere north facing surfaces receive less solar radiation than surfaces in any other direction. Slopes that face north in the aspect raster layer have value less than 22.5 degrees or more than 337.5 degrees. Additionally, if a roof is flat the aspect does not matter, so rooftops that have slopes less than 10 degrees and face north should not be excluded. Therefore, first rooftops with slopes less than 10 degrees were selected. This was done through the use of the Con tool (Figure 23). Where the input conditional raster is the slope raster layer created by the Slope tool, and the input true raster or constant value is the raster layer where slopes steeper than 45 degrees and rooftops with less than 800 kWh/m^2 are removed (Figure 23). Also create the expression where value is less than or equal to 10 (Figure 23).

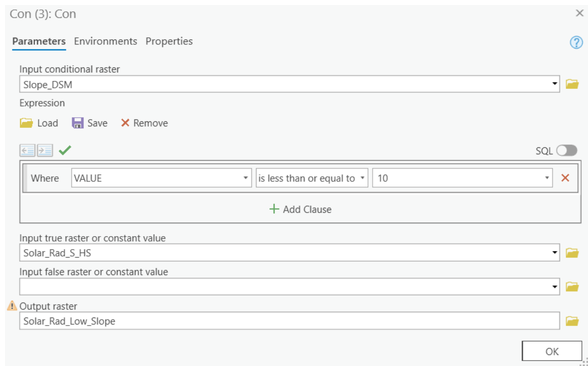

Figure 25: Con tool parameter settings to create a solar radiation layer with rooftops with slopes less than 10 degrees.

Then using the Aspect tool create the aspect raster layer based on your DSM of interest (Figure 24). After that slopes that face north can be removed using the Con tool (Figure 25). Where input conditional raster is the aspect raster layer, input true raster or constant value is the raster layer where slopes steeper than 45 degrees and rooftops with less than 800 kWh/m^2 are removed, and input false raster or constant value is raster layer that includes rooftops with slopes less than 10 degrees (Figure 25). Also, create the expression where value is greater than 22.5 and value is less than 337.5 (Figure 25).

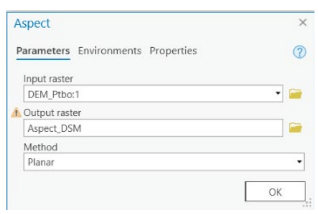

Figure 26: Parameter settings for the Aspect tool.

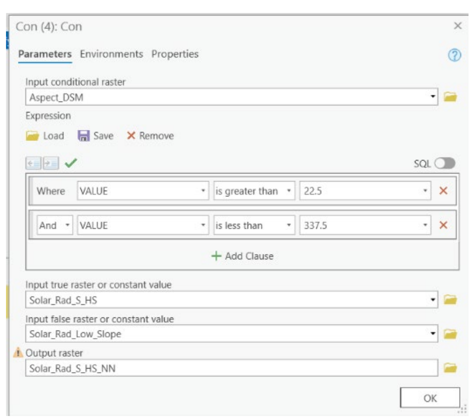

Figure 27: Con tool parameter settings to create raster layer with north facing rooftops removed.

2. Calculate power per building

First, the average solar radiation for each building will be determined using the Zonal Statistics as Table tool (Figure 26). Where input raster or feature zone data is building footprints, zone field is building ID column, input value raster is raster layer created in step 2, and the statistics type is mean (Figure 26).

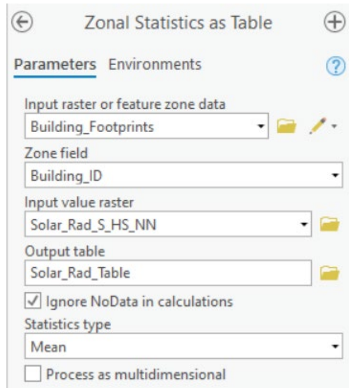

Figure 28: Zonal Statistics as Table tool used to determine average solar radiation for each building.

The table created using the Zonal Statistics as Table creates a stand-alone table with no spatial data connected to it, therefore it will be joined to building footprints. This can be done using the Add Join tool (Figure 27). Where input table is building footprints, input join field is building ID, join table is the table created by the Zonal Statistics as Table tool, and join table field is building ID.

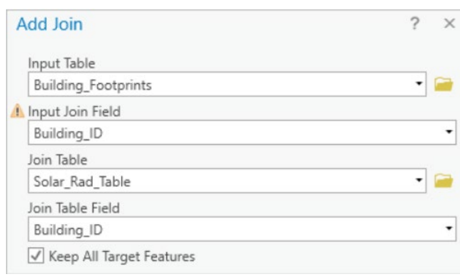

Figure 29: Add Join parameter setting to add spatial data to the table created from the Zonal Statistics as Table tool.

Optional (we did not do this step for our solar potential analysis): Now buildings with less than 30 m^2 of suitable roof surface will be removed. This will done by using Select Layer By Attribute, where input rows is building footprints with average solar radiation for each building, selection type is new selection, and create the expression where area is greater than or equal to 30 (Figure 28).

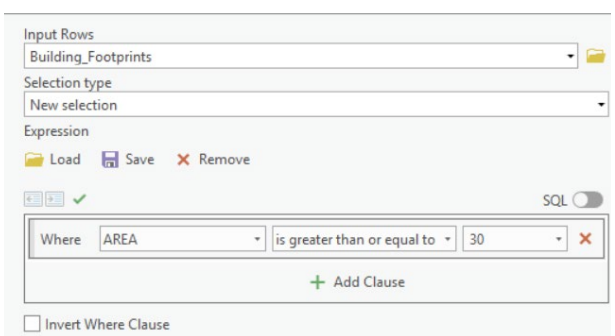

Figure 30: Select Layer By Attribute settings to remove rooftops with less than 30m^2 of suitable roof surface.

Use the Feature Class to Feature Class to take the features selected from the Select Layer By Attribute and create a new layer called suitable buildings. The Feature Class to Feature Class settings should be input features are the building footprints with suitable roof surfaces greater than $30m^2$ and the output name suitable buildings (Figure 29).

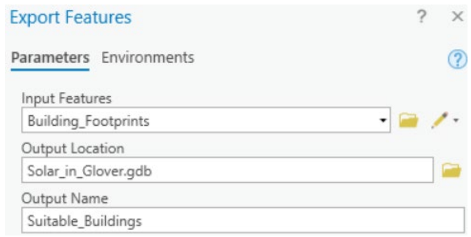

Figure 31: Feature Class to Feature Class settings to create suitable building layer with roof surfaces greater than $30m^2$.

Add a field to the newly created suitable buildings layer called usable_SR_MWh with data type of Double. Then use the Calculate Field tool to populate the newly created field, where the input table is the suitable buildings layer, field name (existing or new) is the newly created usable_SR_MWh field, expression type is python 3, and create the expression usable_SR_MWh = (!AREA! * !MEAN!) / 1000 (Figure 30).

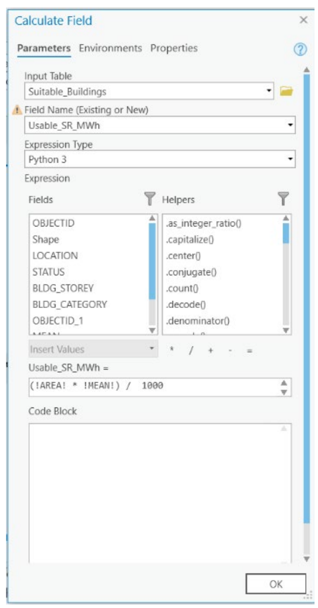

Figure 32: Calculate Field parameter settings to populate the newly created usable_SR_MWh

Lastly, the usable solar radiation values will be converted to electric power production potential considering solar panels' efficiency and the installation's performance ratio. The United States Environmental Protection Agency (EPA) determined a conservative best estimate for efficiency of 15 percent and for performance ratio of 86 percent. First add a new field to the suitable buildings layer called Elec_Prod_MWh of the data type Double. Then use the Calculate Field tool to populate the newly created field, where the input table is the suitable buildings layer, field name (existing or new) is the newly created Elec_Prod_MWh field, expression type is python 3, and create the expression Elec_Prod_MWh= !Usable_SR_MWh! * 0.15 * 0.86 (Figure 31).

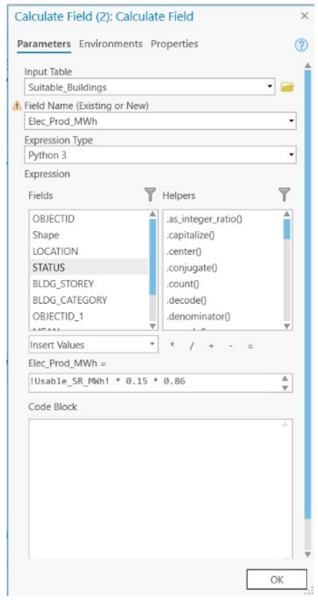

Figure 33: Calculate Field parameter settings to populate the newly created Elec_Prod_MWh

Appendix B

Metadata

Deliverable 1: File Geodatabase

Creation Date: June 23, 2021

Ownership: City of Peterborough

Item Type: File Geodatabase containing polygon feature layer

Extent: City of Peterborough boundary

Maintenance: Needs update when new lidar data becomes available to the city (approximately every 2 years). This will be done by the City's GIS Technologist.

Description: A file geodatabase containing the building footprint layer for the City of Peterborough with associated solar potential attribute data:

COUNT - number of cells within feature

MEAN - the mean solar radiation in MWh/m2

AREA - the total area once unsuitable cells are removed in m2

Usable_Sol_Rad_MWh - MEAN x AREA (MWh)

Elec_Prod_MWh - Usable_Sol_Rad_MWh * 0.15 * 0.86 (MWh)

Accessibility: The file geodatabase will be owned by the City of Peterborough and will not be readily accessible to the public unless requested.

Deliverable 2: Web Application

Currency: June 23, 2021

Ownership: City of Peterborough (will be transferred from Fleming)

Item Type: ArcGIS Online Feature Layer, Tile Layer, Web Map, and Web Experience Application - all hosted on ArcGIS Online

Maintenance: The web map and web application will require updating whenever the solar potential layer is updated with new lidar data (roughly every two years) and when important upgrades are made to the ArcGIS Experience Builder web application. Upgrades and required changes to ArcGIS web applications are usually communicated to ArcGIS Online Clients via web blogs, emails, etc. from Esri. It is up to the Web GIS developer to follow these updates and make the necessary changes. This will fall under the duties of the City's GIS Technologist.

Description: An ArcGIS web map and ArcGIS Experience Builder web application displaying the map. List of items included (*note that these items will be transferred to the City of Peterborough and item URLs will change*):

1. Web Experience: SolarPotentialSubset_AReid_ExperienceBuilder: https://experience.arcgis.com/experience/346690d2fe47480aabfb9c0a72ef1141/
2. Web map: RooftopSolarPotential_ptbo: https://fleming.maps.arcgis.com/home/item.html?id=89b0bc3285664b05b090148baef92c79
3. Feature layer: RooftopSolarPotential_ptbo_WF: https://services1.arcgis.com/pMeXRvgWClLJZr3s/arcgis/rest/services/RooftopSolarPotential_ptbo_WFL1/FeatureServer
4. Tile layer: RooftopSolarPotential_ptbo_WT: https://fleming.maps.arcgis.com/home/item.html?id=76c7880bb8ee4104b0556c082f937cfa

Accessibility: Both the web map and web application will not be editable to the public but can be view by anyone. All items will be made Public.

Deliverable 3: Cartographic Poster

Currency: June 23, 2021

Ownership: City of Peterborough

Item Type: 24 x 36 poster in PDF format

Maintenance: This item will not be updated.

Description: A cartographic poster display of the solar potential map for Peterborough that disseminates the results of the Rooftop Solar Potential Project.

Accessibility: The poster will be displayed publicly and presented in meetings and to policy makers.