Suitability Map of Dalhousie's Studley Campus Renewable Energy Potential

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Executive Summary

The objective of the completed project was to create an asset map that underlines Dalhousie University's potential to harness solar and wind energy on Studley Campus. In an effort to contribute to the advancement of sustainable initiatives within the university, the developed project can be referenced and further utilized by facilities management as part of a guideline for potential future development endeavours. A suitability analysis was performed based on primary and secondary data to determine the percentage of the maximum available total solar and wind gain over an average year. The tools that were most appropriate in measuring the potential for the campus to harness different forms of renewable energy technologies were LiDAR, GIS mapping, Digital Elevation Models, Google maps, and the energy usage of Dalhousie buildings. The resulting GIS maps found the areas that met the requirements suitable for potential solar installation exceeded the areas suitable for potential wind installation. The Killam Library, Mona Campbell Building, Life Science Centre, and the Public Archives were the buildings that had significant positive results. In conclusion, the project found that Dalhousie has tremendous potential to harness solar energy. It is recommended that Dalhousie allocate funding for the implementation of more renewable energy sources, and conduct further research pertaining to the economic feasibility of these energy sources.

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Introduction

Background & Description

Why does this research matter?

Canada is one of the world's biggest contributors to global pollution and energy consumption, the majority of which comes from nonrenewable fossil fuel sources (Stats Can 2012). Post-secondary schools across the country do not represent small contributions to this, nor does Dalhousie. In the Atlantic region, university energy consumption is around 3,628,427 gigajoules (GJ) (NRCan, 2009). In comparison, the 2007 energy use for all houses in Canada was 1,368,955 GJ, with the average house consuming 106 GJ. A regular propane cylinder will burn roughly 0.45 GJ (Statistics Canada, 2012). To match Atlantic Canada's university annual energy consumption, you would have to go through 8,063,171 9kg propane cylinders (Stats Can, 2012). Across Canada, the quantity only increases. Quebec universities total 6,621,471 GJ in consumption, the Prairies use 9,604,469 GJ, and the province with the highest consumption for secondary institutions is Ontario, with 14,108,302 GJ. The lowest amount is from BC and the territories, which amounts to 2,960,091 GJ. The Canada wide total is 36,922,760 GJ (NRCan, 2009). Dalhousie is the maritimes largest university, and is an academic institution with between 15,000 and 20,000 students across 4 campuses in Nova Scotia (Dalhousie Analytics). Accommodating many students and faculty requires an immense amount of resources, and a substantial amount of energy. Halifax campus takes up 79 acres of downtown area, containing 110 buildings over 48 million square feet (Office of Sustainability, 2010). Due to the age of the university, many of these buildings are vastly inefficient in their energy use and are challenging to upgrade to standards of sustainability. It is not hard to understand that because of their capacity, size, and largely non-retrofitted buildings, universities like Dalhousie are enormous contributors to global emissions and energy use, as well as food, water, and material waste. Even if the capacity of consumption used by universities and Dalhousie was not as big a part of Canadian energy use, the institutions are still in a position that demands they take action to lower fossil fuel use and increase provincial sustainability efforts (Vanderbeek, 2013). Post-secondary institutions have the opportunity to make sustainability the norm by fostering organizational changes involving student/faculty behaviors and operations. Universities prepare generations to become the next round of society; they need to start planning how they can serve as a model of sustainability and teach students to be respectful citizens to the environment they live in. Higher education prepares professionals who develop, lead, teach, and work in society's institutions. As such, they have a moral obligation to adapt to sustainable behaviour.

Dalhousie has already taken some initiatives towards a cleaner energy system and a more sustainable campus. There are LEED certified buildings, and a sustainability plan for the university; The Dalhousie University Climate Change Action Plan has developed aims to reduce GHG emissions with the goal of carbon neutrality in 2050 (Campus Energy Master Plan, 2012). Dalhousie has also signed three international declarations (Halifax, Talloires, & UNEP) related to environment and sustainability (Office of Sustainability, 2010). Through the last two decades Dalhousie has also switched to pesticide-free landscaping, renewed a more efficient compost & recycling program, stocks green products, included fair trade food products on residence, and aims to reduce chemical load through green cleaning products (Office of Sustainability, 2010). In relation to the interest of clean energy, there have also been a number of renewable and more efficient technologies implemented on campus; there are solar thermal systems in the Le Merchant and Life Sciences buildings, a 14kW solar generator being connected to the Student Union Building, solar heating in the Mona Campbell, a 20kW solar PV air duct system in the Computer Science building, as well as a plan for a 4kW solar generator on the Weldon Law building (Owen, Personal Communication, 2017). The

Sexton and Agricultural Campuses also have their own solar energy systems, with Sexton in the planning stages of adding geothermal technology along with its 150kW solar capacity, and Agricultural campus containing 1kW PV system and a newly started co-gen biomass project (Owen, Personal Communication, 2017). Aside from mainstream energy initiatives, Dalhousie is also implementing student-led project initiatives, such as Carbon Consultancy (Davis, 2016), as well as installing a trigeneration system in place of the boiler technology used for Studley's heating and cooling (McNutt, 2013). There are resources available, however difficult to find, that give an overview of all these green installations, as well as other categories that Dalhousie has incorporated into its sustainable efforts, including waste management, cycling and transit, and natural environment (Office of Sustainability, 2016). Evidently, Dalhousie recognizes the necessity of holistic sustainable measures, and there are many more projects like these taken up every year as the need for sustainable living grows; clearly there is a desire for these strategies to be implemented on campus. Despite this area of growth, Dalhousie, and effectively all of Nova Scotia, is still comparatively dependent on imported fossil fuels.

It is the group's mission to develop a project proposal, which can be referenced and further utilized by facilities management as part of a guideline for potential development endeavors. Supplementary research will be used with the information already available about sustainable campus resources, but will focus on the areas available for further installation. Fundamentally, the goal of the project is to create an asset map that underlines the university's potential to harness alternative energy sources like solar and wind on the Studley Campus. There is a significant benefit to implementing such a project on a university campus. Apart from the long-term financial benefits, it provides a tremendous opportunity to promote energy consciousness and to stimulate further innovation. The very nature of the project is environmentally feasible, as it would reduce the impact of Dalhousie's most energy inefficient buildings. A large part of this project is to promote social awareness so as to translate that knowledge into action and in turn environmental benefits. Which, as shown by literature, is a trend that campuses are already investing in, and installing renewable energy would be the most direct way to confront aforementioned fossil fuel use. It is equally important to start a conversion about renewable energy, as the establishment of sustainable thinking throughout the city and further beyond its borders is increasingly important. The report has been planned to include the research methods utilized, a brief overview of the literature review, the results, including the type and location of technologies deemed feasible, and a discussion.

Objectives

The goal of the project was to create an asset map and accompanying information of potential sites for renewable energy technologies on Dalhousie's Studley campus, in an effort to contribute to the advancement of sustainable initiatives within the university. Currently, Studley campus focuses on solar energy as an alternative, but it is a goal of this research to understand whether wind energy has potential on campus as well, due to the fact that it is a highly utilized source in other locations around the province (UNSM, 2015). Wind turbines are one of the fastest growing resources for energy; In Atlantic Canada, proximity to coastlines and isolated ridges provide the region with abundant wind energy potential and the opportunity to increase the amount of clean energy used by the province, and Dalhousie specifically (Atlantica Energy, 2016). Urban micro-wind farms, as opposed to large scale farms, are also an often overlooked area of development (Mertens, 2002). The usefulness of micro-wind is, quite literally, up in the air for debate, and is very location specific (Mertens, 2002). Not needing to transport materials over difficult terrain or disrupt rural areas are part of the positives for urban wind energy installation, whereas lower wind speed and higher turbulence account for the disadvantages (Mertens, 2002). Studies in the UK have shown that micro-wind power shows promising future in coastal or inland elevation sites, both of which are features of Halifax's geography (Bahaj, Meyers & James, 2007). Given these observations, it was included in our research to look at the potential of wind energy in our urban setting as well as solar, for the purpose of widening the scope.

The deliverable goals of the project include discovering which buildings on Studley campus meet the minimum requirements to harness solar energy, wind energy, and which would be suitable for both. Given that most research done on implementing renewable energy on campuses, as well as initiatives taking place at Dalhousie, are already figuring out what to do, it makes sense to assist those initiatives in determining where they are suitable.

It was also part of the objectives of the project to contribute to research on Dalhousie case studies specifically. There are resources regarding the university available in media sources and articles, but few accessible on peer-reviewed databases. Also, what is available is not easily accessed. The goal is to produce easily accessible data on a widely used resource, because this information is something that should not be difficult to find and implement. It is a common problem that the population of a post-secondary institution does not know of the many sustainable and environmental initiatives taken on by their school and as such can do little to support them, if the information is not directly accessible or made known.

Methods

I. Study Design

A suitability analysis was performed based on primary and secondary data to determine the percentage of the maximum available total solar and wind gain over an average year. GIS was utilized along with building footprints of Dalhousie University. Building heights were estimated using LiDAR data. The tools that were most appropriate in measuring the potential for Dalhousie's Studley campus to harness different forms of renewable energy technologies were LiDAR, GIS mapping, Digital Elevation Models, Google maps, and the energy usage of Dalhousie buildings.

The University of Texas conducted a similar project to evaluate the potential of solar power on campus. The roof space of the campus provides large areas to capture solar energy for use at locations where energy is demanded. The University conducted its study by utilizing solar mapping in order to educate and inform users about solar technology by estimating the solar energy potential of rooftops. The methods used for the solar mapping were LiDAR and GIS. LiDAR was used because of its accuracy when creating thousands of measured points in 3D space. In a matter of hours LiDAR is able to expand its geographical area and scan large areas. GPS was used in unison with LiDAR to scan the Earth's surface through laser pulses, measure the return times of the pulses, and calculate ranges from known positions on the Earth's plane. A collection point measurement in Cartesian coordinates for the surfaces was then processed (Sounny-Slitine, 2011).

Unlike topographic mapping where buildings are removed from break lines, the conducted study removed terrain instead of buildings in order to create a digital roof elevation model. Isolation maps were developed from the digital elevation models and the total amount of solar radiation was calculated. The results from the conducted study determined the total amount of solar radiation hitting the rooftops of the campus was 4,4465 GWh/year. The solar radiation was the reduced to 1,939GWh/year, as the building of solar panels was isolated to only black shingling (Sounny-Slitine, 2011).

Although the University obtained positive results, the LiDAR and GIS study did not evaluate the economic feasibility of installing solar panels on the campus. The study was furthered by an completing and economic analysis and a payback period greater than 10 years was determined. The study concluded the campus had a high potential for harvesting solar energy but was not economically feasible at this point (Sounny-Slitine, 2011).

II. Procedure

The following steps were taken in order to create the asset mapping that underlines Dalhousie's potential to harness solar and wind energy on Studley Campus. In determining both wind and solar potential on Studley, it is critical to use a ranking system in GIS that differentiates raster pixels into areas of suitability based on the selected attributes of height, and slope. Layers are isolated in GIS with each layer focusing on one attribute of geographic data such as height or slope. Suitable pixels in each layer are de-marked with a "1" while unsuitable areas are de-marked with a "0". Map algebra is then used to create a final layer that displays all the areas that meet the suitable criteria of each layer. This is done by multiplying both layers together via a Boolean operator so that only areas with "1" values in both height and slope layers are marked as suitable in the final layer. This final layer is what displays solar or wind potential at Dalhousie. Suitable criteria for slope and height were determined by conferring with our faculty advisors.

Determining wind potential on Dalhousie Campus:

1. The first step to complete the maps of wind potential is to reclassify the Digital Surface Model (DSM) as two values based on height. Either above or below 1.5 standard deviations of the mean of building height or 67.463 meters. Any buildings below this elevation would not be suitable for wind turbine installation. Values above 67.4623 metres were assigned a “1” and values below were assigned a “0”.

2. The next step for the wind speed maps is to arrive at a layer which contains buildings with suitable slope. Any surface with a slope of 1 degree or less is suitable, and any surface greater than 1 degree is not suitable. A surface slope calculation tool is used in order to split the map into binary values where suitable slopes are assigned a value of “1” and unsuitable slopes are assigned a value of “0” based on the parameters outlined.

3. The third step is to use map algebra to multiply the slope layer and the elevation layer in order to arrive at a final layer that shows areas that are of both suitable elevation and slope.

Determining Solar potential on Dalhousie campus:

1. To discern solar potential via a GIS program, the first step is to reclassify the DSM as two values based on height. Where this differs from wind potential maps is the that 55.44 meters is the height cutoff used for height. Any buildings below this elevation would not be suitable for distributed solar as

the potential for shading both by the terrain and other buildings would be too great. Elevations above 55.44 meters were assigned a value of “1” and elevations below were assigned a value of “0”.

2. The next step for the solar potential maps is the same as mapping wind potential which is to arrive at a layer that contains buildings with a suitable slope. Any surface with a slope of 1 degree or less is suitable and any surface greater than 1 degree is not suitable. A surface slope calculation tool was then used in order to split the map into binary values with raster areas of suitable slope being assigned a value of “1” and raster areas of unsuitable slope being assigned a value of “0” based on the parameters outlined.

3. The third step is to use map algebra to multiply the slope layers and the height layer in order to arrive at a final layer that shows areas that are of both suitable elevation and slope.

Cosmetic fixes are applied to all maps after the above steps in order to increase clarity and comprehension for the user such as moving the building layer into a position where the raster data is readable and adding map elements such as a scale bar and compass. Additionally, colored labeling was added labeling areas suitable for distributed solar systems in yellow and areas suitable for distributed wind systems in blue. Building labels are also added.

III. Limitations and Delimitations

Numerous studies have had success with utilizing GIS and LiDAR to determine the potential for renewable energy, but it has its limitations. GIS is appropriate for identifying rooftops and their photovoltaic panel capacity but it is purely based on static light detection and LiDAR data. This method does not account for dynamic geographical variables, such as weather conditions or solar radiation and wind (Resch, 2014). When using LIDAR the resolution of the DEM measure points and a possible inaccuracy of the points' position are limitations. Misplaced DSM affect the modeling of the buildings outer borders and create problems (Kassner, 2008).

Delimitations for the project would be the area under analysis for the University and the economics of it. It was decided to conduct the project on only Studley Campus, and not on the Sexton or Agricultural Campus. It was also decided that the economics of the project would not be evaluated, as this was outside the scope of the project.

Results

IV. Suitability Analysis

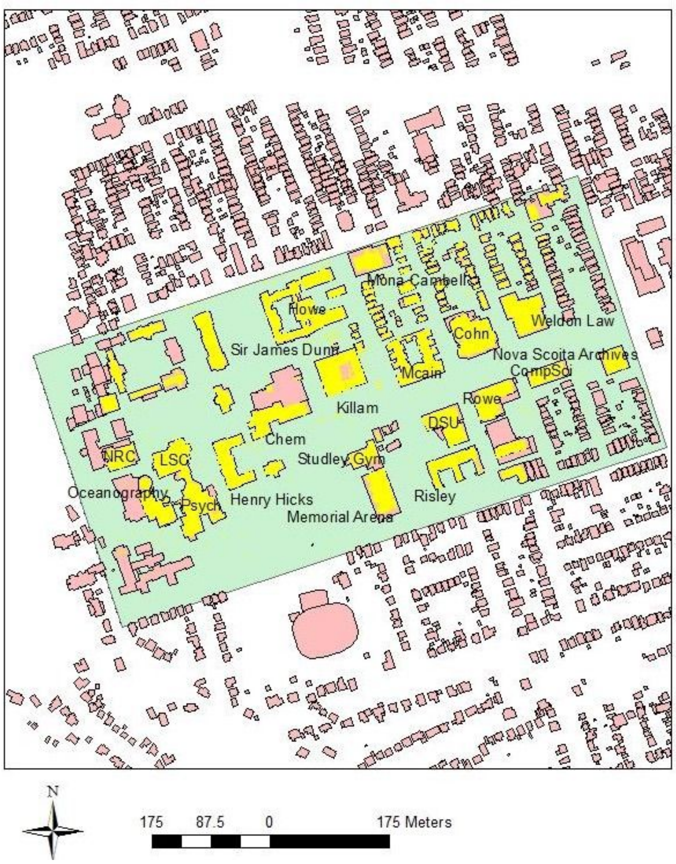

Figure 1. Suitability map of the Solar Energy Potential on Studley Campus

Solar Suitability was determined as any flat building surface above 55.44 meters. This height was selected in order to avoid any shading due to dips and slopes in the terrain of campus as the highest point of ground elevation is 55.44. Thus, any point above 55.44 meters would be tall enough to avoid shading caused by terrain. The buildings that generated a score of “1” meaning they are feasible for solar energy generation are the Killam Library, the Mona Campbell Building, the Life

Science Centre, Nova Scotia Public Archives, the Rowe Building, the Henry Hicks building, the NRC, the Dalhousie Student Union Building, and Howe Hall.

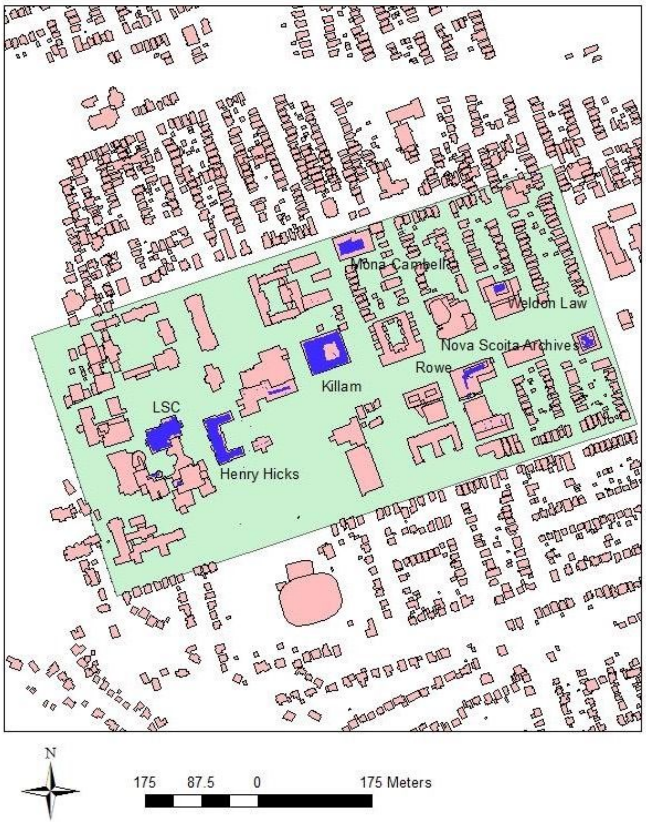

Figure 2. Suitability map of the Wind Energy potential on Studley Campus

Wind Suitability was determined to be any flat surface above a height of 67.463 meters. This figure was arrived at due to the need for large open spaces and unimpeded pathways required in order for winds to reach the sufficient speeds of at least 5.5m/s required by wind generation. Buildings can impede these pathways reducing wind speeds. As such the figure of 67.463 meters was arrived at for suitability as 67.463 meters is 1.5 standard deviations above the mean height of buildings on Studley campus. Above this height, other buildings impeding wind flow is lessened allowing for conditions suitable for wind energy potential.

The buildings on Studley campus that scored a “1” in both elevation and slope based on outlined parameters. The buildings suitable for wind energy generation are the Killam Library, the Mona Campbell Building, the Life Science Centre, and the Nova Scotia Public Archives.

V. Discussion

Our research question involved analyzing the potential of Dalhousie’s Studley Campus to harness different forms of renewable energy technologies. The goal of the project was to create an asset map via GIS of potential sites for renewable energy technologies on Dalhousie’s Studley Campus in an effort to contribute to the advancement of sustainable initiatives within the university. According to the GIS maps, the areas that met the requirements suitable for potential solar installation exceeded the areas suitable for potential wind installation. For wind suitability on Studley Campus the most suitable buildings were the Killam Library, the Mona Campbell Building, the Life Science Centre, and the Nova Scotia Public Archives. There is a greater potential for solar suitability on buildings due to the decreased height threshold being lower as opposed to wind. All of the previously mentioned buildings are suitable for solar with the addition of the Rowe Building, the Henry Hicks building, the NRC, the Dalhousie Student Union Building, and Howe Hall.

The peer-reviewed literature was informative regarding case studies where similar projects have been studied, and considering these cases, our findings both fill a location-specific niche, as well as follow research and development trends among other universities all over North America. Many universities choose to develop maps to highlight sustainability initiatives, energy efficiency, recycling centers, and energy potential; ‘sustainable development’ was rated as a top trend of university mapping projects in 2016 (CampusBird, 2016). Minnesota University, Middlebury College, Earlham College, University of Washington, and Cambridge are a few examples of academic institutions that have created solar and sustainable mapping tools. Closer to home, Cape Breton University has, as of last year, developed their own wind farm (Higgins, 2016). The U.S. also has a program in 12 states that is engaging post-secondary students to join Wind Application Centers and serve as project consultants for small wind turbine installations at rural elementary and secondary schools, and produce an interactive map of all the locations (Dept. of Energy, 2015). The same company, WINDExchange, produces wind potential maps of the entire country under the U.S. Department of Energy (Dept. of Energy, 2015). Our own findings are on a much smaller scale, but do fill the same need. Existing research studies have a much bigger focus on solar energy as well, in terms of peer-reviewed academic literature. Much of what exists for research is from other sources of media. Again, there is a gap here for location-specific academic case studies on energy mapping. Considering this, our findings are further justified as a needed data source.

We believe the installation of solar and wind energies to be a feasible project to implement in the future, however funding may prove itself a challenge. The GIS maps have established that Dalhousie has tremendous potential to harness solar energy, however, similar to the University of Texas, the GIS technology did not evaluate the economic feasibility of implementing such a project (Sounny-Slitine, 2011). Ultimately, more research will be required to determine specific vulnerabilities and adaptation actions for the campus. While it may be difficult to establish a source of funding to take on this endeavor, it is our hope that our asset map will be considered and at the very least stimulates a conversation regarding renewable energy. Nonetheless, it is our hope that our project serves a useful purpose in guiding potential projects for facilities management.

Conclusion

VI. Recommendations

The Killam Library, Mona Campbell Building, Life Science Centre, and the Public Archives were the buildings that we had significant findings for potential renewable energy on Dalhousie's Studley Campus. Four buildings is substantial for the potential of renewable energy and therefore, we recommend that facilities management review our findings and discuss implementing renewable energy projects on campus in these buildings.

We also recommend that Dalhousie University start fundraising and allocating more money for future renewable energy projects. Non-renewable energy cannot last forever, and when the time comes to switch to renewable energy such as wind and solar, it will drastically help to already have the funding. Facilities management should conduct further research on the economic feasibility and payback period for implementing solar and wind energy that can cut back on Dalhousie’s future carbon footprint. With this further research it will be easier to facilitate funding these projects. More research needs to be done on the carbon footprints of each building on Studley campus, and which buildings could be taken off the grid and could possibly provide energy to surrounding buildings.

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