# Future Weather Data is More Important than You Think:

## *The Role of Weather Data in Resilient Design*

**Carrie Brown, PhD**

RESOURCE REFOCUS

University at Buffalo
School of Architecture and Planning

# Learning Objectives

1. Understand differences between and appropriate applications of newer weather files.
2. Understand how weather file selection can impact passive design choices.
3. Understand the major factors driving how future weather impacts predicted building energy use.
4. Understand why future weather data has major impacts on HVAC equipment sizing

# Acknowledgements

**Assessment of FTMY Data Files:** Supported by the New York State Energy Research and Development Authority (NYSERDA)

Team:

- NYSERDA Project Manager: Amanda Stevens
- Resource Refocus: Carrie Brown, Anna LaRue, Vrushali Mendon, Nate Heckman
- University at Buffalo Department of Architecture: Nicholas B. Rajkovich and Elizabeth Gilman

Publications:

- Technical Report: NYSERDA 2021 “Assessment of Future Typical Meteorological Year Data Files Final Report” (pdf)
- Conference Paper: Building Simulation 2023 “The Future of Weather Files for Building Performance Simulation in New York State” https://doi.org/10.26868/25222708.2023.1384

# Scope

## NYSERDA Study Objective

- Gather information about NYSERDA’s current weather file use cases.
- Understand how weather data choice may impact program and code development protocols, as well as other building design and operation applications.
- Gauge whether to prioritize incorporating new weather data into future protocols.

## Additional Analysis

- Added emissions and newly available FTMY files

**Background**

**Modeling**

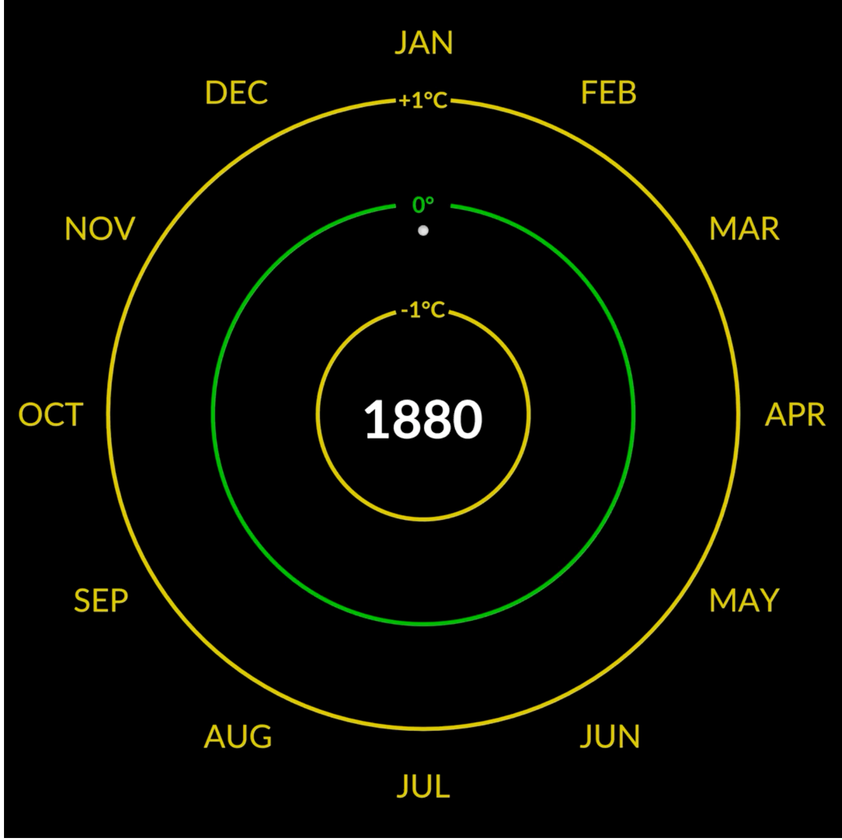
**Passive Strategies**

**Lessons Learned**

# The climate crisis is here.

Increase in intensity, duration, and frequency of severe weather events pose major risks to buildings and occupants.

Should we still use historical weather data to inform building design?




*Source: NASA Climate Spiral 1880-Present. Visualizations by Mark SubbaRao*

# Typical Meteorological Year Files

Building simulation tools require clean data in specific formats to successfully complete simulation runs.

TMY-type weather files include comma-separated hourly data on dry-bulb air temperature, humidity, solar illuminance, cloud cover/sky condition, wind, ground temperature, ground surface albedo, atmospheric pressure, and precipitation.

Composite of typical months, not necessarily from the same year.

*Source: Crawley, D., & Barnaby, C. (2019). "Weather and Climate in Building Performance Simulation." in Building Performance Simulation for Design and Operation.*

# TMY-type files currently in use

**Typical meteorological year (TMY)**

- TMY3: 1991-2005
- TMYx or TMY4: compiled data from 2001 and forward, use of National Solar Radiation Database (NSRDB) satellite data.

**Actual meteorological year (AMY)** include historical data for location for a single year (as opposed to the composite data found in TMY files)

**Extreme meteorological year (XMY)** represent the extremes of climate that the building will experience.

**Future typical meteorological year (FTMY)** attempt to represent future-looking weather changes that result from a changing climate. Wide range of methodologies representing anywhere from ten to hundred years in the future.

# Weather File Availability

**TMY3:** TMY3 data is widely available from sources such as the NREL Data Catalog, EnergyPlus, Climate.OneBuilding, and White Box Technologies

**TMYx:** Climate.OneBuilding, CALMAC, White Box Technologies

**AMY:** CALMAC CA Weather Files, White Box (https://www.calmac.org/weather.asp)

**Resilient Buildings** provides a data set for 16 locations around NYS that includes AMY, XMY-minimum, XMY-maximum, TMY-30 (1986-2015), and TMY-7 (2009-2015) files.

# Weather File Availability

Active research is underway to develop FTMY weather files

**National examples**

- Brazil BrazFuture: 28 locations, TMY for 2010s, 2050s, and 2090s
- Ireland MetEireann: Test Reference Year (TRY) and 3 Design Summer Years (DSY)
- Canadian Future Data: 564 locations, 30-year bins 2003-2094
- Belgium: FTMY and FXMY 1980-2100

# FTMY Methodologies

There are different methodologies used to create future climate data.

In increasing complexity:

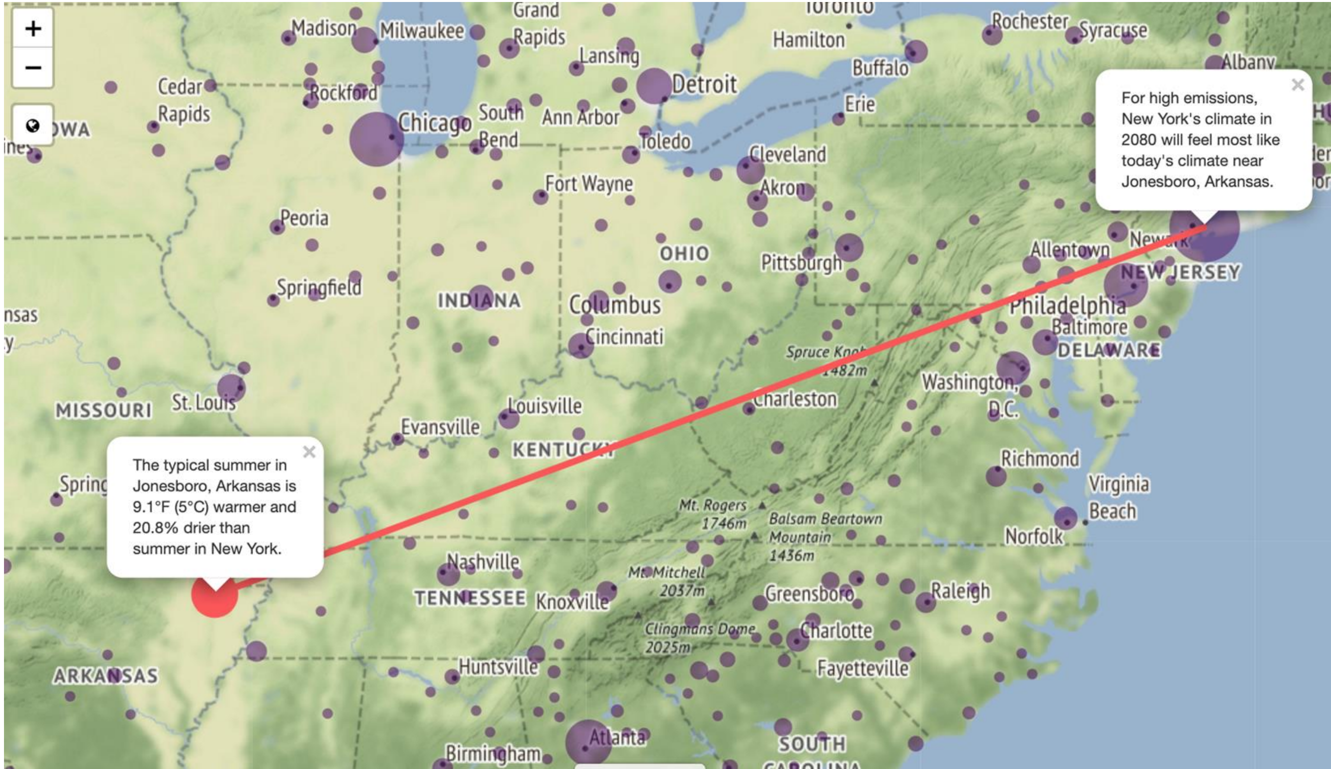
- Analog scenarios
- Morphing, or time series adjustment
- Statistical methods, stochastic models
- Dynamic downscaling

# FTMY Methodologies

**Analog scenarios** find existing locations that align with future climate predictions.

+ Very simple technique
+ Powerful way to communicate climate change impacts

- Inaccurate for simulation




Source: https://fitzlab.shinyapps.io/cityapp/

# FTMY Methodologies

**Morphing, or time series adjustment,** is a very common method that "morphs" current TMY-type datasets. This method applies algorithms that either shift, stretch, or shift and stretch data to align with climate predictions.

- + Simple method that doesn't require a large amount of computing power.
- + More flexible than other methods, can be applied to a large number of weather files from around the world

- \- Several recent studies have raised concerns...

# FTMY Methodologies

**Recent studies have raised concerns about morphed data [1, 2, 3]**

- Variables are morphed individually → linear transformations on a non-linear coupled systems → may not produce psychometrically / atmospherically correct weather

- "Expected changes of intensity, duration, and frequency of weather events such as heat waves, cold waves, clouds, and precipitation will not be reflected in the morphed files because the temporal variation follows that of the weather of today." [3]

1. Moazami, A., Nik, V. M., Carlucci, S., & Geving, S. (2019). Impacts of future weather data typology on building energy performance – Investigating long-term patterns of climate change and extreme weather conditions. Applied Energy, 238, 696–720. https://doi.org/10.1016/j.apenergy.2019.01.085
2. Moazami, A., Carlucci, S., & Geving, S. (2017). Critical Analysis of Software Tools Aimed at Generating Future Weather Files with a view to their use in Building Performance Simulation. Energy Procedia, 132, 640–645. https://doi.org/10.1016/j.egypro.2017.09.701
3. Muehleisen, R. T., Li, Q., Aliosio, R., & Santana, M. (2020). Nationwide Impacts of Future Weather on the Energy Use of Commercial Buildings. 8.

# FTMY Methodologies

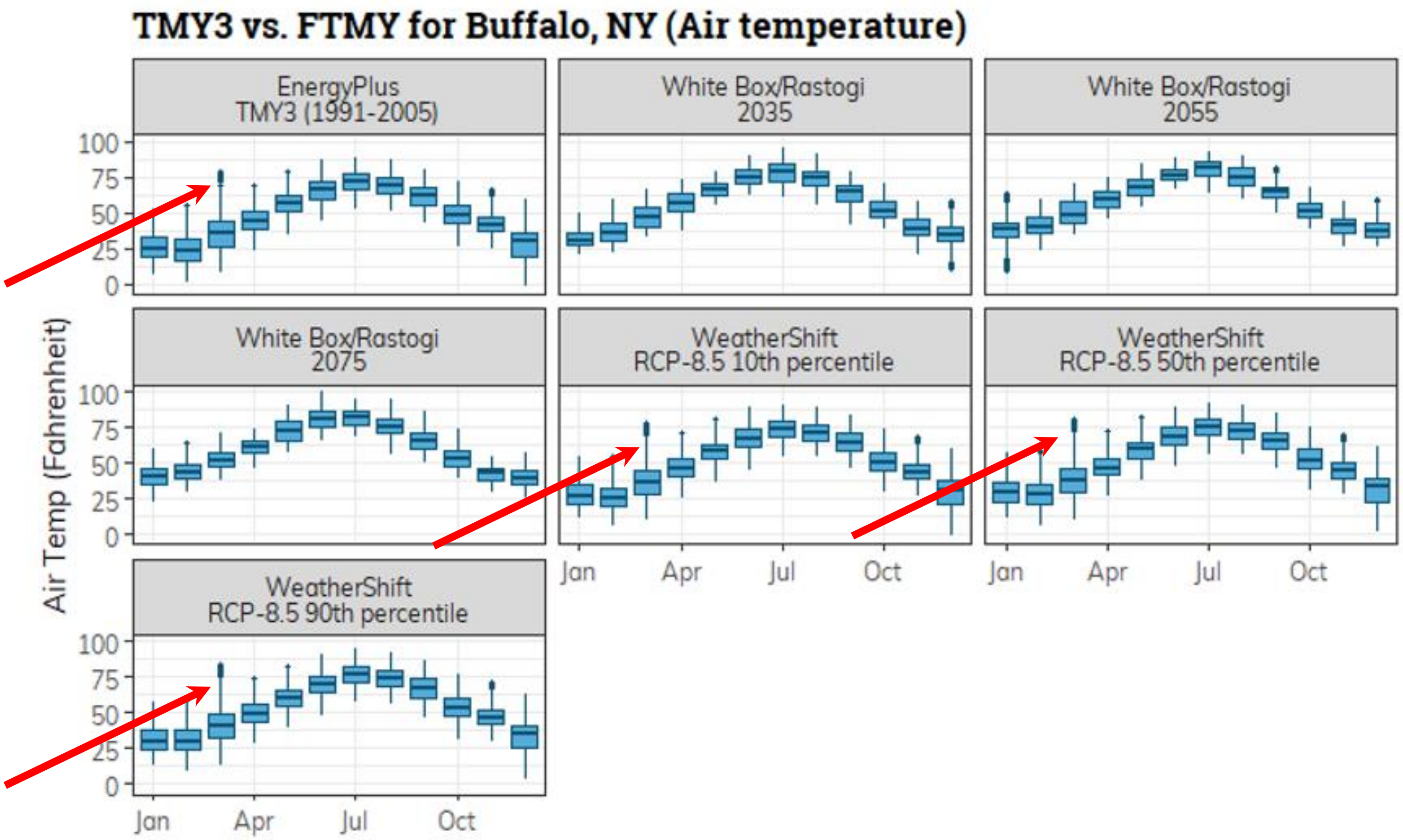
**Statistical methods, stochastic models** use and adjust observed data based on altered frequency distributions of weather variables to generate synthetic weather.

+ Allow simulations to consider extreme weather conditions beyond what has been historically observed while remaining statistically accurate to respective locations.

+ Produce simulations that cover a wide range of possible climate conditions.

- Rely on statistics based on historical observations, which influences the assumption that future weather patterns will resemble those historically recorded.

# Stochastic vs. Morphed Data



# FTMY Methodologies

**Dynamic downscaling** is a physics-based method used to downscaled global climate model (GCM) results

+ Not bound by historical data and observations.

+ Data also remains physically consistent across variables with this method.

- Creates *very* large data sets and, therefore, requires powerful computational resources and expertise.

Source: Rastogi, D., Kao, S.-C., and Ashfaq, M. (2022). How May the Choice of Downscaling Techniques and Meteorological Reference Observations Affect Future Hydroclimate Projections? Earth's Future, 10, e2022EF002734. https://doi.org/10.1029/2022EF002734

# Other future weather

**Emerging research using AI (Argonne and UCLA)**

- Accurate near-term forecasting with low resolution data and less computational needs.
- Climate modeling much more complex, early-stage research.

 Major challenge is that climate and carbon on changing in real time.

Source: Rolnick et al 2025. “Tackling Climate Change with Machine Learning.” https://doi.org/10.1145/348512
ANL, 2024. “Argonne develops new kind of AI model for weather prediction” July 9. https://www.anl.gov/article/argonne-develops-new-kind-of-ai-model-for-weather-prediction

# DOE FEMY: Future and Extreme Weather Data (2021-2023)

## Three Teams: Complementary Data Project Goals

**Argonne National Laboratory**

- Dynamic Downscaling at 4km & 12km over CONUS
- 2045-2054 and 2085-2094
- Multiple RCP-SSCP
- Releasing full data files over entire CONUS grid allowing for time coincident future weather analysis at any geographic scale
- 10's of TB of data to be released

**Oak Ridge National Laboratory**

- Combination of Dynamic Downscaling and Statistical
- 2020-2100
- Multiple RCP-SSCP
- Releasing fTMY at multiple locations in each climate zone
- PB of data processed to 10's of GB

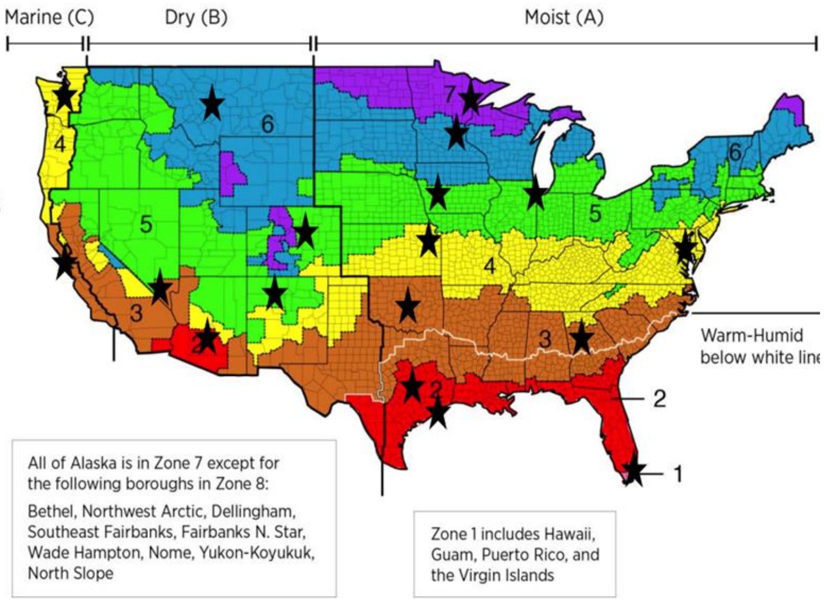
**Sandia National Laboratories**

- Developing Statistical Models for Extreme Weather Generation
- First for Current Weather, next for Future Weather with various RCP-SSCP

Source: 2023 BTO Peer Review Presentation – Future and Extreme Weather Data

# ORNL FTMY Files (Cross-Model Version)

- SSP 5, RCP 8.5
- 2020-2100
- 18 cities in United States
  - Representative cities from each US climate zone
- 6 Climate Models from various climate institutions around the globe
  - ACCESS-CM2
  - BCC-CSM2-MR
  - CNRM-ESM2-1
  - MPI-ESM1-2-HR
  - MRI-ESM2-0
  - NorESM2-MM
- 9 Weather Variables
  - Air Temp
  - Longwave
  - Shortwave
  - Vapor Pressure
  - Vapor Pressure Deficit
  - Relative Humidity
  - Precipitation
  - Wind
  - Pressure



International Code Council (2012)

Source: 2023 BTO Peer Review Presentation – Future and Extreme Weather Data
DOI 10.5281/zenodo.10420669

# 2025 ASHRAE Climate Zone Update (Draft Results)

Major update in 2025.

Changes mostly due to the shift to data-only process.

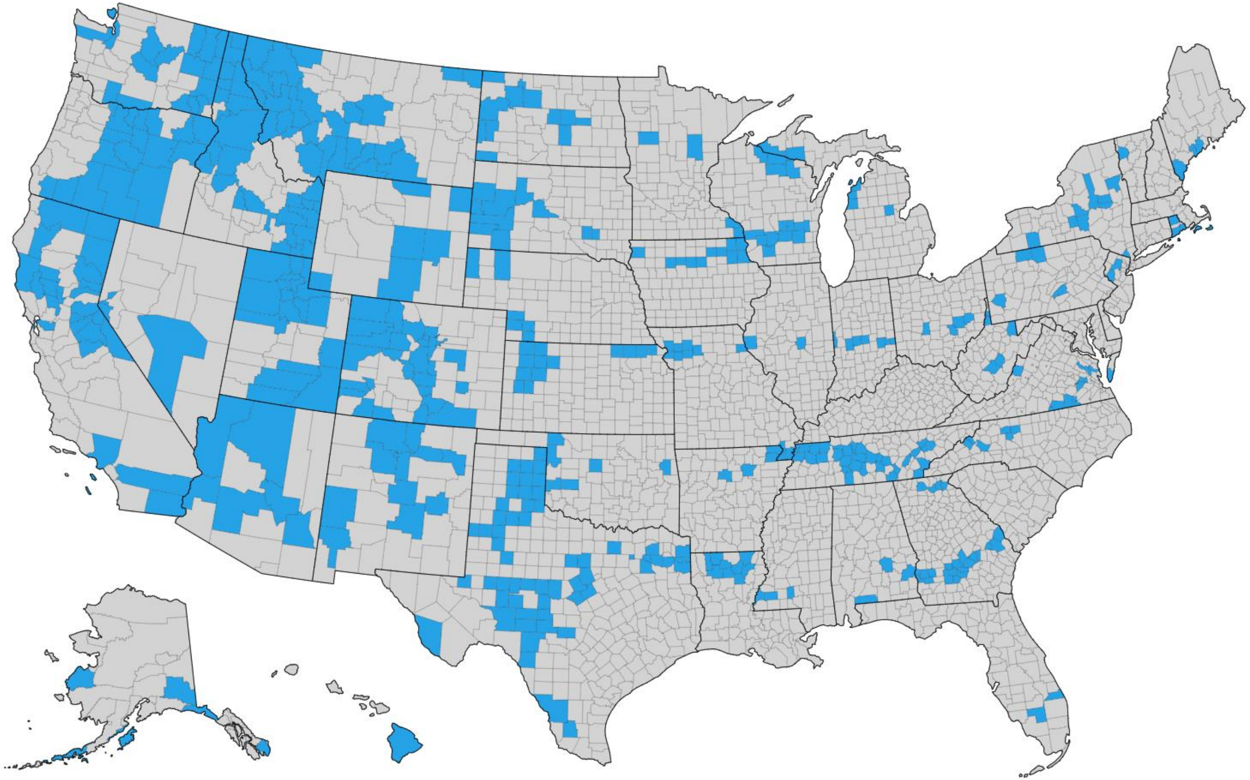


Figure 3.12: Climate Zone Changes from 2021 to 2025

Source: Michael Roth, Draft report "Updating climatic design information for the 2025 ASHRAE Handbook, Standard 169, and the Handbook of Smoke Control Engineering"

# 2025 ASHRAE Climate Zone Update (Draft Results)

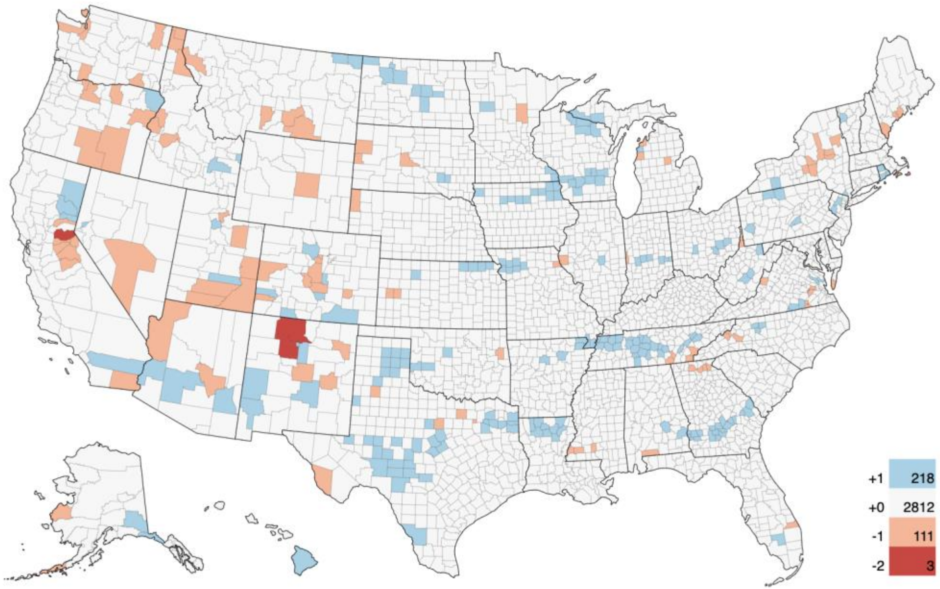



Figure 3.13: Thermal Zone Changes from 2021 to 2025

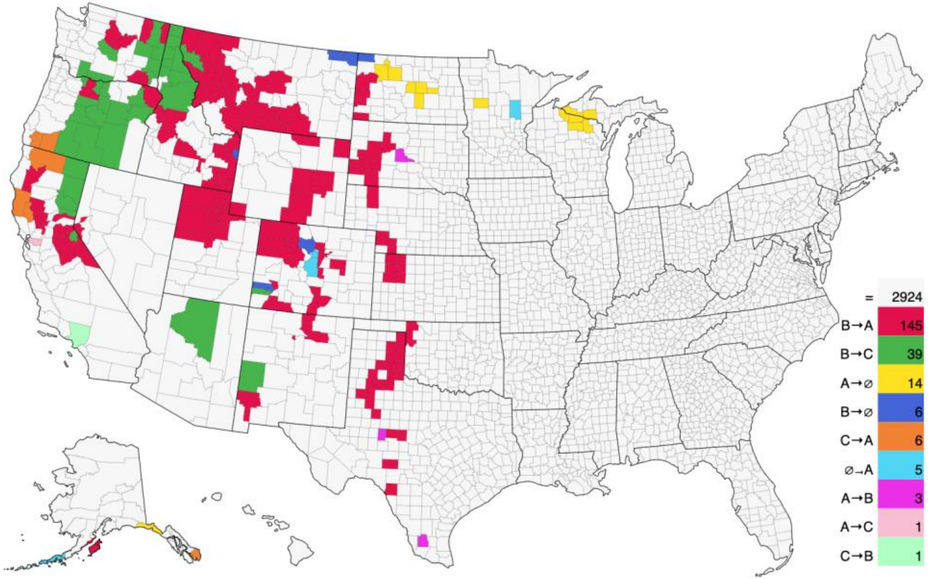



Figure 3.14: Moisture Zone Changes from 2021 to 2025

Source: Michael Roth, Draft report "Updating climatic design information for the 2025 ASHRAE Handbook, Standard 169, and the Handbook of Smoke Control Engineering"

Background

Modeling

Passive Strategies

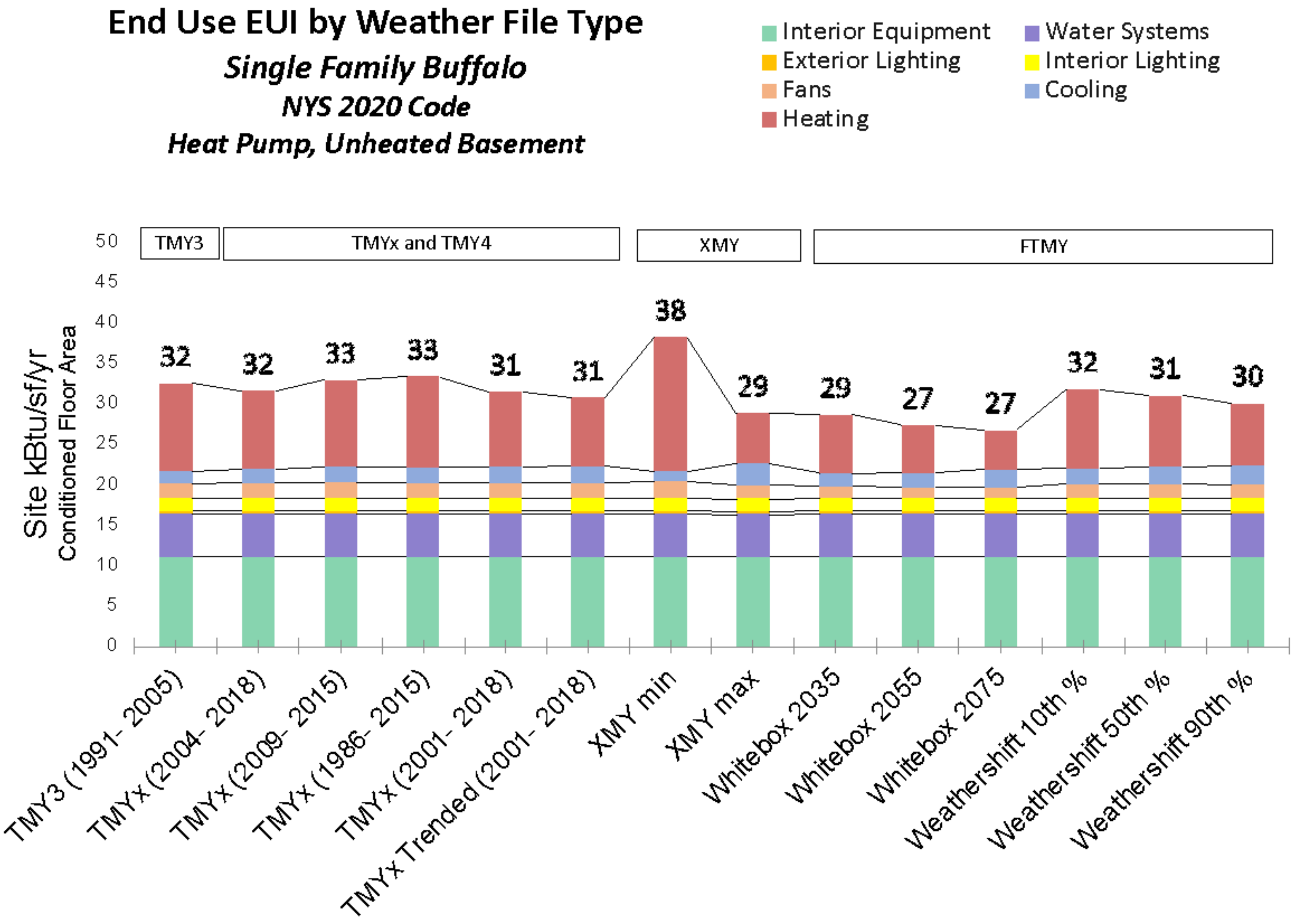
Lessons Learned

# Residential Modeling Case Study

Exploratory modeling exercise to understand how building energy use may be affected by switching to a different weather file type

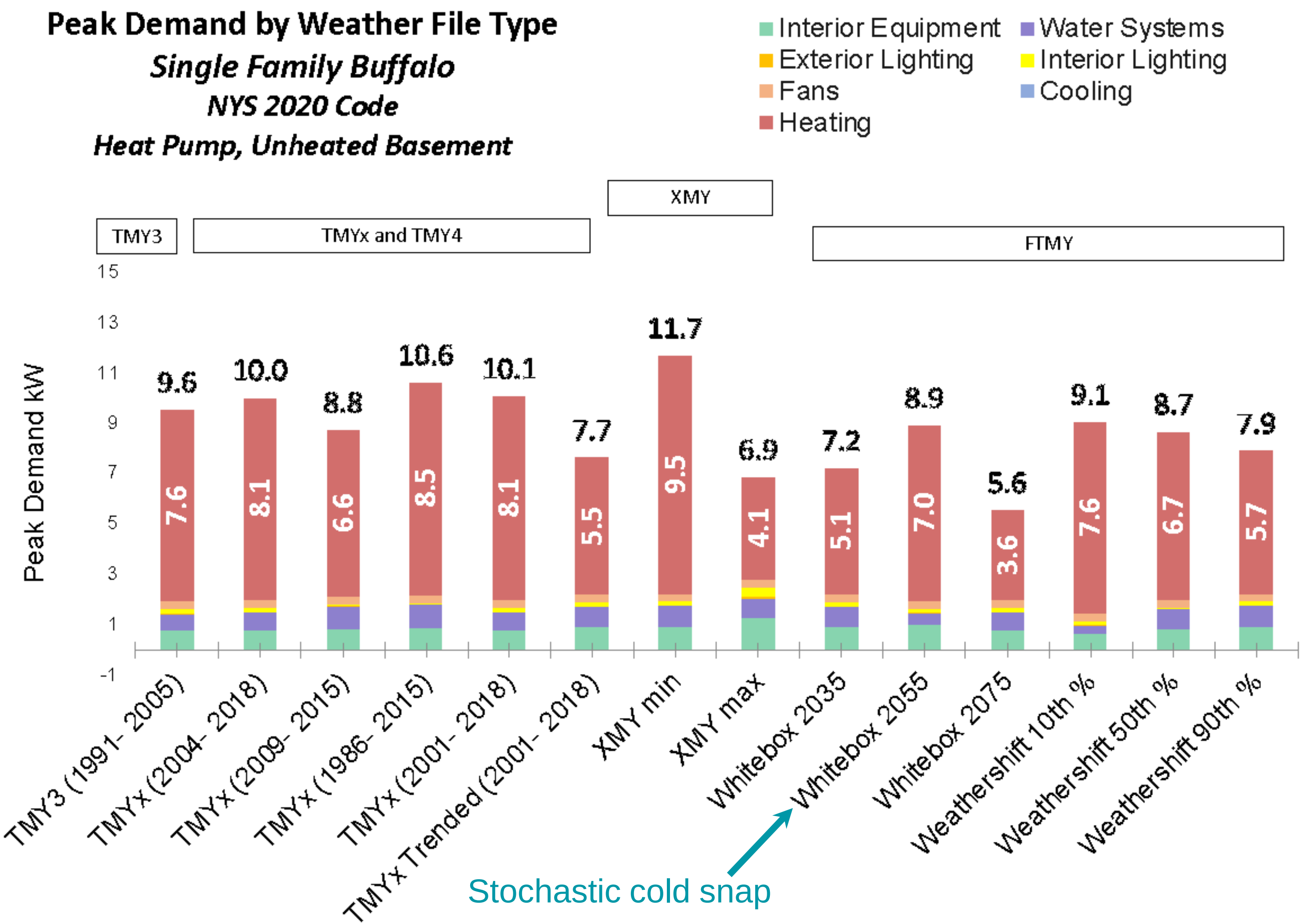
Focused on envelope-dominated buildings (all-electric single family residential 2020 Code)

↓ Heating
↑ Cooling
⇣ EUI

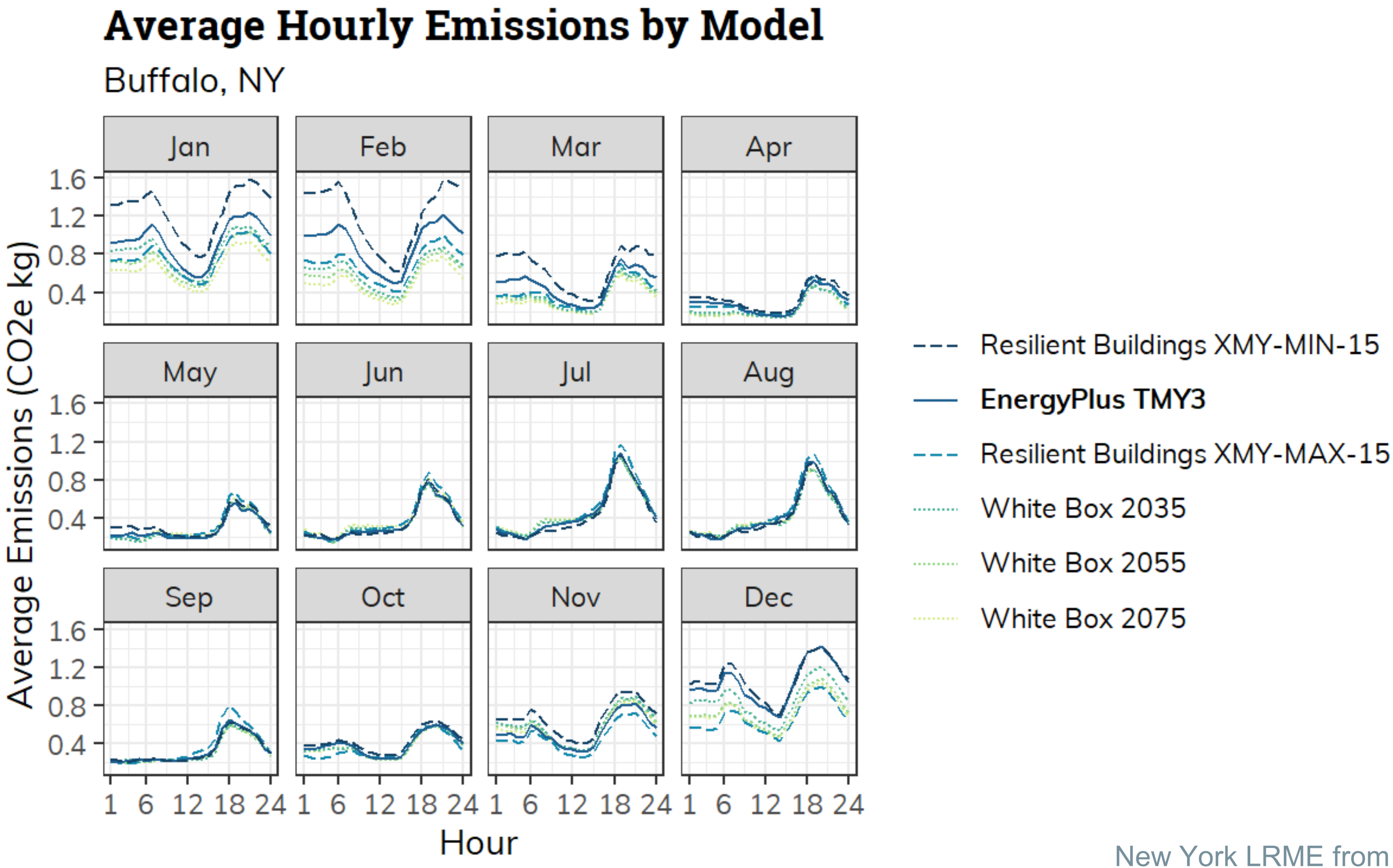


↓ Winter peak ranging anywhere from 12/20-2/20.

Usually occurs in the morning, except for 2055 file.

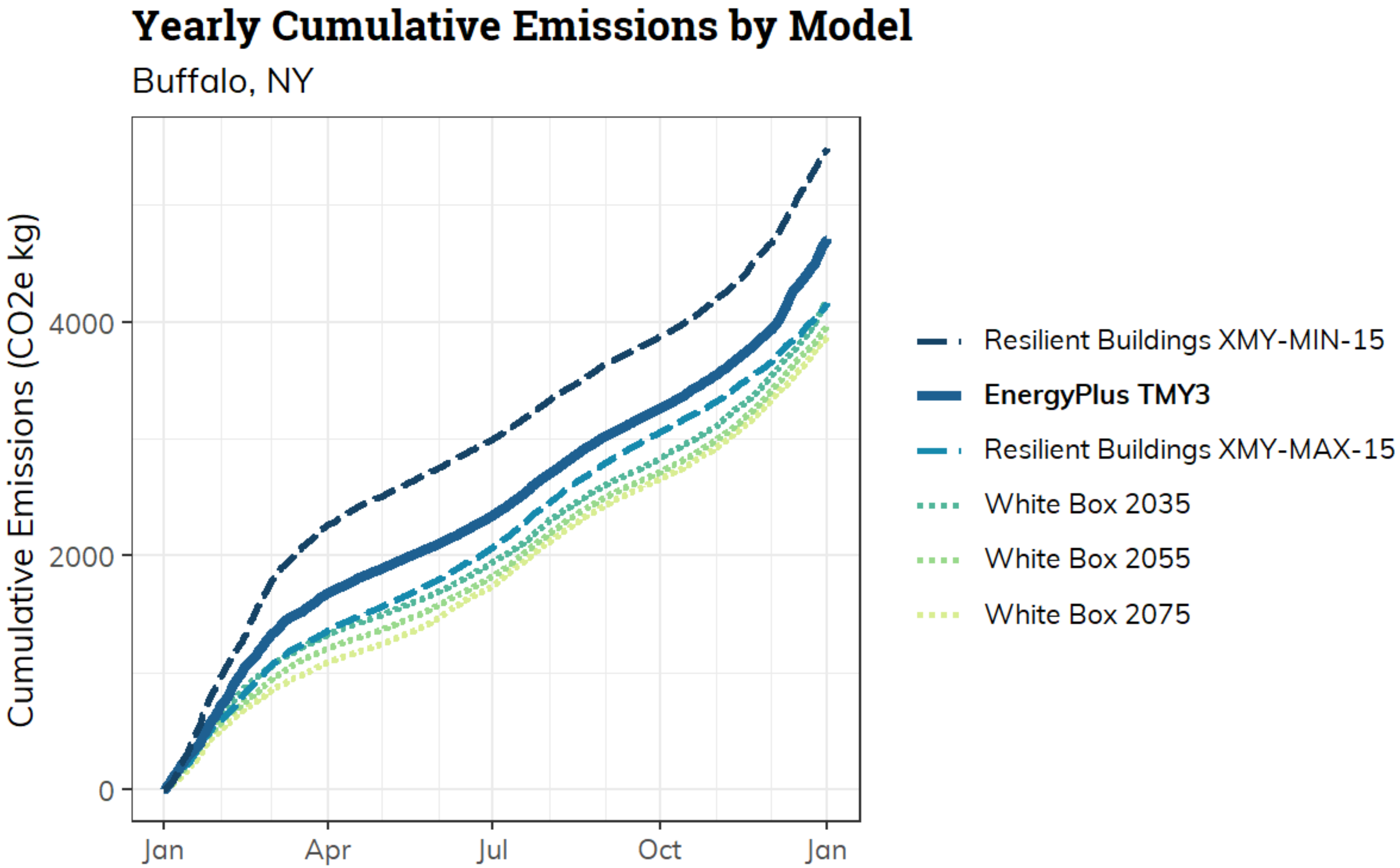


Emissions most sensitive in the winter months.




New York LRME from NREL's Cambium database

Warmer files have lower emissions



# Residential Modeling Results

**For this limited analysis**, the overall trend is for decreased heating and increased cooling, and this is more pronounced in Buffalo than in NYC.

**All-electric:** Site EUI and winter peak demand decrease over time or with increased climate projection percentiles for this single-family heat pump example. But, this occurs with a general shift from heating to cooling needs.

**Mixed fuel:** If a mixed fuel case were explored -- when the peak demand may be driven by air conditioning in the summer months -- we would expect to see an increase in peak summer demand over time.

Background

Modeling

Passive Strategies

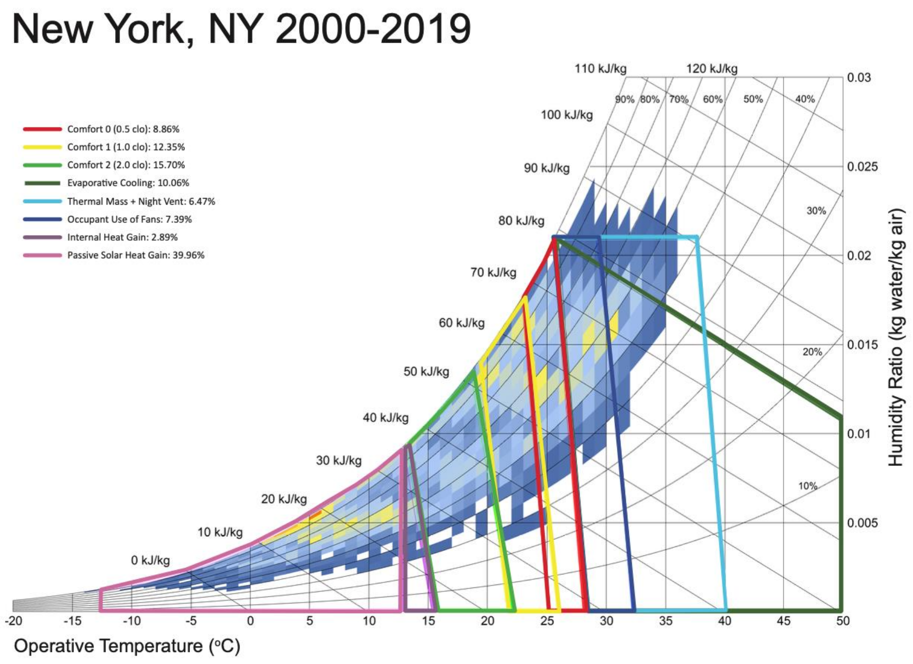
Lessons Learned

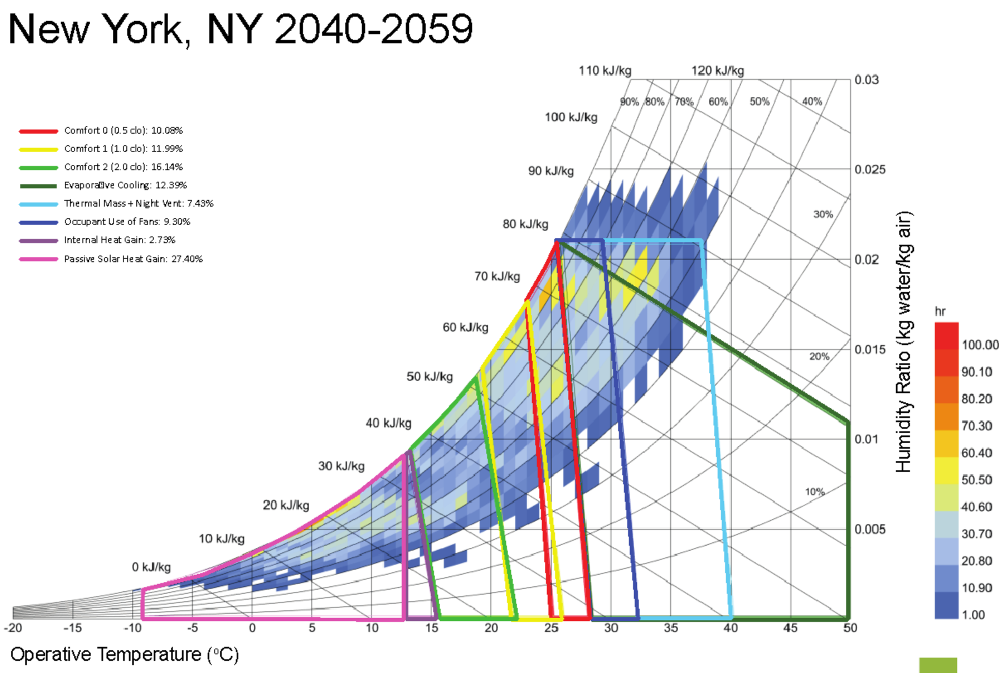
# Passive Strategies

The following charts show the number of hours that strategies are effective during the year, including:

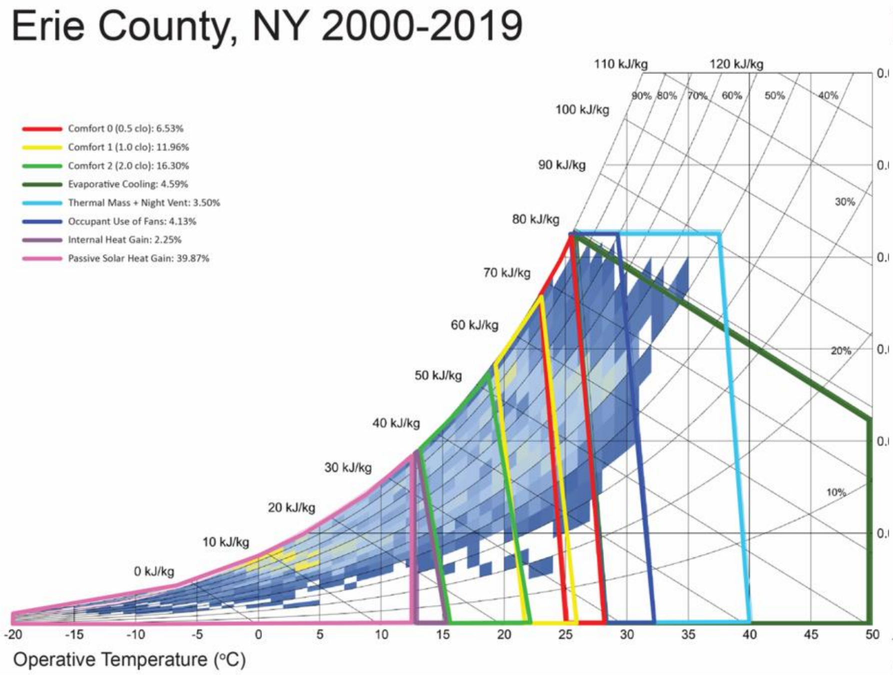
- **Adaptive comfort:** Clothing levels set to 0.5 clo (summer attire), 1 clo (3 piece suit), and 2 clo (winter attire)
- **Passive strategies:** Evaporative cooling, thermal mass and night ventilation, occupant use of fans, capture internal heat gain, and passive solar heat gain

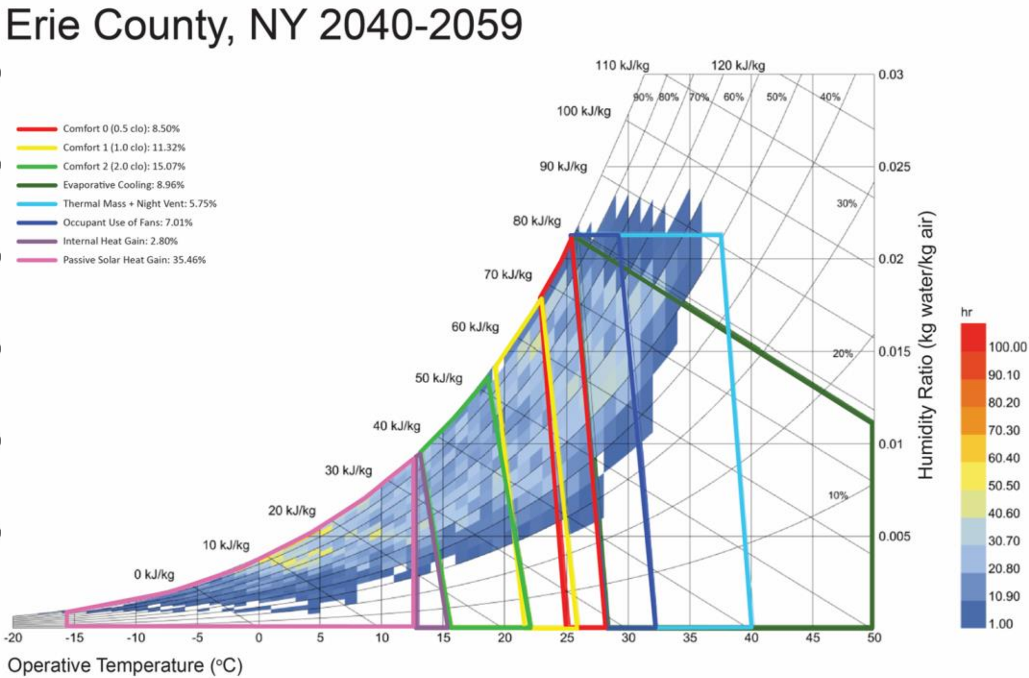
# ORNL FTMY Passive Strategies
# New York County (NYC)



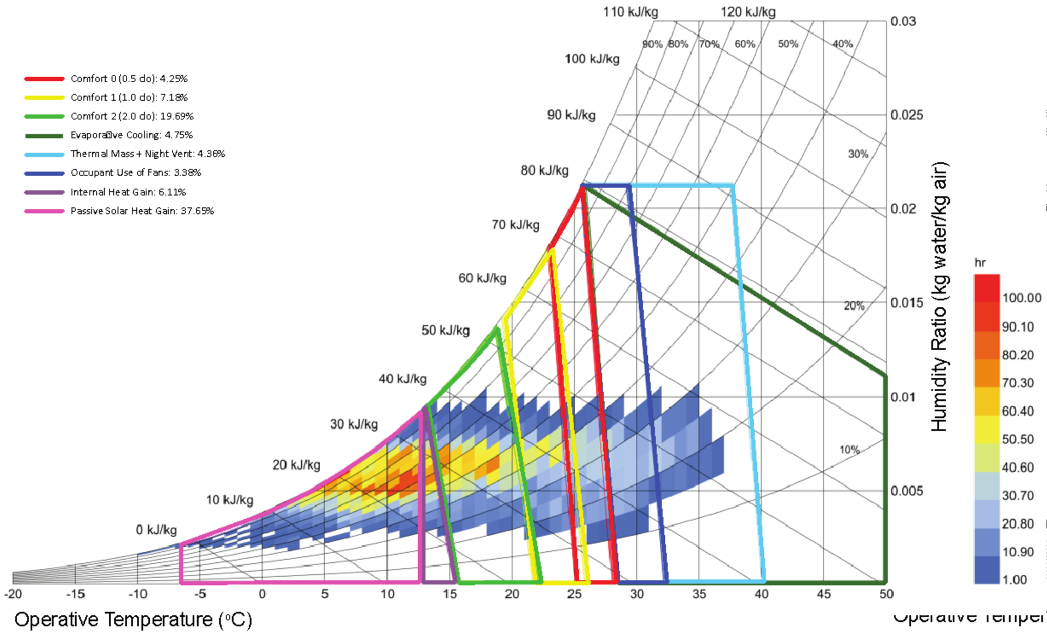
# ORNL FTMY Passive Strategies
# Erie County (Buffalo)



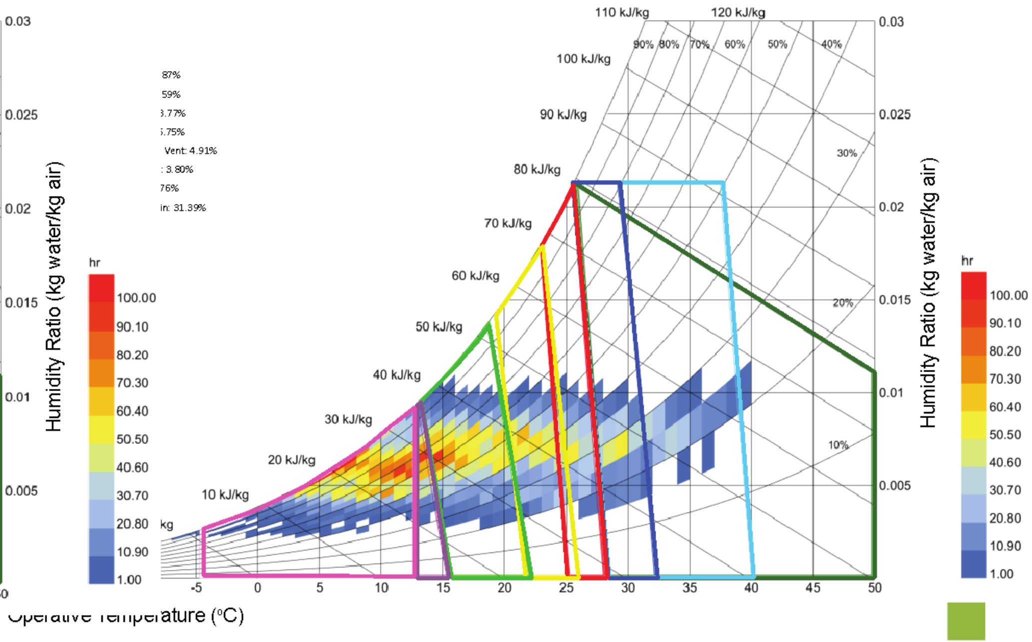



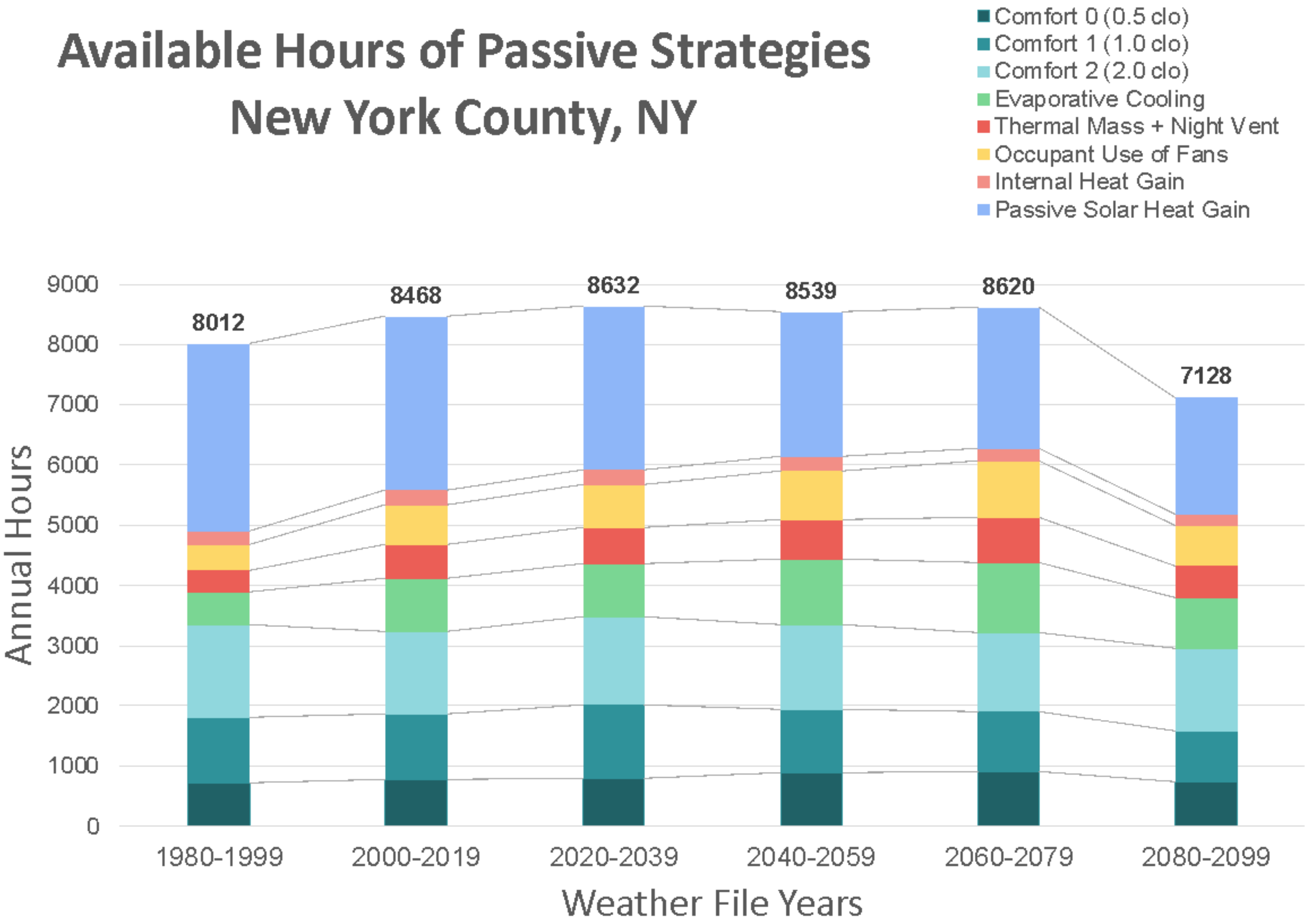
# Passive Strategies

## Lane, OR 2000-2019



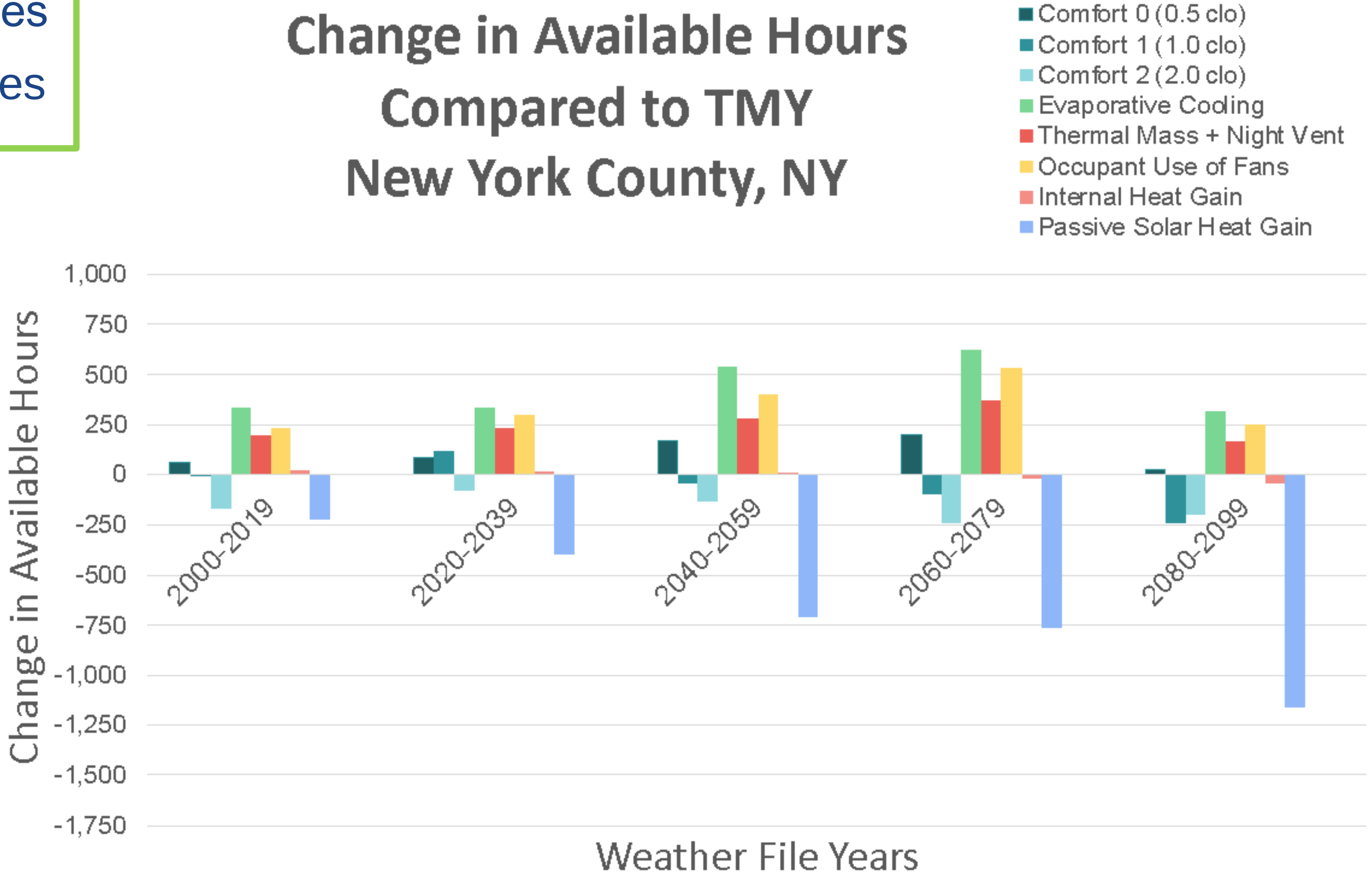

## Lane, OR 2040-2059



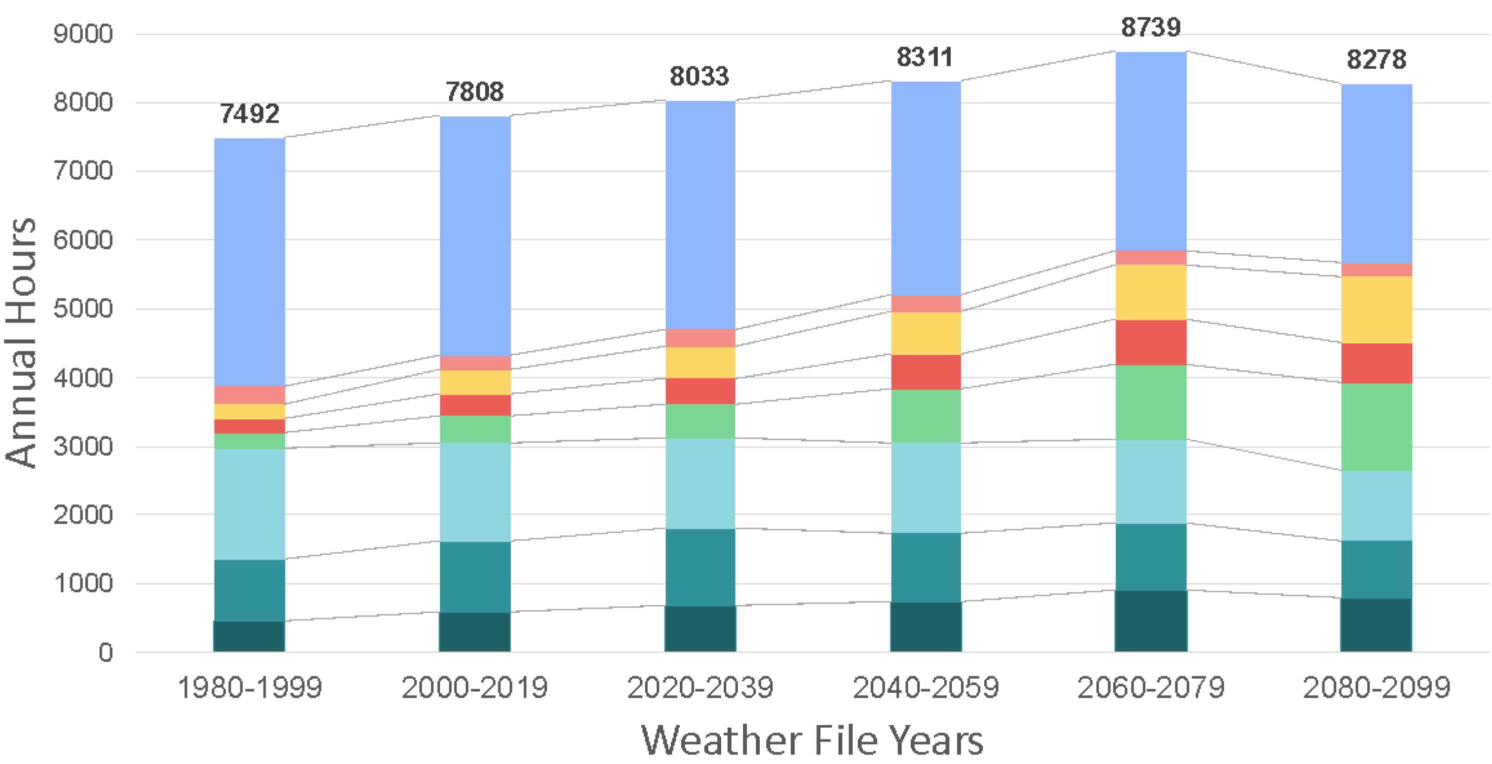

Available Hours of Passive Strategies
New York County, NY
Comfort 0 (0.5 clo)
Comfort 1 (1.0 clo)
Comfort 2 (2.0 clo)
Evaporative Cooling
Thermal Mass + Night Vent
Occupant Use of Fans
Internal Heat Gain
Passive Solar Heat Gain
Annual Hours
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
8012
8468
8632
8539
8620
7128
1980-1999
2000-2019
2020-2039
2040-2059
2060-2079
2080-2099
Weather File Years

↓ Heating strategies

↑ Cooling strategies

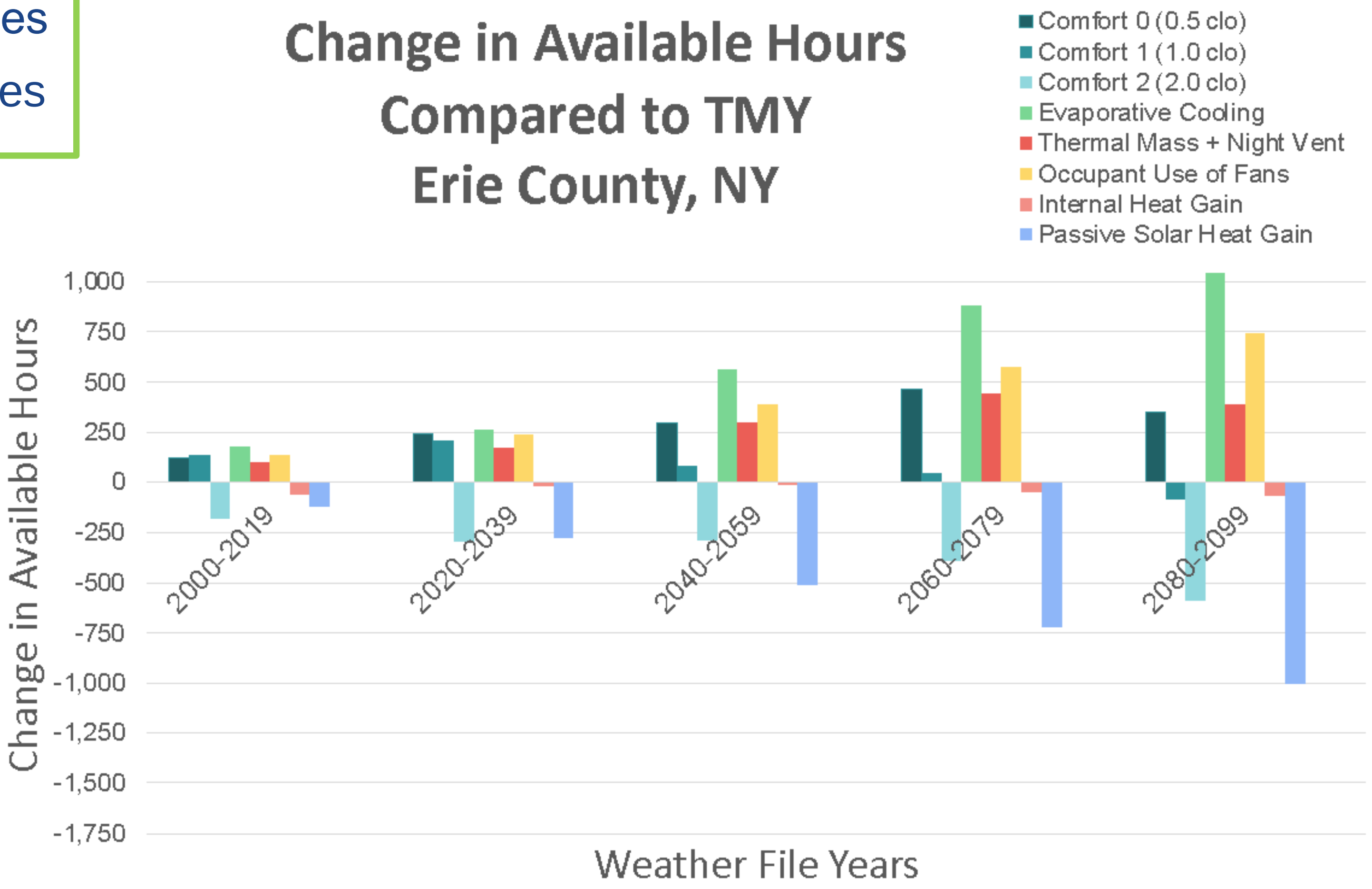


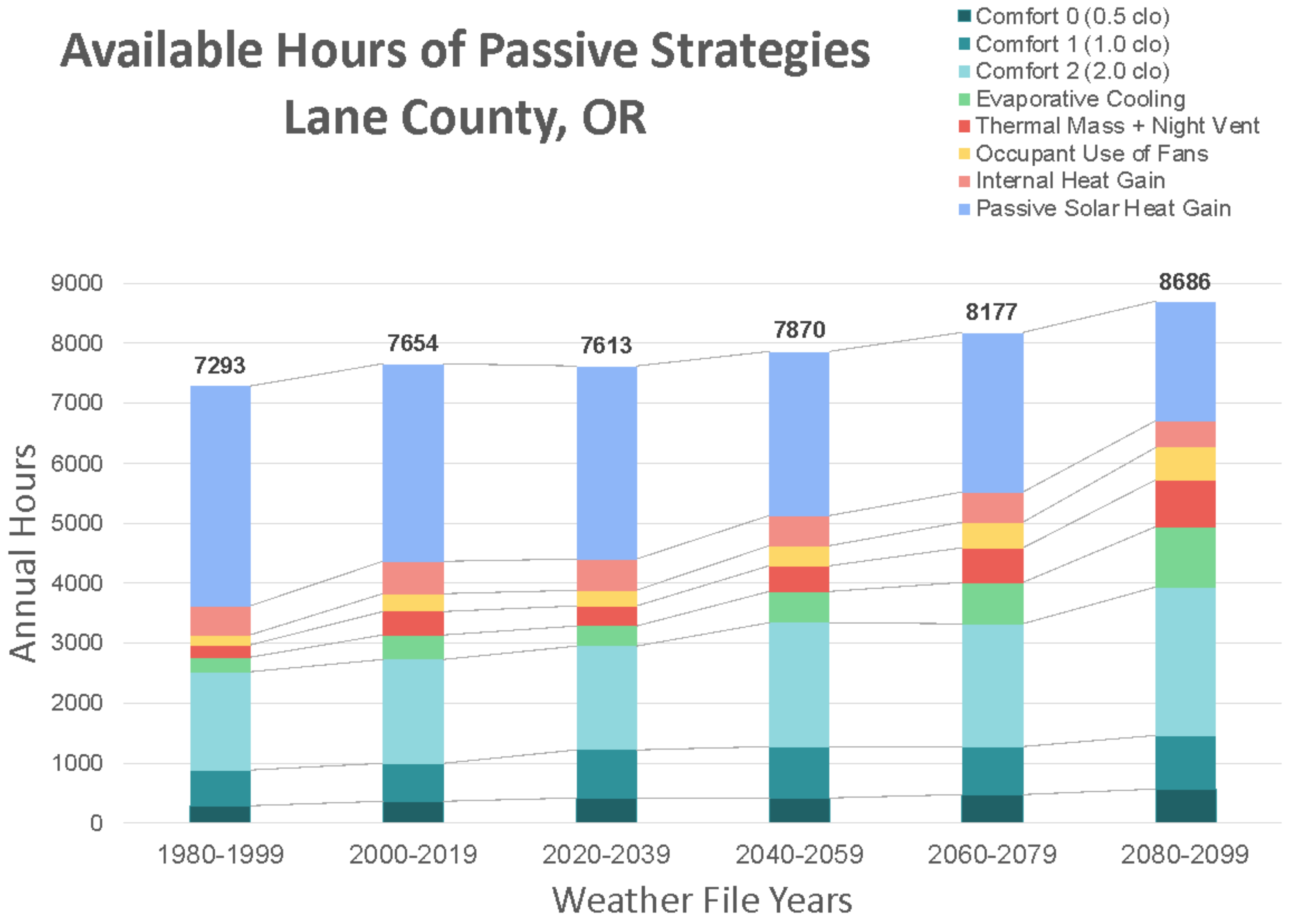
# Available Hours of Passive Strategies
# Erie County, NY



↓ Heating strategies

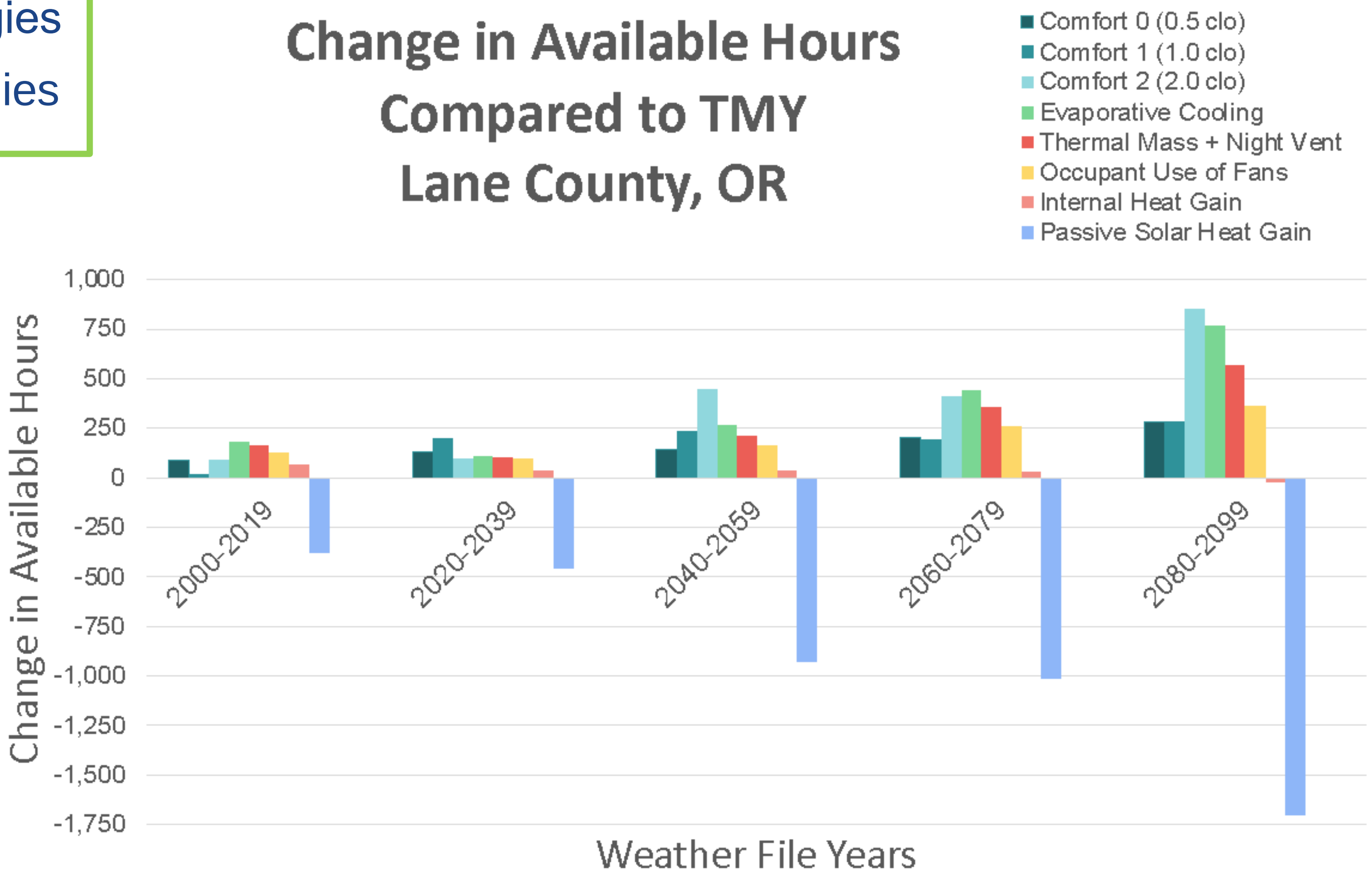
↑ Cooling strategies




Available Hours of Passive Strategies
Lane County, OR
Comfort 0 (0.5 clo)
Comfort 1 (1.0 clo)
Comfort 2 (2.0 clo)
Evaporative Cooling
Thermal Mass + Night Vent
Occupant Use of Fans
Internal Heat Gain
Passive Solar Heat Gain
Annual Hours
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
7293
7654
7613
7870
8177
8686
1980-1999
2000-2019
2020-2039
2040-2059
2060-2079
2080-2099
Weather File Years

↓ Heating strategies

↑ Cooling strategies



# Passive Strategy Trends ORNL FTMY

The later/warmer files usually result in a

- Higher number of passive hours (until 2080-2099).
- Shift from heating to cooling strategies (e.g., decrease in passive heating).

Background

Weather File Analysis

Modeling

Lessons Learned

# Challenges to Switching Weather Data Formats

**Collective Action Problem** that affects multiple stakeholders.

Switching the weather analyzed during the Codes & Standards process should also affect the later Program incentive calculations.

Both rely on national and international protocols (e.g., PHI, Phius, ANSI/RESNET/ICC, and ENERGY STAR), which may not have the flexibility to accommodate new files.

# Challenges to Switching Weather Data Formats

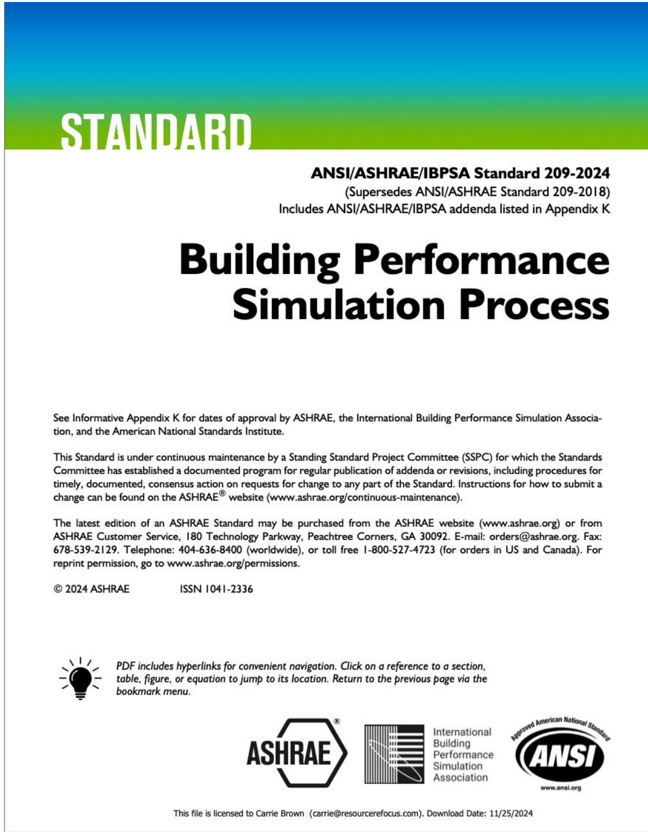
**Available data has outpaced standardized guidance.**

There is a need for standardized protocols for future weather files, for both the methodologies used to create them and the specifications for their use.

# Challenges to Switching Weather Data Formats

ASHRAE does provide some guidance on climatic design, but has not developed FTMY protocols:

- ASHRAE **Fundamentals Handbook:** Chapters 14 Climatic Design Information and 36 Global Climate Change and Standard 169-2020.
- Standard **209-2024** informative appendix A “Climate Information” and **Informative Appendix F “Future Climate Analysis”**
- **TC 4.2** Climatic Information / **Standard 169** Climatic Data For Building Design Standards, **proposed guideline development “Integration of Future Weather Data in Calculations for the Built Environment”**



STANDARD

ANSI/ASHRAE/IBPSA Standard 209-2024
(Supersedes ANSI/ASHRAE Standard 209-2018)
Includes ANSI/ASHRAE/IBPSA addenda listed in Appendix K

**Building Performance Simulation Process**

See Informative Appendix K for dates of approval by ASHRAE, the International Building Performance Simulation Association, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 180 Technology Parkway, Peachtree Corners, GA 30092. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

© 2024 ASHRAE ISSN 1041-2336

*PDF includes hyperlinks for convenient navigation. Click on a reference to a section, table, figure, or equation to jump to its location. Return to the previous page via the bookmark menu.*

ASHRAE
International Building Performance Simulation Association
Approved American National Standard ANSI www.ansi.org

This file is licensed to Carrie Brown (carrie@resourcefocus.com). Download Date: 11/25/2024

# What types are analyses are affected?

# Fuel Switching, Peak Loads, and Resource Planning

Potential for a significant shift in peak HVAC loads at the building level, but in opposite directions seasonally (down in the winter, up in the summer).

Electrification can increase *electric* load in both the winter and the summer as customers switch away from gas heating or add new AC loads.

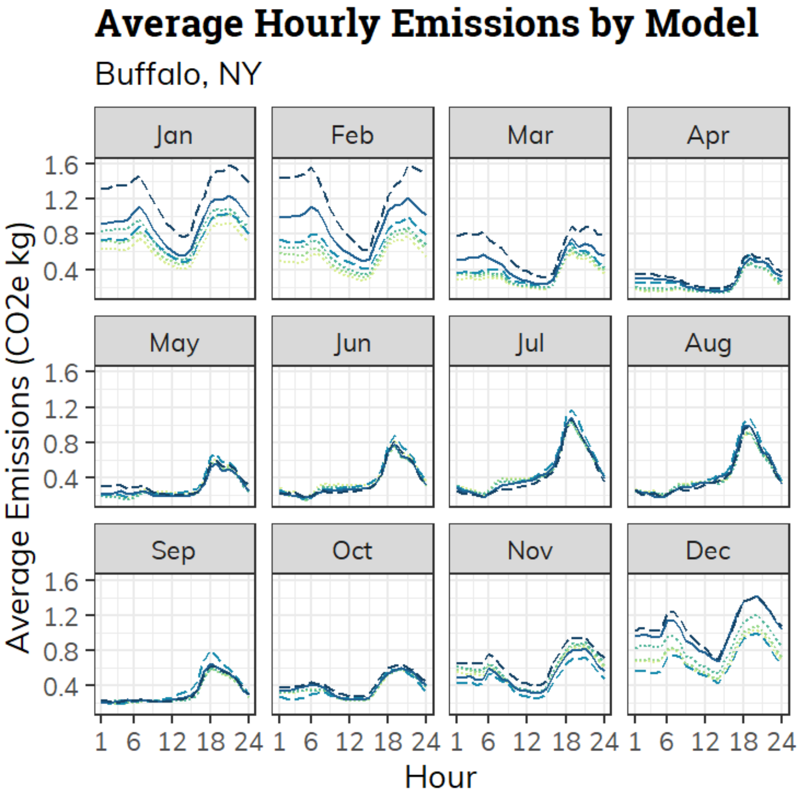
# Codes & Standards and Programs

C&S and Programs usually rely on TMY3 data.

- CA is an exception.

Predicting lifetime operational emissions is challenging

- A warming climate,
- A shift from gas to electric use,
- An increasingly clean electric grid.



# Adaptation and Resiliency

With warming trends,

- Energy consumption is expected to *increase* in strongly cooling dominated climates and *decrease* in strongly heating dominated climates in the long term.
- Hours available for passive strategies may increase with warming trends.
- The distribution of applicable passive strategies is sensitive to the weather file, leading to conflicting recommendations.

# Adaptation and Resiliency

**If we are looking backwards to design resilient buildings of the future, even with the best of intentions, we may select maladaptive solutions.**

Extreme heat events kill more people every year than any other type of natural disaster.[1]

Heat stress deaths are disproportionately seen in black, indigenous, and other people of color (BIPOC) populations and in neighborhoods with high percentages of residents living below the federal poverty line.[2]

[1] National Geographic July 2021. "Heat waves kill people—and climate change is making it much, much worse."
[2] 2021 New York City Heat-Related Mortality Report.

# Adaptation and Resiliency

**Designers need guidance now to make decisions that will support future-ready design.**

- Resilient design can support passive survivability during both sustained stresses (such as increased average temperatures) and shocks (such as an increase in extreme weather events).

- Decisions should account for the expected useful life of the component parts of a building to account for the appropriate level of climate risk.

# Conclusions

As climate change risks grow through this century,

1. Design decisions in adaptation, retrofits, and new construction should use weather files based on the climate projections and expected hazards that align with the building or its systems' life cycle to be cost-effective, sustainable, and future-ready.

2. There is a need for industry guidance on protocols for FTMY development and usage.

3. Implementing updated protocols will require extensive collaboration touching a wide range of stakeholders.

# THANKS!

Carrie Brown

carrie@resourcerefocus.com

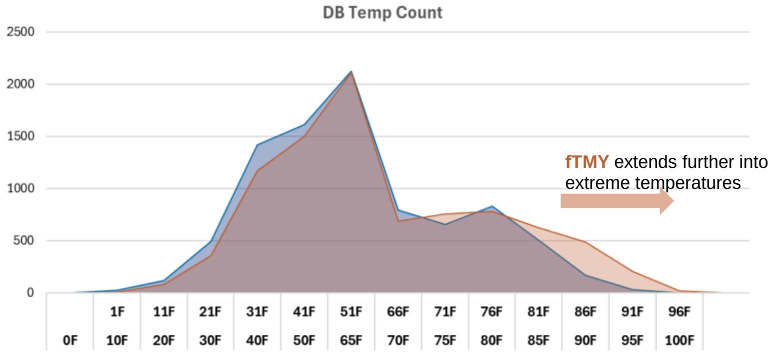

# FUTURE WEATHER IS MORE IMPORTANT THAN YOU THINK

# UPDATING OUR ASSUMPTIONS

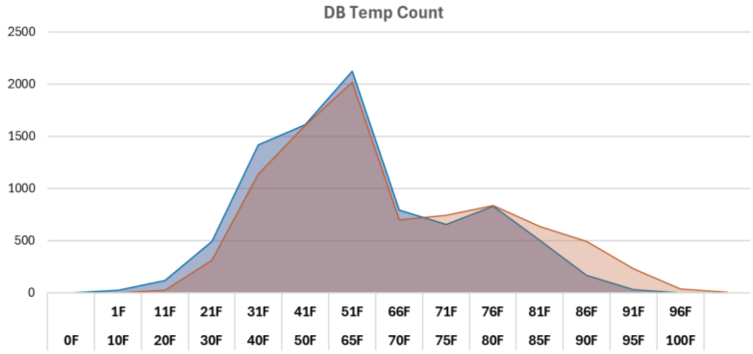
# NEW WEATHER FILES ARE AVAILABLE

## Dry Bulb Distribution

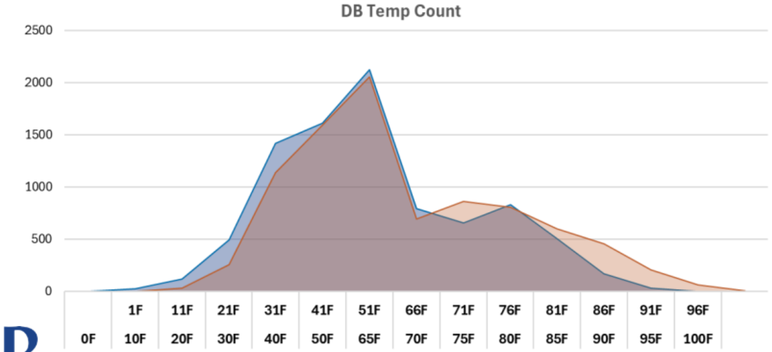
### TMYx vs. fTMYx RCP4.5 2040-2060



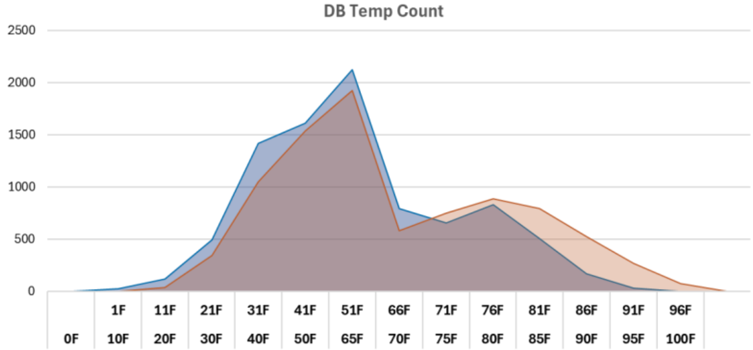

### TMYx vs. fTMYx RCP8.5 2040-2060




### TMYx vs. fTMYx RCP4.5 2060-2080



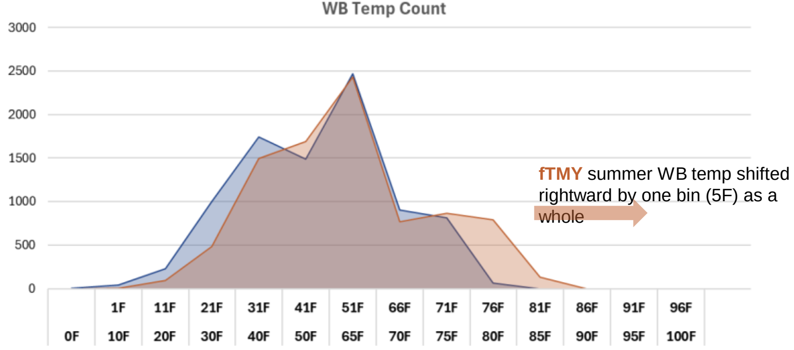

### TMYx vs. fTMYx RCP8.5 2060-2080



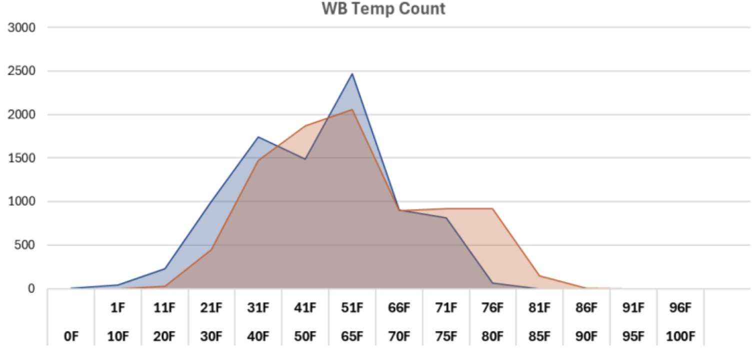
# NEW WEATHER FILES ARE AVAILABLE

## Wet Bulb Distribution

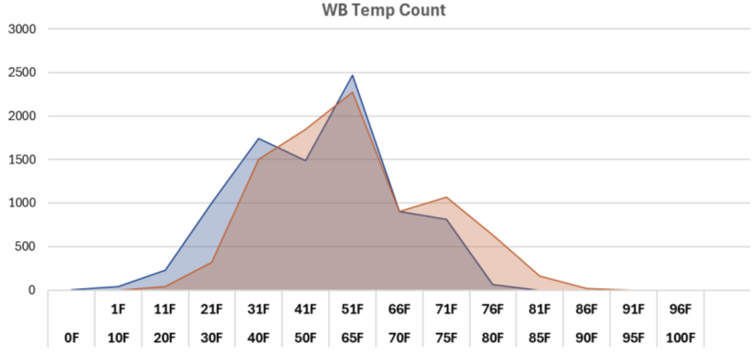
### TMYx vs. fTMYx RCP4.5 2040-2060



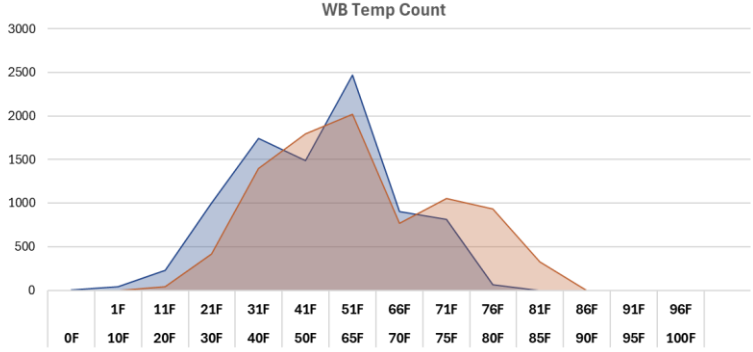

### TMYx vs. fTMYx RCP8.5 2040-2060




### TMYx vs. fTMYx RCP4.5 2060-2080




### TMYx vs. fTMYx RCP8.5 2060-2080



# DESIGNERS ARE USING OUTDATED INFORMATION

2021 ASHRAE Handbook - Foundamentals (IP)

**NEW YORK CENTRAL PARK, NY, USA (WMO: 725053)**

Lat:**40.779N** Long:**73.969W** Elev:**140** StdP: **14.62** Time zone:**-5.00 (NAE)** Period:**95-19** WBAN:**94728** Climate zone:**4A**

**Annual Heating, Humidification, and Ventilation Design Conditions**

| Coldest Month | Heating DB | | Humidification DP/MCDB and HR | | | | | | Coldest month WS/MCDB | | | | MCWS/PCWD to 99.6% DB | | WSF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 99.6% | | | 99% | | | 0.4% | | 1% | | | | |
| | 99.6% | 99% | DP | HR | MCDB | DP | HR | MCDB | WS | MCDB | WS | MCDB | MCWS | PCWD | |
| **1** | **13.0** | **17.3** | **-6.0** | **4.0** | **15.5** | **-1.3** | **5.1** | **20.8** | **25.3** | **33.0** | **21.3** | **33.3** | **9.8** | **300** | **0.423** |

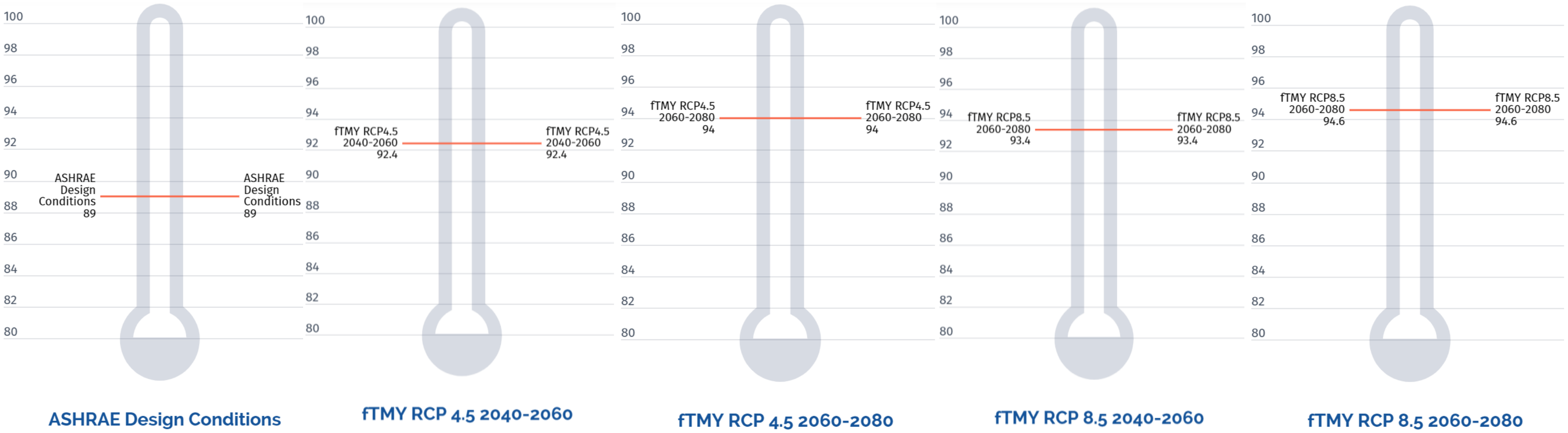
**Annual Cooling, Dehumidification, and Enthalpy Design Conditions**

| Hottest Month | Hottest Month DB Range | Cooling DB/MCWB | | | | | | Evaporation WB/MCDB | | | | | | MCWS/PCWD to 0.4% DB | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.4% | | 1% | | 2% | | 0.4% | | 1% | | 2% | | | |
| | | DB | MCWB | DB | MCWB | DB | MCWB | WB | MCDB | WB | MCDB | WB | MCDB | MCWS | PCWD |
| **7** | **13.7** | **90.7** | **73.6** | **87.9** | **72.3** | **85.3** | **71.1** | **76.7** | **85.3** | **75.4** | **82.9** | **74.2** | **81.2** | **5.8** | **260** |

| Dehumidification DP/MCDB and HR | | | | | | | | | Enthalpy/MCDB | | | | | | Extreme Max WB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.4% | | | 1% | | | 2% | | | 0.4% | | 1% | | 2% | | |
| DP | HR | MCDB | DP | HR | MCDB | DP | HR | MCDB | Enth | MCDB | Enth | MCDB | Enth | MCDB | |
| **74.3** | **128.7** | **80.0** | **73.1** | **123.5** | **79.0** | **72.0** | **118.9** | **78.3** | **40.1** | **85.5** | **38.9** | **83.2** | **37.7** | **80.8** | **81.9** |

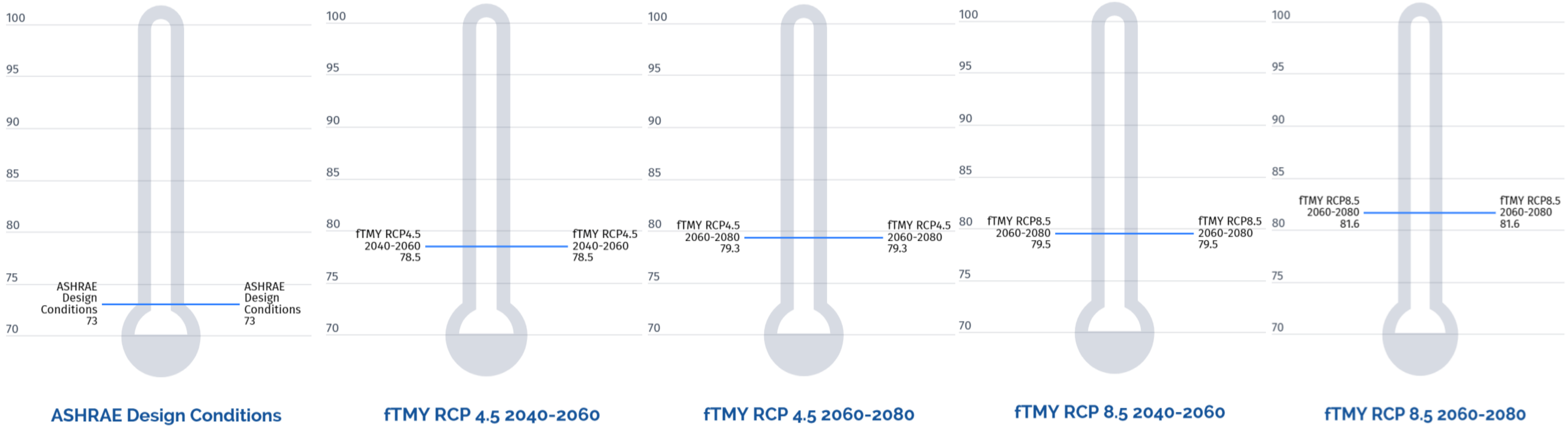
# THE WEATHER IS CHANGING

## Dry Bulb Temp



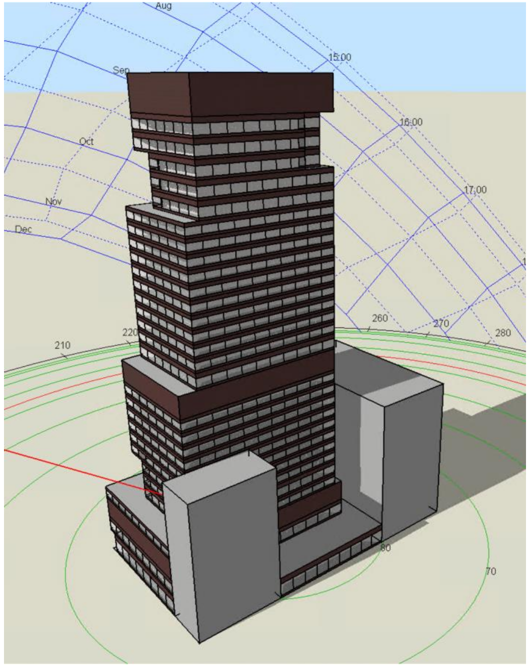
# THE WEATHER IS CHANGING

## Wet Bulb Temp



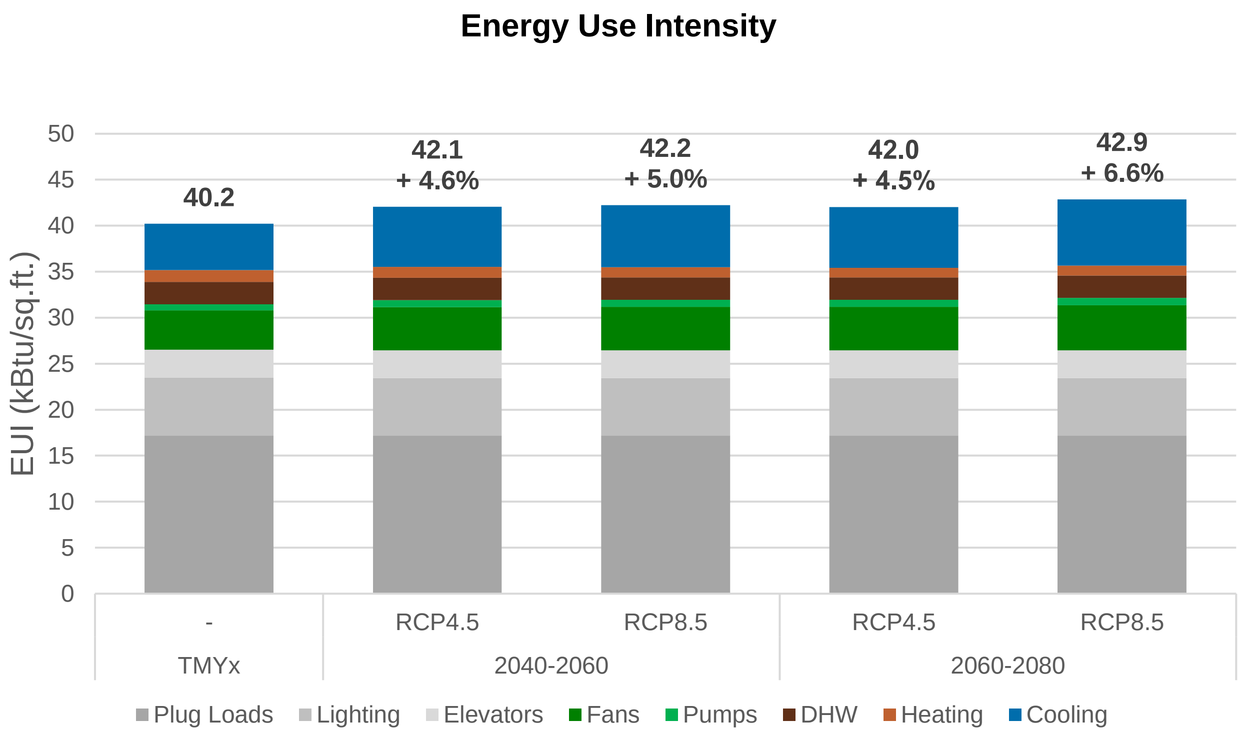
# EVALUATING ENERGY IMPACTS

# BUILDING DESCRIPTION

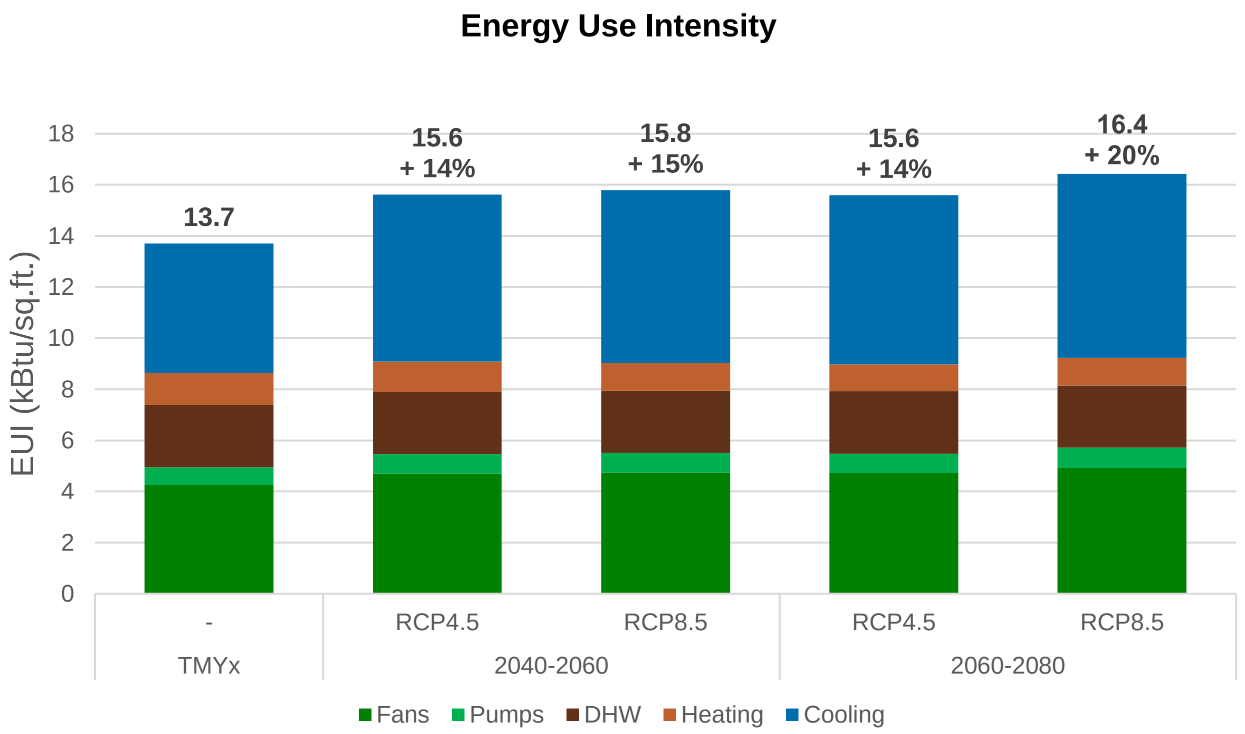



| | Description |
|---|---|
| **Building Type** | Commercial with office, retail, and amenity spaces |
| **Location** | Midtown, NYC |
| **Gross Floor Area** | ~900K sq.ft. |
| **Lighting** | NYCECC 2020 Code Minimum |
| **Ventilation** | DOAHU with energy recovery and desiccant wheels for offices |
| **Heating** | 4-pipe air source heat pumps with energy recovery |
| **Cooling** | 4-pipe air source heat pumps with energy recovery |
| **Domestic Hot Water** | Local electric resistance domestic hot water heaters |
| **Envelope** | Curtail wall + spandrel with stack effect infiltration losses |

# HOW WILL FUTURE WEATHER AFFECT PERFORMANCE?



# HOW WILL FUTURE WEATHER AFFECT PERFORMANCE?



# ENERGY TAKE AWAYS

%

## Overall annual energy consumption impact is relatively small

- Space heating and cooling energy make up X% of the total energy consumption.
- In highly efficient buildings, end uses like plug loads are larger energy drivers

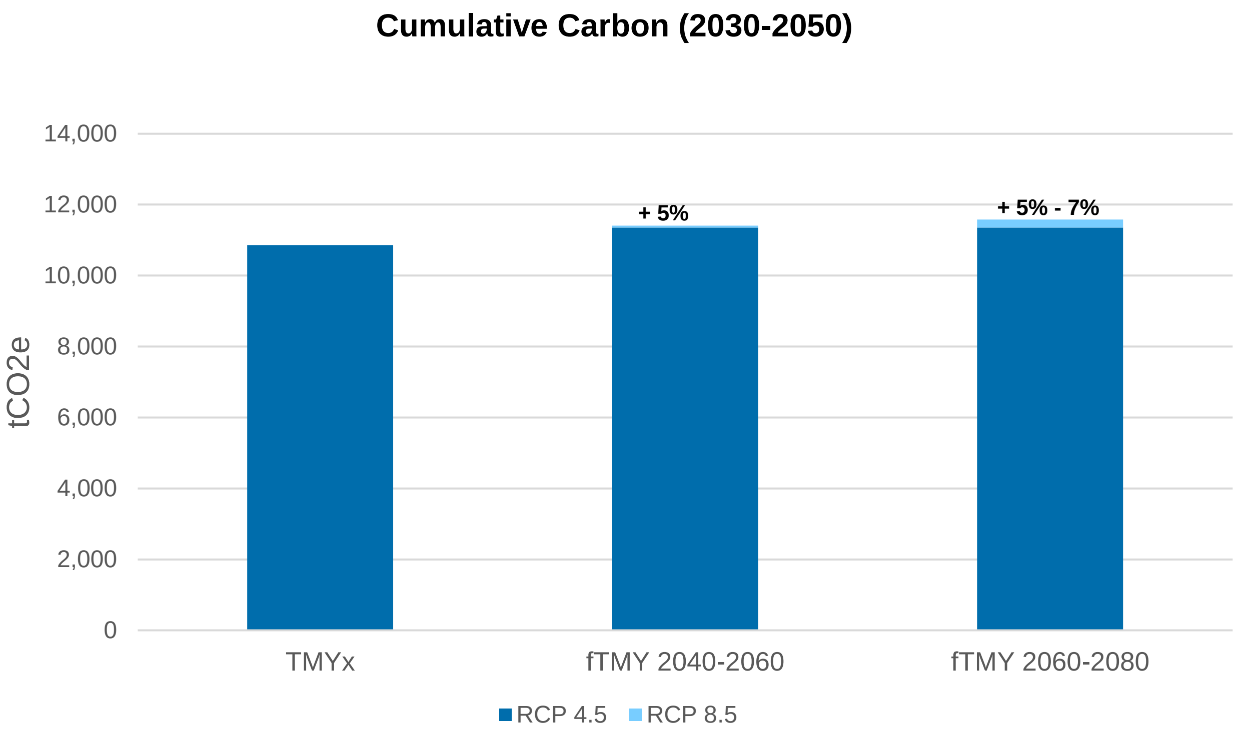
## Energy use increases with warmer weather files in this building

- This building is cooling dominant
- Increase in moisture in the air is a particular driver of energy increase

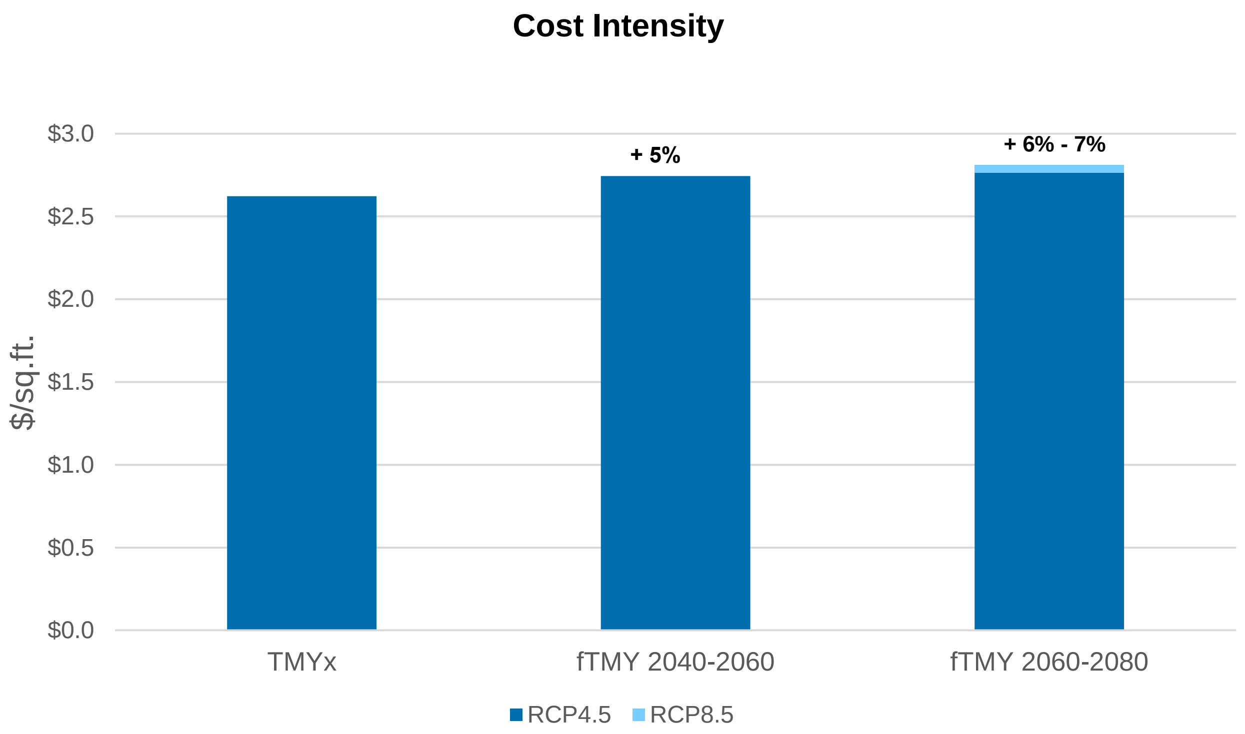
## Other buildings would likely see different results

- Buildings with fewer heat recovery systems and with non electrified heating could see energy decreases with increasing temperatures.

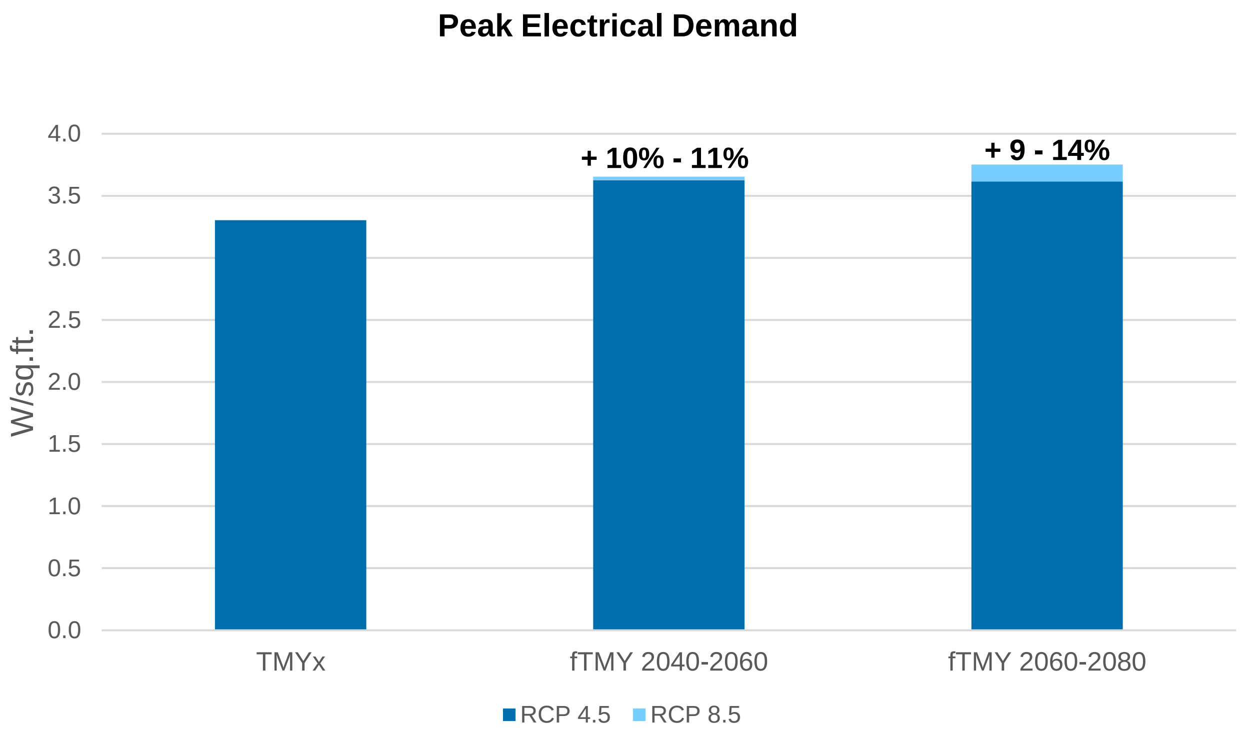
# HOW WILL FUTURE WEATHER AFFECT PERFORMANCE?



# HOW WILL FUTURE WEATHER AFFECT PERFORMANCE?

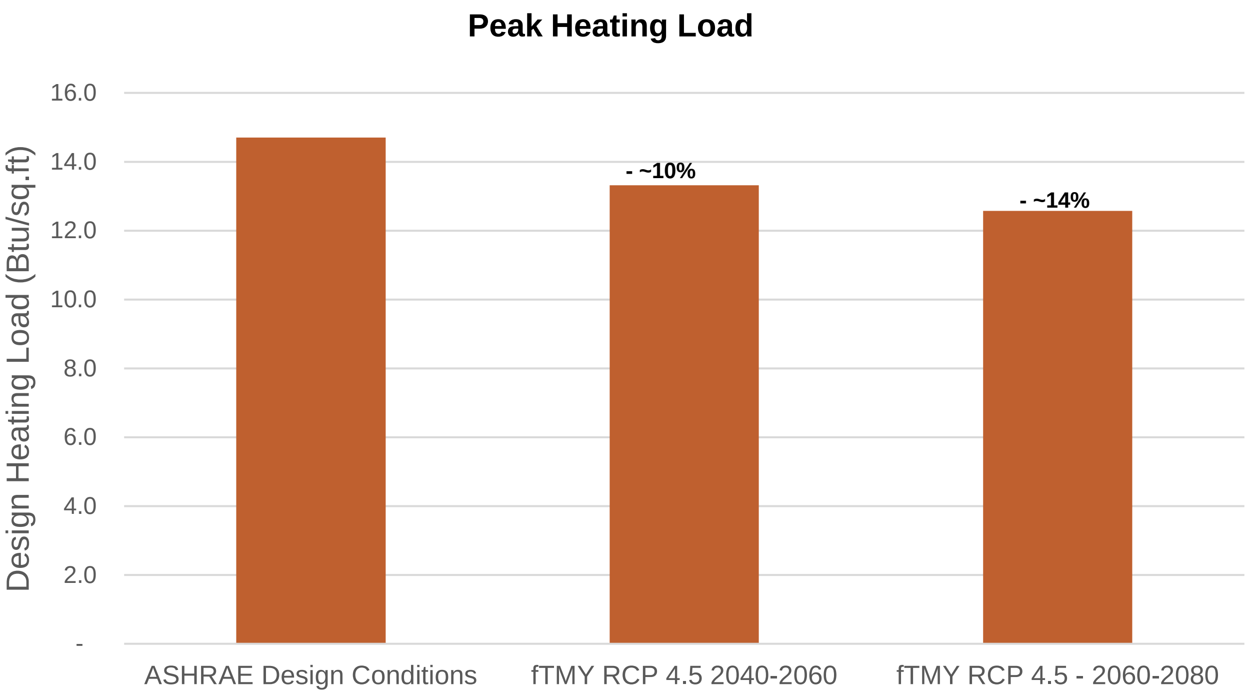


# HOW WILL FUTURE WEATHER AFFECT PERFORMANCE?

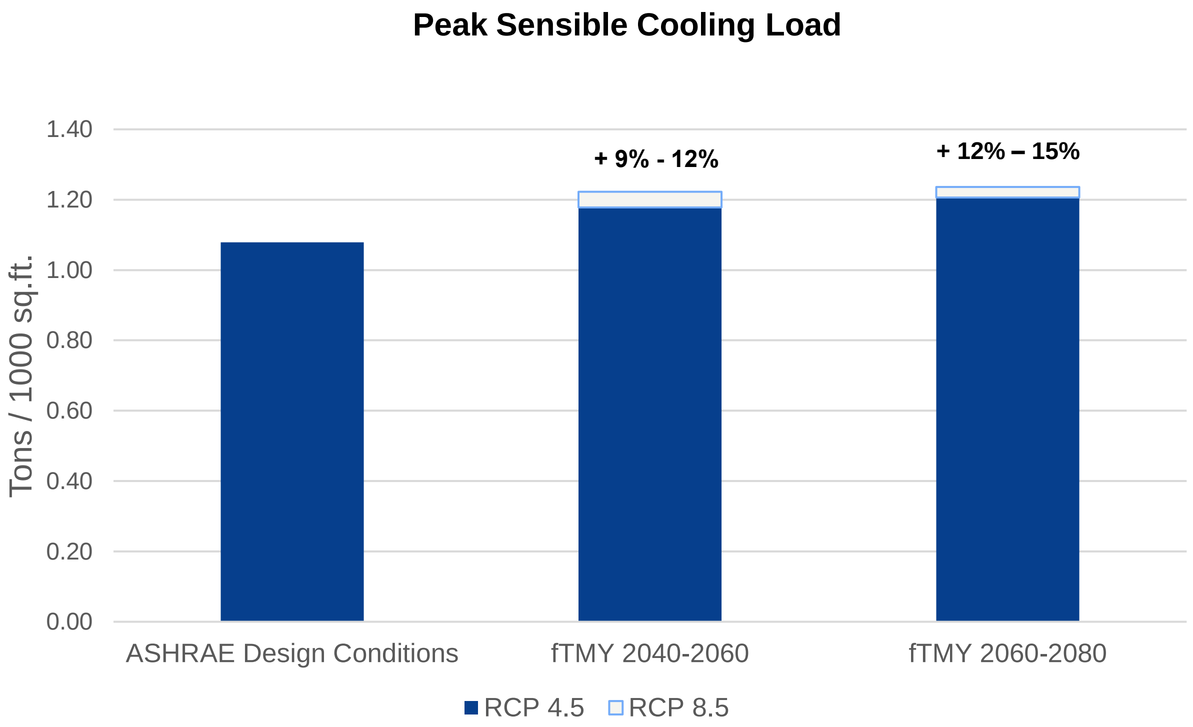


# EQUIPMENT SIZING

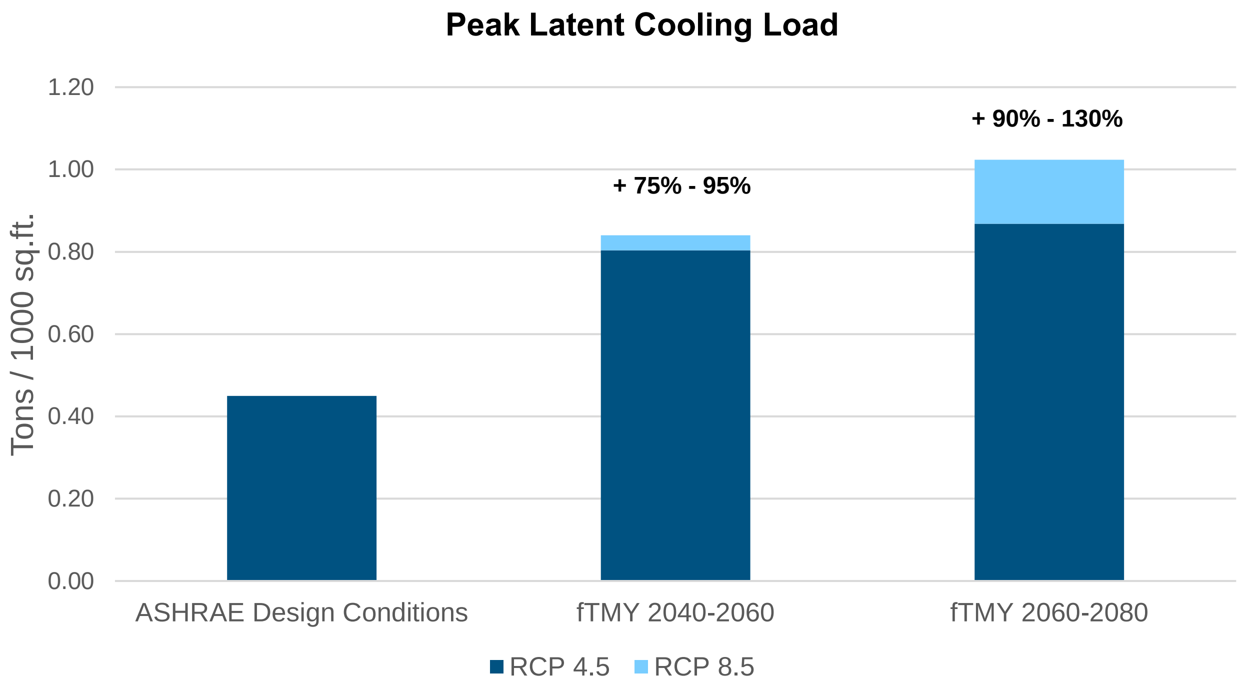
# HOW WILL FUTURE WEATHER AFFECT PERFORMANCE?



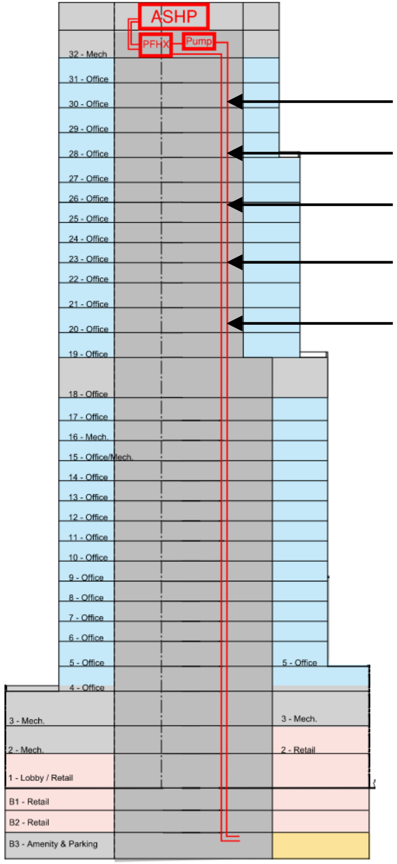
# HOW WILL FUTURE WEATHER AFFECT PERFORMANCE?



# HOW WILL FUTURE WEATHER AFFECT PERFORMANCE?



# WHAT ABOUT EQUIPMENT/DISTRIBUTION SIZING?




TMYx – **12”** Chilled Water Piping

fTMY 2040-2060 RCP 4.5 – 30% higher peak flowrate (**14”** Piping)

fTMY 2060-2080 RCP 4.5 – 35% higher peak flowrate (**14”** Piping & Larger Pumps )

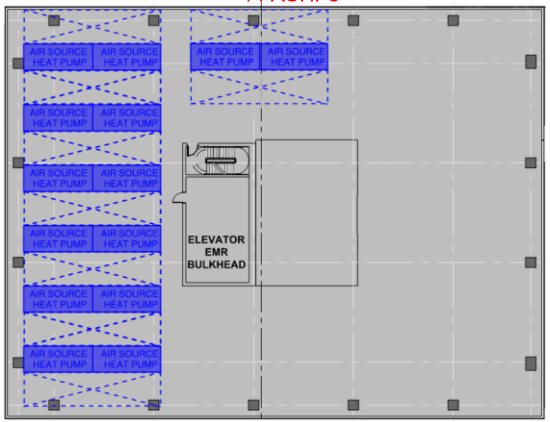
fTMY 2040-2060 RCP 8.5 – 35% higher peak flowrate (**14”** Piping & Larger Pumps )

fTMY 2060-2080 RCP 8.5 – 65% higher peak flowrate (**16”** Piping & Larger Pumps )

# WHAT ABOUT EQUIPMENT SIZING?

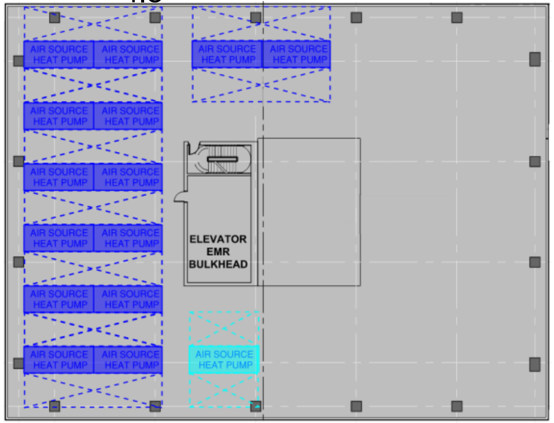
TMYx

14 ASHPs



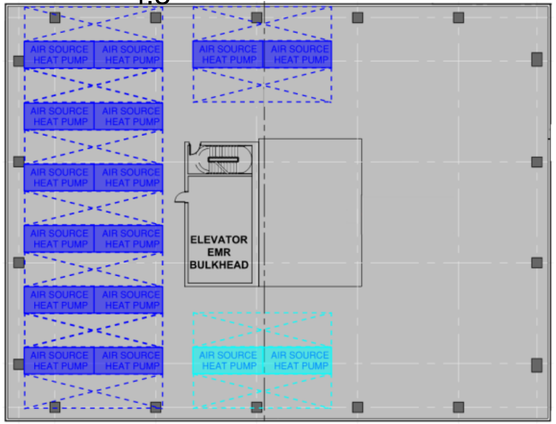

fTMY 2040-2060 RCP 4.5

15 ASHPs



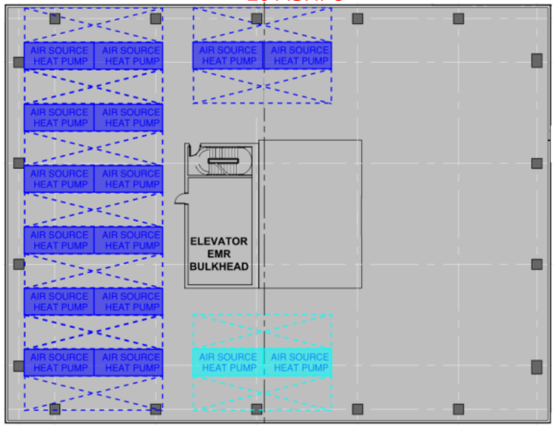

fTMY 2060-2080 RCP 4.5

16 ASHPs



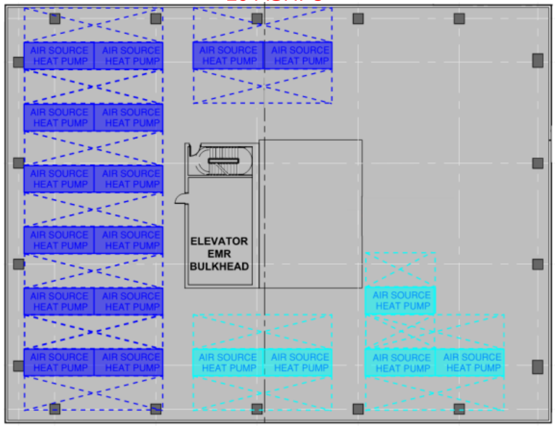

fTMY 2040-2060 RCP 8.5

16 ASHPs




fTMY 2060-2080 RCP 8.5

19 ASHPs

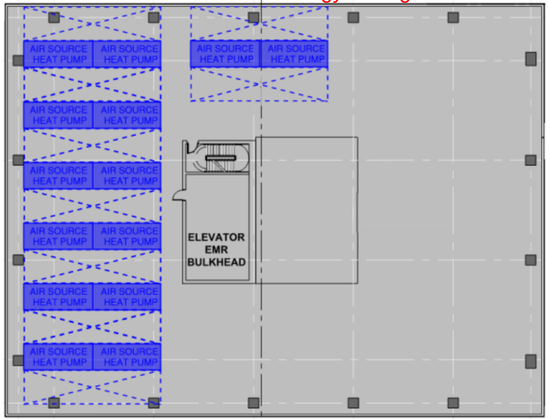


# WHAT ABOUT EQUIPMENT SIZING?

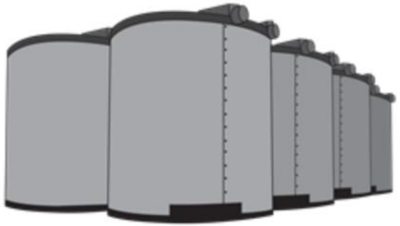
Utilize Energy Storage Technologies to shift load to non-peak hours to lessen the peak equipment required

All Weather Files

14 ASHPs + Energy Storage







THANK YOU!

JB&B DEEP CARBON REDUCTION

JB&B

NEW YORK | 80 PINE STREET, NEW YORK, NY 10005
BOSTON | 125 HIGH STREET, SUITE 220, BOSTON, MA 02110
PHILADELPHIA | 50 SOUTH 16TH STREET, SUITE 1700, PHILADELPHIA, PA 19103

WWW.DEEPCARBONREDUCTION.COM

# Assessment of Learning Questions

1. There is a clear need for standardized protocols for future weather files, for both the methodologies used to create them and the specifications for their use.
2. If we are looking backwards to design resilient buildings of the future, even with the best of intentions, we may select maladaptive solutions.
3. Warmer climate conditions will generally increase cooling energy consumption and reduce heating energy consumption
4. Energy consumption will <u>always</u> decrease with warmer weather conditions
5. The impact of future weather conditions on peak loads is expected to be greater than the impact on energy

# THANK YOU

## PDH Request Form

FUTURE WEATHER/CLIMATE DATA IS MORE IMPORTANT THAN YOU THINK!

https://forms.office.com/r/ALEKbyt0xF

## Presentation Evaluation Form

https://form.jotform.com/212628858013154

- Jean-Simon Venne
  Chief Technology Officer
  js.venne@brainboxai.com


BRAINBOX AI

# THE VIRTUAL ENGINEER WORLD

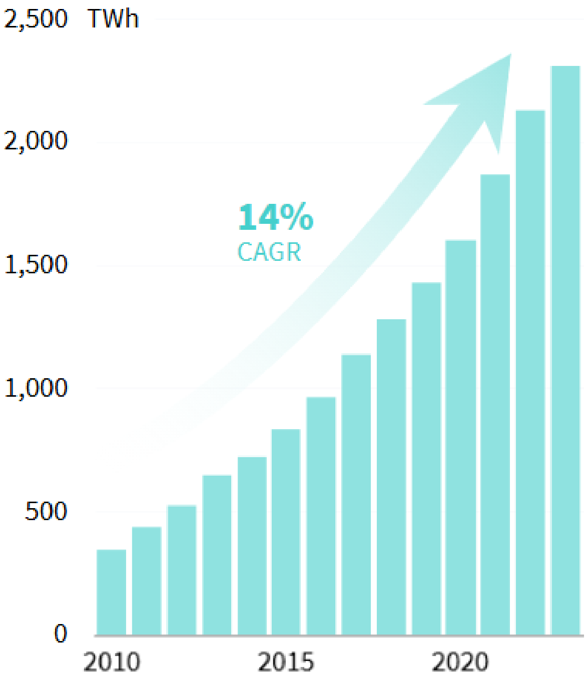
# Learning Objectives

- Demonstrate how a HVAC service industry increase their productivity by 10 x.
- Highlight the benefits of applying artificial intelligence to HVAC assets management.
- Understand how to leverage the existing data in the HVAC industry
- Understand the evolution of AI agent and where we are heading
- Understand the role of AI in our industry and how we will work with it

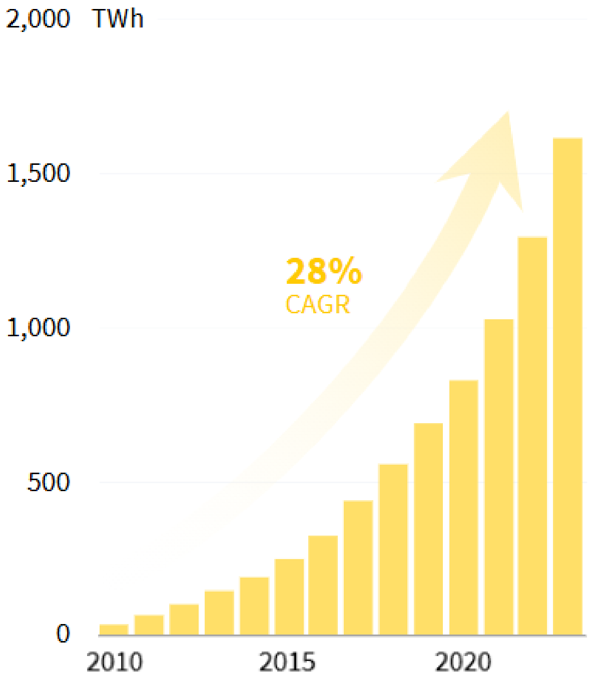
THE ACCELE
SAW COMIN

# The global energy transition is here

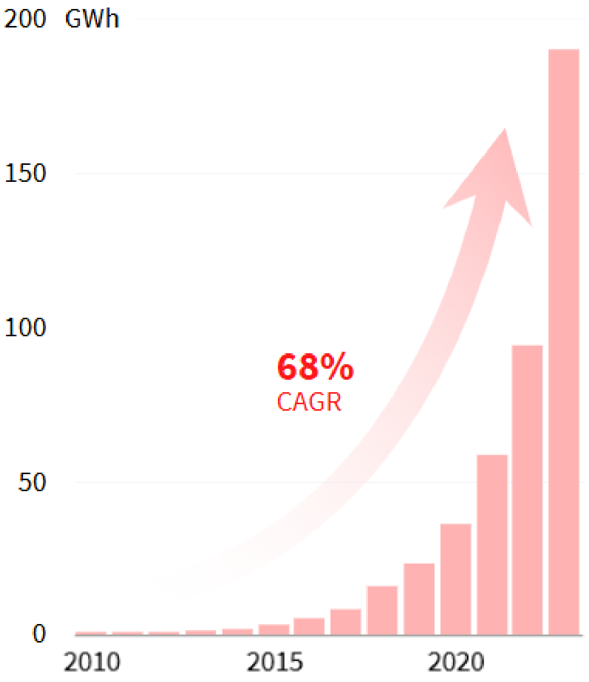
### Wind generation




### Solar generation

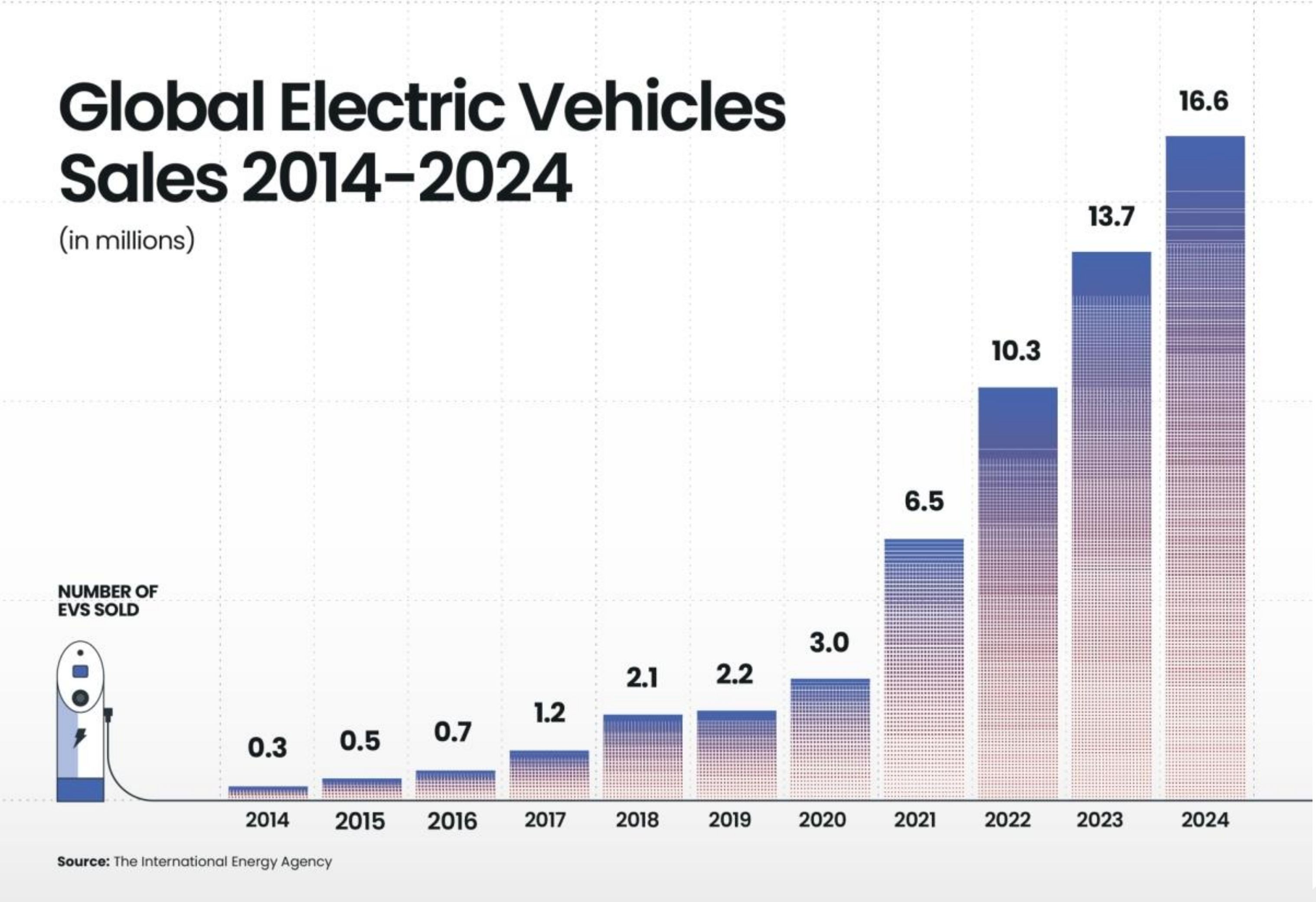



### Battery storage




Source

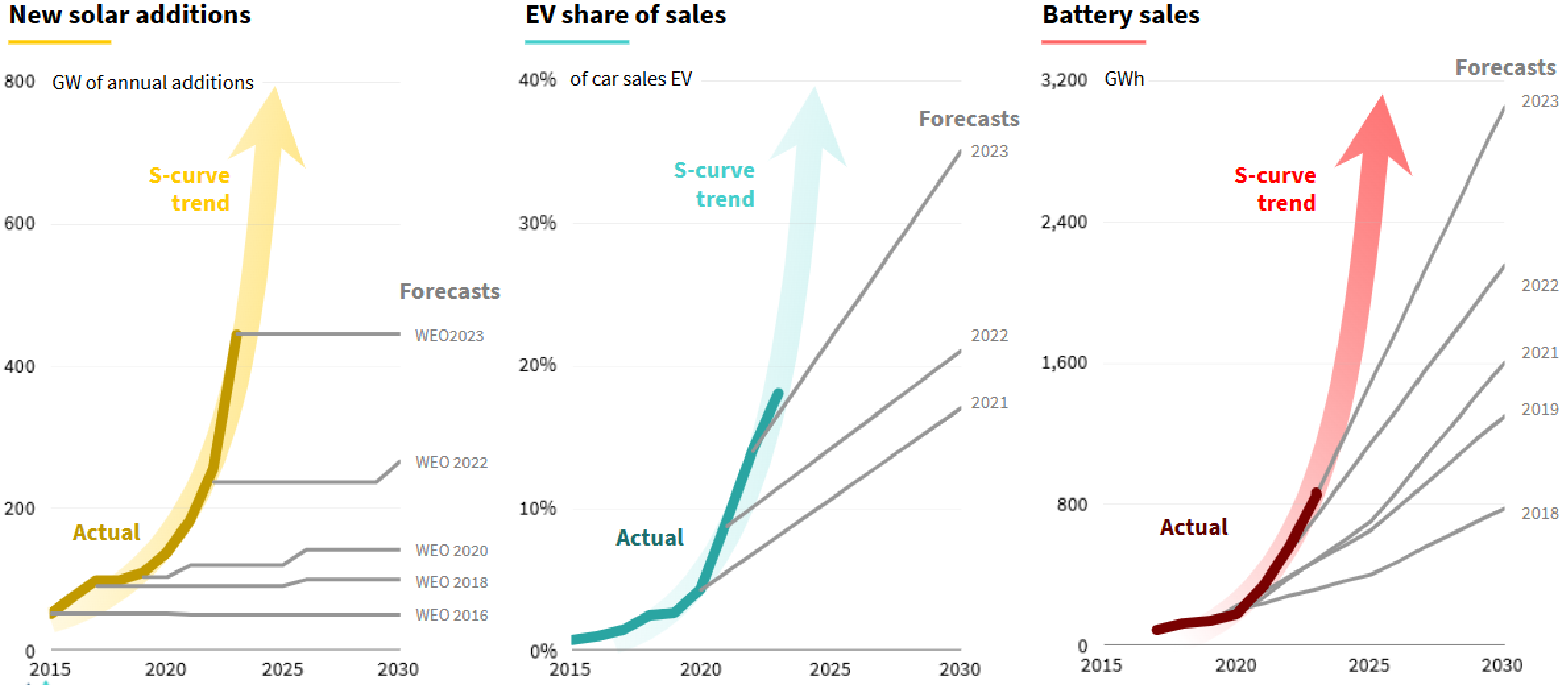
Source: IEA, BNEF; Note: CAGR is the compound annual growth rate between 2013 and 2023.


Global Electric Vehicles Sales 2014–2024
(in millions)
NUMBER OF EVS SOLD
0.3
0.5
0.7
1.2
2.1
2.2
3.0
6.5
10.3
13.7
16.6
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Source: The International Energy Agency

## BYD Seagull is just the beginning

*Starting price <$10,000*

# And we have underestimated the speed of change



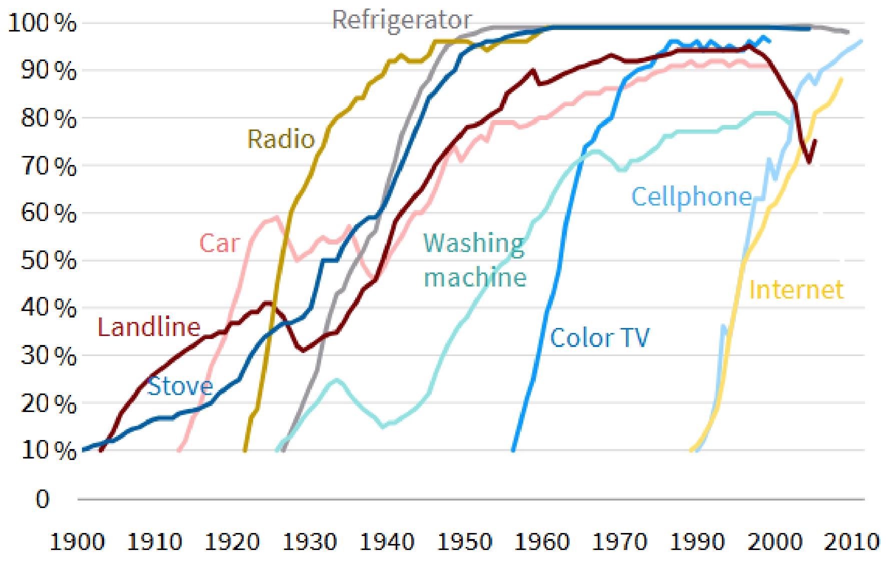

RMI

*Source: BNEF (solar and battery actuals), IEA STEPS for WEO forecasts , RMI annotation.*

# We know how technology revolutions work

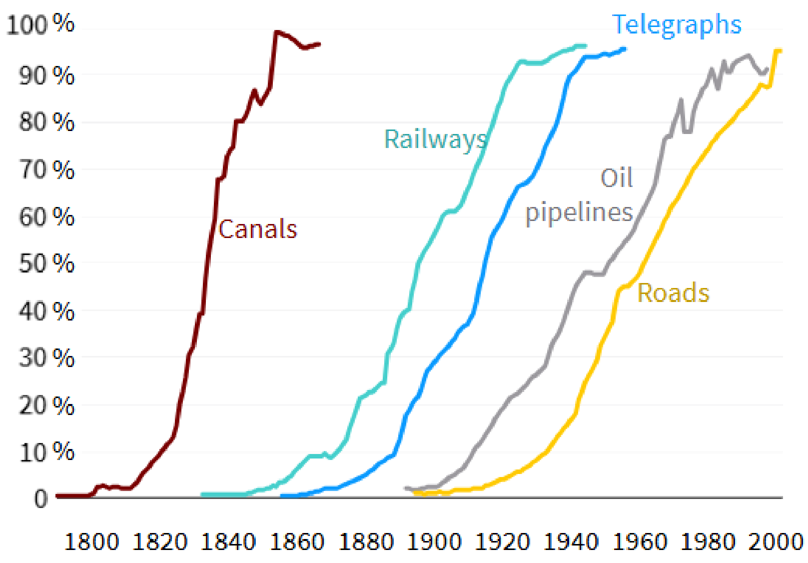
## Individual products

Technological adoption by household in the United States

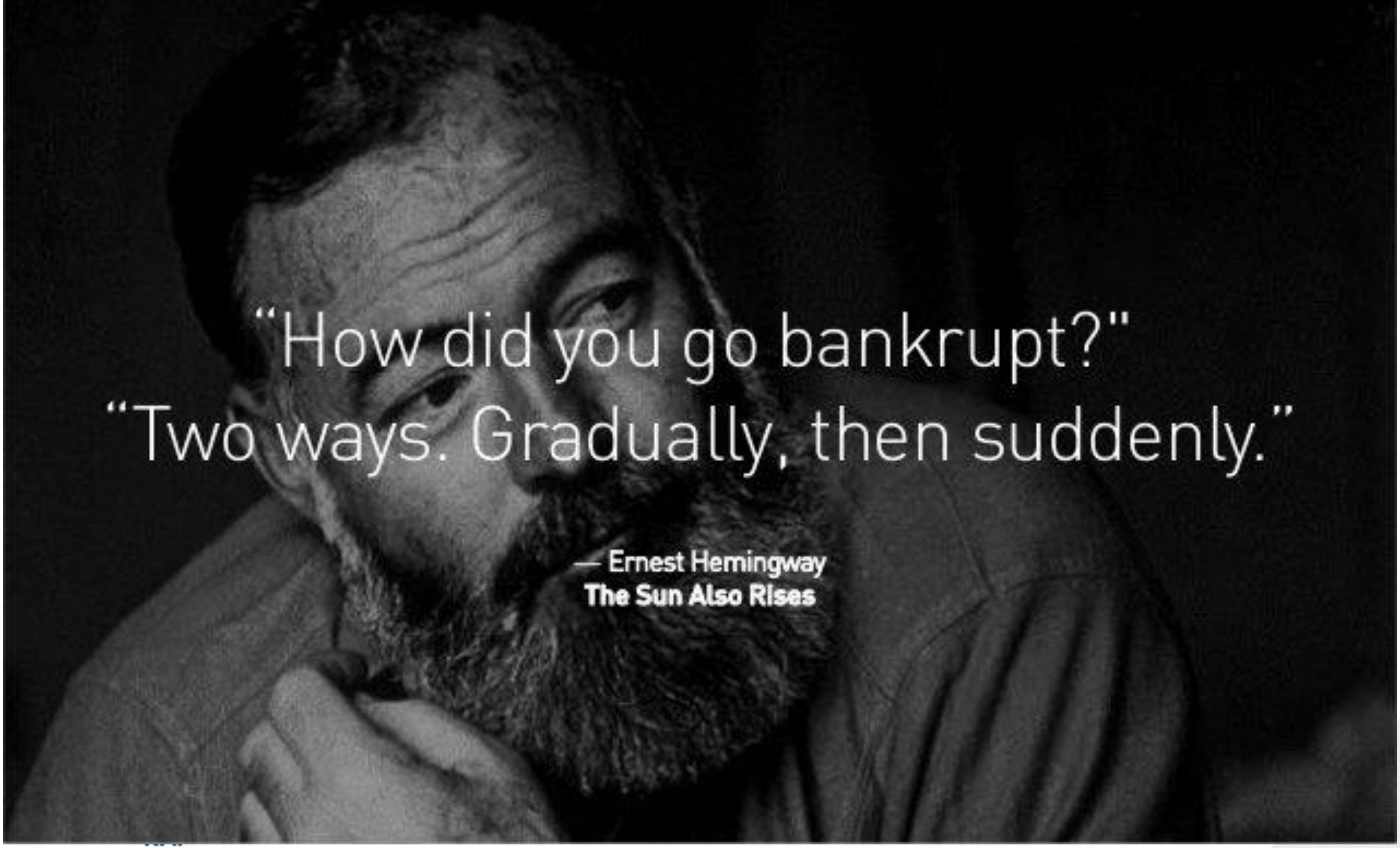



## Infrastructure systems

Share of maximum size in the United States




Source: Comin & Hobijn via OWID (L); Grubler (R).


"How did you go bankrupt?"
"Two ways. Gradually, then suddenly."
— Ernest Hemingway
The Sun Also Rises

AI EVOLUT
DATA SOU
OPPORTU

# AI has surpassed humans at a number of tasks and the rate at which humans are being surpassed at new tasks is increasing

State-of-the-art AI performance on benchmarks, relative to human performance

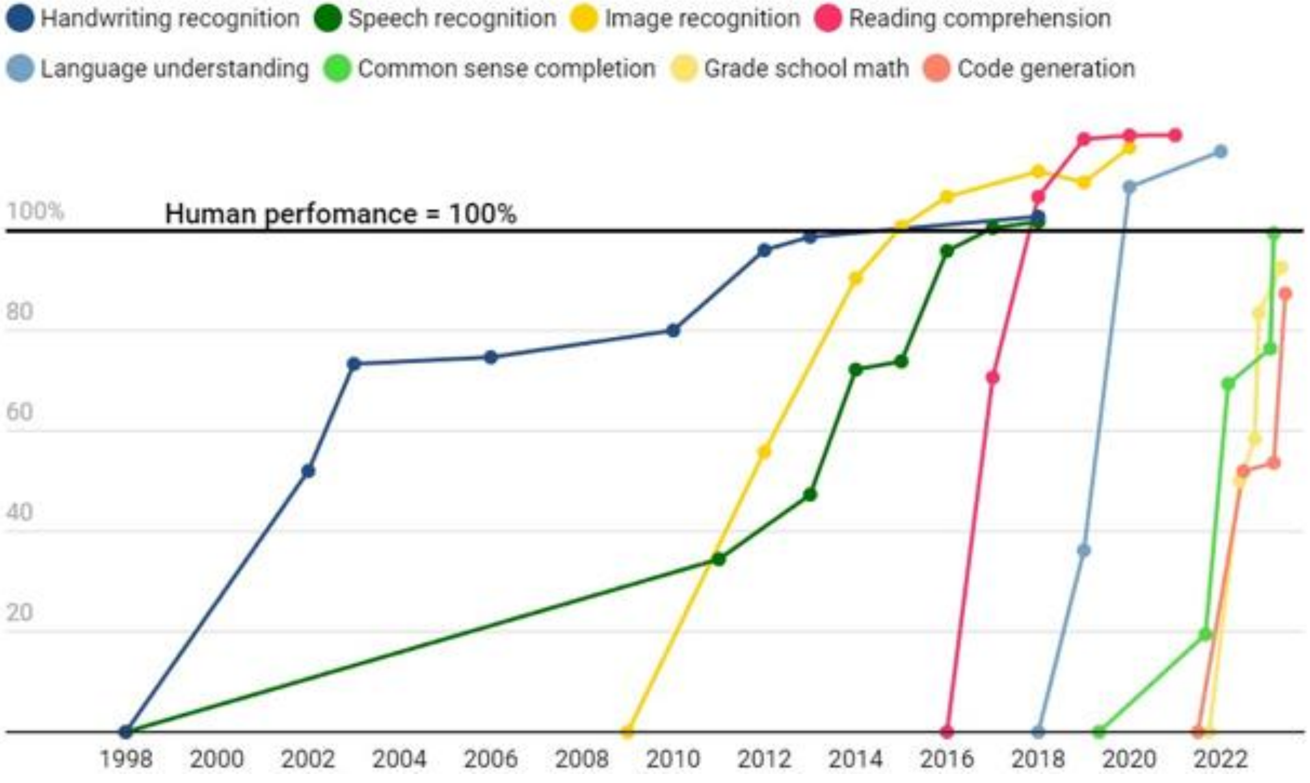



Chart: Will Henshall for TIME • Source: ContextualAI

TIME

# The volume of data in the world is increasing exponentially

Volume of data/information created, captured, copied, and consumed worldwide (zettabytes)

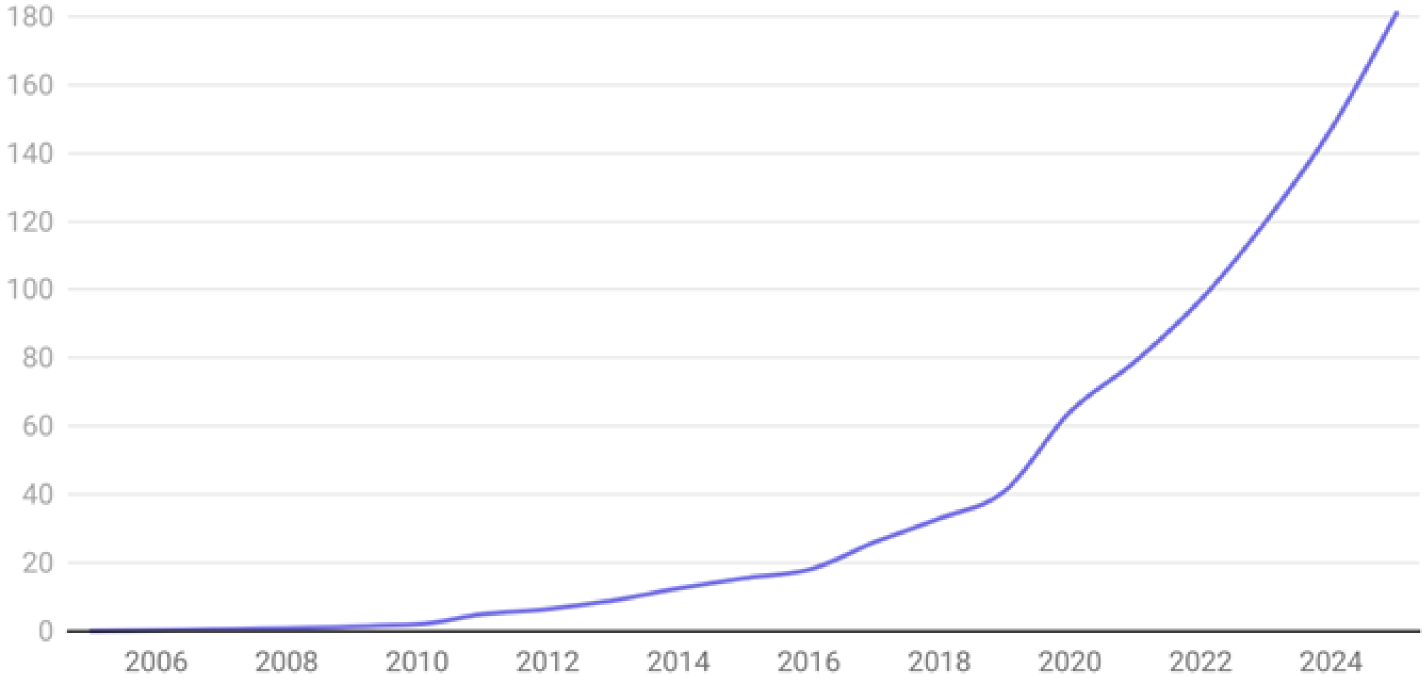
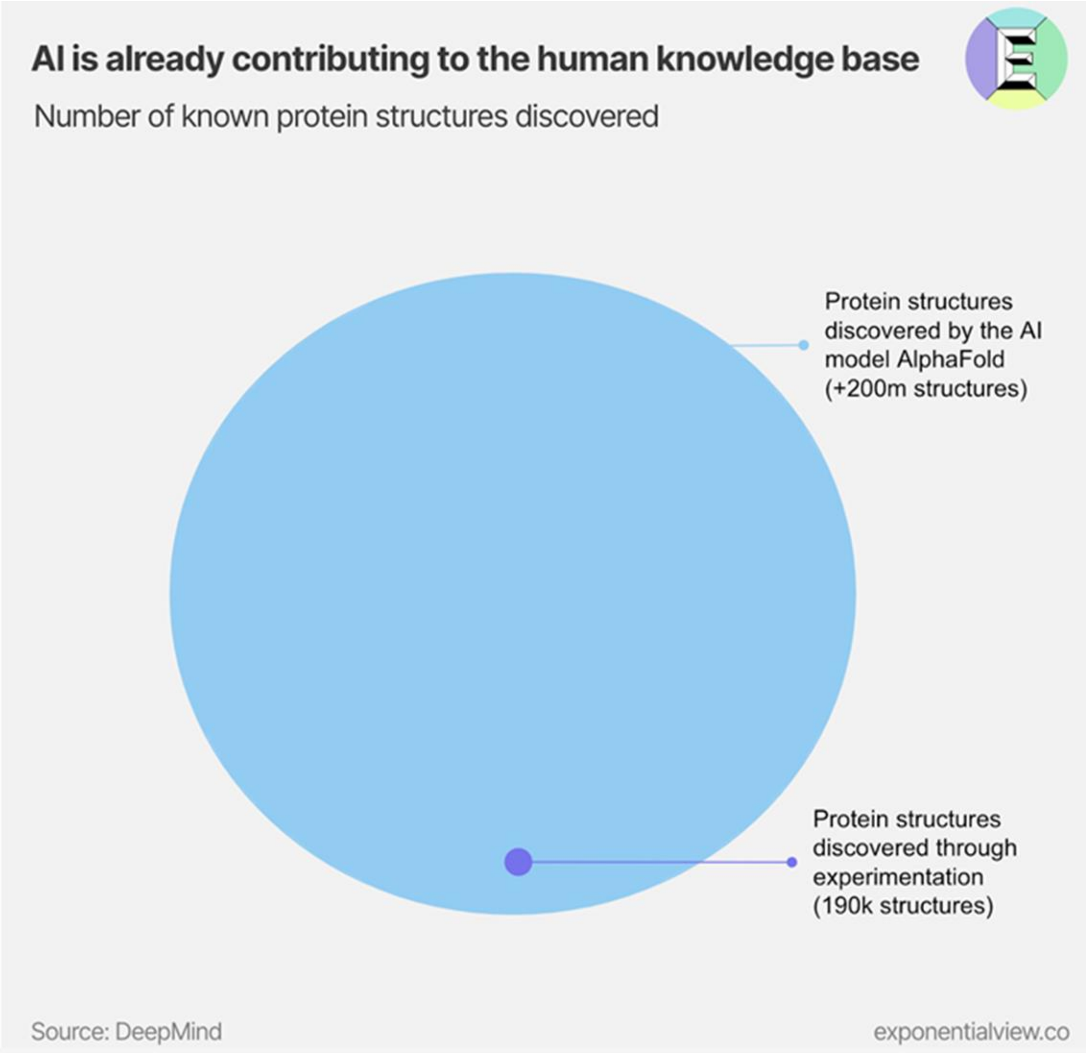



Chart: Exponential View • Source: IDC • Created with Datawrapper


AI is already contributing to the human knowledge base
Number of known protein structures discovered
Protein structures discovered by the AI model AlphaFold (+200m structures)
Protein structures discovered through experimentation (190k structures)
Source: DeepMind
exponentialview.co

## AI is a different form of intelligence

How do you take a massive quantity of streaming data, perform the analysis of it in order to extract what is important and derive the optimal decision base on that data stream in real time?

Only AI could do this.

THE AGENTI

bbycroft.net/llm

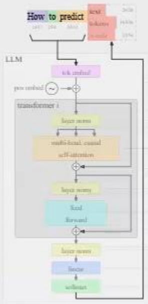
# LLM Visualization

Home

Chapter: Overview

GPT-2 (small) | nano-gpt | GPT-2 (XL) | GPT-3



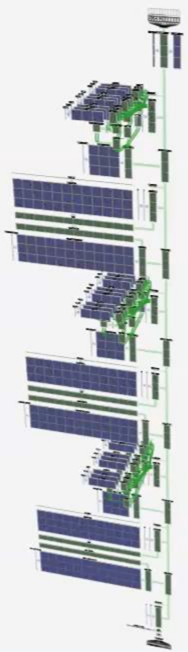



Welcome to the walkthrough of the GPT

Continue | Skip

nano-gpt

n_params = 85,584



To: Araldi, Alessandro <Alessandro.Araldi@tranetechnologies.com>; Tabba, Omar <Omar.Tabba@tranetechnologies.com>

# AI

- A few definitions

Agentic: /əˈd͡ʒɛn.tɪk/, able to make independent decisions in pursuit of a goal. Source: Wiktionary

Agentic AI: uses sophisticated reasoning and iterative planning to autonomously solve complex, multi-step problems. Source: NVIDIA

Autonomous Agents use Agentic AI to independently plan and execute tasks.

Agentic Mesh: an interconnected ecosystem that makes it easy for autonomous agents to find each other, collaborate, interact, and transact.

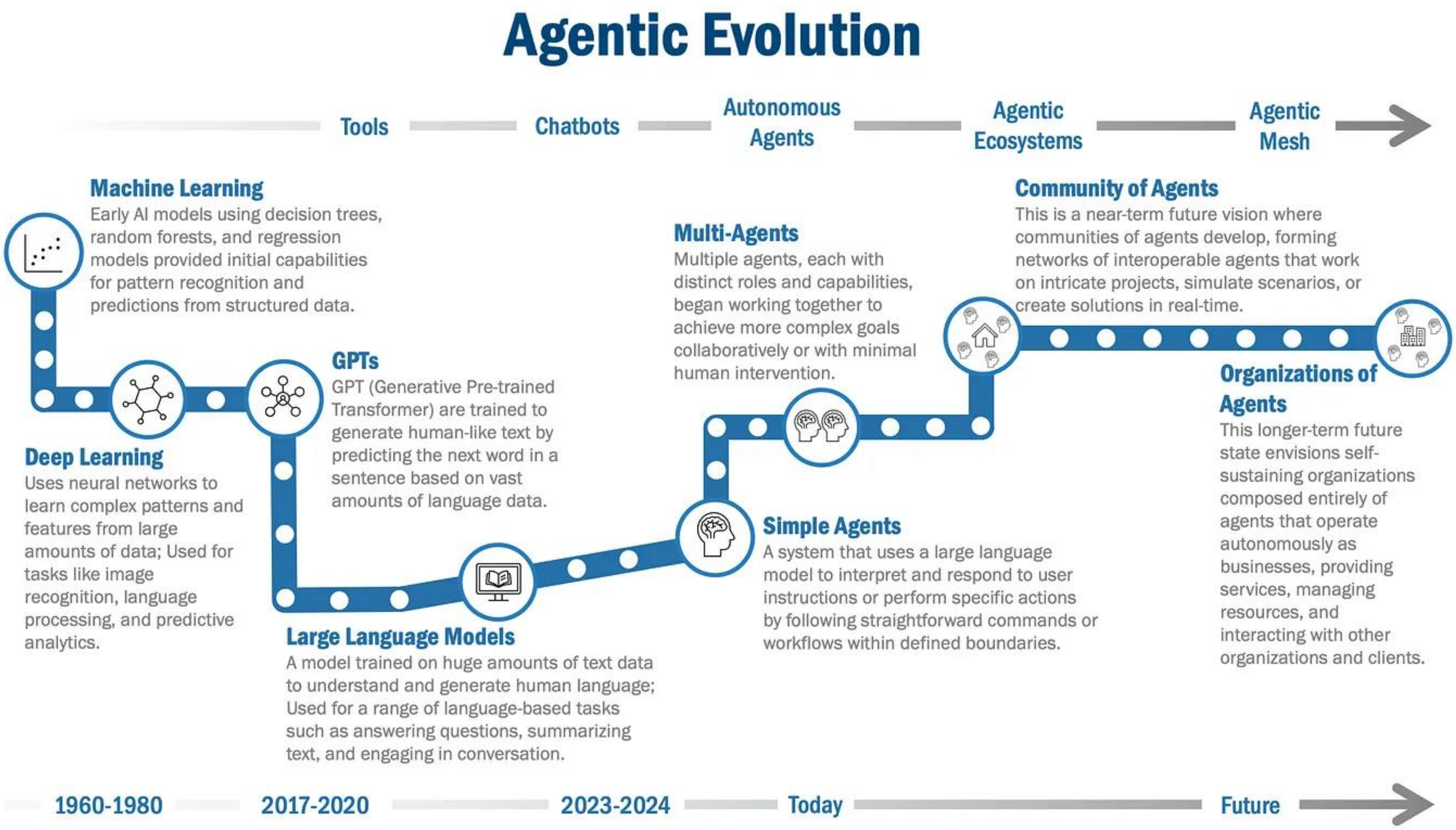
# What is an AI Agent?

- **Definition**: An AI agent is a software entity that perceives its environment, makes decisions and takes actions autonomously to achieve specific goals.

- **Key Features**: Operates with autonomy, adapts to changes, and learns over time using machine learning or other AI techniques. It uses LLM to interact with humans and is capable of deciding on actions to carry out.

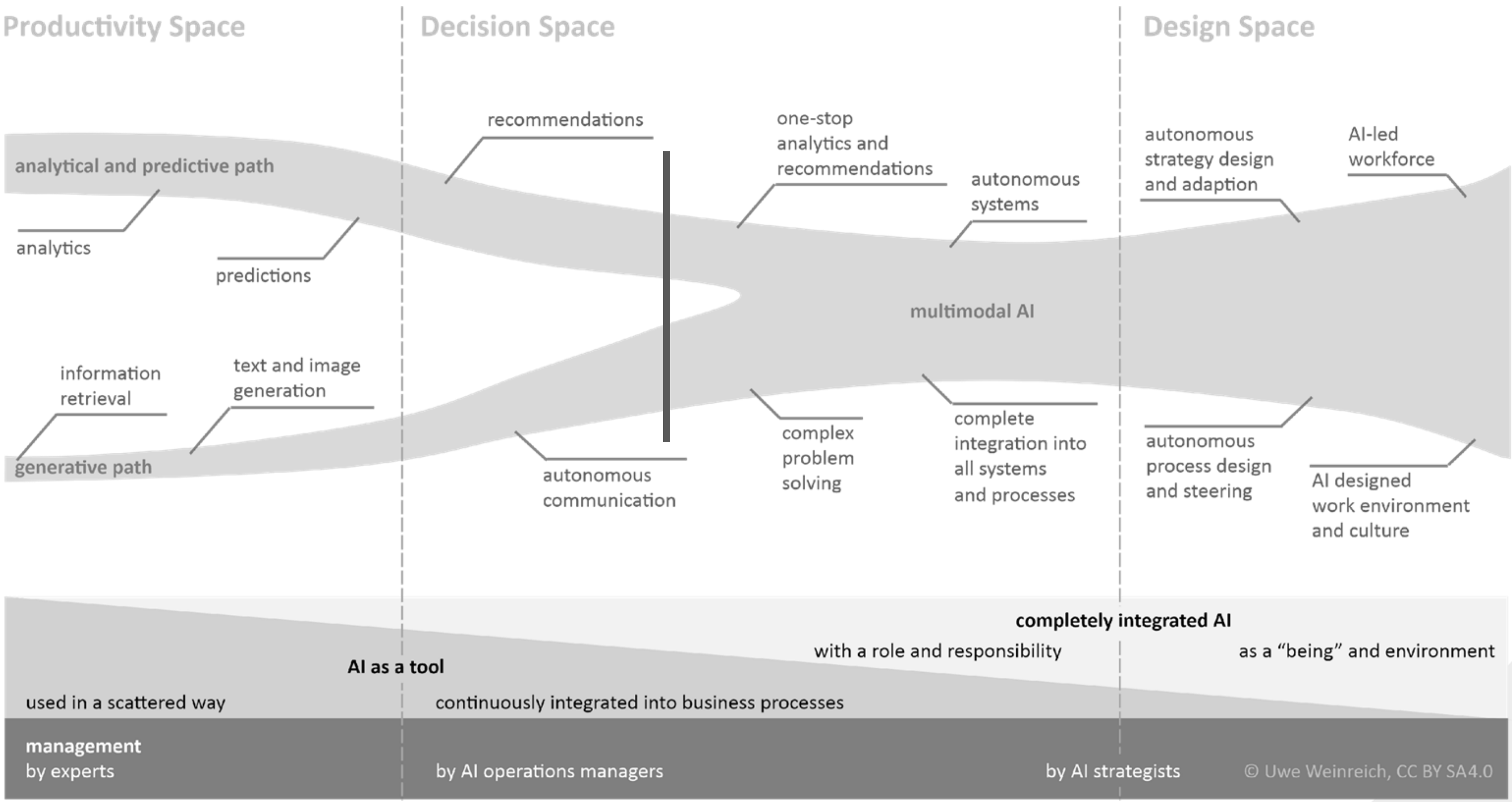
- **Applications**: Used in diverse domains like virtual assistants, robotics, autonomous vehicles, smart buildings, and more.

- **Goal-Oriented**: Designed to optimize outcomes, whether improving efficiency, reducing errors, or enhancing user experiences.

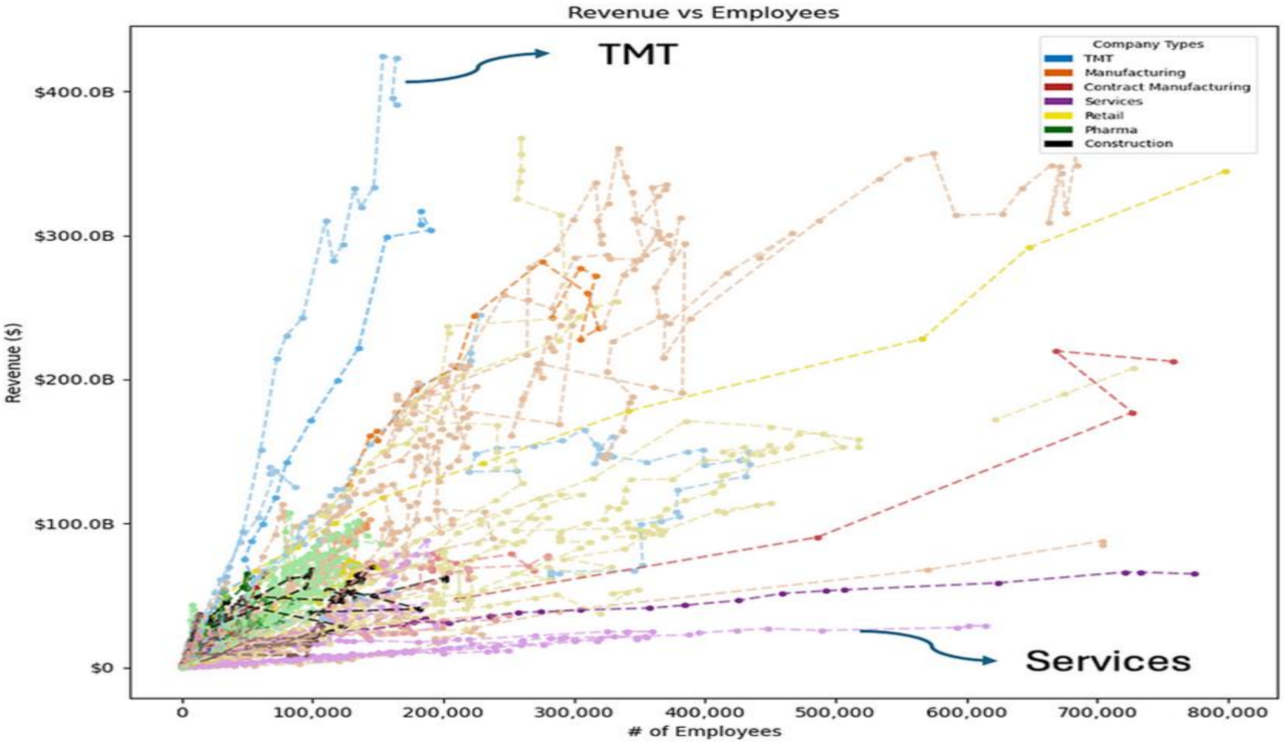

Source: Eric Broda

**AI: The Strategy Game-Changer Everybody is Underestimating – Prepare for impact**
**Uwe Weinreich**



# AI – The productivity story

- Tracking the revenue and number of employees matrix

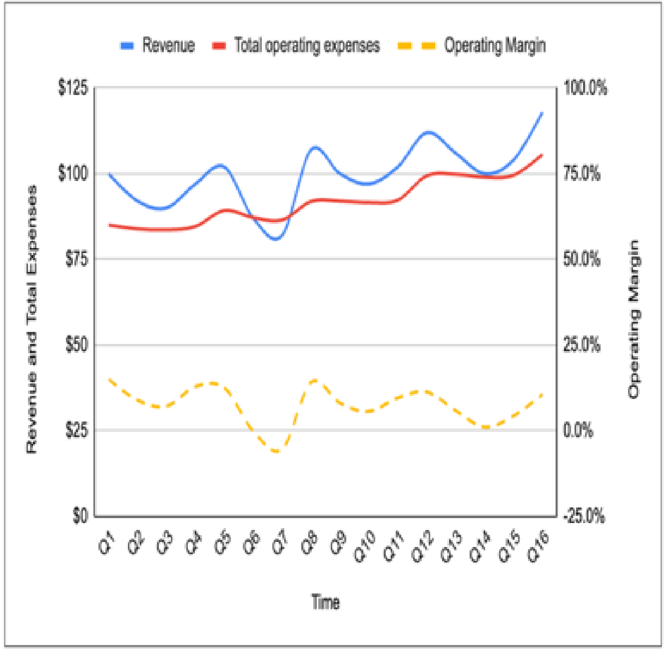


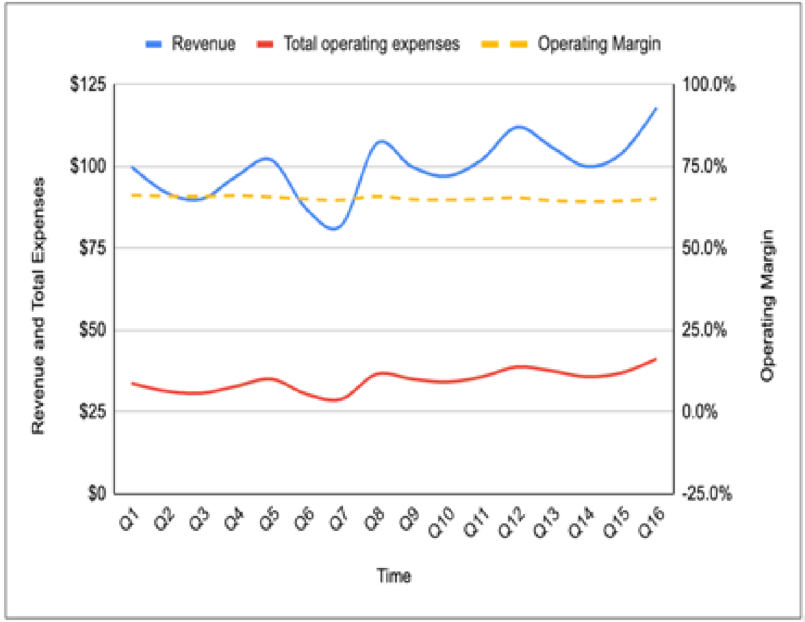

The more automation an organization has, the steeper their productivity curves – they squeeze more from the same capita.

Source: Hemant Mohapatra

# AI – The productivity story

- The transformation of the P&L




Source: Hemant Mohapatra

# AI HVAC
# Optimiza

# Key inputs to service Process in the HVAC world

- Technicians are constantly jumping from one file/ system to another

| Telemetry & Fault Data | Equipment Manuals | Workorder & Asset Data | Parts Data |
|---|---|---|---|
| What's the temp in this zone? | How do I replace this sensor on this unit? | What's the make/model?<br><br>When was this unit last serviced? | What part do I need? |

# Slashing issue resolution time

- Scenario: Hot call received from retail store manager in Boise, Idaho

## Current State

- Search queries on EMS system to create a chart for the space and outdoor air temperature
- Identify which pieces of equipment are feeding that space; see if EMS/BMS is showing faults on that equipment - limited to what is exposed on front end
- Log make & model number of equipment
- Calculate equipment runtime
- Visit the site to start "HVAC CSI" process
- Determine issue, order new parts; more than 1 visit to site

▪ **2 hours of discovery work & 1 initial site visit = $570 (1)**
▪ **Substantially less information available**

## AI Agent

- ***Ask Agent to create a summary of the unit performance including all relevant charts and faults over a recent period***
- ***Before visiting site, the Agent will assemble a summary of all issues found and parts most likely needed based on historical work orders***
- ***Agent shuts down equipment or part of it until issues are fixed, or parts can be received***

▪ **2 hours discovery time reduced to 10 minutes & initial site visit eliminated = 98% or $558 in cost savings (2)**
▪ **Complete information available**

1) Includes 2 hours discovery work ($150) and initial visit (2 hours for $230 + travel charge of $115+ truck charge of $75 = $420).
2) Includes 10 minutes of discovery work ($12) and initial site visit eliminated.

# Slashing issue resolution time

## Scenario: Hot call received from retail store manager

**CURRENT STATE**

01
SEARCH QUERIES →
On EMS & create a chart for space & outdoor air temperature

02
IDENTIFY FAULTS →
In the equipment from limited front end exposure from EMS/BMS

03
LOG INFORMATION
About the faulty equipment's make & model

04
CALCULATE RUNTIME →
For equipment

05
VISIT SITE →
And run a "HVAC CSI" investigation

06
DETERMINE ISSUE
Order required parts

**AI Agent**

01
ASK Agent →
To summarize unit performance, including charts & recent faults

02
ASK Agent →
To compile a report of issues & needed parts all before the site visit

03
ASK Agent
To pause equipment until issues are fixed or parts arrive to prevent further damage

* Includes 2 hours discovery work ($150) and initial visit ($420 from 2 hours of work ($230) + travel ($115) + truck charge ($75))
** Includes 10 minutes of discovery work ($12) and initial site visit eliminated

CURRENT STATE

$570*

2 hour discovery

Site visit(s)

Lack of insights

Agent

$12**

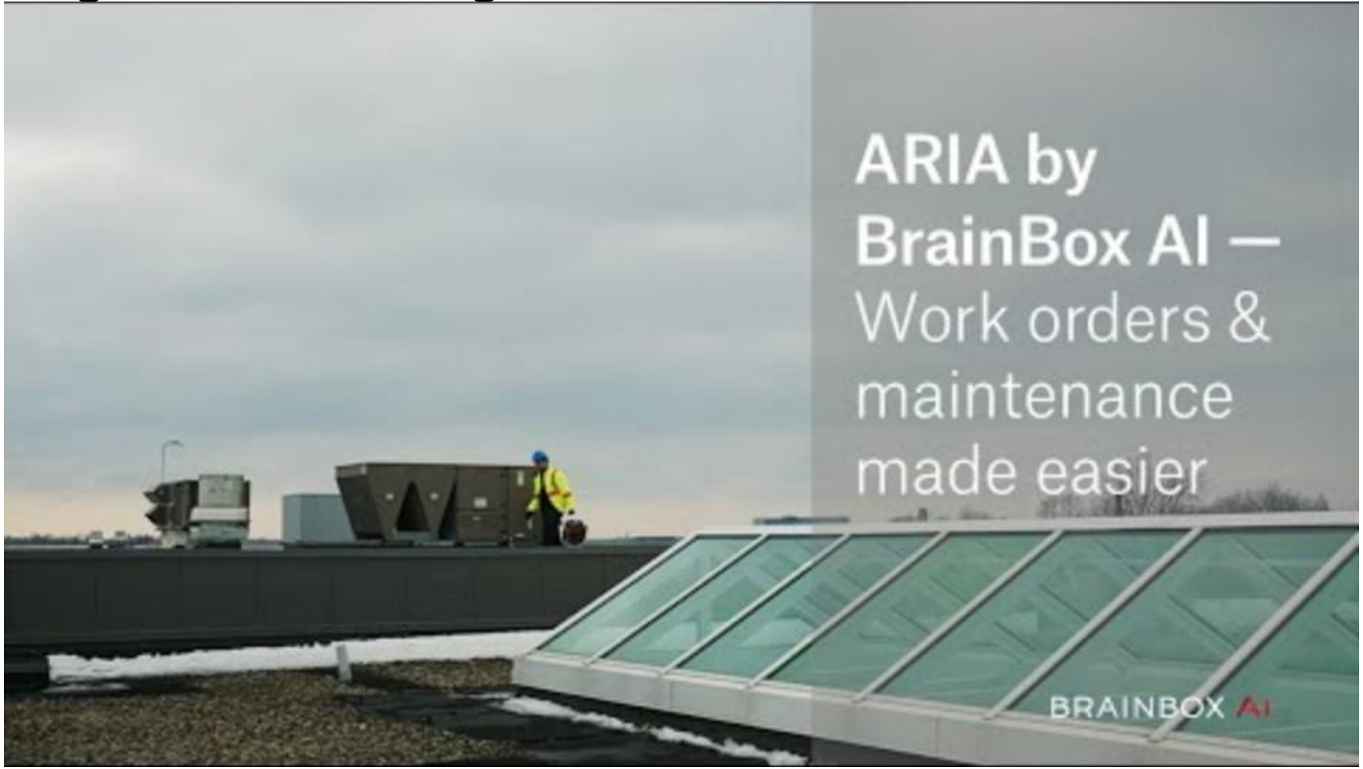
10 minute discovery

No initial site visit

Clear procedure & part list

# What a virtual engineer look like?

- Reducing troubleshooting from 2 hours to 2 minutes



# Every modern business will be a data business

Are you ready?

# Questions (True or False?)

Jean-Simon Venne
Chief Technology Officer
js.venne@brainboxai.com
https:  brainboxai.com

1. AI can perform real-time data analysis and decision-making.
2. The presentation highlights AI’s productivity gains, including the transformation of the P&L.
3. The presentation includes a scenario in which AI agents can reduce discovery work from 2 hours to 10 minutes.
4. The presentation mentions that AI can help in tracking revenue and the number of employees.
5. The Agentic Ecosystem is an evolution of Agentic Mesh.

# Than

BRAINBOX AI


- Jean-Simon Venne
  Chief Technology Officer
  js.venne@brainboxai.com

  https://brainboxai.com

# Secti

# Title

# THANK YOU

## PDH Request Form

THE VIRTUAL ENGINEER WORLD

https://forms.office.com/r/zQCBYD2Snh

## Presentation Evaluation Form

https://form.jotform.com/212628858013154

# Removing the Artificial from Artificial Intelligence: Scalability Requirements and Examples of AI in Building Operations

Jayson Bursill, Ph.D., P.Eng.

jbursill@deltacontrols.com

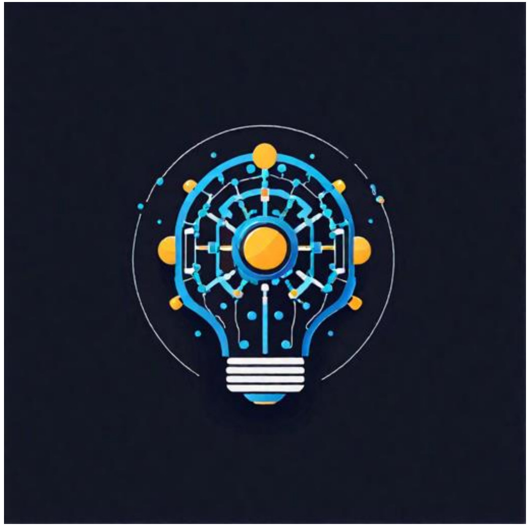
Delta CONTROLS A Brand of Delta

# Learning Objectives

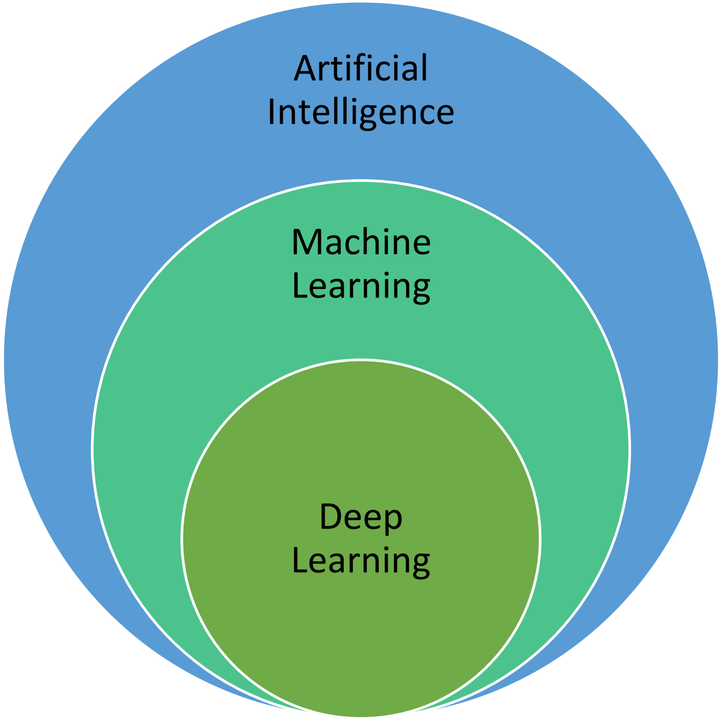
- Define Artificial Intelligence
- Distinguish between different applications of AI in Controls
- Understand the challenges and limitations of implementing AI in the field
- Define the requirements for field implementations of model-based predictive control

# Outline/Agenda

- Defining Artificial Intelligence, Machine Learning, and Deep Learning
- History and the “Booms & Busts” of Artificial Intelligence
- Scalability Requirements
- Machine Learning Applications
    - Sensor Fusion
    - BAS with Large Language Model
    - AI-assisted Coding
    - Predictive Control



# What is "AI"?

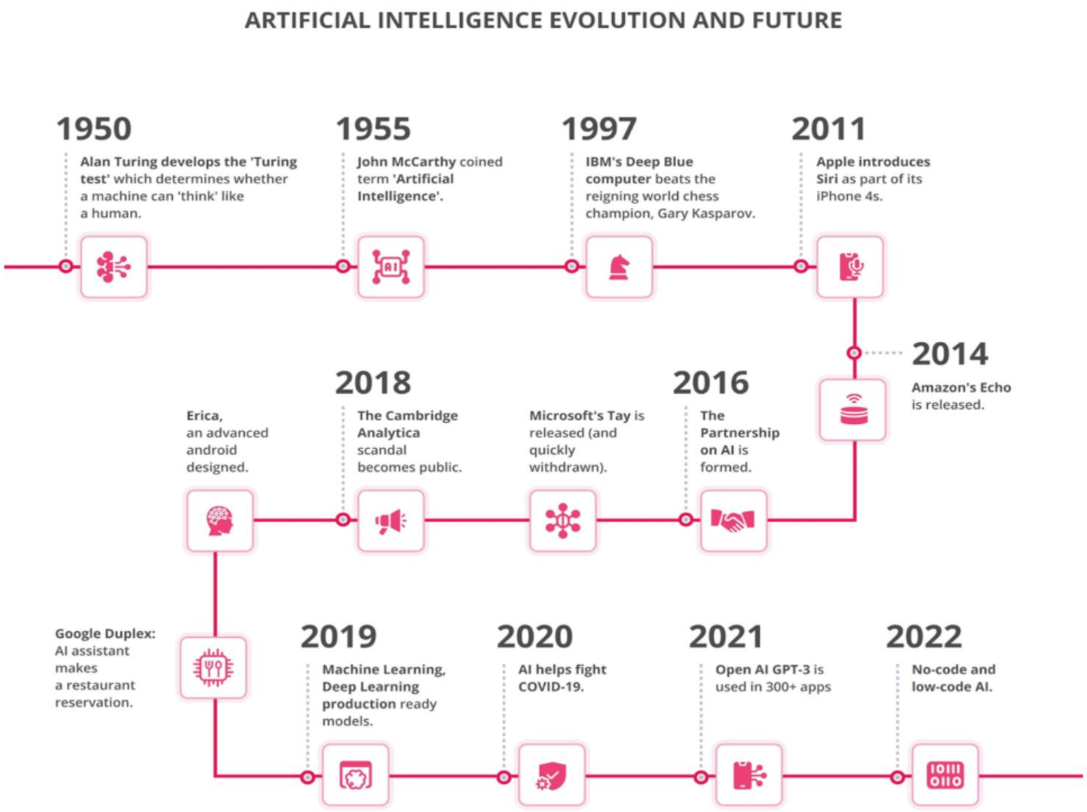



Ability of machine to imitate intelligent human behavior

Application of artificial intelligence that allows a system to learn and improve using data

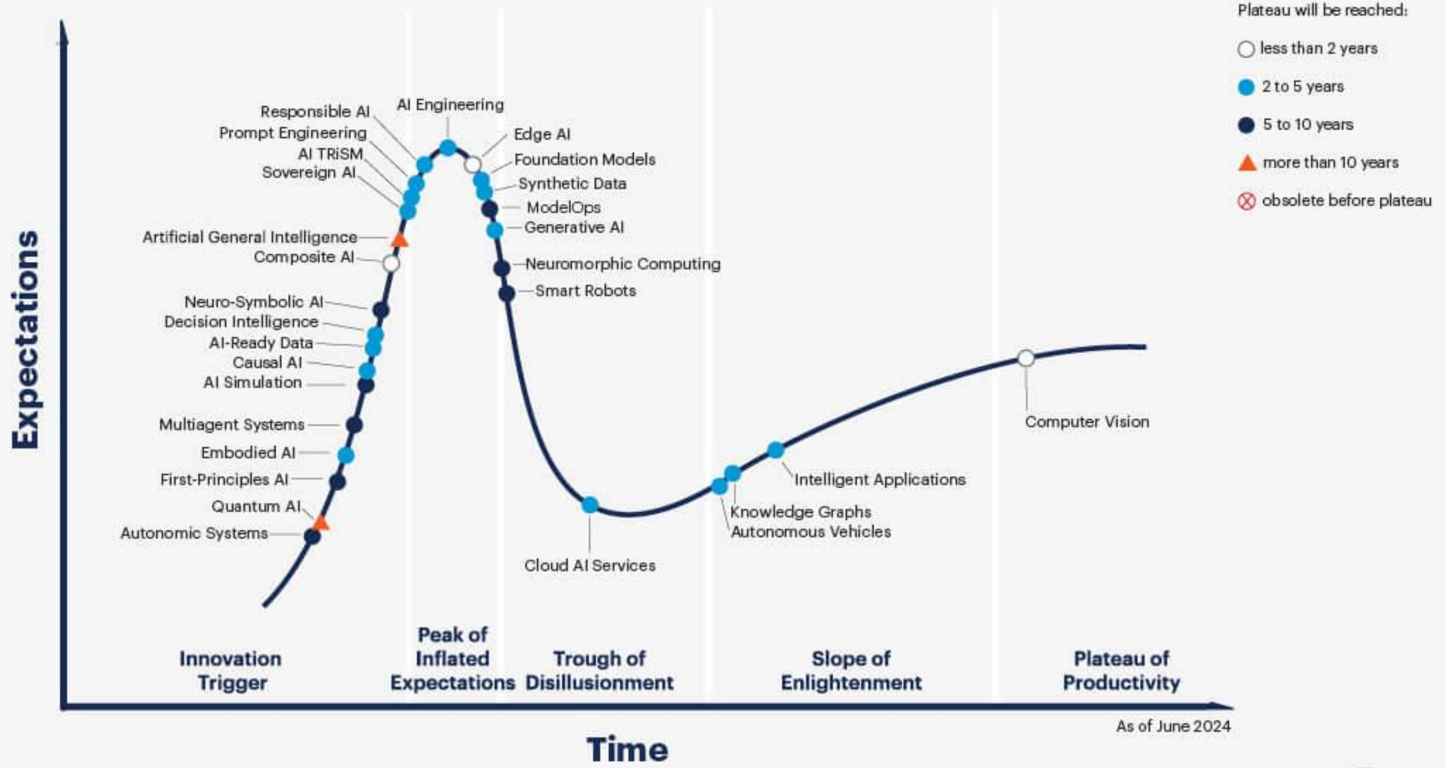
Application of machine learning that uses complex algorithms and usually artificial neural net-based models

# AI History Timeline




https://globalfintechseries.com/artificial-intelligence/what-is-artificial-intelligence-ai/

# Hype Cycle for Artificial Intelligence, 2024




Source: Gartner


Gartner

# AI Booms and Busts

**Boom 1:**

- Powerful electronic digital computers after WWII

**Bust 1:**

- Reduced funding and interest in AI research
- Overly optimistic predictions

**Boom 2:**

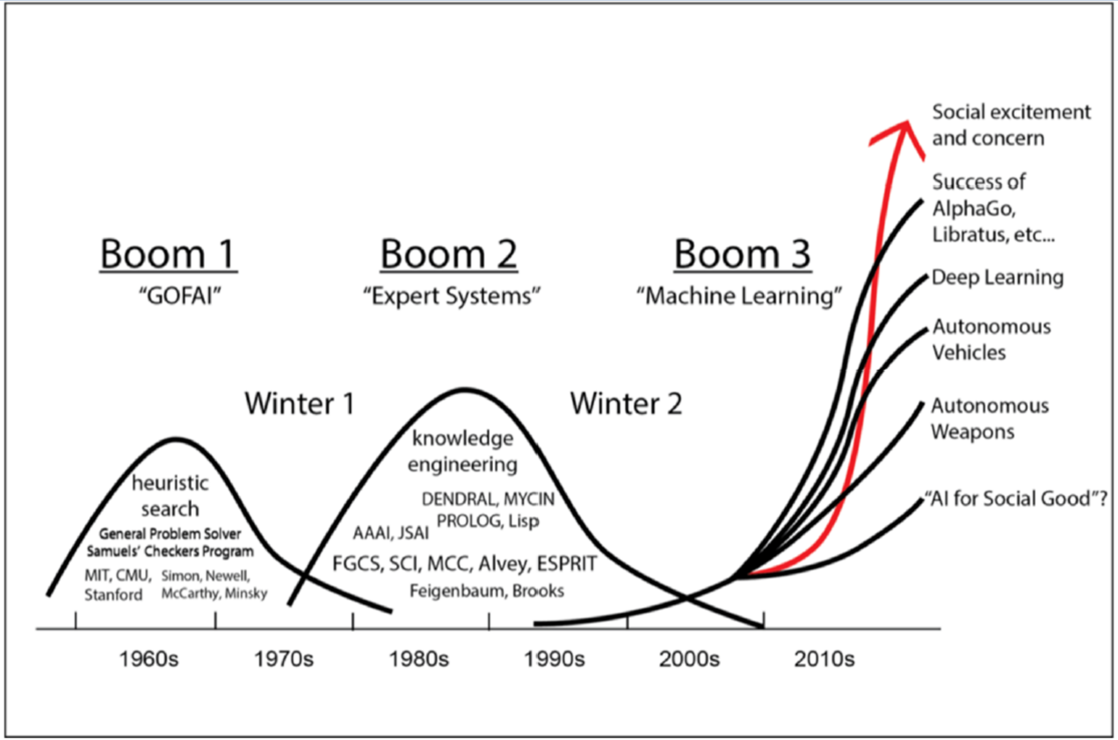
- Personal Computing
- Expert systems
- Surge in AI funding
- Japan's Fifth Generation Computer project

**Bust 2:**

- Limitations to expert systems
- End of the Cold War which cut government AI funding

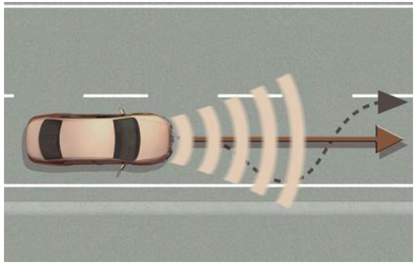
**Boom 3:**

- Parallel compute through video cards
- Combination of public and private capital investments




**"AI in HVAC Industry: Past, Present and Future"**
**Krishnan Gowri**, *Ph.D., Fellow ASHRAE*
Director of Building Performance, Intertek

# Some Modern Applications

Open-mindedness is often celebrated as a hallmark of intellectual curiosity and critical thinking. The ability to consider multiple perspectives, question assumptions, and remain receptive to new ideas is seen as a valuable skill in both personal and professional contexts. However, as with any virtue, open-mindedness can become problematic when taken to an extreme.

```python
import datetime

def parse_expenses(expenses_string):
    """Parse the list of expenses and return the list of triples (date, value, currency).
    Ignore lines starting with #.
    Parse the date using datetime.
    Example expenses_string:
        2016-01-02 -34.01 USD
        2016-01-03 2.59 DKK
        2016-01-03 -2.72 EUR
    """
    expenses = []
    for line in expenses_string.splitlines():
        if line.startswith("#"):
            continue
        date, value, currency = line.split(" ")
        expenses.append((datetime.datetime.strptime(date, "%Y-%m-%d"),
                         float(value),
                         currency))
    return expenses
```

# How Can Algorithms be Scaled in Buildings?

- <u>**We need to “remove the Ph.D. from the loop”**</u>
- Machines need to identify systems
- Machines need to tune system models
- Optimization constraints and parameters need to be presented in an operator-intuitive fashion
- Implementation should begin with simple problems that are common (in this case, bottom-up)
- Implementation should be compatible with contemporary supervisory control (e.g., ASHRAE Guideline 36)

# How Can Algorithms be Scaled in Buildings?

- **We need to "remove the Ph.D. from the loop"**
- Machines need to identify systems
- Machines need to tune system models
- Optimization constraints and parameters need to be presented in an operator-intuitive fashion
- Implementation should begin with simple problems that are common (in this case, bottom-up)
- Implementation should be compatible with contemporary supervisory control (e.g., ASHRAE Guideline 36)

# Emerging Standards for Controls and Metadata

ASHRAE

- Guideline 36: High Performance Sequences of Operation for HVAC Systems
- Standard 223P: Semantic Data Model for Analytics and Automation Applications in Buildings
- Standard 231P: CDL - A Control Description Language for Building Environmental Control Sequences

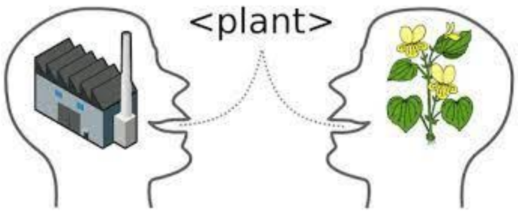
Other

- Brick
- Project Haystack

# Semantic Interoperability

## Goal: Data ownership and streamlined AI deployment

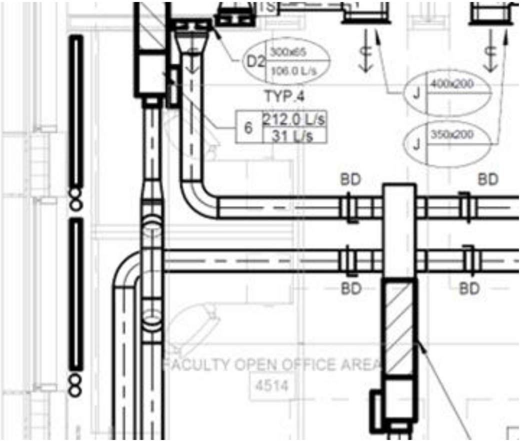
- System: BACnet and other protocols or tools
    - Transport or presentation
- Syntactics: Ontology
    - Dictionary/Language
- Structural: Specifications
    - Structure of the metadata
- Semantic: Context
    - Application of definitions



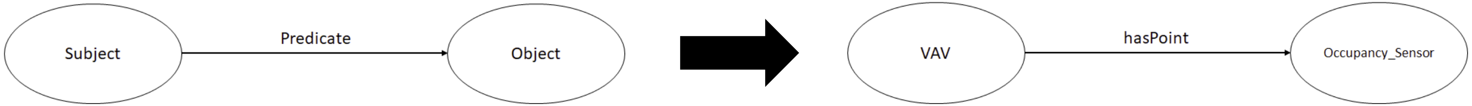

Data → Information → Knowledge

# Metadata Data Sources

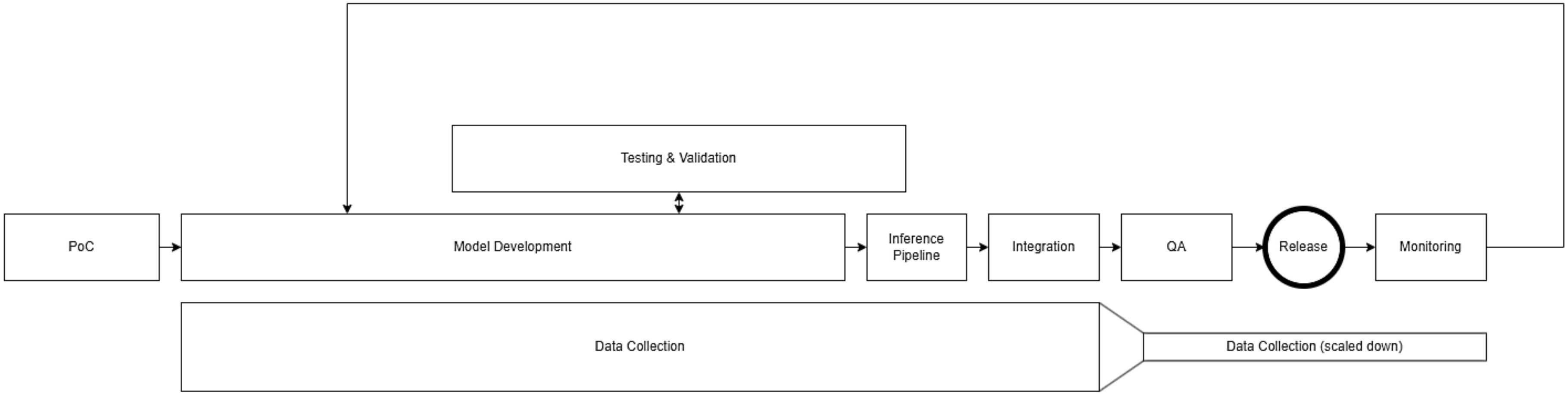
- Building data:
  - BIM architecture and equipment schedules
  - BAS specs
  - Physical I/O
  - Parameters (AV, BV, MV)
  - Algorithms (e.g., guidelines or templates)
- Public metadata libraries/ontologies:
  - Brick/ RealEstateCore (based on Semantic Web)
  - Haystack (based on markers)




| AIR HANDLING UNIT SCHEDULE | | | | |
|---|---|---|---|---|
| NO. | | | AHU-01 | AHU-02 |
| LOCATION | | | WEST ROOF | EAST ROOF |
| SERVICE | | | LEVEL 200 & 300 | LEVEL 400 |
| MANUFACTURER | | | ENGINEERED AIR | ENGINEERED AIR |
| SUPPLY FAN | AIR FLOW | L/s | 9821 | 5147 |
| | | CFM | 20800 | 10900 |
| | MAXIMUM OUTDOOR AIR | L/s | 2016 | 162 |
| | | CFM | 8100 | 650 |
| | MINIMUM OUTDOORR AIR | L/s | 995 | 162 |
| | | CFM | 4000 | 650 |
| | EXTERNAL STATIC PRESSURE | kPa | 0.5 | 0.62 |
| | | in WC | 2 | 1 |
| | MOTOR | kW | 11 | 6 |
| | | HP | 15 | 7.5 |
| | FLA | | 23 | 31 |
| | VOLTAGE | | 460/3/60 | 460/3/60 |
| | QUANTITY | | 2 | 1 |



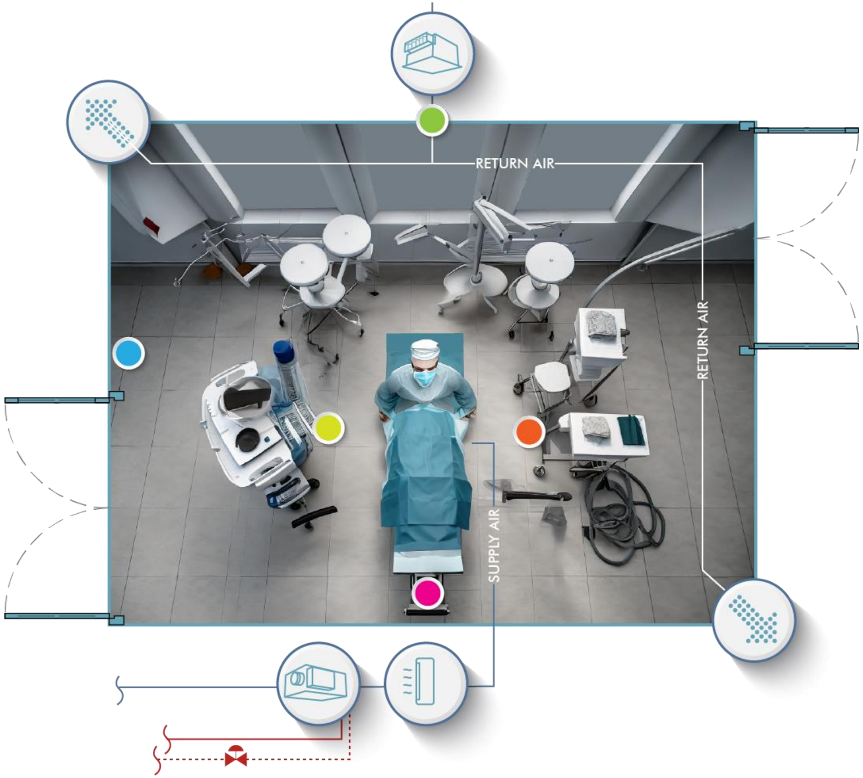
# AI System Validation Process



# AI Applications – Temperature Sensor Fusion

**Code Requirements ASHRAE 170 for Operating Rooms:**

- Primary supply air over patient bed
- Laminar Airflow 25-35 cfm/ft²
- Returns located opposite corners of room, ~8” AFF
- 20-30 ACH
- Positive Pressure +0.01” WC
- Individual Controls
- 20-60% RH
- 68-75°F
- HEPA Filtration

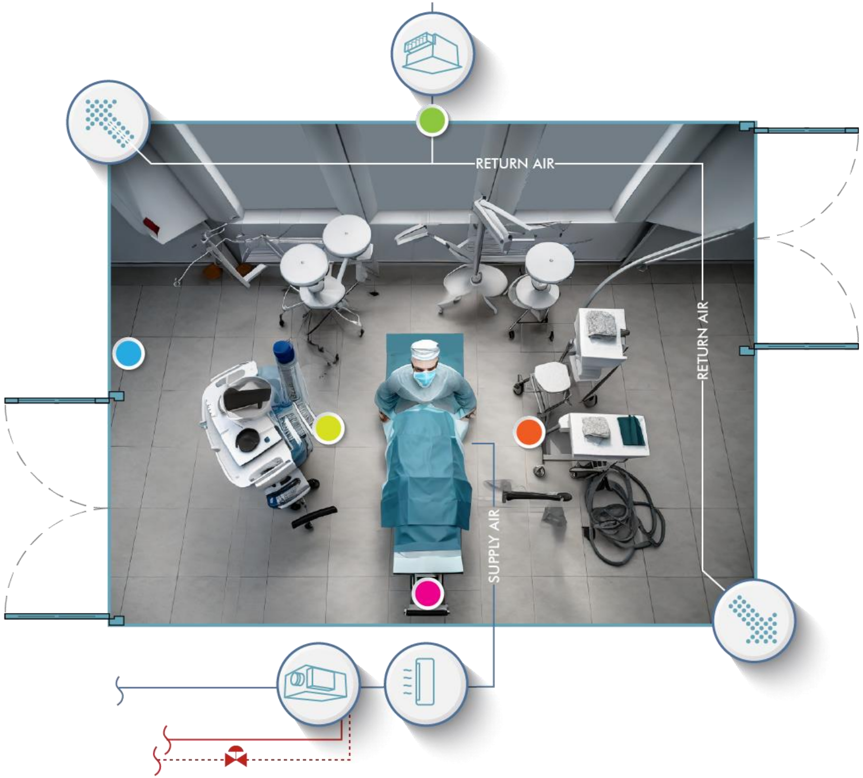


# AI Applications – Temperature Sensor Fusion

**TEMPERATURE/SENSOR LOCATION**

- Return Duct
- Wall Sensor
- #1 Ceiling Mounted Cluster
- #2 Ceiling Mounted Cluster
- #3 Ceiling Mounted Cluster

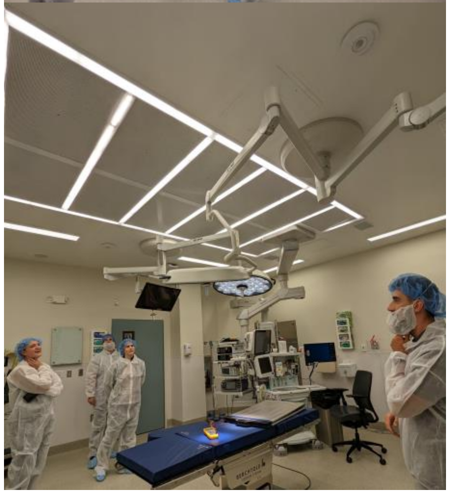
| Sensor | Description |
|---|---|
| Composite Temperature | The estimated occupant temperature based on air temperature and IR temperature. |



# AI Applications – Temperature Sensor Fusion

**Operating Room Case Study Summary:**

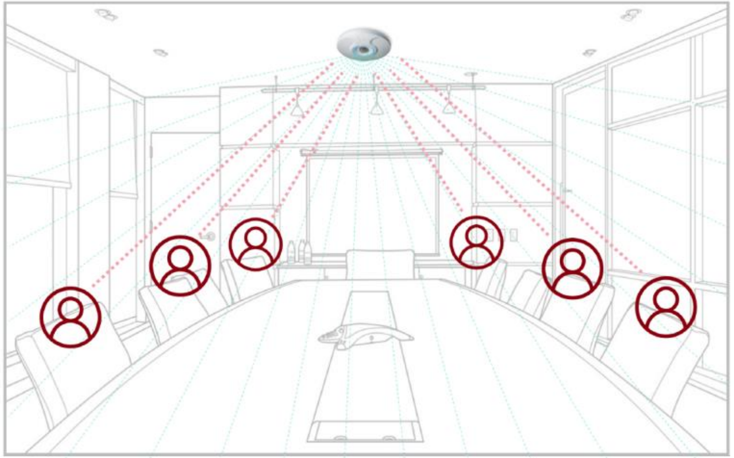
- Significantly **less 'hunting'** of discharge air temperature,
  - **Energy savings** and **greater comfort** for surgeons and staff.
- The sensor cluster is very **responsive** to set-point and space temperature changes
  - Maintains a **steady temperature** in the operating room.
- The sensor clusters are more **accurate** for space temperature in the Operating Room.
  - On average the return and the wall sensor were reading 3F and at worst 8F cooler than the sensor cluster
  - A recorded surgery out of code **compliance** at 64F was potentially still within compliance at the surgical site.
- Ceiling mounted sensors will not be impacted by **room cleaning**.
- **Air curtain** around surgical field does not have a significant influence on readings from the sensor clusters.

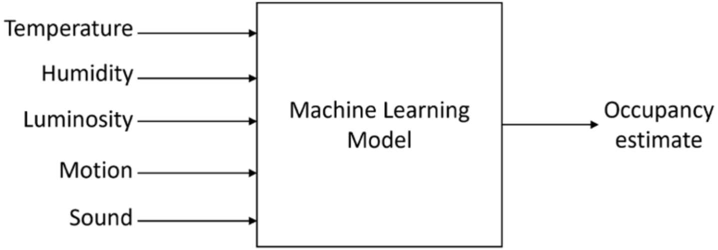


# AI Applications – Occupancy Sensor Fusion

- How can occupancy be estimated without a camera?

| Sensor | Description |
|---|---|
| Composite Temperature | The estimated occupant temperature based on air temperature and IR temperature. |
| Relative Humidity | The occupant height adjusted relative humidity computed from an onboard RH sensor and the composite temperature. |
| Luminosity | Light intensity measured from an onboard light and color sensor. |
| PIR Sensor | Standard PIR sensor |
| Microphones | Two digital MEMs microphones |

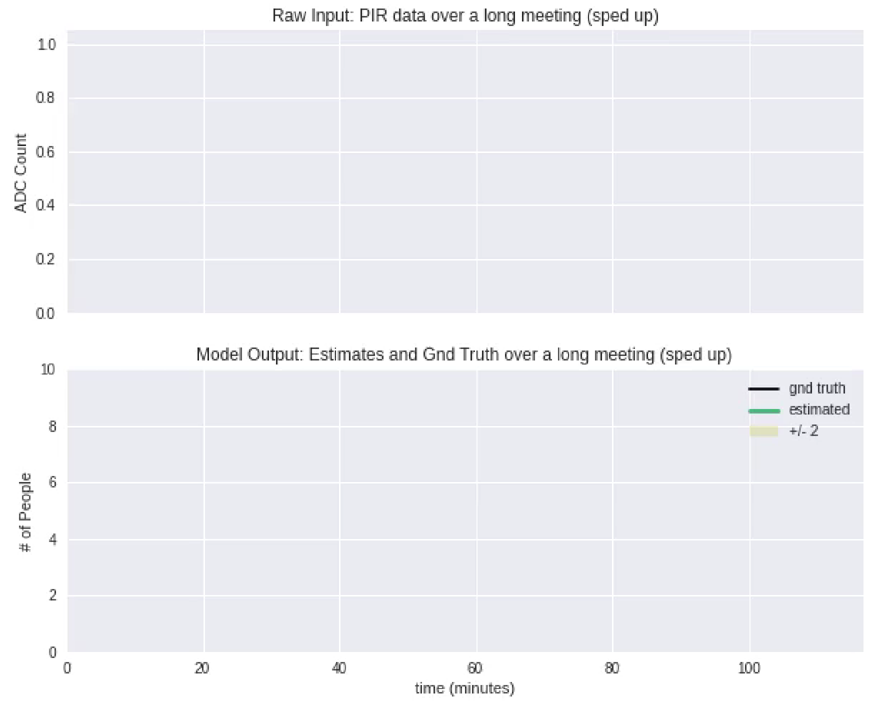


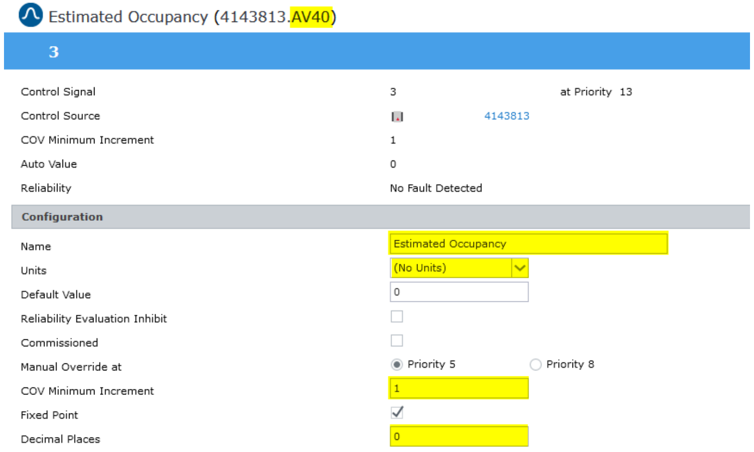



$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - x_i|$$

$$PW2 = \frac{n_{error<2}}{n_{total}}$$

# AI Applications – Occupancy Sensor Fusion

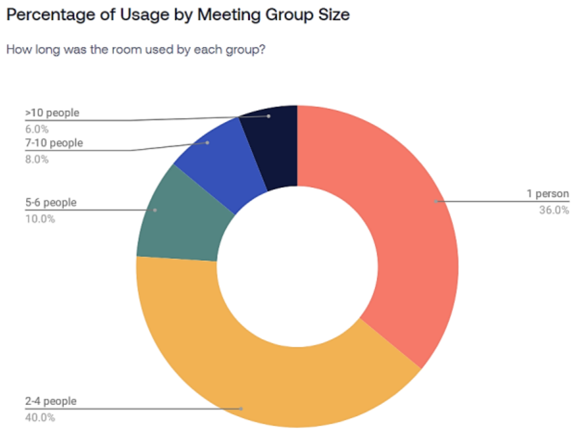


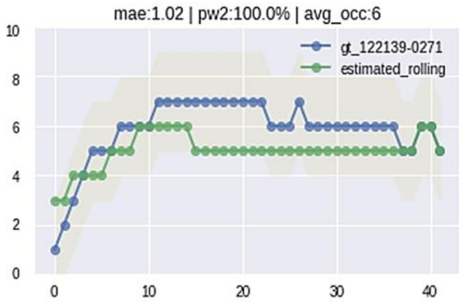




- Privacy preserving, self-contained, approximate-people-counting solution
- Uses machine learning model to estimate # of occupants from a noisy PIR sensor
- Approximate but useful
- Close enough for most applications
- Currently in the process of expanding this technology

# AI Applications – Occupancy Sensor Fusion

We learned that 86% of meetings contain 6 or less occupants




How many in the field?

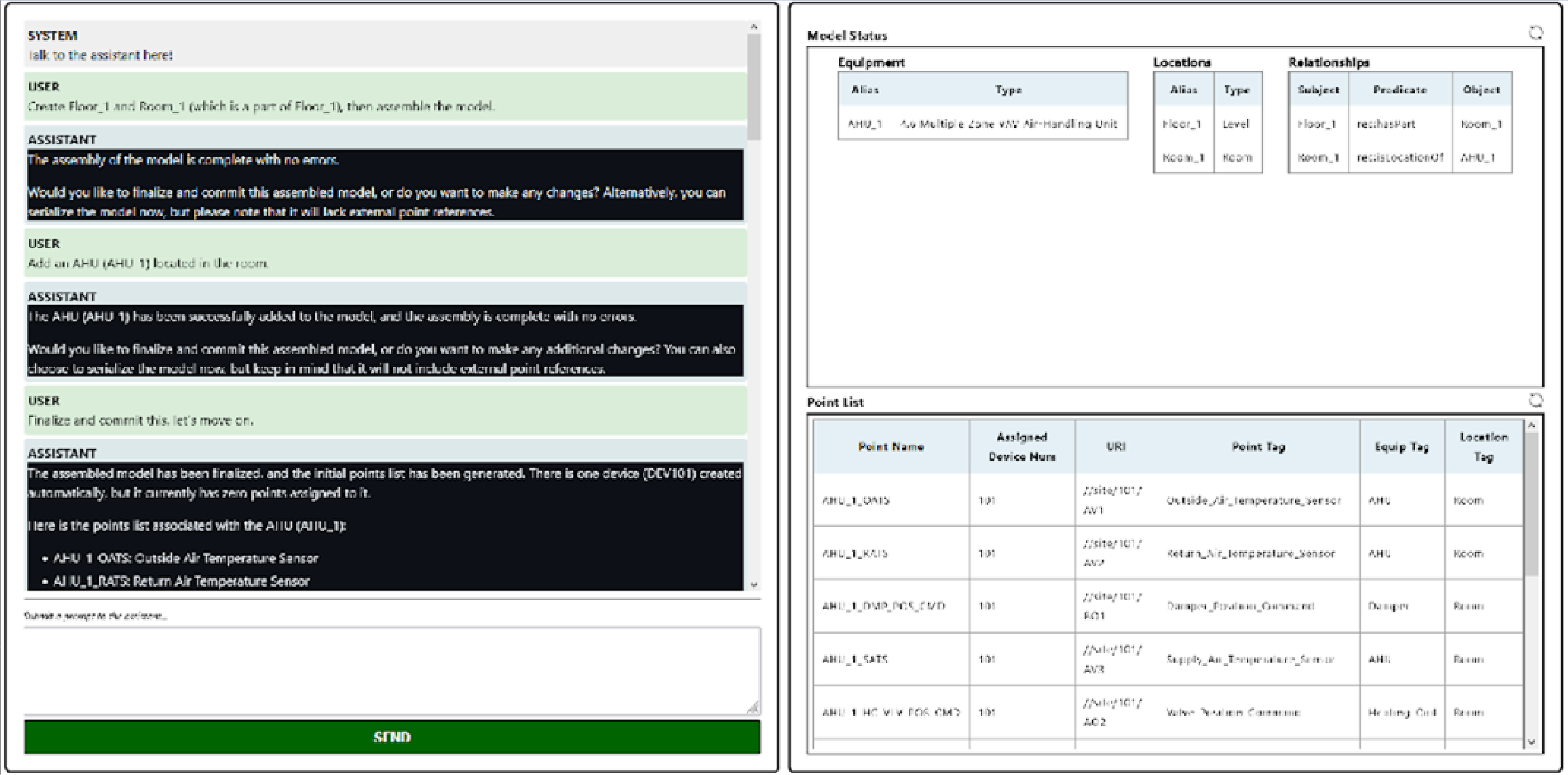
# Generative AI Disclaimer


Please note that the use of generative artificial intelligence (AI) using large language models (LLM) in analysis is subject to the following conditions:

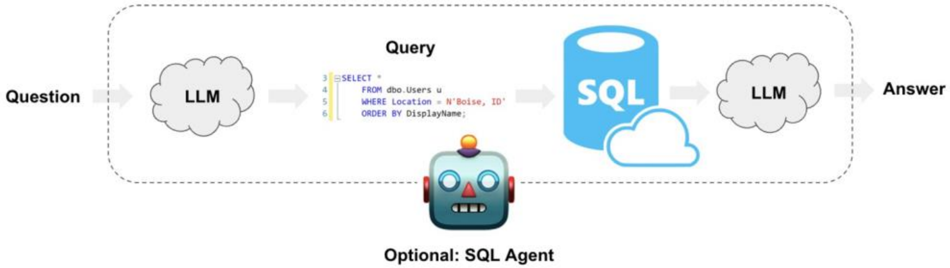
- **Accuracy:** While generative AI strives to provide accurate and insightful data analysis, it is not infallible. The results should be cross-verified for accuracy.
- **Data Sensitivity:** Generative AI may not fully comprehend the sensitivity or context of the data it analyzes. Users are responsible for ensuring the appropriateness of the data used.
- **Bias:** AI models may unintentionally incorporate biases present in their training data. Users should be aware of potential bias in the results.
- **Interpretation:** The interpretation of the results generated by AI requires expertise in the relevant field. Misinterpretation of the results can lead to incorrect conclusions.
- **Responsibility:** The user assumes full responsibility for any decisions or actions taken based on the results generated by the AI.

*"It's almost like talking to real people."* – Someone at ASHRAE

# Creating Semantic Data Models with AI

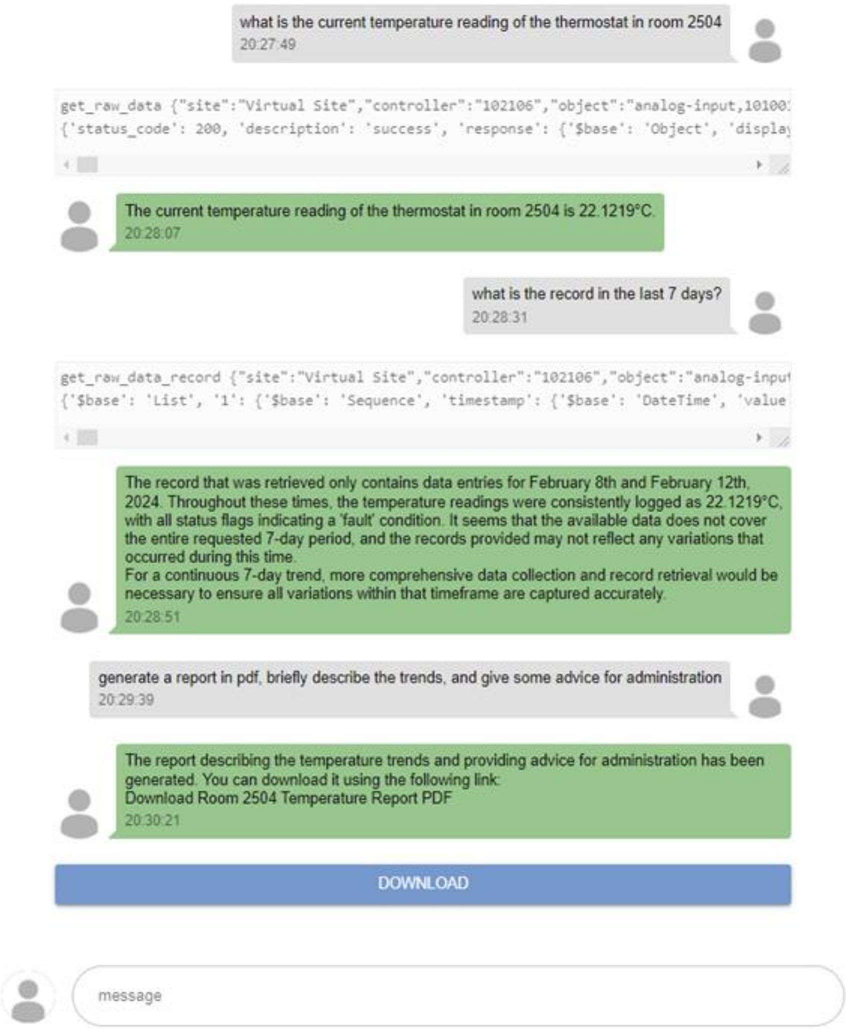


# Using Semantic Data Models





- Tools:
  - BOT Framework
  - GPT 4 Turbo JSON API and Function Calling
  - Building data via BACnet API




# Using Semantic Data Models(cont.)

**Temperature Reading Report for Room 2504**

Report Summary

This report provides an overview of the temperature readings in Room 2504 from the system's records.

Trend Analysis:

The available data shows consistent temperature readings of 22.1219°C throughout the observed time frame (February 8th and 12th, 2024). All log entries indicate a 'fault' status, suggesting that the readings may not fully represent actual conditions.

Advice for Administration:

- Given the consistent 'fault' status flags, it is imperative to conduct an immediate inspection of the temperature sensors and associated equipment in Room 2504 to ensure they are operating correctly.

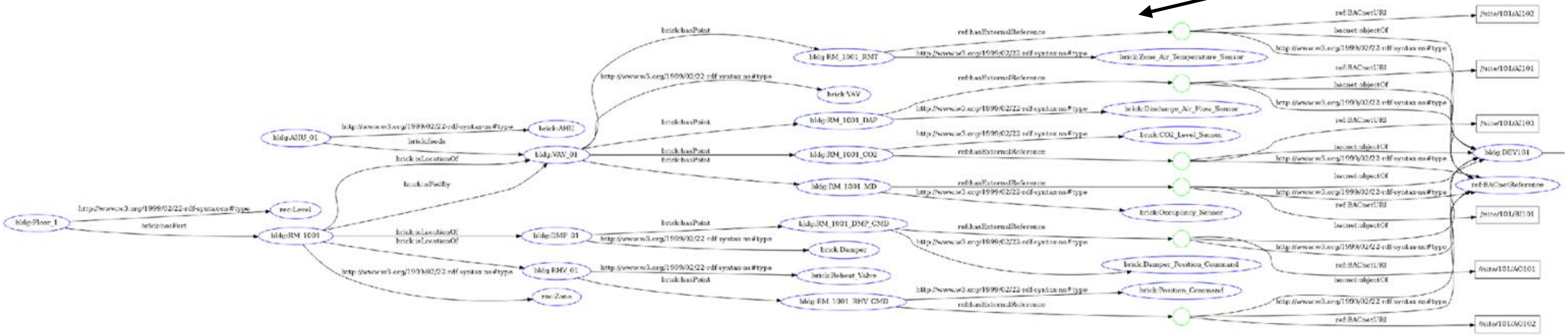
- Implement a more rigorous monitoring and maintenance schedule for the HVAC systems to prevent potential failures and ensure accurate temperature readings.

- Consider incorporating redundant temperature sensors for critical areas like Room 2504 to provide a fallback option in case of sensor malfunctions, enhancing reliability.

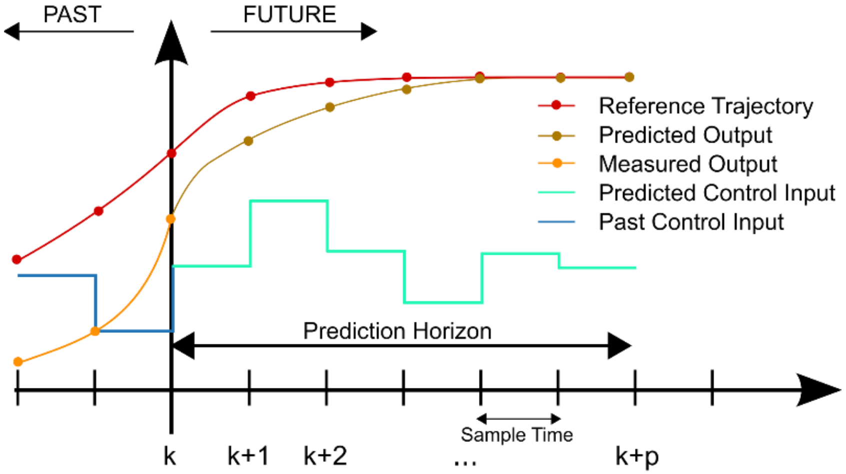
# Connecting Tabular Data to Semantic Data Models

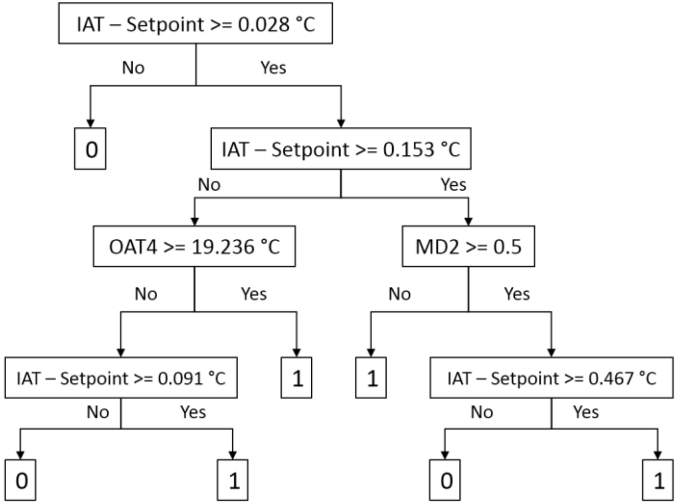
| BACnet_Controller | Point Entity | Point Class | Equipment Class | Location Class | Equipment Entity | Location Entity | bacnet:object-identifier |
|---|---|---|---|---|---|---|---|
| 102101 | 102101_ME_EDC_RM2500_RMT | air_temperature_sensor | thermostat | entrance | RM2500-WallThermostat-thermostat | RM2500 | analog-input,101001 |
| 102101 | 102101_ME_EDC_AHU01_RM2500_VAV_DPS | air_differential_pressure_sensor | vav | entrance | RM2500-Type-04-vav | RM2500 | analog-input,1101 |
| 102101 | 102101_ME_EDC_RM2500A_FFH_AMP | current_sensor | radiant_panel | entrance | FFH-02-radiant_panel | RM2500A | analog-input,1205 |
| 102101 | 102101_ME_EDC_RM2500A_RMT | air_temperature_sensor | hvac_equipment | entrance | RM2500A-WallSensor-hvac_equipment | RM2500A | analog-input,1206 |
| 102102 | 102102_ME_EDC_RM2501_RMT | air_temperature_sensor | thermostat | atrium | RM2501-WallThermostat-thermostat | RM2501 | analog-input,101001 |
| 102102 | 102102_ME_EDC_AHU01_RM2501_VAV_DPS | air_differential_pressure_sensor | vav | atrium | RM2501-Type-10-vav | RM2501 | analog-input,1101 |
| 102103 | 102103_ME_EDC_RM2502_RMT | air_temperature_sensor | thermostat | hallway | RM2502-WallThermostat-thermostat | RM2502 | analog-input,101001 |
| 102103 | 102103_ME_EDC_AHU01_RM2502_VAV_DPS | air_differential_pressure_sensor | vav | hallway | RM2502-Type-04-vav | RM2502 | analog-input,1101 |
| 102104 | 102104_ME_EDC_RM2502_RMT | air_temperature_sensor | thermostat | hallway | RM2502-WallThermostat-thermostat | RM2502 | analog-input,101001 |
| 102104 | 102104_ME_EDC_AHU01_RM2502_VAV_DPS | air_differential_pressure_sensor | vav | hallway | RM2502-Type-04-vav | RM2502 | analog-input,1101 |
| 102105 | 102105_ME_EDC_RM2503_RMT | air_temperature_sensor | thermostat | atrium | RM2503-WallThermostat-thermostat | RM2503 | analog-input,101001 |
| 102105 | 102105_ME_EDC_AHU01_RM2503_VAV_DPS | air_differential_pressure_sensor | vav | atrium | RM2503-Type-04-vav | RM2503 | analog-input,1101 |
| 102106 | 102106_ME_EDC_RM2504_RMT | air_temperature_sensor | thermostat | hallway | RM2504-WallThermostat-thermostat | RM2504 | analog-input,101001 |
| 102106 | 102106_ME_EDC_AHU01_RM2504_VAV_DPS | air_differential_pressure_sensor | vav | hallway | RM2504-Type-04-vav | RM2504 | analog-input,1101 |
| 102107 | 102107_ME_EDC_RM2505_RMT | air_temperature_sensor | thermostat | hallway | RM2505-WallThermostat-thermostat | RM2505 | analog-input,101001 |
| 102107 | 102107_ME_EDC_AHU01_RM2505_VAV_DPS | air_differential_pressure_sensor | vav | hallway | RM2505-Type-04-vav | RM2505 | analog-input,1101 |
| 102107 | 102107_ME_EDC_RM2505_ACH_AMP | current_sensor | radiant_panel | hallway | AC-01-radiant_panel | RM2505 | analog-input,1104 |
| 102108 | 102108_ME_EDC_RM2513_RMT | air_temperature_sensor | thermostat | entrance | RM2513-WallThermostat-thermostat | RM2513 | analog-input,101001 |
| 102108 | 102108_ME_EDC_AHU01_RM2513_VAV_DPS | air_differential_pressure_sensor | vav | entrance | RM2513-Type-10-vav | RM2513 | analog-input,1101 |
| 102108 | 102108_ME_EDC_AHU01_RM2513_VAV_SAT | supply_air_temperature_sensor | vav | entrance | RM2513-Type-10-vav | RM2513 | analog-input,1104 |
| 102108 | 102108_ME_EDC_RM2513_LUX | illuminance_sensor | lighting_equipment | entrance | RM2513-Type-10-lighting_equipment | RM2513 | analog-input,1105 |
| 102108 | 102108_ME_EDC_AHU01_RM2513_EXH_VAV_DPS | air_differential_pressure_sensor | vav | entrance | RM2513-Type-10-vav | RM2513 | analog-input,1201 |
| 102108 | 102108_ME_EDC_RM2592_FFH_AMP | current_sensor | radiant_panel | staircase | FFH-01-radiant_panel | RM2592 | analog-input,1306 |
| 102108 | 102108_ME_EDC_RM2592_RMT | air_temperature_sensor | hvac_equipment | staircase | RM2592-WallSensor-hvac_equipment | RM2592 | analog-input,1307 |
| 102109 | 102109_ME_EDC_RM2515_RMT | air_temperature_sensor | thermostat | workshop | RM2515-WallThermostat-thermostat | RM2515 | analog-input,101001 |

```python
def add_device_address(g, device_address):
    g.add((BLDG[device_address], RDF.type, BRICK.Dev_Address))

def add_equipment(g, equipment_name, equipment_class):
    g.add((BLDG[equipment_name], RDF.type, BRICK[equipment_class]))

def add_room(g, location_name, location_class):
    g.add((BLDG[location_name], RDF.type, BRICK[location_class]))

def define_point_type(g, point_name, point_class, device_instance, object_identifier):
    g.add((BLDG[point_name], RDF.type, BRICK[point_class]))
    point_bnode = BNode()
    g.add((BLDG[point_name], REF.hasExternalReference, point_bnode))
    g.add((point_bnode, RDF.type, REF.BACnetReference))
    g.add((point_bnode, BACNET.deviceInstance, Literal(device_instance)))
    g.add((point_bnode, BACNET.objectIdentifier, Literal(object_identifier)))

def associate_point_with_equipment(g, point_name, equipment_name):
    g.add((BLDG[equipment_name], BRICK.hasPoint, BLDG[point_name]))

def associate_point_with_location(g, point_name, location_name):
    g.add((BLDG[location_name], BRICK.isLocationOf, BLDG[point_name]))
```



# Predictive Control – Field Implementation

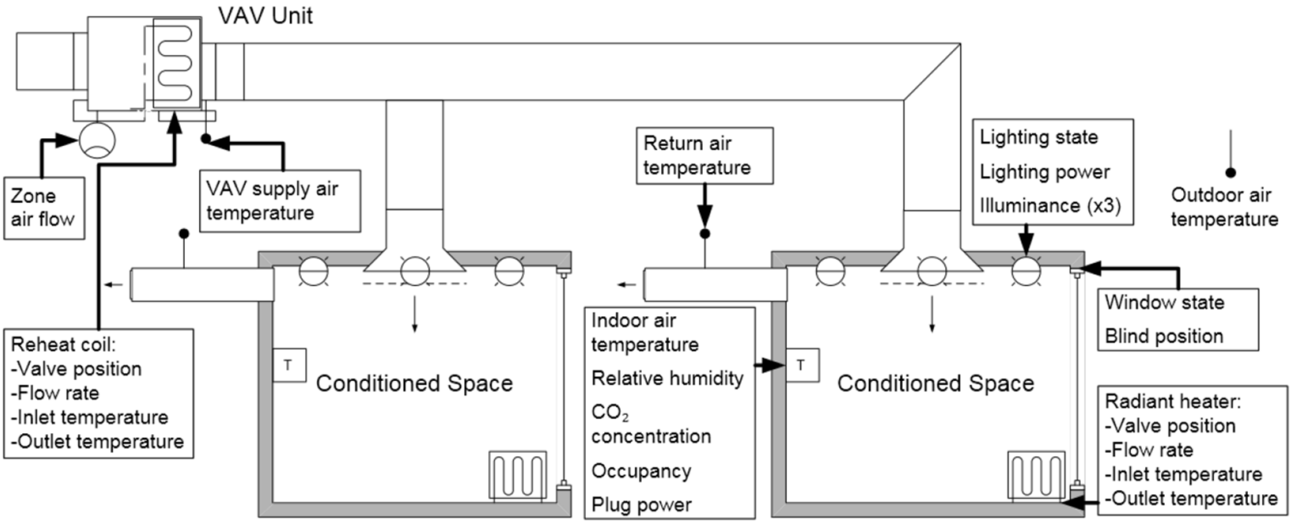


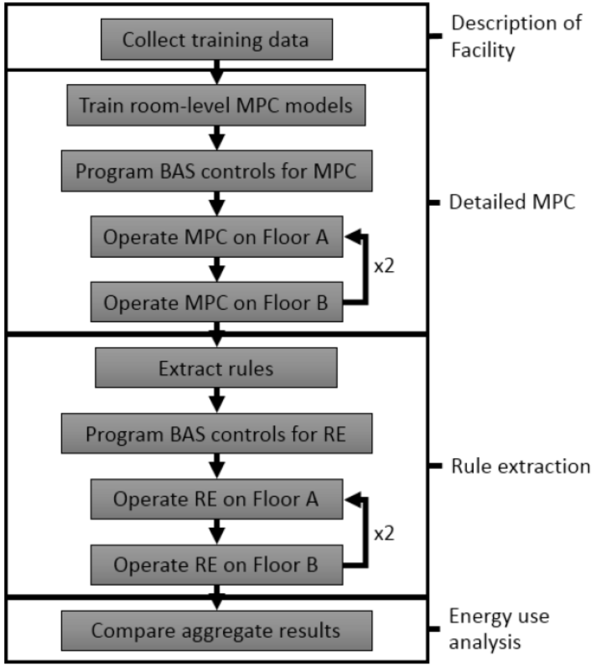




- How can a stack of dynamic thermal models be simplified into an interpretable supervisory control solution?

# Predictive Control - Setup

- How can early predictive control integrations be:
  - Configured
  - Validated
  - Evaluated

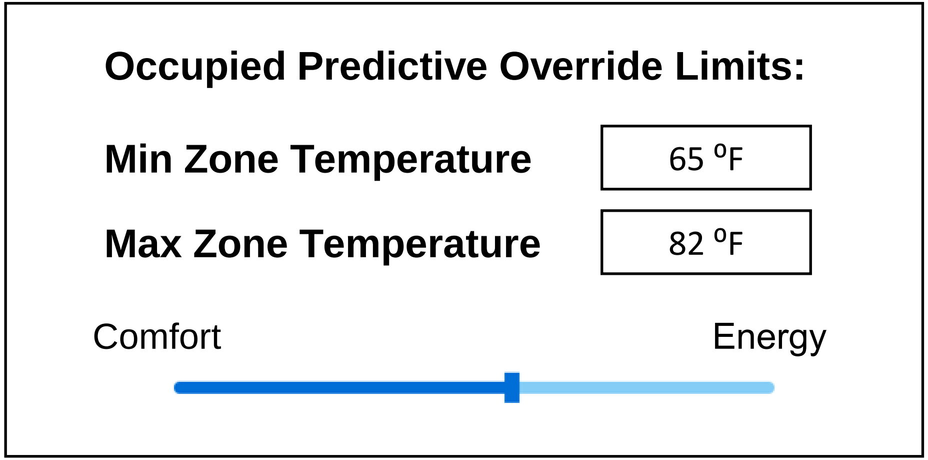


# Predictive Control - Harnessing Constraints

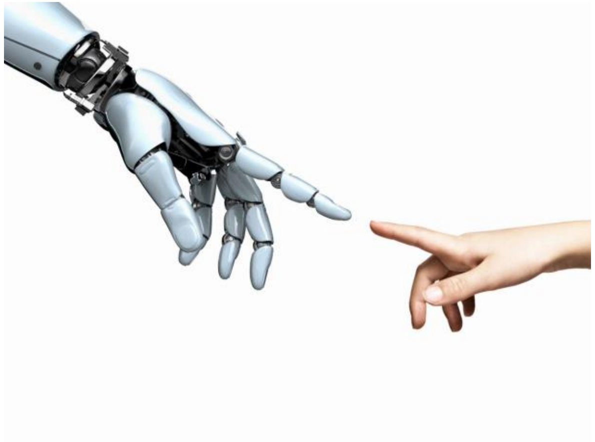
Some Examples:

- Relative Constraints
- Seasonal Constraints
- Occupied Schedule Constraints
- Static Temperature Constraints (see below)



# Conclusion

- Scaling AI in the field requires significant forethought during all phases of design and integration
- Semantic interoperability concepts can improve the success of AI in the field in the Building industry
- Applications constrained to single standardized devices and processes have the most success in the current environment
- More complex system-level applications will see higher uptake and success as structured metadata is leveraged in more AI problems
- Validation of the AI application with “ground-truth” data is essential to reliability



# Learning Questions

1. Data driven models must be "black box“
2. The biggest barrier to the wide-scale adoption of predictive control in buildings is the model forecast accuracy
3. Video card technology has driven the third boom of AI
4. AI tools can generate code to manage semantic metadata
5. Predictive control typically has over 30 inputs for even a simple VAV terminal unit

# Thank You and Q&A

Jayson Bursill

jbursill@deltacontrols.com

# Blank Slide

# THANK YOU

## PDH Request Form

Controls/BMS + AI to Decarbonize NYC Buildings by 2030

https://forms.office.com/r/iEB3HEMPAC

## Presentation Evaluation Form

https://form.jotform.com/212628858013154

# Decarbonizing NYC's Buildings: Challenges & Opportunities

## ASHRAE Earth Day Presentation

April 16, 2025

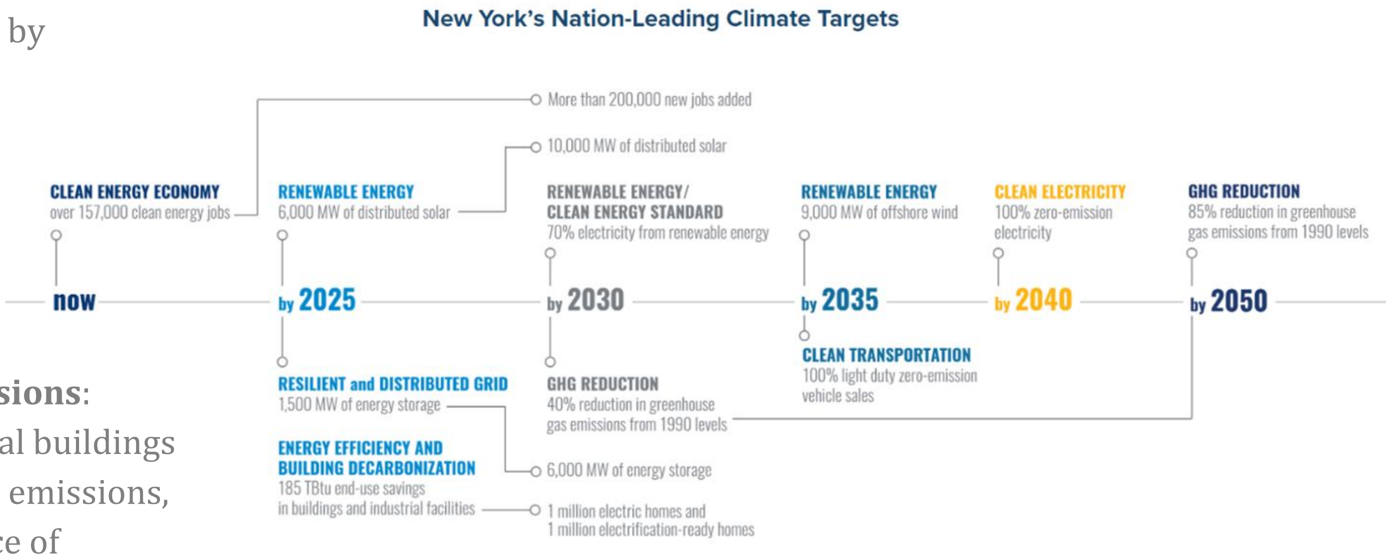
Christine A. McHugh, CEO White Strand Development
and Co-Founder AMPT Advisory Services

# Overview

- Introduction to NYC's climate goals
- Breakdown of NYC's building stock by type
- Emissions profile by sector
- Residential sector focus and associated challenges
- Technical solutions and successful case studies
- Next steps and actionable recommendations

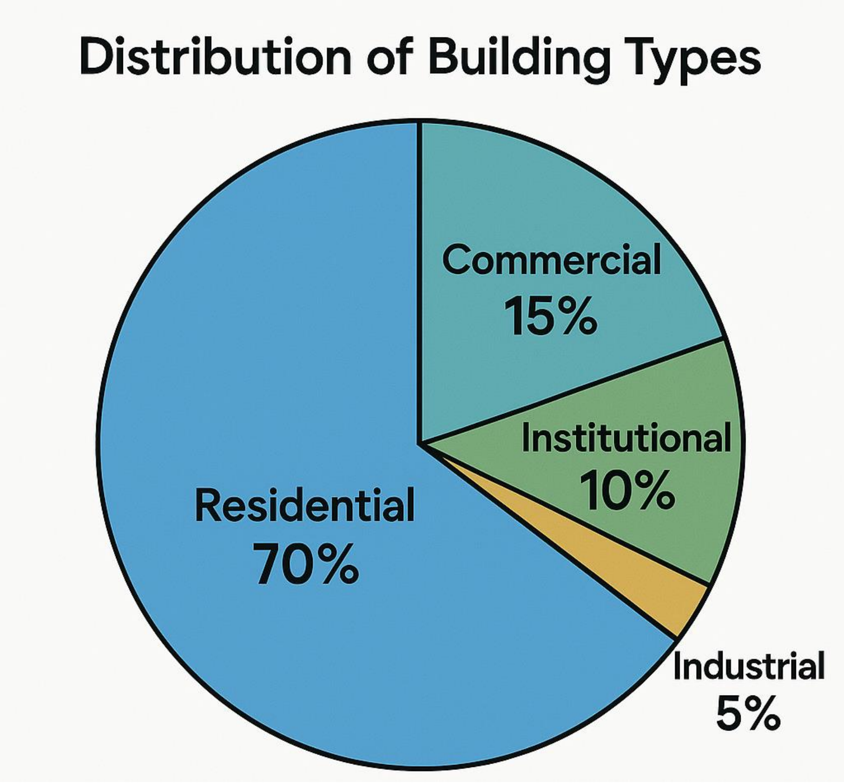
# NYC Climate Goals

- **Carbon Neutrality by 2050**: NYC aims for carbon neutrality by mid-century.
- **Emissions Reduction**:
  - 40% by 2030 (from 2005 levels)
  - 80% by 2050
- **Buildings' Share of Emissions**: Residential and commercial buildings contribute ~70% of NYC's emissions, underlining the importance of building decarbonization.



# NYC Building Stock Overview

- 1 million+ buildings in NYC
- Breakdown of NYC's building stock by type
  - Residential ~70%
  - Commercial ~15%
  - Institutional ~10%
  - Industrial ~5%



# NYC Building Stock Details

New York City's total building stock is approximately 5.6 billion sf. We'll distribute this across the sectors based on the percentage splits provided.

Total Building Stock (Estimate):

- 5.6 billion sf (5,600,000,000 sf)

Distribution by Sector:

- Residential: 70% of total stock
  - 5,600,000,000 * 70% = 3.92 billion sf
- Commercial: 15% of total stock
  - 5,600,000,000 * 15% = 840 million sf
- Institutional: 10% of total stock
  - 5,600,000,000 * 10% = 560 million sf
- Industrial: 5% of total stock
  - 5,600,000,000 * 5% = 280 million sf

# Growth Trends in NYC Building Stock

**Previously Grown Sectors:**

- **Residential:** The residential sector has seen continuous growth, especially with a focus on high-density residential developments to accommodate the city's growing population. Growth has been focused on multifamily housing and mixed-use developments that also include commercial spaces.
- **Commercial:** Commercial growth has also been significant, particularly in office spaces and retail centers in prime areas like Midtown Manhattan and emerging tech hubs like Hudson Yards.

**Targeted Growth:**

- **Institutional:** The institutional sector is receiving a targeted focus, especially for educational institutions, healthcare facilities, and government buildings, as part of urban revitalization and increased demand for services.
- **Industrial:** The industrial sector, particularly in terms of logistics, warehousing, and manufacturing spaces, is becoming a key target due to the rise in e-commerce and the need for more distribution centers in and around NYC.
- **Commercial (Post-Pandemic Adjustment):** As remote work reshapes office demand, the commercial sector is undergoing adjustments. This is particularly true for office spaces that have seen shifts in demand for more flexible, hybrid, or collaborative spaces.

# Impact of Local Law 97 on Building Sectors

Local Law 97 imposes stringent carbon reduction requirements for buildings, and its impact on various sectors could lead to a wave of retrofitting and upgrading buildings to meet the new standards.

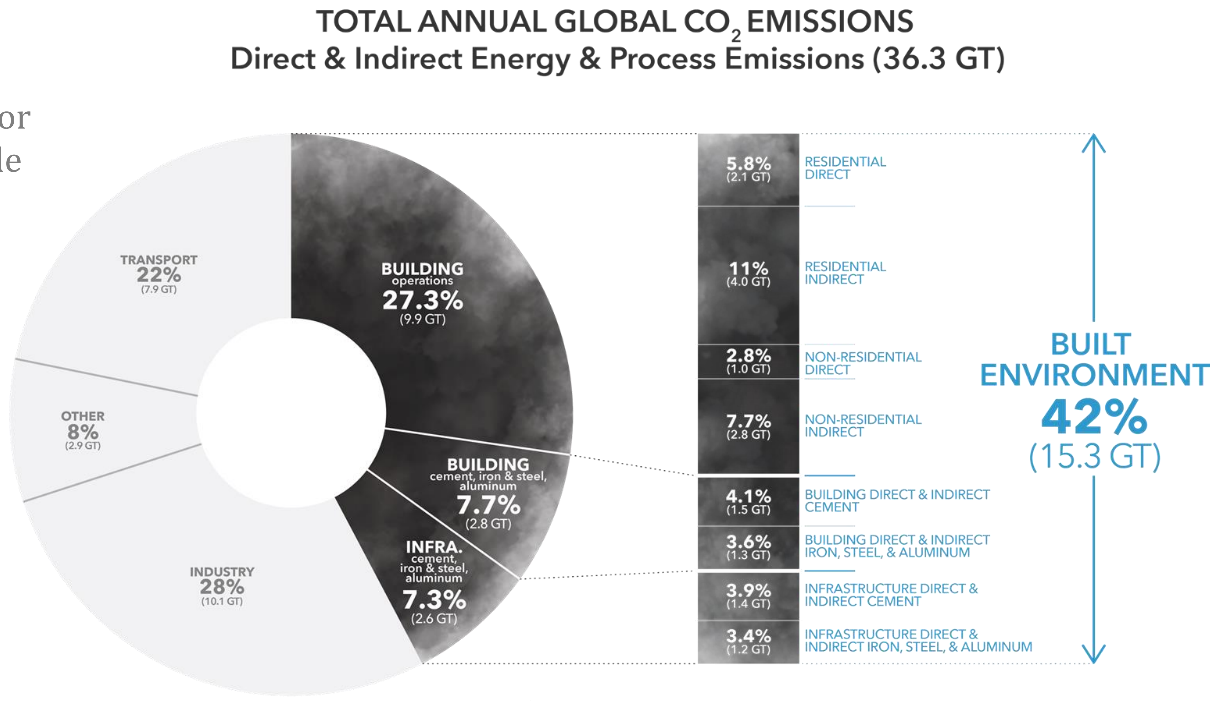
**Key Impacts:**

- **Residential Sector:** Retrofits for older buildings to meet energy efficiency standards could be costly but lead to lower operational costs in the long term. Opportunities include energy-efficient upgrades like better insulation and HVAC systems.
- **Commercial Sector:** Office buildings may need to undergo significant upgrades to comply with stricter energy regulations, affecting building owners and developers in prime areas.
- **Institutional Sector:** Schools, universities, hospitals, and government buildings may require large-scale energy-efficient upgrades to comply with carbon reduction mandates. These retrofits will be heavily targeted for funding.
- **Industrial Sector:** The industrial sector, especially manufacturing and warehouses, may see compliance challenges with emissions regulations. However, energy efficiency improvements in these areas could lead to operational savings

# Carbon Emissions by Building Type

## Key Insights

- While residential buildings account for 70% of the stock, they are responsible for around 60% of emissions

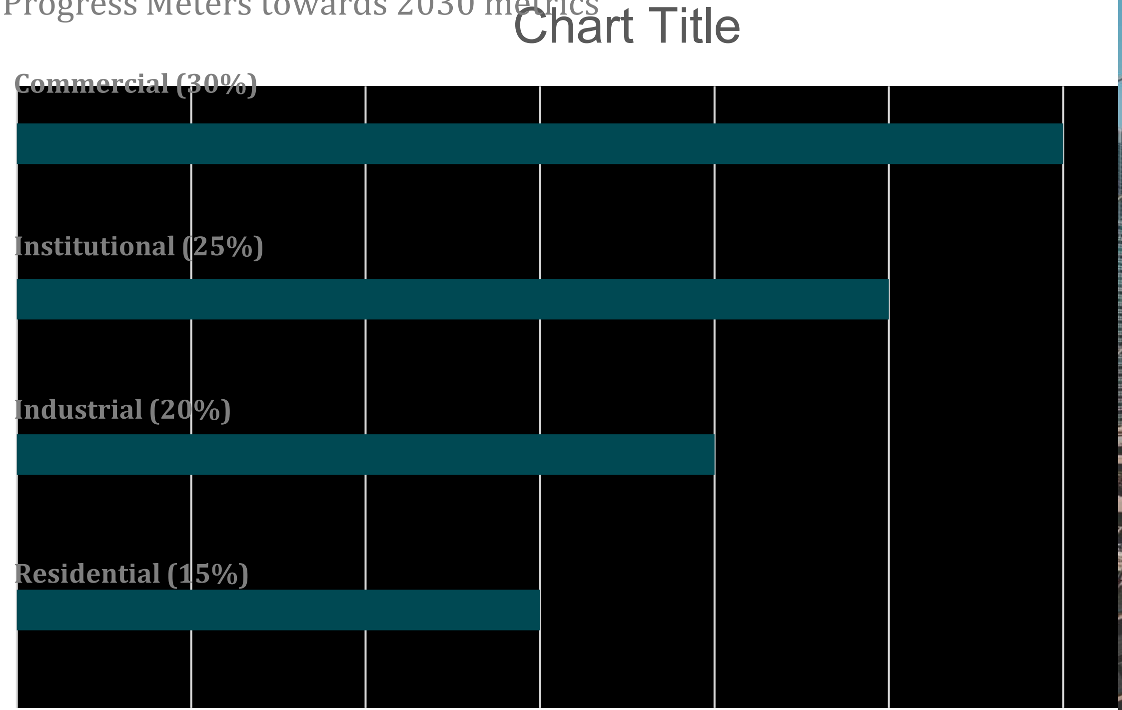




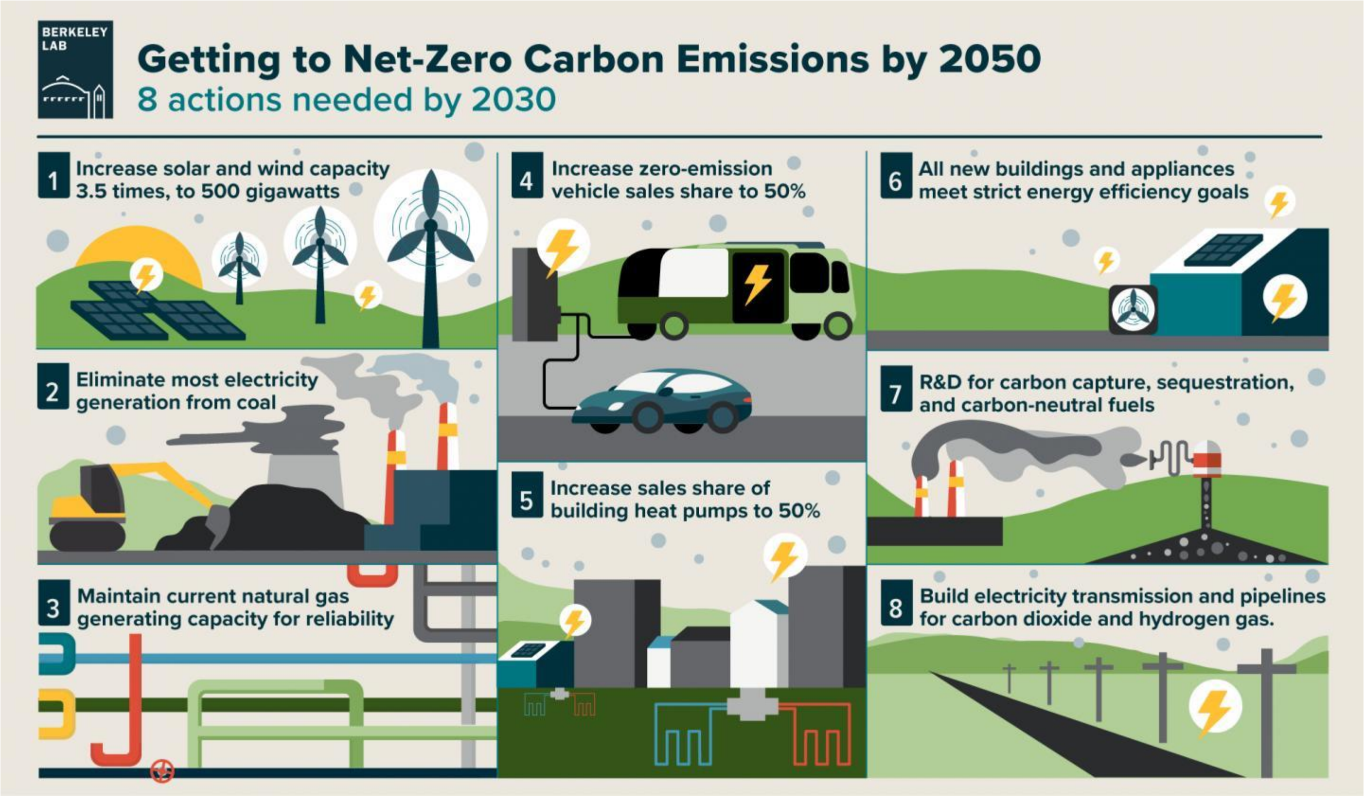
Analysis & Aggregation by Architecture 2030 using data sources from IEA & Statista.

# Building Decarbonization Progress

Progress Meters towards 2030 metrics



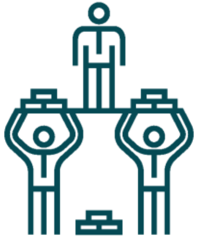

# Building Decarbonization Progress



# Why Residential Buildings are the Greatest Challenge

Scale: Over 700,000 residential buildings

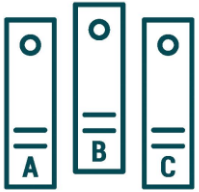
Limited Capital: Many buildings lack funds for large-scale upgrades.



Ownership Fragmentation: Many small owners, complicating coordinated action.

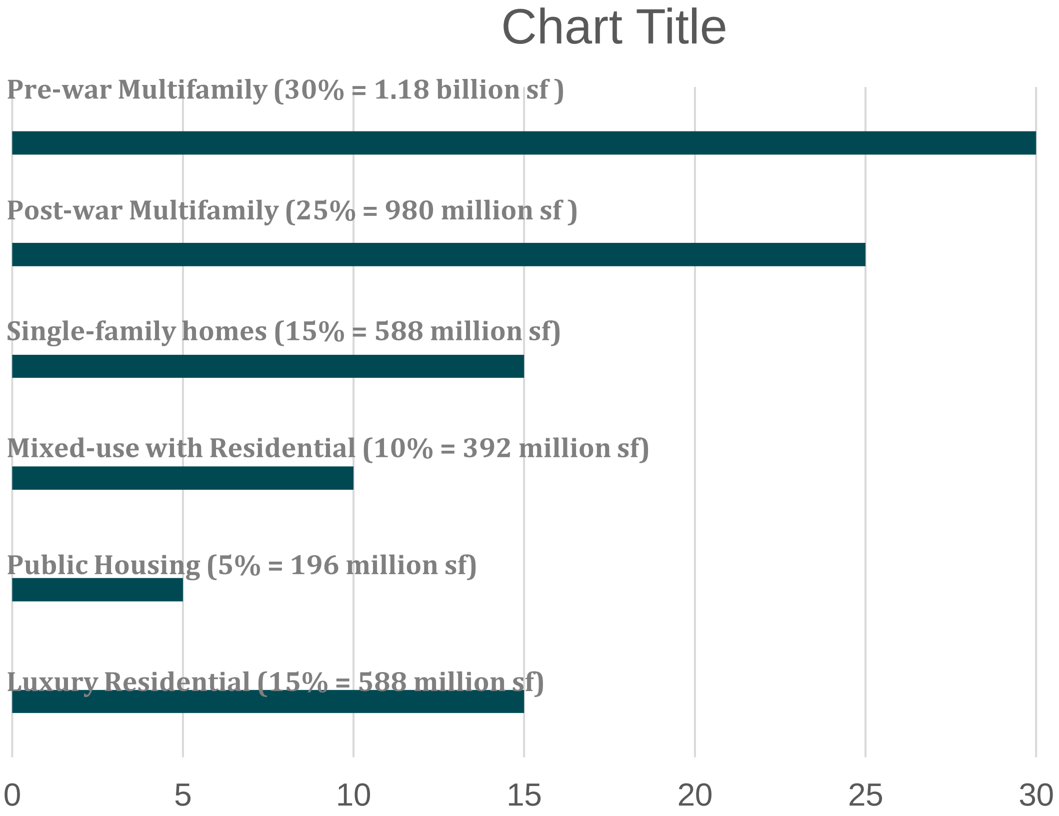
Split Incentives: Owners vs. tenants—who invests in energy savings?

Aging Infrastructure: Median building age > 70 years.




Technical Complexity: Challenges in retrofitting occupied buildings.

# Residential Sector Breakdown




# Residential Sector Breakdown

- **Prewar Multifamily (30%):** These are older buildings built before World War II, typically characterized by high ceilings, thick walls, and architectural details. They represent a significant portion of NYC's rental housing stock, especially in Manhattan.
- **Postwar Multifamily (25%):** Buildings constructed after WWII, often more modern but still with aging infrastructure. They are generally less expensive than prewar buildings but often require modernization and retrofitting to meet modern energy standards.
- **Single Family Homes (15%):** This sector includes standalone homes, which are more prevalent in outer boroughs like Queens and Staten Island. The residential space tends to be larger, though less dense than multifamily units.
- **Mixed-Use with Residential (10%):** These buildings blend residential spaces with commercial or retail spaces, often in city center locations like Brooklyn and parts of Manhattan. These properties are becoming increasingly common in urban revitalization projects.
- **Public Housing (5%):** Managed by the NYC Housing Authority (NYCHA), public housing represents a substantial portion of affordable housing in the city but tends to be older and in need of significant investment for both maintenance and energy upgrades.
- **Luxury Residential (15%):** This includes high-end, often newer, properties that cater to high-income residents. Luxury properties are typically located in prime areas like Manhattan, with high-quality amenities and construction.

# Impact of Local Law 97 on Residential Sectors

Local Law 97 is part of NYC's Climate Mobilization Act, and it aims to reduce greenhouse gas emissions from buildings. The law sets strict carbon caps for buildings, based on their size and usage, with significant penalties for non-compliance. It directly impacts how buildings are operated, retrofitted, and maintained.

## Prewar Multifamily:

- **Challenges:** Prewar buildings are often the hardest to retrofit due to their age, lack of insulation, and outdated infrastructure.
- **Retrofit Needs:** Energy-efficient windows, better insulation, upgrading heating and cooling systems, and improving building envelope efficiency.
- **Opportunities:** Historic tax credits and energy grants for retrofitting.

## Postwar Multifamily:

- **Challenges:** Older postwar buildings may have similar retrofitting challenges as prewar ones but could be slightly more adaptable to modern systems.
- **Retrofit Needs:** LED lighting, improved HVAC systems, insulation, and more energy-efficient windows.
- **Opportunities:** Potential for significant reductions in energy costs with proper retrofits.

# Impact of Local Law 97 on Residential Sectors

## Single Family Homes:

- **Challenges:** Single-family homes in NYC may be individually owned and therefore harder to coordinate large-scale energy upgrades.
- **Retrofit Needs:** Insulation, heating system upgrades (e.g., replacing old boilers), energy-efficient appliances, and better window glazing.
- **Opportunities:** Homeowners can benefit from tax incentives and rebates for energy efficiency upgrades.

## Mixed-Use with Residential:

- **Challenges:** Balancing energy requirements for both residential and commercial parts of the building.
- **Retrofit Needs:** Coordinating energy upgrades for both residential units and commercial spaces within the same structure. This could include installing advanced energy monitoring systems and optimizing HVAC for shared spaces.
- **Opportunities:** Energy-efficient retrofitting can lower costs for both residential and commercial tenants, providing mutual benefits.

# Impact of Local Law 97 on Residential Sectors

## Public Housing:

- **Challenges:** Public housing has the largest need for upgrades and is often the most financially constrained sector. Many buildings in this category are over 50 years old and have outdated infrastructure.
- **Retrofit Needs:** Comprehensive upgrades including energy-efficient windows, insulation, centralized heating systems, and water conservation systems.
- **Opportunities:** New funding models and partnerships for public-private investments can help fund energy retrofits for public housing.

## Luxury Residential:

- **Challenges:** Luxury buildings generally have the resources to comply with Local Law 97, but they may face issues in retrofitting existing high-end buildings with green technologies.
- **Retrofit Needs:** High-performance building systems, solar panel installations, electric heating, and water systems.
- **Opportunities:** High-end luxury buildings can leverage sustainability as a marketing tool, attracting high-income buyers or renters interested in eco-friendly living.

# Residential Building Systems

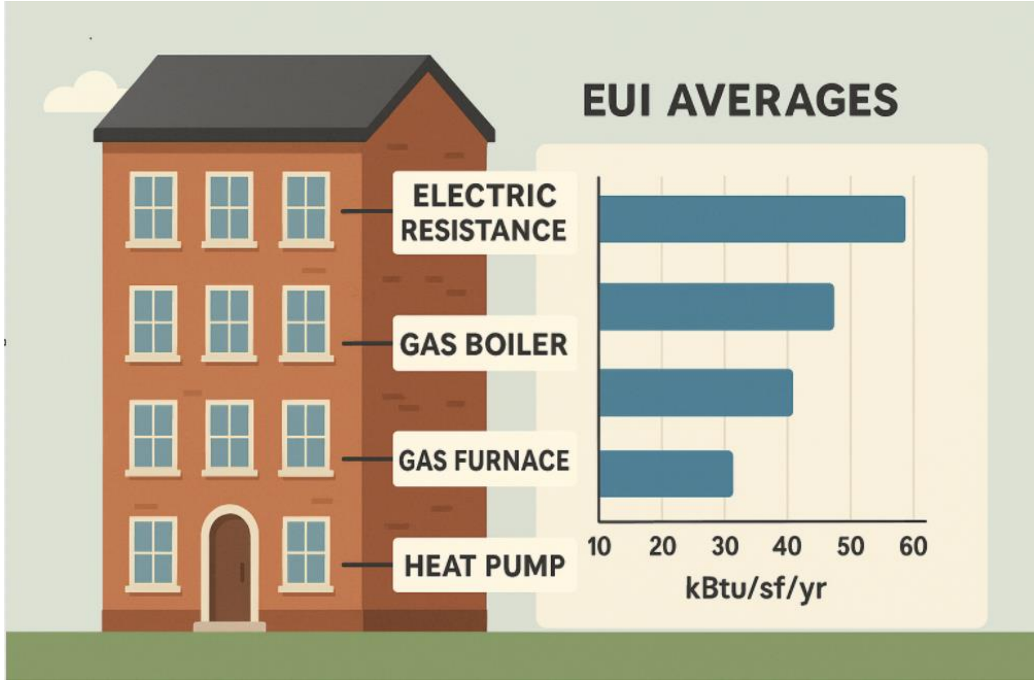
Heating System Breakdown

- Steam/hydronic: 45%
- Forced air: 30%
- Electric resistance: 15%
- Heat pumps: 10%

Building Envelope Stats

- Common insulation levels, window performance, etc.

Energy Use Intensity (EUI): Averages for different building types



# Technical Challenges in Residential Decarbonization

Conversion of Heating Systems: From steam/hydronic to heat pumps.

Space Constraints: Limited room for new equipment on rooftops or in buildings.

Electrical Infrastructure: Many buildings are not equipped for electrification.

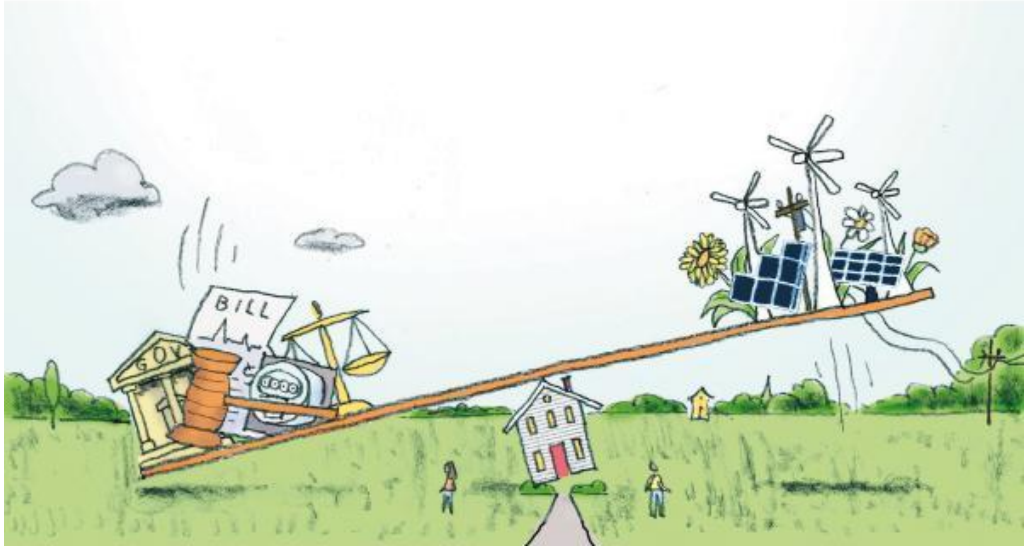
Structural Limitations: Pre-war buildings, for example, often have outdated or fragile structures.

Historic Preservation: Legal restrictions and challenges for retrofits in landmarked buildings.

Tenant Disruption: Potential inconvenience during retrofitting.

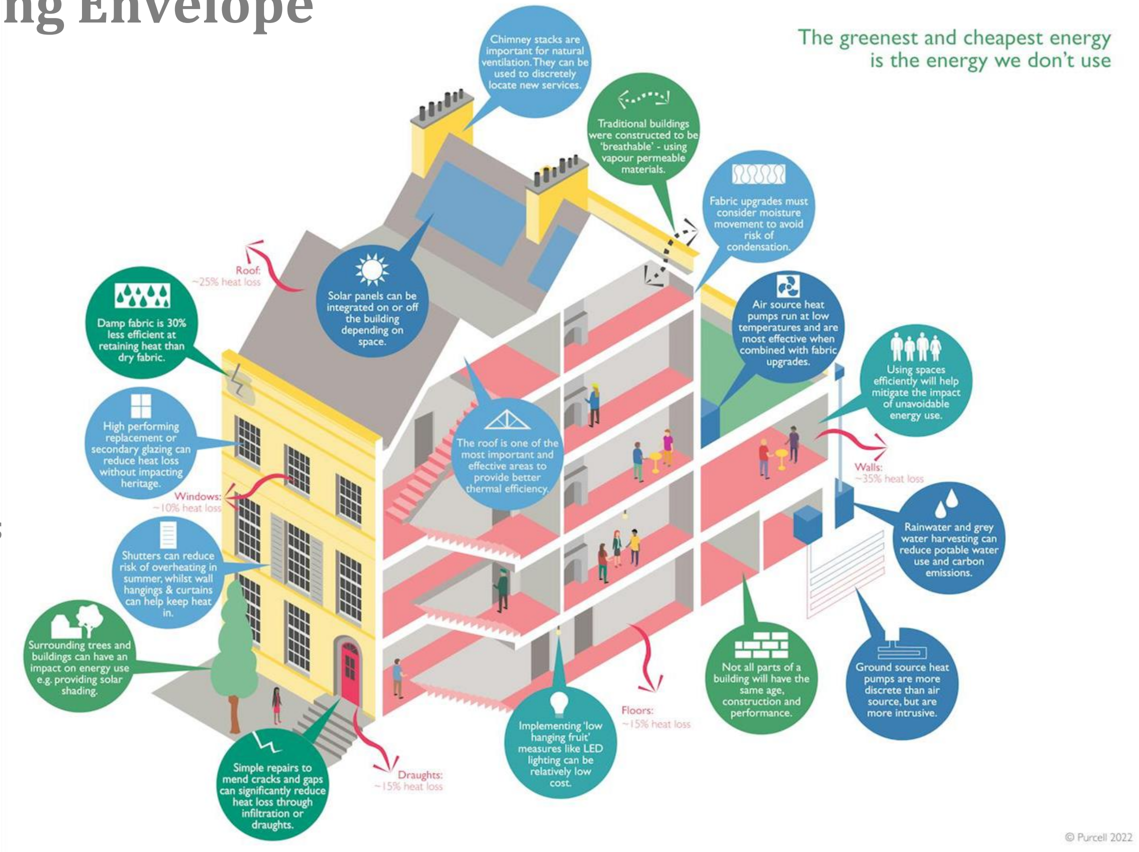
# Financial Challenges in Residential Decarbonization

- **Retrofit Costs per Unit:** Highlight average costs for apartment building retrofits.
- **Payback Periods:** Challenges of long payback periods for property owners.
- **Split Incentives:** Landlords may not see the financial benefits of investments made by tenants.
- **Affordable Housing Impact:** Financial burden on owners of affordable housing.
- **Retrofit Costs vs. New Construction:** Why retrofitting may be more expensive than new builds.



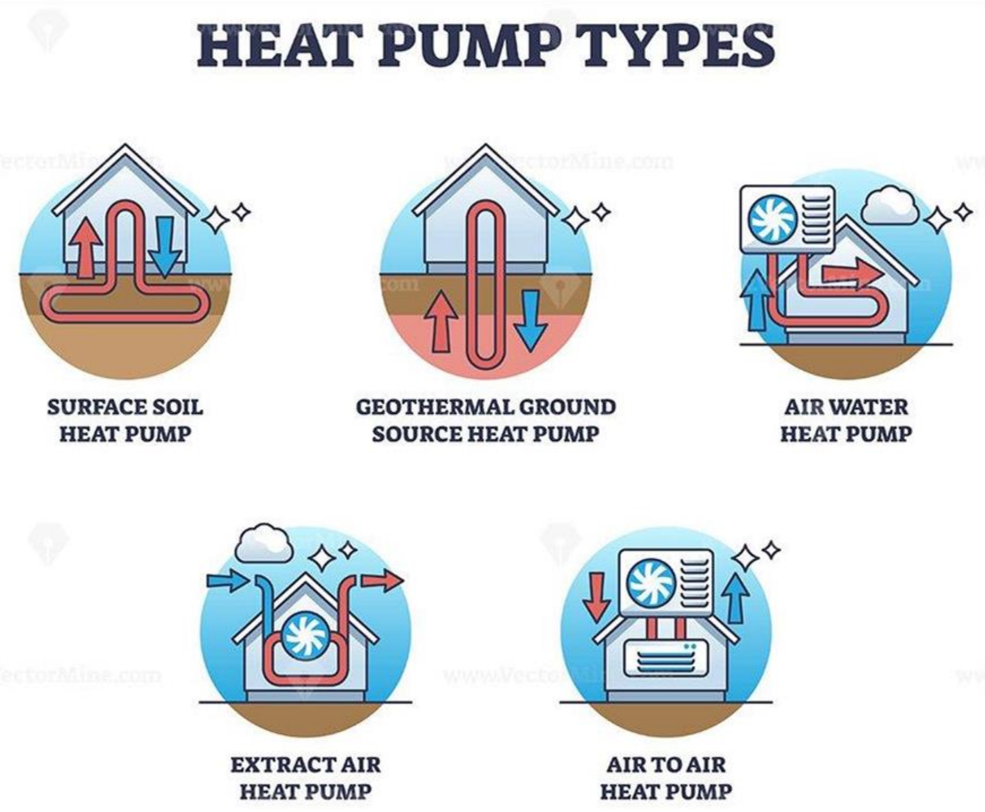
# Technical Solutions: Building Envelope

- **Insulation Strategies:** Different approaches for different building types (pre-war, post-war, etc.).
- **Window Retrofit:** Best practices and technologies (low-E, triple-pane, etc.).
- **Air Sealing:** Solutions to reduce leakage and improve efficiency.
- **Cool Roofs:** Benefits of reflective coatings for reducing heat



# Technical Solutions: HVAC Solutions

- **Heat Pumps:** Discuss different types of heat pumps for various building sizes and conditions.
  - Air-source for smaller buildings
  - Water-source for larger multifamily units
  - Geothermal for specific applications
- **District Energy:** Opportunities for multi-building systems.
- **Ventilation with Energy Recovery:** How to maintain air quality while reducing energy usage.
- **Smart Controls:** Importance of automated building systems for energy savings.



# Electrification Roadmap

Step-by-Step Visualization:

- Energy Audit & Baseline Establishment
- Envelope Improvements
- Distribution System Modifications
- Equipment Replacement
  (e.g., boilers, HVAC systems)
- Renewable Energy Integration
  (e.g., solar, wind)
- Monitoring & Verification

# Albemarle Road Retrofit: Enhancing Efficiency in Historic Buildings

**Project Overview:** Located in Brooklyn, this 83-unit, six-story co-op building was constructed in 1938. The retrofit aimed to enhance energy efficiency while preserving the building's historic brick façade.

**Challenges:**

- Improving thermal efficiency without altering the building's exterior appearance.
- Addressing moisture control due to the uninsulated brick walls.

**Solutions Implemented:**

- Exterior Insulation: Applied continuous insulation using ROCKWOOL Cavityrock® to the building's exterior walls, enhancing thermal performance without compromising interior space.
- Interior Wall Assembly: Installed a vapor-permeable liquid-applied water-resistive barrier and framed with metal studs to allow for moisture management and prevent potential damage to the original brickwork.
- Floor and Ceiling Insulation: Utilized ROCKWOOL Comfortbatt in floors and ceilings to improve thermal comfort and provide fire and sound insulation between units.

# Albemarle Road Retrofit: Enhancing Efficiency in Historic Buildings

Outcomes:

- Achieved significant energy savings by reducing heating and cooling demands.
- Enhanced resident comfort through improved thermal regulation and noise reduction.
- Maintained the building's historical integrity by preserving the exterior façade and carefully planning interior modifications.

This retrofit serves as a model for integrating modern energy-efficient solutions within the constraints of historic preservation, offering valuable insights for similar projects.

# Incentive, Rebate, and Grant Opportunities for Local Law 97 Compliance

**NYC Accelerator Program**

- Energy efficiency support and financial incentives.
- Free audits, personalized recommendations.

**NYSERDA Programs**

- Low-interest loans and incentives for retrofits.
- Grants for energy efficiency in multifamily buildings.

**Green Roofs Tax Abatement**

- Property tax abatements for installing green roofs (up to $100,000).
- Must cover at least 50% of the roof area.

**Con Edison Energy Efficiency Programs**

- Rebates for HVAC, lighting, and custom projects.
- Demand response incentives to reduce peak energy use.

**NYC Retrofit Accelerator**

- Free energy audits and financial assistance.
- Access to rebates and energy-saving solutions.

**PACE Financing**

- Long-term financing for energy retrofits with repayment through property taxes

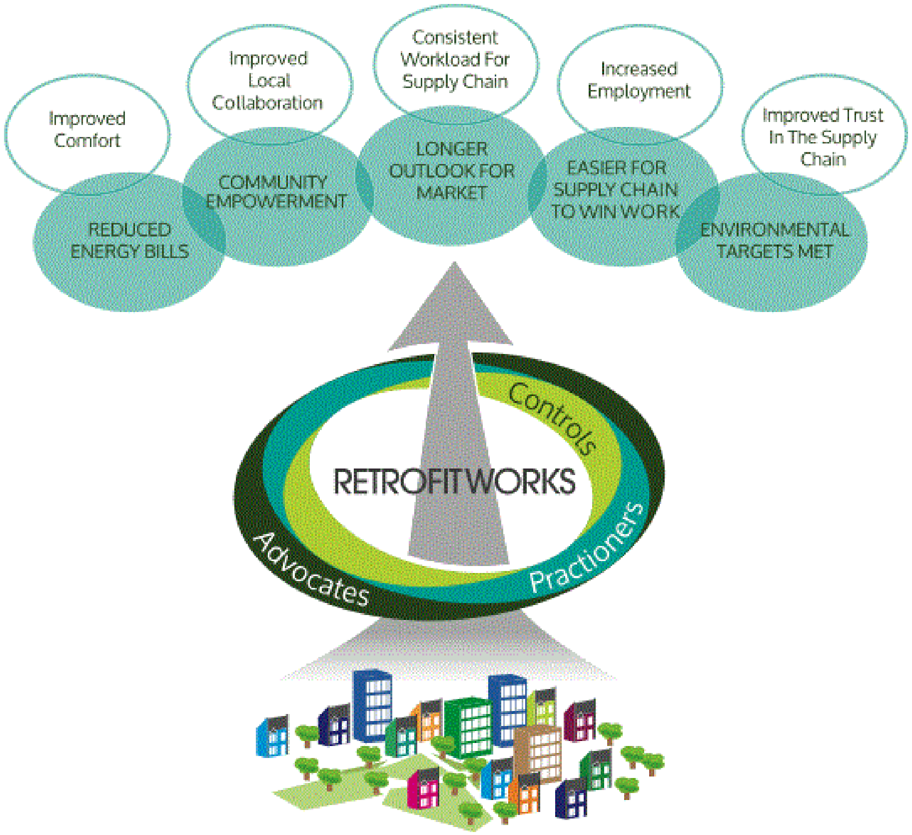
# Key Policies Driving Local Law 97 Compliance

**Local Law 97 of 2019 (Climate Mobilization Act)**

- **Overview:** LL97, passed in 2019, is one of the most ambitious climate laws in the United States, targeting significant reductions in greenhouse gas (GHG) emissions from buildings, which account for about 70% of NYC's emissions.
- **Key Provisions:**
  - Carbon Caps: LL97 sets specific emissions limits for buildings based on their square footage, which will decrease over time, starting in 2024.
  - Penalties for Non-Compliance: Buildings exceeding their carbon cap will face significant fines.
  - Long-Term Goals: By 2050, NYC aims to reduce overall carbon emissions by 80% compared to 2005 levels.
- **Impact:** Buildings over 25,000 sf (including multifamily, commercial, and institutional buildings) must reduce their carbon footprint. This affects thousands of properties across the city, from skyscrapers to older multifamily buildings.

# Implementation Strategies

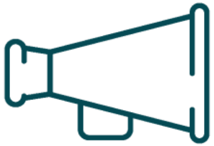
- **Phasing Approaches:** For occupied buildings, especially large multifamily units.
- **Contractor Training:** Importance of skilled workers for retrofitting.
- **Resident Engagement:** Communication strategies for tenants.
- **Performance Monitoring:** Ongoing checks and adjustments post-retrofit.
- **Commissioning:** Ensuring systems are running at optimal efficiency.



# Next Steps for ASHRAE Members

Knowledge Development: Attend workshops and training.


Research Needs: Areas where further innovation is needed.



Advocacy Roles: Helping shape policy and legislation.

Industry Partnerships: Collaborative efforts to scale solutions.

Technical Committees: Opportunities for involvement in ASHRAE.

# Resources

# Assessment of Learning Questions

1) What engineering approaches can be used to retrofit steam heating systems in Prewar multifamily buildings to improve energy efficiency while maintaining compliance with NYC's Local Law 97? How do advanced sensor technologies help optimize the operation of these aging systems?

2) Given the often-poor insulation and air sealing in Prewar multifamily buildings, what specific insulation or air sealing solutions are most effective for minimizing energy loss, and how can smart sensors be used to monitor the effectiveness of these upgrades?

1) In Postwar multifamily buildings, how can heat pump water heaters or on-demand water heating systems replace traditional boiler-based hot water systems to reduce carbon emissions? What challenges might arise during the retrofit process in existing infrastructure?

4) What are the most common challenges in optimizing HVAC systems in Postwar multifamily buildings that lack advanced control systems, and how can the integration of smart thermostats, zone-based controls, and advanced sensors improve HVAC efficiency to help meet Local Law 97 compliance?

5) How can the integration of smart metering systems and real-time energy monitoring in both Prewar and Postwar multifamily buildings provide data to optimize the performance of heating, cooling, and lighting systems, thus supporting compliance with Local Law 97?

# Q&A

**Christine A. McHugh,** CEO White Strand Development and Co-Founder AMPT Advisory Services

www.whitestrand.com
C: 917.940.9383
christine.mchugh@whitestrand.com

# THANK YOU

## PDH Request Form

AI for Smart Buildings

https://forms.office.com/r/ZSGCDWmxM5

## Presentation Evaluation Form

https://form.jotform.com/212628858013154

# LINKS

FUTURE WEATHER/CLIMATE DATA IS MORE IMPORTANT THAN YOU THINK!

https://forms.office.com/r/ALEKbyt0xF

THE VIRTUAL ENGINEER WORLD

https://forms.office.com/r/zQCBYD2Snh

CONTROLS/BMS + AI TO DECARBONIZE NYC BUILDINGS BY 2030

https://forms.office.com/r/iEB3HEMPAC

AI FOR SMART BUILDINGS

https://forms.office.com/r/ZSGCDWmxM5

**PRESENTATION EVALUATION FORM**

https://form.jotform.com/212628858013154