BUILDINGENERGY BOSTON

Electrification of Domestic Hot Water in Multifamily Buildings

Daniel Perez (Petersen Engineering)
James Petersen (Petersen Engineering)

Curated by Keirstan Field and Tom Chase

Northeast Sustainable Energy Association (NESEA)
March 29, 2023

Learning Objectives

1. Classify the options for electric DHW heating systems in large multifamily buildings.
2. Evaluate the current opportunities and obstacles to installing central ASHP DHW plants in existing and new construction multifamily projects.
3. Identify space planning considerations for designing central ASHP DHW plants and for incorporating provisions for future conversion.
4. Assess a multifamily project's feasibility in achieving net-zero carbon emissions by using a central ASHP system as their source for DHW.

Design Case Study – Leland House

Leland House

Owner	2Life Development, Inc.
Architect	PCA, Inc.
MEP/FP	Petersen Engineering,
Civil/Landscape	Stantec
Structural	B+AC, LLC
CPHC	New Ecology, Inc.
CM	Dellbrook JKS

Description – Leland House

Waltham, MA

New construction

Senior housing

68 units / 70 bedrooms

72,000 GSF

Phius 2021

Performance Criteria Calculator v3.3

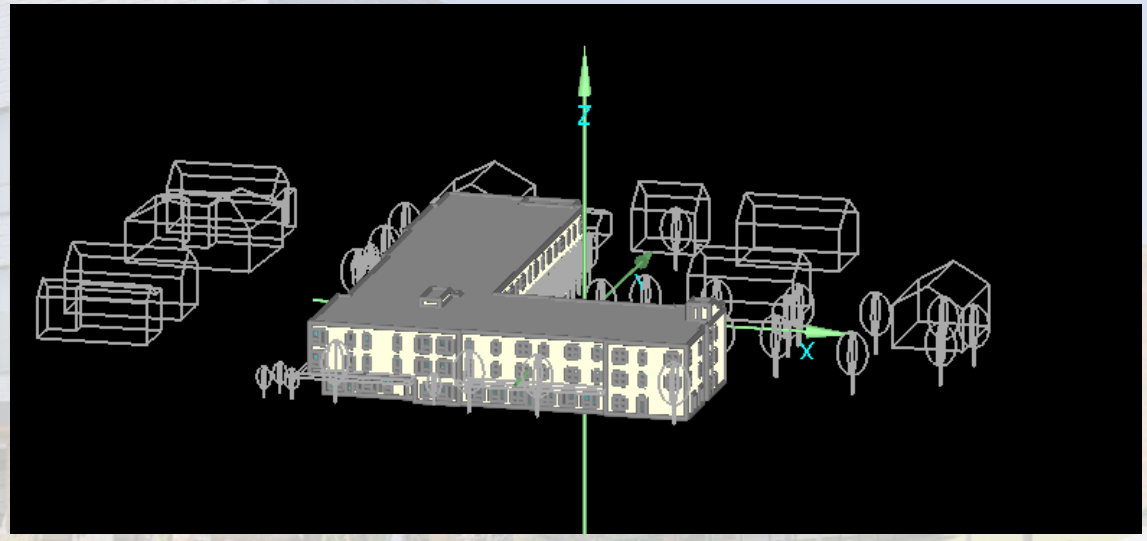
Space Conditioning Criteria		
Annual Heating Demand	5.1	kBtu/ft²yr
Annual Cooling Demand	6.7	kBtu/ft²yr
Peak Heating Load	4.0	Btu/ft²hr
Peak Cooling Load	3.0	Btu/ft²hr
Source Energy Criteria		
Phius CORE	5500	kWh/person.yr

Petersen Engineering Scope – Leland House

MEP/FP Engineer of Record

- Including PV design

PH WUFI energy modeler

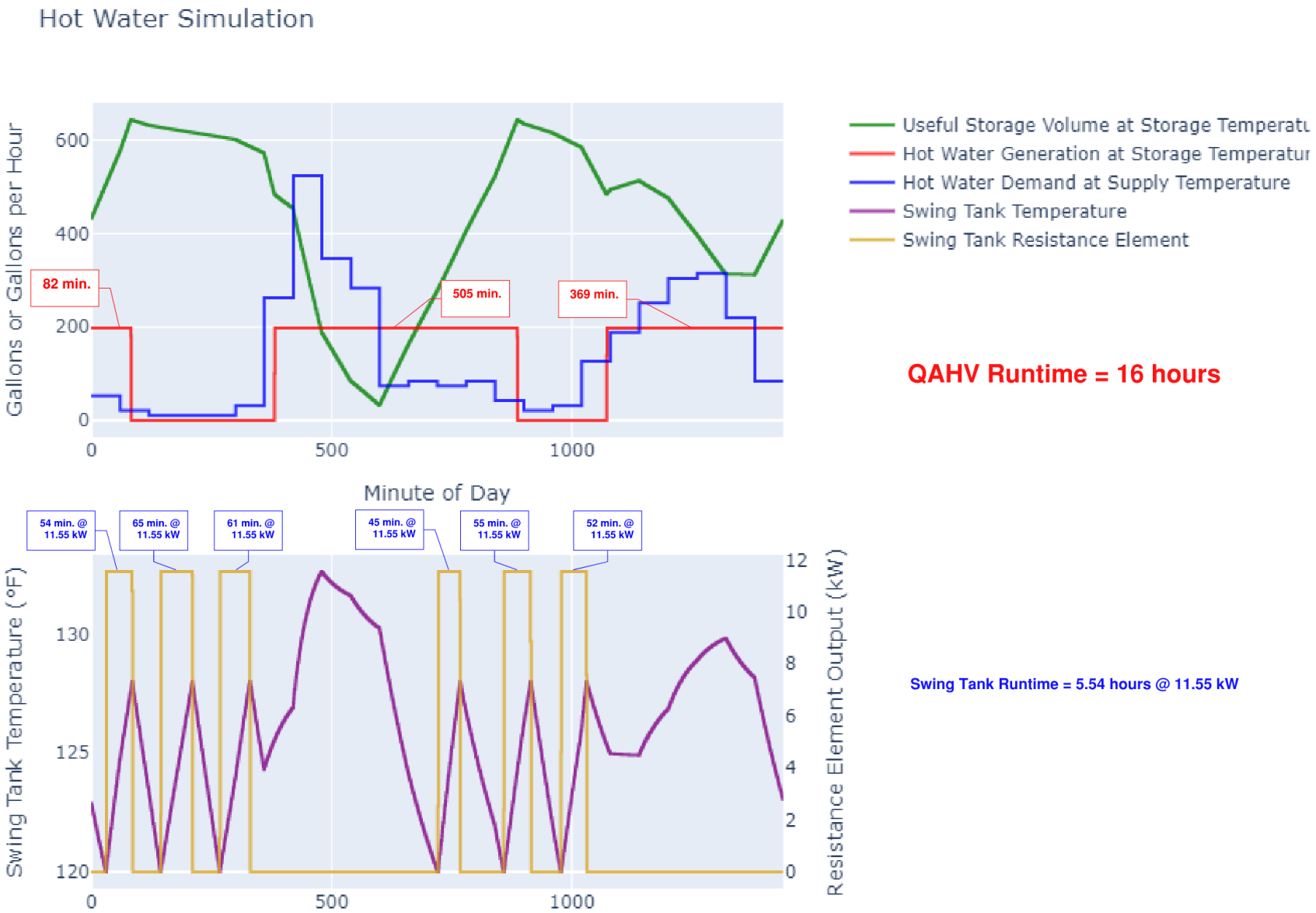


First Cost Information – Leland House

Plumbing	$160,000
HVAC	$216,000
Total $376,000	($5,529/unit)

Estimated $100k for gas-fired DHW of same capacity

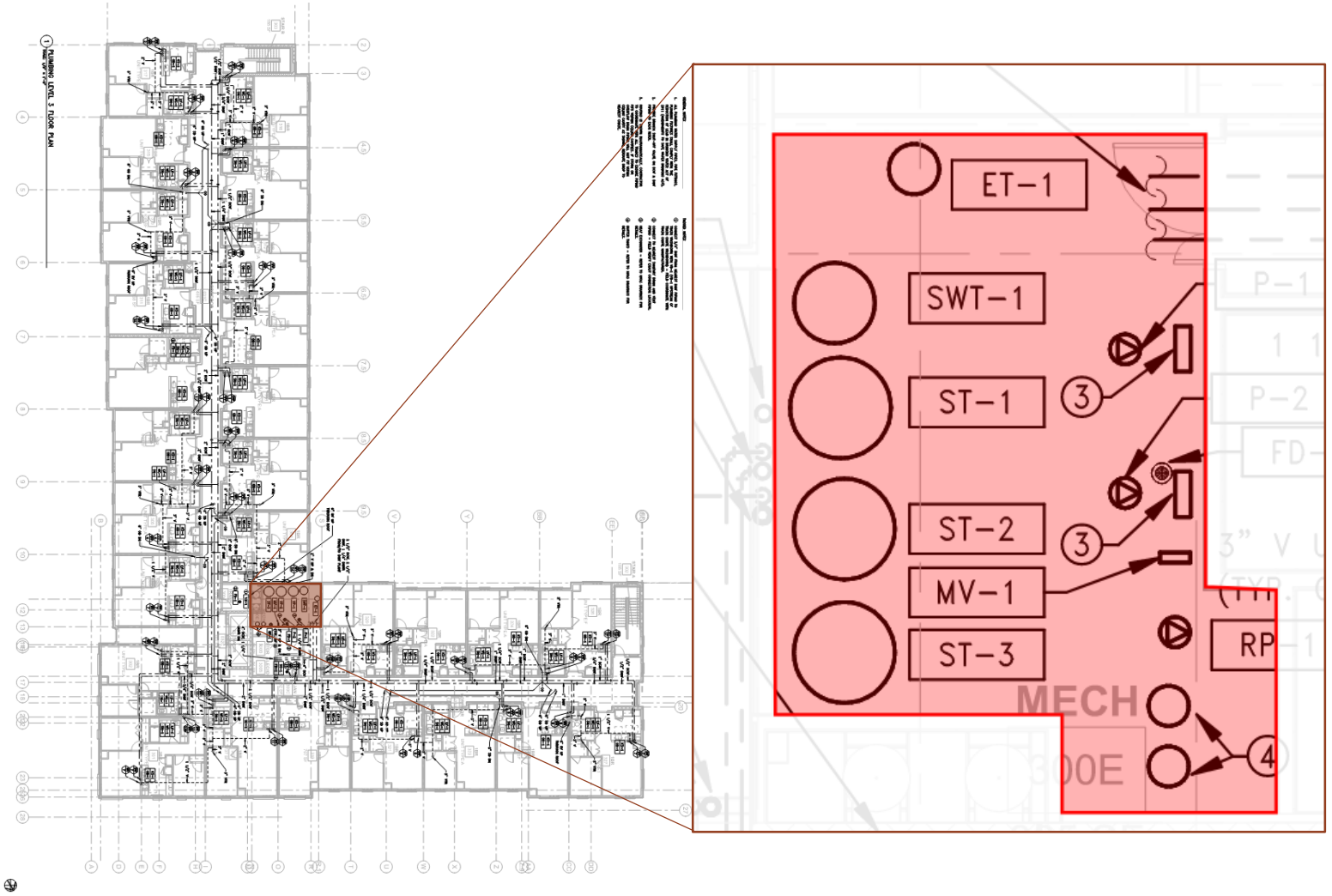
About 4x higher first cost for all-electric central DHW


Hot Water Simulation
Gallons or Gallons per Hour
600
400
200
0
0
500
1000
82 min.
505 min.
369 min.
Useful Storage Volume at Storage Temperatu
Hot Water Generation at Storage Temperatur
Hot Water Demand at Supply Temperature
Swing Tank Temperature
Swing Tank Resistance Element
QAHV Runtime = 16 hours
Minute of Day
54 min. @ 11.55 kW
65 min. @ 11.55 kW
61 min. @ 11.55 kW
45 min. @ 11.55 kW
55 min. @ 11.55 kW
52 min. @ 11.55 kW
Swing Tank Temperature (°F)
130
125
120
Resistance Element Output (kW)
12
10
8
6
4
2
0
Swing Tank Runtime = 5.54 hours @ 11.55 kW

Boston, MA					
Temperature Range	Value	% of Year	Weighted Temperature	COP	Weighted COP
70+	70	16.2%	11.34	4.45	0.72
65-70	65	8.7%	5.655	4.42	0.38
60-65	60	10.6%	6.36	4.42	0.47
55-60	55	8.8%	4.84	4.15	0.37
50-55	50	7.1%	3.55	3.76	0.27
45-50	45	8.7%	3.915	3.76	0.33
40-45	40	8.4%	3.36	2.21	0.19
35-40	35	12.1%	4.235	2	0.24
30-35	30	8.1%	2.43	2	0.16
25-30	25	3.7%	0.925	2	0.07
20-25	20	3.2%	0.64	2	0.06
15-20	15	3.0%	0.45	1.87	0.06
10-15	10	0.9%	0.09	1.64	0.01
5-10	5	0.3%	0.015	1.64	0.00
0-5	0	0.1%	0	1.42	0.00
-5-0	-5	0.1%	-0.005	1	0.00
			47.8 Average Temperature		
			Average COP of		**3.34**

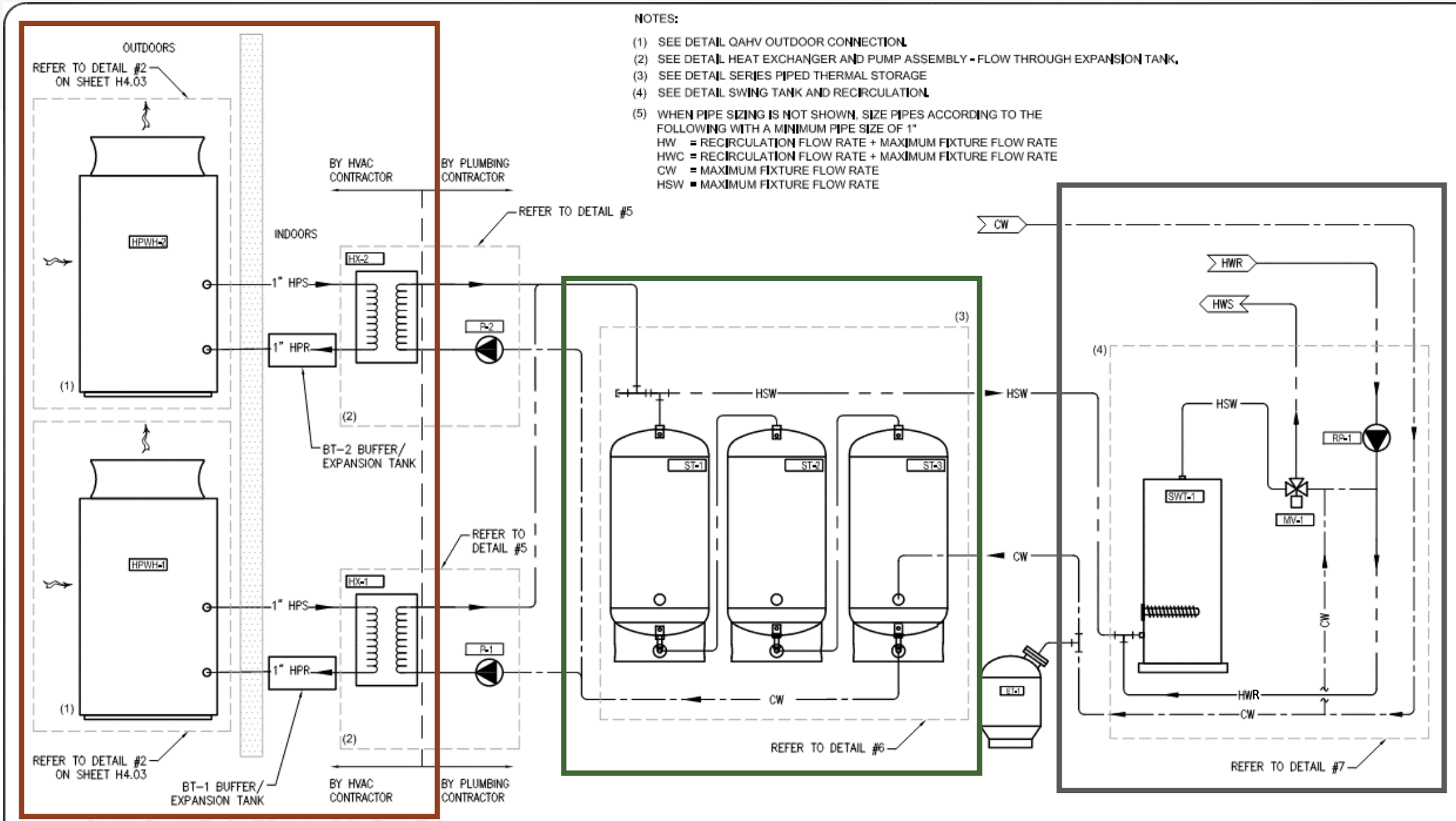
QAHV Heating Capacity @47F		Runtime	Heating Coverage	
kBtu/hr	kW	hours	kWh	%
136	39.9			
136	39.9			
	79.7 Total	16	1275.6	**95.2%**
Swing Tank Heating Capacity				
	kW			
	11.6 Total	5.54	64.3	**4.8%**

Unit Conversions	
kBtu/hr->kW	0.2931
kW->kBtu/hr	3.412



$300\ ft^2$ of mechanical space for Leland QAHV system

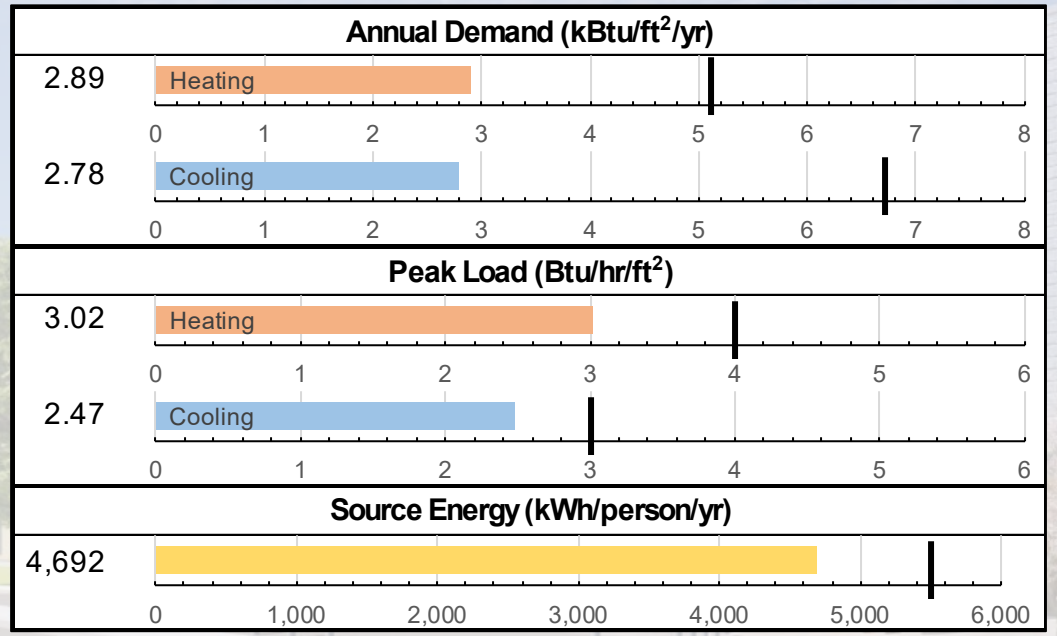
Approximately $150\ ft^2$ of mechanical space if Leland went with gas-fired DHW



4 DHW PLANT OVERALL SCHEMATIC

SCALE: N.T.S.

As Designed – WUFI Results with QAHV



17.8 kBtu/ft²/yr

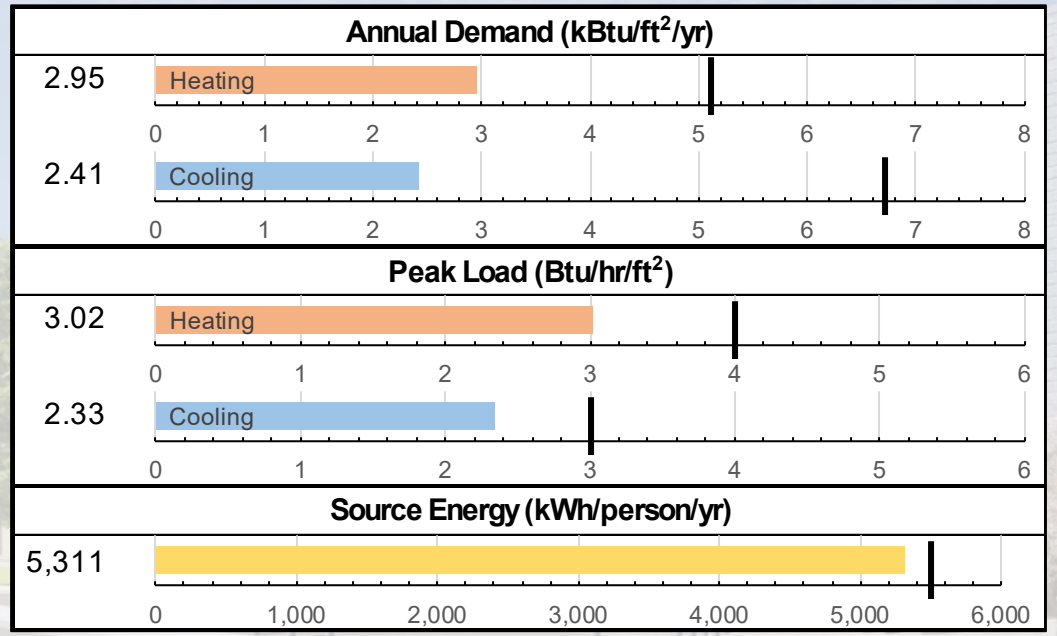
Total site energy use

1.5 kBtu/ft²/yr

site energy use
attributed to DHW

Leland House

Hypothetical – WUFI Results with Electric Resistance



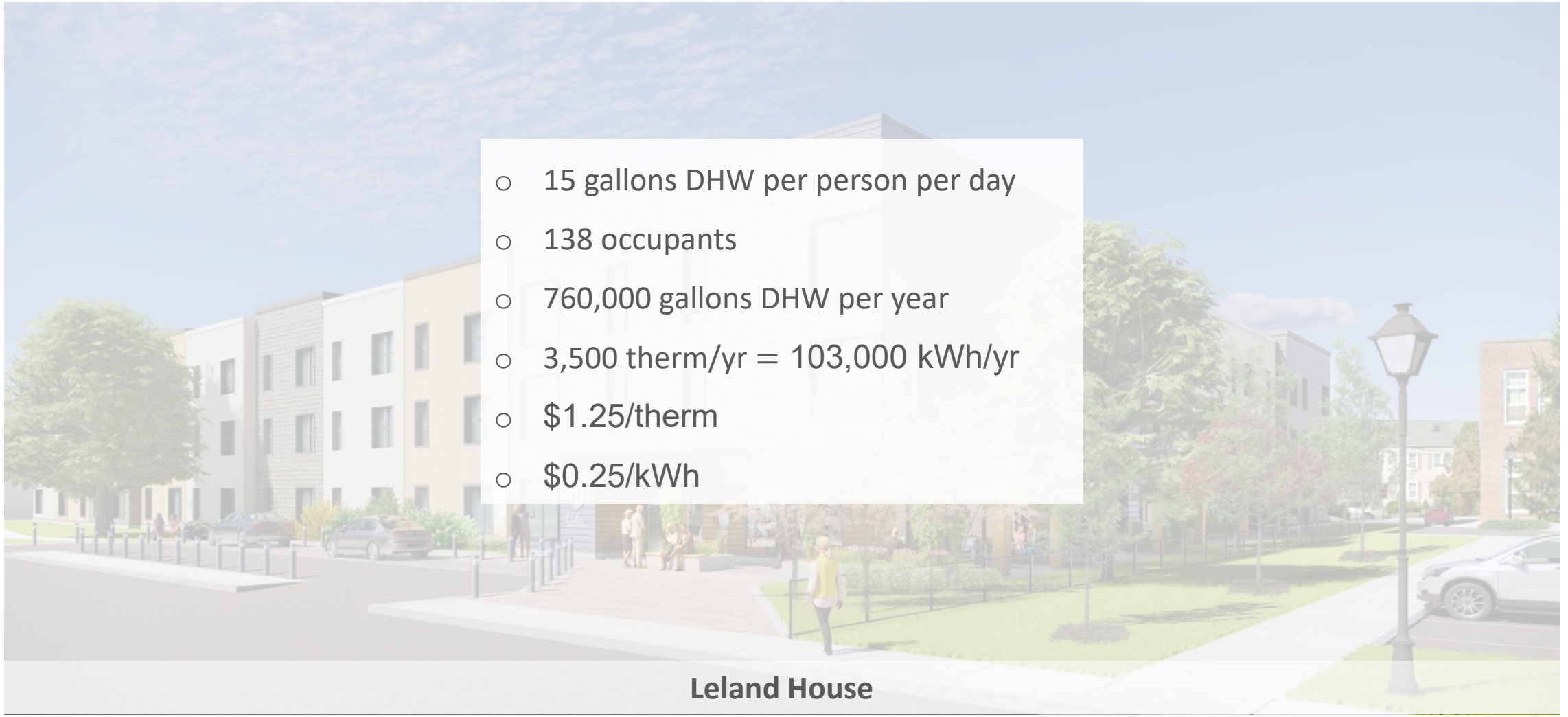
4.1 kBtu/ft²/yr

+175%

site energy use
attributed to DHW

Leland House

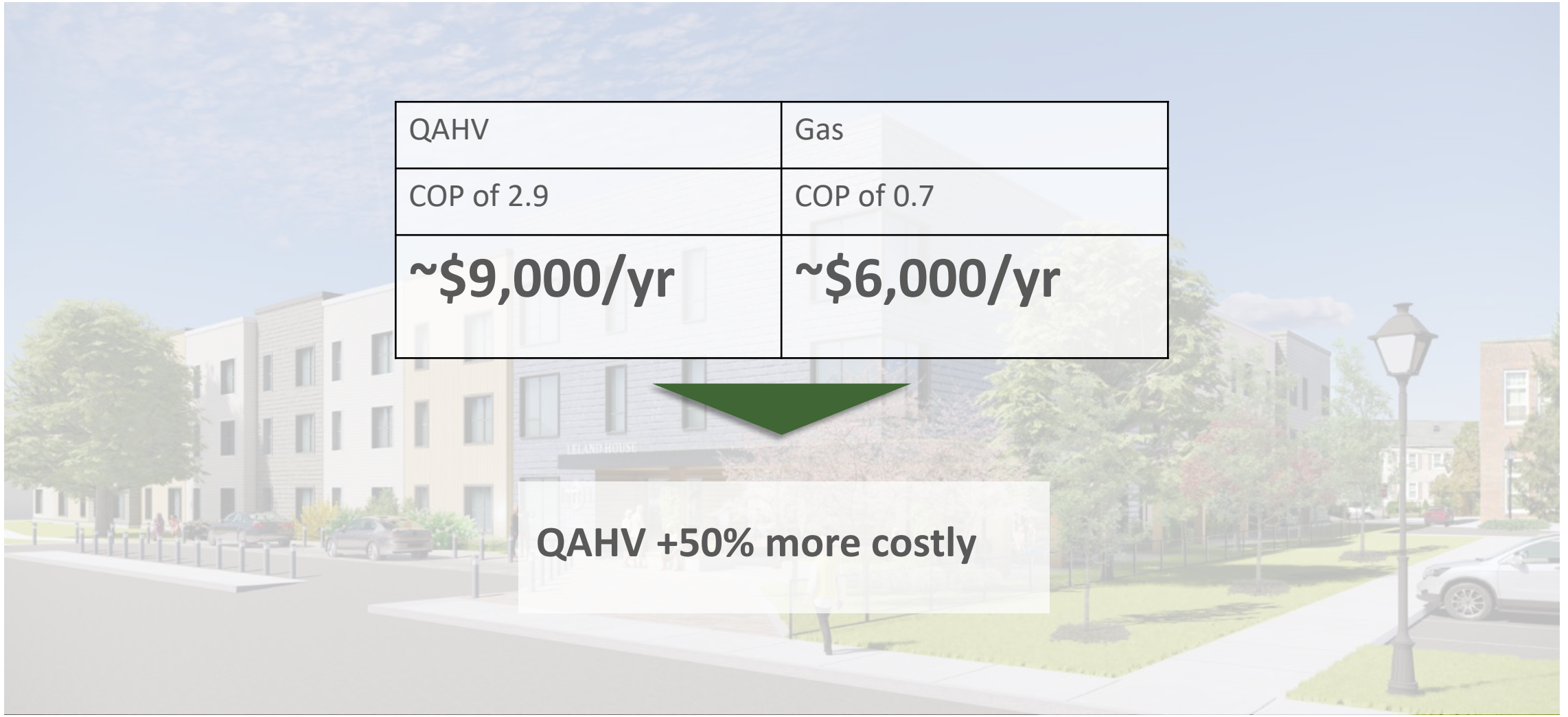
Estimated Annual Energy Use & Cost Assumptions



- 15 gallons DHW per person per day
- 138 occupants
- 760,000 gallons DHW per year
- 3,500 therm/yr = 103,000 kWh/yr
- $1.25/therm
- $0.25/kWh

Leland House

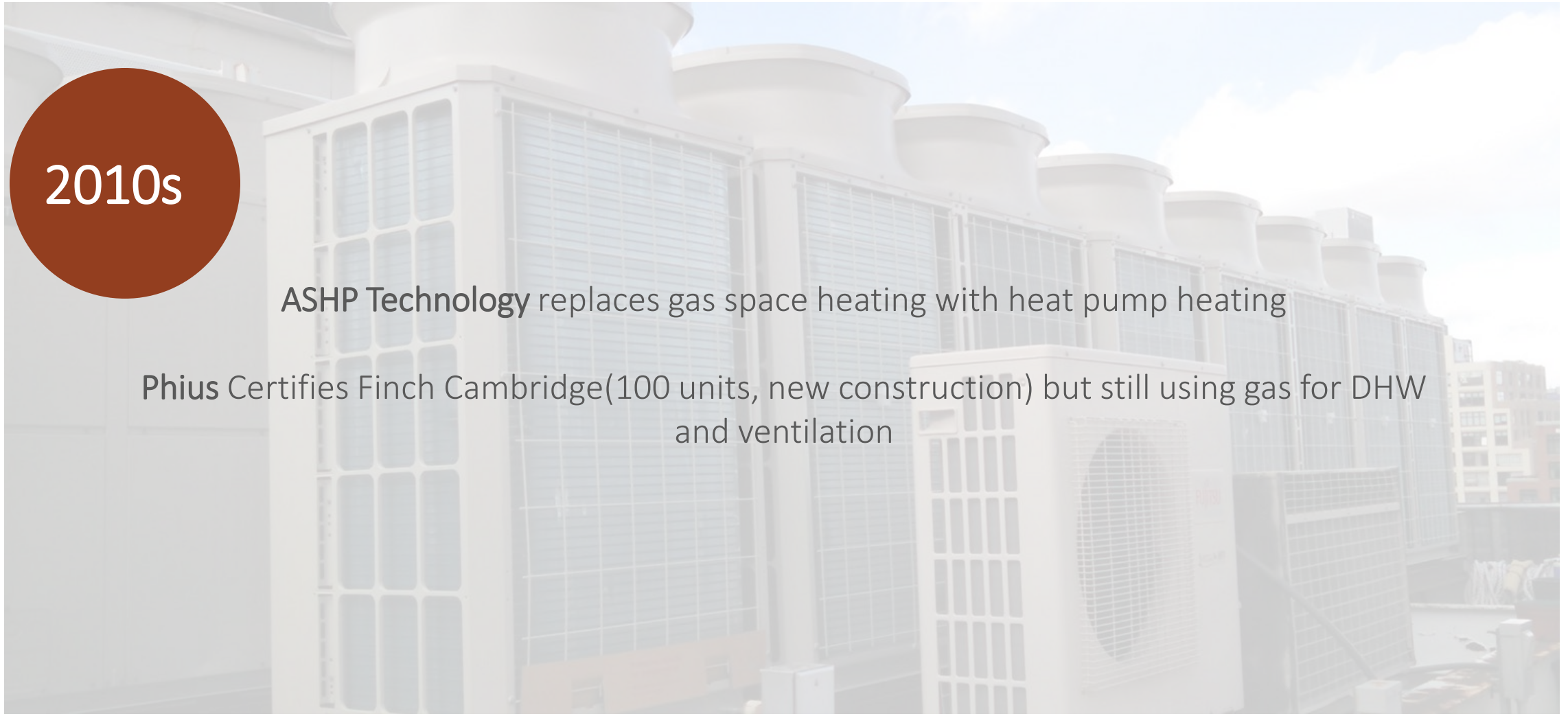
Estimated Annual Energy Cost – Leland House



QAHV	Gas
COP of 2.9	COP of 0.7
~$9,000/yr	**~$6,000/yr**

QAHV +50% more costly

The Rise of Passive House & Electrification



2010s

ASHP Technology replaces gas space heating with heat pump heating

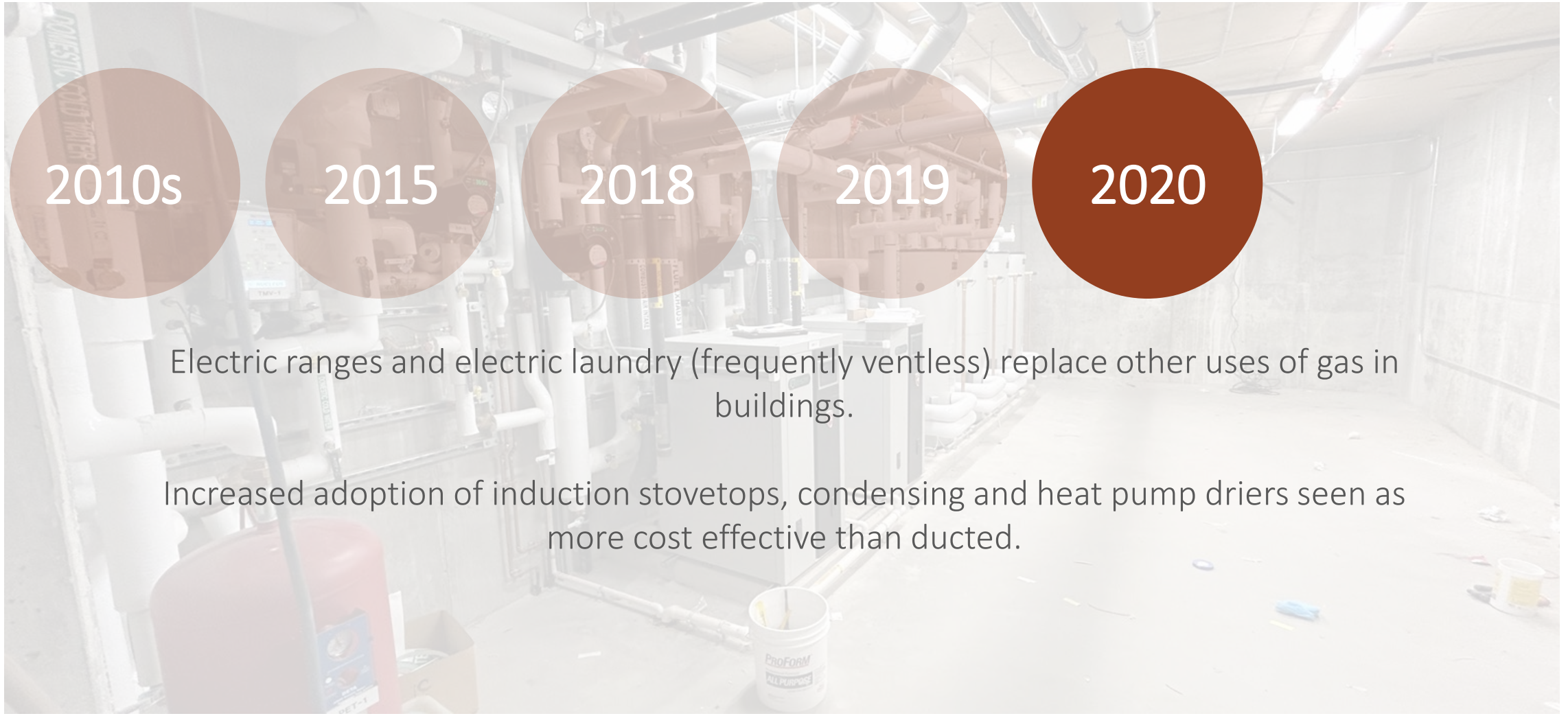
Phius Certifies Finch Cambridge(100 units, new construction) but still using gas for DHW and ventilation

The Rise of Passive House & Electrification

The Rise of Passive House & Electrification

The Rise of Passive House & Electrification

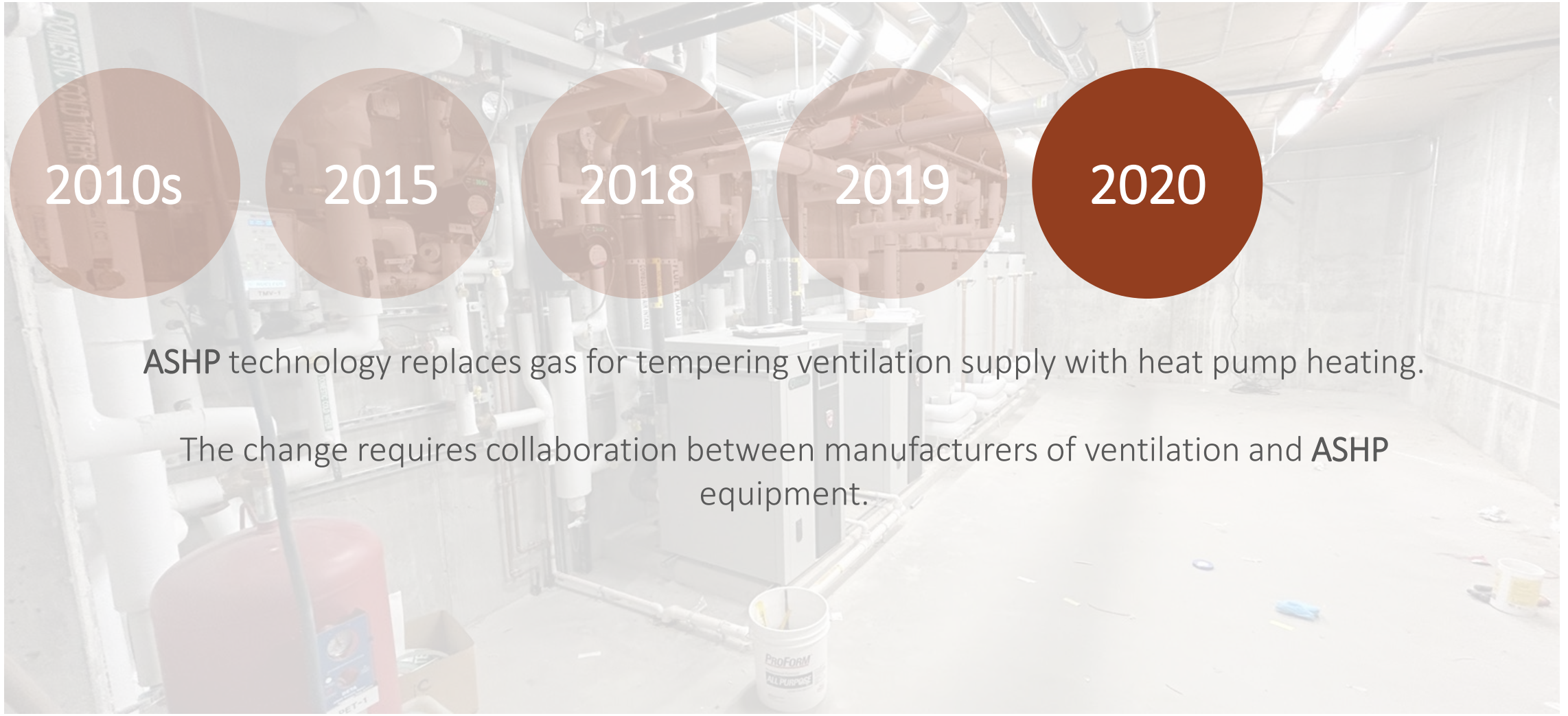
The Rise of Passive House & Electrification



Electric ranges and electric laundry (frequently ventless) replace other uses of gas in buildings.

Increased adoption of induction stovetops, condensing and heat pump driers seen as more cost effective than ducted.

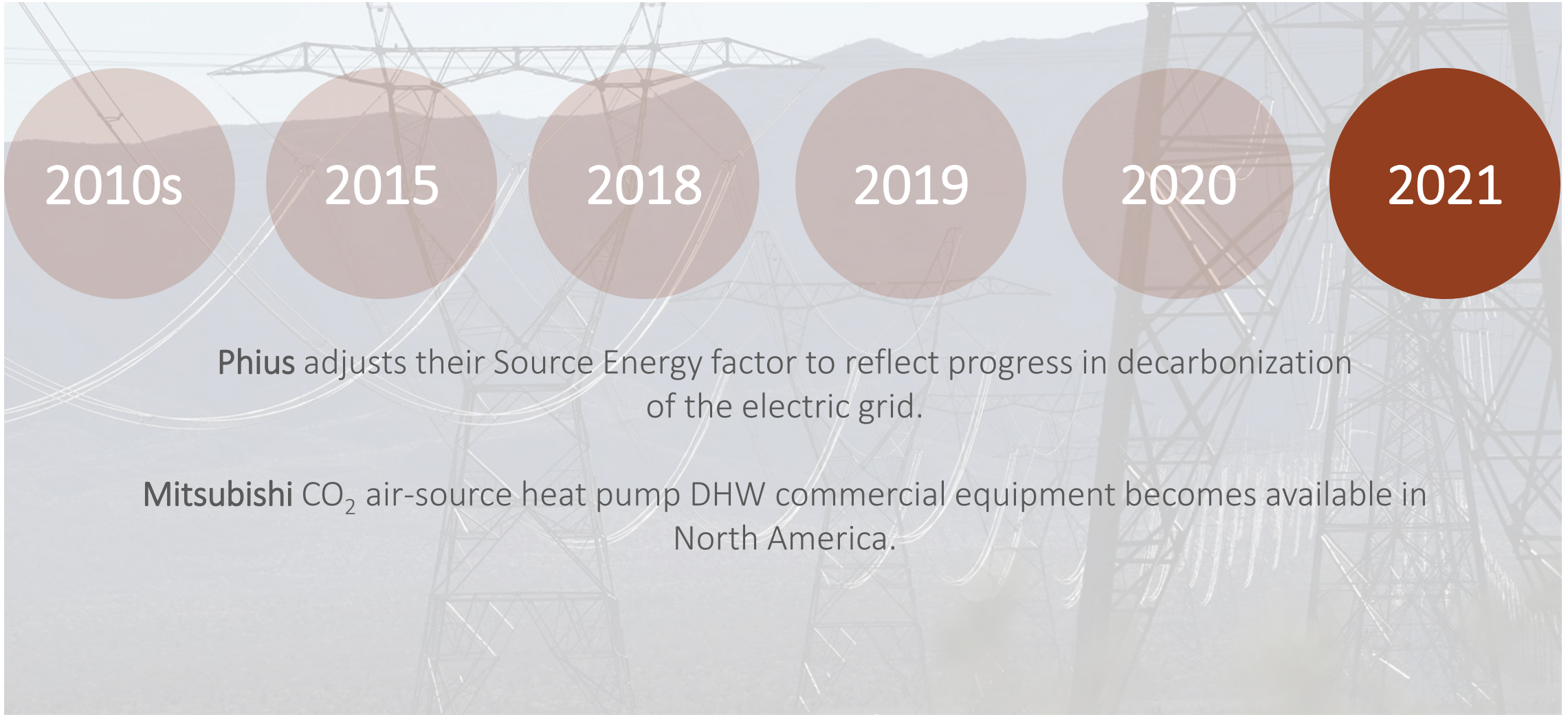
The Rise of Passive House & Electrification



ASHP technology replaces gas for tempering ventilation supply with heat pump heating.

The change requires collaboration between manufacturers of ventilation and **ASHP** equipment.

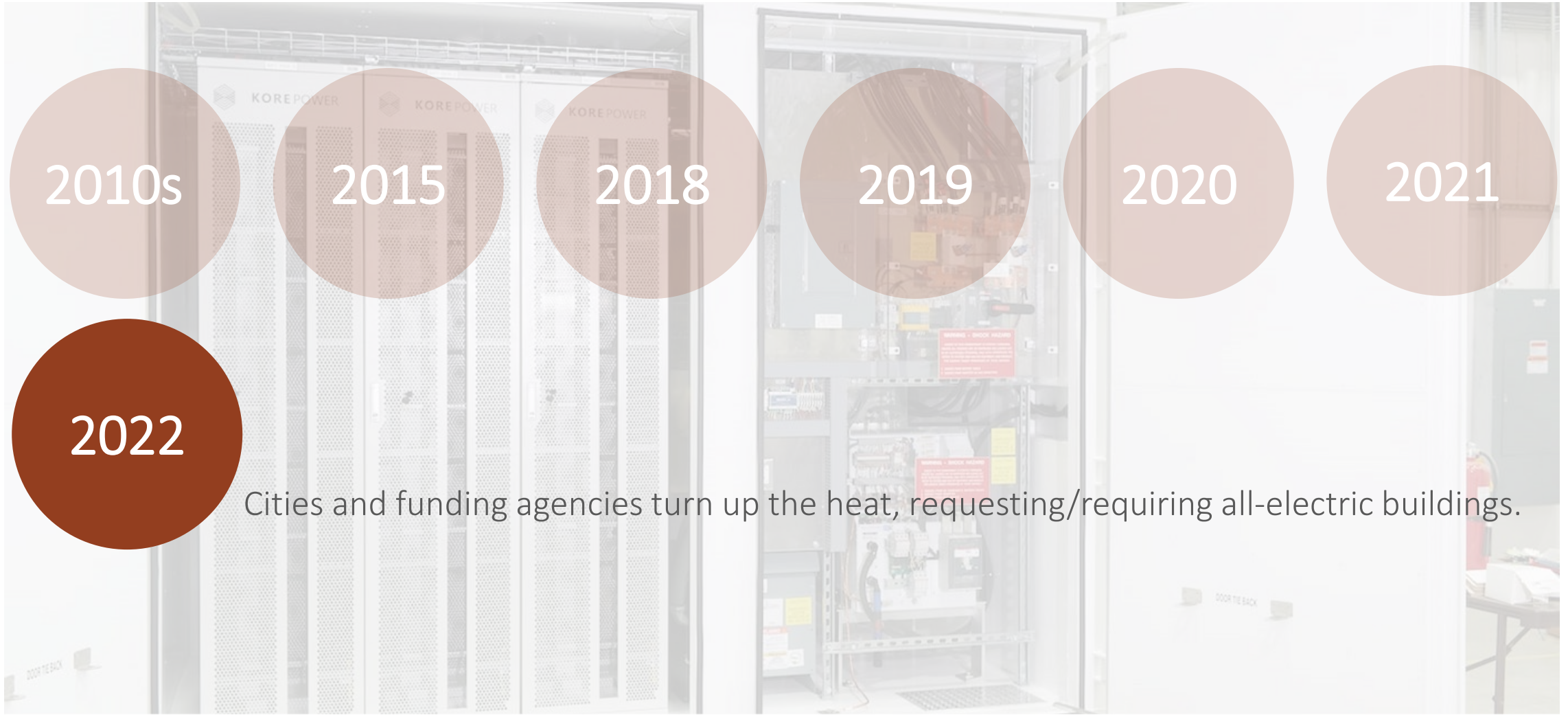
The Rise of Passive House & Electrification



Phius adjusts their Source Energy factor to reflect progress in decarbonization of the electric grid.

Mitsubishi CO_2 air-source heat pump DHW commercial equipment becomes available in North America.

The Rise of Passive House & Electrification



2010s

2015

2018

2019

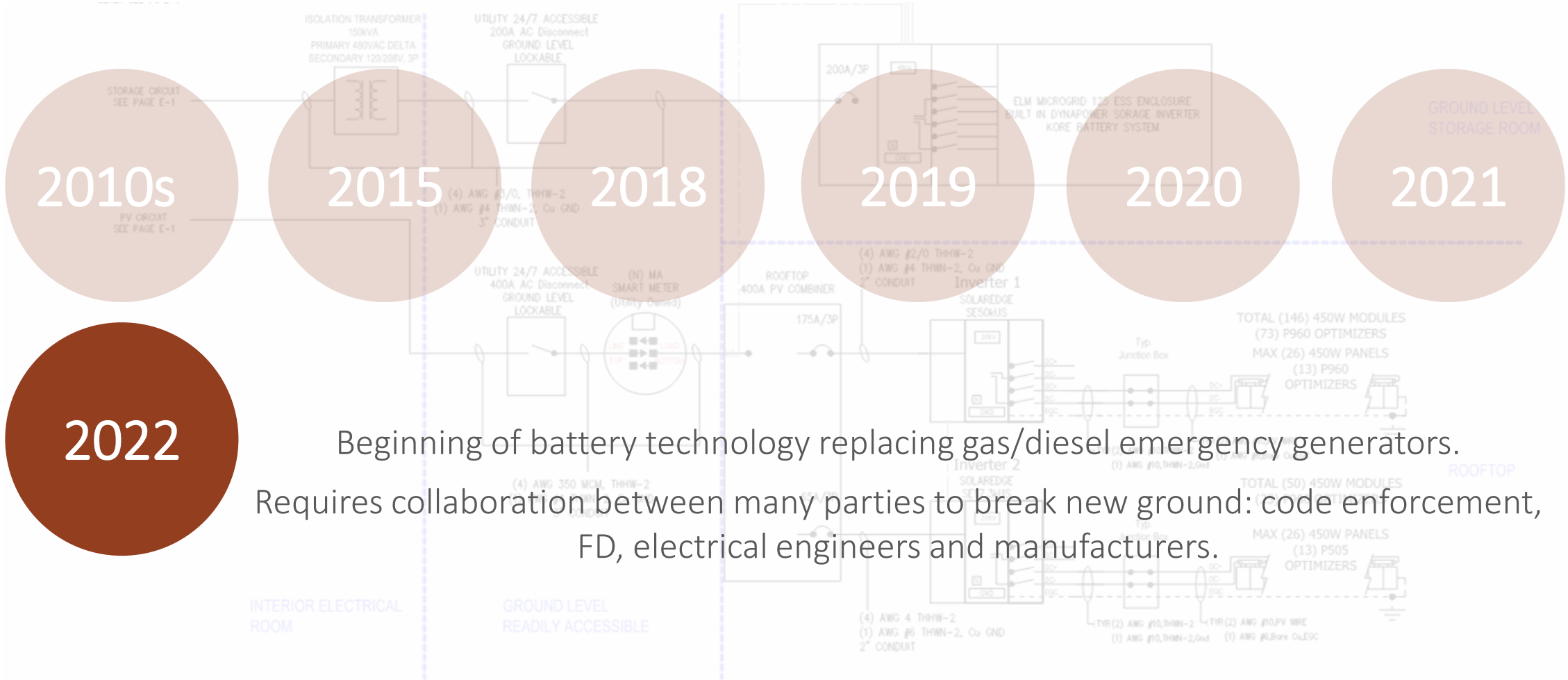
2020

2021

2022

Cities and funding agencies turn up the heat, requesting/requiring all-electric buildings.

The Rise of Passive House & Electrification



2022

Beginning of battery technology replacing gas/diesel emergency generators.

Requires collaboration between many parties to break new ground: code enforcement, FD, electrical engineers and manufacturers.

Chronology

New codes adopted that will lead to more Passive House certification as a path to energy compliance.

Domestic Hot Water Heating Options

1. Gas DHW in Apartments
2. Gas DHW in Central Plant
3. Electric Resistance Individual Tank in Apartment
4. Instantaneous Electric Resistance in Apartment
5. Hybrid ASHP/ER Packaged Tank in Apartment
6. Hybrid Tanks Using Corridor as Heat Source
7. Hybrid Tanks in Central Plant (Small Army Approach)
8. SanCO2 Central (Small Army Approach)
9. Geothermal/GSHP
10. Mitsubishi QAHV CO2 Central Plant

Domestic Hot Water Heating Options

1. Gas DHW in Apartments

2. Gas DHW in Central Plant

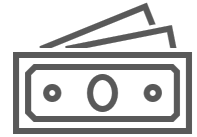
On-Site Fossil Fuels

Domestic Hot Water Heating Options

3 Electric Resistance Individual Tank

4 Instantaneous Electric Resistance

High Operating Cost



Domestic Hot Water Heating Options

5 Hybrid ASHP/ER Packaged Tank

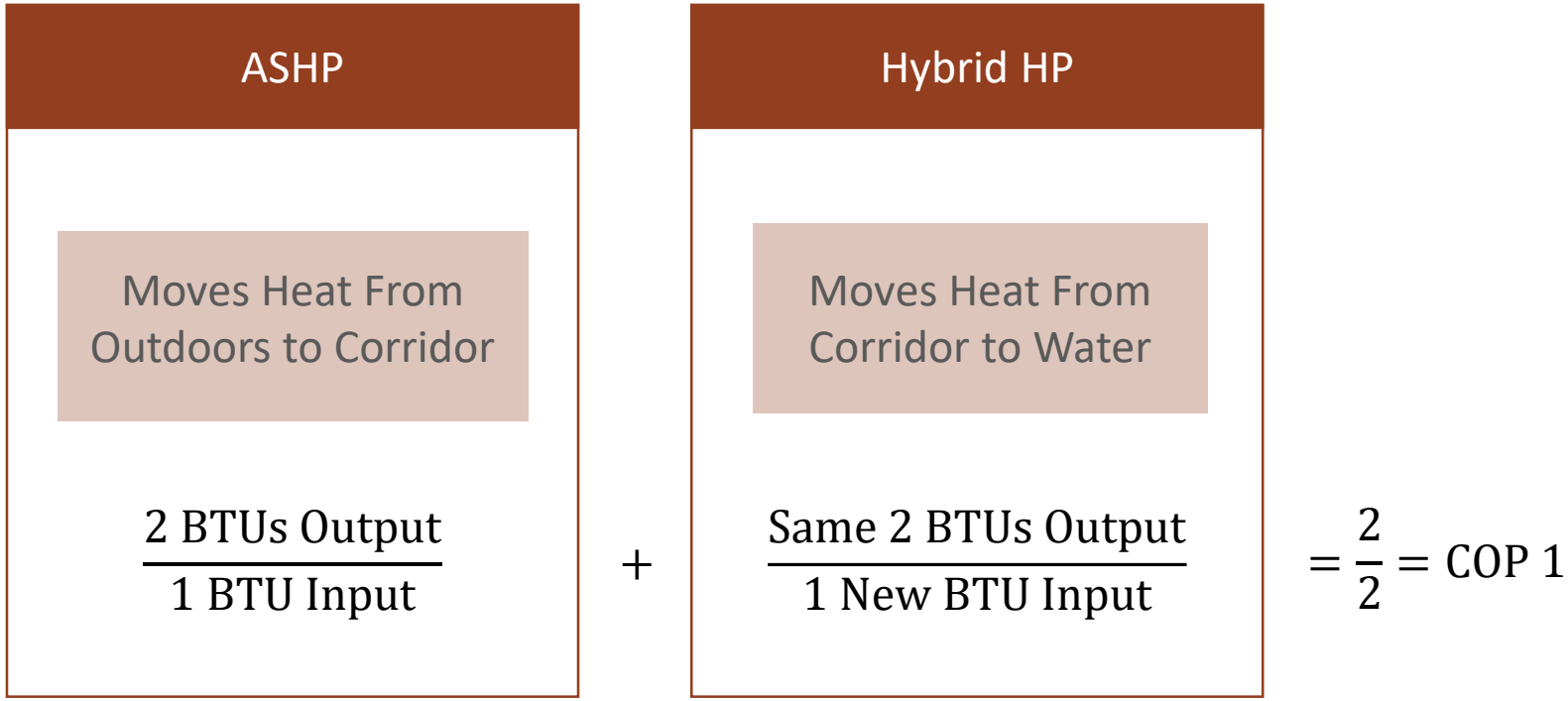
Significant Uncontrolled Cold Draft

Domestic Hot Water Heating Options

6 Hybrid Tanks Using Corridor as Heat Source

Compressors Working in Series Leads to Low COP

The Issue of Compressors in Series



Domestic Hot Water Heating Options

7 Hybrid Tanks Central Plant

8 SanCO2 Central Plant

Small Army of Equipment;
KISS—Keep It Simple Stupid

Domestic Hot Water Heating Options

9 Geothermal/GSHP

High Initial Costs

Domestic Hot Water Heating Options

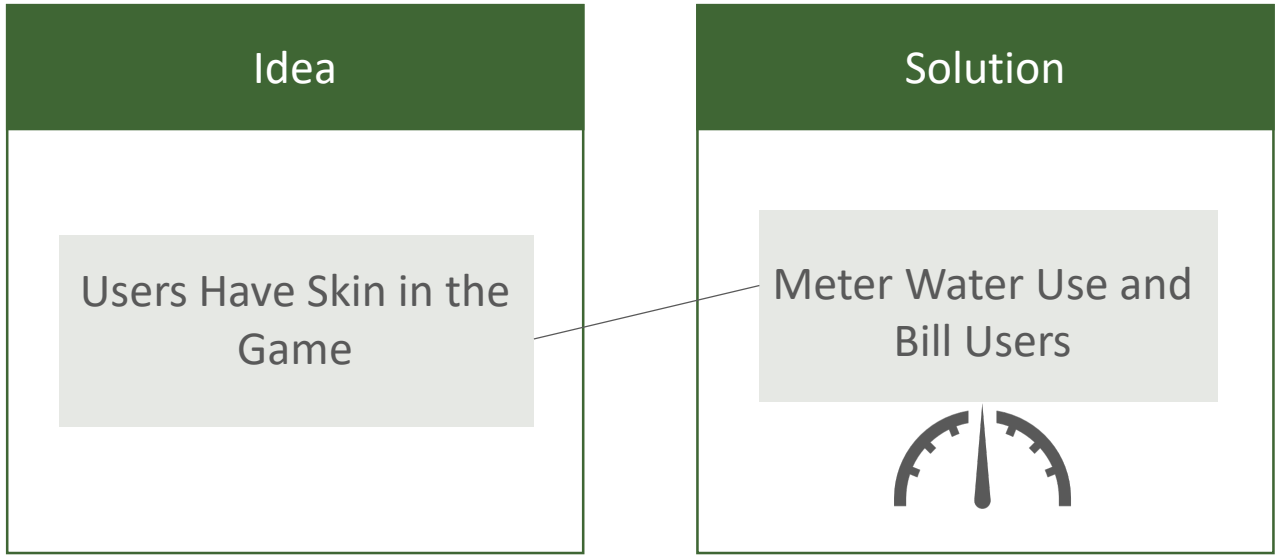
⑩ Mitsubishi QAHV CO2 Central

Lack of Proven Track Record

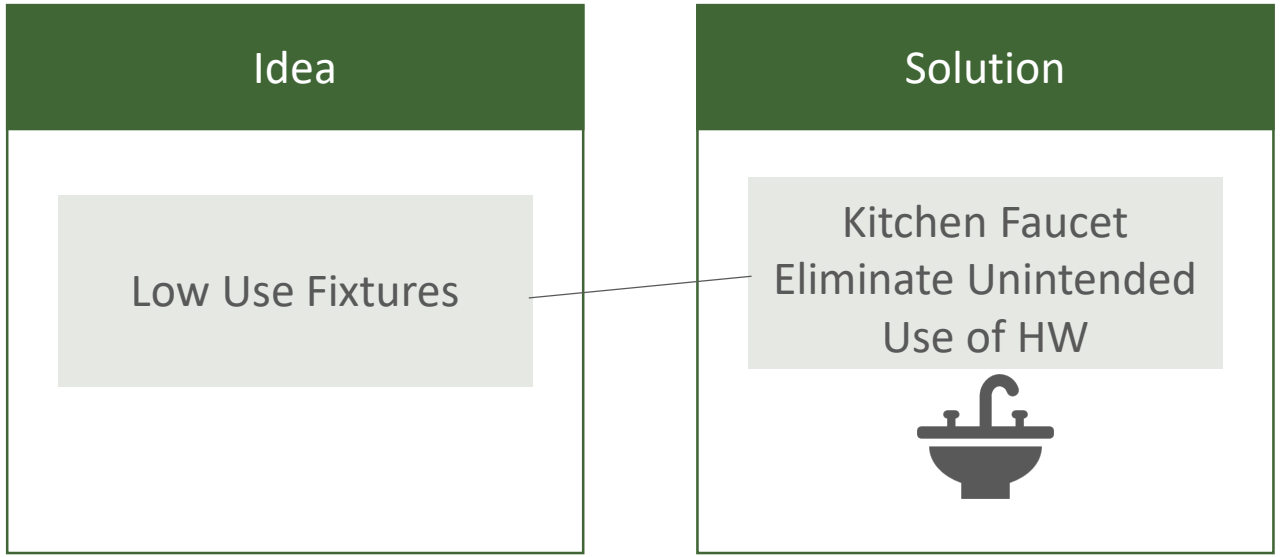
How to Reduce DHW Use/Cost in Buildings

1. Users Have Skin in the Game
2. Low Use Fixtures
3. Solar Thermal Pre-Tempering
4. Drain Water Heat Recovery
5. Down-Sized Distribution Piping
6. Down-Sized DHW Equipment
7. Reduced Distribution Losses
8. Measure $\frac{\text{BTUs OUT}}{\text{Power IN}} = \text{COP}$
9. Rationing/Cold Showers/Timer/Electric Shock
10. Increased Use of Perfume and Cologne

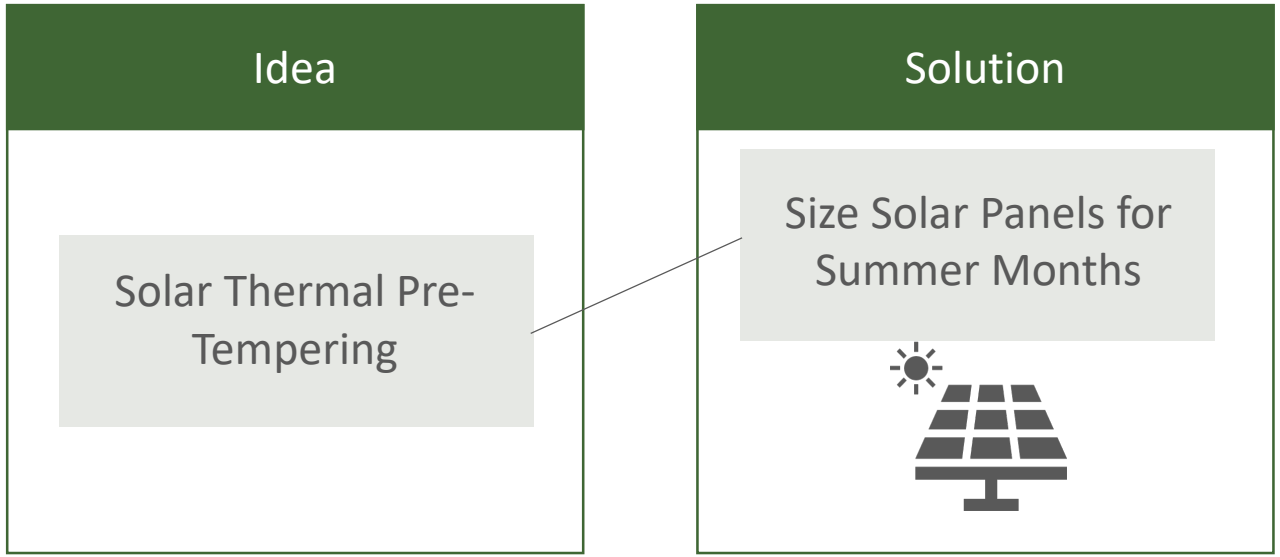
How to Reduce DHW Use/Cost in Buildings



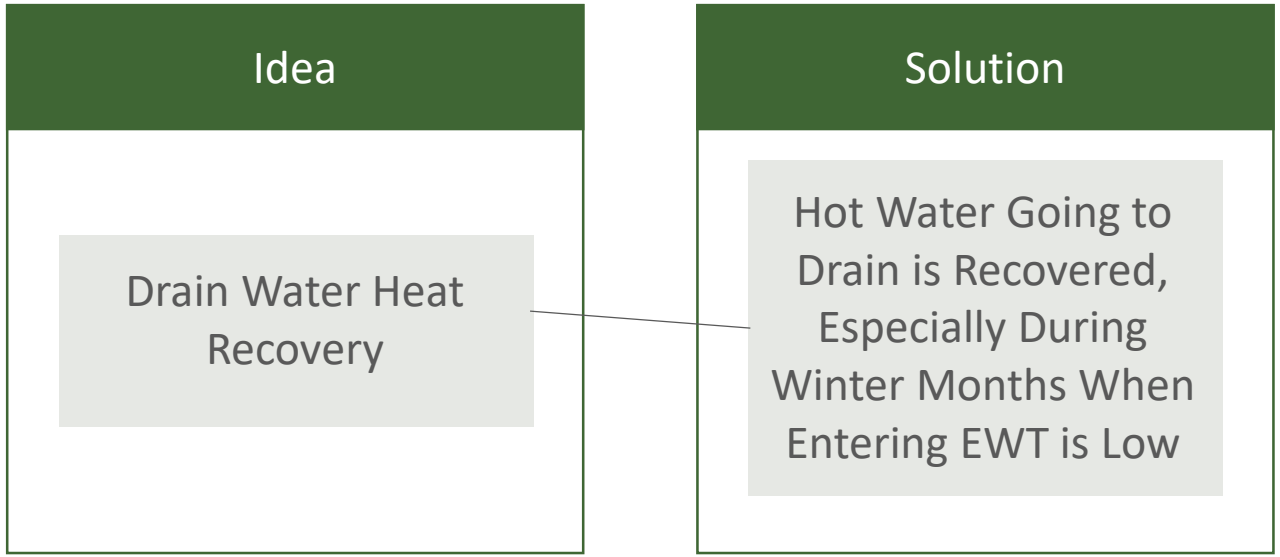
How to Reduce DHW Use/Cost in Buildings



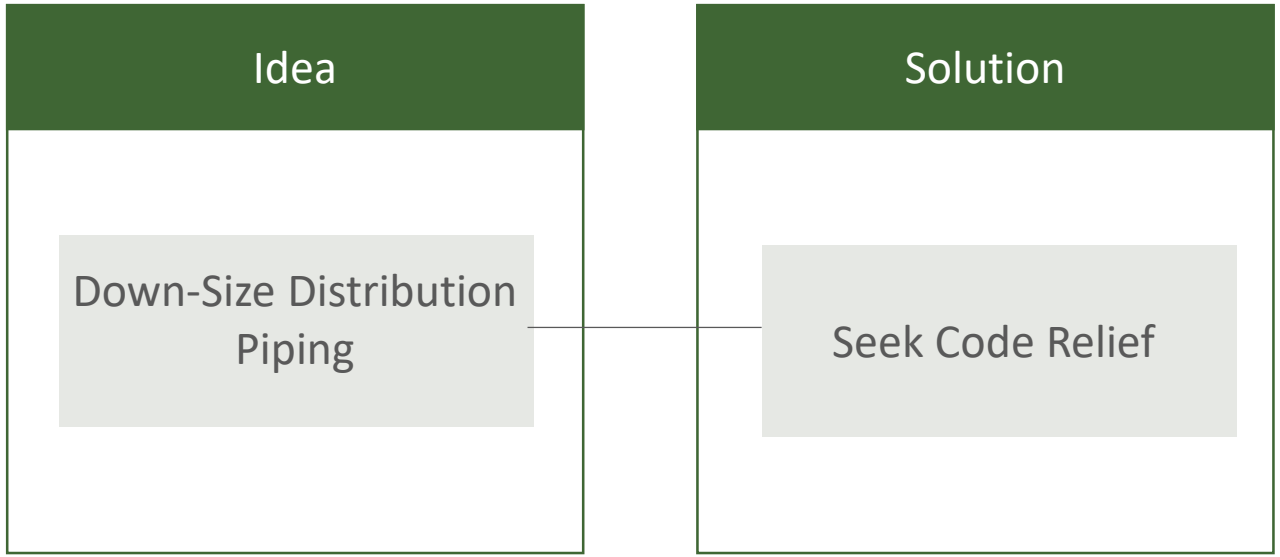
How to Reduce DHW Use/Cost in Buildings



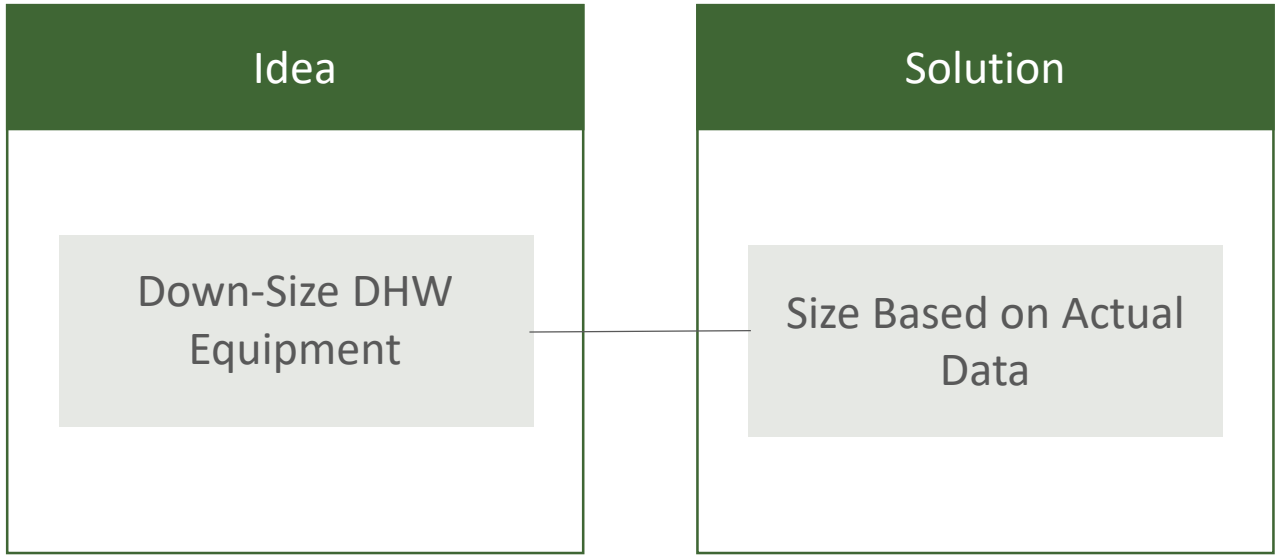
How to Reduce DHW Use/Cost in Buildings



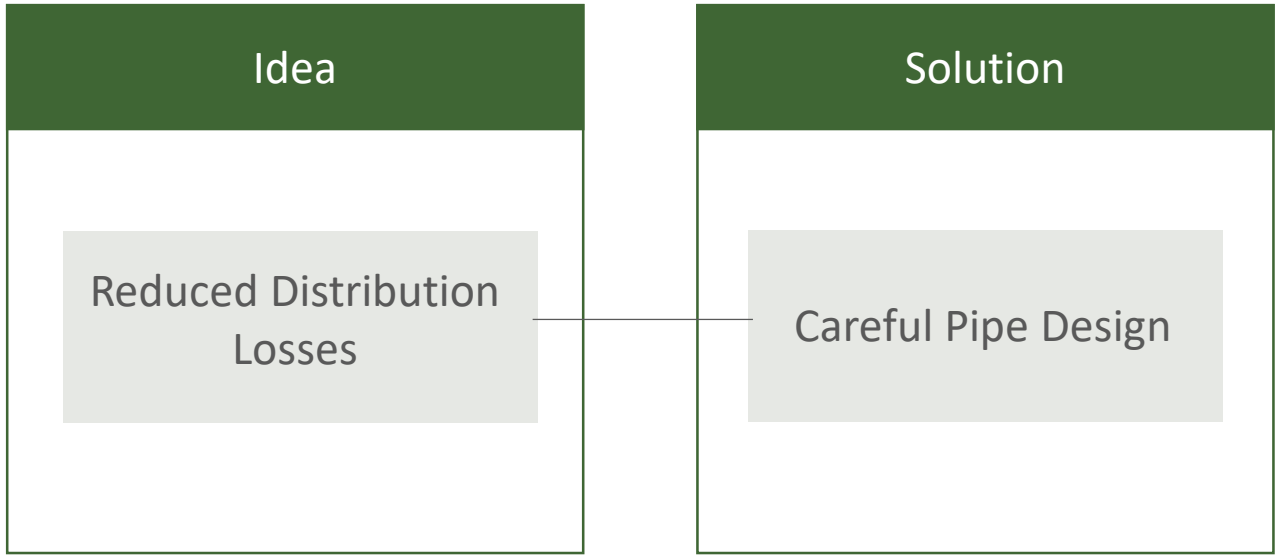
How to Reduce DHW Use/Cost in Buildings



How to Reduce DHW Use/Cost in Buildings



How to Reduce DHW Use/Cost in Buildings



How to Reduce DHW Use/Cost in Buildings

Idea	Solution	Explanation
$\frac{\text{Measure BTUs OUT}}{\text{Power IN}} = \text{COP}$	M & V System	Measure overall COP Measure peak usage Measure daily, monthly & annual usage Use data to ○ inform future designs ○ ID problems to be fixed ○ Downsize future systems M & V Cost $$ in short term

How to Reduce DHW Use/Cost in Buildings

	Idea	Solution
9	Rationing/Cold Showers/Timer/Electric Shock	… just kidding
10	Increased Use of Perfume and Cologne	

Thank You

- james@petersenengineering.com
- dperez@petersenengineering.com