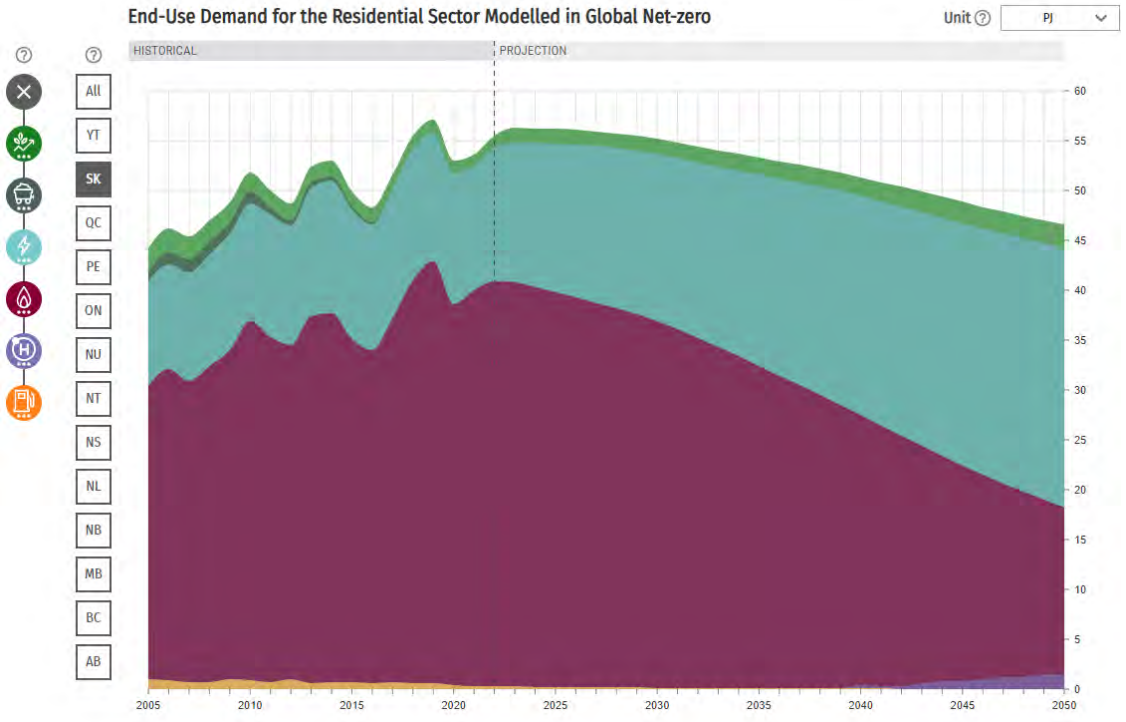
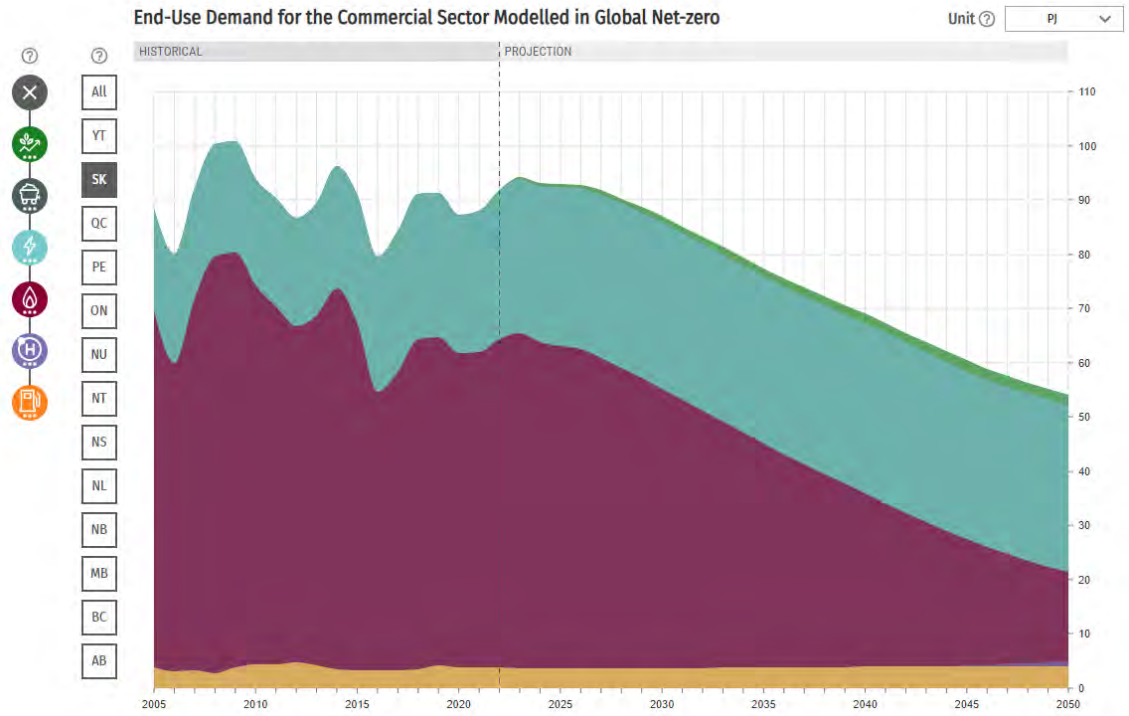
Natural Gas Heat Pumps:
An Alternative for Lower Carbon Heating

SaskEnergy

Megan Bunney and Hadi Ramin

Energy Use in a Low Carbon Future

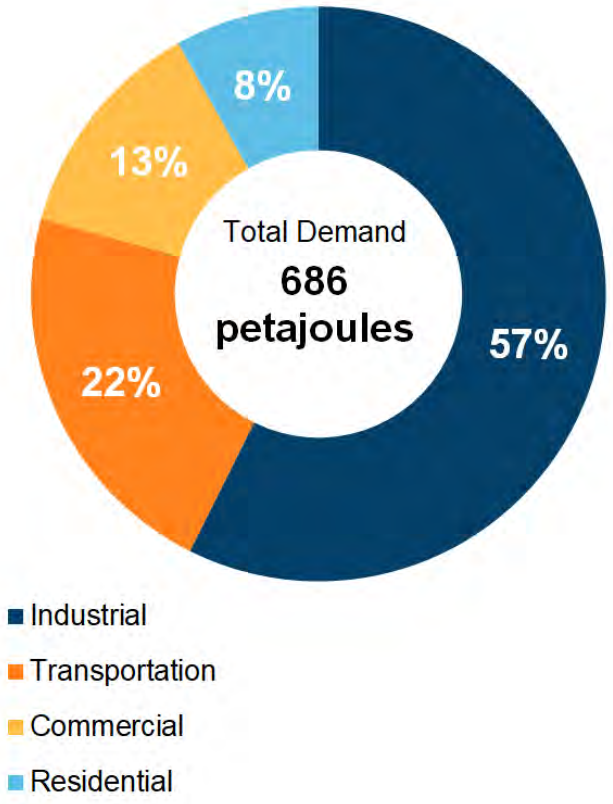


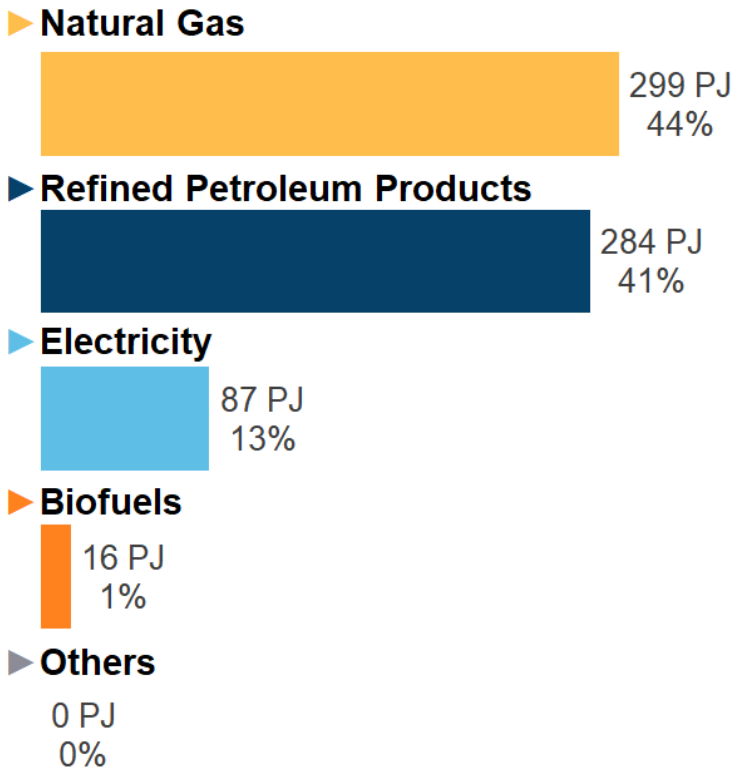


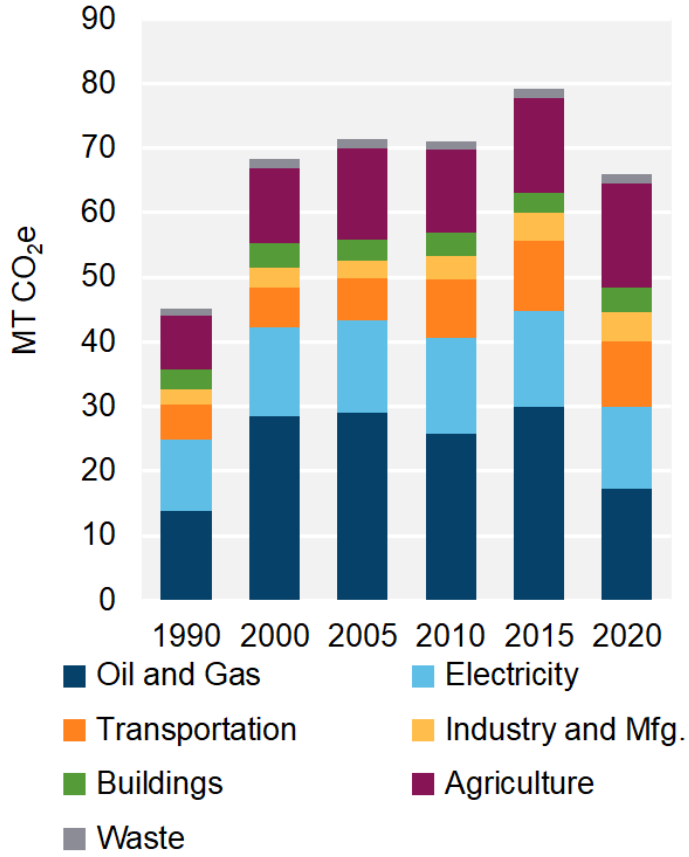
- Natural gas continues provide energy for households and businesses in SK in 2050

Source: Canada Energy Regulator www.cer-rec.gc.ca

Energy Use and GHGs in Saskatchewan

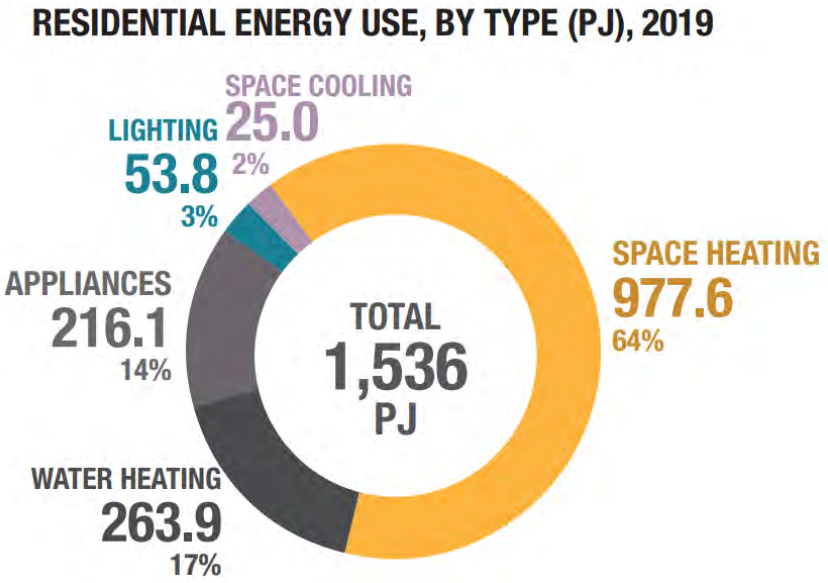


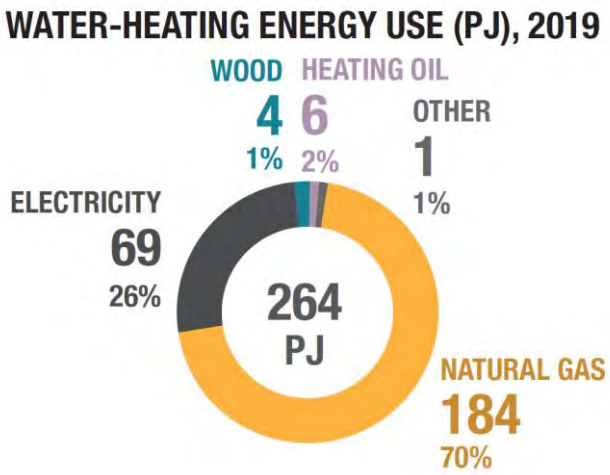


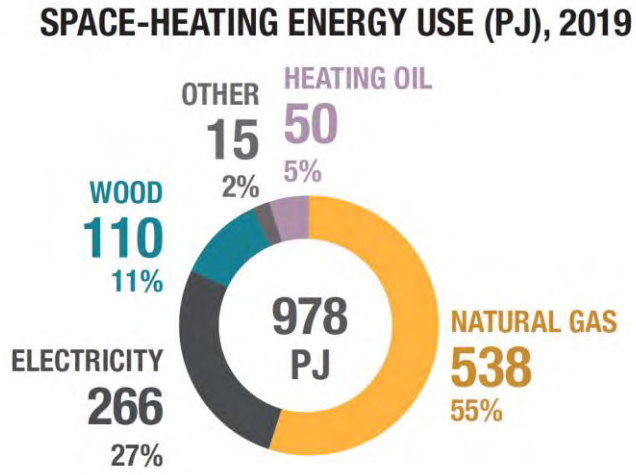


Source: (1) Canada Energy Regulator www.cer-rec.gc.ca

Building Energy Consumption





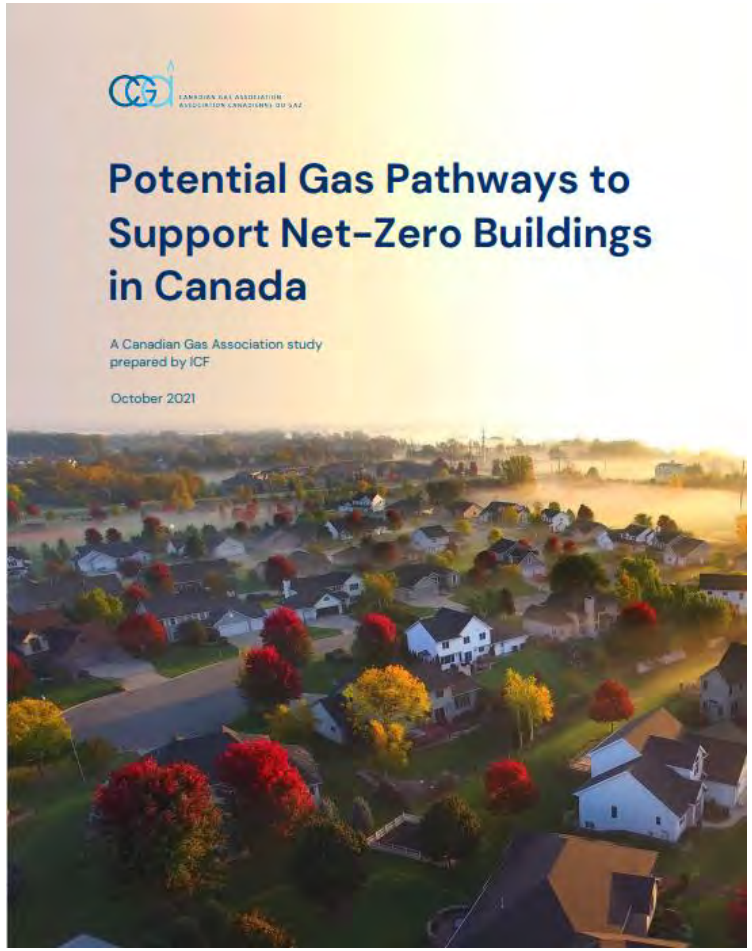


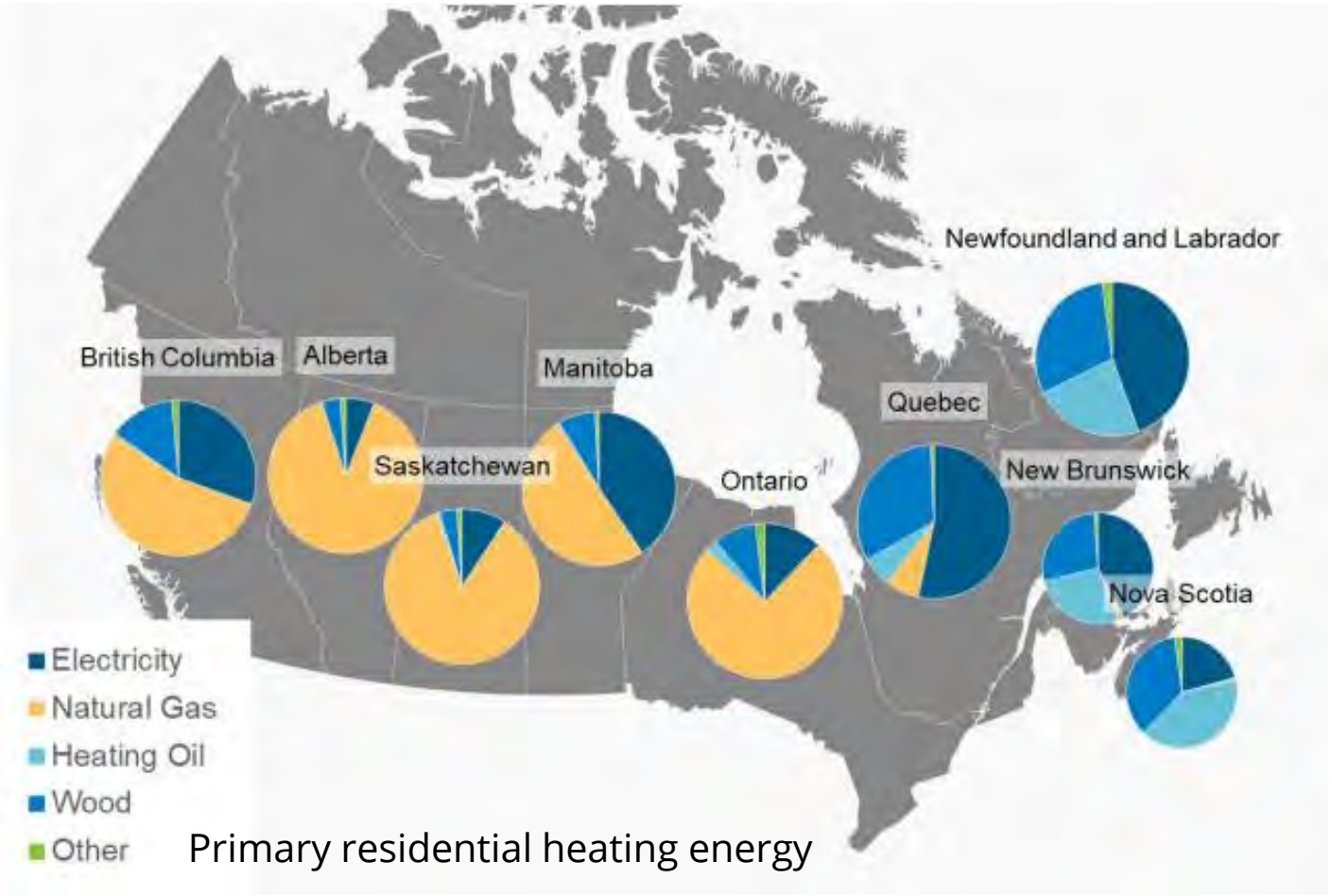
Source: [Energy Fact Book 2022-2023 (canada.ca)]

SaskEnergy's Commitment

Provide critical energy for a greener Saskatchewan
Reduce operational emissions by 35% by 2030
Expand programs, service offerings, and education

Natural Gas in a Low Carbon Future

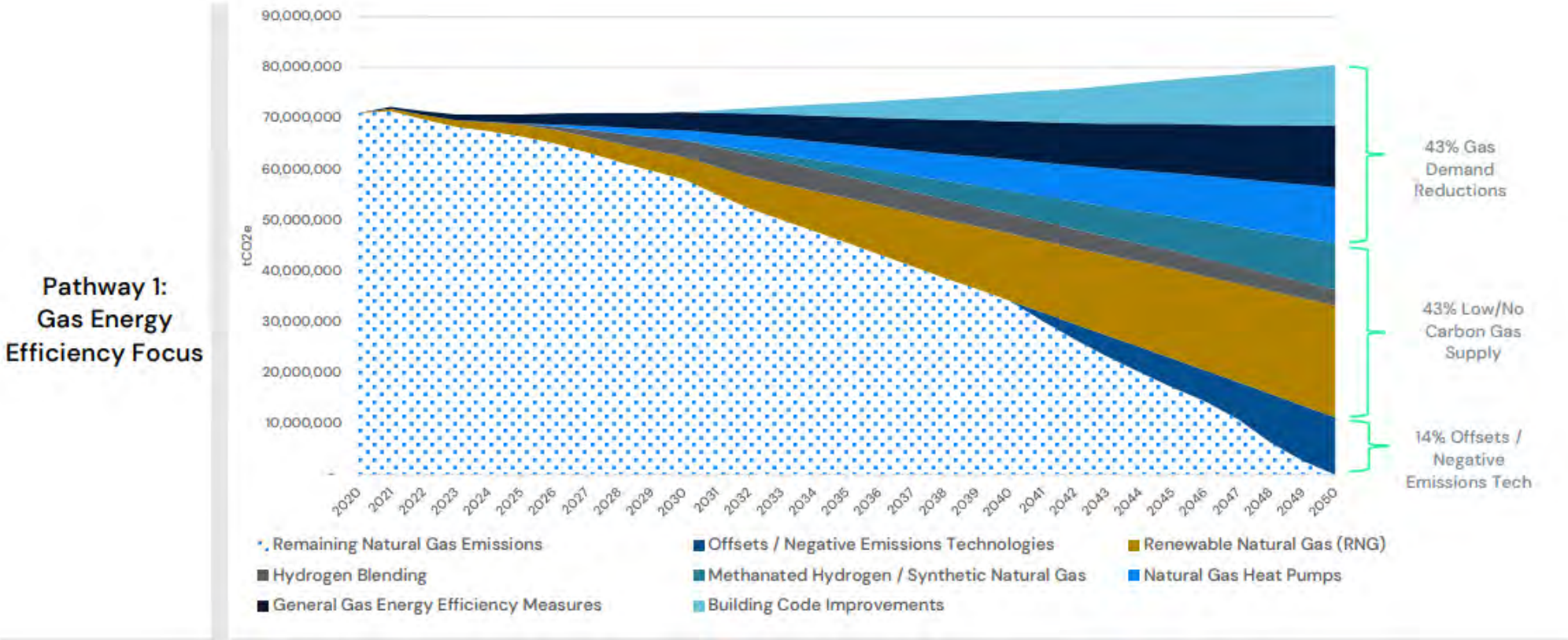




Primary residential heating energy

Source: Canadian Gas Association www.cga.ca

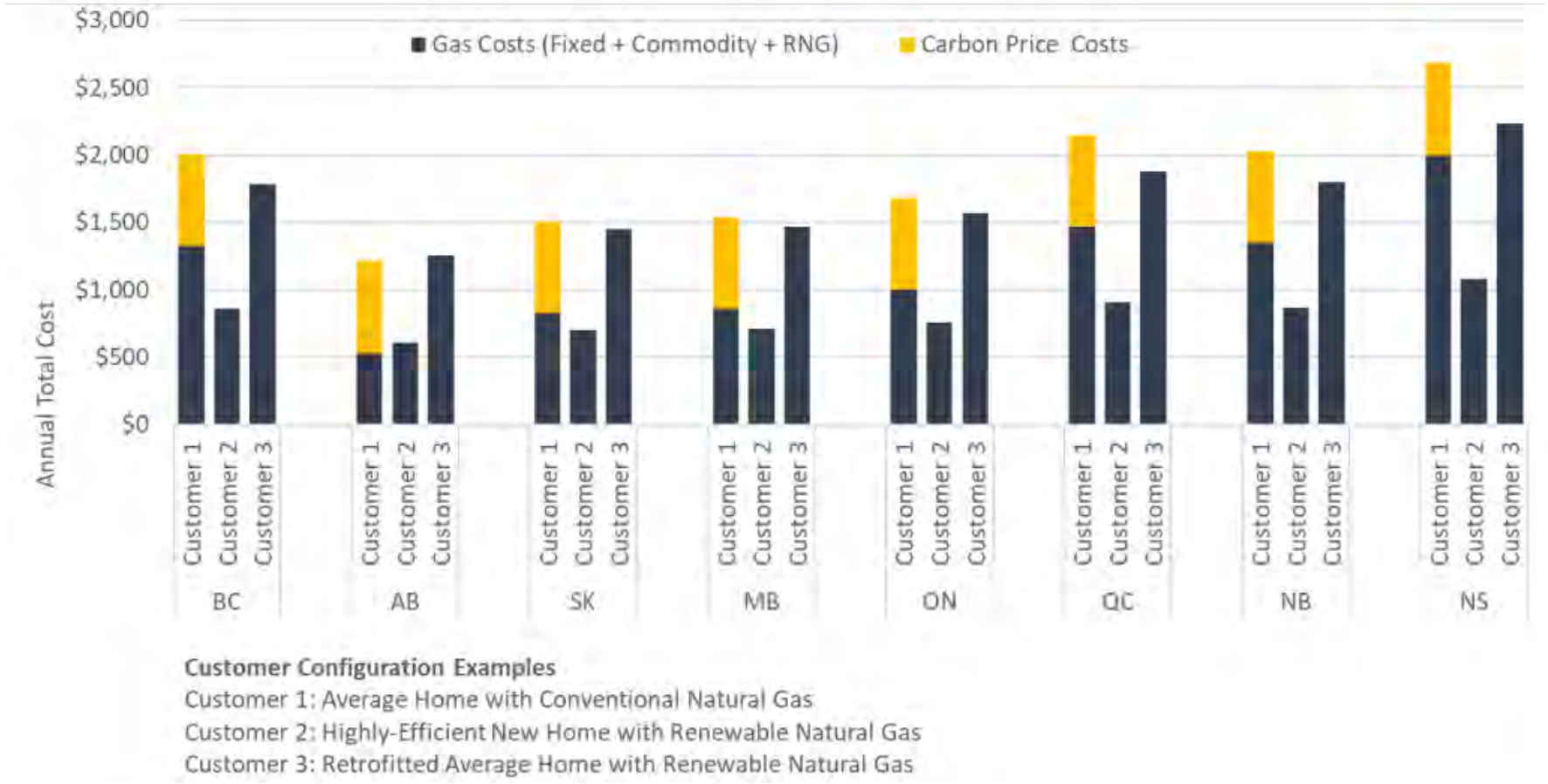
Natural Gas in a Low Carbon Future



- 2021 ICF Potential Gas Pathways to Net Zero
- Reductions: 43% energy efficiency, 43% renewable gas, 14% capture

Source: Canadian Gas Association www.cga.ca

Renewable Natural Gas Analysis (2030)



Customer Configuration Examples

Customer 1: Average Home with Conventional Natural Gas

Customer 2: Highly-Efficient New Home with Renewable Natural Gas

Customer 3: Retrofitted Average Home with Renewable Natural Gas

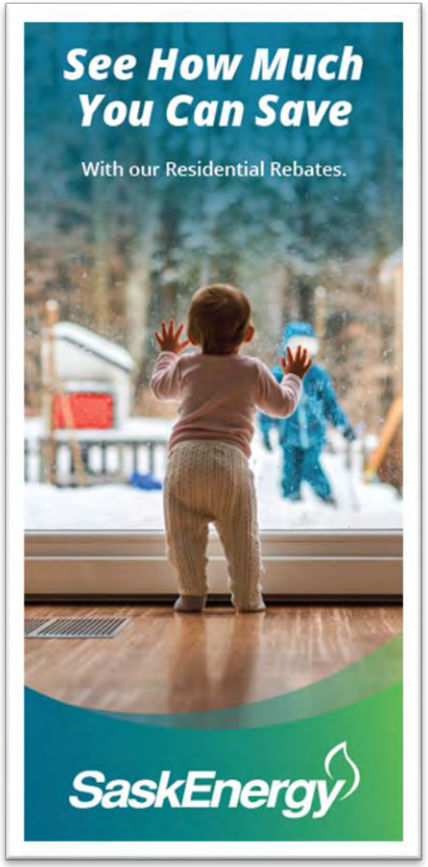
Source: Canadian Gas Association www.cga.ca

Customer Emission Reductions

Rebates

Residential Equipment
- Replacement
- Home Efficiency Retrofit

Commercial Space &
- Water Heating



Education

saskenergy.com
- Ways to save
- Energy Comparison Tool

Emerging Technologies

Energy Efficiency

- Space heating & cooling
- Water heating
- Waste heat recovery

Low Carbon Gases

- Renewable Natural Gas
- Hydrogen

Jaeson Cardiff, left, CEO of Clean02, explains his CARBiN-X technology that uses a chemical process to convert CO2 captured from heating system exhaust into a stable carbonate used in soaps and detergents, at the company's facility in Calgary, Alta., Thursday, July 22, 2021.

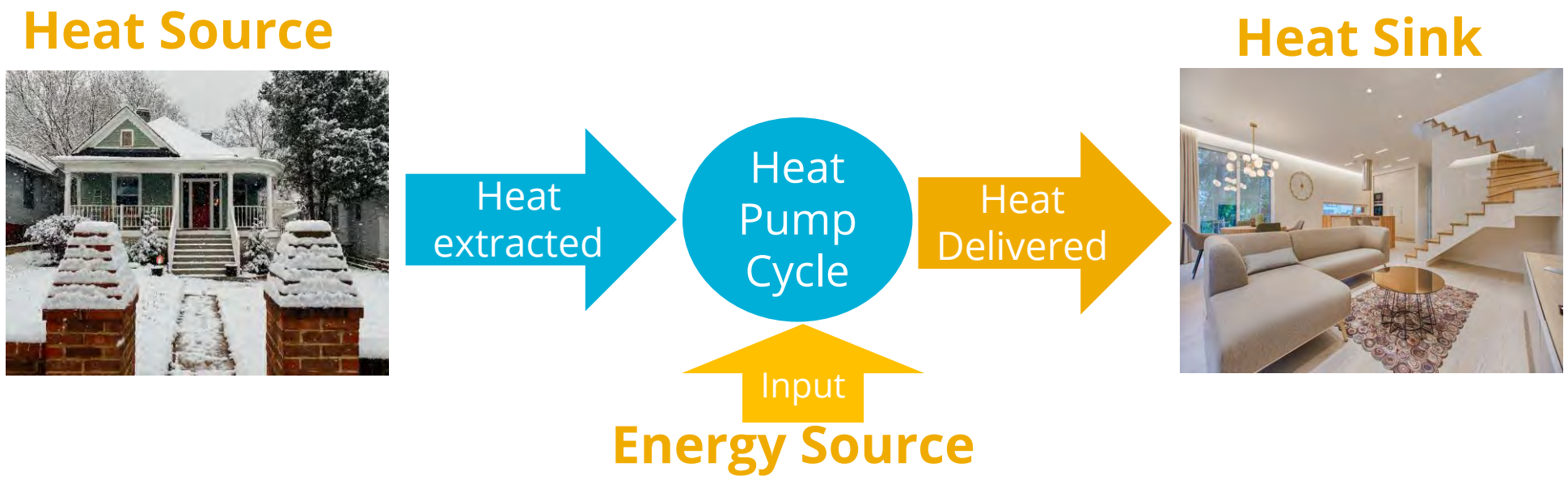
JEFF MCINTOSH/THE GLOBE AND MAIL

Carbon Capture

- Chemical process sequesters carbon from exhaust
- Process is exothermic and preheats boiler water
- ~20% GHG reduction

What is a Heat Pump?

- Device that transfers heat (thermal energy) from outdoor environment to indoor (warmer) via refrigeration cycle.
- Heat flows naturally from a higher-temperature region to a lower-temperature region

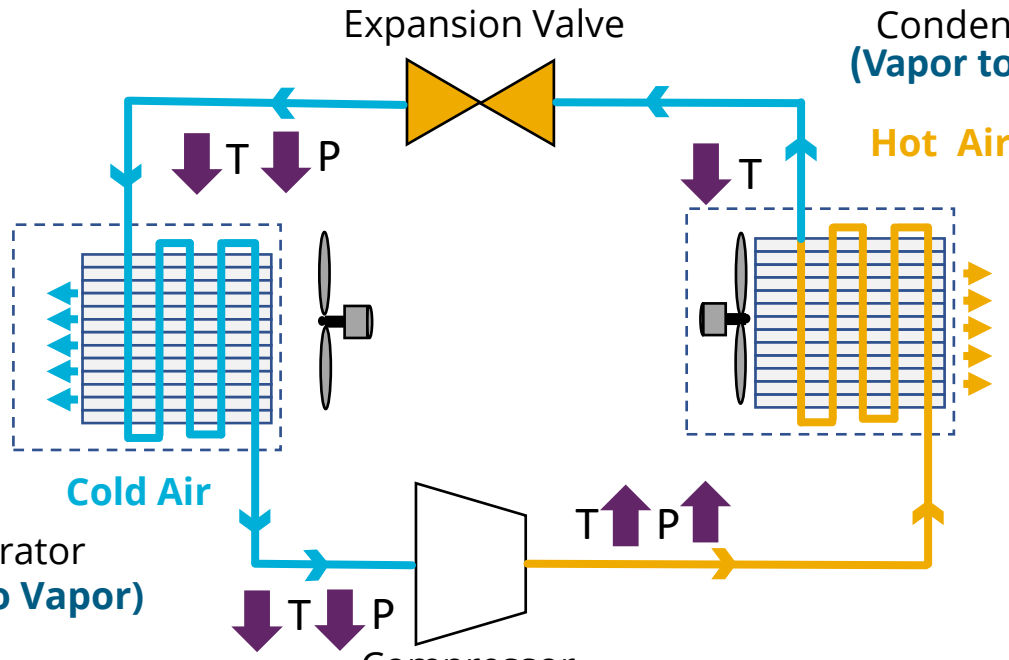


Source: Energy Solutions Center https://www.energysolutionscenter.org/

What is a Heat Pump?

- Uses refrigerants in the cycle that undergoes changes of phase **(HFCs such as R134a, R410a and R407C)**

Heat Source



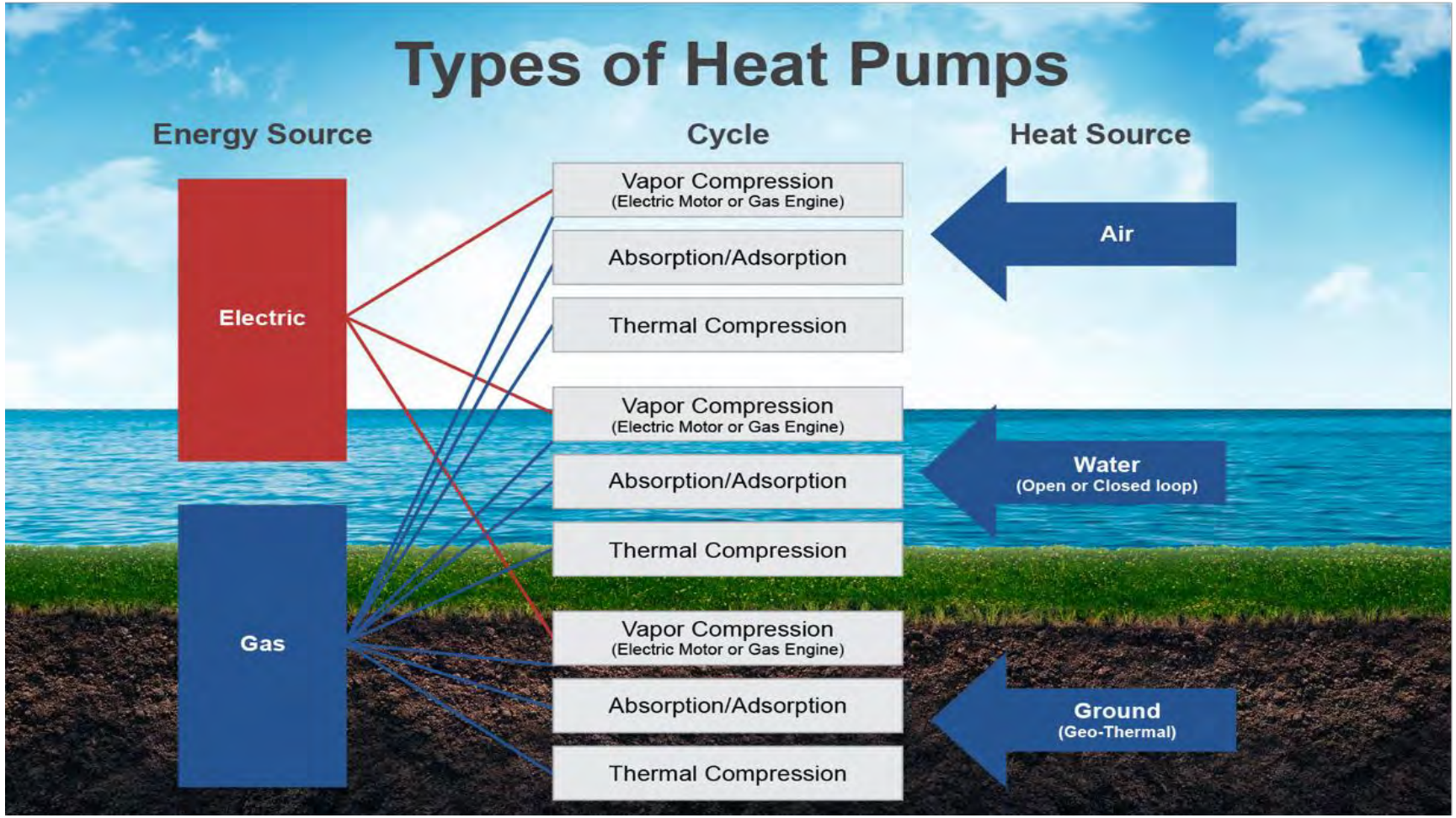
Heat Sink

- **Air at -18 ℃ has 85% of thermal energy as air at 21 ℃**

Heat pump operation could be reversed to provide cooling

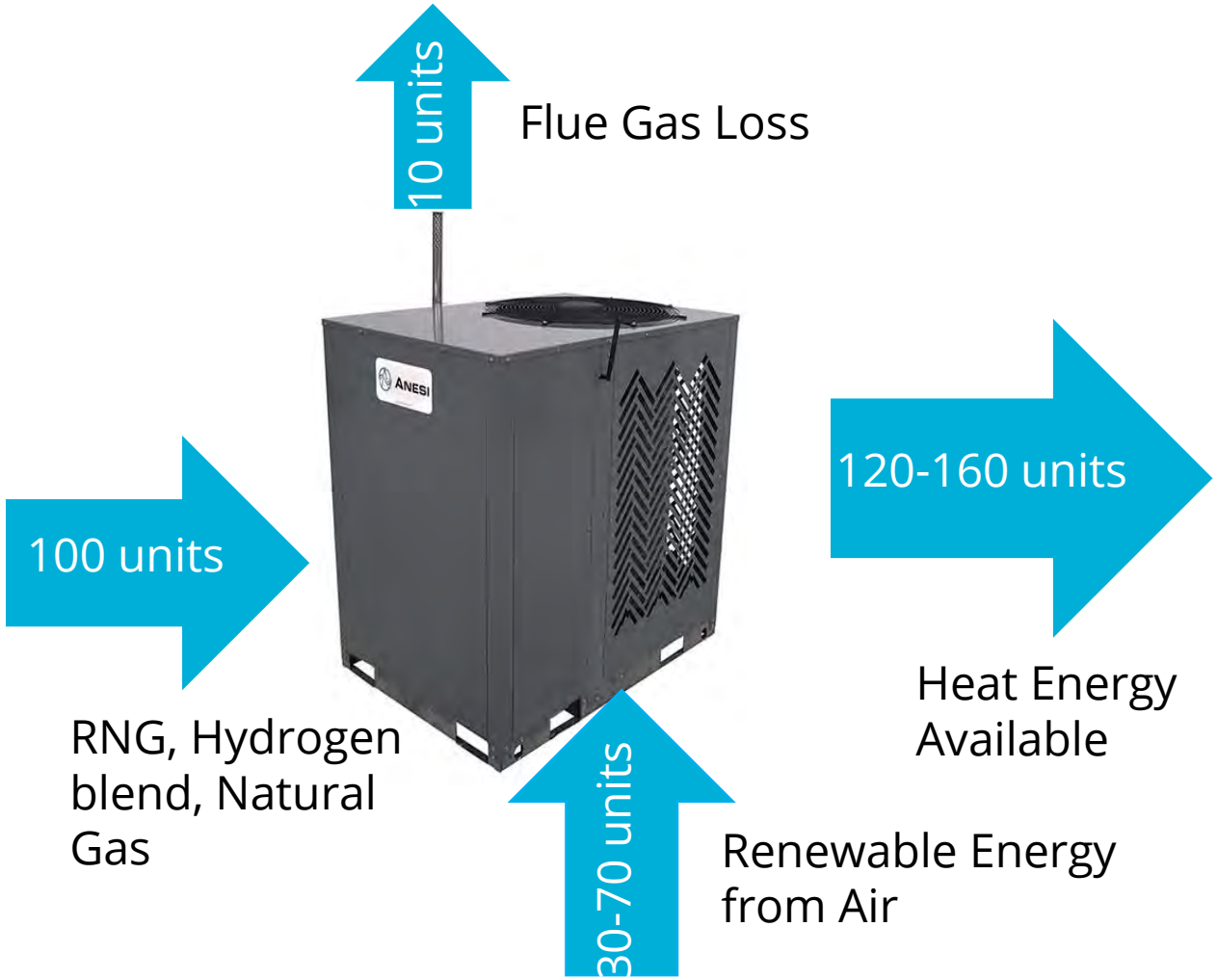
Sources: (1) Energy Solutions Center https://www.energysolutionscenter.org/ (2) Natural Resources Canada Why use a cold climate air source heat pump? (canada.ca)

What is a Heat Pump?



Source: Energy Solutions Center https://www.energysolutionscenter.org/

Performance Metrics



Coefficient of Performance (COP) = ratio of energy drawn out of the heat pump to the energy supplied

COP (heating/cooling) =

$$\frac{\text{Heating/cooling produced}}{\text{Work and/or heat input}}$$

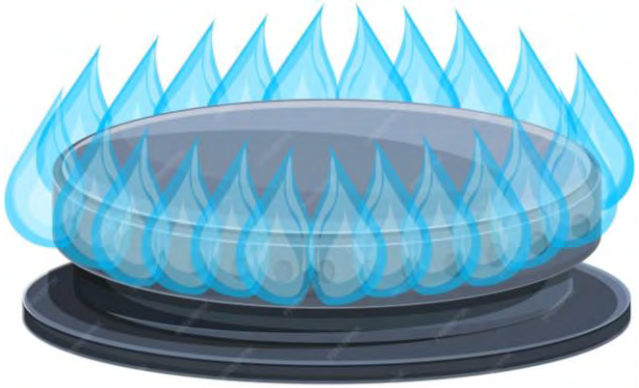
Gas Utilization Efficiency (GUE)=

$$\frac{\text{Heating produced}}{\textit{Heating gas energy consumed}}$$

- **Heat pumps performance depends on outdoor conditions.**
- **Seasonal heating/cooling performance metrics**

Source: Energy Solutions Center https://www.energysolutionscenter.org/

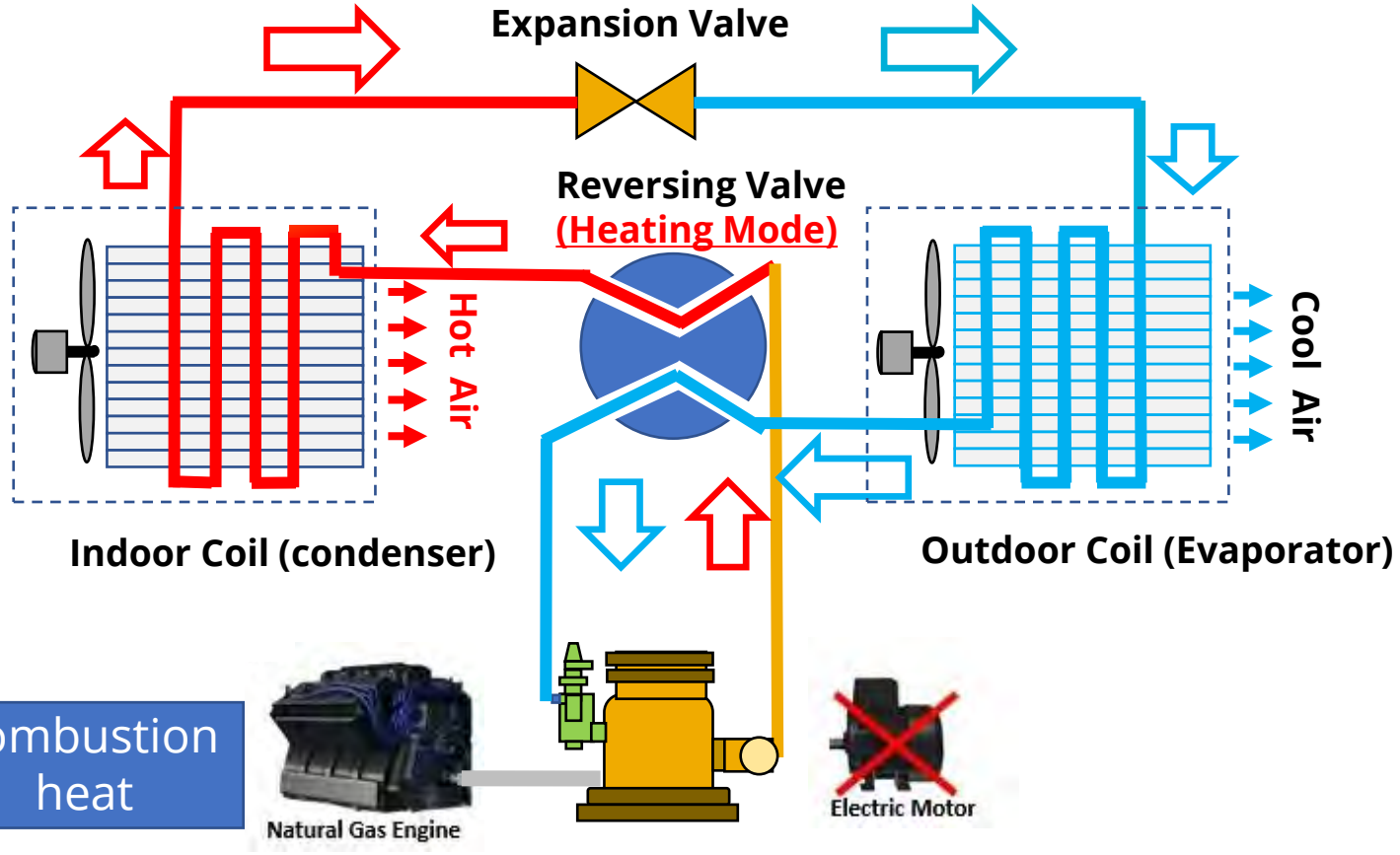
Gas Heat Pumps (GHPs): How They Work?



Gas engine heat pump	Absorption/ Adsorption heat pump	Thermal Compression heat pump

Gas Engine Heat Pump (GEHP)

- Use natural gas instead of electricity
- Low operating cost
- Recovers heat from combustion engine
- Defrosting cycles using heat from combustion



Combustion heat

Frosting

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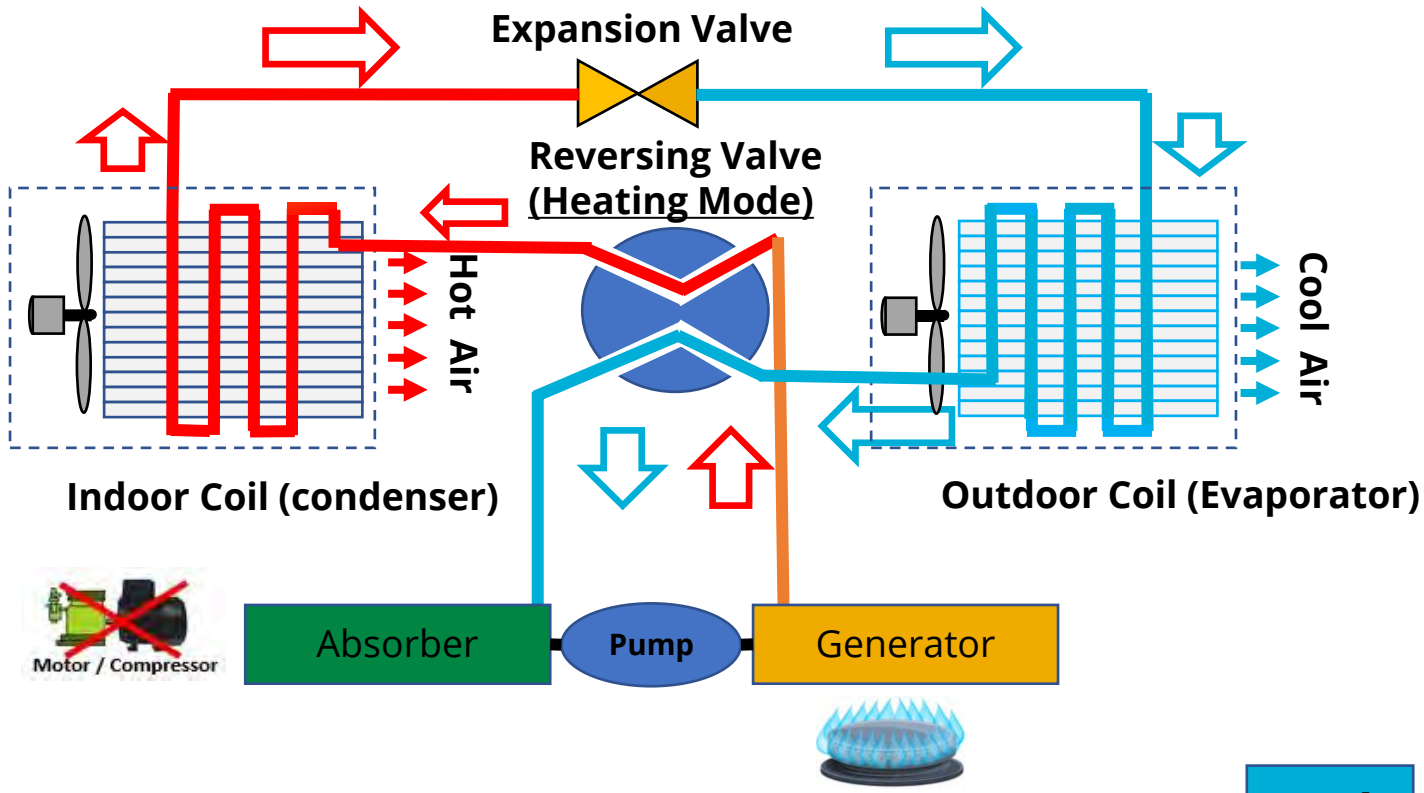
Source: Energy Solutions Center https://www.energysolutionscenter.org/

Absorption Heat Pump (AHP)

- Ammonia and water solution
- Pumps liquid solution instead of compress vapor
- Zero ODP* and GWP** refrigerant
- Low operating cost
- High temperature outlet



* Ozone depletion potential ** Global warming potential

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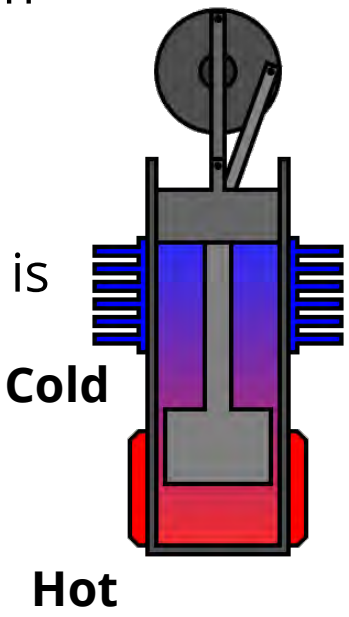
Sources: (1) Energy Solutions Center https://www.energysolutionscenter.org/ (2) High efficiency and low environmental impact heating systems (robur.com)

Thermal Compression Heat Pump (TCHP)

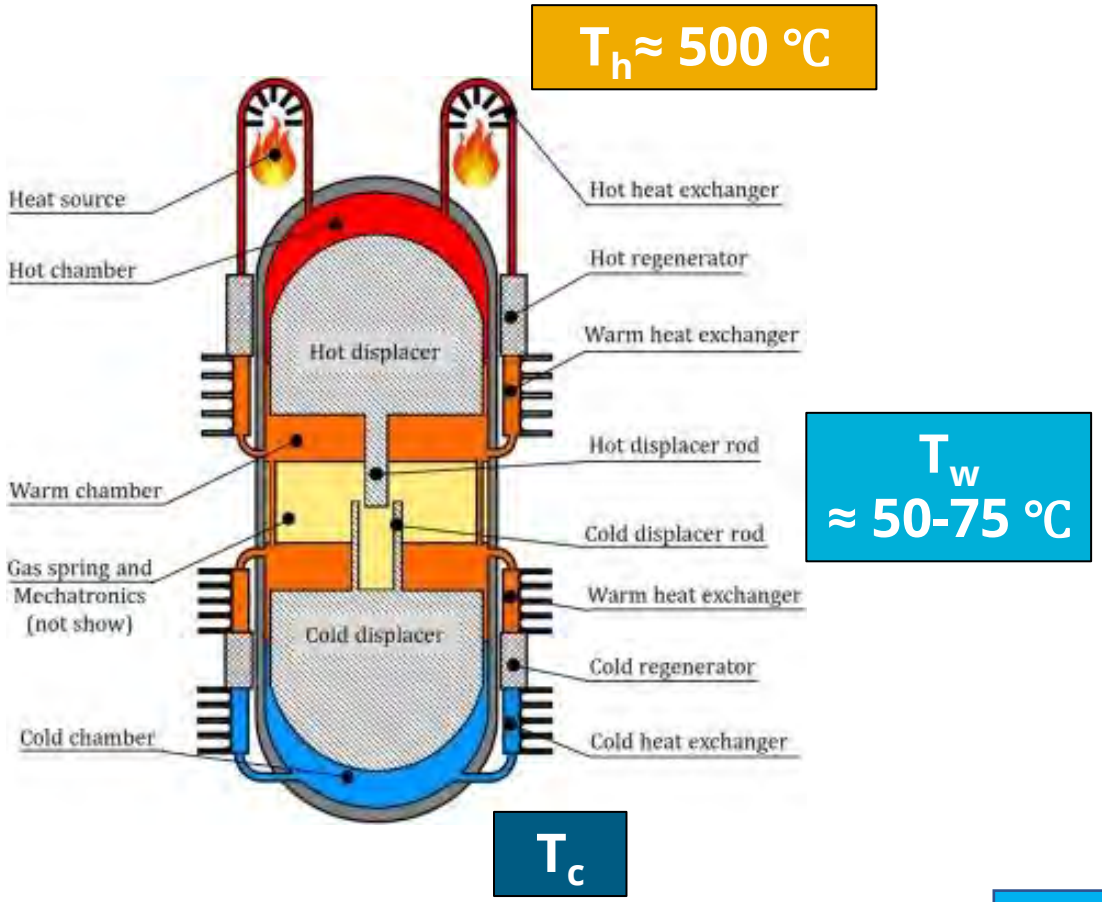
- No pump or compressor, gas moves by thermal compression
- No phase change (no evaporator/condenser)
- Based on Hofbauer cycle which is similar to a Stirling engine
- Refrigerant: Helium
- Zero ODP and GWP
- Lower operating costs
- High temperature outlet



Sources: (1) https://www.sciencedirect.com/science/article/abs/pii/S1359431118318209 (2) Home - Thermolift (thermoliftsolutions.com)

Thermal Compression Heat Pump

- Heat is added (Natural Gas) which increases Helium temperature and subsequently pressure. As **heat is added and then removed** for use, **a pressure wave** is created inside the machine. This pressure wave moves the displacers back and forth to move the refrigerant in the system
- The device is a “Thermal compression” system since **temperature change** is used to create mechanical motion



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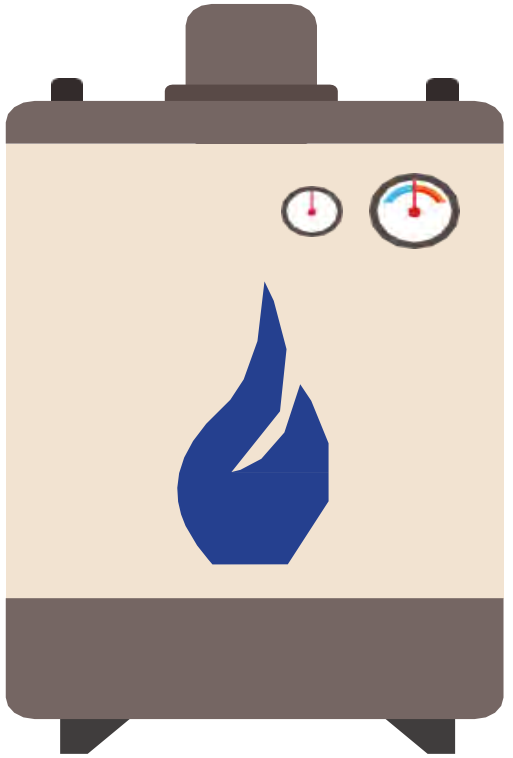
Sources: (1) Performance analysis of a free-piston Vuilleumier heat pump with dwell-based motion - ScienceDirect

Why Gas Heat Pumps?

- Up to 50% reduction in energy cost and CO_2 emissions
- Low GWP refrigerant
- Better performance in cold climates
- Stand-alone heating system
- Suitable for retrofit without needing for major changes in existing heat distribution systems
- Leverages existing energy infrastructure
- Operate on RNG and hydrogen blend to further reduce emissions



Sources: (1) Energy Solutions Center https://www.energysolutionscenter.org/ (2) Hydrogen Vehicles & Refueling Infrastructure (ca.gov) (3) Assessing the Global Warming Potential (GWP) of Blowing Agents — AskARoofer®

GHP Commercial Readiness

- Multiple gas heat pump systems in various stages of development
- Several case studies and demo projects in Canada
- Modular design to meet larger heating and cooling needs

Company	Type	Applications	Sectors	Commercial Readiness*
BLUE MOUNTAIN ENERGY	GEHP			Available
Tecogen Clean Energy Solutions	GEHP			Available
YANMAR	GEHP			Available
	AHP			Available
ROBUR caring for the environment	AHP			Available
ANESI GAS HEAT PUMPS	AHP			Available
VICOT 奇威特	AHP			Available
BOOSTHEAT	AHP			Field Test
HeatAmp	TCHP			Field Test
THERMOLIFT Comfort sourced from nature	TCHP			Demos

Key: Heating, Cooling, Residential, Commercial

*** Please consult with manufacturers to inquire about a GHP tailored to your specific application. GHPs are in the market for commercial sectors, and residential units are expected to be available in 2024.**

Source: Energy Solutions Center [Heat Pump Manufacturers | GasAirConditioning.com]

Thermolift Demo Project

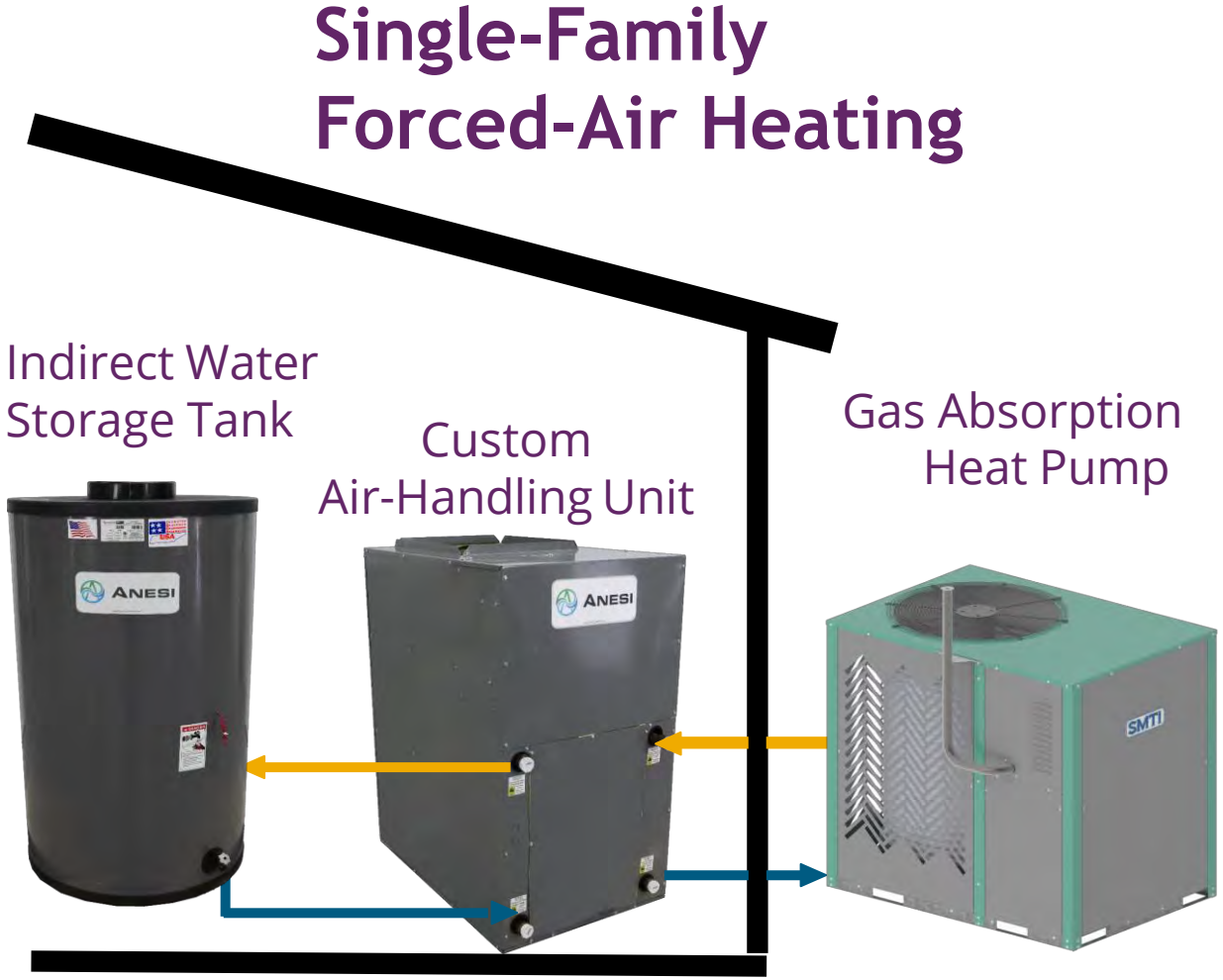
- Tested and Validated at Oak Ridge National Laboratory and CANMET laboratory
- In the Saskatoon training center integrated into existing hydronic system (radiant heating system), (DHW and cooling in summer)
- COP 1.1 at -30℃, expected to be over 1.3 this winter
- Get experience with local contractors
- Observe operating characteristics in Saskatchewan climate and part load performance

Temp(℃)	-25	-8.3	8.3 (47F)
COP	1.3	1.46	1.52

Demonstrated an ability to extract heat from air at -100 (℃)

GHP- Applications

- Reduces Energy, Operating Costs, Emissions – all by 30-50%
- Replaces gas furnace (boiler) & water heater
- No expensive upgrades to home
- Delivers full heating comfort expected by homeowners
- Low noise levels
- All refrigerant remains outdoors
- Outside combustion, venting
- Replacement or New Homes



Sources: Gas Heat Pump (stonemountaintechnologies.com)

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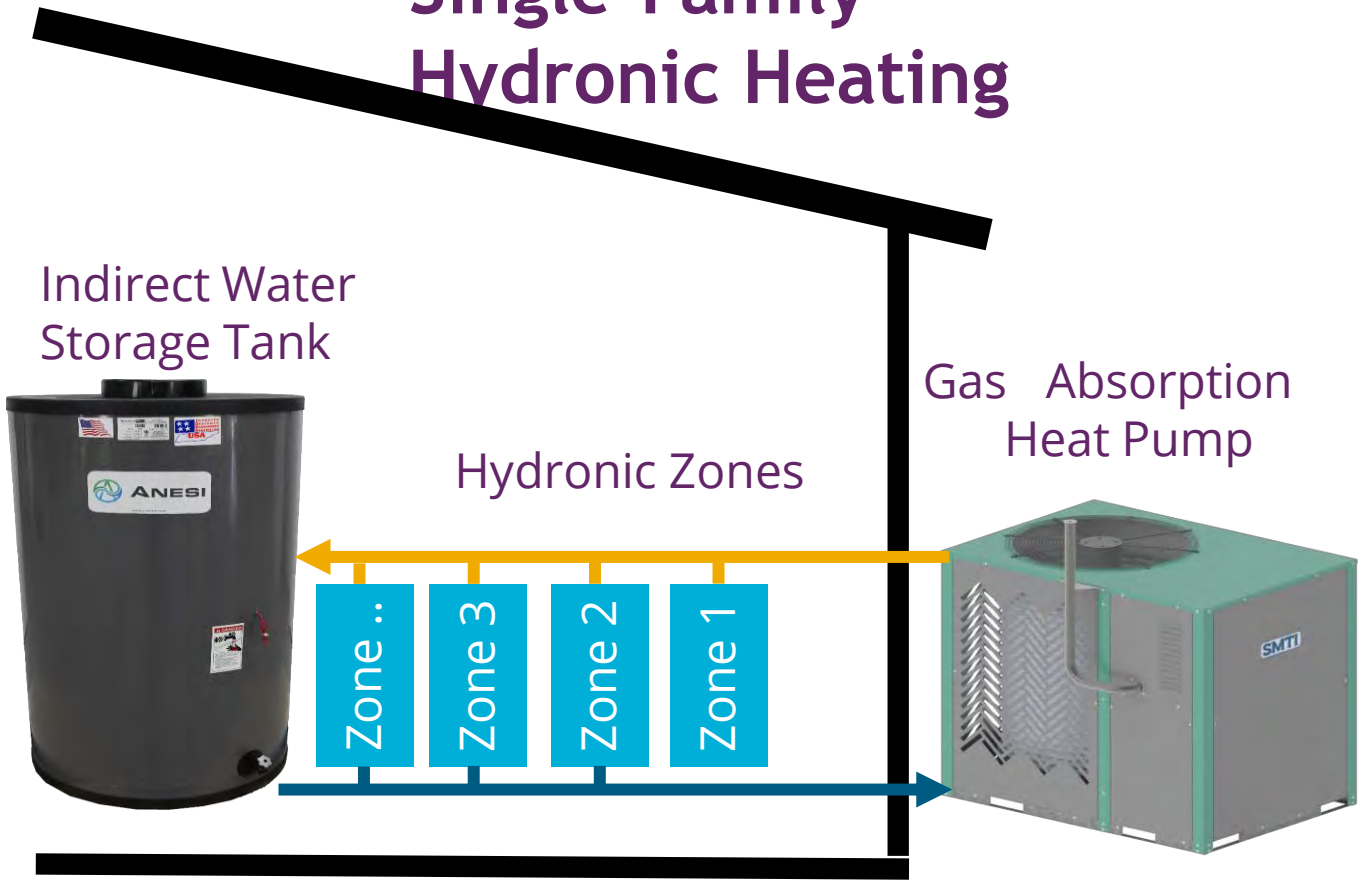


Sources: Gas Heat Pump (stonemountaintechnologies.com)

Gas Heat Pump Specs

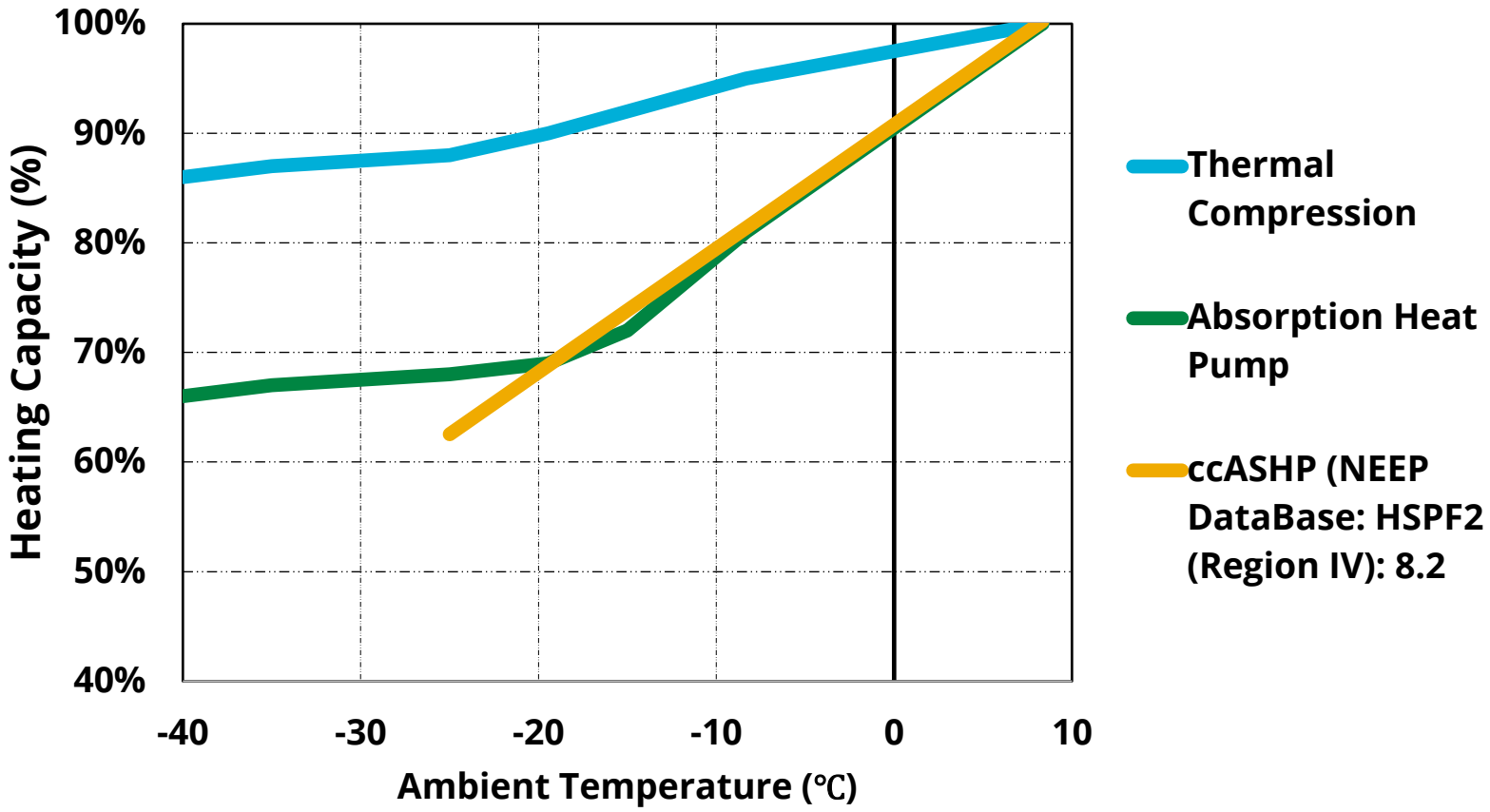
Space Heating | Water Heating

- 80 kBtu output (~ 55kBtu input)
- COP = 1.45
- Air to Water
- Condensing
- 4:1 Modulation
- Refrigerant GWP = 0 (H_2O / NH_3)
- Minimum Ambient Operating Temp: -40°F (-40°C)
- Maximum Supply Water Temperature: 150°F (65°C)
- All combustion and venting outside

Source: ANESI Website (SMTI) Gas Heat Pump (stonemountaintechnologies.com)

Cold Climate Performance

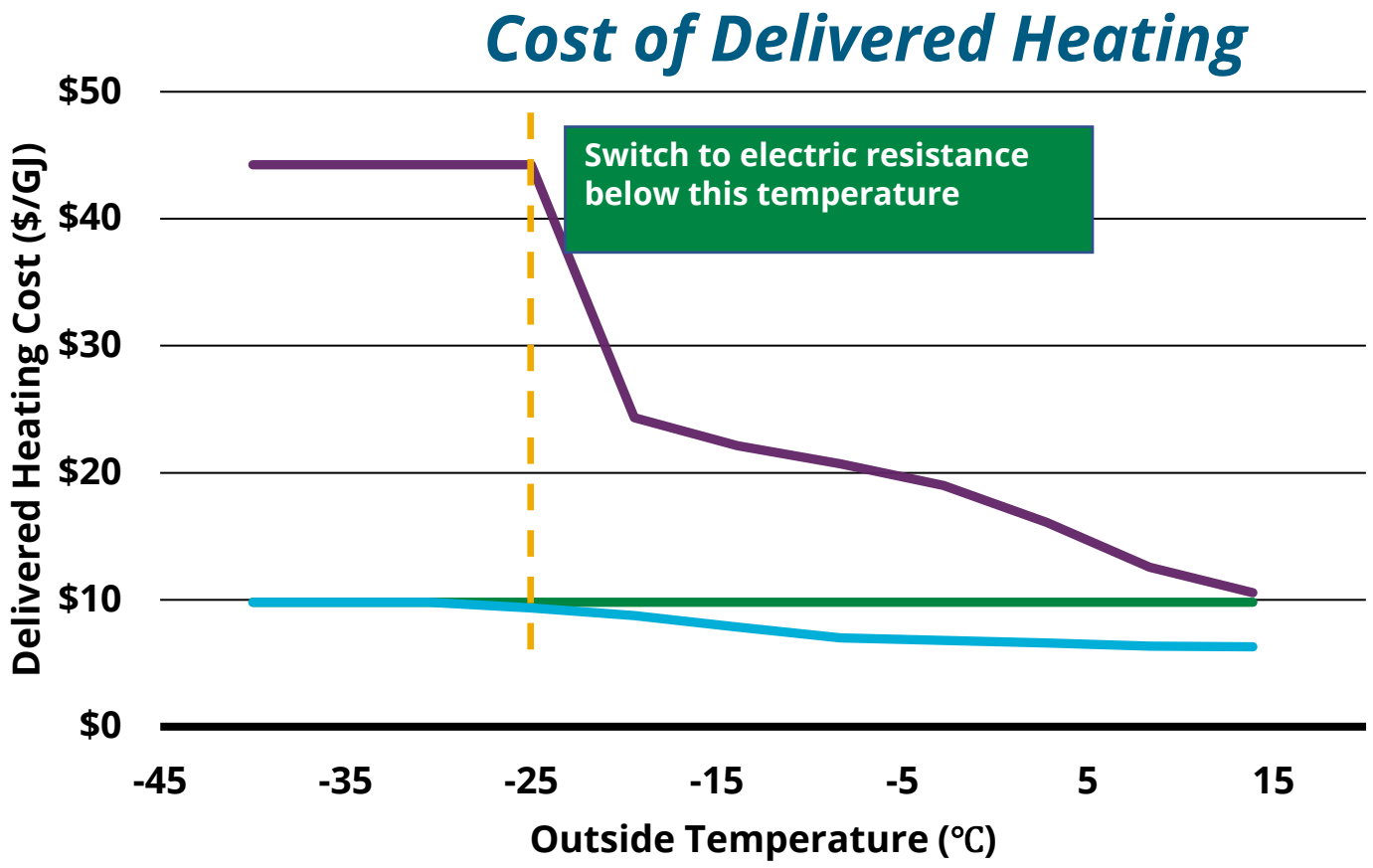
Capacity maintenance



Frosting

Sources: (1) ANESI Website (SMTI) Gas Heat Pump (stonemountaintechnologies.com) (2) Home - Thermolift (thermoliftsolutions.com) (3) ASHP (neep.org)

Benefits: Operating Cost



Key Comparative Metric:

$/GJ (Delivered)

NG Cost:

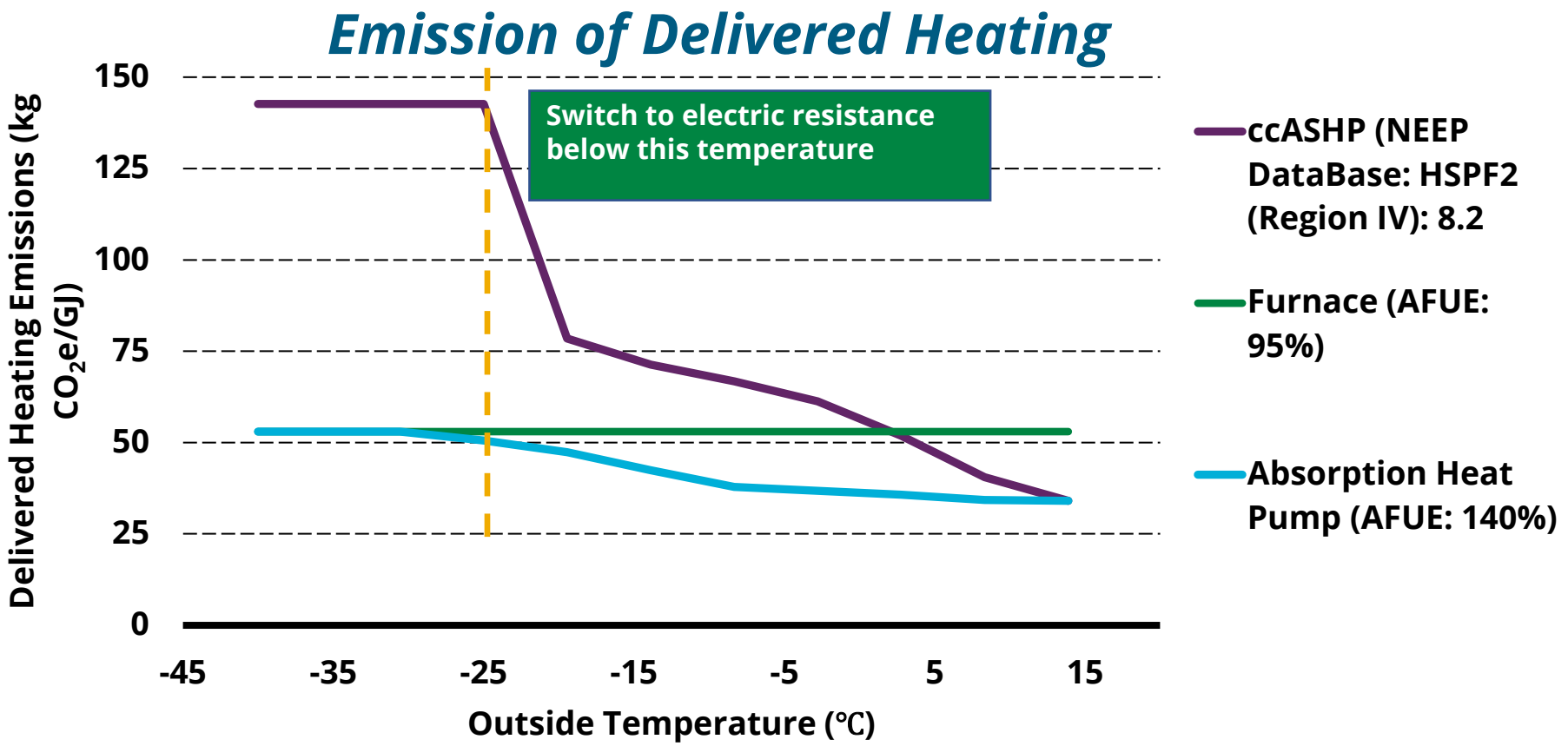
9.15 $/GJ

Electricity Cost:

0.1591 $/kWh

Sources: (1) ANESI Website (SMTI) Gas Heat Pump (stonemountaintechnologies.com) (2) ASHP (neep.org)

Benefits: Emissions



Key Comparative Metric:

Kg CO_2e/GJ (Delivered)

NG Emissions:

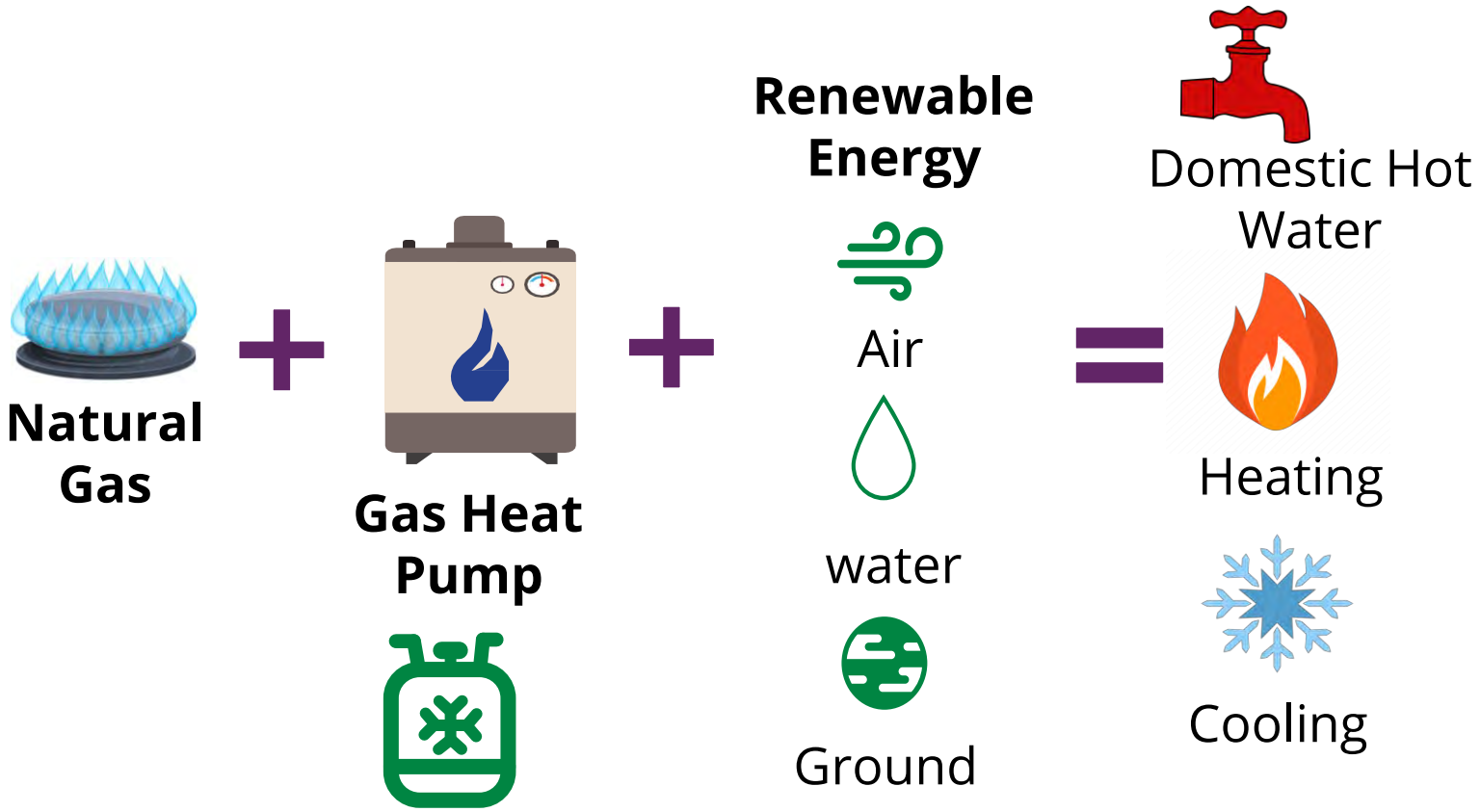
49.0 kg CO_2e/GJ

Electricity Emissions:

0.561 kg CO_2e/kWh

Sources: (1) ANESI Website (SMTI) Gas Heat Pump (stonemountaintechnologies.com) (2) ASHP (neep.org)

GHP Summary



Heating & water heating efficiencies are well over 100%

Source: Energy Solutions Center https://www.energysolutionscenter.org/

Useful Links:

- **Gas Heat Pump Consortium,** Energy Solutions Center, Gas Heat Pump Consortium (energysolutionscenter.org)
- **Gas Heat Pumps, Enbridge,** Gas Heat Pumps (GHP) | Enbridge Gas
- **North American Gas Heat Pump Collaborative,** Resources | North American Gas Heat Pump Collaborative
- **Fortis BC,** What are gas heat pumps and how can they save money and energy? (fortisbc.com)

Source: Energy Solutions Center https://www.energysolutionscenter.org/

Thank you