**ONTARIO ENERGY BOARD**

**EB-2021-0002**

**IN THE MATTER OF** the *Ontario Energy Board Act*, 1998, S. O. 1998, c. 15, Schedule B;

**AND IN THE MATTER OF** an application for leave to construct natural gas pipeline and associated facilities in the Municipality of Chatham Kent, Municipality of Lakeshore, Town of Kingsville and Municipality of Leamington

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# Compendium of Environmental Defence – Volume I

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**November 10, 2023**

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# PROJECT COSTS AND ECONOMICS

1. The purpose of this Exhibit is to provide an overview of the costs of the Project and the economic analysis that was completed to demonstrate that the Project is economically feasible and in the public interest.

2. This Exhibit is organized as follows:
   A. Project Cost
   B. Project Economics
      i. Stage 1 – Project Specific Discounted Cash Flow Analysis
      ii. Stage 2 – Benefit/Cost Analysis
      iii. Stage 3 – Other Public Interest Considerations
      iv. Summary of Stages 1 to 3 Analyses

## A. **Project Cost**

1. The total estimated cost of the Project is $358.0 million, as shown in Exhibit E, Tab 1, Schedule 2. This cost includes: (i) materials; (ii) labour; (iii) external permitting and land; (iv) outside services; (v) contingencies; (vi) interest during construction; and (vii) indirect overheads. Excluding indirect overheads, the total estimated cost of the Project is $289.2 million. /U

2. The costs are based upon a class 3 estimate prepared in Q1 2023, updated to reflect market conditions based on Q4 2022 contractor responses to RFP, as per American Association of Cost Engineers standards, and include a contingency of approximately 8% applied to all direct capital costs reflecting the detailed engineering design stage of the Project and materials received to date. This contingency amount has been calculated based on the risk profile of the Project and is consistent with contingency amounts calculated for projects in similar stages of design and complexity completed by Enbridge Gas. /U

8. Stage 3 analysis considers other quantifiable benefits and costs related to the construction of the Project, not included in the Stage 2 analysis, and other non-quantifiable public interest considerations.

*i. Stage 1 – Project Specific Discounted Cash Flow Analysis* /U

9. The Stage 1 DCF analysis for the Project can be found at Exhibit E, Tab 1, Schedule 5. This schedule indicates that the Project has a NPV of negative $150 million and a PI of 0.48.

10. A summary of the key input parameters, values and assumptions used in the Stage 1 DCF analysis can be found at Exhibit E, Tab 1, Schedule 3.

11. Incremental cash inflows are estimated based on the transmission portion ("transmission margin") of 2023 OEB-approved rates.[2] The revenue calculation for the transmission margin can be found at Exhibit E, Tab 1, Schedule 4. /U

12. Incremental cash outflows, in accordance with E.B.O. 134, include all estimated incremental Project costs. Indirect overhead is not included within cash outflows.

13. The total estimated incremental cost of $289.2 million can be found at Exhibit E,Tab 1, Schedule 2, Line 7.

*ii. Stage 2 – Benefit/Cost Analysis*

14. A Stage 2 analysis was undertaken as the Stage 1 NPV is less than zero (negative $150 million). The Stage 2 analysis considers the estimated energy cost savings that accrue directly to Enbridge Gas in-franchise customers as a result of using natural /U

[2] EB-2022-0133

gas instead of another fuel to meet their energy requirements. The difference in fuel cost is derived as:

*[Weighted Average Alternative Fuel Cost - Cost of Natural Gas] × Energy Use*

15. The Stage 2 NPV of energy cost savings are estimated to be in the range of approximately $226 million over a period of 20 years to $353 million over 40 years. A range is provided as the outcome can vary depending upon the assumptions for alternative fuel mix, energy use, fuel prices, and term. /U

16. The Stage 2 energy cost savings have only been calculated for the general service customer class. It is assumed that contract rate customers will not choose an alternative fuel if natural gas is not available to them. The non-availability of natural gas will cause contract rate customers to expand or move their operations to other jurisdictions, likely outside of Ontario, where their natural gas needs can be served. The resulting impacts to the Ontario economy are addressed in Stage 3.

17. The results and assumptions associated with this analysis can be found at Exhibit E, Tab 1, Schedule 6.

*iii. Stage 3 – Other Public Interest Considerations*

18. There are several other public interest factors for consideration as a result of the Project. Some are quantifiable and others are not readily quantifiable. Quantifiable factors include GDP, taxes, and employment impacts. Applicable other public interest factors are discussed below:

/U

Economic Benefits for Ontario

19. The construction of the Project will provide direct and indirect economic benefits to

ENBRIDGE GAS INC.

Answer to Interrogatory from
Environmental Defence ("ED")

INTERROGATORY

Reference:

Exhibit E, Tab 1, Schedule 5

Question:

(a) Please provide the DCF analysis in a live excel format.
(b) Please re-calculate the project NPV and PI based on there being zero revenue attributable to the expansion project (i) from 2035 onward, (ii) from 2040 onward, and (iii) from 2050 onward. We are not asking Enbridge to opine on these figures as if they are likely scenarios.
(c) If the project is built but demand does not increase above the current capacity of 713 TJ/d, does Enbridge agree that there would be no incremental revenue attributable to the project? If Enbridge disagrees, please explain.
(d) If the project is built, demand initially increases beyond 713 TJ/d, but then declines to below 713 TJ/d from 2035 onward, does Enbridge agree that there would be no incremental revenue attributable to the project from 2035? If Enbridge disagrees, please explain.
(e) In light of federal decarbonization mandates, what is the probability that the design day demand of the panhandle system is at or below 713 TJ/d in (i) 2035, (ii) 2040, or (iii) 2050. Please provide an answer on a best estimate basis.

**Response**

a) Please see Attachment 1.

b) See Table 1 below. /U

Table 1: Project NPV and PI Based on Zero Revenue from 2035, 2040, and 2050 Onwards

| Scenario | | NPV ($million) | PI |
|---|---|---|---|
| i | 2035 onward | (202) | 0.30 |
| ii | 2040 onward | (186) | 0.35 |
| iii | 2050 onward | (165) | 0.43 |

c) and d)
Enbridge Gas agrees that incremental revenue is tied to incremental demands.

However, as set out in Exhibit B, Tab 1, Schedule 1, the needs for the Project were determined by demands reported by customers through the EOI process. As such, the Company has no basis to expect system demands will decline in the manner suggested by ED.

e) ED's question seeks to have the Company create new evidence based on hypothetical scenarios that would see demand for natural gas decline significantly from current levels. It is not reasonably possible to produce the forecast sought by ED with any certainty as it is unclear how and when the Federal Guidelines will be implemented in Ontario, and what the rate of adoption and/or conversion to alternative energy sources will ultimately be.

Not only does Enbridge Gas not routinely produce forecasts for the durations sought by ED (in part due to escalating forecast uncertainty that is increasingly inherent in longer term forecasts), but it is not practically possible for the Company to completely re-assess the hydraulic models, demand forecasting methodology, engineering design principles, and other factors that currently guide its assessment of projects as part of a response to interrogatories in the current proceeding.

ENBRIDGE GAS INC.

Answer to Interrogatory from
Environmental Defence ("ED")

INTERROGATORY

Reference:

Ex. B, Tab 1, Schedule 1.

Preamble:

Enbridge states as follows on page 9: "Approximately 45% of the firm demand served by the Panhandle System is for general service customers. Enbridge Gas forecasts that general service customer demand in the Panhandle Market will increase by approximately 3.7% between winter 2021/2022 and 2030/2031. Incremental demands from general service customers make up approximately 2.5% of the incremental capacity of the proposed Project."

Question:

(a) Please provide a table listing the forecast number of general service customers, broken down by customer type, and showing the per-customer average demand for each customer type, for 2021/2022 and 2030/2031, for the relevant area.
(b) Please provide the customer attachment forecast for the 2021/2022 and 2030/2031, including a breakdown by customer type and a breakdown by new construction versus conversion of existing building

**Response**

a) and b)
Please see Table 1 below.

Table 1: Forecast General Service Attachments, Panhandle Market (2022-2031)

| **Year** | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|
| Residential Attachments | 1,487 | 1,473 | 1,454 | 1,424 | 1,394 | 1,333 | 1,277 | 1,221 | 1,158 |
| Commercial Attachments | 106 | 117 | 115 | 112 | 109 | 105 | 101 | 98 | 94 |
| Industrial Attachments | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 1 |

The number of general services customers in the relevant area is estimated to be approximately:

- Residential: 180,500
- Commercial/Industrial: 15,500

The per-customer average demand for each customer attachment type is assumed to be 0.89 $m^3$/hr and 9.72 $m^3$/hr for commercial/industrial.

The general service attachments on the Panhandle System is assumed to be approximately 1-5% fuel conversions.

Stage 2 (Customer Fuel Savings) Data for Panhandle Regional Expansion Project

Assumptions

| Line | (a) | (b) | (c) | (d)=(b)-(c) |
|---|---|---|---|---|
| | Fuel Prices | $/m^3 | Gas $/m^3 | Diff $/m^3 |
| 1 | Heating Oil | 1.90 | 0.30 | 1.60 |
| 2 | Propane | 1.14 | 0.30 | 0.84 |
| 3 | Electricity | 1.08 | 0.30 | 0.78 |

Fuel Mix in the Event Gas is Not Available

| Line | | (e) | (f)=(d)*(e) |
|---|---|---|---|
| | | General Service | |
| | | Fuel Mix | Wt Ave Diff $/ M^3 |
| 1 | Heating Oil | 24% | 0.382 |
| 2 | Propane | 10% | 0.080 |
| 3 | Electricity | 67% | 0.520 |
| 4 | Total % | 100% | |
| 5 | Weighted Savings $/m^3 | | 0.982 |

6

7 Gas and alternative fuel prices are the average posted prices for the 12 month period ending March 2023

8 Prices in the above table are before the added cost of Carbon.

9

10 **Carbon Prices** The cost of carbon is added to the price of each fuel in above table

| Line | | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|
| 12 | Cost per tonne | $80 | $95 | $110 | $125 | $140 | $155 | $170 |
| 13 | | Future Yrs 2031 and beyond | | | | | | |
| 14 | Cost per tonne | $0 | | | | | | |

15

16

17 **Calculation for Stage 2 Incremental Energy Demand**

18 Estimated Energy Demand with Pipeline Built

19 Equals Potential annual energy demand (for Stage 2 calculations)

20 Times Weighted Average Savings per M3

21 Equals Annual Fuel Savings: Natural Gas Vs Alt Fuels

22

23 **Discount Rate for Net Present Values** 4.0%

24

25 **Length of Term for Fuel Savings**

26 Stage 2 estimated based on 20 years and 40 years

27

28 **Present Value of Customer Fuel Savings**

29 For conservatism, the NPV is assessed over 20 years with sensitivity at 40 years

30

31

| Line | Figures in $ Millions | 20 Years | 40 Years |
|---|---|---|---|
| 33 | General Service Fuel Savings | 226 | 353 |

34

35 NPV Fuel Savings Range from $226 Mil over 20 yrs to $353 Mil over 40 yrs

| Incremental Growth | Constant | **Units** | **Total** | **2024**<br>1 | **2025**<br>2 | **2026**<br>3 | **2027**<br>4 | **2028**<br>5 | **2029**<br>6 | **2030**<br>7 | **2031**<br>8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Discount Rate | 4.00% | | | | | | | | | | |
| Discount Factor (Mid Period) | 0.5000 | | | 0.9806 | 0.9429 | 0.9066 | 0.8717 | 0.8382 | 0.8060 | 0.7750 | 0.7452 |
| **Assumed Mix of Alt Fuel Market Share if Gas Not Available** | | | | | | | | | | | |
| **Residential & Commercial** | | | | | | | | | | | |
| Heating Oil | % | | | 24% | 24% | 24% | 24% | 24% | 24% | 24% | 24% |
| Propane | % | | | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% |
| Electricity | % | | | 67% | 67% | 67% | 67% | 67% | 67% | 67% | 67% |
| Total | | | | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Energy Prices | $/m^3 | Gas $/m^3 | Diff $/m^3 | | | | | | | | |
| Natural Gas | 0.300 | | | 0.3000 | 0.3000 | 0.3000 | 0.3000 | 0.3000 | 0.3000 | 0.3000 | 0.3000 |
| Heating Oil | 1.903 | 0.30 | 1.6033 | 1.9033 | 1.9033 | 1.9033 | 1.9033 | 1.9033 | 1.9033 | 1.9033 | 1.9033 |
| Propane | 1.140 | 0.30 | 0.8402 | 1.1402 | 1.1402 | 1.1402 | 1.1402 | 1.1402 | 1.1402 | 1.1402 | 1.1402 |
| Electricity | 1.080 | 0.30 | 0.7799 | 1.0799 | 1.0799 | 1.0799 | 1.0799 | 1.0799 | 1.0799 | 1.0799 | 1.0799 |
| Factors for Carbon Calc | | | | | | | | | | | |
| Natural Gas | 0.001958 | | | | | | | | | | |
| Heating Oil | 0.002872 | | | | | | | | | | |
| Propane | 0.002384 | | | | | | | | | | |
| Electricity | - | | | | | | | | | | |
| Carbon Cost Estimate (ICF) | $/ ton | | | 80 | 95 | 110 | 125 | 140 | 155 | 170 | 170 |
| Cost of Carbon Applied to Fuel Price Forecast | | | | | | | | | | | |
| Natural Gas | $/ M3 | | | 0.1566 | 0.1860 | 0.2154 | 0.2448 | 0.2741 | 0.3035 | 0.3329 | 0.3329 |
| Heating Oil | $/ M3 | | | 0.2298 | 0.2728 | 0.3159 | 0.3590 | 0.4021 | 0.4451 | 0.4882 | 0.4882 |
| Propane | $/ M3 | | | 0.1907 | 0.2265 | 0.2623 | 0.2980 | 0.3338 | 0.3695 | 0.4053 | 0.4053 |
| Electricity | $/ M3 | | | - | - | - | - | - | - | - | - |
| Trigger to Apply Carbon Cost | 1 | | | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| Fuel Prices Applied | | | | | | | | | | | |
| Natural Gas | | | | 0.4566 | 0.4860 | 0.5154 | 0.5448 | 0.5741 | 0.6035 | 0.6329 | 0.6329 |
| Heating Oil | | | | 2.1331 | 2.1761 | 2.2192 | 2.2623 | 2.3054 | 2.3485 | 2.3915 | 2.3915 |
| Propane | | | | 1.3309 | 1.3667 | 1.4025 | 1.4382 | 1.4740 | 1.5098 | 1.5455 | 1.5455 |
| Electricity | | | | 1.0799 | 1.0799 | 1.0799 | 1.0799 | 1.0799 | 1.0799 | 1.0799 | 1.0799 |
| YoY change Incremental Growth Residential | 10^3M^3/Yr | | 16,629 | 1,492 | 2,953 | 2,891 | 2,798 | 2,678 | 2,564 | 1,254 | |
| YoY change Incremental Growth Small Commercial | 10^3M^3/Yr | | 5,103 | 465 | 910 | 882 | 853 | 821 | 788 | 384 | |
| YoY change Incremental Growth Large Commercial | 10^3M^3/Yr | | 3,129 | 261 | 521 | 521 | 521 | 521 | 521 | 261 | |
| YoY change Incremental Growth Small Industrial | 10^3M^3/Yr | | 45 | - | 8 | 8 | 8 | 8 | 8 | 8 | |
| Total YoY Gen Serv Incremental Growth | 10^3M^3/Yr | | 24,906 | 2,218 | 4,392 | 4,302 | 4,180 | 4,027 | 3,881 | 1,906 | - |
| Cumulative Growth Residential | 10^3M^3/Yr | | 616,993 | 1,492 | 4,445 | 7,336 | 10,134 | 12,812 | 15,376 | 16,629 | 16,629 |
| Cumulative Growth Small Commercial | 10^3M^3/Yr | | 189,367 | 465 | 1,376 | 2,258 | 3,111 | 3,931 | 4,719 | 5,103 | 5,103 |
| Cumulative Growth Large Commercial | 10^3M^3/Yr | | 115,758 | 261 | 782 | 1,304 | 1,825 | 2,346 | 2,868 | 3,129 | 3,129 |
| Cumulative Growth Small Industrial | 10^3M^3/Yr | | 1,646 | - | 8 | 15 | 23 | 30 | 38 | 45 | 45 |
| Total Cummulative Gen Serv Incremental Growth | 10^3M^3/Yr | | 923,764 | 2,218 | 6,610 | 10,912 | 15,092 | 19,120 | 23,000 | 24,906 | 24,906 |
| Assumed Fuel Mix | $/ M3 | | | | | | | | | | |
| Heating Oil | $1.90 | | | 24% | 24% | 24% | 24% | 24% | 24% | 24% | 24% |
| Propane | $1.08 | | | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% |
| Electricity | $1.14 | | | 67% | 67% | 67% | 67% | 67% | 67% | 67% | 67% |
| Weighted Cost of Alt Fuels | $/ M^3 | | | $1.35 | $1.37 | $1.38 | $1.40 | $1.41 | $1.42 | $1.44 | $1.44 |
| Cost of Gas | $/ M^3 | | | $0.46 | $0.49 | $0.52 | $0.54 | $0.57 | $0.60 | $0.63 | $0.63 |
| Difference | $/ M^3 | | | $0.90 | $0.88 | $0.87 | $0.85 | $0.84 | $0.82 | $0.80 | $0.80 |
| Cumulative Gen Serv & Contract | 10^3M^3/Yr | | | 2,218 | 6,610 | 10,912 | 15,092 | 19,120 | 23,000 | 24,906 | 24,906 |
| Alt Fuel Saving | $/ M^3 | | | 0.90 | 0.88 | 0.87 | 0.85 | 0.84 | 0.82 | 0.80 | 0.80 |
| Res & Comm Fuel Savings with Gas | $ 000's | | | 1,992 | 5,832 | 9,456 | 12,841 | 15,967 | 18,847 | 20,017 | 20,017 |
| Discount Factor (Mid Period) | | | | 0.981 | 0.943 | 0.907 | 0.872 | 0.838 | 0.806 | 0.775 | 0.745 |
| Fuel Savings Discounted | | | | 1,953 | 5,499 | 8,573 | 11,194 | 13,384 | 15,190 | 15,513 | 14,916 |
| Cumulative Fuel Savings: Discounted | $ 000's | | | 1,953 | 7,451 | 16,024 | 27,218 | 40,601 | 55,791 | 71,304 | 86,220 |

| | | |
|---|---|---|
| NPV Term (yrs) | 20 | 40 |
| NPV of Fuel Savings $millions | 226 | 353 |

Government of Canada / Gouvernement du Canada



# Heating and Cooling With a Heat Pump

## Table of Contents

# Introduction

If you are exploring options to heat and cool your home or reduce your energy bills, you might want to consider a heat pump system. Heat pumps are a proven and reliable technology in Canada, capable of providing year-round comfort control for your home by supplying heat in the winter, cooling in the summer, and in some cases, heating hot water for your home.

Heat pumps can be an excellent choice in a variety of applications, and for both new homes and retrofits of existing heating and cooling systems. They are also an option when replacing existing air conditioning systems, as the incremental cost to move from a cooling-only system to a heat pump is often quite low. Given the wealth of different system types and options, it can often be difficult to determine if a heat pump is the right option for your home.

If you are considering a heat pump, you likely have a number of questions, including:

- What types of heat pumps are available?
- How much of my annual heating and cooling needs can a heat pump provide?

- What size of heat pump do I need for my home and application?
- How much do heat pumps cost compared with other systems, and how much could I save on my energy bill?
- Will I need to make additional modifications to my home?
- How much servicing will the system require?

**This booklet provides important facts on heat pumps to help you be more informed, supporting you to make the right choice for your home. Using these questions as a guide, this booklet describes the most common types of heat pumps, and discusses the factors involved in choosing, installing, operating, and maintaining a heat pump.**

## Intended Audience

This booklet is intended for homeowners looking for background information on heat pump technologies in order to support informed decision making regarding system selection and integration, operation and maintenance. The information provided here is general, and specific details may vary depending on your installation and system type. This booklet should not replace working with a contractor or energy advisor, who will ensure that your installation meets your needs and desired objectives.

## A Note on Energy Management in the Home

Heat pumps are very efficient heating and cooling systems and can significantly reduce your energy costs. In thinking of the home as a system, it is recommended that heat losses from your home be minimized from areas such as air leakage (through cracks, holes), poorly insulated walls, ceilings, windows and doors.

Tackling these issues first can allow you to use a smaller heat pump size, thereby reducing heat pump equipment costs and allowing your system to operate more efficiently.

A number of publications explaining how to do this are available from Natural Resources Canada.

# What Is a Heat Pump, and How Does It Work?

Heat pumps are a proven technology that have been used for decades, both in Canada and globally, to efficiently provide heating, cooling, and in some cases, hot water to buildings. In fact, it is likely that you interact with heat pump technology on a daily basis: refrigerators and air conditioners operate using the same principles and technology. This section presents the basics of how a heat pump works, and introduces different system types.

## Heat Pump Basic Concepts

A heat pump is an electrically driven device that extracts heat from a low temperature place (a **source**), and delivers it to a higher temperature place (a **sink**).

To understand this process, think about a bicycle ride over a hill: No effort is required to go from the top of the hill to the bottom, as the bike and rider will move naturally from a high place to a lower one. However, going up the hill requires a lot more work, as the bike is moving against the natural direction of motion.

In a similar manner, heat naturally flows from places with higher temperature to locations with lower temperatures (e.g., in the winter, heat from inside the building is lost to the outside). A heat pump uses additional electrical energy to counter the natural flow of heat, and *pump* the energy available in a colder place to a warmer one.

So how does a heat pump heat or cool your home? As energy is extracted from a **source**, the temperature of the source is reduced. If the home is used as the source, thermal energy will be removed, *cooling* this space. This is how a heat pump operates in cooling mode, and is the same principle used by air conditioners and refrigerators. Similarly, as energy is added to a **sink**, its temperature increases. If the home is used as a sink, thermal energy will be added, heating the space. A heat pump is fully reversible, meaning that it can both heat and cool your home, providing year-round comfort.

## Sources and Sinks for Heat Pumps

Selecting the source and sink for your heat pump system goes a long way in determining the performance, capital costs and operating costs of your system. This section provides a brief overview of common sources and sinks for residential applications in Canada.

**Sources:** Two sources of thermal energy are most commonly used for heating homes with heat pumps in Canada:

- **Air-Source:** The heat pump draws heat from the outside air during the heating season and rejects heat outside during the summer cooling season.
  It may be surprising to know that even when outdoor temperatures are cold, a good deal of energy is still available that can be extracted and delivered to the building. For example, the heat content of air at -18°C equates to 85% of the heat contained at 21°C. This allows the heat pump to provide a good deal of heating, even during colder weather.
  Air-source systems are the most common on the Canadian market, with over 700,000 installed units across Canada.
  This type of system is discussed in more detail in the *Air-Source Heat Pumps section*.
- **Ground-Source:** A ground-source heat pump uses the earth, ground water, or both as the source of heat in the winter, and as a reservoir to reject heat removed from the home in the summer.
  These heat pumps are less common than air-source units, but are becoming more widely used in all provinces of Canada. Their primary

advantage is that they are not subject to extreme temperature fluctuations, using the ground as a constant temperature source, resulting in the most energy efficient type of heat pump system. This type of system is discussed in more detail in the *Ground-Source Heat Pumps* section.

**Sinks:** Two sinks for thermal energy are most commonly used for heating homes with heat pumps in Canada:

- Indoor air is heated by the heat pump. This can be done through:
  - A centrally ducted system or
  - A ductless indoor unit, such as a wall mounted unit.
- Water inside the building is heated. This water can then be used to serve terminal systems like radiators, a radiant floor, or fan coil units via a hydronic system.

## An Introduction to Heat Pump Efficiency

Furnaces and boilers provide space heating by adding heat to the air through the combustion of a fuel such as natural gas or heating oil. While efficiencies have continually improved, they still remain below 100%, meaning that not all the available energy from combustion is used to heat the air.

Heat pumps operate on a different principle. The electricity input into the heat pump is used to *transfer* thermal energy between two locations. This allows the heat pump to operate more efficiently, with typical efficiencies well over
100%, i.e. *more* thermal energy is produced than the amount of electric energy used to pump it.

It is important to note that the efficiency of the heat pump depends greatly on the temperatures of the **source** and **sink**. Just like a steeper hill requires more effort to climb on a bike, greater temperature differences between the source and sink of the heat pump require it to work harder, and can reduce efficiency. Determining the right size of heat pump to maximize seasonal efficiencies is critical. These aspects are discussed in more detail in the *Air-Source Heat Pumps* and *Ground-Source Heat Pumps* sections.

## Efficiency Terminology

A variety of efficiency metrics are used in manufacturer catalogues, which can make understanding system performance somewhat confusing for a first time buyer. Below is a breakdown of some commonly used efficiency terms:

**Steady-State Metrics:** These measures describe heat pump efficiency in a 'steady-state,' i.e., without real-life fluctuations in season and temperature. As such, their value can change significantly as source and sink temperatures, and other operational parameters, change. Steady state metrics include:

**Coefficient of Performance (COP):** The COP is a ratio between the rate at which the heat pump transfers thermal energy (in kW), and the amount of electrical power required to do the pumping (in kW). For example, if a heat pump used 1kW of electrical energy to transfer 3 kW of heat, the COP would be 3.

**Energy Efficiency Ratio (EER):** The EER is similar to the COP, and describes the steady-state cooling efficiency of a heat pump. It is determined by dividing the cooling capacity of the heat pump in Btu/h by the electrical energy input in Watts (W) at a specific temperature. EER is strictly associated with describing the steady-state cooling efficiency, unlike COP which can be used to express the efficiency of a heat pump in heating as well as cooling.

**Seasonal Performance Metrics:** These measures are designed to give a better estimate of performance over a heating or cooling season, by incorporating “real life” variations in temperatures across the season.

Seasonal metrics include:

**Heating Seasonal Performance Factor (HSPF):** HSPF is a ratio of how much energy the heat pump delivers to the building over the full heating season (in Btu), to the total energy (in Watthours) it uses over the same period.
Weather data characteristics of long-term climate conditions are used to represent the heating season in calculating the HSPF. However, this calculation is typically limited to a single region, and may not fully represent performance across Canada. Some manufacturers can provide an HSPF for another climate region upon request; however typically HSPFs are reported for Region 4, representing climates similar to the Midwestern US. Region 5 would cover most of the southern half of the provinces in Canada, from the B.C interior through New Brunswick [1].

**Seasonal Energy Efficiency Ratio (SEER):** SEER measures the cooling efficiency of the heat pump over the entire cooling season. It is determined by dividing the total cooling provided over the cooling season (in Btu) by the total energy used by the heat pump during that time (in Watt-hours). The SEER is based on a climate with an average summer temperature of 28°C.

# Important Terminology for Heat Pump Systems

Here are some common terms you may come across while investigating heat pumps.

## Heat Pump System Components

The **refrigerant** is the fluid that circulates through the heat pump, alternately absorbing, transporting and releasing heat. Depending on its location, the fluid may be liquid, gaseous, or a gas/vapour mixture

The **reversing valve** controls the direction of flow of the refrigerant in the heat pump and changes the heat pump from heating to cooling mode or vice versa.

A **coil** is a loop, or loops, of tubing where heat transfer between the source/sink and refrigerant takes place. The tubing may have fins to increase the surface area available for heat exchange.

The **evaporator** is a coil in which the refrigerant absorbs heat from its surroundings and boils to become a low-temperature vapour. As the refrigerant passes from the reversing valve to the compressor, the accumulator collects any excess liquid that did not vaporize into a gas. Not all heat pumps, however, have an accumulator.

The **compressor** squeezes the molecules of the refrigerant gas together, increasing the temperature of the refrigerant. This device helps to transfer thermal energy between the source and sink.

The **condenser** is a coil in which the refrigerant gives off heat to its surroundings and becomes a liquid.

The **expansion** device lowers the pressure created by the compressor. This causes the temperature to drop, and the refrigerant becomes a low-temperature vapour/liquid mixture.

The **outdoor unit** is where heat is transferred to/from the outdoor air in an air-source heat pump. This unit generally contains a heat exchanger coil, the compressor, and the expansion valve. It looks and operates in the same manner as the outdoor portion of an air-conditioner.

The **indoor coil** is where heat is transferred to/from indoor air in certain types of air-source heat pumps. Generally, the indoor unit contains a heat exchanger coil, and may also include an additional fan to circulate heated or cooled air to the occupied space.

The **plenum** , only seen in ducted installations, is part of the air distribution network. The plenum is an air compartment that forms part of the system for distributing heated or cooled air through the house. It is generally a large compartment immediately above or around the heat exchanger.

### Other Terms

Units of measurement for capacity, or power use:

**A Btu/h**, or British thermal unit per hour, is a unit used to measure the heat output of a heating system. One Btu is the amount of heat energy given off by a typical birthday candle. If this heat energy were released over the course of one hour, it would be the equivalent of one Btu/h.
A **kW**, or **kilowatt**, is equal to 1000 watts. This is the amount of power required by ten 100-watt light bulbs.
A **ton** is a measure of heat pump capacity. It is equivalent to 3.5 kW or 12 000 Btu/h.

## Air-Source Heat Pumps

Air-source heat pumps use the outdoor air as a source of thermal energy in heating mode, and as a sink to reject energy when in cooling mode. These types of systems can generally be classified into two categories:

**Air-Air Heat Pumps.** These units heat or cool the air inside your home, and represent the vast majority of air-source heat pump integrations in Canada. They can be further classified according to the type of installation:

- **Ducted:** The indoor coil of the heat pump is located in a duct. Air is heated or cooled by passing over the coil, before being distributed via the ductwork to different locations in the home.

- **Ductless:** The indoor coil of the heat pump is located in an indoor unit. These indoor units are generally located on the floor or wall of an occupied space, and heat or cool the air in that space directly. Among these units, you may see the terms mini- and multi-split:
  - **Mini-Split:** A single indoor unit is located inside the home, served by a single outdoor unit.
  - **Multi-Split:** Multiple indoor units are located in the home, and are served by a single outdoor unit.

Air-air systems are more efficient when the temperature difference between inside and outside is smaller. Because of this, air-air heat pumps generally try to optimize their efficiency by providing a higher volume of warm air, and heating that air to a lower temperature (normally between 25 and 45°C). This contrasts with furnace systems, which deliver a smaller volume of air, but heat that air to higher temperatures (between 55°C and 60°C). If you are switching to a heat pump from a furnace, you may notice this when you begin using your new heat pump.

**Air-Water Heat Pumps:** Less common in Canada, air-water heat pumps heat or cool water, and are used in homes with hydronic (water-based) distribution systems such as low temperature radiators, radiant floors, or fan coil units. In heating mode, the heat pump provides thermal energy to the hydronic system. This process is reversed in cooling mode, and thermal energy is extracted from the hydronic system and rejected to the outdoor air.

Operating temperatures in the hydronic system are critical when evaluating air-water heat pumps. Air-water heat pumps operate more efficiently when heating the water to lower temperatures, i.e., below 45 to 50°C, and as such are a better match for radiant floors or fan coil systems. Care should be taken if considering their use with high temperature radiators that require water temperatures above 60°C, as these temperatures generally exceed the limits of most residential heat pumps.

## Major Benefits of Air-Source Heat Pumps

Installing an air-source heat pump can offer you a number of benefits. This section explores how air-source heat pumps can benefit your household energy footprint.

### Efficiency

The major benefit of using an air-source heat pump is the high efficiency it can provide in heating compared to typical systems like furnaces, boilers and electric baseboards. At 8°C, the coefficient of performance (COP) of air-source heat pumps typically ranges from between 2.0 and 5.4. This means that, for units with a COP of 5, 5 kilowatt hours (kWh) of heat are transferred for every kWh of electricity supplied to the heat pump. As the outdoor air temperature drops, COPs are lower, as the heat pump must work across a greater temperature difference between the indoor and outdoor space. At –8°C, COPs can range from 1.1 to 3.7.

On a seasonal basis, the heating seasonal performance factor (HSPF) of market available units can vary from 7.1 to 13.2 (Region V). It is important to note that these HSPF estimates are for an area with a climate similar to Ottawa. Actual savings are highly dependant on the location of your heat pump installation.

### Energy Savings

The higher efficiency of the heat pump can translate into significant energy use reductions. Actual savings in your house will depend on a number of factors, including your local climate, efficiency of your current system, size and type of heat pump, and the control strategy. Many online calculators are available to provide a quick estimation of how much energy savings you can expect for your particular application. NRCan’s ASHP-Eval tool is freely available and could be used by installers and mechanical designers to help advise on your situation.

## How Does an Air-Source Heat Pump Work?

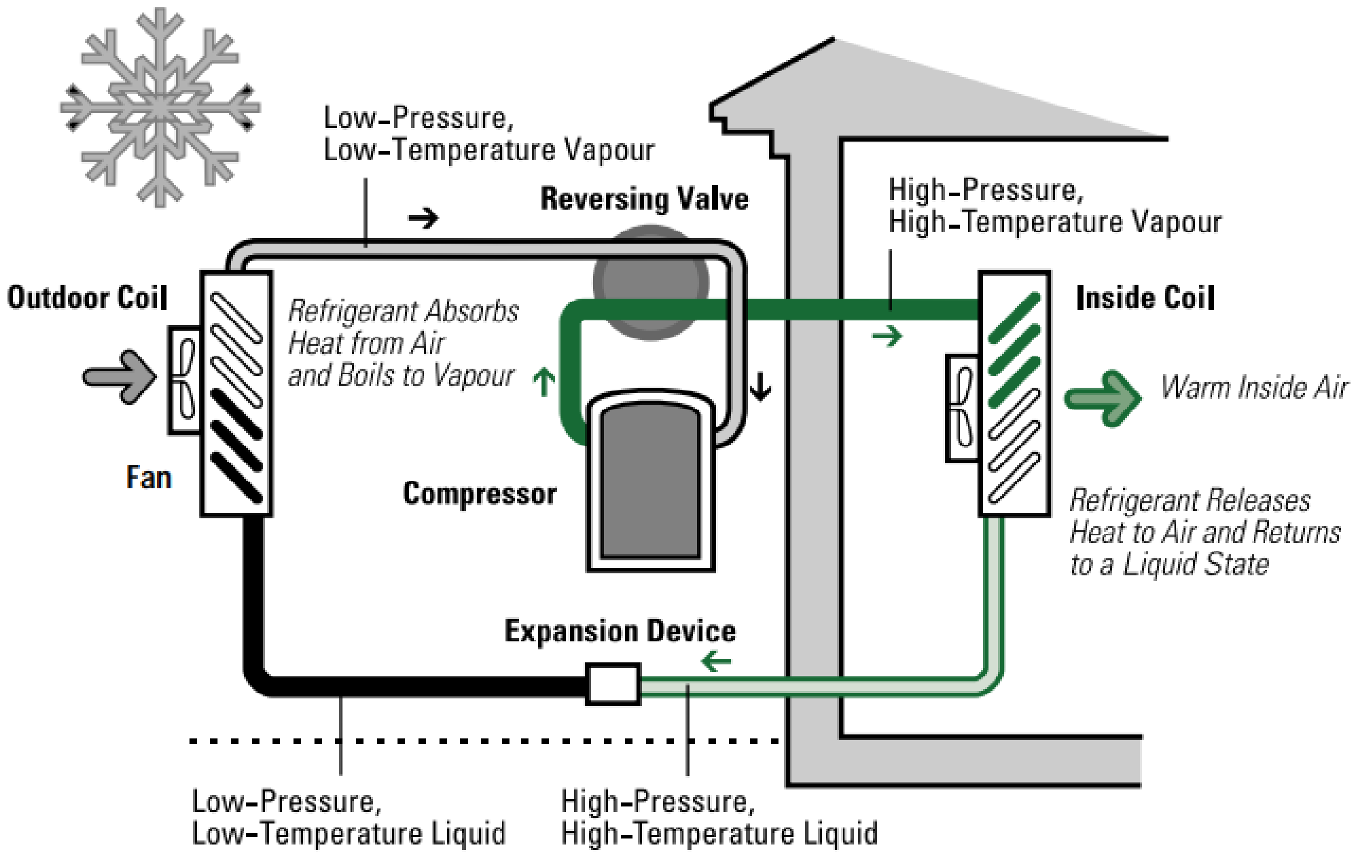
▶ Transcript

An air-source heat pump has three cycles:

- The Heating Cycle: Providing thermal energy to the building
- The Cooling Cycle: Removing thermal energy from the building
- The Defrost Cycle: Removing frost build-up on outdoor coils

### The Heating Cycle

During the heating cycle, heat is taken from outdoor air and "pumped" indoors.

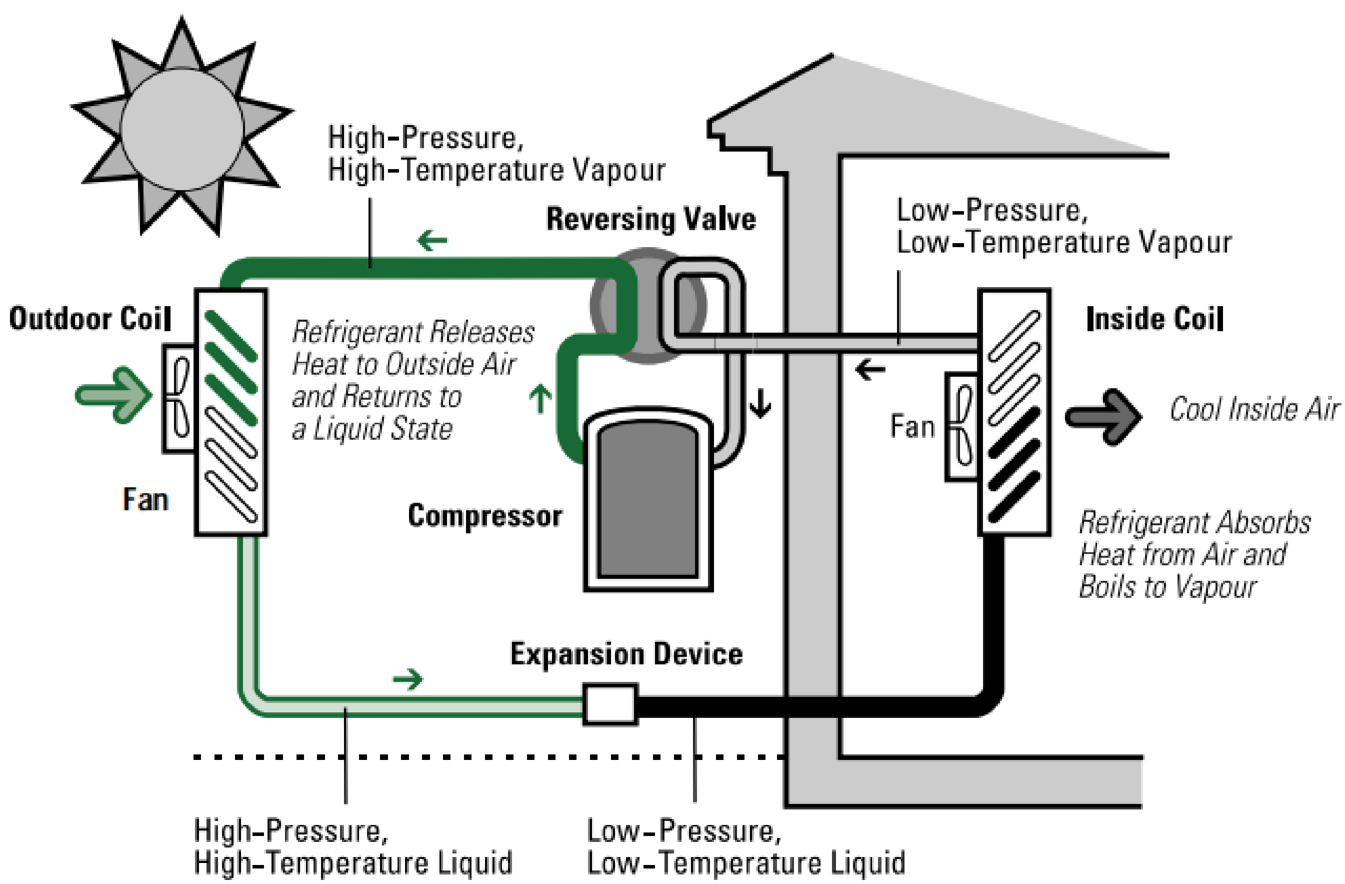



- First, the liquid refrigerant passes through the expansion device, changing to a low-pressure liquid/vapour mixture. It then goes to the outdoor coil, which acts as the evaporator coil. The liquid refrigerant absorbs heat from the outdoor air and boils, becoming a low-temperature vapour.
- This vapour passes through the reversing valve to the accumulator, which collects any remaining liquid before the vapour enters the compressor. The vapour is then compressed, reducing its volume and causing it to heat up.
- Finally, the reversing valve sends the gas, which is now hot, to the indoor coil, which is the condenser. The heat from the hot gas is transferred to the indoor air, causing the refrigerant to condense into a liquid. This liquid returns to the expansion device and the cycle is repeated. The indoor coil is located in the ductwork, close to the furnace.

The ability of the heat pump to transfer heat from the outside air to the house depends on the outdoor temperature. As this temperature drops, the ability of the heat pump to absorb heat also drops. For many air-source heat pump installations, this means that there is a temperature (called the thermal balance point) when the heat pump's heating capacity is equal to the heat loss of the house. Below this outdoor ambient temperature, the heat pump can supply only part of the heat required to keep the living space comfortable, and supplementary heat is required.

It is important to note that the vast majority of air-source heat pumps have a minimum operating temperature, below which they are unable to operate. For newer models, this can range from between -15°C to -25°C. Below this temperature, a supplemental system must be used to provide heating to the building.

### The Cooling Cycle



The cycle described above is reversed to cool the house during the summer. The unit takes heat out of the indoor air and rejects it outside.

- As in the heating cycle, the liquid refrigerant passes through the expansion device, changing to a low-pressure liquid/vapour mixture. It then goes to the indoor coil, which acts as the evaporator. The liquid refrigerant absorbs heat from the indoor air and boils, becoming a low-temperature vapour.
- This vapour passes through the reversing valve to the accumulator, which collects any remaining liquid, and then to the compressor. The vapour is then compressed, reducing its volume and causing it to heat up.
- Finally, the gas, which is now hot, passes through the reversing valve to the outdoor coil, which acts as the condenser. The heat from the hot gas is transferred to the outdoor air, causing the refrigerant to condense into a liquid. This liquid returns to the expansion device, and the cycle is repeated.

During the cooling cycle, the heat pump also dehumidifies the indoor air. Moisture in the air passing over the indoor coil condenses on the coil's surface and is collected in a pan at the bottom of the coil. A condensate drain connects this pan to the house drain.

### The Defrost Cycle

If the outdoor temperature falls to near or below freezing when the heat pump is operating in the heating mode, moisture in the air passing over the outside coil will condense and freeze on it. The amount of frost buildup depends on the outdoor temperature and the amount of moisture in the air.

This frost buildup decreases the efficiency of the coil by reducing its ability to transfer heat to the refrigerant. At some point, the frost must be removed. To do this, the heat pump switches into defrost mode. The most common approach is:

- First, the reversing valve switches the device to the cooling mode. This sends hot gas to the outdoor coil to melt the frost. At the same time the outdoor fan, which normally blows cold air over the coil, is shut off in order to reduce the amount of heat needed to melt the frost.
- While this is happening, the heat pump is cooling the air in the ductwork. The heating system would normally warm this air as it is distributed throughout the house.

One of two methods is used to determine when the unit goes into defrost mode:

- Demand-frost controls monitor airflow, refrigerant pressure, air or coil temperature and pressure differential across the outdoor coil to detect frost accumulation.
- Time-temperature defrost is started and ended by a pre-set interval timer or a temperature sensor located on the outside coil. The cycle can be initiated every 30, 60 or 90 minutes, depending on the climate and the design of the system.

Unnecessary defrost cycles reduce the seasonal performance of the heat pump. As a result, the demand-frost method is generally more efficient since it starts the defrost cycle only when it is required.

## Supplementary Heat Sources

Since air-source heat pumps have a minimum outdoor operating temperature (between -15°C to -25°C) and reduced heating capacity at very cold temperatures, it is important to consider a **supplemental heating source** for air-source heat pump operations. Supplementary heating may also be required when the heat pump is defrosting. Different options are available:

- **All Electric:** In this configuration, heat pump operations are supplemented with electric resistance elements located in the ductwork or with electric baseboards. These resistance elements are less efficient than the heat pump, but their ability to provide heating is independent of outdoor temperature.
- **Hybrid System:** In a hybrid system, the air-source heat pump uses a supplemental system such as a furnace or boiler. This option can be used in new installations, and is also a good option where a heat pump is added to an existing system, for example, when a heat pump is installed as a replacement for a central air-conditioner.

See the final section of this booklet, *Related Equipment*, for more information on systems that use supplementary heating sources. There, you can find discussion of options for how to program your system to transition between heat pump use and supplementary heat source use.

## Energy Efficiency Considerations

To support understanding of this section, refer to the earlier section called *An introduction to Heat Pump Efficiency* for an explanation of what HSPFs and SEERs represent.

In Canada, energy efficiency regulations prescribe a minimum seasonal efficiency in heating and cooling that must be achieved for the product to be sold in the Canadian market. In addition to these regulations, your province or territory may have more stringent requirements.

Minimum performance for Canada as a whole, and typical ranges for market-available products, are summarized below for heating and cooling. It is important to also check to see whether any additional regulations are in place in your region before selecting your system.

Cooling Seasonal Performance, SEER:

- Minimum SEER (Canada): 14

- Range, SEER in Market Available Products: 14 to 42

Heating Seasonal Performance, HSPF

- Minimum HSPF (Canada): 7.1 (for Region V)
- Range, HSPF in Market Available Products: 7.1 to 13.2 (for Region V)

**Note:** HSPF factors are provided for AHRI Climate Zone V, which has a similar climate to Ottawa. Actual seasonal efficiencies may vary depending on your region. A new performance standard that aims to better represent performance of these systems in Canadian regions is currently under development.

The actual SEER or HSPF values depend on a variety of factors primarily related to heat pump design. Current performance has evolved significantly over the last 15 years, driven by new developments in compressor technology, heat exchanger design, and improved refrigerant flow and control.

### Single Speed and Variable Speed Heat Pumps

Of particular importance when considering efficiency is the role of new compressor designs in improving seasonal performance. Typically, units operating at the minimum prescribed SEER and HSPF are characterized by **single speed** heat pumps. **Variable speed** air-source heat pumps are now available that are designed to vary the capacity of the system to more closely match the heating/cooling demand of the house at a given moment. This helps to maintain peak efficiency at all times, including during milder conditions when there is lower-demand on the system.

More recently, air-source heat pumps that are better adapted to operating in the cold Canadian climate have been introduced to the market. These systems, often called **cold climate heat pumps**, combine variable capacity compressors with improved heat exchanger designs and controls to maximize heating capacity at colder air temperatures, while maintaining high efficiencies during milder conditions. These types of systems typically have higher SEER and HSPF values, with some systems reaching SEERs up to 42, and HSPFs approaching 13.

## Certification, Standards, and Rating Scales

The Canadian Standards Association (CSA) currently verifies all heat pumps for electrical safety. A performance standard specifies tests and test conditions at which heat pump heating and cooling capacities and efficiency are determined. The performance testing standards for air-source heat pumps are CSA C656, which (as of 2014) has been harmonised with ANSI/AHRI 210/240-2008, Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment. It also replaces CAN/CSA-C273.3-M91, Performance Standard for Split-System Central Air-Conditioners and Heat Pumps.

## Sizing Considerations

To appropriately size your heat pump system, it is important to understand the heating and cooling needs for your home. It is recommended that a heating and cooling professional be retained to undertake the required calculations. Heating and cooling loads should be determined by using a recognized sizing method such as CSA F280-12, "Determining the Required Capacity of Residential Space Heating and Cooling Appliances."

The sizing of your heat pump system should be done according to your climate, heating and cooling building loads, and the objectives of your installation (e.g., maximizing heating energy savings vs. displacing an existing system during certain periods of the year). To help with this process, NRCan has developed an *Air-Source Heat Pump Sizing and Selection Guide*. This guide, along with a companion software tool, is intended for energy advisors and mechanical designers, and is freely available to provide guidance on appropriate sizing.

If a heat pump is undersized, you will notice that the supplemental heating system will be used more frequently. While an undersized system will still operate efficiently, you may not get the anticipated energy savings due to a high use of a supplemental heating system.

Likewise, if a heat pump is oversized, the desired energy savings may not be realized due to inefficient operation during milder conditions. While the supplemental heating system operates less frequently, under warmer ambient conditions, the heat pump produces too much heat and the unit cycles on and off leading to discomfort, wear on the heat pump, and stand-by electric power draw. It is therefore important to have a good understanding of your heating load and what the heat pump operating characteristics are to achieve optimal energy savings.

## Other Selection Criteria

Apart from sizing, several additional performance factors should be considered:

- **HSPF:** Select a unit with as high an HSPF as practical. For units with comparable HSPF ratings, check their steady-state ratings at −8.3°C, the low temperature rating. The unit with the higher value will be the most efficient one in most regions of Canada.
- **Defrost:** Select a unit with demand-defrost control. This minimizes defrost cycles, which reduces supplementary and heat pump energy use.
- **Sound Rating:** Sound is measured in units called decibels (dB). The lower the value, the lower the sound power emitted by the outdoor unit. The higher the decibel level, the louder the noise. Most heat pumps have a sound rating of 76 dB or lower.

## Installation Considerations

Air-source heat pumps should be installed by a qualified contractor. Consult a local heating and cooling professional to size, install, and maintain your equipment to ensure efficient and reliable operations. If you are looking to implement a heat pump to replace or supplement your central furnace, you should be aware that heat pumps generally operate at higher airflows than furnace systems. Depending on the size of your new heat pump, some modifications may be needed to your ductwork to avoid added noise and fan energy use. Your contractor will be able to give you guidance on your specific case.

The cost of installing an air-source heat pump depends on the type of system, your design objectives, and any existing heating equipment and ductwork in your home. In some cases, additional modifications to the ductwork or electrical services may be required to support your new heat pump installation.

## Operation Considerations

You should note several important things when operating your heat pump:

- **Optimize Heat Pump and Supplemental System Set-points.** If you have an electric supplemental system (e.g., baseboards or resistance elements in duct), be sure to use a lower temperature set-point for your supplemental system. This will help to maximize the amount of heating the heat pump provides to your home, lowering your energy use and utility bills. A set-point of 2°C to 3°C below the heat pump heating temperature set-point is recommended. Consult your installation contractor on the optimal set-point for your system.
- **Set Up for an Efficient Defrost.** You can reduce energy use by having your system set up to turn off the indoor fan during defrost cycles. This can be performed by your installer. However, it is important to note that defrost may take a little longer with this set up.

- **Minimize Temperature Setbacks.** Heat pumps have a slower response than furnace systems, so they have more difficultly responding to deep temperature setbacks. Moderated setbacks of not more than 2°C should be employed or a "smart" thermostat that switches the system on early, in anticipation of a recovery from setback, should be used. Again, consult your installation contractor on the optimal setback temperature for your system.
- **Optimize Your Airflow Direction.** If you have a wall mounted indoor unit, consider adjusting the airflow direction to maximize your comfort. Most manufacturers recommend directing airflow downwards when heating, and towards occupants when in cooling.
- **Optimize fan settings.** Also, be sure to adjust fan settings to maximize comfort. To maximize the heat delivered of the heat pump, it is recommended to set the fan speed to high or 'Auto'. Under cooling, to also improve dehumidification, the 'low' fan speed is recommended.

## Maintenance Considerations

Proper maintenance is critical to ensure your heat pump operates efficiently, reliably, and has a long service life. You should have a qualified contractor do annual maintenance on your unit to ensure everything is in good working order.

Aside from annual maintenance, there are a few simple things you can do to ensure reliable and efficient operations. Be sure to change or clean your air filter every 3 months, as clogged filters will decrease airflow and reduce the efficiency of your system. Also, be sure that vents and air registers in your home are not blocked by furniture or carpeting, as inadequate airflow to or from your unit can shorten equipment lifespans and reduce efficiency of the system.

### Operating Costs

The energy savings from installing a heat pump can help to reduce your monthly energy bills. Achieving a reduction in your energy bills greatly depends on the price of electricity in relation to other fuels such as natural gas or heating oil, and, in retrofit applications, what type of system is being replaced.

Heat pumps in general come at a higher cost compared to other systems such as furnaces or electric baseboards due the number of components in the system. In some regions and cases, this added cost can be recouped in a relatively short time period through the utility cost savings. However, in other regions, varying utility rates can extend this period. It is important to work with your contractor or energy advisor to get an estimate of the economics of heat pumps in your area, and the potential savings you can achieve.

### Life Expectancy and Warranties

Air-source heat pumps have a service life of between 15 and 20 years. The compressor is the critical component of the system.

Most heat pumps are covered by a one-year warranty on parts and labour, and an additional five- to ten-year warranty on the compressor (for parts only). However, warranties vary between manufacturers, so check the fine print.

## Ground-Source Heat Pumps

Ground-source heat pumps use the earth or ground water as a source of thermal energy in heating mode, and as a sink to reject energy when in cooling mode. These types of systems contain two key components:

- **Ground Heat Exchanger:** This is the heat exchanger used to add or remove thermal energy from the earth or ground. Various heat exchanger configurations are possible, and are explained later in this section.

- **Heat Pump:** Instead of air, ground-source heat pumps use a fluid flowing through the ground heat exchanger as their source (in heating) or sink (in cooling).
  On the building side, both air and hydronic (water) systems are possible. Operating temperatures on the building side are very important in hydronic applications. Heat pumps operate more efficiently when heating at lower temperatures of below 45 to 50°C, making them a better match for radiant floors or fan coil systems. Care should be taken if considering their use with high temperature radiators that require water temperatures above 60°C, as these temperatures generally exceed the limits of most residential heat pumps.

Depending on how the heat pump and ground heat exchanger interact, two different system classifications are possible:

- **Secondary Loop:** A liquid (ground water or anti-freeze) is used in the ground heat exchanger. The thermal energy transferred from the ground to the liquid is delivered to the heat pump via a heat exchanger.
- Direct Expansion (DX): A refrigerant is used as the fluid in the ground heat exchanger. The thermal energy extracted by the refrigerant from the ground is used directly by the heat pump - no additional heat exchanger is needed.
  In these systems, the ground heat exchanger is a part of the heat pump itself, acting as the evaporator in heating mode and condenser in cooling mode.

Ground-source heat pumps can serve a suite of comfort needs in your home, including:

- **Heating only:** The heat pump is used only in heating. This can include both space heating and hot water production.
- **Heating with "active cooling":** The heat pump is used in both heating and cooling
- **Heating with "passive cooling":** The heat pump is used in heating, and bypassed in cooling. In cooling, fluid from the building is cooled directly in the ground heat exchanger.

Heating and "active cooling" operations are described in the following section.

## Major Benefits of Ground-Source Heat Pump Systems

### Efficiency

In Canada, where air temperatures can go below –30°C, ground-source systems are able to operate more efficiently because they take advantage of warmer and more stable ground temperatures. Typical water temperatures entering the ground-source heat pump are generally above 0°C, yielding a COP of around 3 for most systems during the coldest winter months.

### Energy Savings

Ground-source systems will reduce your heating and cooling costs substantially. Heating energy cost savings compared with electric furnaces are around 65%.

On average, a well designed ground-source system will yield savings that are about 10-20% more than would be provided by a best in class, cold climate air-source heat pump sized to cover most of the building heating load. This is due to the fact that underground temperatures are higher in winter than air temperatures. As a result, a ground-source heat pump can provide more heat over the course of the winter than an air-source heat pump.

Actual energy savings will vary depending on the local climate, the efficiency of the existing heating system, the costs of fuel and electricity, the size of the heat pump installed, borefield configuration and the seasonal energy balance, and the heat pump efficiency performance at CSA rating conditions.

## How Does a Ground-Source System Work?

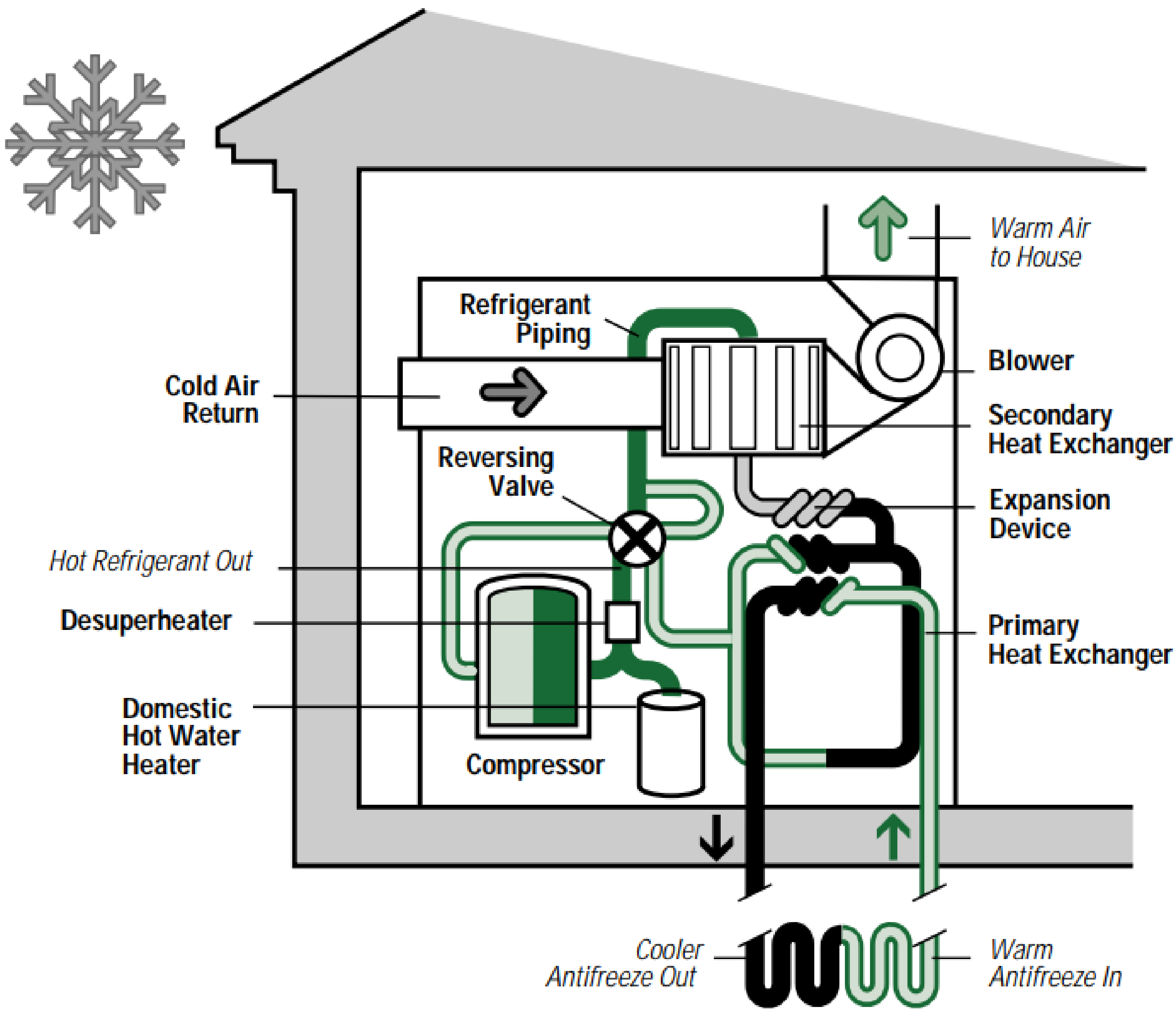
Ground-source heat pumps consist of two main parts: A ground heat exchanger, and a heat pump. Unlike air-source heat pumps, where one heat exchanger is located outside, in ground-source systems, the heat pump unit is located inside the home.

Ground heat exchanger designs can be classified as either:

- **Closed Loop:** Closed-loop systems collect heat from the ground by means of a continuous loop of piping buried underground. An antifreeze solution (or refrigerant in the case of a DX ground-source system), which has been chilled by the heat pump's refrigeration system to several degrees colder than the outside soil, circulates through the piping and absorbs heat from the soil.
  Common piping arrangements in closed loop systems include horizontal, vertical, diagonal and pond/lake ground systems (these arrangements are discussed below, under *Design Considerations*).
- **Open Loop:** Open systems take advantage of the heat retained in an underground body of water. The water is drawn up through a well directly to the heat exchanger, where its heat is extracted. The water is then discharged either to an above-ground body of water, such as a stream or pond, or back to the same underground water body through a separate well.

The selection of outdoor piping system depends on the climate, soil conditions, available land, local installation costs at the site as well as municipal and provincial regulations. For instance, open loop systems are permitted in Ontario, but are not permitted in Quebec. Some municipalities have banned DX systems because the municipal water source is the aquifer.

### The Heating Cycle




In the heating cycle, the ground water, the antifreeze mixture or the refrigerant (which has circulated through the underground piping system and picked up heat from the soil) is brought back to the heat pump unit inside the house. In ground water or antifreeze mixture systems, it then passes through the refrigerant-filled primary heat exchanger. In DX systems, the refrigerant enters the compressor directly, with no intermediate heat exchanger.

The heat is transferred to the refrigerant, which boils to become a low-temperature vapour. In an open system, the ground water is then pumped back out and discharged into a pond or down a well. In a closed-loop system, the antifreeze mixture or refrigerant is pumped back out to the underground piping system to be heated again.

The reversing valve directs the refrigerant vapour to the compressor. The vapour is then compressed, which reduces its volume and causes it to heat up.

Finally, the reversing valve directs the now-hot gas to the condenser coil, where it gives up its heat to the air or hydronic system to heat the home. Having given up its heat, the refrigerant passes through the expansion device, where its temperature and pressure are dropped further before it returns to the first heat exchanger, or to the ground in a DX system, to begin the cycle again.

### The Cooling Cycle

The “active cooling” cycle is basically the reverse of the heating cycle. The direction of the refrigerant flow is changed by the reversing valve. The refrigerant picks up heat from the house air and transfers it directly, in DX systems, or to the ground water or antifreeze mixture. The heat is then pumped outside, into a water body or return well (in an open system) or into the underground piping (in a closed-loop system). Some of this excess heat can be used to preheat domestic hot water.

Unlike air-source heat pumps, ground-source systems do not require a defrost cycle. Temperatures underground are much more stable than air temperatures, and the heat pump unit itself is located inside; therefore, the problems with frost do not arise.

## Parts of the System

Ground-source heat pump systems have three main components: the heat pump unit itself, the liquid heat exchange medium (open system or closed loop), and a distribution system (either air-based or hydronic) that distributes the thermal energy from the heat pump to the building.

Ground-source heat pumps are designed in different ways. For air-based systems, self-contained units combine the blower, compressor, heat exchanger, and condenser coil in a single cabinet. Split systems allow the coil to be added to a forced-air furnace, and use the existing blower and furnace. For hydronic systems, both the source and sink heat exchangers and compressor are in a single cabinet.

## Energy Efficiency Considerations

As with air-source heat pumps, ground-source heat pump systems are available in a range of different efficiencies. See the earlier section called *An introduction to Heat Pump Efficiency* for an explanation of what COPs and EERs represent. Ranges of COPs and EERs for market available units are provided below.

**Ground water or Open-Loop Applications**

Heating

- Minimum Heating COP: 3.6
- Range, Heating COP in Market Available Products: 3.8 to 5.0

Cooling

- Minimum EER: 16.2
- Range, EER in Market Available Products: 19.1 to 27.5

**Closed Loop Applications**

Heating

- Minimum Heating COP: 3.1
- Range, Heating COP in Market Available Products: 3.2 to 4.2

Cooling

- Minimum EER: 13.4
- Range, EER in Market Available Products: 14.6 to 20.4

The minimum efficiency for each type is regulated at the federal level as well as in some provincial jurisdictions. There has been a dramatic improvement in the efficiency of ground-source systems. The same developments in compressors, motors and controls that are available to air-source heat pump manufacturers are resulting in higher levels of efficiency for ground-source systems.

Lower-end systems typically employ two stage compressors, relatively standard size refrigerant-to-air heat exchangers, and oversized enhanced-surface refrigerant-to-water heat exchangers. Units in the high efficiency range tend to use multi-or variable speed compressors, variable speed indoor fans, or both. Find an explanation of *single speed and variable speed heat pumps in the Air-Source Heat Pump* section.

## Certification, Standards, and Rating Scales

The Canadian Standards Association (CSA) currently verifies all heat pumps for electrical safety. A performance standard specifies tests and test conditions at which heat pump heating and cooling capacities and efficiency are determined. The performance testing standards for ground-source systems are CSA C13256 (for secondary loop systems) and CSA C748 (for DX systems).

## Sizing Considerations

It is important that the ground heat exchanger be well matched to the heat pump capacity. Systems that are not balanced and unable to replenish the energy drawn from the borefield will continuously perform worse over time until the heat pump can no longer extract heat.

As with air-source heat pump systems, it is generally not a good idea to size a ground-source system to provide all of the heat required by a house. For cost-effectiveness, the system should generally be sized to cover the majority of the household's annual heating energy requirement. The occasional peak heating load during severe weather conditions can be met by a supplementary heating system.

Systems are now available with variable speed fans and compressors. This type of system can meet all cooling loads and most heating loads on low speed, with high speed required only for high heating loads. Find an explanation of *single speed and variable speed heat pumps* in the *Air-Source Heat Pump* section.

A variety of sizes of systems are available to suit the Canadian climate. Residential units range in rated size (closed loop cooling) of 1.8 kW to 21.1 kW (6 000 to 72 000 Btu/h), and include domestic hot water (DHW) options.

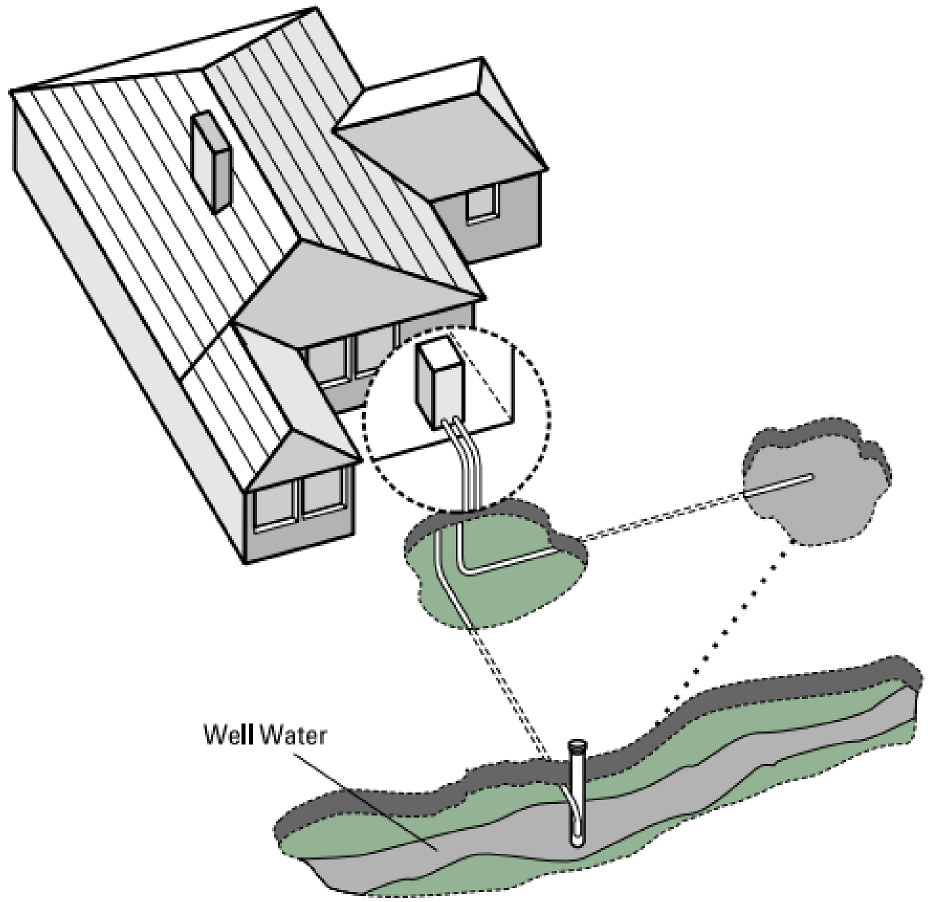
## Design Considerations

Unlike air-source heat pumps, ground-source heat pumps require a ground heat exchanger to collect and dissipate heat underground.

### Open Loop Systems

An open system uses ground water from a conventional well as a heat source. The ground water is pumped to a heat exchanger, where thermal energy is extracted and used as a source for the heat pump. The ground water exiting the heat exchanger is then reinjected into the aquifer.

Another way to release the used water is through a rejection well, which is a second well that returns the water to the ground. A rejection well must have enough capacity to dispose of all the water passed through the heat pump, and should be installed by a qualified well driller. If you have an extra existing well, your heat pump contractor should have a well driller ensure that it is suitable for use as a rejection well. Regardless of the approach used, the system should be designed to prevent any environmental damage. The heat pump simply removes or adds heat to the water; no pollutants are added. The only change in the water returned to the environment is a slight increase or decrease in temperature. It is important to check with local authorities to understand any regulations or rules regarding open loop systems in your area.




The size of the heat pump unit and the manufacturer's specifications will determine the amount of water that is needed for an open system. The water requirement for a specific model of heat pump is usually expressed in litres per second (L/s) and is listed in the specifications for that unit. A heat pump of 10-kW (34 000-Btu/h) capacity will use 0.45 to 0.75 L/s while operating.

Your well and pump combination should be large enough to supply the water needed by the heat pump in addition to your domestic water requirements. You may need to enlarge your pressure tank or modify your plumbing to supply adequate water to the heat pump.

Poor water quality can cause serious problems in open systems. You should not use water from a spring, pond, river or lake as a source for your heat pump system. Particles and other matter can clog a heat pump system and make it inoperable in a short period of time. You should also have your water tested for acidity, hardness and iron content before installing a heat pump. Your contractor or equipment manufacturer can tell you what level of water quality is acceptable and under what circumstances special heat-exchanger materials may be required.

Installation of an open system is often subject to local zoning laws or licensing requirements. Check with local authorities to determine if restrictions apply in your area.

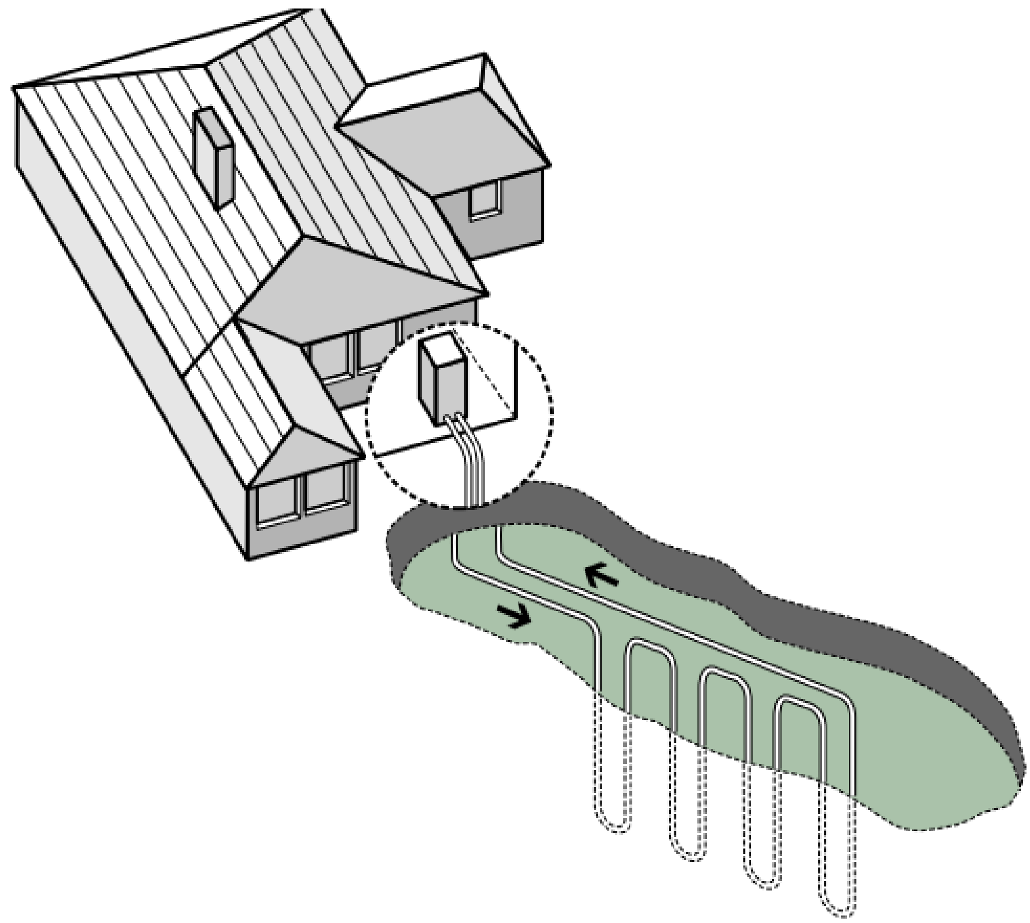
### Closed-Loop Systems

A closed-loop system draws heat from the ground itself, using a continuous loop of buried plastic pipe. Copper tubing is used in the case of DX systems. The pipe is connected to the indoor heat pump to form a sealed underground loop through which an antifreeze solution or refrigerant is circulated. While an open system drains water from a well, a closed-loop system recirculates the antifreeze solution in the pressurized pipe.

The pipe is placed in one of three types of arrangements:

- **Vertical:** A vertical closed-loop arrangement is an appropriate choice for most suburban homes, where lot space is restricted. Piping is inserted into bored holes that are 150 mm (6 in.) in diameter, to a depth of 45 to 150 m

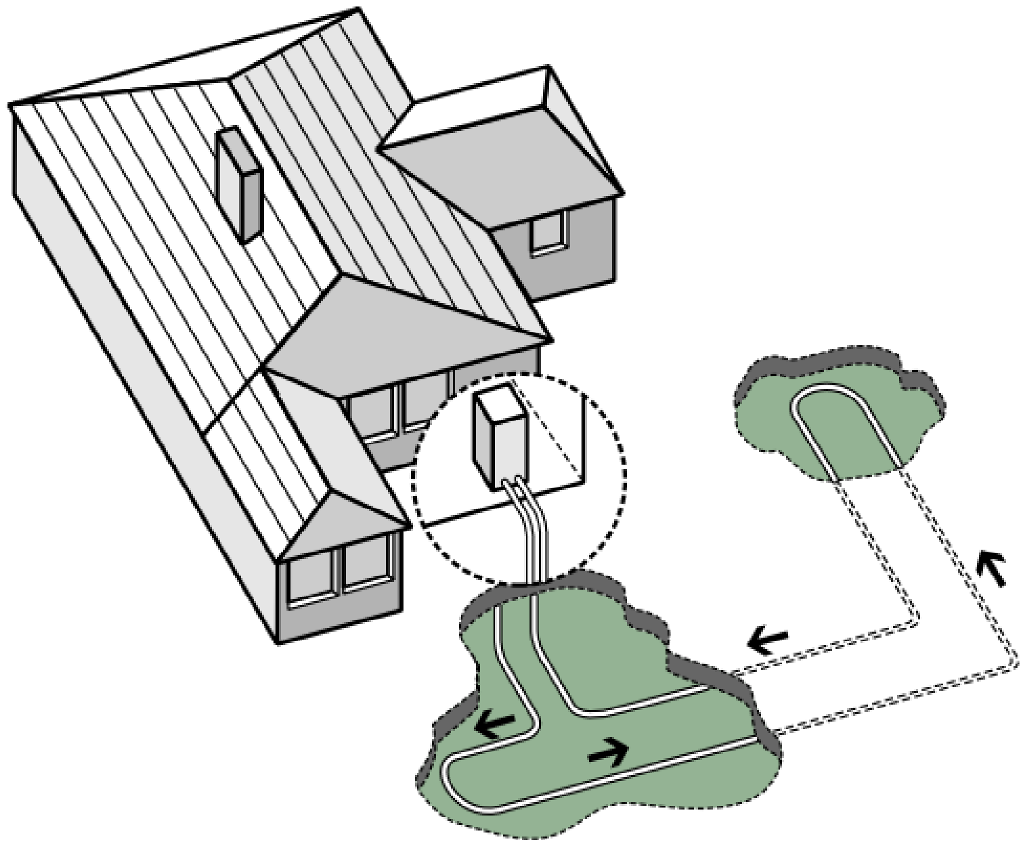
(150
to
500
ft.),



depending on soil conditions and the size of the system. U-shaped loops of pipe are inserted in the holes. DX systems can have smaller diameter holes, which can lower drilling costs.

- **Diagonal (angled):** A diagonal (angled) closed-loop arrangement is similar to a vertical closed-loop arrangement; however the boreholes are angled. This type of arrangement is used where space is very limited and access is limited to one point of entry.
- **Horizontal:** The horizontal arrangement is more common in rural areas, where properties are larger. The pipe is placed in trenches normally 1.0 to 1.8 m (3 to 6 ft.) deep, depending on the number of pipes in a trench. Generally, 120 to 180 m (400 to 600 ft.) of pipe is required per ton of heat pump capacity. For example, a well-insulated, 185 m2 (2000 sq. ft.) home would usually need a three-ton system, requiring 360 to 540 m (1200 to 1800 ft.) of pipe.

The most



common horizontal heat exchanger design is two pipes placed side-by-side in the same trench. Other horizontal loop designs use four or six pipes in each trench, if land area is limited. Another design sometimes used where area is limited is a “spiral” – which describes its shape.

Regardless of the arrangement you choose, all piping for antifreeze solution systems must be at least series 100 polyethylene or polybutylene with thermally fused joints (as opposed to barbed fittings, clamps or glued joints), to ensure leak-free connections for the life of the piping. Properly installed, these pipes will last anywhere from 25 to 75 years. They are unaffected by chemicals found in soil and have good heat-conducting properties. The antifreeze solution must be acceptable to local environmental officials. DX systems use refrigeration-grade copper tubing.

Neither vertical nor horizontal loops have an adverse impact on the landscape as long as the vertical boreholes and trenches are properly backfilled and tamped (packed down firmly).

Horizontal loop installations use trenches anywhere from 150 to 600 mm (6 to 24 in.) wide. This leaves bare areas that can be restored with grass seed or sod. Vertical loops require little space and result in less lawn damage.

It is important that horizontal and vertical loops be installed by a qualified contractor. Plastic piping must be thermally fused, and there must be good earth-to-pipe contact to ensure good heat transfer, such as that achieved by Tremie-grouting of boreholes. The latter is particularly important for vertical heat-exchanger systems. Improper installation may result in poorer heat pump performance.

## Installation Considerations

As with air-source heat pump systems, ground-source heat pumps must be designed and installed by qualified contractors. Consult a local heat pump contractor to design, install and service your equipment to ensure efficient and reliable operation. Also, be sure that all manufacturers' instructions are followed carefully. All installations should meet the requirements of CSA C448 Series 16, an installation standard set by the Canadian Standards Association.

The total installed cost of ground-source systems varies according to site-specific conditions. Installation costs vary depending on the type of ground collector and the equipment specifications. The incremental cost of such a system can be recovered through energy cost savings over a period as low as 5 years. Payback period is dependent on a variety of factors such as soil conditions, heating and cooling loads, the complexity of HVAC retrofits, local utility rates, and the heating fuel source being replaced. Check with your electric utility to assess the benefits of investing in a ground-source system.

Sometimes a low-cost financing plan or incentive is offered for approved installations. It is important to work with your contractor or energy advisor to get an estimate of the economics of heat pumps in your area, and the potential savings you can achieve.

## Operation Considerations

You should note several important things when operating your heat pump:

- **Optimize Heat Pump and Supplemental System Set-points.** If you have an electric supplemental system (e.g., baseboards or resistance elements in duct), be sure to use a lower temperature set-point for your supplemental system. This will help to maximize the amount of heating the heat pump provides to your home, lowering your energy use and utility bills. A set-point of 2°C to 3°C below the heat pump heating temperature set-point is recommended. Consult your installation contractor on the optimal set-point for your system.
- **Minimize Temperature Setbacks.** Heat pumps have a slower response than furnace systems, so they have more difficultly responding to deep temperature setbacks. Moderated setbacks of not more than 2°C should be employed or a “smart” thermostat that switches the system on early, in anticipation of a recovery from setback, should be used. Again, consult your installation contractor on the optimal setback temperature for your system.

## Maintenance Considerations

You should have a qualified contractor perform annual maintenance once per year to ensure your system remains efficient and reliable.

If you have an air-based distribution system, you can also support more efficient operations by replacing or cleaning your filter every 3 months. You should also ensure that your air vents and registers are not blocked by any furniture, carpeting or other items that would impede airflow.

### Operating Costs

The operating costs of a ground-source system are usually considerably lower than those of other heating systems, because of the savings in fuel. Qualified heat pump installers should be able to give you information on how much electricity a particular ground-source system would use.

Relative savings will depend on whether you are currently using electricity, oil or natural gas, and on the relative costs of different energy sources in your area. By running a heat pump, you will use less gas or oil, but more electricity. If you live in an area where electricity is expensive, your operating costs may be higher.

### Life Expectancy and Warranties

Ground-source heat pumps generally have a life expectancy of about 20 to 25 years. This is higher than for air-source heat pumps because the compressor has less thermal and mechanical stress, and is protected from the environment. The lifespan of the ground loop itself approaches 75 years.

Most ground-source heat pump units are covered by a one-year warranty on parts and labour, and some manufacturers offer extended warranty programs. However, warranties vary between manufacturers, so be sure to check the fine print.

## Related Equipment

### Upgrading the Electrical Service

Generally speaking, it is not necessary to upgrade the electrical service when installing an air-source add-on heat pump. However, the age of the service and the total electrical load of the house may make it necessary to upgrade.

A 200 ampere electrical service is normally required for the installation of either an all-electric air-source heat pump or a ground-source heat pump. If transitioning from a natural gas or fuel oil based heating system, it may be necessary to upgrade your electrical panel.

## Supplementary Heating Systems

### Air-Source Heat Pump Systems

Air-source heat pumps have a minimum outdoor operating temperature, and may lose some of their ability to heat at very cold temperatures. Because of this, most air-source installations require a supplementary heating source to maintain indoor temperatures during the coldest days. Supplementary heating may also be required when the heat pump is defrosting.

Most air-source systems shut off at one of three temperatures, which can be set by your installation contractor:

- **Thermal Balance Point:** The temperature below which the heat pump does not have enough capacity to meet the heating needs of the building on its own.
- **Economic Balance Point:** The temperature below which the ratio of electricity to a supplemental fuel (e.g., natural gas) means that using the supplementary system is more cost effective.
- **Cut-Off Temperature:** The minimum operating temperature for the heat pump.

Most supplementary systems can be classed into two categories:

- **Hybrid Systems:** In a hybrid system, the air-source heat pump uses a supplemental system such as a furnace or boiler. This option can be used in new installations, and is also a good option where a heat pump is added to an existing system, for example, when a heat pump is installed as a replacement for a central air-conditioner.

These types of systems support switching between heat pump and supplementary operations according to the thermal or economic balance point.
These systems cannot be run simultaneously with the heat pump – either the heat pump operates or the gas/oil furnace operates.

- **All Electric Systems:** In this configuration, heat pump operations are supplemented with electric resistance elements located in the ductwork or with electric baseboards.
These systems can be run simultaneously with the heat pump, and can therefore be used in balance point or cut-off temperature control strategies.

An outdoor temperature sensor shuts the heat pump off when the temperature falls below the pre-set limit. Below this temperature, only the supplementary heating system operates. The sensor is usually set to shut off at the temperature corresponding to the economic balance point, or at the outdoor temperature below which it is cheaper to heat with the supplementary heating system instead of the heat pump.

### Ground-Source Heat Pump Systems

Ground-source systems continue to operate regardless of the outdoor temperature, and as such are not subject to the same sort of operating restrictions. The supplementary heating system only provides heat that is beyond the rated capacity of the ground-source unit.

## Thermostats

### Conventional Thermostats

Most ducted residential single-speed heat pump systems are installed with a **"two-stage heat/one-stage cool"** indoor thermostat. Stage one calls for heat from the heat pump if the temperature falls below the pre-set level. Stage two calls for heat from the supplementary heating system if the indoor temperature continues to fall below the desired temperature. Ductless residential air-source heat pumps are typically installed with a single stage heating/cooling thermostat or in many instances a built in thermostat set by a remote that comes with the unit.

The most common type of thermostat used is the **"set and forget"** type. The installer consults with you prior to setting the desired temperature. Once this is done, you can forget about the thermostat; it will automatically switch the system from heating to cooling mode or vice versa.

There are two types of outdoor thermostats used with these systems. The first type controls the operation of the electric resistance supplementary heating system. This is the same type of thermostat that is used with an electric furnace. It turns on various stages of heaters as the outdoor temperature drops progressively lower. This ensures that the correct amount of supplementary heat is provided in response to outdoor conditions, which maximizes efficiency and saves you money. The second type simply shuts off the air-source heat pump when the outdoor temperature falls below a specified level.

Thermostat setbacks may not yield the same kind of benefits with heat pump systems as with more conventional heating systems. Depending upon the amount of the setback and temperature drop, the heat pump may not be able to supply all of the heat required to bring the temperature back up to the desired level on short notice. This may mean that the supplementary heating system operates until the heat pump "catches up." This will reduce the savings that you might have expected to achieve by installing the heat pump. See discussion in previous sections on minimizing temperature setbacks.

### Programmable Thermostats

Programmable heat pump thermostats are available today from most heat pump manufacturers and their representatives. Unlike conventional thermostats, these thermostats achieve savings from temperature setback during unoccupied periods, or overnight. Although this is accomplished in different ways by different manufacturers, the heat pump brings the house back to the desired temperature level with or without minimal supplementary heating. For those accustomed to thermostat setback and programmable thermostats, this may be a worthwhile investment. Other features available with some of these electronic thermostats include the following:

- Programmable control to allow for user selection of automatic heat pump or fan-only operation, by time of day and day of the week.
- Improved temperature control, as compared to conventional thermostats.
- No need for outdoor thermostats, as the electronic thermostat calls for supplementary heat only when needed.
- No need for an outdoor thermostat control on add-on heat pumps.

Savings from programmable thermostats are highly dependant on the type and sizing of your heat pump system. For variable speed systems, setbacks may allow the system to operate at a lower speed, reducing wear on the compressor and helping to increase system efficiency.

## Heat Distribution Systems

Heat pump systems generally supply a greater volume of airflow at lower temperature compared to furnace systems. As such, it is very important to examine the supply airflow of your system, and how it may compare to the airflow capacity of your existing ducts. If the heat pump airflow exceeds the capacity of your existing ducting, you may have noise issues or increased fan energy use.

New heat pump systems should be designed according to established practice. If the installation is a retrofit, the existing duct system should be carefully examined to ensure that it is adequate.

## Footnotes

1. The Region 5 HSPF is most reflective of heat pump performance in the Ottawa region. Actual HSPFs may be lower in regions with increased heating degree days. While many colder Canadian regions are still classified under Region 5, the HSPF value provided may not fully reflect actual system performance.

**Date modified:**
2022-08-09

# ONTARIO ENERGY BOARD

| | | |
|---|---|---|
| **FILE NO.:** | **EB-2022-0157** | **Enbridge Gas Inc.** |
| **VOLUME:** | **Technical Conference** | |
| **DATE:** | **October 6, 2022** | |

I am trying to clarify and I think I understand why Enbridge doesn't include distribution revenue in your project economics for a transmission project.

I think it is in part because if you are connecting a new customer that often requires some kind of additional distribution infrastructure and that will be in essence paid for using the incremental distribution revenue. Is that fair to say?

MR. SZYMANSKI: Rich Szymanski, Enbridge Gas. Yes. That is correct.

MR. ELSON: So you can't count the incremental distribution revenue as a benefit to existing ratepayers from a transmission upgrade, because at least a portion of that distribution revenue is going to pay for incremental distribution infrastructure costs. Right?

MR. SZYMANSKI: If there are any distribution costs, yes, the distribution margin would be applied to it.

MR. ELSON: And any attempt to calculate the distribution infrastructure costs at the outset will be speculative and a lot more speculative than, for instance, the transmission costs that are clear. Is that fair to say?

MR. SZYMANSKI: I have no knowledge as to the current state of the development of the various distribution projects and costs.

MR. ELSON: Now, I believe in JT1.4 you are going to be putting some distribution revenue figures together.

Are those going to be net of taxes or gross before

MR. ELSON: Thank you. Could you turn to page 4. This is describing a ground coupled heat pump system. Are you familiar with this technology, i.e. geothermal heat pumps for greenhouses?

MR. MacPHERSON: We are.

MR. ELSON: And were you familiar with this technology prior to this proceeding?

MR. MacPHERSON: We were.

MR. ELSON: And it says here that this energy efficient technology is saving growers on operational costs at a time when natural gas prices are skyrocketing.

Are you in a position to agree or disagree with that statement?

MR. MacPHERSON: Ian MacPherson, Enbridge. I am not in a position to agree with that statement, but absent a real situation, an actual operation with identified technologies and infrastructure, building, et cetera, that allows us to do that.

MR. ELSON: So I take it you are not in a position to agree or disagree with that. Is that fair to say?

MR. MacPHERSON: Agreed. Do not have enough information. Thank you.

MR. ELSON: Thank you. If we could turn to the second document in this package, which is on PDF page 11.

And this at the bottom left describes what we're looking at, which is a publication produced by the National Centre for Appropriate Technology through the ATTRA sustainable agriculture program under a cooperative agreement with the USDA Rural Development.

That was just to situate us, if we could turn to page 3 of this document and the highlighted portion, it says here that standard geothermal heating and cooling systems are rated on their coefficient of performance as a ratio of a product's heat output to the electrical energy input required. Standard systems have efficiencies of 300 to 600 percent. Compare this to the efficiency of a standard fossil fuel furnace which varies from 75 to 90 percent.

Is this consistent with your understanding of geothermal technology?

MR. MacPHERSON: Ian MacPherson, Enbridge. I don't believe anyone on our panel is qualified to confirm, to agree with this statement.

MR. ELSON: So this is another one you wouldn't agree or disagree with?

MR. MacPHERSON: Yes. We're not -- there is no one on this group that is expert in these technologies.

MR. ELSON: And further down on this page, and I should be wrapping up this question line shortly, it says:

> "An active system would be capable of providing adequate heating and cooling for greenhouses of various sizes with an appropriately sized heat pump and enough linear feet of underground piping."

Is that consistent with your understanding of geothermal, or is this another one where you can't agree or disagree with the statement?

MR. MacPHERSON: Ian MacPherson, Enbridge. Again, we would not -- this group would not be qualified to be able to respond to this. The limit of our understanding is based on conversations with greenhouse market customers as to the suitability of these kind of technologies to their business operation.

MR. ELSON: And one last reference, which is page 23 of this document package. As it is getting pulled up, this is a document from the Centre for Agriculture, Food and the Environment from the University of Massachusetts, and it is about geothermal heat for greenhouses.

I am on page 23 of this document package. For the first page, you will see there -- and I specifically had a question on the second page, which is page 24. This will be my last question and it may be answered in the same fashion, but just to confirm it says:

> "In New England, the only choice that we have for geothermal heating is with low temperature heat. There are several systems that appear to be feasible that have a reasonable pay back period."

Is this something that Enbridge, again, can't agree or disagree with this statement coming out of the University of Massachusetts?

MR. MacPHERSON: Ian MacPherson, Enbridge. Again, we would not be in a position to judge and these kind of assessments are, again, they're particular to a given situation, customer building, and not to mention the local energy prices, natural gas, electricity, and also the geology of an area. They would all be needed to perform an appropriate assessment of the, of this statement.

MR. ELSON: And carbon pricing, I assume too?

MR. MacPHERSON: Agreed.

MR. ELSON: Thank you. If we can turn back to ED 2. And, in particular, page 1 of ED 2. There is a forecast of general service attachments.

Could you undertake to provide a breakdown between how many of those residential attachments will be new developments as opposed to fuel-switching?

MS. DEBEVC: Melissa Debevc, Enbridge Gas. If you turn to the second page of the response, the last sentence says the general service attachments on the Panhandle system is assumed to be approximately 2 to 5 percent conversions.

So you would be able to do the math on the table.

MR. ELSON: So the rest of them are developments? Like new residential developments?

MS. DEBEVC: That would be correct.

MR. ELSON: Thank you. And could you provide an approximate capital cost, all-in capital cost to connect those new developments on a per-customer basis?

We had similar information in the DSM proceeding and it came to approximately 3,000 dollars per customer. It is always different depending on the development, of course. But could you go back and provide on a best efforts basis the capital costs to connect new developments. I am fine if I have understood what's been done.

The achievable potential study was applied to just the general service customers, which are about 45 percent of the demand. Is that correct?

MS. WADE: The general service customers within the APS, yes, yes. It took the general service customers from the APS and we used our Union Gas rate zone. Union Gas South rate zone.

MR. ELSON: So this has estimated the energy efficiency that could be achieved if there were programs targeting just the general service customers in the Panhandle region?

MS. WADE: In the Leamington-Kingsville-Wheatley area, that's right. And the potential and the costs were determined using proxies based on the Union Gas South region which was from the APS.

MR. ELSON: But it's only applied --

MS. WADE: Not out of the APS.

MR. ELSON: But it only applied it to 45 percent of the demand i.e., the general service demand, is that correct?

MS. WADE: That's correct.

MR. ELSON: What I am asking is for it to be applied to the other 55 percent.

MS. WADE: Yes. And what we're saying is that is not meaningful or valuable, because the proxy that was applied to general service is not the same factor that you would apply to a contract customer.

And so when we have real information from the relationships and the consultation that we have been having with these customers, we're going to use that information over an APS that was completed a number of years ago and uses the number as a proxy.

MR. ELSON: But you haven't done that either. You haven't included any assumed efficiency gains from greenhouses.

MS. WADE: The efficiencies are assumed to be embedded within the expression of interest and that the customers understand what their demand is post implementing these energy efficiency measures and/or building to the higher efficiency.

So we have -- we have assumed that in our work with our customers, they understand what their demand will be and they have expressed that in their expression of interest.

MR. ELSON: Well, an express of interest is only new customers. So you have assumed your new customers can't do anything more than they're planning to do. And your existing customers who haven't put an express of interest in can't do any more than they're already doing.

MR. CIUPKA: Matt Ciupka, Enbridge Gas. That is incorrect. The expression of interest was not limited to new customers. It was open to all customers, existing and new.

So an example would be existing customers that have expansion plans, whether on the same site or a new site.

And in addition to that, I would like to also point out that despite the implementation of energy efficiency measures, we went out to market twice offering customers an explicit formal opportunity to turn back firm or interruptible capacity, and we received no bids during that process.

I think Ms. Wade earlier also stated that, again, a lot of our greenhouse customers, all of them are concerned with maximizing production output and utilizing any energy they have available to continue to grow their operations.

MR. ELSON: I don't think we should get into a debate. That's been decided by the Board many times as to whether industrial customers have implemented and planned to implement all cost effective energy efficiency just because they have an economic interest in doing so.

So I am going to turn back to attachment 3 and ask some other specific questions relating to the general service area.

Could you provide this table in peak day reductions, please?

MS. DEBEVC: Melissa Debevc, Enbridge Gas. Could you clarify which table?

MR. ELSON: The one that is on the screen, Environmental Defence 7, attachment 3, page 1.

MS. WADE: Cara-Lynne Wade, Enbridge. I cannot confirm that we are able to do that. I can check with Posterity, best efforts. We could provide it if they can.

MR. ELSON: Why don't I ask it -- I was going to ask

NAVIGANT

# 2019 Integrated Ontario Electricity and Natural Gas Achievable Potential Study

**Prepared for**

ieso Connecting Today. Powering Tomorrow.

ONTARIO ENERGY BOARD

**Submitted:** 2019-09-13

**Prepared by:**

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**Table 5-7. Top 20 Measures for Commercial Natural Gas Measure-Level Technical Potential in 2038**

| Measure Rank | Measure Name | Potential ($Mm^3$) | % of Pot. |
|---|---|---|---|
| 1 | Condensing Boiler \| Std | 359 | 15% |
| 2 | Gas Fired Rooftop Units | 242 | 10% |
| 3 | Demand Control Ventilation | 225 | 10% |
| 4 | Building Recommissioning, Operations and Maintenance (O&M) Improvements | 200 | 9% |
| 5 | Boilers - Advanced Controls (Steam Systems) | 152 | 7% |
| 6 | Adaptive Thermostats | 135 | 6% |
| 7 | Condensing Make Up Air Unit | 123 | 5% |
| 8 | Gas Fired Heat Pump | 102 | 4% |
| 9 | Advanced BAS/Controllers | 78 | 3% |
| 10 | Demand Control Kitchen Ventilation | 76 | 3% |
| 11 | Air Handler with Dedicated Outdoor Air Systems | 75 | 3% |
| 12 | Condensing Unit Heaters or other Efficient Unit Heating System | 72 | 3% |
| 13 | Energy Recovery Ventilation and Ventilation (Enhanced) | 69 | 3% |
| 14 | Education and Capacity Building/Energy Behavior | 64 | 3% |
| 15 | Steam System Optimisation | 40 | 2% |
| 16 | Destratification | 38 | 2% |
| 17 | Furnace Tune-Up | 38 | 2% |
| 18 | Super-High Efficiency Furnaces (Emerging Tech) | 31 | 1% |
| 19 | Heat Recovery Ventilator | 29 | 1% |
| 20 | High Efficiency Condensing Furnace AFUE 95% from 80% code | 28 | 1% |

*Source: Navigant analysis*

Table 5-8 presents the top 20 industrial natural gas measures in 2038 ranked by technical potential. The top five measures come from the process heating (direct), process heating (water and steam), and multiple end use end uses, with three of the top five measures associated with the process heating (direct) end use. Process heat improvements ranks as the highest impact technical potential measure.

**Table 5-8. Top 20 Measures for Industrial Natural Gas Measure-Level Technical Potential in 2038**

| Measure Rank | Measure Name | Potential ($Mm^3$) | % of Pot. |
|---|---|---|---|
| 1 | Process Heat Improvements | 905 | 35% |
| 2 | Boiler Upgrade | 350 | 14% |
| 3 | Process Heat Recovery (Gas) | 303 | 12% |
| 4 | Recommissioning | 218 | 8% |
| 5 | High Efficiency Burners | 171 | 7% |
| 6 | Improved Controls -Process Heating Gas | 139 | 5% |
| 7 | Greenhouse Envelope Improvements | 95 | 4% |

| Measure Rank | Measure Name | Potential (GWh) | % of Pot. |
|---|---|---|---|
| 9 | High Efficiency HVAC Fans | 226 | 5% |
| 10 | Greenhouse Grow Lights | 143 | 3% |
| 11 | Material Handling Improvements | 65 | 1% |
| 12 | Fan System Optimisation | 62 | 1% |
| 13 | Pulp and Paper Process Improvements | 62 | 1% |
| 14 | Process Optimisation (Elec) | 60 | 1% |
| 15 | Refiner Plate Improvements | 46 | 1% |
| 16 | Process Heat Recovery | 36 | 1% |
| 17 | VAV Conversion Project | 26 | 1% |
| 18 | Improved Controls - Process Cooling | 21 | 0% |
| 19 | High Efficiency Battery Charger | 20 | 0% |
| 20 | Process Improvements | 17 | 0% |

*Source: Navigant analysis*

Table 7-26 presents the top 20 industrial natural gas measures of Scenario B in 2038 ranked by achievable potential. Four of the top five measures seen in economic potential remain in the top five in achievable potential. The one measure that dropped out of the top five was high efficiency burners. Process heat improvements retained its top spot and ranks as the highest impact achievable potential measure.

**Table 7-26. Top 20 Measures for Natural Gas Energy Achievable Savings Potential for Scenario B in 2038 (Million $m^3$)**

| Measure Rank | Measure Name | Potential ($Mm^3$) | % of Pot. |
|---|---|---|---|
| 1 | Process Heat Improvements | 693 | 33% |
| 2 | Boiler Upgrade | 309 | 15% |
| 3 | Process Heat Recovery (Gas) | 292 | 14% |
| 4 | Recommissioning | 211 | 10% |
| 5 | Improved Controls -Process Heating Gas | 134 | 6% |
| 6 | High Efficiency Burners | 131 | 6% |
| 7 | Greenhouse Envelope Improvements | 85 | 4% |
| 8 | Insulation - Steam | 40 | 2% |
| 9 | High Efficiency HVAC Fans (Gas) | 37 | 2% |
| 10 | VAV Conversion Project (Gas) | 33 | 2% |
| 11 | Direct Contact Water Heaters | 26 | 1% |
| 12 | HE HVAC Controls | 23 | 1% |
| 13 | Insulation - Steam (AG) | 19 | 1% |
| 14 | Air Compressor Heat Recovery | 15 | 1% |
| 15 | Steam Turbine Optimisation | 9 | 0% |
| 16 | High Efficiency Furnaces | 8 | 0% |
| 17 | HE Stock Tank | 7 | 0% |
| 18 | Gas Turbine Optimisation | 7 | 0% |

| Measure # | Measure Name | Technical Potential (million_m3) | Economic Potential (million_m3) | Economic Potential as a % of Technical Potential (%) |
|---|---|---|---|---|
| 43 | ENERGY STAR Steam Cooker | 1 | 1 | 100% |
| 44 | Drain Water Heat Recovery (DWHR) \|New | 1 | 1 | 100% |
| 45 | Low Flow Pre-Rinse Spray Nozzle | 1 | 1 | 100% |
| 46 | Solar Water Preheat (Pools/DHW) | 0 | 0 | 96% |
| 47 | Gas Convection Oven | 0 | 0 | 0% |
| 48 | Air Curtains | 0 | 0 | 100% |
| 49 | Solar Preheat Make up Air | 0 | 0 | 0% |
| 50 | Super High Perf Glazing \|RET | 0 | 0 | 0% |
| 51 | Super High Perf Glazing \|New | 0 | 0 | 0% |
| 52 | Auto Off Time Switch or Time Clock control | 0 | 0 | 100% |
| 53 | LED RECESSED DOWNLIGHTS | 0 | 0 | 4% |
| 54 | Freezer Case Light Sensor | -1 | -1 | 100% |
| 55 | Occupancy Sensors | -3 | -3 | 100% |
| 56 | Indoor Daylight Sensors/Photocell Dimming Control | -3 | 0 | 1% |
| 57 | ENERGY STAR LED LAMPS (General Service Lamps) | -4 | -4 | 98% |
| 58 | Refrigerated Display Case LED | -4 | -3 | 80% |
| 59 | Adding reflective (White) roof treatment or a green roof | -12 | 0 | 0% |
| 60 | Networked/Connected - Low Impact Application | -15 | -1 | 4% |
| 61 | Networked/Connected - High Impact Application | -16 | -1 | 9% |
| 62 | LLLC - Low Impact Application | -17 | -6 | 34% |
| 63 | LLLC - High Impact Application | -17 | -9 | 54% |
| 64 | LED Replacement Lamp (Tube) | -19 | -19 | 100% |
| 65 | LED Troffer/Surface/Suspended | -20 | -20 | 100% |
| 66 | LED Low/High Bay | -25 | -25 | 100% |
| 67 | ENERGY STAR LED LAMPS (REFLECTOR LAMPs/MR16/PAR 16) | -27 | -23 | 86% |
| 68 | Anti-sweat heat (ASH) controls - Cooler/Freezer | -36 | 0 | 0% |

*Source: Navigant analysis*

### Table E-6. Industrial Natural Gas – Technical and Economic Potential in 2038

| Measure # | Measure Name | Technical Potential (million_m3) | Economic Potential (million_m3) | Economic Potential as a % of Technical Potential (%) |
|---|---|---|---|---|
| 1 | Process Heat Improvements | 905 | 905 | 100% |
| 2 | Boiler Upgrade | 350 | 350 | 100% |
| 3 | Process Heat Recovery (Gas) | 303 | 303 | 100% |
| 4 | Recommissioning | 218 | 218 | 100% |
| 5 | High Efficiency Burners | 171 | 171 | 100% |
| 6 | Improved Controls -Process Heating Gas | 139 | 139 | 100% |
| 7 | Greenhouse Envelope Improvements | 95 | 95 | 100% |
| 8 | Boiler Tune Up | 43 | 0 | 0% |
| 9 | High Efficiency HVAC Fans (Gas) | 43 | 43 | 100% |

# Nature Fresh Farms

naturefresh.ca/biomass-boilers-how-we-heat-our-greenhouses/

October 23, 2019

Every fall, when the cold weather starts to arrive in southern Ontario, our Energy department fires up our **biomass boilers**. We use biomass boilers to help heat our greenhouses because the fuel they use is renewable – making them a green energy source!

Let's take a closer look at how biomass boilers work and what benefits they provide our farm, our community, and the environment.

## How Do Biomass Boilers Work?

### Fuel: Clean Waste Wood

A **biomass boiler** uses renewable fuel to create energy. We could use several different substances to power our biomass boilers (we've experimented with materials such as corn cobs and oat hull pellets), but we've come to the conclusion that the best fuel for our boilers is **clean waste wood**.

When we talk about clean waste wood, we are referring to wood that has not been chemically treated and that may have ended up in a landfill if we did not burn it in our biomass boilers. During the summer months, when we are not using our biomass boilers to heat our greenhouses, we are hard at work collecting as much clean wood as we can to fuel the boilers from October to May.

We acquire our clean waste wood from a few different local sources. A local wood products company will save broken pallets for us to burn, and Windsor Disposal Services (WDS) will sort and grind clean scrap wood out of their collections and deliver it to us.

One of our most unique sources of clean scrap wood is from Hiram Walker, a whiskey producer based in Windsor, ON. To date, we have received over 20,000 empty whiskey barrels from Hiram Walker that we have burned in our biomass boilers. With roughly 400 barrels arriving at our wood yard every month, this partnership with Hiram Walker has been positive for all parties involved – the wood provides us with a renewable fuel source, Hiram Walker can dispose of barrels in an environmentally-friendly way, and the barrels do not end up in a landfill! In addition to barrels, Hiram Walker also provides us with used bungs, wood shavings, and damaged pallets.

In addition to receiving wood from different sources in our community, we also burn any clean wood products that we have on our farm, including damaged pallets and scrap wood from construction sites.

When we are collecting scrap wood, our Energy team is continuously sorting through our supply to make sure all the wood that we have collected over the months is suitable for burning. This sorting is essential to keep our biomass boilers running efficiently and to avoid mechanical issues with our machinery.

### Heating Our Greenhouses

The time of year when we start burning wood in our biomass boilers is largely determined by the weather and temperature outside. If the cold weather starts earlier in the fall, we fire up the biomass boilers early. If we have a longer summer with warmer temperatures maintained, we wait to start burning wood until the temperature outside starts to drop.

Once it’s time to fire up our biomass boilers, we start the process of grinding our clean wood products into small wood chips – the smaller size makes the wood more digestible for the boilers. We use different types of grinders for different types of wood products with outputs of up to 50 tons of wood chips every hour!

To grind up our whiskey barrels, we use a slow-speed shredder that rips the barrels apart but does not yet grind it down into a usable size. This shredder has a large magnet attached, so any steel bands from the barrels are easily separated from the wood. Once the steel has been separated, we can run the larger wood pieces through our regular grinders to cut the wood down to the proper size.

Next, the wood chips are introduced to our feeding system. With the help of a hydraulic walking floor, wood chips are fed into a chain conveyor and transported from our wood chip storage room to the fuel launch station bunker. When it’s time to burn the wood, the wood chips are moved from the bunker to the biomass boiler’s fire box (or combustion chamber). Inside the chamber, the wood chips are burned up in a fire that reaches 1200 degrees Celsius. We burn at such high temperatures in order to ensure a clean burn.

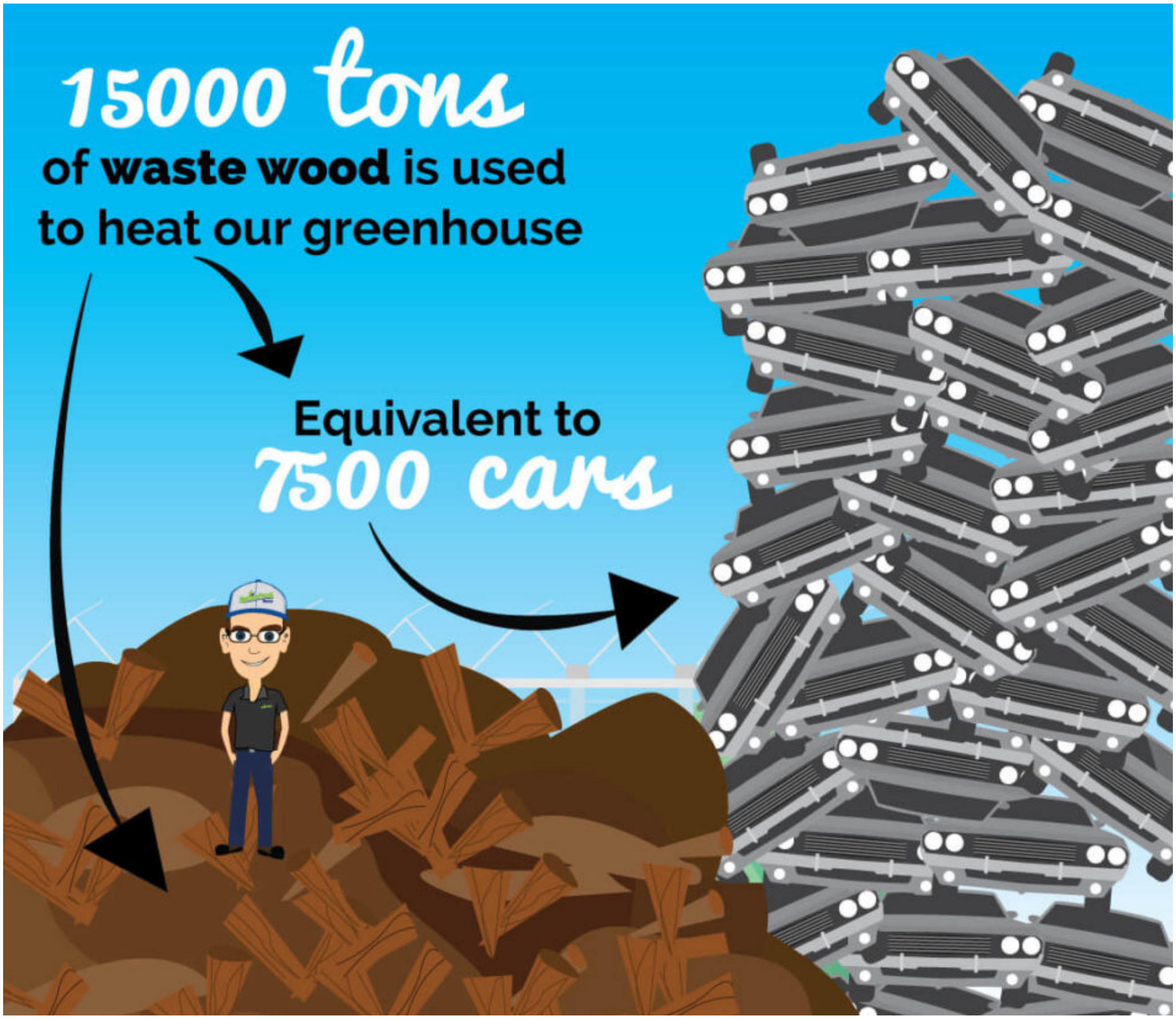
The heat that is produced from the boiler is captured and used to heat up water. This water can then be transported into our greenhouses through **heating rails** placed within each row of plants. If the water is not immediately sent into our greenhouses through the heating rails, it is stored in a hot water storage tank for use in the next 24-48 hours. The water we use to heat our greenhouses is continuously circulated and heated up to the optimal temperature for our plants – making it a closed-loop system.

### Energy Maintenance

As the wood burning season kicks into high gear, it is up to our Energy department to keep our wood yard organized and well-stocked, as well as to maintain the different pieces of equipment and machinery they use. From excavators to a pay loader to walking floor trailers and trucks, our Energy team needs to keep these machines in excellent condition in order to successfully fuel our biomass boilers and keep our greenhouses warm during the cold winter months.

It is also the responsibility of our Energy team to constantly monitor heat storage volumes, greenhouse temperatures, and boiler functionality. During the winter months, our Energy team is also called upon to use their special machinery for snow removal! Working with biomass boilers provides a wide variety of work for our Energy department.

## Why We Use Biomass Boilers: The Impact




Biomass boilers allow our farm to produce the energy we need to heat our greenhouses in a sustainable way. By using a renewable fuel source such as clean waste wood, we are diverting this useful resource from landfills and keeping our greenhouses warm in the process.

With this program, **we save roughly 15,000 tons** of waste wood from entering landfills every year – that's equivalent to **600 truckloads**!

As wood is being burned, our Energy team is also collecting the ashes and saving them for later use – as we continue to expand our operations, these ashes will be spread underneath new parking lots and driveways to create a solid base! And the metal scraps we collect from the whiskey barrels? We send all of them to a local metal recycling company to ensure proper disposal and reuse. These are just more examples of how our team is constantly finding smarter ways to be efficient with important resources.

## A Green Energy Strategy

Using biomass boilers to create greener energy is just one part of the overall energy strategy at NatureFresh Farms.

Interested in learning more about how we create, manage, and save energy? Read about our high efficiency energy screen technology, or catch up with Dave F., our Energy Manager, in his blog on energy management!

# Contact Us | Nature Fresh Farms

naturefresh.ca/contact/

## Contact Nature Fresh Farms Today

If you have any questions, concerns or ideas please feel free to contact us! We love hearing from you! *We will attempt to reply to all inquiries within 48 hrs.*

** Indicates a required field.*
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## Nature Fresh Farms Media Inquiries

For all media requests or inquiries please send an email to:

### Media Inquiries

mediainquiries@naturefresh.ca

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Monday - Friday

8 am - 4 pm

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info@naturefresh.ca

## Join Our Team

We are always excited to be accepting new individuals to be part of the team! Apply now to be part of a fast growing, innovative and forward thinking environment.

Apply Now

## Have More questions?

We love answering your questions & being able to provide knowledge! Check out some of our frequently asked questions.

Read our faqs

Build and Operations, Climate Control, Commercial, Design, Ecoloop and GAHT

# How To Mitigate Rising Gas Prices With Electric Greenhouses

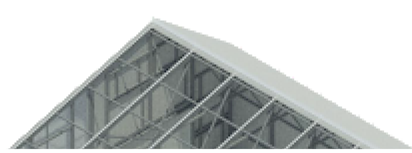
June 30, 2022

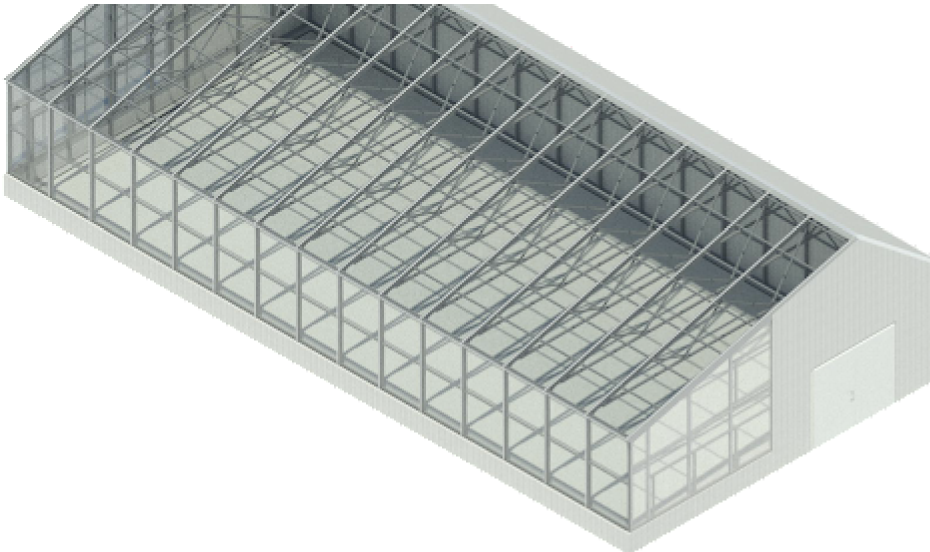
The cost of energy is rising at an alarming rate. Natural gas prices, in particular, have greenhouse growers nervous about their operational costs and questioning their business viability. This trend should act as an incentive for cultivators to look towards gas-free and energy-efficient greenhouse solutions in order to thrive. Luckily, these alternative energy solutions are more attainable than one might think and are already proving to be successful for many growers. In this blog we will discuss electric greenhouses and their equipment, and how they produce the same end result (if not higher yields and better quality) as a traditional gas-powered greenhouse.


(Markets Insider graph of natural gas prices (Henry Hub) in the US over the last 6 months (snapshot taken 6/23/22) https://markets.businessinsider.com/commodities/natural-gas-price)

## The Greenhouse Envelope

While we will focus on electricity-based environmental control options, it's important to think about the thermal envelope of the greenhouse as a first step. Traditional greenhouses are poorly insulated (or not insulated at all), which means they require more heat, and more gas, to keep them operating in colder temperatures. Highly insulated greenhouses, on the other hand, can reduce heating loads by as much as 70% based on their design and materials used, reducing heating needs significantly.





## From gas-powered greenhouses to electric greenhouses

Traditionally, commercial greenhouses use central gas boilers to heat water or steam that is distributed through the greenhouse via a piping system. This method of heating is similar to a radiant heating system you may have in your home. While tried and true by many commercial greenhouse operators, this method of heating is becoming less sustainable with natural gas prices reaching an all time high across the globe.

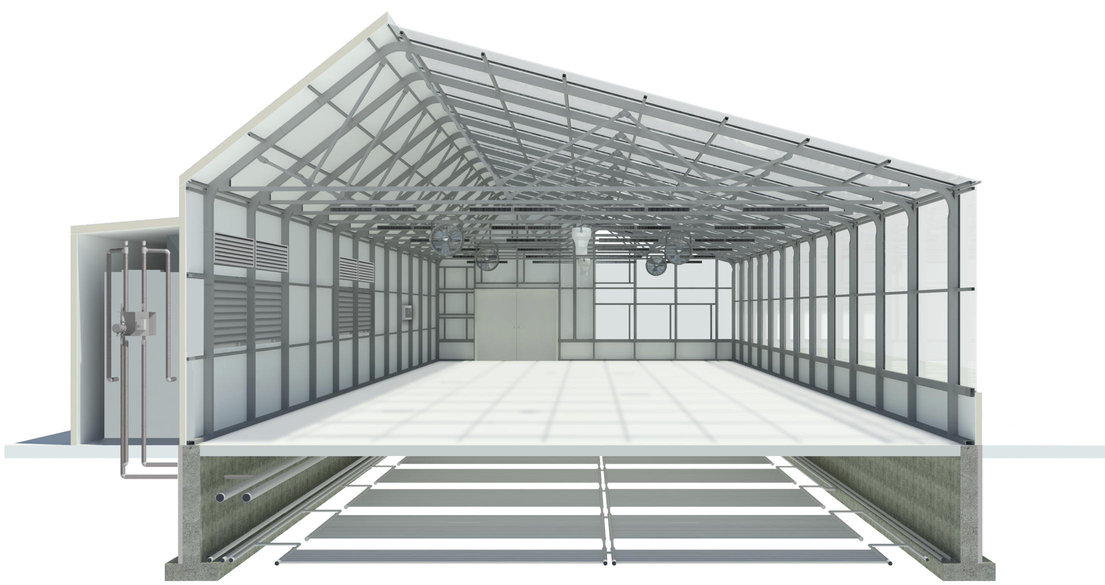
Natural gas powered boilers in a commercial greenhouse. Image from shutterstock.com

So what's the alternative? Well, just as many people are turning to electric vehicles to skip out on gasoline prices and lessen their impact on the environment, growers are turning to electric greenhouses to grow crops. You may be thinking, "well, isn't the price of electricity rising too?".

This is true, but at Ceres, we have developed energy-efficient heating, cooling, and dehumidification systems that use less electricity because they rely on heat pump technologies to condition the greenhouse environment. These energy-efficient HVACD systems are called EcoLoop™ and EcoPack™, and they enable our growers to cut their ties to natural gas and propane.

## How the "Eco" HVACD series saves you money

The EcoLoop™ is a hybrid ground coupled heat pump system. This means it includes a ground loop component that lies underneath the footprint of the greenhouse that constantly circulates water through the underground system. The circulating water either absorbs heat from the earth surrounding the mats or dissipates heat back into the earth – depending on whether the system is in heating or cooling mode. The ground loop component transfers thermal energy to and from the heat pump component of the HVACD system which sits above ground on the exterior of the north wall of the greenhouse. Through this process, the system utilizes free geothermal energy to regulate the temperature of the greenhouse space. This energy-efficient technology is saving growers on operational costs at a time when natural gas prices are sky-rocketing.



A SunChamber™ integrated with the EcoLoop geothermal HVACD system

The EcoPack™ is a very similar system to the EcoLoop™ in that they are both use heat pumps and they combine heating, cooling and dehumidification into one system. The main difference is the EcoPack™ doesn't utilize the geothermal ground coupling, nor does it use external evaporation as part of its cooling methodology. While the EcoPack™ is slightly less efficient than the EcoLoop™, the system is simpler and cheaper to install. While it can utilize natural gas for heating, it can also be used as an electric only unit. Either way, it is significantly more efficient than traditional gas powered boiler systems.

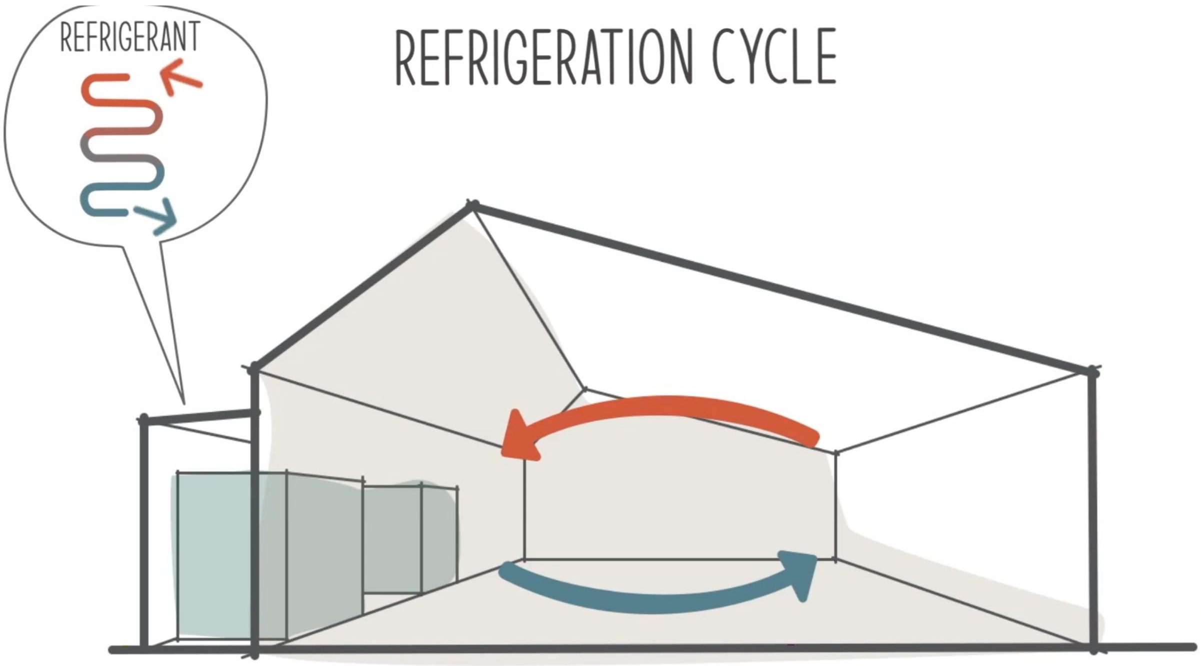
A SunChamber integrated with the EcoPack™ HVACD system

*To learn more about how HVAC systems and the EcoLoop™ works, watch this informational video.*

## What other greenhouse systems are gas-powered?

Desiccant dehumidification systems. When plants transpire into the greenhouse space, this extra moisture in the air needs to be dealt with, either through ventilation or dehumidification. Dehumidification systems are an important aspect of a commercial greenhouse, and depending on what kind of system is used, it may use gas to function. If you are unfamiliar with how dehumidification systems work, visit our blog, "Greenhouse Dehumidification Strategies for Vented and Sealed Commercial Greenhouses".

With the EcoLoop™ and the EcoPack™, dehumidification is built into the system. The heat pump component uses a refrigerant to cool the incoming moist air to dew point, and then after condensation happens, waste heat from the heat pump reheats the dehumidified air back to a comfortable temperature suitable for plant growth before it's exhausted back into the greenhouse. By combining dehumidification with heating and cooling, we ensure that our growers can reach specified vapor pressure deficit (VPD) levels. And like we mentioned above, the Eco HVACD Series runs entirely on electricity – eliminating your reliance on gas.

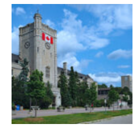



## Other benefits of geothermal and electric greenhouses

The Ceres EcoLoop™ and EcoPack™ are just one component of Ceres' holistic greenhouse solution called the SunChamber™ – a sealed design with full system integration. The SunChamber™ uses the power of the sun along with innovative climate control technology to create a highly productive growing environment. With this holistic solution, you can grow higher quality crops and reduce the risk of crop failure by taking advantage of the SunChamber™'s biosecure and highly controlled environment. Combine the growing capabilities of a SunChamber™ with the lower cost it takes to operate it, and you have a growing capabilities/ abilities that will allow your business to thrive even with rising energy prices and unstable fuel markets.

Why the Ceres HighYield™ Kit is Better than Other Commercial Greenhouse Kits

Funding Awarded for Energy Efficiency Research in Ceres Greenhouse



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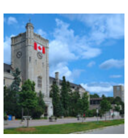

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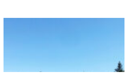

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# Geothermal Greenhouses: Exploring the Potential

By Victorian Smart, NCAT Energy Program Assistant;
Danielle Miska, NCAT Energy Engineer; and
Katie Simpson-Johnson, Energy Corps
Published Nov. 2021

IP617

## Contents



This publication is produced by the National Center for Appropriate Technology through the ATTRA Sustainable Agriculture program, under a cooperative agreement with USDA Rural Development.
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This publication provides basic information on geothermal energy technology and its potential in greenhouses. It explains how geothermal heating and cooling systems may expand the features of a growing structure while maintaining minimal energy usage. This publication discusses active and passive ground-source geothermal energy systems and provides design examples for passive system design suited to agricultural operations.

*Photo: Lance Cheung, USDA*

## Introduction: Geothermal Energy for Agricultural Growing Structures

Agricultural growing structures, such as greenhouses and high tunnels, are used for plant propagation, season extension, and to enhance and control crop production. Greenhouses and high tunnels can have the same basic structure: metal frames and plastic polyethylene, polycarbonate, or glass walls and roof. Both provide varying degrees of temperature and climate control to extend the growing season. High tunnels, sometimes called hoop houses, differ from greenhouses in that they include non-automated climate controls (like vents or roll-up sides) and are typically used for season extension rather than year-round growing. Traditional greenhouses are primarily used for plant propagation, require heat usually provided through automated climate controls, and generally built with more durable materials. This also allows for more consistent year-round growing. A third variation, passive solar greenhouses, consists of structures typically smaller than high tunnels that do not use power-generated heat sources like greenhouses do.

Traditional greenhouses protect crops in temperature extremes by using temperature, humidity, and ventilation controls to maintain an ideal climate (Rimol Greenhouse Systems, 2019). Generating such a climate can result in significant energy costs. Heating and electric combined is typically the third-largest cost for operating a traditional greenhouse (Penn State Cooperative Extension Service, 2020). By contrast, high tunnels and solar greenhouses are passive in design and do not require extra energy for heating and cooling, making them a more cost-effective option for certain operations. However, growers can further benefit from these structures when they are supplemented with an equally cost-effective climate-control system. Perhaps surprisingly, an efficient source of supplemental energy can be found right below our feet.

Renewable geothermal energy is heat derived from the subsurface of the earth (EPA, 2016). Underground temperature becomes stable starting roughly two feet below the earth's surface and continues to stabilize at deeper depths. Underground soil maintains a constant temperature year-round, averaging 55°F throughout the United States. Geothermal systems allow us to take advantage of these stable temperatures. In general, a system is comprised of two main components: underground tubing or piping to support the flow of a fluid (either air or a glycol solution) and the mechanism to push the air or fluid in and out of the piping. These primary components work to turn over the air in the structure to meet heating or cooling needs. Movement of air or fluid is achieved in various ways, such as using a heat pump or a simple inline fan.

This publication provides basic information on geothermal energy technology and its potential in greenhouses. It explains how geothermal heating and cooling systems could expand the features of a growing structure while maintaining minimal energy usage. This publication focuses on two types of ground-source geothermal energy systems, one of which is more sophisticated in design and requires a heat pump. The other is a more "passive" system that is similar in design but does not require a heat pump. Lastly, it provides design examples for a passive greenhouse system design that best suits agricultural operations.

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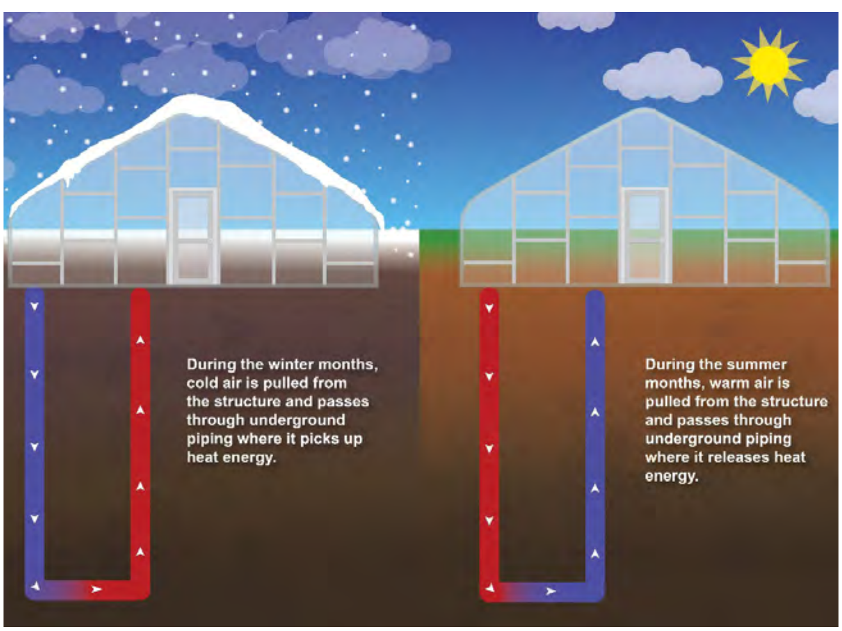


*Figure 1. Flow of Heat Energy in a Geothermal System. Graphic: Marisa Larson, NCAT*

## How Geothermal Systems Work

The flow of heat energy within a geothermal system can be utilized to heat or cool a space, depending on seasonal needs. Air is moved from inside a building and pushed through a network of underground piping. Convection through this piping heats or cools the air, which is then exhausted back into the structure at a more desirable temperature. When the underground temperature is warmer than the ambient temperature above ground, the heat pump or fan pushes the warmer air up to the growing structure that needs to be heated. When the temperature in the growing structure is too warm, the pump or fan removes the warm air from the building and pushes it into the pipe below ground, returning cooler air to the building (Figure 1).

### *Active Systems*

An active system utilizes a water-to-air heat pump, a liquid (either water or a glycol solution) as the medium for heat exchange, and evaporator and condenser coils. It uses the basic refrigeration cycle of evaporation, compression, condensation, and expansion to heat or cool the air before it is delivered to the space. The piping can be organized in the ground horizontally (trenches) or vertically (bore holes). Horizontal trenches are most applicable for small-scale operations because a vertical system requires drilling several deep holes (about 200 to 500 feet) to install the piping. This can become expensive because of the deep drilling that is required, although it does have greater ability to offset energy needed for heating or cooling in more sophisticated buildings and large operations (EPA, 2016). In this system, the liquid runs through piping in the ground, either absorbing or diffusing heat, depending on the temperature needs of the building above.

If the property has a private water source such as a pond, lake, or well, other options are available that do not require excavation. In these systems, water is pumped into the piping from the pond, for example, and this functions as the medium for heat exchange. These are active systems because they use a heat pump to pump the water from the water source into an exchanger, which heats or cools the air and then sends it into the building.

Standard geothermal heating and cooling systems are rated on their coefficient of performance, as a ratio of a product's heat output to the electrical energy input required (Kamoshida et al., 1990). Standard systems have efficiencies of 300 to 600%. Compare this to the efficiency of a standard fossil-fuel furnace, which varies from 75 to 90% (ASHRAE, 2018). "Geothermal systems are [at least] twice as efficient as the top-rated air conditioners and almost 50% more efficient than the best gas furnaces, all year round" (Alexander, 2018).

## *Passive Systems*

A passive geothermal system is often called an "earth battery," "climate battery," or "low-grade geothermal system." This system is comprised of piping, risers, manifolds, fans, and the insulated mass of soil. It uses the same fundamentals of thermodynamics as a ground-source system with a heat pump but has less intensive installation, which significantly reduces cost and requires only the energy needed to keep a fan or two running. Fans blow hot air from the growing structure into perforated piping that runs underground. When warm air is pushed into the piping below ground, the heat in the air traveling through the tubing is allowed to diffuse throughout the soil. This "charges" the soil with warm air that can later diffuse back into system (Osentowski and Thompson, 2021).

These passive systems rely on perforated tubing coming into contact with as much soil as possible for the maximum energy exchange to occur. Many of these systems are modified by growers who layer piping at two and four feet, or four and six feet, or six and eight feet. This piping must be organized horizontally for the system to function properly and for the growing structure to maximize its efficiency (Figure 2). Rigid foam insulation running around the perimeter of the underground portion of the system is necessary to maximize a passive system's output. This system also functions with no heat exchanger, as the cooled or heated air simply blows out of the other end of the piping, back into the growing structure.

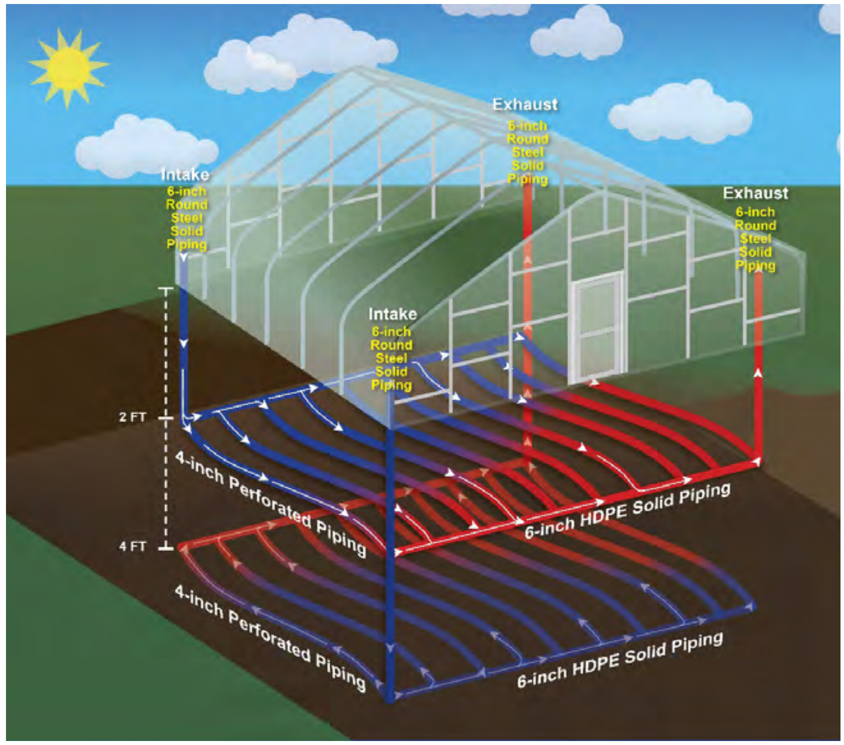


*Figure 2. Example design of groundwork in a passive geothermal system. Two layers of piping are depicted here, showing the flow of heat energy. As cool air is being pulled in, warm air is being pushed out. This is organized so the flow in one layer moves inversely to the other layer. Graphic: Marisa Larson, NCAT*

# Geothermal Applications

## *Passive Solar Greenhouse*

Although a passive solar greenhouse typically requires little to no energy input for climate control, using a passive geothermal system can further improve the season extension utility of the greenhouse and allow for diversity in crop production. An active system would provide the same benefits, but it would reduce the passive solar greenhouse's energy efficiency. Passive solar greenhouses tend to be small, therefore holding a small volume of air. The passive system functions most efficiently with smaller volumes of air and therefore would not need the amount of energy produced by an active system. A length-width ratio of 2:1 for any structure is ideal for energy efficiency (Bradford Research Center, no date).

## *Traditional Greenhouse*

Traditional greenhouses are often larger than passive solar greenhouses and would most likely not be adequately heated or cooled by a passive system. An active system would be capable of providing adequate heating and cooling for greenhouses of various sizes with an appropriately sized heat pump and enough linear feet of underground piping. As well, a greenhouse of substantial size may provide the necessary payback from crops to make the expensive installation of an active system feasible. Some large-scale commercial growers have many acres of greenhouses. These settings would be most appropriate for installing active systems, because such a grower would likely see a faster payback on the investment.

### High Tunnel

Heating or cooling a low-cost structure such as a high tunnel with an active system would not be cost-effective because of the tunnel's less-sturdy design with intended use of season extension only. Both the high tunnel structure and the passive system are low-cost options; however, a high tunnel is typically constructed with minimal insulation. Because the design is minimalistic, with one layer of plastic covering, climate control with a passive geothermal system would not be sustained for very long. In seasonal extremes, the "battery" that is the passive geothermal system will eventually reach its full capacity and will no longer heat or cool the space. Consequently, the passive, climate-battery system is the most feasible ground-source geothermal system for a small-scale grower, but it is primarily suited to a passive solar greenhouse or a double-walled, insulated high tunnel.

***Growing structures should be oriented to maximize sunlight and with end walls facing the winter winds.***

## Before You Build

When designing a geothermal system, first consider your hardiness zone (USDA, 2012), the temperature variance your area experiences throughout the year, and what your temperature needs are for your crops. You should also assess the value of the additional produce the season extension would afford. Consider the marketability throughout the growing season and whether it is worth the investment of finances and labor for heating and cooling a structure, especially a low-cost structure, such as a high tunnel. Other questions to ask yourself include these:

- What are my heating and cooling needs?
- Which technologies can provide the necessary heating and cooling energy?
- How do renewable heating and cooling options compare with conventional technologies?
- What renewable resources are cost-effective in this part of the country?
- What renewable heating and cooling products should I choose?
- Who will install and maintain my system?
- How will I finance the system?
- Does the value of additional produce offset this cost?
- How much value is there in reducing the risk from freezing or overheating?
- What if fossil fuels are cheaper?

### Energy Efficiency

The grower must first ensure that a structurally sound and well-insulated building is capable of keeping air inside, before installing a geothermal heating and cooling system. Otherwise, the effort and expense is wasted. In general, growing structures are more effective when constructed on well-drained, level land. Do not construct where the water table is known to be high or where you have an impermeable soil layer. Growing structures should be oriented to maximize sunlight and with end walls facing the winter winds. If these two requirements contradict, experts advise that the structure should capture as much winter sunlight as possible. It is also important to build the structures twice as far from any potential shading obstacle as the height of that obstacle (USDA, 2014).

It is necessary to seal a high tunnel to all ambient air, so it may be heated adequately by the geothermal system. Construct your high tunnel with a double-layered wall of greenhouse plastic and inflate the space between with a blower fan to enhance insulation. As well, use twin-wall hard covering for end walls. This kind of rigid covering performs better than simple greenhouse plastic in strong winds and requires less maintenance over time. Seal or insulate doors, vents, or shutters when the high tunnel is not in use. These openings may appear tightly sealed when shut, but they are typically where these structures experience a huge loss of energy. One way to overcome this is to seal these openings with scraps of greenhouse plastic. Seal the base perimeter of the high tunnel and use frost blankets to cover crops inside the high tunnel. It is also important to install ventilation in these structures, to let in cooler air during the warm months. Many high tunnels utilize roll-up sides for ventilation during warmer months, so any type of sealing done during cold months needs to be temporary. Maximizing the efficiency of the growing structure prior to geothermal installation will only serve to maximize profits (Alexander, 2019).

Follow similar rules for constructing a greenhouse. Do not construct where you know the water table is high or where the land experiences ponding. Construct to maximize sunlight and to face end walls into the winter winds. Choose the appropriate style, doors and hardware, covering material, and ventilation system to suit your growing needs (Rimol Greenhouse Systems, 2020). Design experts advise that environmental controls be set up alongside the geothermal heating and cooling system to maximize the structure's energy efficiency.

A modification of the traditional greenhouse is the passive solar greenhouse. This type of greenhouse does not use an artificial heat source but, rather, stores solar heat within a medium to be released at colder periods, like at night or during cold months. Storage mediums are typically black barrels filled with water, situated along the north wall. Alternatively, the entire north wall can be made of concrete to create an exceptional thermal mass. The north wall is much taller than the south wall in this design, to maximize southern sun exposure to charge the storage mediums. Although the use of barrels is popular, it is worth investigating for your operation, because their heat storage capability is questionable, and they take up much space that could otherwise be used for crop production. This style of greenhouse has a large, angled south-facing wall, covered entirely in greenhouse plastic, glass, or another transparent material. Additionally, east- and west-facing inner walls can be lined with a reflective material. Pitch of the roof and overall orientation of a passive solar greenhouse are primary components of effective design and should be considered, as well as carefully calculated, to maximize efficiency for the grower's latitude. All considerations for traditional greenhouses, from location to hardware and additional systems, are necessary for this type of greenhouse, as well.

Unless the greenhouse or high tunnel is exceptionally well-insulated, significant heat loss will inevitably occur, especially in colder climates. This loss can exceed the capacity of the passive system itself. To prevent depleting the underground soil of its stored heat energy and causing the average, stable temperature to drop below 55°F, experts recommend shutting off the climate battery and using an alternative heating method during extended periods of extreme cold (Osentowski and Thompson, 2021).

### *Energy Needs*

Conducting an energy assessment of an existing growing structure can provide you with a better understanding of current energy usage and reveal inefficiencies that may have gone unnoticed (Penn State Cooperative Extension Service, 2020). Improvement of on-farm energy efficiency can only occur from a foundational understanding of the current operation. You may hire a professional energy auditor or use an energy calculator as a "do it yourself" alternative. In an assessment, consider your building structure, its structural soundness, and any energy conservation measures (ECMs) that you may already have in place. The shape of the frame, the length of the structure, height of side walls, layers of plastic poly-film covering, air pockets between a double-layered wall, ventilating roll-up walls, energy curtains (inside of the structure), shade curtains (on top of the structure), and row coverings are all ECMs that can contribute to reaching the desired temperature for growth. If you utilize some or many of these measures, then consider a smaller geothermal system to supplement them. If these measures are not implemented yet in the operation, consider how they can be paired with this type of heating and cooling system to increase efficiency and further extend the growing season.

As part of a conference presentation, Milton Geiger from the University of Wyoming provided this calculation for heating requirements in a building:

> Square feet of structure surface x temperature difference (inside temperature minus outside temperature) x 1.2 = Heat needed in BTU/hour

## Design and Installation

Despite the relatively simple design of geothermal systems, having the right plan in place prior to installation is essential, as small mistakes could undermine the effectiveness of the system. Important preliminary steps are to ensure that tubing or piping size is appropriate for the structure and that the organization of tubing

***A modification of the traditional greenhouse is the passive solar greenhouse. This type of greenhouse does not use an artificial heat source but, rather, stores solar heat within a medium to be released at colder periods, like at night or during cold months.***

*For maximum benefit from a climate-battery system, it should primarily run only when excess heat is in the structure or any time the structure temperature is lower than subsoil temperature.*

or piping is secure before the backfilling stage occurs. Hiring an excavation service is expensive and excavating the pit yourself is time consuming, so re-excavation to modify the underground system should be avoided. According to Ceres Greenhouse Solutions, fan size, pipe diameter, pipe length, proper sealing in the infrastructure, drainage, pipe blockage, fan operation in humid environments, and how long the system runs are all things to consider and adapt to the grower's operation (2015). Pipe diameter, pipe length, and air flow interact with each other and should be balanced in order to determine how much energy will be transferred between air and soil, how much air flow the grower will see, and ultimately the total heating/cooling capacity of the system (Ceres Greenhouse Solutions, 2015). Additionally, piping used for the passive system should be perforated. Condensate naturally occurs from the evaporative cooling process, so perforated piping is important to prevent water from collecting and plugging the pipe.

Appropriate sizing of hardware and equipment is crucial for gaining optimal efficiency from a geothermal system. Particularly with a low-grade/earth-battery design, the pipe size and fan power should match the volume of the growing structure and therefore produce a certain number of air turnovers per hour. Five air turnovers per hour is the ideal rate for reaching optimal efficiency for any greenhouse or high tunnel (Osentowski and Thompson, 2021). Fans used in this system should generate enough cubic feet per minute (CFM) to reach five turnovers. Some calculating is needed to determine this:

$$\frac{\text{Volume (cubic feet)}}{\text{Exchange rate (minutes)}} = \text{CFM needed for system}$$

Note that a fan with a higher flow rate is going to be significantly higher in cost. Consider fan options that are rated for outdoor use because they are more likely to withstand the operating environment of an agricultural structure.

For maximum benefit from a climate-battery system, it should primarily run only when excess heat is in the structure or any time the structure temperature is lower than subsoil temperature. Use a two-stage thermostat, or an integrated control system if other automated systems are being controlled, in order to avoid depleting the climate battery of its stored heat. When the structure's temperature becomes equal to the subsoil "battery" temperature, heat transfer is no longer occurring; therefore, the fans do not need to be running.

The installer should note that because of the design of the passive earth-battery system and its interaction with surrounding soil, it is crucial that the area in which the underground tubing is laid is insulated around its perimeter. Two-inch-thick rigid foam insulation serves to contain the heat stored underground and prevents heat energy from being leached into the cooler surrounding soil. Additionally, soil type plays a role in installation and maintenance of this system. Sandy, loam soil is ideal for this, not to mention its effectiveness for plant growth. Too much clay in the soil can harden around the tubing from the wetting and drying cycles, eventually plugging the system. If your soil is high in clay, consider replacing the soil during excavation or amending the soil to lower clay content (Osentowski and Thompson, 2021).

Hot air flowing through the pipes in a passive system will heat up the soil for about a foot surrounding the piping on all sides. Consequently, allow two feet of space between each row and each level of piping to ensure the soil is "charging" at its maximum capacity. If you are able to install a geothermal system and its groundwork prior to installing the actual high tunnel or greenhouse, the piping or tubing system would sit directly underneath the structure. If a structure is already in place, the underground piping for a retrofitted geothermal system should be buried next to the north or south-facing wall. This system would still require the same amount of linear feet of piping to be effective, and this pipe also needs to be spaced two feet away from the next pipe on all sides. Below, we will further explain calculating energy needs and the expense of installing a low-cost version of a geothermal system.

## Costs and Payback

Remember to include operating costs in project cost calculations. A small amount of energy is needed for the heat pump in an active system, to drive the heating and cooling processes, but as much as five times this much energy is being brought up from the ground, resulting in a net gain of energy for the system. Fans in a passive system need even less energy to run.

Cost can vary widely, depending on system mechanics and design. Parts and installation can range from $1,200 to $25,000, depending on the system. There can be significant variation in upfront costs because, as this technology becomes more understood and utilized in agriculture, growers are developing and implementing passive systems that require less sophisticated equipment and fewer parts. Additionally, growers may already have access to equipment, like an excavator or tractor, whose rental or hire typically accounts for the majority of system installation cost. An example of costing a passive geothermal system is described in the first case study, below.

On the other hand, in an active system, the heat pump itself can represent as much as 60% of the system cost (Stimson, 2016). The size of the heat pump, as well as the design of the underground piping, will vary from one application to the next. Because of the sophistication of the system and extensive design requirements, an active system should be designed by an engineer and installed by a professional. A heat pump may further accommodate your seasonal and operational needs by providing you with a more direct means of climate control, provided it is financially appropriate. Contact your local HVAC equipment provider or a geothermal systems vendor for sizing and pricing.

## Case Studies

### *Dave McCarson, Alpine Organic Farms, Montana*

Dave McCarson specializes in design and construction of passive solar greenhouses and has expertise in horizontal open-loop, ground-air geothermal systems. He explains that this low-cost, climate-battery type of system is particularly effective in agriculture and farming. Systems he has designed and installed are typically small, 10 feet by 20 feet, and are comprised of piping layered at two feet and at four feet deep in the earth. For McCarson's own system, installation was cheap because he had excavation equipment available, and he has general knowledge of using the hardware. He has seen success with installations and overall efficacy of this type of system in Plant Hardiness zones 3 and 4.

McCarson suggests that unless a high tunnel has double-layered, insulated walls, any geothermal system would be cost-inefficient for this application. This is because a typical uninsulated high tunnel will quickly release heat energy. Conversely, geothermal systems can generate a significant amount of energy, and an active system will produce too much energy for a single-layered high tunnel and its crops. McCarson points out that the nature of a high tunnel is to become too hot in the summer but not stay warm enough for the winter. Without double-layered insulated walls, the same problem would continue, even with a geothermal system.

*The two-foot layer of perforated piping and insulation in a passive system. Photo: Dave McCarson*

***Because of the sophistication of the system and extensive design requirements, an active system should be designed by an engineer and installed by a professional.***

The dimensions of McCarson's structure and the hardware used can provide a cost estimate. Ten feet by 20 feet by 8 feet (typical height at the ridgeline for a high tunnel this size) constitutes 200 square feet of floor space and 1,600 cubic feet of volume. Using the calculation above, 133 CFM from inline fan(s) is needed for this size structure to achieve five air turnovers per hour. To get cubic feet per minute, the structure's volume in cubic feet is divided by 12 minutes, since we desire five turnovers per hour (12 × 5 = 60).

$$\frac{(1{,}600 \text{ cu ft})}{(12 \text{ min})} = 133 \text{ CFM needed for system}$$

The groundwork involves two layers of piping, one at four feet deep and the other at two feet deep, running the length of the structure. To create a bidirectional air flow between the two layers, two intake pipes (one for each layer) are situated at opposite ends of the structure and pull air from near the ridgeline. Four-inch perforated pipe is used for the lengthwise tubing. Six-inch perforated pipe is used for the manifolds at opposite ends of the system for each layer. Table 1 breaks down the costs of a geothermal system for a high tunnel this size. Keep in mind that the grower may not need to hire an excavator.

**Table 1. Cost Breakdown of a Passive Geothermal System.**
*Source: Gordian, 2020*

| Hardware | Quantity | Unit Price | Cost |
|---|---|---|---|
| Inline Fans, rated for outdoor use, 133 CFM | 2 | $150 | $300 |
| Perforated HDPE piping<br>(4-inch for lengthwise 20 ft) X 12 rows, six at each level<br>(6-inch for manifold 10 ft) X 4 manifolds, two at each level | 240 ft.<br>40 ft. | $0.83/ft.<br>$2/ft. | $199<br>$80 |
| Corrugated wyes, 6” | 12 | $15 | $180 |
| Reducers, 6” × 4” | 24 | $17 | $408 |
| Subsoil insulation:<br>(4 ft deep X 20 ft long) X 2 walls = 160<br>(4 ft deep X 10 ft wide) X 2 ends = 80 | 240 sq. ft. | $2 | $480 |
| Hired excavation (soil with clay and rock will increase the price) | 20 ft. | $5/linear ft. | $100 |
| | | | Total: $1,747 |

## *Russ Finch, Greenhouse in the Snow, Nebraska*

Russ Finch specializes in passive solar greenhouse design complemented with open-loop, ground-source passive geothermal systems. The original unit attached to Finch’s home runs 78 feet long and 17 feet wide. However, this is smaller than the typical size of the units Finch commercially produces, which range up to 138 feet long, although efficiency is maximized at 102 feet. At his home greenhouse in eastern Nebraska, Finch grows large crops of citrus, figs, feijoa, grapes, and dozens of flower varieties. A typical lemon tree will produce 125 pounds per year, fetching $4.30 a pound at farmers market prices. It is notable that Finch is able to grow these crops in this part of Nebraska, an area that is rated at Plant Hardiness zone 4 or 5. In the winter, the temperature can drop to -27°F, and in the summer, it can climb to 105°F.

Finch’s system utilizes the stability of soil temperature at eight feet below the earth. Along with this system, Finch also utilizes a unique passive solar greenhouse design that minimizes the volume of air that needs to be heated or cooled. Finch suggests that these systems are not feasible for hoop houses (high tunnels) or even for traditionally sized greenhouses. Both contain a large volume of air and conditioning this much air could potentially raise costs to the point where they would exceed the benefits of the system.

The greatest accomplishment of the systems Finch designs is their simplicity. The systems can easily be installed by anyone with access to a backhoe and the ability to do the labor. In an 8-foot-deep trench, extending from one end of the greenhouse to another, a series of perforated pipes are laid. Finch states that for every six feet of

***Construction of Finch’s passive solar greenhouse. Photo: Russ Finch***

***Citrus grown on Russ Finch’s operation. Photo: Russ Finch***

greenhouse length, an additional tube is required. For instance, a 96-foot greenhouse would require 16 tubes. Finch arrived at the numbers purely through trial and error and notes that it is difficult to set up hard calculations for this. This system regularly delivers a temperature difference of 35 to 40°F between the air being put into the ground and the air coming out. To develop estimates for your greenhouse and geothermal system, you can use an online climate battery calculator such as the one provided by Eco Systems Design (ecosystems-design.com/climate-battery-calculator.html).

## Conclusion

The use of growing structures for season extension and the application of geothermal heat technology impact the sustainability of a growing operation. Unheated high tunnels can extend the growing season at minimal cost to the grower. With the help of structures that extend the growing season, the grower has more capacity for production and can grow their market and promote local food security. Adding a geothermal system can provide enhanced protection to crops and extend the growing season even further. Geothermal heating and cooling systems require very little dependence on conventional energy sources such as oil and gas, resulting in reduction of greenhouse gas emissions and air pollutants.

Geothermal energy is a renewable energy source, and with simple but durable design, a system can last a long time. A geothermal system is easy to maintain and requires little ongoing maintenance when built properly. There are many considerations regarding the economics of a geothermal system, but in some cases the investment can be worth it. A passive design variation in the form of a "climate battery" or other type of low-grade geothermal system is most feasible in agriculture when paired with an insulated high tunnel or passive solar greenhouse. Tapping into this renewable energy tool that is cost-effective and long-lasting can be invaluable for extending the growing season, increasing capacity for providing fresh produce, and contributing to the sustainability of food and energy systems.

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# Notes

# Notes

**Geothermal Greenhouses: Exploring the Potential**
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UMass Extension Greenhouse Crops and Floriculture Program (/greenhouse-floriculture)

# Geothermal Heat for Greenhouses

Soil and water below ground contains a vast reservoir of thermal energy. Geothermal heating systems recover this energy and convert it to heat that can be utilized in greenhouses and other buildings. Geothermal heat can be classified into three categories.

## Low temperature (50°F)

The soil temperature at the surface varies considerably over the year and closely follows the air temperature. At the 10-12' depth it is more uniform averaging about 50°F with a variation of about 6°F above and below this level. There is also a lag time of about 8 weeks between the maximum surface temperature and the maximum soil temperature at the 12' level which is helpful in winter heating and summer cooling. For the greenhouse production of perennials, herbs, nursery stock and some vegetables that require a temperature from 32-45°F this low grade soil heated air or water can be used directly. For heating the greenhouse to a higher temperature, a heat pump is necessary. These are available as air to air, air to water, water to water or water to air systems.

## Medium temperature (140-300°F)

Thermal wells and springs in some parts of the world including the west coast of the U.S. provide hot water that can be used directly for heat. There are currently over 40 greenhouse operations in Oregon, California and Washington that are heated by geothermal energy. The heated water that comes from the ground is distributed through fin radiation or root zone heating.

## High temperature (>300°)

The steam from geysers in California, Nevada and Utah is being tapped for power generation. Currently there are about 20 sites in operation with several more under construction. These produce power for 5-8 cents/kW hr.

## Greenhouse heating systems

In New England, the only choice that we have for geothermal heating is with low temperature heat. There are several systems that appear to be feasible that have a reasonable payback. Before considering the installation of one of these systems, it is important to address energy conservation. Reducing infiltration, installing energy curtains, insulating sidewalls and the foundation perimeter, making good use of growing space and installing electronic controls should be done first. This will save considerable heat and reduce the size of the heating system needed.

## Air systems

Earth tubes are piping that is buried 6' to 12' below the soil surface. The simplest and least expensive systems gather heat during the winter by drawing air through corrugated plastic tubes and direct it into the space to be heated. The air passing through the tubes is warmed by the soil that has a higher temperature than the air. During the summer the system can be used to cool building space by drawing the heated air in the greenhouse through the buried tubes and then returning it to the building. The heat is absorbed by the cooler earth.

In the above system the air can be warmed or cooled to near the soil temperature. For example, the average soil temperature 8' below the surface in central Massachusetts varies between 60°F in early Fall to 46°F in early March. To increase the temperature to 80°F - 90°F for air heating for ornamentals or bedding plants, an air to air heat pump could be employed. This process is similar to what happens in a refrigeration system.

## Water systems

Liquid systems utilize either the soil heat to warm a liquid, such as water or antifreeze or directly use water from ponds or well and extract the heat. There are several systems that have been used successfully.

Closed-loop systems circulate water or an antifreeze solution through loops of small diameter underground pipes. In cold weather this solution absorbs heat from the ground and carries it to a heat exchanger that extracts it. In may also go to a heat pump that amplifies it so that the temperature is warmer.

Horizontal loops may be used where adequate land is available. Pipes are placed in trenches in lengths to 400'. Multiple loops are used to capture the amount of heat needed to heat the greenhouse. Vertical loops are an alternative were land area is limited. Well drilling equipment is used to bore small diameter holes from 75' to 500'; deep. The hole may be filled with a grout to transfer the soil heat to the pipes.

Pond or lake loops are economical to install when a body of water is nearby. This system eliminates the excavation cost. Water or antifreeze is circulated through coils of pipe that are placed in the bottom of the pond or lake. A depth of at least 12' is needed to avoid the influence of the freezing that occurs on the surface during the winter.

An open loop system utilizes ground water directly. Water is usually pumped from one well and returned to a second, adjacent well. The distance between wells has to be far enough so that the return water doesn't influence the intake water. The water may also be pumped out of a pond or lake at one location and returned a distance away. Open loop systems can be economical if the source of water is located nearby.

## Conclusions

The use of ground heat is becoming more popular for residential and commercial applications. Due to the high temperature needed for conventional greenhouse heating, a heat pump is needed. Today's equipment is more reliable at a lower cost than a few years ago. Where low temperature heat is needed, such as maintaining an air temperature just above freezing, direct use of the heat is possible.

As the cost of fossil fuels increases, the payback for alternative heating systems shortens. For most geothermal systems the payback is in less than ten years with energy prices at $25/MBtu. (#2 fuel oil =

$2.50/gal) Additional information is available at: [Mass.Gov (https://www.mass.gov/)](https://www.mass.gov/)

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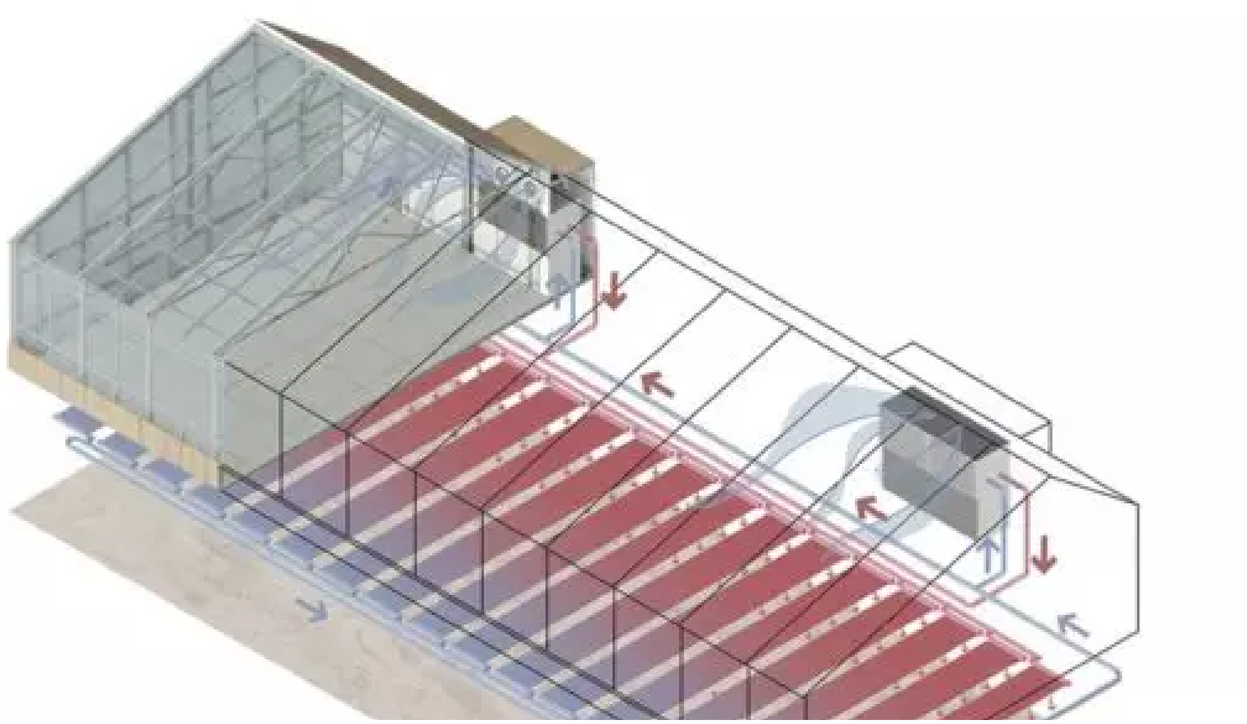
Climate Control, Ecoloop and GAHT

# Introducing The EcoLoop™: Ceres Most Energy-Efficient Heating And Cooling System Yet

January 3, 2020



At Ceres we are challenging the idea that “high tech” means “expensive” when it comes to greenhouse design. Between our patented passive solar structural design and our Ground to Air Heat Transfer (GAHT™) System, innovation is at our core and we aim to provide growers with the most energy-efficient growing solutions. We help our growers achieve the most productive growing environments possible while simultaneously saving them money on operational costs. This year has been a big year in developments for Ceres and we’d like to introduce our newest climate control greenhouse system to date: the Ecoloop™.

**Function**

The Ceres Ecoloop™ is a ground coupled heat pump system that heats, cools and dehumidifies our sealed greenhouses. It acts as an innovative geothermal HVAC system that utilizes the Earth’s steady temperature (between 45°- 60°F) to create precise climates in each greenhouse environment.

To break it down, the Ecoloop™ is made up of two primary components: a ground source heat pump and a ground loop. The ground source heat pumps are attached to the North wall of the greenhouse, above ground. The pumps filter and condition $CO_2$ rich air from inside the sealed greenhouse environment. The ground loop component transfers thermal energy to or from the greenhouse heat pumps. This is achieved by recirculating water through subsurface piping. The recirculating water will either absorb heat from the ground (Ecoloop™ in heating mode) or disperse heat back into the ground (Ecoloop™ in cooling mode). The two components together make up a completely closed-loop system.

We should probably mention the fluid coolers as they are on the diagram and are an integral part of the GCHP system. The fluid coolers are basically there to add an extra boost of cooling when the ground alone cannot handle the cooling load. The fluid coolers are there to dump excess heat into the air, via evaporative cooling, before it enters the ground to ensure our ground temperature does not increase over time year after year. Basically the fluid coolers are our “Turbo” when we really need it.

#### Cooling

When the Ecoloop™ is in cooling mode during peak summer months, hot air will enter the heat pumps and refrigerants inside will absorb and transfer heat to the water recirculating underground in the ground loop. The earth surrounding the ground loop acts as a heat sink and will disperse the heat back into the ground. To add an extra boost of cooling on especially hot days, the Ecoloop™ is equipped with fluid coolers to dump excess heat into the outside air via evaporative cooling. This is done before the air enters the ground to ensure the ground temperatures do not increase over time year after year.

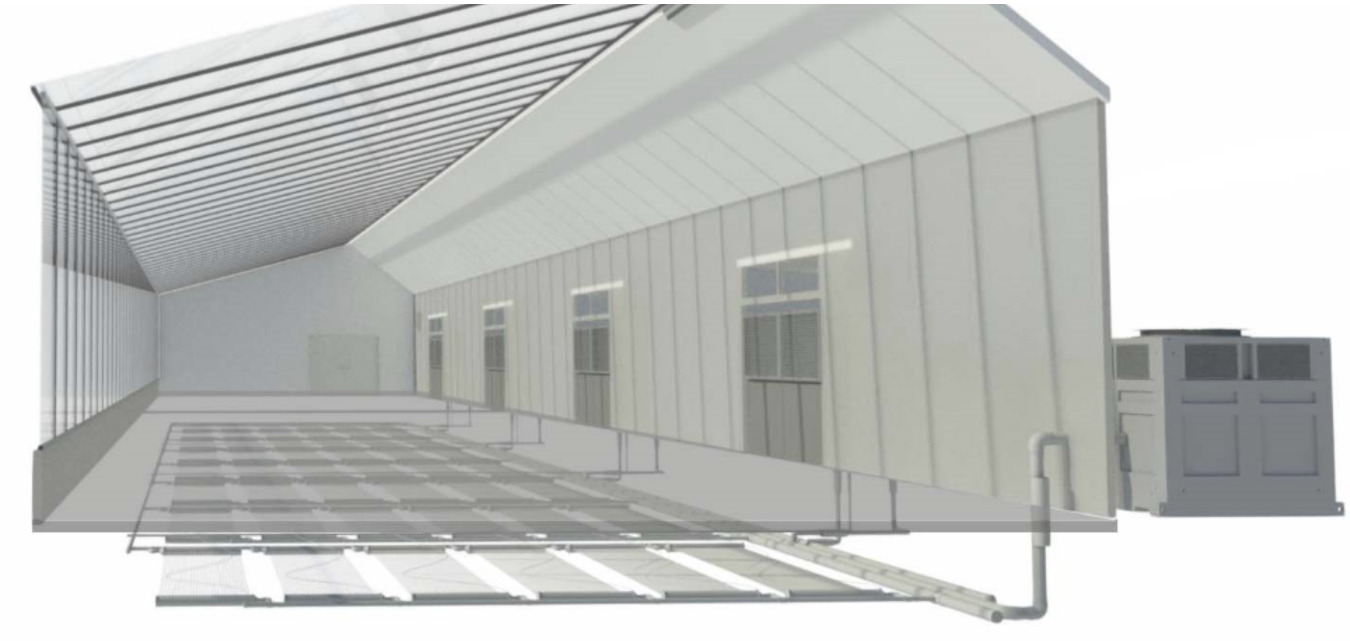
When the heat pump is in this cooling mode, it pulls moisture out of the air and this moisture can be collected in a reservoir and used on site for irrigation purposes. In this way the Ecoloop™ is recycling water by taking moisture transpired by the plants, collecting it and then giving it back to the plants at a later time when it is needed.

#### Heating

When the Ecoloop™ is in heating mode it absorbs heat from the ground through the water recirculating in the ground loop. The heat pumps concentrate and transfer absorbed heat to the air recirculating in the grow environment. The Ecoloop™ also recovers waste heat from the compressors for reheating dehumidified air. Traditionally HVACs need additional energy to reheat dehumidified air to the desired temperature but the Ecoloop™ recycles energy from the heat compressors via heat exchangers. This innovative concept contributes to its low operational costs.

#### Dehumidification

In most greenhouses, the HVAC and dehumidification systems are two separate entities working together (or sometimes against each other) to create the perfect growing environment. With the Ceres Ecoloop™ we have combined these two systems so growers can easily achieve exact VPD levels. The Ecoloop™ dehumidifies the greenhouse environment by intaking air and cooling it to dew point inside the heat pump. The heat pumps then reheat the air with waste heat recovery to bring the air back to the desired temperature. The system can dehumidify the air down to 40% relative humidity.



**Why go with a Ceres Ecoloop™?**

The Ecoloop™ is designed exclusively for our sealed HighYield Kit™design and is a perfect solution for growers seeking heightened biosecurity and precise climate control. Also, the Ecoloop™ is designed for all climate zones and can be built in redundancy for modular expansion. And unlike traditional HVAC systems that create unwanted shading, the Ceres Ecoloop™ takes up no room inside the greenhouse which increases the potential for optimal sun harvesting.

The geothermal qualities of the Ecoloop™ classifies it as a renewable energy source and thus qualifies growers for rebate offers from state and utility programs. Ground coupled heat pump systems have a comparable upfront cost to chillers but GCHP system's life expectancy is longer and its energy consumption is significantly lower.

**The Numbers**

We crunched the numbers and determined that growers can expect to save more than 60% on energy costs compared to a traditional HVAC system. A traditional HVAC system uses 87.5 kilowatts of energy per square foot per year whereas the Ecoloop™ uses 35 kilowatts. To translate that to dollars, growers will spend about $10.50/ sq ft/ year to use their HVAC system and they could be spending $4.20/ sq ft/ year with the Ecoloop™.

The development of this product forced us to go back to our roots and come up with a solution that would be revolutionary in terms of energy-efficiency but also be simplistic in terms of concept. A smart grow operation starts with smart design. Contact a greenhouse expert today to discuss your energy-efficient greenhouse project.

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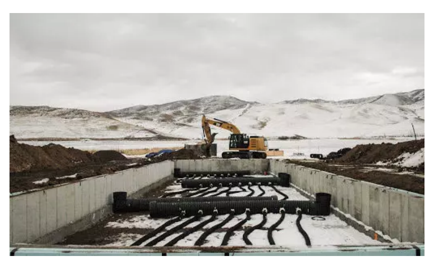

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