Advancing Building Decarbonization through High Performance Measures

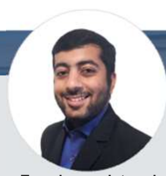
Joel Logan, PE
Tarunkumar Jotwani

Iowa Energy Summit
October 10, 2024

1

Speakers

Joel Logan
Program Manager
Willdan



Tarunkumar Jotwani
Energy Specialist
Willdan

2

Course Description

The importance of energy efficiency in the built environment has become well accepted over the past few decades. Significant advances have been made in design practices, codes, and technology that contribute to improved building energy efficiency. Despite these advances, there remains urgency in making additional gains in energy efficiency to advance building decarbonization and address climate change.

This session will review how establishing specific energy goals at the design stage for a project and implementing emerging high-performance measures provide significant additional opportunity for built environment energy efficiency gains and decarbonization. Technologies across the building envelope, mechanical system and end uses will be reviewed, highlighting how intentional design choices can drive these advancements.

3

Learning Objectives

At the end of this course, participants will be able to:

1. Compare and contrast different energy-related goals for the built environment and their impact on the intent of the design.
2. Understand the intersection of built environment energy efficiency and built environment decarbonization.
3. Identify emerging high-performance measures that reduce building energy consumption and help decarbonize the built environment.
4. Identify methods and tools for evaluating high-performance measures during the design process to determine the benefits for a specific project.

4

Course title:
Advancing Building Decarbonization through High Performance Measures

Course ID:
0920030894

Approved for:
1.0 CE hour(s)

Course is approved for: General

Approval date:
August 27th, 2024

THANKS TO

IOWA

GBCI GREEN BUSINESS CERTIFICATION INC.™

This course is approved by GBCI for continuing education. Approval for this course indicates it will be monitored by GBCI to ensure that it upholds the quality, relevance and rigor necessary to contribute to ongoing learning in knowledge areas relevant to the green building industry.

5

Agenda

01 Goal Setting

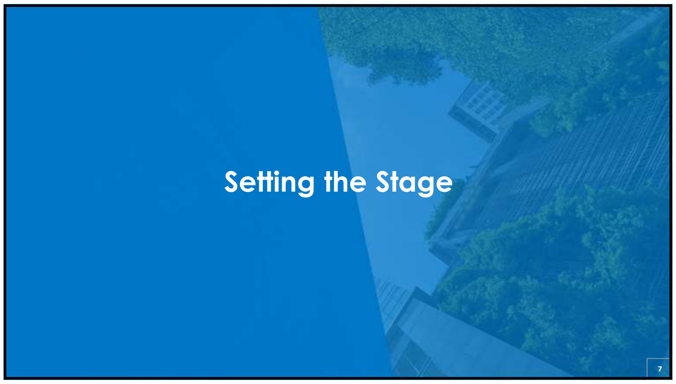
02 High Performance Measures

- Building Envelope
- Mechanical
- Domestic Hot Water
- Equipment

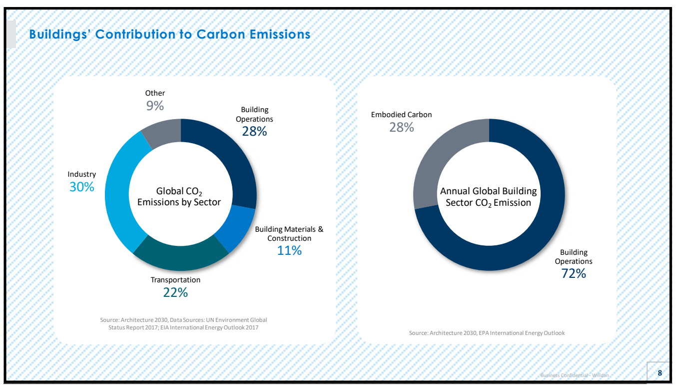
03 Evaluating Measures

04 Conclusion

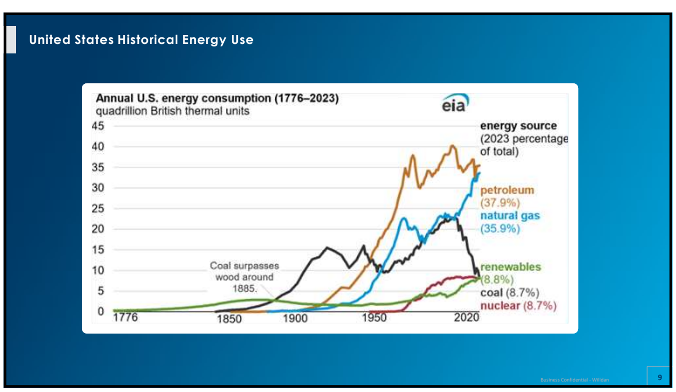
6


Setting the Stage
7

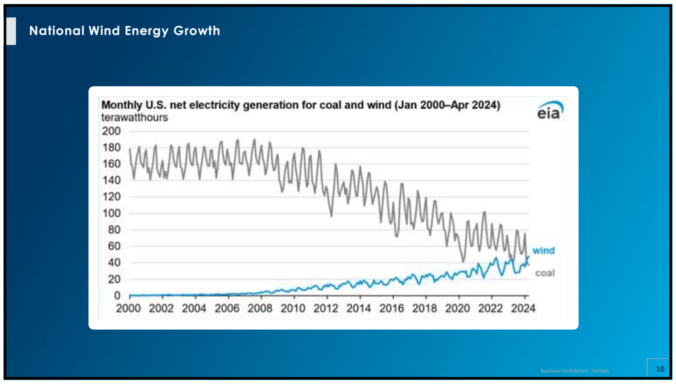
7


Buildings' Contribution to Carbon Emissions
Other
9%
Building Operations
28%
Industry
30%
Global CO_2 Emissions by Sector
Building Materials & Construction
11%
Transportation
22%
Source: Architecture 2030, Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017
Embodied Carbon
28%
Annual Global Building Sector CO_2 Emission
Building Operations
72%
Source: Architecture 2030, EPA International Energy Outlook
8

8

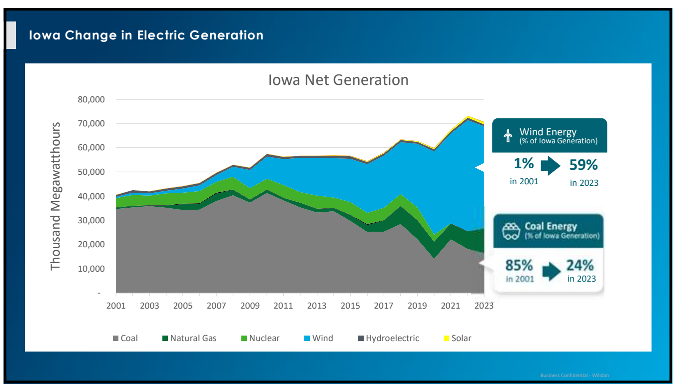

United States Historical Energy Use
Annual U.S. energy consumption (1776–2023)
quadrillion British thermal units
eia
45
40
35
30
25
20
15
10
5
0
1776
1850
1900
1950
2020
Coal surpasses wood around 1885.
energy source (2023 percentage of total)
petroleum (37.9%)
natural gas (35.9%)
renewables (8.8%)
coal (8.7%)
nuclear (8.7%)
9

9



National Wind Energy Growth
Monthly U.S. net electricity generation for coal and wind (Jan 2000–Apr 2024)
terawatthours
eia
wind
coal
200
180
160
140
120
100
80
60
40
20
0
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024

10

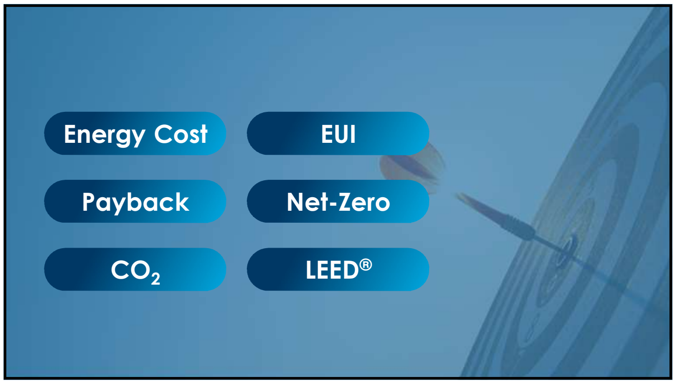


Iowa Change in Electric Generation
Iowa Net Generation
Thousand Megawatthours
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021 2023
Wind Energy
(% of Iowa Generation)
1%
in 2001
59%
in 2023
Coal Energy
(% of Iowa Generation)
85%
in 2001
24%
in 2023
Coal
Natural Gas
Nuclear
Wind
Hydroelectric
Solar

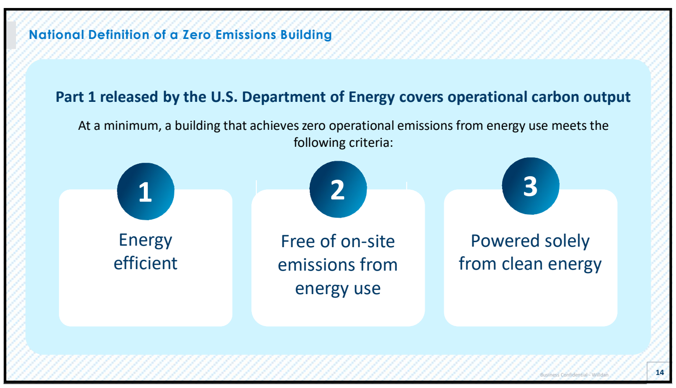
11

Goal Setting

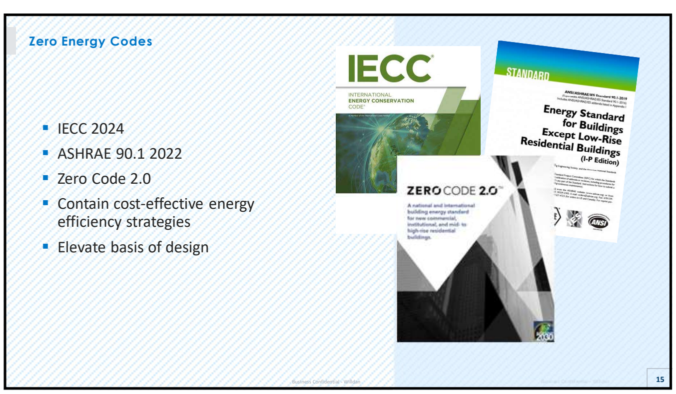
12


Energy Cost
EUI
Payback
Net-Zero
CO_2
LEED®

13


National Definition of a Zero Emissions Building
Part 1 released by the U.S. Department of Energy covers operational carbon output
At a minimum, a building that achieves zero operational emissions from energy use meets the following criteria:
1
Energy efficient
2
Free of on-site emissions from energy use
3
Powered solely from clean energy
14

14


Zero Energy Codes
IECC 2024
ASHRAE 90.1 2022
Zero Code 2.0
Contain cost-effective energy efficiency strategies
Elevate basis of design
IECC
STANDARD
Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)
ZERO CODE 2.0
15

15

Zero Energy EUI Targets

EUI Targets, kBTU/ft^2/year

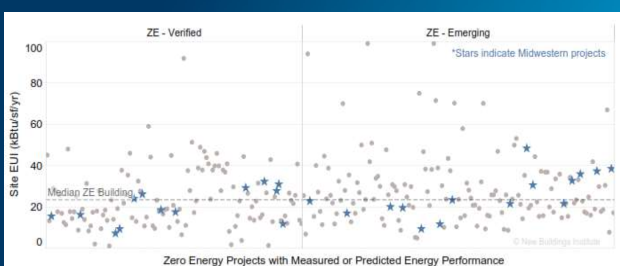
Building Type	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Primary School	26	25	26	25	27	23	21	27	24	24	28	25	24	29	26	30	39
Low-Rise Apartment	20	21	19	20	21	19	17	21	20	20	24	21	20	24	23	27	31
Medium Office	24	24	23	23	23	21	17	22	20	20	24	21	20	25	23	22	27
Small Office	19	20	18	19	18	18	16	17	18	17	18	17	16	18	18	20	24
Secondary School	29	29	26	27	26	25	22	24	26	26	25	29	23	24	24	25	35
Public Assembly	27	28	27	27	28	26	24	28	26	26	30	28	27	31	29	34	40
Standalone Retail[21]	27	30	26	28	25	26	21	25	26	26	26	28	26	27	26	29	35
Mid-Rise Apartment	22	23	21	22	23	21	19	24	22	22	26	23	23	27	25	30	34
Strip Mall[21]	30	33	31	32	33	29	25	34	29	31	39	34	33	41	37	46	60
High-Rise Apartment[21]	28	28	27	27	28	26	22	29	27	27	33	29	27	33	30	37	43
Warehouse	5	8	6	8	7	7	7	9	8	8	11	9	9	11	10	15	16
Small Hotel[21]	36	35	35	35	35	34	32	36	34	34	38	35	34	39	37	41	47
Fire Station[22]	29	30	29	29	30	28	25	30	28	28	33	30	29	33	31	36	43

Source: New Buildings Institute, Zero Energy Commercial Building Targets

16

16

Peer Comparisons



Source: New Buildings Institute, 2020 Midwest Getting to Zero Buildings List

17

17

Additional Resources

- ZEROTool
- 2030 Palette
- AIA Design Data Exchange
- COTE® Super Spreadsheet
- COTE® Top Ten Award Projects
- CNC Excellence in Energy Efficient Design Awards
- Advanced Energy Design Guides
- Utility Programs

18

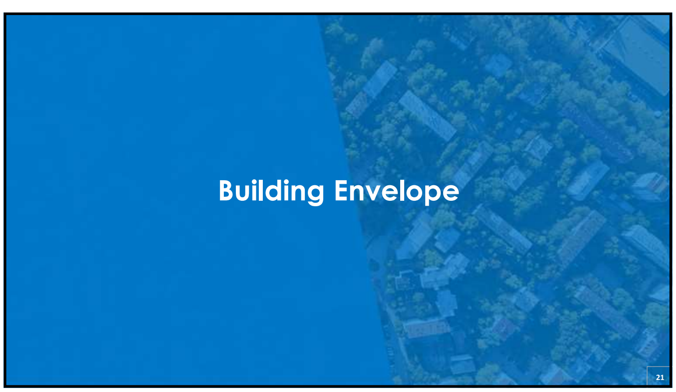
18


Goal Setting Take Away
1
Energy efficient
2
Free of on-site emissions from energy use
3
Powered solely from clean energy

19


High Performance Measures
20

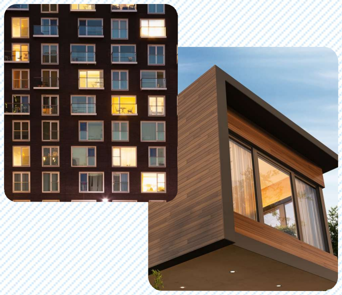
20


Building Envelope
21

21

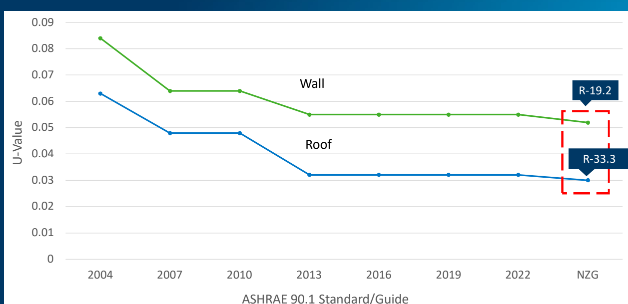
Building Envelopes

- Improve Insulation
- Good air sealing
- Improve the glazing
- Proper window placement and shading



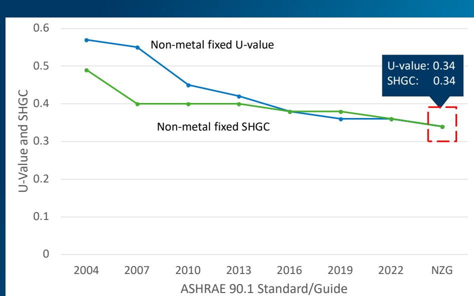
22

Roof and Wall Insulation

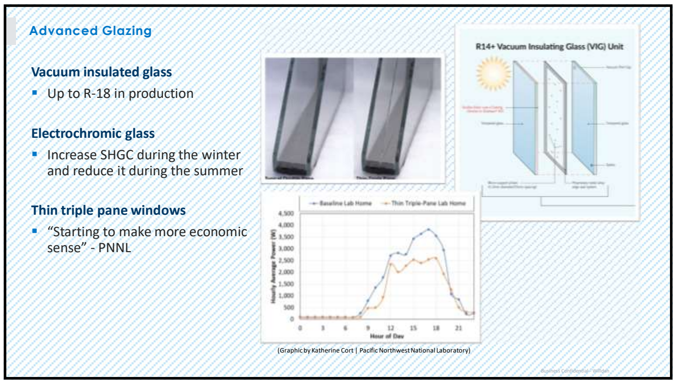


23

Glazing



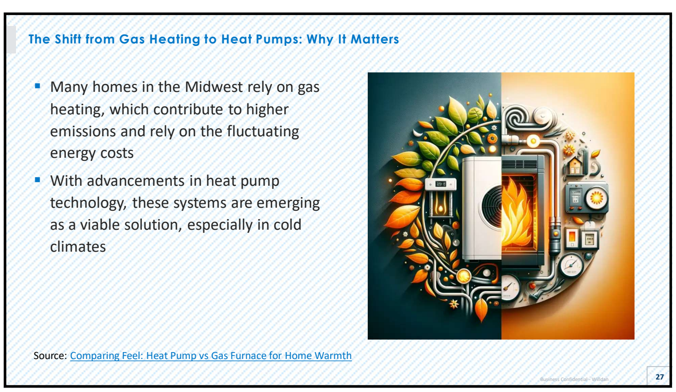
24


Advanced Glazing
Vacuum insulated glass
▪ Up to R-18 in production
Electrochromic glass
▪ Increase SHGC during the winter and reduce it during the summer
Thin triple pane windows
▪ "Starting to make more economic sense" - PNNL
R14+ Vacuum Insulating Glass (VIG) Unit
Baseline Lab Home
Thin Triple-Pane Lab Home
Hourly Average Power (W)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
3
6
9
12
15
18
21
Hour of Day
(Graphic by Katherine Cort | Pacific Northwest National Laboratory)
Business Confidential - Willdan

25


Efficient Electric Heat
26

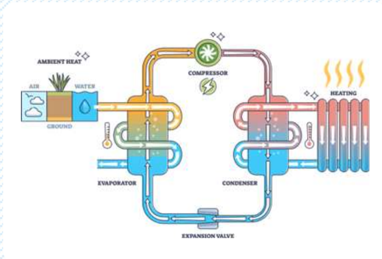
26


The Shift from Gas Heating to Heat Pumps: Why It Matters
▪ Many homes in the Midwest rely on gas heating, which contribute to higher emissions and rely on the fluctuating energy costs
▪ With advancements in heat pump technology, these systems are emerging as a viable solution, especially in cold climates
Source: Comparing Feel: Heat Pump vs Gas Furnace for Home Warmth
27

27

Heat Pumps - Configurations

- Common Nomenclature for Heat Pumps follows the following construct:
  - *(Blank)* to *(Blank)*
  - Heat Source to Distribution Fluid
- Air Source Heat Pumps
  - Air to Air
  - Air to Water
- Water Source Heat Pumps
  - Water to Air
  - Water to Water
- Ground Source Heat Pumps
  - Ground to Air
  - Ground to Water
- Dual Fuel Heat Pumps
- Absorption Heat Pumps



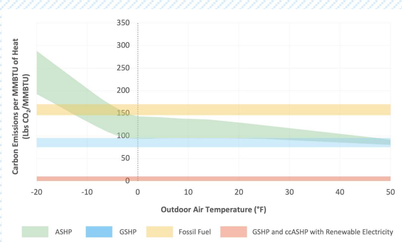
Source: Comprehensive Guide to Heat Pumps for California Homeowners

28

28

Carbon Emissions Per MMBTU of Heat

Demand-Side

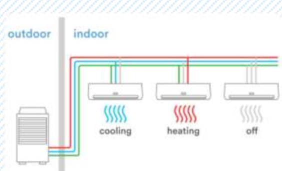


29

29

Heat Pump-VRF

- VRF stands for "variable refrigerant flow"
- VRF systems move refrigerant directly rather than using air or water as an in-between
- Refrigerant phase changes pack a lot of punch – more energy per unit pound or volume
- This requires that they have variable capacity, and thus excellent part load performance.
- Some systems can provide simultaneous heating and cooling
  - Important for hotels, hospitals, offices, schools
  - This gives us the SCHE – Simultaneous Cooling and Heating Efficiency – for VRF units



Source: Introduction to VRF Technology

30

30

Heat Pump Applications

Heat Pump Configuration	Applications
Air-to-Air Heat Pump	Residential homes, small offices, retail spaces, and restaurants
Air-to-Water Heat Pump	Residential buildings, small to medium-sized offices, educational institutions, and hotels
Water-to-Air Heat Pump	Large residential homes, commercial buildings, data centers, and healthcare facilities
Water-to-Water Heat Pump	Large commercial properties, manufacturing facilities, and theatres/auditoriums
Ground-to-Air Heat Pump	Residential homes, educational buildings, office buildings, and hotels
Ground-to-Water Heat Pump	Residential homes, large commercial buildings, fire stations, and healthcare facilities

31

31

Heat Pumps vs. Gas Heating: A Comparative Analysis

Advantages

- Energy Efficiency
- Cost Savings
- Environmental Benefits
- Dual Functionality

Disadvantages

- Upfront Costs
- Performance in extreme cold
- Electrical usage

Source: Heat Pump vs Gas Furnace: Which one is better?

32

32

Overcoming Challenges in Heat Pump Adoption

- Cost Mitigation
  - Incentives and Rebates
  - Financing options
- Improving Performance
  - Advanced Technology
  - Supplemental Heating
- Electrical Upgrades
  - System Assessments
  - Energy Efficiency Improvements

Source: Home Upgrades

Source: Do heat pumps work in cold climates?

33

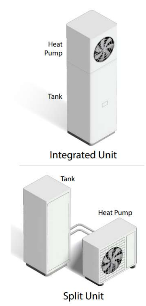
33

Domestic Hot Water

34

Heat Pump Water Heating System

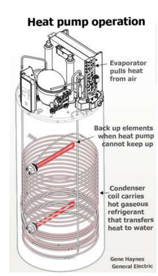
- A system that heats water by transferring heat from one place to another using a refrigeration cycle, rather than generating heat directly
- Typically includes an evaporator, compressor, condenser, and expansion valve
- Extracts heat from the air, ground, or water and transfers it to the water in the tank
- Uses electricity to move heat rather than generate it, often resulting in efficiency 2 to 4 times more than traditional electric resistance water heater



35

Packaged HPWH unit

- A compressor and evaporator are integrated into a single appliance to draw in ambient heat from surrounding air.
- Refrigerant condenser coils wrap the inside of the storage tank to heat the water.
- This type of equipment can be used in building types where the tank storage volume and recovery rate are sufficient to meet the domestic hot water demands.

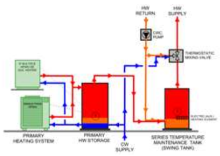


Source: Water Heater Timers Save Money

36

Central HPWH Systems

- Central HPWH systems are typically found in larger buildings or those with high hot water demands (e.g., hotels, hospitals, multi-family, etc.) and combine multiple storage tanks and HPWHs engineered to meet specific hot water usage demands.
- Central HPWH systems can consist of split units or packaged units.
- Central systems serve the entire building out of one DHW plant and includes a hot water recirculation line with circulating pump.



Source: NEEA Advanced Water Heating Specification v 8.1

37

Refrigerants

38

Low Global Warming Potential Refrigerants

- Traditional refrigerants with high GWP significantly contribute to global warming and climate change.
- In the United States, the American Innovation and Manufacturing (AIM) Act, signed into law in December 2020, mandates a phasedown of HydroFluoroCarbons (HFCs).
- Under this act, the Environmental Protection Agency (EPA) has mandated a 700 GWP limit as on January 1, 2025.
- Benefits of Low GWP Refrigerants
  - Environmental Impact
  - Regulatory Compliance
  - Performance

39

Low Global Warming Potential Refrigerants

Refrigerant	GWP*	Notes
R-410a	2,088	Currently one of the most common refrigerants in the US Used for new light commercial AC equipment
R-22	1,810	AKA Freon®, Discontinued in 2010 for use in new HVAC equipment
R-407C	1,774	Currently one of the most common refrigerants in the US Used for AC and medium temperature refrigeration
R-134a	1,430	Currently one of the most common refrigerants in the US Used in small appliances and large commercial screw chillers
R513a	629	Used for low and medium temperature refrigeration systems. Used in Chillers and hot water heaters.
R-32	675	Wide global use – intended replacement for R-134a and may be in development for some VRF systems.
R-454b	466	Wide global use as a substitute for R-410a. R454b is currently used in some VRF systems, packaged RTUs, and residential split systems
R-600a	3	AKA Isobutane, Highly flammable Used for small (dorm) refrigerators and commercial display coolers
R-514a	2	Used in chillers
R-1233zd	1	Used in chillers
R-1234ze	1	Used in chillers and commercial AC *Past studies have indicated that R-1234ze might form high-GWP HFC-23 in open air, however more recent studies have contested those findings.*
R-744 (CO_2)	1	Extremely low GWP – used in Heat Pump water heaters and refrigerated cases.

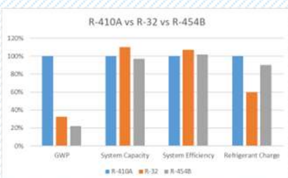
*Sources: CARB, EPA

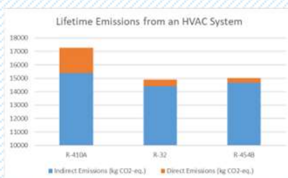
Business Confidential - Willdan

40

40

Comparison of Refrigerant Lifetime Emissions





Source: The facts about R-32 and R-454B

Business Confidential - Willdan

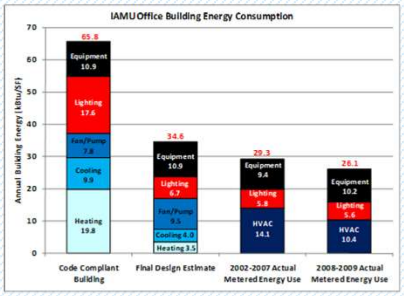
41

41

Equipment Loads

42

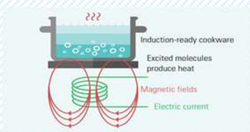
Equipment Loads In High Performance Building



43

All Electric Commercial Kitchen

- Electric equipment exists for all common gas equipment
- Induction Cooktops



Source: Richard Young, Mark Duesler, Hot New Induction Technologies for Cooler Kitchens

Tips

- Start conversation early with end user
- Engage with Kitchen consultant

44

All-Electric Commercial Kitchen

Challenges

- Unfamiliarity with technology
- First Cost
- Maintenance availability
- Multifamily projects
  - Residents may not have compatible cooking equipment

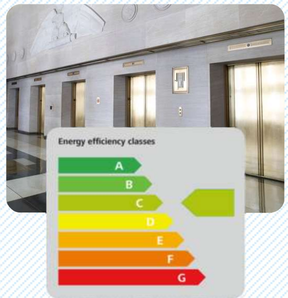
Benefits

- Faster cook times
- Precise Control
- Improved energy efficiency and reduced EUI
  - Source to food
    - Induction 85%
    - Gas 35%
- Cooler kitchen
- Improved air quality
- Potential for reduced ventilation requirements
- Smaller footprint—33% reduction

45

Elevators

- ISO Standard 25745-2 assigns letter grades
  - Running Energy
  - Idle/Standby Power
- In Codes and Standards
  - ASHRAE 90.1-2016 – Put ISO rating on Design documents
  - ASHRAE 90.1-2022 – minimum of an ISO E rating
- Savings
  - Middle Level—save 65% compared to bottom
  - Top Level—save 92% compared to bottom



Source: Photographs in the Carol M. Highsmith Archive, Library of Congress, Prints and Photographs Division

46

Elevators

Table 2: Traction elevator technologies

A variety of technologies can provide basic to advanced efficiency capabilities.

Component	Basic efficiency	Intermediate efficiency	Advanced efficiency
Hoist drive	Motor-generator or direct-current with silicon-controlled rectifiers	Gearless	Permanent magnet, gearless
Car lift	Wire rope	Wire rope	Polyurethane-coated belts, multiple rope
Controls	Electromechanical relays, group controller	Microprocessor	Software-defined (e.g., destination dispatch)
Lighting, ventilation	Incandescent, halogen	CFLs, efficient fans	LEDs, efficient fans, occupancy sensors
Energy sources	Grid	Grid plus regeneration	Regeneration plus solar
Considerations	Single operating mode, needs machine room	Standby mode, better power factor	Standby mode, variable door motors, power factor near 1, MRL, quick installation

Note: MRL = machine room–less.

Source: American Council for an Energy-Efficient Economy

47

Evaluating Measures

48

Manual Calculator

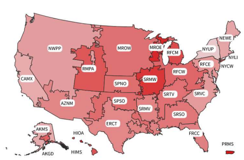
Quantifying and Tracking

Electricity	Annual Electricity Usage (kWh) / 1000 * Carbon Emission Rate / 2205 = Metric Tons of CO_2 889,704 kWh / 1000 * 790 lbs/mWh / 2205 = 319 Metric Tons of CO_2 per Year
Natural Gas	Annual Gas Usage (therms) * Carbon Emission Rate = Metric Tons of CO_2 13,276 therms * 0.0053 Metric Tons/therm = 70 Metric Tons of CO_2 per Year

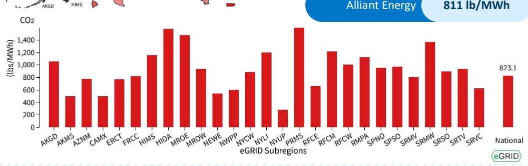
49

49

Regional CO_2 Electric Grid Emission Factors



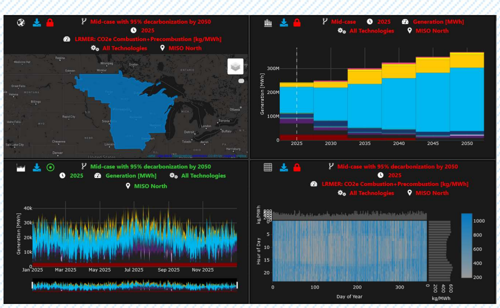
MROW	937 lb/MWh
IOWA	622 lb/MWh
MidAmerican	140 lb/MWh
Alliant Energy	811 lb/MWh



50

50

NREL Cambium Data



51

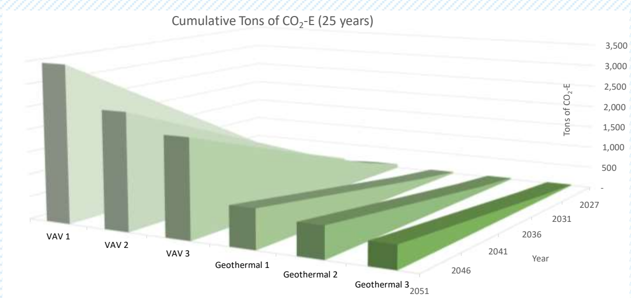
51

Cambium Data

MISO-North, 95% Decarb by 2050, lb of CO2 per MWh												
Hour of the day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	363.7	366.4	255.9	203.5	292.4	357.2	534.2	514.0	391.7	256.0	381.7	466.1
1	361.4	355.0	262.4	194.6	283.4	351.9	518.3	524.9	396.2	262.8	394.0	447.2
2	348.4	359.6	270.7	200.8	285.3	346.0	517.3	527.1	406.6	266.2	400.1	452.4
3	347.0	356.8	278.8	206.5	287.0	350.2	528.7	523.8	420.7	259.3	390.2	453.6
4	369.6	378.9	294.9	220.2	299.0	325.1	536.2	555.6	412.5	265.4	407.6	448.7
5	366.1	395.4	299.9	191.7	232.4	268.3	445.0	426.4	411.0	274.1	430.3	435.5
6	374.0	403.0	266.0	175.5	217.6	265.2	423.1	359.9	331.0	240.4	410.7	440.6
7	364.3	344.5	239.8	157.3	220.6	277.3	407.2	342.7	285.8	205.5	330.6	422.5
8	311.2	344.1	226.8	168.0	205.5	260.9	402.0	349.8	294.2	211.0	302.6	414.7
9	304.0	337.6	219.4	165.0	208.7	249.8	387.6	335.7	283.8	212.7	308.8	428.0
10	314.6	328.0	204.4	163.0	191.1	248.0	387.6	347.3	274.6	214.3	315.5	453.6
11	322.9	317.8	203.6	162.5	192.5	241.4	397.8	339.3	275.7	206.0	311.7	459.2
12	312.1	315.2	206.0	158.4	193.3	247.5	410.6	329.3	281.6	208.8	307.8	459.5
13	303.4	315.6	203.4	155.0	197.8	248.2	399.5	341.8	285.3	201.1	289.2	450.5
14	314.0	310.1	211.1	154.0	195.8	246.4	406.5	359.6	279.6	202.3	325.9	480.9
15	353.7	323.2	209.9	156.4	193.8	262.1	397.8	376.8	325.8	252.4	406.1	509.9
16	414.4	411.0	275.8	169.4	229.8	284.7	419.0	406.3	398.7	319.2	459.3	521.9
17	424.1	445.8	359.9	245.4	281.4	344.9	472.9	518.8	518.2	320.1	454.5	510.7
18	414.5	460.4	337.8	291.7	376.1	454.2	586.4	583.9	479.8	312.2	424.7	500.7
19	407.1	418.6	313.5	270.9	346.9	446.3	624.0	560.0	475.3	293.0	394.0	493.5
20	386.1	412.1	303.7	249.9	318.3	400.5	592.8	528.2	423.2	267.3	407.0	462.7
21	375.7	391.5	284.6	217.4	293.1	385.1	567.1	527.9	422.2	255.3	405.5	452.6
22	357.7	366.1	273.9	221.9	291.3	354.0	552.2	499.1	403.1	251.2	372.8	430.3
23	359.0	365.5	266.9	207.4	292.3	348.0	531.9	505.8	414.1	235.8	373.1	454.6

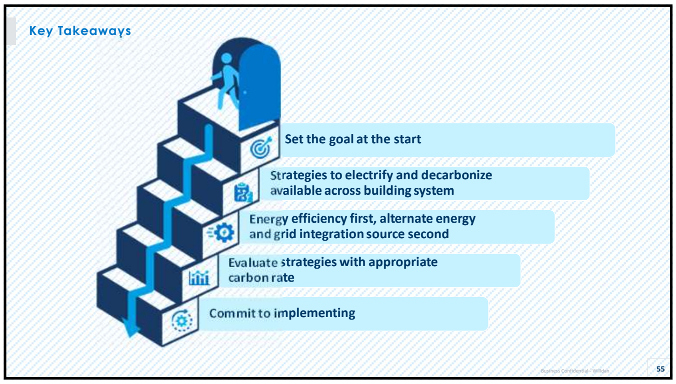
52

Carbon Performance



53

54


Key Takeaways
Set the goal at the start
Strategies to electrify and decarbonize available across building system
Energy efficiency first, alternate energy and grid integration source second
Evaluate strategies with appropriate carbon rate
Commit to implementing
55

55


Don't Make Sustainability the Icing on the Cake
Mix it into the batter at the beginning
56

56


Thank you!
Joel Logan
Tarunkumar Jotwani
jlogan@willdan.com
tjotwani@willdan.com
EnergyAssistance.Willdan.com
877.939.1001
WILLDAN

57