FINAL OUTCOMES REPORT (Non-CONFIDENTIAL)

1.0 PROJECT INFORMATION

1. ERA PROJECT ID #	E0160842
2. CALL / ROUND	Natural Gas Challenge
3. PROJECT TITLE	Green Natural Gas-Powered Tri-generation
4. COMPANY NAME	Enersion Inc.
5. PROJECT TYPE (R&D, Development, Demonstration, Implementation)	Demonstration
6. LOCATION (primary location the project took place by address, land description, or GPS coordinates)	
7. PROJECT START DATE	01 Jan 2021
8. PROJECT COMPLETION DATE	30 November 2024
9. TECHNOLOGY READINESS LEVEL (TRL) AT PROJECT INITIATION	6
10. TRL AT PROJECT COMPLETION	8
11. JOBS CREATED	
12. GHG EMISSIONS REDUCED (Project-level: annual, cumulatively by 2030 and by 2050)	111 tCO2e annually 666 tCO2e by 2030 2,886 tCO2e by 2050
13. TOTAL ERA FUNDING	$1,795,000
14. TOTAL PROJECT VALUE	$4,004,468
15. ERA PROJECT ADVISOR	Murray Gray

16. SUBMISSION DATE	
17. KEY PROJECT CONTACT NAME AND EMAIL	Hanif Montazeri Hanif.montazeri@enersion.com
18. QUOTE (why was ERA a pivotal funder for this project? How did ERA funding help advance on the TRL scale? Etc.)	The high capital cost of a new technology coupled with the risk would have made it a difficult solution to adopt and test by a real-world customer. ERA funding allowed the project to be scaled up to 50RT of cooling and be tested in a real-world setting.
19. NOTABLE COMMUNICATIONS	
20. IMAGE (please insert or link a photo capturing the technology for ERA publications)	

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5.0 EXECUTIVE SUMMARY

The "Green Natural Gas-Powered Tri-Generation" project aimed to showcase an innovative energy system that integrates natural gas-based heating, cooling, and power generation, while significantly reducing greenhouse gas (GHG) emissions. The technology centers around Enersion's adsorption-based chiller, which uses low-grade heat from a natural gas-powered Combined Heat and Power (CHP) unit to produce cooling. Unlike conventional systems, the chiller uses water as a refrigerant, avoiding synthetic refrigerants with high Global Warming Potential (GWP), and reduces electricity consumption by over 89%. This technology allows the heat from the CHP, which is around half of the output of the CHP and otherwise wasted, to be used for synthetic refrigerant free cooling. This combination not only increases the environmental benefit of using a CHP, but also reduces the payback period of installing a CHP by at least 30%.

The successful implementation of a 50RT cooling capacity unit at Hart Land Farming demonstrated the feasibility of this technology, achieving the key goals of the project. The system was fully integrated with the farm's operational CHP, leveraging its heat output to drive the chiller. This innovative approach will allow the CHP to operate year-round, enhancing its utility and reducing energy waste. The chiller achieved exceptional performance metrics, including a high electrical Coefficient of Performance (COP), significantly lowering operational costs and energy consumption compared to traditional compressor-based systems.

The project successfully demonstrated Enersion's 50-ton adsorption cooling system, achieving an electrical COP of 27.3 and reducing natural gas consumption by lowering the CHP power demand due to cooling from waste heat instead of electricity. It could result in a 87% reduction in GHG emissions, eliminating 111 metric tons of CO_2e annually.

This project provides a tangible example of how adsorption cooling technology can reduce GHG emissions by minimizing electricity consumption and eliminating harmful refrigerants. At Hart Land Farming, the system will deliver substantial energy and cost savings while maintaining consistent cooling performance. The results align closely with the initial objectives, despite challenges encountered during implementation. This demonstration paves the way for broader adoption in commercial and industrial sectors, including office buildings, hospitals, hotels, and agricultural applications. By addressing key market barriers such as high energy costs and environmental impacts, this project exemplifies the potential of Enersion's technology to drive sustainable energy solutions.

6.0 PROJECT DESCRIPTION

6.1 INTRODUCTION

This project focused on demonstrating a novel nano-porous material-based cooling technology developed by Enersion Inc., integrated with a Combined Heat and Power (CHP) unit. Unlike traditional cooling technologies, which rely on compressor-based systems and synthetic refrigerants, Enersion's technology uses water as a refrigerant and low-grade heat (as low as 70°C) as the primary energy source. This revolutionary approach not only eliminates the environmental harm caused by refrigerants with high Global Warming Potential (GWP) but also reduces electricity consumption by over 89%, offering significant energy and cost savings.

The system is powered by waste heat from sources such as combined heat and power (CHP) units, consuming only one-tenth of the electricity required by traditional cooling systems. The process begins when low-grade waste heat (above 58°C) drives the cooling cycle, triggering an adsorption-based refrigeration cycle where nano-porous materials absorb and release water vapor, generating cooling. In the Enersion system, water under vacuum evaporates on the surface of a nano-porous material. These nano-porous materials have high surface area - around 6 grams has an equivalent surface area of an entire football field. The adhesion of molecules onto the surface of solid nano-porous materials is called adsorption. This unique cycle eliminates the need for mechanical compression, resulting in a high-efficiency, low-maintenance cooling solution.

The refrigeration cycle relies solely on using nano-porous materials that can adsorb significant amounts of water vapour (refrigerant) under very low pressures. Unlike a conventional refrigeration process, the Enersion technology cycles two working materials in temperature and pressure: the water and adsorbent nanoporous material. The thermodynamic cycle of Enersion's heat pump can be explained either via Clapeyron diagram or P-T diagram, Fig. 1 depicts the P-T diagram of the Enersion adsorption. The water cycle is 1-2-3-4 and back to one, while the adsorbent is 1-2-3'-4'. As shown in Fig. 1 during the adsorption/evaporation process (step 4-1, 4'-1) which is an isobaric process, the refrigerant (water) uses ambient air energy to evaporate in the evaporator. Next, the vapor is adsorbed by nano-porous material which is an exothermic reaction. When the adsorbent material (i.e., nano-porous material) gets saturated, the evaporation process slows down. At this stage a valve closes the connection of the adsorption chamber to the evaporator.

Then, through an internal heat exchanger, the adsorber is heated such that the temperature and pressure increases (step 1-2) to reach the regeneration temperature (Treg.). At this point, the refrigerant (water) is separated from the nano-porous material. The high temperature refrigerant vapour (85°C) is then collected by a condenser that rejects its thermal energy to a building domestic hot water (DHW) line (Step 2-3), while the hot regenerated nano-porous material (85°C) also cools down by rejecting its thermal energy to the DHW line (2-3'). By depressurizing the refrigerant, its pressure reaches the evaporator pressure thus reaching point 4. This is similar to passing through expansion valve in the refrigeration cycle. Similarly, the depressurization of the adsorbent goes from 3' to 4'. The regenerated nano-porous material and water in the evaporator then return to their initial state 1, and the system is ready to repeat the cycle.

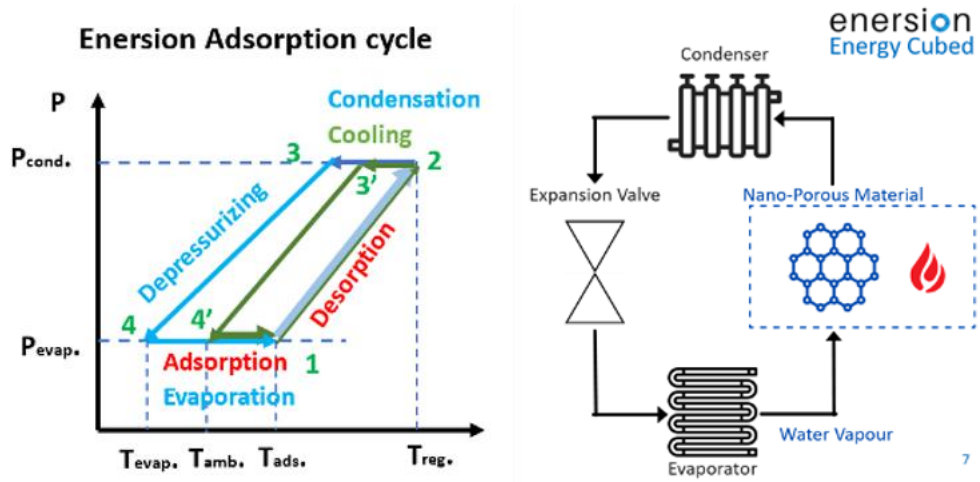

Fig 1. P-T diagram of Enersion Adsorption Cycle

The integration of Enersion's adsorption chiller with a natural gas-powered CHP unit at Hart Land Farming in Alberta aimed to demonstrate the operational efficiency and environmental benefits of this system. The technology enables year-round utilization of CHP heat output, which is often wasted during summer months, transforming it into valuable cooling energy. This maximizes the overall efficiency of natural gas-based systems, delivering heating, cooling, and power with minimal environmental impact.

This demonstration at a commercial scale provided a proof-of-concept for deploying the technology in various applications, including office buildings, hospitals, industrial facilities, and agricultural sites. By significantly reducing dependency on electricity for cooling and eliminating harmful refrigerants, Enersion's system addresses critical challenges in the HVAC sector and promotes the transition to cleaner, more sustainable energy solutions.

6.2 BACKGROUND OF THE PROJECT

The project addresses significant challenges in energy efficiency and greenhouse gas (GHG) emissions reduction in the heating, cooling, and power generation sector. Traditional cooling systems depend on electricity and synthetic refrigerants, contributing substantially to global warming. At the same time, Combined Heat and Power (CHP) systems often operate inefficiently during summer months due to the lack of demand for heating, leading to wasted energy.

Recognizing this opportunity, Enersion Inc. developed an innovative adsorption-based cooling technology that utilizes low-grade heat from CHP units, converting it into valuable cooling energy. This technology eliminates the use of synthetic refrigerants, which have high Global Warming Potential (GWP), by using plain water as a refrigerant. The system significantly reduces electricity consumption for cooling, making it a sustainable and cost-effective alternative to traditional technologies. By enabling year-round operation of CHP systems, this project offers a transformative solution to energy efficiency and decarbonization challenges.

Enersion's team is led by experts in adsorption technology and system integration, including Dr. Hanif Montazeri, a seasoned mechanical engineer with extensive experience in computational physics and thermo-fluid systems. Their expertise has been instrumental in designing a novel thermo-fluid mechanical system that significantly reduces the cost and complexity of adsorption cooling technology, enabling it to compete with conventional compressor-based systems.

The project was originally intended for deployment at the Current Prairie Fishermen facility but faced unforeseen logistical challenges, leading to its relocation to Hart Land Farming in Alberta. Hart Land Farming offered the necessary infrastructure and operational CHP systems, ensuring a seamless transition and successful demonstration. The collaboration between Enersion Inc. and Hart Land Farming showcased the scalability and reliability of this technology for diverse applications, including agricultural facilities, commercial buildings, and industrial processes.

This project represents a significant milestone in advancing sustainable energy technologies, providing a practical pathway to reduce GHG emissions, increase energy efficiency, and promote environmentally friendly practices across various sectors.

Figure 2: Photo of chiller

6.3 PROJECT OBJECTIVES

The primary objective is to demonstrate a green integrated Tri-Generation system that provides year-round energy (heating, cooling and electricity) at reduced costs; and minimize GHG emissions to a farm using natural gas.

6.4 PERFORMANCE/SUCCESS METRICS IDENTIFIED IN THE CONTRIBUTION AGREEMENT

Table 1: PERFORMANCE/SUCCESS METRICS

Success Metric	Project Target	Project Achievement	Explanation
COP Electrical	16	27.3	
Electrical Saving	70%	89%	
Heat Inlet Temperature of the chiller	85 deg C	87 deg C	This was the temperature of the heat output of the CHP at site
Cooling Outlet Temperature of the chiller	9 deg C	7 deg C	

6.5 PROJECT CHANGES

Initially planned for implementation at the Current Prairie Fishermen facility, the project was relocated to Hart Land Farming in Bashaw, Alberta. This change was necessitated due to logistical challenges and the original partner's inability to meet infrastructure and resource requirements. Hart Land Farming offered a fully operational CHP system and adequate manpower, ensuring the project's seamless continuation. The change from Quad-generation in the original plan to trigeneration at Hart Land had little effect on the GHG benefits because the intended carbon dioxide utilization at Current Prairie Fishermen was small. The tri-generation mode is more compatible with the needs of the majority of installations with CHP systems, which focus on electric power, space heating, hot water, and space cooling.

The project also faced delays in component shipments, particularly with the adsorption chiller and heat transfer systems, due to global supply chain disruptions. These delays impacted key milestones, pushing back fabrication, installation, and testing schedules. To mitigate these setbacks, Enersion reallocated resources to other tasks, such as engineering studies, site preparation, and system integration planning, ensuring that overall progress continued despite unforeseen disruptions.

6.6 TECHNOLOGY RISKS

Table 2: Risks identified at beginning and impact in project

Key Risks	Risk Mitigation and Response Strategy	Outcome and impact in project
Technical		
Leak into the system thereby losing vacuum pressure	Comprehensive pressure test on all individual components before final assembly	After conducting comprehensive pressure tests, the system did not experience any leaks
Vapour contamination in evaporator that equalizes system pressure	Install valves to isolate evaporator, desorber, dissipator and condenser	Valves were installed to create isolation and there was no vapour contamination
Commercialization & Market Adoption		
Market hesitant to adopt new technology	Pilot demonstrations will be used for educating the HVAC value chain	Pilot in this project as well as another helped us secure customer trust and future deals
Regulatory & Permitting Risks		
Technology does not meet ASHRAE standards	Consult certification and regulation requirements during design phase and use them as a constraint	We have reviewed the ASHRAE standards and got assurance that the technology meets ASHRAE standards
Project Plan & Timelines		
Design phase exceeds time due to scale up	Use of simulations and experimentations to predict issues with scale up and vacuum, keep scaling up in mind	The design phase went smoothly with the help of experimentations and theoretical analysis.
Delay in timeline due to project partner	Maintain constant communication with written commitments from each partner	Although we maintained constant communication, there were delays from vendors due to shipment delays and delays from the first demonstration partner due to their inability to proceed with site installation
Budget & Cost Uncertainties		
The cost of the prototype exceeds the expectations	Keep constant communication with part vendors and subcontractors during the design process	Although communication was maintained there were price fluctuations due to market forces that cannot be avoided
Financing		
One of the organizations encounters financial problems which disallow them to contribute to the cost of this project.	Since Enersion is actively raising capital, the company will be able to adsorb the cost	There were no financial contribution related problems
Team/Management/Partnership Risks		

IP or design getting stolen by subcontractors	Maintain legal documents with all subcontractors and divide the work among different subcontractors to avoid giving away the design secrets	We were very careful while dealing with subcontractors and vendors, maintaining legal documents as well as masking the impact of their work / overall design by dividing the manufacturing and working multiple vendors
One of the partners is not able to fulfill its technical obligation towards the project	Enersion will try to source the product from other companies, and replace the partner with a new one.	While we had backup vendors for most products, some components were unique (CO2 scrubber) and the shipping delays affected all overseas vendors.

Risks That Emerged During the Project Implementation

Partner Change: The original site at Current Prairie Fishermen was unable to provide the necessary infrastructure and support, leading to a delay and additional logistical challenges.

- Mitigation: The project was relocated to Hart Land Farming, which had an operational CHP system and adequate resources.
- Outcome: This unanticipated change caused delays but did not affect the project's overall success.

Unforeseen Challenges

Shipping Delays: Delays in component shipments, including the CO_2 scrubber (which was later excluded), caused disruptions in the project timeline.

- Mitigation: Project milestones were revised, and resources were reallocated to ensure progress in other areas.
- Outcome: The overall timeline was extended, but the project was completed successfully.

Overall Risk Management Assessment

The mitigation strategies employed during the project were largely effective in addressing the identified risks. While some challenges, such as delays and partner changes, required mid-course adjustments, the project team demonstrated adaptability and resourcefulness. Unforeseen risks, such as logistical delays, were managed without compromising the project's primary objectives. Overall, the risk management approach ensured a successful demonstration of the technology under realistic commercial conditions.

6.7 METHODOLOGY

- System Design and Engineering: The project adopted a phased approach, initially developing a smaller-scale adsorption chiller to validate design parameters before scaling up to a 50-ton system. Computational simulations and detailed engineering studies modeled heat transfer, fluid flow dynamics, and operational parameters to ensure optimal performance at Hart Land Farming. The adsorption chiller was designed to utilize low-grade heat (85°C) as its primary energy source, leveraging Enersion's proprietary nano-porous material technology and plain water as the refrigerant.
- Fabrication and Pre-Testing: The 50-ton chiller was manufactured at Enersion's facility, where it underwent quality assurance checks to validate its thermal and electrical performance. A specialized test bed with heaters to simulate CHP heat output was used to measure the cooling capacity, electrical COP, and outlet temperature under controlled conditions. Key performance metrics, such as cooling output and electrical consumption, were recorded to ensure that the chiller met design specifications before shipment.
- Integration with the CHP: The system was installed at Hart Land Farming and integrated with their existing operational CHP unit. A custom-designed pump station was used to facilitate efficient heat transfer and system balance. Piping systems were optimized to maintain a steady heat inlet temperature of 85°C, while ensuring minimal heat loss during transfer.
- On-Site Testing and Measurements: Following integration, the chiller was tested under real-world operating conditions since October 2024.
  The performance evaluation involved:
  - Temperature Measurements: Sensors were placed at the heat inlet and cooling outlet to monitor the temperature gradient. Measurements confirmed a cooling outlet temperature of 10°C.
  - Flowrate measurement: Sensors were placed to measure the heat being consumed and the cooling being produced along with the temperature differences measured.
  - Energy Consumption Monitoring: Electrical meters recorded the power consumption of the chiller to calculate the electrical Coefficient of Performance (COP). The measured COP was 27.3. Cooling Capacity: Flow meters and temperature differentials across the heat exchangers were used to determine the chiller's cooling output.
  - Heat Utilization: The amount of heat transferred from the CHP unit to the chiller was measured using flow rate and temperature data to ensure the system's efficiency.
- Performance Validation Data loggers continuously recorded system performance at Enersion's facility and then at the test site for a period totalling over 2 months to capture variations and assess reliability. The results were compared against project targets, with adjustments made to optimize flow rates and thermal transfer if discrepancies were observed. The final data confirmed that the system achieved significant energy savings (89%) and met cooling demands, while delivering the required cooling outlet temperature (7°C).
- Data Analysis Performance data was analyzed to calculate energy savings, GHG reduction, and operational efficiency. The cooling capacity and electrical COP were validated against the revised success metrics in the Contribution Agreement. The system demonstrated reliable and consistent operation, achieving the project's objectives within the revised scope.

6.8 TECHNOLOGY DEVELOPMENT

Technology Development
The core technology demonstrated in the project was Enersion's adsorption-based cooling system, integrated with a Combined Heat and Power (CHP) unit to provide cooling, heating, and electricity in one efficient package. This innovative system utilizes plain water as a refrigerant, eliminating synthetic refrigerants with high Global Warming Potential (GWP) and reducing electricity consumption for cooling by 89%.

Key steps in the technology development included:
Design and Engineering:
Enersion's adsorption chiller was designed to operate efficiently with low-grade heat (~85°C) from CHP units. The design leveraged Enersion's patented nano-porous materials for enhanced adsorption performance and thermal efficiency.
Experimentations, thermodynamic caluculations and analysis were conducted to optimize heat transfer and flow dynamics in both the smaller 20-ton test system and the final 50-ton chiller.

Prototyping and Pre-Testing:
The smaller 20-ton chiller was developed first to validate design parameters. Data from this prototype informed adjustments to scale the system up to a 50-ton capacity.
The 50-ton chiller was fabricated at Enersion's facility, where rigorous pre-installation testing was conducted using simulated heat input to verify cooling capacity, electrical Coefficient of Performance (COP), and thermal efficiency.

Technology Adjustments:
Based on pre-testing results, the system was fine-tuned to optimize energy use, with a focus on maintaining steady operation at heat inlet temperatures of 87°C and delivering a cooling outlet temperature of 7°C.

Installation
The installation phase involved integrating the 50-ton adsorption chiller with Hart Land Farming's existing CHP unit. The process included:

- Site Preparation:
  After the project site was shifted from Current Prairie Fishermen to Hart Land Farming, a detailed engineering plan was developed, including custom piping and pump station designs.

  Infrastructure adjustments were made to accommodate the 50-ton chiller, including connecting the CHP unit's heat output to the chiller's inlet via a custom-designed piping system.
- Transportation and Setup:
  The chiller was transported to Hart Land Farming after completing pre-testing and quality checks at Enersion's facility.
  On-site setup included aligning the chiller with the CHP unit and integrating additional components, such as flow meters, heat exchangers, and temperature sensors.
- Integration with the CHP System:
  The chiller was connected to the CHP unit's heat output loop, ensuring minimal heat loss during transfer. The pump station was calibrated to provide steady heat flow at the required temperature.

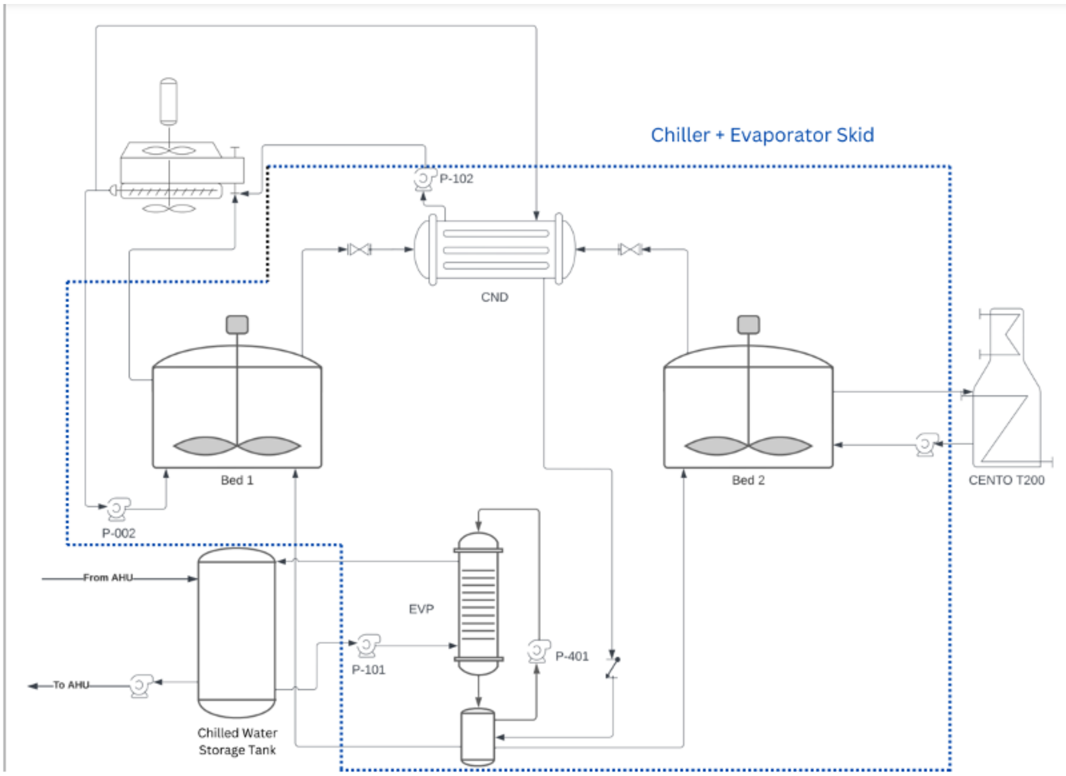

Figure 3: Connections of the internal components with the facility

The diagram above presents the main components of the chiller system and their connections with external elements within the facility. The dashed blue line contains the key internal components, which include two beds of adsorbent, the condenser, and the evaporator.
Externally, the system interfaces with various components to deliver and regulate cooling and heating within the facility. The evaporator is connected to a chilled water tanks for storage, which then link to an air handling unit. This setup enables the cooling effect produced by the evaporator to be transferred to the working and living spaces at the site, with chilled water storage allowing for controlled cooling delivery on a chilled water loop as needed.

The system also integrates with a Combined Heat and Power (CHP) unit, referred to as the CentoT200 in the diagram. This CHP unit connects to the adsorbent beds (Bed 1 and Bed 2), providing the heat energy supply for the regeneration of the adsorbent materials. Finally, at the upper left corner of Figure 3 the condenser is linked to air dissipator, enabling the rejection of heat from condensation to the external atmosphere. This heat could be used in future for hot water circuits, giving additional savings in facility energy consumption,

Commissioning:
The commissioning phase focused on validating the integrated system's performance under real-world conditions:

- Initial Testing:
  The chiller was tested using the heat input from the operational CHP unit. Sensors were installed to monitor inlet and outlet temperatures, flow rates, and electrical consumption.

Flow meters and temperature differentials across the heat exchangers were used to calculate cooling capacity and verify energy efficiency.

- Performance Optimization:
  On-site adjustments were made to optimize flow rates, thermal transfer, and system balance. This included recalibrating the pump station and fine-tuning the control systems for the chiller.

- Data Collection and Analysis:
  Continuous data logging was employed to monitor performance metrics, such as electrical COP, cooling output, and heat utilization.
  The system achieved a cooling outlet temperature of 7°C, an electrical COP of 27.3, and a 89% reduction in electricity consumption for cooling.

The integrated system demonstrated reliable operation and substantial energy savings, meeting the project's revised success metrics. The commissioning process validated the scalability and feasibility of Enersion's adsorption cooling technology for commercial and industrial applications.

6.9 PROJECT ACHIEVEMENTS, RESULTS, AND ANALYSIS

The project successfully demonstrated the integration of Enersion's adsorption chiller with a Combined Heat and Power (CHP) system, achieving significant energy efficiency gains and GHG reductions.

Despite logistical delays and changes in demonstration partners, the project met and exceeded its key performance metrics, validating Enersion's technology for commercial deployment.

Key findings from system testing at the Hart Land Farming site include:

1. COP (Coefficient of Performance) Exceeded Targets
   Electrical COP: Achieved 27.3 vs. the project target of 16, indicating high energy efficiency.
2. Cooling Performance
   Achieved 7°C chilled water output, surpassing the target of 9°C.
   The system successfully extracted heat from the CHP unit at 87°C, with expectations to reach 89°C in summer months.
   Enabled cooling of 759,672 kWh annually and heating of 2,633,530 kWh annually.
3. Energy & Emissions Reductions
   Reduced natural gas consumption of CHP by 53,915 m3 per year.
   This results in GHG emission reductions of 111 metric tons of CO_2e annually (87% reduction).

The successful validation of Enersion's adsorption cooling system exceeded expectations, demonstrating a higher-than-expected efficiency with a COP of 27.3. This confirmed its economic viability and environmental benefits, proving the technology's strong compatibility with Combined Heat and Power (CHP) systems, where waste heat can be fully utilized for cooling and heating applications.

During implementation, the project encountered operational challenges, including a strainer blockage in the evaporator pump, which initially limited cooling output but was resolved during commissioning.

Additionally, fine-tuning was required to maintain vacuum stability in the adsorption cycle. These learnings have led to future design enhancements, with Enersion developing a new horizontal evaporator design to make the system more compact and efficient.

The successful demonstration of the technology at the project site confirmed that Enersion's adsorption chiller can be seamlessly integrated with existing CHP systems, making it an ideal solution for industrial and commercial cooling applications.

7.0 LESSONS LEARNED

7.1 CHALLENGES

The project faced multiple challenges, delays, and logistical constraints throughout its lifecycle, requiring adaptive strategies to keep it on track. These challenges included site changes, supply chain disruptions, performance variances, and integration complexities, all of which were carefully managed to ensure project success.

The original implementation site at Current Prairie Fishermen had to be abandoned due to insufficient infrastructure and manpower for on-site installation work, delaying the project while a new site was identified. The project was relocated to Hart Land Farming in Bashaw, Alberta, which provided an operational CHP system and adequate human and facility resources to support integration and testing. This transition ensured the project continued within a revised scope without compromising its objectives.

Delays in the shipment of key components, including the adsorption chiller and heat transfer systems, were caused by supply chain disruptions. These setbacks postponed several milestones, particularly the fabrication and testing of the chiller. To mitigate this, Enersion adjusted the project schedule, reallocating resources to engineering studies and site infrastructure preparation, allowing work to continue despite delays.

The integration of the 50-ton chiller with the operational CHP system at Hart Land Farming presented logistical challenges due to site-specific constraints and the need for custom piping and pump stations. The installation process took longer than expected, requiring detailed engineering studies and calibration to achieve efficient heat transfer. Close collaboration with the Hart Land Farming team ensured that operational requirements were met, enabling a successful system rollout.

External factors, including global supply chain disruptions, further affected component availability and shipment timelines, extending the project schedule. Enersion navigated these challenges by maintaining flexibility in scheduling and focusing on parallel activities, ensuring steady progress despite unpredictable external conditions.

7.2 PRACTICAL LEARNINGS

The phased approach of first developing a smaller 20-ton chiller before scaling to a 50-ton system was crucial in identifying and addressing design challenges early. This iterative methodology reduced technical risks and ensured scalability, proving that small-scale pilot projects are essential for validating innovative technologies before commercial deployment. Additionally, optimizing heat transfer was critical to the efficiency of the tri-generation system, as minimizing heat losses played a significant role in overall performance. Custom piping and pump stations were key in integrating the chiller with the CHP system, highlighting the importance of site-specific solutions in achieving energy efficiency targets.

The successful deployment of the system at Hart Land Farming validated its readiness for agricultural and industrial applications, but adoption depends on increasing awareness among potential customers about its economic and environmental benefits. A strong commercialization strategy must include targeted outreach campaigns emphasizing cost savings and sustainability advantages.

Engagement with Hart Land Farming played a crucial role in ensuring the system met operational needs, building trust and facilitating smooth integration. Early and continuous engagement with implementation partners is fundamental to project success, as it helps align expectations and streamline deployment. The project also demonstrated that while achieving 89% electricity savings for cooling makes the system cost-effective, initial capital costs may present a barrier to widespread adoption. Exploring financial incentives and partnerships can help lower upfront costs for early adopters and accelerate market penetration.

Aligning with government decarbonization goals positioned the project for funding and regulatory support, though navigating natural gas and CHP-related regulations required careful planning. Understanding government policies early in the process is crucial for securing funding and avoiding unnecessary delays. The project's GHG reductions further reinforced the value of leveraging carbon pricing and tax credits to enhance the financial feasibility of environmentally friendly technologies. Developing business models that incorporate these incentives can significantly improve market adoption.

Flexibility in project planning proved essential when the implementation site had to be shifted from Current Prairie Fishermen to Hart Land Farming. Adjustments to the project timeline and scope were necessary, but they ultimately contributed to a successful outcome. This experience underscores the importance of building contingency plans into project timelines and budgets to account for unexpected changes. Additionally, delays in component shipments highlighted the need for robust logistics planning and risk mitigation strategies to address supply chain disruptions. Diversifying suppliers and incorporating buffer periods into project schedules can minimize delays and keep projects on track.

The project validated the scalability of Enersion's adsorption chiller technology for larger commercial applications, setting the stage for broader adoption. Partnering with operational facilities like Hart Land Farming allowed for real-world testing, strengthening the project's credibility and demonstrating the importance of industry collaboration. Addressing site-specific challenges with tailored solutions further optimized performance and cost-effectiveness, reinforcing the need for targeted innovation in clean technology deployment. Finally, early engagement with government policy and funding programs significantly enhanced the feasibility of the project, showing that aligning with regulatory frameworks can support long-term commercialization success.

7.3 ORGANIZATIONAL LEARNINGS

- Adaptability and Flexibility: The shift from the originally planned implementation site at Current Prairie Fishermen to Hart Land Farming underscored the importance of being adaptable in the face of unforeseen challenges. This experience strengthened Enersion’s ability to respond quickly and effectively to changing circumstances.

- Collaboration and Stakeholder Engagement: Partnering with Hart Land Farming demonstrated the importance of building strong relationships with stakeholders. Regular communication and collaboration ensured the project aligned with the operational needs of the site.
- Technical Validation: The project validated the scalability of Enersion’s adsorption chiller technology from a 20-ton prototype to a 50-ton commercial system. The engineering and testing process deepened the organization’s understanding of scaling up innovative technologies.
- Variabilities within Real-World Testing: Testing the technology under operational conditions at Hart Land Farming highlighted the importance of accounting for real-world variables such as heat loss, flow rate variability, and site-specific constraints. Learning: Laboratory conditions often differ from real-world environments.
- Risk Mitigation and Planning: Delays in component shipments and logistical issues emphasized the need for robust risk management strategies and contingency planning. Proactively addressing supply chain risks and operational delays helped the team mitigate disruptions.
- Commercialization Insights: The project provided insights into market readiness for Enersion’s technology, particularly in agricultural and industrial applications. While the technology demonstrated significant cost and energy savings, the organization learned that market adoption requires clear communication of benefits to potential customers.
- Technology Improvement Opportunities While the project met performance metrics, the development and installation of the system lead to the opening of 2 new revenues for refinement and additional functionality: Evaporator design and increasing heat exhaust temperature.

7.4 HIGHLIGHTS

Successful Commercial-Scale Demonstration – Enersion’s 50-ton adsorption chiller was successfully integrated with an operational CHP system at Hart Land Farming, proving the feasibility of tri-generation for cooling, heating, and electricity generation.

Higher-than-Expected Efficiency – The system achieved an electrical COP of 27.3, surpassing the target of 16, demonstrating exceptional energy efficiency and cost savings.

Significant Energy and GHG Reductions – The project resulted in a projection of 53,915 m3 of natural gas savings per year and a 87% reduction in GHG emissions, eliminating 111 metric tons of CO_2e annually.

First-of-Its-Kind Cooling Application – This project marked the first full-scale deployment of Enersion’s adsorption cooling system in an agriculture CHP setting, validating its commercial viability.

Performance Refinements and System Enhancements – Based on real-world testing, flow rate adjustments and system balancing improved performance, and new design enhancements were identified for future optimization.

Discovery: Condenser Heat Utilization for Hot Water – The project revealed that condenser heat output temperature can be raised and amplified by 1.5 times, opening possibilities for domestic hot water applications, making the system more versatile.

Scalability Proven for Larger Deployments – The success of the 50-ton system confirmed that the technology can be scaled for commercial and industrial applications, paving the way for future installations.

Adaptability and Site Flexibility – Despite the transition from Current Prairie Fishermen to Hart Land Farming, the project successfully adapted to a new operational environment, reinforcing the system's ability to function in diverse settings.

8.0 GHG BENEFITS

8.1 PROJECT BASELINE EMISSIONS

The baseline scenario represents the emissions profile of the project site before the implementation of Enersion's technology. The site was initially planning to install a conventional compressor-based chiller for its cooling requirements, relying on additional electricity from an on-site natural gas-based Combined Heat and Power (CHP) system, which already is working through the year.

In the baseline case, cooling demand of 50 refrigeration tons (RT) would be met using a compressor-based chiller with a Coefficient of Performance (COP) of 3.5, operating for 6 months per year. The electricity required to operate the chiller would be drawn from the CHP, leading to additional natural gas consumption beyond what the CHP already consumes.

The key parameters of the baseline scenario include:

- Cooling Output: 759,672 kWh
- Electricity Consumption from CHP: 217,049 kWh
- CHP Efficiency:
  - Electrical Efficiency: 33%
  - Thermal Efficiency: 52%
- Additional Natural Gas Consumption for Cooling: 62,302 m^3
- Refrigerant Used: R134A (GWP = 1430)
  - Leakage Rate: 10%
  - Refrigerant Mass: 0.9 kg per ton of cooling

Baseline Emissions Quantification

1. GHG Emissions from Natural Gas Consumption:
   - Additional natural gas consumption for cooling: 62,302 m^3
   - Corresponding emissions: 121,970 kg CO_2e
2. GHG Emissions from Refrigerant Leakage:
   - Leakage emissions from R134A refrigerant: 6,435 kg CO_2e
3. Total Baseline Emissions:
   - 128,405 kg CO_2e

8.2 PROJECT EMISSIONS

The proposed project involves the installation of Enersion's heat-driven cooling technology, which utilizes the waste heat generated by the existing CHP instead of relying on electricity to drive a conventional chiller. This significantly reduces additional natural gas consumption and eliminates synthetic refrigerant usage.

The Enersion system will also deliver 50 RT of cooling, maintaining the same cooling output as the baseline case. However, instead of consuming additional natural gas for electricity, the system operates using the waste heat from the CHP that would otherwise be discarded during the summer months.
The only additional energy requirement in the project scenario is a small amount of electricity needed to operate the Enersion chiller, which has a significantly higher COP of 26. While the test was conducted for a limited time, the emission calculations are projections based on the performance of the technology.
The key parameters in the project scenario include:

- Cooling Output: 759,672 kWh
- Electricity Consumption: 29,218 kWh
- Additional Natural Gas Consumption for CHP Electricity Production: 8,387 m^3
- Refrigerant Used: None

Project Emissions Quantification

1. GHG Emissions from Additional Natural Gas Consumption:
    a. Additional natural gas required: 8,387 m^3
    b. Corresponding emissions: 17,285 kg CO_2e (natural gas emission factor= (2.061 kgCO2e/m3)
2. GHG Emissions from Refrigerant Leakage:
    a. 0 kg CO_2e (No synthetic refrigerants used)
3. Total Project Emissions:
    a. 17,285 kg CO_2e

GHG Emissions Reduction Calculation
Total Emission Reductions = Baseline Emissions – Project Emissions
= 128,405 kg CO_2e – 17,285 kg CO_2e
= 111,120 kg CO_2e
Percentage Reduction in Emissions:
= (111,120 / 128,405) × 100
= 87% Reduction

As mentioned earlier, the project site was changed to a location where a CHP system was already in use, which impacted the emissions calculations. However, as we move forward with commercializing the technology, we plan to introduce the concept of tri-generation and quad-generation to customers in Alberta. This approach will involve integrating a CHP system with a CO2 scrubber, resulting in substantial emissions reductions—exceeding 600 tons of CO2 annually, as originally estimated for this project.

8.3 EMISSIONS REDUCTION IMPACT

Table 3: Emissions Reduction Impact

Year	Baseline Emissions @Year (tCO2e)	Project Emissions @Year (tCO2e)	Estimated Annual Production (if applicable)	Unit of Production (RTs cooling capacity)	Emissions Reduction @Year (tCO2e)
2023					
2024					
2025	128	17	1	50	111
2026	128	17	-	50	111
2027	128	17	-	50	111
2028	384	51	2	50	333
2029	1,408	187	8	50	1,221
2030	2,944	391	12	50	2,553
2031-2040	223,570	29,693	368	500	193,877
2041-2050	1,222,206	162,324	1,194	500	1,059,882

The successful implementation of Enersion's adsorption cooling technology aligns with Alberta's Emissions Reduction and Energy Development Plan (EREDP), which aims for net-zero emissions by 2050. By utilizing waste heat from Combined Heat and Power (CHP) systems, this technology reduces reliance on fossil fuels and decreases greenhouse gas emissions, supporting Alberta's goal to reduce methane emissions from upstream oil and gas production by 45% by 2025. The project's scalability in industrial applications positions it as a key contributor to Alberta's low-carbon transition, enhancing energy efficiency and environmental sustainability.

9.0 ENVIRONMENTAL, ECONOMIC, AND SOCIAL IMPACTS

9.1 OTHER ENVIRONMENTAL IMPACTS

The Green Natural Gas-Powered Tri-Generation project resulted in both immediate and long-term environmental benefits beyond greenhouse gas (GHG) reductions. The implementation of adsorption cooling technology integrated with a Combined Heat and Power (CHP) system contributes to sustainability in multiple ways:

1. Criteria Air Contaminant Reductions
By reducing reliance on grid electricity for cooling, the project indirectly reduces emissions of nitrogen oxides (NOx), sulfur oxides (SOx), and particulate matter (PM2.5) that are typically associated with electricity generation from fossil fuels.
The efficient use of natural gas in the CHP system results in lower emissions per unit of energy produced compared to traditional energy systems.

2. Land Use and Resource Efficiency
The adsorption chiller does not require additional land for cooling infrastructure, making it ideal for urban and rural applications without increasing environmental footprint.
The system is designed to be installed within existing facilities, making efficient use of available space and avoiding unnecessary land expansion.

3. Water Consumption
Unlike traditional evaporative cooling systems, Enersion's adsorption chiller uses plain water as a refrigerant but does not rely on evaporative cooling methods such as water cooled chillers, significantly reducing water consumption compared to traditional cooling towers.
By eliminating the need for synthetic refrigerants, the system also prevents water contamination risks associated with refrigerant leaks.

4. Potential Future Environmental Benefits
The adoption of this technology in large-scale commercial and industrial applications across Alberta could lead to massive reductions in energy consumption, refrigerant use, and GHG emissions.
Scaling the technology could displace outdated energy-intensive cooling systems, further lowering Alberta's carbon footprint and supporting net-zero climate goals.

9.2 PROJECTED ECONOMIC IMPACT

The project has the potential to transform Alberta's energy landscape by enhancing energy efficiency, attracting investment in sustainable technologies, and driving economic diversification.

1. Cost Savings and Economic Benefits
The tri-generation system reduces cooling-related electricity costs by 89%, leading to significant operational savings for businesses and industries.
The longer lifespan and low maintenance requirements of adsorption chillers compared to conventional compressor-based chillers contribute to long-term cost reductions.

2. Investment Attraction and Economic Diversification
The project strengthens Alberta's position as a leader in cleantech innovation, making the province more attractive for investment in sustainable HVAC (heating, ventilation, and air conditioning) solutions.
Potential expansion of the technology could drive further investments in clean energy and energy-efficient systems.

3. Tax Revenue and Financial Growth
Increased adoption of this technology could generate new corporate tax revenue from cleantech companies expanding in Alberta.
Reduction in electricity demand could decrease reliance on government subsidies for energy-intensive industries, leading to indirect fiscal benefits.

4. Job Creation
During the Project:
The project supported highly skilled engineering, manufacturing, and installation jobs, including system integration and testing at Hart Land Farming.

- On-site construction and testing activities engaged technicians, field engineers, and logistics personnel.

Projected Job Creation:

- Scaling this technology will generate employment in engineering, HVAC system manufacturing, field services, and research & development leading to at least 20 new hires in the next 5 years
- Service and maintenance sectors will benefit from the deployment of adsorption cooling systems across industries resulting in at least 20 part time jobs in the next 2 years

9.3 RESULTED INNOVATION CAPACITY

The project significantly contributed to Alberta's innovation ecosystem by advancing clean technology research, developing new expertise, and strengthening industry-academic collaboration.

1. Development of Highly Skilled Personnel
The project involved highly specialized engineers and researchers in the development, manufacturing, and testing of the adsorption cooling system.
Training and upskilling were provided to professionals involved in CHP integration, adsorption cooling system operations, and efficiency optimization.

2. Knowledge Development and Research Partnerships
The project enhanced industry knowledge of adsorption-based cooling technology and how it can be integrated with CHP systems for greater energy efficiency.
Future collaborations with research institutions and technical universities are expected to build on this knowledge, fostering Alberta's role as a hub for cleantech innovation.

3. Support for Startup Companies
By successfully demonstrating the commercial feasibility of adsorption cooling, the project has paved the way for more cleantech startups to develop energy-efficient solutions in the HVAC sector.
Alberta could see increased entrepreneurship and startup activity focused on low-carbon cooling and heating technologies.

9.4 SOCIAL IMPACT AND EDI OUTCOMES

The project had a positive social impact, particularly in rural communities and the broader clean energy sector, where job opportunities and sustainability initiatives are growing.

1. Impact on Local Communities
By implementing the project at Hart Land Farming in rural Alberta, the initiative directly supported local employment and economic growth in the region.
The reduction in energy costs benefits agricultural businesses, helping them stay competitive and improve profitability.

2. Expanding Opportunities in Underserved Communities
The project provides a scalable solution for remote and off-grid communities where energy costs are disproportionately high.
Future deployments of this technology could enhance energy access in Indigenous and rural communities, reducing their reliance on expensive diesel generators and grid electricity.

3. Equity, Diversity, and Inclusion Initiatives
The project involved diverse teams of engineers, technicians, and field experts, contributing to Alberta's growing talent pool in clean energy innovation.
As Enersion expands, there is potential for the company to increase hiring and training opportunities for underrepresented groups in STEM (Science, Technology, Engineering, and Mathematics) fields.

4. Supporting Sustainable Agriculture and Food Security
The deployment of energy-efficient cooling at Hart Land Farming supports sustainable agriculture by reducing operational costs.

As energy savings allow farms to allocate more resources to food production, this technology indirectly contributes to food security and sustainable farming practices.

10.0 SCIENTIFIC ACHIEVEMENTS

Enersion had started filling patents before the project on the design that was developed prior to the project. Although the IP that was patented does not arise from this project, publications of the patents took place during the project. Enersion has a PCT patent in 13 jurisdictions which has been granted in 10 and is in examination in 3. Additionally, Enersion has 6 divisional patents of which 4 have been granted. The patents cover the mechanical design of the system which is key to the innovation.

11.0 POST-PROJECT STEPS

11.1 NEXT STEPS AND FOLLOW-UP PROJECTS

Following the successful demonstration of Enersion's adsorption cooling technology integrated with a Combined Heat and Power (CHP) system, the next steps for further optimization, commercialization, and deployment include:

Optimization of Technology Performance

- Enhancing Efficiency: Further refinement of the adsorption cycle to increase overall system efficiency.
- Lowering Heat Input Requirements: Improving material design and system control to reduce the required intake heat temperature from 85°C to 55°C, making it compatible with a wider range of low-grade heat sources.
- Increasing heat output temperature: Optimizing the condenser design so that the heat exhaust can be used for domestic hot water applications.

Further Demonstration Projects

- Expanding technology deployment to additional sites, including:
- Utility headquarters (US), where the system will be tested in a commercial urban setting to validate energy savings in densely populated areas.
- New industrial and agricultural sites in Alberta, demonstrating its effectiveness in reducing energy costs for manufacturing and food production sectors.
- Collecting additional performance data in varied operational environments to further refine system parameters and prove scalability.

Scaling Manufacturing and Production Capacity:
Setting up an assembly line to increase production capacity and meet growing demand.
Streamlining supply chains and identifying manufacturing partners to ensure cost-effective scaling.
Exploring automation and modular designs to reduce assembly costs and increase throughput.

Regulatory Approvals and Certifications:
Obtaining certifications such as ASHRAE, CSA, and AHRI, which will help with

- Regulatory compliance in major markets (Canada, U.S., and Europe).

- Enhancing customer confidence and making it easier to enter commercial contracts.
- Compliance with government incentives for energy efficiency and refrigerant-free cooling solutions.
- Strengthening Marketing and Sales Efforts

Developing sales and service channels:

- Expanding the marketing team and improving promotional efforts to increase awareness of Enersion's technology.
- Building distributional channels through partnerships with energy consulting firms and HVAC distributors
- Engaging with key stakeholders, including commercial real estate developers, industrial facility managers, and sustainability consultants, to drive adoption.
- Developing partnerships with HVAC service providers to create an ecosystem for sales, installation, and maintenance.

11.2 PARTNERSHIPS

Enersion has been developing strategic partnerships with key industry players that will support technology integration and commercialization efforts. Some of the key partnerships include:

An established manufacturer of HVAC components
Role: Assisting in manufacturing and design optimization.
Contribution: Helping with finalizing product design for mass production and reducing costs.

A subsidiary of a large energy company that supports scaling up of new technology
Role: Supporting design and supply chain optimization.
Contribution: Offering technical guidance on engineering and manufacturing scalability.

ConEdison, utility and energy provider to New York
Role: Demonstration partner in urban commercial office setting in New York City.
Contribution: Showcasing energy savings and grid load reduction benefits in a major metropolitan area.

Daisy Energy, an experienced Canadian company offering energy solutions to the commercial and industrial sector
Role: Sales and market expansion partner.
Contribution: Assisting in the commercialization of the technology by handling customer engagement, sales, and market penetration strategies.

Architectural and Engineering Firms
Enersion has established relationships with leading engineering and design firms who would be actively introducing Enersion's technology to their commercial and industrial clients.

Utilities and Energy Companies
To help push the technology to large industrial / commercial facilities.

Industry associations helping facilitate connections between Enersion and potential customers.

Hospitals & Institutional Partners
Enersion has Memorandums of Understanding (MOUs) with 2 major hospitals interested in retrofitting their campuses with energy-efficient cooling.

Alberta-Based Network

Recognizing Alberta's significance as a key market, Enersion has engaged in multiple partnerships to accelerate commercialization and technology adoption in the province. These include:

- Enersion has been in discussions with a company specializing in server chip cooling heat exchangers. We are exploring collaboration opportunities to integrate our technology into liquid-cooled data centers. By using waste heat from servers to produce cooling, our technology presents an innovative and energy-efficient solution for data centers, enhancing their sustainability and operational efficiency.
- Enersion is in discussions with an Alberta-based company specializing in closed-loop geothermal energy solutions. We are exploring the opportunity to integrate our technology with their geothermal systems to produce sustainable cooling, leveraging geothermal heat as a primary energy source.
- Enersion has developed an agreement with a manufacturer of combined heat and power (CHP) systems. They have a significant presence in the agricultural sector, having deployed numerous CHP units. They are keen to offer our solution to both their existing and new agricultural customers based on the success of this project. Enersion will work with them to identify and engage additional agricultural customers in Alberta, demonstrating the benefits of our technology in the sector.
- We are collaborating with a CHP distributor to target Alberta-based tri-generation customers, particularly within commercial and industrial sectors. This initiative will help expand the reach of our cooling solution in Alberta and showcase its effectiveness in reducing energy consumption.
- Enersion is in talks with an Alberta based solar thermal technology provider to integrate solar thermal energy with our cooling technology. This collaboration aims to utilize solar heat as an energy source to drive our cooling systems, further adding application to the technology.

12.0 OVERALL CONCLUSIONS

The Green Natural Gas-Powered Tri-Generation Project successfully demonstrated Enersion's adsorption cooling technology, proving its commercial viability, energy efficiency, and environmental benefits. The project showcased how waste heat from a Combined Heat and Power (CHP) system can be efficiently utilized for cooling, heating, and electricity generation, significantly reducing grid electricity demand and greenhouse gas (GHG) emissions.

By integrating the 50-ton adsorption chiller at Hart Land Farming in Alberta, the project achieved an electrical COP of 27.3, exceeding expectations and demonstrating up to 89% electricity savings for cooling. The system resulted in a projected annual reduction of 53,915 m3 of natural gas consumption annually along no emissions related to refrigerant usage, leading to a 87% reduction in GHG emissions—equivalent to 111 metric tons of CO_2e per year. The reduction in natural gas is because the CHP would have otherwise needed to produce more electricity in the scenario that the facility would have used a conventional cooling system, whereas in the project scenario, Enersion's cooling uses heat as the energy source from CHP output that is anyway being generated in the base case scenario.

This project validated that Enersion's adsorption cooling system is scalable and can be integrated with existing CHP systems, making it an ideal solution for industrial and commercial applications. The findings from this demonstration support Enersion's plans for future deployments at commercial and industrial facilitied in Canada and the US. Additionally, the discovery that condenser heat output can be amplified by 1.5 times for domestic hot water applications expands the technology's potential uses.

Overall, the project reinforced the role of adsorption cooling in decarbonizing industrial and commercial sectors, reducing reliance on electricity-driven cooling, and offering a cost-effective, environmentally friendly alternative. The success of this project sets the foundation for large-scale commercialization, further contributing to GHG reductions in Alberta and beyond.

13.0 COMMERCIALIZATION AND TECHNOLOGY TRANSFER PLAN

13.1 PROJECT COMMERCIALIZATION ADVANCEMENTS

Advancements Toward Commercialization and Market Adoption
1. Securing Commercial Deployment Projects
Since the completion of the ERA-funded project, Enersion has successfully secured multiple commercial projects and feasibility studies with major organizations, indicating strong market interest and growing adoption of the technology.

Utility Headquarter (US):
Enersion has secured a high-profile project with one of the largest utility providers in the U.S.
The installation at their headquarters will demonstrate the technology in a commercial urban setting, serving as a major proof point for the utility sector.

Solar powered project in California, Supported by the California Energy Commission:
Enersion's technology will be installed at a commercial facility in California, with support from the California Energy Commission.
This deployment will further validate the system's performance in warm climate conditions where cooling demand is high.

Feasibility Studies with Large Commercial and Industrial Customers:
Enersion is conducting feasibility studies for adoption with:
A manufacturing facility in the US – for integration in manufacturing processes.
A brewery in Boston – exploring adsorption cooling for brewery operations.
A data center in Toronto – evaluating adoption for energy-efficient cooling in data centers.

2. Expansion of Sales and Market Channels

- Partnership with Daisy Energy:
  Enersion has established a working partnership with Daisy Energy, which is acting as a sales channel for the technology.
  Daisy Energy will help connect Enersion with potential customers, assisting in the expansion of commercial deployments across North America, starting initially with Ontario and Alberta.
- Engagement with HVAC and Engineering Firms:

Enersion is collaborating with engineering and HVAC design firms that are actively introducing the technology to their clients in industrial, commercial, and institutional sectors.

3. Recognition and Market Validation

- The project has helped Enersion gain industry credibility by validating performance metrics under real-world conditions.
- Participation in government-funded initiatives (ERA, California Energy Commission) has increased investor and customer confidence in the technology.
- Enersion was recently listed in the Global Cleantech 100, a prestigious list put together by the Cleantech Group comprising of the most innovative companies in the cleantech space.

Despite these significant advancements, certain challenges remain in scaling up commercialization efforts:

- Limited Manufacturing Capacity
  Current production capacity is not sufficient to meet growing market demand. Enersion is currently raising funds to establish a dedicated manufacturing assembly line that will allow for:
    - Increased production volume to support larger commercial orders.
    - Lower unit costs through economies of scale.
    - Faster delivery times to meet customer expectations.

  Need for Certifications and Standardization
  While performance has been demonstrated, obtaining industry-standard certifications (ASHRAE, CSA, AHRI) will further accelerate adoption by ensuring compliance with building codes and regulations.

  Market Awareness and Education
  Many customers are still unfamiliar with adsorption cooling technology and its benefits over traditional systems.
  Increased marketing efforts, customer education initiatives, and case studies are required to drive adoption.

Table 4: Commercialization Targets

Success Metric	Commercialization targets from CA	Commercialization targets after project completion	Explanation
COP Electrical	18	27.3	
Electrical Saving	85%	89%	
Heat Inlet Temperature of the chiller	75 deg C	87 deg C	Enersion's unit worked with the heat from the CHP which was at a higher temperature
Cooling Outlet Temperature of the chiller	8 deg C	7 deg C	

Enersion has successfully met all its commercialization targets during this project, except for the heat and lead temperature. Moving forward, Enersion will focus on achieving a target temperature as low as 55°C in the next development phase. The feasibility of this improvement became evident through the work conducted in this project, giving Enersion confidence that it will achieve this goal with the next system iteration.

13.1.1 PROJECT TECHNOLOGY ADVANCEMENTS

Technology Advancements Over the Course of the Project
During the implementation of the Green Natural Gas-Powered Tri-Generation project, two major technological advancements were made to enhance the efficiency and performance of Enersion's adsorption-based cooling system:

- Redesign and Expansion of the Evaporator
  Enersion identified that the original evaporator design limited cooling efficiency and output. A new, larger evaporator was designed and incorporated, significantly improving heat transfer and system performance.
  The new evaporator design increased overall system efficiency, leading to higher cooling capacity without increasing machine size or energy consumption.

- Enhancement of the Condenser Heat Output Temperature
  Enersion developed a method to increase the condenser heat output temperature, creating an opportunity to repurpose waste heat for domestic hot water applications.
  This advancement means that the heat output from the condenser can now be utilized more effectively, amplifying the heat from the source by up to 1.5 times.
  Future demonstrations will refine and optimize this capability, making Enersion's technology even more valuable for applications requiring both cooling and hot water.

- Reducing intake heat temperature requirement to 55 deg C
  Enersion found a method to reduce the heat intake temperature by using different nano-porous materials and changing certain operating conditions. This will be used for future systems that need to work with heat temperatures that are low such as liquid cooled data centres.

Impact of These Advancements on the Technology and Company
The advancements made during the project have significant long-term implications for Enersion's technology and business strategy:

- Higher Cooling Capacity Without Increasing Machine Size
  The redesigned evaporator allows the same physical unit to be rated for higher cooling output, making the technology more competitive.
  This means better performance at lower costs, making the system more attractive to commercial and industrial users.

- Expanded Market Applications
  The ability to capture condenser heat for domestic hot water opens new market opportunities in residential and commercial heating applications.
  This advancement makes the system ideal for hotels, hospitals, and multi-residential buildings that require both cooling and hot water.
- Increased Energy Savings and Efficiency
  The improved evaporator and enhanced heat utilization mean that Enersion's technology can deliver more useful energy output per unit of input heat.
  This improves the system's overall Coefficient of Performance (COP) and strengthens its economic value proposition.
- Competitive Edge in the Market
  With these advancements, Enersion's adsorption cooling system is now more versatile and efficient, positioning the company as a leader in next generation cooling and heating solutions.
  The enhancements also make the system more appealing to potential customers and investors, accelerating commercialization efforts.

13.1.2 PROJECT TRL ADVANCEMENTS

At the beginning of the Green Natural Gas-Powered Tri-Generation project, Enersion's adsorption cooling technology was at TRL 6, meaning it had been validated in a relevant environment but had not yet undergone large-scale commercial demonstration.

Through this project, the technology advanced to TRL 8, demonstrating commercial viability in a real-world setting at Hart Land Farming. This progression marks a significant milestone toward full-scale market deployment.

13.2 TECHNOLOGY PROVISION AND THIRD-PARTY VENDORS

Technology Production and Delivery to Customers
Enersion's adsorption cooling technology will be manufactured in-house, ensuring quality control, product consistency, and cost optimization. Currently, Enersion produces its own units, and to meet growing demand, the company will set up a dedicated manufacturing line to scale up production.

The technology provision process involves the following steps:

- In-House Manufacturing
  Enersion will continue to design, fabricate, and assemble its adsorption chillers at its manufacturing facility.
  As demand increases, a new assembly line will be established to support larger-scale production.
- Installation Services
  Enersion will directly handle installation for early-stage deployments to ensure seamless integration with customer facilities.
  The company will work closely with engineering and HVAC teams to optimize installation processes.
- After-Sales Maintenance and Support

Enersion will provide direct maintenance services during the initial deployment phase to ensure reliability and performance.
As Enersion scales its deployment, the company will transition to partner networks for service and maintenance, ensuring a wider coverage.

- Expansion of Service and Installation through Partner Networks
  Over time, Enersion will train and certify partner service providers to expand installation and maintenance capabilities.
  This will allow for rapid deployment and after-sales support in multiple geographic regions.

Third-Party Vendors and Existing Relationships:
To scale production, Enersion relies on key suppliers, manufacturing partners, and service providers.

- Component Suppliers – Sourcing nano-porous materials, heat exchangers, pumps, and control systems from trusted vendors.
- Manufacturing Partner – Bempro supports manufacturing scale-up and design optimization for cost-effective production.
- Sales and Service Partner – Daisy Energy acts as a sales channel partner, helping expand market reach.

13.3 COMPETITIVE SCAN

Industry Overview & Competitive Landscape
Enersion's adsorption cooling technology operates in the commercial and industrial cooling market, a sector currently dominated by vapor-compression-based chillers using synthetic refrigerants. The industry is experiencing a shift toward energy-efficient and environmentally sustainable cooling solutions due to:

- Regulatory pressures to phase out high Global Warming Potential (GWP) refrigerants (e.g., HFC bans).
- Rising electricity costs, increasing demand for lower-energy cooling alternatives.
- Net-zero carbon commitments by businesses and industries.

The primary competitors in this space fall into 2 categories:

- Traditional Vapor-Compression Chillers
- Absorption Chillers

1. Competitor Analysis: Traditional Vapor-Compression Chillers Major Players:

Carrier, Trane, Daikin, York (Johnson Controls), Mitsubishi, LG, and Danfoss These companies dominate the conventional cooling market, offering highly efficient but electricity-intensive systems. Most of their solutions rely on HFC-based refrigerants, which are being phased out due to environmental concerns. Disadvantages (Compared to Enersion's Technology):

- High electricity consumption, increasing operational costs.
- Dependence on synthetic refrigerants, leading to regulatory and environmental concerns.

- Grid dependency, which makes them less sustainable.2. Competitor Analysis: Absorption Chillers

Major Players: Yazaki, Broad, Thermax, Carrier, Trane.

These companies offer lithium-bromide absorption chillers, which, like adsorption chillers, use heat instead of electricity for cooling. They are common in large-scale industrial applications but have higher complexity and maintenance costs.

Disadvantages (Compared to Enersion's Technology):

- Higher maintenance requirements due to corrosive lithium-bromide solutions.
- Larger footprint, requiring more space and infrastructure.
- More complex operation, requiring skilled personnel.

13.4 MARKET AND END-USERS

Target Market and Customer Demographics
Enersion’s adsorption-based cooling technology is designed for commercial, industrial, and institutional sectors that are looking for solutions t:

- Reduce energy costs
- Reduce emissions or decarbonize their buildings.

The primary customers are businesses and organizations that consume large amounts of cooling and heating energy.

Key Target Market Segments:

- Industrial Facilities – Factories, manufacturing plants, and processing facilities with high cooling and waste heat availability.
- Commercial Buildings – Office complexes, hospitals, hotels, and shopping malls seeking energy savings and refrigerant-free cooling.
- Data Centers – Facilities requiring continuous, high-efficiency cooling while minimizing electricity costs.
- Breweries and Food Processing – Industries with consistent cooling demand, such as breweries, dairy farms, and cold storage facilities.
- District Energy Systems – Utilities and cities adopting low-carbon HVAC solutions for district cooling.
- Agriculture & Greenhouses – Farms and greenhouses looking to improve climate control using waste heat.

End-Users and Adoption Timeline
Short-Term (0-2 years)
Commercial and Industrial Early Adopters – Businesses already using CHP systems or have access to waste heat that can integrate adsorption cooling with minimal retrofits.

Pilot Installations & Demonstrations – High-profile projects like Utility HQ (US), California commercial facility supported by CEC, and feasibility studies with various other facilitated in the US and Canada will drive awareness and validation.

Medium-Term (2-5 years)
Scalability in Industrial, Commercial, and Data Centers – More industries adopting adsorption cooling to reduce electricity costs as manufacturing capacity expands.
Market Expansion Through Service Partnerships – Collaborations with Daisy Energy and HVAC contractors will streamline installations.

Long-Term (5+ years)
Broad Market Adoption – Enersion's technology will become a widely accepted cooling alternative, particularly as refrigerant bans and net-zero commitments drive industries to adopt low-GWP, energy-efficient solutions.
District Energy Integration – Expanding into municipal heating and cooling networks.

13.5 MARKETING

Enersion's marketing strategy combines direct and indirect approaches to maximize market penetration. The primary channels include:

- Direct Sales: Focused on early adopters in commercial and industrial sectors through one-on-one engagements.
- Industry Conferences & Trade Shows: Participation in HVAC and energy industry events to showcase the technology.
- Commission-Based Partnerships: Collaborations with boutique energy consulting firms and sustainability-focused architectural/engineering firms to introduce Enersion's solution to their clients.
- Digital and Content Marketing: Leveraging LinkedIn, company blog posts, and case studies to educate the market and generate leads.
- Pilot and Demonstration Projects: Showcasing technology performance through real-world installations, such as the utility headquarters project in the US and a commercial facility in California.
- Partnership with complimenting technology providers: We are also building relationships with companies that provide products with which Enersion can pair it's technology and gain access to a larger market. These include:
    - CoolIt Systems from Alberta, for data center cooling
    - Eavor from Alberta, for geothermal energy based cooling
    - SolarSteam from Alberta, for solar thermal based cooling

Timing and Location of Marketing Activities
2024-2025 (Early Adoption Phase): Targeting government and office buildings with decarbonization mandates through direct sales and participation in energy efficiency forums.
2025-2027 (Market Consolidation): Expanding outreach to commercial and industrial sectors via engineering firms and distribution partnerships.

2027+ (Scaling Phase): Partnering with large HVAC distributors to expand market reach into multi-residential buildings, data centers, and liquid cooling applications.
This multi-phase strategy ensures sustained customer engagement and widespread adoption of Enersion's innovative heat pump technology.

13.6 DISTRIBUTION

Existing and Planned Distribution Channels

1. Direct Sales and Installations (Existing)

Current Approach: Enersion directly engages with industrial, commercial, and institutional customers, handling manufacturing, sales, installation, and maintenance.
Key Customers: Large commercial buildings, manufacturing plants, hospitals, and data centers.
Steps for Expansion:
Develop an in-house sales team to expand outreach to high-energy-consuming industries.
Secure additional pilot projects to showcase real-world performance and drive customer interest.

2. Engineering and Energy Consulting Firms (Existing & Expanding)

Role: Partner with sustainability consultants, engineering firms, and HVAC contractors to integrate Enersion's technology into their clients' projects.
Current Partners:
Daisy Energy – Sales channel partner introducing Enersion's solution to commercial and industrial clients.
Martin Energy – CHP provider across North America with a strong foothold in the agricultural space in Alberta
Architectural and Engineering Firms – Early-stage collaborations with firms like Guttman & Blaevort, Alter Engineers, Eva Green Power, Ecosystem, and SPG.
Steps for Expansion:

- Establish a commission-based model to incentivize engineering firms and HVAC designers to include Enersion's system in their specifications.
- Develop a certified partner program for consulting firms, ensuring proper technology integration.
- Use results from this project to win trust in firms and partners

3. HVAC & Energy Efficiency Distributors (Planned Expansion)

Future Plan: As production scales, Enersion will partner with large-scale HVAC distributors to reach a wider market.
Target Distributors: Companies specializing in energy-efficient and sustainable HVAC solutions.
Steps to Build Access:

- Secure ASHRAE, CSA, and AHRI certifications to meet industry standards.
- Identify regional HVAC partners that align with Enersion's sustainability mission.
- Develop training programs to ensure third-party distributors and installers understand system requirements.

The following steps are required to build the channels:

- Engage with energy policymakers to align with energy efficiency incentive programs.
- Collaborate with utilities offering rebate programs for sustainable cooling technologies.
- Manufacturing Scale-Up – Establish an assembly line to increase production capacity, supporting larger distribution efforts.
- Certification & Compliance – Obtain ASHRAE, CSA, and AHRI certifications to meet industry regulations and expand into certified distributor networks.
- Partner Training Programs – Develop a training and certification program for HVAC contractors and energy consultants to ensure proper installation and maintenance.

13.7 TECHNOLOGY PROTECTION

Enersion protects its adsorption cooling technology through patents and trade secrets covering mechanical design, chiller assembly, and nanoporous material synthesis.

- Patents: Filed in 15 jurisdictions, with 7 granted (Canada, USA, India, China). Managed by Gowling WLG for legal protection.
- Trade Secrets: Proprietary manufacturing and material synthesis techniques enhance security beyond patents.
- Ongoing Protection: Inertion will continue filing patents to strengthen IP and prevent replication.
- No Conflicts: No known competing patents threaten commercialization.
- Enersion's patent portfolio and trade secrets ensure long-term competitive advantage in the market.

13.8 COST OF COMMERCIALIZATION

Enersion was born in 2016, since which Enersion has spent capital and resources in R&D and building of various prototypes, along with funds spent on IP protection and a small amount spend on marketing, totalling up to around $5Million.

The commercialization transfer plan for Enersion's adsorption cooling technology is designed to maximize investment returns by leveraging strategic partnerships, manufacturing scale-up, and market expansion. The plan focuses on reducing production costs, securing funding, and accelerating revenue generation through early adopters in industrial and commercial sectors.

- Proven Market Demand – Successful demonstrations at Hart Land Farming, ConEdison (New York), and a commercial facility in Califonria show strong interest from industrial and commercial clients, reducing market entry risk.
- Cost Savings and Efficiency – The system cuts electricity consumption for cooling by 89%, making it an economically attractive solution for businesses seeking lower operational costs and carbon reductions.
- Scalability – The modular design of the adsorption chiller allows for easy scale-up, ensuring higher production volumes reduce per-unit costs, increasing profitability.
- Strategic Partnerships – Enersion is partnering with Daisy Energy for sales and service expansion and engaging with engineering firms and HVAC distributors to facilitate large-scale adoption.

Table 6: Implementation costs and funding

Cost Category	Estimated Cost	Funding Source
Manufacturing Scale-Up	$5M – Establish assembly line (160 units/year)	Equity investment, government grants
Remaining Development & Optimization	$500k– Improve evaporator design, heat output	Internal R&D budget, government R&D support
Marketing & Sales Expansion	$500K – Canada & US team expansion, industry events	Revenue reinvestment
Patent & IP Protection	$500K – Global patent filings (15+ jurisdictions)	Revenue reinvestment, government grants

Total implementation costs are estimated at ~$6.5M, with funding sources including equity investments, government grants, internal reinvestment, and early revenue generation. Enersion is actively seeking private investors and public funding to support manufacturing scale-up and commercialization.

Revenue Potential:
Enersion's technology has strong revenue potential, with early sales traction and increasing market demand for low-carbon cooling solutions.

- Average Unit Price – $200,000 per system
- Target Sales (First 3 Years Post-Scale-Up) – 100 units/year, growing to 160 units/year after full-scale production
- Projected Annual Revenue (After Full Scale-Up) – $24M per year at full production capacity

Additional revenue streams include technology licensing and service contracts.

To manage risks, Enersion has established contingency strategies, including:

- Alternative Manufacturing Locations – Exploring overseas production to reduce costs and mitigate supply chain disruptions.
- Alternative manufaccturing options – Using contract manufacturing until financial capacity is met
- Diversified Sales Channels – Expanding partnerships with HVAC distributors and engineering firms to drive demand.
- Government Funding Backup – Leveraging carbon reduction incentives and grants to support early commercialization.
- Financial Reserves – Maintaining capital buffers to handle unexpected cost overruns in production or market expansion.

13.9 SHORT-TERM ACTIONS

Enersion will focus on scaling production, expanding market presence, and securing certifications to accelerate commercialization.

Manufacturing Scale-Up

- Establish an assembly line capable of producing 160 units per year with a single-shift operation.
- Streamline supply chain and production processes to meet growing demand.

Marketing Expansion

- Grow the marketing team in Canada and the U.S. to drive awareness and sales.
- Strengthen industry partnerships and direct outreach to target customers.
- Engage with Alberta-based companies such as CoolIt Systems, SolarSteam, and Eavor to explore potential commercialization opportunities.
- Work closely with Alberta agricultural businesses and farms that have deployed CHP systems to drive adoption of Enersion's cooling technology.
- Engage with Alberta-based manufacturers such as Martin Energy to integrate our technology into CHP-based agricultural applications.

Certifications & Industry Compliance

- Obtain ASHRAE and other industry certifications to enhance credibility and ease market adoption.
- Align with regulatory standards to enter new markets.

Industry Engagement & Brand Awareness

- Present technology at major industry exhibitions to showcase benefits and attract customers.
- Participate in HVAC, energy efficiency, and cleantech events to expand visibility.
- Engage with Alberta-based industry groups and energy companies such as Solar Alberta collaborative promotional activities
- Hold Lunch and Learn sessions for energy companies like ATCO gas to create awareness about the solution.

These actions will position Enersion for rapid market growth and large-scale adoption of its adsorption cooling technology.

13.10 LONG-TERM COMMERCIALIZATION

Enersion's long-term strategy focuses on global expansion, strategic partnerships, and scaling production to maximize market reach and impact.

- Geographic Expansion Through Partnerships
  - Collaborate with distributors and service providers to expand into new regions and accelerate adoption.
  - Build a network of certified installation and service partners for seamless deployment.
- Technology Licensing for Non-Core Markets
  - License Enersion's adsorption cooling technology in regions outside key markets to extend global reach.
  - Enable local companies to manufacture and deploy the technology, reducing market-entry barriers.

- Overseas Manufacturing & Production Scale-Up
  - Establish international manufacturing units to meet growing demand in Europe, Asia, and other high-potential markets.
  - Optimize supply chains and logistics to reduce production costs and improve delivery times.

14.0 COMMUNICATIONS PLAN

14.1 KNOWLEDGE SHARING DURING PROJECT

Knowledge Sharing During the Project:
During the project, Enersion consistently shared progress updates and technical information with key stakeholders.

Milestone Reports to Emissions Reduction Alberta (ERA):
Enersion submitted detailed milestone reports to ERA, outlining project progress, achievements, and deliverables for each phase.

Continuous Communication with the Project Site:
Enersion maintained regular collaboration with the project site, sharing engineering drawings, technical specifications, and required information to ensure smooth implementation.
These efforts ensured transparency, alignment, and successful execution of the project.

14.2 KNOWLEDGE SHARING POST PROJECT

Post-project, Enersion will implement an expanded knowledge-sharing strategy to maximize industry adoption, foster technology transfer, and strengthen commercial partnerships.

Industry Engagement & Knowledge Dissemination Activities

- Regular Webinars & Workshops: Organize targeted sessions like lunch n learn sessions for Alberta-based cleantech firms, HVAC engineers, and agribusiness operators to demonstrate system benefits and real-world applications. Enersion has already held such sessions in the past and will now utilize the results from this project in upcoming sessions.
- Publication of Technical Whitepapers & Reports: Create comprehensive documentation detailing system performance, energy savings data, and environmental impact, particularly for agriculture and CHP applications in Alberta.
- Conference Participation: Present findings at ASHRAE, AHR Expo, Buildex, and Calgary Home Show, focusing on cooling efficiency improvements, renewable heat utilization, and economic benefits.

Technology Transfer Activities for Alberta’s Commercial & Agricultural Sectors

- Pilot Expansion with Alberta-Based Companies:
  - Work with Martin Energy and CoGenergy to convey results and benefits of this technology to agricultural customers in Alberta
  - Implement technology trials with Alberta based technology providers like Eavor and SolarSteam to explore more applications applications.

- Training Programs for Alberta-Based HVAC & Energy Service Providers:
  - Enersion is currently develop a certification program for local installers, ensuring broad technology transfer within Alberta.
  - Establish a dedicated training facility in partnership with a local technical college.

Digital & Public Outreach

- Dedicated Knowledge Hub on Enersion's Website:
  - Host a digital repository of case studies, videos, and best practices for industry stakeholders.
  - Enersion will also create a feature to showcase real time savings and results from real deployments like the one from this project.
  - Enersion has already developed the first iteration of an interactive tool for potential customers to model energy savings and CO_2 reduction benefits, and is working on improving this.
- LinkedIn & Industry Media Campaigns:
  - Publish thought-leadership articles focused on Alberta-specific use cases, addressing agricultural and industrial cooling challenges.
  - Feature customer success stories from NuLeaf Farms, Sunterra Farms, and greenhouse operators using Enersion's technology.

Target Audiences for Post-Project Knowledge Sharing

- Commercial & Industrial End-Users – Businesses seeking energy-efficient cooling solutions.
- Agricultural Operators – Greenhouses, vertical farms, and food processing facilities exploring low-cost cooling and tri-generation.
- HVAC Engineers & Sustainability Consultants – Professionals involved in energy system design and implementation.
- Government & Policymakers – Supporting provincial clean energy transition efforts.
- Investors & Cleantech Accelerators – Driving funding for further commercialization and scale-up.

By aligning these knowledge-sharing efforts with Alberta's cleantech ecosystem, Enersion will maximize technology transfer, commercialization success, and industry-wide adoption in the province.

15.0 LITERATURE REVIEWED.

16.0 DEFINITIONS

Coefficient of performance:
a measure of a cooling system's efficiency. It is defined as the ratio of the useful cooling output (heat removed from a space) to the energy input required to achieve that cooling.

Chiller:
a refrigeration device used to remove heat from a liquid, typically water or a water-glycol mixture, which is then circulated through a cooling system to regulate temperature in buildings, industrial processes, or equipment.

Nano-porous materials:
a class of materials that contain pores with diameters typically less than 100 nanometers (nm). These pores provide a high surface area, making them highly effective for applications that require adsorption, filtration, catalysis, or heat and mass transfer.

Combined Heat and Power (CHP):

also known as cogeneration, is a highly efficient process that simultaneously produces electricity and useful heat from a single energy source, such as natural gas, biomass, or waste heat.