GRID INNOVATION FUND
POWERING GREENHOUSE SECTOR EXPANSION WITH DISTRIBUTED ENERGY RESOURCE SOLUTIONS

University of Windsor

Environmental Energy Institute

Turbulence and Energy Lab

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1. Executive Summary

The overarching objective of this project is to further enable the planned rapid economic expansion of Ontario's Greenhouse Sector through the delivery of innovative distributed energy resource (DER) project options. These options will be positioned improve energy flexibility, efficiency, and resilience. Recently, applications for expansion and increased demand of the greenhouse industry in the Leamington/Kingsville area have challenged the capacity of central grid infrastructure expansion. Installing DERs can allow greenhouses to provide their own power and assist with the growing demand by supplying excess electricity to others through grid interconnection. This helps alleviate massive grid infrastructure modifications as well as major utility upgrades; and increases available electricity for the sector's needs. Modeling a hypothetical five-grower greenhouse network in Leamington, ON, illustrated that a connected DER architecture could provide a reduction in design sizing, excess electricity, and fuel consumption with millions saved on capital spending. DERs can be strategic in the planning of future electrical grid supply and the growth of the Ontario Greenhouse Sector.

2. Introduction and Goal

2.1 Introduction

The Leamington/Kingsville area is home to the greatest concentration of greenhouses in North America. Over 3500 acres of under glass agriculture accounts for $2B in economic activity in the province. The sector is undergoing rapid expansion and transformation. Individual operations are increasingly integrating supplemental lights to extend daily and seasonal growing times. A significant portion of operations are also becoming automated, from packing processes to harvesting routines. These non-trivial load additions are being multiplied through massive expansions of the sector. Planned expansions will exceed the capacity of centralized grid infrastructure to meet new loads that have been drastically increased by crop lighting. To meet this demand with conventional grid supplied electricity will require the buildout of new transmission infrastructure.

New transmission lines and infrastructure upgrades for the region have been approved. While this should be acknowledged, the future expansion requirements of the sector are difficult to predict. It is presently unrealistic to expect completion of a transmission project of this magnitude in the time frame required. For this reason, a flexible and adaptable solution is important in the efforts to develop a resilient and reliable distribution system that meets the needs of current and future customers. This project will provide insights for how to integrate resources and maximize the value of new relationships between agencies and system variables to optimize sustainable electricity supply between central and decentralized solutions.

Significant benefits can be realized by aggregating multiple prosumer behind-the-meter technology such as DERs. While the benefits are notable, there are significant barriers, especially in the highly competitive agricultural sector. This project aspires to connect growers while maintaining confidentiality surrounding sensitive growing practices. Another challenges is a lack of knowledge of how growers can optimally use their DER assets to benefit their operations, which this project will examine. Growers who are looking to expand at a rate faster than what new transmission can provide will be particularly interested in overcoming any obstacles to the meet the needs of their operations. Furthermore, from an economic development perspective, this project fits into local initiatives to enhance agri-business in Essex County and increased awareness of the many benefits of growing in the region. The outcomes from this project will address several of Ontario's energy initiatives and will drive progress towards building a strong culture of innovation in the sector.

2.2 Goal

The goal of this project is to enable and bolster the economic expansion of Southwestern Ontario's Greenhouse Sector through the strategic development and engagement of new and existing distributed energy resources. Successful outcomes from this program will highlight options that may reduce reliance on grid supplied electricity and enable the deferral of costly transmission infrastructure construction; mitigating additional costs that could be shouldered by the ratepayer.

3. Approach/Methodology

The Leamington/Kingsville region of Ontario is home to the highest concentration of Greenhouse Horticulture in North America. The region has a history of growing practice innovation and has recently been interested in advancing the energy management of their sector. Concerns over operational reliability and resilience are not new for these large operations, a number have onsite generation capacity, which has, to some degree, reduced their grid reliance. While a select few have even gone off-grid. Much of the sector operates individually, without coordination between organizations to optimize resources and minimize costs. This project will advance a novel harmonized effort to establish a resource map of DER assets across the sector. It will investigate, for the first time, the potential of DERs for five greenhouses in the Leamington/Kingsville area through expertise from the University of Windsor, 360 Energy, Hydro One, Ontario Greenhouse Vegetable Growers (OGVG), and five local greenhouses. To do so, the electrical loads of these greenhouses will be analyzed: individually and collaboratively as a Five-Grower Network. From there, DER designs will be developed using the software HOMER and team expertise. The following five DER combinations will be constructed for each of the five greenhouses as well as the combined Five-Grower Network:

1. Photovoltaic & Battery
2. Cogeneration & Battery [Fuel: Natural Gas (NG)]
3. Cogeneration & Battery [Fuel: Biogas]
4. Cogeneration, Photovoltaic, & Battery [Fuel: Natural Gas (NG)]
5. Cogeneration, Photovoltaic, & Battery [Fuel: Biogas]

Based on major criteria like land availability, cost, ease of implementation, and greenhouse owner preference a DER design winner will be chosen for the greenhouses. These winners will then be totaled and compared to the Five-Grower Network to determine if there are significant benefits from greenhouse resource collaboration.

3.1 Greenhouse Participants Profile

The greenhouse profile for the participants in this project can be found in Table #1. Greenhouses #1 and #2 do not use supplemental lighting whereas greenhouses #3, #4, and #5 use HPS lights. The electrical load of greenhouses #1 and #2 will reflect what is often referred to as "base load": irrigation, boiler operations, fans, pumps, etc. Greenhouses #3, #4, and #5 have electrical loads that reflect base load as well as supplemental lighting load from the HPS lights. To fully understand the difference between these greenhouses, electricity demand and consumption need to be analyzed. From this analysis, key electricity figures can be made that illustrate greenhouse material and lighting differences.

Table #1: Five-Grower Network Overview

Greenhouse	Crop	Supplemental Lighting
1	Pepper	Unlit
2	Pepper	Unlit
3	Cucumbers & Tomatoes	HPS
4	Cucumbers & Tomatoes	HPS
5	Long English Cucumbers	HPS

3.1.1 Electricity Demand

Electricity demand is defined by the highest amount of electricity consumed in a one-hour period during a month. In Figure #1, this demand in kW/acre is shown for the five greenhouses from January to December. Note that during the summer months, the demand for lit greenhouses is significantly lower due to the lack of supplemental lighting usage as there is natural sunlight.

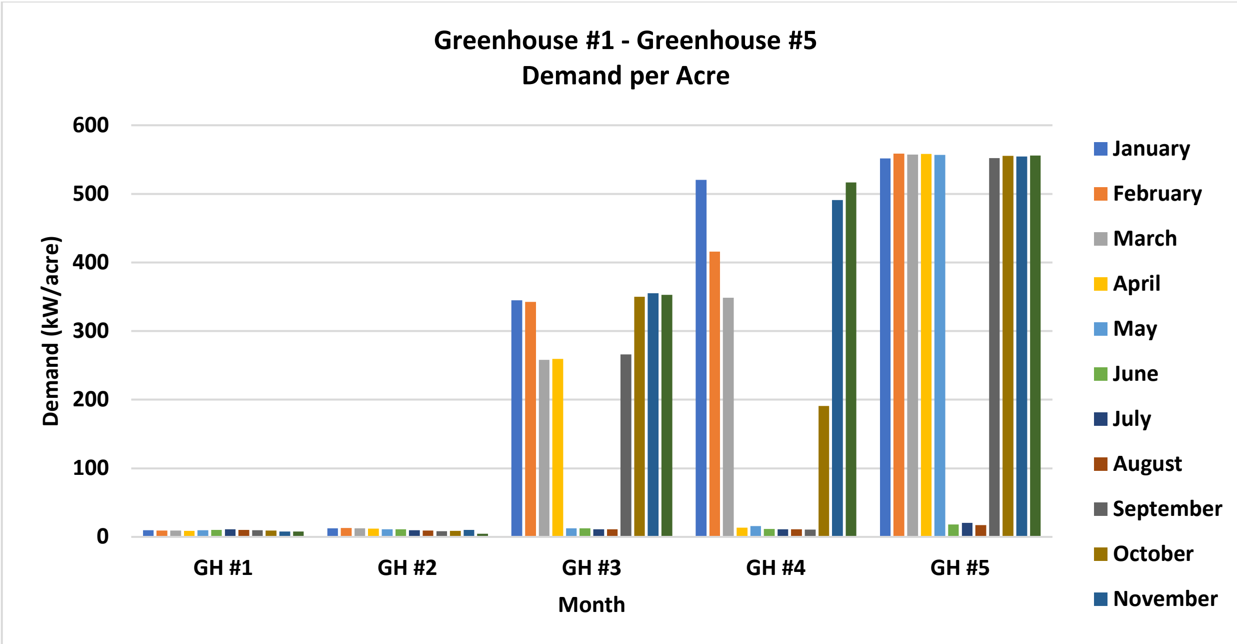

Figure #1: Demand per Acre

3.1.2 Average Hourly Electricity Consumption

The average hourly electricity consumption is on average what an hour's consumption is for each greenhouse in that month. In Figure #2, this average electricity consumption in kW/acre is shown for the five greenhouses from January to December. This varies from demand as it demonstrates an average of all the hours in the month rather than looking at the highest one-hour period. For the lit greenhouses, this is especially important during the Winter months where the average hourly consumption remains relatively high in comparison to the Spring and Fall months. This is due to the Spring and Fall months having more sunlight than the Winter months, which means that lighting may not be used every single day of that month, reducing the overall average hourly consumption.

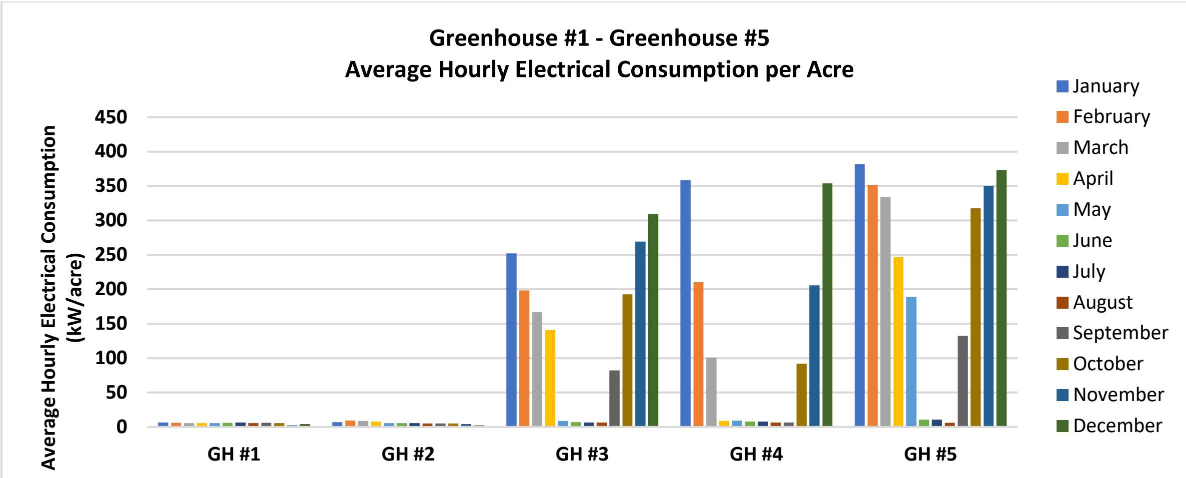

Figure #2: Average Hourly Electrical Consumption per Acre

3.1.3 Key Electricity Figures

Two key figures for DER designs include the maximum one-hour demand and the total annual consumption. These figures can be found in Table #2.

Table #2: Electrical Summary

Greenhouse	Maximum Annual Demand (kW/Acre)	Total Annual Electrical Consumption (kWh/Acre)
1	11	46,899
2	13	51,830
3	355	1,199,135
4	520	996,735
5	559	1,977,416

3.2 Distributed Energy Resource Designs

DERs that will be considered in this study include cogeneration, battery, and photovoltaic (solar panels). The specifications for these systems are found in Table #3-#5. Using the design software HOMER Pro and industry expertise, the electrical load analysis is here used to generate a DER system that serves to meet greenhouse needs at minimized costs.

Table #3: DER Specifications

Resource	Company	Specifications	Lifetime
Battery	Generic	○ Initial State of Charge at 60% ○ Minimum State of Charge 20%	15
Cogenerator	Gruppo Ab	○ Can operate on both NG and RNG ○ 5% downtime per year	25
Inverter	Generic		15
Photovoltaic Panels	Canadian Solar	○ Power Capacity: 425W	25

Table #4: DER Costs

Category	Cost
Battery Capital ($/kWh)	$520
Battery Replacement ($/kWh)	$365
Battery O&M ($/kW)	$14
Cogeneration Capital ($/MW)	$1,750,000
Cogeneration O&M ($/MW-yr)	$75,000
Inverter Capital ($/W)	$0.13
Inverter O&M ($/yr)	Included in PV
Inverter Replacement ($/W)	$0.052
Photovoltaic Capital ($/W)	$2.87
Photovoltaic O&M ($/kW/yr)	$12

Table #5: Fuel Costs

Fuel	Cost
Natural Gas ($/m^3)	$0.23

Biogas ($\$/m^3$)	$0.81

This project features thirty total designs. Five DER designs are developed for each of the five greenhouses and five designs for the Five-Grower Network (which is all five greenhouses connected as one load). From these designs, three key figures will be noted: project cost ($), cost of electricity (COE) ($/kWh), and grid consumption (%). Project cost is the total project cost over the course of 25 years. This includes savings from no longer purchasing the electricity generated and boiler savings from generated thermal when possible. The cost of electricity is the cost of electricity over the course of 25 years. This is the total project cost over the total electricity produced. Grid consumption is the percentage of the load that is still purchased from the grid. To understand the benefits of combining the system as a five-grower network, design winners for each of the five greenhouses will be chosen. The design winners will be chosen based on the following: cost optimization, greenhouse owner preference, land/roof availability at the site, and diversifying DER choice. Using these parameters and the design winning factors, the DERs from the design winners of the five greenhouses will be compared to the Five-Grower Network to determine if there is any benefit from the combination.

4. Results

4.1 Electricity Results

When comparing a double-poly greenhouse to a glass greenhouse for unlit peppers is:

- 1.09x more demand in a double-poly greenhouse
- 1.11x more monthly electricity consumption in a double-poly greenhouse

When comparing annual averages of unlit to a lit:

- Greenhouse using heavy lighting trends (September-May), it has 43x more demand and 40x more electrical consumption per acre
- Greenhouse using moderate lighting trends (October-March with less lighting fixtures), it has 22x more demand and 22x more electrical consumption per acre

Comparing an unlit pepper crop to a lit cucumber crop:

- Yearly consumption for the lit crop was 43x more the amount per acre than of an unlit crop
- Yearly average demand for the lit crop was 46x more the amount per acre than of an unlit crop

4.2 DER Design Results – 5 Greenhouses

The DER design results for the 5 greenhouses can be found in Tables #6-#10.

Table #6: Greenhouse #1 Design Results

Design	Project Cost	Cost of Electricity ($/kWh)	Grid Consumption (%)
#1 Photovoltaic & Battery	$5,908,198	$0.19	15.1
#2 Cogeneration & Battery (NG)	$7,642,758	$0.25	1.50
#3 Cogeneration & Battery (Biogas)	$16,317,115	$0.52	1.36
#4 Cogeneration, PV, & Battery (NG)	$7,720,234	$0.25	1.36
#5 Cogeneration, PV, & Battery (Biogas)	$16,394,870	$0.53	1.36

Table #7: Greenhouse #2 Design Results

Design	Project Cost ($)	Cost of Electricity ($/kWh)	Grid Consumption (%)
#1 Photovoltaic & Battery	$6,753,918	$0.24	15.0
#2 Cogeneration & Battery (NG)	$9,340,093	$0.325	2.01
#3 Cogeneration & Battery (Biogas)	$37,554,834	$1.31	2.01
#4 Cogeneration, PV, & Battery (NG)	$5,701,496	$0.199	2.03
#5 Cogeneration, PV, & Battery (Biogas)	$24,983,551	$0.87	2.03

Table #8: Greenhouse #3 Design Results

Design	Project Cost	Cost of Electricity ($/kWh)	Grid Consumption (%)
#1 Photovoltaic & Battery	$289,549,150	$0.44	25.2
#2 Cogeneration & Battery (NG)	$16,933,656	$0.026	0.269
#3 Cogeneration & Battery (Biogas)	$117,324,841	$0.18	0.269
#4 Cogeneration, PV, & Battery (NG)	$43,890,807	$0.133	29.2
#5 Cogeneration, PV, & Battery (Biogas)	$146,126,101	$0.23	29.2

Table #9: Greenhouse #4 Design Results

Design	Project Cost	Cost of Electricity ($/kWh)	Grid Consumption (%)
#1 Photovoltaic & Battery	$848,479,600	$1.76	21.7
#2 Cogeneration & Battery (NG)	$72,351,655	$0.068	0.398
#3 Cogeneration & Battery (Biogas)	$269,270,003	$0.25	0.398
#4 Cogeneration, PV, & Battery (NG)	$70,428,560	$0.066	0.24
#5 Cogeneration, PV, & Battery (Biogas)	$264,712,387	$0.25	0.24

Table #10: Greenhouse #5 Design Results

Greenhouse #5 Design	Project Cost	Cost of Electricity ($/kWh)	Grid Consumption (%)
#1 Photovoltaic & Battery	$344,407,800	$0.70	30
#2 Cogeneration & Battery (NG)	$52,563,815	$0.05	0.26
#3 Cogeneration & Battery (Biogas)	$233,571,830	$0.21	0.26
#4 Cogeneration, PV, & Battery (NG)	$52,346,940	$0.05	0.24
#5 Cogeneration, PV, & Battery (Biogas)	$223,663,326	$0.20	0.24

The design winners for the five greenhouses can be found in Table #11.

Table #11: Greenhouse Design Winners

Greenhouse	Design Winner	Size (MW)	Project Cost	COE ($/kWh)	Electricity Produced (MWh/yr)	Excess Electricity (%)	Capacity Shortage (%)
1	Battery & Solar	1.338	$5,908,198	$0.19	1,700	37.2	15.1
2	Battery & Solar	1.287	$6,753,918	$0.24	1,637	39.5	15.1
3	Battery & Cogen NG	6.49	$16,933,656	$0.026	24,310	7.77	0.269
	Battery & Cogen BG		$117,324,841	$0.18			
4	Battery, PV, & Cogen NG	13.107	$70,428,560	$0.066	52,990	26.6	0.338
	Battery, PV, & Cogen BG		$264,712,387	$0.25			
5	Battery & Cogen NG	13.107	$52,563,815	$0.05	42,048	6.79	0.26
	Battery & Cogen BG		$233,571,830	$0.21			

4.3 DER Design Results – Five Grower Network

The five grower network DER results can be found in Table #12.

Table #12: Five-Grower Network Design Results

Design	*Project Cost*	*Cost of Electricity ($/kWh)*	*Grid Consumption (%)*
#1 Cogeneration & Battery (NG)	$88,074,434	$0.03	10.1
#2 Cogeneration & Battery (Biogas)	$547,192,788	$0.19	10.1
#3 Cogeneration, Solar, & Battery (NG)	$114,881,477	$0.049	10.1
#4 Cogeneration, Solar, & Battery (Biogas)	$114,881,477	$0.16	10.1
#5 Solar & Battery	$2,672,159,203	$0.911	10.1

The DERs were then totaled for total cogeneration, solar, and battery capacity. An analysis on the five greenhouse design winners as a total was completed, also referred to as "original total" and the same five designs were done for the five-grower network to see if any reduction of DERs can be made from the combination. These results are found in Table #13.

Table #13: Original Total vs. Five-Grower Network

	Battery (MW)	Cogen (MW)	Solar (MW)	Electricity Produced (MWh/yr)	Excess Electricity (MWh/yr)
Original Total	12	41.45	3.214	120,628	20,364
Five Grower Network					
Cogen & Battery	2	31.52	0	105,786	5,715
Cogen, Solar, & Battery	11	30.58	0.66	107,121	6,648
Solar & Battery	920	0	430.35	567,013	459,327

Due to the solar and battery design being unrealistic for a load this large, the conclusions will be made on the cogeneration designs. Based on these results, the five-grower network results in the following:

- Reduction of up to 10 MW of batteries and ~11 MW of cogeneration
- Capital savings of approximately $22 million dollars
- ~12% less electricity produced
- ~70% less excess electricity

5. Conclusion

The following conclusions are made from the limited, but reasonably representative 5 grower operation cross-section examined in this study:

- When comparing a double-poly greenhouse to a glass greenhouse, the pepper crop has 1.09x and 1.11x more demand and electricity consumption respectively in a double-poly greenhouse.
- Lighting methodology has a major influence on the electricity required.
- Greenhouse lighting measured for a specific operation from September to May had 43x more electrical demand and 40x and consumption per acre in comparison to an unlit acre.
- Greenhouse lighting measured from October to March using less fixtures had 22x electrical demand and 22x more consumption per acre in comparison to an unlit acre.
- The annual consumption for the lit crop was up to 43x more than an unlit crop.
- The average demand for the lit crop was 46x more than an unlit crop.
- When installing DERs, creating a network of greenhouses can reduce the overall infrastructure costs.
- In a case study of a hypothetical five-grower greenhouse network in Leamington, ON, the results showed the following when a connected DER architecture is used there was:
    - Reduction in design sizing
    - Reduction in excess electricity
    - Reduced fuel consumption
    - Millions saved on capital spending

6. Lessons Learned

6.1 Lessons from the project implementation

- The addition of supplemental lighting significantly increases greenhouse loads.
- Greenhouse electrical loads are highest in the months of September to May when supplemental lighting is used.
- DER implementation can be optimized through the development of connected DER networks that also have central grid connection.
- Photovoltaic (PV) projects without storage in Ontario for supplementally lit greenhouses are not strategic. This is due to the misalignment of the peaking summer performance for PV and the winter peaking demand for lighting; which results in underutilized asset usage.
- Cogeneration provides greenhouses the ability to generate their own electricity, heat, and CO_2 however, these assets are oversized in the summer months and could be used for meeting peak loads of other industries.
- Biogas could be a potential solution in the future, however, the fuel cost and requirement is not feasible today.

7. Next Steps

NB: Statements provided in 7.1 and 7.2 are verbatim remarks from Stakeholder Webinar Exercise held with growers and other sector contributors.

7.1 Where does the project go next?

- Investigation of the innovative use of transmission contracted wind farms in a hybrid role to also serve local markets – see **"Hydrogen Integrated Greenhouse Horticultural (HIGH) Energy" Proposal in APPENDIX 1.**
- Evaluate the impact of future electric demand forecast erosion that may occur in the Greenhouse industry due to high electricity prices.
- Investigate other potential electrification projects such as Electric transport charging and the impact/opportunities it will create in the electricity marketplace.
- A micro grid in the Leamington area may not yet be cost efficient for the customers in the end. Growth and power demand in Southern Ontario, and specifically Leamington/Essex area, may be too fast and large to be able to sustain this area with energy with micro grids alone.

- Look at a system where local generators are focused on the local market rather than the Ontario market. Currently we operate based on the Market Clearing Price and HOEP. These are based on supply and demand for all of Ontario and are not looking at the specific loads in our area. If large loads are present in our area and there are generators available in the area, they should turn on. This is currently not the case.

- Create incentives for the increased installation of Battery Energy Storage Systems (BESS) that will increase local grid dynamism and enable valuable peak shaving capabilities to growers that need it.

7.2 Are there opportunities to scale up the project/program, provide IESO market services or participate in IESO programs?

- Treat Leamington/Kingsville area as a pilot area to implement DERs.

- Simplify the interconnection process for end-use customers to add additional generation at the facility. The current process is seen as resource intensive and a financial burden. Make the process easy, cost-effective, and quick for clients to evaluate and implement power production in whole or for a part of their electrical needs and allow for the ability to sell excess power to clients within the pilot area.

- Provide funding for education or expertise in the region for DER implementation by clients.

- Facilitate a blockchain infrastructure that allows the end-to-end clients to sell and buy an electron commodity.

- Provide incentives to sites to produce their own power.

Appendix 1 – Hydrogen Integrated Greenhouse Horticultural (HIGH) Energy

HIGH Energy Project | Hydrogen Integrated Greenhouse Horticultural Energy

Clean Energy Growing the Canadian Greenhouse Sector

PARAMETRIC ECONOMIC MODEL PROPOSAL

1.1. BACKGROUND SUMMARY

The Canadian Greenhouse Sector is experiencing explosive growth. The energy demand of the sector has been projected expand at an unprecedented rate over the next 5 years. Central electricity and gas grids are seeing new Greenhouse-slated infrastructure projects fully subscribed prior to completion. Continued economic expansion of this nationally critical sector will require innovative distributed energy resource (DER) solutions. The greatest concentration of Greenhouses in North America is in Southern Ontario, which is also home to one of the densest regions of established Wind Energy in Canada. Maturing power purchase agreements in the wind sector have owners looking ahead to novel market opportunities. A new collaboration will develop a Parametric Economic Model (PEM) to illustrate the potential for wind farms to supply electricity and hydrogen to the Greenhouse Sector. Massive crop lighting loads will be served by wind farm-supplied electricity that will also drive water electrolysis for hydrogen production. Emission-free electricity and hydrogen for heat will offer significant reductions in the Sector's carbon footprint. Specifically, it will enable increased deployment of blended-fuel and hydrogen only cogeneration - directly increasing sustainable farming capability. Ultimately this will feed growing microgrid opportunities through the panhandle region. High-resolution heat and power demand characterizations of several commercial greenhouses, and detailed historic production data from two large wind farms will be leveraged to build relationships between fundamental process variables.

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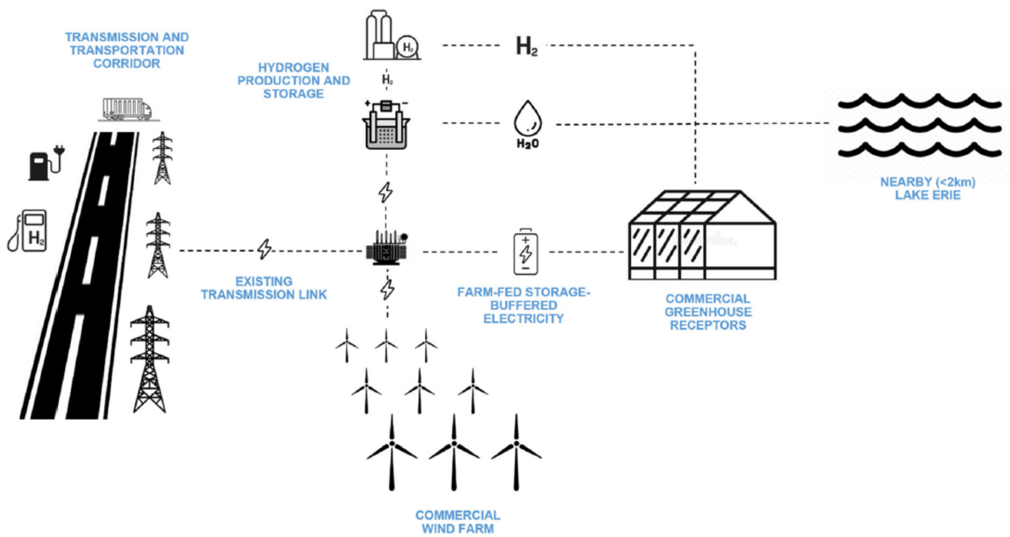
Economic sensitivity analyses from the PEM will drive the development of transparent business cases to illustrate the opportunities and challenges associated with the direct coupling of wind farms and Canadian Greenhouses. Figure 1 provides a schematic overview of a proposed "HIGH Energy" solution template that is the ultimate objective of the collaboration.

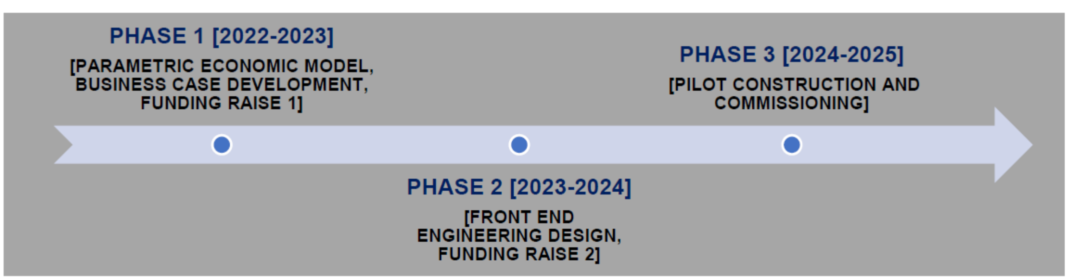


1.2. OVERARCHING HIGH ENERGY PROJECT OBJECTIVE AND TIMELINE

The Overarching Objective of the HIGH Energy Project:

> **OA1. To Establish a Pilot Facility That Farms Wind to Provide Electricity and Hydrogen to Deliver Power and Heat to Commercial Greenhouse Receptors.**

The Parametric Economic Model (PEM) proposed herein is Phase 1 of a larger collaboration that will ultimately also include a Phase 2 Front End Engineering Design and Phase 3 Pilot Construction/Commissioning.



2. PARAMETRIC ECONOMIC MODEL OBJECTIVES

2.1. Form a Conceptual Model that defines all key variables critical to the utilization of a wind farm to deliver electricity and hydrogen to the commercial greenhouse sector.

2.2. Identification of all relevant applicable regulations and existing agreements that will require compliance or a request for modification to deliver the HIGH Energy solution template.

2.3. Evolve the Conceptual Model (2.1.) to a progressively determinant Parametric Economic Model of the HIGH Energy solution template.

2.4. Engage the Parametric Economic Model to generate a spectrum of transparent business cases that will illustrate the eco-environmental opportunities and challenges presented by the direct coupling of wind energy to a demand for greenhouse power and heat.

2.5. Produce a Sensitivity Analysis that identifies which variables are most influential on project economics, environmental footprint, and policy ramifications.

3. METHODOLOGY

3.1. Conceptual Model.

Working with PEM stakeholders, a comprehensive digital project schematic will be designed to illustrate all major inputs, conversion processes, and outputs. Critical process variables will be identified and named. Typical value ranges for variables will be collected by researchers and stakeholder consultation.

3.2. Regulatory Identification, Compliance, and Request for Modification.

A process flow diagram based on the digital project schematic will be developed and annotated to identify all relevant regulations that will correspond to the operation of the facility. Flags will be assigned where new policy development is required and/or modifications may be required. The critical agencies and associated contacts will be tied to each regulation.

3.3. Parametric Economic Model Construction.

Founded on the Conceptual Model and Process Flow diagrams developed in 3.1. and 3.2., a progressively determinant Parametric Economic Model of wind-driven power production, hydrogen production, and energy storage/delivery will be constructed. The PEM will begin as a simplified lumped parameter model that will be parted out and validated against idealized theoretical representations of each suboperation from the overall process flow. These steps will leverage HYSYS and/or Simulink software to more easily facilitate parameterization of the relationships between key process variables. In manageable increments, the resolution and complexity of the model will be increased to better reflect the real conditions in a physical facility. These modeling outputs will continue to be back-checked against original idealized theoretical results to manage model integrity.

3.4. Business Case Development.

Using the Parametric Economic Model, an array of business cases will be built to explore a variety of paths forward for the project. Sliding scales of pricing, process configurations, commodity proportioning, policy variants, etc. will be applied to the modeled relationships between variables.

3.5. Sensitivity Analysis.

Based on the PEM, a sensitivity analysis will be conducted to determine which variables are the most influential on key project performance indicators. This process will aid in revealing ways to inform improvements to project configuration. Beyond this, optimization routines can be exercised here to deliver maximum process returns under required project constraints.

4. DELIVERABLES

4.1. HIGH Energy Conceptual Model.

Comprehensive digital project schematic will illustrate all major inputs, conversion processes, and outputs.

4.2. Schedule of Regulatory Requirements for Compliance and/or Modification.

The regulations and policies essential to operation of the planned Pilot will be flagged and summarized with relevant contact agencies and personnel identified.

4.3. Parametric Economic Model.

Flexible Economic Model capable of techno-enviro-economically simulating the HIGH Energy solution template will be produced. The PEM will be used to generate a spectrum of business cases to advance progress towards the planned Pilot.

4.4. Business Cases for Demonstration Pilot.

Leveraging the PEM, business cases that address a variety of economic, environmental, technical, and policy priorities will be built and presented to stakeholders. Commentary on the sensitivity of key performance indicators to project variables will also be highlighted here.

5. ESTIMATED TIMELINE*

	PROJECT MONTH											
MAJOR DELIVERABLES	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
D1. HIGH Energy Conceptual Model. Comprehensive digital project schematic will illustrate all major inputs, conversion processes, and outputs.	■	■	■	■								
D2. Schedule of Regulatory Requirements for Compliance and/or Modification. The regulations and policies essential to operation of the planned Pilot will be flagged and summarized with relevant contact agencies and personnel identified.		■	■	■								
D3. Parametric Economic Model. Flexible Economic Model capable of techno-enviro-economically simulating the Turbines and Tomatoes energy solution template will be produced. The PEM will be used to generate a spectrum of business cases to advance progress towards the planned Pilot.		■	■	■	■	■	■	■	■			
D4. Business Cases for Demonstration Pilot. Leveraging the PEM, business cases that address a variety of economic, environmental, technical, and policy priorities will be built and presented to stakeholders. Commentary on the **sensitivity of key performance indicators** to project variables will also be highlighted here.			■	■	■	■	■	■	■	■	■	■

***Note that the timely and accurate completion of all Deliverables are dependent on the availability of data and other relevant Project partner inputs.**

6. GENERAL PARTNER EXPECTATIONS FOR PEM DEVELOPMENT

6.1. University of Windsor

- Direction and management of Project.
- Development of the PEM and provision of Project Deliverables.

6.2. Ontario Greenhouse Vegetable Growers

- Representation of Greenhouse Growers (energy consumers).
- Support PEM development with provision of necessary grower segment data.
- Lead government and regulatory liaising where appropriate.

6.3. Kruger Energy

- Provide relevant wind energy, power producer expert support to Project.
- Provide relevant data and other strategic inputs requested by UWin to PEM.

6.4. Enbridge Inc.

- Provide relevant hydrogen production and transport expert support to Project.
- Provide relevant data and other strategic inputs requested by UWin to PEM.