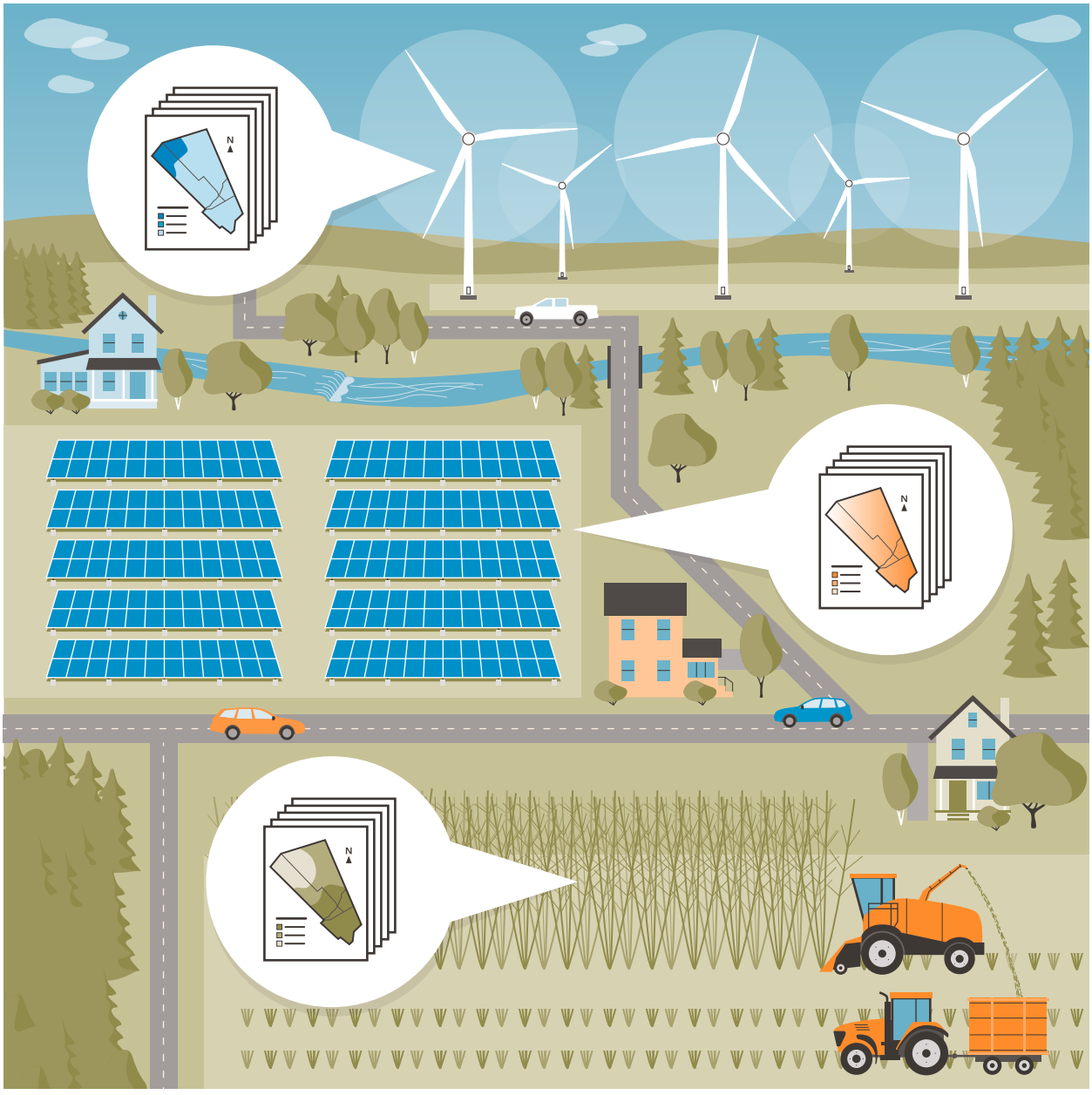
Mapping opportunities for land-based renewable energy generation in Ontario: a guidebook for local planners and analysts



CEKAP
Community Energy Knowledge - Action Partnership

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Preface

The transition to distributed renewable energy (RE) production is well underway, especially in the electricity sector. Technological innovation and changing electricity markets, supported by government policy and consumer demand, have made RE systems cost-competitive against electricity generation from coal, nuclear, and natural gas. This electricity transition is driving knock-on effects as the transport and heating sectors are electrifying to take advantage of a cleaner and cheaper grid. Renewable electricity is also opening up new opportunities for sustainable hydrogen production. Social movements and political leaders are emboldened by these developments, evidenced by the growing number of communities, corporations and governments setting goals to be "100% renewable" over the coming decades.

The purpose of this guidebook is to help local communities and local governments to identify and manage the opportunities and impacts of this transition. Our focus is on land-based RE, namely wind farms, ground-mounted photovoltaics (solar), and cellulosic biomass.[1] We offer a set of concepts, techniques, and tools through which planners and communities can produce a map that indicates where land-based RE systems are likely to be implemented. These maps can be used as the basis for public dialogue and public policy in order to capture the opportunities and minimize the impacts of the transition. The guidebook breaks down as follows. In Part 1, we explain the rationale behind our emphasis on land-based RE, and offer a high-level overview of our mapping approach including a case study of the Regional Municipality of Peel, Ontario. In Part 2, we provide detailed instructions on how to produce maps of RE resources and opportunities for their development. In Part 3, we provide guidance on how to use these maps to facilitate effective community engagement and cross-sector dialogue

1 Cellulosic biomass includes corn stover, straw, and woody materials. These are biological materials that are considered food for direct human consumption, although some of these materials have uses as animal feed, animal bedding, pulp and paper, lumber, and other non-energy uses.

around these opportunities. Throughout the guidebook, we provide examples based on a pilot case-study of the Regional Municipality of Peel, Ontario.

Why 'land-based' renewable energy? What about rooftop solar?

The transition to RE is in many ways a landscape transformation. For many decades, our primary energy supply has mostly come from fossil fuels (coal, oil, natural gas), which exist below ground and are transported long distances before they are converted into heat or electricity. Increasingly, we are deriving our energy from renewables which, for the most part, can only be recovered above ground (wind, solar, biomass), and must be converted into heat or electricity on-site (or, in the case of biomass, a relatively short distance away). As a result of localized nature of RE, opportunities for our local communities are tremendous. RE systems can be very small scale and less capital intensive, which enables home-owners, property owners, and community cooperatives to participate in energy generation through direct ownership or manageable investments. So the financial benefits can be more evenly distributed across society. As RE systems become the primary source of energy for electric vehicles, local air quality and therefore health outcomes are vastly improved. Local efforts to maximize RE generation will also help to address the global climate crisis.

With these opportunities come challenges. Renewable energy systems introduce landscape impacts and land-use tradeoffs that need to be identified and managed – think about solar panels covering what used to be an active pasture; wind turbines altering a natural view and introducing a new risk to local wildlife; or agricultural fields growing crops for energy rather than food. RE infrastructure is also highly visible and covers wide areas; energy generation is no longer 'out of site, out of mind' like coal or nuclear. In other words, the energy transition is a profound landscape transformation. They can often be in conflict with existing land-based economies and ecosystem services, and their high visibility raises concerns about landscape aesthetics among local citizens.



Figure 1: Images (taken by authors) of the kinds of RE technologies this guidebook is focused on: utility scale wind (top); ground-mount photovoltaics (middle); and cellulosic biomass (bottom, showing short-rotation willow production for energy end-use).

How much land, and what kind of land, will be needed to power a sustainable energy future? Can we allocate significant tracts of land to RE production and still ensure that our local landscapes continue to provide food, habitat, spaces for recreation, and other land-based economies and ecosystem services? How are these land-use tradeoffs perceived by the general public? How will changing technologies mitigate or exacerbate these issues? And how should our existing land-use planning systems evolve to help manage these trade-offs?

These are just some of the questions that our guidebook will help answer. Using the tools described in this guidebook, local communities and governments will have some of the critical information they need to prepare for this integrated energy-land transition.

"What about rooftop solar which does not require any new land?"

Indeed, some of our RE supply can be recovered with rooftop solar energy systems, and therefore without significant landscape transformation. Rooftop solar energy is necessary, but by itself insufficient as a means to achieve a sustainable energy future. Detailed energy assessments at the city-scale have shown that rooftop solar energy potential is about half of total current electricity use across most cities in North America; by 'current use', this does not account for the electrification of transport and heating.[2] In other words, renewable energy generation will need to sprawl beyond our rooftops and existing infrastructure if we hope to achieve ambitious goals around RE generation while decarbonizing heating and transport systems.

"But total land requirements for RE generation are small".

This is also correct. Previous research from our group estimates that Ontario would need approximately 3 per cent of its farmland if it were to power itself entirely on photovoltaics. But the proportion is misleading. Absolute land requirements, in terms of total actual hectares or acres needed, are large. And virtually every hectare we would consider for RE generation is already supporting an economy, a livelihood, an ecosystem, and a lifestyle. So we need to be thoughtful in how we allocate land to RE production. The same is true for off-shore wind or tidal energy, although our work-to-date does not focus on those options.

Why is this guidebook speaking to Municipal and local audiences?

Increasingly, the responsibility to deliver on the Province's climate change mitigation ambitions is falling to local and regional governments. The emergence of community energy plans and local climate plans express that responsibility. And as markets open up for RE development, especially rural communities are at the front lines as developers approach land-owners to host new

2 Gagnon, P. et al. 2016. Rooftop solar photovoltaic technical potential in the United States: a detailed assessment. Technical Report NREL/TP-6A20-65298, National Renewable Energy Laboratory (USA). See https://www.nrel.gov/docs/fy16osti/65298.pdf. For some guidance on how to map rooftop solar energy resources, see https://www.aimspress.com/article/10.3934/energy.2015.3.401

systems. Recently, Municipalities (re)gained some control over RE development and now have the authority to shape the market through the design of land-use plans and by-laws that regulate RE development. In other words, Municipal Councils and local planners need to facilitate RE development while managing the land-use tradeoffs described above. These responsibilities are unfamiliar to Municipalities in Ontario, and there are very few resources available to help Councilors and planners make decisions in this new role. Our guidebook is meant to provide capacity to fill that role. Since the guidebook considers the Ontario energy market and land-use policy framework, users of the guidebook outside of Ontario should be careful not to directly extrapolate the methods and findings. Still, the general approach will be useful.

How to Use the Guidebook



The guidebook is broken down into two sections. Section 1 provides details on the data and techniques used to produce maps that communicate possible opportunities for PV, wind, and biomass energy development. Section 2 provides detailed guidance on how to leverage those maps for community and stakeholder engagement. These workflows can be used for stand-alone projects, depending on research needs and priorities. For example, if a few possible sites have already been identified for renewable energy development, skip to Section 2 for ideas on how to engage the public around those opportunities. If the goal is only to identify possible sites based on technical criteria, work only from Section 1 (but you've been warned: the social dimension of RE development is a hugely important factor in determining the success of a project, and so we really think you should incorporate public engagement as part of the assessment).

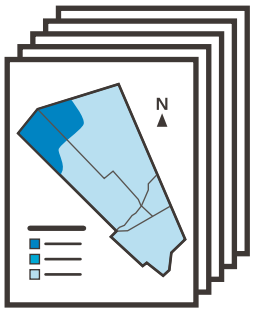
The guidebook has been written for a reader with some technical background in renewable energy siting, land-use planning, and/or geographic information systems (GIS). We have tried, to the best of our ability, to be clear in our description of the workflow, without providing extraneous detail. We decided to leave out very detailed step-by-step instructions, given the rapid pace of change in the software and data that are used for this type of work. We didn't want the toolkit to be obsolete upon publication! Instead, we describe our approach at a conceptual level, but with enough detail such that the processing and analytical steps will be intuitive for someone with a GIS background, and that the logic underlying map outputs will be comprehensible to someone with expertise in renewable energy and/or land-use planning. In all cases we demonstrate the intermediate and final results of our workflow using examples from our recent work in the Regional Municipality of Peel, funded by the IESO. These examples represent the kinds of outputs that can be produced from the workflow.

List of Resources Available in this Guidebook

The guidebook makes reference to resources or assets that can be leveraged in order to replicate our mapping process, or at least some variant of our mapping process tailored to your needs. Below is a list of those resources:

- An inventory and description of best-available data to map wind speeds, solar irradiance, and biomass production in Ontario. Find it here.
- A conceptual framework to standardize the process through which to identify opportunities to develop renewable energy resources in a region based on technical, regulatory, and economic factors. See Figure 3 and Table 1.
- A GIS model, with the data from Peel and the cartographic model in ESRI's ModelBuilder, through which to replicate our findings. These input data can be swapped out for local data, allowing someone with GIS expertise to use the model to produce maps for their own area of interest. Find the model package for solar (PV) here. Find the model package for wind here. Find the script to map biomass resources, as well as an excel spreadsheet that can be used to estimate supply-cost curves based on outputs from that script here.
- A .CSV file that includes the average quantity of agricultural residue, on a county-level basis, for a 20 m by 20 m pixel. This can be used to convert a land cover category (e.g., corn) into a biomass yield (i.e., tonnes of stover per cell). Find it here.
- An inventory of all data used to operationalize the conceptual framework and the cartographic model. Find it here.
- A classification system to interpret and classify regulatory restrictions on where particular RE systems can be located, along with examples of how the classification system is applied. See Table 2.
- A framework to organize in-depth, targeted public engagement and participatory mapping exercises through which to gather public sentiment and identify stakeholder concerns around RE development. See Table 15. In addition, an agenda and list of materials needed to conduct focus-group style participatory mapping exercises. Find it here.
- A survey tool that can be issued to assess local sentiment around renewable energy generally, along with particular technologies. This has been made available in .pdf format, and can be replicated in any survey software (we used Qualtrics). Find it here.

Phase 1: Mapping Land-Based Renewable Energy Resources



This section reviews the data, techniques and tools that are used to map land-based RE resources – specifically ground-mount photovoltaics (PV), large-scale wind, and biomass – up to 'relative economic potential'. We provide details on how to map 'relative social potential' in the next section of this guidebook. In all cases, we draw on our recent work in the Regional Municipality of Peel, Ontario, in order to demonstrate the methods and outputs.

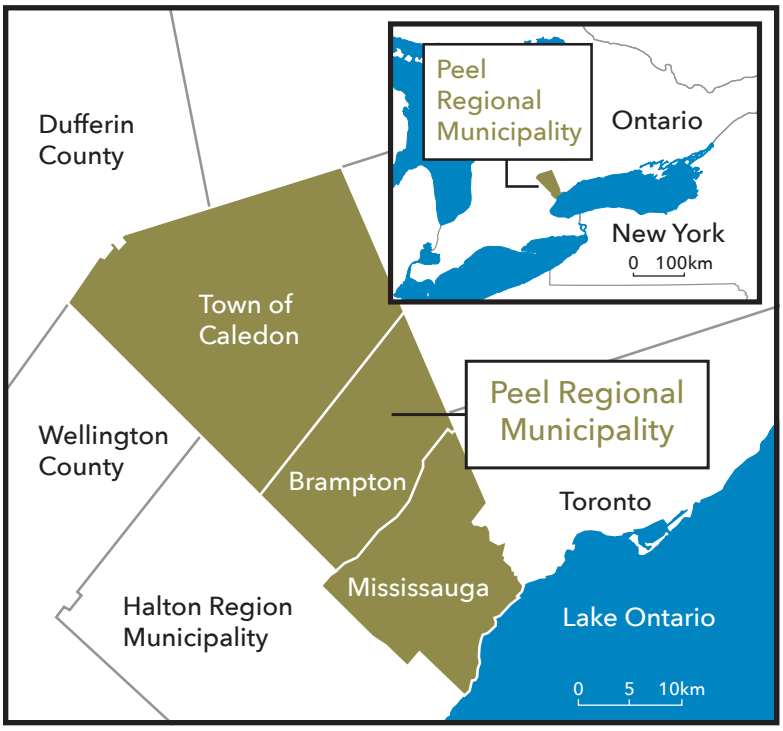


Figure 2: Study area.

Context and Overview

The transition from fossil fuels toward renewable energy is one from subterranean and vertically concentrated energy stocks to above ground and horizontally diffuse energy flows. Framing the transition in these terms draws attention to the challenge of integrating renewable energy systems into existing land-use systems and landscapes. Although land area might seem plentiful, all of the land resource that might seem accessible is already providing either an economic function (food production, recreation) or an ecosystem function (habitat, water regulation). The purpose of this section is to provide a resource for land-use planners and GIS analysts to identify and plan for these possible tradeoffs in their area. We provide tools and techniques through which to produce a rigorous estimation of renewable energy (RE) potential while accounting for, and aiming to minimize, land-use tradeoffs and environmental impacts.

In order for RE to compete at the agenda-setting stage of an energy strategy or investment decision, and in order to facilitate meaningful public engagement around RE impacts and opportunities, information about an area's RE resource base must be presented with clarity. To ensure this, the mapping process developed in this guidebook is based on a standardized nomenclature and logical framework, visualized below and described in detail in Table 1.

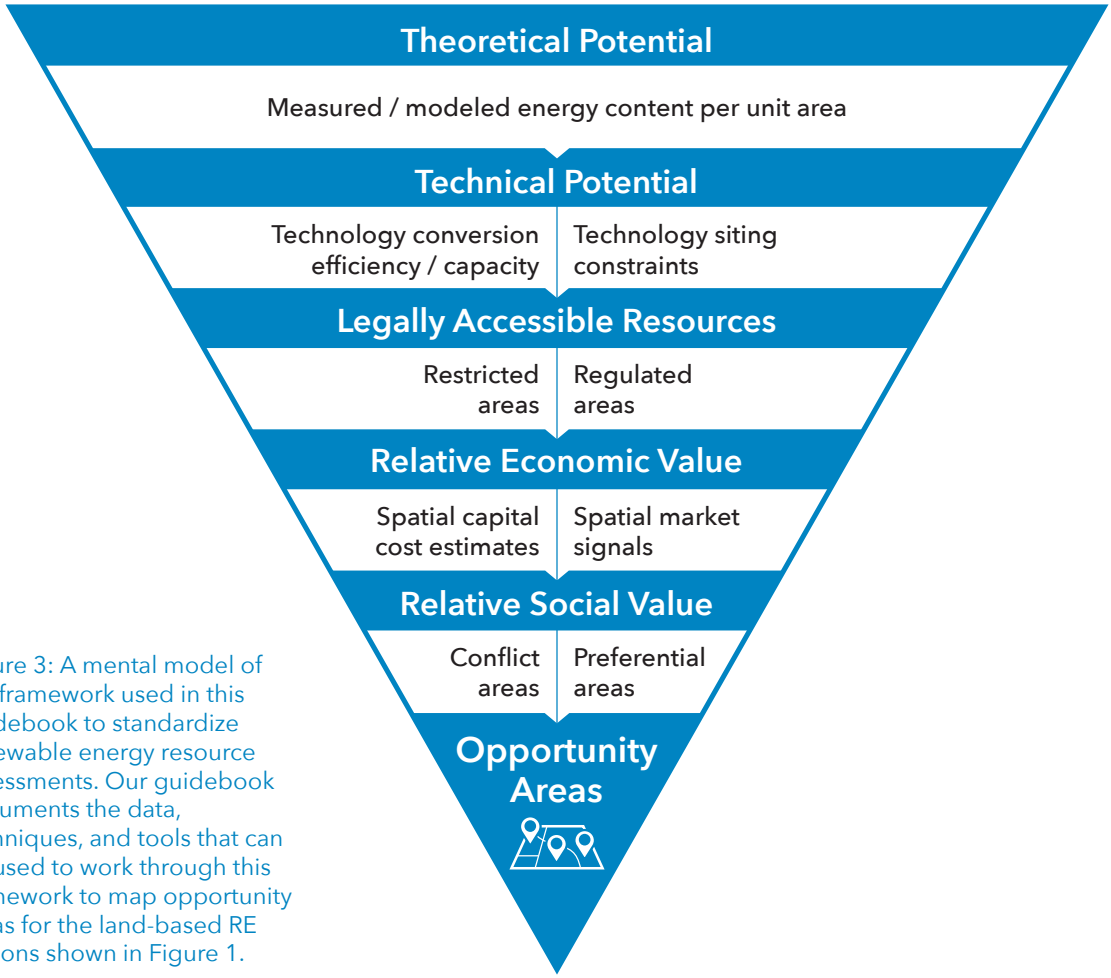


Figure 3: A mental model of the framework used in this guidebook to standardize renewable energy resource assessments. Our guidebook documents the data, techniques, and tools that can be used to work through this framework to map opportunity areas for the land-based RE options shown in Figure 1.

Table 1: RE Mapping Process

Category	Definition		Example Distinguishing Factors
Theoretical Potential	Measured or modeled energy potential across a geographic area. These maps depict physical expressions of energy flows across Earth's surface. Also referred to as physical limit or gross potential.		Irradiance; wind speed; heat value of biomass;
Technically Recoverable Resources	Theoretical resources are mapped as 'technically recoverable' or 'not technically recoverable'. These maps depict theoretical resources that can be converted into useful energy by prevailing technologies (technology conversion efficiency limit), at sites that can be accessed using reasonable engineering solutions (technology siting constraints). Both are dependent on interactions between the technology and site characteristics.	Technology conversion efficiency / capacity factor limit (a.k.a. 'production ceiling'): estimated net energy recovered based on system efficiencies and system capacity factors, typically assuming conversion technologies at or beyond the research and development stage of innovation chain. This limit will increase through technical innovation.	Technology resource requirements (e.g., wind power profiles; biomass type); technology capacity factor and conversion efficiency
		Technology siting constraints (a.k.a. 'carrying capacity'): includes site-specific barriers to infrastructural development and to system engineering and operation. In the case of biomass, residue coefficients are applied to account for the organic content that needs to be returned to the landscape to maintain a soil health.	Land cover; slope; altitude and other site specific physical attributes that are incompatible with technology implementation
Legally Accessible Resources	Technically recoverable resources that are accessible without violating existing regulations related to land-use and infrastructure siting. Prohibited areas are removed from consideration. Regulated areas are mapped along a gradient of 'regulatory risk' from high to low based on the discretionary powers held by government to approve or decline a project.	Prohibited areas: includes those areas and features that are protected from development by inhibitive regulations. Often, these areas are protected from all infrastructure development. In some cases, they are protected from specific kinds of renewable energy development (e.g., solar farms not permitted on "prime agricultural land")	Protections on cultural and natural heritage; zoning by-laws; infrastructure set-back requirements
		Regulated areas: represents permissive regulations. The level of permissiveness relative to a specific technology is interpreted so that we can distinguish the likelihood of project approval	

Table 1: RE Mapping Process - contunied

Category	Definition		Example Distinguishing Factors
Relative Economic Value	Legally accessible resources are mapped according to relative economic potential, based on relatively low spatial capital costs and relatively high market readiness. Map outputs created for this category become an input into community / stakeholder engagement exercises. Note: this does not map site-level economic viability. Outputs at this level provide spatial information necessary to determine viability based on site-level techno-economic analysis.	Spatial capital costs: mapped on a gradient from relatively lower to relatively higher capital costs of development. These costs are a function of site access, site preparation, and connection to distribution systems. These costs vary as a function of total system costs depending on the resource in question.	Distance to transmission / distribution infrastructure; distance to access roads; land value; land-cover; topography
		Market readiness: where relevant, indicators of market readiness are mapped to indicate sites at which RE resources may be more 'market ready', all else being equal.	Local market price (e.g., locational marginal price of electricity); larger parcel sizes (scale economies)
Relative Social Value	Sites that are likely to be developed with least social conflict and / or are perceived as preferential areas by multiple decision-makers. Mapped primarily through participatory mapping with the general public, stakeholder groups, and organizations that have capacity to implement projects	Least social conflict: mapped on a gradient from more to less acceptable. Participants indicate areas that they might find 'acceptable', 'not acceptable', or 'conditional' for the development of a particular resource. Those are compiled into a single map layer.	Proximity to home, work, and / or places of recreation; land-cover type and land-use trade-offs; risk of wildlife impacts
		Regulated areas: represents permissive regulations. The level of permissiveness relative to a specific technology is interpreted so that we can distinguish the likelihood of project approval	Land-owner willingness; utility needs;

Mapping Beyond Theoretical RE Resource Potential

It is important to note that our approach does not create new data or maps of theoretical resource potential. A handful of agencies produce publicly available data of solar irradiance, wind speed and biomass production at national and local scales. These data are updated regularly as new methods and new data collection techniques become available, and have associated metadata. Our RE mapping approach builds on these efforts, rather than duplicating them. Maps of 'Theoretical potential', shown below, are derived from these publically available data. In a separate report we provide a brief summary of the resource data we use for this work. Below, we give examples of how those data are classified and mapped in order to improve their usefulness for mapping RE development possibilities.

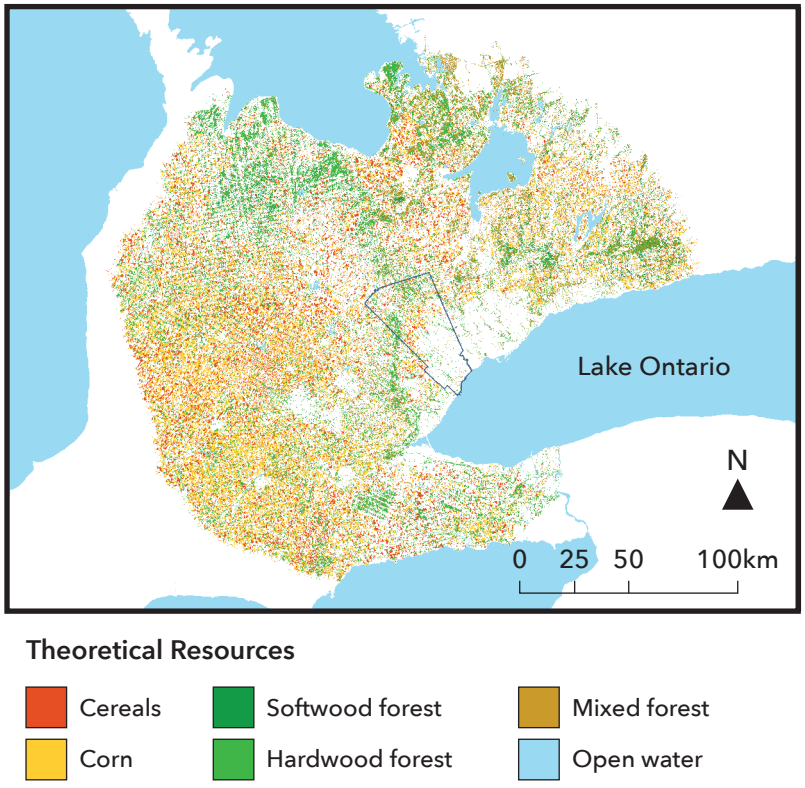


Figure 4

Biomass Theoretical Resources Map

Map of theoretical biomass resources in Peel. Since biomass can be transported, we have mapped biomass within a 150km radius of Peel Generally speaking, biomass can be transported approximately 150km before the economic and energetic costs exceed the benefits. As such, we consider any biomass resource within 150km of Peel as theoretically available to Peel. Here, we have re-classified the map to show only those land cover categories that are producing biomass types we are interested in – crop residues and forestry residues.

Figure 5

Solar Theoretical Resources Map

Theoretical solar resources in the Regional Municipality of Peel. Data are visualized in their global context, to be able to communicate theoretical resources in relative terms. Peel's resource is not as strong as California's but is much stronger than Germany's. Both jurisdictions have seen significant solar energy development in recent years, substantiating the point that the strength of the resource itself is not by itself sufficient to explain opportunities for development.

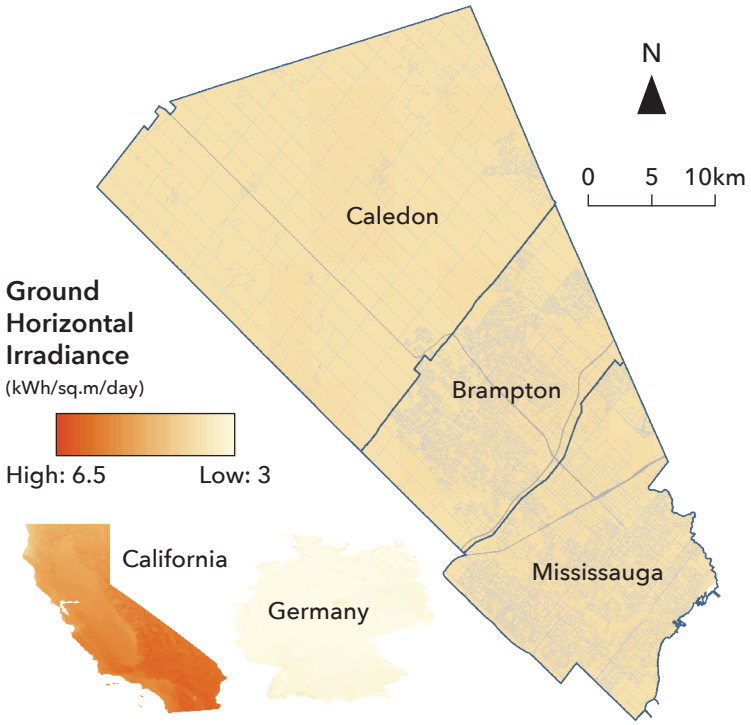
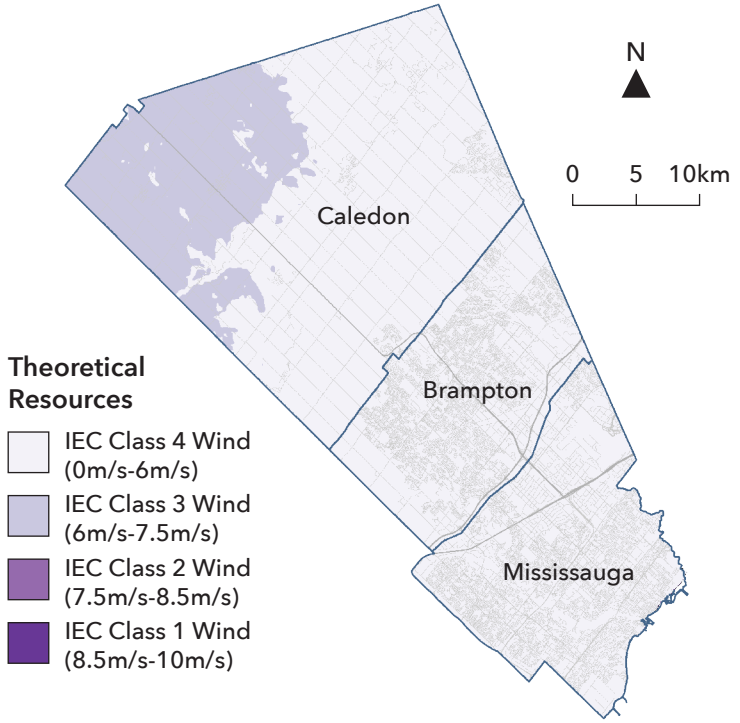


Figure 6

Wind Theoretical Resources Map

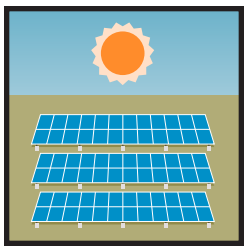
The International Electrotechnical Comission (IEC) 61400 standard is used to communicate which turbine technologies are suitable for use in an area based on annual average wind speed, and is not indicative of the overall generating potential that wind energy has in the region.



We have developed strategies to communicate resource potential in ways that might be meaningful to a wider audience. In the case of solar, data are visualized in their global context, to be able to communicate theoretical resources in relative terms. Peel's resource is not as strong as California's but is much stronger than Germany's. Both jurisdictions have seen significant solar energy development in recent years, substantiating the point that the strength of the resource itself is not by itself sufficient to explain opportunities for development. Wind resources are classified into standardized categories from the International Electrotechnical Commission (IEC); these classifications are used by developers to make technology selection decisions. Generally speaking, biomass can be transported approximately 150km before the economic and energetic costs exceed the benefits and as such we consider any biomass resource within 150km of Peel as theoretically available. Here, we have re-classified the land-use map to show only those- categories that are producing biomass types we are interested in – crop residues and forestry residues.

Of course, the presence of the resource is a necessary but by itself insufficient condition for RE development. There are a host of technical, legal, economic, and social parameters that shape where and under what conditions a resource might be accessed. These parameters depend on resource option and technology type. As such, the remainder of the toolkit provides guidance on a resource-by-resource basis at each level of analysis. The approach we have designed and describe below is raster-based, because most of the input data are in raster format. Data are resampled to the coarsest resolution (for our work, 20 meters), and re-projected into a standard projection system (for our study area, UTM Zone 17N). Constraints and factors are modeled using data reclassification and map overlay / raster calculator techniques.

Mapping Opportunities for Utility-Scale PV Development



Mapping Technically Recoverable PV Resources

Technically recoverable PV resources are modeled based on the following exclusions:

- Areas with a slope above 35%. Steeper slopes would require additional supports or costly changes to the landscape.
- North-facing slopes above 10 degrees. North-facing slopes at and above this angle do not receive sufficient solar irradiance.
- Land-cover types that are not capable of hosting utility-scale PV systems for technical reasons, including:
  - Urbanized areas
  - Roads
  - Railways
  - Waterbodies
  - Aggregate extraction sites
  - Airports
  - Areas smaller than 4ha, which is the minimum size to host a 1 MW PV facility

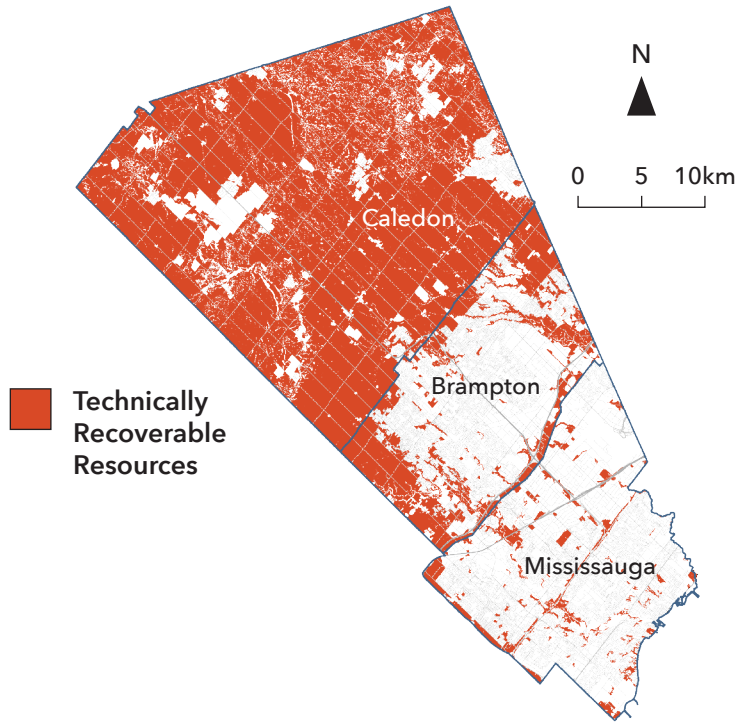


Figure 7
Recoverable Resources Map

Since our data are in raster format, exclusions are modeled through data reclassification to NoData. Areas assigned to NoData will no longer be considered in the modeling process regardless of other characteristics those areas may have.

The impact of these exclusions on PV development opportunities depends on geographic context. The total land-area that is deemed 'accessible' in our study area after applying these exclusions is shown in Figure 7.

Mapping Legally Accessible PV Resources

An audit and analysis of land-use regulations from multiple levels of government is used to identify 'legally accessible' resources. 'Restricted areas' are removed from consideration through binary mapping similar to the exclusions above, where the prohibited area is assigned 'NoData'. Not all regulations are clear 'go/no-go' decisions however. Some regulations influence, rather than restrict, RE development – what we call 'regulated areas'. We map 'regulated areas' on a gradient based on the extent of their influence on RE resource access. The process unfolds as follows:

1. Identify all policies and regulations that apply to renewable energy development in a particular area. For our study, we identify these as 'Source' documents in the tables below.

2. Extract information about the specific natural features and land-cover/land-use categories to which the policies and regulations from step (1) apply.

3. Interpret the level of protection that each policy or regulation assigns to a given natural feature or land-cover/land-use category relative to renewable energy development. We have created four levels of protection, described below in Table 2.

4. Gather digital spatial data on the natural features and land-covers/land-use categories identified in step (2). Using data reclassification techniques in a geographic information system, assign the level of protection from step (3) accordingly to create a map of environmental protections for each policy / regulation.

5. Repeat step (4) for all policies and regulations, and their associated natural features and land-cover/land-use categories. See Tables 3-5 for a summary of the restricted and regulated areas that have been identified for PV systems in our study area.

6. Combine all of the maps from step (5) into a single map, showing the levels of protection across all natural features and land-cover/land-use categories in the study area. Where multiple policies/regulations apply to the same natural feature or land-cover/land-use category, the most stringent protection level is applied.

Table 2: The classification system used to interpret and map restricted and regulated areas.

Regulatory Screening Level	Description	Example	Legend Label (see map)
1	Regulations inhibit RE development of all types or a specific type	The Province of Ontario has prohibited the development of PV farms on 'prime agricultural land'.	Restrictive
2	Regulations inhibit most forms of RE development with some exceptions.	The Province of Ontario has regulations that inhibit significant site alterations within 30 metres of a body of water, however, if an EIA demonstrated that the facility's environmental impact is minimal, then the facility may move forward with construction. As such, the 30m setback for bodies of water is a level 2	Somewhat restrictive
3	Regulations inhibit some forms of RE development, with more exceptions.	The Federal Government has a set of recommendations for the construction of wind farms in proximity to aerodromes. It is suggested that wind farms of more than 6 turbines should not be within 10km of a VOR facility, however, required consultations with the airport may result in the passing of a proposed wind farm within the recommended buffer. This makes the 10km setback a level 3.	Not very restrictive
4	There are no pre-determined regulations applying to RE, but an EIA will still be required	Open areas such as active or abandoned farmland that do not fall within any specific regulatory control relative to RE development.	No pre-determined restrictions

In the series of tables (Tables 3-5), we provide our interpretations of regulatory controls on PV development according to Federal, Provincial and Municipal regulations. See Figure 8 for the final result of the regulatory mapping process.

At this point, a few issues should be noted:

1. It is difficult to discern between a 'level 2 – Somewhat restrictive' and a 'level 3 – not very restrictive'. The user may decide to simply merge these two levels, given how blurry the boundaries are between these categories. As indicated by the examples, however, we felt there are some cases in which an area is more likely to receive approval than others, which justifies more nuance in the categorization.

2. In many jurisdictions, RE technologies are not named specifically in regulations, but can be interpreted to fall under 'infrastructure development' generally.

3. Conducting a rigorous assessment of this sort enables analysis of the influence of policy change. Multiple scenarios can be developed simply by changing the values to make certain regulatory controls weaker or stronger, and / or by adding/deleting specific regulatory controls entirely.

4. Many of the regulatory controls listed above apply to wind turbines also, and so the reader will see most of this context duplicated in the next section.

Table 3: Level of protection from Federal regulations that apply to PV systems. The values are in meters, and represent the distance from the feature to which the respective classification applies. For example, a value of '3' is applied to any area within 1000 meters of a communications tower.

Protection Level	Communication Tower	Airport
1	/	/
2	/	/
3	0 - 1,000	0 - 10,000
4	No data	No data
Sources	Technical Information and Coordination Process Between Wind Turbines and Radio communication and Radar Systems	TP 1247 E Aviation - Land Use in the Vicinity of Aerodromes

Table 4: Level of protection from Provincial regulations that apply to PV systems. The values are in meters, and represent the distance from the feature to which the respective classification applies. For example, utility-scale PV systems cannot be developed in Provincial Parks, and as such the entire park is excluded, hence a value of 0. In addition, an area within 120 meters of a Provincial Park would be tightly regulated, hence a value of '2' between 1-120.

Protection Level	Provincially significant wetlands	Provincial Parks	ANSI Earth	ANSI Life	Lakes & Kettle Lakes	Streams	Seepage Sites	Prime Agricultural Land
1	0	0	/	/	0-30	0-30	0-30	Classes 1-3
2	1-120	1-120	1-120	1-120	31-120	31-120	/	/
3	/	/	/	/	/	/	/	/
4	No data	No data	No data	No data	No data	No data	No data	Classes 4-7

*ANSI = Areas of Natural and Scientific Interest
Source: Environmental Protection Act O.Reg 359/09 – Renewable Energy Approvals

Table 5: Level of protection from Municipal regulations that apply to PV systems.

Protection Level	Open Spaces	Environmentally Protected Areas	Greenland / Natural Heritage System	Growth Plan Areas
1	/	/	/	/
2	0	0-120	0-120	0-30
3	/	/	/	/
4	No data	No data	No data	No data
Sources	Local Official Plans	Environmental Protection Act O.Reg 359/09 – Renewable Energy Approvals	Local Official Plans	Municipal Official Plans

The influence of regulatory controls on possibilities to develop PV systems will depend on in our study area is shown in Figure 8. Note that the map legend is presented as a pie chart which shows the area of land under each level of protection as described in Table 2.

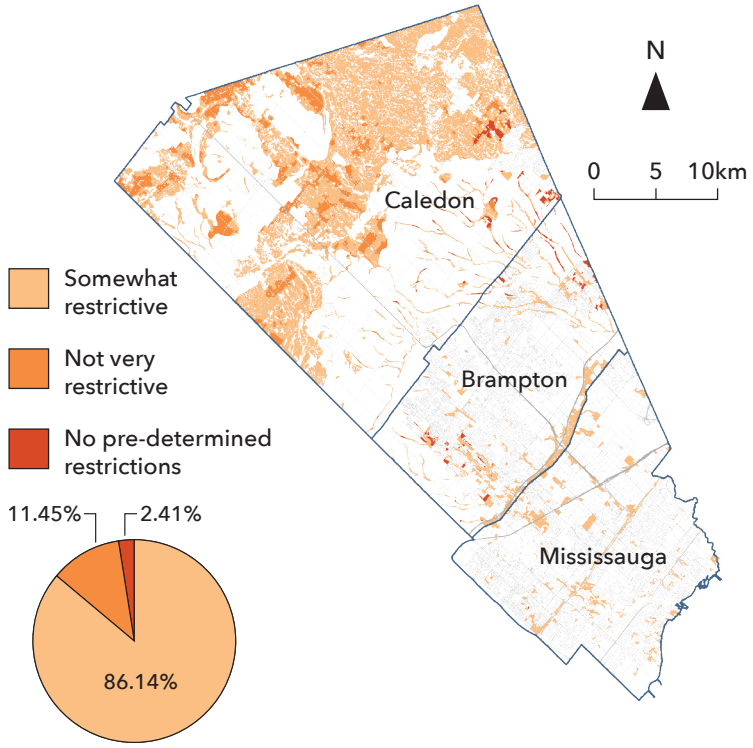


Figure 8

Legally-Accessible Resources Map

All areas legally restricted from hosting ground-mounted PV development have been removed from consideration, leaving only those areas that are legally accessible. In the remaining area, the darker the color, the fewer and looser the regulatory controls and the more likely development would be approved. See Table 2 for a description of the categories shown in the pie chart.

Mapping 'Relative Economic Value' of Accessible PV Resources

'Relative economic value' is broken down into two dimensions. First, a combination of site-specific factors that shape the costs of development – i.e., 'capital costs'. These are costs that will vary spatially, depending on where a PV system is located, and ultimately represent a relatively small proportion of total system costs relative to the costs of the panels and other installation materials. Our model accounts for factors related to site preparation (land clearing); building site access roads; and connection to the electricity grid. We have not been able to incorporate land acquisition costs due to limited data availability. Our model adds the cost of connecting to the grid, building access roads, and preparing the site. Table 6 below provides a breakdown of those costs.

The second dimension of relative economic value includes factors that might make one site more viable than another, even if those capital costs are equal – i.e., 'market readiness'. One example might be an area where locational marginal price of electricity is higher, indicating high demand and / or grid congestion issues that might be alleviated with a new distributed electricity generation system such as PV. In this study, we have not included any market readiness indicators.

The mapping process unfolds as follows:

1. Run cost distance tool, using the utility grid as the source layer. Be sure to include utility lines that are outside of your study area, since a system built in your study area could technically connect to those lines. The cost distance tool requires an input cost

raster, which is a cost-per-cell. The first cost is the cost of the line itself. We use a cost of $1100 per meter or 1.1 million dollars per linear kilometer of line. Note that this only includes the cost of the line, but not the cost of permitting and land acquisitions. There may be policies that do not allow for transmission lines to be built in certain areas. In this case, reclassify to a very high cost, to ensure they are avoided. For example, we assume that significant wetlands would not be crossed with a new transmission corridor, and so those areas would be assumed a very high value. The model would then be encouraged to go around these areas rather than through them. The tool will then calculate the cost of connecting from any given cell to the source layer (utility line)

2. Run cost distance tool, using the road network as the source layer. NOTE: Depending on your geographic context, you would also want to repeat these steps for the road network in order to estimate site access costs. Our study area is in a relatively developed region with sufficient road infrastructure to make this cost negligible and therefore not worth incorporating.

3. Apply a standard site-clearing and site preparation cost on a per cell basis. These costs are very small relative to other spatially varying costs and, as a result, are very unlikely to change the model outputs.

Table 6: Cost breakdown for PV resource development.

	Costs	Source
Transmission Lines	$1,000 - 1,200/Meter	Ontario Power Authority. (2005). Northern York Region Electricity Supply Study Submission to the Ontario Energy Board. York, Ontario. Retrieved from: https://www.oeb.ca/documents/cases/EB-2005-0315/exhibit_c_300905.pdf
Roads	$441.78/Meter	Values were obtained from an industry specialist in Ontario
Clearing Costs	Forest - $3,000/Acre	Haaren, R. V., & Fthenakis, V. (2011). GIS-based wind farm site selection using spatial multi-criteria analysis (SMCA): Evaluating the case for New York State. Renewable and Sustainable Energy Reviews, 15(7), 3332–3340. doi: 10.1016/j.rser.2011.04.010
	Shrub land - $1,000/Acre	
	Cropland - $40/Acre	
	Barren / sparse vegetation - $40/Acre	
	Grassland - $40/Acre	
	Pasture - $60/Acre	

4. Combine the outputs by summing all of these cost rasters. Make sure to keep only the sites that have already been deemed legally accessible. You can use raster calculator tool to multiply the combined cost distances with the regulated layer.

The combination of this map output and the output for 'legally accessible resources' communicate which sites/areas/regions are relatively more likely to be economical, and relatively less likely to impact existing protections, in the context of PV development. In other words, sites/areas/regions that appear dark on both maps are more likely to attract interest from a developer. We have identified two promising regions in the image below.

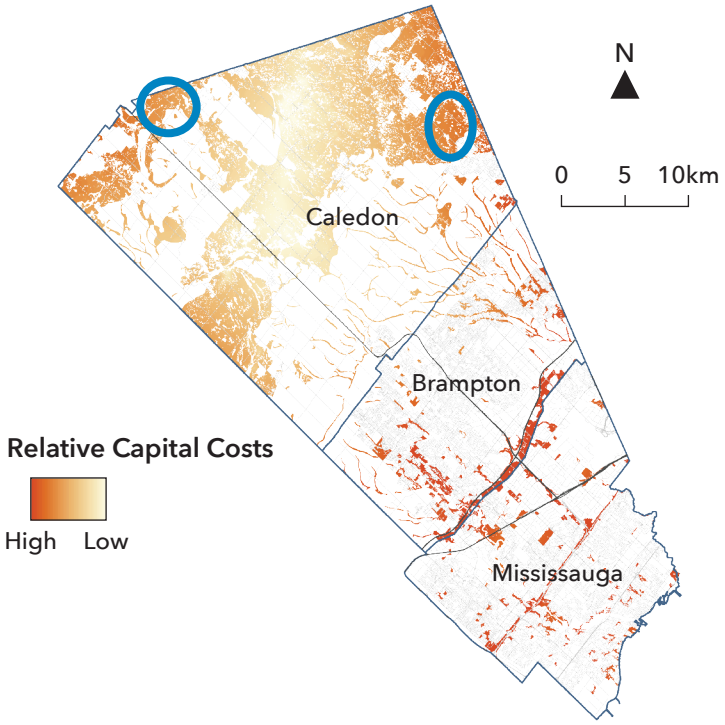


Figure 9

Relative Economic Value Map

Our assessment indicates that approximately 10,800 hectares of land are accessible for development, representing approximately 2,700 MW of potential installed capacity. Here we are also indicating areas most likely to receive interest from developers based on our modeled results – these areas are projected to be relatively lower in capital cost, and are in the most permissible areas according to existing regulations.

Mapping Policy Scenarios for PV Systems

Running multiple scenarios can help pinpoint the main regulatory obstruction to development for each technology, and can also help to understand the implications of land-use policy decisions on RE development potential in a specific area. The analysis described above is best considered the 'base case' against which any hypothetical changes or proposed changes to any renewable energy policies and regulations can be compared. For PV systems, the scenario analysis is primarily driven by two factors: whether or not to allow PV systems to be built on high quality agricultural land, and environmental protections. Our work uses a matrix to organize how these might be treated. Here, we are varying the setback distance requirement as well as strengthening protections on all ecological features that currently fall 'level 2' or 'somewhat protected' - i.e., we convert them into 'restricted'. See Table 7 for a description of these scenarios. We provide the outputs from only a few scenarios, to give the reader a sense of the kind of outputs that can emerge from this analysis.

Table 7: Descriptions of scenarios we are able to model to assess policy-technology dynamics for PV systems in Peel Region.

	With Regulatory Screening level 2	**Without Regulatory Screening level 2**
Excluding Prime Agricultural Land	**Solar Scenario 1** This map excludes prime agricultural land as defined by the Province of Ontario, which includes land classes 1-3 of the Canada Land Inventory.	**Solar Scenario 2** This map excludes prime agricultural land as defined by the Province of Ontario, which includes land classes 1-3 of the Canada Land Inventory, as well as areas with pre-defined environmental protections against ground mounted solar development.
Including Prime Agricultural Land	**Solar Scenario 3** This map includes prime agricultural land as defined by the Province of Ontario (i.e. classes 1-3 of the Canada Land Inventory), as well as all other agricultural land.	**Solar Scenario 4** This map includes prime agricultural land as defined by the Province of Ontario (i.e. classes 1-3 of the Canada Land Inventory), as well as all other agricultural land, and excludes areas with pre-defined environmental

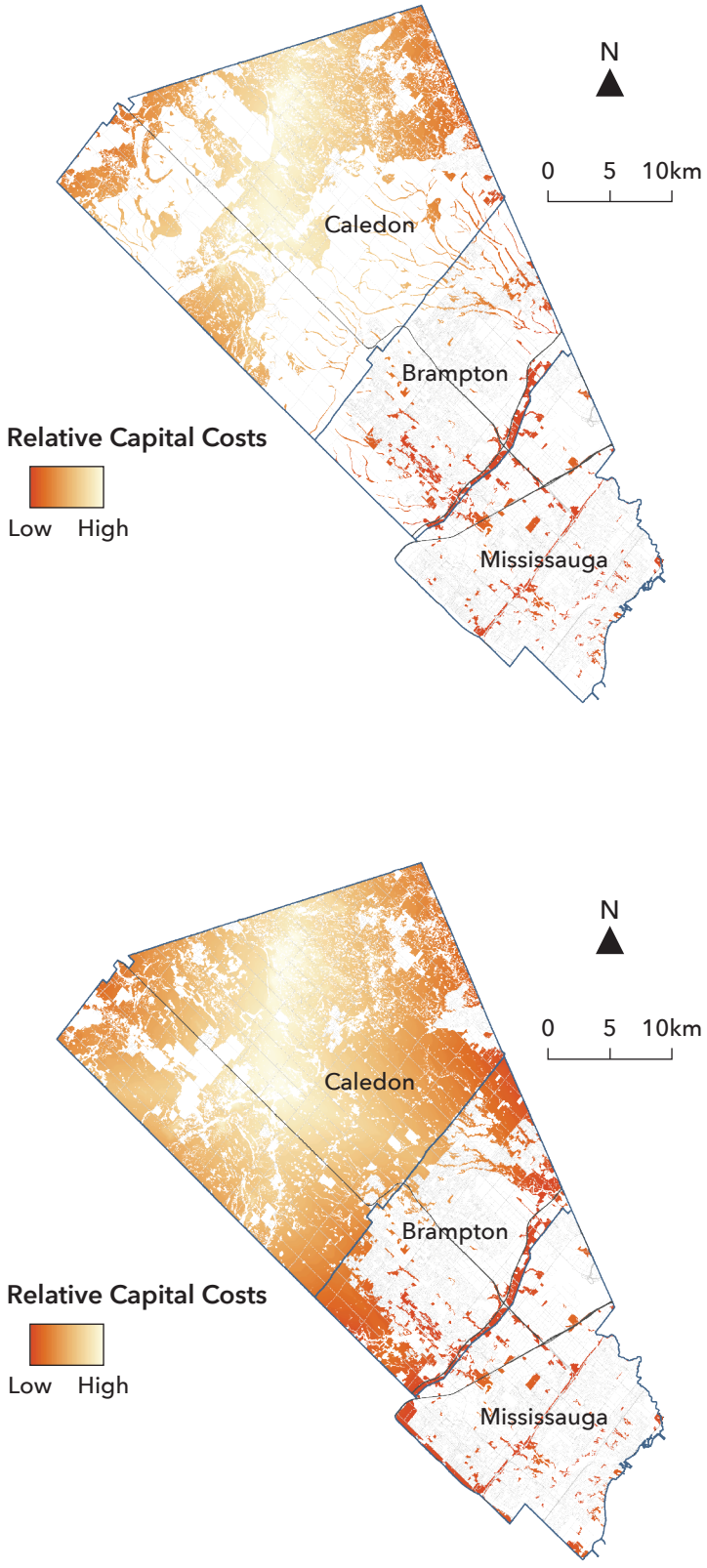
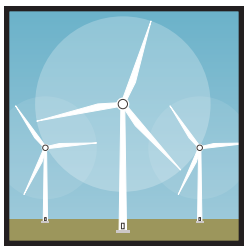


Figure 10

Relative Capital Costs Maps

Land availability for solar from excluding high quality agricultural land (top) and including high quality agricultural land (bottom).

Mapping Opportunities for Utility-Scale Wind Development



The process to map opportunities for utility-scale wind development is similar to PV, with some important differences. Given the nature of those differences, we have separated the two, even as much of the content is duplicated. The process is based on the same logic communicated in Figure 3 and Table 1.

Before proceeding with wind, it is important to consider the scale of the system, because area-based constraints are modeled in relation to specific technologies and system designs. For example, regulated set back distances for wind turbines would apply to all wind energy technologies, but they are likely to be further for larger wind turbines and for wind farms with more wind turbines, than they are for smaller wind turbines or wind farms with fewer turbines. In what follows, we are assuming 3MW turbines, with a hub height of 100 meters which is currently the standard commercial size for utility-scale on-shore wind systems.

Mapping Technically Recoverable Wind Resources

Technically recoverable wind resources are modeled based on the following exclusions:

- Areas with a slope above 35%. Steeper slopes would require additional supports or costly changes to the landscape.
- Land-cover types that are not capable of hosting utility-scale wind turbine for technical reasons, including:
  - Urbanized areas
  - Roads
  - Railways
  - Waterbodies
  - Aggregate extraction sites
  - Airports
  - Areas smaller than 1ha, which is the minimum size to host a 3 MW wind turbine

Since our data are in raster format, exclusions are modeled through data reclassification to NoData. Areas assigned to NoData will no longer be considered in the modeling process regardless of other characteristics those areas may have.

The impact of these exclusions on wind development opportunities depends on geographic context. The total land-area that is deemed 'accessible' in our study area after applying these exclusions is shown in Figure 11.

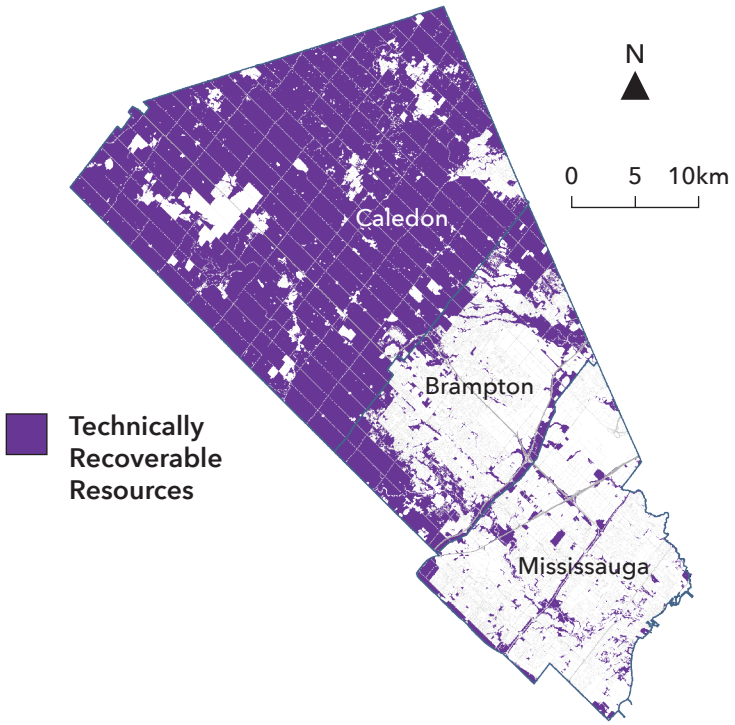


Figure 11
Recoverable Resources Map

Mapping Legally Accessible Wind Resources

An audit and analysis of land-use regulations from multiple levels of government is used to identify 'legally accessible' resources. 'Restricted areas' are removed from consideration through binary mapping, where the prohibited area is assigned 'NoData'. Not all regulations are clear 'go/no-go' decisions. Some regulations influence, rather than restrict, RE development – what we call 'regulated areas'. We map 'regulated areas' on a gradient based on the extent of their influence on RE resource access. The process unfolds as follows:

1. Identify all policies and regulations that apply to renewable energy development in a particular area. For our study, we identify these as 'Source' documents in the tables below.

2. Extract information about the specific natural features and land-cover/land-use categories to which the policies and regulations from step (1) apply.

3. Interpret the level of protection that each policy or regulation assigns to a given natural feature or land-cover/land-use category relative to renewable energy development. We have created four levels, described below in Table 8.

4. Gather digital spatial data on the natural features and land-covers/land-use categories identified in step (2). Using a geographic information system, assign the level of protection from step (3) accordingly and create a map of environmental protections for each policy / regulation.

5. Repeat step (4) for all policies and regulations, and their associated natural features and land-cover/land-use categories. See Tables 9-12 for a summary of the restricted and regulated areas that have been identified for wind turbines in our study area.

6. Combine all of the maps from step (5) into a single map, showing the levels of protection across all natural features and land-cover/land-use categories in the study area. Where multiple policies/regulations apply to the same natural feature or land-cover/land-use category, the most stringent protection level is applied. See Figure 12 for the final result.

Table 8: The classification system used to interpret and map restricted and regulated areas.

Regulatory Screening Level	Description	Example	Legend Label (see map)
1	Regulations inhibit RE development of all types or a specific type	The Province of Ontario has prohibited the development of PV farms on 'prime agricultural land'.	Restrictive
2	Regulations inhibit most forms of RE development with some exceptions.	The Province of Ontario has regulations that inhibit significant site alterations within 30 metres of a body of water, however, if an EIA demonstrated that the facility's environmental impact is minimal, then the facility may move forward with construction. As such, the 30m setback for bodies of water is a level 2	Somewhat restrictive
3	Regulations inhibit some forms of RE development, with more exceptions.	The Federal Government has a set of recommendations for the construction of wind farms in proximity to aerodromes. It is suggested that wind farms of more than 6 turbines should not be within 10km of a VOR facility, however, required consultations with the airport may result in the passing of a proposed wind farm within the recommended buffer. This makes the 10km setback a level 3.	Not very restrictive
4	There are no pre-determined regulations applying to RE, but an EIA will still be required	Open areas such as active or abandoned farmland that do not fall within any specific regulatory control relative to RE development.	No pre-determined restrictions

When accounting for regulated setback distances - e.g., from dwellings and 'noise receptors' or from sensitive habitats - it will be important to include spatial data for those specific features that lay outside of the boundaries of the study region. A wind turbine placed at the very edge of the municipal border may be far enough away from a dwelling within the municipality, but may be just meters away from a dwelling that is located within a neighbouring municipality.

In the series of tables below, we provide our interpretations of regulatory controls on wind energy development according to Federal, Provincial and Municipal regulations. At this point, a few issues should be noted:

1. It is difficult to discern between a 'level 2 – Somewhat restrictive' and a 'level 3 – not very restrictive'. The user may decide to simply merge these two levels, given how blurry the boundaries are between these categories. As indicated by the examples, however, we felt there are some cases in which an area is more likely to receive approval than others, which justifies more nuance in the categorization.

2. In many jurisdictions, RE technologies are not named specifically in regulations, but can be interpreted to fall under 'infrastructure development' generally.

3. Conducting a rigorous assessment of this sort enables analysis of the influence of policy change. Multiple scenarios can be developed simply by changing the values to make certain regulatory controls weaker or stronger, and / or by adding/deleting specific regulatory controls entirely.

Table 9: Level of protection from Federal regulations that apply to wind turbines. The values are in meters, and represent the distance from the feature to which the respective classification applies. For example, a value of '3' is applied to any area within 1000 meters of a communications tower.

Protection Level	Communication Tower	Airport
1	/	/
2	/	/
3	0 - 1,000	0 - 10,000
4	No data	No data
Sources	Technical Information and Coordination Process Between Wind Turbines and Radio communication and Radar Systems	TP 1247 E Aviation - Land Use in the Vicinity of Aerodromes

Table 10: Level of protection from Provincial regulations that apply to wind turbines. The values are in meters, and represent the distance from the feature to which the respective classification applies. For example, wind turbines cannot be developed in Provincial Parks, and as such the entire park is excluded, hence a value of 0. In addition, an area within 120 meters of a Provincial Park would be tightly regulated, hence a value of '2' between 1-120m.

Protection Level	Provincially significant wetlands	Provincial Parks	ANSI Earth	ANSI Life	Railway Network	Road Net-work	Lakes & Kettle Lakes	Noise Re-ceptors	Streams	Seepage Sites
1	0	0	/	/	0-80	0-80	0-30	0-550*	0-30	0-30
2	1-120	1-120	1-120	1-120	/	/	31-120	/	31-120	/
3	/	/	/	/	/	/	/	/	/	/
4	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data

*Noise receptors include residential dwellings, churches, and schools. A setback distance of 550 meters would apply to any wind turbine developed in the province. The setback distance would be further if the system included a large number of wind turbines – see Table 12 below
Source: Environmental Protection Act O.Reg 359/09 – Renewable Energy Approvals

Table 11: Level of protection from Municipal regulations that apply to wind turbines.

Protection Level	Open Spaces	Environmentally Protected Areas	Greenland / Natural Heritage System	Growth Plan Areas
1	/	/	/	/
2	0	0-120	0-120	0-30
3	/	/	/	/
4	No data	No data	No data	No data
Sources	Local Official Plans	Environmental Protection Act O.Reg 359/09 – Renewable Energy Approvals	Local Official Plans	Municipal Official Plans

Table 12: Setback distances for wind turbines according to Provincial regulations in Ontario. The distance is based primarily on the anticipated sound power level from each turbine which itself is dependent on wind speed and wind direction. Turbine manufacturers will publish their sound power level specs for planning purposes.

Sound power level	1 to 5 turbines within 3km	6 to 10 turbines within 3km	11 to 25 turbines within 3km	26+ turbines within 3km
102 dBA	550m	650m	750m	Noise study required
103-104 dBA	600m	700m	850m	Noise study required
105 dBA	850m	1000m	1250m	Noise study required
106-107 dBA	950m	1200m	1500m	Noise study required
>108 dBA	Noise study required	Noise study required	Noise study required	Noise study required
Sources	Local Official Plans	Environmental Protection Act O.Reg 359/09 – Renewable Energy Approvals	Local Official Plans	Municipal Official Plans

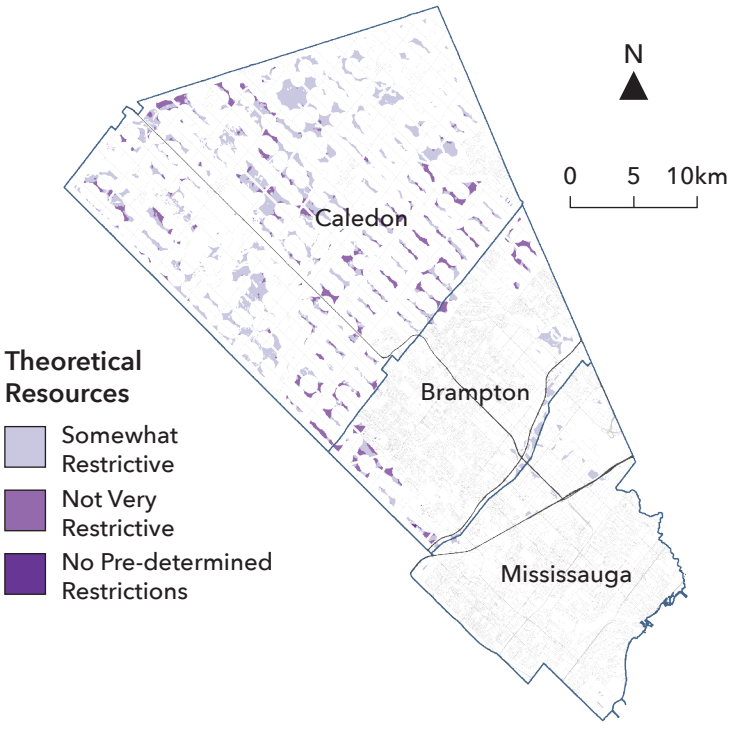
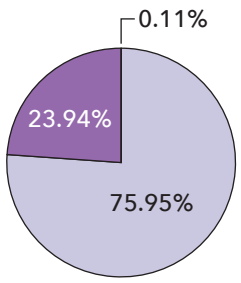


Figure 12

Legally-Accessible Resources Map

This map excludes land within 550m of noise receptors (e.g. dwellings, school etc.). The pie chart is communicating area of land under each category.



Mapping 'Relative Economic Value' of Accessible Wind Resources

'Relative economic value' is broken down into two dimensions. First, a combination of site-specific factors that shape the costs of development – i.e., 'capital costs'. These are costs that will vary spatially, depending on where a wind turbine is located. As with PV systems, the spatially varying costs are a relatively small proportion of total system costs. Our model accounts for factors related to site preparation (land clearing); building site access roads; and connection to the electricity grid. We have not been able to incorporate land acquisition costs due to limited data availability. Our model adds the cost of connecting to the grid, building access roads, and preparing the site. The table below provides a breakdown of those costs.

Table 13: Cost breakdown for wind resources development.

	Costs	Source
Transmission Lines	$1,000 - 1,200/Meter	Ontario Power Authority. (2005). Northern York Region Electricity Supply Study Submission to the Ontario Energy Board. York, Ontario. Retrieved from: https://www.oeb.ca/documents/cases/EB-2005-0315/exhibit_c_300905.pdf
Roads	$441.78/Meter	Values were obtained from an industry specialist in Ontario
Clearing Costs	Forest - $3,000/Acre	Haaren, R. V., & Fthenakis, V. (2011). GIS-based wind farm site selection using spatial multi-criteria analysis (SMCA): Evaluating the case for New York State. Renewable and Sustainable Energy Reviews, 15(7), 3332–3340. doi: 10.1016/j.rser.2011.04.010
	Shrub land - $1,000/Acre	
	Cropland - $40/Acre	
	Barren / sparse vegetation - $40/Acre	
	Grassland - $40/Acre	
	Pasture - $60/Acre	

The second dimension of relative economic value includes factors that might make one site more viable than another, even if those capital costs are equal – i.e., 'market readiness'. One example might be an area where locational marginal price of electricity is higher, indicating high demand and / or grid congestion issues that might be alleviated with a new distributed electricity generation system such as wind turbines. In this study, we have not included any market readiness indicators.

The mapping process unfolds as follows:

1. Run cost distance tool, using the utility grid as the source layer. Be sure to include utility lines that are outside of your study area, since a system built in your study area could technically connect to those lines. The cost distance tool requires an input cost raster, which is a cost-per-cell. The first cost is the cost of the line itself. We use a cost of $1100 per meter or 1.1 million dollars per linear kilometer of line. Note that this only includes the cost of the line, but not the cost of permitting and land acquisitions. There may be policies that do not allow for transmission lines to be built in certain areas. In this case, reclassify to a very high cost, to ensure they are avoided. For example, we assume that significant wetlands would not be crossed with a new transmission corridor, and so those areas would be assumed a very high value. The model would then be encouraged to go around these areas rather than through them. The tool will then calculate the cost of connecting from any given cell to the source layer (utility line).

2. Run cost distance tool, using the road network as the source layer. NOTE: Depending on your geographic context, you would also want to repeat these steps for the road network in order to estimate site access costs. Our study area is in a relatively developed region with sufficient road infrastructure to make this cost negligible and therefore not worth incorporating.

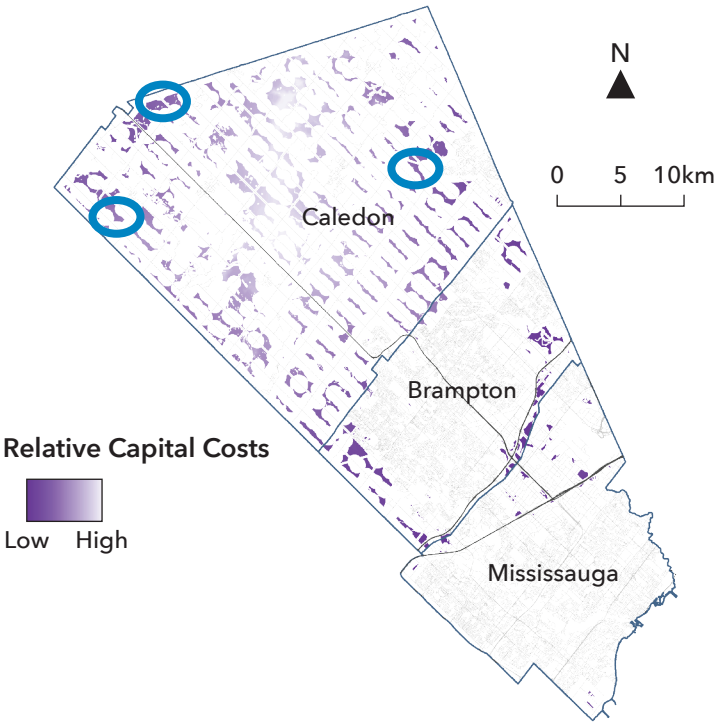
3. Apply a standard site-clearing and site preparation cost on a per cell basis. These costs are very small relative to other spatially varying costs and, as a result, are very unlikely to change the model outputs.

4. Combine the outputs by summing all of these cost rasters. Make sure to keep only the sites that have already been deemed legally accessible. You can use raster calculator tool to multiply the combined cost distances with the regulated layer.

The combination of this map output and the output for 'legally accessible resources' communicate which sites/areas/regions are relatively more likely to be economical, and relatively less likely to impact existing protections, in the context of wind turbine development. In other words, sites/areas/regions that appear dark on both maps are more likely to attract interest from a developer. We have provided a few indications on the map where these conditions present themselves.

Figure 13

Relative Economic Value Map



Mapping Policy Scenarios for Wind Farms

Running multiple scenarios can help pinpoint the main regulatory obstruction to development for each technology, and can also help to understand the implications of land-use policy decisions on RE development potential in a specific area. The analysis described above is best considered the 'base case' against which any hypothetical changes or proposed changes to any renewable energy policies and regulations can be compared. For wind, the scenario analysis is primarily driven by two factors: set back distances from noise receptors and environmental protections. Our work uses a matrix to organize how these might be treated. Here, we are varying the setback distance requirement as well as strengthening protections on all ecological features that currently fall 'level 2' or 'somewhat protected' - i.e., we convert them into 'restricted'. See Table 14 for a description of these scenarios. We provide the outputs from only a few scenarios, to give the reader a sense of the kind of outputs that can emerge from this analysis.

Table 14: Descriptions of scenarios we are able to model to assess policy-technology dynamics for wind farms in Peel Region.

	With Regulatory Screening level 2	Without Regulatory Screening level 2
550m Setback	**Wind Scenario 1** This map excludes land within 550m of noise receptors (e.g. dwellings, schools etc.).	**Wind Scenario 2** This map excludes land within 550m of noise receptors (e.g. dwellings, schools etc.), as well as any area with predefined formal protection against wind turbine development.
1,000m Setback	**Wind Scenario 3** This map excludes land within 950m of noise receptors (e.g. dwellings, schools etc.).	**Wind Scenario 4** This map excludes land within 950m of noise receptors (e.g. dwellings, schools etc.), as well as any area with predefined formal protection against wind turbine development.
15,000m Setback	**Wind Scenario 5** This map excludes land within 1500m of noise receptors (e.g. dwellings, schools etc.)	**Wind Scenario 6** This map excludes land within 1500m of noise receptors (e.g. dwellings, schools etc.), as well as any area with predefined formal protection against wind turbine development.

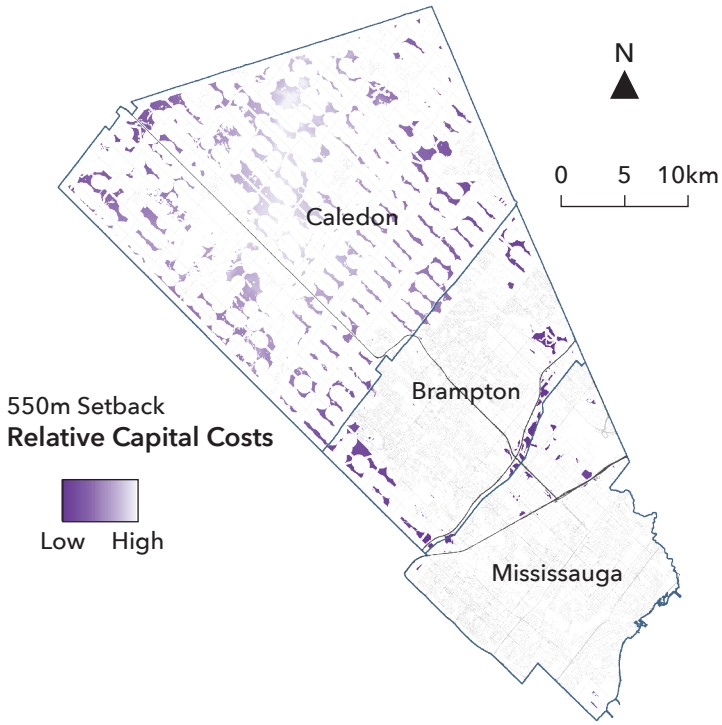


Figure 14

Wind Scenarios Maps

Available land decreases as setback distances from noise receptors increase. This figure shows the base case 550m setback for wind (this page), scenario 3 with a 950m setback and scenario 5 with a 1500m setback (next page). Notice that under the strictest set back distances, no land is accessible for wind turbines in this region.

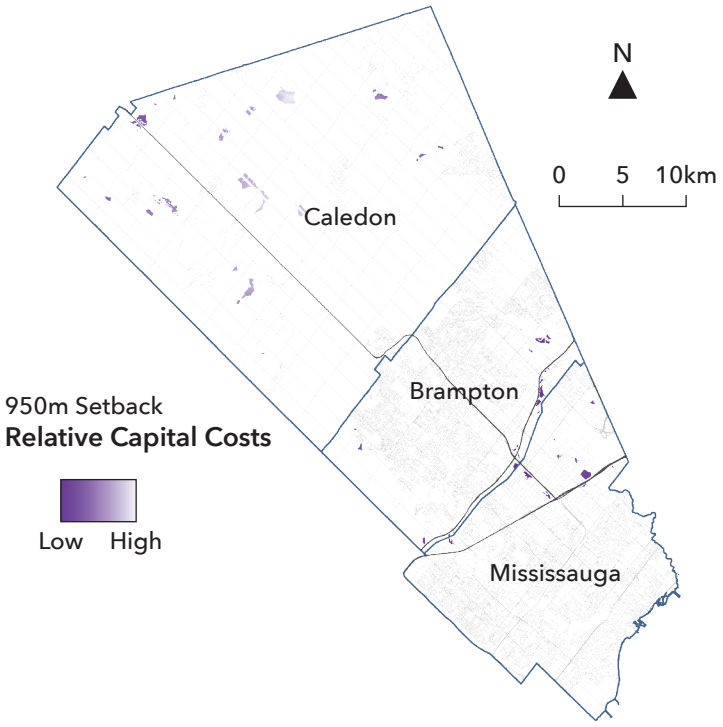
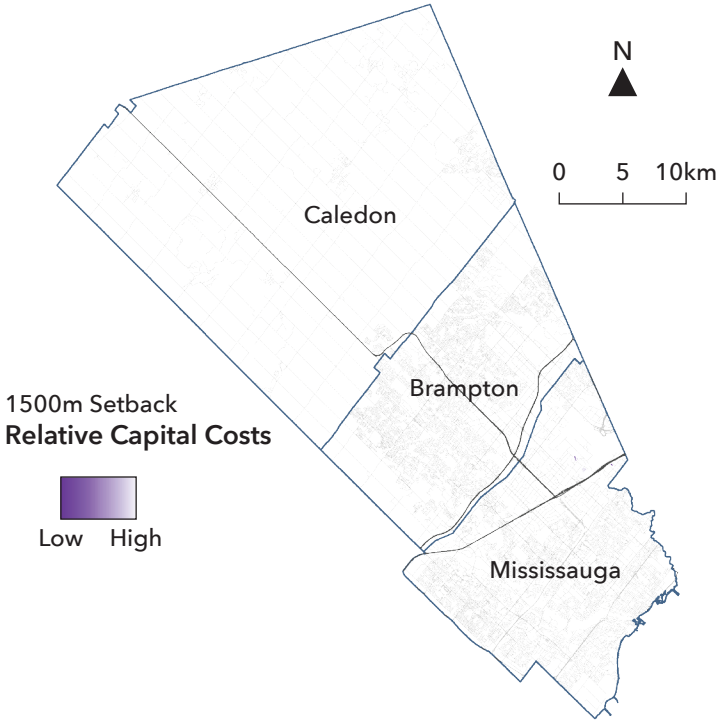
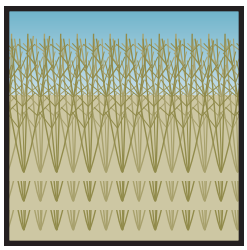


Figure 14 contiued

Wind Scenarios Maps



Mapping Opportunities for Biomass Energy Development



The process to map opportunities for biomass energy development is very different from the process to map opportunities for PV or wind energy. The difference is primarily rooted in the fact that biomass can be transported – i.e., it does not need to be converted on-site. Furthermore, biomass can be converted in solid, liquid, or gaseous fuels (pellets, ethanol, biogas), or burned directly and used for heat. Although the same general logic applies, the mapping process.

For this project, we are considering only agricultural residues including stover (residues left over after corn harvest) and straw (residues left over after harvesting wheat or barley). In this way, we mostly avoid the issue of using food for fuel; the kinds of resources we are considering are inedible for humans. That said, more detailed assessments would be required in order to understand the quantity of residue that might be used without harming other markets such as animal feed of bedding.

Mapping Technically Recoverable Biomass Resources

The methods calculate available biomass within a study area, and derive supply-distance curves relative to a particular site.

Extract a 'fuel-shed'. In general, it is possible to transport agricultural residues up to 150km; if the travel distance is further, it will be too costly and / or require too much energy. Hence, we estimate total availability within a 150km radius of the region – this radius is what we call a 'fuel-shed'. The fuelshed is centered on the study area (will explain why later).

Clip the 'theoretical biomass resources' layer (see above) to the fuelshed and reclassify spatial crop data into masks that represent the spatial distribution of Canola, Cereals, and Corn. Cereals include Barley, Oats, Rye, and Spring and Winter Wheats. These masks will be used to extract information for stover and cereals, respectively. This is important, because some biomass conversion technologies are better suited for stover, others for straw.

Join known crop residue rates to the spatial masks. Crop residue rates are available here in a CSV, for all crops in all counties across Ontario. These are derived per the following: calculate the 8 year average yield of a given crop for a given county; convert from bushels/acre to tonnes/acre; apply a residue production factor, which estimates the amount of residue produced for a given yield of crop; take only 30 per cent of that value; and convert from tonnes/acre into a tonne/cell unit (in this case, 30m). That value, the tonne/cell unit, is what we've made available in this spreadsheet.

2016 Statistics Canada Census Division boundaries covering the study area, stored as a polygon feature class in the project file geodatabase. The key field CDUID links tabular residue yields back to this layer.

We acquire the annual crop yield data. For automation purposes, field headings must follow

the format "Cropname_CropCode", where CropCode is the AAFC class code for a particular crop. These final values are stored as a standalone table in the project file geodatabase. The key field CDUID links these data to the polygon boundaries. A custom Python script for ArcGIS automates the process to generate biomass residue distribution maps for Canola, Cereals, and Stover. Currently this script is hard-coded, meaning that application to other study areas requires minor edits to the code itself. Future work will refine this into a stand-alone tool.

Compute total available tons of biomass residue at various driving distances (5 km, 10 km, 15 km, 20 km, 25 km, 30 km, 40 km, 50 km, 75 km, 100 km, 125 km, and 150 km) from a given study point, in this case the geographic centroid of the Region of Peel. Minor post processing is required to convert script outputs from above to total residue supply within the service area for each distance listed. Service area polygons are calculated (pre-processed) for each of the 12 distances listed above by creating a basic travel network using ArcGIS Network Analyst and publically available road data. Due to the scale of this work, detailed network data governing turn restrictions, one-way streets, etc. are not necessary.

Mapping Legally Accessible Biomass Resources

Currently, there are not any regulations that restrict access to biomass residues. Our analysis does, however, consider non-regulated sustainability concerns in two ways:

1. We do not assume conversion of land into biomass energy production, but rather assume that biomass would come from the existing agricultural land base.

2. We limit the recovery of biomass residues to only 30 per cent of what would be theoretically available. In this way, we ensure that at least 70 per cent of the residue base is left on the field to maintain soil nutrient levels.

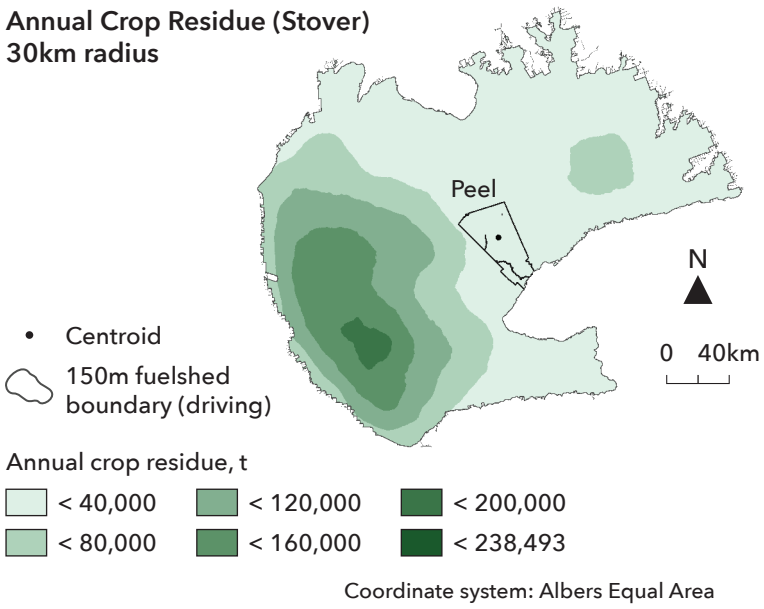
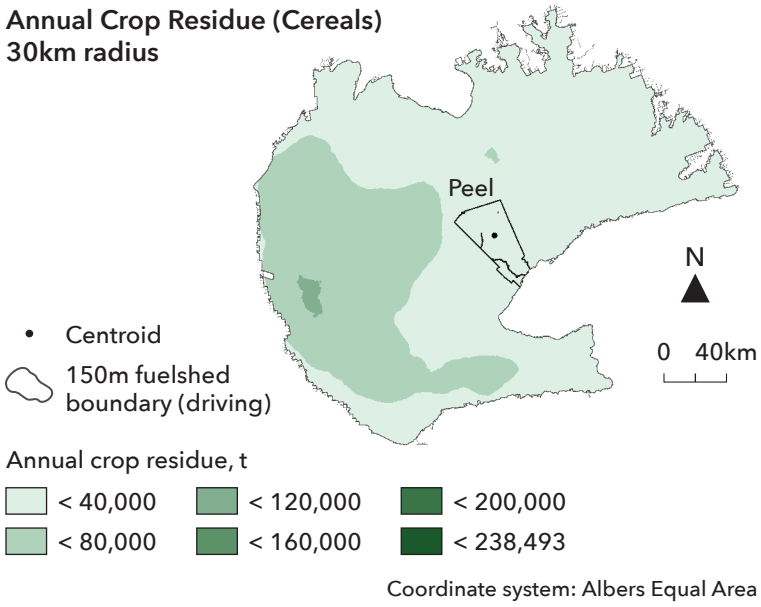


Figure 15
Recoverable Resources Maps

Spatial density of biomass resources over a 30km collection radius show that the resource is in its highest concentration in the southwest portion of the fuelshed.



Mapping 'Relative Economic Value' of Biomass Resources

With total available biomass at each distance (supply-distance) computed for stover and straw, respectively, it is now possible to calculate supply-cost curves for each of these resources. This calculation uses an excel spreadsheet, made available here, which includes all cost assumptions as well as the ability to change those assumptions.

Agricultural residues can be converted into any number of biofuels, including pellets or ethanol (a liquid fuel). Here we are assuming they will be converted into ethanol. The bar graph below is estimating the size of the ethanol conversion facility that can be established depending on the cost that a facility is willing. This bar graph is based on many assumptions about production and transport costs, which can be examined in this spreadsheet.

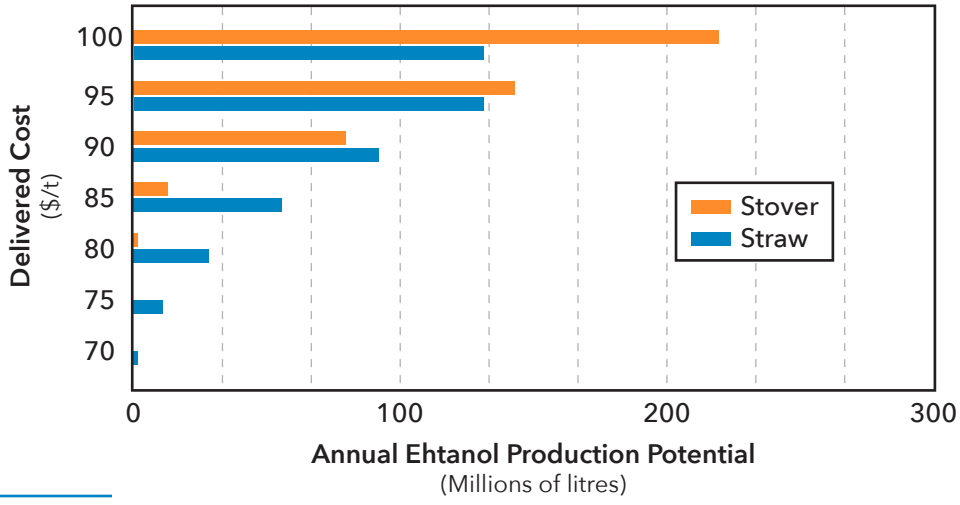


Figure 16
Recoverable Economic Value

Part 2: Participatory Mapping and 'Relative Social Potential' of Renewable Energy Development

Context and Overview

As market and policy changes facilitate more RE development, local landscapes and land-use systems are changing. Agricultural land will be utilized for solar farms. Regions that attract tourists for their scenic vistas are now hosting wind turbines. New biomass-to-energy production facilities are appearing in small towns. Some of these changes are supported by local communities, while others are opposed and divisive. Opposition to new renewable energy projects is strongest when community members are not incorporated into the planning process. This opposition can delay and, in some cases, deny projects entirely. In turn, this slows the pace at which the transition toward renewable, low-carbon energy systems can occur and constrains climate change mitigation at a broad scale. Research suggests that collaborative and inclusive planning processes are more likely to generate public support for RE development.

In the context of the integrated framework described in Phase 1 of the Guidebook, the purpose of this Section is to describe how participatory mapping is used to assess 'relative social potential' for RE development in a particular area. The goal of this exercise is two-fold: 1) engage and hopefully mobilize the general community and key stakeholder groups through a highly interactive, place-based approach; and 2) create a GIS output that is easily integrated into the technical mapping exercise described in Part 1 of the guidebook. The tools and techniques described here are so much more than a mapping exercise: they provide an opportunity to facilitate cross-sector and community-wide dialogue about RE development and energy transitions generally, and to raise awareness of the opportunities and challenges that come along with it. The map products themselves, although directly useful, might be considered secondary to the community-based process through which they are created. In other words, this section of the guidebook will provide local governments and local planners with guidance on how to develop and implement collaborative and inclusive RE spatial planning processes.

Our **principles of public engagement** are:

- Foster a place-based conversation, by speaking about places and landscapes that matter to people
- Focus on preferences rather than problems
- Elicit narratives and stories rather than diatribes
- Take the engagement on-the-road and into public spaces, working hard to involve individuals and groups that are not always 'heard' in town-halls or public meetings
- Move from awareness raising to mobilization, aiming to help individuals and organizations find a role for themselves in the energy transition

The participatory mapping process unfolds in three stages, described in Table 15; as illustrated below, each stage operates through different channels, and has different objectives depending on the nature of engagement. In all cases, the process centers around a map that indicates to the participants where, according to technical analysis from Part 1, new RE systems are most likely to be viable. The challenge now is to identify the conditions under which community members, key organizations, and key decision-makers are likely to support the development of those resources. You can use this document to help you organize the kinds of engagement activities we describe below.

Table 15 - Participatory mapping process.

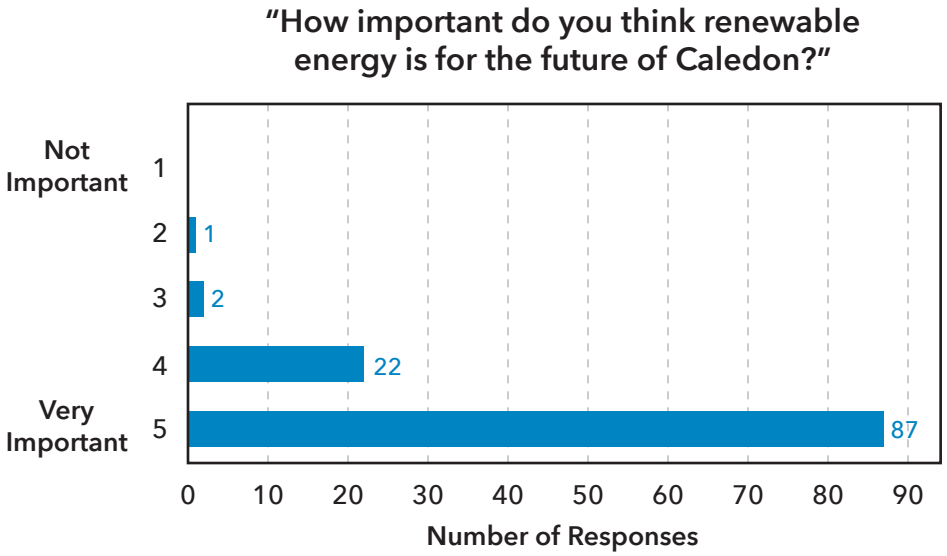
	Community Engagement	Stakeholder Engagement	Capacity-holder Engagement
Who?	Individuals entitled to participate in discussions about major changes to their local landscape	Individuals / organizations who stand to directly gain or lose from decisions about RE development	Individuals / organizations who possess resources and mandates that can drive RE projects
Why?	• Identify key concerns across population • Raise awareness	• Discuss specific issues and impacts, including options to mitigate	• Facilitate cross-sector dialogue to identify common opportunities
How?	• Bring information to community spaces (library, farmer's market) • Open-ended surveys	• Targeted invitations to key constituencies • Focus group centered on specific theme / issue	• Targeted invitations to key constituencies • Focus group centered on specific theme / issue

Participatory Mapping and Community Engagement

Although community engagement centers on a mapping exercise, we begin with a survey that is used to assess pervasive narratives around RE generally. See Figure 17 for examples of the kind of information that can be derived from this survey. It combines typical likert-scale questions with open-ended questions. The survey is administered at various public spaces, using a tablet computer. Respondents submit their answers with support from a researcher, but without directly communicating to the researcher. This allows for some anonymity in the survey responses and hopefully encourages respondents to be honest. At the same time, administering the survey in person helps to facilitate conversations, along with opportunities for shared learning and correcting common misperceptions about specific technologies. In the meantime, this personal approach builds good-will among the community, because someone has taken time to bring the survey to them. Future iterations of this methodology will, however, also include an online option to increase accessibility to the survey.

Responses to the open-ended questions will need to be organized in order to extract key themes that can be communicated to decision-makers. We suggest using the organizational framework below, called the VESPA model, which is based on recent academic research. It encapsulates the major themes that tend to arise in relation to renewable energy: visual aspects (e.g., landscape impacts), environmental aspects (e.g., impacts on wildlife), socioeconomic aspects (e.g., distribution of costs and benefits), and procedural aspects (e.g., transparency of the decision-making process). Simple frequency counts provide a sense of the relative prevalence of these themes in the sentiment shared by respondents. Perhaps more importantly, responses are coded a second time to determine whether they are negative, positive, or conditional. Again, simple frequency counts provide a sense of whether the sentiment in general was more positive or negative. But the 'conditional' category is especially important. Here, you would include a comment such as "I support renewable energy, but not if it is owned by a major company. I want it to be community owned". These sorts of statements help to understand the conditions under which individuals are likely to support or oppose a project.

Coupled with this rapid response survey, participants placed a marker on a mounted paper map (see Figure 18) to indicate their concerns and preferences around possible PV development opportunities. In red, they indicated where they did not want to see new PV systems developed and in green they indicated where they would like to see new PV systems developed. Now we have information about the locations at which the community is likely to support or oppose a project. As you can see, a few locations had clusters of indicators which suggest more interest, either positive or negative.



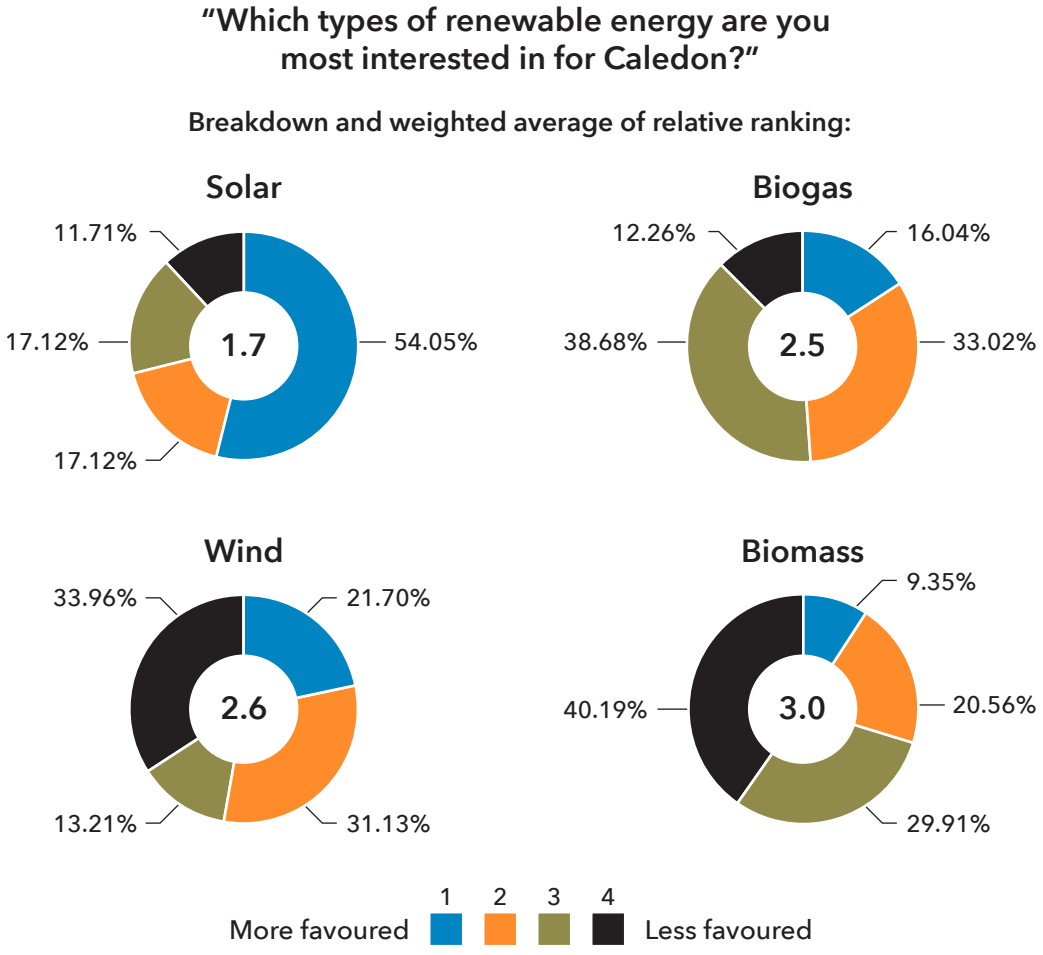
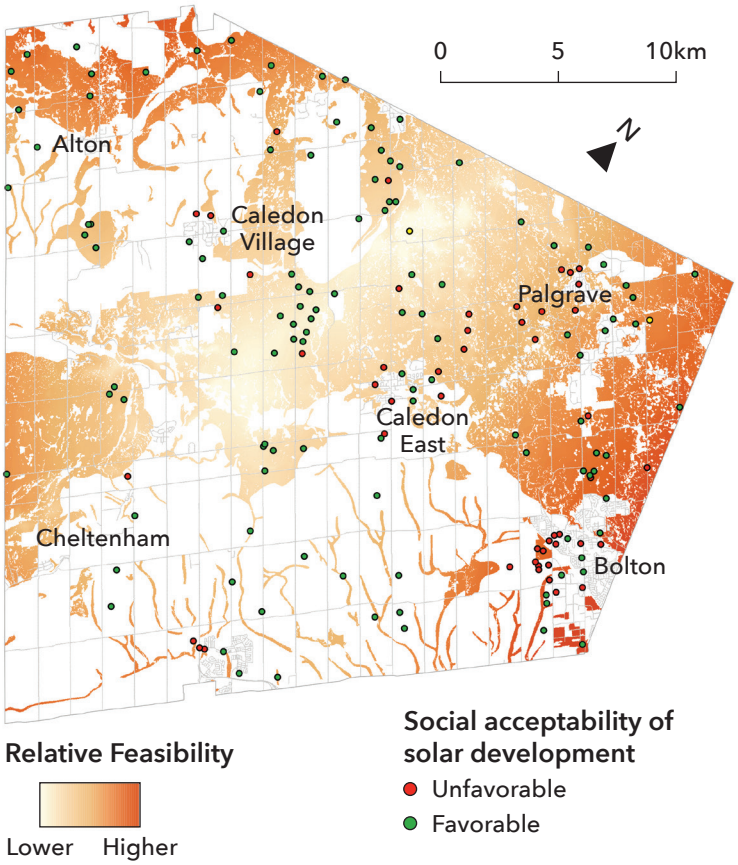


Figure 17 - Example output from our online/paper-based survey. In these examples, we are able to 'take the pulse' of local residents in terms of their sentiment toward renewable energy, and gather information on the kinds of technologies that local residents feel are most appropriate for their region.

Figure 18

Community Perspective Map

Mapping results from community engagement. Blue stars indicate locations at which a booth was set up to receive input from the community. There are a few clusters of green (favorable) indicators which, when overlayed on the map of relative technical feasibility, help to identify locations that are more technically feasible and more socially acceptable for development. Note in particular the cluster of green just north of Bolton, which is also highly technically suitable.



This information provides a starting point for planners, policy-makers and developers as they enter into decision-making processes and work with communities on specific projects. Perhaps more importantly, the process helped to raise awareness about RE development, which gets the community thinking about the subject and prepared to enter into higher level conversations as specific projects are considered.

Participatory Mapping and Stakeholder Engagement

Our work focuses primarily on two stakeholder groups: farmers and naturalists / recreationalists. These two groups have historically been at the 'front lines' of support and opposition to RE systems, primarily because they have a very intimate relationship with the landscape that is so fundamentally altered by RE technologies. Focus-group style participatory mapping is used as a way to engage deeply and foster peer-to-peer knowledge exchanges.

The process unfolds in two parts. First, participants are provided with an individual map. They are given time to place indications on the map and answer a couple high-level questions. In this way, we allow the participant to gather their thoughts before moving to the focus group. In addition, we ensure that every individual has an opportunity to be heard. If we moved straight to the focus group, we run the risk of the responses being dominated by one or two strong personalities around the table. After completing their individual map, participants are asked

to engage in a group discussion. The group discussion is fairly unstructured, but we typically start with searching for any areas where there is consensus, either positive or negative. Either a compilation of individual maps, or the final group map, can then move forward as a piece that can be combined with the community map, and with the technical map, to provide some direction when it comes time to plan for RE development in a region. An example of what that might look like is shown below. The written responses are used to identify the individual and shared sentiments that underlies the indicators on the maps. Here, again, the VESPA framework can be used to organize those responses.

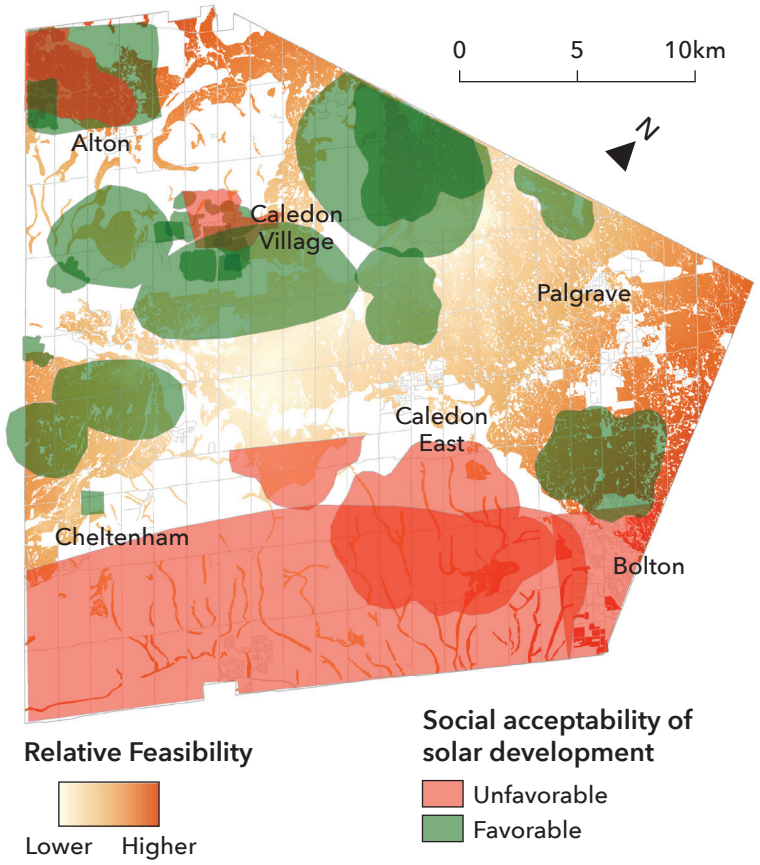


Figure 19

Stakeholder Perspective Map

Mapping results from stakeholder engagement. This is showing an overlay of all of the individual maps produced by stakeholders in the focus group meeting. Darker colors indicate multiple individuals indicated a particular site. Note again the favorable indications in the region north of Bolton.

Participatory Mapping and Capacity-Holder Engagement

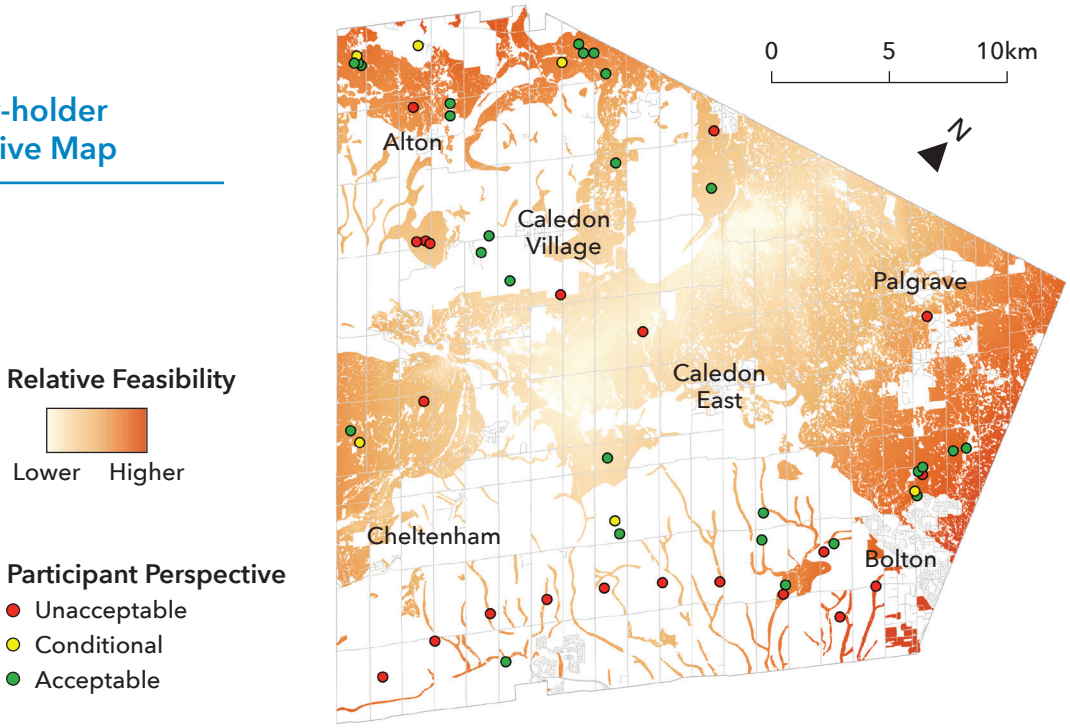
RE projects are only developed if/when individuals and organizations that hold 'capacity' facilitate them – e.g., if land-owners choose to participate; if developers are willing to invest at a location; if the electric utility company enables connection; if planners zone accordingly; and so on.

Similar to stakeholder mapping, engaging capacity holders unfolds in a two-part process. First, participants are provided with an individual map. They are given time to place indications on the map and answer a couple high-level questions. In this way, we allow the participant to gather their thoughts before moving to the focus group. In addition, we ensure that every individual has an opportunity to be heard. If we moved straight to the focus group, we run the risk of

the responses being dominated by one or two strong personalities around the table. After completing their individual map, participants are asked to engage in a group discussion. The group discussion is fairly unstructured, but we typically start with searching for any areas where there is consensus, either positive or negative. Either a compilation of individual maps, or the final group map, can then move forward as a piece that can be combined with the community map, and with the technical map, to provide some direction when it comes time to plan for RE development in a region. An example of what that might look like is shown above. The written responses are used to identify the individual and shared sentiments that underlies the indicators on the maps. Here, again, the VESPA framework can be used to organize those responses.

Figure 20

Capacity-holder Perspective Map



Our capacity-holder focus-group allows us to identify specific areas that might be of common interest among these enablers, as you can see on the map. By engaging these individuals separately, rather than as part of community and stakeholder engagement, we reduce the chance that these 'experts' will dominate the conversation at a public meeting and ensure that we are separating their role as the audience of the community and stakeholder mapping stages, but also as contributors to the overall mapping process.

Summary of Phase 2

Renewable energy development has been subject to significant public opposition, expressed as site-level demonstrations, explosive town hall meetings, and Municipalities declaring themselves 'unwilling hosts' of wind farms. Opposition is common to all forms of development. But for many, the strength of the opposition to RE was surprisingly widespread given that opinion polls had indicated widespread support for RE development. In literature this is called the 'social gap' problem: i.e., the gap between support in general, but opposition to specific projects. This gap was widened in Ontario in large part because communities did not feel they had a voice in the decision-making process, and the benefits of development were limited to land-owners and developers even as the impacts were felt by the entire community. One way to close the gap around opposition-support for renewables is to ensure meaningful engagement at the agenda-setting stage of RE development.

The two-phase approach described above offers a framework through which to incorporate community and stakeholder voices into spatial and land-use planning process in a way that tries to balance the need to develop RE at scale, with the desire to limit its impacts on local landscapes and the people who derive meaning and livelihood from those landscapes. In theory, the outputs from all stages of participatory mapping can be combined, to show high density of 'green' and therefore willingness to accept a project. That said, these outputs do not provide answers – i.e., they do not in and of themselves make a decision about where the next RE system will be implemented. But they are a way to advance the conversation across communities and stakeholder groups, and they are crucial inputs into local land-use and energy planning.


CEKAP
Community Energy Knowledge - Action Partnership