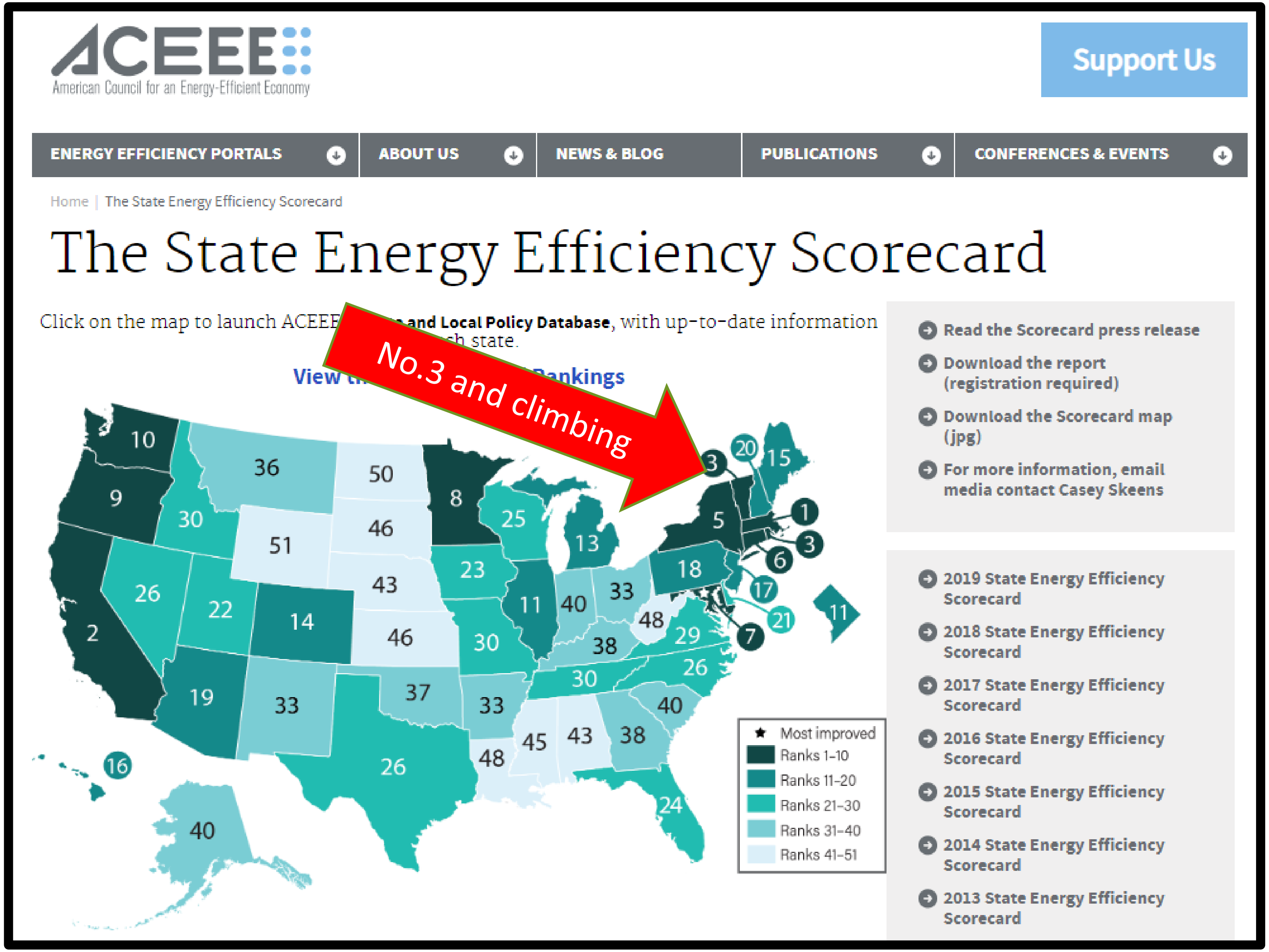
Efficiency Vermont
BETTER BUILDINGS BY DESIGN

Mechanical System

Deep and Holistic Energy Applications

Energy Conservation AND Energy Efficiency

Thomas H. (Tom) Durkin, PE
ASHRAE Fellow
thdurkin46@gmail.com
(317) 402-2292



Congrats!

E^4

Energy
Efficiency
Efforts are
Effective.


It’s not easy being green.
KERMIT THE FROG
PHOTO BY CSMACLAREN

Tom Friedman

3-time Pulitzer Prize Winner, talking about politicians who refuse to accept climate science.

From her speech at the U.N. Climate Action Summit, September 2019

"For more than 30 years, the science has been crystal clear. How dare you continue to look away and come here saying that you're doing enough, when the politics and solutions needed are still nowhere in sight…”

My background…

Registered Professional Engineer

18 years as a facilities/maintenance engineer and plant operator

35 years as a design engineer

LEED Accredited Professional

Licensed Boiler Inspector

Certified Energy Auditor

ASHRAE Fellow

Awards

1997, 98	Consulting Engineers of Indiana *Grand Project Award*
1998, 99	American Consulting Engineers Council *Honor Award*
1999, 2010	Governor's Pollution Prevention Award - Indiana
2002	Governor's Energy Efficiency Award - Ohio
2007	PM Magazine Design Excellence Award
2009, 2013	ASHRAE Technology Award
2012	Election to ASHRAE College of Fellows
2016	Association of Energy Engineers 2016 Achievement Award

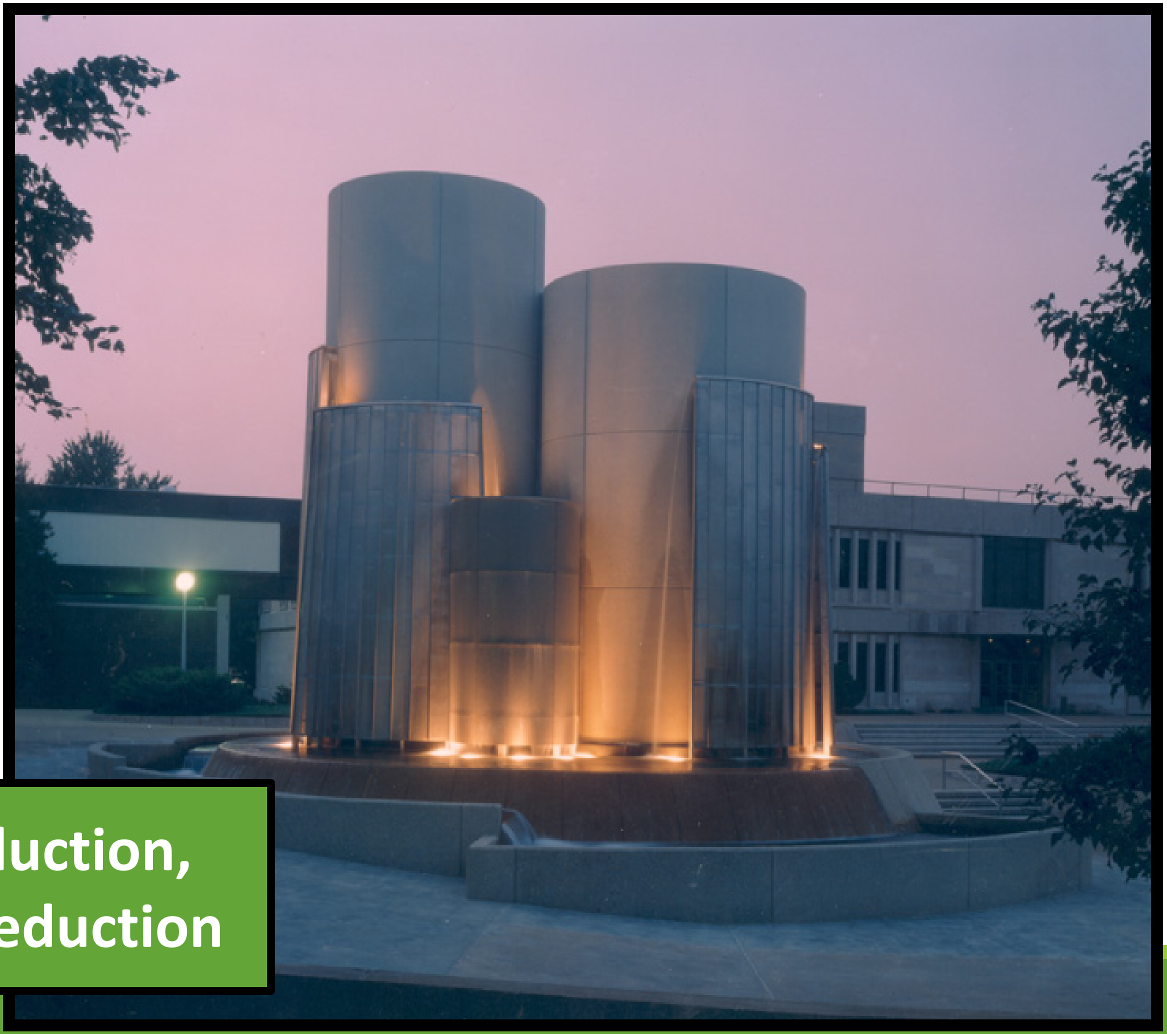
17 articles about HVAC innovations

Co-author of
HVAC Pump Handbook, Rev. 2

My Engineering philosophy

Our clients are our partners, and we are stewards of their resources.

- Up-to-date, high-performance technology, judiciously applied.
- Environmentally-friendly, energy-efficient design.
- Affordable solutions that are less expensive to build.
- Simpler solutions that are easier to operate and maintain.
- On-going relationships that our clients can trust.



60% energy reduction, 95% water use reduction

A Healthy and Effective Indoor Environment

Never Compromise

- Indoor air quality
- Occupant comfort
- Humidity control

The Quest…

Systems that do all the above and are

Less expensive to build

Less expensive to operate, and

Easier to maintain

Energy Conservation and **Energy Efficiency**

Gas and Electric Rates

Burlington Electric Co

LARGE GENERAL SERVICE (LG)

Energy usage over 3,000 kWh per month for three consecutive months in the last 12 mon

Customer Charge <= 25 KW	$13.68
Customer Charge > 25 KW	$41.04
Energy (kWh)	$0.083003 per kWh
Demand (kW)	$20.03
EEC (LG)	$0.00512/kWh + $1.3115/kW
EEC (L2, >=1000 kW Demand)	$0.00361/kWh + $1.4185/kW
Vermont Sales Tax	6.0%
City Franchise Fee	3.5% (exclusive of Vermont Sales Tax)
Local Option Sales Tax	1.0%

Vermont Gas Co.

Type	Current Rates
Daily Access Charge (per day)	$3.8388
Natural Gas Charge (per CCF)	$0.3891
Distribution Charge (per CCF)	$0.3697
Energy Efficiency (per CCF)	$0.0354
Assistance Program Fee *	$1.05

Definitions

(not found in the Fundamentals Handbook)

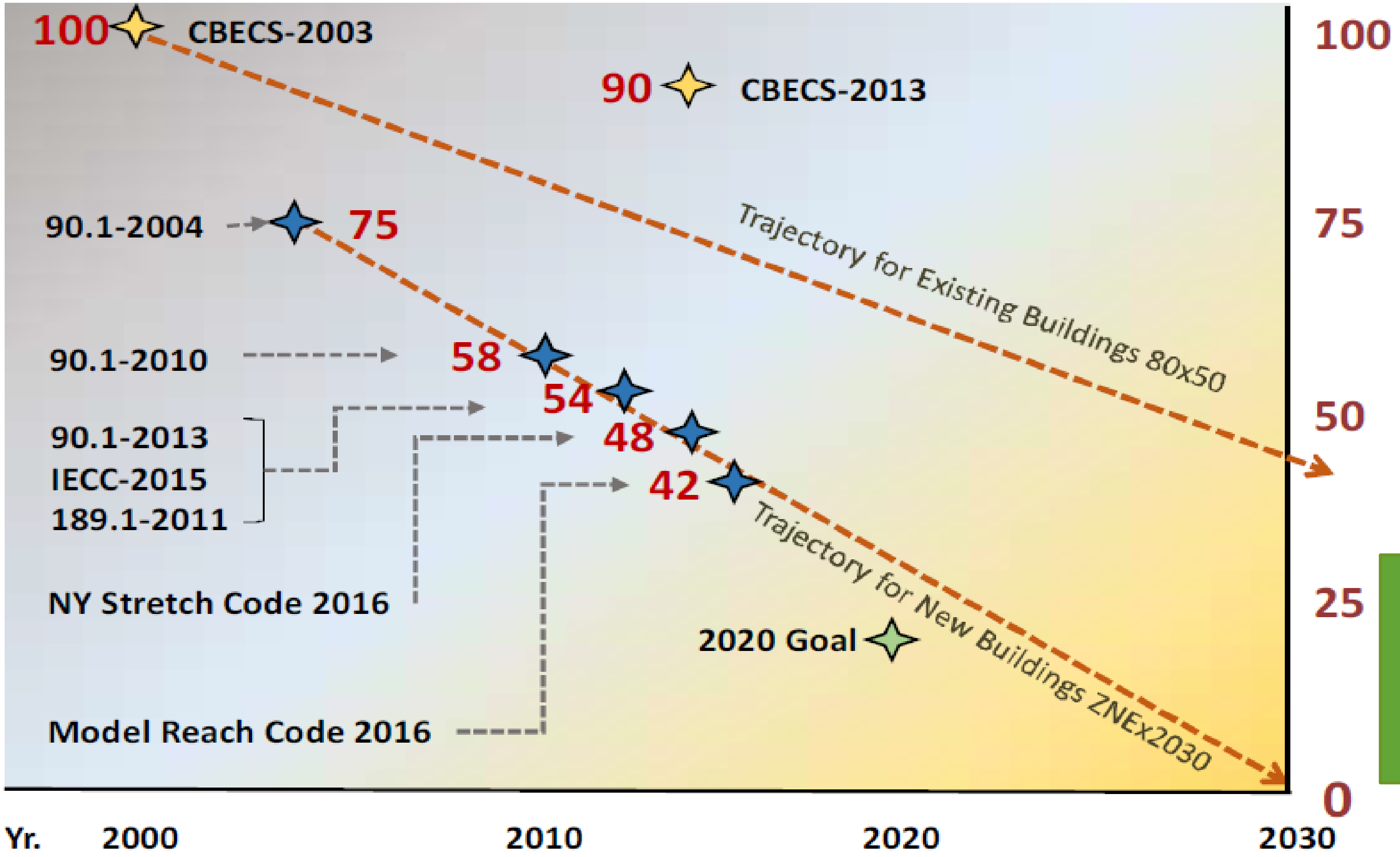
Holistic Energy Efficiency

- Identifying and addressing all the factors that impact the mechanical design. Not just the obvious, but all the potential impacts.

Deep Energy Efficiency

- Going beyond the usual or traditional…striving for and achieving exceptional results. And sometimes, inventing a new/better solution.

Zero Energy Performance Index (zEPI)



zEPI Score

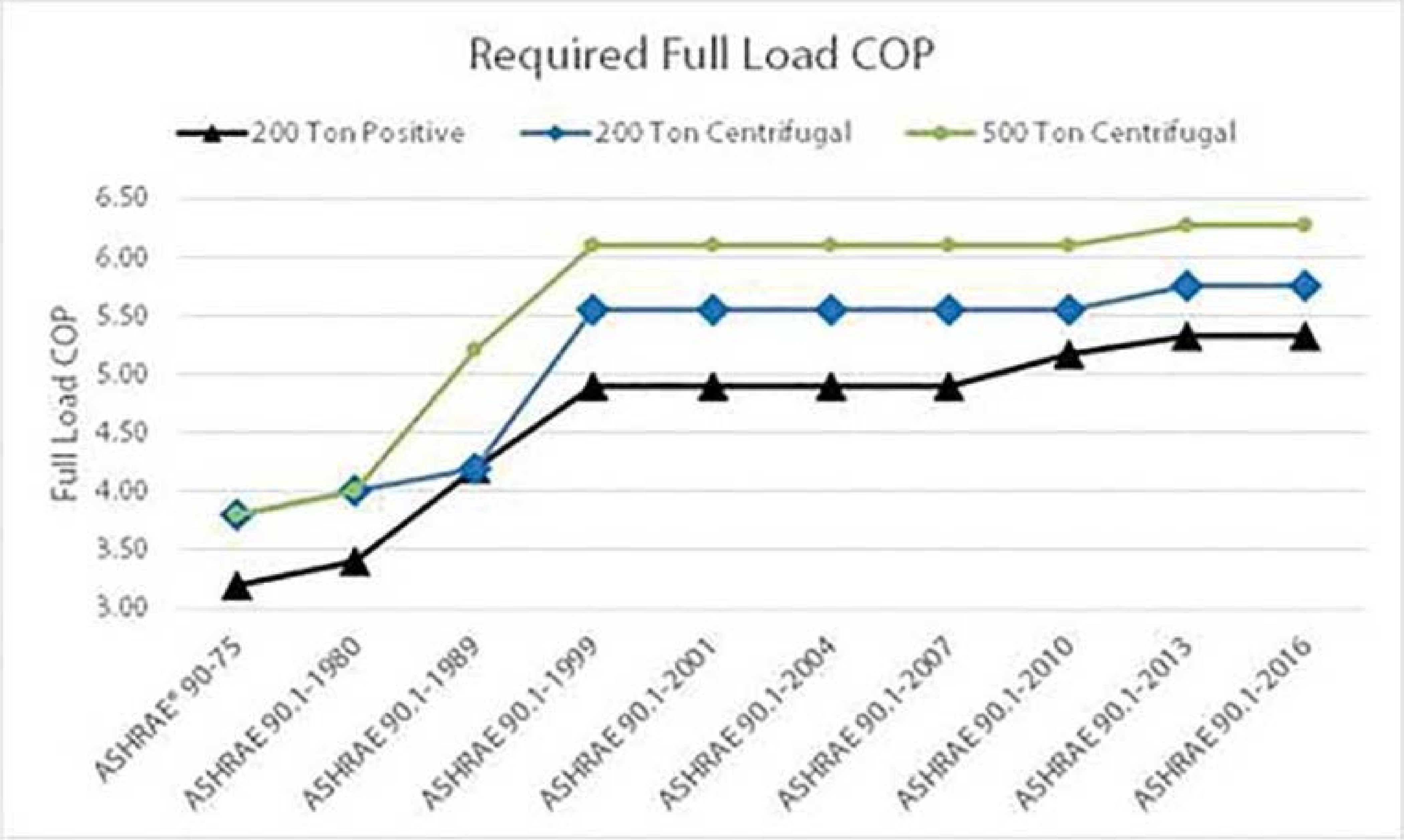
8 in Vermont

2018

nbi new buildings institute

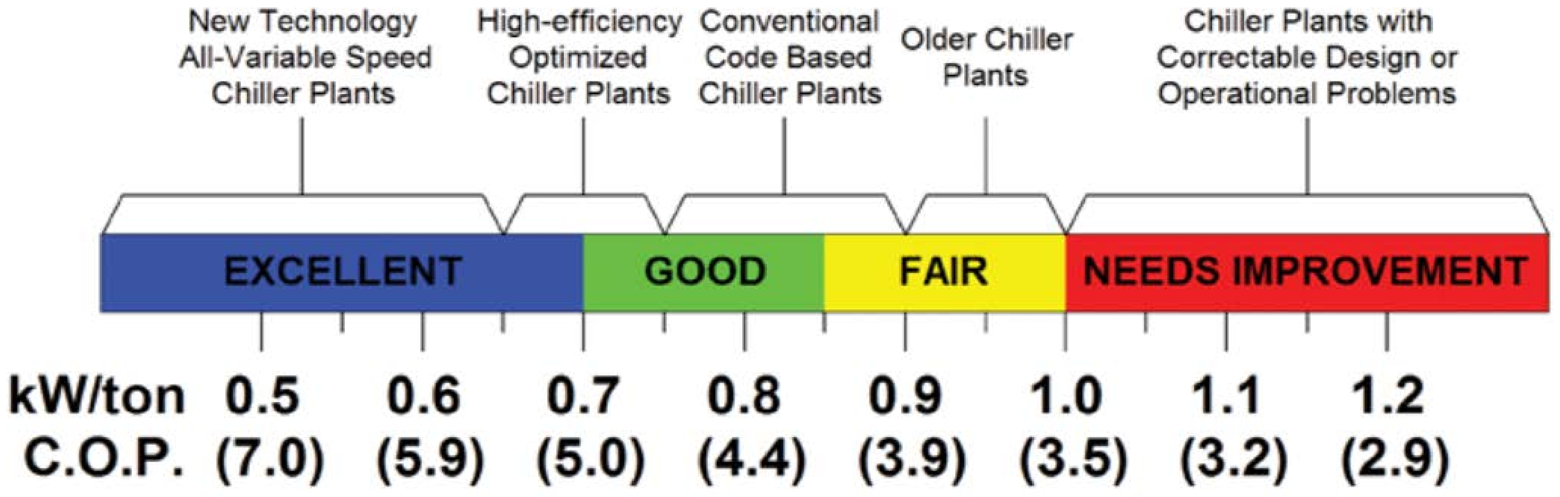
Is your roof big enough?

This one isn't!



Required Full Load COP
200 Ton Positive
200 Ton Centrifugal
500 Ton Centrifugal
Full Load COP
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
ASHRAE® 90-75
ASHRAE 90.1-1980
ASHRAE 90.1-1989
ASHRAE 90.1-1999
ASHRAE 90.1-2001
ASHRAE 90.1-2004
ASHRAE 90.1-2007
ASHRAE 90.1-2010
ASHRAE 90.1-2013
ASHRAE 90.1-2016

Chiller Plant Energy Use Spectrum



AVERAGE ANNUAL CHILLER PLANT EFFICIENCY IN KW/TON (C.O.P.)
(Input energy includes chillers, condenser pumps and tower fans)

Based on electrically driven centrifugal chiller plants in comfort conditioning applications with 42F (5.6C) nominal chilled water supply temperature and open cooling towers sized for 85F (29.4C) maximum entering condenser water temperature. Local Climate adjustment for North American climates is +/- 0.05 kW/ton

If I wrote the energy codes…

- Engineers would have more control over budget
- Envelope testing at substantial completion
- 2-year testing of performance
- Low temperature (130F max) heating
- Energy Recovery and/or Heat Recovery Chillers
- Evaluate geothermal and solar

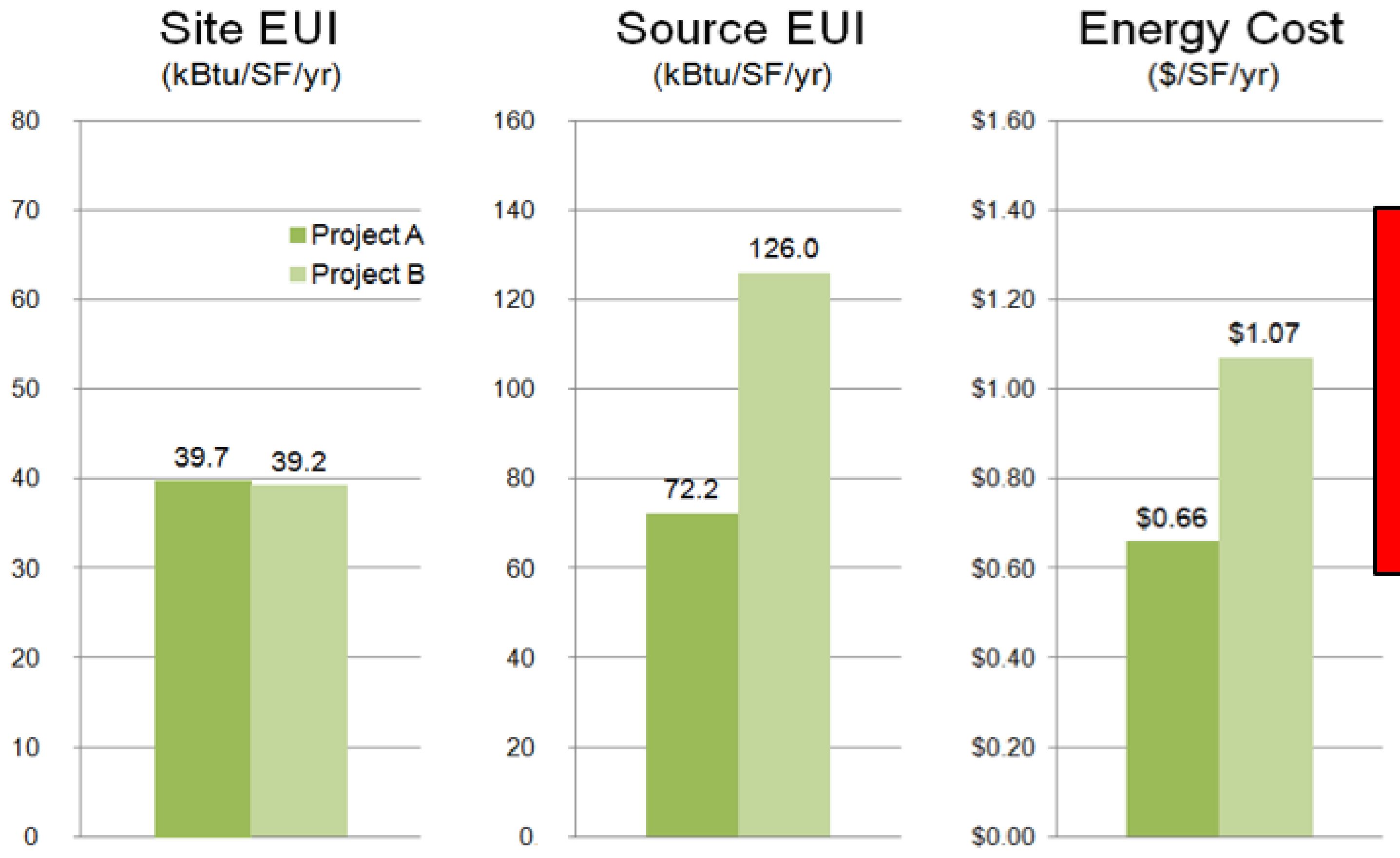
Integrating all of this into a coherent package

Engineers control the budget ???

Am I in Fantasy Land ?

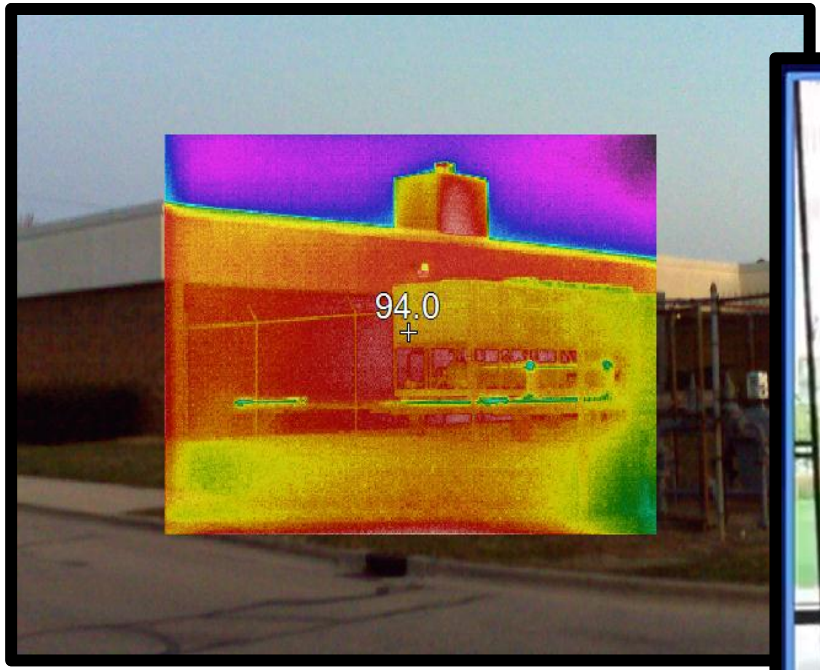
Site vs. Source vs. Cost

Courtesy of Mosley Architects



Less than 4 Yr. payback vs. gas.

Thermoscans & Air Door Testing



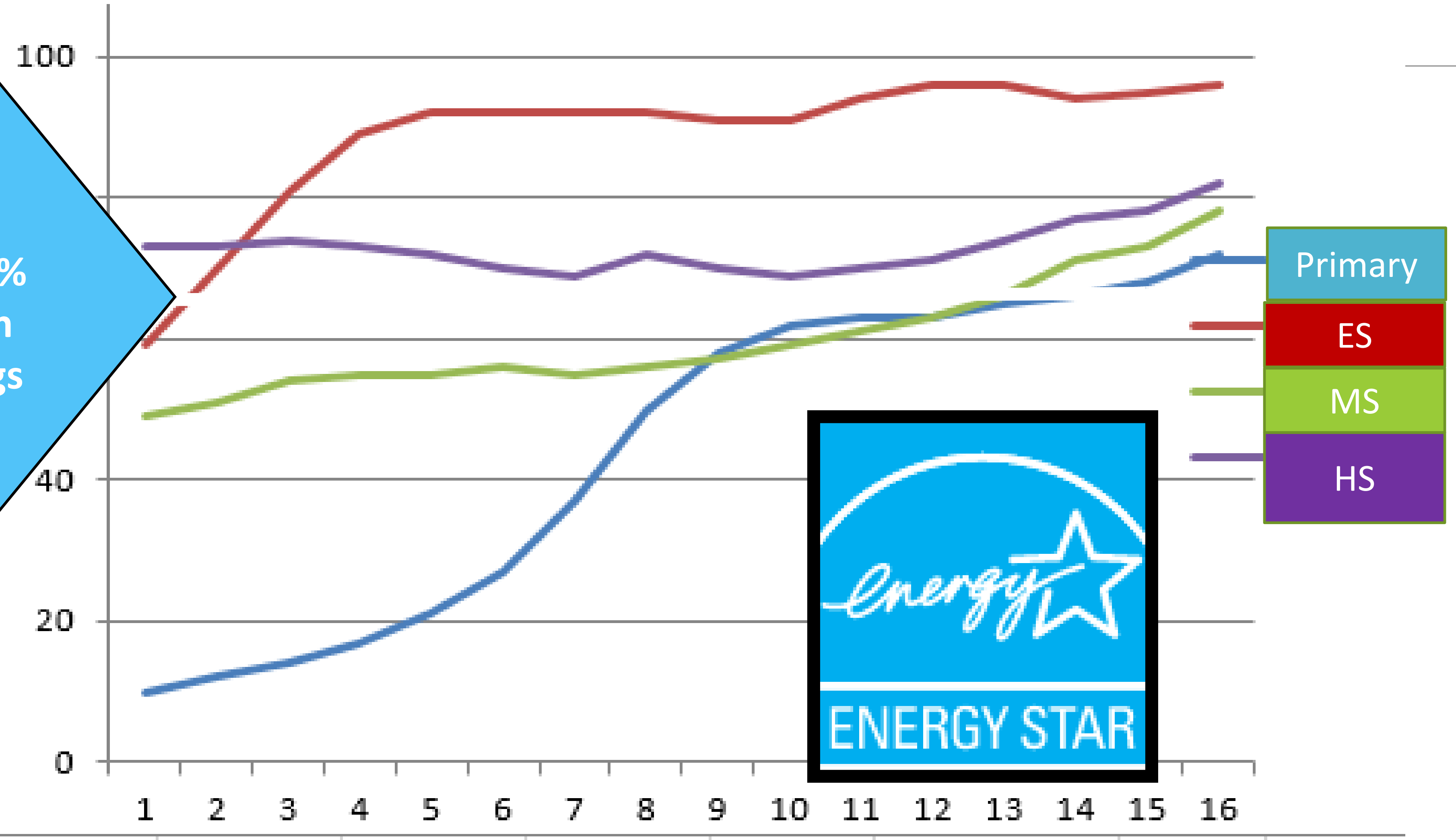
Why is my office always cold?

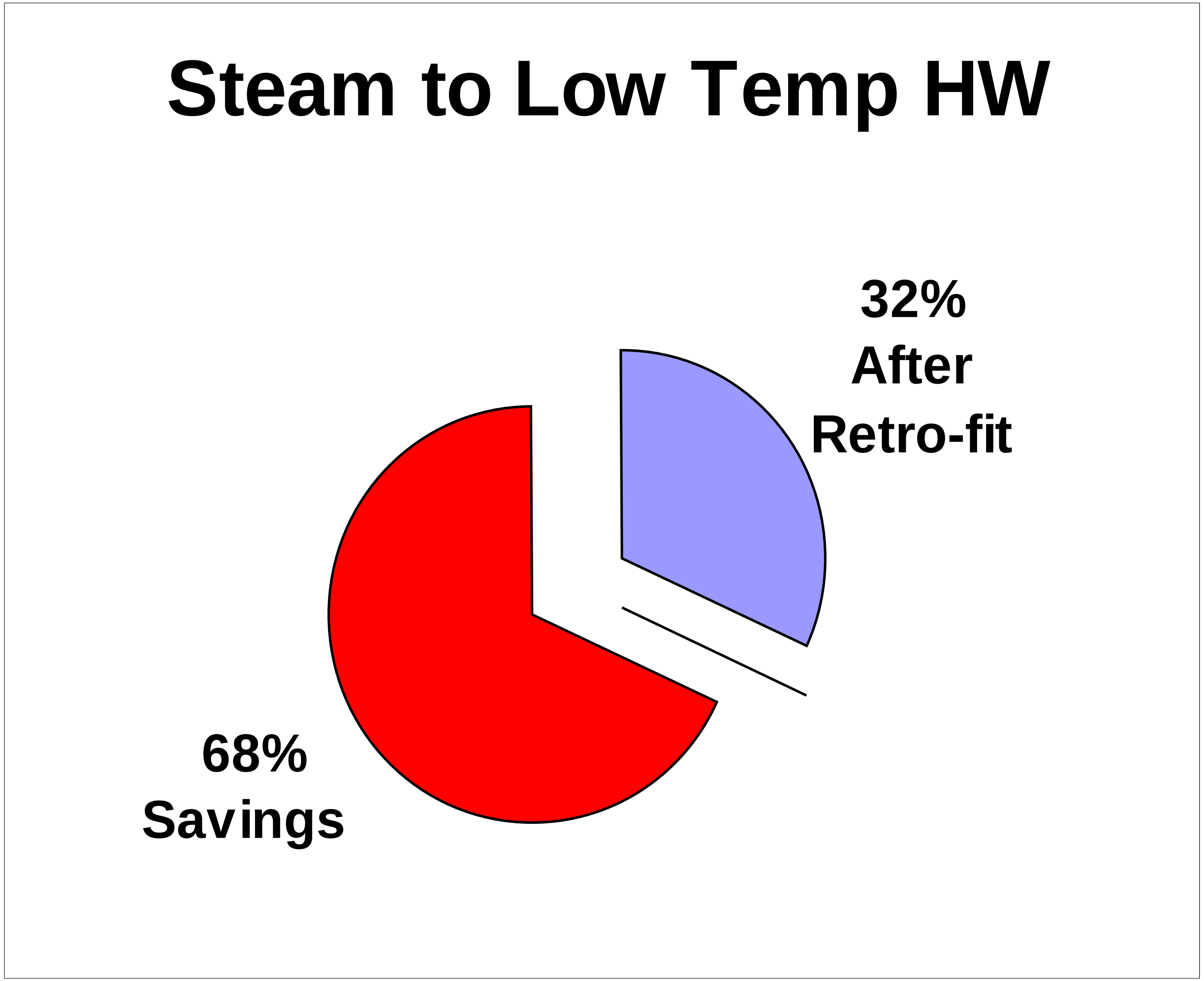
Courtesy of Bledsoe Environmental

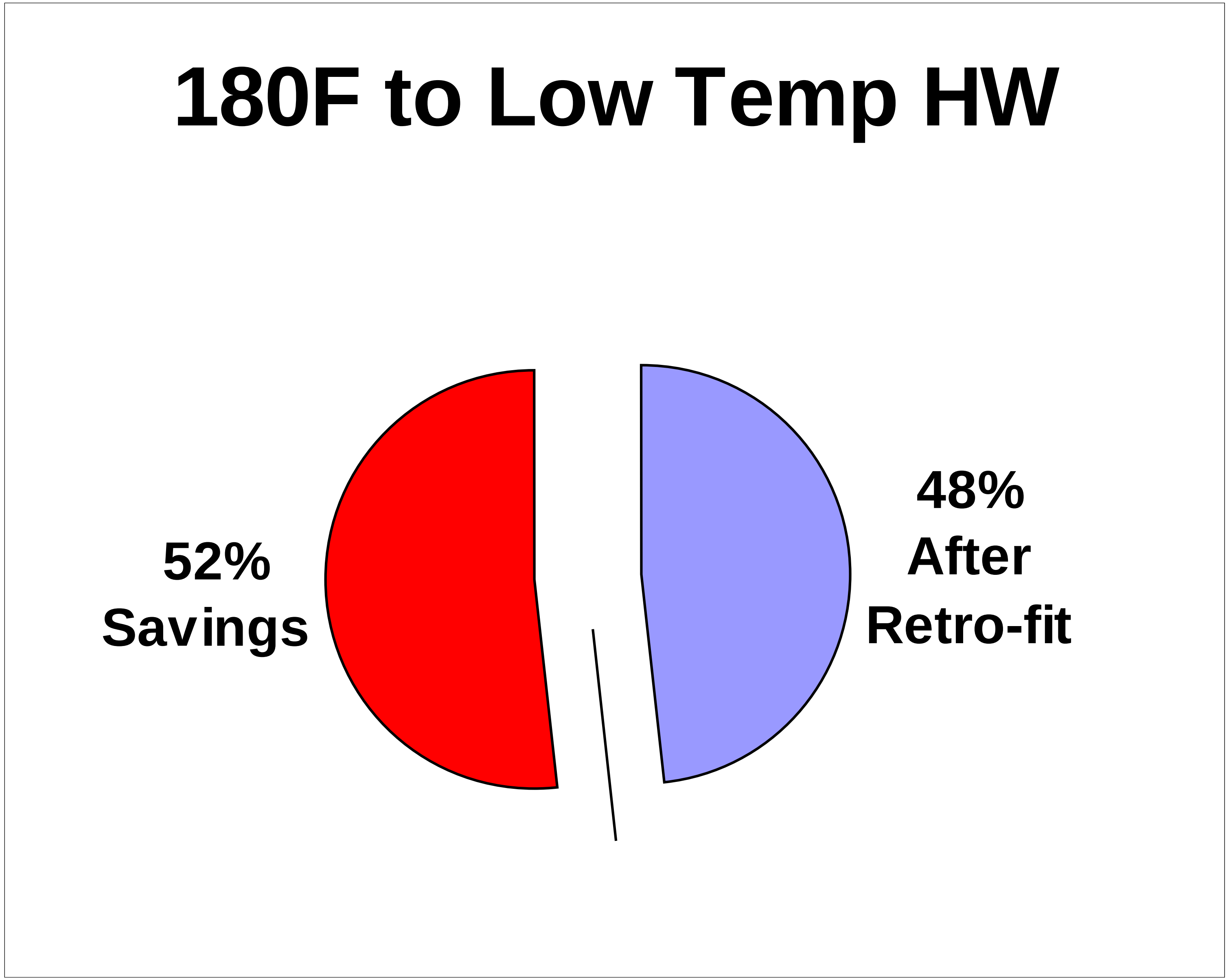
It only took 18 years to find out the soffit was never sealed

Let's fix this!

Energy Star ® buildings use 40% less energy than average buildings




Steam to Low Temp HW
32%
After
Retro-fit
68%
Savings


180F to Low Temp HW
52%
Savings
48%
After
Retro-fit

My (your?) new favorite number

130

Max HW Supply Temp

Reset vs. outside air temp down to 90F

Reasons to Recover Energy

Model Energy Code
- "…do not reheat with new energy…"

ASHRAE Std. 90.1
- 6.5.2.1 "…controls shall prevent reheating or recooling…"
- 6.5.6.1 "…exhaust air energy recovery…"

Conditioning outside air is expensive and energy intensive

The exhaust stream that accompanies the make-up air contains energy that we need to recover.

At least 25% of your total HVAC cost

Tom’s Rules of Energy Recovery

1. Never compromise IAQ, occupant comfort or humidity control.
2. Don’t spend more to save energy than energy is worth.
3. Try to engineer the need for heat recovery out of a project.
4. Anything goes…BTUs = BTUs.

BTUs = BTUs

One shower = 4.4 Tons of Cooling

BTUs = BTUs

Turn Gray BTUs into **Green** BTUs

by

Heating your buildings with BTUs from the people and the lights, BTUs that were being rejected at the condensing units or relief vents.

They're your BTUs, you bought them…don't just throw them away.

Reasons to Recover Energy

Cost of Energy

- Electric = \$2.49/Therm
- Conventional Boiler = \$1.17/Therm
- Condensing Boiler = \$0.82/Therm
- District steam = \$0.86/Therm
- Recovered heat < \$0.60/Therm>
- **Reduced CHW & HW demand = <\$1.03/Therm>**

Green house gas reductions

Ways to Recover Energy

On the air side…

2016 ASHRAE Systems Handbook Chapter 26, nine options

- Process to Process
- Process to comfort
- Comfort to comfort (lower the enthalpy, if possible)

On the water side…

2016 ASHRAE Systems Handbook Chapter 9 and 43, several options

Systems Handbook Chapter 26

Comparison of 8

Air-to-air Energy Recovery Devices

Table 3 Comparison of Air-to-Air Energy Recovery Devices

	Fixed Plate	Membrane Plate	Energy Wheel	Heat Wheel	Heat Pipe	Runaround Coil Loop	Thermosiphon	Liquid Desiccant
Airflow arrangements	Counterflow Cross flow[a]	Counterflow Cross flow[a]	Counterflow Parallel flow	Counterflow	Counterflow Parallel flow	—	Counterflow Parallel flow	—
Equipment size range, cfm	50 and up	50 and up	50 to 74,000 and up	50 to 74,000 and up	100 and up	100 and up	100 and up	—
Typical sensible effectiveness ($m_s = m_e$), %[c]	50 to 75	55 to 75	65 to 80	65 to 80	40 to 60[b]	45 to 65[b]	40 to 60	40 to 60[b]
Typical latent effectiveness,* %[c]	0	25 to 60	50 to 80	0	0	0	0	50 to 75[b,d]
Total effectiveness,* %[c]	20 to 50	35 to 70	55 to 80	25 to 60	15 to 35	—	—	40 to 75[d]
Face velocity, fpm	200 to 1000	200 to 600	500 to 1000	400 to 1000	400 to 800	300 to 600	400 to 800	300 to 450
Pressure drop, in. of water	0.4 to 4	0.4 to 2	0.4 to 1.2	0.4 to 1.2	0.6 to 2	0.6 to 2	0.6 to 2	0.7 to 1.2
EATR, %	0 to 2	0 to 5	0.5 to 10	0.5 to 10	0 to 1	0	0	0
OACF	0.97 to 1.06	0.97 to 1.06	0.99 to 1.1	1 to 1.2	0.99 to 1.01	1.0	1.0	1.0
Temperature range, °F	–75 to 1470	–40 to 140	–65 to 1470	–65 to 1470	–40 to 200	–50 to 930	–40 to 104	–40 to 115
Typical mode of purchase	Exchanger only Exchanger in case Exchanger and blowers Complete system	Exchanger only Exchanger in case Exchanger and blowers Complete system	Exchanger only Exchanger in case Exchanger and blowers Complete system	Exchanger only Exchanger in case Exchanger and blowers Complete system	Exchanger only Exchanger in case Exchanger and blowers Complete system	Coil only Complete system	Exchanger only Exchanger in case	Complete system
Advantages	No moving parts Low pressure drop Easily cleaned	No moving parts Low pressure drop Low air leakage Moisture/mass transfer	Moisture/mass transfer Compact large sizes Low pressure drop Available on all ventilation system platforms	Compact large sizes Low pressure drop Easily cleaned	No moving parts except tilt Fan location not critical Allowable pressure differential up to 2 psi	Exhaust airstream can be separated from supply air Fan location not critical	No moving parts Exhaust airstream can be separated from supply air Fan location not critical	Latent transfer from remote airstreams Efficient microbiological cleaning of both supply and exhaust airstreams
Limitations	Large size at higher flow rates	Few suppliers Long-term maintenance and performance unknown	Supply air may require some further cooling or heating Some EATR without purge	Some EATR with purge	Effectiveness limited by pressure drop and cost Few suppliers	Predicting performance requires accurate simulation model	Effectiveness may be limited by pressure drop and cost Few suppliers	Few suppliers Maintenance and performance unknown
Heat rate control (HRC) methods	Bypass dampers and ducting	Bypass dampers and ducting	Bypass dampers and wheel speed control	Bypass dampers and wheel speed control	Tilt angle down to 10% of maximum heat rate	Bypass valve or pump speed control	Control valve over full range	Control valve or pump speed control over full range

[a]Rated effectiveness values are for balanced flow conditions for cross flow. Effectiveness values increase slightly if flow rates of either or both airstreams are higher than flow rates at which testing is done.

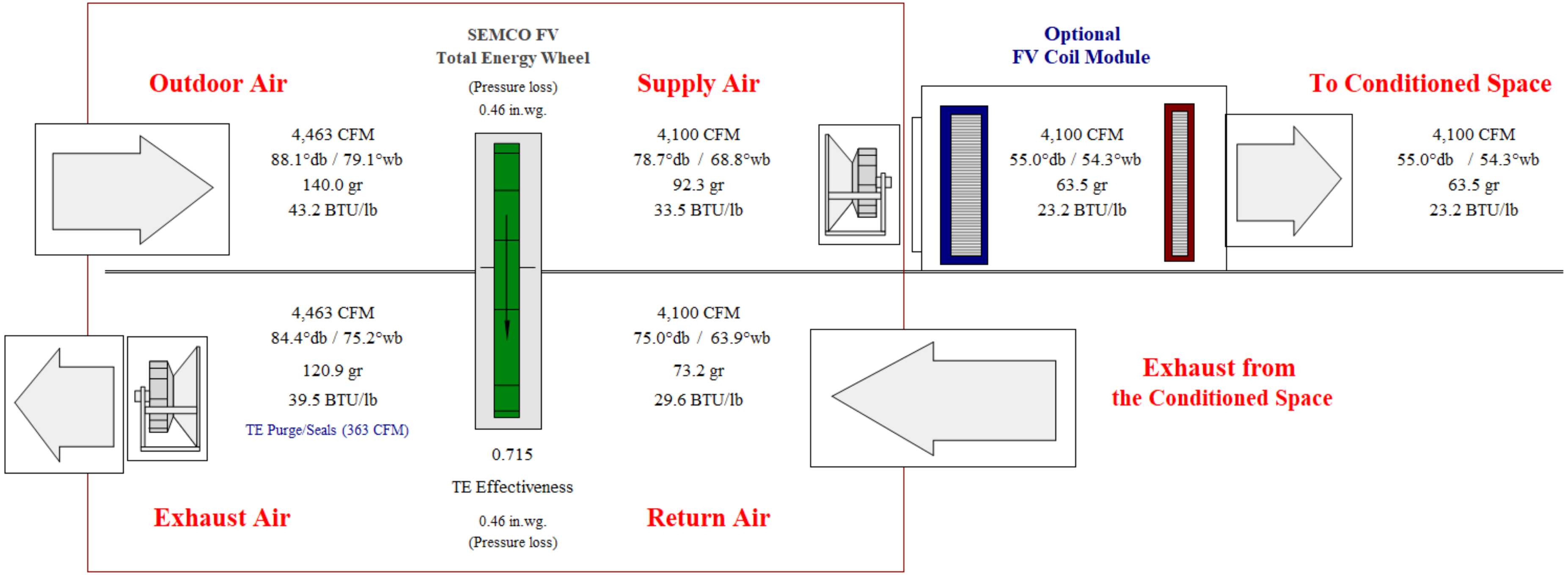
[b]Data not based on third-party certified data.
[c]Data based on typical range of third-party certified data.
[d]Face velocity of 250 to 500 fpm.

EATR = exhaust air transfer ratio
OACF = outdoor air correction factor

Highlights of the Chart

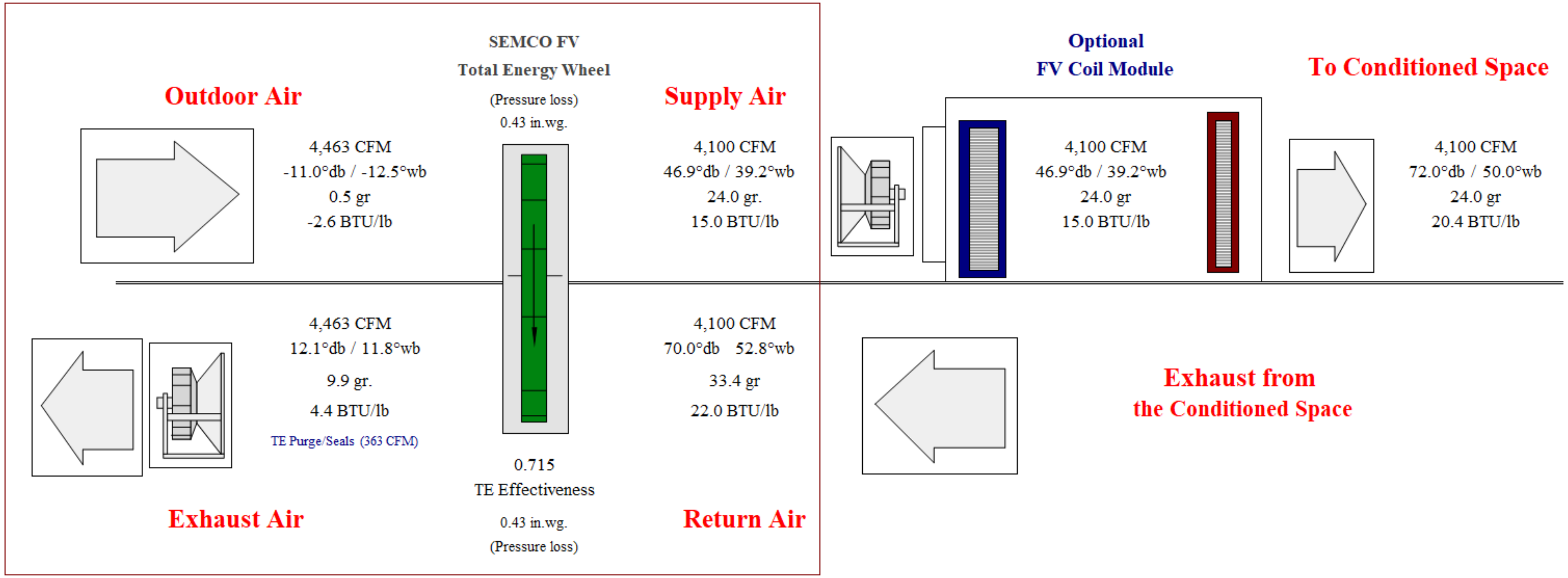
- Most efficient…Energy Wheels and membrane plate
- Least efficient…heat pipes and runaround coils
- Membrane plate and energy wheel only ones with "latent effectiveness"
- Air pressure drops included for fan Hp
- Size and cost not listed
- Most require air streams to be side-by-side

Energy Wheel in Cooling



Cooling reduced by half

Energy Wheel in Heating



Heating reduced by 75%

Not in Chapter 26…

- Better options when the air streams aren’t together

- Heat recovery chillers

- Potential mis-applications

Mis-applications

Even the best ideas can be poorly applied…

- Energy wheels on a VAV system…
  - can only contribute when OAT is above 75 or below 25F

Chesterton MS - 2000
(Deep Energy Example)

Large internal area, below grade, two stories above

- Heat positive 12 months/Yr

Typical solutions

- Economizers
  - Low head room, limited access for ductwork,
- Low ambient chiller

Alternative Solution…resurrect the old “heat recovery chiller” concept…**HRC**

Heat Recovery Chiller?

An old concept, at least 1971

Water cooled chiller

Condenser connection to building heating system

Applicable any time there are concurrent heating and cooling loads

Cost effective in any utility rate structure

Key Element - Elevated condensing temperatures ~ 130F

Coefficient of Performance

Approximate seasonal averages, equipment only, not system COP

Central Steam COP = 0.86 at building

Site generated LP steam COP = 0.5

Conventional 180F boiler COP = 0.66

Condensing boiler COP = 0.9

Geothermal COP = 4.2

HRC COP = **7.7** (Htg and Clg)

At average Indiana rates, per therm, electricity is 3.5 times more expensive than gas.

Great idea and Compelling Economics, but…

You have to have a place to put the heat in summer

- Reheat for humidity control
- Domestic water heating
- Process heating

You have to have a place to put the chilled water in the winter

- Heat positive rooms
- Computer centers

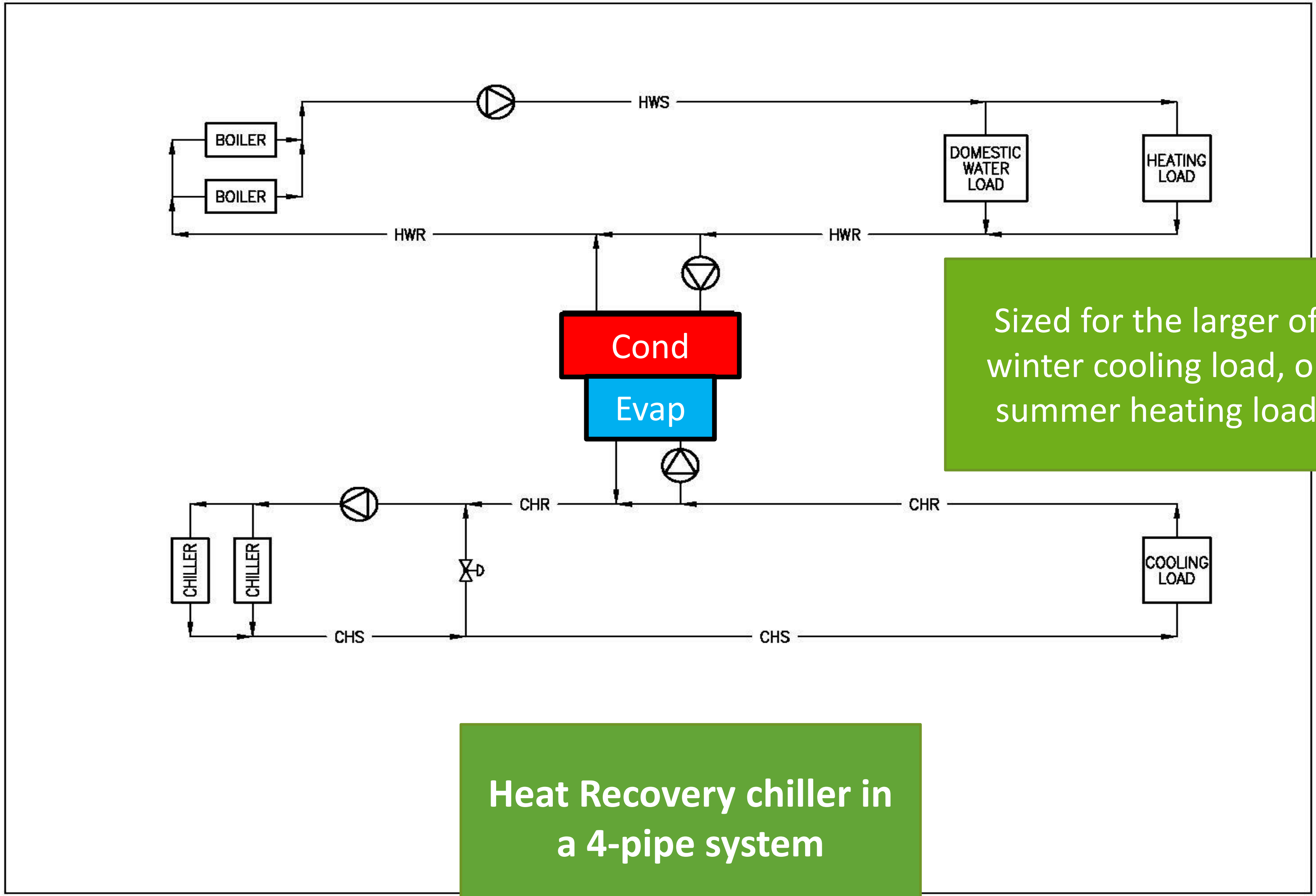
Few successful Applications, Why now?

No place to put low grade heat… **130F max HWST stands on its own**

Cost of gas… **100% increase since 1998**

Tough enough machine to handle duty… **scroll compressors, HP refrigerants, small size**

Smart enough controls to stay on-line… **fourth or fifth generation**



Sized for the larger of winter cooling load, or summer heating load

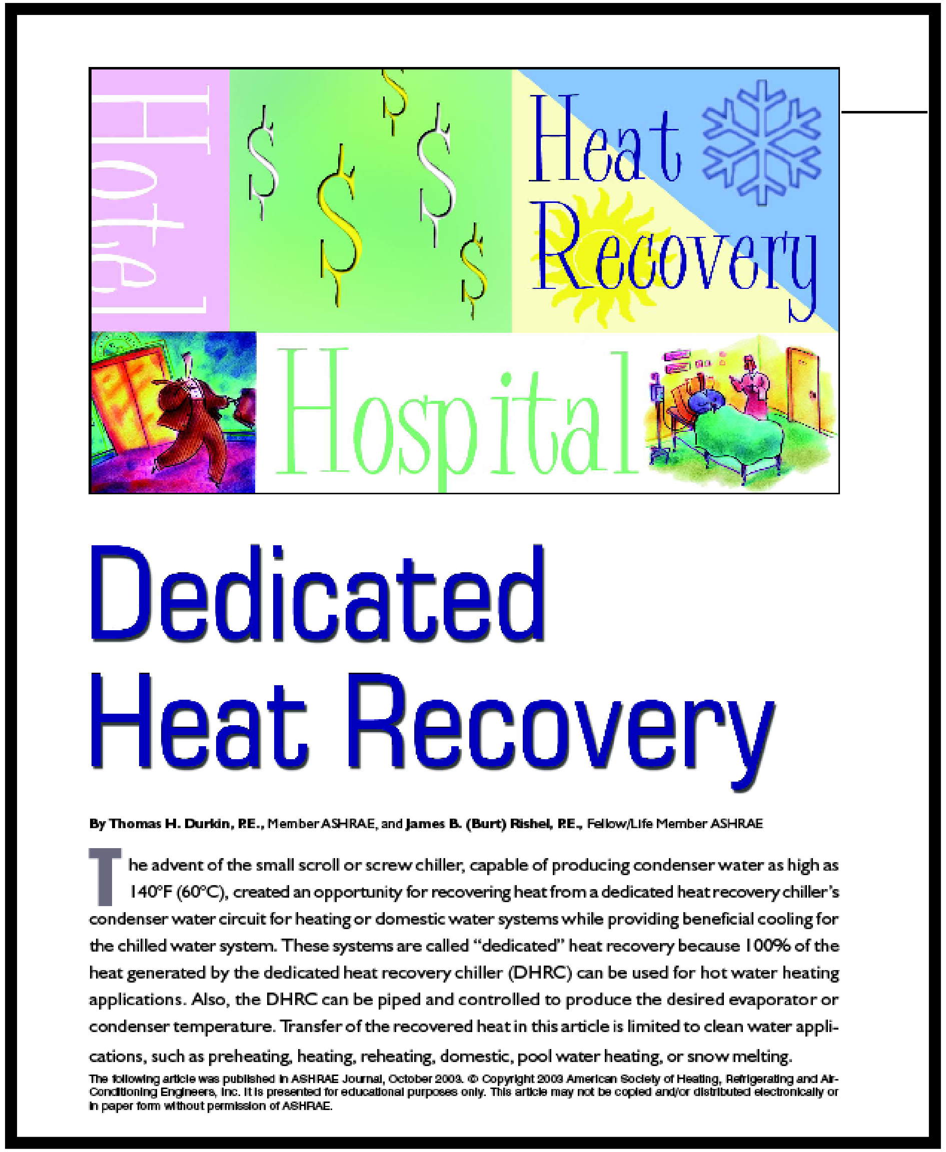
Heat Recovery chiller in a 4-pipe system

Cooling & Heating Cost

OAT	Economizer Cooling and Heating Per Hr	Low Ambient Chiller and Heating Per Hr	Heat Recovery Chiller Per Hr	Savings/Yr HRC vs. Econ	Savings/yr HRC vs. Low Amb Chl
50	$6.80	$10.46	$4.42	$803.42	$2,035.36
40	$6.60	$9.64	$4.86	$667.58	$1,834.07
30	$6.39	$8.87	$5.40	$459.46	$1,610.98
20	$6.20	$8.22	$6.00	$75.48	$859.45
10	$6.00	$7.70	$6.70	($140.04)	$202.49
				$1,865.90	**$6,542.34**

Deep Energy Example

Plus domestic water pre-heat and summer RH for humidity control



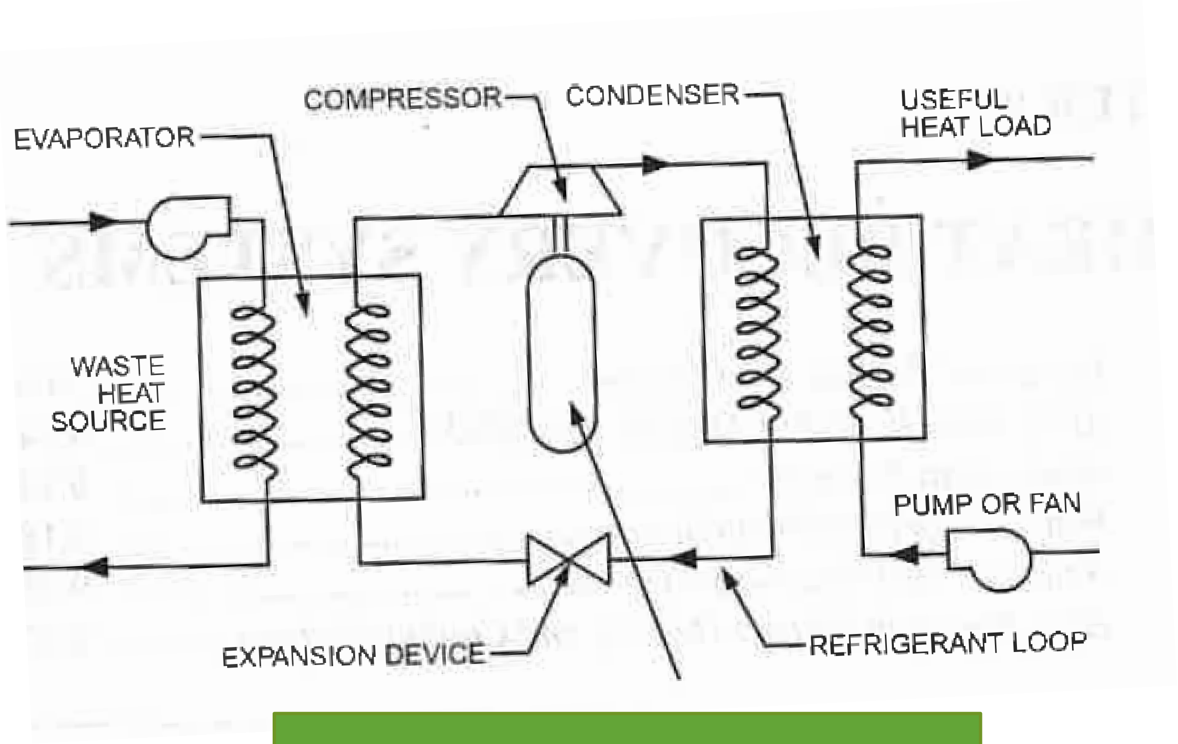
Hotel Heat Recovery Hospital

Dedicated Heat Recovery

By Thomas H. Durkin, P.E., Member ASHRAE, and James B. (Burt) Rishel, P.E., Fellow/Life Member ASHRAE

The advent of the small scroll or screw chiller, capable of producing condenser water as high as 140°F (60°C), created an opportunity for recovering heat from a dedicated heat recovery chiller's condenser water circuit for heating or domestic water systems while providing beneficial cooling for the chilled water system. These systems are called "dedicated" heat recovery because 100% of the heat generated by the dedicated heat recovery chiller (DHRC) can be used for hot water heating applications. Also, the DHRC can be piped and controlled to produce the desired evaporator or condenser temperature. Transfer of the recovered heat in this article is limited to clean water applications, such as preheating, heating, reheating, domestic, pool water heating, or snow melting.

ASHRAE Journal October 2003



2016 Systems Handbook Chapters 9 and 43

In-Patient Psychiatric Hospital

BTU Meter calculates recovered heat

April to August 2006 = 1,386.4 MMBTU recovered

Value of recovered heat = $18,500 plus $585 chiller efficiency differential

Payback when planned……………..6 yrs

As operated (Katrina Effect) …..**1.9 years**

Tri-North Middle School

Utility Costs

Electric was $0.55/kWh, up to $0.63/kWh

Gas was $0.54/Therm, up to $1.09/Therm

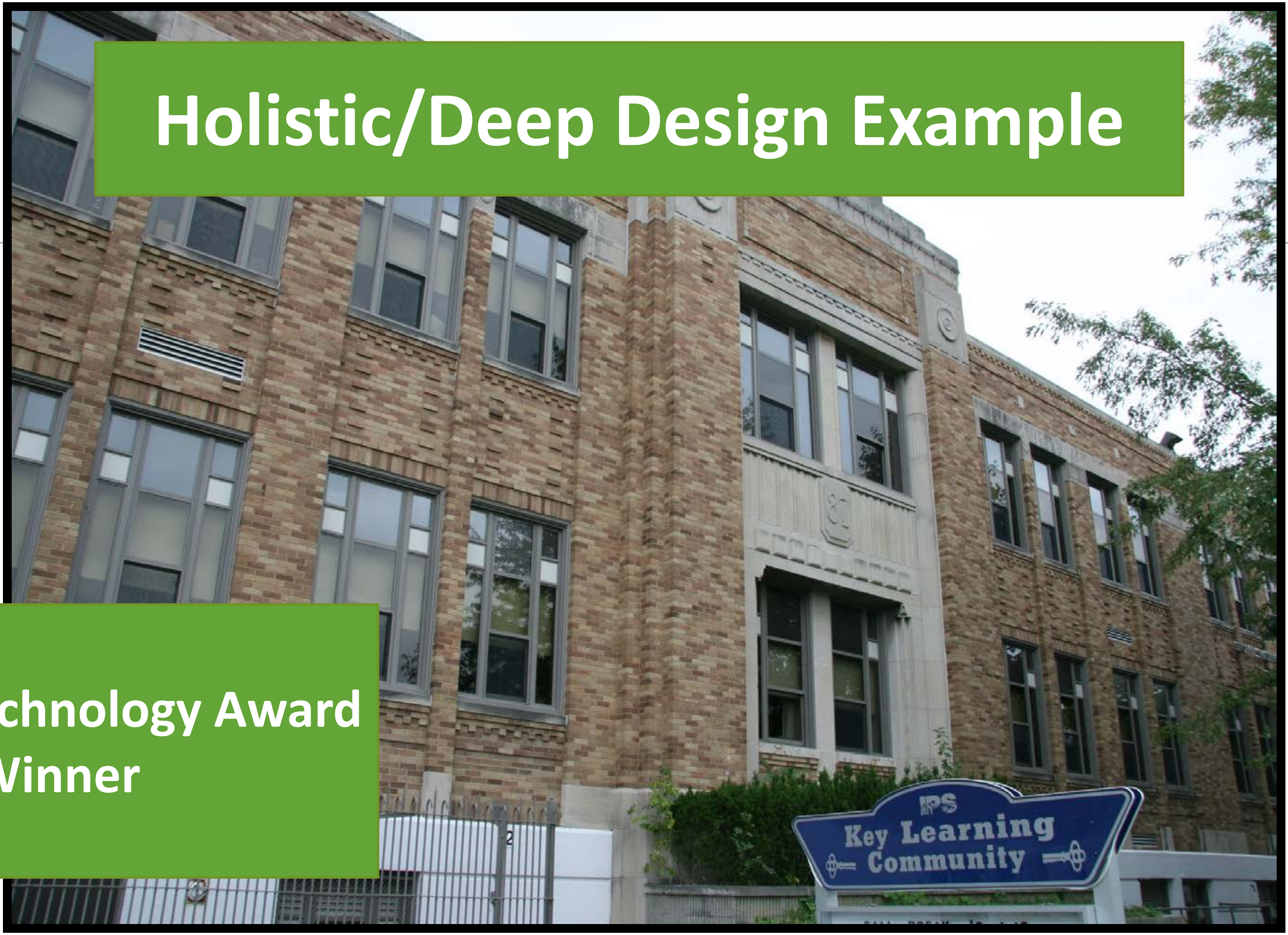
Normalized for Utility Cost and HDD

2005……………………………………..$94,700

2002 usage at 2005 rates…… ….$143,907

Payback……………………………… **2.0 years**

Holistic/Deep Design Example



ASHRAE Technology Award Winner

George Washington Carver Elementary

Adding air conditioning as part of system wide up-grade

Built in 1935, traditional 3 story school with the boiler room below lower level (16 Ft below street level)

Underground stream, 150 GPM into boiler room

- Several floods
- Sump pumps on emergency generator
- Raised switchgear out of danger

IPS #87 (2005)

If we can use the ground water, we'll get Geothermal efficiency without the investment in bore field.

Synthesis of four technologies that, independently, were proven to be cost effective and very efficient.

- Low Temperature Heating
- 2-pipe HVAC
- Heat recovery chillers
- Geothermal central systems

Turning a Liability into an A$$et

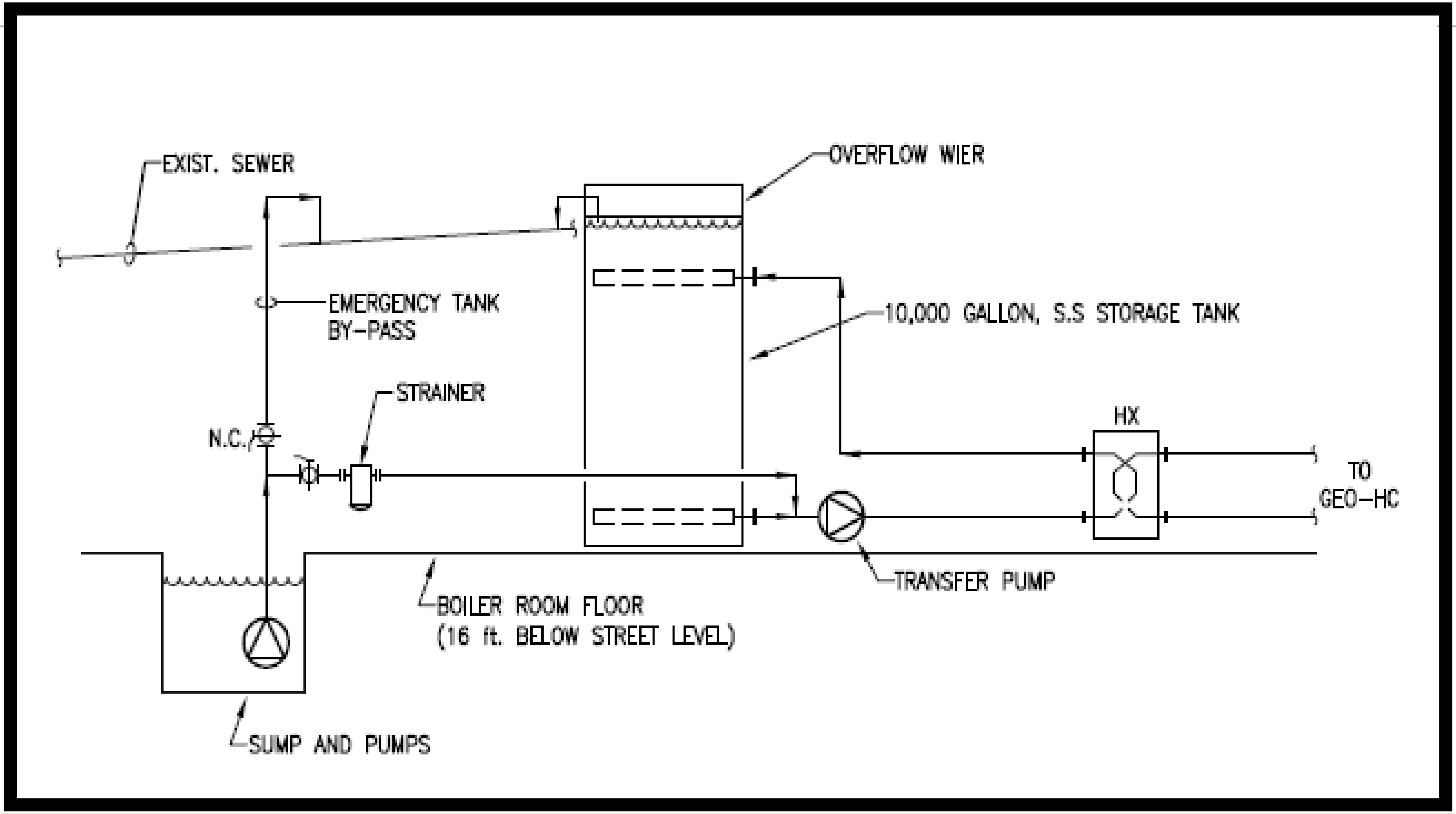
<u>An earth coupled heat recovery chiller</u>

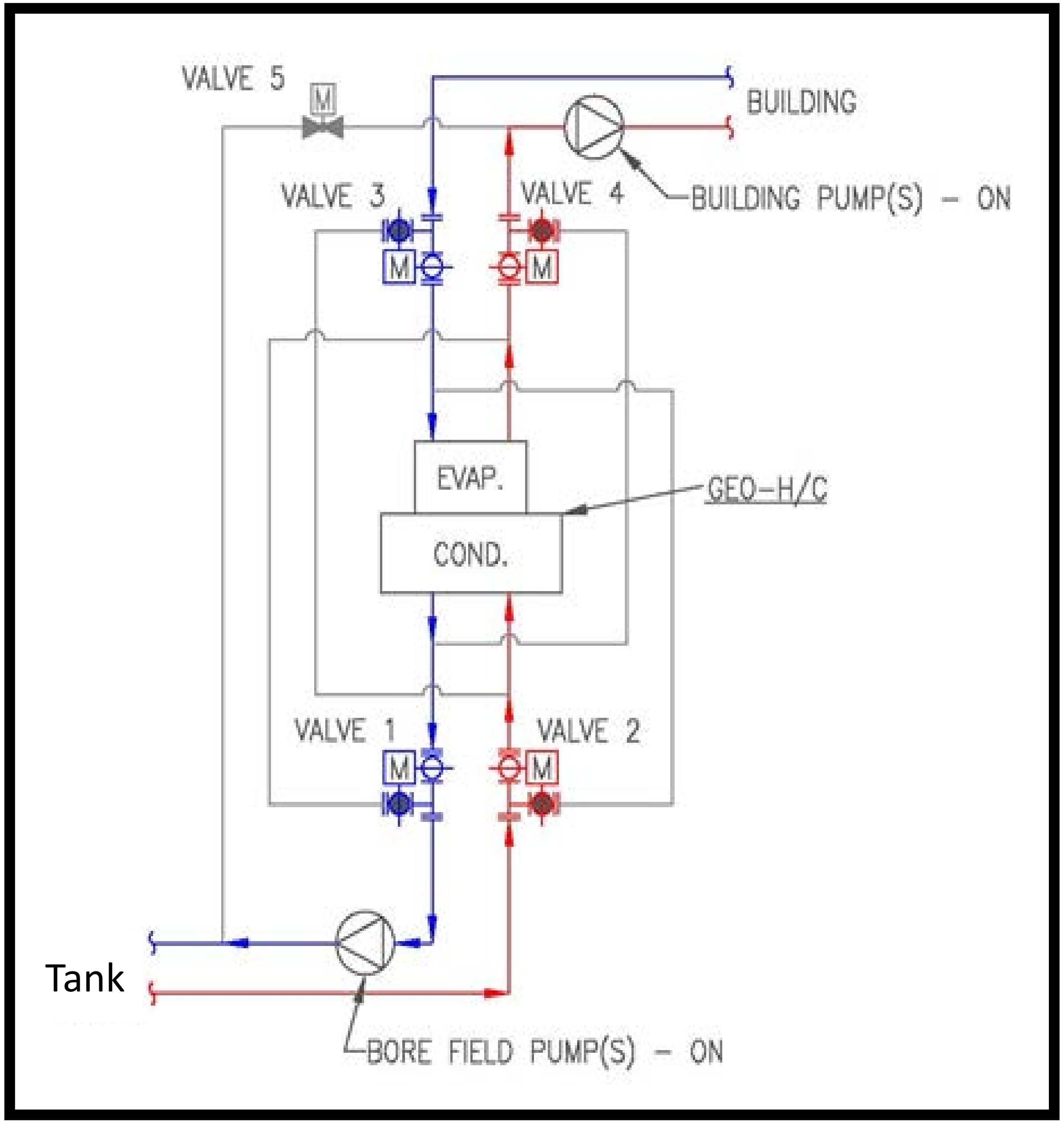
- Evaporator connected to building cooling system
- Condenser connected to building heating system
- Earth coupled for heat rejection (summer)
- Earth coupled for heat absorption (winter)
- One compressor provides both heat and cool

Conventional air side equipment (AHUs, UVs, FCUs, VAVs) with air side economizers, DOAS not required.

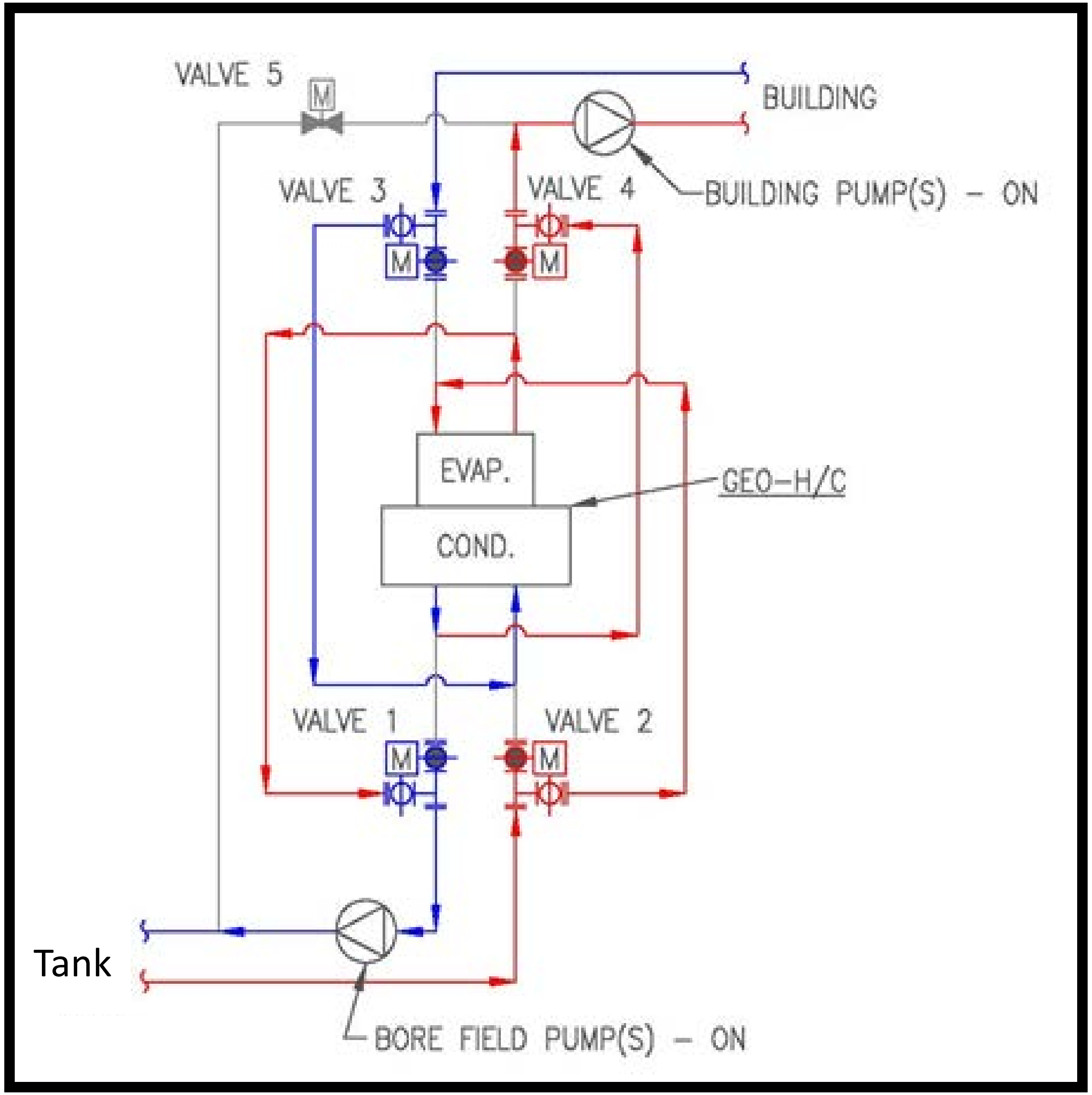
Can be an easy alternate for tight budgets

IPS #87 Ground Water

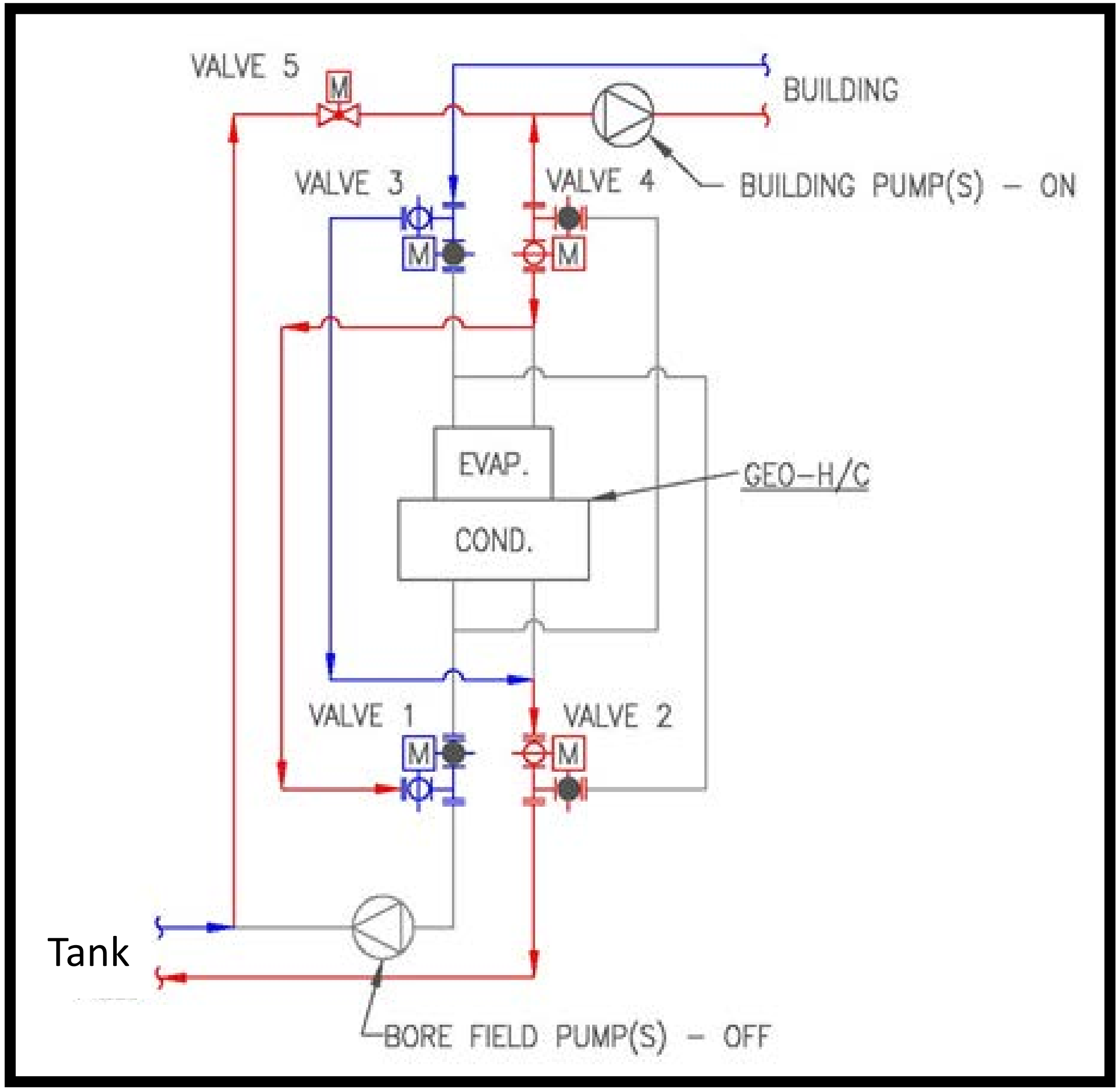




2-Pipe
Geo Central System
Cooling Mode



2-Pipe
Geo Central System
Heating Mode



2-Pipe
Geo Central System
Sensible Cooling
Mode

ASHRAE Journal

August 2007

Geothermal Central System

By **Thomas H. Durkin, P.E.,** Member ASHRAE; and **Keith E. Cecil, P.E.,** Member ASHRAE

The next generation of geothermal systems for school buildings is a recent synthesis of three technologies that separately have proven to be effective: geothermal (earth-coupled) heating and cooling; dedicated heat recovery chillers; and the modern two-pipe HVAC system.

From two-pipe HVAC, comes economy and simplicity for school designs, and the proven ability to heat large buildings with low-temperature water (see sidebar on *Modern Two-Pipe System*). From dedicated heat recovery chillers comes a proven machine that can be programmed to simultaneously produce 44°F (7°C) cooling water and 130°F (54°C) heating water. And, from geothermal, comes an efficient heating and cooling source. The geothermal systems discussed in this article are closed systems, circulating an engineered heat transfer solution.

Another Heat Pump Article?

Rather than multiple distributed compressorized units throughout a building (conventional geothermal heat pumps), this concept has a single unit located in a central mechanical room. The heart of the system is a heat recovery chiller/heater, or Geo-H/C. It is a single unit (multiple refrigeration circuits provide redundancy) that will heat the building in the winter, cool it in the summer, do both in the spring and fall, and preheat the domestic hot water if demand is high enough.[1]

Geo-H/C can be connected to either a two-pipe or a four-pipe building system. All of the air-side equipment would be standard air handlers, unit ventilators or fan coils. This configuration can operate air-side economizers, and it can use the well water to cool the building directly when the ground temperature and indoor humidity allow, thus giving two sources of free cooling. When outside temperatures are cool, air-side economizers on AHUs and unit ventilators provide cooling without any compressors running; and when the well return temperature is cool enough, the sensible cooling mode provides air conditioning, again without compressors operating. Economizer availability in this scheme is seen as a significant efficiency benefit (see sidebar on *Economizers in Schools*).

About the Authors

Thomas H. Durkin, P.E.; and **Keith E. Cecil, P.E.,** are partners at Durkin & Villalta Partners Engineering in Indianapolis.

Criteria for a Technology Award

- Energy Efficiency
- Indoor air quality and thermal comfort
- Innovation
- Operations and Maintenance
- Cost Effectiveness
- Environmental Impact
- Value added

Operating Cost

	Before Renovation 2005-06	After Renovation 2007-08
Electric	$22,770	$42,499
Gas	$28,500	$662
Total	**$51,270**	**$43,111**

33% savings, corrected for cost of energy
IPS most efficient building ($0.86/SF/Yr)

Added cooling and switched to 12-month school calendar
Energy Star® eligible

IEQ and Thermal Comfort

- Std 62.1 compliance
- Continuous monitoring of CO_2, temperature and humidity
- Location right on an Interstate, now able to keep windows closed

IPS #87 vs. other IPS projects

- Comparable construction cost to 4-pipe fan coil system
- Fewer hot/cold calls
- Fewer maintenance calls
- Only outage GEO-H/C due to clogged strainer
- Most efficient building (30+ without A/C)
- Boilers run only for testing

Operations and Maintenance

"Saving money is important, but we like **Durkin's 2-Pipe** systems because they're so **trouble free**. We get **fewer temperature complaints and fewer maintenance calls** from his buildings than the others. We would gladly pay more for improved reliability, the **cost savings is a bonus**."

Steve Young
Facilities Management Division Chief
Indianapolis Public Schools

Environmental Impact

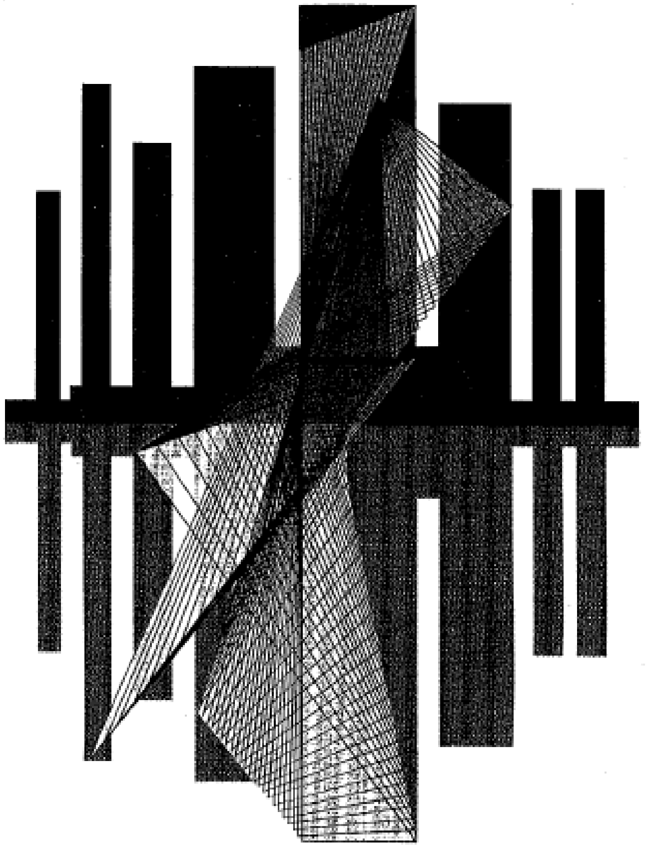
(Pounds per year, source)

	Before				After	
Pollutant	Gas	Electric	Total		Electric	Change
CO2	302,823	676,800	979,623		1,113,000	+133,377
Sox	0	1,178	1,178		1,937	+759
NOx	238	1,963	2,201		3,229	+1,028
Particulate	18	68	86		111	+25
Total			983,088		1,118,277	+135,189

Added air conditioning
12 month school calendar

Value Added

- Window into mech room
- Color coding all piping
- Lots of visible gages
- TCC donated 30 read-only copies of control software
- Earth science curriculum



Thomas H. Durkin, P.E.

Durkin & Villalta Partners Engineering

HVAC Renovations
at George Washington Carver
Elementary School
Indianapolis, Indiana

2009
ASHRAE Technology Award

First Place

In recognition of outstanding achievement in the design and operation of energy-efficient buildings

Category II - Institutional Buildings - Existing

ASHRAE®

PME Magazine

2007

Excellence in Design Award

PME Excellence in Design Award Winners

by Jim Camillo

PM Engineer is proud to announce that one winner and an honorable mention have been chosen to receive *PME* Excellence in Design Awards for 2007. Congratulations to Durkin & Villalta Partners Engineering of Indianapolis, IN, for its innovative upgrade of an HVAC system at George Washington Carver Elementary School; and to Peter Basso Associates, Inc., Troy, MI, for its LEED® Silver-winning design of an HVAC system for new Whitmore Lake High School in Whitmore Lake, MI. (See page 89.)

These designs were judged by our panel of editors and engineers based on the following criteria: innovation in design, customer satisfaction, ability to meet schedules, cost-efficient strategies and community improvement. The winners were selected from several outstanding submittals; in fact, many judges feel it was the best group of submittals ever received. Nominated designs could be submitted by consulting, specifying or design engineering firms.

28 PMEngineer | November 2007

Engineered Systems Magazine

continuing a Creative Legacy

When George Washington Carver School was built in 1935, boiler room excavation inadvertently intercepted an underground spring. Ever since, sump pumps ran continuously to remove approximately 150 gpm of ground water from the school's basement. This is the story of using imagination, a central reversing chiller, and smart pumping to forge a sustainable solution that would make the school's namesake proud. Adding cooling while reducing overall energy costs significantly made school officials pretty happy, too.

by Steve Young, Steve Johnson, and Tom Durkin

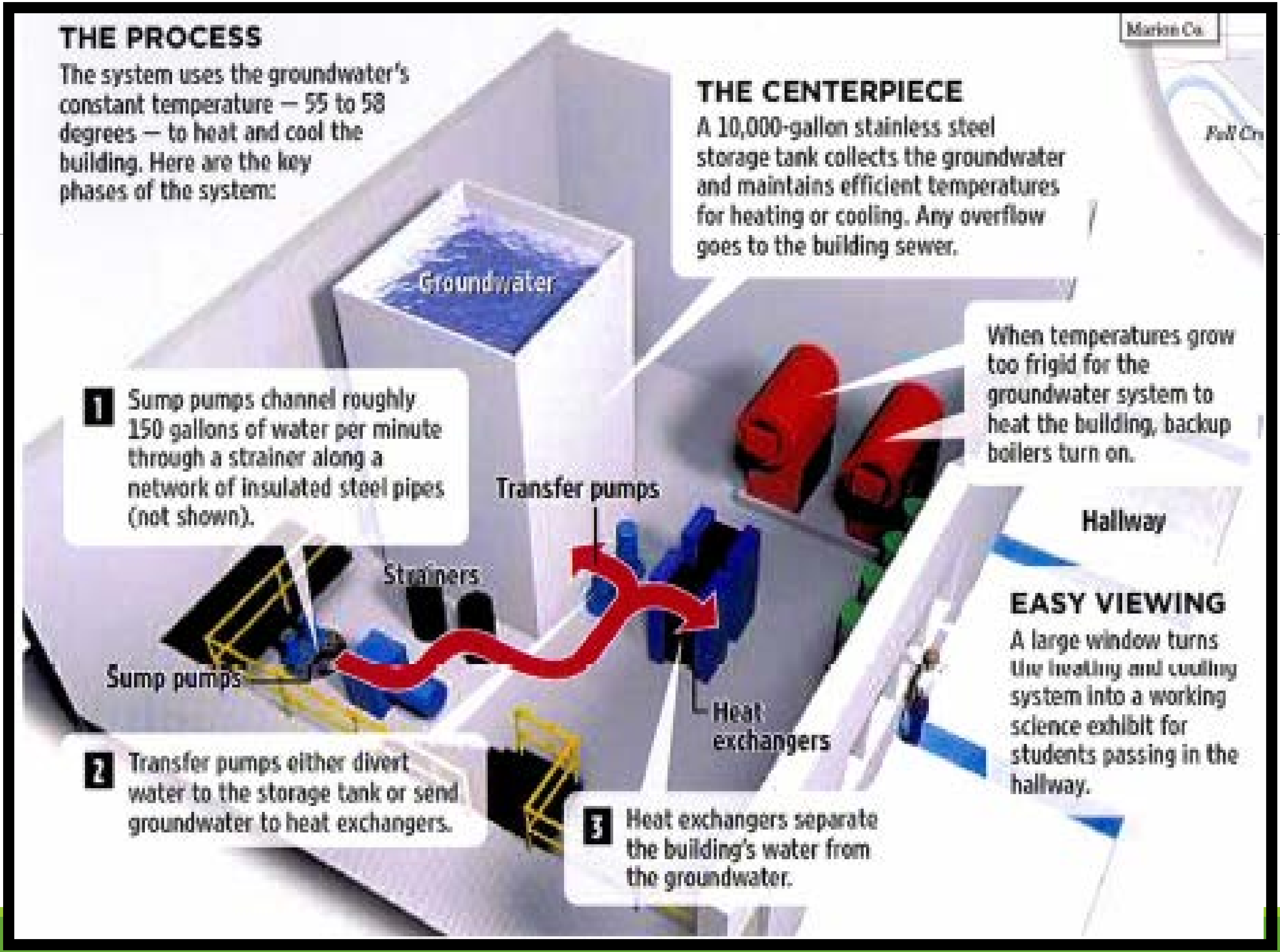
When George Washington Carver Elementary School in Indianapolis (#87) was built in 1935, an underground spring was inadvertently intercepted by the boiler room excavation. Ever since, sump pumps have run continuously to remove approximately 150 gpm of ground water from the school's basement. For 70 years, the ground water was seen as a significant liability, since several power outages had disabled the sump pumps and flooded the boiler room.

In 2006, Indianapolis Public Schools (IPS) chose school #87 to be a year-round, inner city magnet school, requiring the addition of air conditioning. IPS sought out a consultant who had a vision to use the ground water for the building's heating and cooling system. The design now provides cooling at half the cost of conventional equipment, and heating for about one quarter the cost of the old system. The ground water is now a significant asset. The creative legacy of George Washington Carver continues at his namesake school.

THE DESIGN

"Since new developments are the products of a creative mind, we must therefore stimulate and encourage that type of mind in every way possible."
— George Washington Carver

Geothermal heating and cooling will almost always be more efficient to operate than conventional systems. The first-cost premium is usually the cost of drilling the wells (bore holes), which may be as much as $3,000 per installed ton of cooling. In urban settings like this one, there is seldom enough acreage for a well field (bore field). For example, at nominal well spacing of 20 ft, a football field would be big enough for about 350 tons of cooling, given reasonable subsurface


Marion Co.
THE PROCESS
The system uses the groundwater's constant temperature — 55 to 58 degrees — to heat and cool the building. Here are the key phases of the system:
THE CENTERPIECE
A 10,000-gallon stainless steel storage tank collects the groundwater and maintains efficient temperatures for heating or cooling. Any overflow goes to the building sewer.
Groundwater
When temperatures grow too frigid for the groundwater system to heat the building, backup boilers turn on.
1 Sump pumps channel roughly 150 gallons of water per minute through a strainer along a network of insulated steel pipes (not shown).
Transfer pumps
Hallway
Strainers
EASY VIEWING
A large window turns the heating and cooling system into a working science exhibit for students passing in the hallway.
Sump pumps
Heat exchangers
2 Transfer pumps either divert water to the storage tank or send groundwater to heat exchangers.
3 Heat exchangers separate the building's water from the groundwater.


V-5
EVAPORATOR WATER
CONDENSER WATER
ARTESIAN WATER
GEO-H/C

The “Mini-Campus”

(Holistic Energy Efficiency example)

Can a heat recovery project help another building?

Are there concurrent heating and cooling opportunities?

Is it cost effective?

Does it save energy?

CTD and TNMC

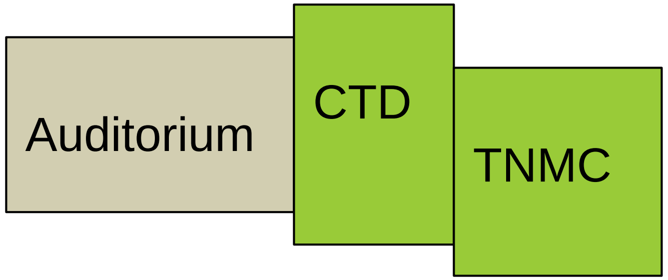
2/3 of the Fine Arts Plaza at Indiana University

CTD (1930s) renovations were planned in 1998 when TNMC was built

- HW and CHW connections in TNMC

The issues…

- Both require summer reheat for humidity control
- TNMC requires 12 month cooling



CTD and TNMC

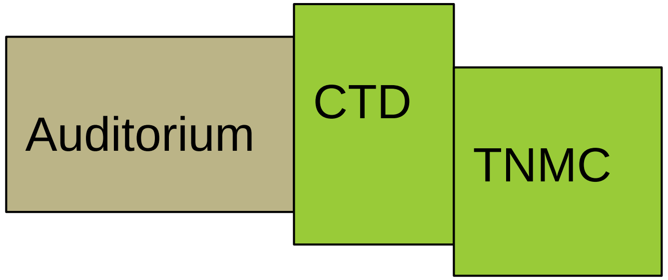
2/3 of the Fine Arts Plaza at Indiana University

CTD (1930s) renovations were planned in 1998 when TNMC was built

- HW and CHW connections in TNMC

The issues…

- Both require summer reheat for hun
- TNMC requires 12 month cooling



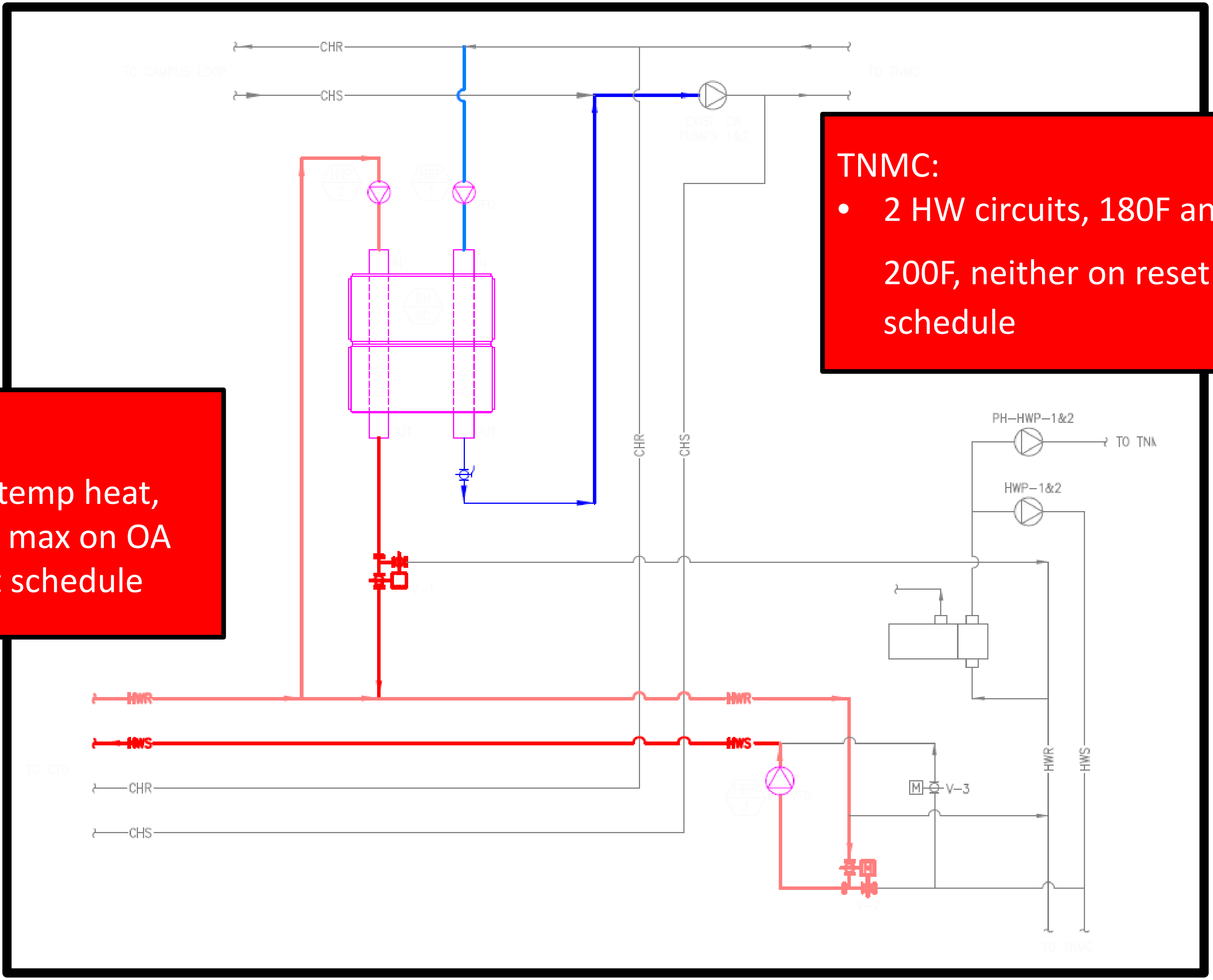
Our design proposal

- Design CTD for low temp heating
- HRC as heat source
- Backfeed TNMC when appropriate

IU said okay, but only as an alternate.

CTD

- Low temp heat, 130F max on OA reset schedule

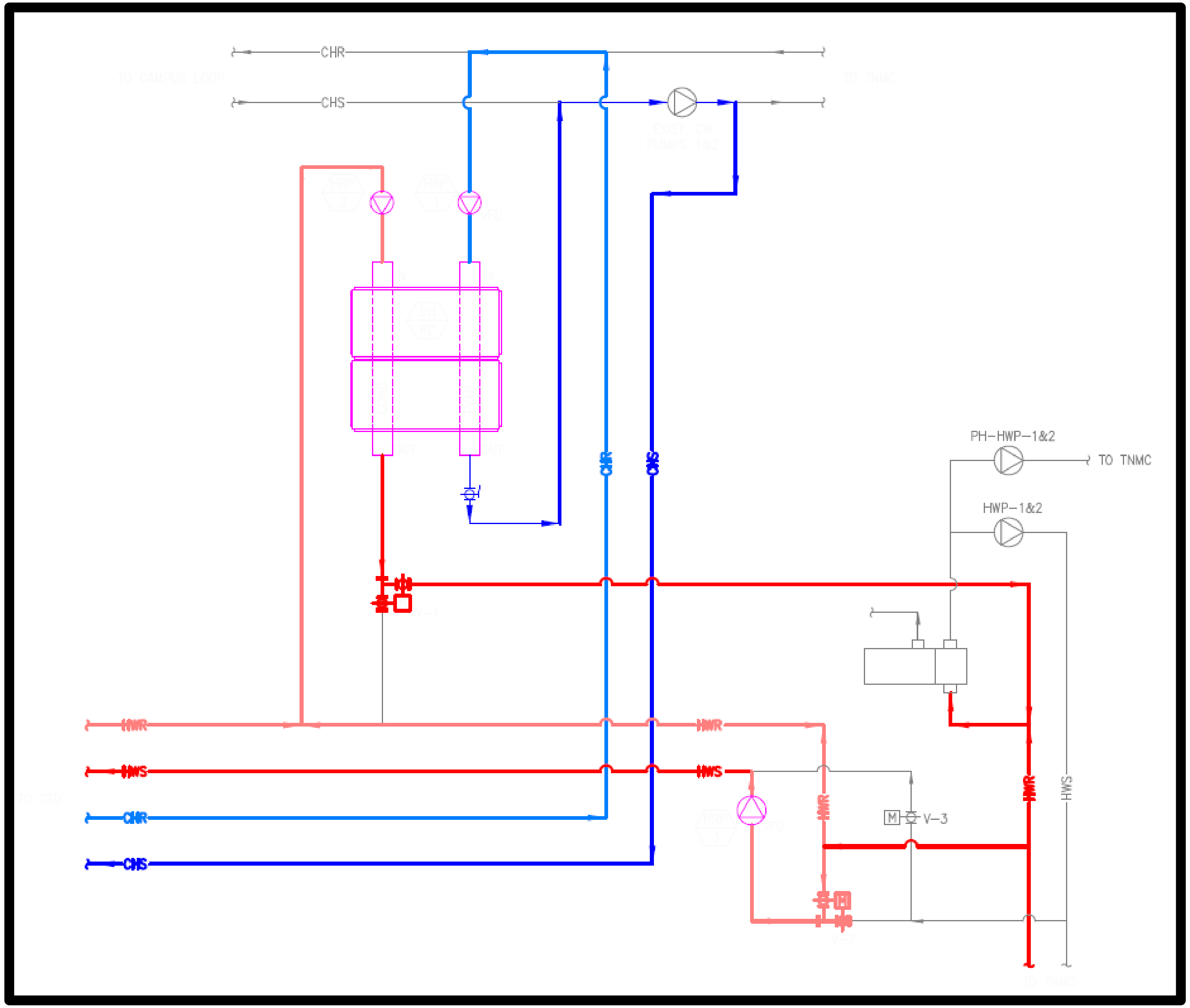


TNMC:

- 2 HW circuits, 180F and 200F, neither on reset schedule

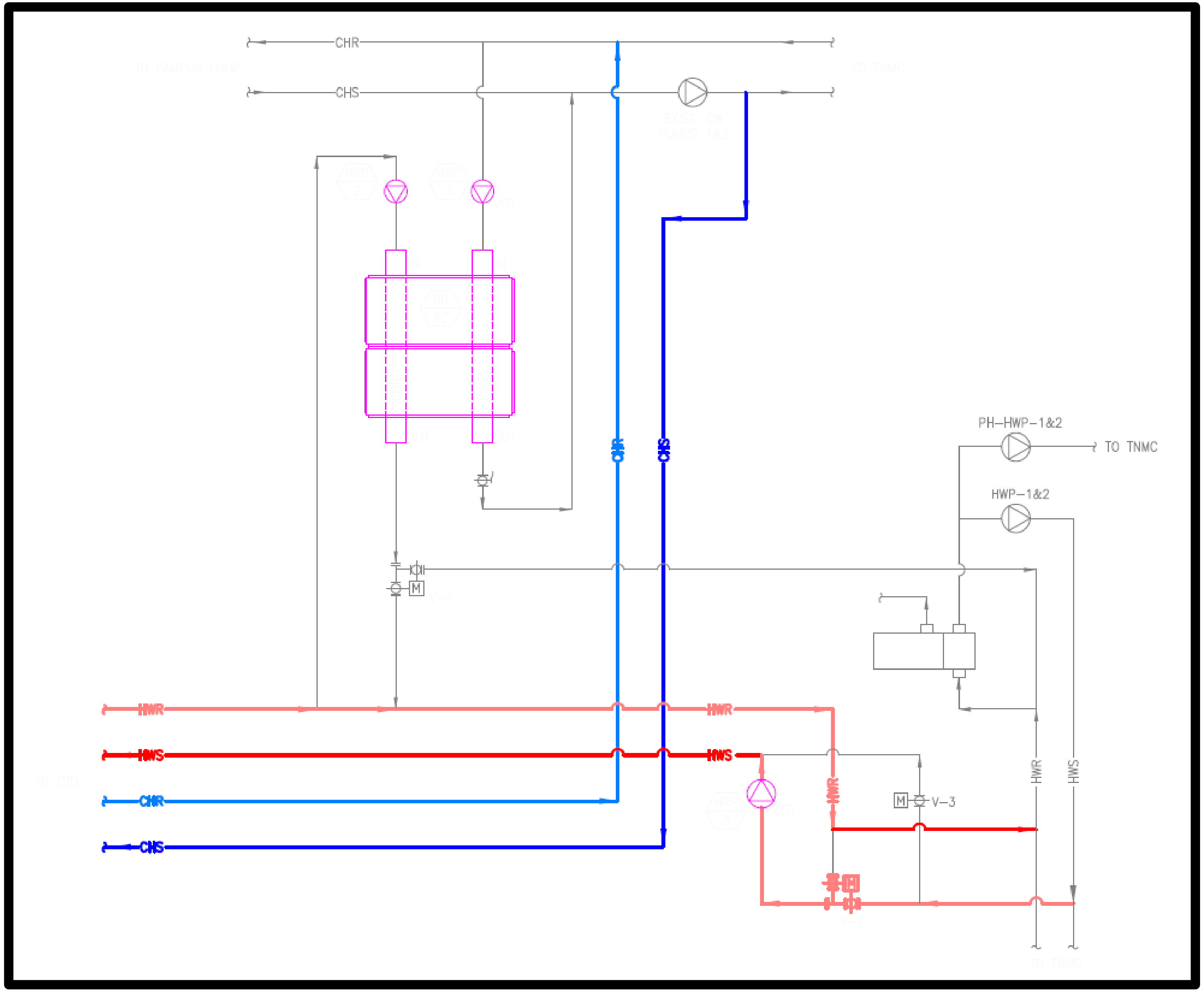
At OAT below 40F,

- HRC provides all the heat for CTD
- Condenser outlet on HW reset schedule vs. OA
- TNMC heating on old schedule from steam HX



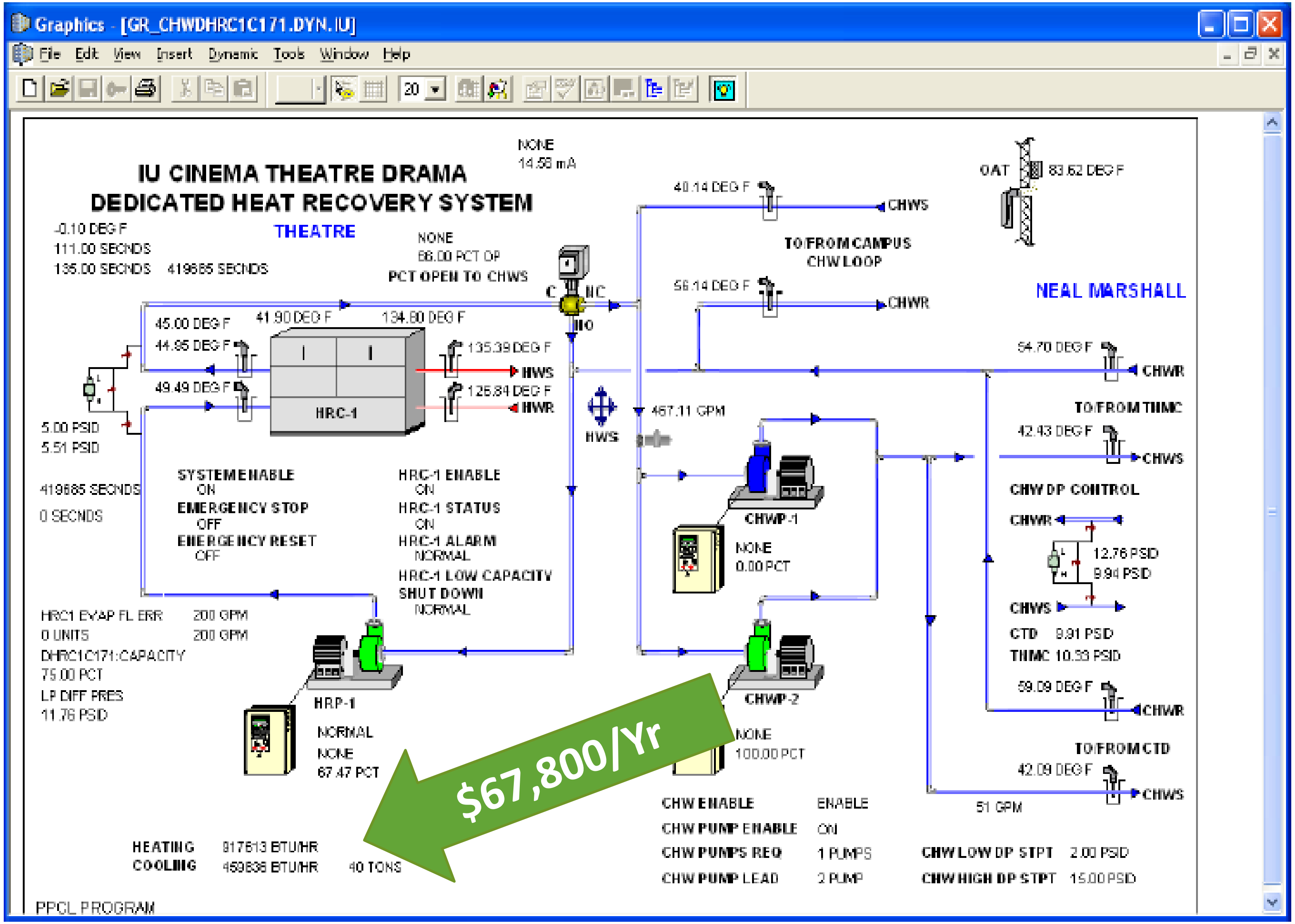
At OAT above 40F,

- HRC provides all the heat for CTD and TNMC
- 120F condenser outlet set point
- Steam HX is off



HRC off

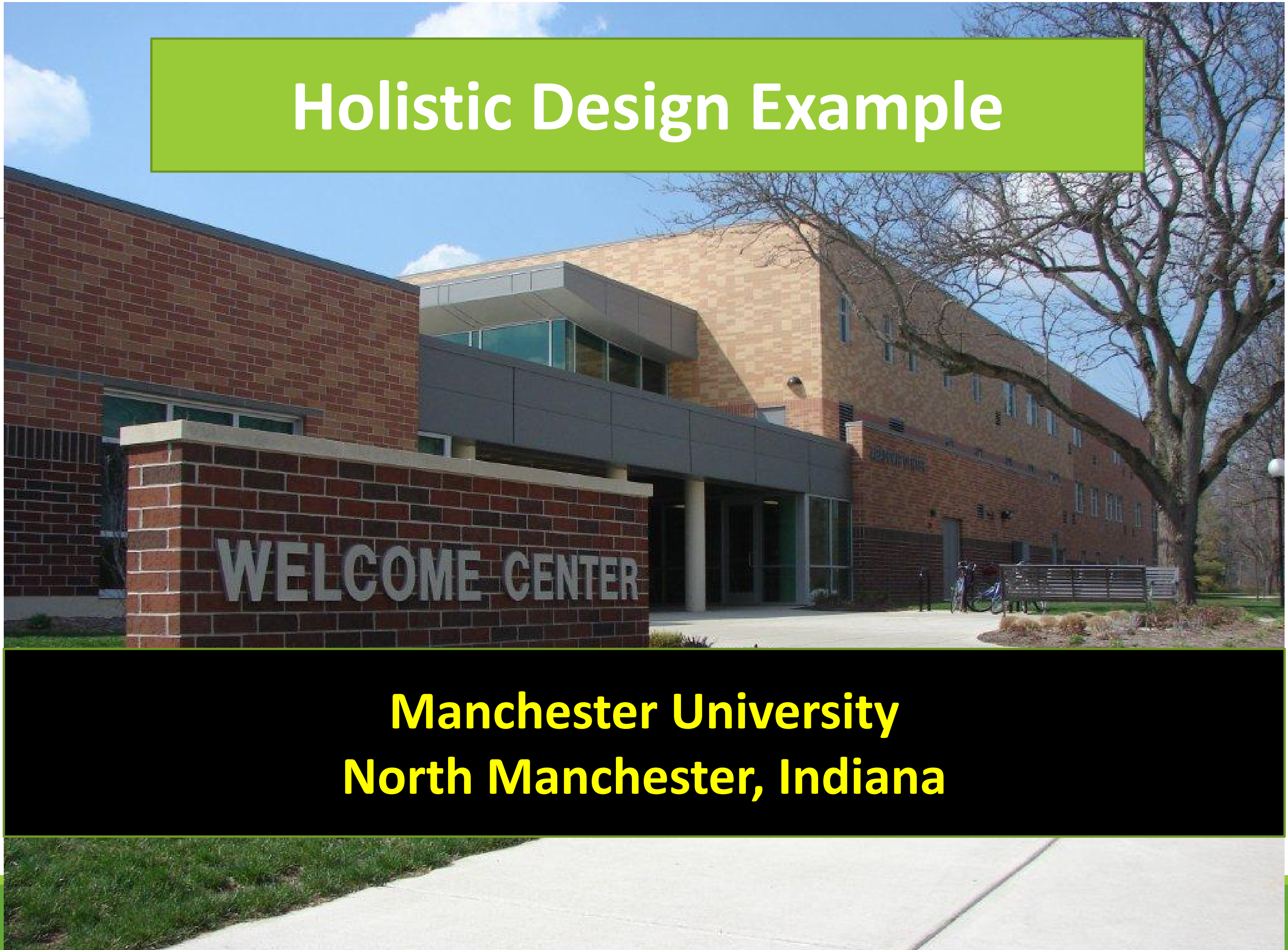
- CTD and TNMC heating on old schedule from steam HX, per original plan



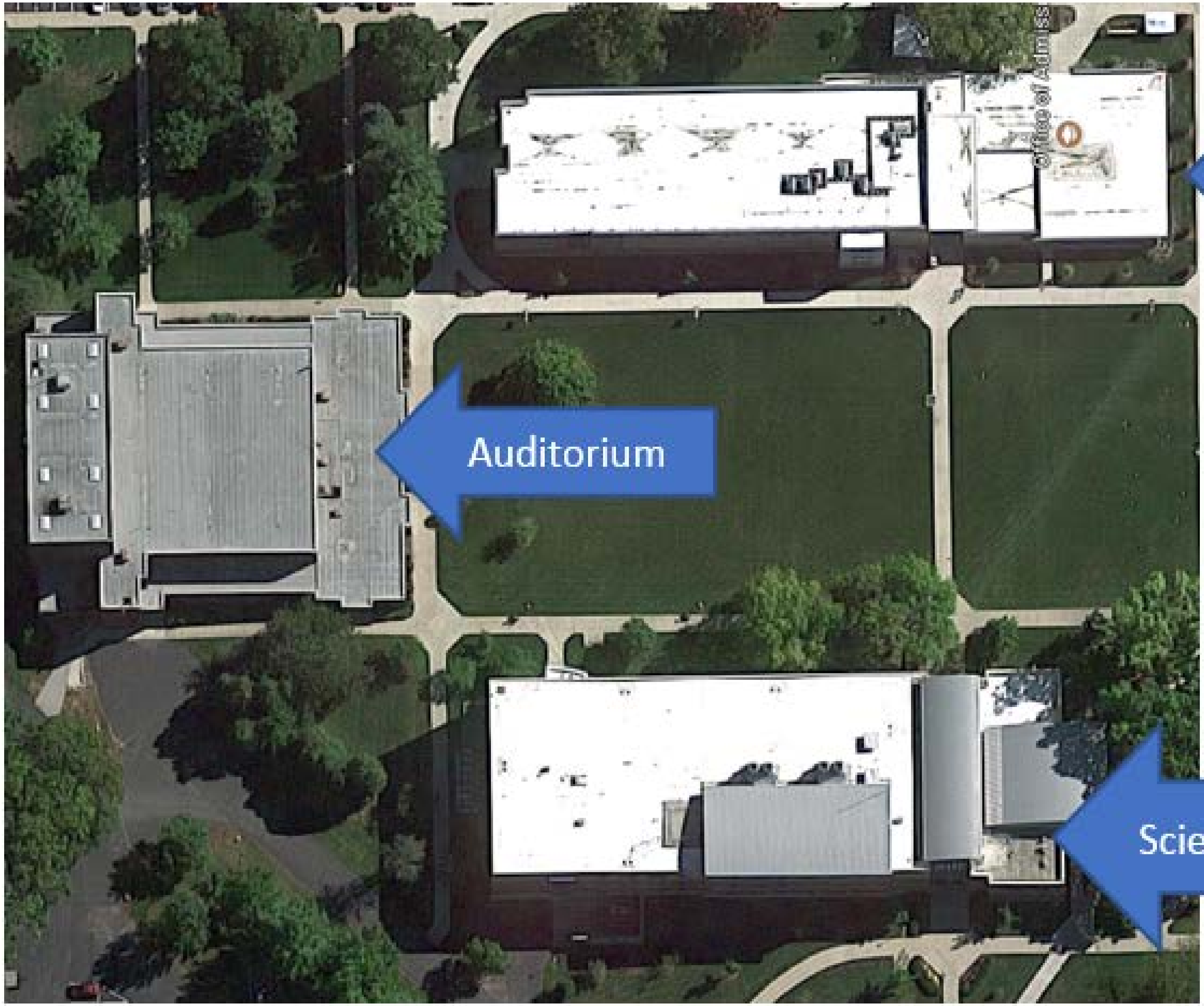
Bid as an alternate: $159,000; payback = 2.3 Yrs (1/2 of projected)

One of four performance spaces in CTD. Murals are historic from 1930’s by Thomas Hart Benton

Holistic Design Example



Manchester University
North Manchester, Indiana



Manchester University
North Manchester, Indiana

Existing Conditions

- Renovation and expansion of H-K into The Academic Center
- Utility tunnels (CHW) connect all three; steam to H-K and Auditorium
- H-K and Auditorium need reheat for summer humidity control, but not available because steam off from April to October
- Science has its own boilers, phase 1 of steam system phase out.
- Campus loop short of CHW capacity.

Two Approaches

1. Stand alone - boilers and chiller at Academic Center

2. Energy recovery (Holistic) approach that would
   - Provide heating and cooling for Academic Center
   - Connect Academic Center with its two neighbors
   - Address summer reheat requirements at Academic Center, Science and Auditorium

What changes?

Stand Alone Approach, all at Academic Center

- Air cooled chiller
- Two low temperature boilers

What changes?

Energy recovery (Holistic) Approach

- Heat recovery chiller at Science
  - Air cooled condenser for both chilled water and heat recovery
  - Geo alternate was designed but not built
- Low temp boiler serving all three buildings
  - Utilize spare capacity for redundancy
- New HW lines connecting all three
  - 1,000 Ft of steam mains repurposed as HW return
- Academic Center required mechanical space reduced

Cost Implications

Net cost **increase 1%** of total Academic Center construction budget

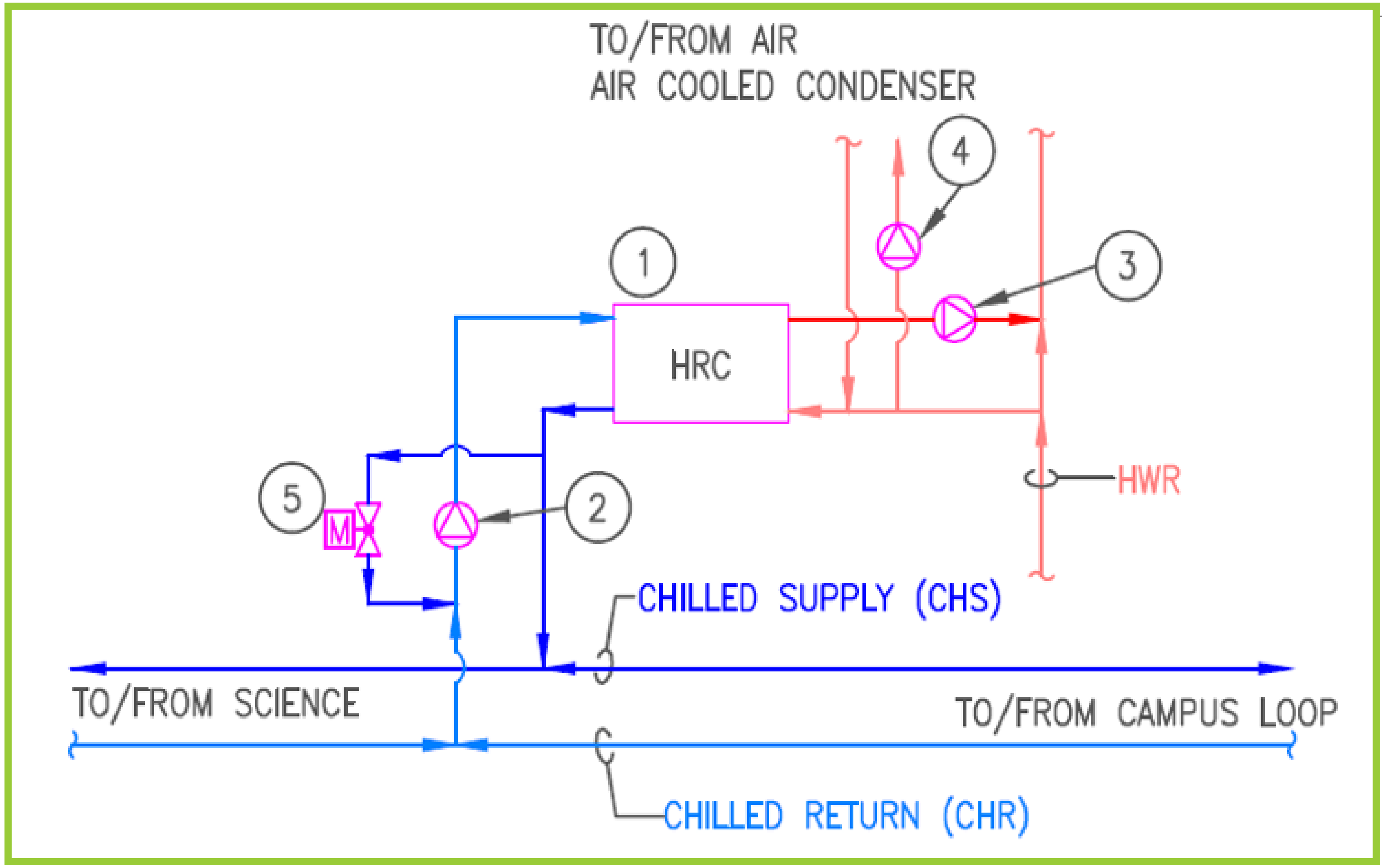
But

If we include campus master plan $ for boilers at Auditorium,

Net Budget **decrease of $83,000.**

Additional **300 S.F.** at Academic Center now available for academic uses at average cost of $150 per S.F.

Chilled Water Schematic at Science



1. 100T heat recovery chiller
2. Variable speed primary pump
3. Constant speed condenser pump
4. Constant speed heat rejection pump
5. Minimum flow/HRC discharge temperature control valve

An Efficient Heating System

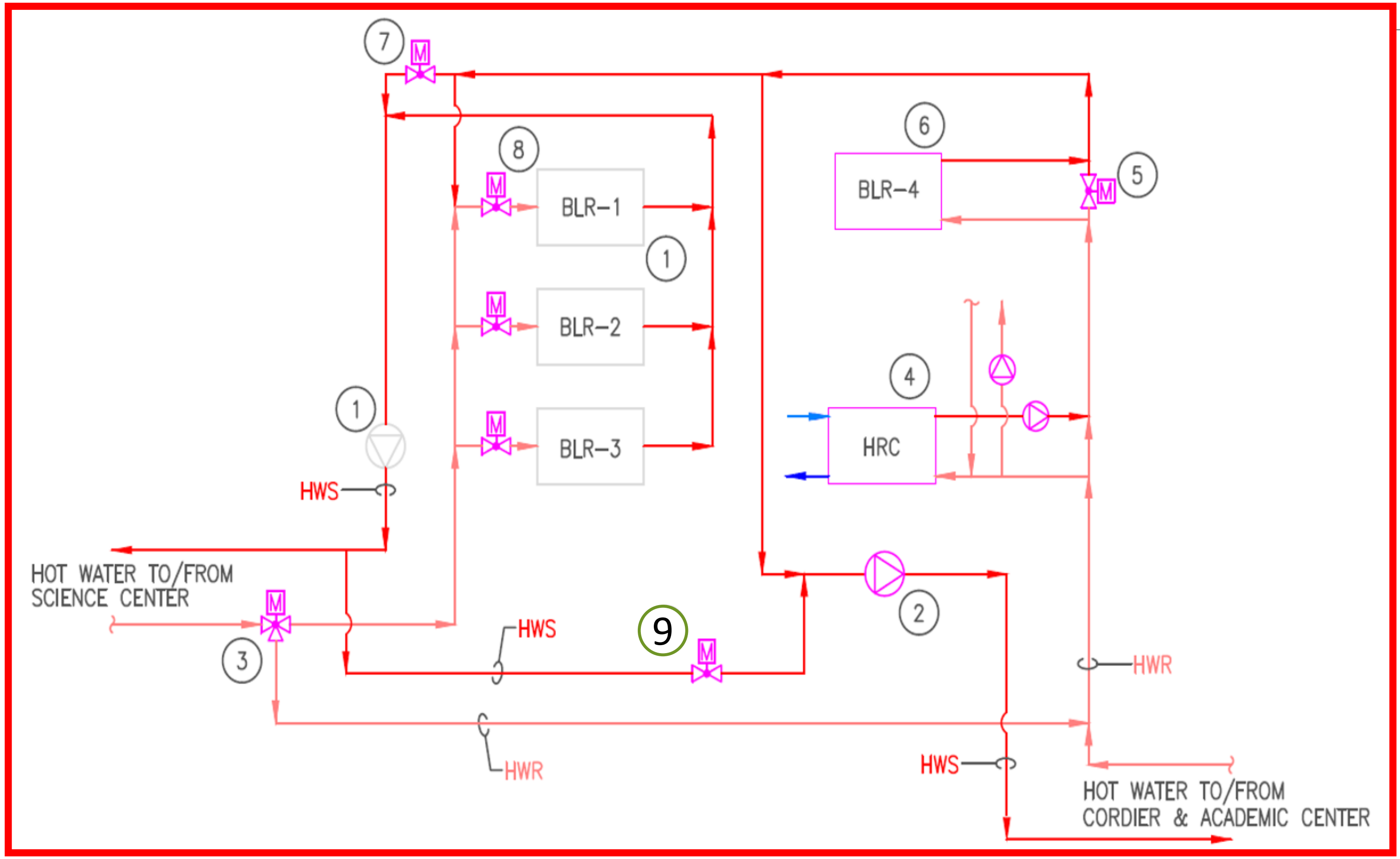
Tying two designs together

Academic Center and Auditorium heating designed for 130F

Science Building heating designed for 180F

- Revise Science HW supply schedule based on control valve position, not outside air
- If Science HW return is cool enough, < 130F, divert to HRC inlet

Hot Water Schematic at Science



1. Exist HW boilers (3) and pumps for Science (2)
2. New HW pumps for Academic Center and Auditorium (2)
3. New HW diverting valve
4. Heat Recovery Chiller (HRC)
5. BLR-4 by-pass valve
6. New low temp boiler for Academic Center and Auditorium
7. Exist Boiler by-pass
8. Boiler isolation valves
9. Supplemental heat for Academic Center and Auditorium

Sequences

Hot Water

- HRC runs to meet low temp reset schedule

  Stage 1 heating, $0.19/Therm.

- BLR-4 runs if HRC cannot meet HW load

  Stage 2 heating, $1.25/Therm.

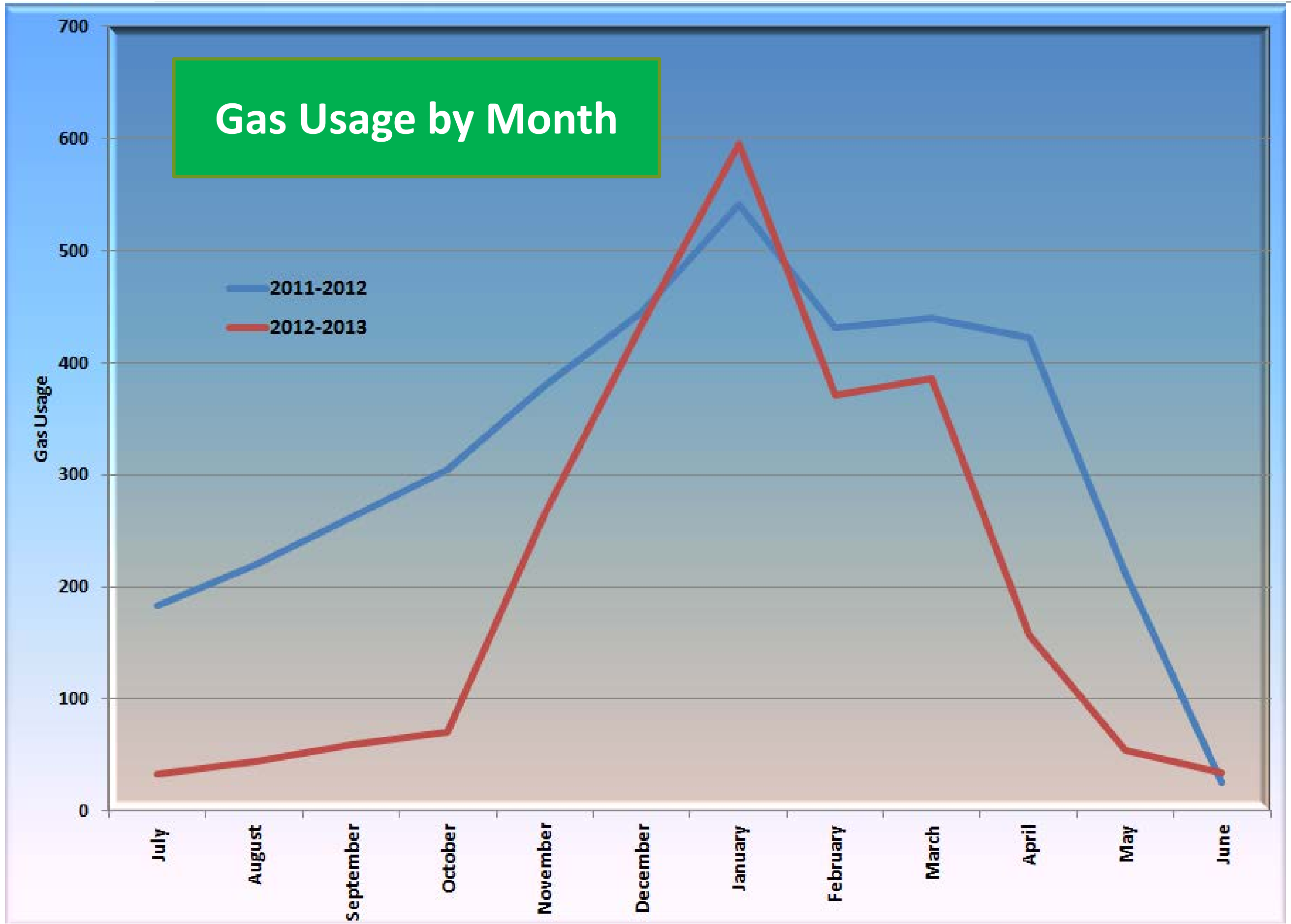
- Existing boilers run to meet Science HW load if HRC and BLR-4 cannot

  Stage 3 heating, $1.88/Therm.

Results

	Before Project 2011-2012	After Project 2012-2013	% Change
Gas Used at Science Center, Decatherms	2,803	2,182	Down 22%
Gas used at University, Decatherms	37,376	36,641	Down 2%
Steam Used at Cordier, Lbs./Yr	433,696	-0-	
Steam Used at H-K, Lbs./Yr	883,935	-0-	
Steam Main Line Loss, Lbs./Yr	474,100	-0-	
Area Heated from Science Center, Sq. Ft.	85,000	164,316	Up 93%
Heating Degree Days/Yr	4,546	4,689	Up 3%

Conclusions



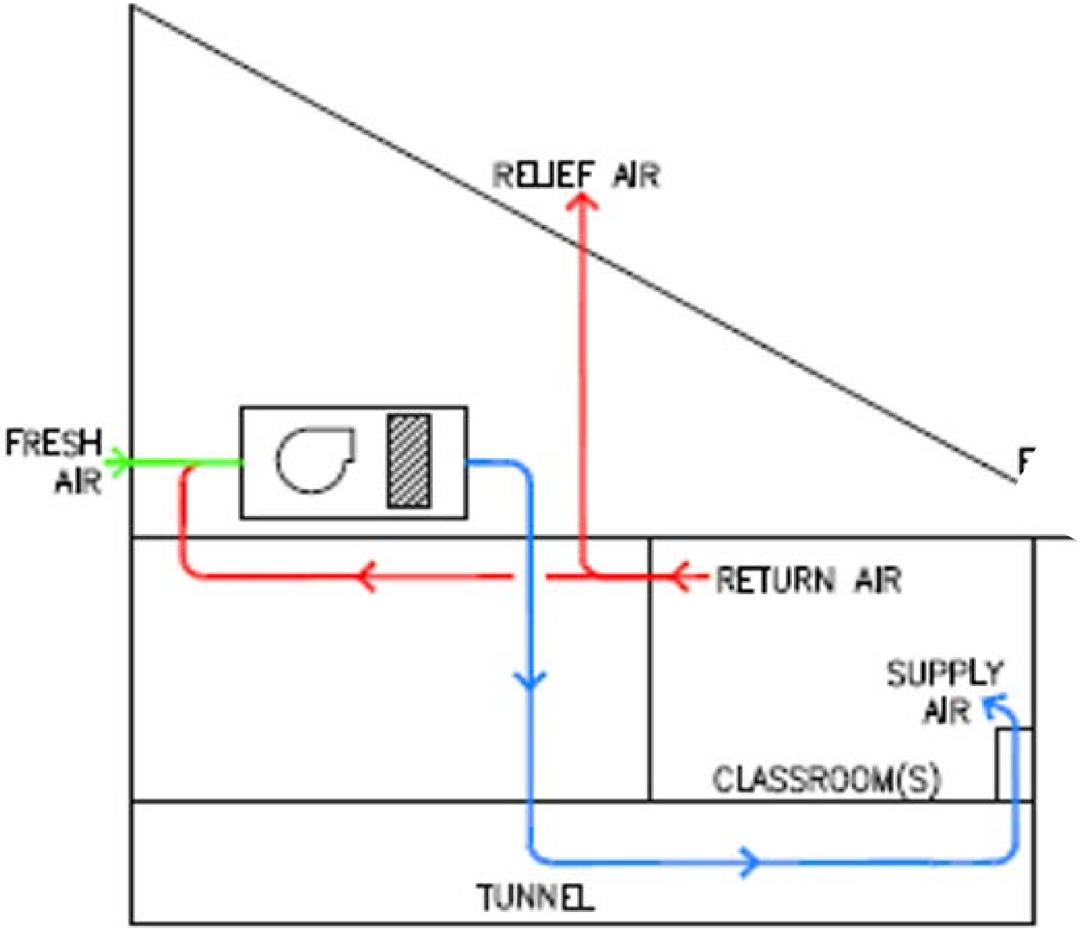
Less gas to heat three buildings than to heat one

Including the steam no longer used, **41% decrease** in gas usage

Similar approaches will have tremendous energy efficiency potential!

Deep Energy Design

Update the HVAC



The issues…

- Old tunnel induction system
- DX cooling added to MUA
- Poor temp control
- Temp degradation of primary air
- IAQ concerns about using tunnels for fresh air
- Don't just abandon the tunnels
- Code requires energy recovery

Design Concerns

What to do with the tunnels?

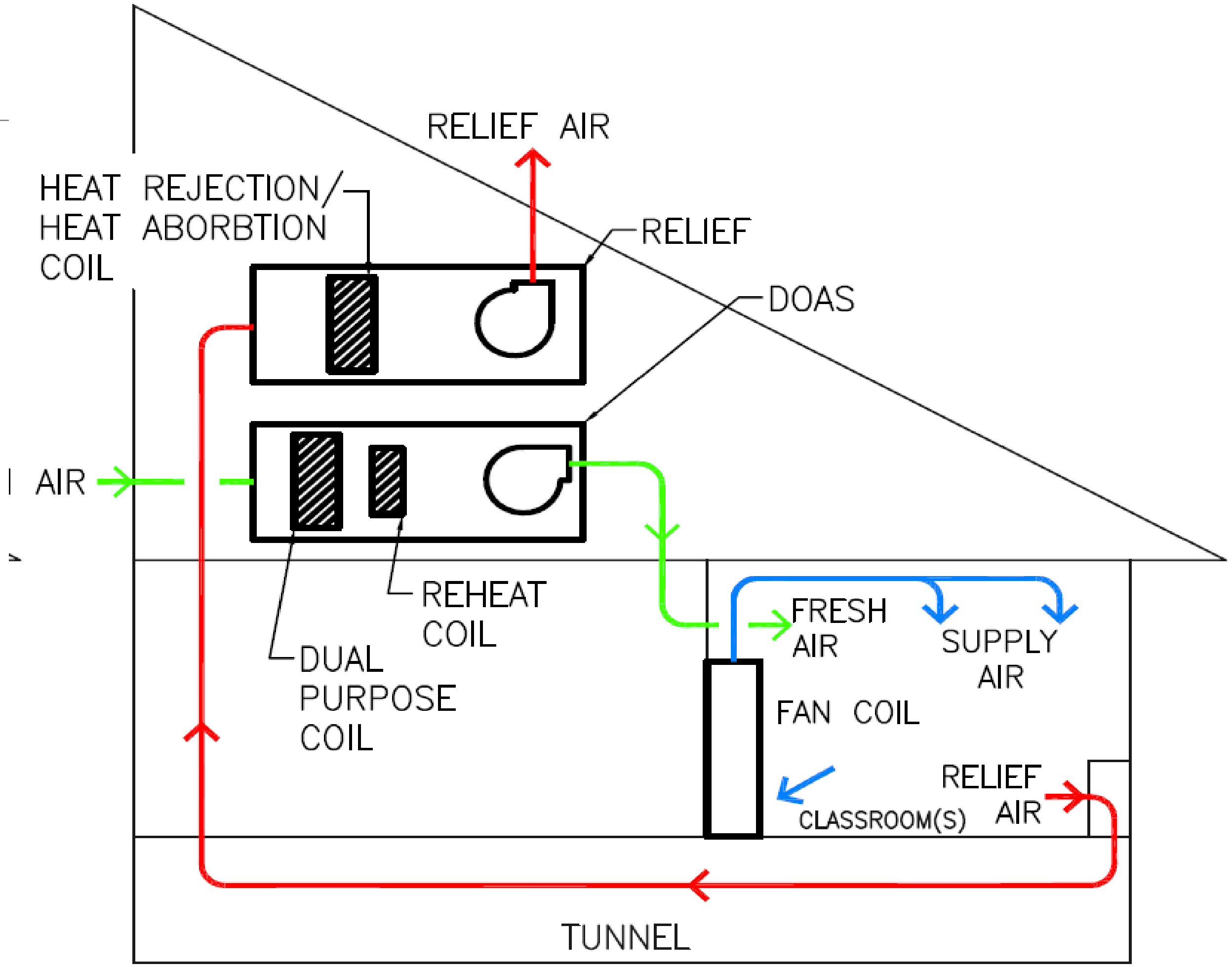
- High humidity from water below floor?
- Possible radon accumulation?
- Costly to fill?

How can we recovery energy?

Limited space for new equipment

- Existing mezzanines

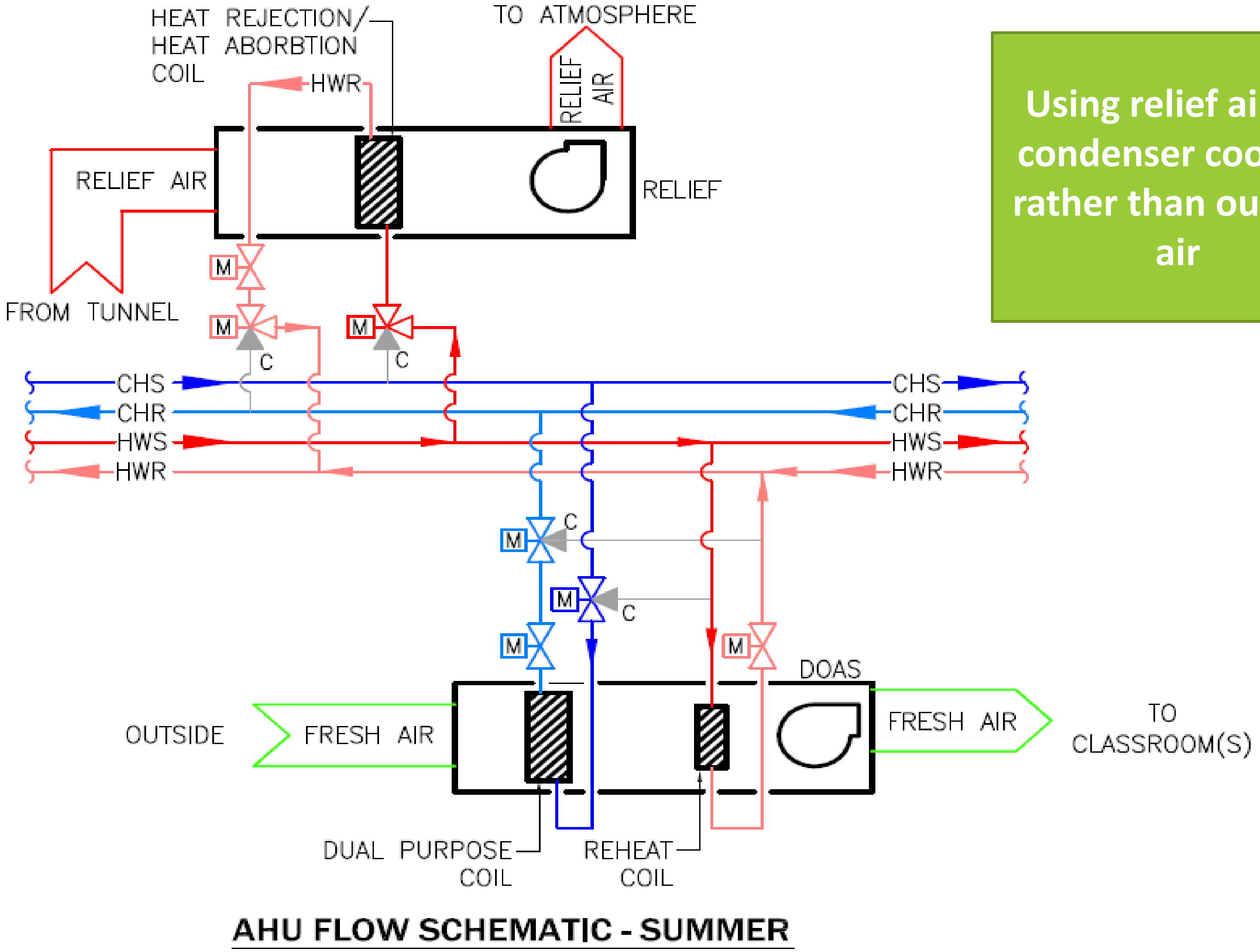
When Nothing Else Fits



AIR FLOW SCHEMATIC - NEW

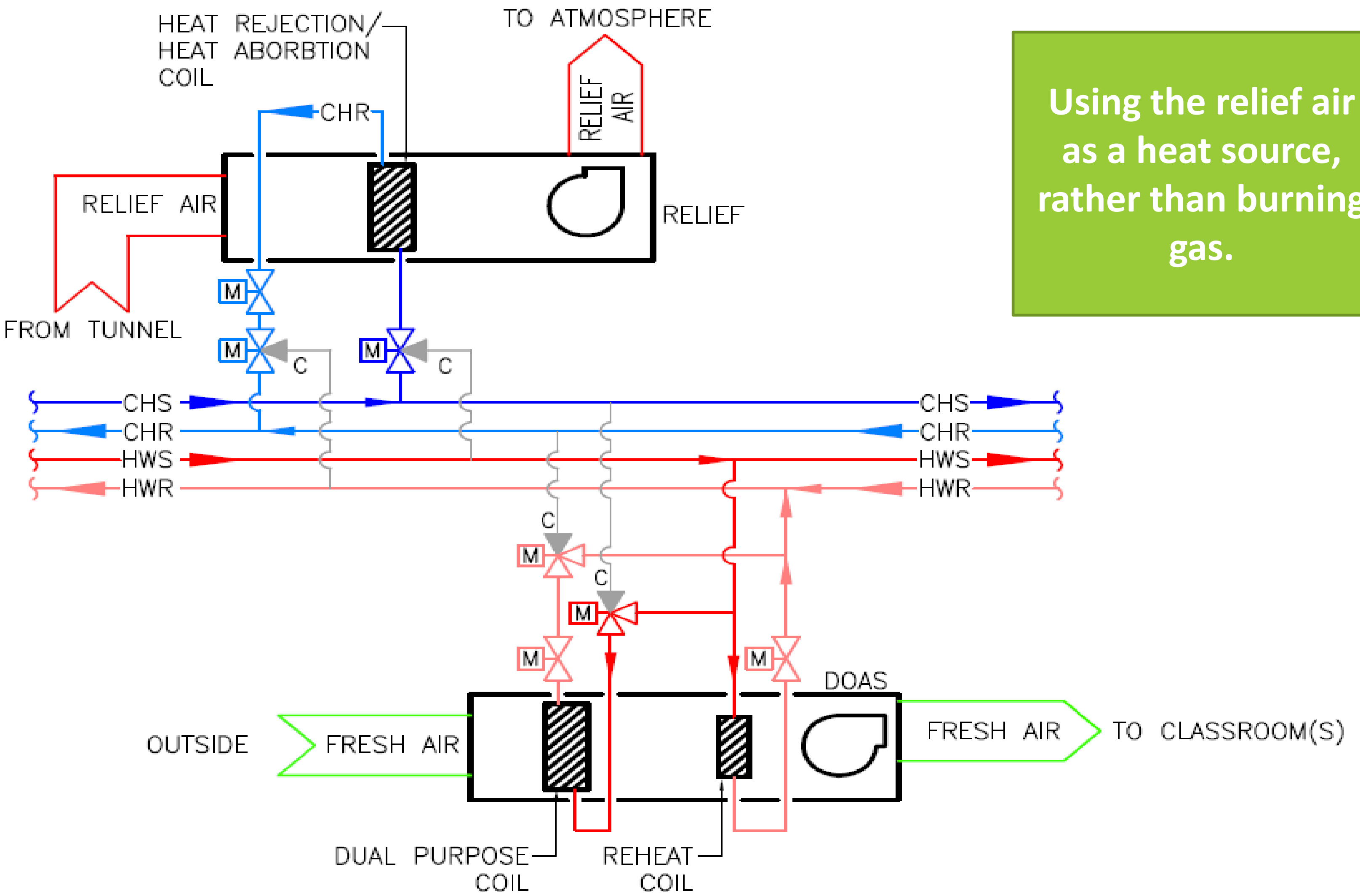
DERAC

(DHRC Enhanced Runaround Coils)



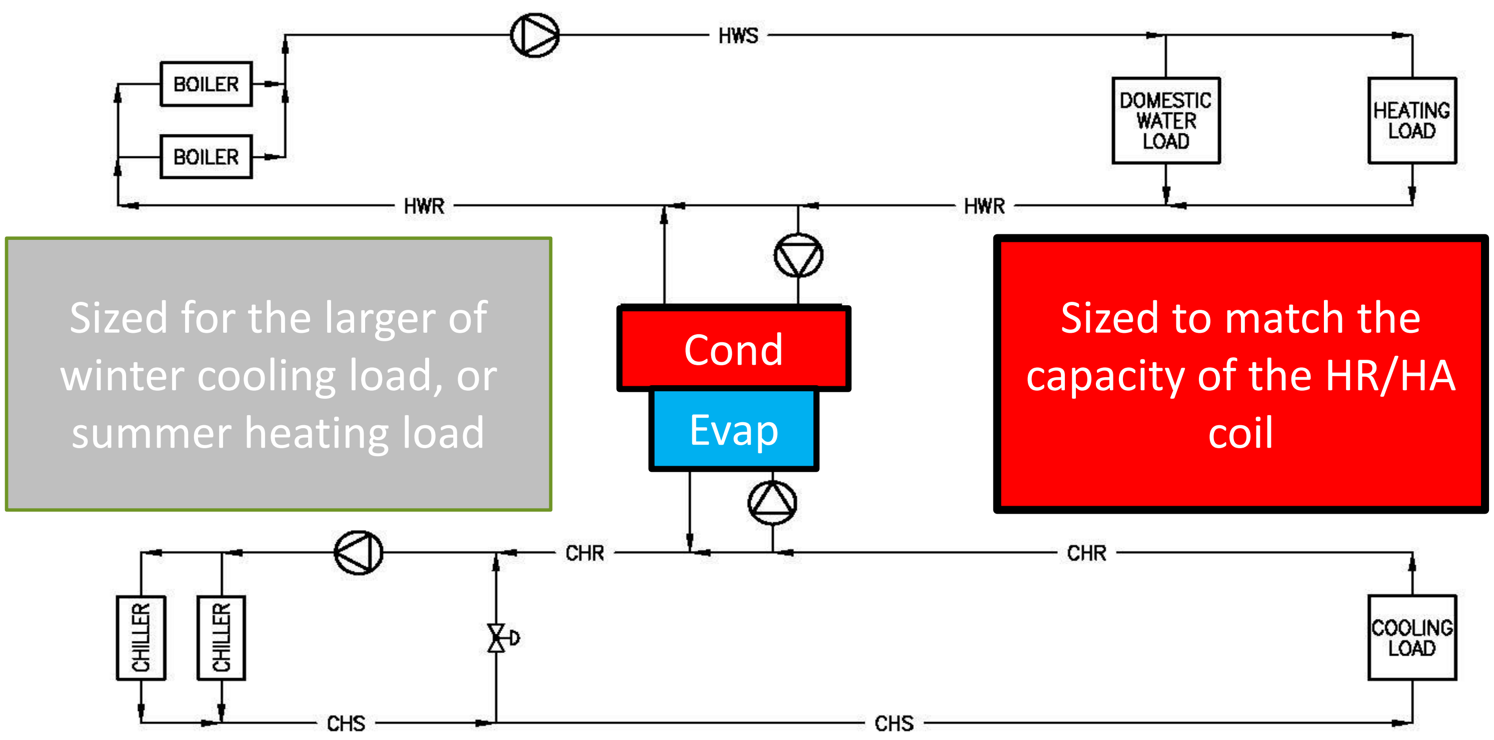
Using relief air for condenser cooling, rather than outside air

DERAC



AHU FLOW SCHEMATIC - WINTER

Using the relief air as a heat source, rather than burning gas.



Heat Recovery chiller in a 4-pipe system

Why do we do this?

A HR chiller operates to address con-current heating and cooling loads

Naturally occurring con-current loads

- **Combined C.O.P. ~ 7.7**

Artificially occurring con-current loads

- **Heating C.O.P ~ 5.0**
- **Cooling C.O.P. ~ 3.6, or +/- 0.88 kW/T**

Potential savings at HHES ~ $4.98/Hr in summer

Potential savings at HHES ~ $0.53/Hr in winter

At Various O/A Conditions

	Energy and Cost to Precondition 10,000 CFM to Room Neutral Conditions										
	No Energy Recovery			Run-Around Coil (RAC)				DHRC Enhanced (DERAC)			
OAT, F	HTG[1]	CLG[1]	$/Hr	HTG[1]	CLG[1]	kWh	$/Hr	HTG[1]	CLG[1]	kWh	$/Hr
5	727	0	$8.08	483	0	1.5	$5.49	413	0[3]	22.8	$6.53
20	564	0	$6.27	329	0	1.5	$3.79	251	0[3]	22.8	$4.72
35	401	0	$4.46	234	0	1.5	$2.73	88	0[3]	22.8	$2.91
50	239	0	$2.65	139	0	1.5	$1.68	0[2]	0[3]	17.4	$1.48
55	184	0	$2.05	108	0	1.5	$1.32	0[2]	0[3]	13.4	$1.14
65/57	71	0	$0.79	71	0	0	$0.79	0[2]	0[3]	5.2	$0.44
75/63	208	289	$4.38	208	289	0	$4.38	0[2]	32	23.9	$2.26
85/69	208	515	$6.43	208	515	0	$6.43	0[2]	150	23.9	$3.11
95/76	208	789	$9.58	208	789	0	$9.58	0[2]	424	23.9	$5.07

Highlights of The Chart

- DERAC contributes at all OAT
  - Only energy recovery option that does
    - Free heating available at temps above 35F
    - Free cooling available at temps below 75F
- Capacity limited by size of HR/HA coil
- Can be connected to any exhaust/relief location
- Not as efficient at very cold temps as a RAC

Turbocharged Runaround Coils

DOAS Energy Requirement	DOAS Net Energy Intensity kBTU/SF/Yr (site)	DOAS $/Yr Htg/Clg	DOAS and RAH $/Yr Incl Fan Hp.
No Energy Recovery	16.545	$18,018	$22,601
Conventional Runaround coil (RAC)	12.653 24% Energy Saving	$13,853	$20,023
DHRC Enhanced Runaround Coil (DERAC)	**6.109** **63% Energy Saving**	$10,999	$15,169

Results vs. Original

Hamilton Heights Elementary School	Energy Intensity (source) kBTU/SF/Yr	$/SF/Yr	Energy Star® Rating
2008-09	175.2	$0.99	40
2011-12	91.2	$0.64	96

Saved $37,450/Yr.

Less Expensive to Build?

Equipment	No Energy Recovery	Run-Around Coil	Enhanced Run-Around Coil
Main Chiller	235T	235T	200T
Heat Recovery Chiller	15T	15T	50T
Boilers	4.6 MMBH	4.2 MMBH	4.0 MMBH
DOAS	3 coils, 9.4 BHp	4 coils, 13.1 BHp	2 coils, 7.2 BHp
Relief Fan	No coil, 4.0 BHp	HR coil, 5.05 BHp	HR coil, 5.05 BHp
Run around loop	No	Yes	No
Pumps	6	8	6

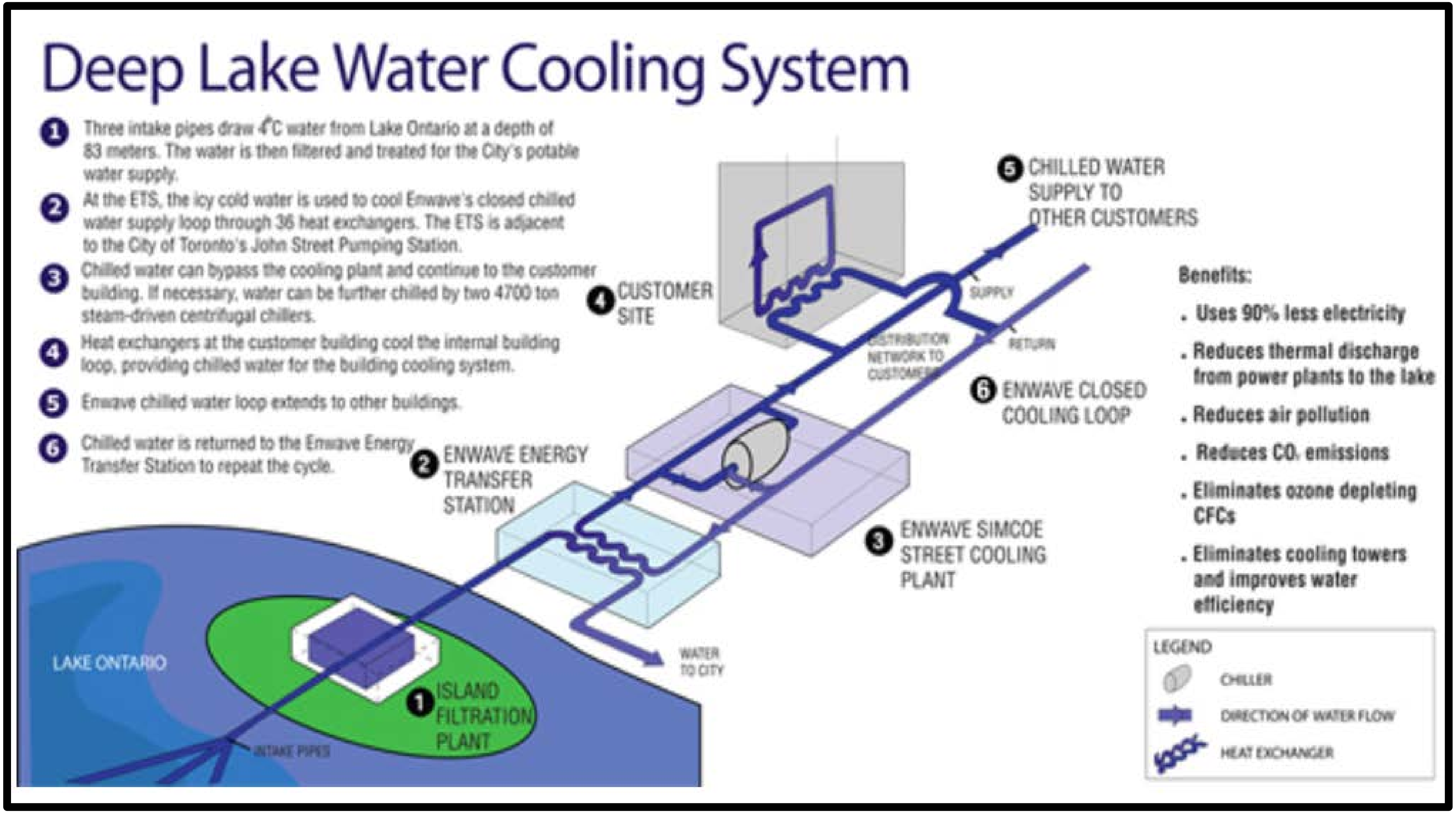
Highlights of the Chart

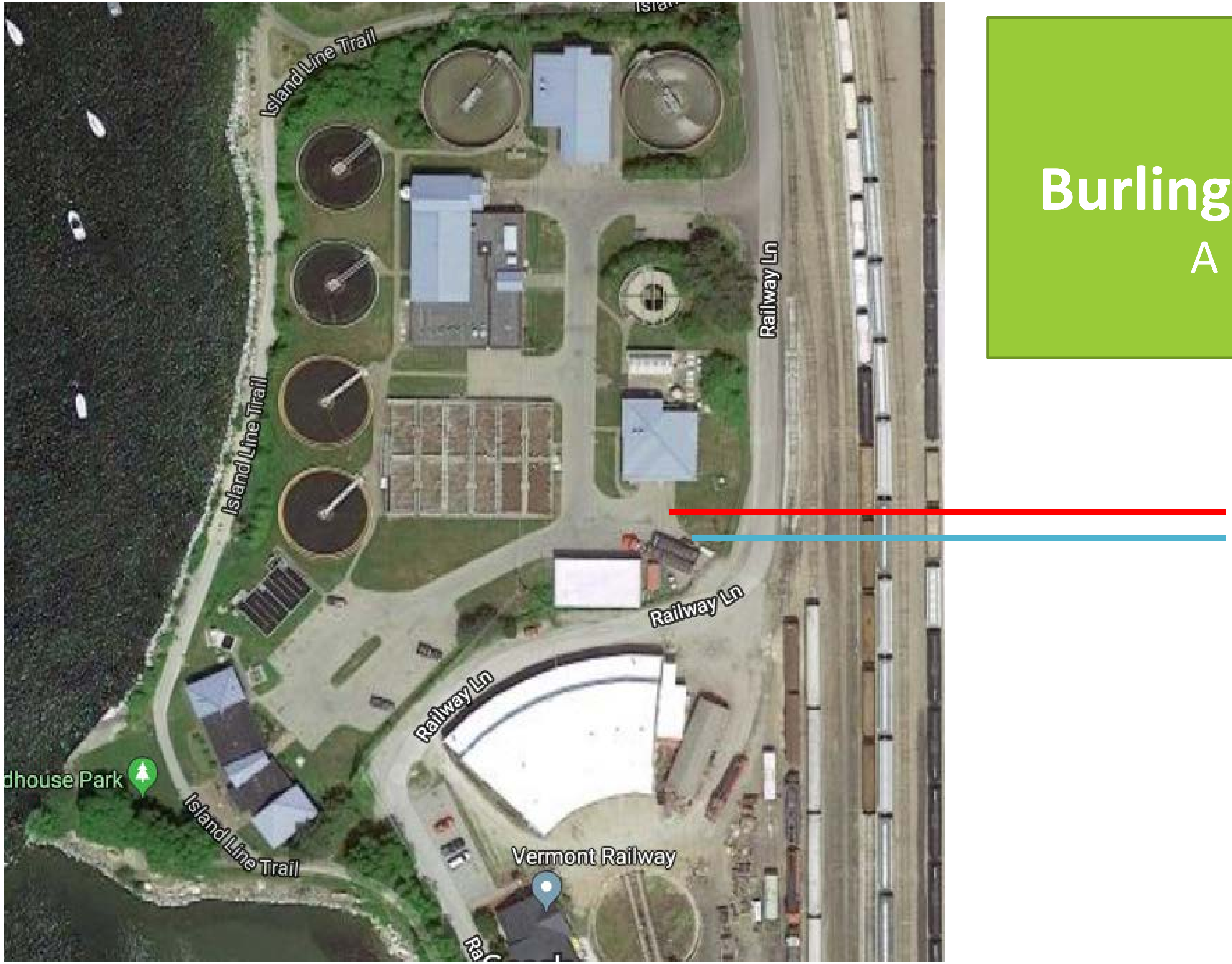
- The most efficient solution (DERAC) was the least expensive, even less than the *no energy recovery* option
- The least expensive and most efficient solution (DERAC) took less mechanical room space
- Easy and cost-effective addition to existing runaround coils

ASHRAE Journal March 2013
2013 Technology Award

Hamilton Heights Elementary School

Engineering outside the box


Deep Lake Water Cooling System
1 Three intake pipes draw 4°C water from Lake Ontario at a depth of 83 meters. The water is then filtered and treated for the City's potable water supply.
2 At the ETS, the icy cold water is used to cool Enwave's closed chilled water supply loop through 36 heat exchangers. The ETS is adjacent to the City of Toronto's John Street Pumping Station.
3 Chilled water can bypass the cooling plant and continue to the customer building. If necessary, water can be further chilled by two 4700 ton steam-driven centrifugal chillers.
4 Heat exchangers at the customer building cool the internal building loop, providing chilled water for the building cooling system.
5 Enwave chilled water loop extends to other buildings.
6 Chilled water is returned to the Enwave Energy Transfer Station to repeat the cycle.
5 CHILLED WATER SUPPLY TO OTHER CUSTOMERS
4 CUSTOMER SITE
SUPPLY
RETURN
DISTRIBUTION NETWORK TO CUSTOMERS
6 ENWAVE CLOSED COOLING LOOP
2 ENWAVE ENERGY TRANSFER STATION
3 ENWAVE SIMCOE STREET COOLING PLANT
WATER TO CITY
LAKE ONTARIO
1 ISLAND FILTRATION PLANT
INTAKE PIPES
Benefits:
. Uses 90% less electricity
. Reduces thermal discharge from power plants to the lake
. Reduces air pollution
. Reduces CO_2 emissions
. Eliminates ozone depleting CFCs
. Eliminates cooling towers and improves water efficiency
LEGEND
CHILLER
DIRECTION OF WATER FLOW
HEAT EXCHANGER



Introducing

Burlington "Metro-Thermal"

A Deep Energy Solution

Geothermal Source/Sink for downtown

NIMBY to OKIMBY?

Affordable Energy and Better Buildings

Run on the voltage of

new ideas

and

questioning traditional solutions.

Efficiency Vermont
BETTER BUILDINGS BY DESIGN

Mechanical System

Deep and Holistic Energy Applications

Energy Conservation AND Energy Efficiency

Thomas H. (Tom) Durkin, PE
ASHRAE Fellow
thdurkin46@gmail.com
(317) 402-2292