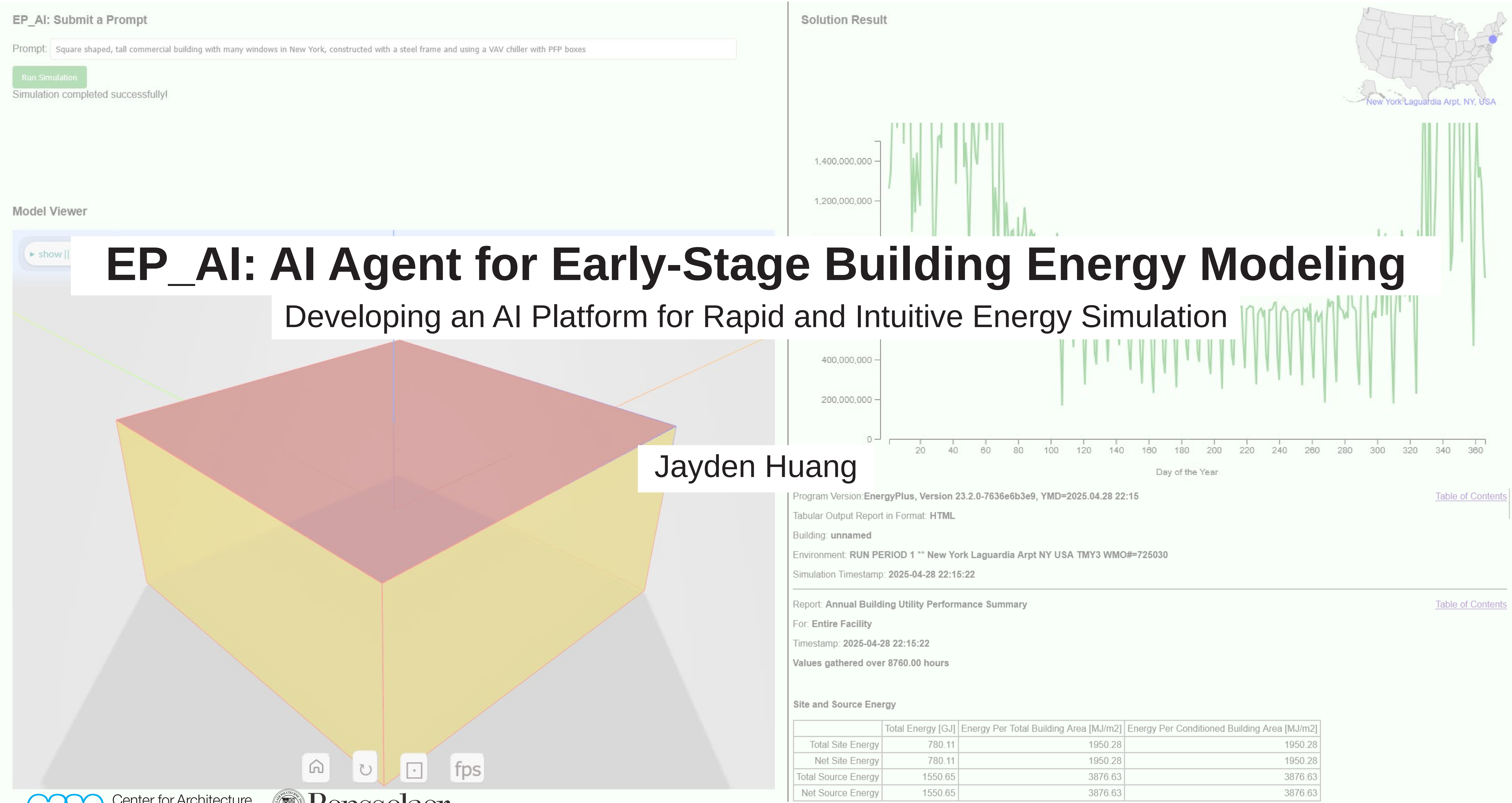
EP_AI: AI Agent for Early-Stage Building Energy Modeling

Developing an AI Platform for Rapid and Intuitive Energy Simulation

Jayden Huang



	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	780.11	1950.28	1950.28
Net Site Energy	780.11	1950.28	1950.28
Total Source Energy	1550.65	3876.63	3876.63
Net Source Energy	1550.65	3876.63	3876.63

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Research Overview

Topic: AI for Early-Stage Building Energy Modeling

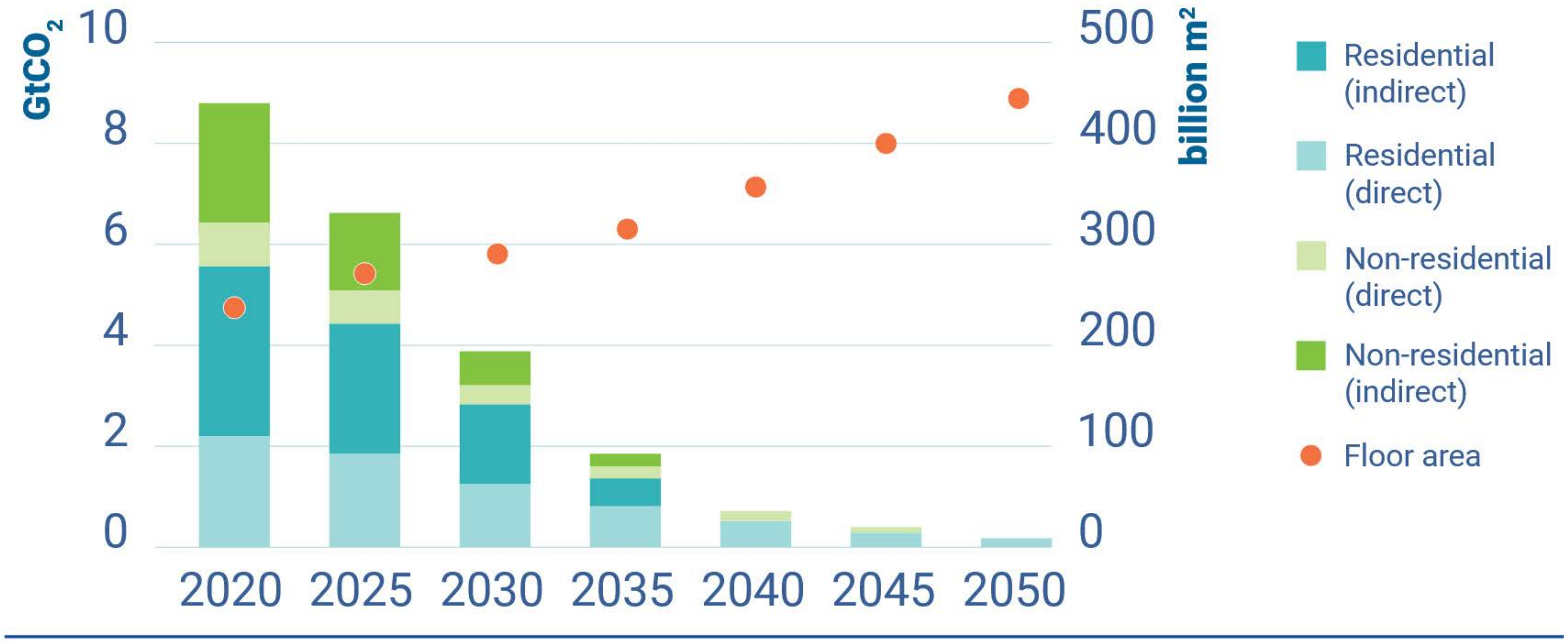
Question: How can AI reduce the complexity of energy modeling to make it more accessible?

Significance: Accessible energy modeling allows architects, engineers, and clients to make informed, energy-efficient decisions at the speed of design.

The Problem: Buildings need to reduce their energy usage

The building industry makes up for over a third of global emissions. To mitigate this, there must be radical changes in how we design and occupy buildings. Currently, operational energy of buildings accounts for 75% of building emissions, making it a major target for change.[1] Governments worldwide are setting sustainability goals to lower these values[2], and design tools will be required to do so.

How will we build more and use less?



Source: IEA 2021. All rights reserved. Adapted from "Tracking Clean Energy Progress" (IEA 2021c).

1: Cdb, Penrose. "2022 GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION," 2022.
2: Hoffman, Emily. "Local Law 97." NYC DOB. Accessed January 31, 2025. https://www.nyc.gov/assets/buildings/pdf/presentations/2023bsls/ll97.pdf.

Building Energy Modeling (BEM)

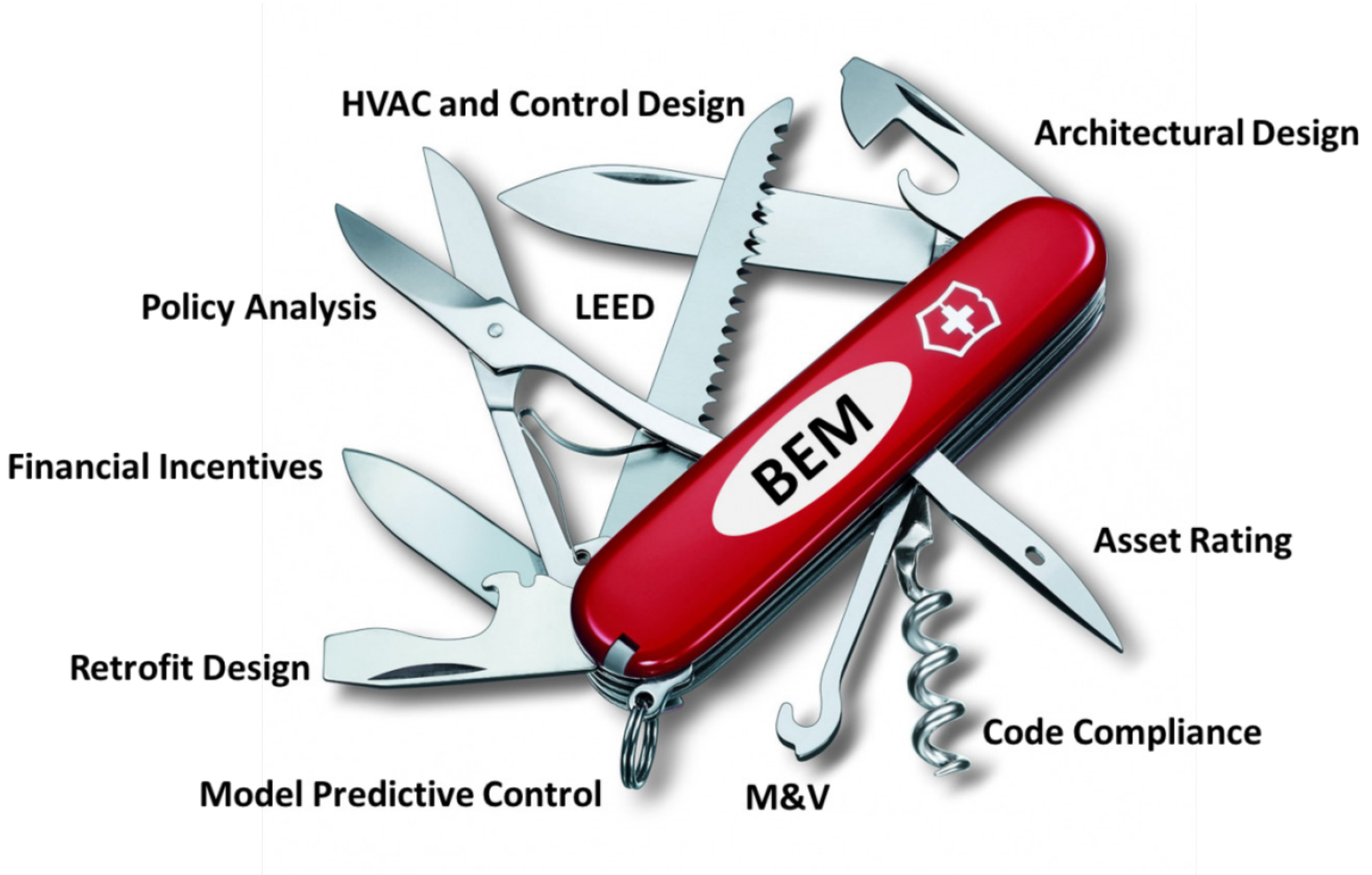
What is it?

BEM simulates a building to predict its energy use. This provides useful metrics that help inform design to be more energy conscious.[1]

Why do we do it?

- Design Optimization
- Code Compliance
- Cost Reduction

As architects, we already consider these factors in the design process, building off intuition and general rules of thumb. BEM builds off of this, providing real measurement to our design sense.



BEM is a multipurpose tool crucial to making our buildings energy efficient. Image © US Department of Energy

1: Roth, Amir. “Building Energy Modeling.” Energy.gov, August 28, 2014. https://www.energy.gov/eere/buildings/building-energy-modeling.

How do we energy model?

Energy modeling is predominately based on EnergyPlus, an application developed by the Department of Energy.[1] It is a powerful but complex way of simulating a building and its energy performance.

The workflow consists of four major steps:

Create Geometry: Building surfaces/window surfaces

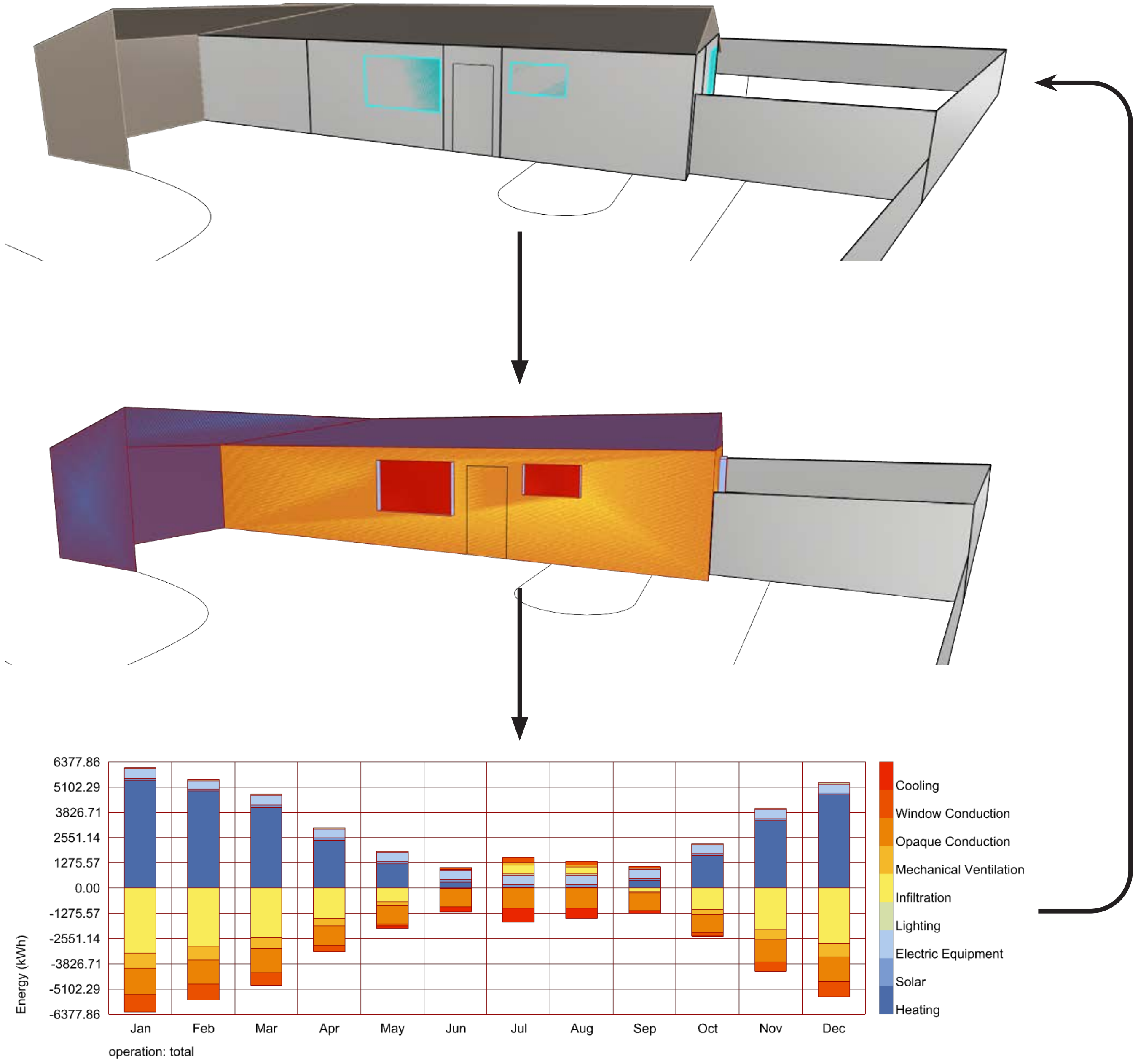
Assign Attributes: Materials, HVAC, equipment, weather, etc.

Analyze Results: Process simulation, extract relevant data

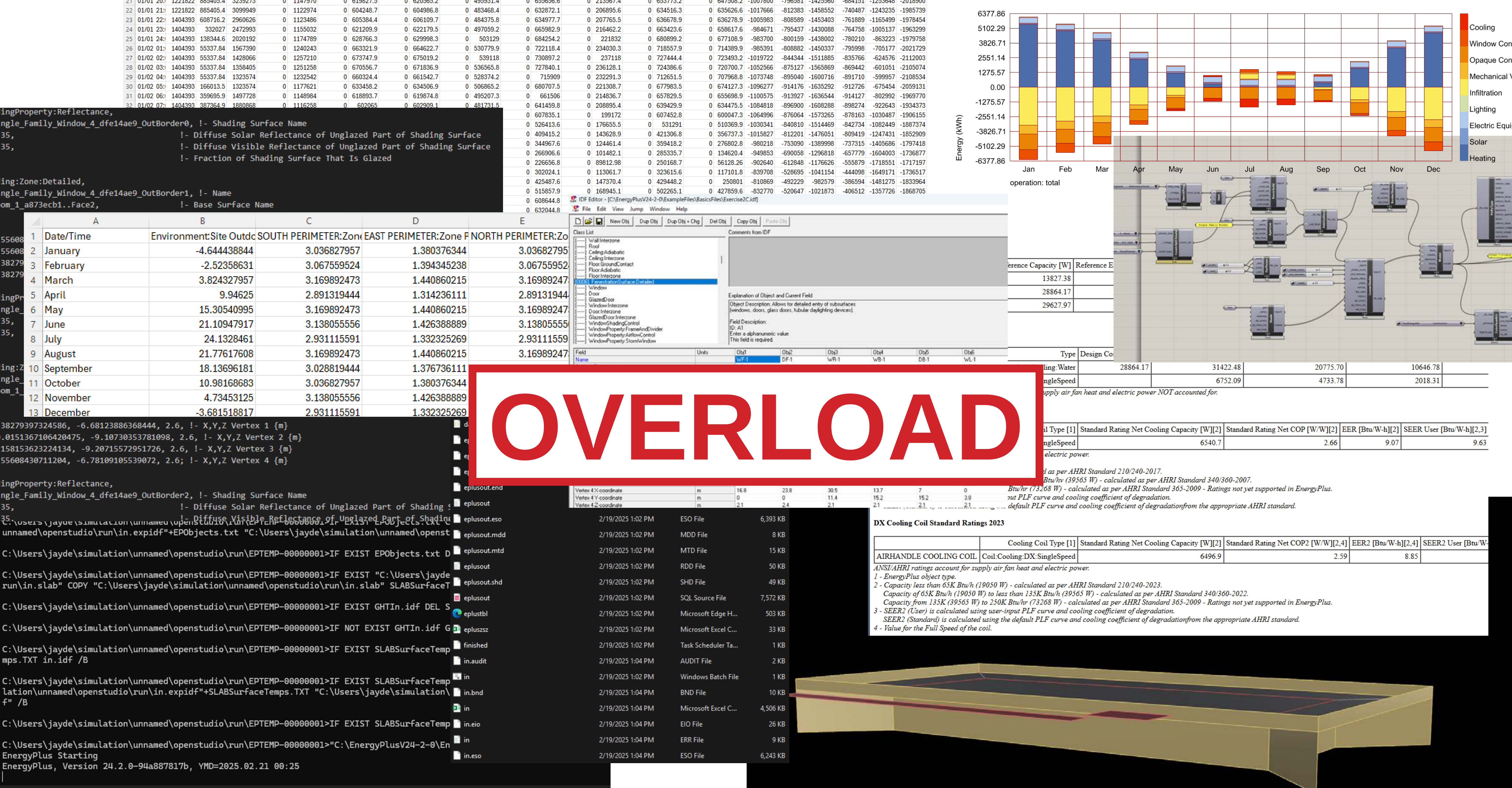
Repeat: An effective energy model is never made in one shot

Programs like Ladybug and OpenStudio provide interfaces for EnergyPlus, creating input files to be ran through the EnergyPlus calculation engine. They are easier to use and understand, and integrate readily with BIM software.

If energy modeling is an established practice, and there are tools to simplify it, what's the problem?



1: https://www.youtube.com/watch?v=w-yVgOvcQaA&list=PLRW2KXkdSVUdY2iQ6yjohNT5E5ElLVIhU



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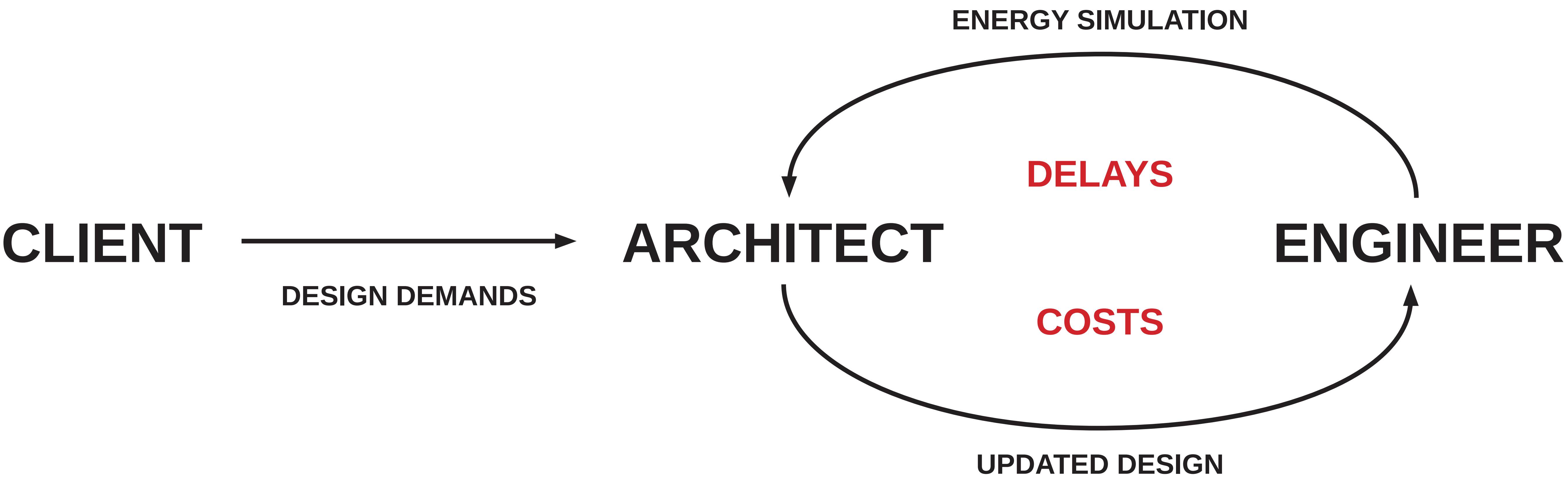
BEM in Practice



Due to complexity, BEM is typically outsourced to specialists. The added costs and delays limit BEM to projects with specific energy targets, rather than being employed more broadly.[1]

1: Credit, Kevin, Qian Xiao, Jack Lehane, Juan Vazquez, Dan Liu, and Leo De Figueiredo. “LuminLab: An AI-Powered Building Retrofit and Energy Modelling Platform.” arXiv, April 14, 2024. https://doi.org/10.48550/arXiv.2404.16057.

Finding a Research Problem

Buildings account for 30% of global energy use, resulting in high carbon emissions.[1]

↓

Energy modeling can help address this, yet remains underutilized.[2] The workflow relies on complex software and script-based tools, resulting in high costs and low accessibility.[3]

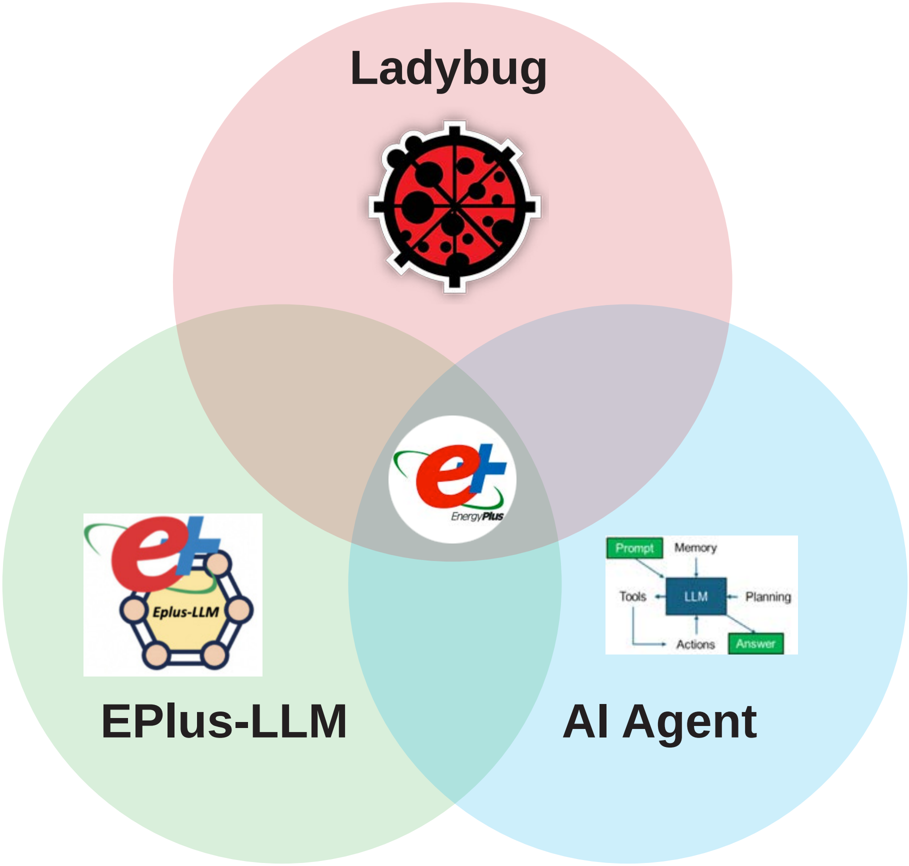
↓

How do we simplify energy modeling?

1: Delmastro, Chiara, and Olivia Chen. "Buildings - Energy System." IEA. Accessed February 21, 2025. https://www.iea.org/energy-system/buildings#tracking.
2: Roth, Amir. "Building Energy Modeling." Energy.gov, August 28, 2014. https://www.energy.gov/eere/buildings/building-energy-modeling.
3: Credit, Kevin, Qian Xiao, Jack Lehane, Juan Vazquez, Dan Liu, and Leo De Figueiredo. "LuminLab: An AI-Powered Building Retrofit and Energy Modelling Platform." arXiv, April 14, 2024. https://doi.org/10.48550/arXiv.2404.16057.

State of the Art

EnergyPlus remains at the heart of energy modeling for its reputation as a reliable, proven energy calculator. Simplifying energy modeling involves alternate methods of generating inputs for calculation.



Ladybug and OpenStudio: Existing, industry-standard methods for energy modeling.

Benefits: Programming-oriented interface of EnergyPlus is replaced with visual workflows that integrate directly with BIM software.
Drawbacks: Remains manually-intensive, requires expertise in buildings and energy systems.

EPlus-LLM: User-friendly AI interface that translates human input into files for simulation and output of results.[1]

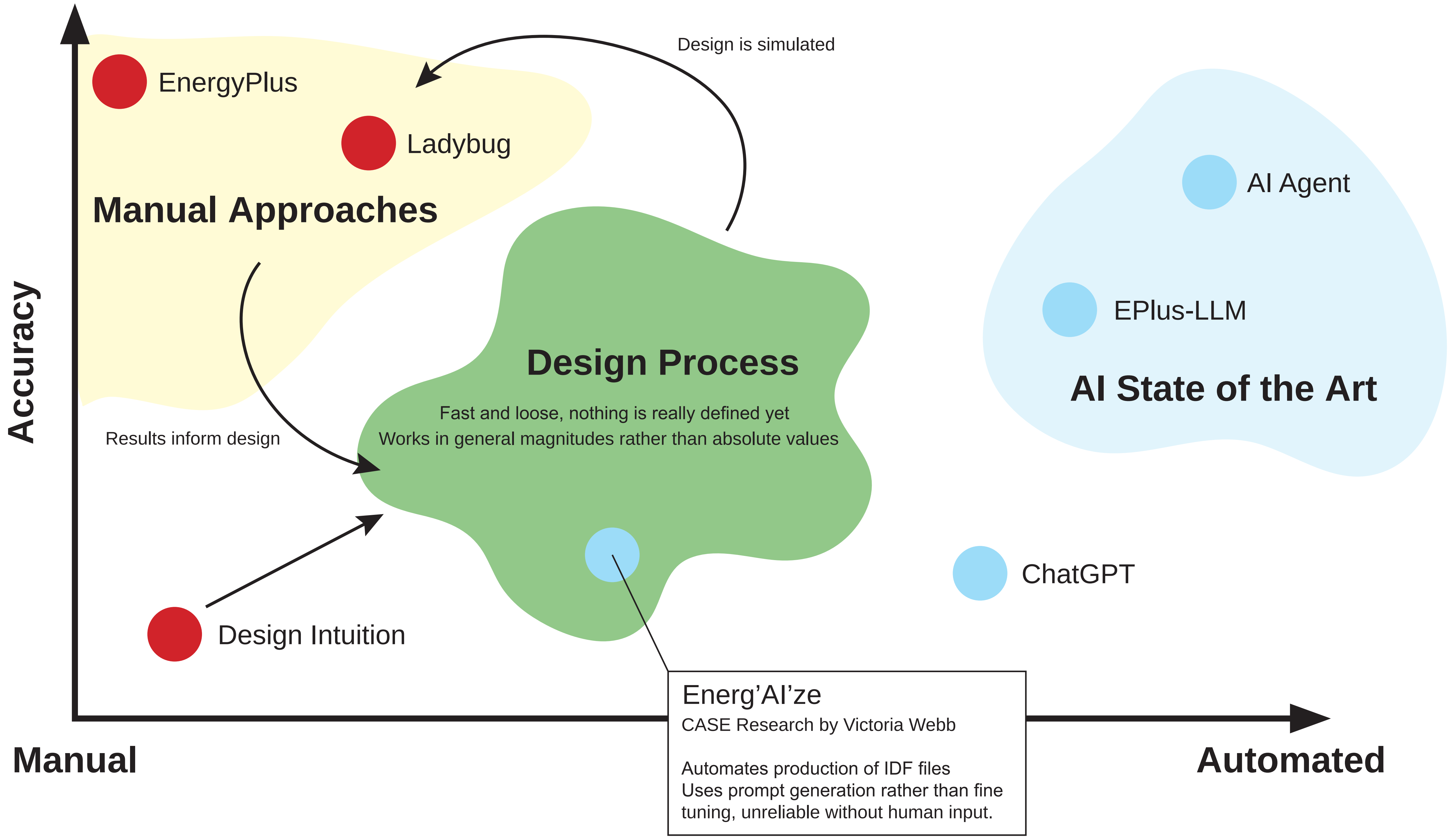
Benefits: Works with natural language, **opening energy modeling to non-energy professionals.**
Drawbacks: Limited prompt types don't allow for quick iteration.

Agentic Workflow: Agentic AI (structured decision-making and reasoning) creates IDF files and debugs them through a routine of sub-steps.[2]

Benefits: Follows a sequence of logic to produce highly accurate models.
Drawbacks: Relies on iterative processes that are expensive and resource-intensive.

1: Jiang, Gang, Zhihao Ma, Liang Zhang, and Jianli Chen. "EPlus-LLM: A Large Language Model-Based Computing Platform for Automated Building Energy Modeling." Applied Energy 367 (August 1, 2024): 123431. https://doi.org/10.1016/j.apenergy.2024.123431.
2: Zhang, Liang, Vitaly Ford, Zhelun Chen, and Jianli Chen. "Automatic Building Energy Model Development and Debugging Using Large Language Models Agentic Workflow." Energy and Buildings 327 (January 15, 2025): 115116. https://doi.org/10.1016/j.enbuild.2024.115116.

The Gap



Design is simulated
EnergyPlus
Ladybug
Manual Approaches
AI Agent
EPlus-LLM
AI State of the Art
Accuracy
Design Process
Fast and loose, nothing is really defined yet
Works in general magnitudes rather than absolute values
Results inform design
ChatGPT
Design Intuition
Energ'AI'ze
CASE Research by Victoria Webb
Automates production of IDF files
Uses prompt generation rather than fine tuning, unreliable without human input.
Manual
Automated

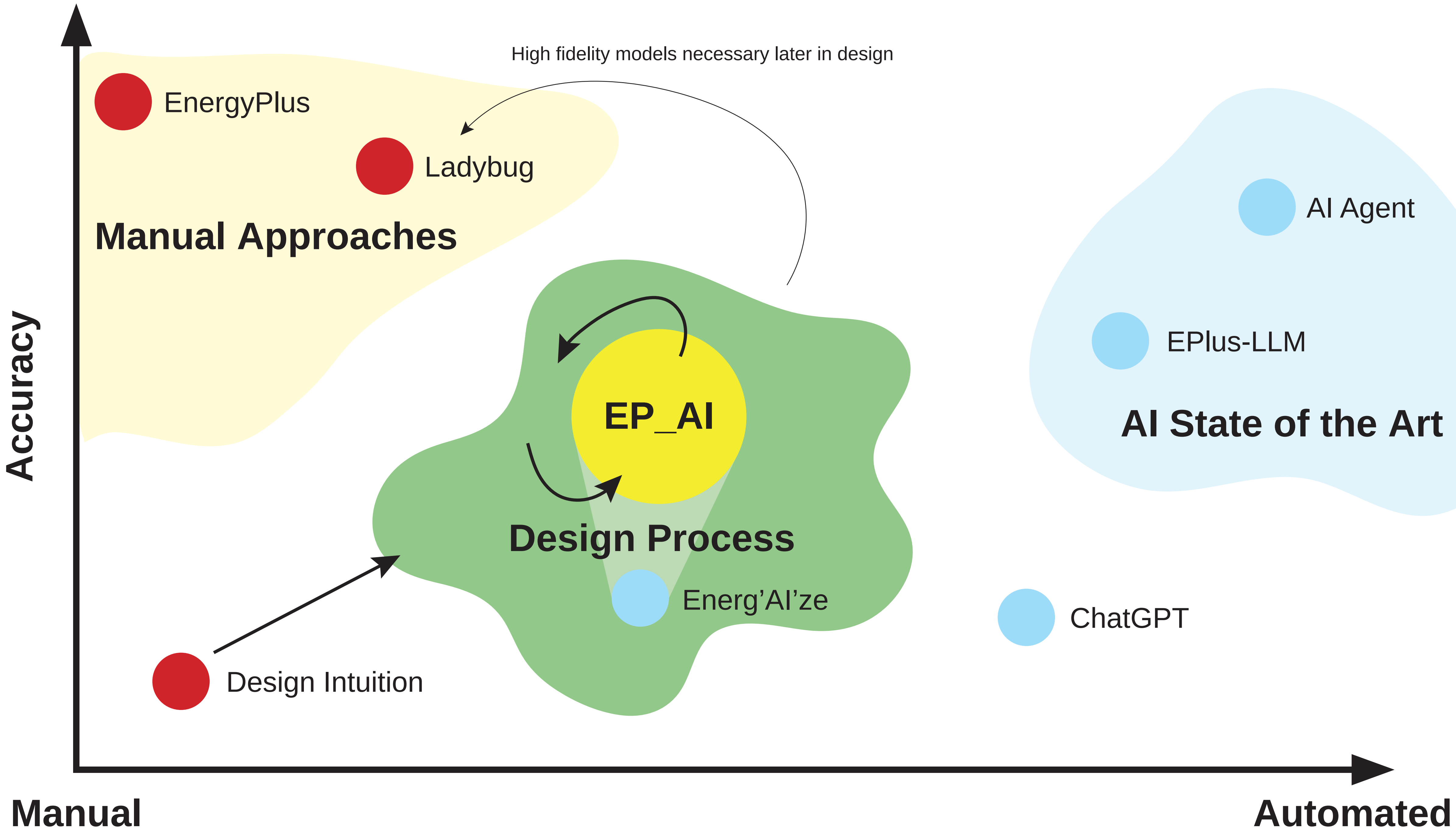
Research Hypothesis

BEM allows architects and engineers to simulate performance and modify design.
BEM workflows are costly and time-consuming, requiring specialized knowledge and complex, manual processes. In practice, this requires outsourcing to specialists, adding costs and delays.

Current research like EPlus-LLM or agentic workflows, involve large language models (LLMs) to automate BEM, reducing the barrier to entry as fast, accessible, and comparatively accurate alternatives. However, these projects **prioritize reliability and accuracy, requiring a degree of specificity and heavy computation that are excessive for loose, early-stage design applications.**

If an AI is instead trained on a broader range of data, then it can perform as a design tool to match the speed of design and its fluidity.

Bridging The Gap



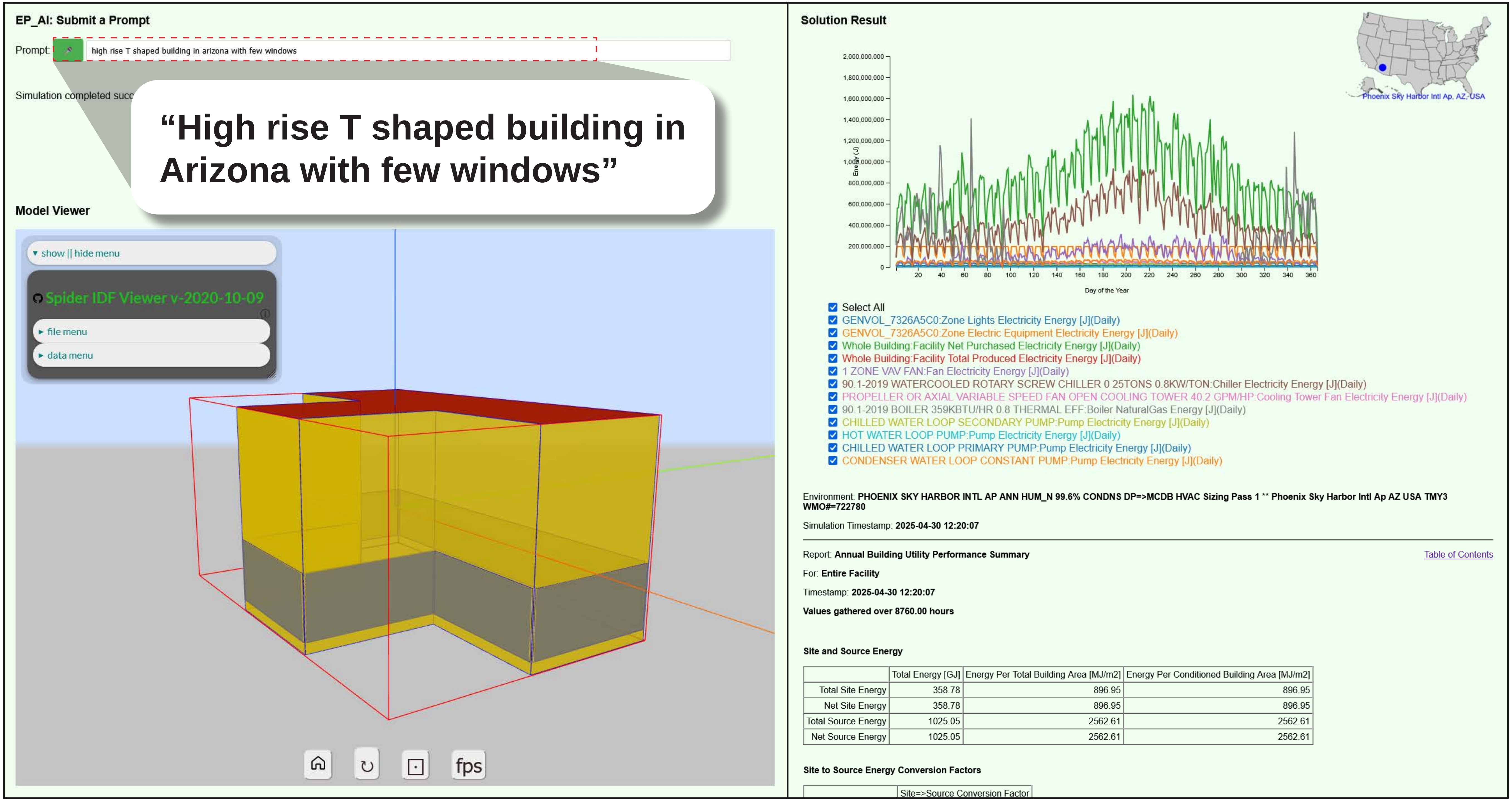
Where does this research stand?

expands on natural design intuition

Low to High	Design Intuition	EnergyPlus	Ladybug	ChatGPT	EPlus-LLM	AI Agent	EP_AI
		existing, good for code compliance		generative ai, automated			
Speed	Fast	Slow					Fast
Accuracy		Accurate		Inaccurate			General ranges for early design
Automation		Manual			Automatic		Requires user feed-back
Required Knowledge		Needs Specialists			Entry Level		Energy knowledge not needed
Scalability (to diff. bldg. types)		Works for Most			Limited Types		Trained on high prompt variety
Cost		Hiring Specialists				LLM API Calls	No specialists, light-er LLM platform

reinforms design intuition

EP_AI



EP_AI: Submit a Prompt
Prompt:
high rise T shaped building in arizona with few windows
Simulation completed succ
“High rise T shaped building in Arizona with few windows”
Model Viewer
▾ show || hide menu
Spider IDF Viewer v-2020-10-09
▸ file menu
▸ data menu
fps
Solution Result
Phoenix Sky Harbor Intl Ap, AZ, USA
Energy (J)
Day of the Year
Select All
GENVOL_7326A5C0:Zone Lights Electricity Energy [J](Daily)
GENVOL_7326A5C0:Zone Electric Equipment Electricity Energy [J](Daily)
Whole Building:Facility Net Purchased Electricity Energy [J](Daily)
Whole Building:Facility Total Produced Electricity Energy [J](Daily)
1 ZONE VAV FAN:Fan Electricity Energy [J](Daily)
90.1-2019 WATERCOOLED ROTARY SCREW CHILLER 0 25TONS 0.8KW/TON:Chiller Electricity Energy [J](Daily)
PROPELLER OR AXIAL VARIABLE SPEED FAN OPEN COOLING TOWER 40.2 GPM/HP:Cooling Tower Fan Electricity Energy [J](Daily)
90.1-2019 BOILER 359KBTU/HR 0.8 THERMAL EFF:Boiler NaturalGas Energy [J](Daily)
CHILLED WATER LOOP SECONDARY PUMP:Pump Electricity Energy [J](Daily)
HOT WATER LOOP PUMP:Pump Electricity Energy [J](Daily)
CHILLED WATER LOOP PRIMARY PUMP:Pump Electricity Energy [J](Daily)
CONDENSER WATER LOOP CONSTANT PUMP:Pump Electricity Energy [J](Daily)
Environment: PHOENIX SKY HARBOR INTL AP ANN HUM_N 99.6% CONDNS DP=>MCDB HVAC Sizing Pass 1 ** Phoenix Sky Harbor Intl Ap AZ USA TMY3 WMO#=722780
Simulation Timestamp: 2025-04-30 12:20:07
Report: Annual Building Utility Performance Summary
Table of Contents
For: Entire Facility
Timestamp: 2025-04-30 12:20:07
Values gathered over 8760.00 hours
Site and Source Energy
	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	358.78	896.95	896.95
Net Site Energy	358.78	896.95	896.95
Total Source Energy	1025.05	2562.61	2562.61
Net Source Energy	1025.05	2562.61	2562.61
Site to Source Energy Conversion Factors
Site=>Source Conversion Factor

EP_AI contd.

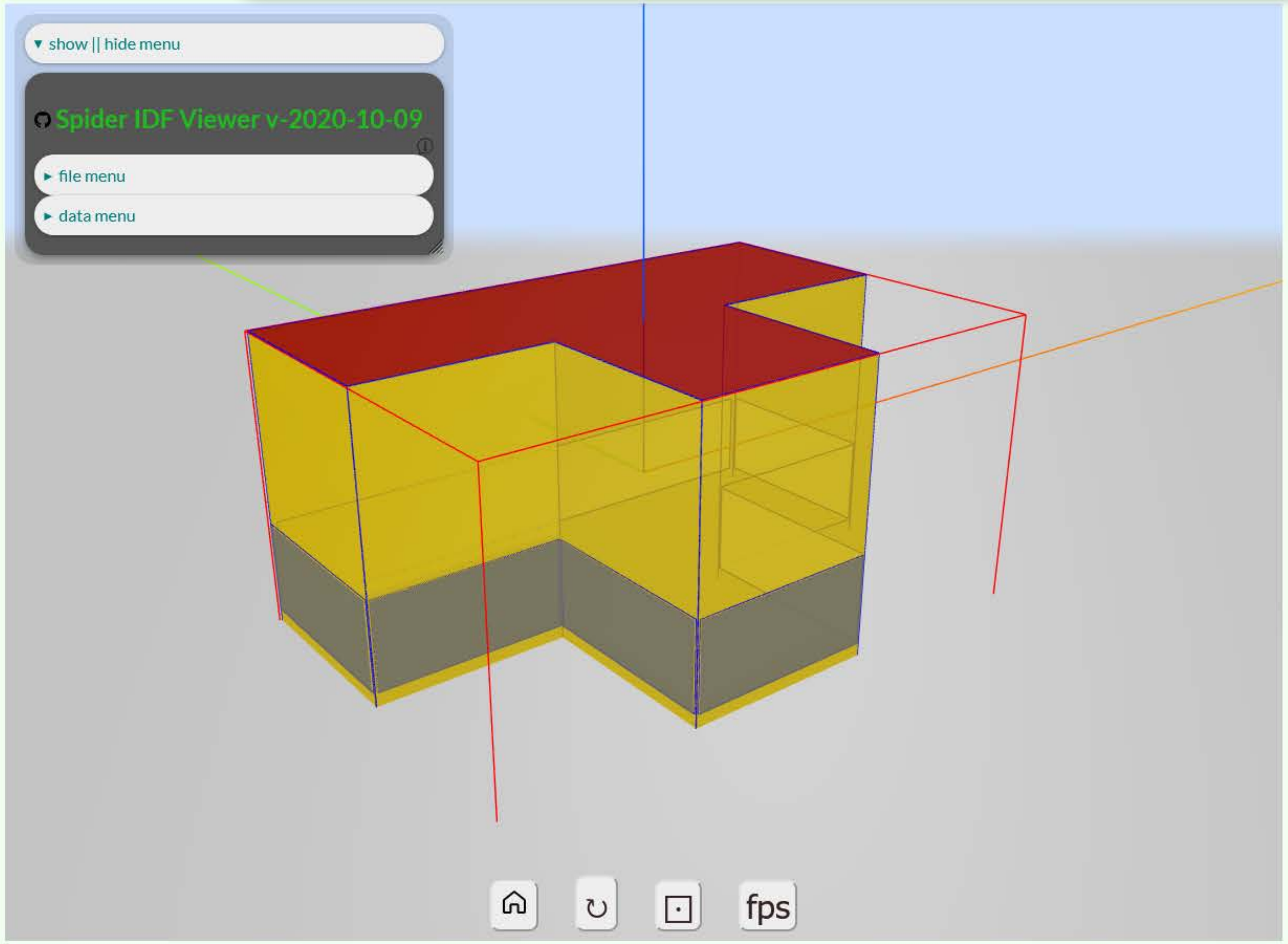
EP_AI: Submit a Prompt

Prompt: high rise T shaped building in arizona with few windows with VAV air-cooled chiller with central air source heat pump reheat

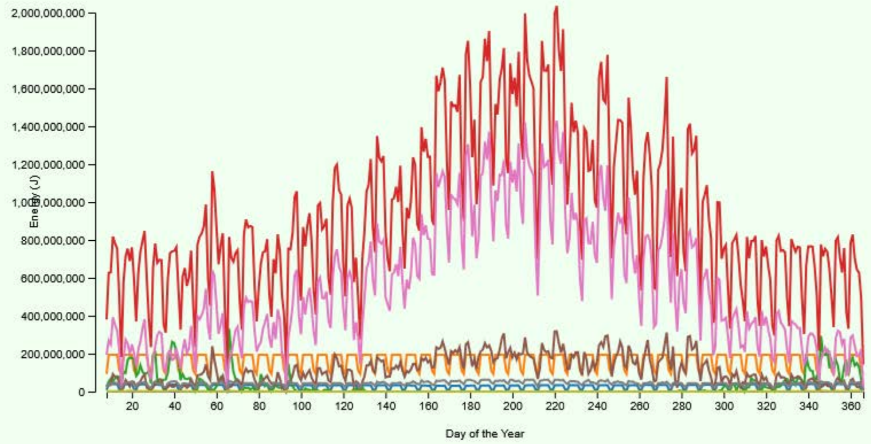
Simulation completed succ

“High rise T shaped building in Arizona with few windows with VAV air-cooled chiller with central air source heat pump reheat”

Model Viewer



Solution Result



- [x] Select All
- [x] GENVOL_D06C55DA:Zone Lights Electricity Energy [J](Daily)
- [x] GENVOL_D06C55DA:Zone Electric Equipment Electricity Energy [J](Daily)
- [x] EMS:Hot_Water_Loop_Central_Air_Source_Heat_Pump Electricity Consumption [J](Daily)
- [x] Whole Building:Facility Net Purchased Electricity Energy [J](Daily)
- [x] Whole Building:Facility Total Produced Electricity Energy [J](Daily)
- [x] 1 ZONE VAV FAN:Fan Electricity Energy [J](Daily)
- [x] 90.1-2019 CHILLER 0 25TONS 1.2KW/TON:Chiller Electricity Energy [J](Daily)
- [x] CHILLED WATER LOOP PUMP:Pump Electricity Energy [J](Daily)
- [x] HOT WATER LOOP PUMP:Pump Electricity Energy [J](Daily)

Environment: **RUN PERIOD 1 ** Phoenix Sky Harbor Intl Ap AZ USA TMY3 WMO#=722780**

Simulation Timestamp: **2025-04-30 12:34:44**

Report: **Annual Building Utility Performance Summary** — Table of Contents

For: **Entire Facility**

Timestamp: **2025-04-30 12:34:44**

Values gathered over 8760.00 hours

Site and Source Energy

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	341.91	854.77	854.77
Net Site Energy	341.91	854.77	854.77
Total Source Energy	1082.82	2707.06	2707.06
Net Source Energy	1082.82	2707.06	2707.06

Site to Source Energy Conversion Factors

	Site=>Source Conversion Factor
Electricity	3.167

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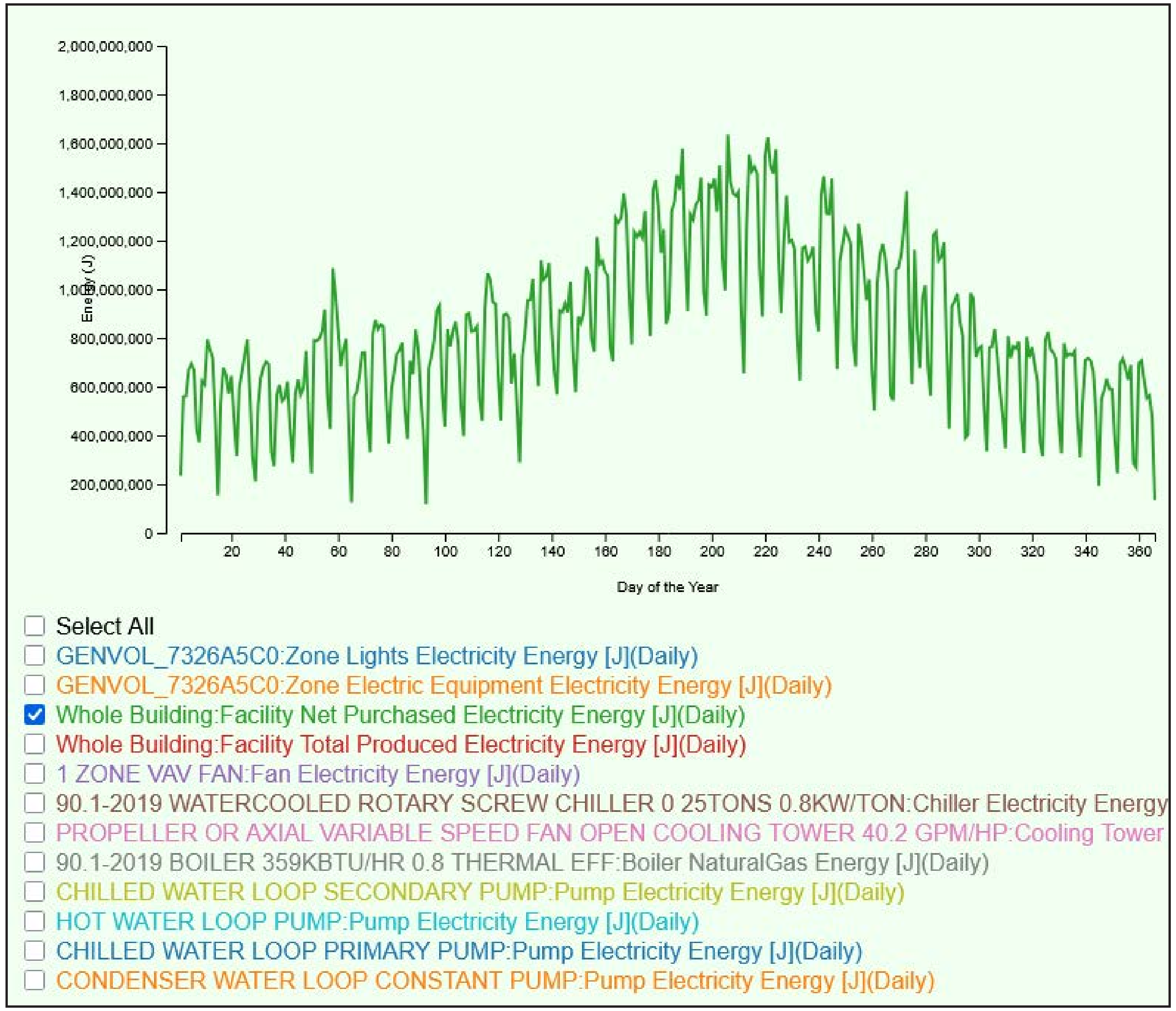
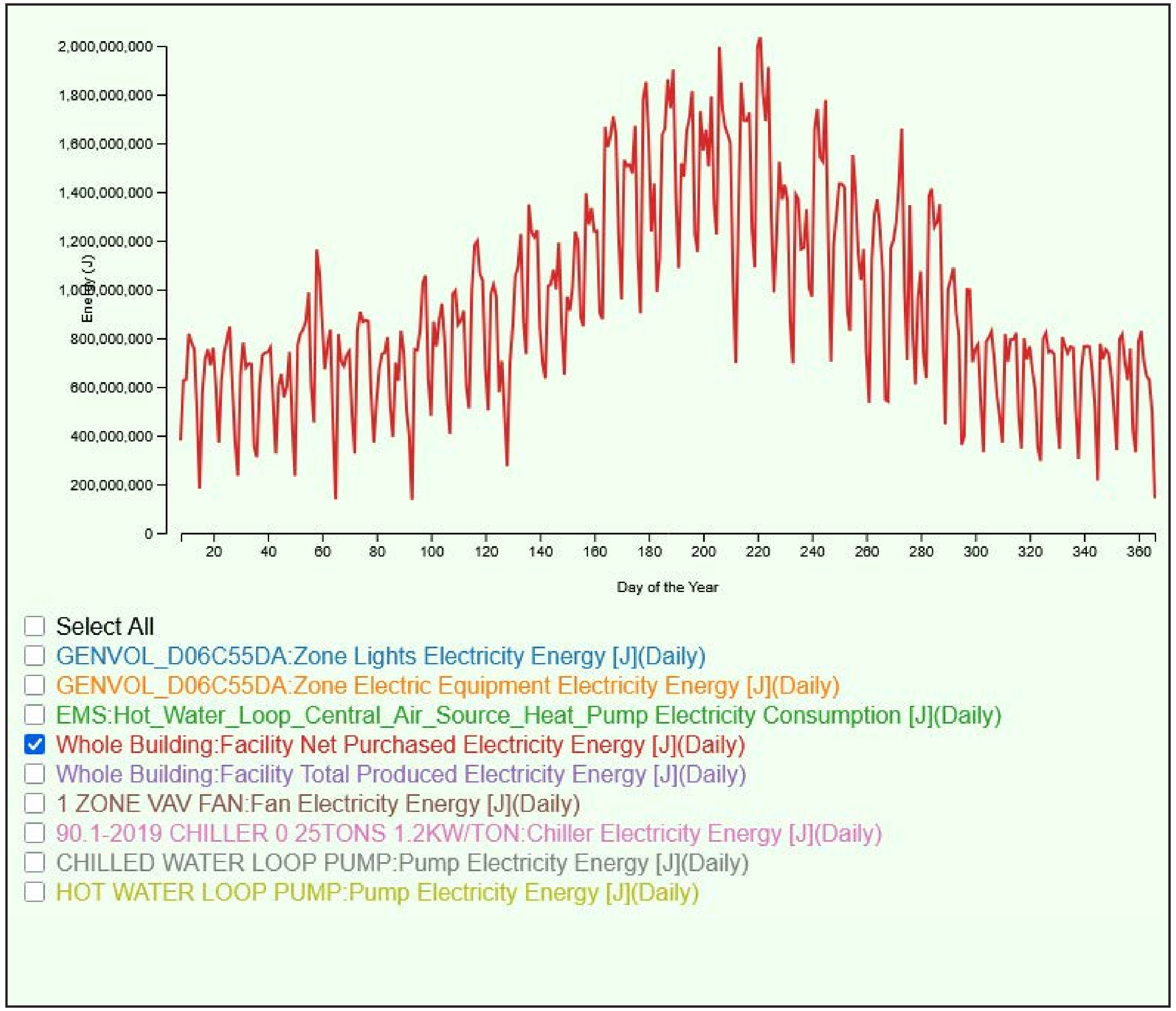
EP_AI contd.

Rapid iteration allows the user to quickly visualize what effect design changes can have on energy consumption.

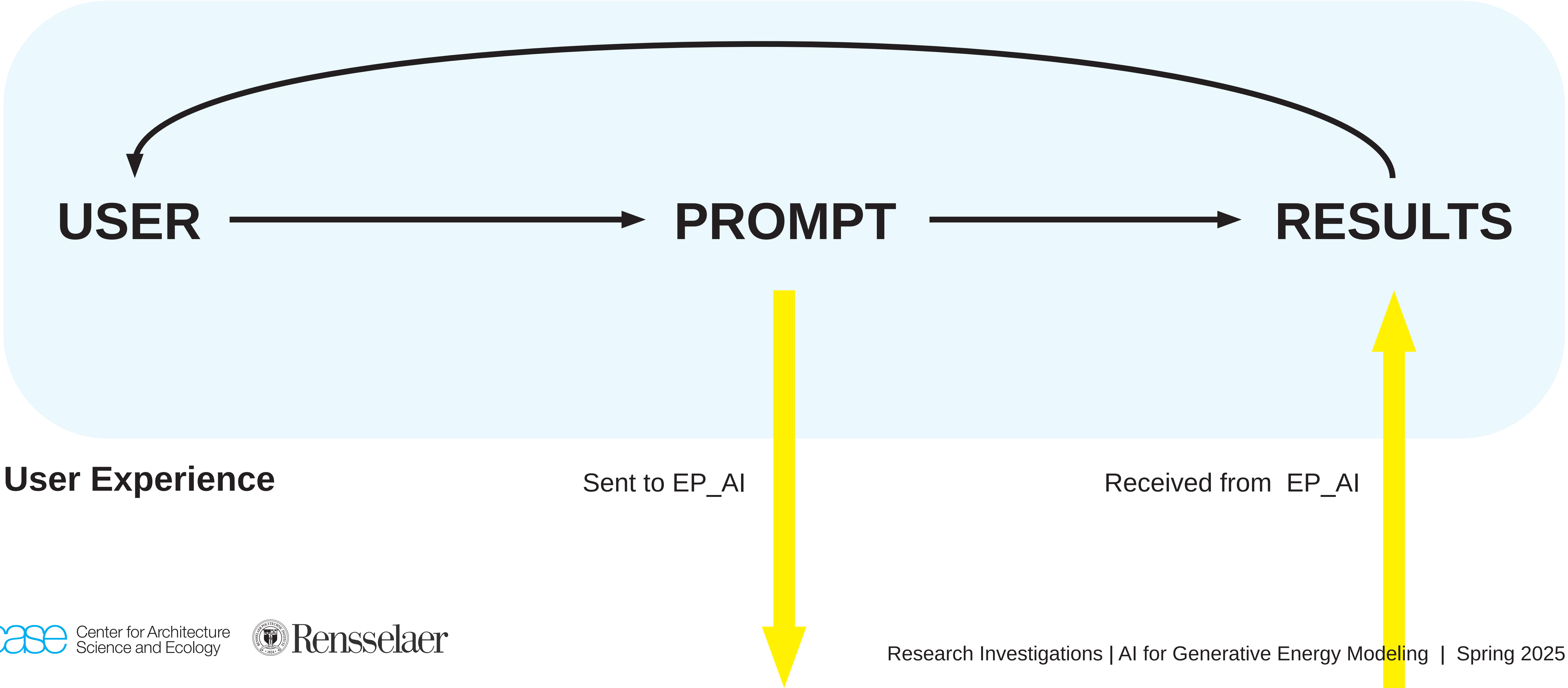


Example 1 (standard gas boiler)

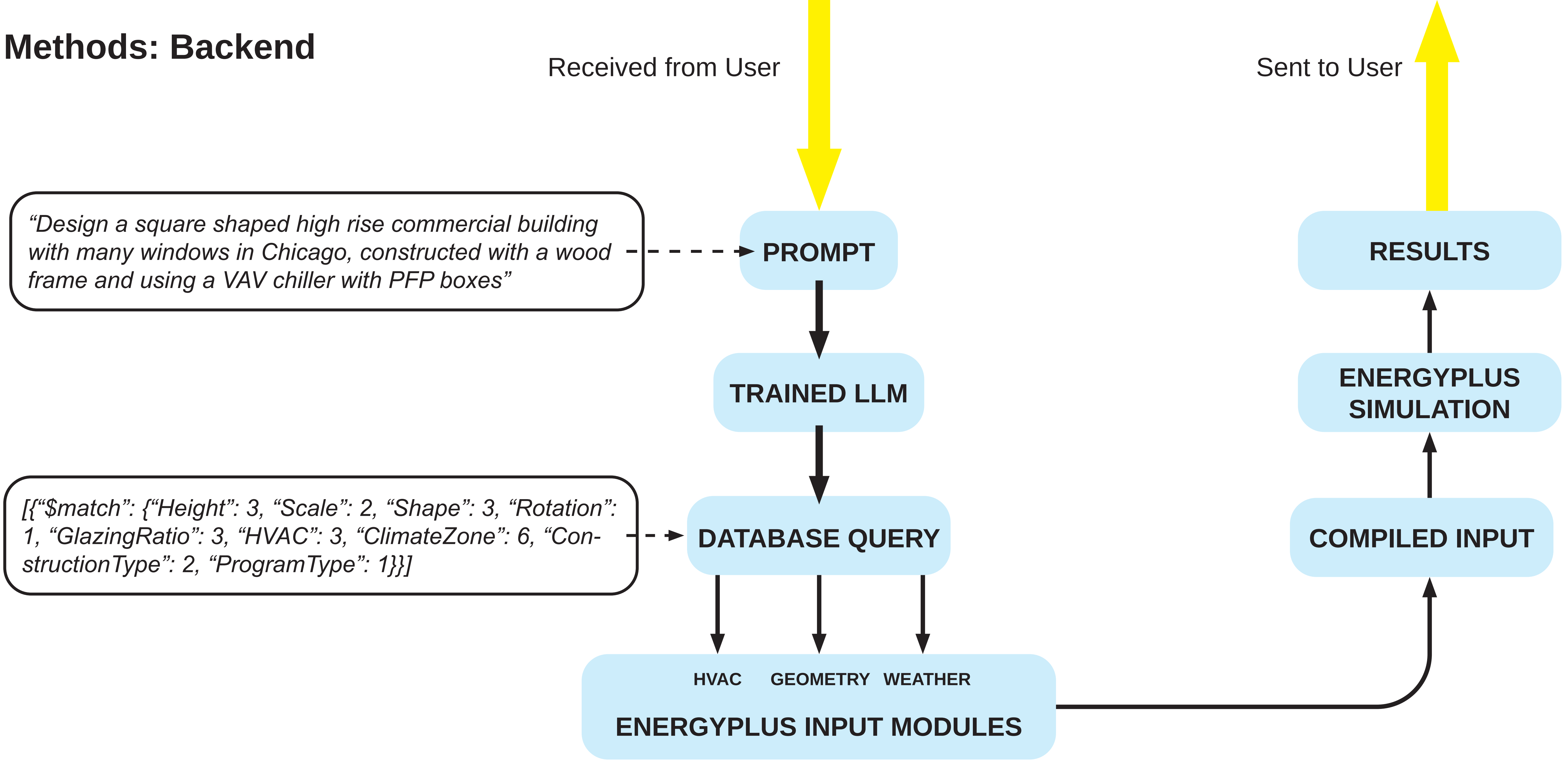


Example 2 (VAV chiller with central air heat pump)

Methods: Frontend

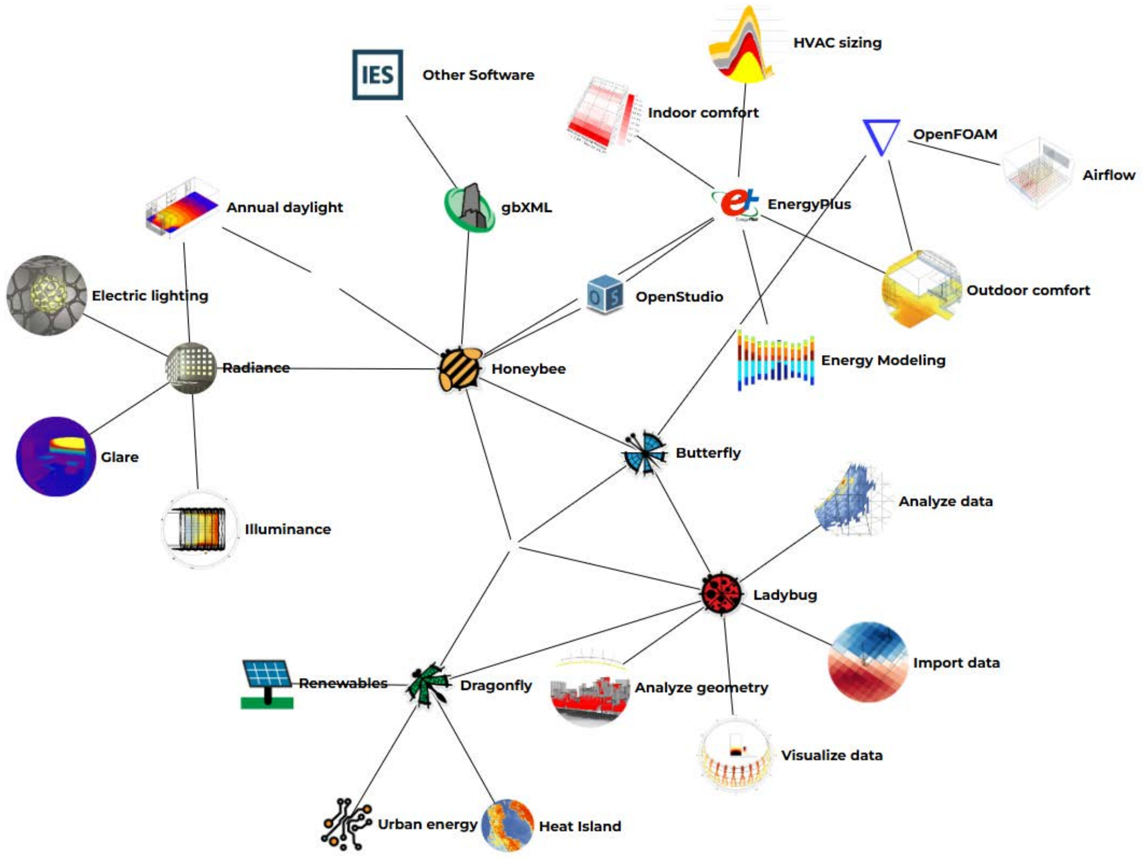


Methods: Backend

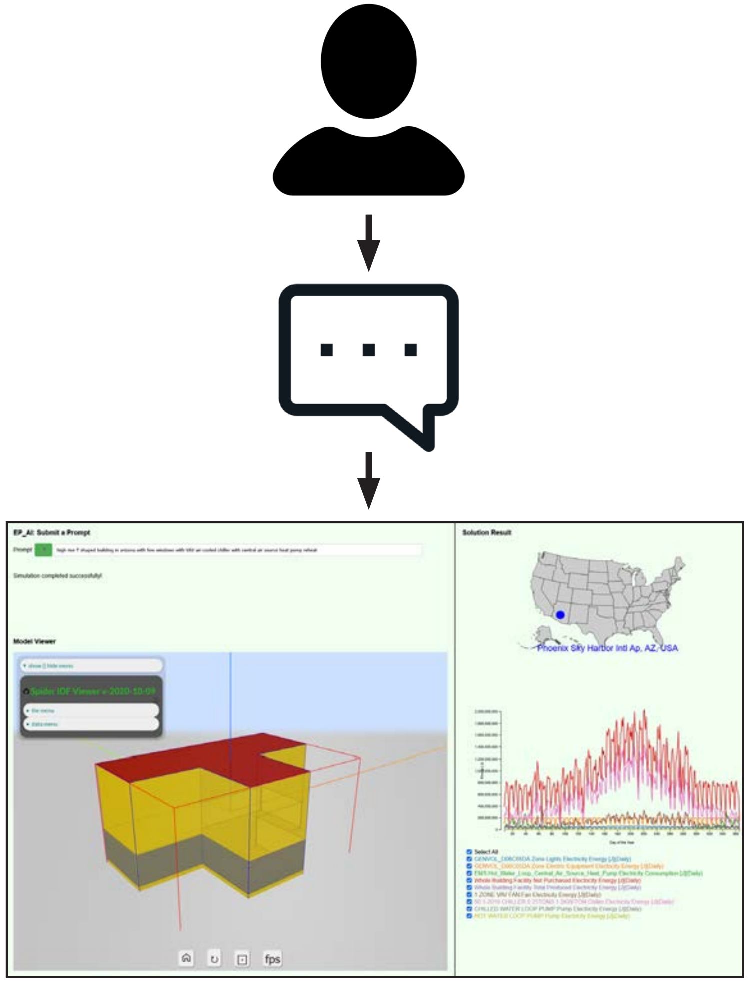


Why does this matter?

The user experience is simplified from the chaos of creating an energy model to a simple prompt-result interaction. By accelerating and simplifying a typically hours-long process, non-energy professionals have the opportunity to practice energy-conscious decision making.



NORMATIVE



PROPOSED

Conclusion and Looking Ahead

Buildings account for 30% of global energy use, resulting in high carbon emissions. Energy modeling can help design more efficient buildings that use less energy, but is underutilized due to complexity.

By simplifying building energy modeling,

- It can be done faster and earlier in the design process
- Non-professionals have access to it

This project uses AI to accelerate BEM by translating descriptive design language into performance-oriented results, allowing energy modeling to be not just a late-stage compliance check, but an early-stage design driver.