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Development of a comparative renewable energy decision support tool.

Daniel Roth[1], Stephanie Shaw[1], Dave Wood[1], Robert Anderson[2], Bill Van Heyst[1*], David Lubitz[1]

[1] School of Engineering, University of Guelph, Guelph, Ontario, N1G 2W1
[2] Department of Food, Agriculture and Resource Economics
[*] corresponding author: bvanheys@uoguelph.ca

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ABSTRACT Renewable and alternative forms of energy are providing communities with greener and more sustainable sources of energy. In particular, farms offer a plethora of energy resources due to the land, topography and the agricultural products they produce. While farms offer these resources, it can be difficult for farmers to determine their optimal renewable energy technology configuration. Current electronic calculators provide a means for assessing one type of renewable energy at a time but do not provide a side-by-side comparison of different technologies. Work at the University of Guelph is focusing on developing a decision support tool that will fulfill the needs of farmers who wish to compare the value of different renewable energy systems. The scope of this project is large and involves solving many problems. First, the complexity of the components that go into the calculator were mapped out to find the interrelations between the calculator elements and information sources. Once the calculator framework was established, focus was directed at the underlying decision making process for the decision support tool. Decision algorithms were investigated to determine where the accuracy of renewable energy assessments could be improved. Next steps for the project include performing case study assessments using data collected from farmers currently using renewable energy technology to support and validate the results of the renewable energy decision support tool.

Keywords: Renewable Energy, Decision Support Tool, Agriculture, Farm, Energy Calculator.

INTRODUCTION The Blackout of 2003 was an event that left Southern Ontario without electricity for three days and caused the province to take emergency measures to cope with the loss of power (CE, 2003). This event illustrated what life would be like if our electricity supply was to be abruptly caught off. Although the 2003 blackout was caused by a grid malfunction (CE, 2003), there are different ways the Canadian electricity supply could be jeopardized, including the depletion of coal, oil or natural gas reserves.

The majority of Canadian electricity is produced by hydroelectric generating stations, fossil fuel plants, and nuclear reactors (OEE-NRC, 2011 and OPG, 2010). Fossil fuel reserves and the potential for expanding nuclear energy are both limited, while electricity demand is growing. Global warming and climate change, caused by greenhouse gases (GHG), are significant environmental issues facing not only Canada, but the world as a whole, and thus people are seeking to minimize the amount of GHGs that are being emitted into the atmosphere (Jones, 2011).

In order to address the threats of energy resource depletion, increasing electricity demand and global warming, nations including Canada are turning to renewable and alternative forms of energy generation. Renewable energy (RE) systems are able to generate electricity without resource depletion, and have minimal GHG emissions and environmental repercussions. Hydroelectricity is the most commonly used form of RE in Canada (OPG, 2010). In order to encourage companies and individuals to pursue the development of RE, the Province of Ontario developed the Feed-in-Tariff (FIT) program which pays the energy producers for the RE they feed into the electricity grid (OPA, 2010). As a result, large scale wind and solar photovoltaic (PV) developments have been constructed and are constantly increasing the fraction of Ontario electricity supply generated by RE.

Reducing the environmental impact of electricity generation not only involves clean electricity generation but also involves reducing the amount of energy being consumed from the grid. Energy conservation, passive thermal energy systems (such as geothermal and solar thermal) or on-site energy generation, are all avenues through which electricity consumption can be minimized.

BACKGROUND While RE can be implemented on large commercial scales producing mega-watts of electricity, it can also be implemented by individuals on smaller ‘micro’ scales producing kilowatts of electricity. When looking at the smaller scale microFIT program (<10kW of production capacity), farms offer a plethora of possible RE resources. These include large flat fields that allow for high wind speeds, fields and barn roofs that offer locations for solar PV systems, animal waste that can be used to generate gases for combustion and also great opportunities for thermal energy systems such as geothermal or solar thermal.

Utility-scale project assessments typically involve hiring consulting firms to perform in-depth, professional surveys of land using both human expertise and sophisticated software in order to assess the feasibility of a potential RE system. While this method of assessment is appropriate for large projects backed by well-capitalized investors, it is not necessarily best for small groups or individuals.

The decision by a farmer to install a RE system can come from many different avenues. Generally it is the result of auditing or installation companies going door-to-door to approach property owners promoting a specific system and performing an on-site assessment (COFS, 2010). Leasing land to large RE developers is another avenue for farm operators or property owners to capitalize on the RE movement.

Farmers wanting to assess the feasibility of installing technologies, prior to or without being approached by an auditor or leasing representative, need accessible tools to assess their operation’s RE feasibility. These tools include online calculators that perform rough initial assessments of an individual RE system and professional audits which come with a cost to the farmer. Alternatively the farmer may simply decide to immediately seek development of the RE technology that is most interesting to them or most commonly seen. Although these are different assessment avenues a farmer can follow, they are not necessarily the best way to go about initiating or assessing a RE development. Additionally, none of the tools available to farmers provide a way of comparing different RE technologies to determine which is the most feasible for their operation (Appendix A).

LITERATURE REVIEW With the growth and increasing development of RE systems across the globe, it is not surprising that tools have been created to aid in the process of location-specific RE system evaluations. The potential of various RE technologies can be very dependent on geographic location since assessments may require specific inputs. As such, a site being considered for RE development should first be evaluated to assess the potential for RE generation. This assessment should not only include the estimated RE generation, but also the costing and economic information needed for farmers to realistically evaluate the feasibility of installing the RE system at their site.

One of the most popular portals of accessing RE evaluation tools is through the internet. There are hundreds of different calculators currently available online which focus on assessing a single RE system, some examples of these are provided in Appendix A. While each calculator is unique, the overarching goal of all the calculators is the same: to provide an assessment as to how feasible a RE system is and how quickly the owner can expect a return on their investment. In North America, RETScreen (NRCan, 2010) and HOMER (Lilienthal et al., 2010) are two RE calculating tools commonly used by energy assessment and auditing companies.

For two of the most well-known technologies, wind and solar photovoltaic (PV) energy, there are many available calculators. Generally, these calculators first ask the user to input the location of interest. The calculator then pulls irradiation or wind speed data from a database or the internet, calculates the energy that could be produced from either the solar panel or wind turbine, and then produces a feasibility assessment and payback period prediction. This information is presented to the user in various ways and allows them to determine whether the cost of setting up the RE system will produce a viable financial return.

Numerous wind and solar calculators were evaluated in the beginning stages of this project. PVWatts (NREL, 2008), and PVSys (LeJeune and Mermoud, 2010) are solar calculators available online to assess solar PV energy in North America. Wind energy assessment calculators examined included the CanWEA Small Wind Calculator (CanWEA, 2005), Windustry (Orrell and Antonich, 2007), and the Danish Wind Energy Association (DWIA, 2003). Additionally there are calculators, such as SolarEstimator.org (SEO, 2010), HOMER (Lilienthal, 2010) and RETScreen (NRCan, 2010) that can evaluate either solar or wind depending on what the user desires. All of these calculators are available to the general public, however this does not mean that they are user-friendly or produce reliable results.

Through this literature review, it was found that as the user-friendliness of calculators increased, the reliability of the assessment results decreased. For example, SolarEstimator.org is a very simplistic calculator in that it only requires the user to enter a zip code, technology type (solar or wind), and some basic electricity information to produce a financial analysis for the user (SEO, 2010). While this calculator is very easy to use, it lacks important features and components to help accurately assess the RE system. Information such as system position and orientation, features on or surrounding the property, system size, etc. are critical in accurately projecting the performance of a system. On the other side of the spectrum, calculators like HOMER offer a more detailed and extensive assessment of the RE potential of a site but are very complicated and confusing to use for individuals not familiar with the calculator (Lilienthal et al., 2010).

Calculators also exist for anaerobic digestion, geothermal and other RE technologies. Some examples of anaerobic digestion calculators are Digester1.1 (de Vries et al., 2007) and FarmWare (EPA, 2010). Calculators for geothermal include the Geothermal System Cost Estimator (Kavanaugh et al., 2011) and the E-PipeAlator08 (UoA, 2011). All of these calculators showed similar trends to wind and solar in that as the calculators become more complex and produce extensive assessments they become significantly harder and more complicated for the user to use. It was also found that most calculators are targeted at residential and commercial applications, and few focused on agriculture.

RETScreen, developed by Natural Resources Canada, is a free energy calculator designed for international use (NRCan, 2010). It is based in Microsoft Excel and, depending on the type of project selected by the user, can be used to evaluate almost any type of energy system; cogeneration, hydro, biomass, heat pumps, wind, and solar PV as examples (NRCan, 2010). After the project type and geographic location are selected, RETScreen pulls information from climate databases and opens worksheets with climate and technology information necessary to perform the energy assessment. The user works through the worksheet and enters in appropriate system information and also has the ability to alter some of the default climate and technology data if more accurate values are known. Upon filling in all the required cells, a financial assessment and feasibility projection are produced. The user is able to see the anticipated payback period, projected annual operation and maintenance expenses, annual income, internal rate of return and simple payback period. It is the hope that with this information the user can then make an educated decision as to whether or not to install a certain energy system at the given location.

RETScreen has proven to be a valuable tool for many people and organizations. It has been shown to be robust through the multiple years it has been used across the globe (NRCan, 2010). Being based in Excel makes RETScreen easy to use as most individuals have access to it, are familiar with it and are able to use the program instead of learning how to use a new software application. It offers the option of choosing between multiple energy systems and each technology comes with an extensive manual on how to use the worksheet and descriptions of the logic and equations behind the program. Not only has RETScreen been around for multiple years and offered a wide range of supporting material and courses, but with this extensive support network the program has been able to go through modifications and updates to improve and enhance the program.

There are many benefits offered by RETScreen, but there are also negatives associated with the program. RETScreen is intended for industrial and commercial assessments and lacks an agricultural focus. The assessment methodologies for some technologies, such as wind or solar PV, are independent of whether the system will be installed in an agricultural or commercial setting. In contrast thermal energy systems, such as geothermal, are highly dependent on the use of the system and therefore it is essential that the energy calculator focus on agricultural applications.

Although RETScreen may be based in Excel, a program that most people are comfortable with, it is not very easy for people to use. Individuals with limited or no knowledge of energy systems, terminology, etc. are likely to get lost and struggle with using the calculator. Even people using RETScreen on a regular basis have commented that the program is not user-friendly (COFS, 2010). Cells requiring inputs are marked but it is hard to know what data is required or what is not. In some locations there are no default values making it difficult to know what to enter if the user is unsure. There are also no descriptions of the cells within the program so the user manual must be used simultaneously to address any uncertainties the user might have.

RETScreen climate data is available for some, but not all, cities and is on a macro scale rather than for specific locations. Resources, wind energy in particular, can vary drastically over short distances as a result of topography changes. As a result, using resource data for the closest city to the location of interest does not provide an accurate depiction of what would actually be available. This is a major short coming with RETScreen. Although the user can modify the resource data to be location specific, RETScreen lacks instruction and guidance for the user to obtain this data. As a result, users have a high probability of using the closest available location to their site rather than using specific climatic data.

Overall RETScreen was found to fit into the general RE calculator trends. Being a more complex calculator to produce an extensive feasibility assessment comes with a decrease in user-friendliness, especially for someone new to the world of RE. It also does not meet the growing demands of the agricultural world since it is not tailored to agricultural RE applications.

COMPLIMENTARY ENERGY DECISION SUPPORT TOOL (CEDST)

Intention After reviewing the various RE calculators available it has been determined that there is a need for a tool that can site-specifically assess the feasibility of a range of RE technologies for an agriculture setting. The tool needs to be easy to use and educate the farmer as they go through the calculator to ensure information entered into it is as accurate as possible. It should also provide a reliable comparison between technologies so that the farmer can identify which system works best for their operation.

With these characteristics in mind, none of the RE calculators currently available meet these requirements for aiding in assessment and comparison of RE technologies for agricultural applications. This gap is what this project is hoping to fill.

The goal of this project is to develop a 'Complimentary Energy Decision Support Tool' (CEDST) which will be a RE calculator designed to evaluate and compare different RE systems; solar PV, wind, geothermal, anaerobic digestion, solar thermal, and energy conservation. The tool will perform site-specific assessments using a Google Earth interface to pinpoint exact farm locations (Google, 2011). Minimizing the required number of inputs, as well as providing educational descriptions and images, will help the program not only be user-friendly but also informative, teaching the user about the different systems and terminology associated with them.

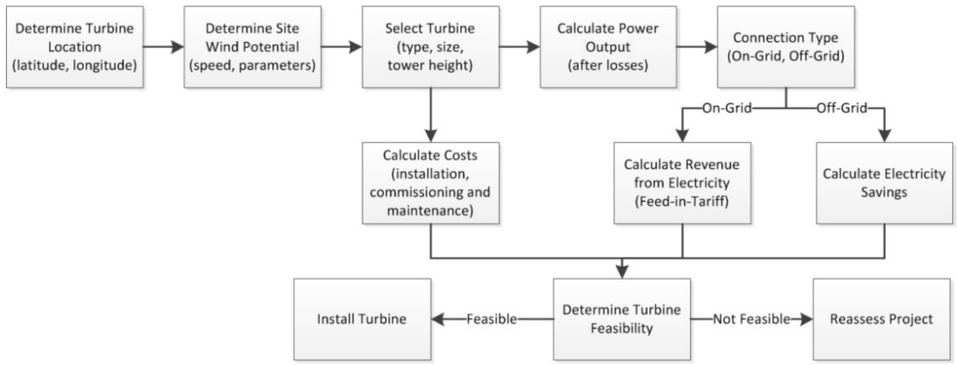
The CEDST tool will be developed specifically for agricultural applications in the province of Ontario and will be available to farmers free of charge. With the incorporation of Google Earth and education into the design of the calculator, farmers conducting assessments will gain a better understanding of RE systems and thus be able to enter more accurate information regarding site location and system characteristics. More accurate information will provide a precise and reliable energy generation prediction. Financing and economic return variables will be incorporated into the calculator to provide farmers the option of mimicking their financing plan for the RE system they wish to install.

Decision Making Process One of the first and most critical steps in creating the CEDST calculator is to develop and critically review the decision making process required for each of the RE systems. A step-by-step breakdown of all information that needs to be gathered and decisions that need to be made provides the skeleton of calculation sequences for each RE system. These individual decision and calculation sequences will be incorporated together to provide the underlying structure for the CEDST program.

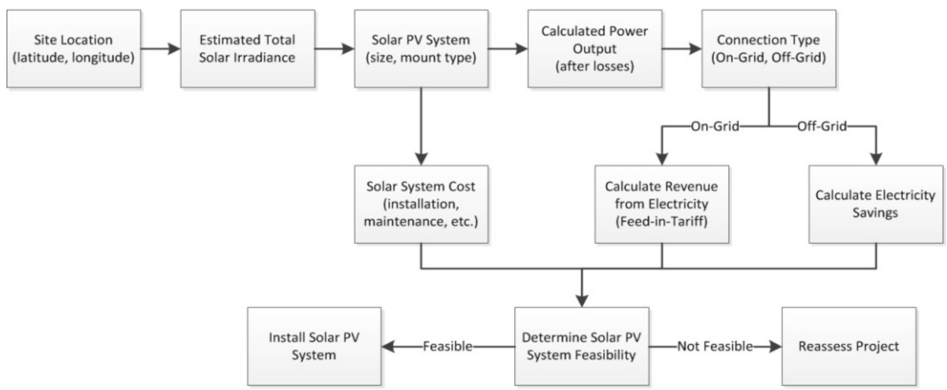
Initial decision-making processes for solar PV, wind, geothermal and anaerobic digestion have been constructed. These are illustrated in Figure 1, and extend from the initial site identification, to resource assessment, to the final feasibility assessment of the project. Examining each step highlights areas for improvement in CEDST when compared to other RE calculators currently available. Some improvements can include accurate site-identification and using high resolution resource data.

Challenges While it will be a challenge to enhance the accuracy of the calculator predictions, the biggest challenge will be integrating all of the decision making processes into one calculator. All the required inputs for each RE system evaluation will have to be identified and condensed so that there is no overlap and the minimum inputs are needed.

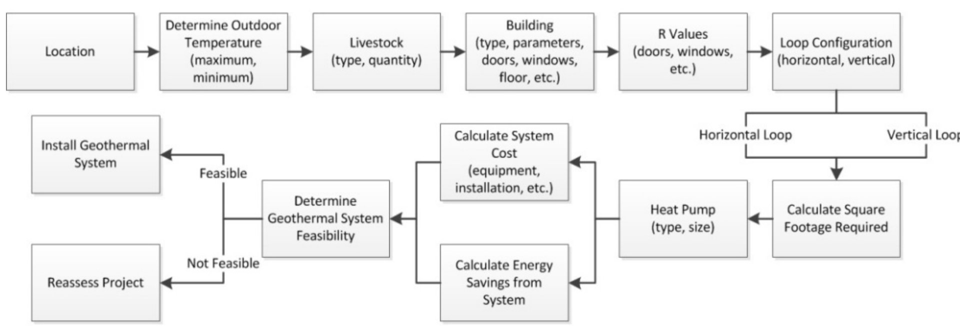
Wind



Solar PV



Geothermal



Anaerobic Digestion

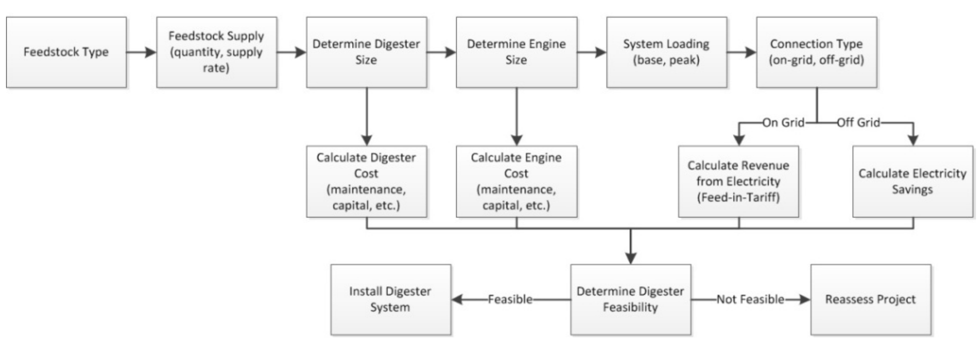


Figure 1: Decision making flow diagrams for Wind, Solar PV, Geothermal and Anaerobic Digestion

One of these avenues for reducing farmer input is with the use of Google Earth to identify property location, and building: size, orientation and location. Even though the use of Google Earth will be instrumental in getting accurate information about the RE site, it will be fairly complicated to link Google Earth with the calculator, feed in the required information and tie to resource databases.

The comparison of RE technologies comes with the challenge of determining the best way to present the economic comparison since RE technologies can offer completely different incentives. For example solar PV systems offer a farmer another income stream created from electricity sales to the power grid. In contrast, geothermal heating/cooling systems do not offer a revenue stream but rather an avenue for annual savings in heating and cooling costs. These represent two different economic scenarios and therefore work needs to be done to present them to the CEDST user in equal light. The overarching challenge of the project is keeping the CEDST calculator simple, educational and succinct at the same time as offering farmers a high quality feasibility comparison of the RE systems.

CASE STUDIES In order to verify the initial decision support processes and RE calculations developed for the CEDST, initial CEDST calculators were compared to RETScreen and specific site cases where available. RETScreen was chosen because it is one of the main RE energy calculators used by industry today since: it is free to use, robust and can assess RE potential for a variety of RE systems in both industrial and residential settings. The following section outlines the case studies carried out for the CEDST Solar PV, Wind and Geothermal processes.

Solar PV The solar PV case study was completed using data from the Integrated Learning Center (ILC) Live Building solar PV system at Queens University. The PV system at the ILC is a 19.8 kW fixed axis system with an azimuth angle of 5 degrees (west of south) and a slope of 70 degrees (from the horizontal)(ILC, 2011)**.** Figure 2 compares the ILC system's recorded monthly electricity production to the projected amout calculated by CEDST-SolarPV and RETScreen. Overall it can be seen that the CEDST-SolarPV monthly electricity predictions and trends are similar to those predicted by RETScreen and what was actually produced by the ILC system. These results validate the methodology and performance of the CEDST-SolarPV calculator. Although the results were similar, further work will be conducted to minimize the difference between CEDST predictions and actual solar PV system performance.

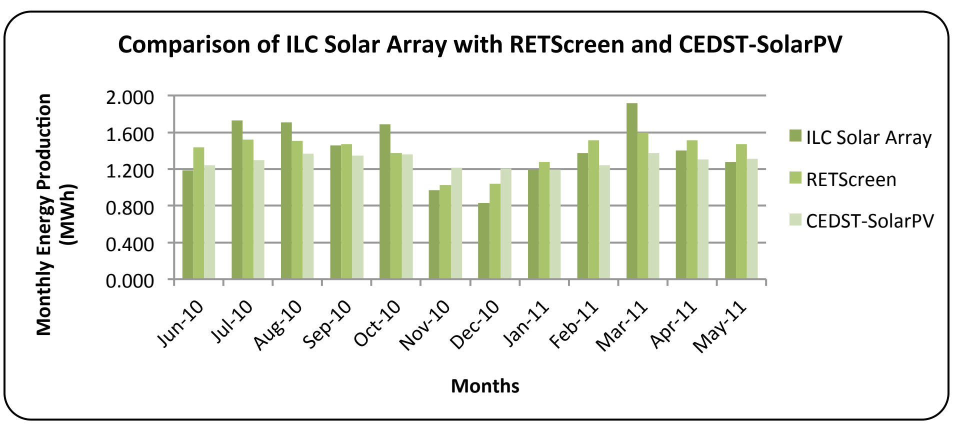


Figure 2: Comparison of ILC Solar Array to RETScreen and CEDST Solar Energy Calculator

Wind To examine the accuracy of energy predictions by the CEDST-Wind Energy Calculator (WEC), a comparison was performed using data from an operational 10kW Wind Turbine located in Madison County, New York and RETScreen. Onondaga County, NY (Syracuse specifically) was the closest city to the turbine site from the locations able to be selected in RETScreen (approximately 60kms away). As a result two RETScreen assessments were performed, one using the default climatic information for Onondaga County and another where site specific climatic information, taken from the Canadian Wind Energy Atlas (CWEA) (EC, 2008), was manually entered for Madison County. The first RETScreen-Onondaga case, using the default climatic data, was performed to illustrate the results that would be generated if the user was not familiar with wind resource tools and thus could not enter more accurate information. For the WEC, site specific wind data was required and was taken from the CWEA (EC, 2008), entered into the calculator and used to generate a wind energy prediction. As can be seen in Figure 3, the default RETScreen-Onondaga case severely over predicts the energy generation by the wind turbine. In contrast, the RETScreen-Madison and WEC cases are much closer at predicting the trends and actual energy production (AEP). Overall, the WEC predictions; are very similar to the RETScreen-Madison case, follow the seasonal AEP trends and are a conservative estimate of the AEP (21% lower than the annual AEP). As a result, this case study reveals that the methodology of the WEC is consistent with AEP but has room for improvements to be made to increase the accuracy of energy predictions.

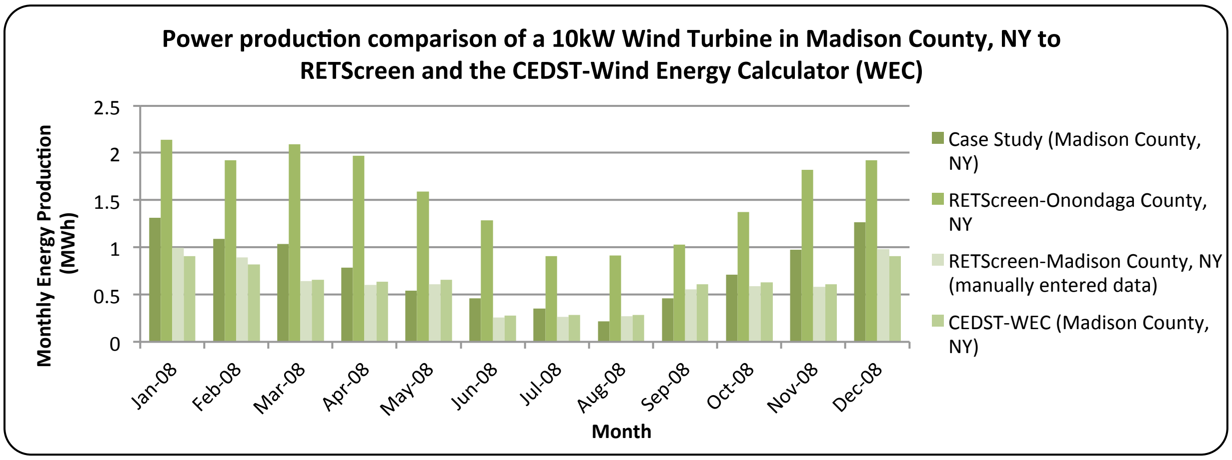


Figure 3: Comparison of a 10kW Bergey Wind Turbine in Oneida, NY to RETScreen and CEDST Wind Energy Calculator (WEC)

Geothermal A validation case study was completed to demonstrate the efficacy of the CEDST preliminary Ground Source Heat Pump calculator (CEDST-GSHPc). A comparative analysis between GSHPc and RETScreen was conducted assuming a warehouse with 1000m^2 of floor space to be conditioned, and weather data from the Ottawa International Airport. The peak heating and cooling loads were 30.3kW and 57.5 kW, respectively (NRCan, 2010). Table 1 outlines the comparison between the ground heat exchanger sizes reported from both calculators and presented in the percent deviation from the RETScreen value. The highest percent deviation for this case was 11%, for a horizontal ground heat exchanger configuration based on the heating load. The lowest percent deviation was determined to be 6%, for a vertical loop configuration based on the outlined cooling load. This analysis demonstrates that the CEDST-GSHPc is giving comparable predictions to RETScreen.

Table 1: Validation Case Study

Validation Case Study – Ground Heat Exchanger Size				
	Comparative Element	**CEDST-GSHPc Size Prediction (m)**	**RETScreen Size Prediction (m)**	**Percent Difference (%)**
Cooling	Vertical	731	692	6
	Horizontal	1041	972	7
Heating	Vertical	353	386	-8.5
	Horizontal	425	479	-11

Overall, the case studies help illustrate that the initial CEDST calculator methodologies are consistent with RETScreen predictions and actual RE system data (when it was available). These results also support the project direction and help define the project's next steps.

NEXT STEPS Initial decision support tools for solar PV, wind and geothermal have been completed. Moving forward, emphasis will be put on assessing the initial CEDST calculators and decision support processes. Additional case studies will be run, using sites with actual operational RE systems. This process will help further identify areas where improvements can be made to increase the accuracy of CEDST predictions, and provide insight into any anomalies that may be seen with each RE system. Algorithms for technologies such as anaerobic digestion, energy conservation, and solar thermal will be developed, as well as, a common economic framework to compare each of the RE technologies. The project will also be developing the CEDST application framework and preliminary user interface, compiling wind, solar and soil data into a usable database, and integrating the Google Earth platform into the underlying application.

CONCLUSION With the growing market utilizing RE technologies around the world, and specifically farmers who possess a plethora of RE resources, leaves a gap for the farmers to identify which RE energy solution is best for their location and operation. The Complementary Energy Decision Support Tool (CEDST) focuses on filling this gap by providing an agriculturally based tool to help farmer compare RE systems. Initial calculators for solar PV, wind and geothermal energy have been created and case studies illustrate that their methodology is consistent with RETScreen, a widely used RE assessment tool. The CEDST solar PV and wind tools also showed trends and energy predictions that were similar to electricity generation from actual systems. Future work will help increase the accuracy of CEDST predictions and expand the tool to include other RE systems.

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REFERENCES

COFS. 2010. Personal Communication with Canadian Energy Expo Exhibitors. Canada's Outdoor Farm Show. September 15, 2010.

CanWEA. 2005. Planning for Your Small Wind Turbine – The Ballpark Cost. Canadian Wind Energy Association. Available at: http://www.smallwindenergy.ca/en/SmallWindAndYou/Planning/Ballpark Cost.html. Accessed October 3, 2010.

CE. 2003. Blackout Hits Ontario and seven US States. The Canadian Encyclopedia. Available at: http://www.thecanadianencyclopedia.com/index.cfm?PgNm=TCE&Params=M1ARTM0012504. Accessed May 20, 2011.

De Vries, A., Wilkie, A., Giesy, R., Nordstedt, R. 2007. Digester 1.1. University of Florida, Institute of Food and Agricultural Sciences.

DWIA. 2003. Wind Turbine Economics Calculator. Danish Wind Industry Association. Available at: http://guidedtour.windpower.org/en/tour/econ/econ.htm. Accessed October 4, 2010.

EC. 2008. Canadian Wind Energy Atlas. Environment Canada (EC). Available at: http://www.windatlas.ca/en/maps.php. Accessed June 28, 2011.

EPA. 2010. FarmWare 3.5. U.S. Environment Protection Agency. AgStar. Available at: http://www.epa.gov/agstar/tools/project-dev/farmware.html. Accessed January 15, 2011.

Google. (2011). Google Earth 6.0. Available at: http://www.google.com/earth/download/ge/agree.html. Accessed June 2, 2011.

ILC. 2010. Live Building Integrated Learning Center – Solar PV Array. Faculty of Engineering and Applied Science, Queens University. Available at: http://livebuilding.queensu.ca/access_data. Accessed June 15, 2011.

Jones, J. 2011. Canadian study sees global warming for centuries. Thomson Reuters. Available at: http://af. Reuters.com/article/energyOilNews/idAFN0828153820110109?pageNumber=2&virtualBrandChannel=0. Accessed May 20, 2011.

Kavanaugh, S.P., et al. 2011. Geothermal System Cost Estimator. University of Alabama Engineering. Accessed on: January 15, 2011.

LeJeune, T., Mermoud, A. 2010. PVSys Decision Making Tool Ver. 5.21. Updated: September 2010, Available at: http://www.pvsyst.com/5.2/index.php . Accessed October 14, 2010.
Lilienthal, P., et al. 2009. HOMER Version 2.68. HOMER Energy, USA. July 24, 2009.
NRCan. 2010. RETScreen4: Clean Energy Project Analysis Software. Ministry of Natural Resources Canada. RETScreen International, September 4, 2010.
NREL. 2008. PVWatts Decision Making Tool: National Renewable Energy Laboratory Ver.1.0. National Renewable Energy Laboratory , U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Available at: http://www.nrel.gov/rredc/pvwatts/. Accessed October 27, 2010.
OEE-NRC. 2011. Electricity Generation Energy Use and Generation by Energy Source. National Resources Canada: Office of Energy Efficiency. Available at: http://oee.nrcan.gc.ca/corporate/statistics/ neud/dpa/tableshandbook2 /egen_00_1_e_4.cfm?attr=0. Accessed May 15, 2011.
OPA. 2010. What is the Feed-in Tarriff Program? The Ontario Power Authority. Available at: http://fit.powerauthority. on.ca/what-feed-tariff-program. Accessed May 20, 2011.
OPG. 2010. Power Generation. Ontario Power Generation Inc. Available at: http://www.opg.com/power/. Accessed: June 10, 2011.
Orrell, A., Antonich, B. 2007. The Windustry Wind Project Calculator. Windustry. Available at: http://www.windustry. org/your-wind-project/community-wind/community-wind-toolbox/chapter-3-project-planning-and-management/wi. Accessed October 4, 2010.
SEO. 2010. My Solar and Wind Estimator. Solar-Estimate.Org. Energy Matters LLC. Available at: http:// www.solar-estimate.org/index.php?page=wind-calculator. Accessed October 4, 2010.
UoA. 2011. E-Pipe Alator 08. University of Alabama. HVAC and Energy Conservation Course Work. Available for download: http://electrical-engineering-portal.com/download-center/hvac-software. Accessed January 15, 2011.

APPENDIX A

Table 2: Literature review of currently available renewable energy calculators

Calculator	Solar PV	Wind	Geothermal	Anaerobic Digestion	Solar Thermal	Conservation	Biofuels/ Biodiesel	Technology Comparison	Reference
RETScreen	√	√	√	√	√				NRCan, 2010
HOMER	√	√				√	√		Lilenthal et al., 2010
PVWatts	√								NREL, 2008
PVSys	√								LeJeune and Mermoud, 2010
Solar and Wind Energy Estimator	√	√							SEO, 2010
CanWEA		√							CanWEA, 2005
Windustry		√							Orrell and Antonich, 2007
Danish Wind Energy Association		√							DWIA, 2003
FarmWare				√					US EPA, 2010
Digester1.1				√					De Vries et al., 2007
Geothermal System Cost Estimator			√						Kavanaugh et al., 2011
E-PipeAlator08			√						UoA, 2011