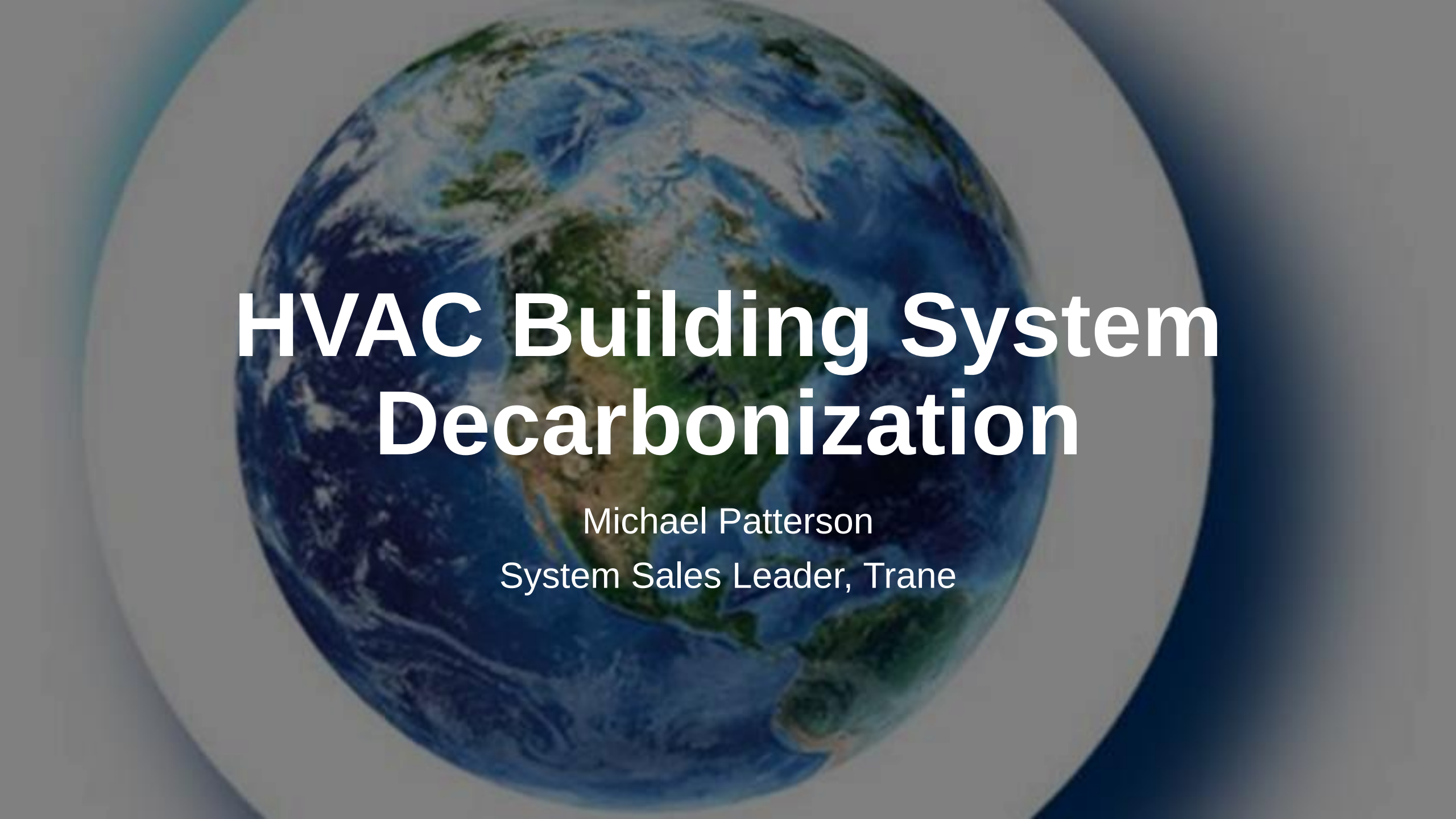


HVAC Building System Decarbonization

Michael Patterson

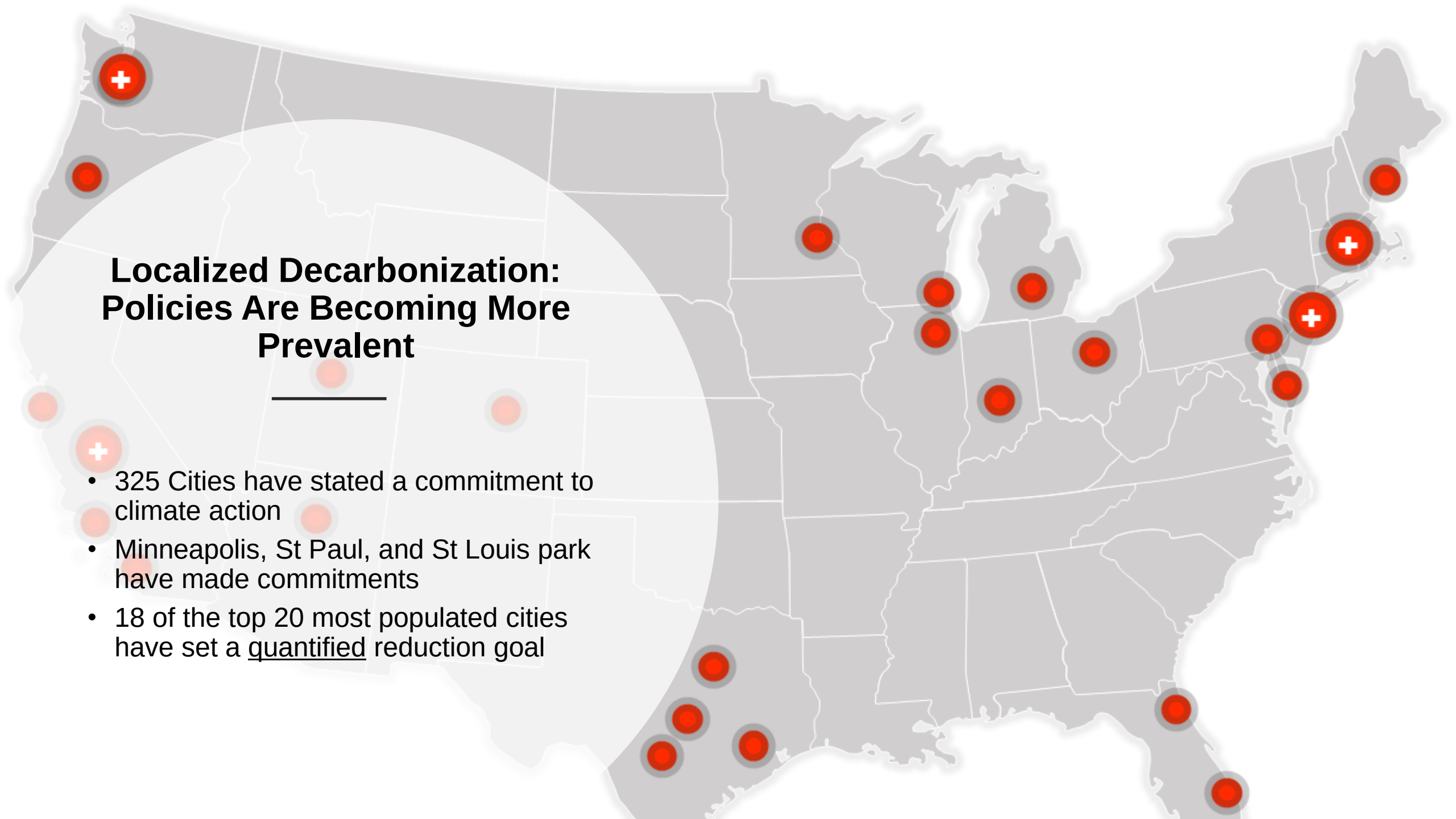
System Sales Leader, Trane

What is Decarbonization?

“A low-carbon economy (LCE) or decarbonized economy is an economy based on low-carbon power sources that therefore has a minimal output of greenhouse gas (GHG) emissions into the atmosphere, specifically carbon dioxide.” - Wikipedia

Localized Decarbonization: Policies Are Becoming More Prevalent

- 325 Cities have stated a commitment to climate action
- Minneapolis, St Paul, and St Louis park have made commitments
- 18 of the top 20 most populated cities have set a quantified reduction goal



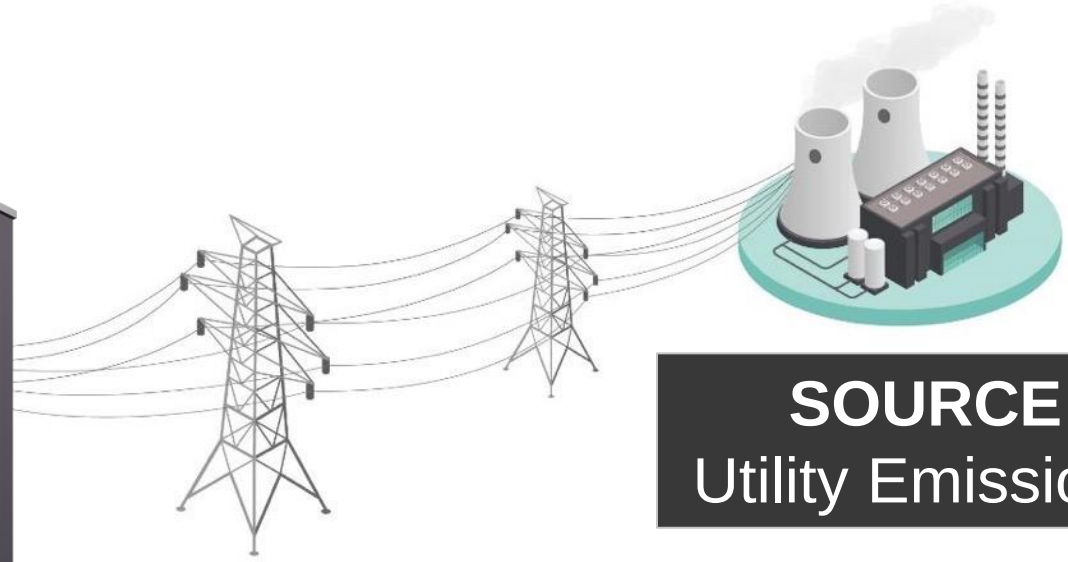
New U.S. Policies will Focus on Reduced GHG Emissions

- United States re-signs Paris Agreement: Commitment to reduce GHC emissions
  - Initial commitment:
    26-28% below 2005 levels by 2025
  - Latest commitment:
    50-52% below 2005 levels by 2030
- Department of Energy efficiency standards
- Environmental Protection Agency give authority to regulate high GWP refrigerants

Pathways to Decarbonization

- **Efficiency**
- **Refrigerants**
- **Electrification**

Efficiency



SOURCE
Utility Emissions

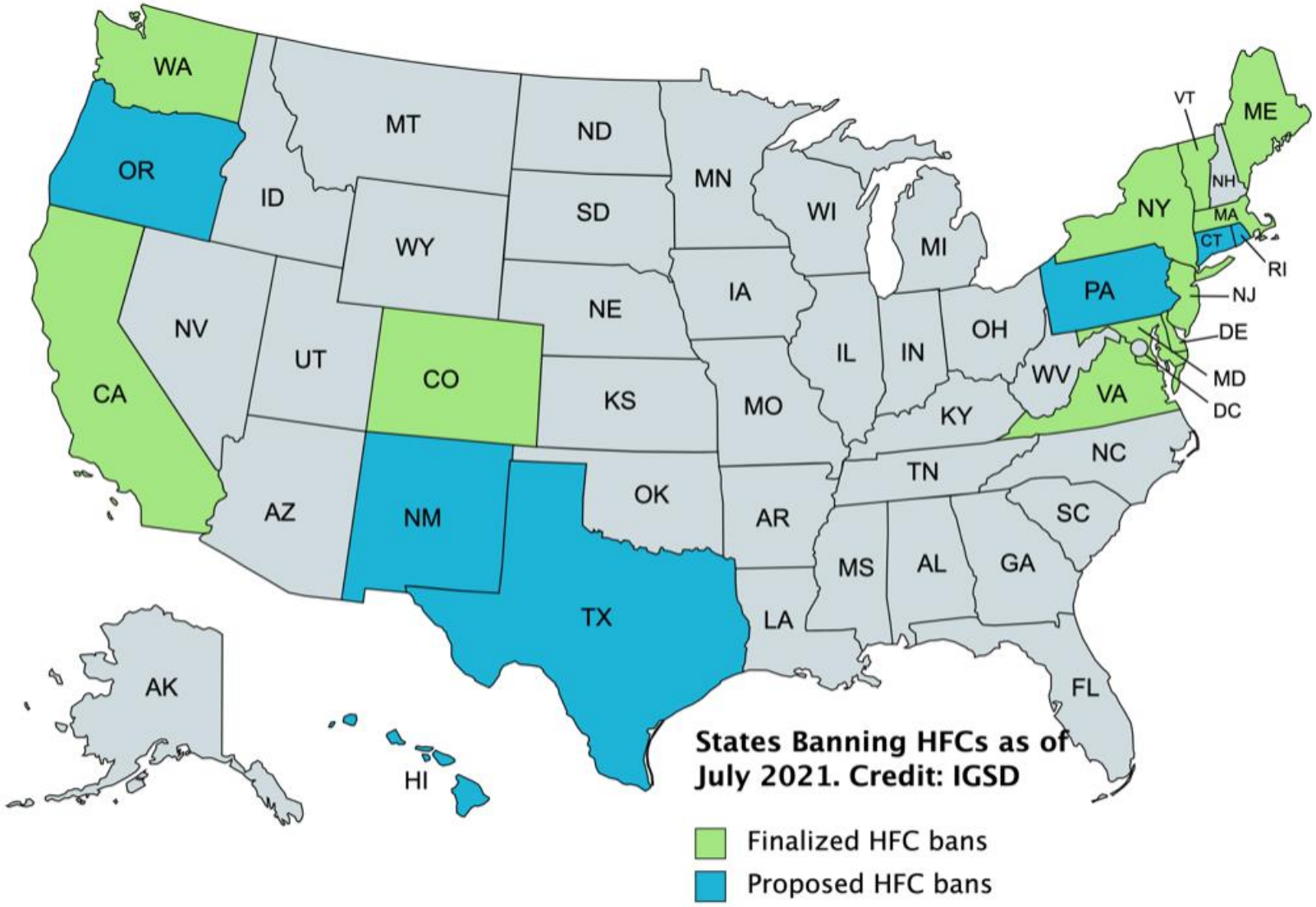
SITE
Building Emissions

Lower Energy Usage = Lower Carbon

OPPORTUNITIES

- Modeling during design (Documentation)
- Building upgrades (lighting, windows, etc.)
- Higher efficiency products/systems
- Controls/optimization

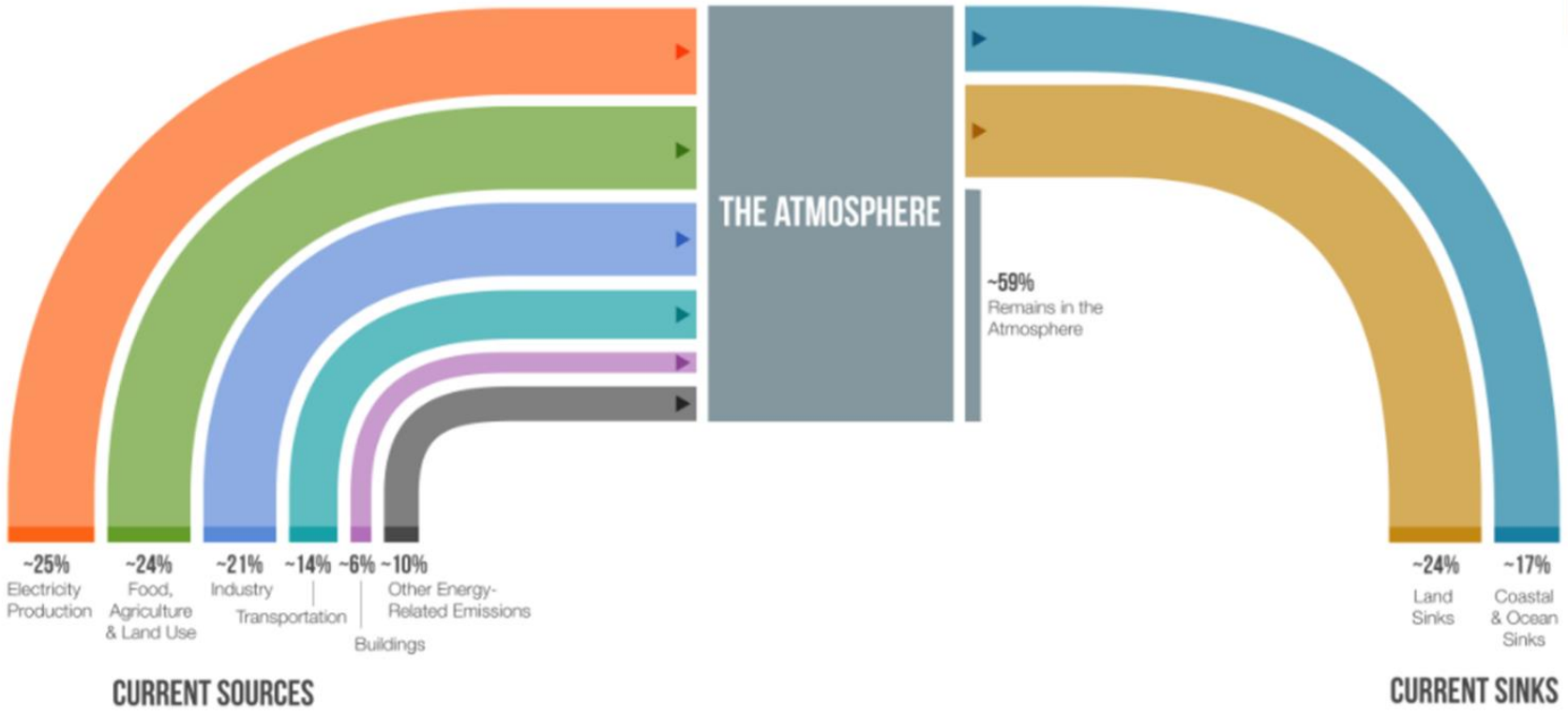
Refrigerants

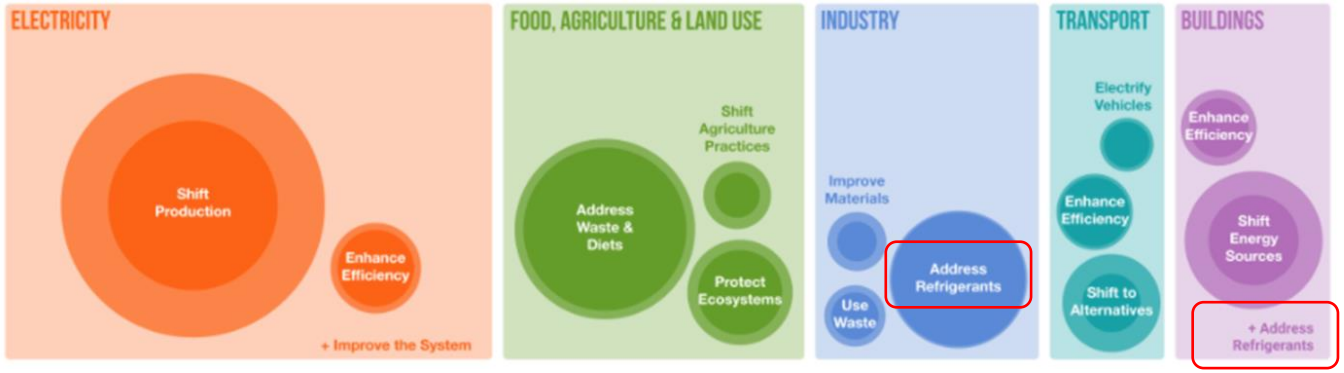


Source: hfcbans.com

Refrigerants

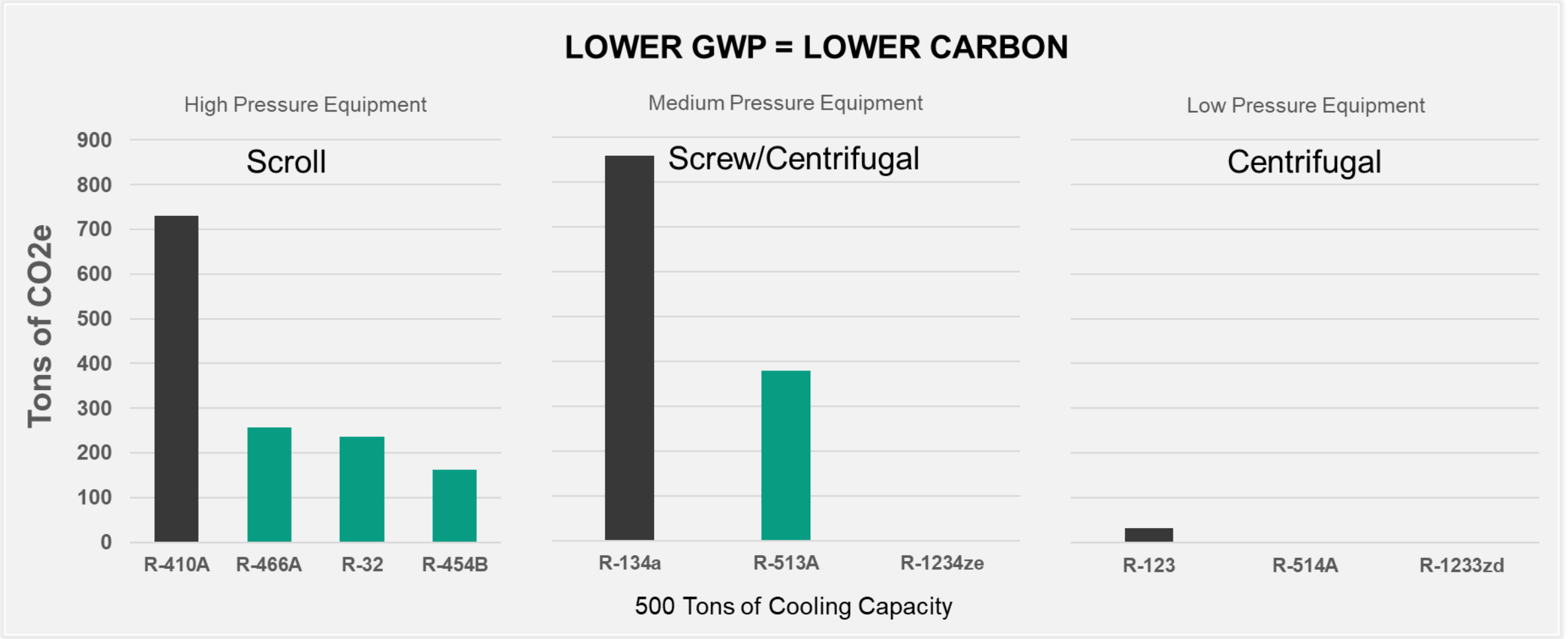
PROJECT DRAWDOWN





Source: drawdown.org

Refrigerants



Electrification

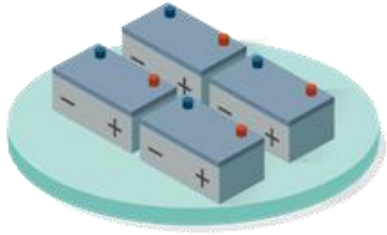
Utilizing electricity in place of burning fossil fuels

Gas Fired Burners and Boilers

Electric Heat Pumps

Solar

Wind

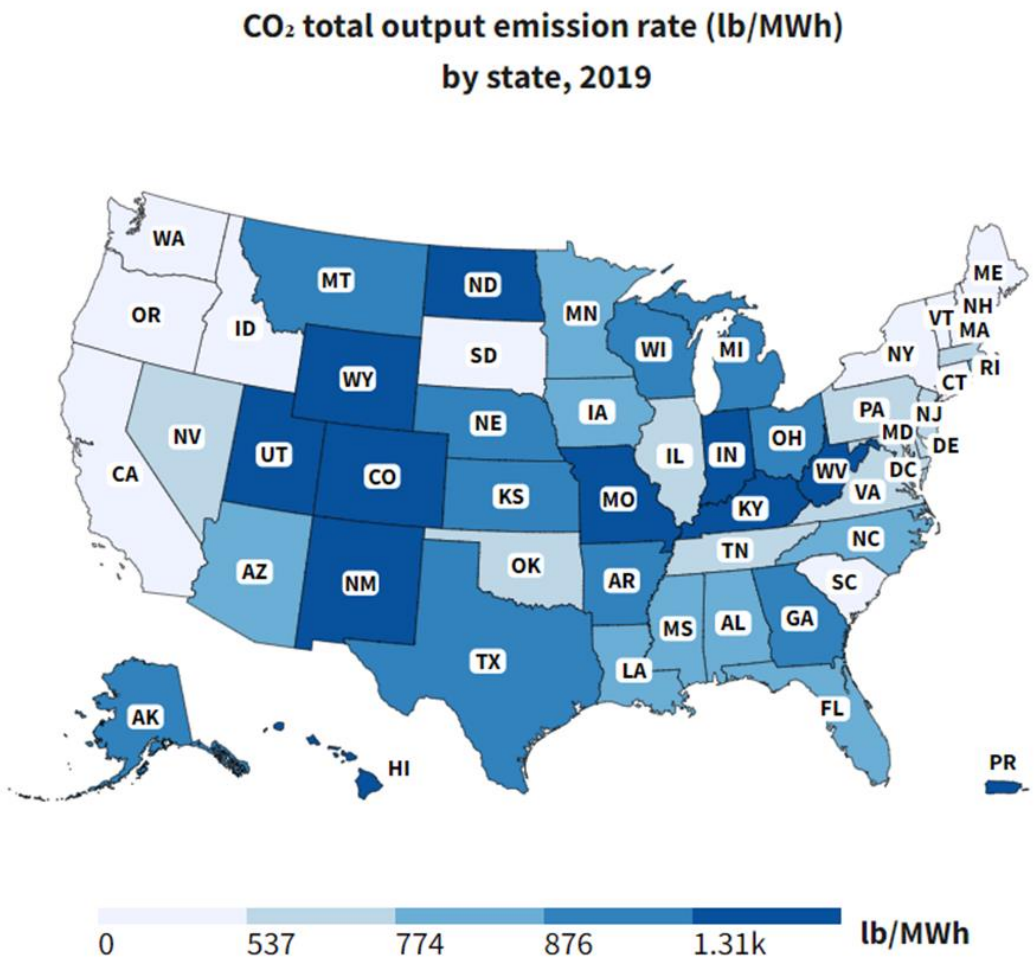


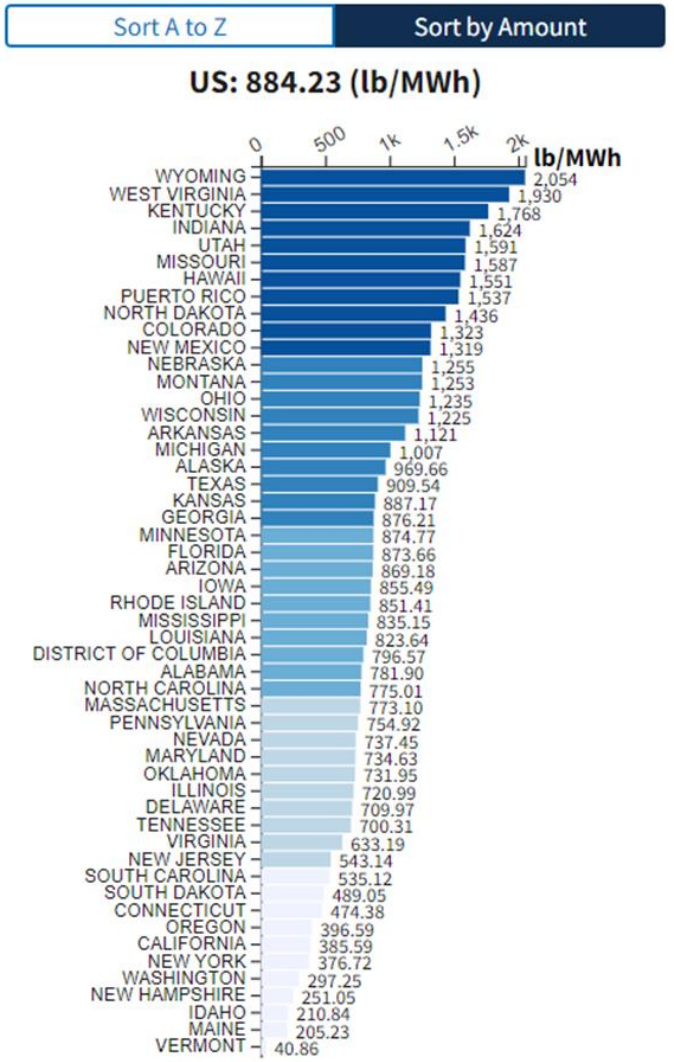
Storage

Decarbonization Impact Example

Minnesota

eGRID Output by State





Source: epa.gov/egrid/data-explorer

Spotlight on Minnesota

Principal building activity	Electricity energy intensity (kwh/square foot)			
	North-east	Mid-west	South	West
Education	8.7	10.3	12.6	10.0
Food sales	45.0	50.5	56.2	42.7
Food service	39.7	43.1	49.7	41.1
Health care	22.0	25.1	29.5	24.6
Inpatient	26.3	28.9	34.3	32.5
Outpatient	17.6	20.1	21.7	14.3
Lodging	14.0	15.4	16.6	14.1
Mercantile	16.3	17.5	19.7	17.6
Retail (other than mall)	12.8	14.1	16.3	15.8
Enclosed and strip malls	19.9	21.4	22.5	19.1
Office	17.1	15.3	16.0	14.9
Public assembly	14.1	13.2	16.3	13.2
Public order and safety	15.1	10.3	18.3	Q
Religious worship	4.5	4.5	6.1	4.7
Service	6.6	7.3	9.8	8.8
Warehouse and storage	4.9	6.6	8.4	4.8
Other	43.2	20.2	32.0	20.3
Vacant	Q	5.3	4.0	5.6

Principal building activity	Natural gas energy intensity (cubic feet/square foot)			
	North-east	Mid-west	South	West
Education	46.6	38.8	16.5	27.9
Food sales	Q	Q	59.1	Q
Food service	130.7	162.4	178.0	139.7
Health care	68.8	85.7	77.0	86.0
Inpatient	107.4	111.7	88.3	109.0
Outpatient	33.1	48.0	24.8	45.2
Lodging	43.9	49.3	33.1	56.3
Mercantile	40.4	43.0	26.1	31.4
Retail (other than mall)	25.1	33.9	15.1	15.2
Enclosed and strip malls	50.3	50.9	31.2	44.4
Office	34.8	33.2	17.2	22.2
Public assembly	42.6	40.5	26.0	26.7
Public order and safety	Q	Q	23.4	Q
Religious worship	25.8	38.9	22.2	29.1
Service	64.8	38.1	44.6	35.3
Warehouse and storage	27.6	20.3	11.3	25.5
Other	Q	Q	41.6	74.0
Vacant	Q	Q	Q	Q

Source: U.S. Energy Information Administration, Commercial Buildings Energy Consumption Survey

Spotlight on Minnesota

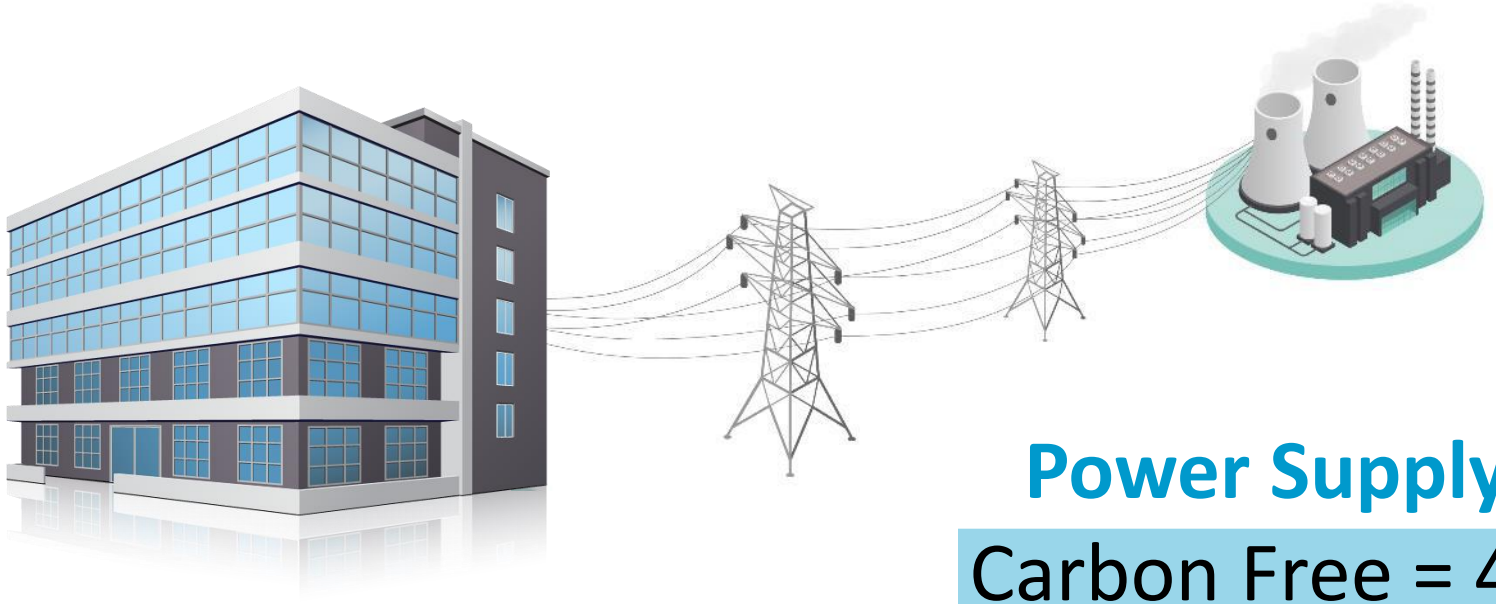
100,000 SqFt Office Building

61% Electric = 1,530 MWh

39% Natural Gas = 1,009 MWh

Site Carbon Emissions = 182 metric Tons CO2e

Spotlight on Minnesota



MN eGRID

Power Supply Mix:

Carbon Free = 48.8%

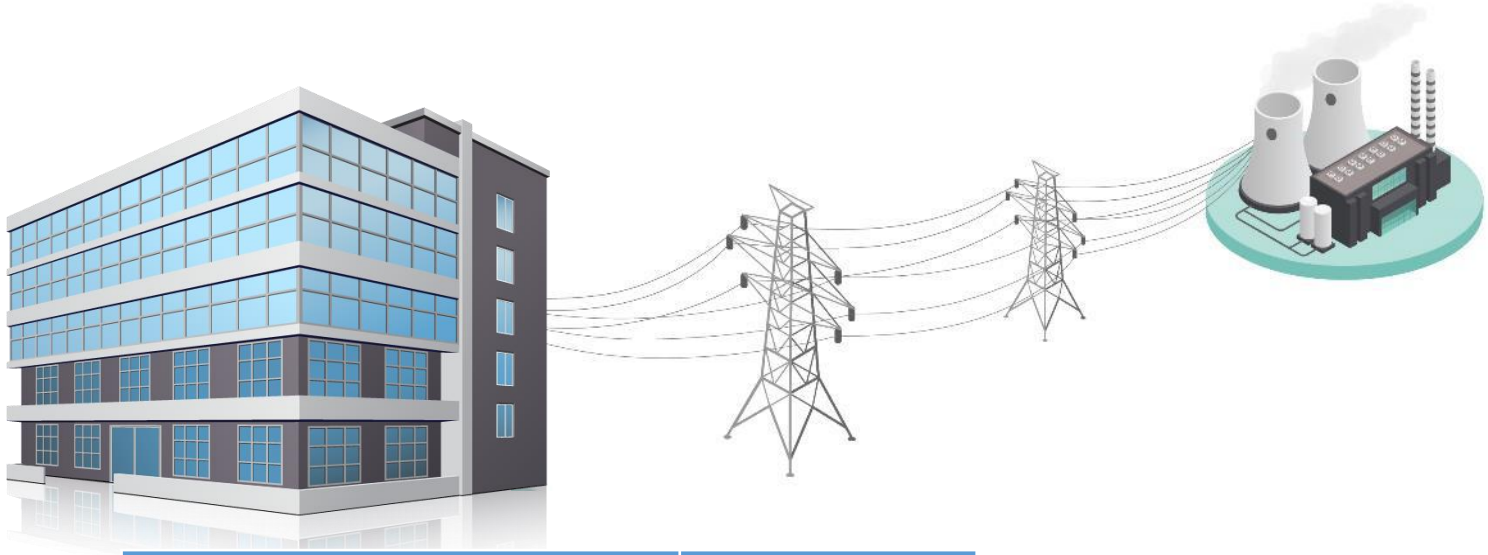
Coal = 30%

NG = 21.2%

874.77 lbs CO2e/MWh

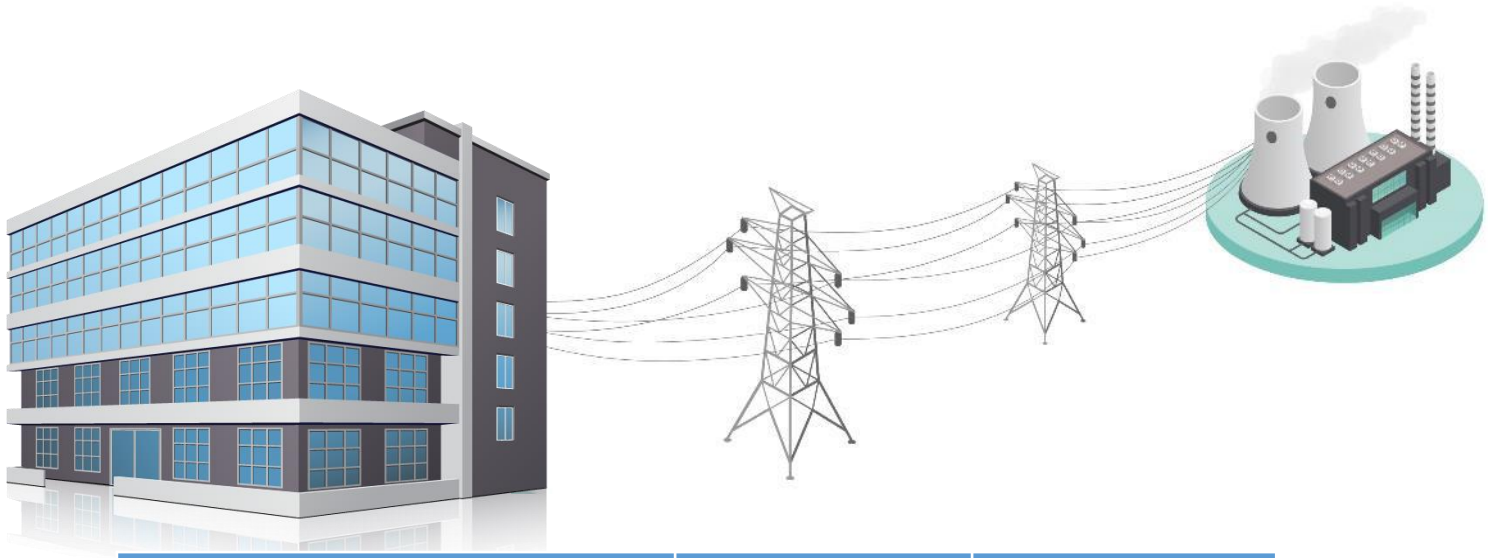
Source Carbon Emissions = 607 metric Tons CO2e

Spotlight on Minnesota



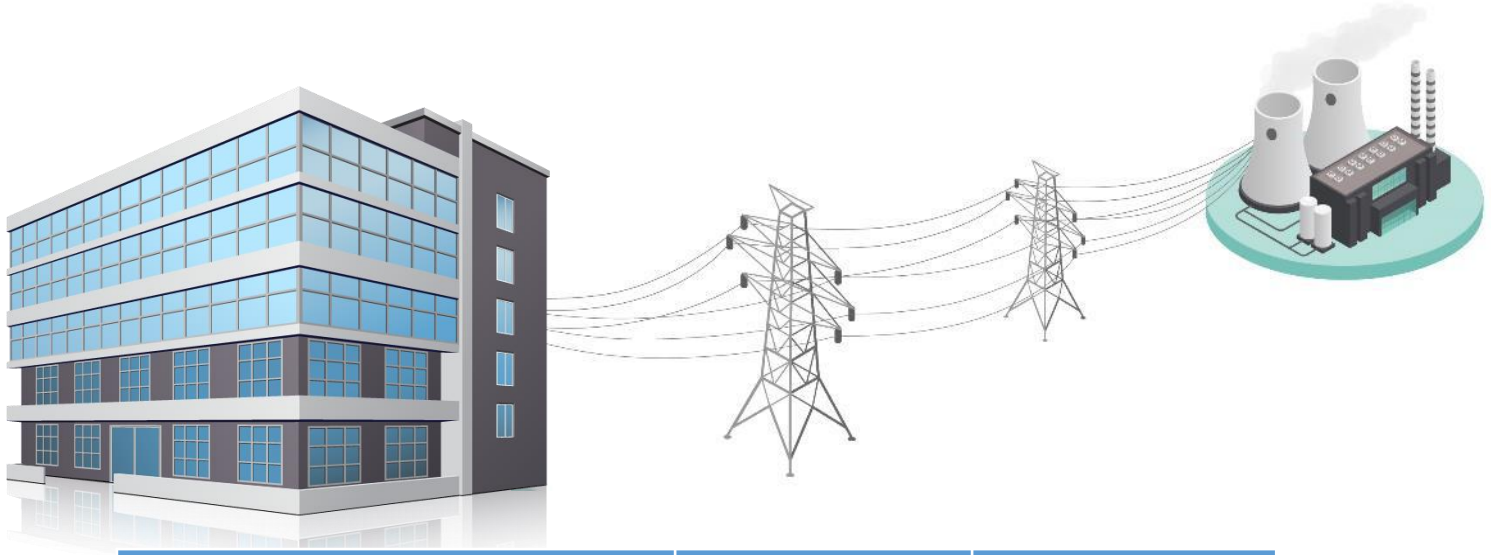
	Gas/Electric Today
Total Energy	2,539 MWh
On Site Natural Gas	1,009 MWh
Electricity	1,530 MWh
Site Carbon CO2 Emissions	182 mTons
Source Carbon CO2 Emissions	607 mTons
Total CO2e Emissions	**789 mTons**

Spotlight on Minnesota



	Gas/Electric Today	All Electric Today
Total Energy	2,539 MWh	1,791 MWh
On Site Natural Gas	1,009 MWh	0 MWh
Electricity	1,530 MWh	1,791MWh
Site Carbon CO2 Emissions	182 mTons	0 mTons
Source Carbon CO2 Emissions	607 mTons	714 mTons
Total CO2e Emissions	**789 mTons**	**714 Tons (10%)**

Spotlight on Minnesota



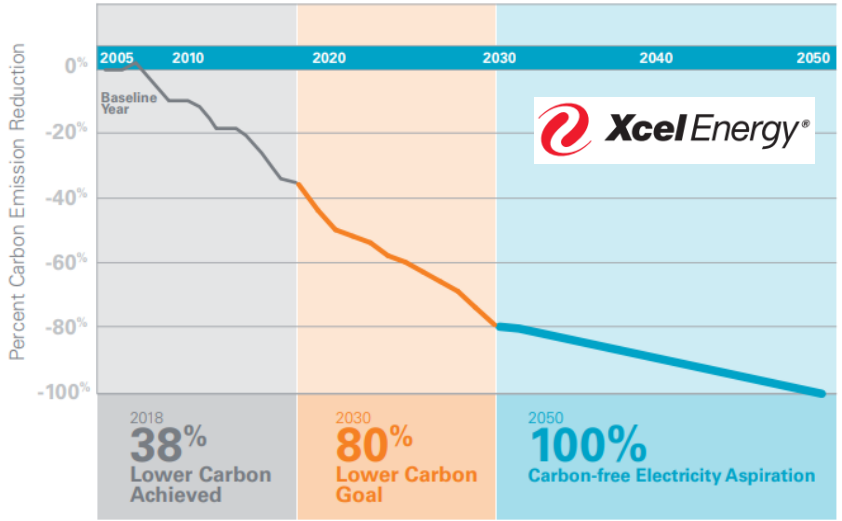
Power Supply Mix:

Carbon Free = 48.8% 75%

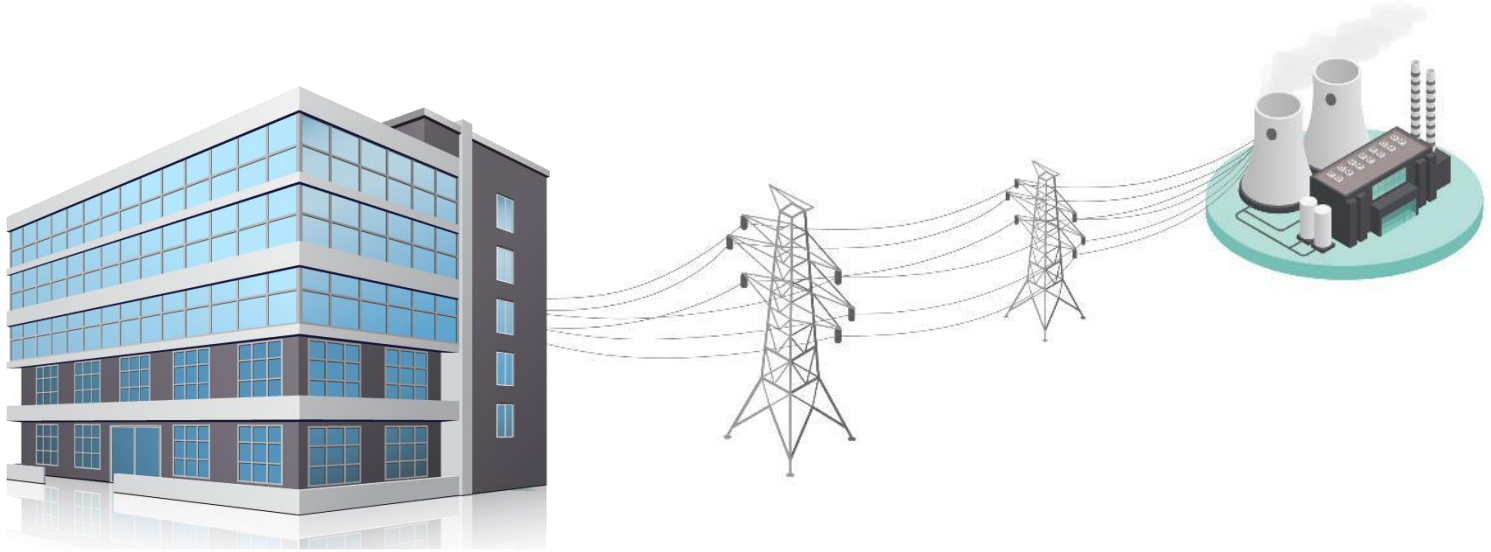
Coal = 30% 5%

NG = 21.2% 20%

	Gas/Electric Today	All Electric Today
Total Energy	2,539 MWh	1,791 MWh
On Site Natural Gas	1,009 MWh	0 MWh
Electricity	1,530 MWh	1,791MWh
Site Carbon CO2 Emissions	182 mTons	0 mTons
Source Carbon CO2 Emissions	607 mTons	714 mTons
Total CO2e Emissions	**789 mTons**	**714 Tons (10%)**



Spotlight on Minnesota



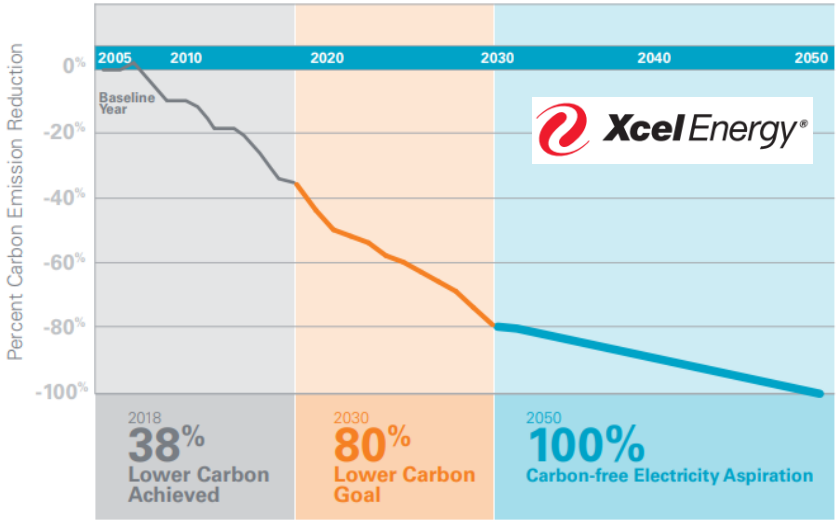
Power Supply Mix:

Carbon Free = 48.8% 75%

Coal = 30% 5%

NG = 21.2% 20%

	Gas/Electric Today	All Electric Today	All Electric 2030
Total Energy	2,539 MWh	1,791 MWh	1,791 MWh
On Site Natural Gas	1,009 MWh	0 MWh	0 MWh
Electricity	1,530 MWh	1,791MWh	1,791MWh
Site Carbon CO2 Emissions	182 mTons	0 mTons	0 mTons
Source Carbon CO2 Emissions	607 mTons	714 mTons	251 mTons
Total CO2e Emissions	**789 mTons**	**714 Tons (10%)**	**251 Tons (68%)**

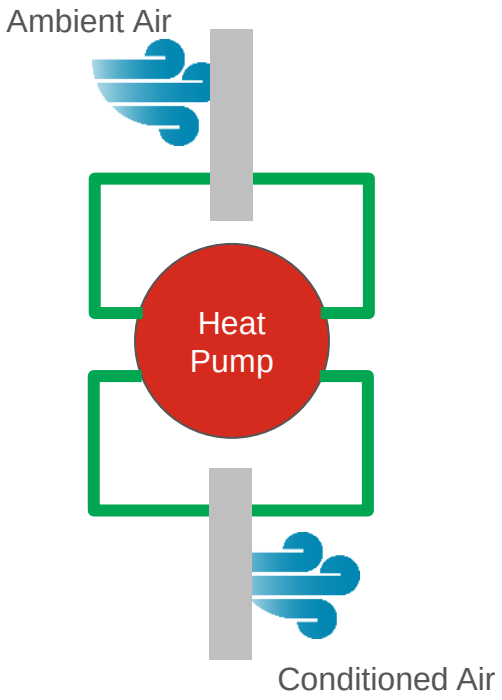


System Ideas for Decarbonization

- Heat Pump Definition
- Design Considerations
- Applied Systems
- Domestic Water Heating
- Other Heat Sources

Heat Pump Definition

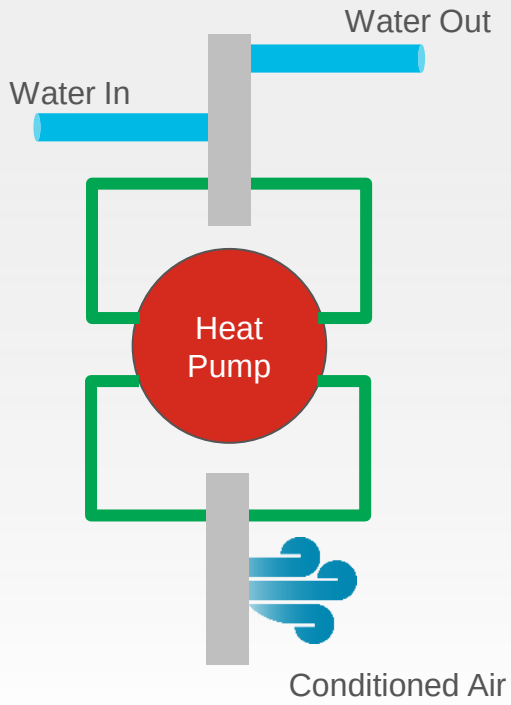
Air to Air



Example:
Rooftop Units
VRF

Reversing

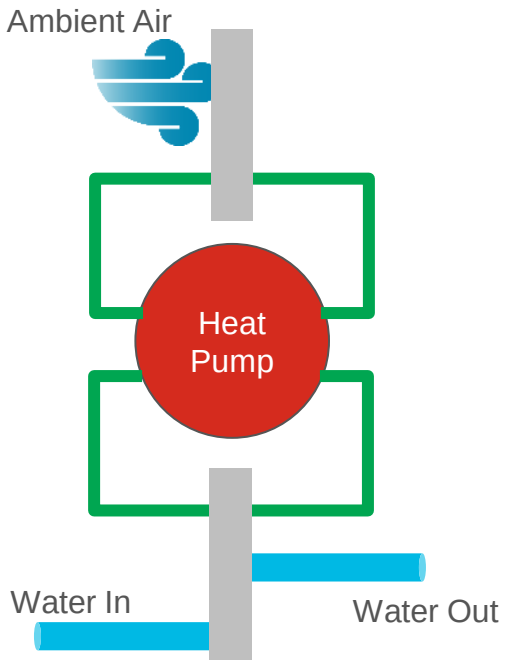
Water to Air



Example:
WSHP

Reversing

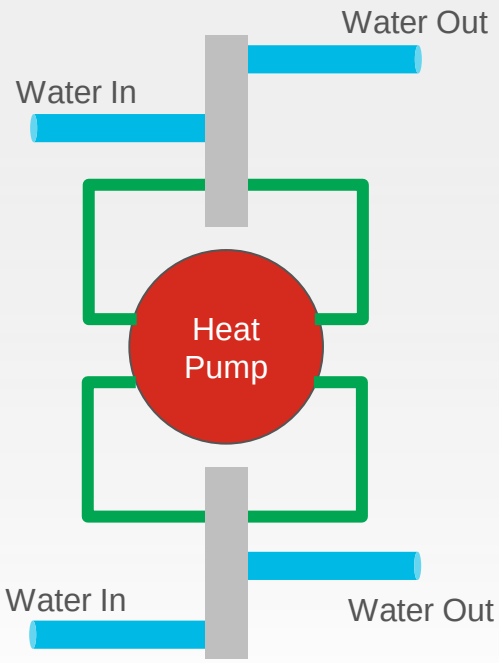
Air to Water



Example:
Air-Source Heat Pump Chiller

Reversing

Water to Water



Example:
Chiller/Heater

Reversing / Non-Reversing

Design Considerations

MINNEAPOLIS-ST PAUL INTL, MN, USA (WMO: 726580)

Lat:**44.883N** Long:**93.229W** Elev:**872** StdP: **14.24** Time zone:**-6.00** Period:**90-14** WBAN:**14922**

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
	99.6%	99%	99.6%			99%			0.4%		1%			
			DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
1	-10.6	-5.8	-19.1	2.0	-9.4	-14.7	2.6	-4.7	26.0	17.3	23.5	19.4	8.1	300

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

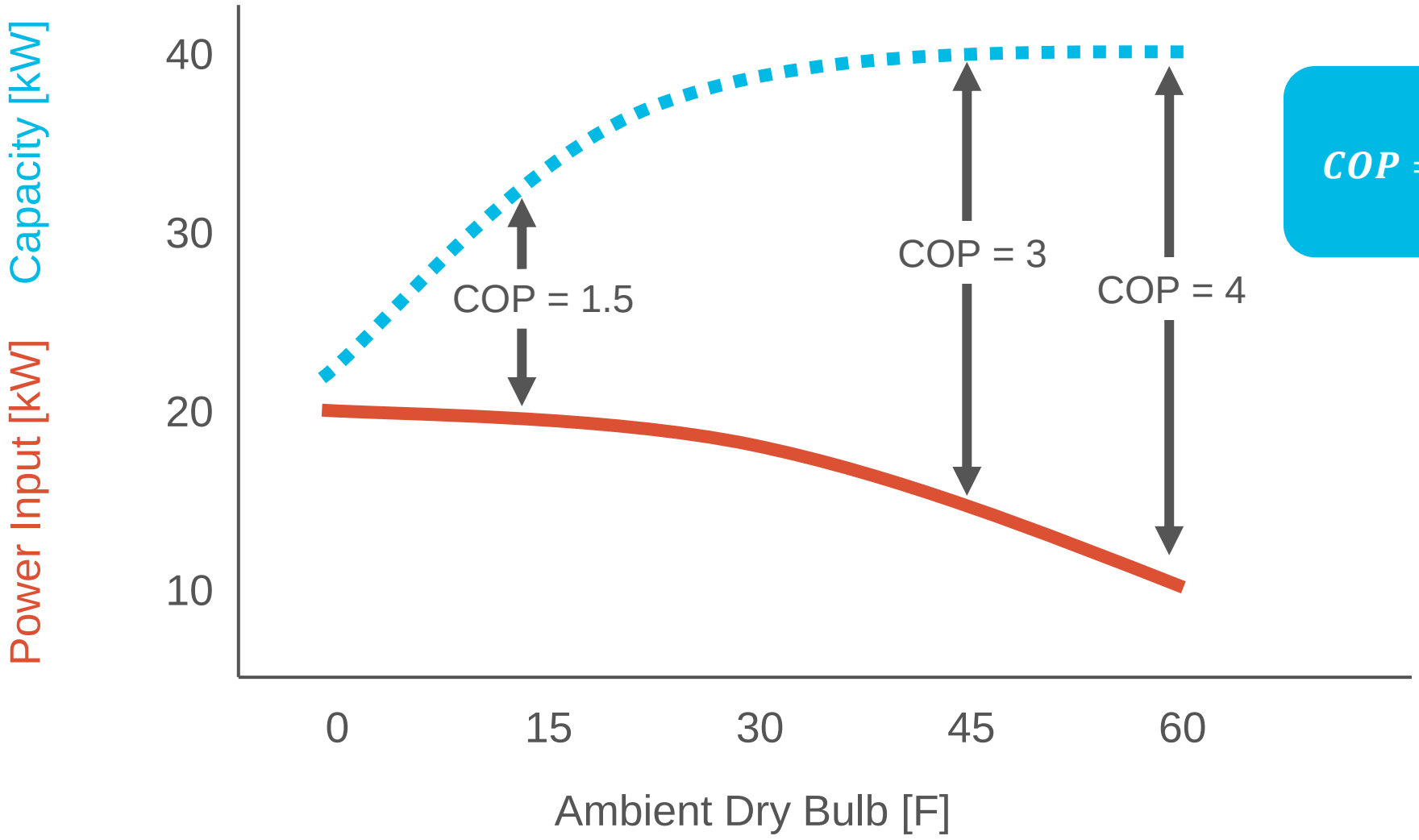
Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	17.3	90.8	73.3	87.8	72.0	84.9	70.2	76.9	87.2	74.8	84.0	72.9	81.8	12.5	180

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
73.7	129.4	83.5	71.7	120.9	81.2	69.6	112.6	78.6	41.0	87.1	38.9	84.2	37.0	82.0	84.9

Extreme Annual Design Conditions

Extreme Annual WS				Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
24.0	20.6	18.8	DB	-16.7	96.0	5.9	3.5	-20.9	98.5	-24.4	100.6	-27.8	102.5	-32.1	105.1
			WB	-17.1	80.2	5.6	2.0	-21.1	81.6	-24.3	82.7	-27.4	83.8	-31.5	85.3

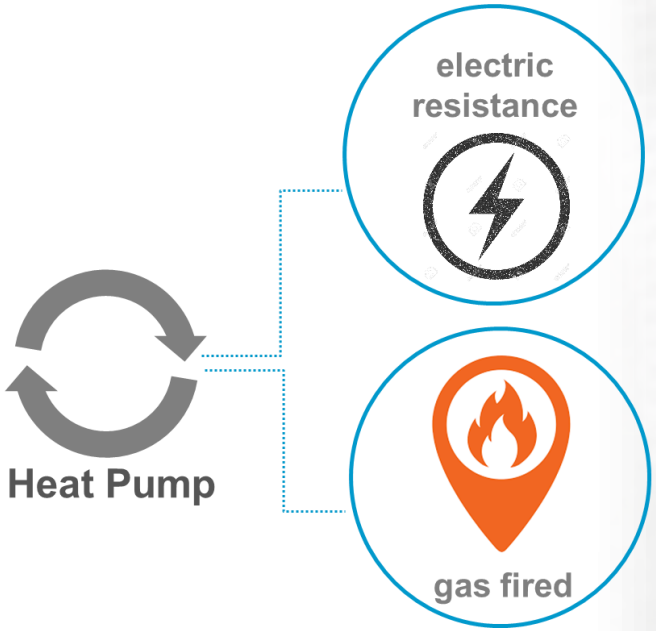
Design Considerations



$$COP = \frac{Capacity\ Output\ [kW]}{Power\ Input\ [kW]}$$

Design Considerations

- **Defrost**
- **Dual / Auxiliary fuel**



Design Considerations

Split System Heat Pumps
Sizes: <20 Tons

Applications:
- Classrooms
- Small Office
- Small Retail

Options:
- Dual / Aux Fuel
- Cold Climate Operation

Retrofits Capability:

Design Considerations

Rooftop (RTU) Heat Pumps
Sizes: <20 Tons

Applications:
- Classrooms
- Small Office
- Retail
- Warehouse/Distribution Center

Options:
- Dual / Aux Fuel
- Cold Climate Operation

Retrofit Capability:

Design Considerations

Variable Refrigerant Flow (VRF)
Sizes: <40 Tons

Applications:
- Schools
- Office
- Mixed Use

Options:
- Dual / Aux Fuel
- Cold Climate Operation
- Smart Defrost

Retrofit Capability:

Applied Systems

HEAT PUMP

Heating and Cooling
Typically Reversable

Heating and Cooling
Controlled to Cooling

HEAT RECOVERY

HEATER

Heating and Cooling or Just Heating
Controlled to Heating

Heating and Cooling
Controlled to Either or Both

CHILLER/HEATER

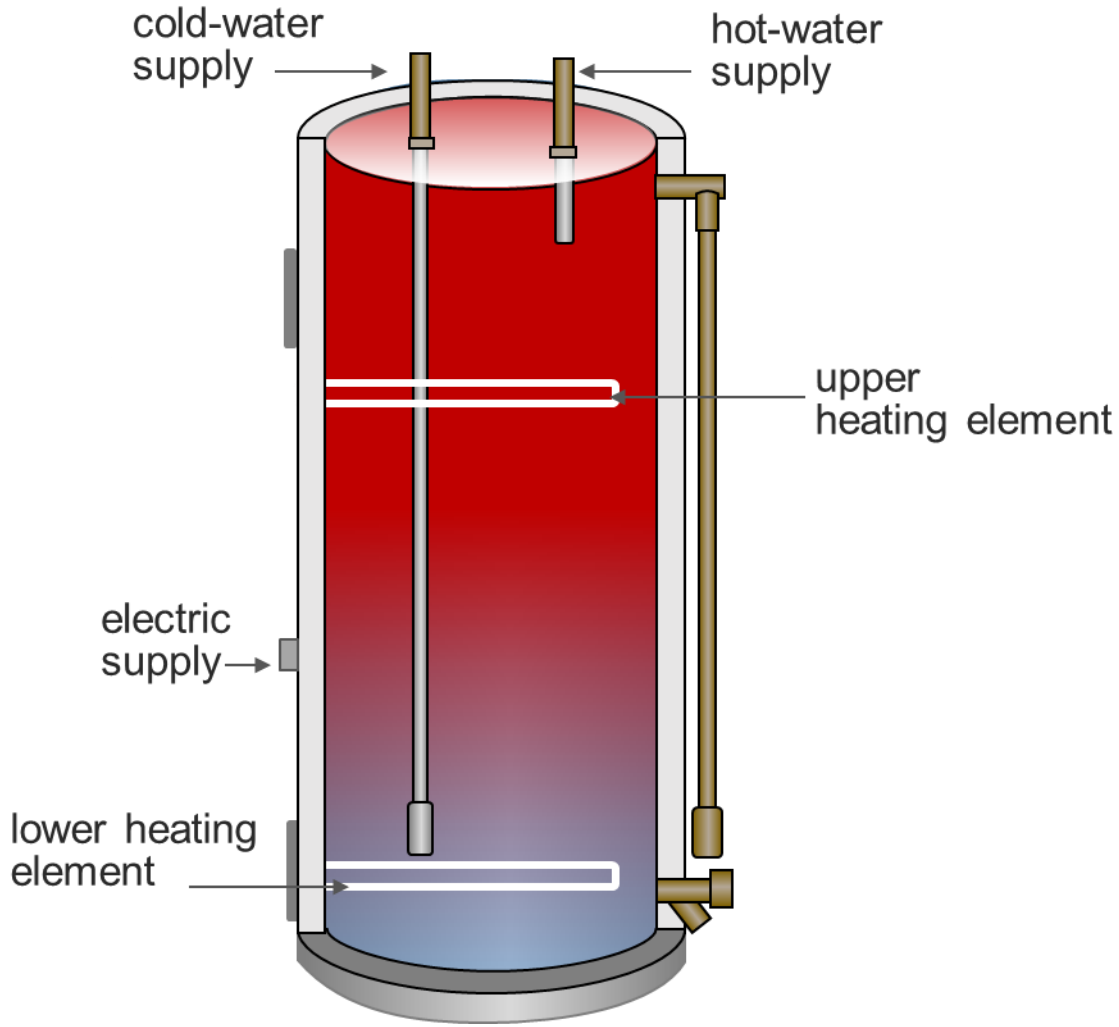
Domestic Hot Water

Potable Hot Water Electric Resistance

Output Capacity: 15-350 MBH

Considerations:

- Electric service
- Storage capacity
- Cost to operate



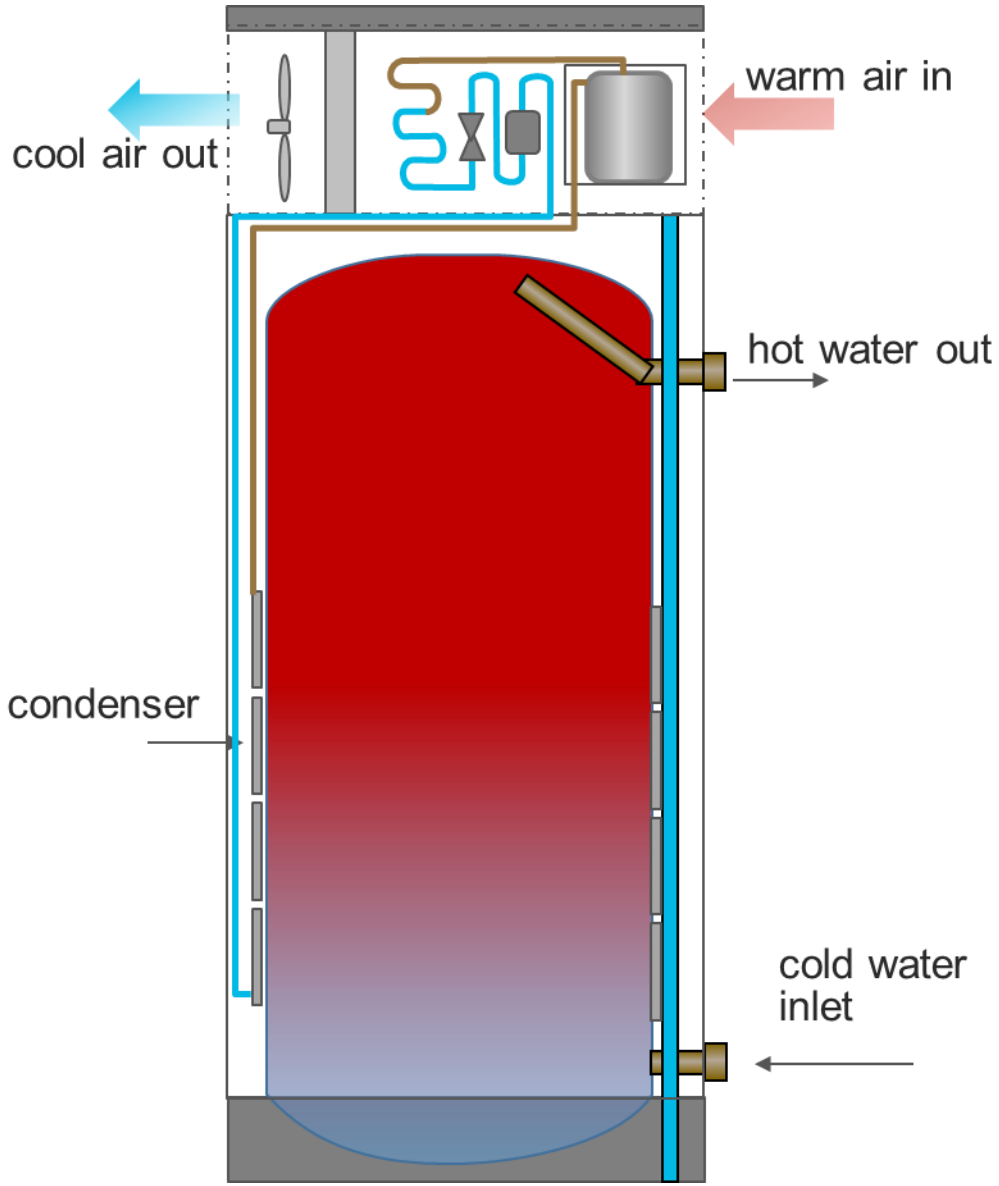
Domestic Hot Water

Potable Hot Water Electric Packaged Heat Pump

Output Capacity: 15-60 MBH

Considerations:

- First Cost
- Space Impacts



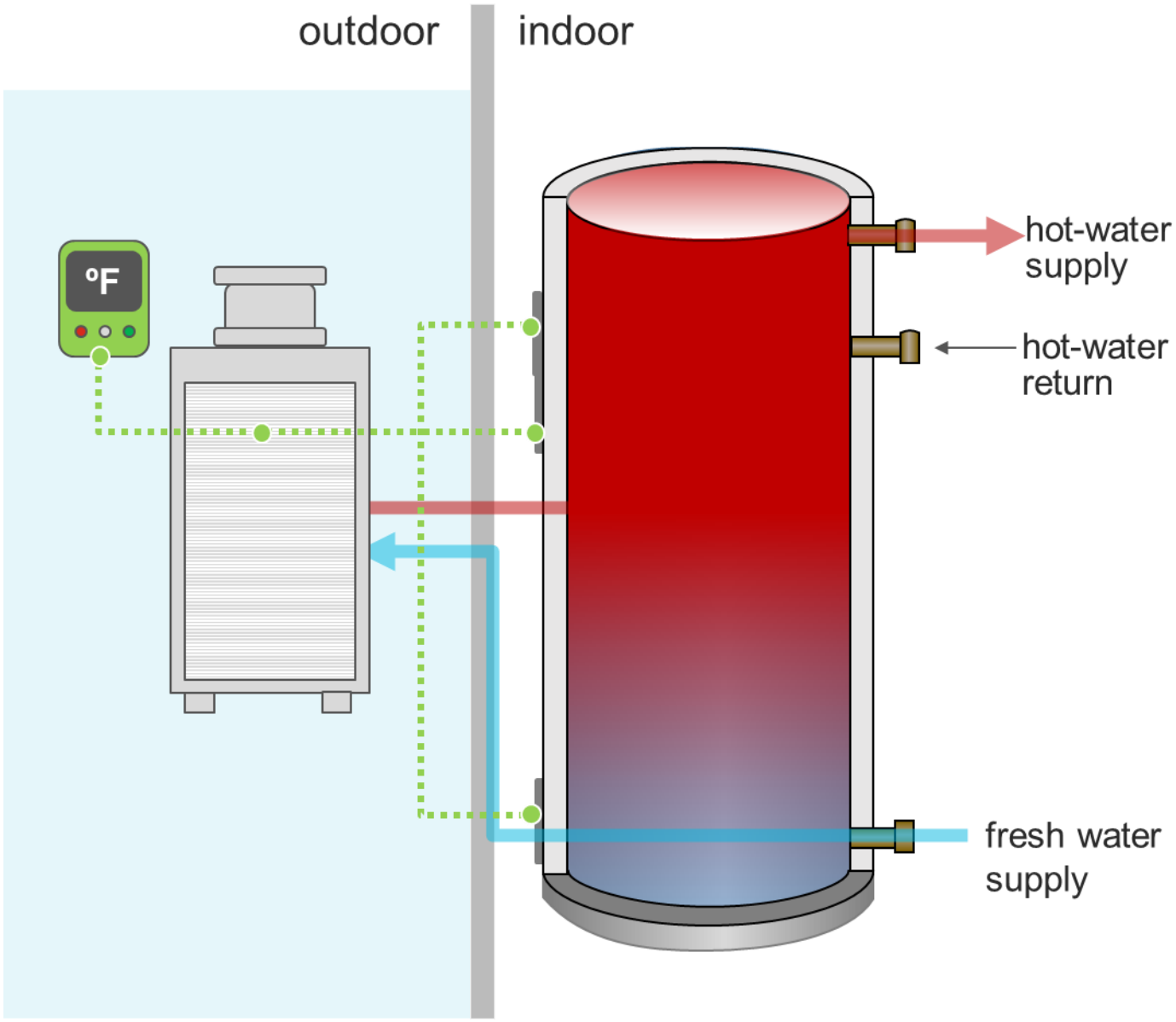
Domestic Hot Water

Potable Hot Water Split Heat Pump

Output Capacity: 15-2000 MBH

Considerations:

- Ambient
- Freeze protection



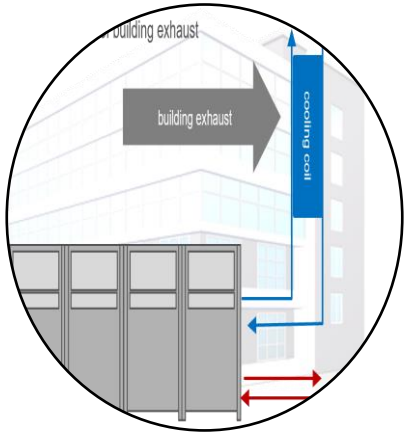
Other Heat Sources

Geothermal Loop

Lake, River, Pond

Storm and Sewer

Thermal Energy Storage



Exhaust Air Coil


Thank you!
Any Questions?