Low-Cost High-Temperature Thermal Storage for Load Shifting in Residential Applications

NEEA Product Council
November 28, 2023

Introduction of Topic		
Christopher Dymond	*NEEA*	~ 15 min
Steffes Presentation		
Al Takle	*Steffes*	
Paul Steffes	*Steffes*	~ 45 min

Thermal Storage

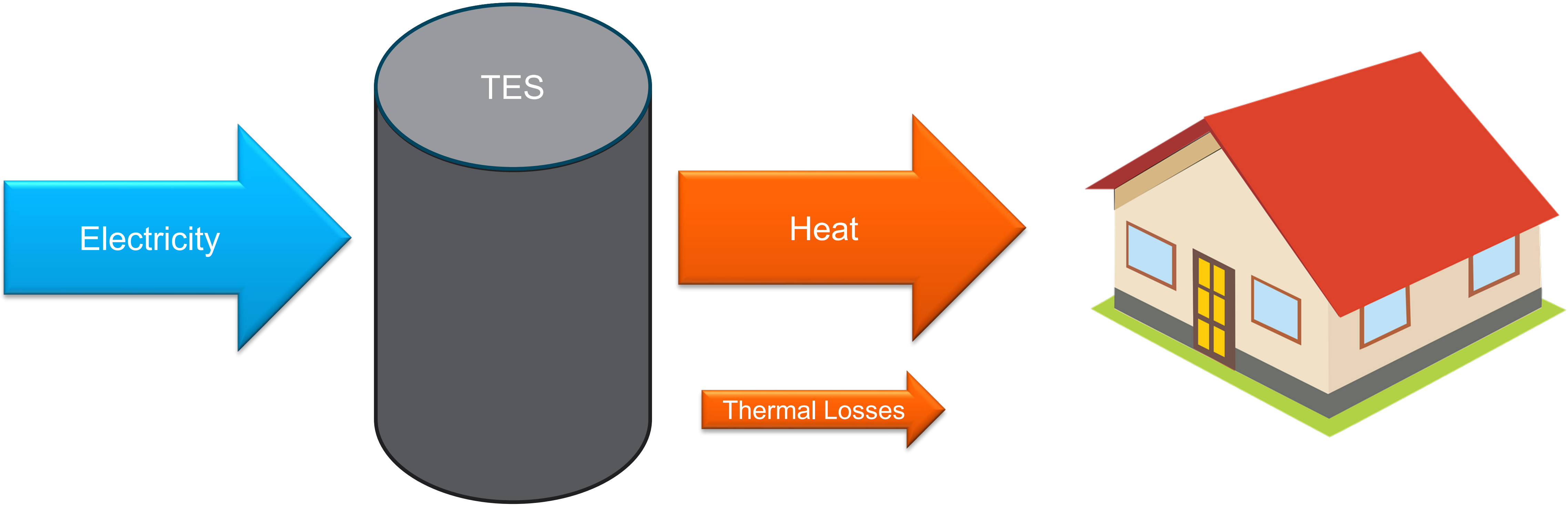
- Purpose
- Time Period
- Application
- Temperature Range
- Heat Source
- CapEx, OpEx
- Physical Space

District heating accumulation tower in Austria with a thermal capacity of 2,000,000 kWh

Todays Focus --- Residential Space Heat

• Purpose:	Space heating load shifting
• Time Period:	up to about 24 hours
• Application:	Single family housing
• Temperature Range:	60-130°F
• Source:	Electricity

Thermal Electric Storage



How much heat do we need?

- What if we wanted meet half a typical home's heating need for 4 hours when it is 36°F outside?

Amount

17,000 ÷ 2 x 4 hrs = 34,000 Btu
~10 kWh

Flow

Need 8,500 Btuh/hr to keep house warm

Building UA	500	Btuh/F
Tindoor	70	F
Toutdoor	36	F
DeltaT	34	F
Heat Loss per hour	17,000	Btu/hr

Residential Constraints

- Low Cost (end user price)
- Easy to install
- Meets building codes
- Doesn't take up much space

How about a 50-gallon water tank?

Questions

- How much of the stored energy is useable?
- How fast can it deliver this heat?
- What does it cost to replenish this heat?
- Are their any unrecoverable or non-useful standby losses?

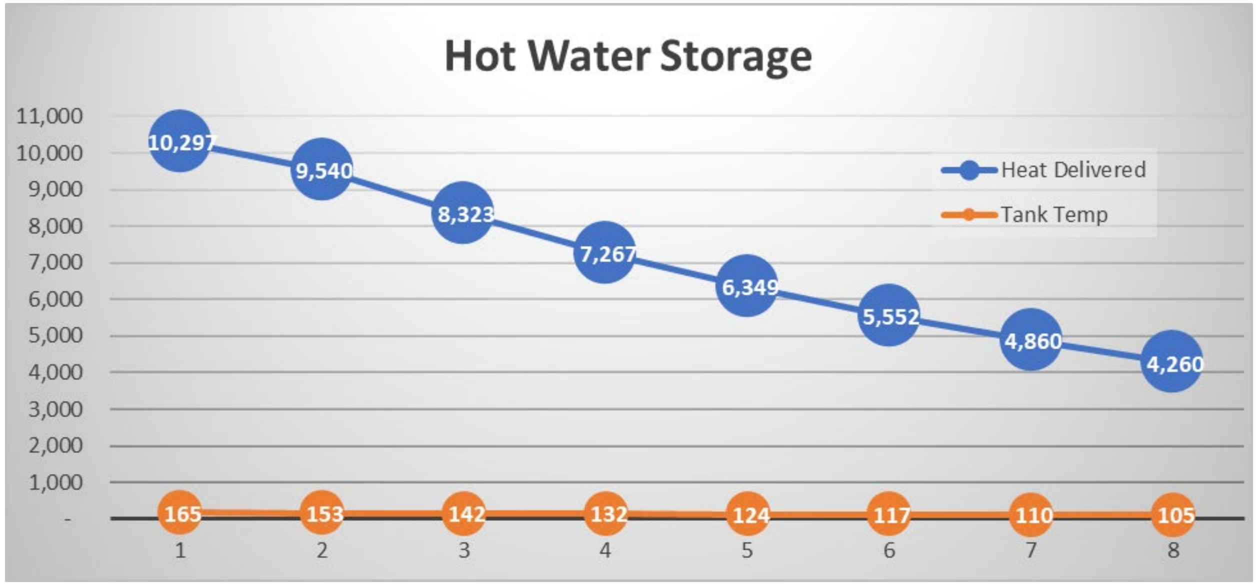
Example

- Two 50 gallon water heaters
- Hydronic wall heater
- Pump
- Thermostat

- Hardware Cost ~$1800

Two 50-gallon hot water heaters

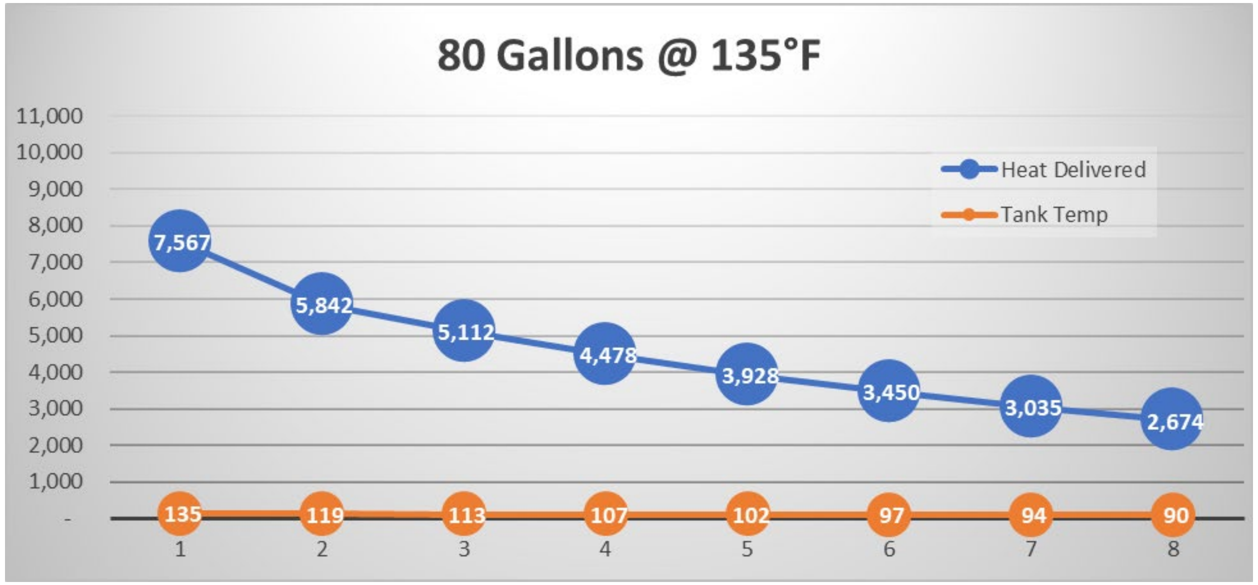
- First 4 hours 35,400 Btu
- Second 4 hours 20,800 Btuh



* Assumes max temp = 165°F, Min temp 100°F

80 gallon Heat Pump Water Heater*

- First 4 hours 23,000 Btu
- Second 4 hours 13,100 Btuh



* Assumes max temp = 135°F, Min temp 100°F

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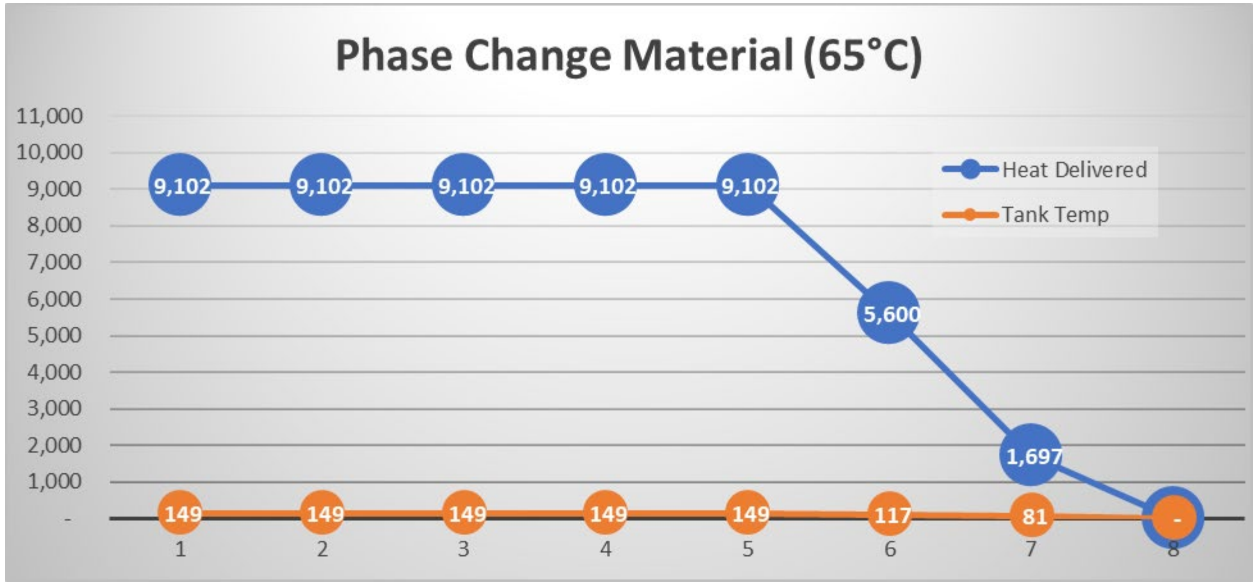
6.7ft³ of Phase Change Material*

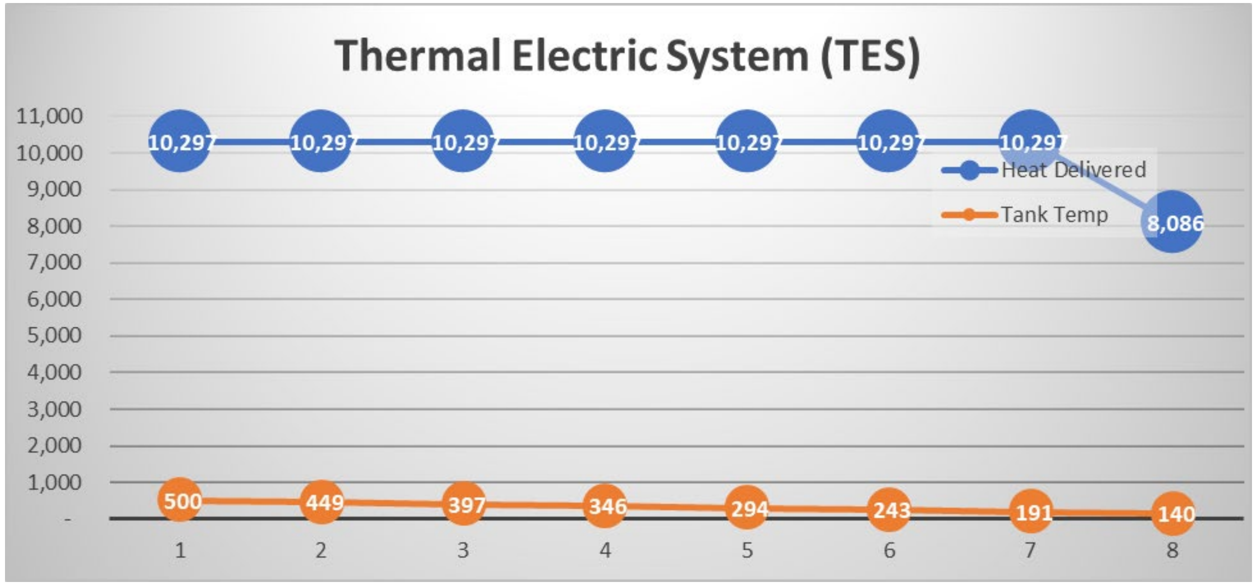
- First 4 hours 36,400 Btu
- Second 4 hours 16,400 Btuh



Tank Temp at end of hour
*149°F phase change, same hydronic fancoil

6.7ft^3 of Bricks*

- First 4 hours 41,200 Btu
- Second 4 hours 38,900 Btuh



*Charged to 500°F

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Setback Recovery vs Storage

2,200	20,000 ft3 of air (6°F DeltaT)	
+ 5,600	2,000 ft2 of 5/8” sheetrock (3°F DeltaT)	
7,800	Heat needed to setback (6°F DeltaT for ~12 hrs)	

Storage for same Size (6.7ft^3 – volume of 50 gallon tank)

8,300	Hot Water (w/20°F DeltaT)	110%
31,700	Phase Change Material	410%
77,800	Bricks (w/400°F DeltaT)	1000%

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Heat Pump Defrost vs Storage

Defrost Energy Needs = 3-10 minutes @ 10 kW
~2,500Btu (rough average)

Storage for same Size (6.7ft^3 – volume of 50 gallon tank)

8,300	Hot Water (w/20°F DeltaT)	332%
31,700	Phase Change Material	1268%
77,800	Bricks (w/400°F DeltaT)	3112%

4 hour Demand Response Call

34,000 Btu to provide 50% of typical home heating need when it is 34 F outside

Storage for same Size (6.7ft^3 – volume of 50 gallon tank)

8,300	Hot Water (w/20°F DeltaT)	24%
31,700	Phase Change Material	93%
77,800	Bricks (w/400°F DeltaT)	229%

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Energy Recovery Is Key Determinant

- Roundtrip Efficiency
  - Efficiency of the recovery system
  - Standby losses
    - Non-recoverable losses
    - Recoverable losses
- Cost
  - Time of use pricing
  - Efficiency of recovery system
- Carbon
  - CO2 emissions could be much different during recovery

Thermal Electric Storage
While standby losses are recoverable, they are provided by electric resistance heating with a COP =1.0

In our example house*, maintaining the storage at 300°F, increases the energy consumption by 6% compared to a HP that is sized to meet 100% of the load.

*Tamb = 34 ° F, Heat Pump COP at 34°F = 2.5

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Low-Cost, High Temperature Thermal Storage
for Load Shifting in Residential Applications

Presented to the NEEA Product Council

11/28/2023

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Agenda

- What is Electric Thermal Storage?
- Why is ETS important?
  - Peak Load Reduction
  - Renewable Integration
  - Enhanced Heat Pump Operation
  - Not all kWh is created equal
- How does ETS Compare to other Storage Options?

What is Electric Thermal Storage?

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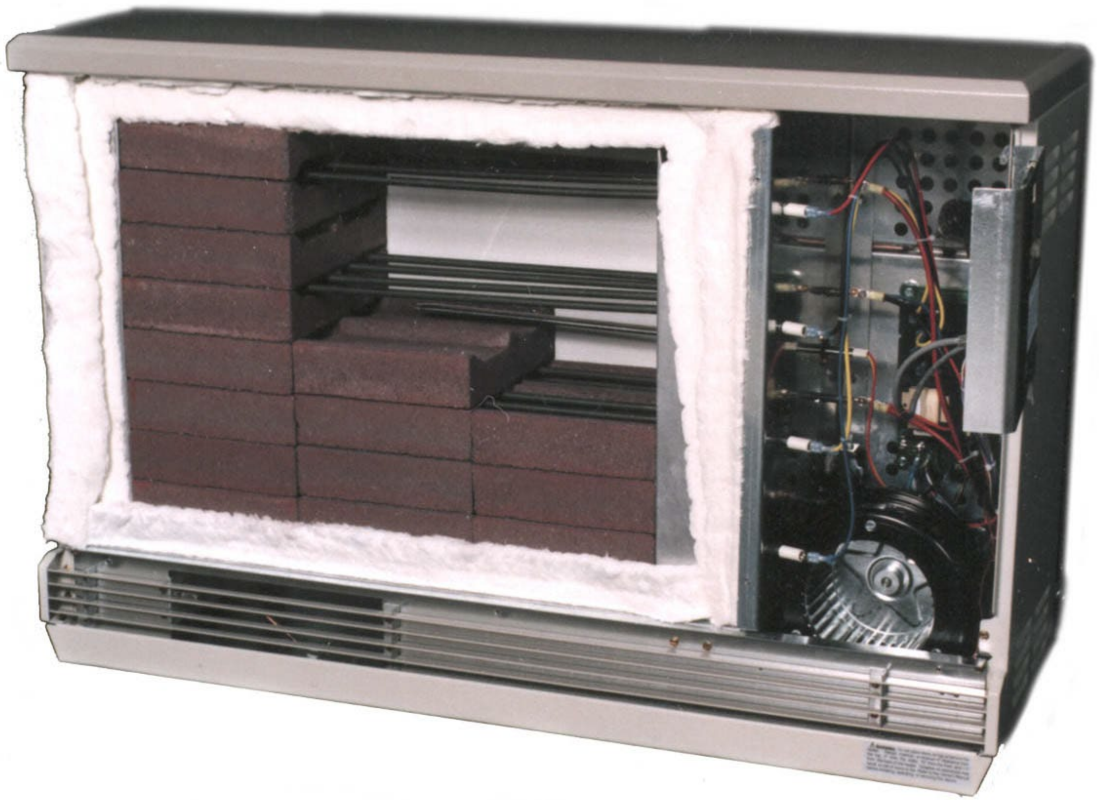
What is Electric Thermal Storage?

Storage of Renewable or Off-Peak Electricity in the form of Heat



Is this New Technology?

- Technology Started in Europe & Great Britain after WWII
- Came to North America in the early 1970’s
- Today, there are hundreds of thousands of systems installed across North America.

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It all began with Room Units

80,000 SYSTEMS INSTALLED SINCE 1987

EZ ZONING

COMFORT

2100 SERIES

Forced Air Heating

- <u>Option Number 1</u>
  - Stand Alone Furnace
- <u>Option Number 2</u>
  - Furnace w/ Air Conditioning
- <u>Option Number 3</u>
  - Furnace w/ Heat Pump

Forced Air Heating

High Efficiency Heat Pump

+

Low-Cost Off-Peak ETS

=

The MOST economical heating & cooling system available

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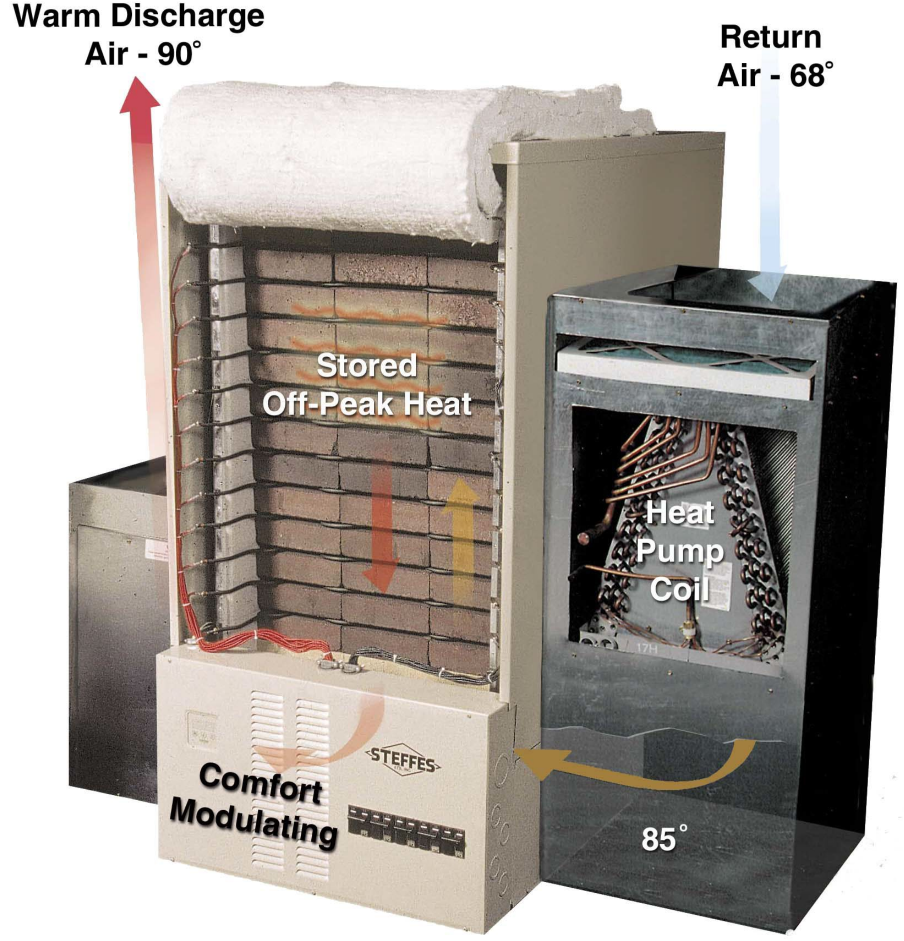
Enhanced Heat Pump Performance

Storage of Renewable or Off-Peak Electricity in the form of Heat



(Transparent View)

- Electricity is stored as heat in a well insulated brick core.
- Combination of heat pumps and Electric Thermal storage maximizes home and the electric grid system efficiency.
- On-board controls regulate charging and discharging.
- Internal blower system delivers the heat to the conditioned space as needed to maintain total home comfort 24/7.

It's FULLY AUTOMATIC

A typical installation

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Functions of High Temp TS with HP

- Setback Recovery
- No ER Defrost needed
- Load Shifting

Recharge storage with lower cost or lower carbon sourced electricity

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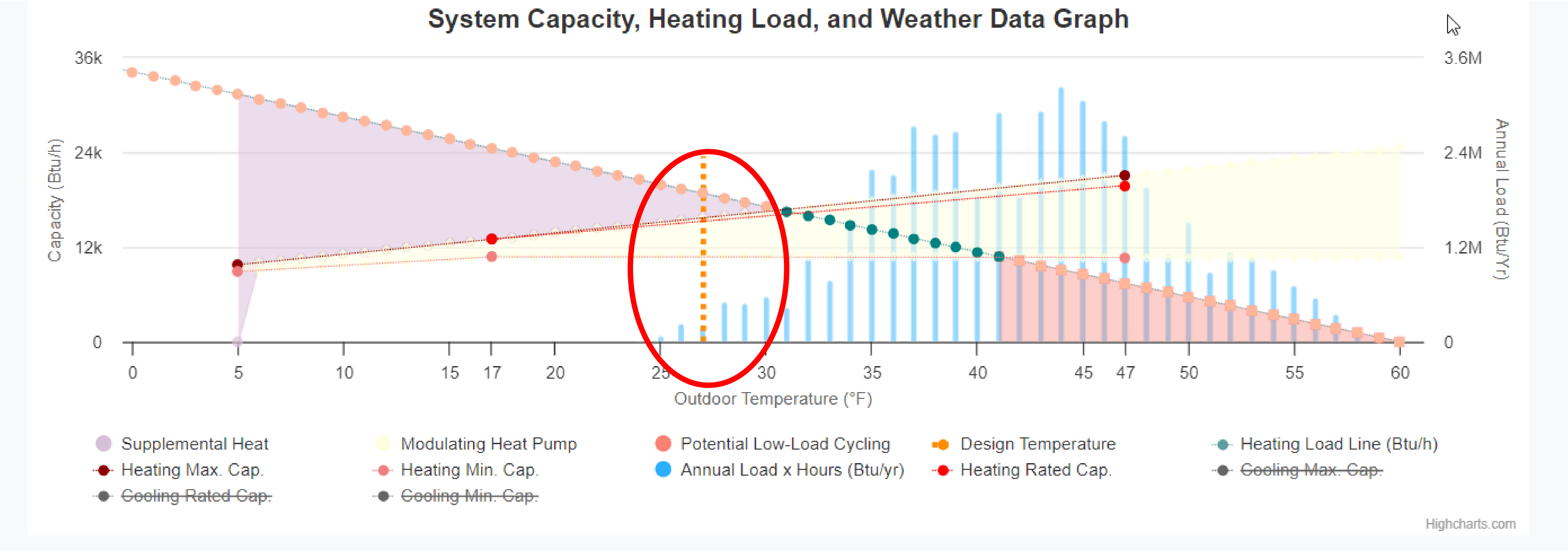
Load Shifting with Heat Pump



2-Tone Two Speed Heat Pump - Portland, Oregon

rane **4TWL9024A1**

https://ashp.neep.org/#!/product/28391/7/25000///0

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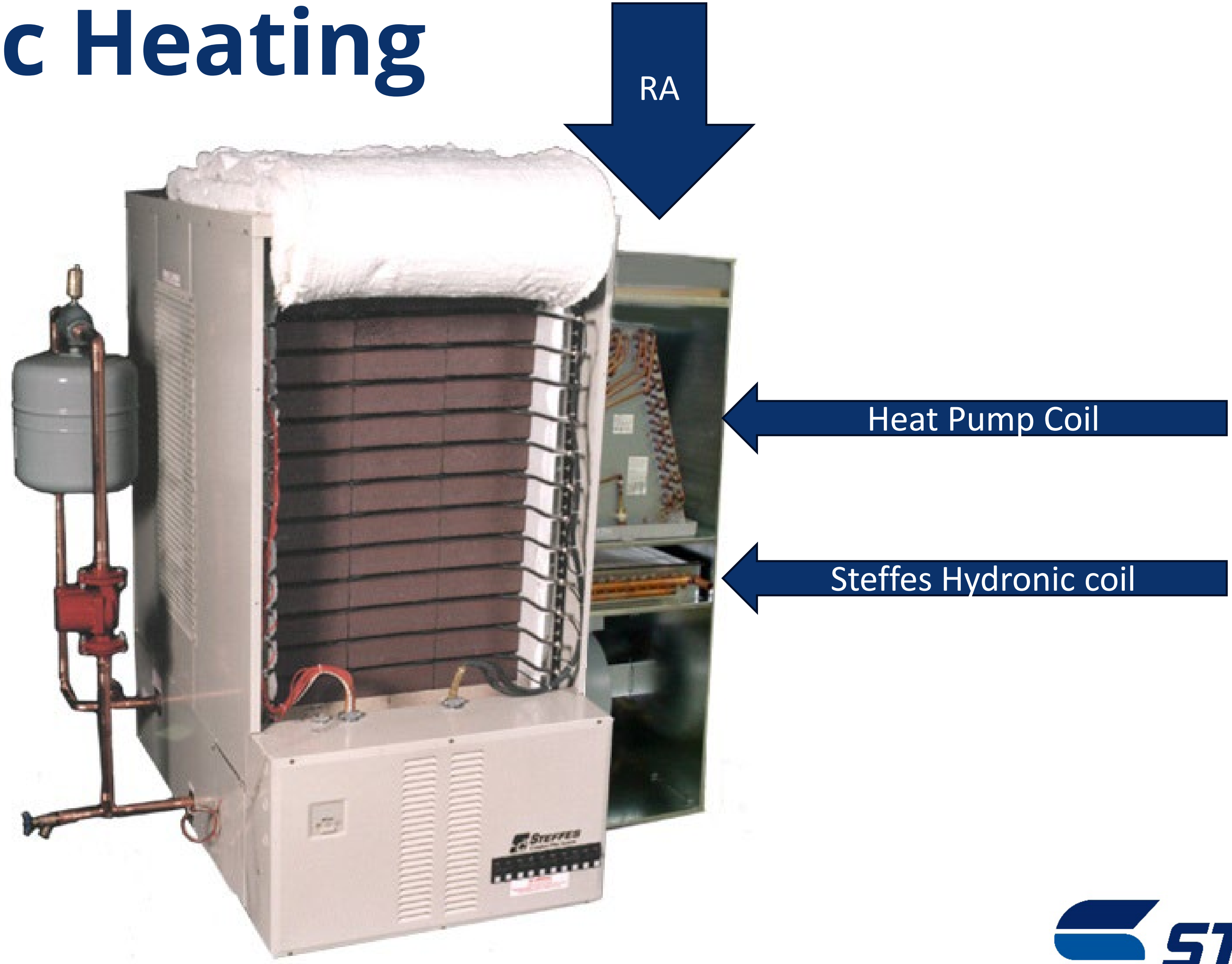
Hydronic Heating



9100 Series ThermElect

Each Unit holds 480 kWh of thermal Storage 1.6 Million Btu

Connect them in parallel

Largest system to date = 23 Million Btu (14 units)

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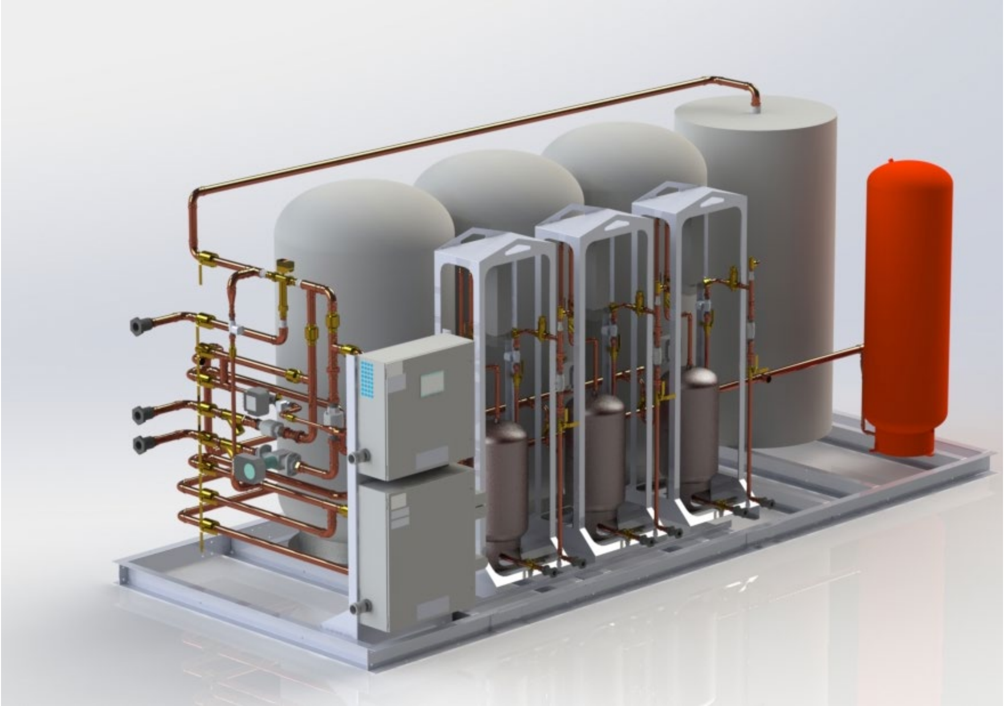
Heat Pump Water Heating

- Multi-Residential
- Up to 1500 gallons of Storage
- CTA-2045 for Utility Control
- Plug and Play Design



Why Electric Thermal Storage?

Societal Benefits

- Beneficial Electrification
- Green House Gas Targets
- De-carbonizaion
- Grid Interactive Buildings

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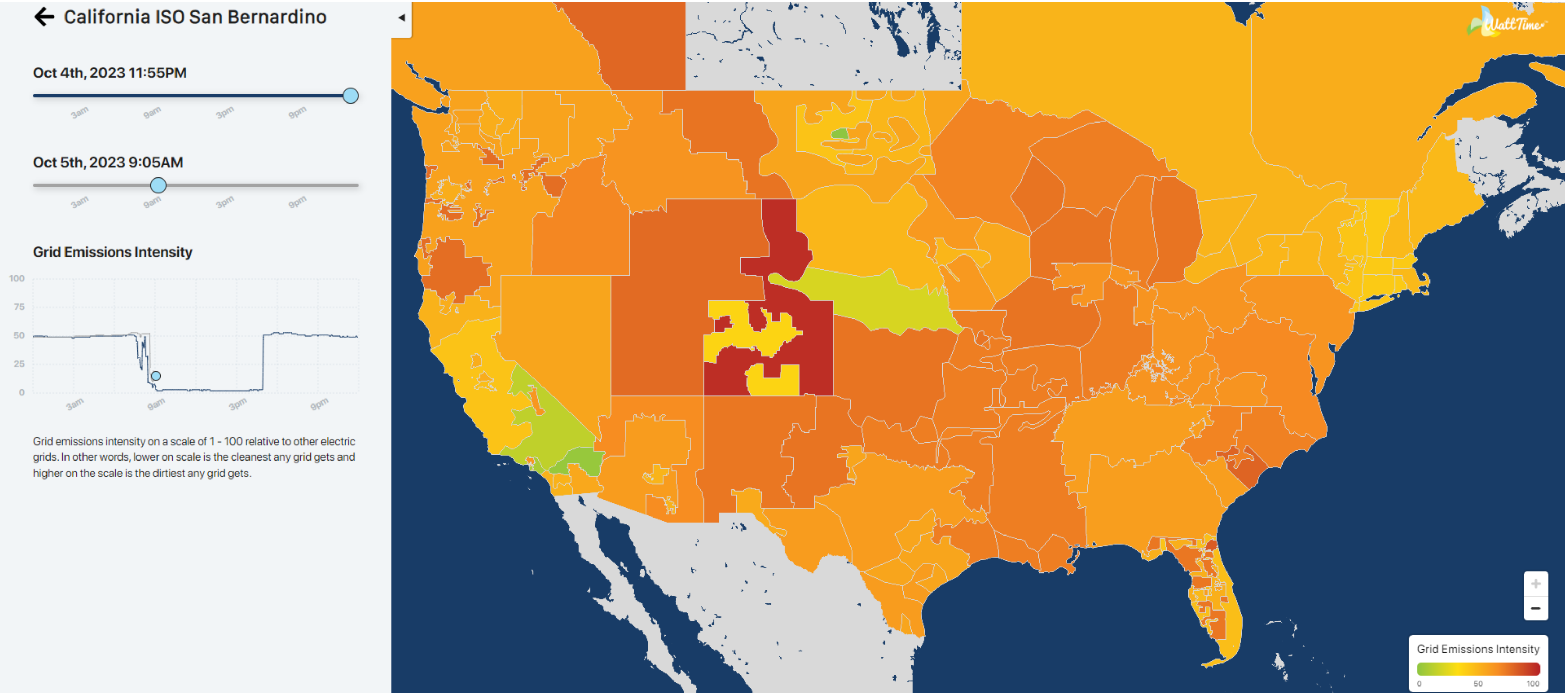
Not all kWh are Created Equal



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Resiliency

- Keeping the grid operational on the Coldest Days
- Coldest Days in the Northwest since 2002
  - Seattle 14
  - Portland 6
  - Spokane -22

Unit is only charged for the next 24-hour peak needs

"Buy" Low
"Sell" High

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Why Electric Thermal Storage?

Utility Benefits

- Provides Grid Reliability, Stabilization, and Optimization
- Improves System Efficiency
- Helps Integrate Large Quantities of Renewables
- Product is Smart Grid compatible

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Strategic Energy Sales

Off-Peak Hours:

- Those hours when demand for electricity is lower.
- Hours when the Power Company can provide electricity more economically and/or at a reduced price.

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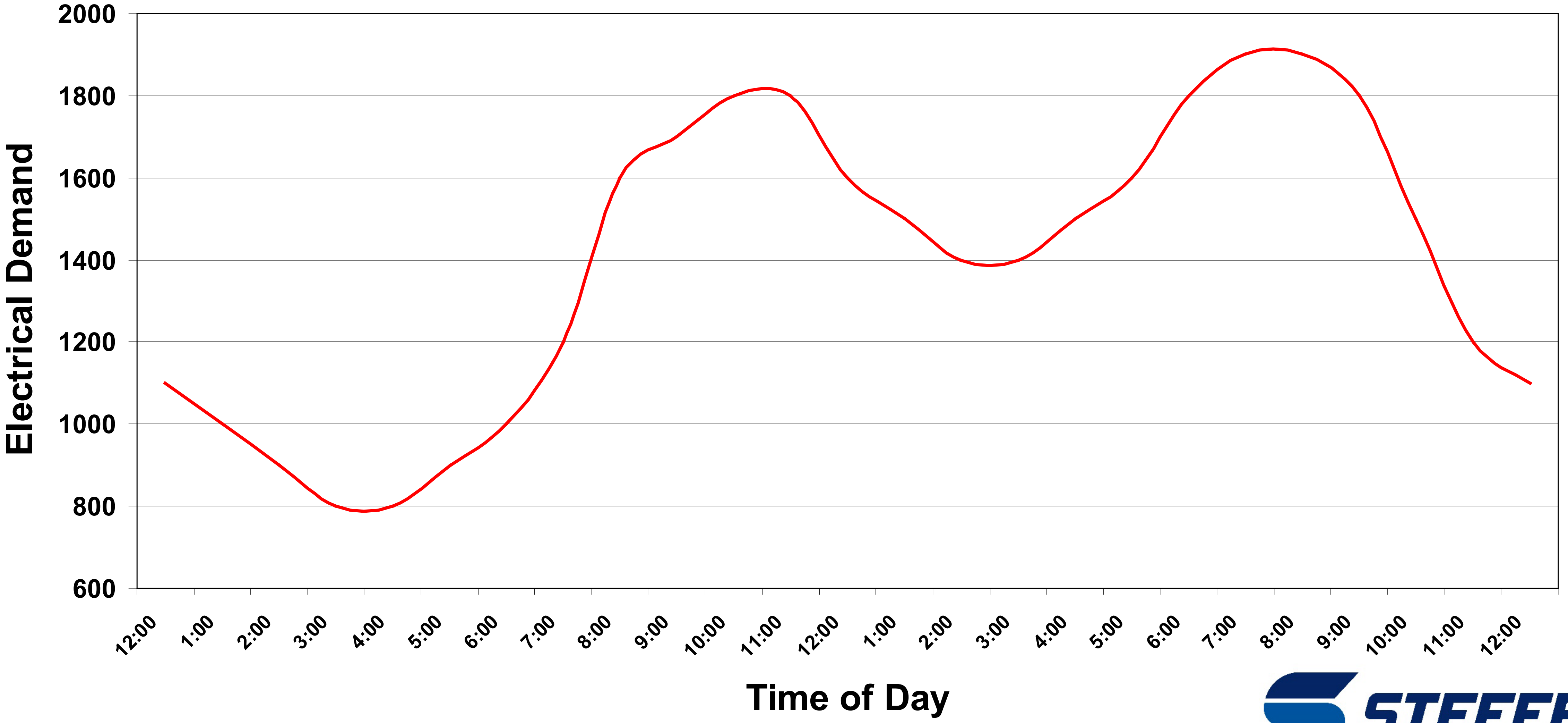
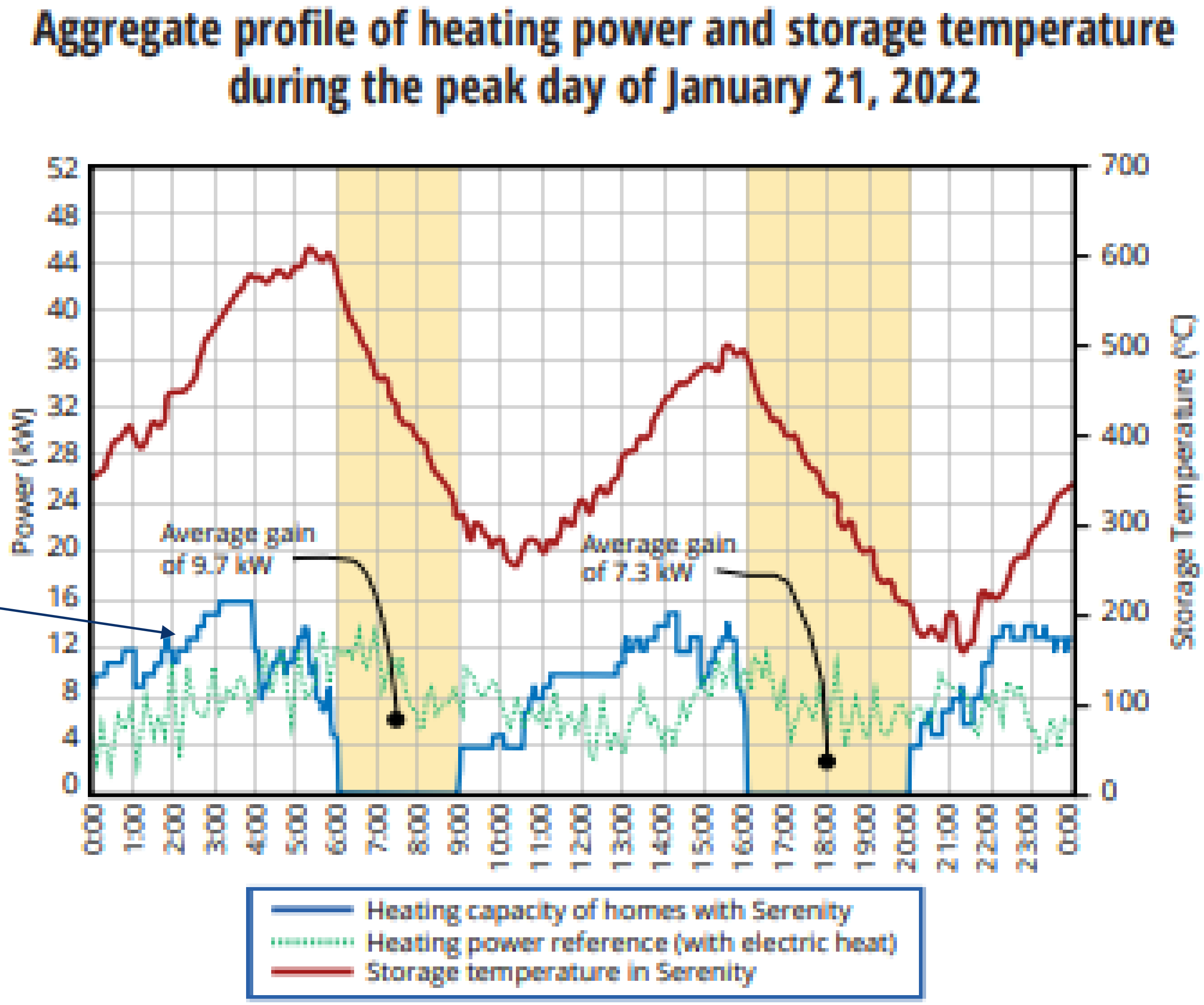
Typical Winter Load Profile



Hydro Quebec Results



Pre charge hours

Renewable Integration

- Wide use of renewables requires storage
- ETS provides low cost, long life storage
- Use of renewables with ETS significantly reduces carbon footprint of home heating

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What is the Utility Value

- Price of Purchasing Energy on the Coldest Days
- Price of Lower Carbon
- Generation Elimination or Deferral
- Transmission Elimination or Deferral
- Distribution Elimination or Deferral

  - $500/kW

    or
  - $9000/kW

    or
  - ????

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Steffes Heating Systems

Electric Thermal Storage

Provides "Double Green" benefits:

Economic

And

Environmental

Why Electric Thermal Storage?

Consumer Benefits

- Efficiency
- Low Energy Bills/Low cost
- Comfort 24/7/365
- Easy to use
- Low / No maintenance
- Reliable
- Safety
- Flexibility
- Up front cost
- Warmth
- No carbon emissions
- Green Options

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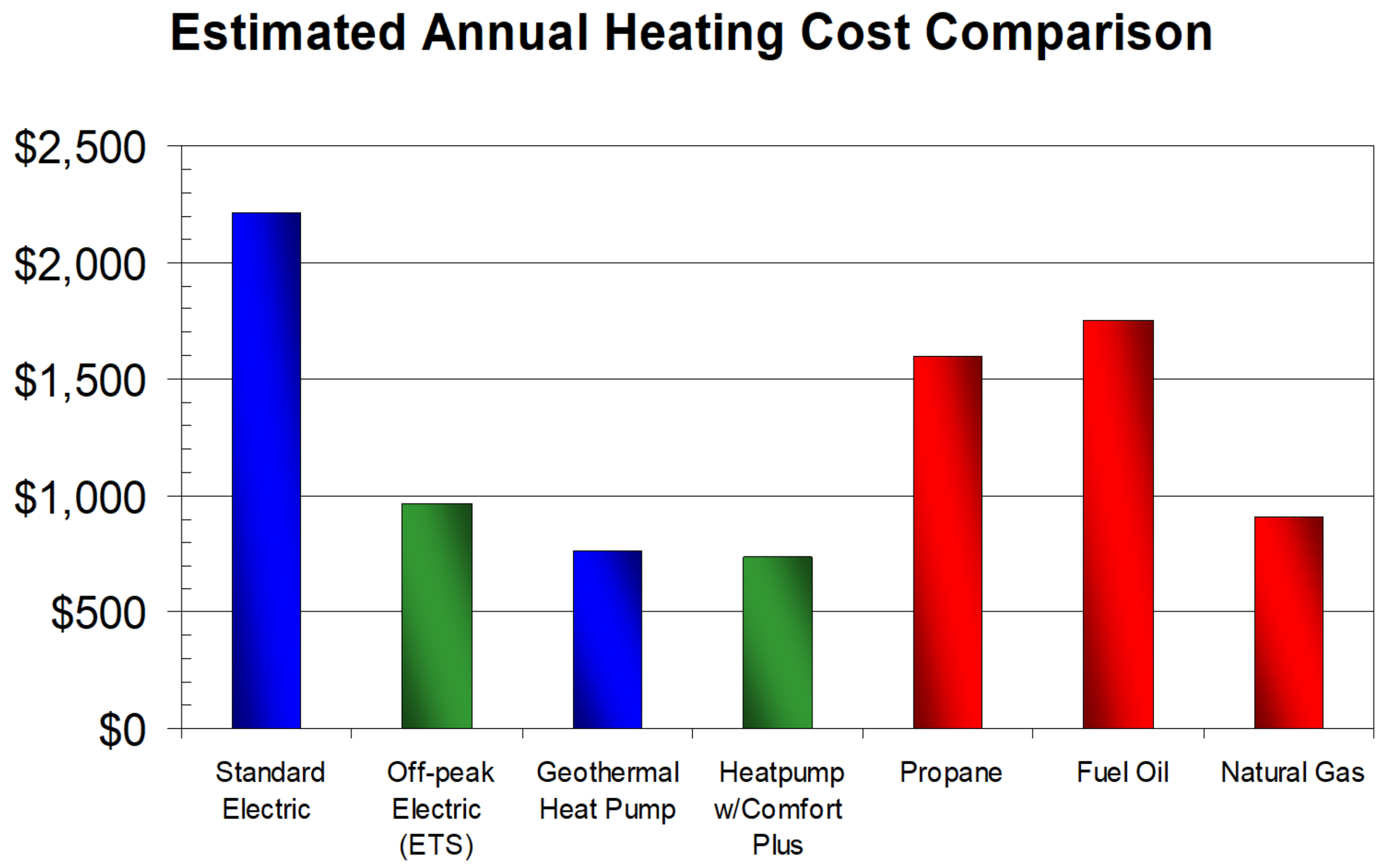
Operating Costs

Propane $2.05/Gal - Nat. Gas $1.05/Therm - Off-Peak $.053/kWh



Steffes Connect

CTA-2045 (OpenADR) Implementation

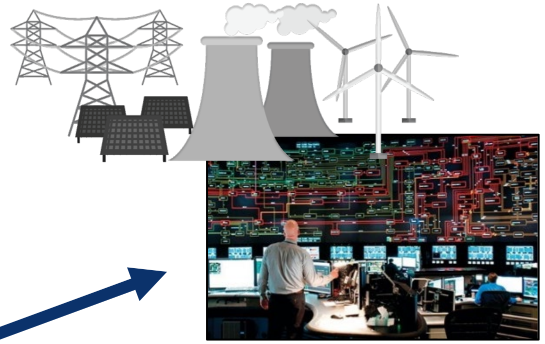
Smart Grid Device (SGD)

Steffes Device

Non-Steffes Device

Communication
Wi-Fi
Cell (1nce)
LoRa
AMI

Steffes Cloud



Flexible loads provide real time control for the grid while maintaining comfort.

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THANK YOU!

Stay connected with us at www.steffes.com.

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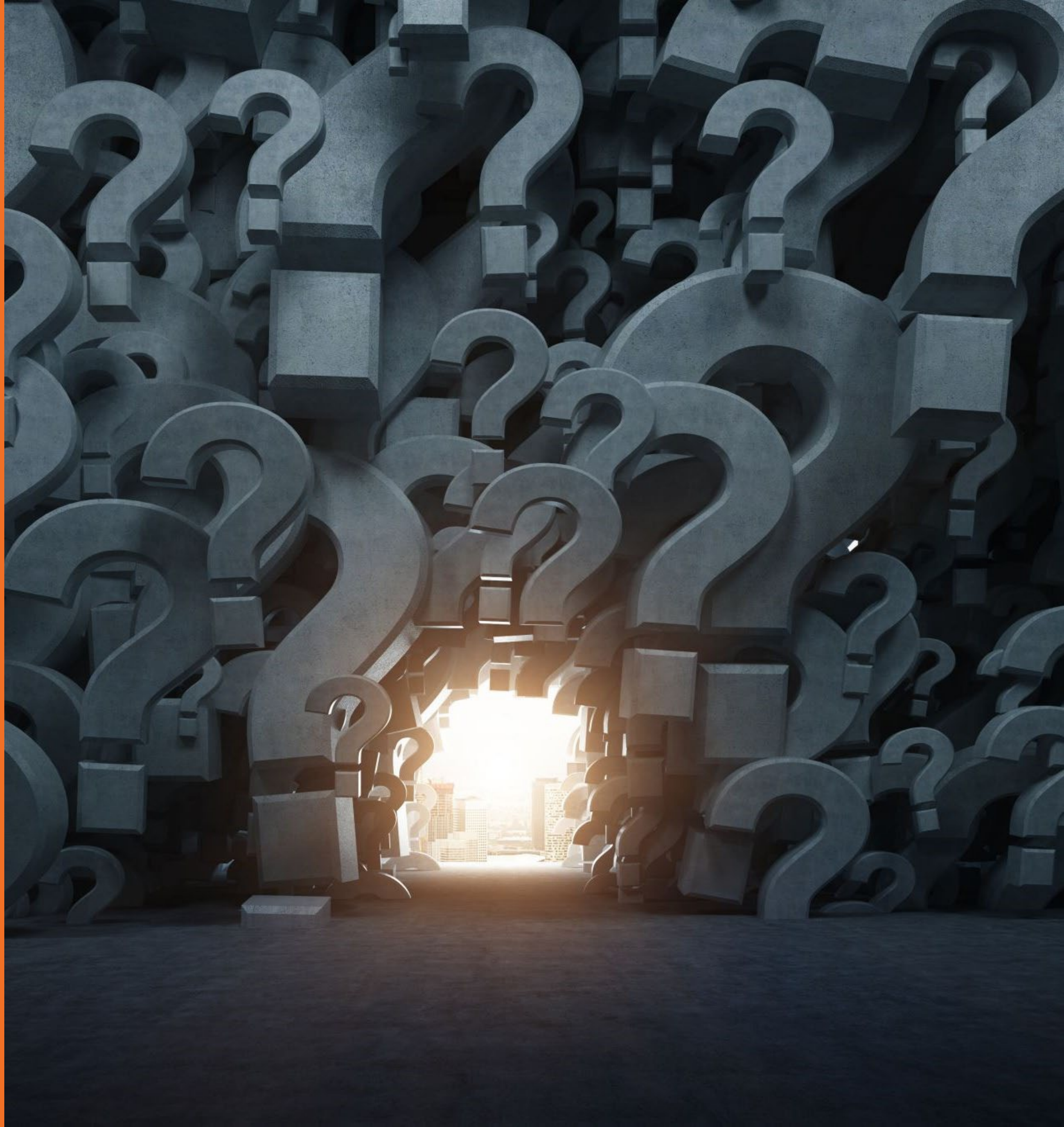
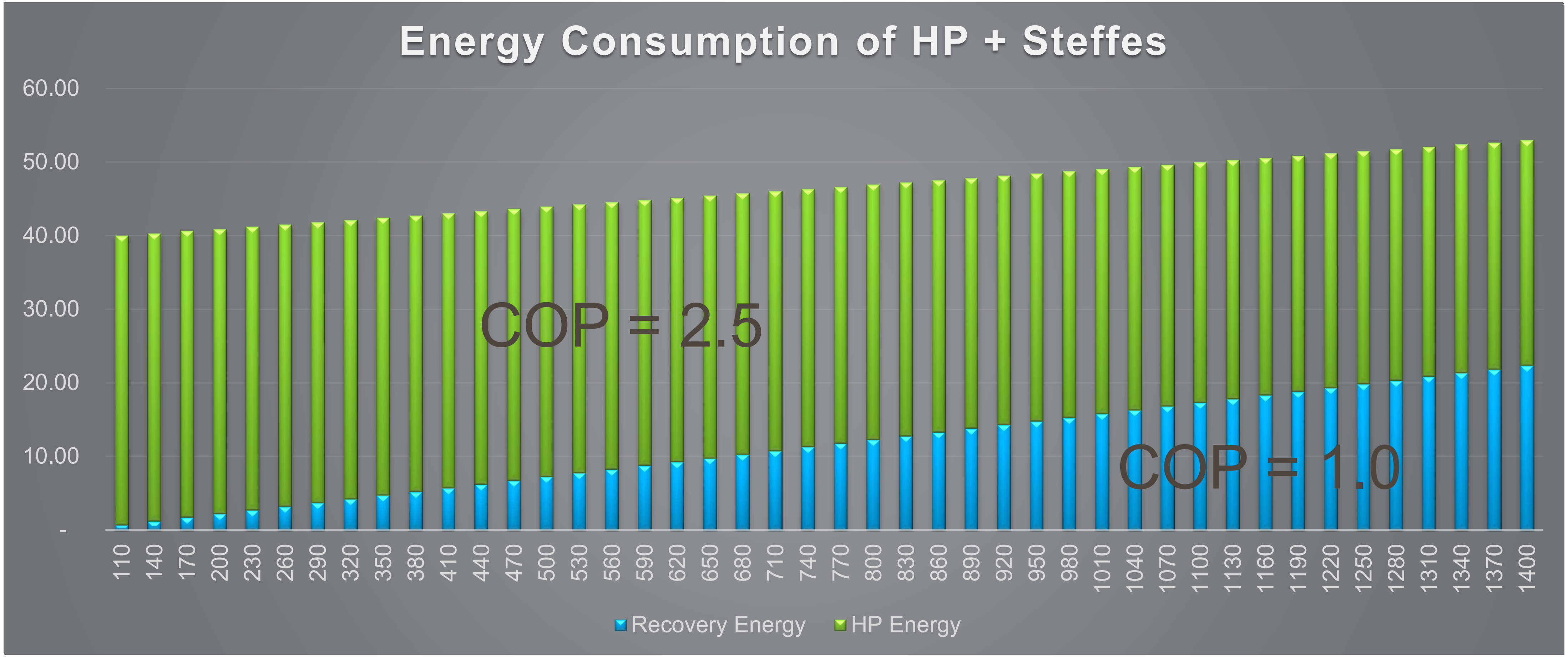
Questions and Discussion



Thank You

Example Daily Total Energy vs Temp of Storage



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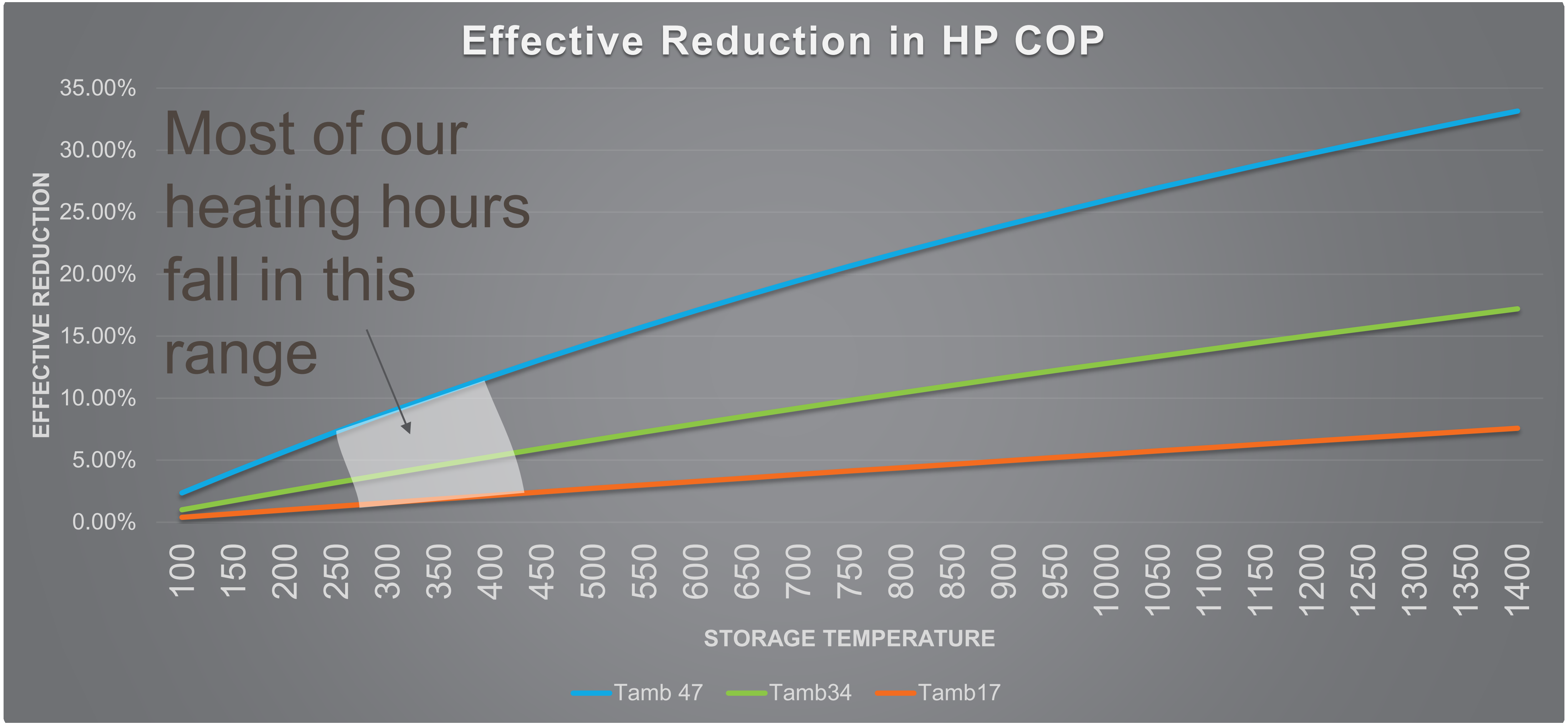
Effective Reduction in HP COP



HP has a COP of 2.5 @ 34F, COP slope = 0.32/F, Cap slope = 400 Btu/F

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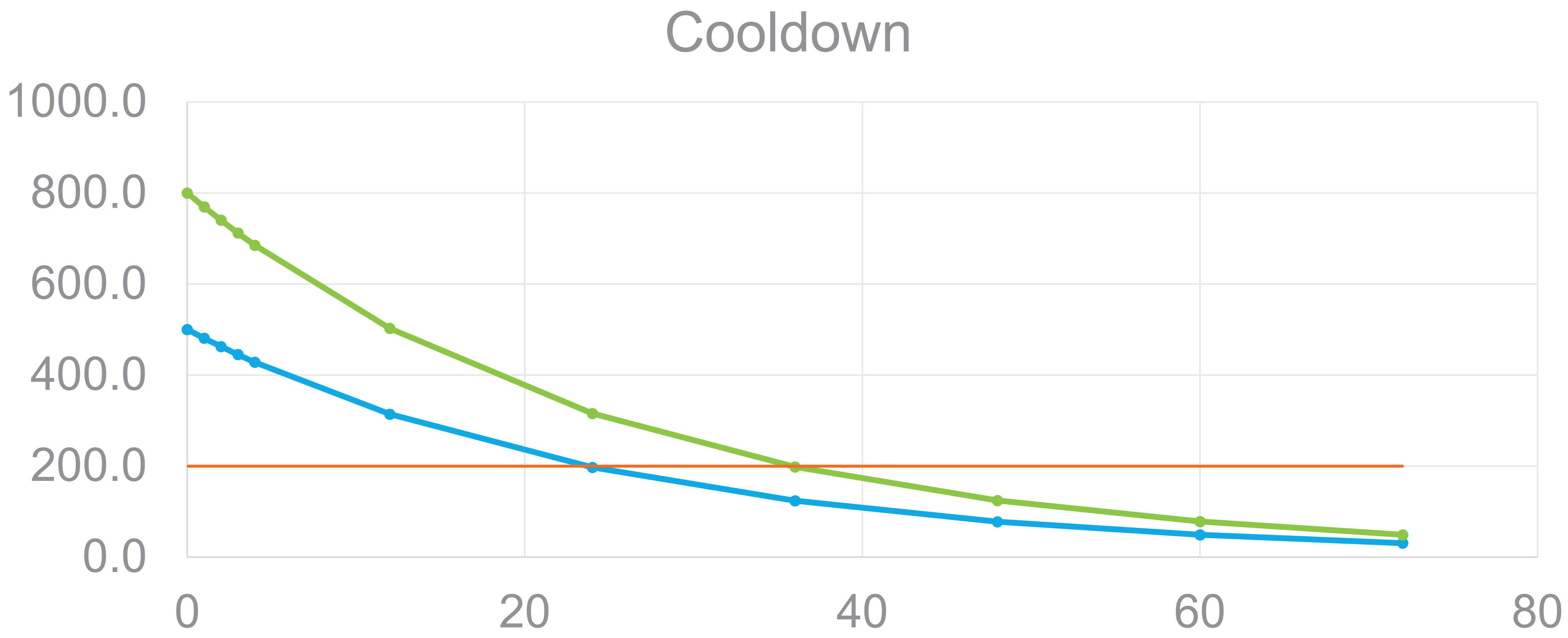
Cooldown



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