# AI Home Science Platform

Sara Lin / 2025 MSCDP / Summer Capstone Project

Translating Building Science into Everyday Energy Advice
And Open source Platform for everyone to share the resources

## WHAT IS IT ...?

A computational design project that uses AI tools to translate architectural thermal behavior into accessible, localized energy guidance.

+

platform where users can upload their own data and share personalized energy reports with others.

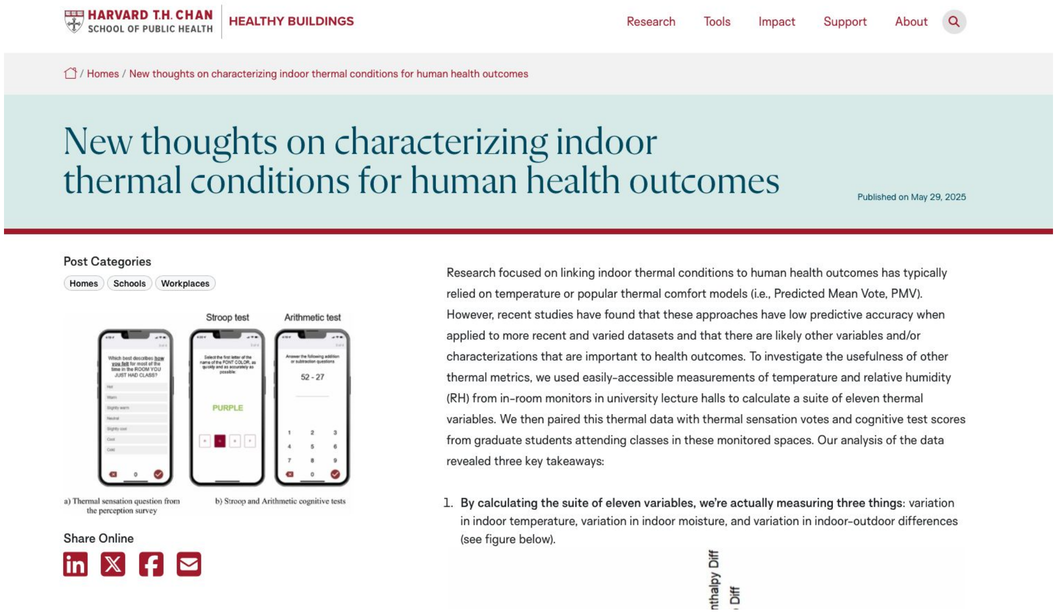
## INTENTION

Many urban residents have limited control over essential building systems such as HVAC, windows, and insulation, yet they are the ones most affected by high energy costs and uncomfortable indoor conditions. While energy modeling tools exist for new construction, residents of older or rental housing, especially in dense cities like New York or Los Angeles, often lack access to useful data, performance feedback, or strategies to improve their living environments.

This project introduces a AI-powered tool designed to help everyday occupants better understand and enhance the energy performance of their buildings. Drawing on fundamental building science principles, including heat transfer, solar exposure, ventilation, and envelope behavior, the tool aims to make energy literacy more accessible and actionable for a broader public.

After receiving personalized energy insights, users can choose whether to share their data with the platform. If they opt in, others can view their project information and learn from real-world examples, helping to foster a collaborative, citizen-driven approach to improving home energy performance.

WHY IS IT INDOOR THERMAL CONDITIONS IMPORTANT ? WHY SHOULD WE BE AWARE OF?



HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH | HEALTHY BUILDINGS

Research Tools Impact Support About

/ Homes / New thoughts on characterizing indoor thermal conditions for human health outcomes

# New thoughts on characterizing indoor thermal conditions for human health outcomes

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Post Categories

Homes Schools Workplaces



a) Thermal sensation question from the perception survey

b) Stroop and Arithmetic cognitive tests

Share Online

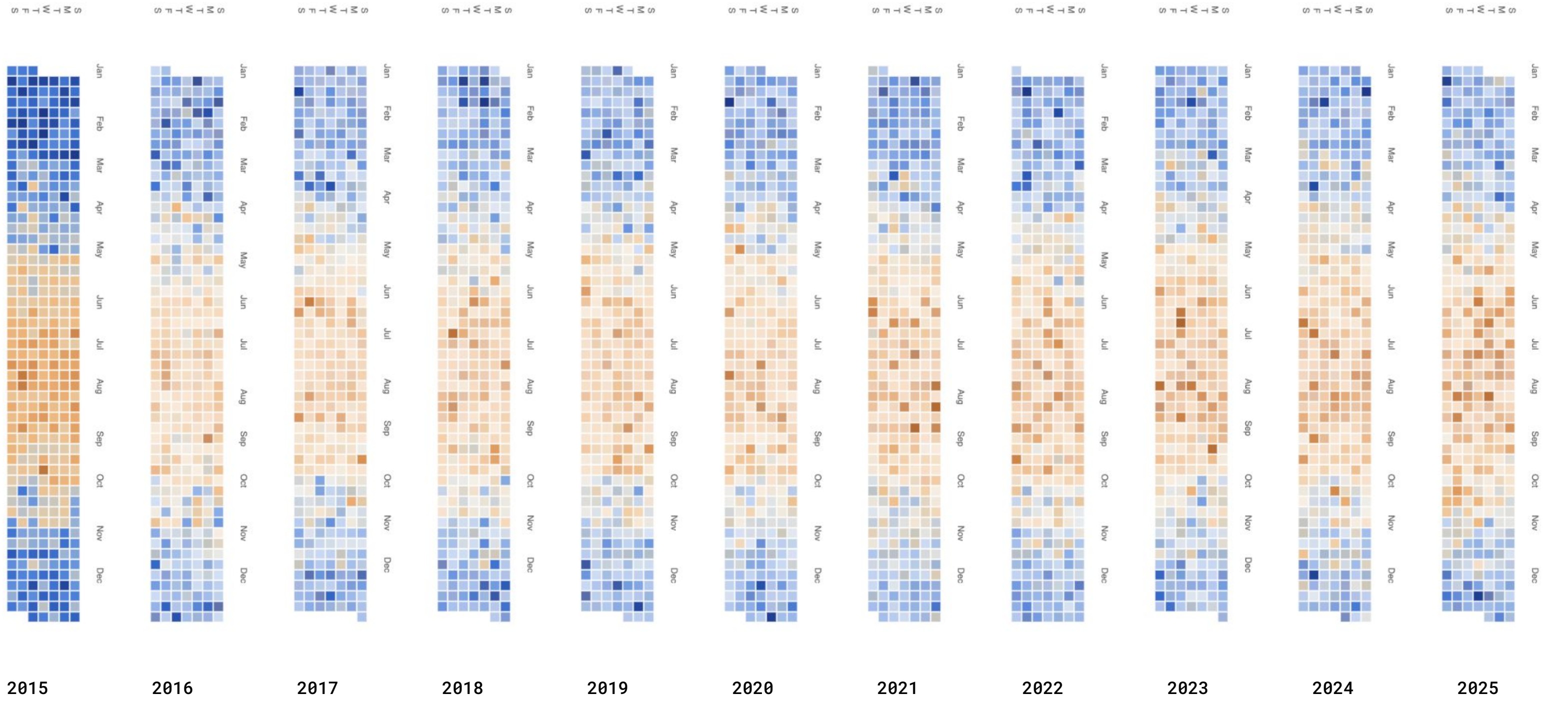
Research focused on linking indoor thermal conditions to human health outcomes has typically relied on temperature or popular thermal comfort models (i.e., Predicted Mean Vote, PMV). However, recent studies have found that these approaches have low predictive accuracy when applied to more recent and varied datasets and that there are likely other variables and/or characterizations that are important to health outcomes. To investigate the usefulness of other thermal metrics, we used easily-accessible measurements of temperature and relative humidity (RH) from in-room monitors in university lecture halls to calculate a suite of eleven thermal variables. We then paired this thermal data with thermal sensation votes and cognitive test scores from graduate students attending classes in these monitored spaces. Our analysis of the data revealed three key takeaways:

1. **By calculating the suite of eleven variables, we're actually measuring three things**: variation in indoor temperature, variation in indoor moisture, and variation in indoor-outdoor differences (see figure below).

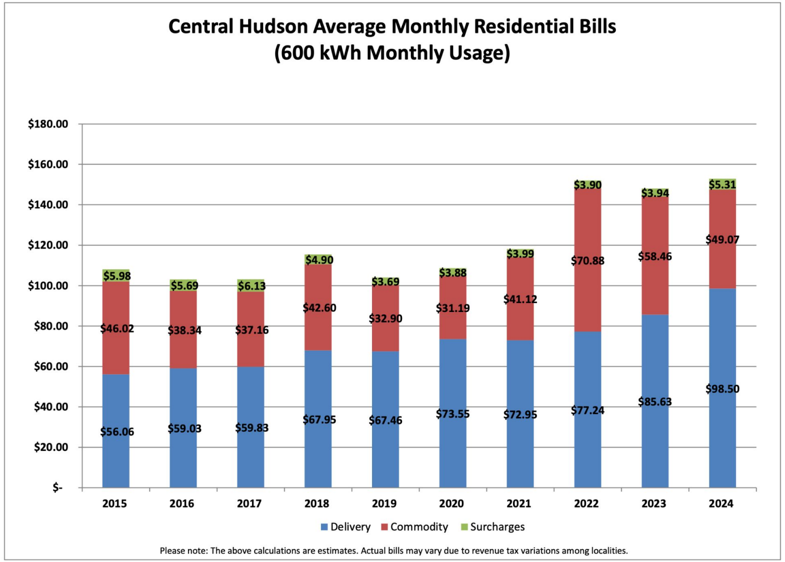
Indoor thermal conditions have a prominent influence on occupant health, performance, and satisfaction [1], [2], [3], and buildings consume substantial amounts of energy to maintain comfortable thermal conditions that support occupants and their activity ...

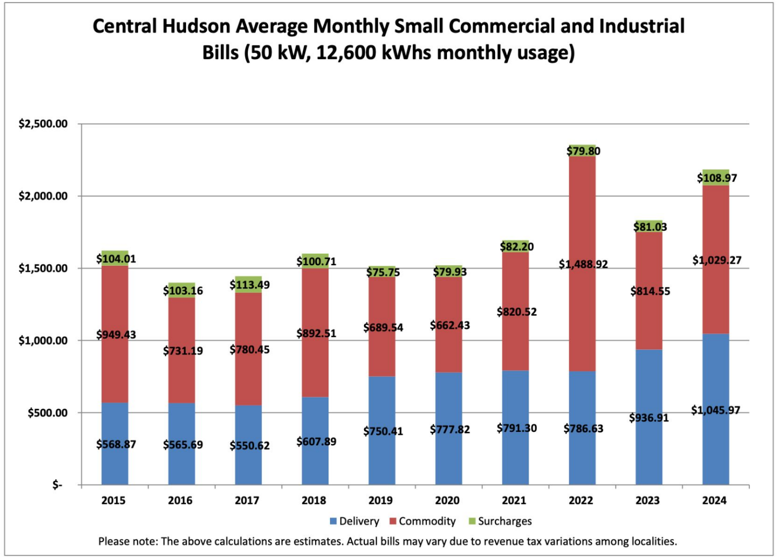
https://healthybuildings.hsph.harvard.edu/new-thoughts-on-characterizing-indoor-thermal-conditions-for-human-health-outcomes/
https://www.sciencedirect.com/science/article/pii/S295036202500027X?via%3Dihub

# NYC Temperature Calendar Heatmap



Average Energy Bill from 2015 to 2014 for Residential and Small Commercial




https://www.nyc.gov/site/buildings/codes/energy-and-water-data.page

## What are the factors that might affect energy bill?

1. Increase Electricity rates

Rates fluctuate seasonally and tend to rise during summer and winter due to higher demand for heating and cooling.

2. Energy usage has increased

Higher electricity consumption leads directly to a higher bill.

3. Energy plan may not match usage needs

In deregulated markets, plans vary. High-usage homes need different plans than low-usage ones. Choosing the wrong plan can cost more.

4. Extreme weather or temperature spikes

Sudden increases in demand during weather extremes can drive prices higher.

5. Home maintenance issues

Poor insulation, air leaks, or an overworked HVAC system increase energy use. Old or inefficient appliances

6. Older devices often use more energy.

ENERGY STAR–certified appliances are more efficient and cost-effective.

## What are factors that people might feel uncomfortable in their living space?

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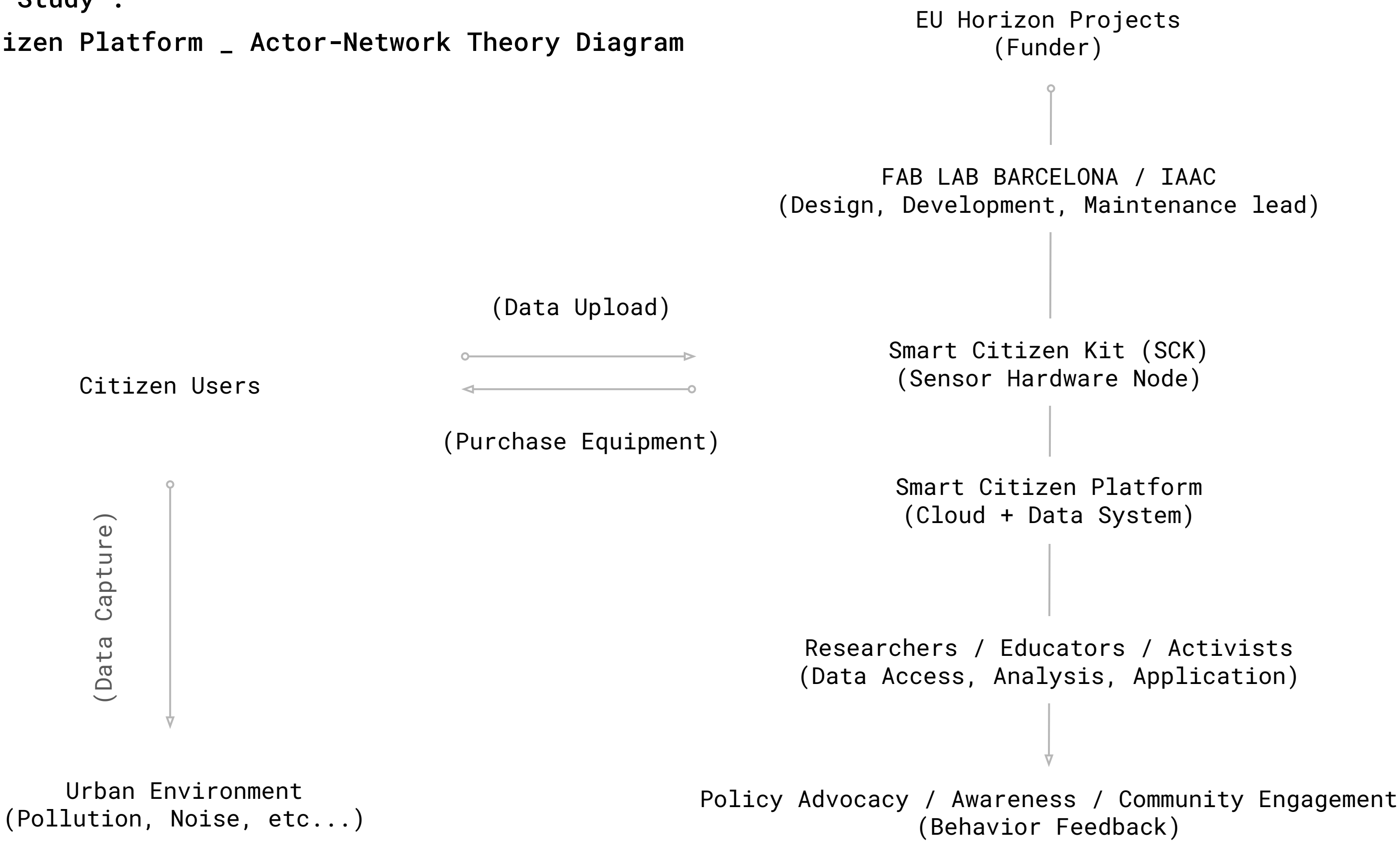
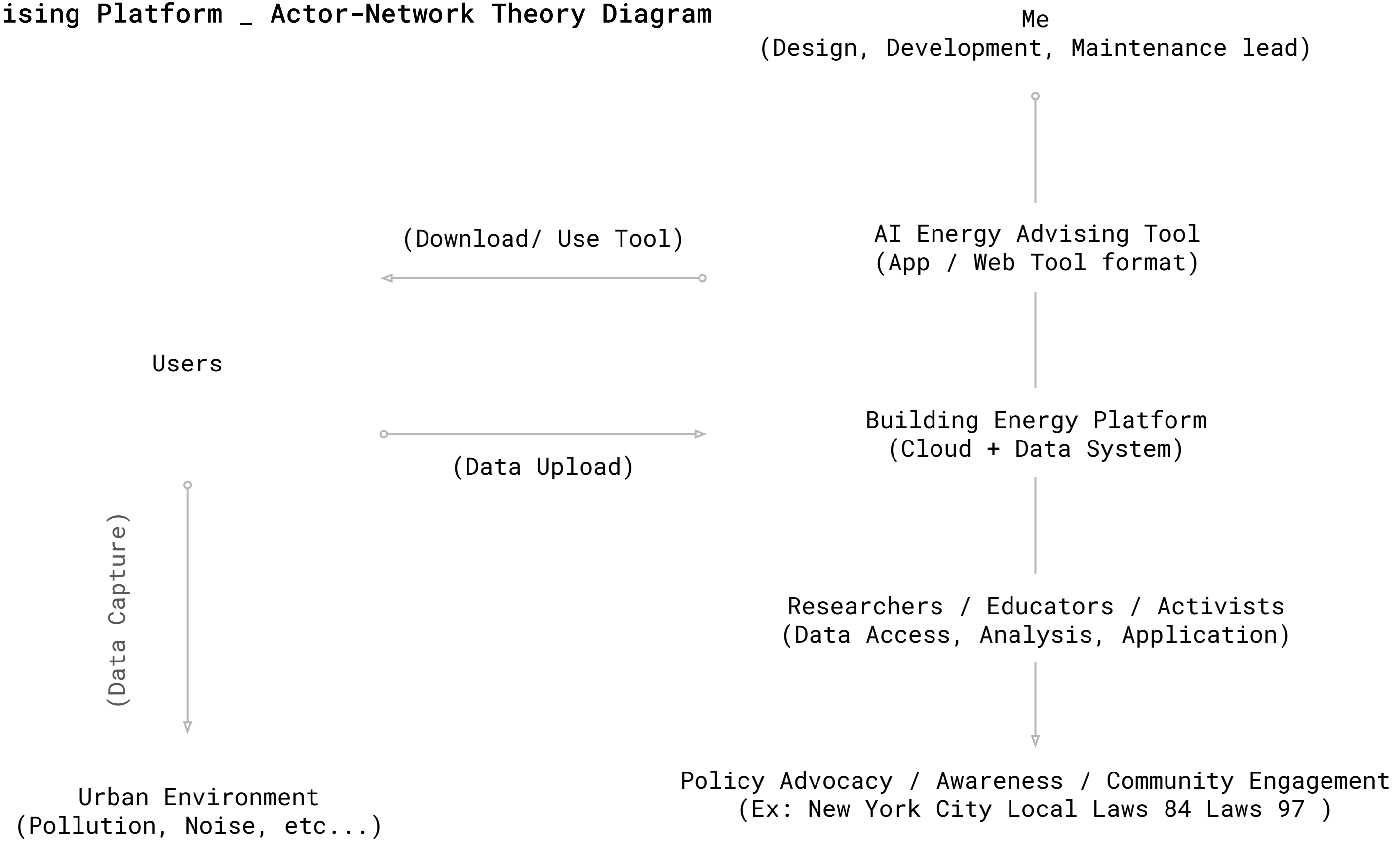
**Precedent Study :**

**Smart Citizen Platform _ Actor-Network Theory Diagram**



My Design Framework :

Energy Advising Platform _ Actor-Network Theory Diagram



## Targeted Users

1. Home owner
2. Tenant
3. Architect
4. Interior Designer

## Research Question:

From the perspective of a daily what factor can I change to make the difference so I can save more energy and decrease my energy bill but at the same time maximizing my comfort level in the space? What are things that I can do instead of tearing off the entire building?

## Hypothesis:

Poor insulation, air leaks, or an overworked HVAC system increase energy use. Old or inefficient appliances

## Intersecting Fields

1. Computational Building Science

   e.g., comfort simulation, daylighting

2. Web/ App Interface Development (Visual Representations)
3. Architectural Space/ Building Modeling
4. Building Science

   e.g., building performance, building envelope strategies

**Keywords**

1. Citizen Science
2. AI Feedback Systems
3. High Performance Building
4. Passive House Strategies
5. Indoor Thermal Comfort

# Key solutions data that I can feed into my AI tool

1. Passive House Institute (PHI) & PHIUS

- Focus: Ultra-low energy buildings through insulation, airtightness, high-performance windows, and heat-recovery ventilation.
- Use: Industry standard for net-zero-ready housing.
- Tools:
  - PHIUS+ 2021 Standard – North American adaptation
  - PHPP (Passive House Planning Package) – simulation-based design tool

2. Building America Solution Center (U.S. DOE)

- Focus: Practical construction details for high-performance homes.
- Use: Retrofit strategies, thermal enclosure guidance, HVAC sizing.
- Best For: Existing homes, builders, and actionable improvements.
- Link: [basc.pnnl.gov](basc.pnnl.gov)

3. ASHRAE Standards & Adaptive Comfort

- Focus: Indoor thermal comfort based on climate, clothing, and behavior.
- Use: Comfort modeling (PMV, PPD, adaptive models).
- Tool: UC Berkeley Thermal Comfort Tool
- Standard: ASHRAE 55

4. WELL Building Standard

- Focus: Human-centered design for comfort, air quality, lighting, and health.
- Use: Projects combining wellness and energy performance.
- Best For: Healthy buildings, workplace comfort, and occupant well-being.
- Link: [wellcertified.com](wellcertified.com)

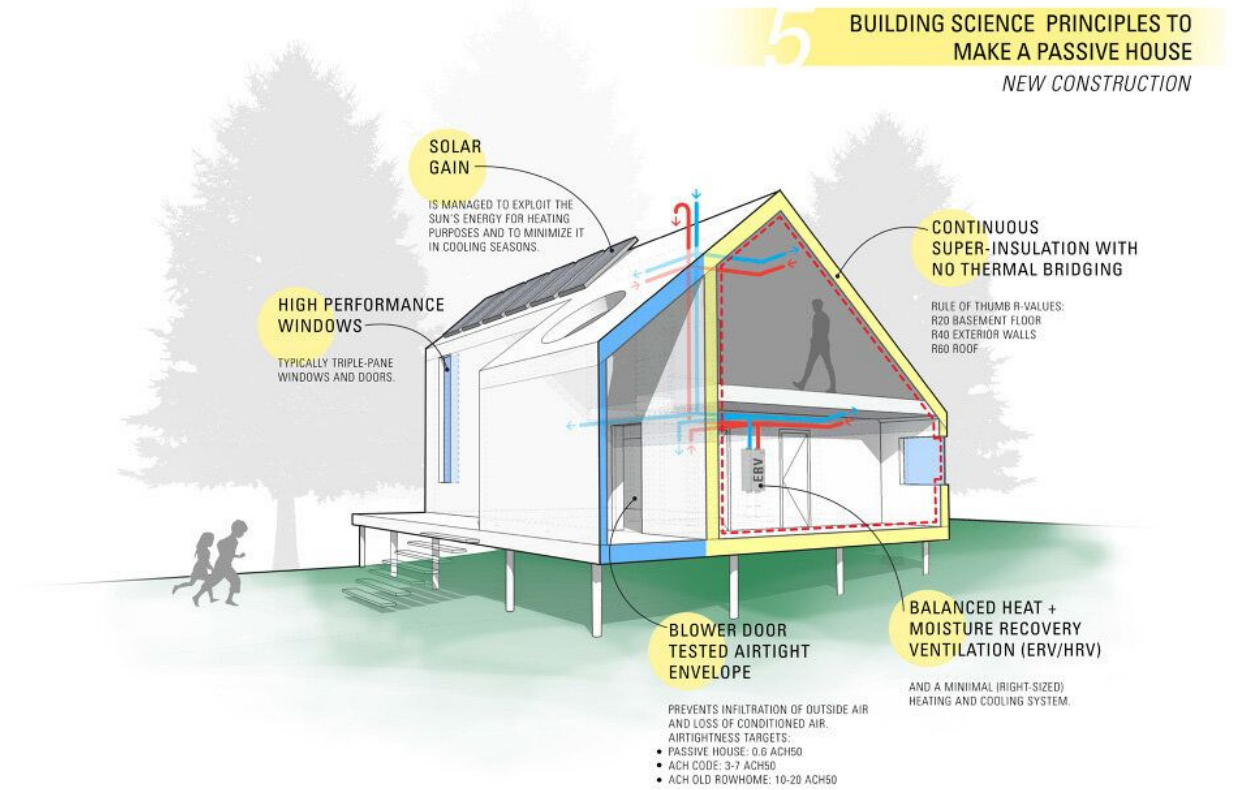
5. LEED v4.1 Residential Guide

- Focus: Sustainable design across multiple categories (energy, materials, air).
- Use: Envelope strategies, energy modeling, and certification frameworks.
- Best For: Comparing strategies across building types.
- Link: USGBC LEED Resources

6. High Performance Manual (NYC HPD)

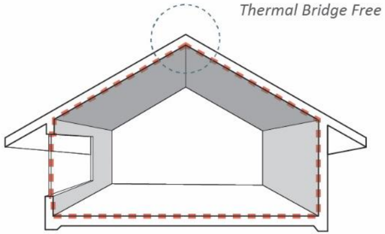
- Focus: NYC-specific high-performance retrofits and construction.
- Use: Design strategies, materials, detailing, and benchmarks.
- Best For: Multifamily housing and urban rental contexts.
- PDF: NYC HPD Manual

Solution strategies example 1 -Passive House Design Strategies



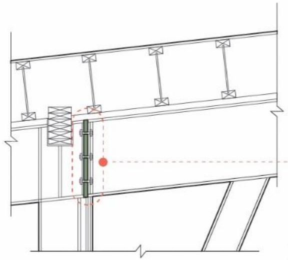
# Solution strategies example 2 -High Performance Building

## 1) Reduce Air Transfer : Infiltration & Exfiltration

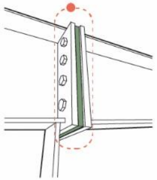



Continuous Air Tight Layer
High Peformance Window
Thermal Bridge Free at Connection

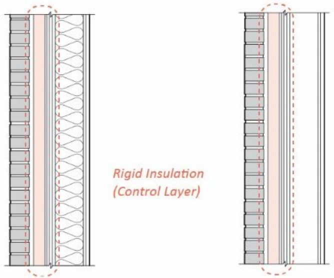
## 2) Introduce Thermal Break



Thermal breaks can also be referred to as thermal barriers. These elements are used to assist in reducing the flow of thermal energy between conductive materials.
Ex: Polyamide or polyurethane.



## 3) Adding Insulation: Ex: The Best Residential Wall / Commercial Wall

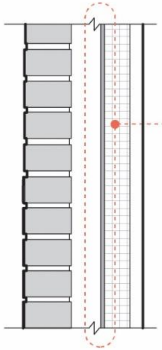


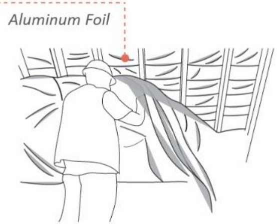

The Best Residential Wall

The Best Commercial Wall

## 4) Increase Reflectivity Surface Ex: Empire State Building

Aluminum foil or aluminized polyester are common material use as the reflective surface. It reflects heat by up to 95% and prevents it from transferring to the other side of its panel.



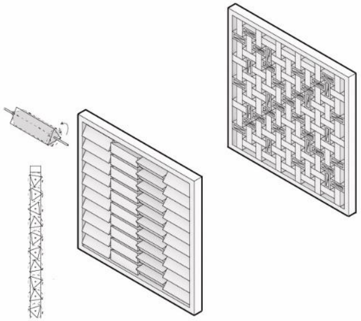



## 5) Increase Absorptive Surface

Green Facade

Living Wall

## 6) Exterior Cladding System



Modified From
Yiting's 2024 work

## Historical Lineage

1. Tools: Ladybug Tools, EnergyPlus, EPW files, ASHRAE adaptive models
2. Cybernetic Theory: Cedric Price’s responsive architecture, Reyner Banham’s “The Architecture of the Well-Tempered Environment”
3. Experiments: 1960s environmental control theories, 2000s responsive housing prototypes, modern energy dashboards
4. Political Debates: Right to energy, tenant agency, comfort equity under climate change

## Situated Technology

This project aligns with CDP's themes of situated computation and critical tool-making by:

- Centering user agency in the home
- Treating thermal data as culturally and materially embedded
- Challenging the assumption that high-tech systems always lead to efficiency
- Proposing computation as a conversational practice between buildings and bodies

## Rhetoric Argument

This project challenges the idea that knowledge about energy and climate should be limited to experts. By using design to translate complex building and environmental data into simple, visual feedback, it makes energy impact understandable and accessible to everyone.

## Method : Idea of the Home Energy Tool Workflow

### User Inputs

1. Building Age (Ex: Built in ____)
2. Material Use / Basic Structure ( Ex: Steel Framing / Brick Veneer)
3. Building Type (Ex: Residential / Small Commercial)
4. Program Type (Ex: Office / Bedroom)
5. Draw your space look
6. Encounter Problems ( Ex: Daylight ? / Visual ? / Ventilation ? ..)
7. HVAC system Type

### Outputs

1. Estimate Energy Consumption (kwh)
2. Potential Building Problems
3. Solutions that one could adopt to improve
4. The potential outcome

## AI Tool Demo Website

User Type in the basic information of their home / building

1. Building Age (Ex: Built in ____)
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# Grasshopper Tools Develop so far for Calculating Energy Consumption

# Grasshopper Tools Develop so far for Simulating the Indoor Comfortness

# Outline Capstone Trajectory

## Summer

1. Define the Research Scope / Scale / Content
2. Set up thesis framework
3. Background Research (By Mapping)
    a. The current building type distribution NYC
    b. The current energy computations in NYC
    c. The current living qualities in NYC
4. Develop Custom Tool (Grasshopper)
    a. Tools to calculate building energy consumption
    b. Analyse indoor thermal comfort
    c. Give Passive design strategies suggestion

## Fall / Spring

1. Design the AI Tool
2. Collect the data sources
3. Develop Web / App Interface
4. Put together Everything ?

# Related Tools

## Building America Solution Center (U.S. DOE)

1. What it does: Offers high-performance building details and retrofit guidance.
2. Audience: Builders, designers, energy consultants.
3. Limitations: Not AI-driven, not personalized, not user-friendly for lay people.
4. My distinction: I offer dynamic, contextual advice, framed through human-readable diagrams and schedules.

## MIT's "Designing Responsive Environments" (DRL) / Comfort Tool

1. What it does: Allows users to explore comfort zones based on adaptive or PMV models.
2. Audience: Researchers, climate engineers.
3. Limitations: No AI, no behavioral feedback, not location-specific by default.
4. My distinction: I combine these models with personalized data and real-time feedback loops.

## Ladybug Tools + Honeybee + Pollination

1. What they do: Parametric plugins for Rhino/Grasshopper that simulate thermal comfort, solar radiation, and daylight.
2. Audience: Architects and advanced modelers.
3. Limitations: Requires geometric modeling and technical expertise.
4. My distinction: I make those simulations usable by non-experts in a guided, web-based interface.

## Cove.Tool

1. What it does: A web-based generative simulation platform for architects to optimize buildings for energy, daylight, cost, and carbon.
2. Audience: Architects and engineers during schematic design.
3. Limitations: Requires detailed BIM inputs; not accessible to renters or non-professionals.
4. My distinction: I shift the agency from designers to occupants, and focusing on behavioral, not just material, strategies.

# Related Tools-2

## “Nest Renew” + Smart Thermostats

1. What it does: Uses AI to optimize home heating and cooling schedules, aligned with grid carbon intensity.
2. Audience: Homeowners with smart devices.
3. Limitations: Black-box logic; doesn't educate the user about building science or spatial logic.
4. My distinction: Expose the spatial and architectural reasoning — not just automate it.

## Smappee, Sense, Neurio (Home Energy Monitors)

1. What they do: Monitor electricity usage appliance-by-appliance.
2. Audience: Energy-conscious homeowners.
3. Limitations: Focused on electricity; not holistic thermal comfort; not spatial.
4. My distinction: My model combines thermal envelope logic, behavior patterns, and spatial reasoning.

# Challenges

1. Data Source Collection

   The Existing Building Typology data and their basic information

   Potential Solutions Data

2. To decide the level of professionalism for those the suggestions

   (How to make the solution more approachable to users)

# Reference Readings

## Decision Making Using AI in Energy and Sustainability

https://books.google.com/books?id=RGLdEAAAQBAJ&printsec=frontcover&source=gbs_ViewAPI#v=onepage&q&f=false

- Chapter 14. Syrian Household Energy Consumption Behavior Analysis In Turkey: Bayesian Belief Network
- Chapter 17. A Multi-Criteria Decision-Making Model for Technology Selection in Renewable-Based Residential Microgrids

Reference Website:


1. https://qsel.columbia.edu/nycenergy/
2. https://energy.cusp.nyu.edu/#/
3. https://www.urbangreencouncil.org/what-we-do/explore-nyc-building-data-hub/

### Other Tools & Data Sources

- Smart Citizen Platform – Open-source environmental sensing kits
- NYC Building Data Hub – Energy benchmarking and building profiles
- OpenStudio + EnergyPlus – Energy modeling software by DOE
- Ladybug Tools – Parametric environmental simulation for designers
- Cove.Tool Blog – Performance-based design strategies and cost trade-offs

### Recommended Books

- The Architecture of the Well-Tempered Environment – Reyner Banham (systems thinking)
- Passive House Details – Corner, Fillinger, Kwok (case studies + wall sections)
- The Passive Solar Design Handbook – James Kachadorian (climate-based logic)
- Thermal Delight in Architecture – Lisa Heschong (human experience of heat)
- Designing With Climate – Victor Olgyay (bioclimatic design strategies)