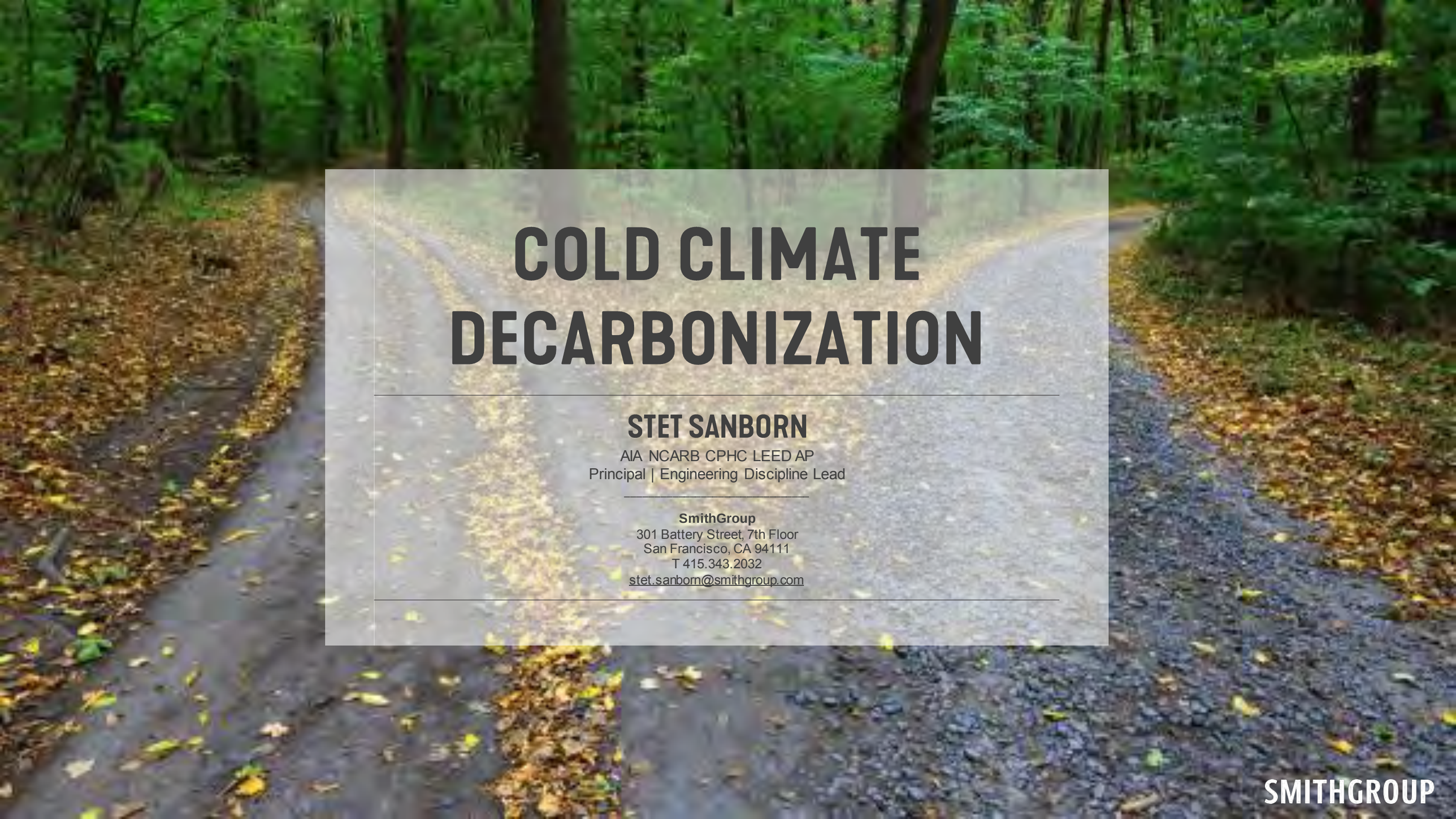

COLD CLIMATE DECARBONIZATION

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Principal | Engineering Discipline Lead

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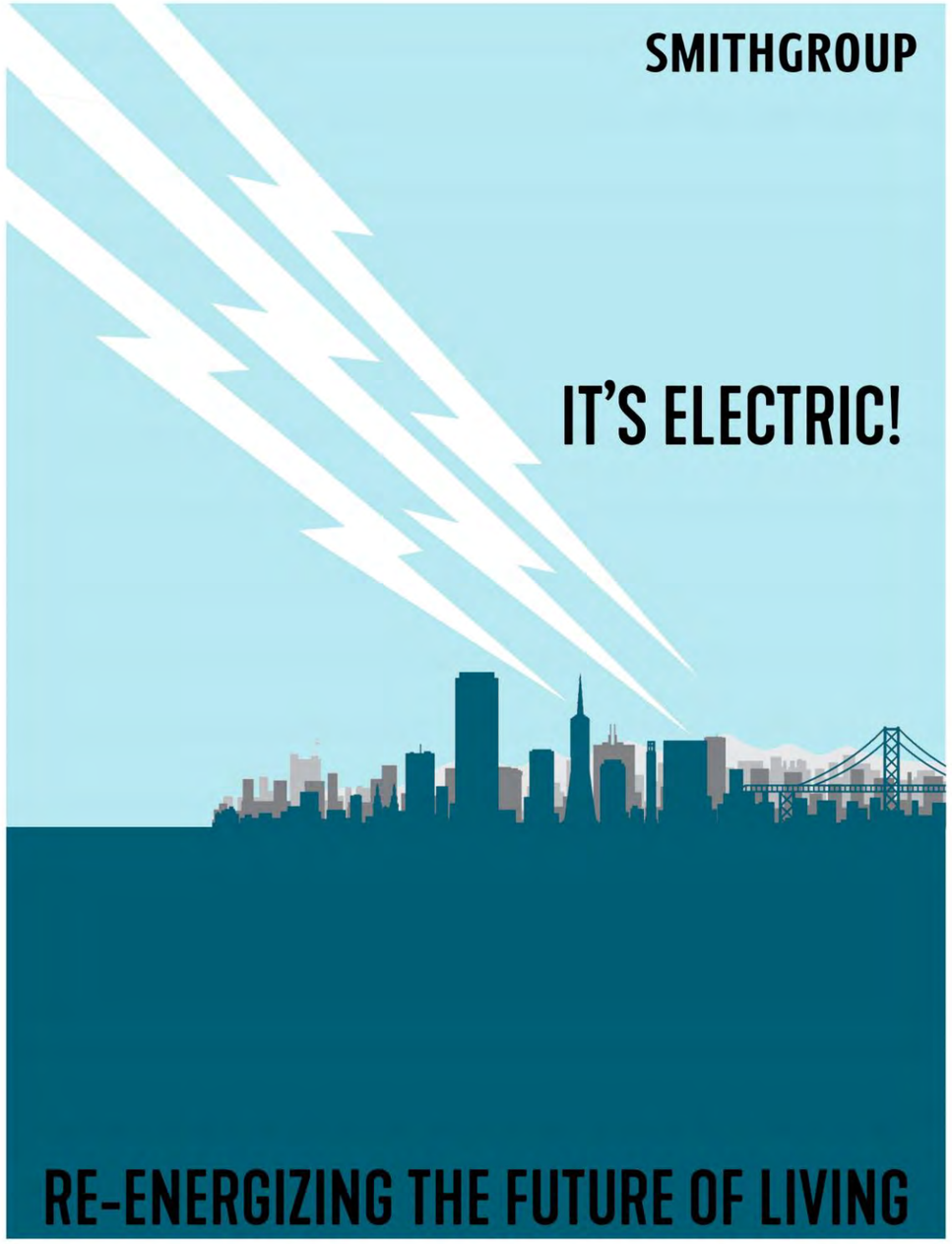
SMITHGROUP

AGENDA

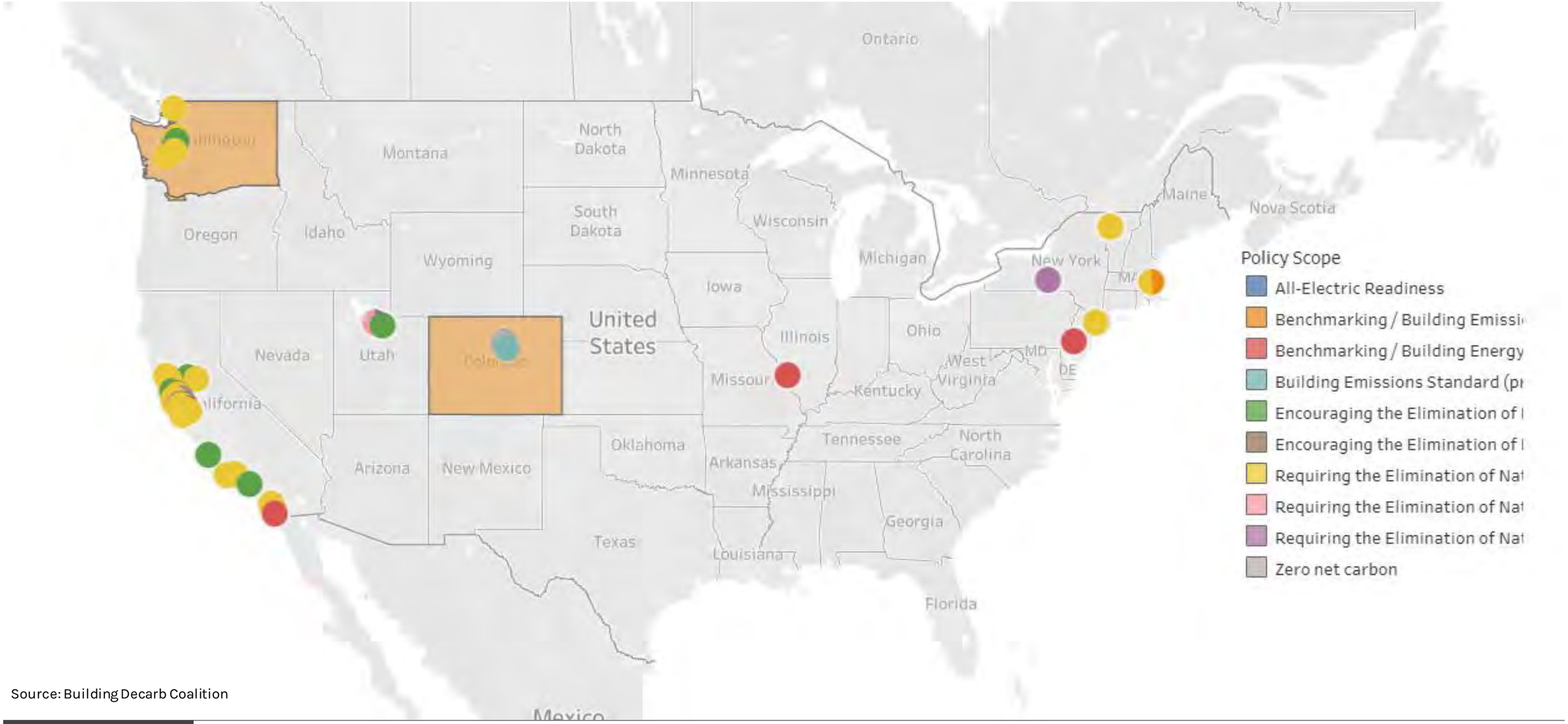
RAPID CHANGES IN RESPONSE TO CLIMATE CRISIS

- Policy Drivers
- Understanding Your Regional Electrical Grid
- Cold Climate Design Strategies
- What to do with Existing Buildings
- Resources



CITY AND STATE POLICY DRIVERS

NATIONAL ELECTRIFICATION REACH CODES AND DECARB CODES



Source: Building Decarb Coalition

DECARBONIZATION

LOCAL POLICY TAKING THE REIGNS

Northern California Jurisdictions with Decarbonized Reach Code

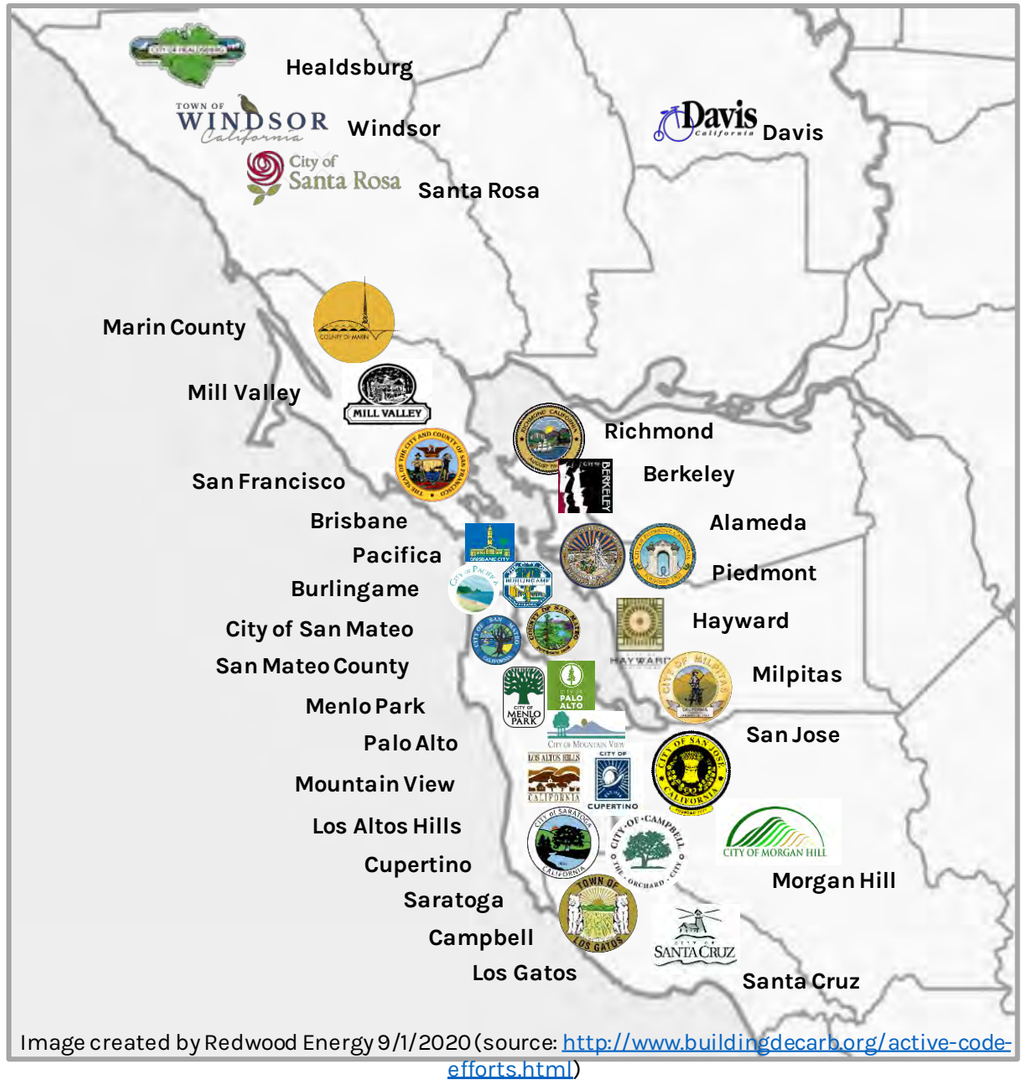
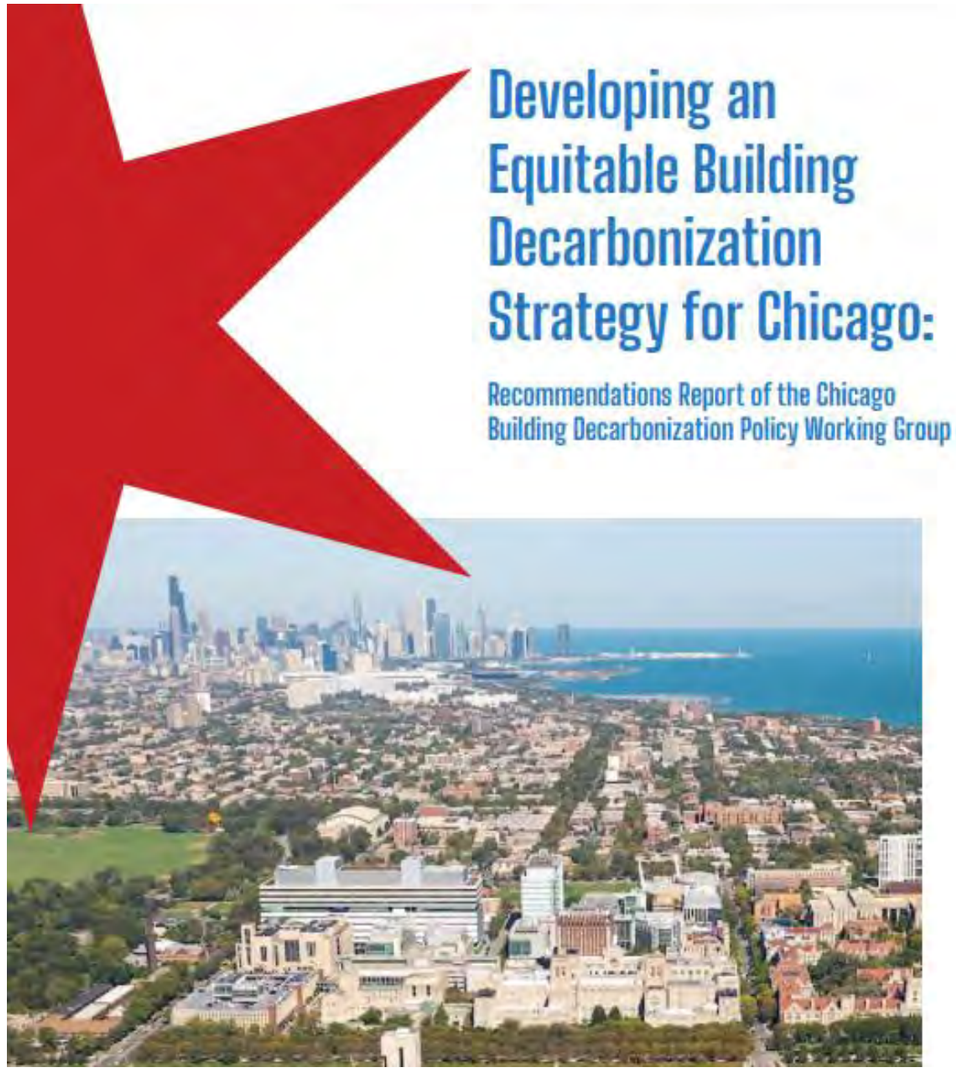


Image created by Redwood Energy 9/1/2020 (source: http://www.buildingdecarb.org/active-code-efforts.html)

Image created by Redwood Energy 9/1/2020
(source: http://www.buildingdecarb.org/active-code-efforts.html)

CITY AND STATE POLICY DRIVERS

CHICAGO TAKING UP THE DECARB CAUSE



Source: City of Chicago

Chicago commits to 100% renewable energy at city facilities by 2025

Published Aug. 15, 2022

By Katie Pyzyk
Contributor

Tim Boyle via Getty Images

SEC FILING FOR PUBLICLY TRADED COMPANIES

ESG REPORTING AND CLIMATE RISK ANALYSIS DRIVE THE MARKET

2021 Report (filed in 2022)
- Proposed release

2022 (filed in 2023)

2023 (filed in 2024)
- All disclosures excl. Scope 3 for larger accelerated filers

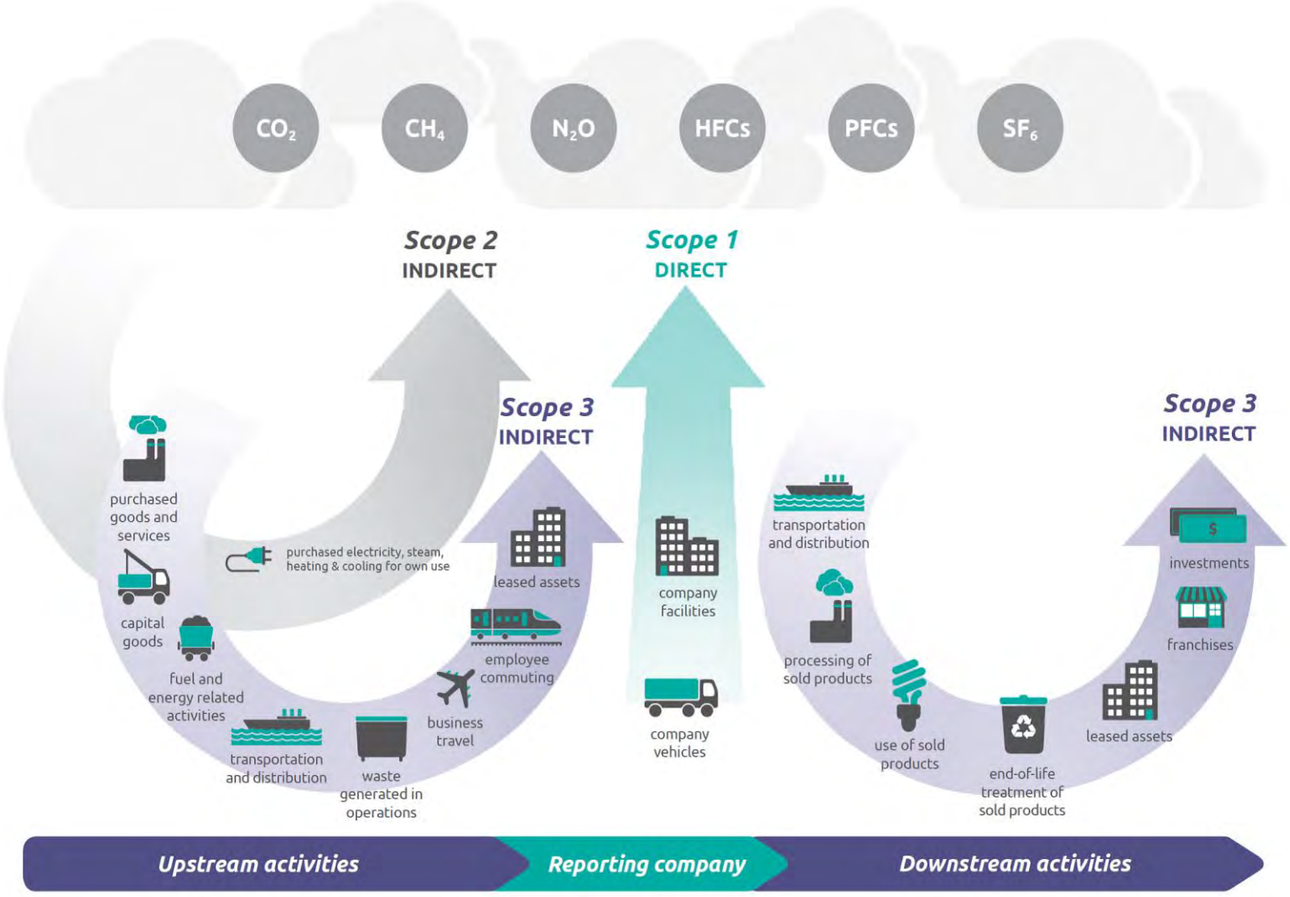
2024 (filed in 2025)
- All disclosures for **large accelerated filers** with limited assurance
- All disclosures excl. Scope 3 for **accelerated filers**
- All disclosures excl. Scope 3 for **nonaccelerated filers**

2025 (filed in 2026)
- All disclosures for **accelerated filers** with limited assurance
- All disclosures for **nonaccelerated filers**
- All disclosures excl. Scope 3 for **smaller reporting companies**

2026 (filed in 2027)
- **Large accelerated filers** with reasonable assurance

2027 (filed in 2028)
- **Accelerated filers** with reasonable assurance

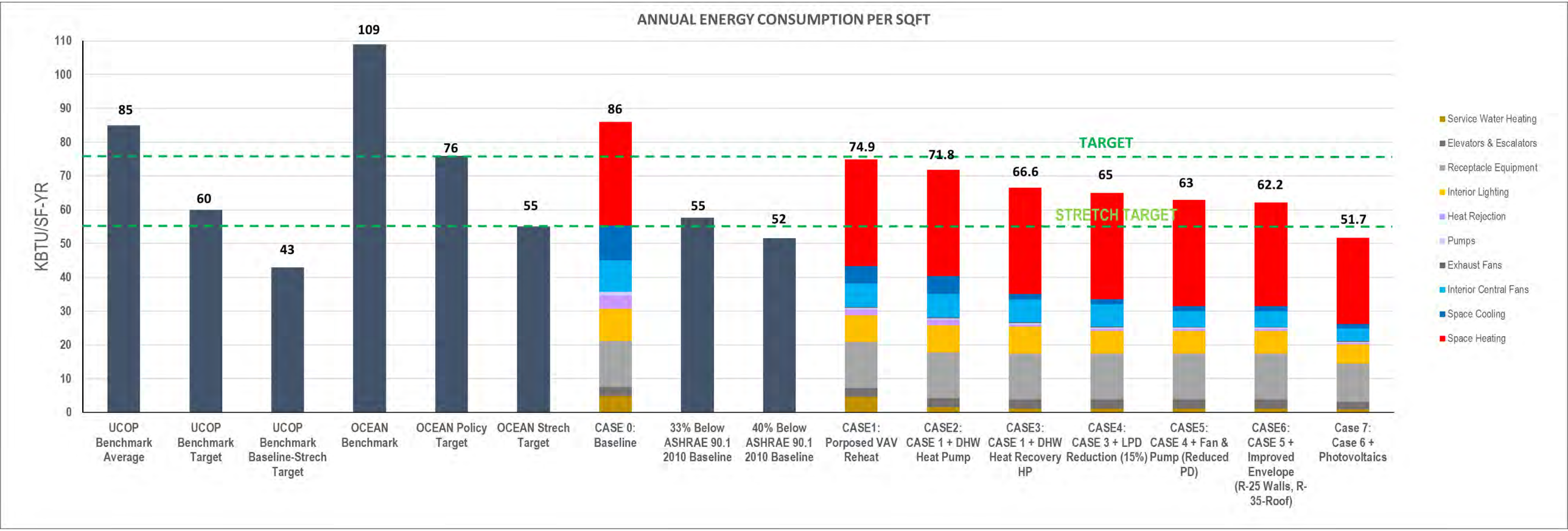
Source: Deloitte



Source: US Environmental Protection Agency

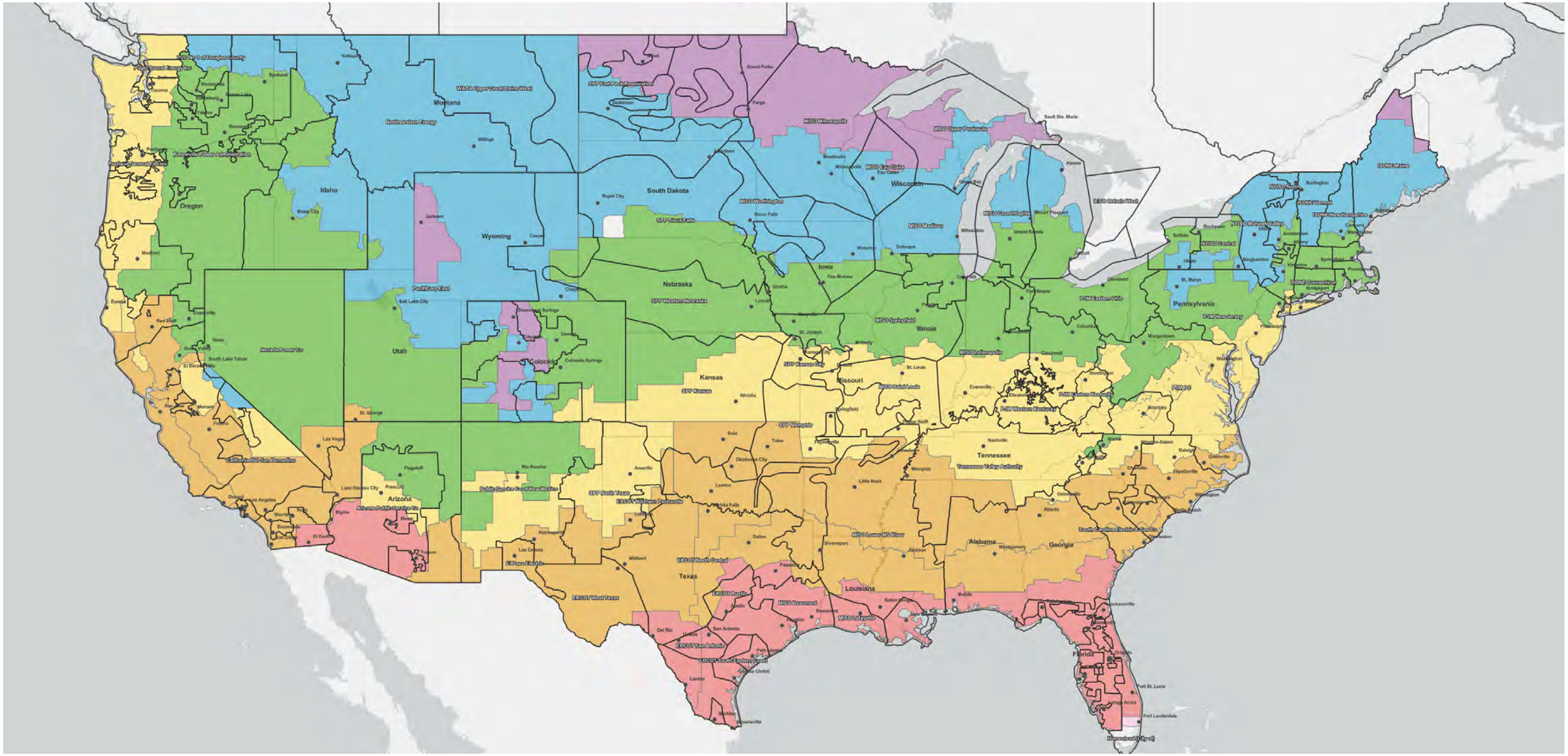
RE-ALIGNING AROUND CARBON$_{EQUIV.}$

EFFICIENCY AND…..



UNDERSTANDING YOUR REGIONAL GRID

REGIONAL GRID OPERATORS VS. CLIMATE ZONE



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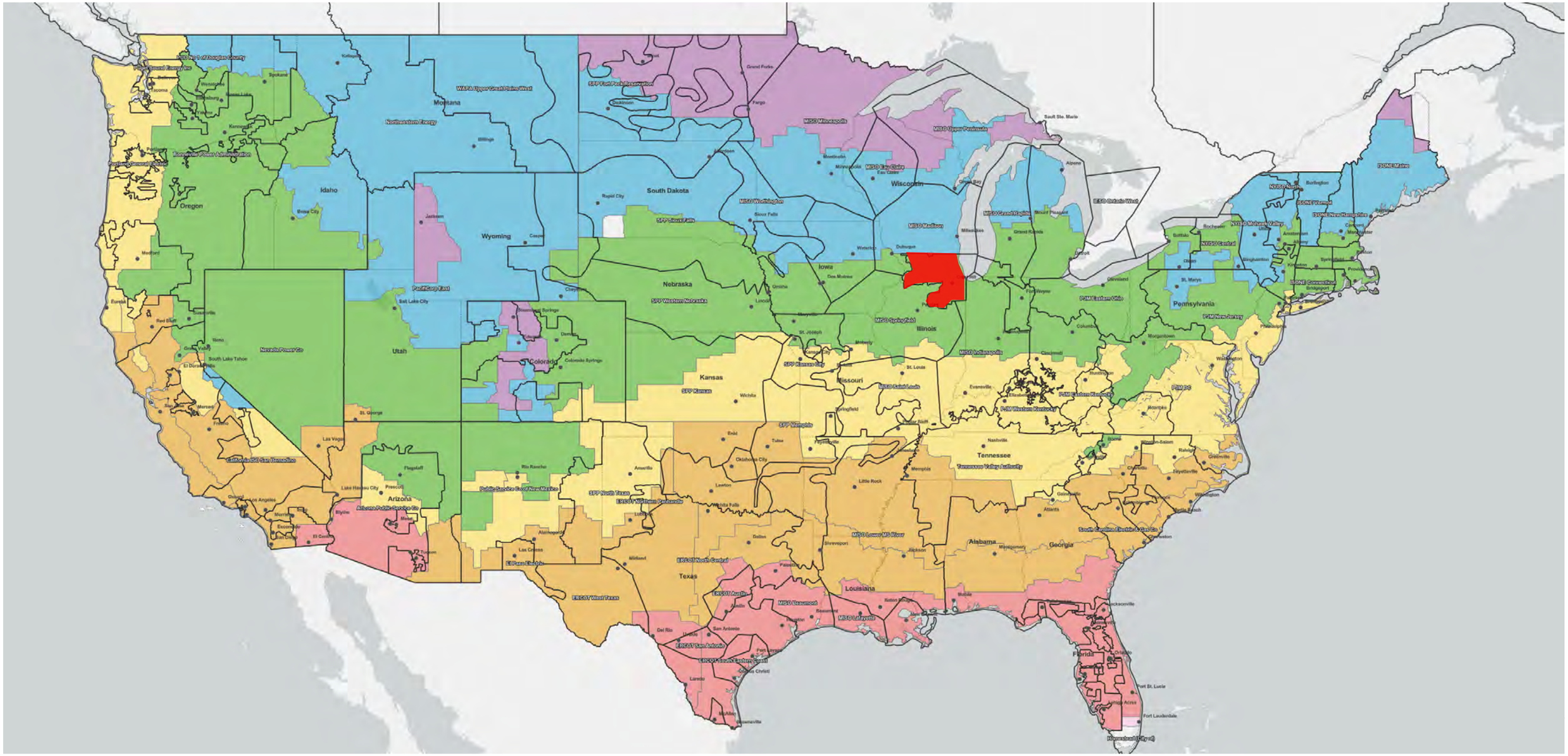
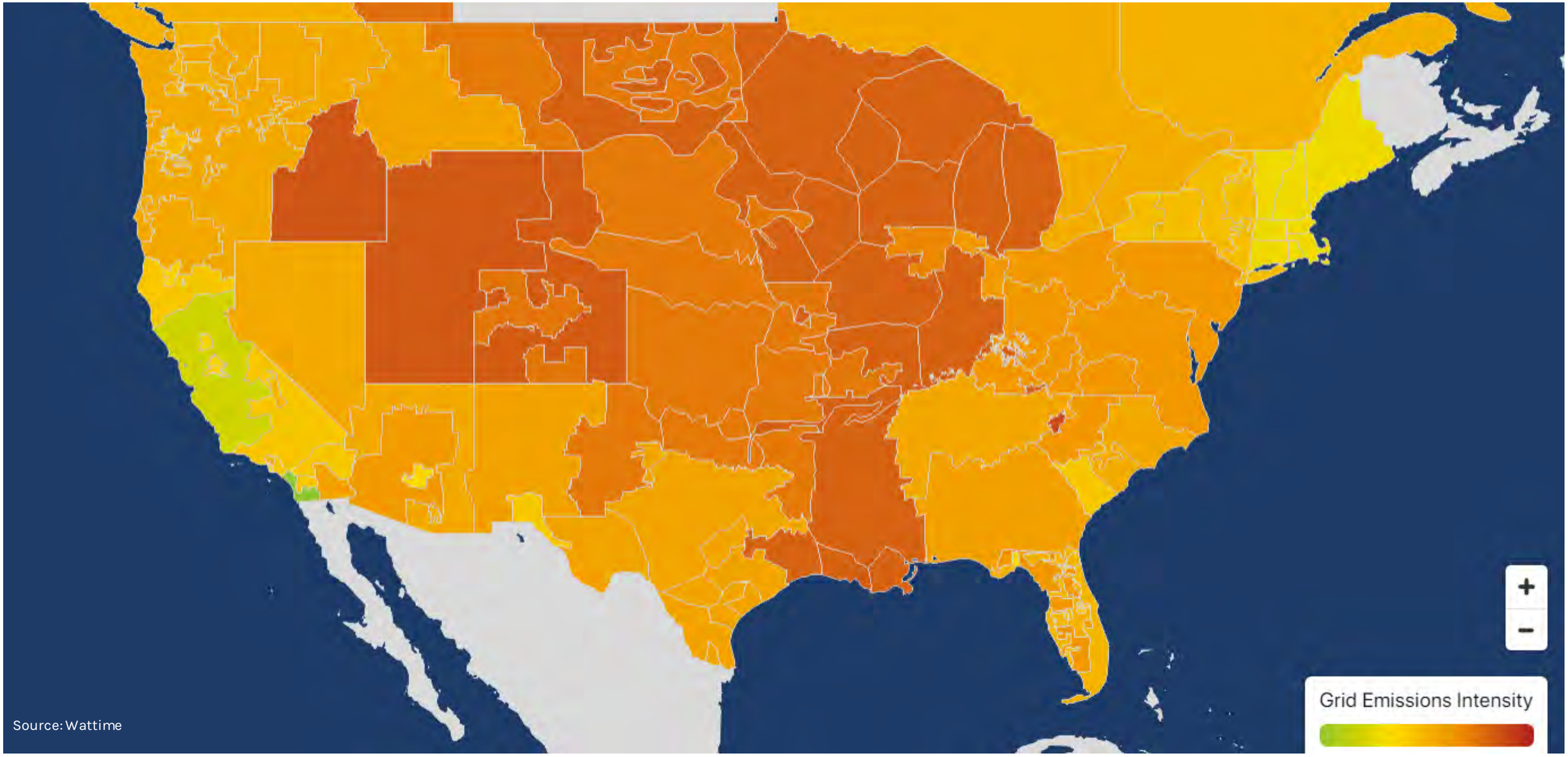


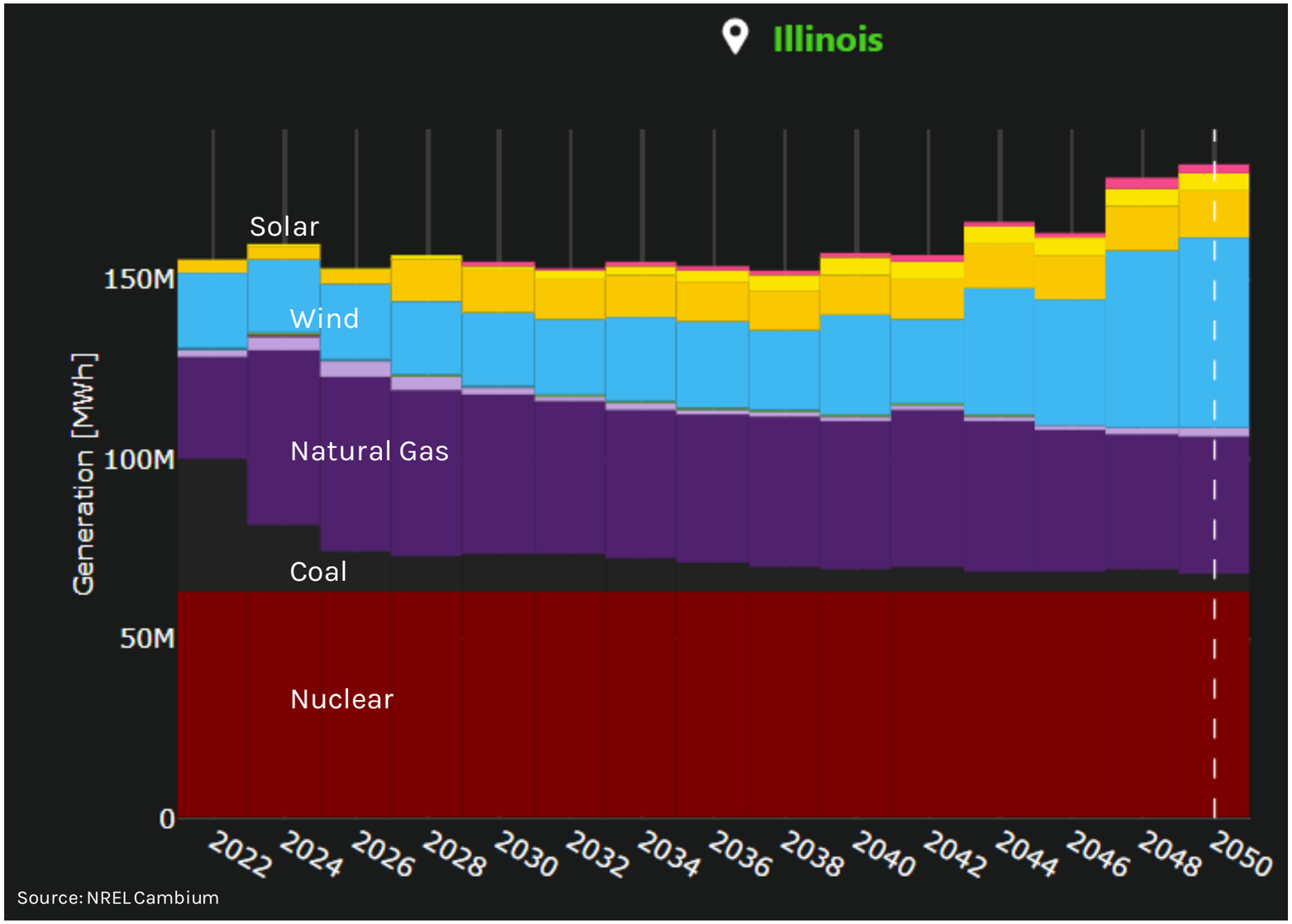
UNDERSTANDING YOUR REGIONAL GRID

REGIONAL GRID MARGINAL EMISSIONS RATES



UNDERSTANDING YOUR^CHANGING REGIONAL GRID

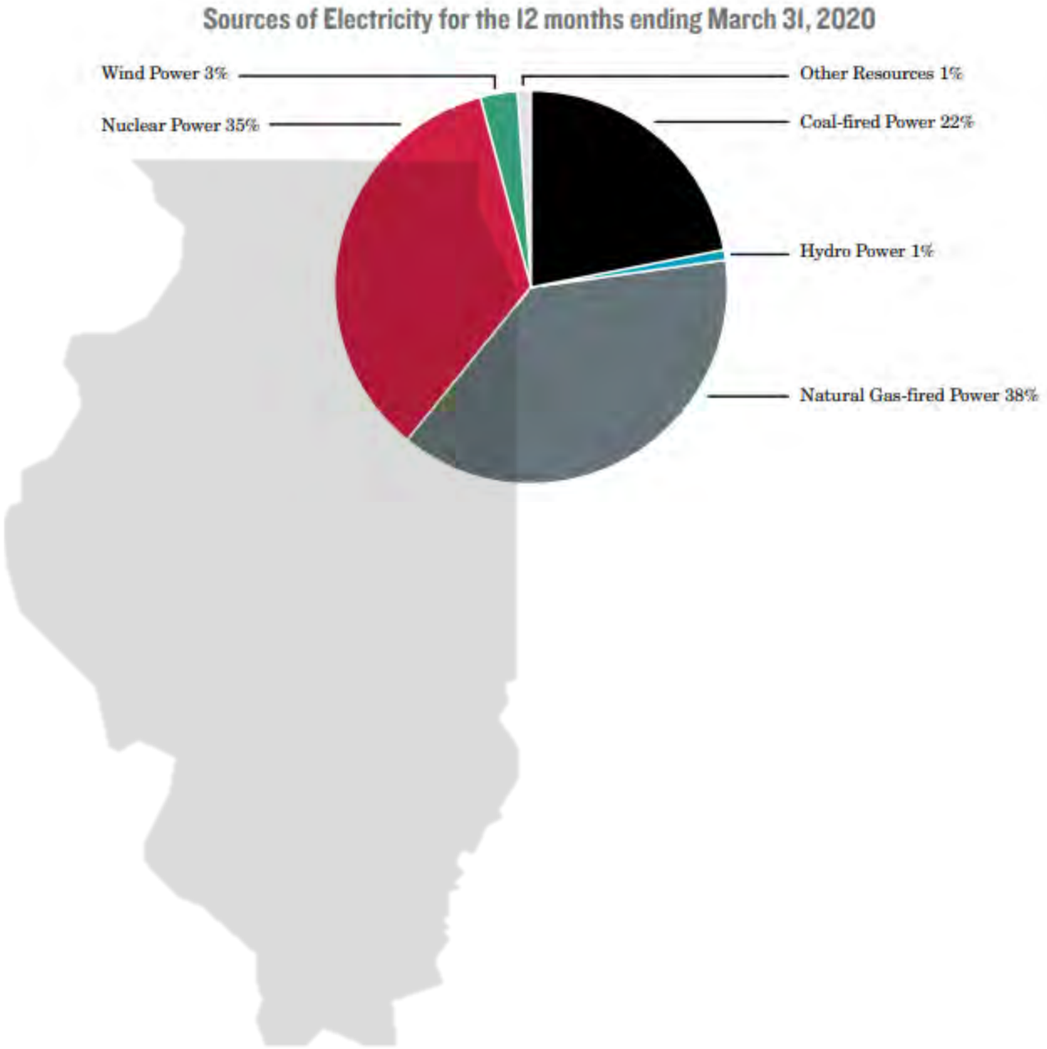
REGIONAL GRID MARGINAL EMISSIONS RATES



Source: NREL Cambium

UNDERSTANDING YOUR REGIONAL GRID

CARBON-FREE SOURCES: IL VS CA



UNDERSTANDING YOUR REGIONAL GRID

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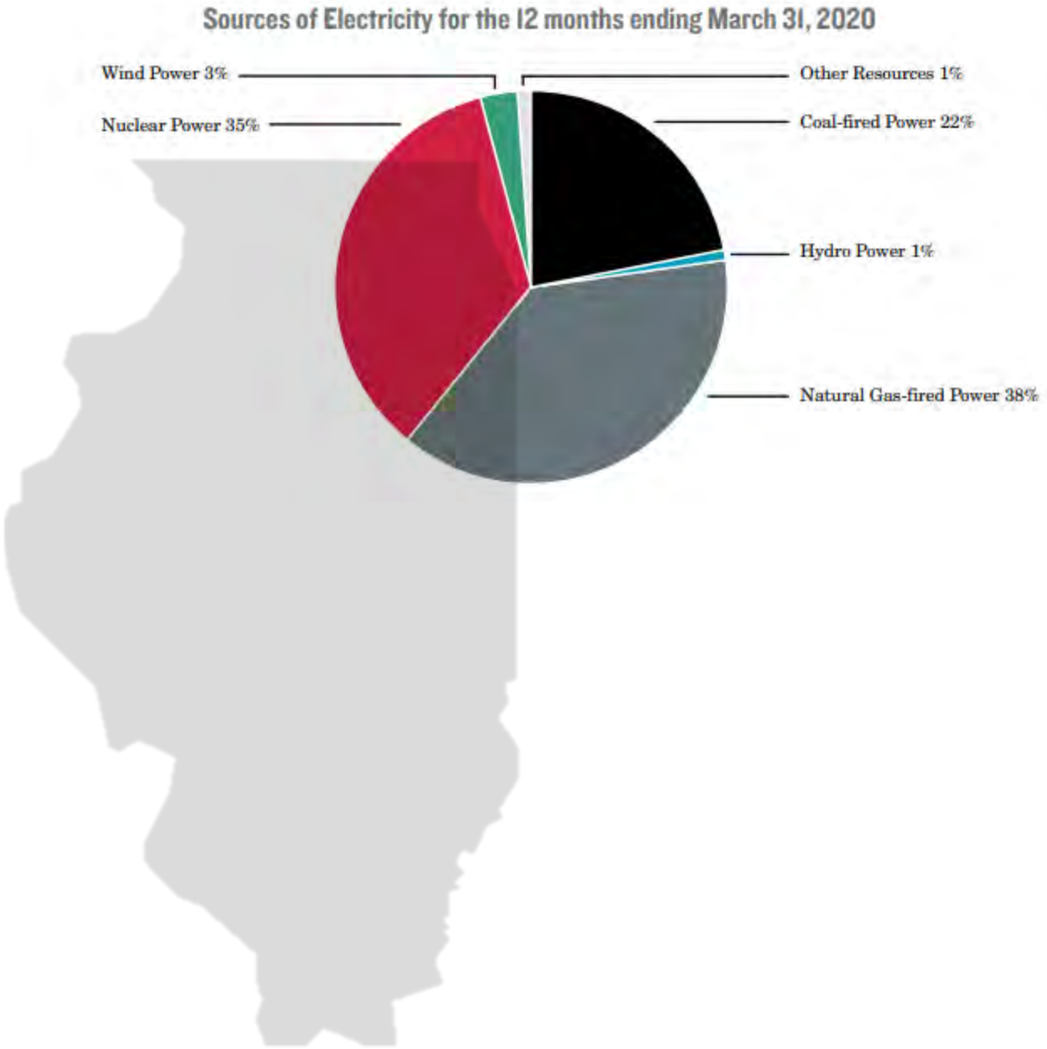

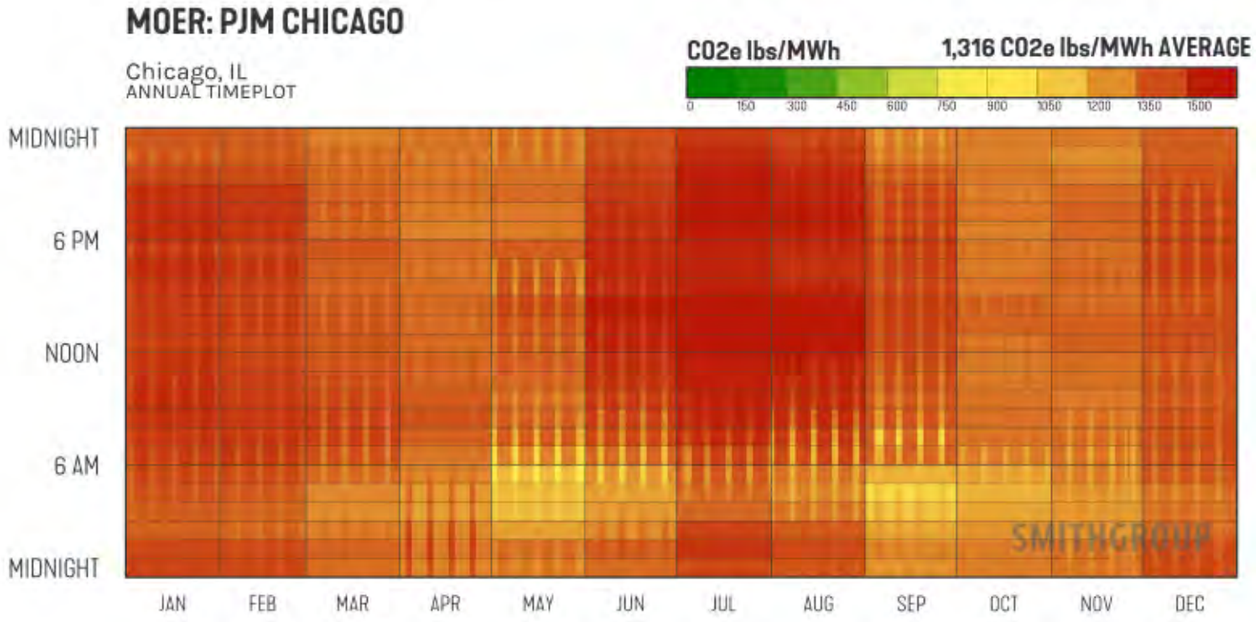

UNDERSTANDING YOUR REGIONAL GRID

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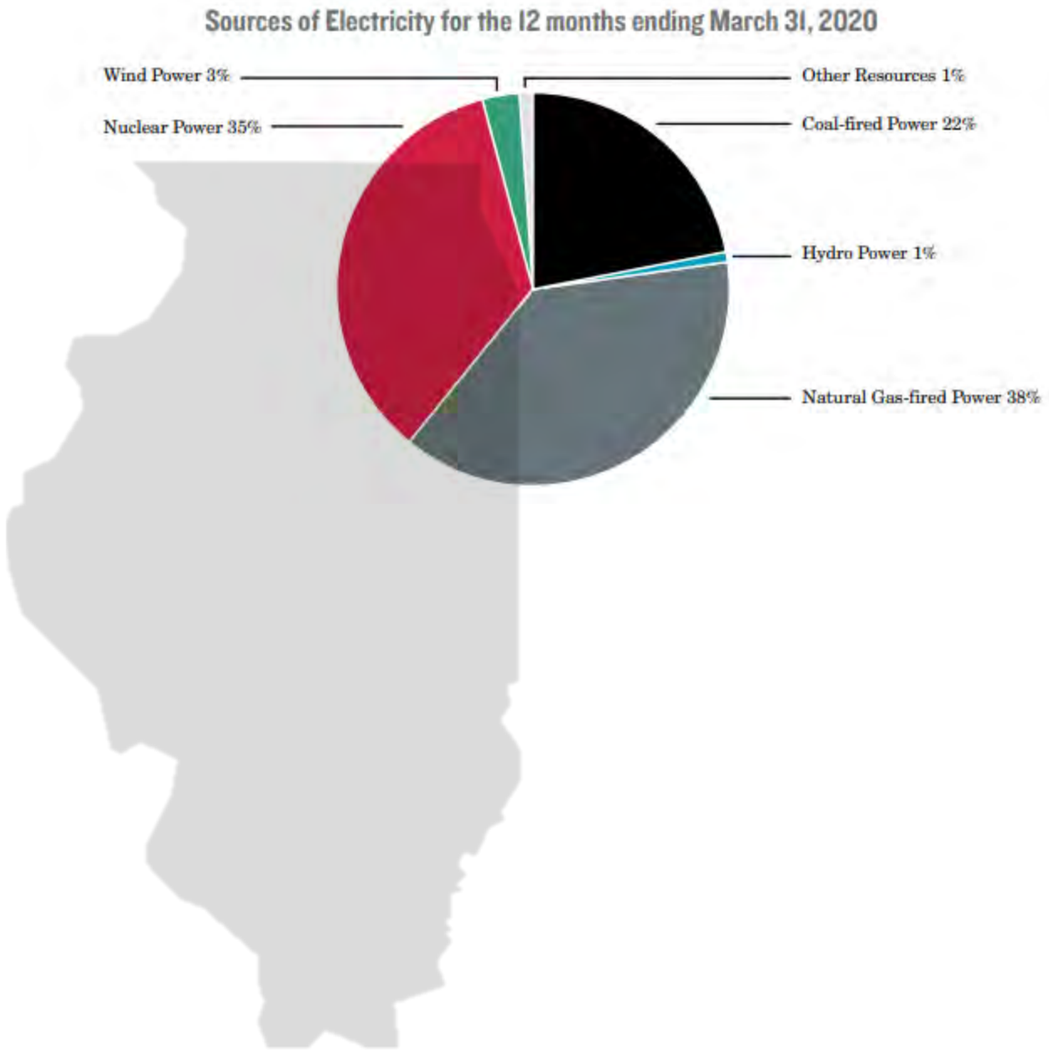
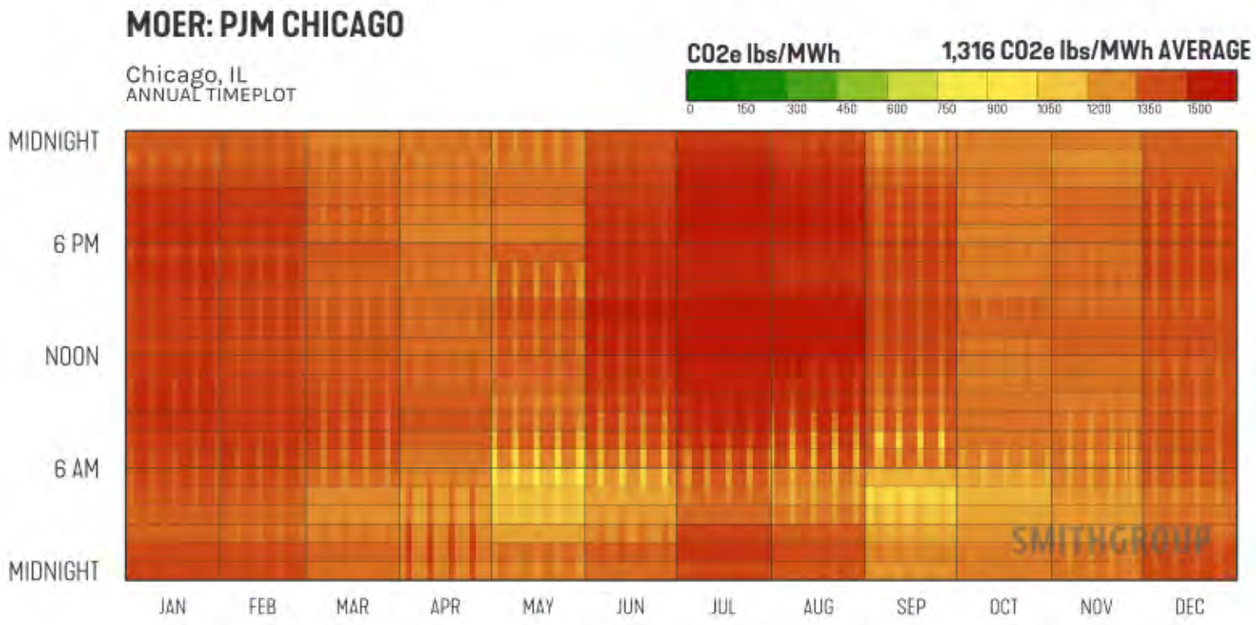
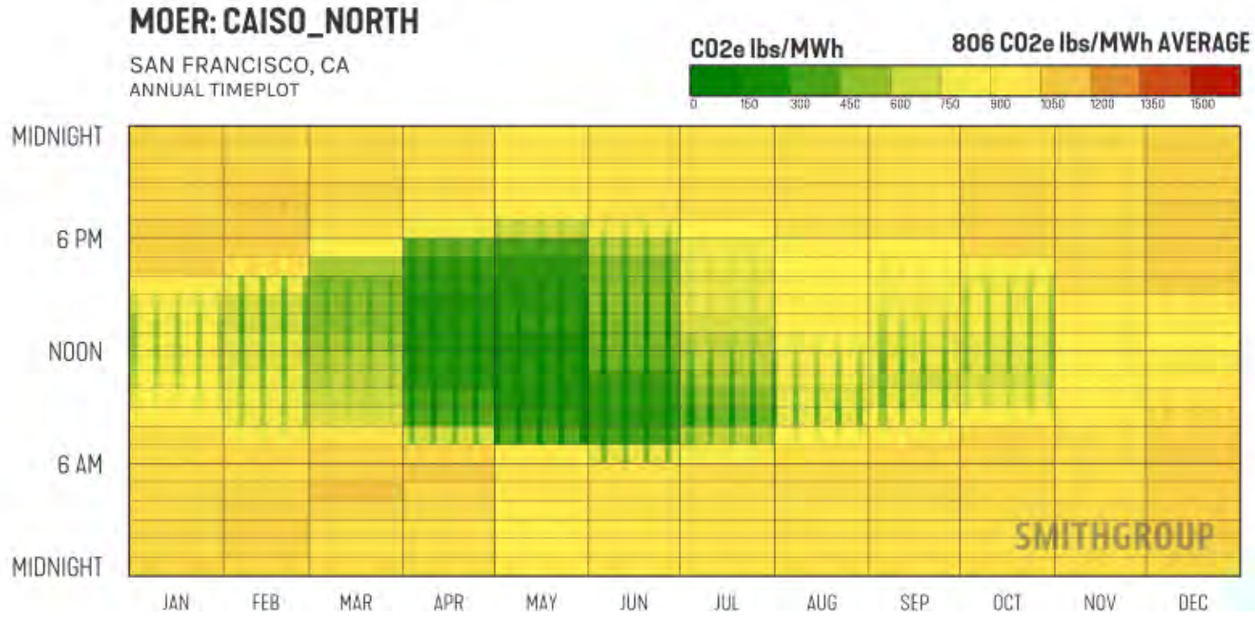


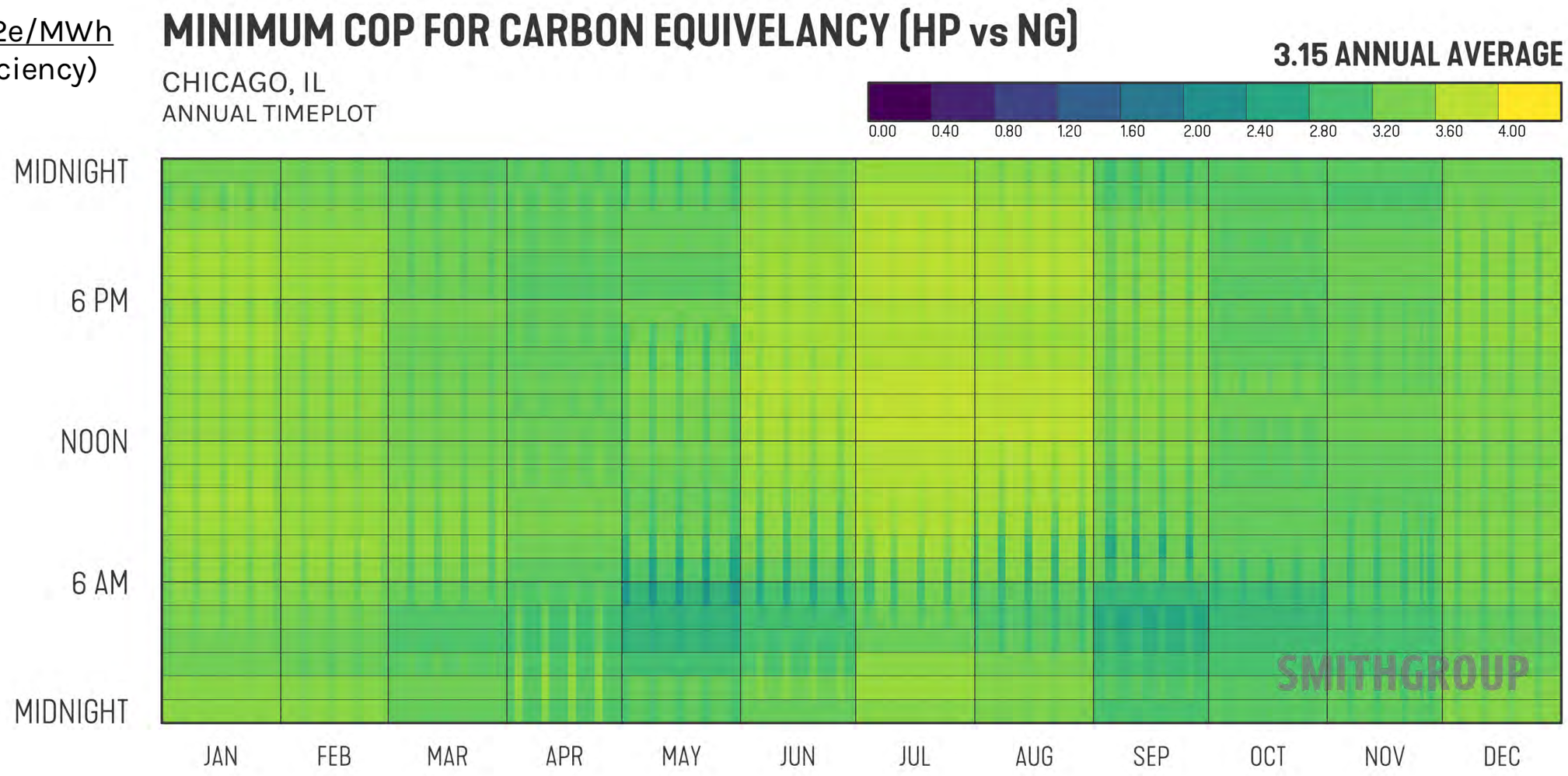




UNDERSTANDING YOUR REGIONAL GRID

TARGETING PERFORMANCE THAT WILL DECARBONIZE

Hourly Elec Marginal CO2e/MWh
(Nat Gas Emissions/Efficiency)



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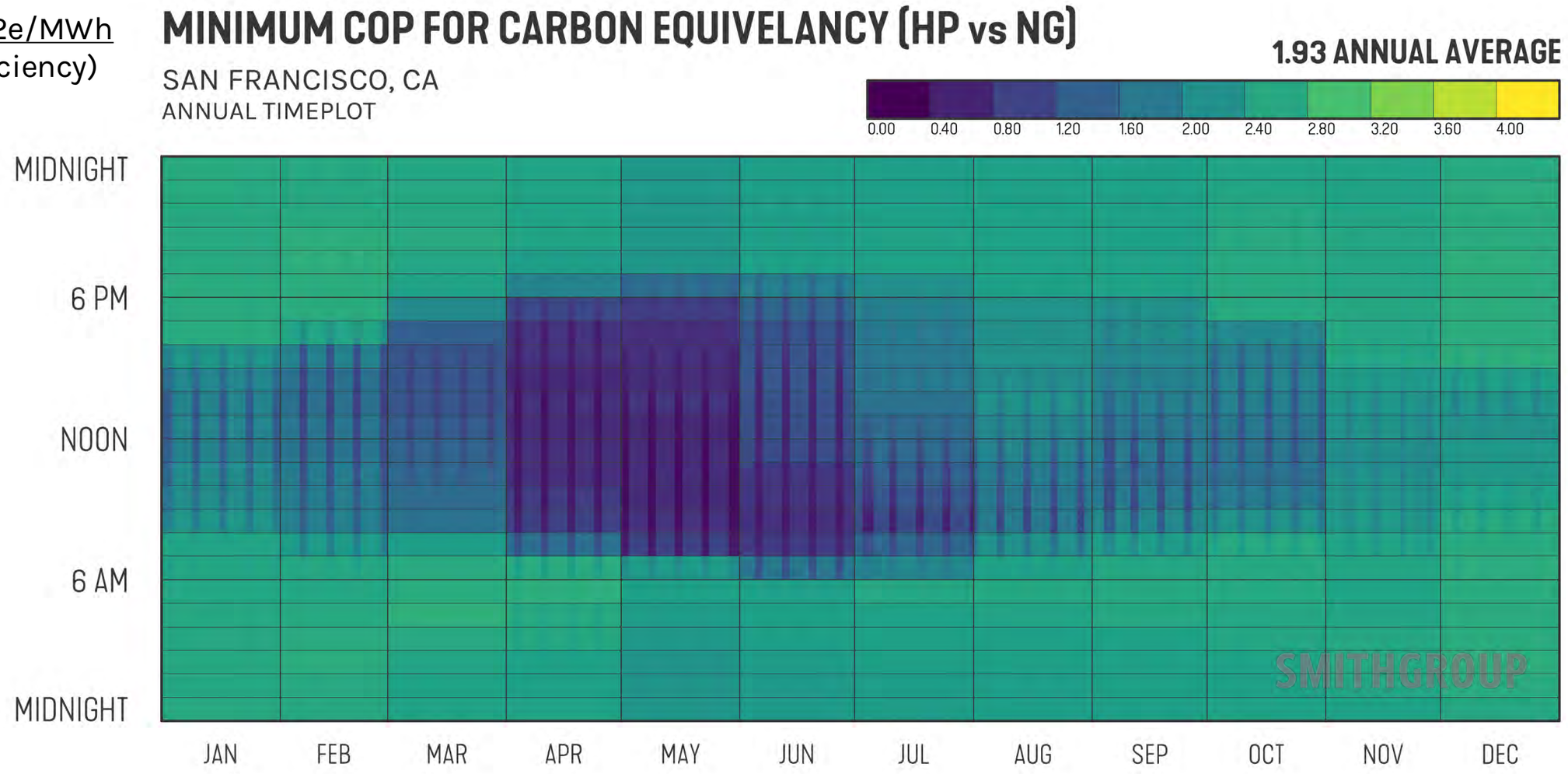
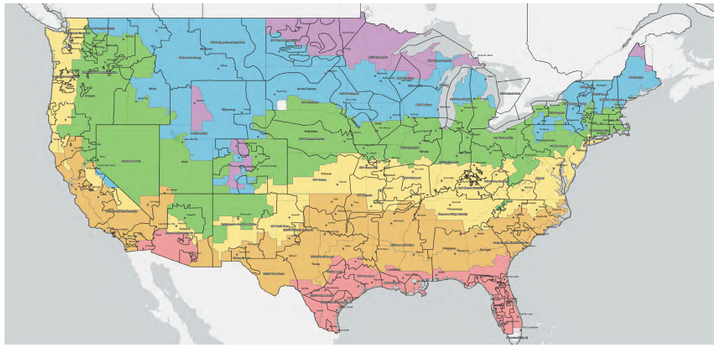
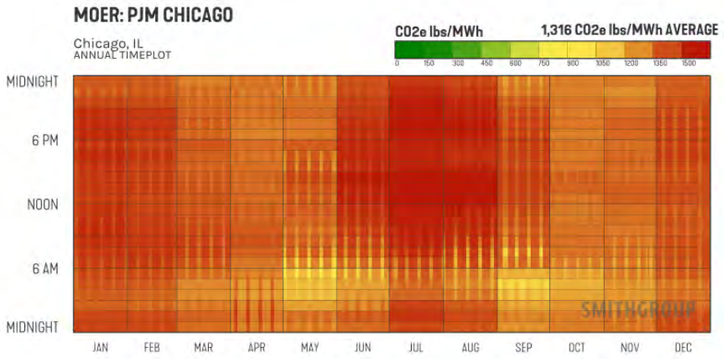


MATCHING DECARB'ED SYSTEMS TO BUILDING TYPES

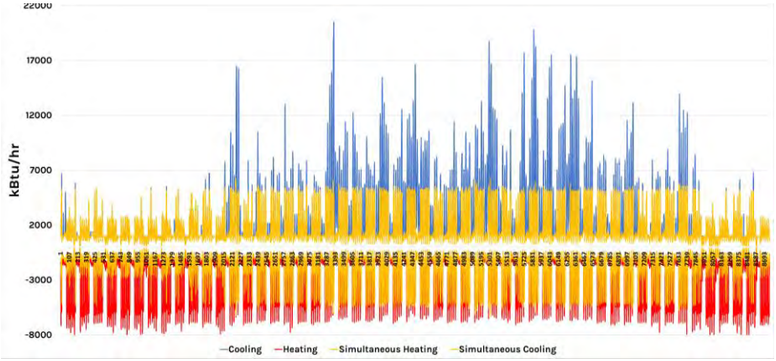
INFLUENCING FACTORS



Climate Zone



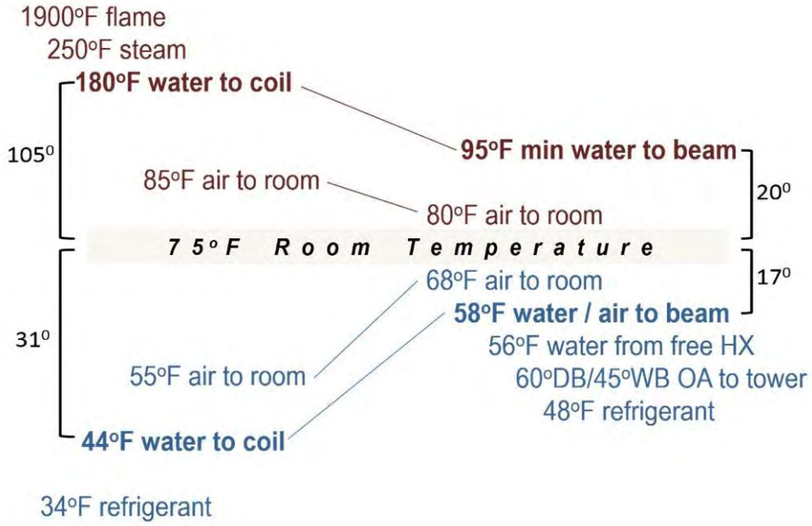
Grid Emissions Profile



Load Profile

Type of Equipment

Distribution Temperatures



MATCHING ALL-ELECTRIC SYSTEMS TO BUILDING TYPES

SIMPLE REPLACEMENTS – SMALL OFFICES, SCHOOLS, ETC

Heat Pump Rooftop Package Units

VRF

Considerations & Strategies:

- Integrated HRV/ERV
- Select for Correct OAT
- Minimize Electric Resistance Heating

MATCHING ALL-ELECTRIC SYSTEMS TO BUILDING TYPES

MEDIUM OFFICE AND SIMILAR VAV/REHEAT SYSTEMS

Heat Pump AHU's, ASHP-HR

VRF

Considerations & Strategies:

- Consider Heat Recovery Heat Pump Integrated with AHU & Reheat Loop
- Integrated HRV/ERV

MATCHING ALL-ELECTRIC SYSTEMS TO BUILDING TYPES

CENTRAL CHILLER / BOILERS WITH HYDRONIC SYSTEMS

6, 4 and 2-pipe ASHP's

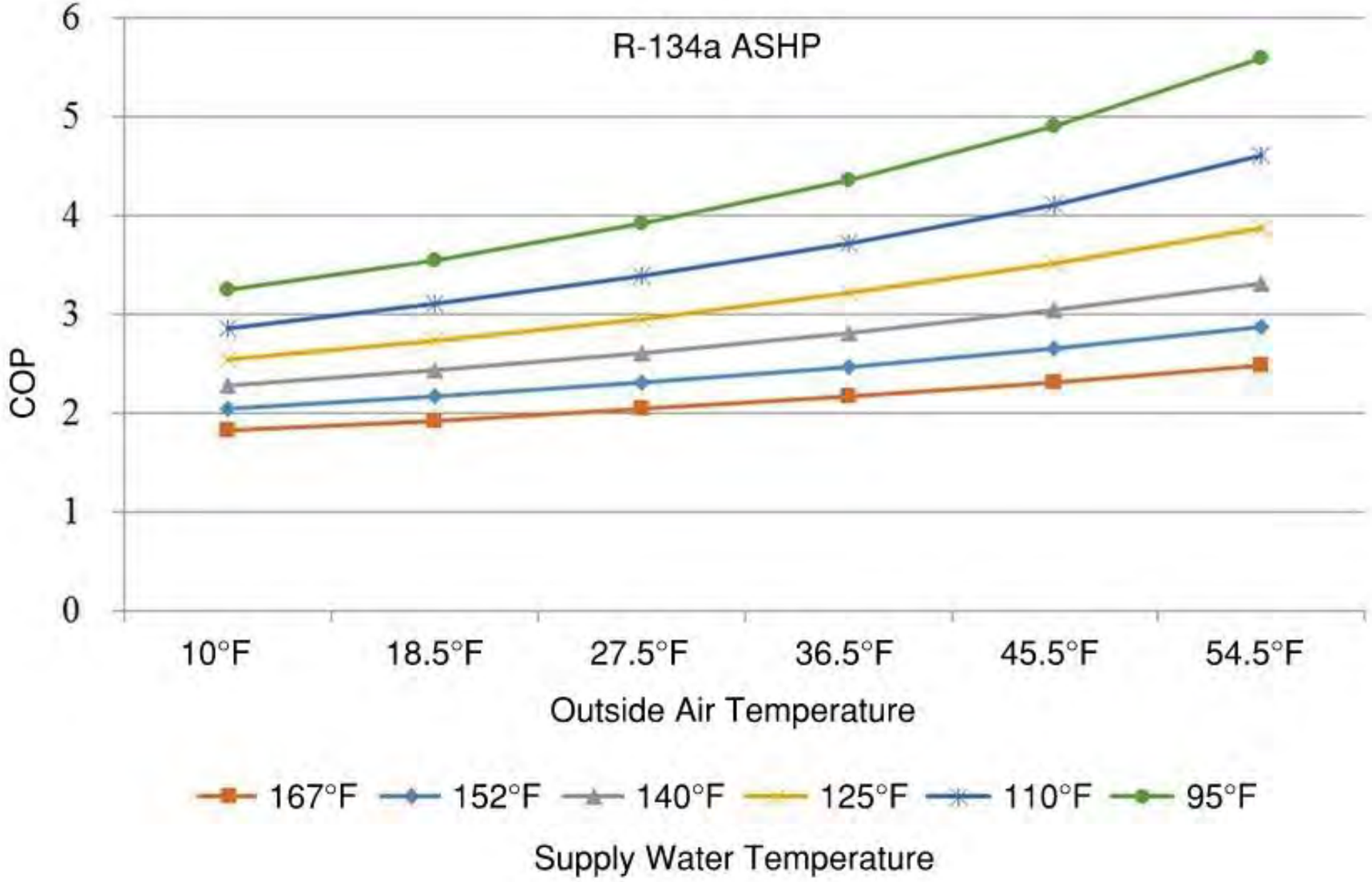
Heat Recovery Chillers

Considerations & Strategies:

- Maximize Heat Recovery
- Consider adding Thermal Energy Storage to increase Heat Recovery Potential
- Consider adding TES for shifting heating load into daytime hours
- Footprint will be challenging
- Consider Augmenting with Ground-Source Heat Exchange
- Can be challenging to maintain consistent Delta T

DESIGN PRINCIPLES FOR COLD CLIMATE DECARB

WHERE DO YOU START AND HOW TO ACHIEVE REDUCTIONS



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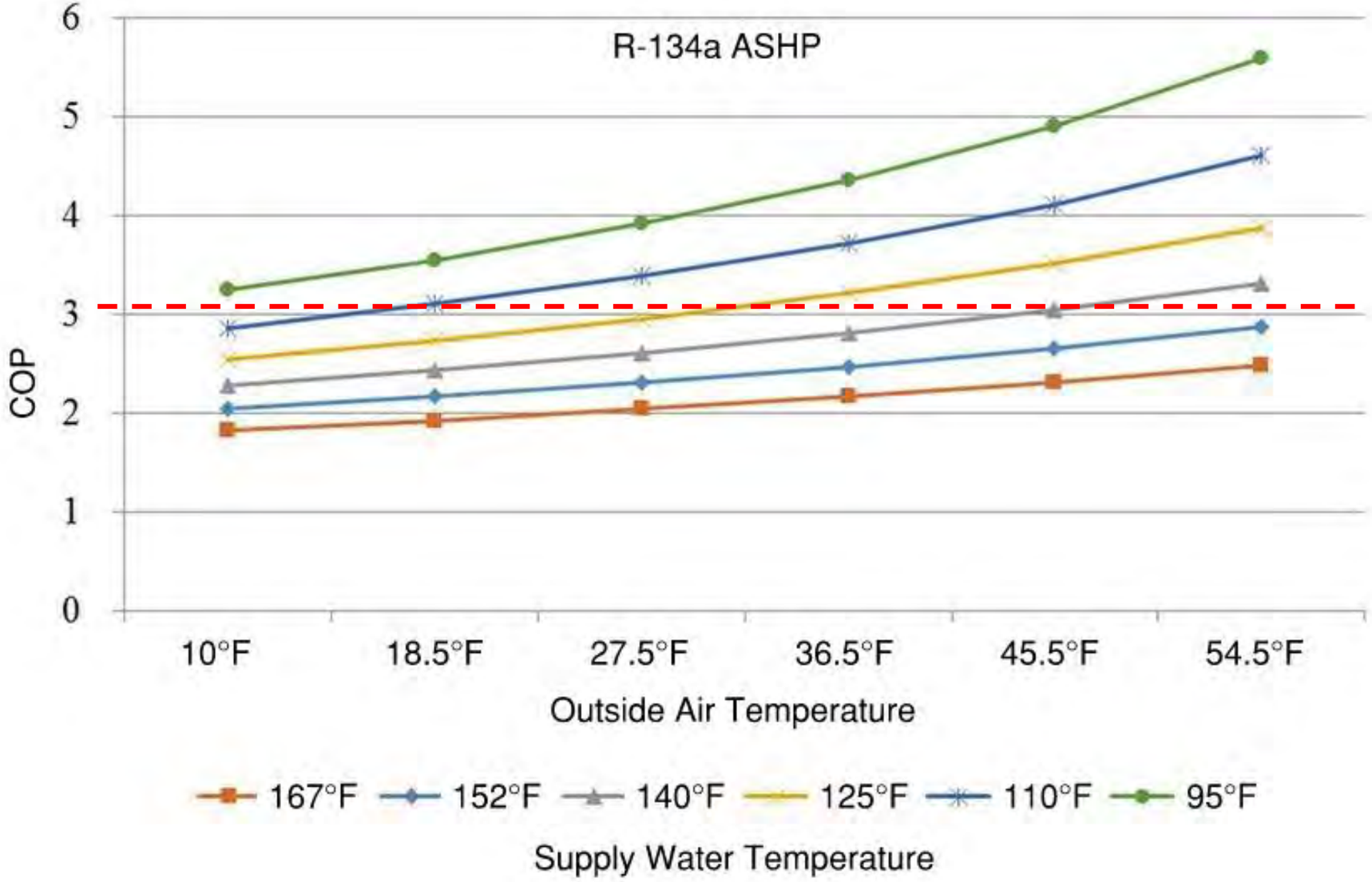
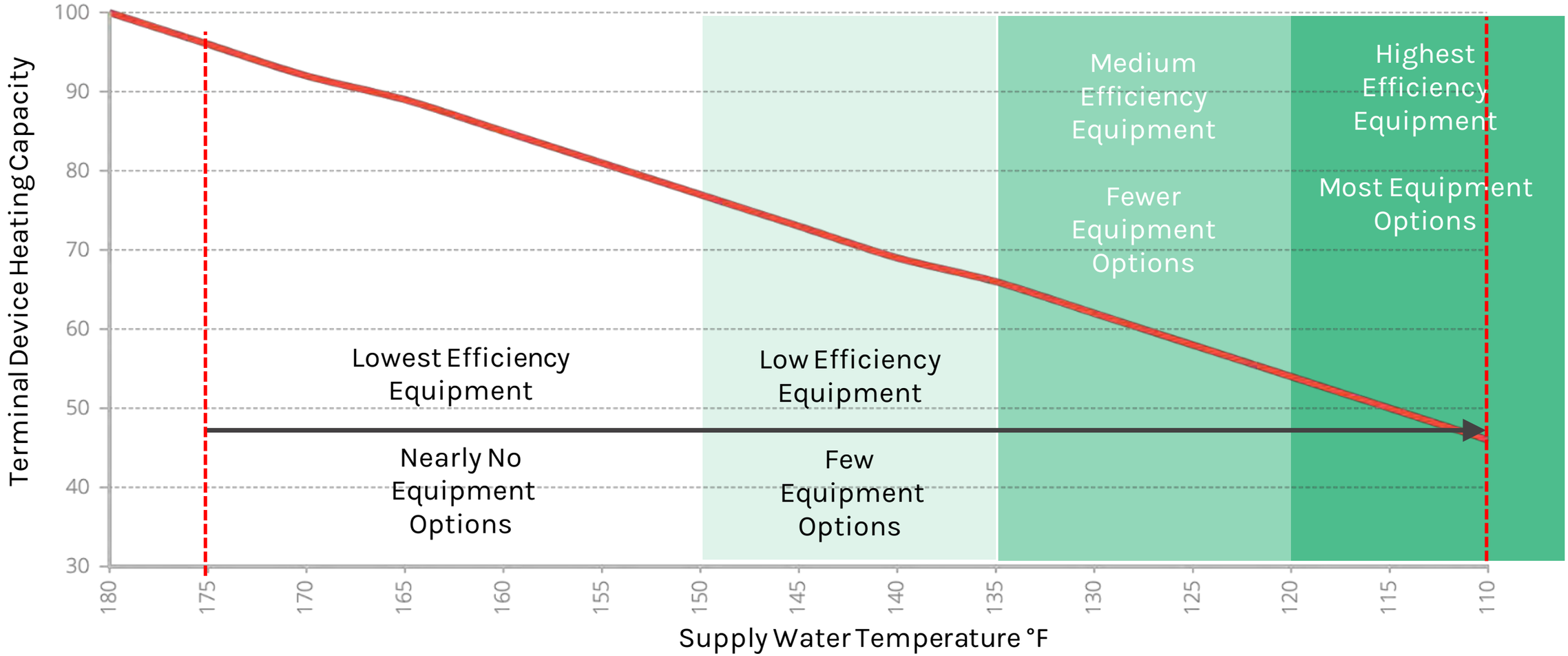


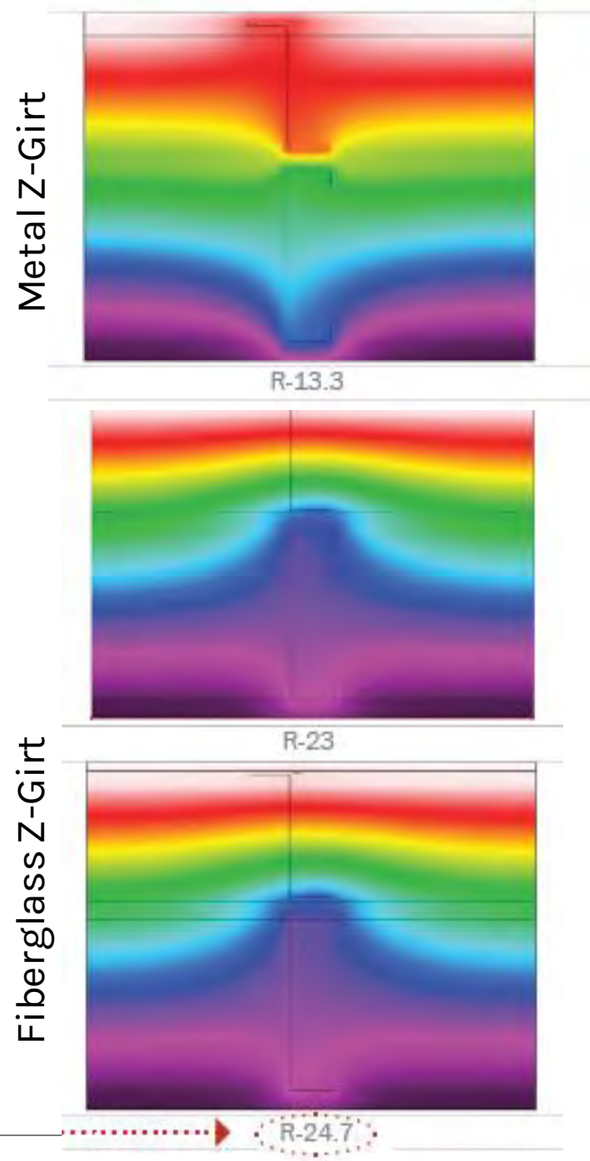
COLD CLIMATE ENG. DECARB PRINCIPLE #1

REIMAGING HHWS TEMPERATURE REGIMES



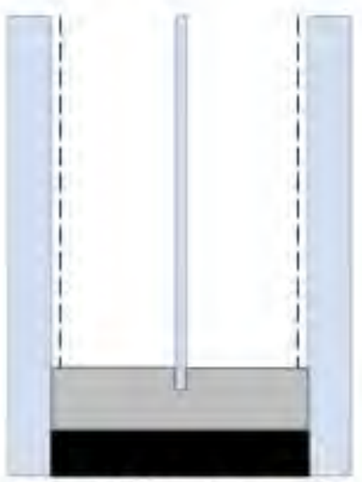
COLD CLIMATE ENG. DECARB PRINCIPLE #2

ENVELOPE, ENVELOPE, ENVELOPE



COLD CLIMATE ENG. DECARB PRINCIPLE #2

ENVELOPE, ENVELOPE, ENVELOPE



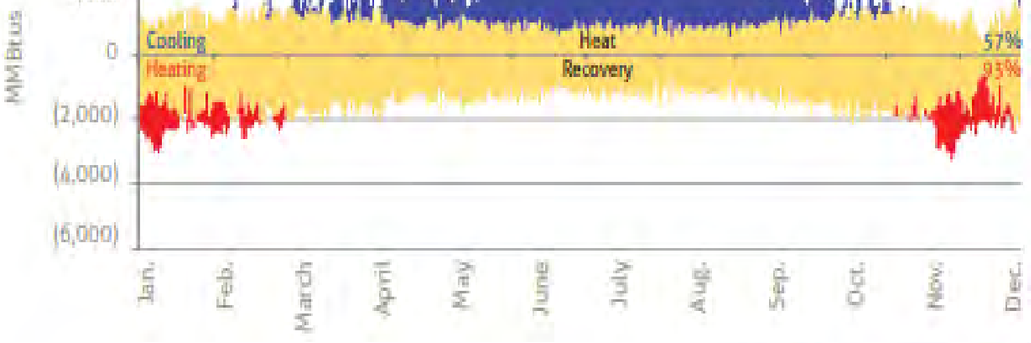
Thin glass
triple pane

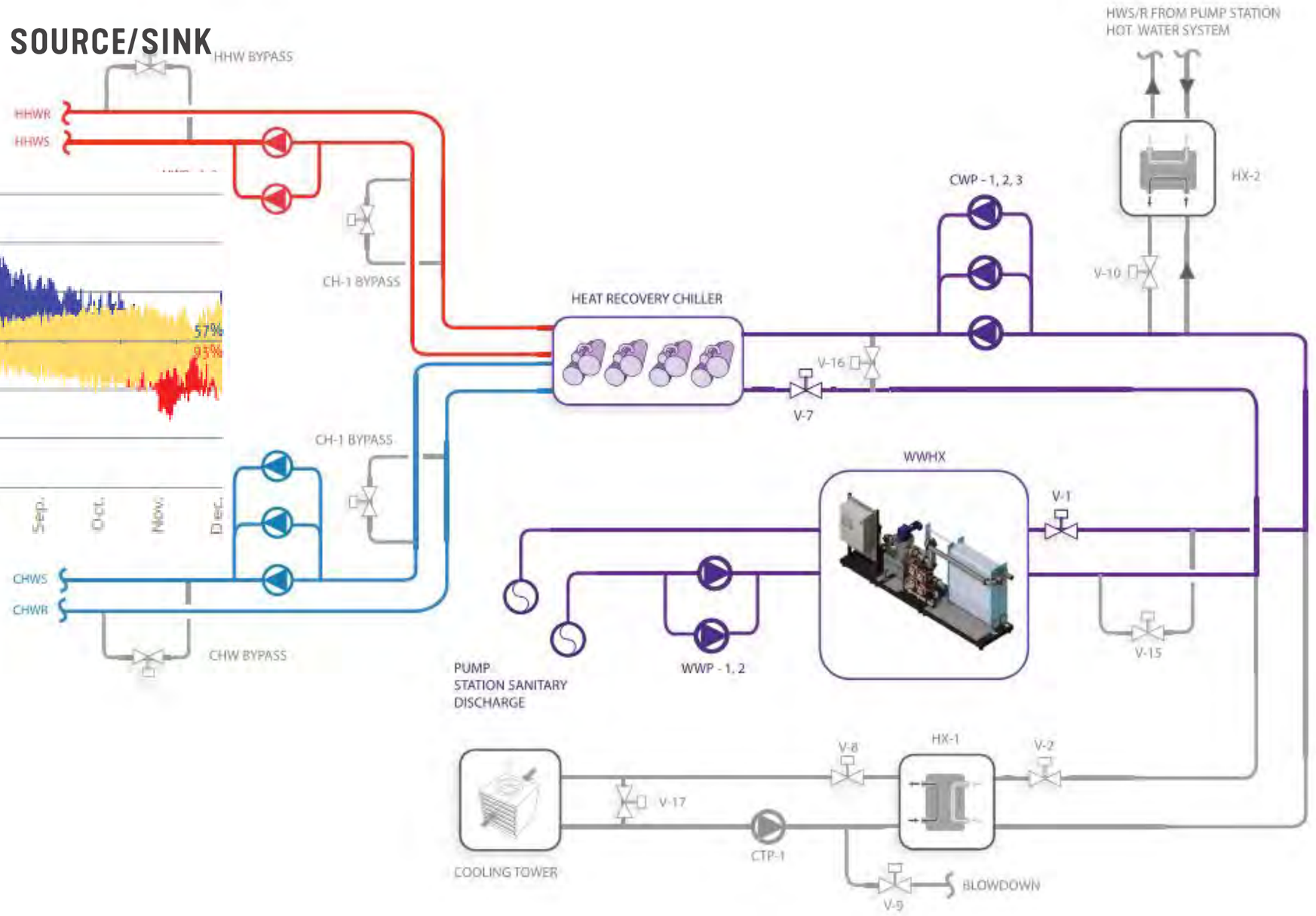
COLD CLIMATE ENG. DECARB PRINCIPLE #3

HEAT RECOVERY….ALL OF IT

WASTE HEAT RECOVERY

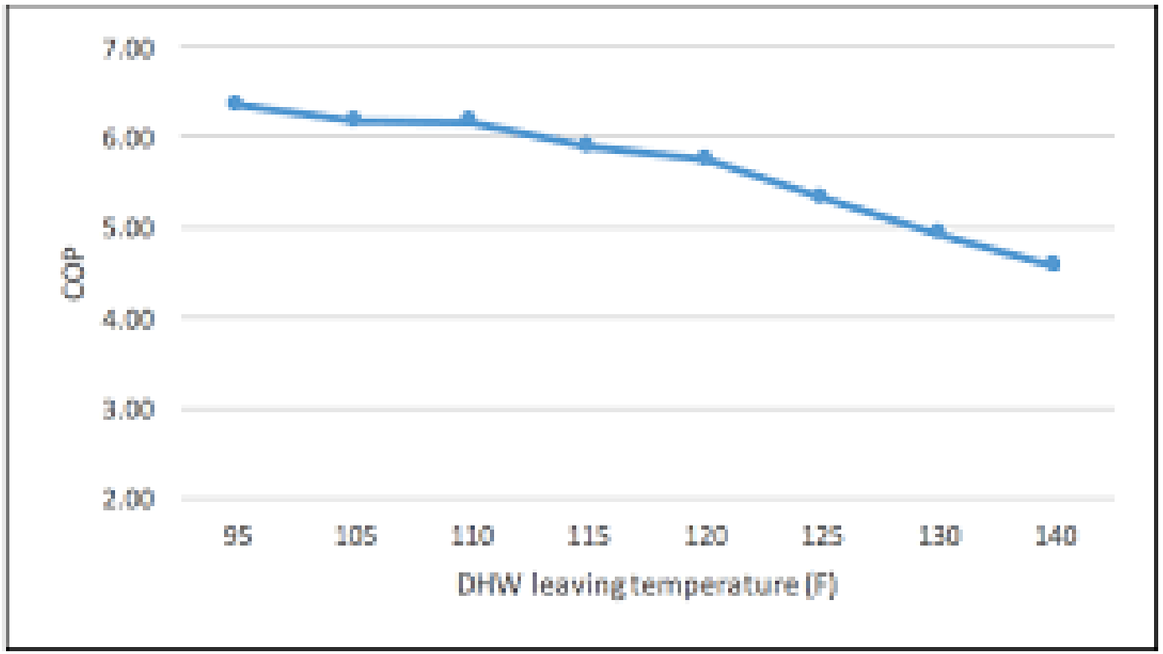
USING SANITARY SEWER AS ENERGY SOURCE/SINK

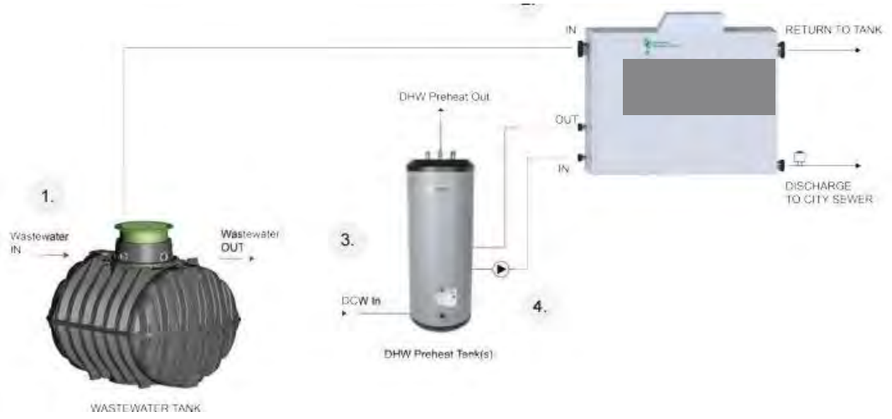




DECARB ELECTRIC SYSTEMS

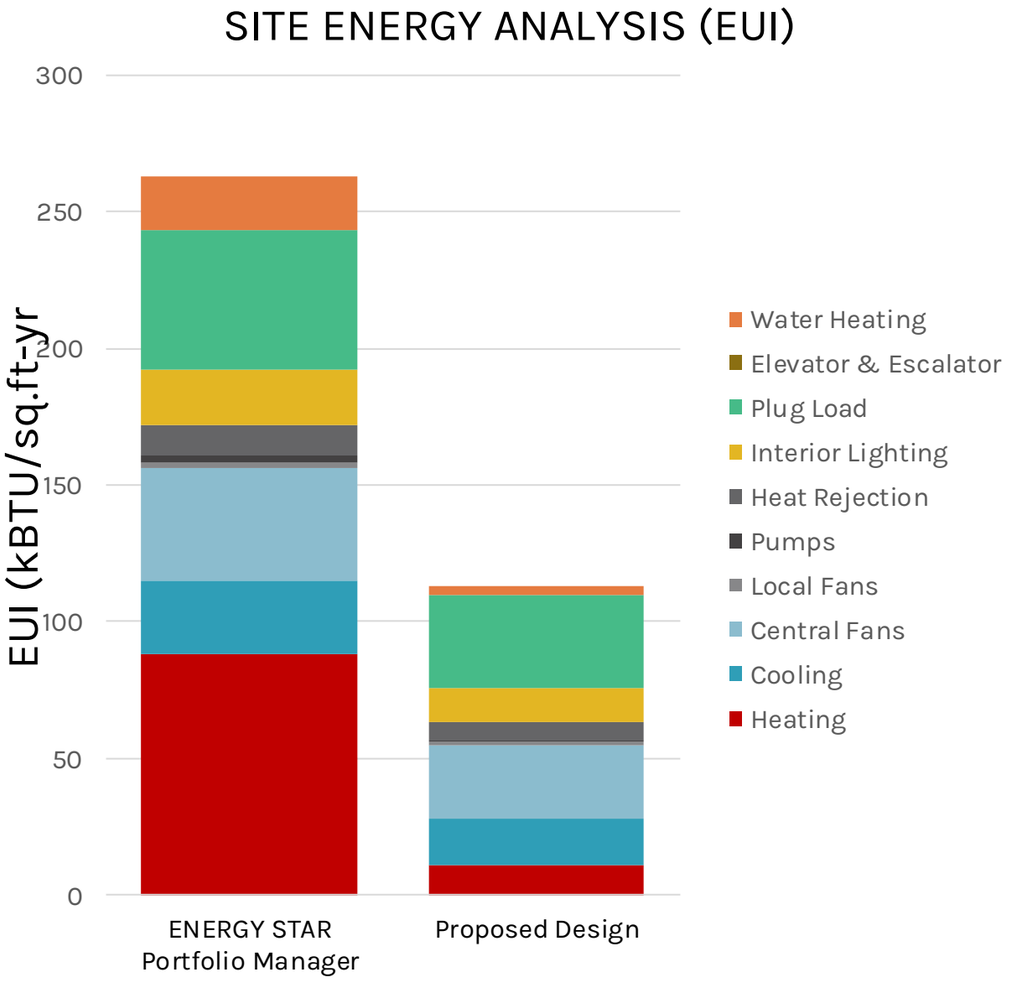
DOMESTIC HOT WATER: THE POWER OF POOP





COLD CLIMATE ENG. DECARB PRINCIPLE #4

OPTIMIZE THE EQUIPMENT

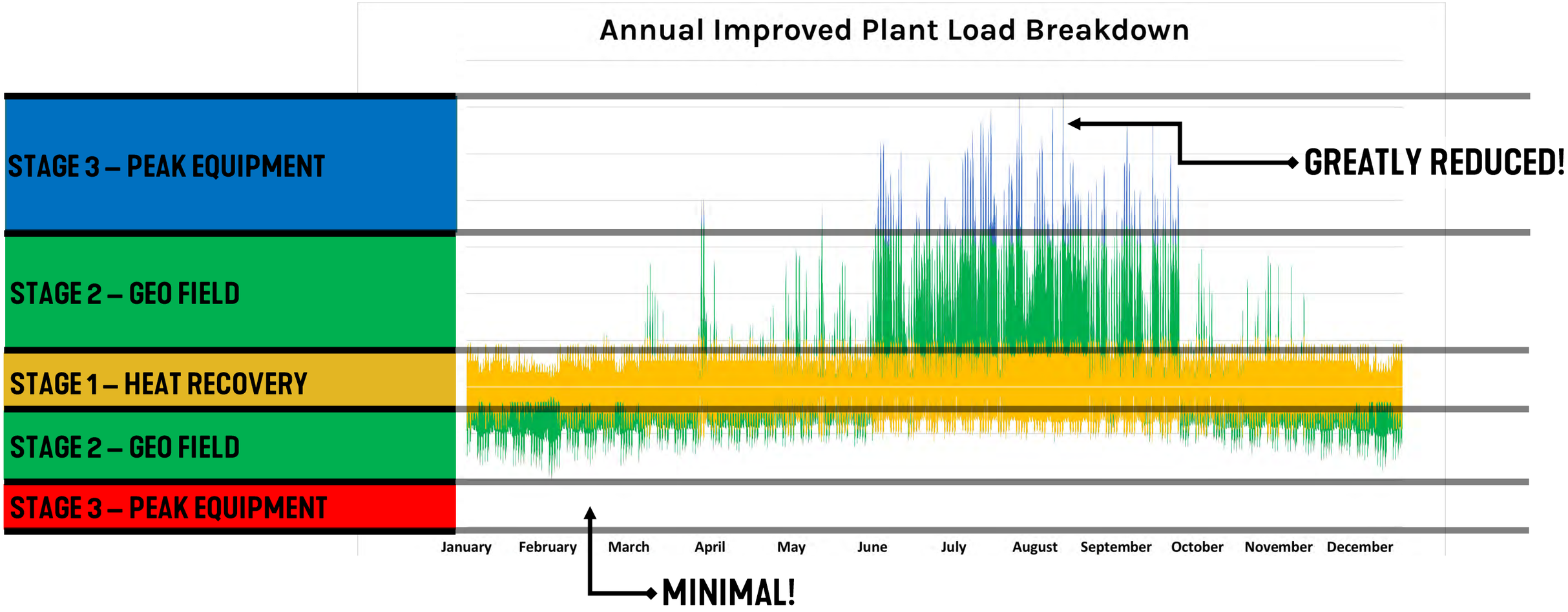


COLD CLIMATE ENG. DECARB PRINCIPLE #4

OPTIMIZE THE EQUIPMENT

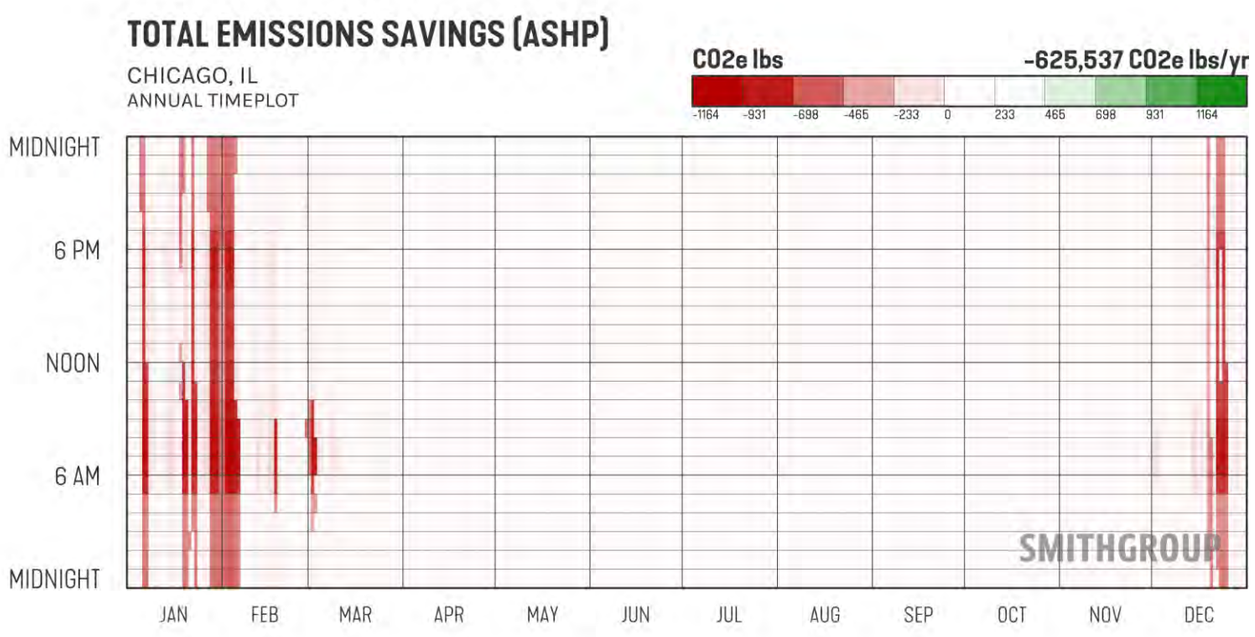
COLD CLIMATE ENG. DECARB PRINCIPLE #4

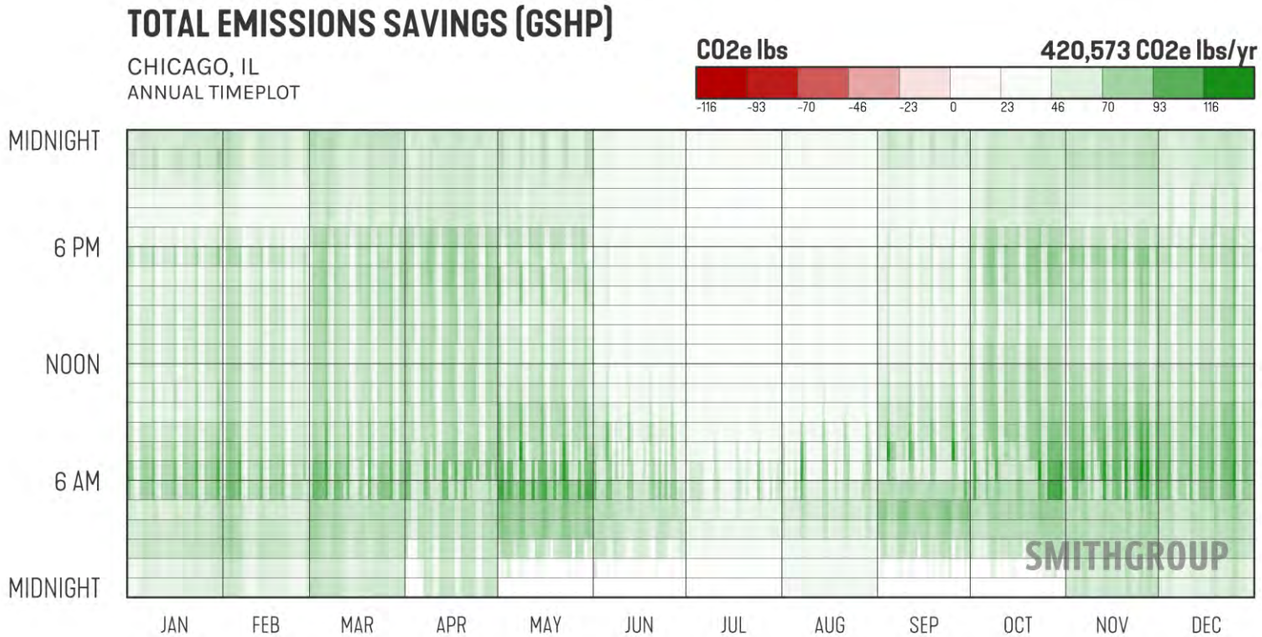
OPTIMIZE THE EQUIPMENT



COLD CLIMATE ENG. DECARB PRINCIPLE #4

OPTIMIZE THE EQUIPMENT



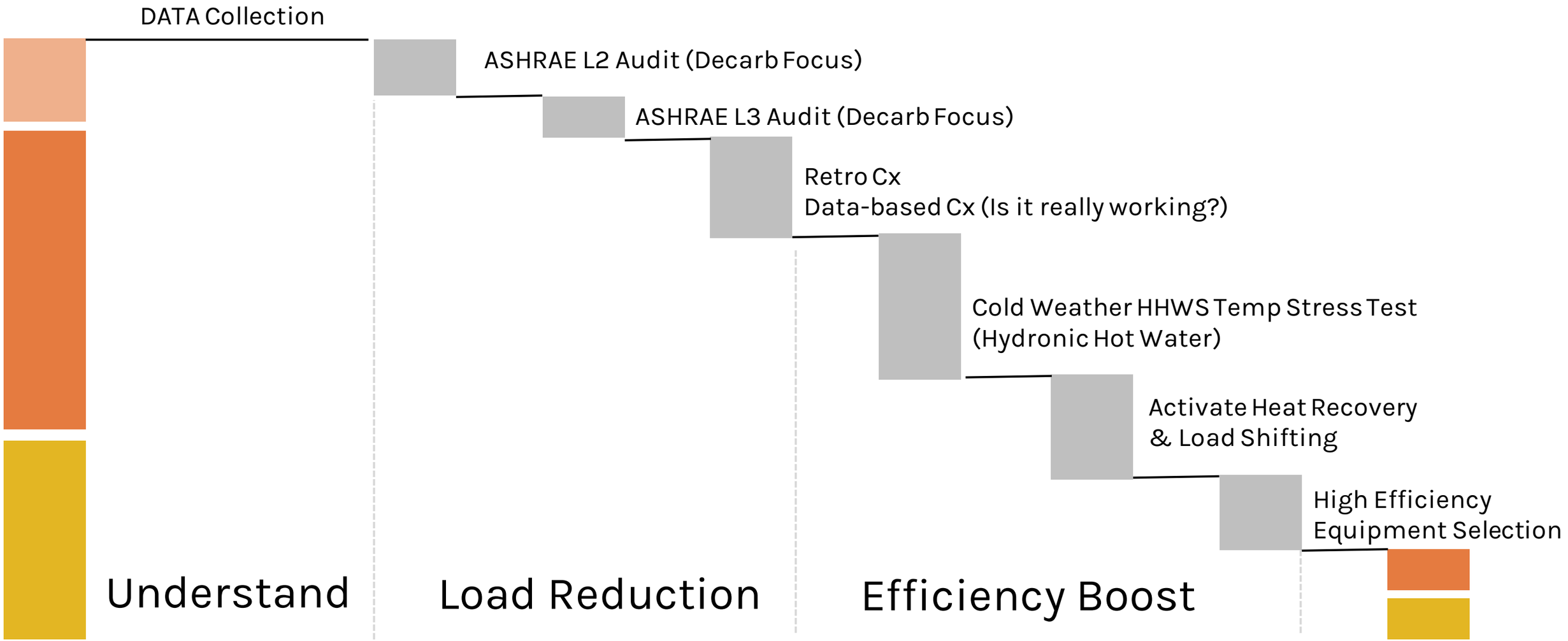


ADDRESSING COLD CLIMATE RETROFITS

EFFICIENCY FIRST; DON'T REPLACE LIKE-FOR-LIKE WITH A HEAT PUMP

DECARB ELECTRIFICATION RETROFIT PROCESS

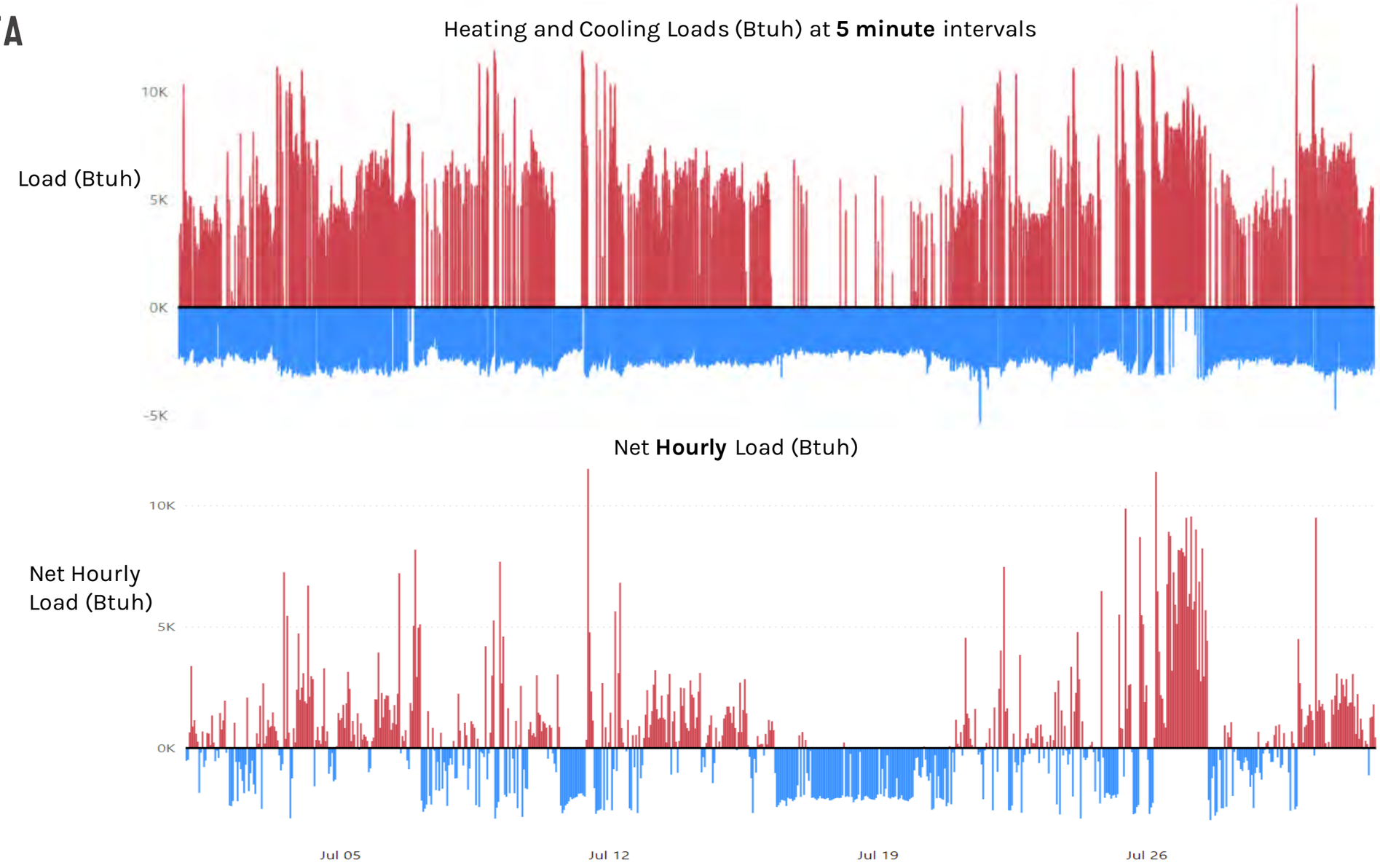
STACKING ORDER FOR A COST-EFFECTIVE DESIGN



ELECTRIFICATION RETROFIT PROCESS

AGGREGATE SENSOR DATA

- Comparison of a single Patient Zone in July 2020
- Aggregating data from 5 minute intervals to hourly smooths Load



COLD CLIMATE DECARB + ELECTRIFICATION

DESIGN STRATEGIES TO MAXIMIZE PERFORMANCE AND REDUCE COST

- Design around mild Supply Temp systems
  - Do a cost analysis for adding TES to load shift for better time of day temperatures or cost
  - COP can double for the same OAT
- Demand a High-Performance Enclosure
- Maximize heat recovery
- Optimize the Equipment
  - Design for > 3 annual COP Average
  - (Typical cost parity with Fossil Gas)

RESOURCES FOR COST MODELING

HTTPS://ELECTRIFICATION.ORNL.GOV/

Electrification for Decarbonization

Reset Data | Use Example

Annual Operating Hours: 8760 hrs/yr

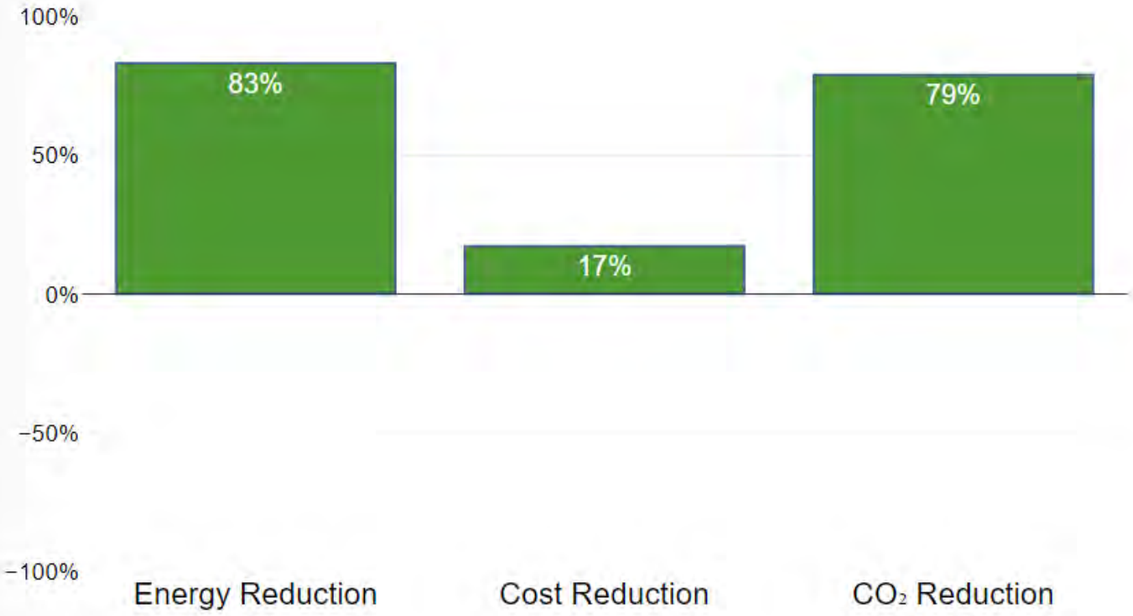
Current Fuel Based Equipment

Energy Source	Natural Gas
Fuel Cost	4 $/MMBtu
Fuel-Fire Equipment Efficiency	60 %
Heat Input for Fuel-Fire Equipment	10 MMBtu/hr
Carbon Emissions	53.06 kg CO_2/MMBtu
Methane Emissions	1 g CH_4/MMBtu
Nitrous Oxide Emissions	0.1 g NO_2/MMBtu
Current CO_2 Emissions	4,648.06 tonne CO_2/yr
Current Fuel Costs	$350,400 /yr

Potential Electrical Equipment

Electricity Cost	0.066 $/kWh
Electrically Heated Equipment Efficiency	350 %
Estimated Electric Peak Demand	502.28 kW
eGrid Region	WECC
eGrid Subregion	CAMX: WECC California
Carbon Emissions	225.2 kg CO_2/MWh

Results | Help



Current Fuel Usage

Fuel Use	87,600 MMBtu/yr

FINANCIAL TOOLS TO MAKE IT HAPPEN

INCREASING THE RETURN ON INVESTMENT






		179D Commercial Buildng Energy Tax Deduction	Modified Accelerated Cost Recovery System	Bonus Depreciation	Business Energy Investment Tax Credit	Renewable Energy Production Tax Credit	Rural Energy for America Program Grants
Basic Project Attributes	Project Type	New Construction	New Construction	New Construction	New Construction	New Construction	New Construction
		Retrofits	Retrofits	Retrofits	Retrofits	Retrofits	Retrofits
	Eligible Technology	Energy Efficiency	Energy Efficiency	Energy Efficiency	Energy Efficiency	Renewables	Energy Efficiency
			Renewables	Renewables	Renewables		
			Energy Storage	Energy Storage	Energy Storage		Renewables
	Eligibility Notes	Envelope, HVAC, Hot Water, Lighting	Equipment or property must largely be used for commercial purposes	Recovery Period for depreciation must be less than 20 years	Technology Dependent	As of 2022, only applicable to wind energy	Only available to Rural Businesses or Agricultural Producers

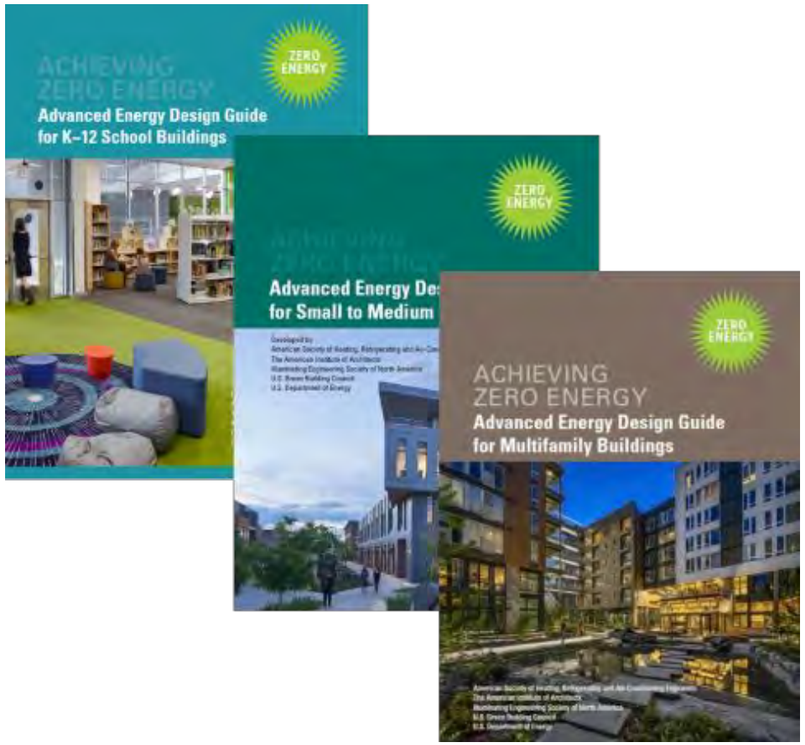
FINANCIAL TOOLS TO MAKE IT HAPPEN

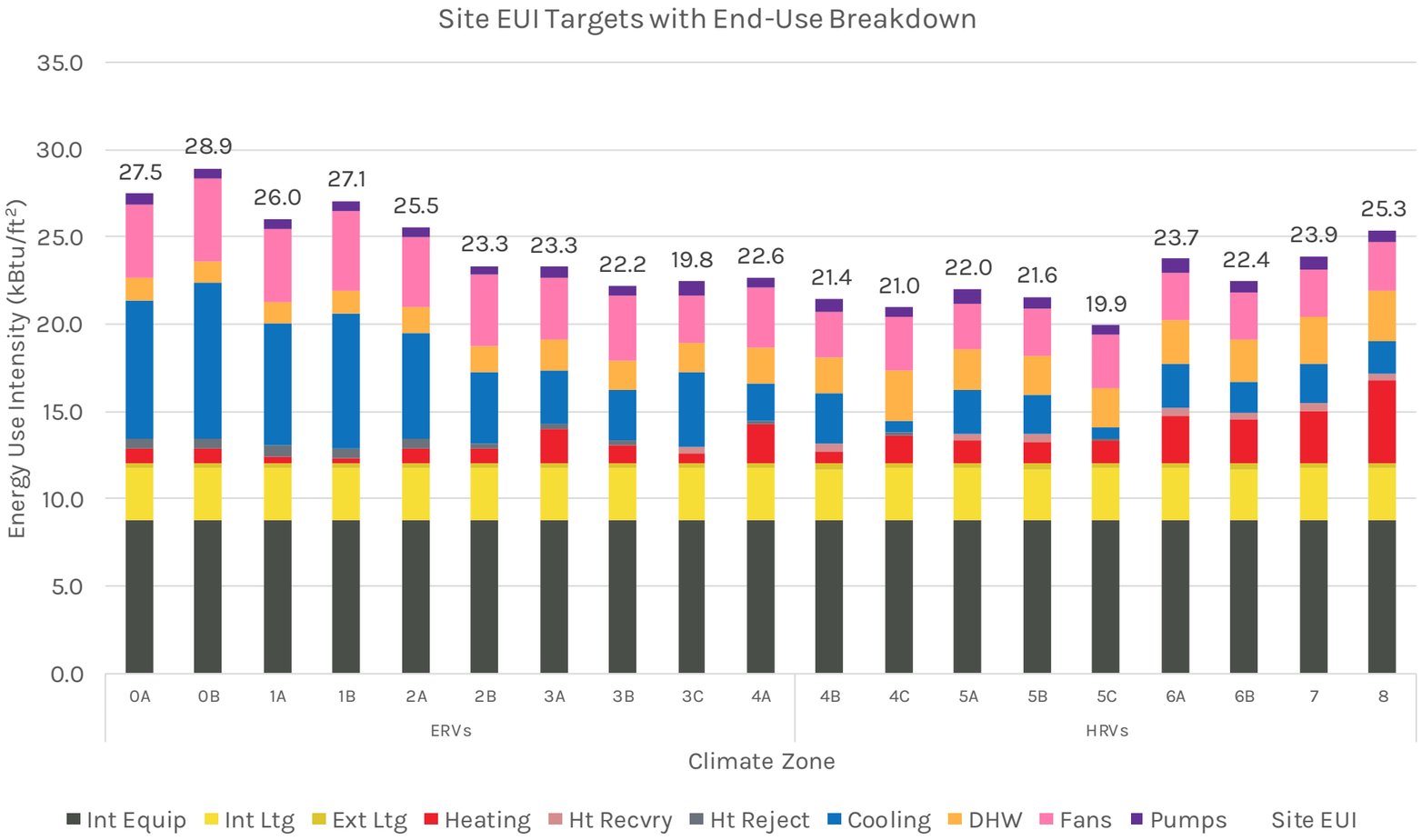
INCREASING THE RETURN ON INVESTMENT – GEOTHERMAL

Tax Mechanism	Description	Description
Investment Tax Credit	6-30% of installed cost of Geothermal systems including distribution.	Base Rate is 6%. If prevailing wage requirements and apprenticeship requirements are met, ITC increases to 30%
ITC Domestic Content Bonus	10% on top of Base ITC (Up to total of 40%)	100% Domestic Material is used*
179d Tax Deduction	$2.50-$5.00/sf Tax Deduction	For projects meeting the prevailing wage requirements, energy reduction standards will be: 25% better than 90.1 will yield a §179D Tax Deduction of $2.50/SF and for every 1% of additional reduction above 25% it will provide an additional $0.10/SF of deduction up to $5.00/SF
Accelerated Depreciation	TBD for Changes to Bonus Depreciation	5-Year Depreciation period provides significant tax savings

ASHRAE ADVANCED ENERGY DESIGN GUIDES

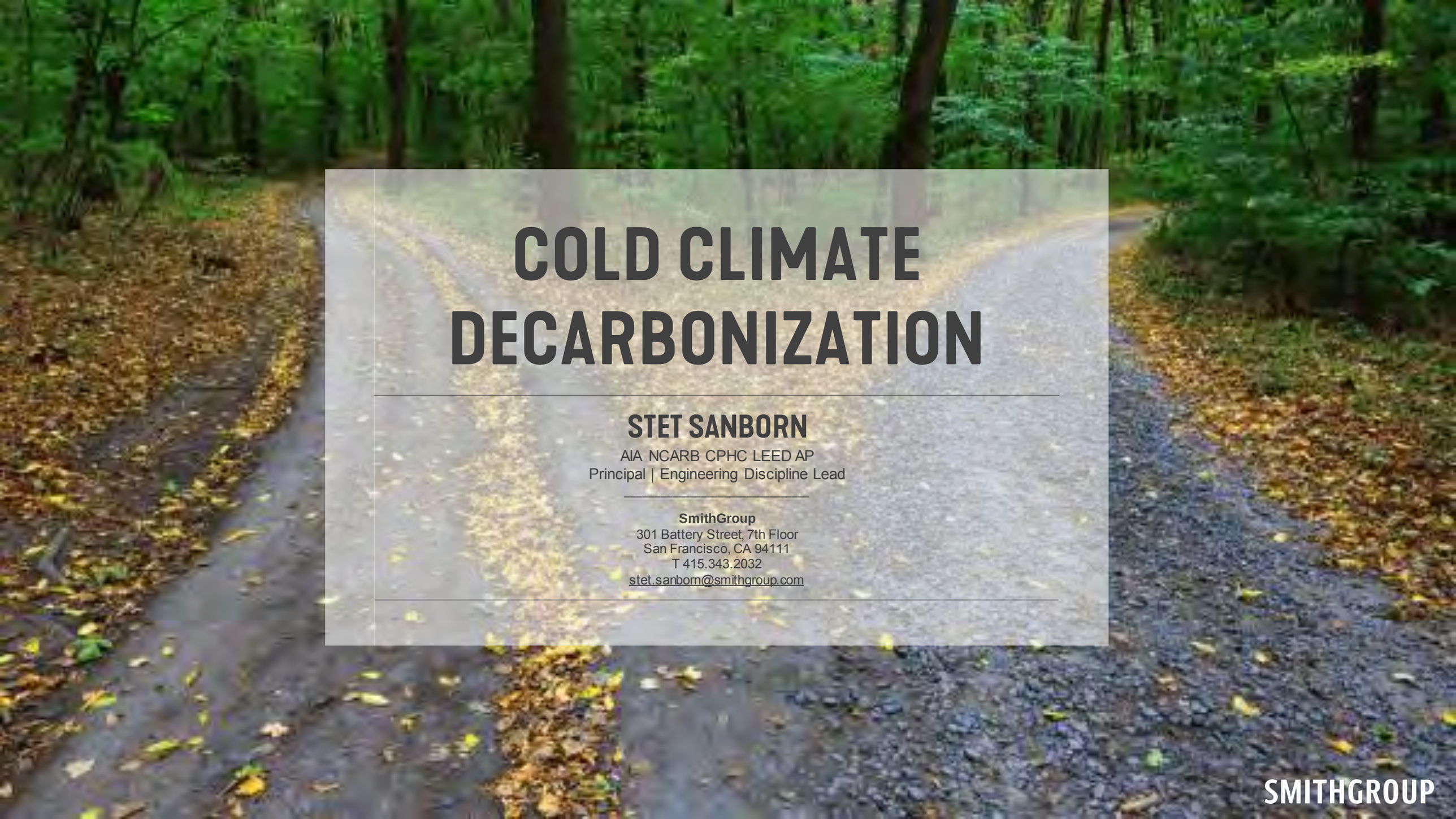
MEP SYSTEMS FOR ZERO ENERGY DESIGN





DECARBONIZATION DESIGN GUIDES COMING SOON!

COMING SOON!



COLD CLIMATE DECARBONIZATION

STET SANBORN

AIA NCARB CPHC LEED AP
Principal | Engineering Discipline Lead

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SMITHGROUP

DECARB ELECTRIC SYSTEMS

DOMESTIC HOT WATER: WHY CO2 HEAT PUMPS AND POOP MAY BE YOUR BEST FRIEND

- 100x 1-Bedroom
- 100x 2-Bedroom

- ASPE
  - Peak: 1,433 gph for 3 hours
  - Off-peak: 158 gph for 8 hours

DECARB ELECTRIC SYSTEMS

DOMESTIC HOT WATER: WHY CO2 HEAT PUMPS AND POOP MAY BE YOUR BEST FRIEND

- 100x 1-Bedroom
- 100x 2-Bedroom

- ASPE
  - Peak: 1,433 gph for 3 hours
  - Off-peak: 158 gph for 8 hours

4 Air-Source R-134a Heat Pumps
4 x 70 A CB @ 480v
176 KVA
COP ~<2 @ 5F OAT
COP: 4.1 @ 40F OAT

2,750 Gallons of Storage
(@ 140F)

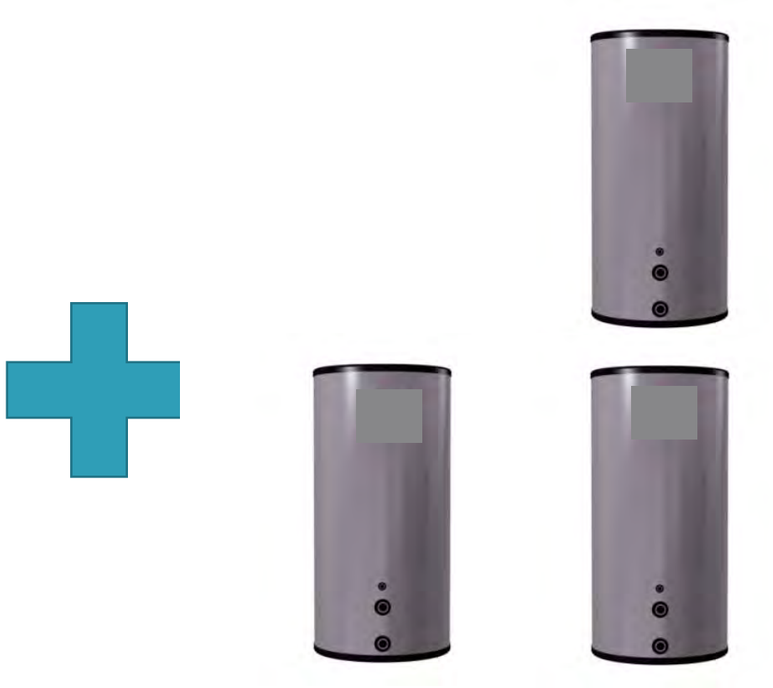
DECARB ELECTRIC SYSTEMS

DOMESTIC HOT WATER: WHY CO2 HEAT PUMPS AND POOP MAY BE YOUR BEST FRIEND

- 100x 1-Bedroom
- 100x 2-Bedroom

- ASPE
  - Peak: 1,433 gph for 3 hours
  - Off-peak: 158 gph for 8 hours

2 x C02 Heat (R744)
2x 125A CB at 480v
138KVA
COP 2.2 at 5F OAT
COP 3 at 40 F OAT



1,500 Gallons of Storage
(@ 180F)

DECARB ELECTRIC SYSTEMS

DOMESTIC HOT WATER: WHY CO2 HEAT PUMPS AND POOP MAY BE YOUR BEST FRIEND

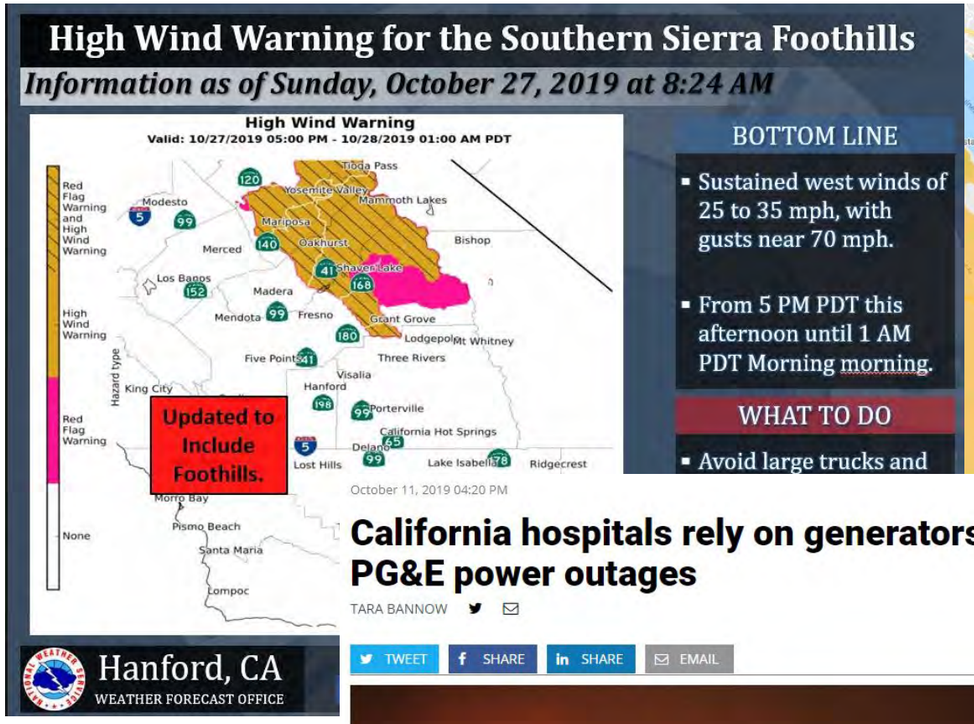
- 100x 1-Bedroom
- 100x 2-Bedroom

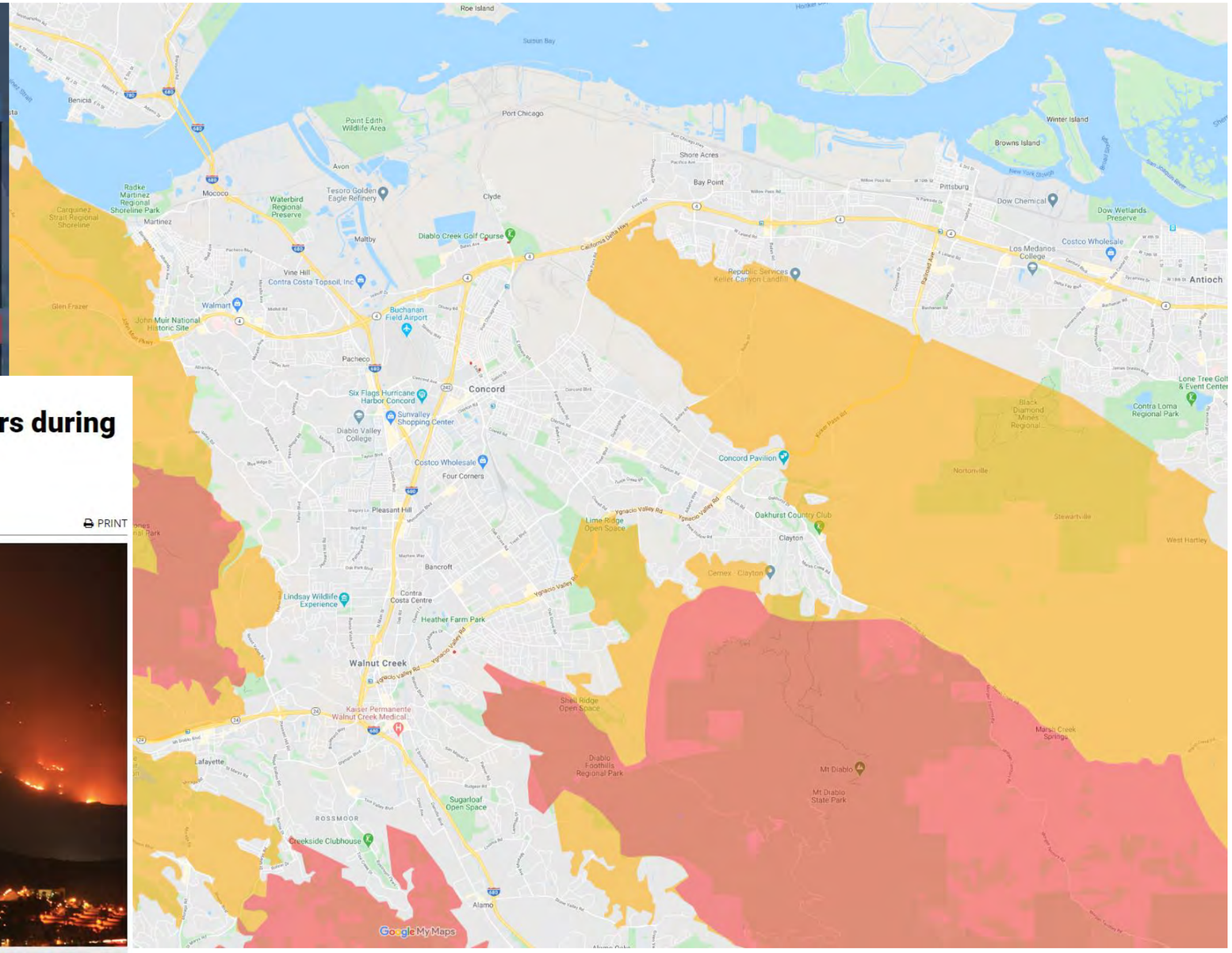
- ASPE
  - Peak: 1,433 gph for 3 hours
  - Off-peak: 158 gph for 8 hours

2 x Waste Heat Recovery Heat Pump (R-513a)
2x 110A CB @ 480v
88 kVA
COP 4.1

2,750 Gallons of Storage (@ 140F) + ~2,250 Gal Waste Storage Below Grade

REDUCING RISK: RESILIENCY



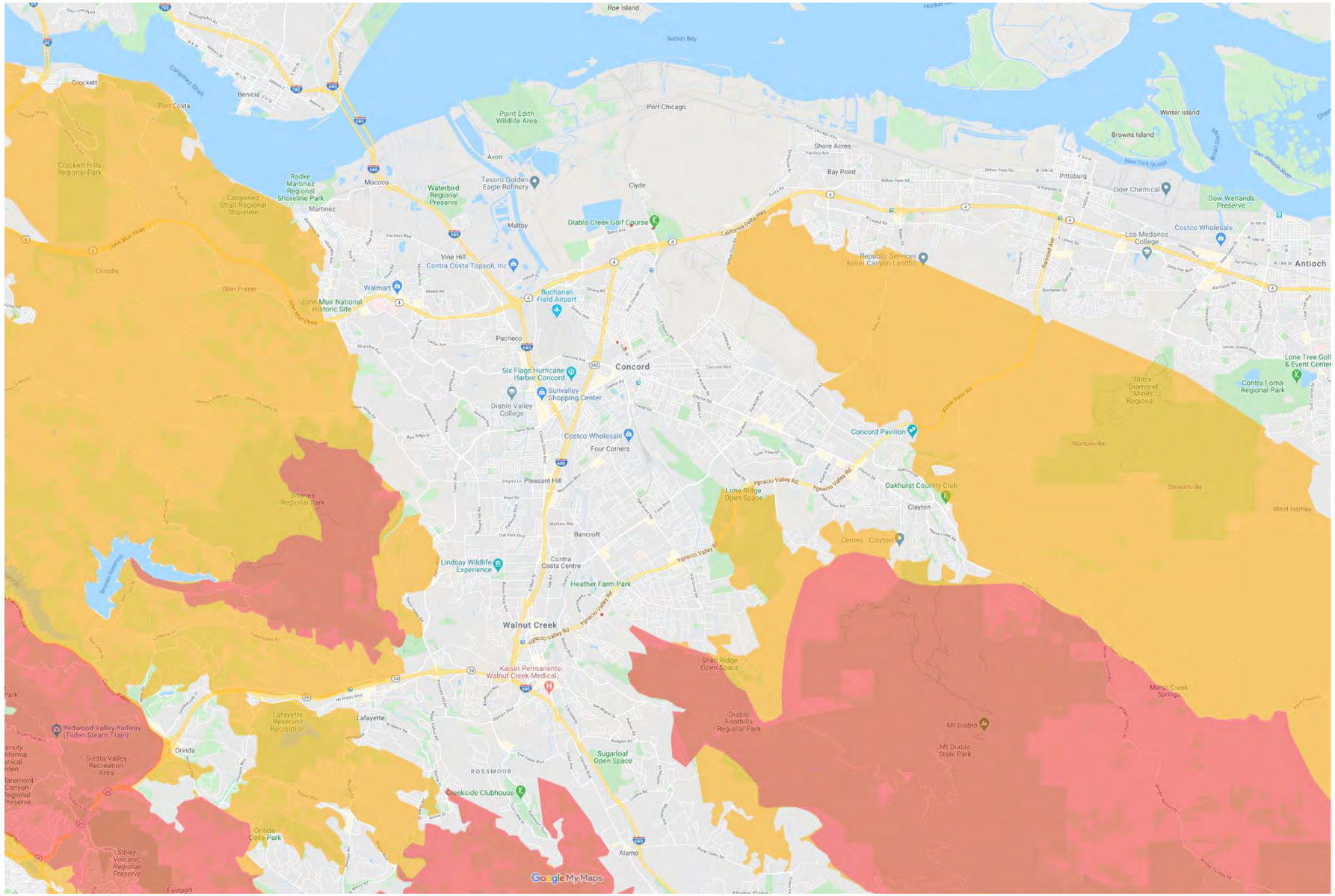


REDUCING RISK: RESILIENCY

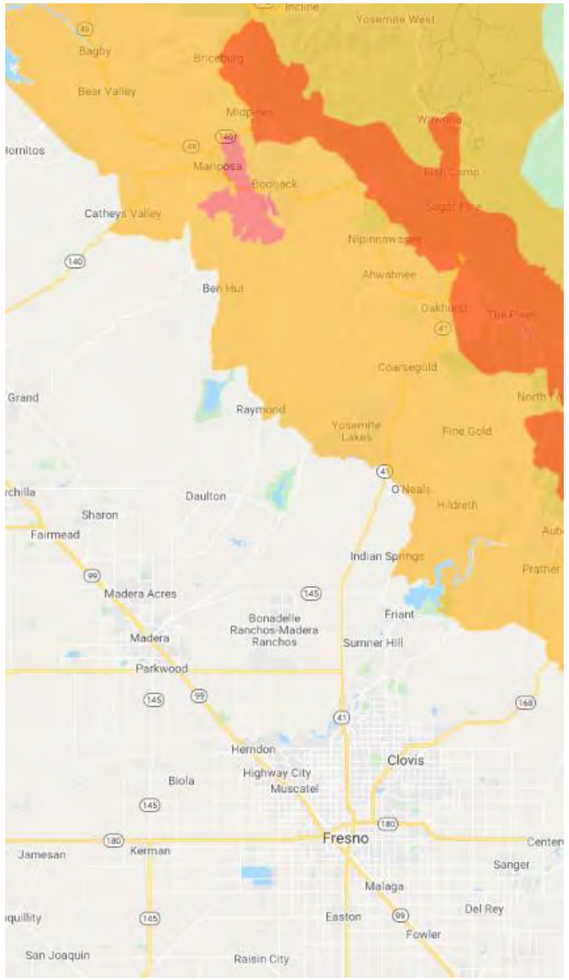
Preemptive Power Safety Shutoffs

- Operational Impact during outage
- Scheduling Impacts, uncertainty of power restoration

Outage Scheduling Impact



RESILIENCY: FUTURE FOCUSED



October 11, 2019 04:20 PM

California hospitals rely on generators during PG&E power outages

TARA BANNOW

TWEET SHARE SHARE EMAIL PRINT

Details of PG&E Electric Delivery Charges

12/23/2019 - 01/22/2020 (31 billing days)

Service For: AVE 9 NW 19-12-20
Service Agreement ID: 6710113215

12/23/2019 – 12/31/2019

Rate Schedule: E20T
Rate Description: Service to Custs with Max Demands of 1000 kW or More

Customer Charge	9	days	@ $49.28131	$443.53
Demand Charge [1]				
Max Demand	2,927.000000	kW	@ $9.76000	8,293.80
Energy Charges				
Part Peak	197,297.000000	kWh	@ $0.10008	19,745.48
Off Peak	315,351.000000	kWh	@ $0.08534	26,912.05
Power Factor Adjustment (@ 96.00% Power Factor)				-281.96
Revenue Cycle Service Credits				-9.33
Generation Credit				-36,476.35
Power Charge Indifference Adjustment				10,611.82
Franchise Fee Surcharge				281.96

01/01/2020 – 01/22/2020

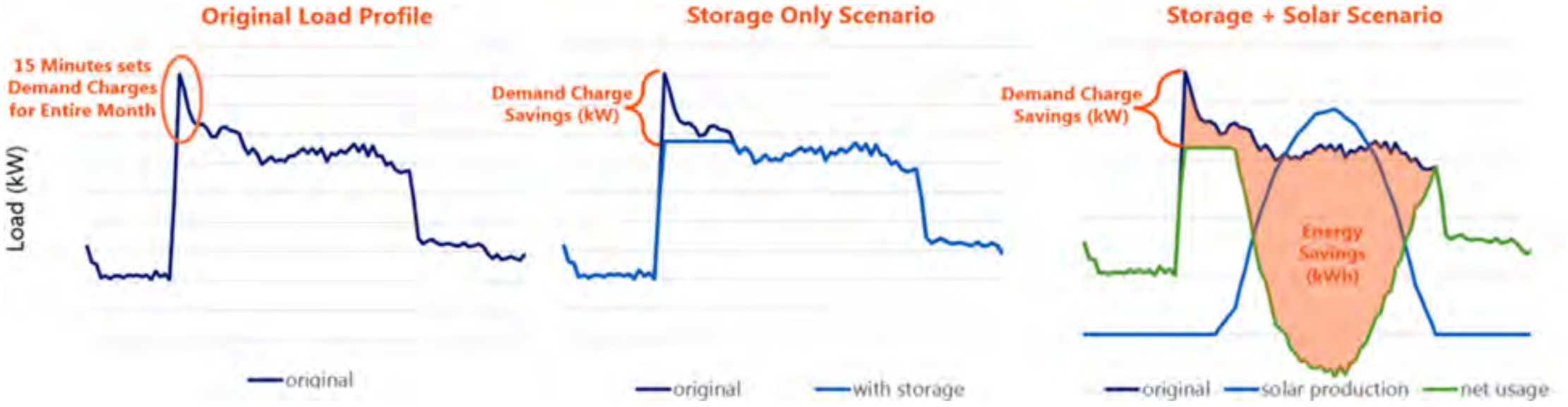
Rate Schedule: E20T
Rate Description: Service to Custs with Max Demands of 1000 kW or More

Customer Charge	22	days	@ $49.28131	$1,084.19
Demand Charge [1]				
Max Demand	3,173.000000	kW	@ $10.65000	23,981.74
Energy Charges				
Part Peak	515,382.000000	kWh	@ $0.10070	51,898.97
Off Peak	762,372.000000	kWh	@ $0.08596	65,533.50
Power Factor Adjustment (@ 96.00% Power Factor)				-702.76
Revenue Cycle Service Credits				-22.82
Generation Credit				-91,264.04
Power Charge Indifference Adjustment				26,449.51
Franchise Fee Surcharge				702.76

Details of charges continue on next page.

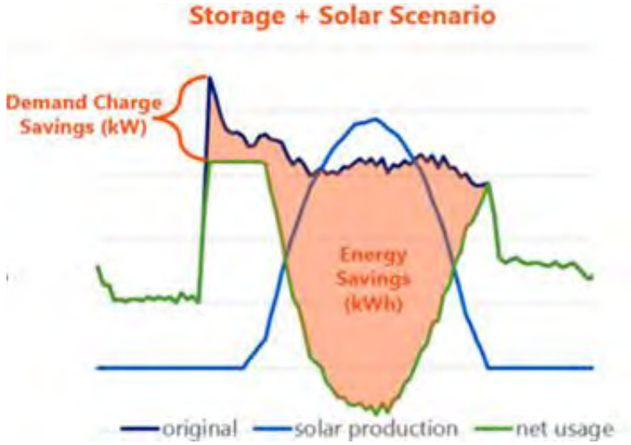
16-45% Cost
Driven by Demand Charge

RESILIENCY: FUTURE FOCUSED



RESILIENCY: FUTURE FOCUSED

99%



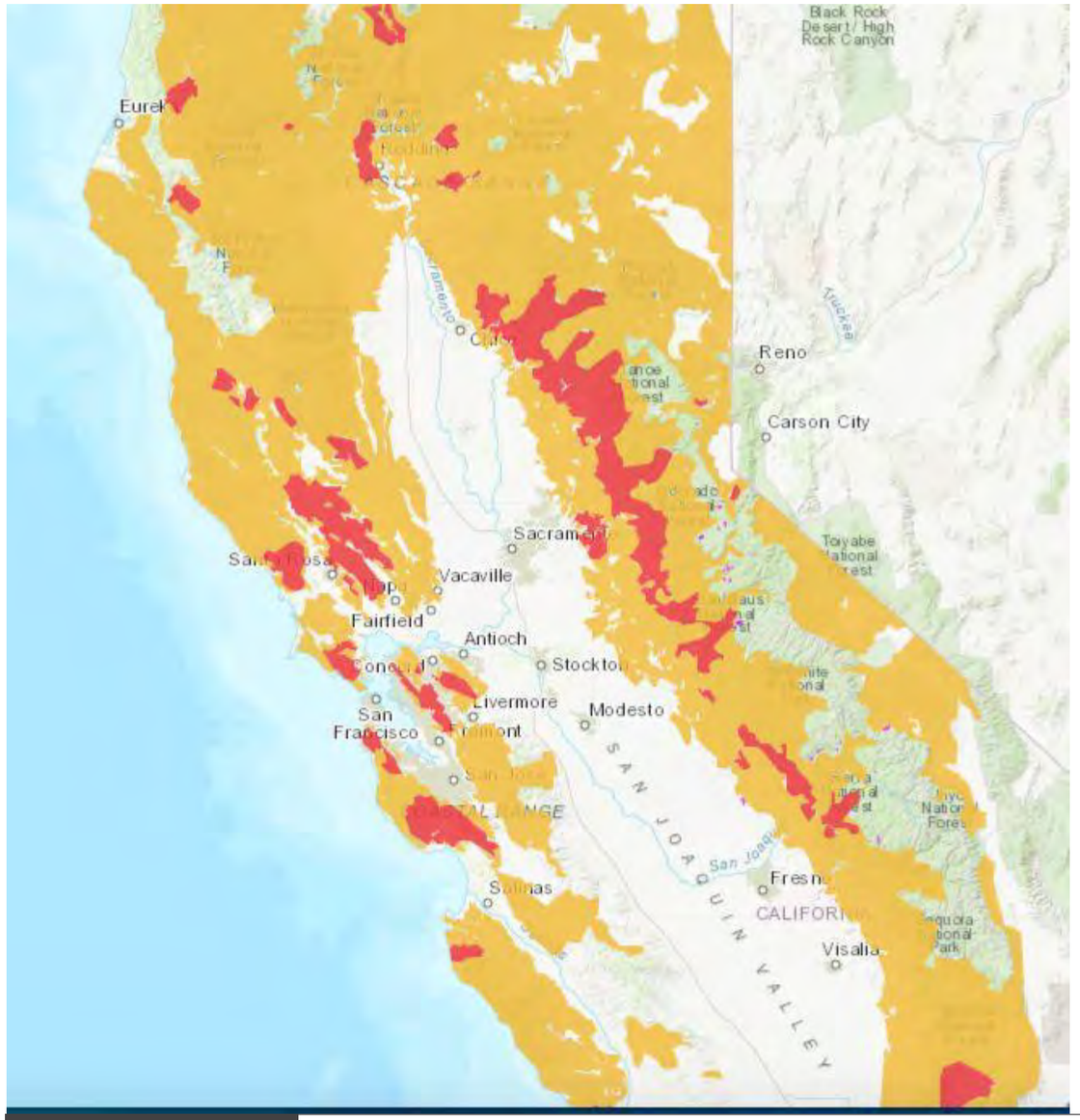
- Cost Effective
  - Daily Price Arbitrage
  - Cost effective if you pay > $0.10/kWh
  - Green PR & Marketable
  - Reducing GHG for your community

1%

- Emergency Resilience
  - Operational Stability
  - Scheduling Stability
  - Regional Resource

RESILIENCE

RESILIENCE SCENARIOS AND EQUIPMENT OPTIONS



Outage Duration
0 - 5 Days

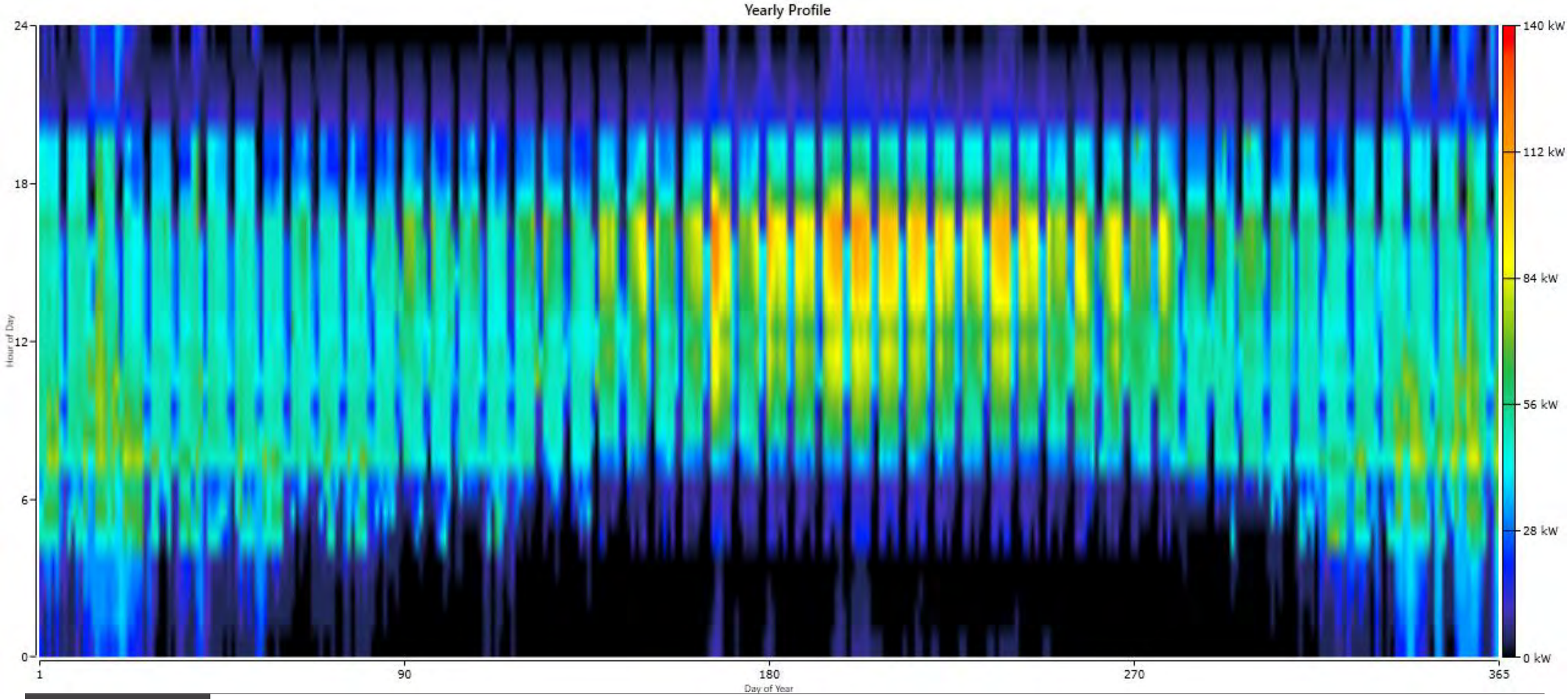
RESILIENCE

RESILIENCE SCENARIOS AND EQUIPMENT OPTIONS

Outage Duration
0 - 12 Days

HEALTHCARE MICROGRID

ENERGY USE PROFILE – ADMIN BLD



HEALTHCARE RESILIENCE

SUMMARY: INITIAL OPTIMIZATION VS UPDATED COST FROM CONTRACTOR BID

	Resilience Days	PV KWdc	Battery kWh	Initial Capital Modeled $	Simple Payback years	Levelized Cost of Energy	Internal Rate of Return %	Cont PV Cost $	Cont Battery Cost	Cont Total $	Delta $
Updated Model	**0**	**205**	**0**	**$ 443,636**	**12**	**$ 0.0934**	**%**	**$ 443,620**	**$ -**	**$443,620**	**$ 16**
	1	205	59	$ 517,204	12.3	$ 0.1240	6.8%	$ 443,620	$ 91,450	$535,070	$ (17,866)
	2	**352**	**195**	**$ 1,010,000**	**17**	**$ 0.1050**	**3.6%**	**$ 754,688**	**$ 242,580**	**$997,268**	**$ 12,732**
	3	311	197	$ 933,146	20	$ 0.1270	2.5%	$ 700,061	$ 245,068	$945,129	$ (11,983)
	4	**393**	**216**	**$ 1,130,000**	**14**	**$ 0.0990**	**3.9%**	**$ 841,806**	**$ 263,952**	**$1,105,758**	**$ 24,242**
	5	414	316	$ 1,300,000	23	$ 0.1230	1.3%	$ 872,712	$ 375,724	$1,248,436	$ 51,564

Summary:

The following options give you the lowest Levelized cost of energy; beating your $0.11/kWh current cost

- **0 – Day Resilience, Net Zero Energy ($0.0934/kWh)**
- **2 – Day Resilience, Net Positive Energy ($0.105/kWh)**
- **4 – Day Resilience, Net Positive Energy ($0.0990/kWh)**

All systems are compared against a 130kw Generator ($135,000).