Active Energy Recovery Utilizing Near Frictionless Chillers

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Presented at: Better Buildings by Design 2014
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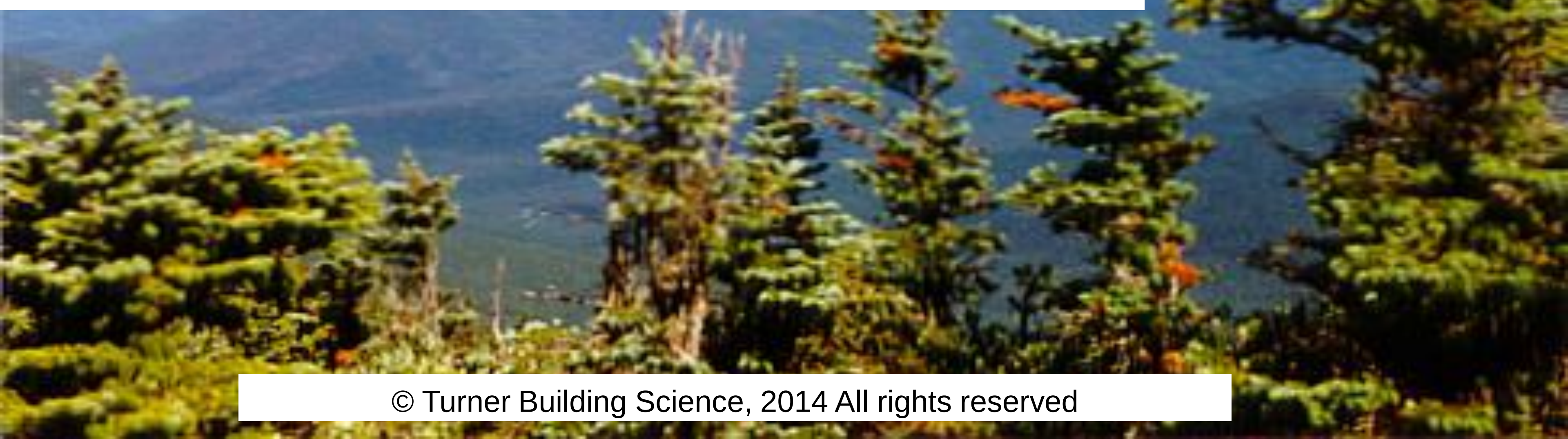
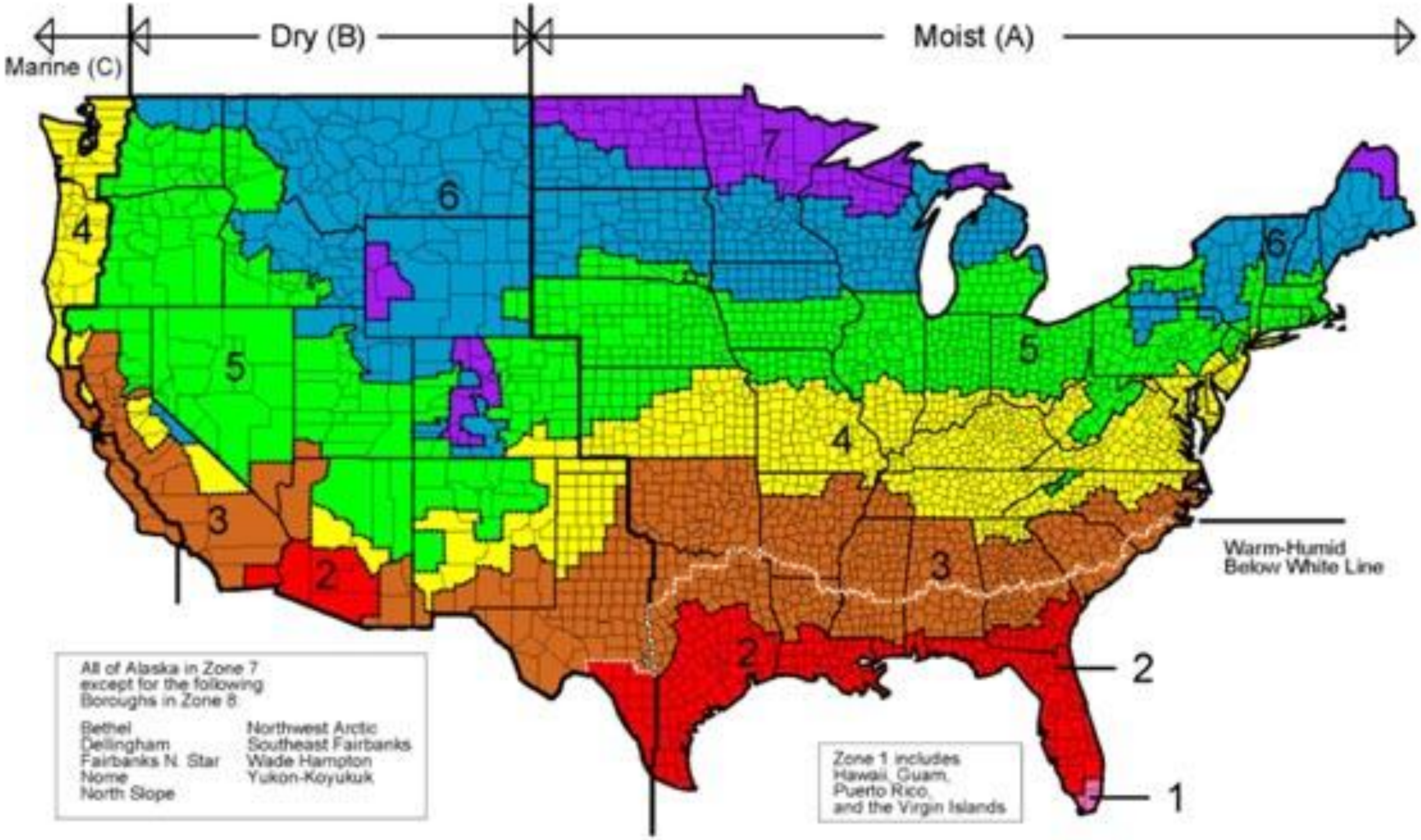
Clients throughout North America



ASHRAE CLIMATE ZONES



Who is here, what climate zones?
What types of Industries?

Active Energy Recovery Utilizing Near-Frictionless Chillers (NFC)
Mechanical, Commercial   3:14 to 4:45

Jeff Harrison, *PE, LEED AP, The Blake Group*
William Turner, *MS, PE, Turner Building Science & Design, LLC*

Learn how near-frictionless compressors for chillers capture waste exhaust energy for reuse, reducing the need for fossil fuels.

We'll cover systems for K-12 schools, offices, and universities, from theory of operation to type and configuration of chiller equipment.

Participants will learn to recognize opportunities for application and the tools necessary for success.

Level: Advanced
Room: Amphitheatre

Disclaimer

This is the best and most current general information of which we are aware. It is not intended to be used as legal or design advice. Individual projects require individual attention.

Comments and feedback are always welcome

Today's Objectives

- What is a **N**ear **F**rictionless **C**hiller (**NFC**)
- Applications in Energy Recovery That Likely Make Economic Sense when using a **NFC**
- Components That Are Needed & How They Are Sized to optimize a **NFC**
- Engineering Needed & Operator Education

General Principle:

HVAC Changes Are Often Costly:

Look For "Value Added" Opportunities & Funding Incentive Programs

Marginal Cost

of doing it better with a **NFC**

Utility programs can often be used to "buy down" the cost of premium efficiency improvements to reduce KWH

Marginal Cost

It needs replacing or repairing, if we are going to renovate, “now” is the time to consider:

- HVAC Systems
  - More Efficient Boilers
  - More Efficient Chillers
  - Smarter Controls
  - Energy Recovery
  - Other Energy Sources
    - Wood Fuels
    - Geo-Exchange
    - Waste Energy Recovery
    - Thermal Solar
    - Others?

General Principle: Look For "Value Added" Opportunities & Incentives

Once The Significant Deficiencies of the HVAC System Have Been Identified:

Upgrades Are Most Cost Effectively Made When A Component or Components Are In Need Of Replacement so you only have to justify the "added cost" compared to a "replacement in-kind"

What type of energy do you need?

Hot Water? Steam? Chilled Water?

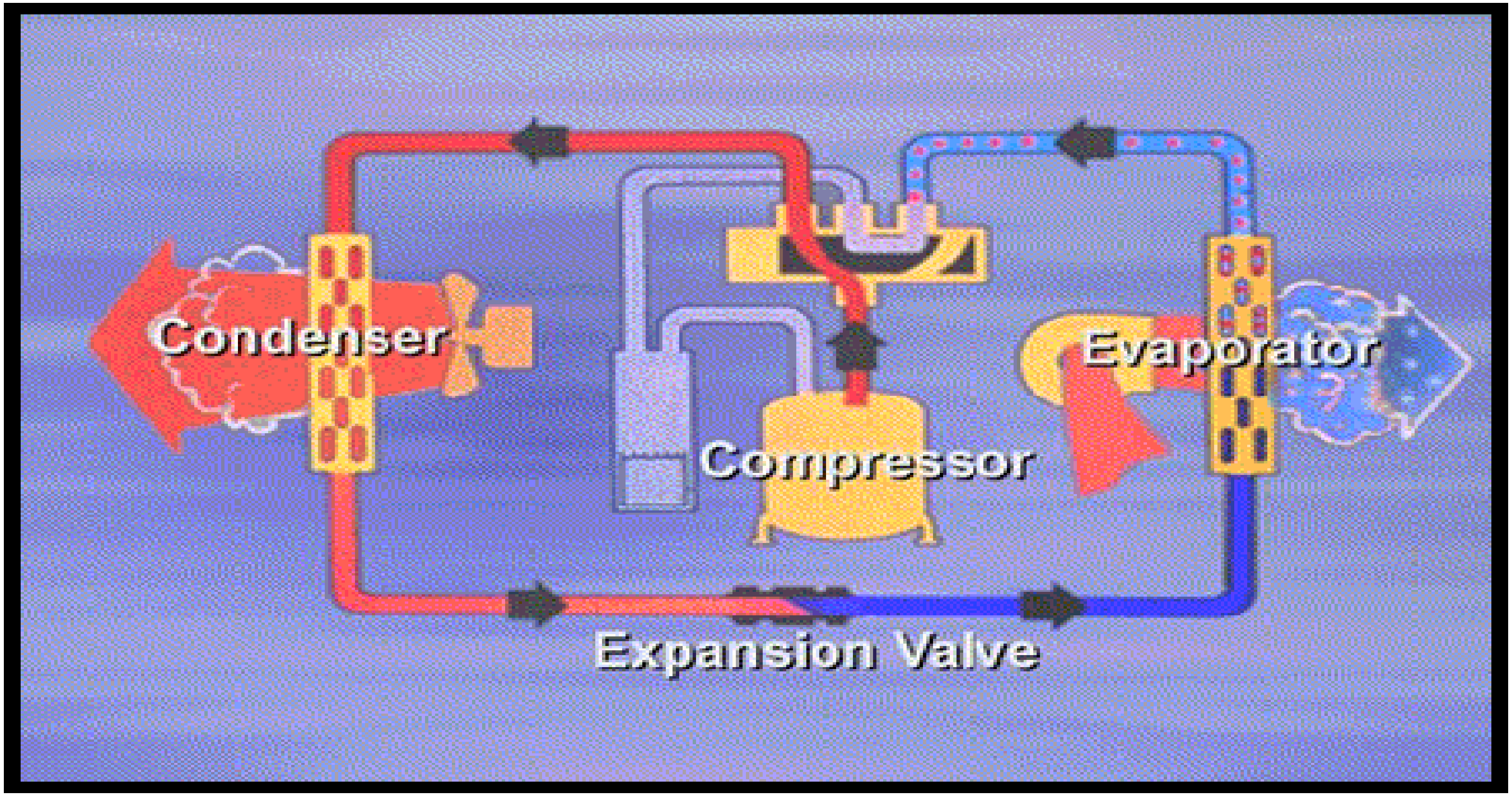
What fuels do you have available?

Fuel Oil? Propane? Natural Gas? Electric?

What is a Near Frictionless Chiller (NFC)

The Vapor Compression Cycle

Moves heat from the evaporator to the condenser, while also changing its state of energy from a lower level (40°F to 55°F) to a higher level (80°F to 95°F)



Compressor Machine Basics

- **Working Fluid:** Uses a working fluid with a mechanically produced and reversible **phase change** to **move energy from one location to another**.

- **Electrical Energy:** Uses electrical energy to drive a compressor to change a vapor back to a liquid.

- **Proven:** "refrigeration" Technology
  - very reliable
  - widely used,
  - since 1930's **(80 years)**

The shaft of the compressor floats in the air on a magnetic field bearing, uses no oil, operates over 30,000 RPM

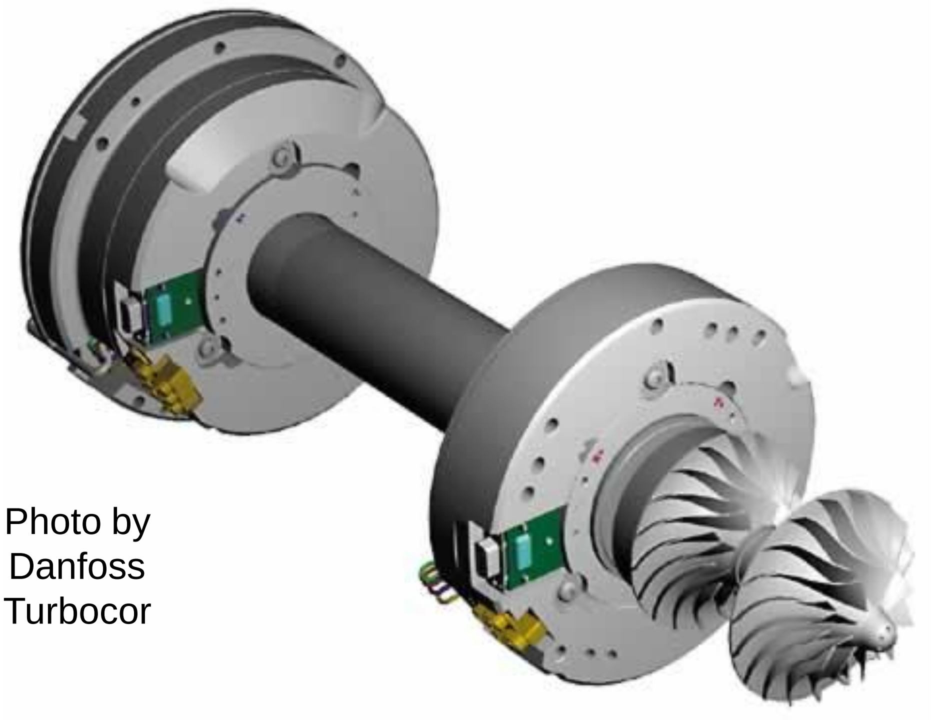


Photo by Danfoss Turbocor

The Danfoss Turbocor

Near
Frictionless
Compressor

Near Frictionless Compressor
Near Frictionless Chiller

AAON
AERMEC air conditioning
AIREDALE air conditioning for every environment
ARCTIC
BLUE STAR

CLIMAVENETA
COFELY GDF SUEZ
COLDEX TOSI AR CONDICIONADO
EMICON AIR CONDITIONING AND INDUSTRIAL APPLICATION
FRIGOPOL

GEOCLIMA PROFESSIONAL AIR CONDITIONING
G.I. INDUSTRIAL HOLDING SPA
Haier Qingdao Haier Intelligent Electronics Co., Ltd
HEINEN & HOPMAN ENGINEERING BV

hekra COOL TECHNOLOGY
Mammoth
DAIKIN
MULTISTACK
OCHSNER WÄRMEPUMPEN

opk
clever cooling powerpax
rcgroup.it
Kältetechnischer Anlagenbau Reisner
SMARDT
STAR REFRIGERATION

THERMALCARE
UNIFLAIR™
Wettstein Kältetechnik

OEM companies using the Danfoss Near Frictionless Compressor

Near Frictionless Chiller

There are four basic types of mechanical compression chillers. .

Common Chiller Type	Size Range (Tons)	Full-Load Efficiency (kW/ton)
Thermal Care TCW - Magnetic Bearings	60 - 700 +	0.35 - 0.58 (0.2 part Load)
Centrifugal	100 - 1500+	0.49 - 0.68
Screw	40 - 1100	
water-cooled		0.61 - 0.70
air-cooled		1.1 - 1.3
Scroll	1/2 - 130	
water-cooled		.70 - .95
air-cooled		1.2 - 1.4
Reciprocating	1 - 400	
water-cooled		0.8 - 1.0
air-cooled		1.4 - -1.6

Chillers are typically designed for maximum efficiency at 70% to 80% of their full-load.

Generally below about 30% full-load, their part-load efficiency starts to deteriorate rapidly.

The N.F.C. is at its peak efficiency at about 30% to 40% full load when bin hours are highest

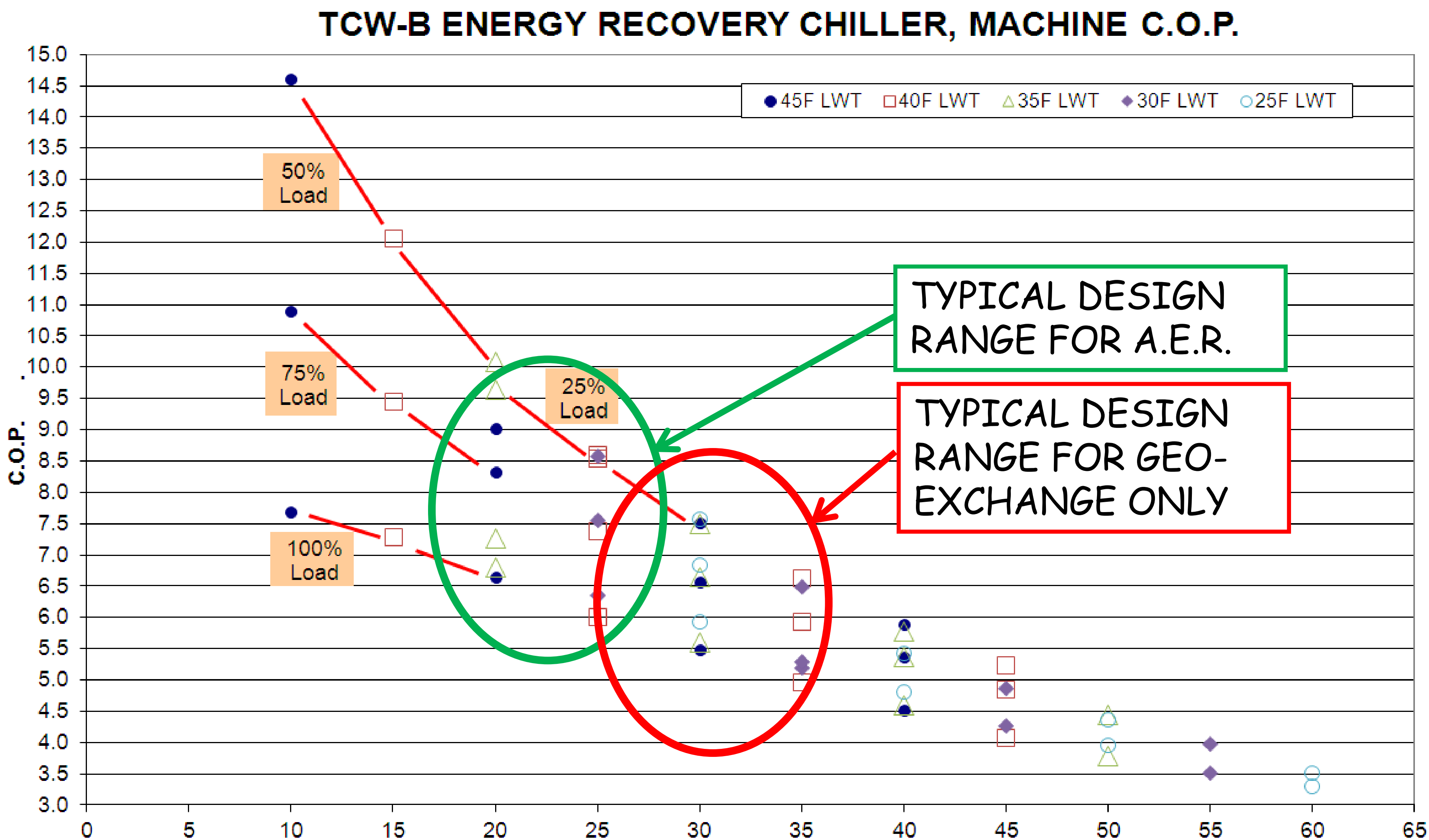
Cooling EER = 15 to 40

IPLV= 31+/- Full Load=19+/-

Near Frictionless Compressors = Ultra High Efficiency Chillers, Unloadable to 10-20% With High Efficiency

www.turbocor.com

Lowest Operating KW / TON = Highest C.O.P.'s

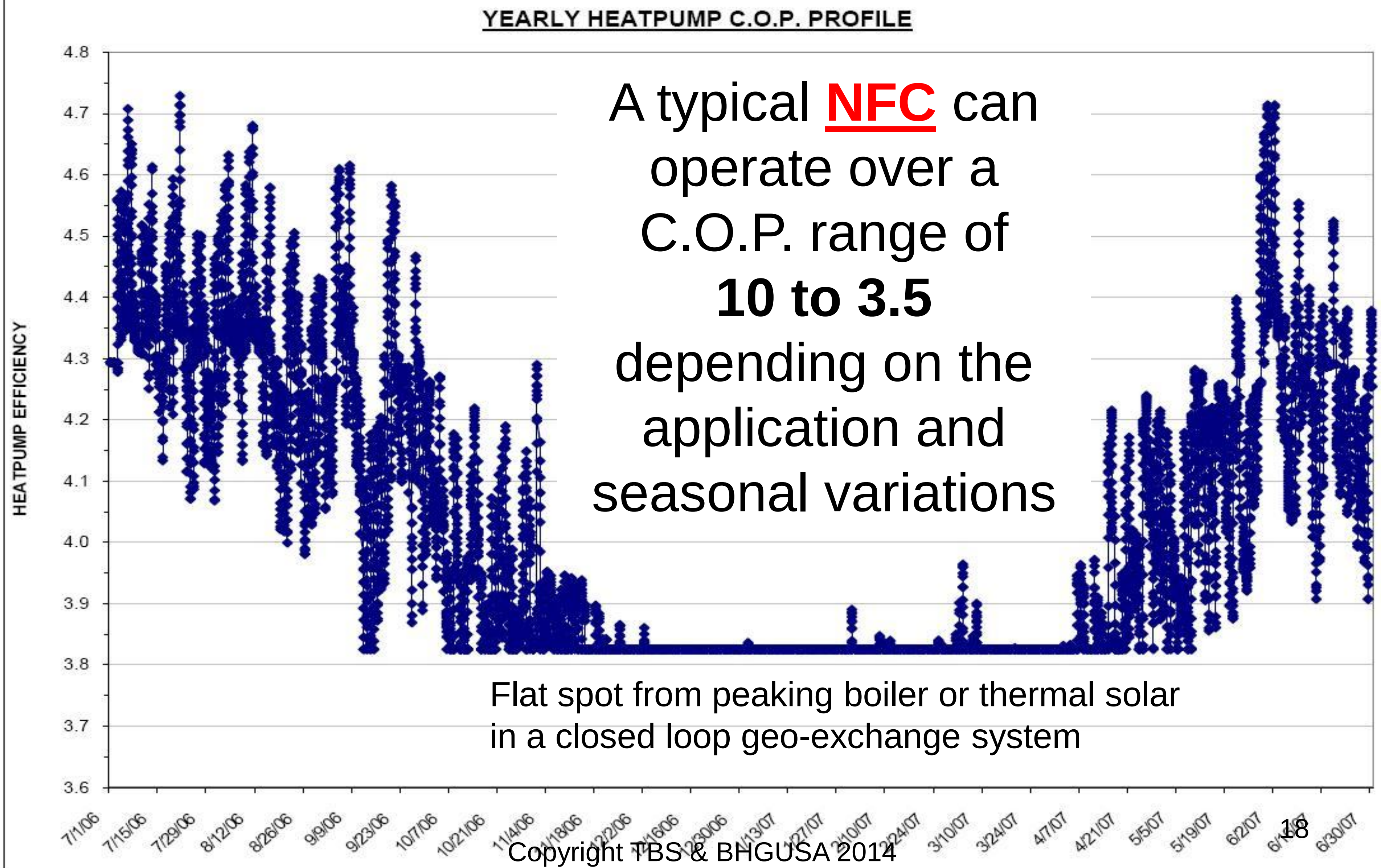


Each supply water temp. is graphed at various part load conditions and operating differiential temperatures.

Blake Equipment Co.: Jeff Harrison

ECWT = ENT COND WATER TEMP
LCWT = LEAV CHILL WATER TEMP

Non-Linear Efficiency Example



A typical **NFC** can operate over a C.O.P. range of **10 to 3.5** depending on the application and seasonal variations

Flat spot from peaking boiler or thermal solar in a closed loop geo-exchange system

- ✓ **The ability of a NFC to move energy from one place to another with low cost has changed what makes sense to do today**

Calculating Fuel Switching Economics

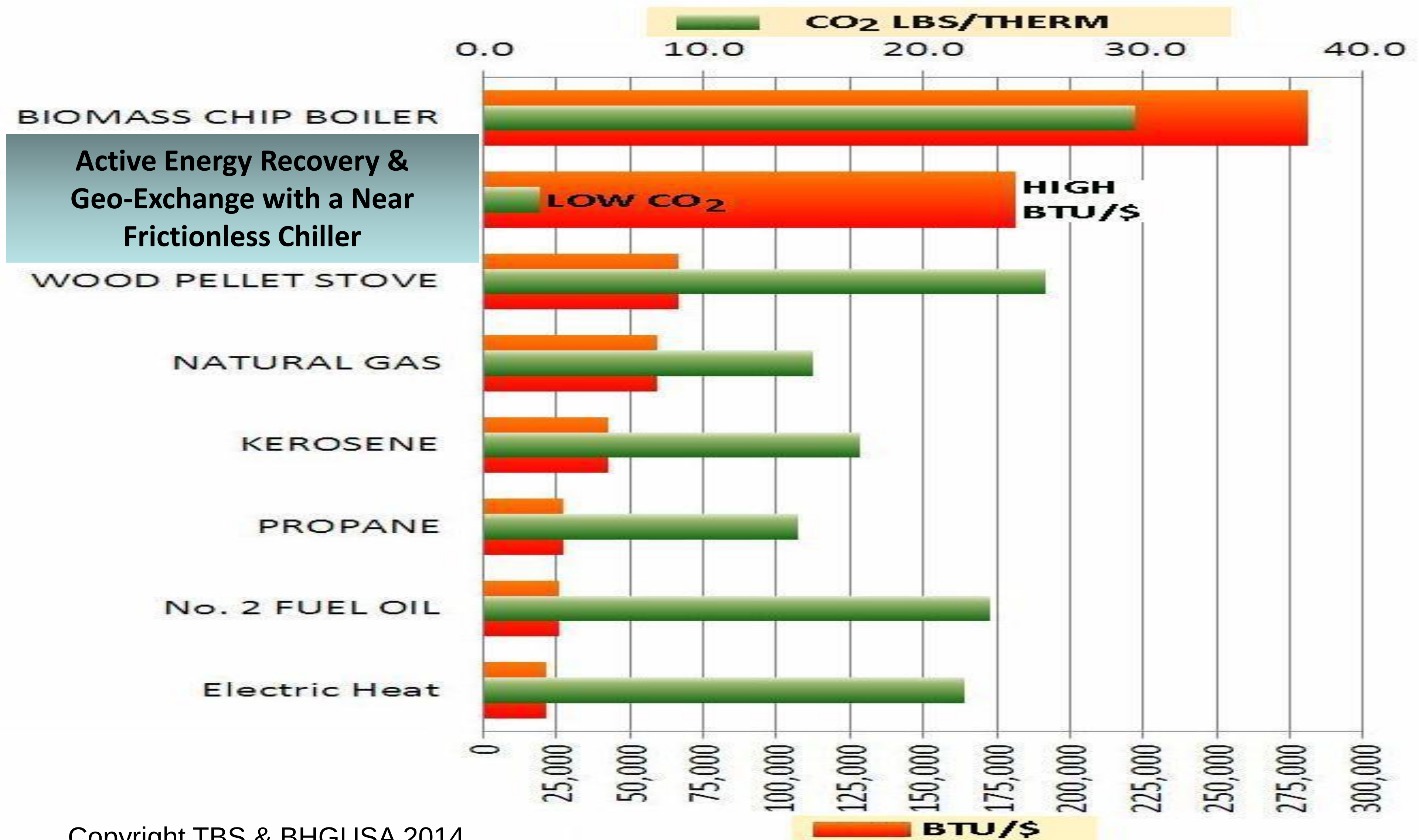
BTU/$ @ System Efficiency

Heating System Efficiencies and Fuel Costs

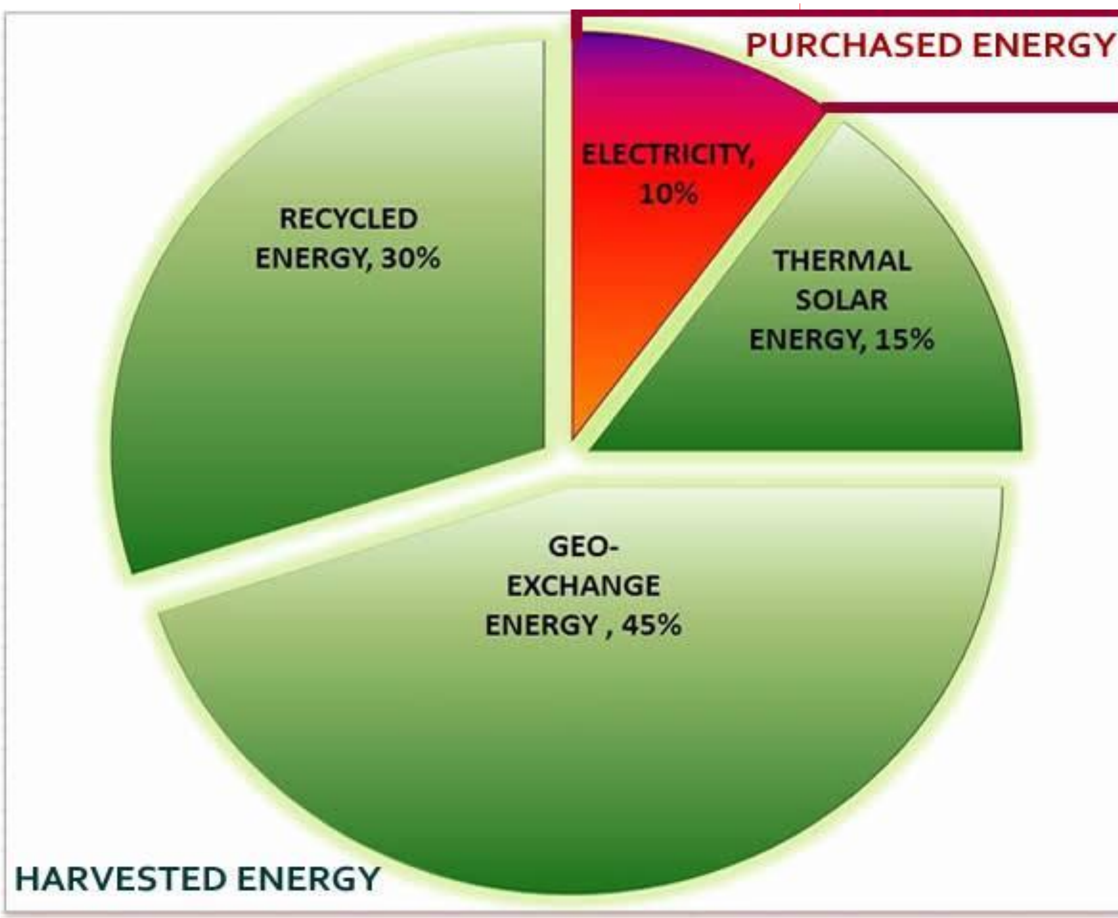
FUEL	UNITS	Equivalent No.2 Fuel Oil Price	$/UNIT	BTU/UNIT	BTU/$ AT SYS. EFF.	SYSTEM EFF.	CO2 LBS/THERM
Electric	KWH, peak	**$3.73**	$0.13	3,415	**26,269**	100%	35.86
Propane, atmospheric	Gallon	**$3.36**	$1.88	91,500	**29,202**	60%	23.17
No. 2 oil	Gallon		$2.27	140,000	**43,172**	70%	23.06
Propane, condensing	Gallon	**$2.08**	$1.88	91,500	**47,210**	97%	14.33
Natural Gas, atmospheric	Therm	**$1.88**	$1.15	100,000	**52,174**	60%	23.17
Geothermal (cop 2.5)	KWH, peak	**$1.70**	$0.13	3,415	**57,792**	220%	16.30
Kerosene (monitor)	Gallon	**$1.68**	$2.15	135,000	**58,395**	93%	17.15
Wood	Cord (20%moi	**$1.31**	$200.00	30,000,00	**75,000**	50%	44.39
Geothermal (cop 3.2)	KWH, peak	**$1.29**	$0.13	3,415	**76,181**	290%	12.37
Natural Gas, condensing	Therm	**$1.16**	$1.15	100,000	**84,348**	97%	14.33
Geothermal (cop 5.0)	KWH, peak	**$0.79**	$0.13	3,415	**123,465**	470%	7.63
N.F.C. (COP 8)	KWH, peak	**$0.48**	$0.13	3,415	**202,273**	770%	4.66

High BTU / $ … & … Low CO2

The incentive to conserve - Payback



THE ENERGY INDEPENDENCE PIE



- Alternative Energy Harvesting
- Energy Recycling
- High Efficiency Cooling

Save 50% to 60% on your operating costs

Burning Biomass?

- Wood Chips & Wood Pellets

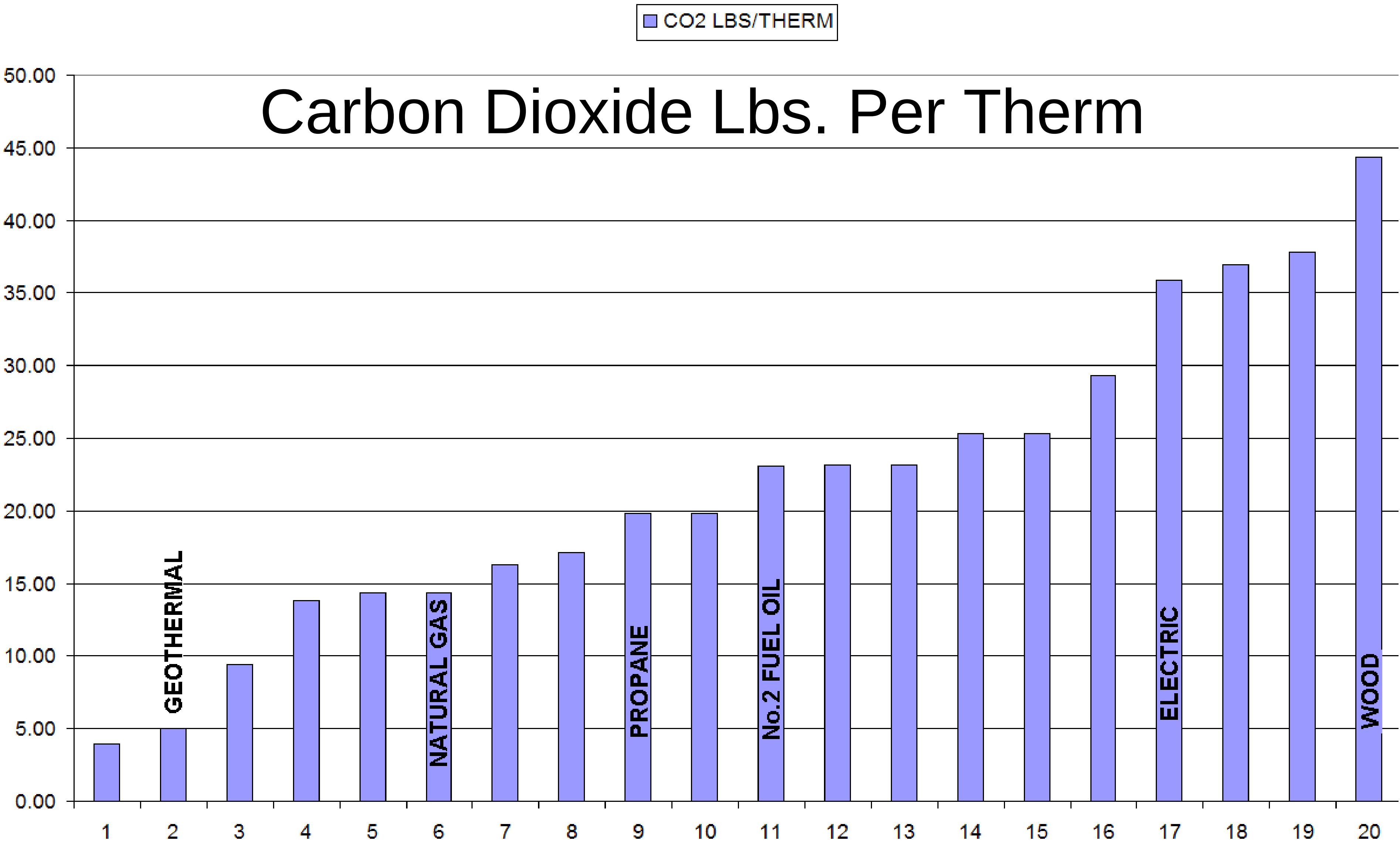
Likely Damp

Likely Dry

Great for low BTU/$ but still emits high CO2

Often has hidden higher maintenance costs

The Carbon Factor



Applications for the:

Near Frictionless Compressor

Near Frictionless Chiller

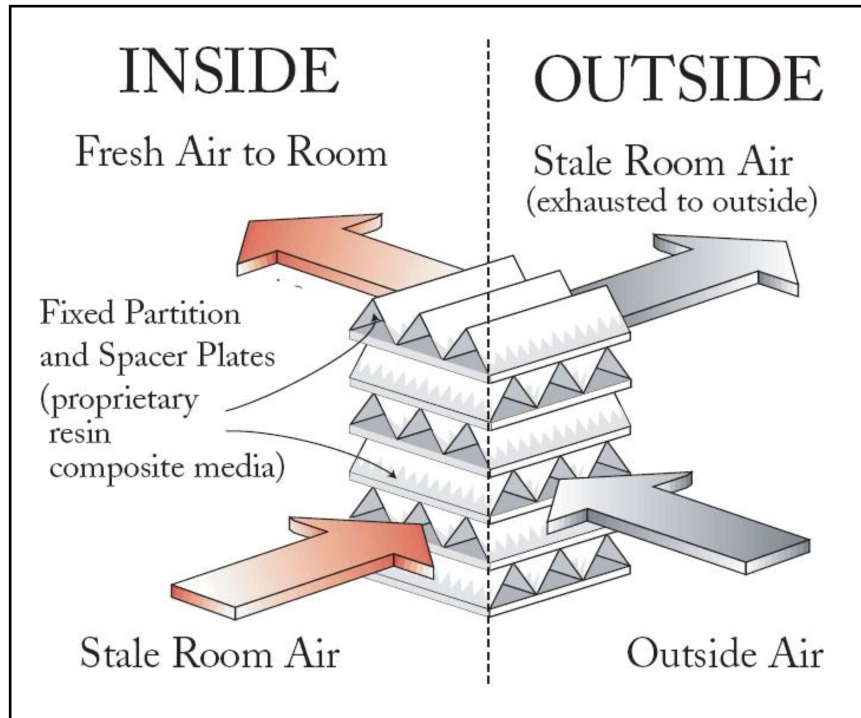
In New England Conditioning Outdoor Air Is Costly ($3-$5/Yr.CFM)

often up to 40% of your energy $

Nearly all of this energy can be recovered with the NFC using **Active Energy Recovery**

Ventilation Energy Recovery

- **Air to Air Energy Recovery Units**
  - **Heating or Cooling**
  - **50-70% efficient**
  - **Fixed Plate or Wheels**
  - **Do not over ventilate !**
  - **Check CO2**



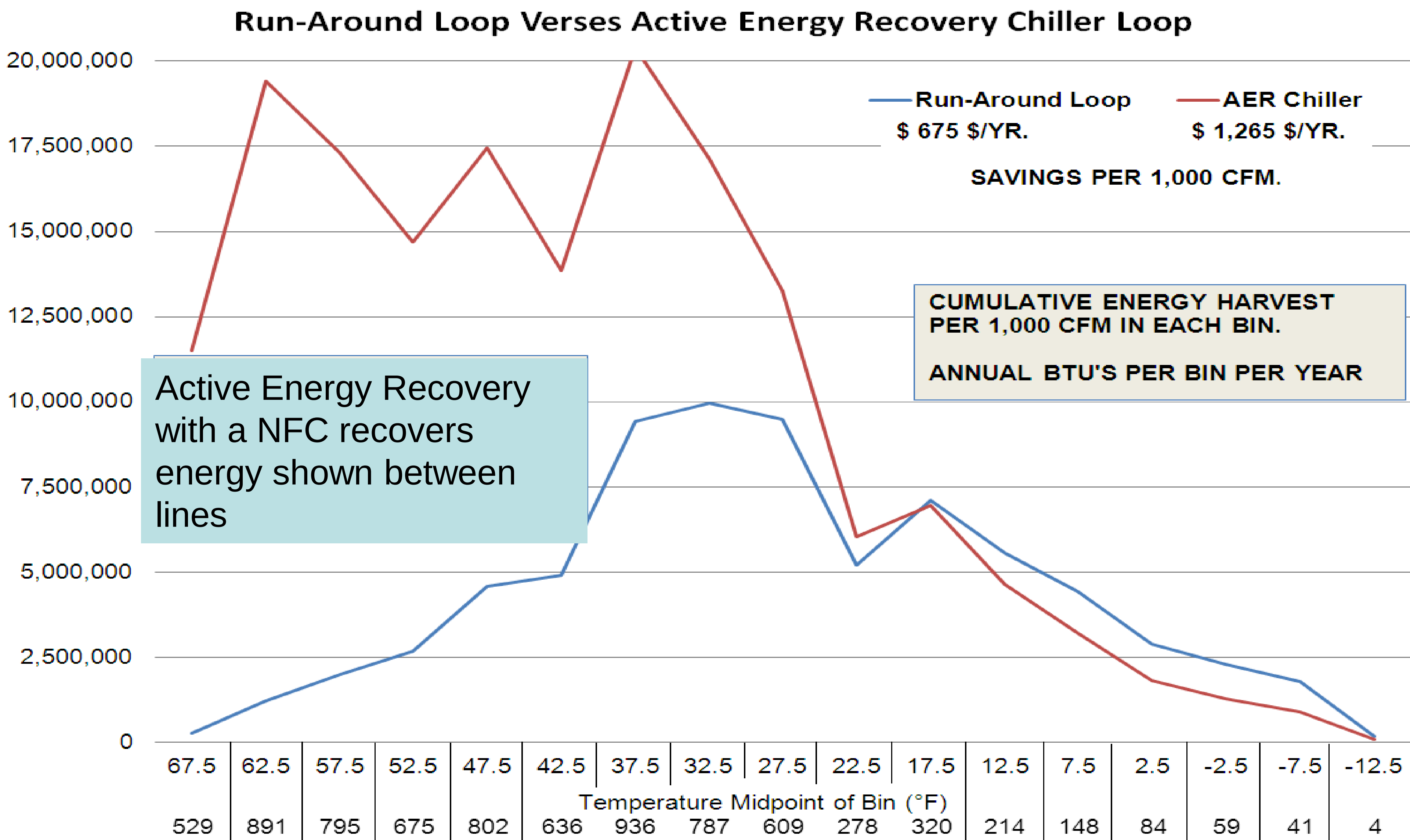
Courtesy Renewaire

Active Energy Recovery

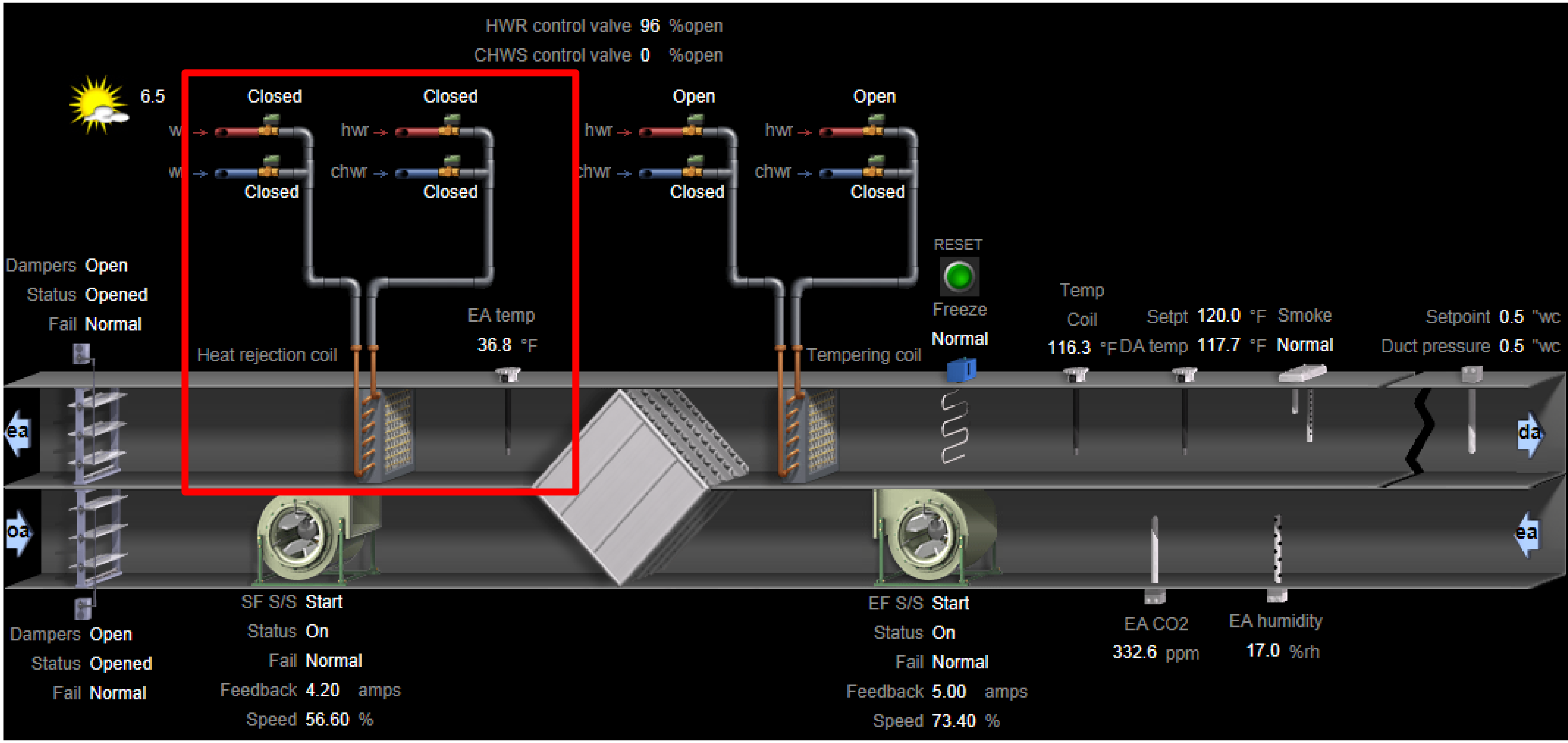
The 40°F chilled water created by the operation of the NFC can be used 24/7 to recover energy from any source warmer than the 40°F chilled water,

Other types of heat exchangers typically work efficiently when natural conditions create low temperatures for energy recovery, but many hours of potential energy recovery are missed when temperatures are more moderate.

More Energy Recovery with a NFC – Active Energy Recovery



Multi Source Geo = More Energy Recovery



D.O.A.S. fresh air unit with secondary “dual purpose” energy recovery coil and heat rejection coil.

Recovers more energy in mild weather when heat exchangers are less efficient

Multi-Source Geo-Exchange

Applications for the:

Near Frictionless Compressor

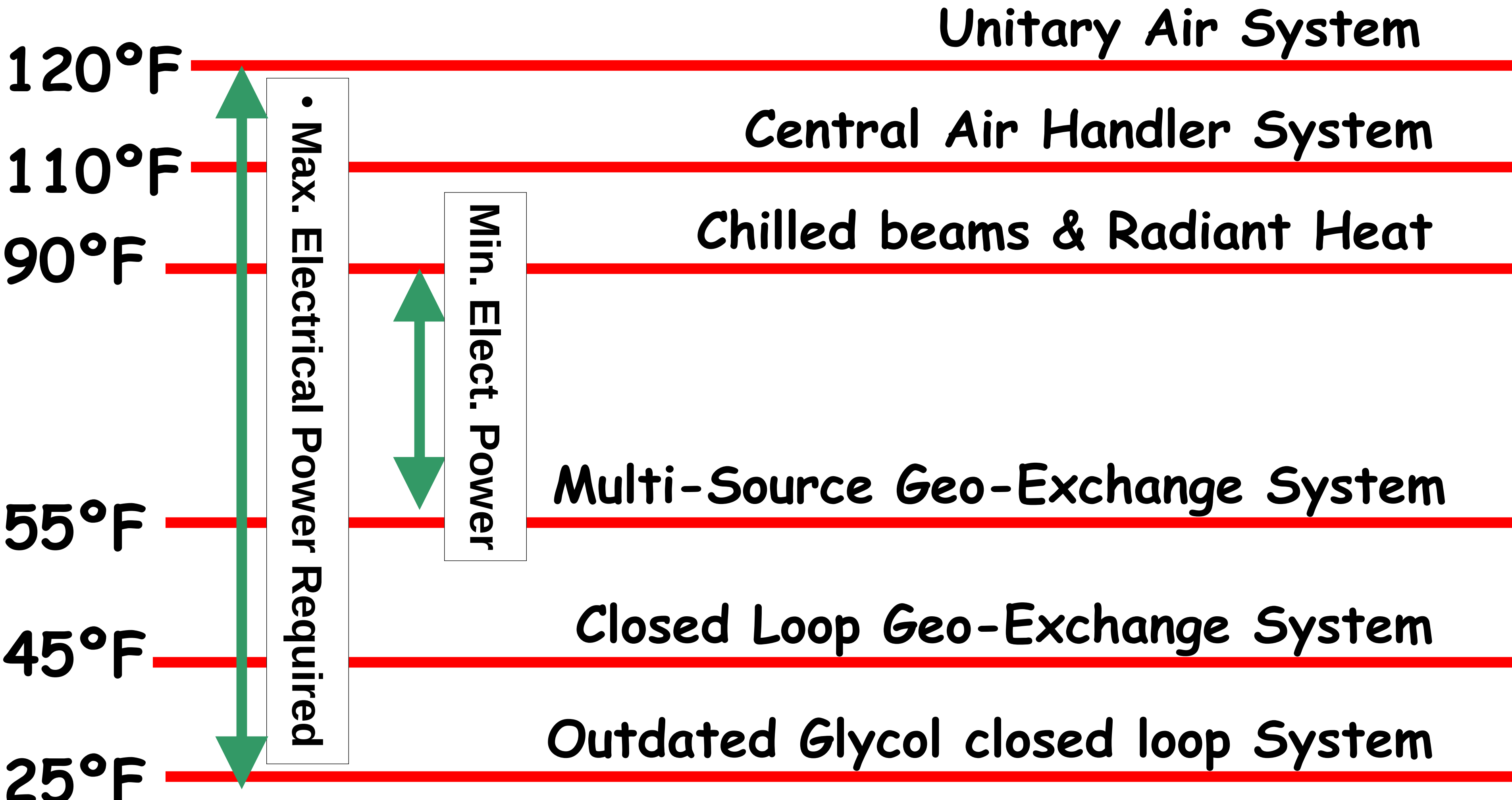
Near Frictionless Chiller

What energy stream are your throwing away that a <u>NFC</u> could recover?

- **Exhaust Air:** 70°F
- **Waste Water:** 100°F
- **Thermal Solar:** 55°F to 80°F?

  By using solar panels as "source energy" when they are too cold to be effective making DHW

Source & Load Temperatures & System Design Variations



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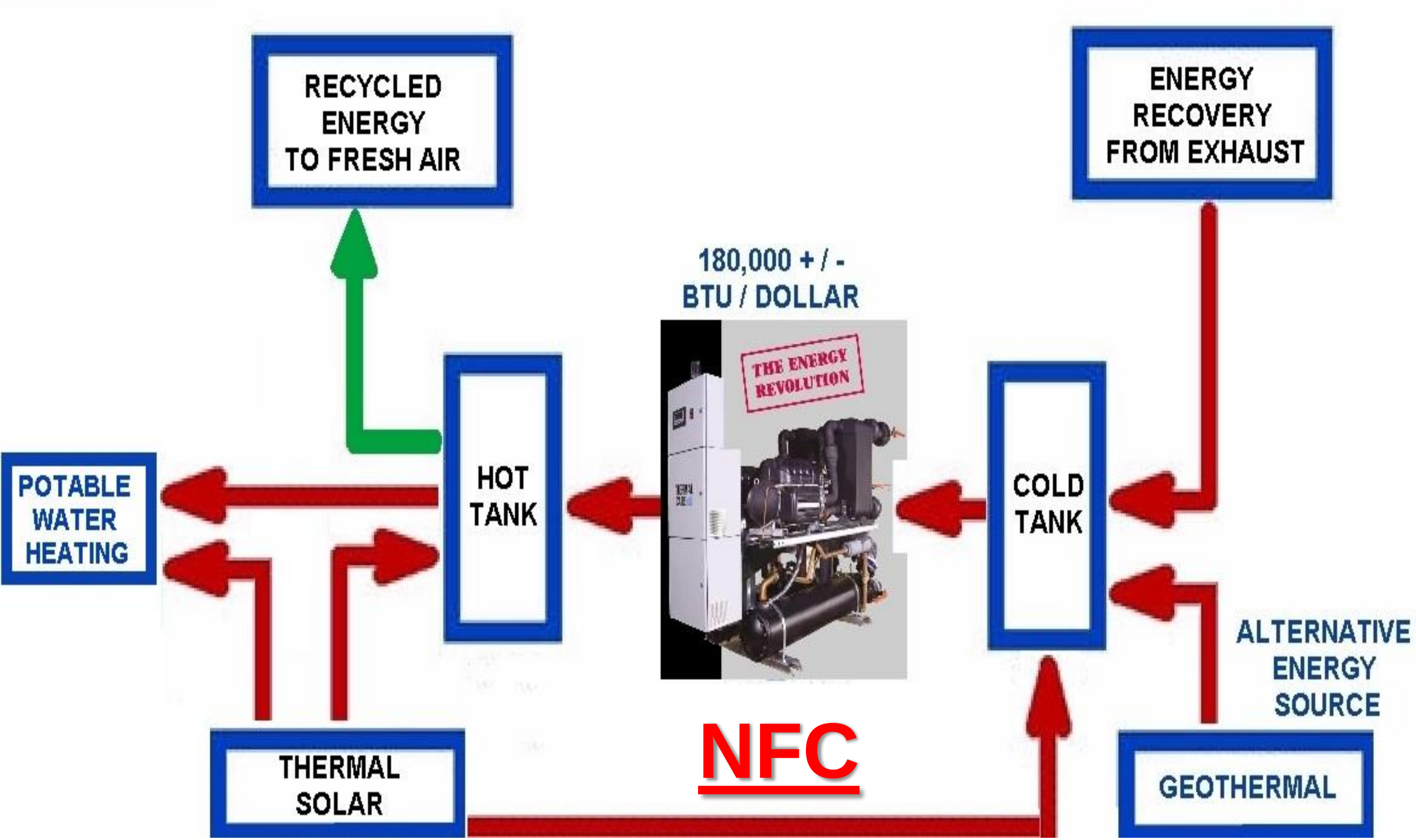
Multi-Source NFC Concepts

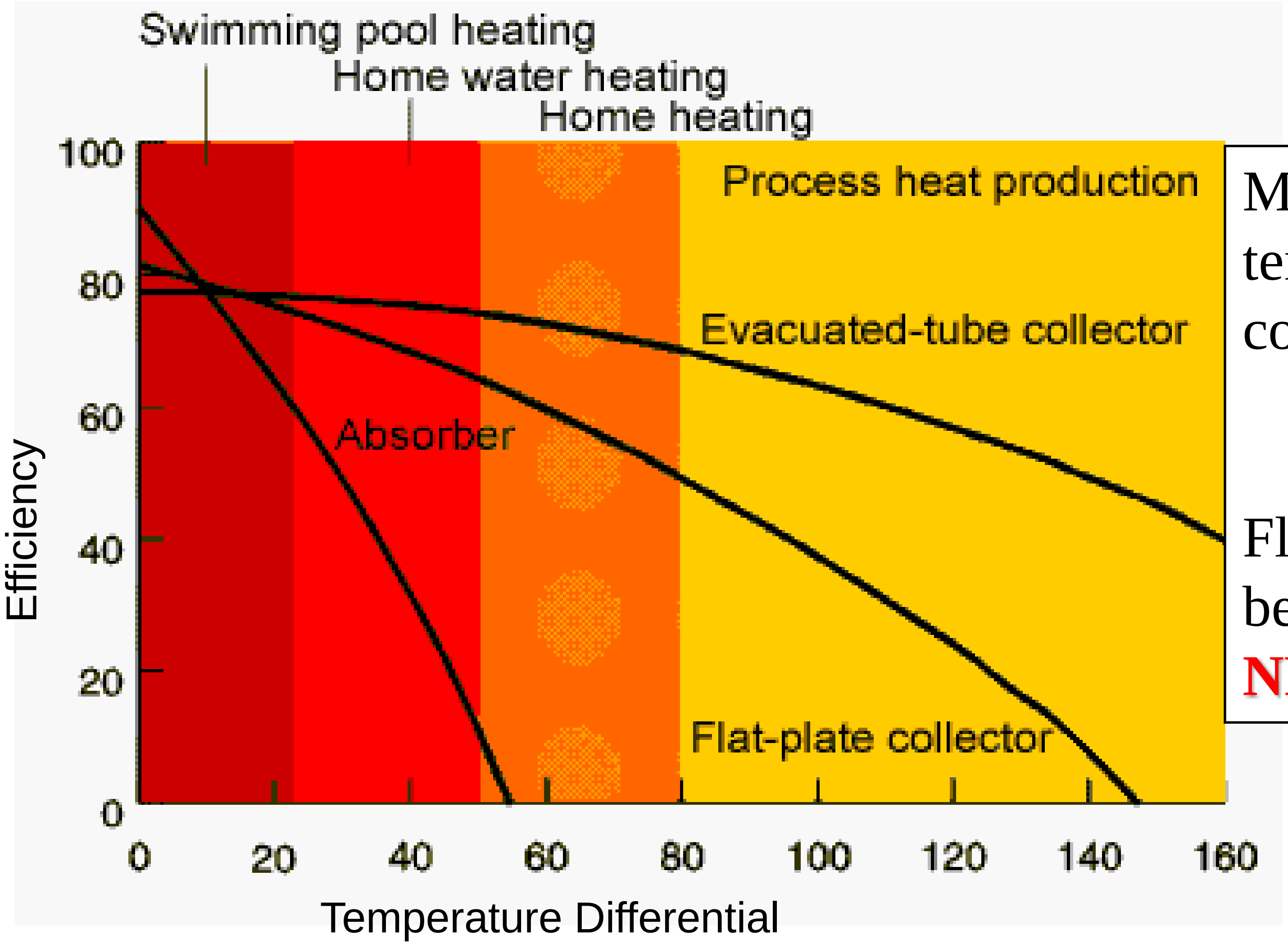


Solar Hot Water Heating System

NFCs' can quadruple the operating hours of thermal solar panels in the winter

Drain back solar panels provide direct solar heat AND can switch to use 40°F NFC chilled water for multi source geo-exchange when DHW is not being produced.

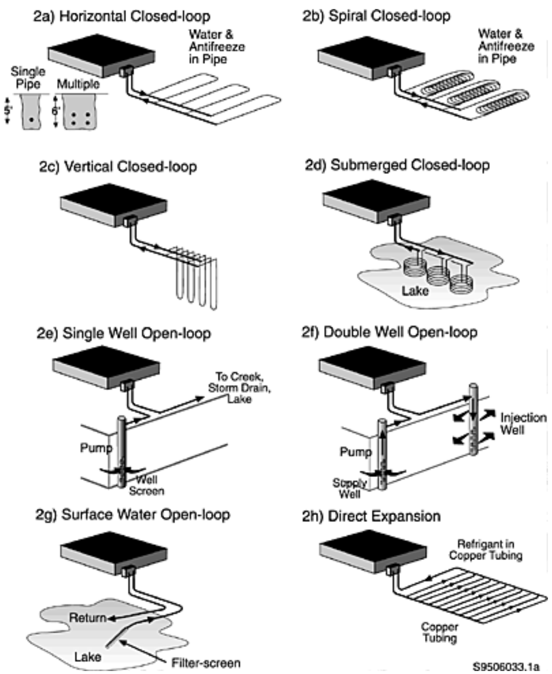
Selecting Solar Collector Type



Match operating temperature to collector type.

Flat plate type best for use with **NFC**s'

Geo-Exchange Design with NFCs'



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New Geo-Exchange Methods:

1. **Under-slab Horizontal**
2. **Thermally enhanced HDPE (GPX)**
3. **Increased surface area:**
   a. 4"x2" Concentric w/ GPX

   b. Twister 4 ¾" U-Tube

Blake Equipment Co.: Jeff Harrison

Horizontal Grid & Header

GeoPerformX Tubes

30 $\frac{3}{4}$" tubes

150' long

9" O.C.

4500' total

760' per ton

Under slab geo-exchange bed installed inside the building foundation requires less area where the field is shielded from radiational cooling to space,

640' per ton

Enhanced Thermal Conductivity

Versa Profiles

Enhanced thermal conductivity GeoPerformX pipe can reduce the required borehole length for a geo-exchange field by 10% TO 25%.

The pipe has a greater advantage in buildings that cool by day and heat by night. "put and take" Geo-Exchange

Horizontal Header & Grid Bed

Spacer made of 2x4's with holes driller 9" O.C. then ripped down middle to make a "comb" type spacer easily applied.

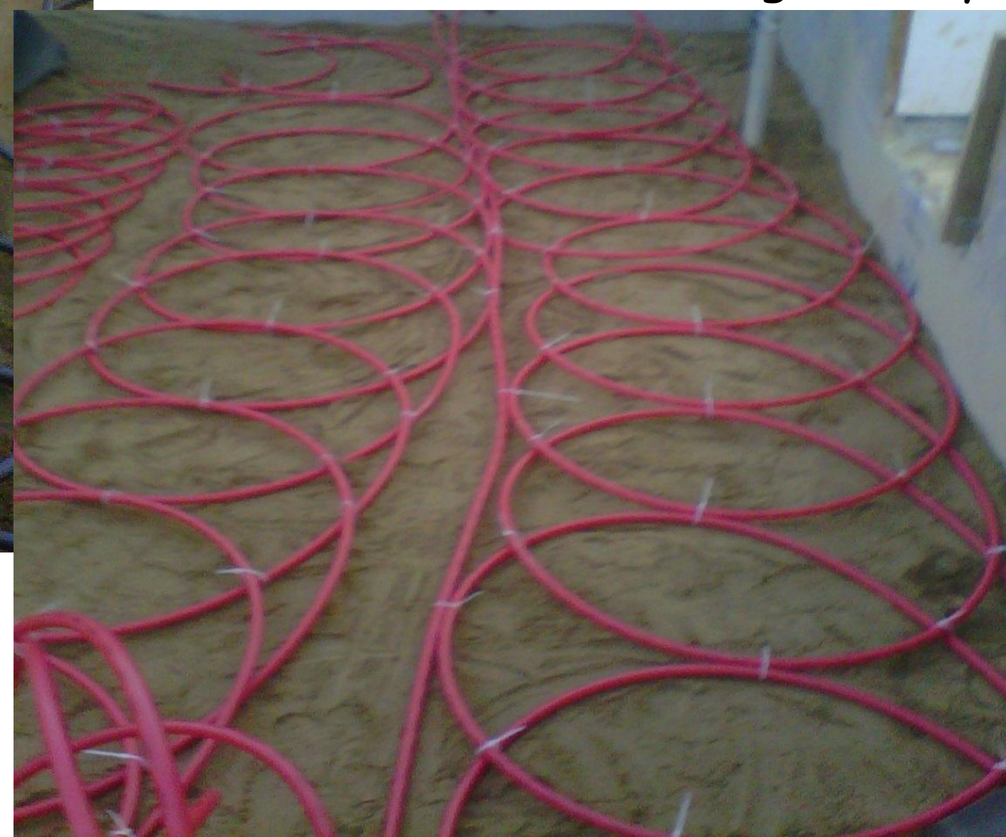
Total bed = 96 300' long $\frac{3}{4}$" GeoperformX Tubes

Total bed = 32 150' long $\frac{3}{4}$" GeoperformX Tubes

Under slab Horizontal Hybrid Thermal Solar – Geo-Exchange

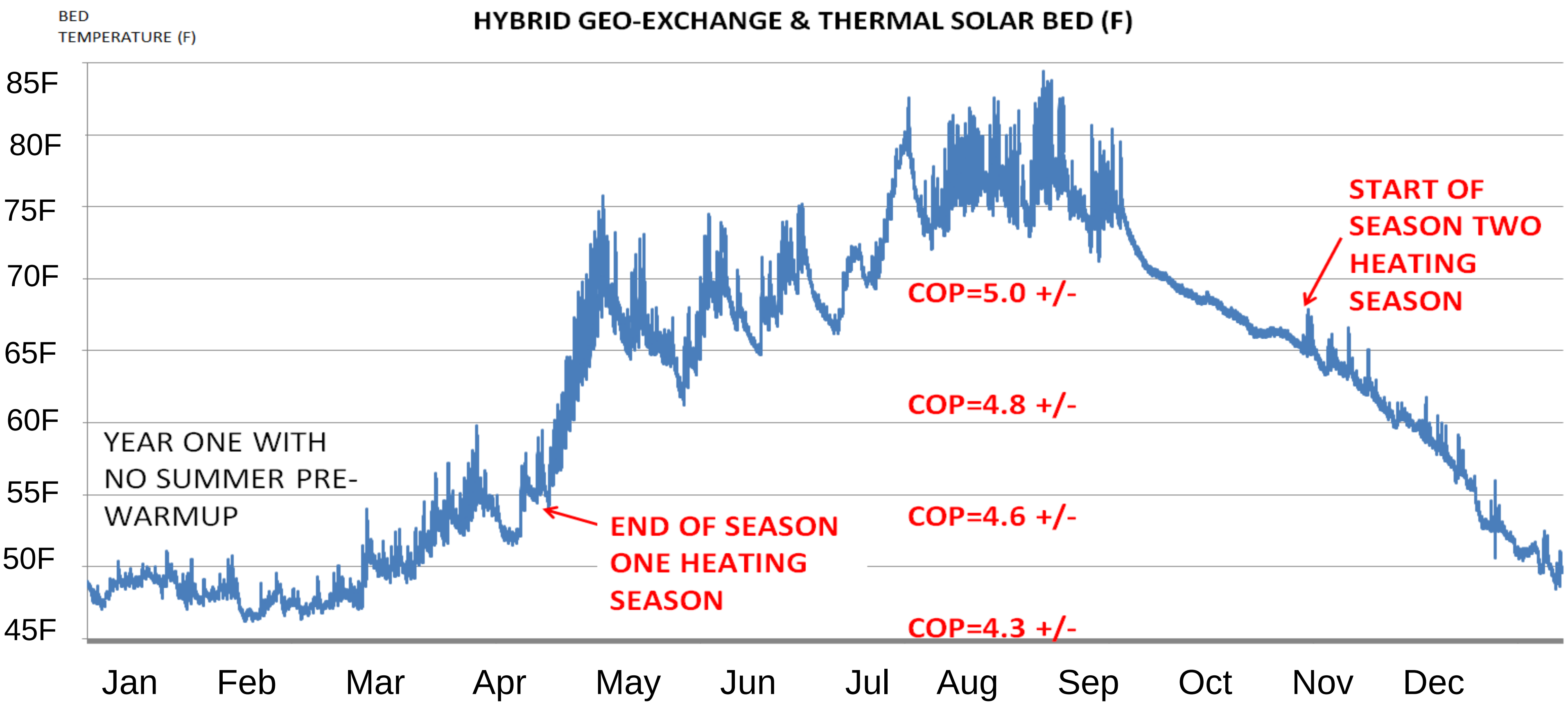
Enhanced thermal conductivity GeoPerformX tube to extract heat

A layer of PEX tubing to store thermal solar heat in the same area as the Geo-exchange Slinky



Hybrid Geo Ground Temperature

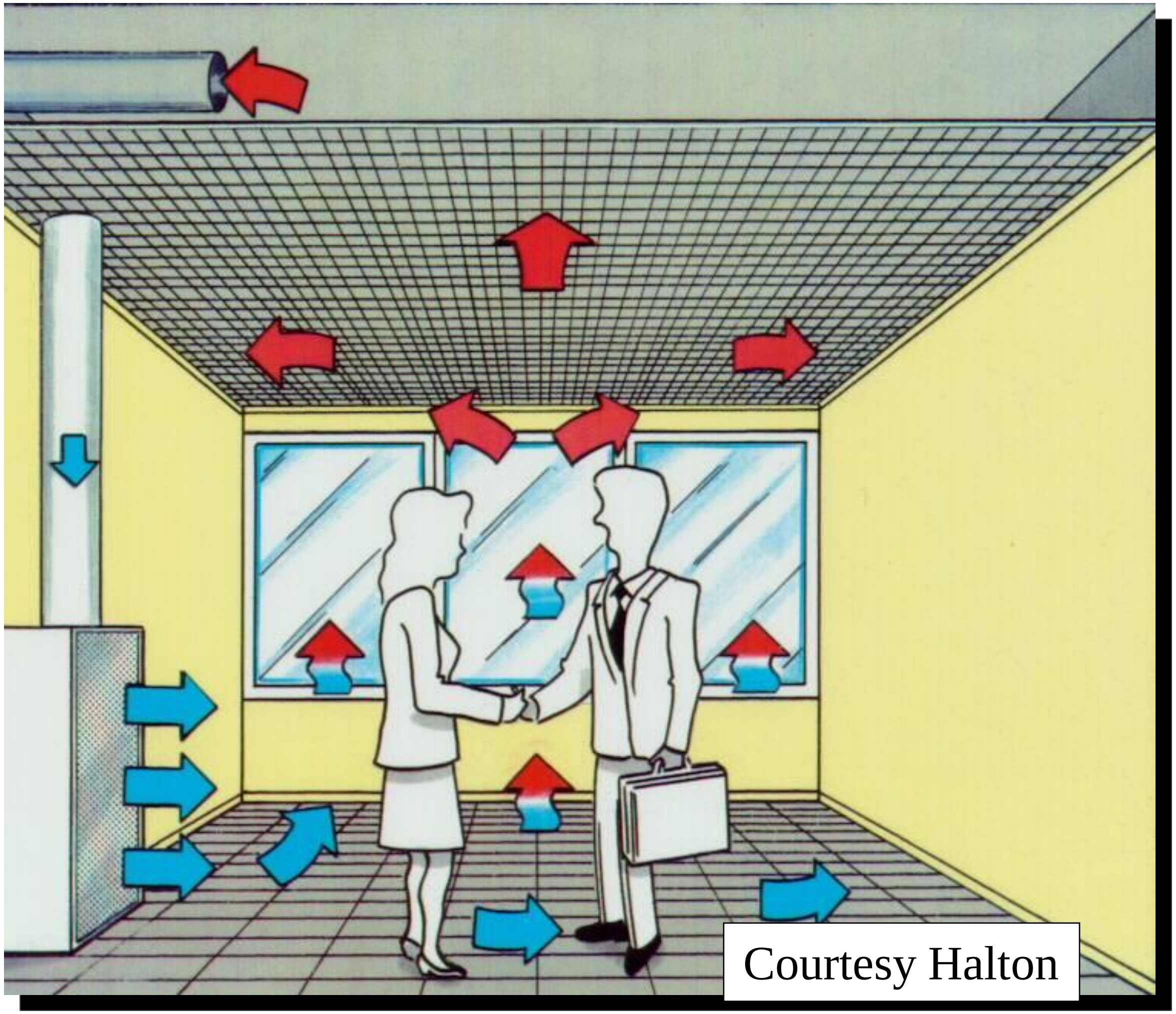
Traditional GSHP designs result in COP's from a low of about 2.8 to a high of about 3.6 compared to this hybrid design with COP's of 4.4 to 5.0, reducing operating KWH by about half, making net zero attainable.



Using a Near Frictionless Compressor can about double these COPs' from a system with "box" compressors

Displacement Ventilation
(cooling energy saving, less pollutants)

Uses lower temperature heating air, well suited for <u>NFC</u> application



High Efficiency Cooling & Drying

Use a NFC to recycle energy from dehumidification systems and other cooling zones to locations where heating is needed.

Case Studies

Using The Danfoss Turbocor
Near Frictionless Compressor

The Community Music School of Springfield, MA

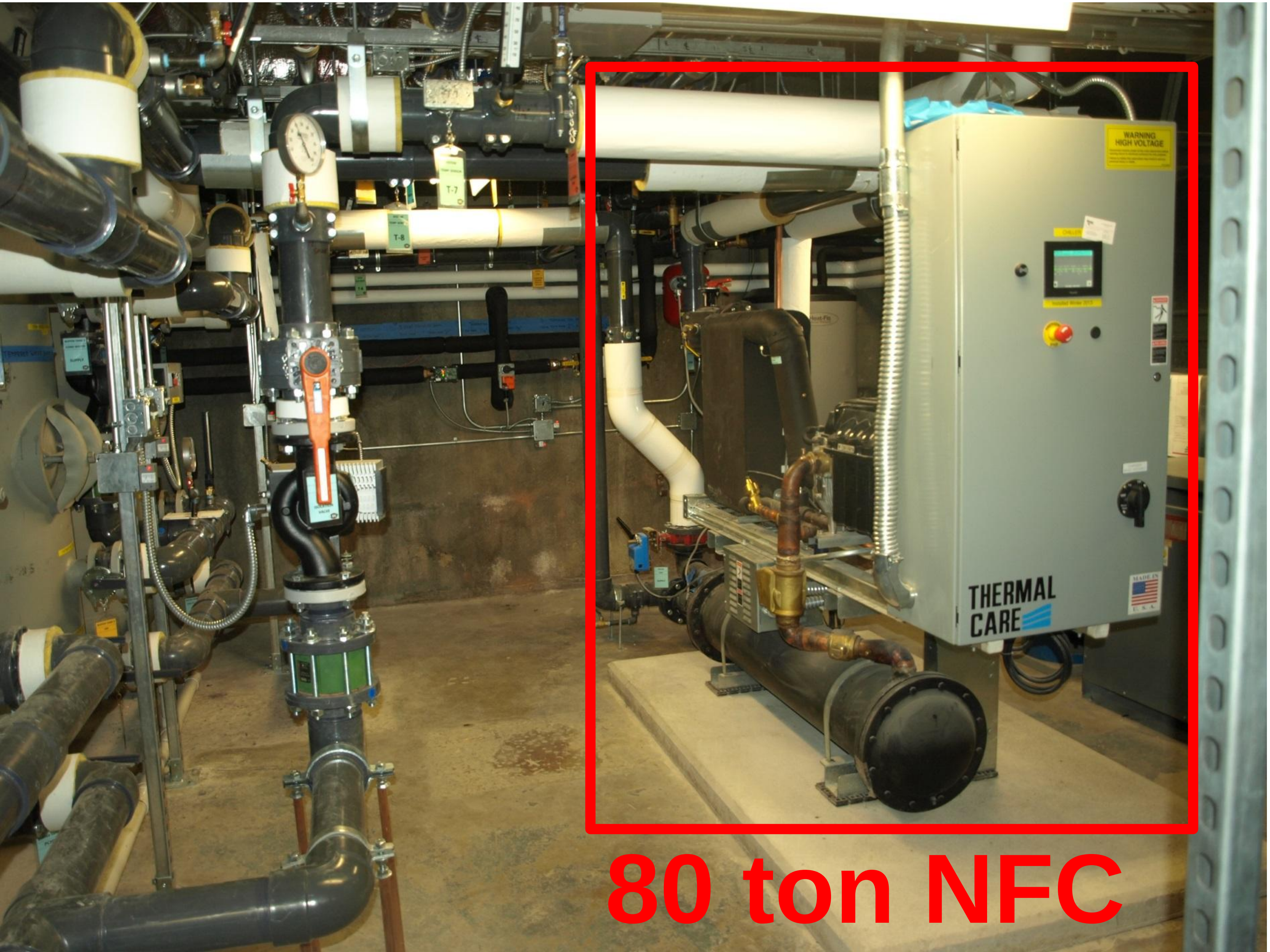
Reduced Energy Use by 55%

A projected geo-exchange borefield of **27**, 500' HDPE U-Tubes was replaced with a design of **6**, 1,100' deep concentric GeoperformX® borehole heat exchangers

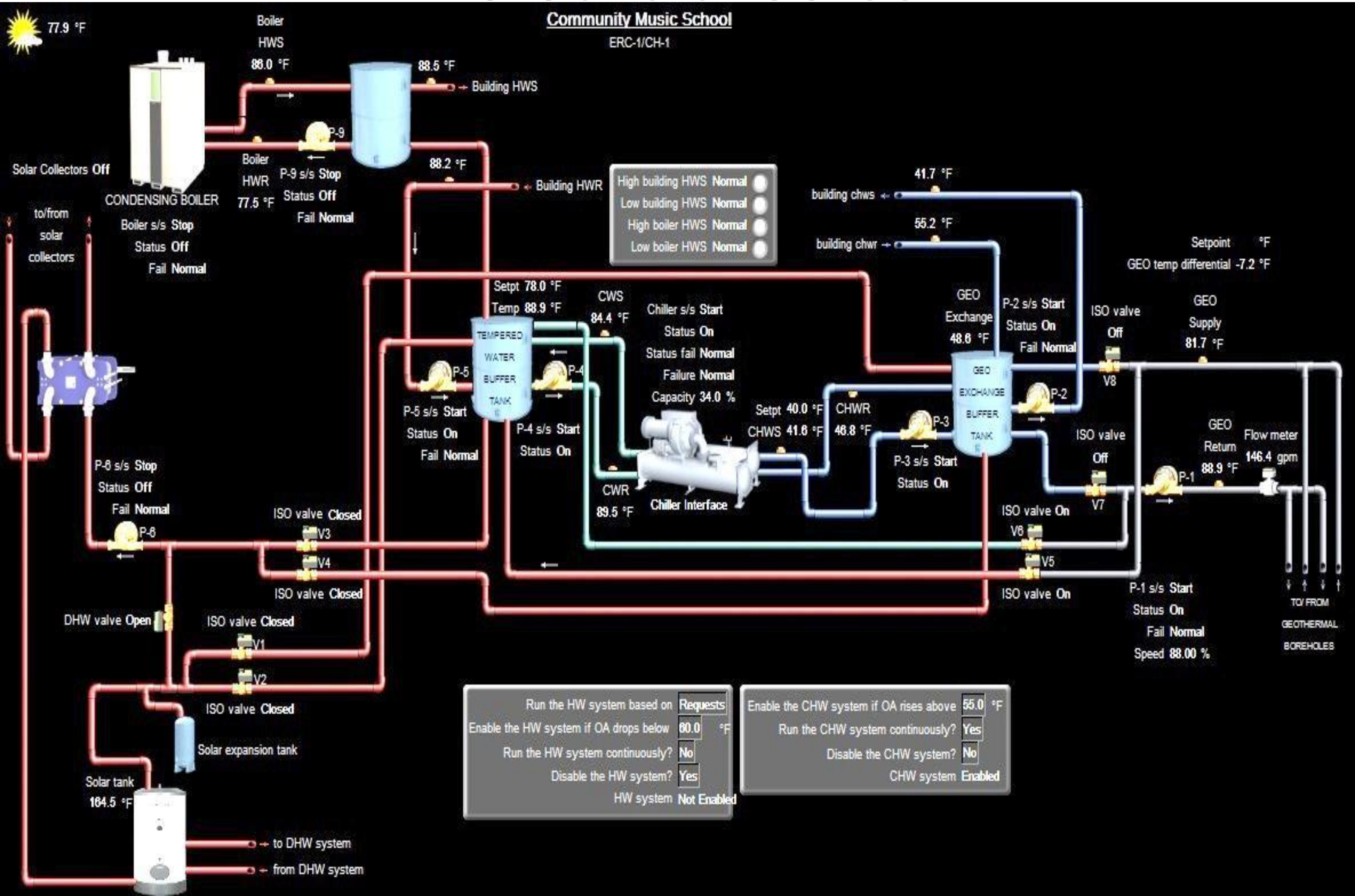
6 borehole heat-exchangers located in side alley

Graphic Courtesy of Jeffrey. J. Harrison, PE ,The Blake Group

Community Music School of Springfield



CMSS Solar-Geo Hybrid Energy System DDC Control Screen



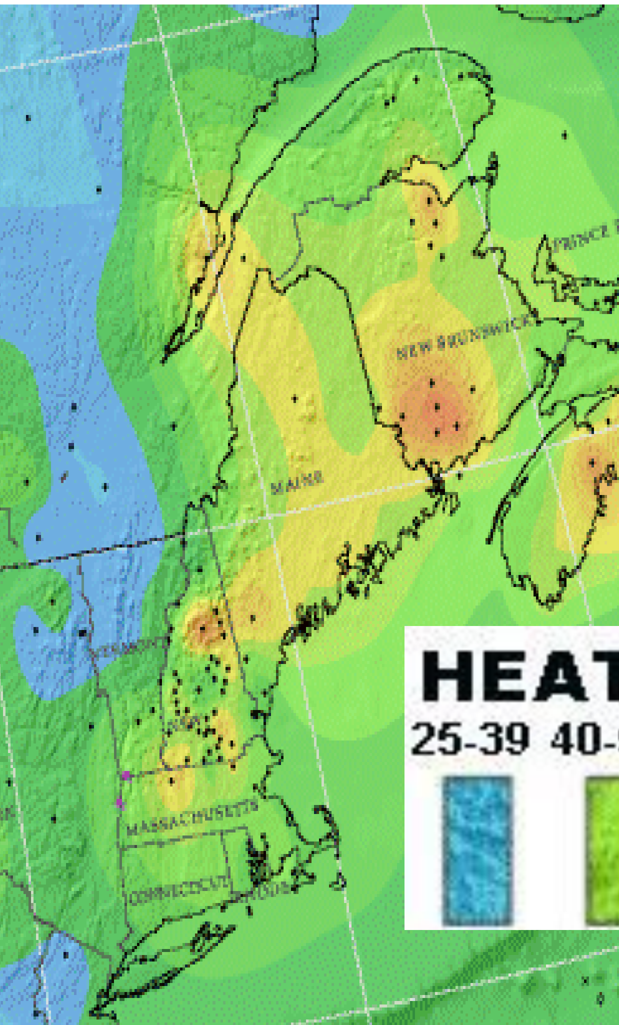
Community Music School of Springfield

Panels operate 400% more hours for multi-source operation than for DHW alone

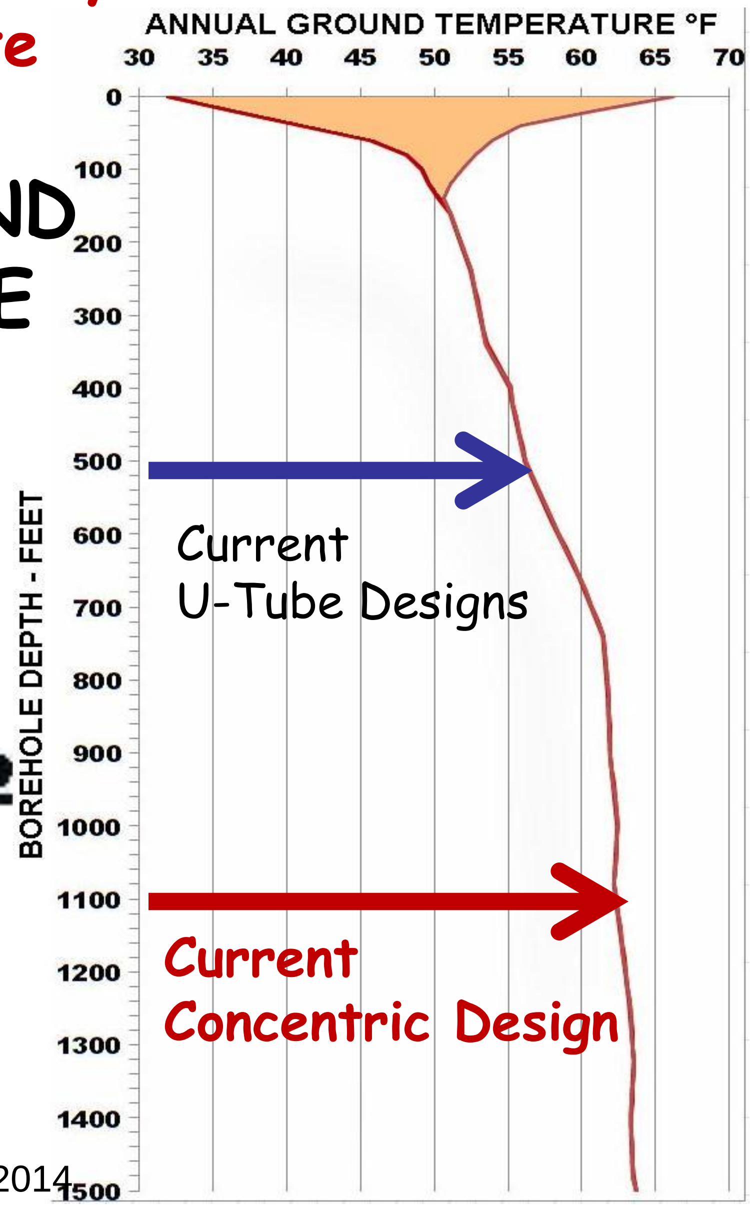
18 4’x10’ drain back solar panels provide direct solar heat or use 40°F chilled water for multi source geo-exchange

Concentric Borehole @ 1,100'Depth

Deeper boreholes produce higher quality energy with a faster recovery rate



NEW-ENGLAND TEMPERATURE GRADIENT AVERAGES ABOUT .9°F/100'



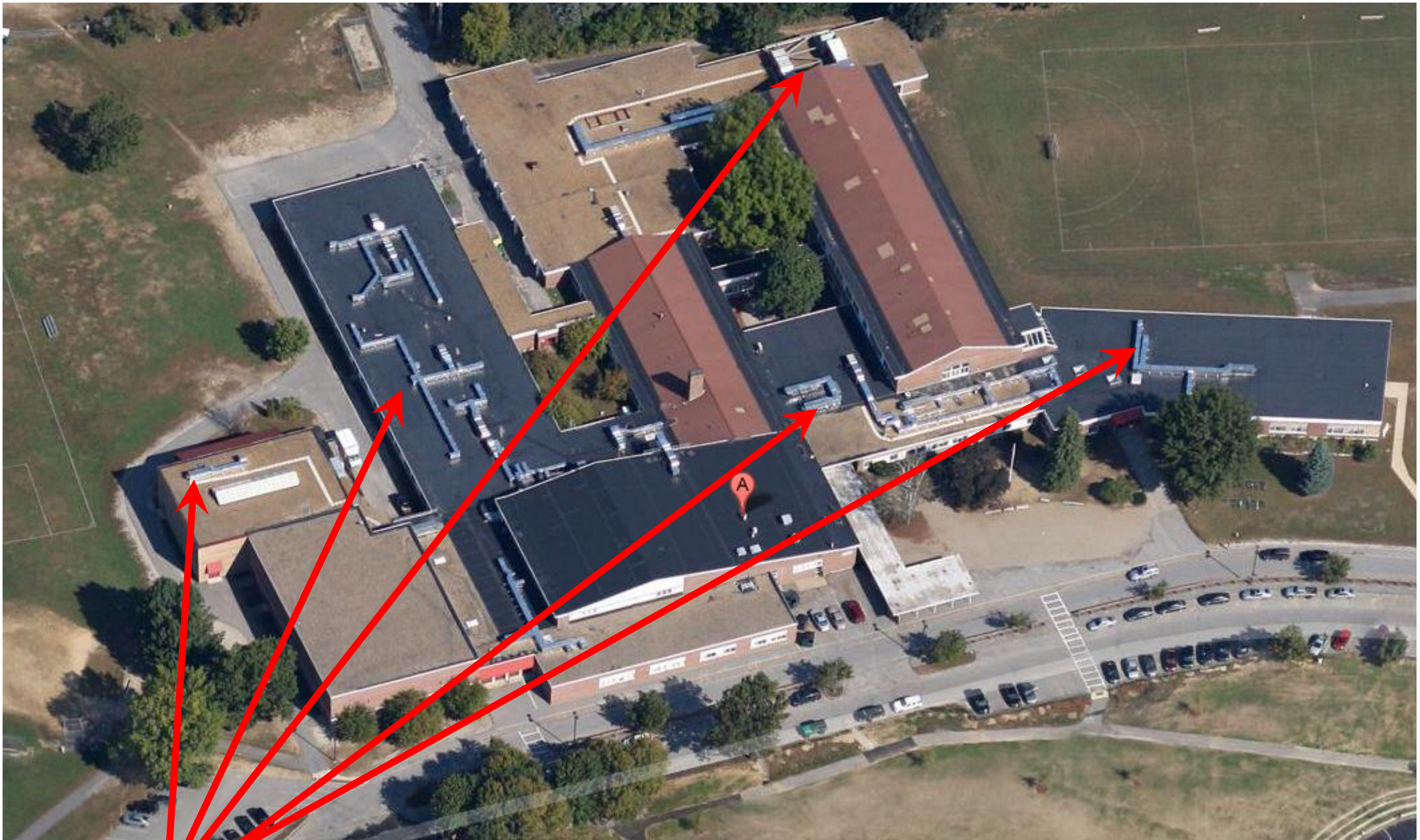
The Community Music School of Springfield, MA

Existing Energy used compared to a computer simulation of alternative energy harvested and purchased energy, 33,000 SQ-Ft Office Building								
A/C Loads	**Existing Energy**		**Calculated Base Case Distributed Heat Pumps**		**Hybrid Solar / Geothermal New Conditions Energy**		**Hybrid % Savings**	
Peak Energy	67,237	KWH	55,131	KWH	22,888	KWH	**66%**	
Off Peak Energy	1,492	KWH	988	KWH	587	KWH	**61%**	
Fuel Gas, Heating								
Peak Energy	19,512	Therms	14,634	Therms	1,836	Therms	**91%**	
Off Peak Energy	11,195	Therms	8,396	Therms	1,203	Therms	**89%**	
Peak Energy			141,462	KWH	54,363	KWH		
Off Peak Energy			81,164	KWH	31,147	KWH		
Solar Energy Used								
Peak Energy	0	Therms	0	Therms	1,920	Therms	**56223**	KWH
Off Peak Energy	0	Therms	0	Therms	659	Therms	**19297**	KWH
Geothermal Energy Used								
Peak Energy	0	Therms	0	Therms	16,911	Therms	**495198**	KWH
Off Peak Energy	0	Therms	0	Therms	9,650	Therms	**282577**	KWH
Recycled Energy Used								
Peak Energy	0	Therms	6	Therms	6	Therms	**163**	KWH
Off Peak Energy	0	Therms	0	Therms	0	Therms	**0**	KWH
All sources Heat Therms	30,707	Therms	23,030	Therms	32,185	Therms		
KWH converted to Therms	2347		9519		3722			
Total all energy in Therms	33,054		32,549		35,906			
Purchased Energy in Therms	33,054		32,549		6,761		**80%**	

Overall reduction in KBTU/SF/Yr

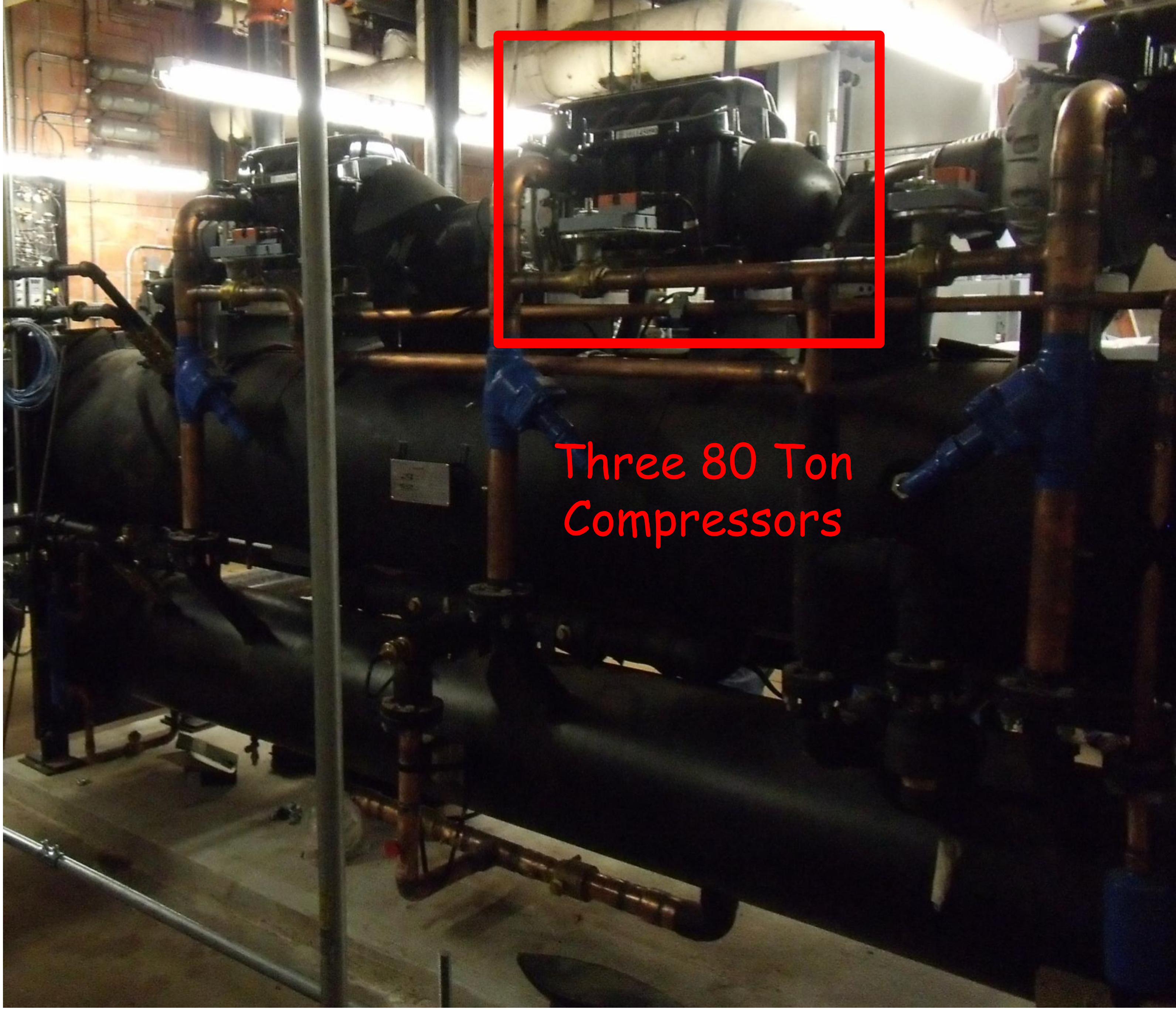
The Rundlett Middle School, Concord NH

Reduced Ventilation Energy, Saving $62,600/Yr.



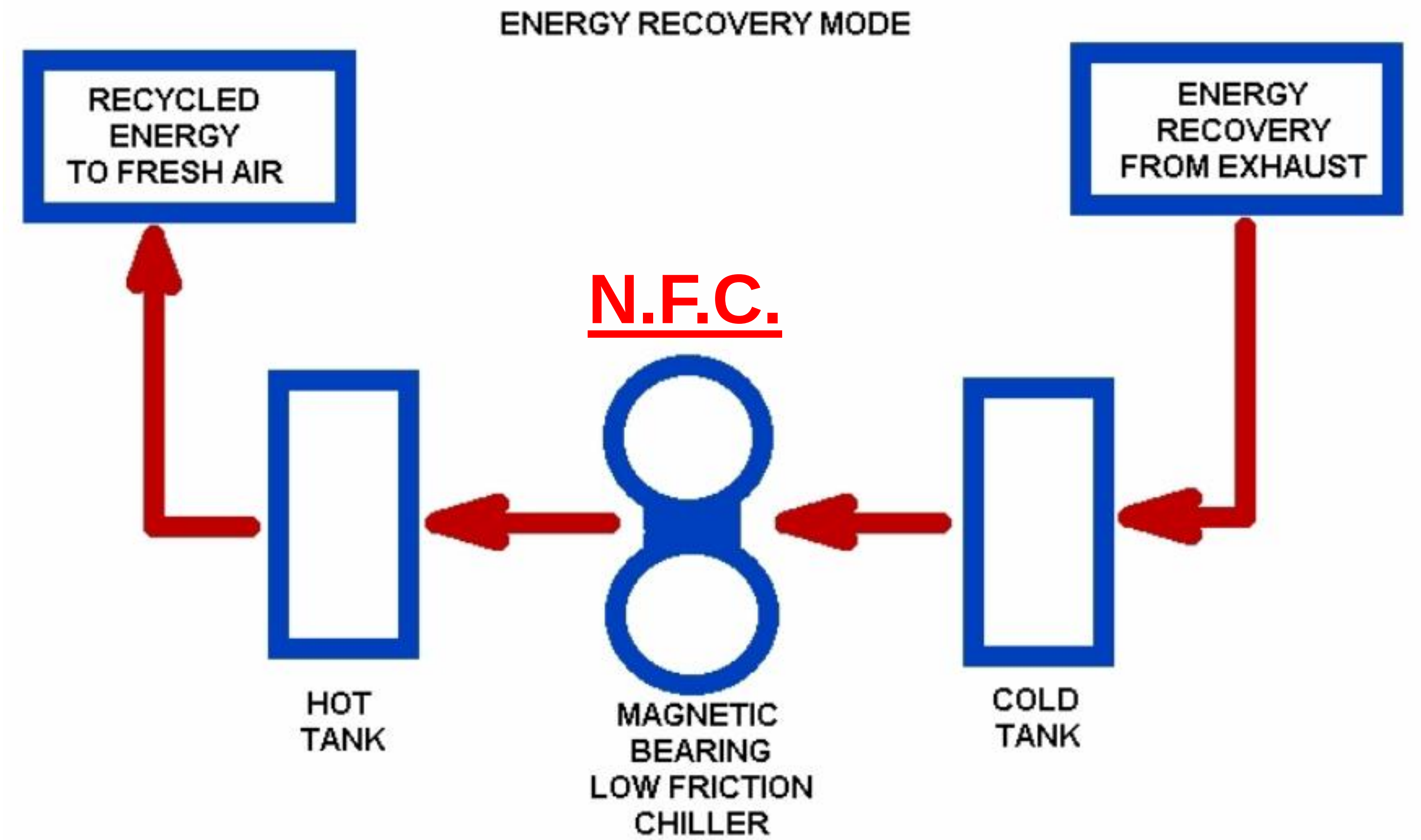
Retrofit the full building with
Active Energy Recovery ventilation systems

Rundlett Middle School 240 ton Smardt N.F.C. used for active energy recovery



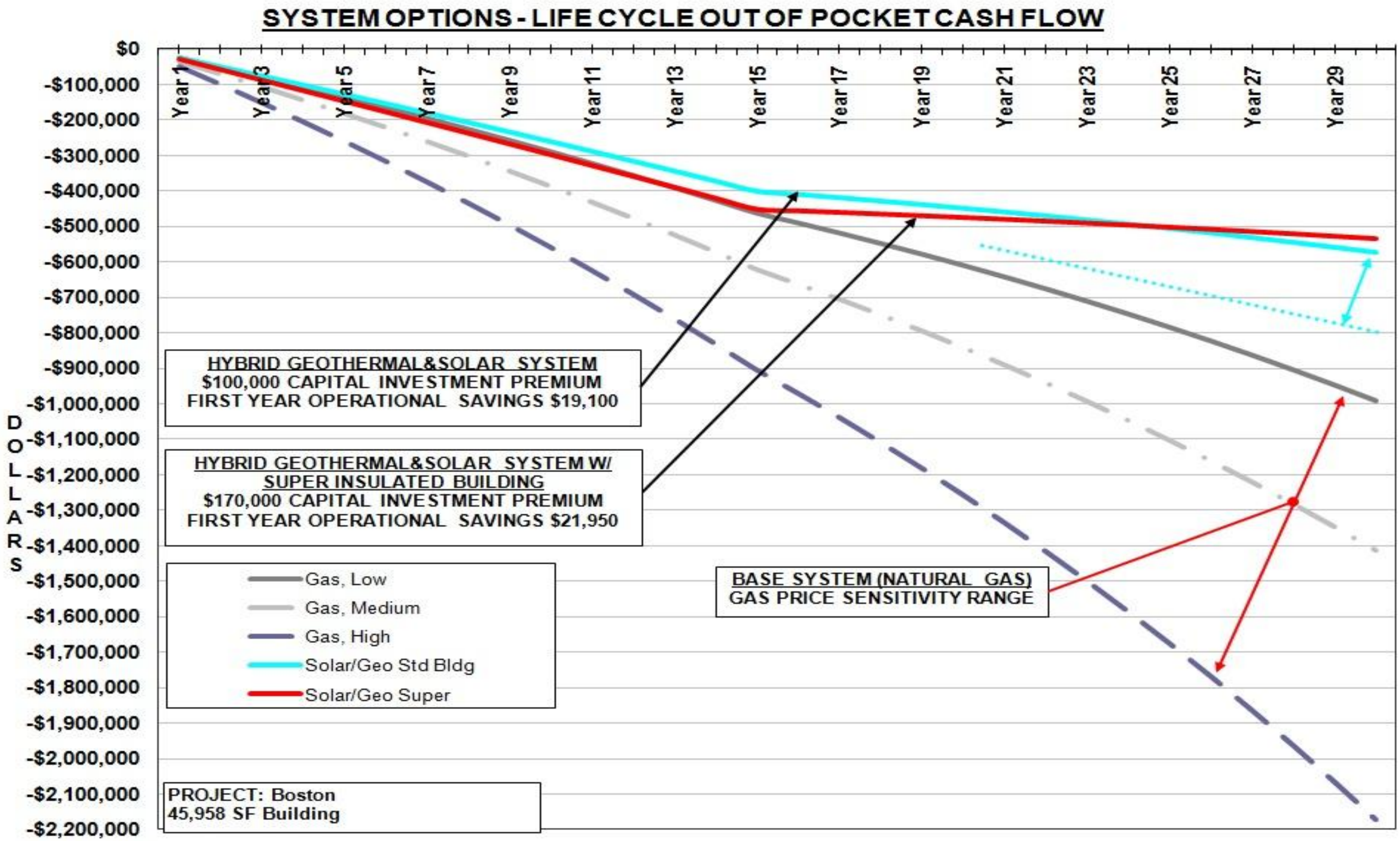
Rundlett Active Energy Recovey

For a retrofit where a DOAS is not pratical, installing multiple coils for active energy recovery can make a lot of sense



Calculating Energy Recovery Economics

Fuel Cost Sensitivity



Questions ……..

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Thank You