



Designing Sustainable Building Assemblies with Knowledge Graph Workflows

AI in AEC

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Adaptive Product Assembly



From Intent to Experience



Generative Assembly Design



Research Themes

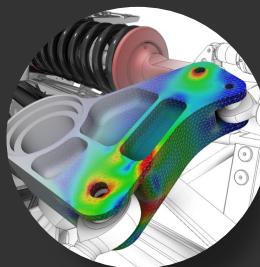
Enlivened Design



Industrialization of Construction



Living Product Design and Manufacturing



Net-Zero Buildings

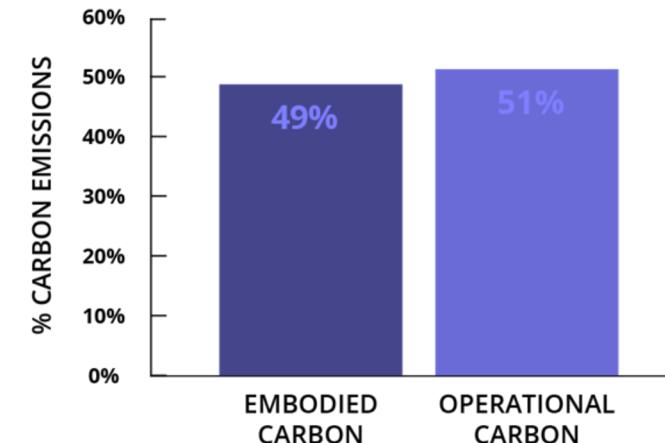


Embodied Carbon of Building Assemblies



Total Carbon Emissions of Global New Construction from 2020-2050

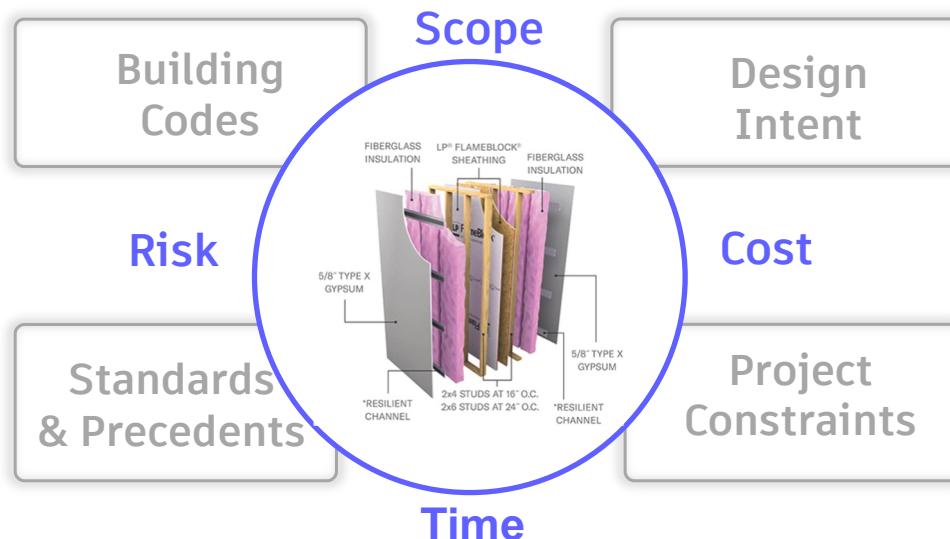
Business as Usual Projection



Source: 2030, Inc. / Architecture 2030. All Rights Reserved.

Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017.

Current Assembly Development Workflow



Architect & Designer

- *project goals*
- *site constraints*
- *code compliance*



Engineering Consultant

- *code compliance*
- *assembly performance*
- *constructability*



Sustainability Consultant

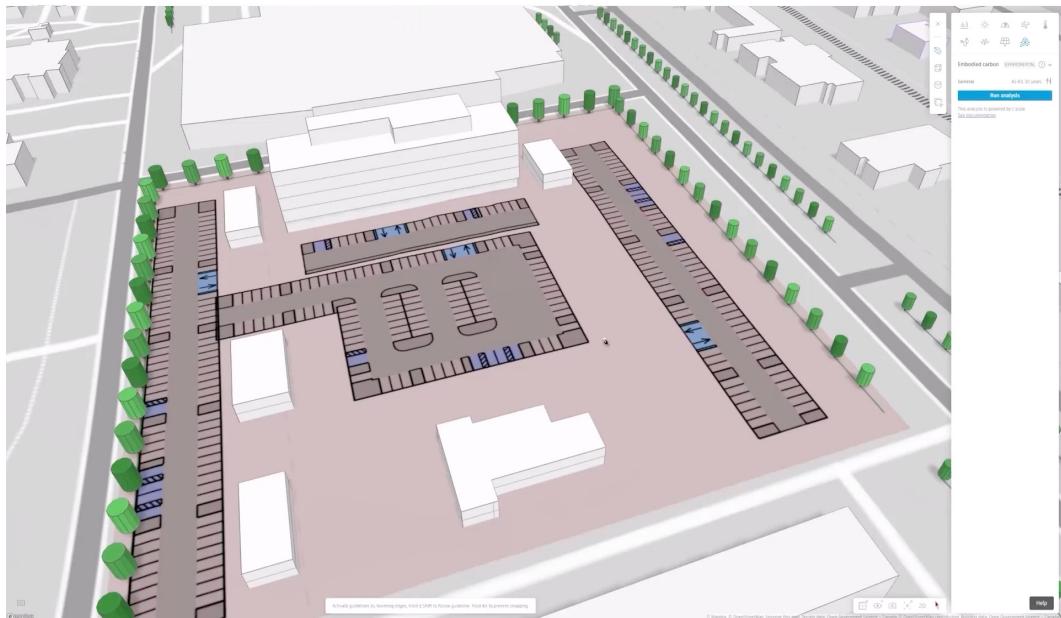
- *energy efficiency*
- *embodied carbon*
- *circularity*

New
Architect
Workflow



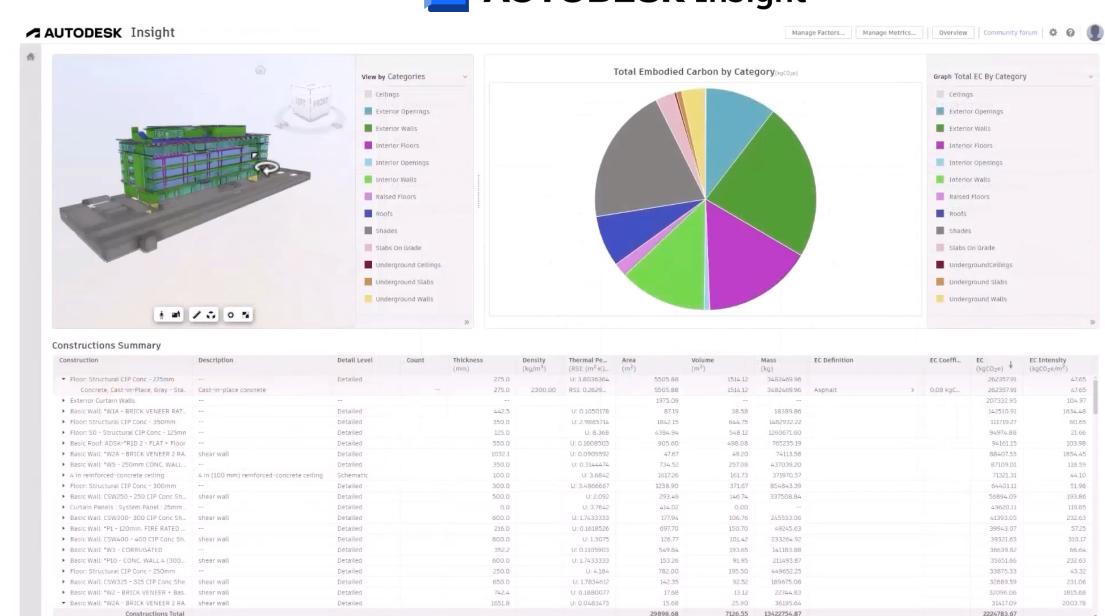
Current Embodied Carbon Workflow

AUTODESK Forma



Early Design Stage
(Statistical Data)

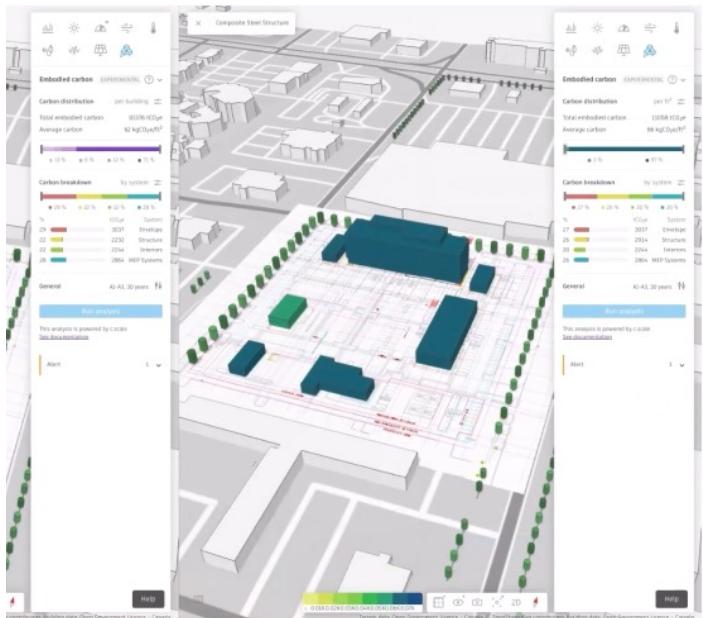
AUTODESK Insight



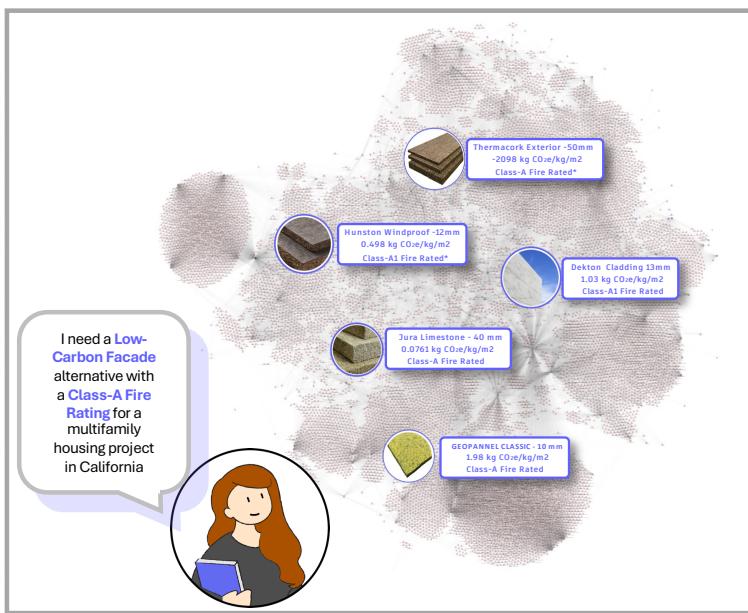
Detail Design Stage
(Product Specific Data)

Enhanced Embodied Carbon Workflow

 **AUTODESK Forma**

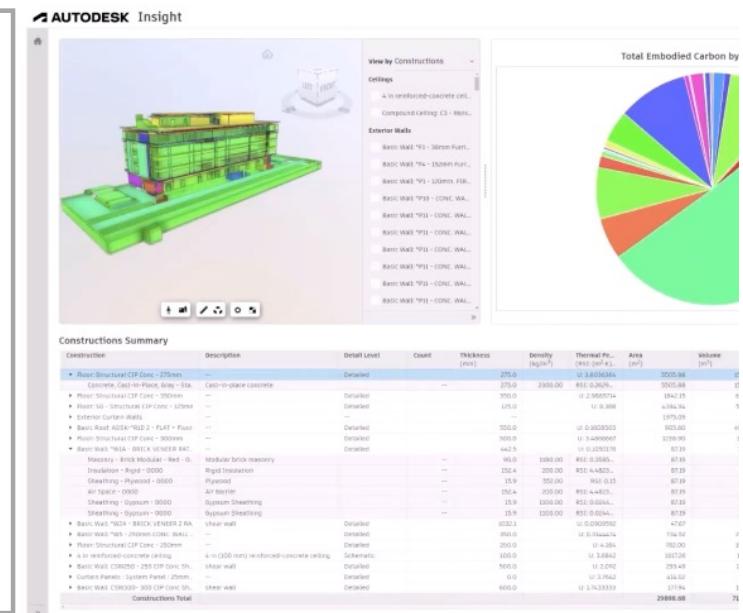


Early Design Stage ►
(Statistical Data)



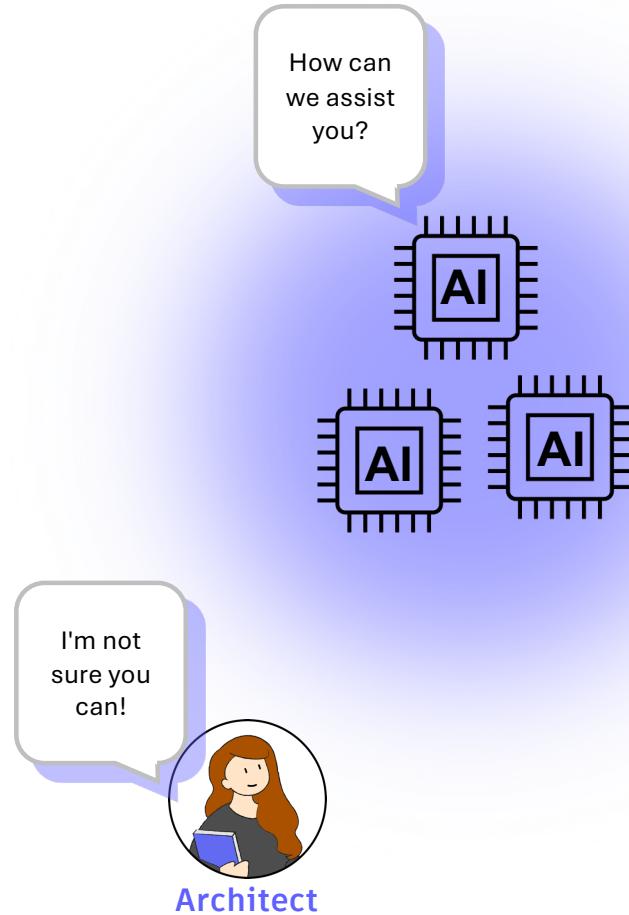
Concept Design Stage
(Statistical & Product Specific Data)

 **AUTODESK Insight**

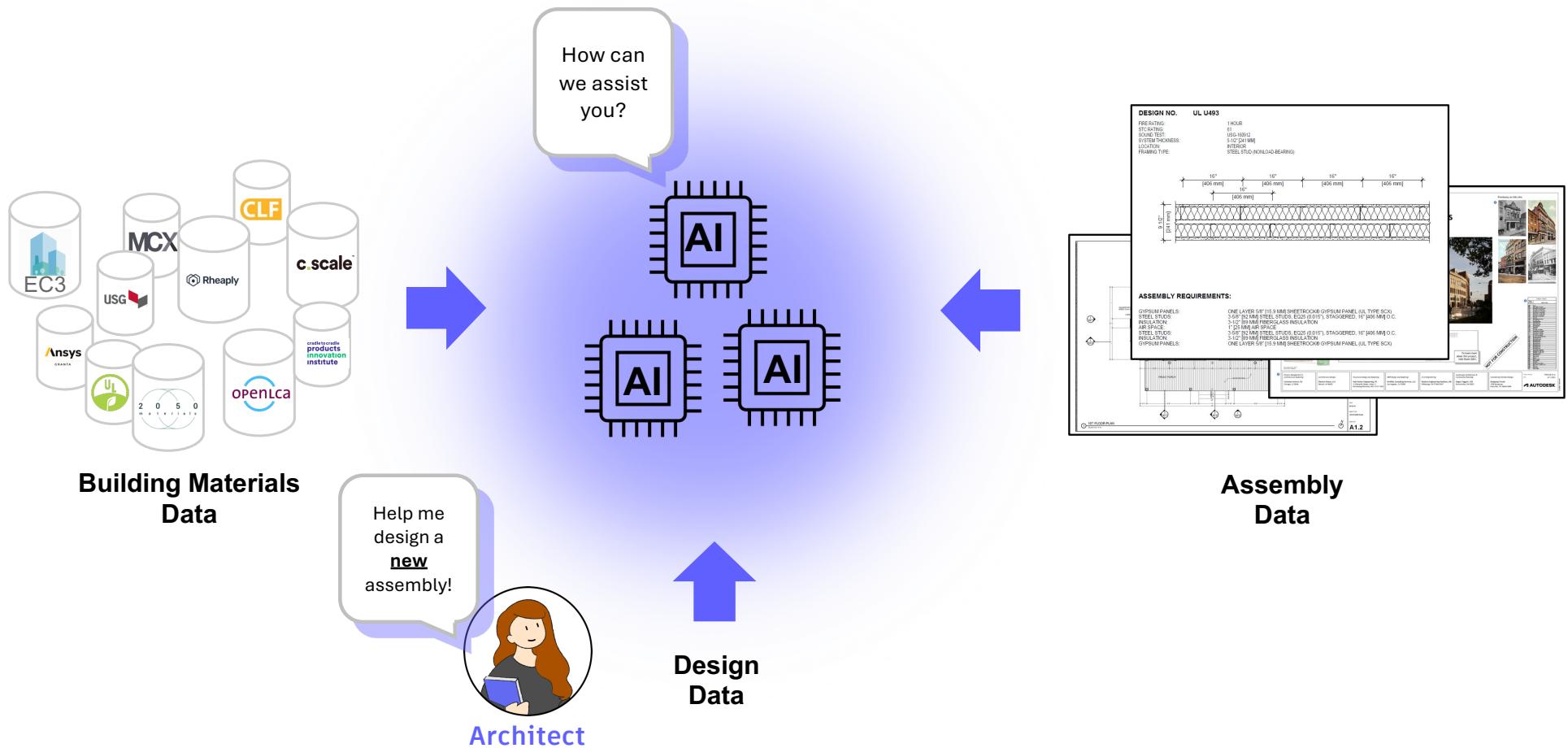


► Detail Design Stage
(Product Specific Data)

Models Are Lacking

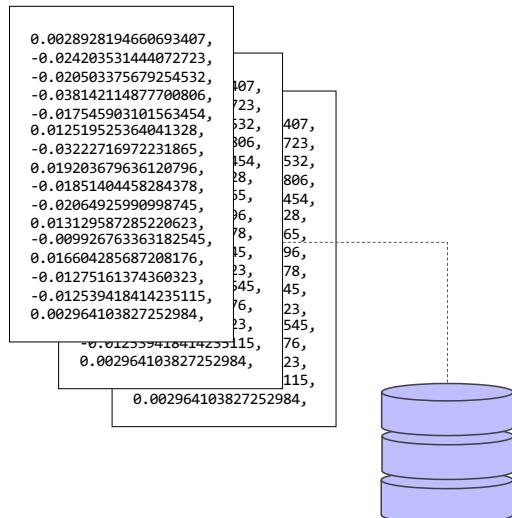


Sufficient Context!

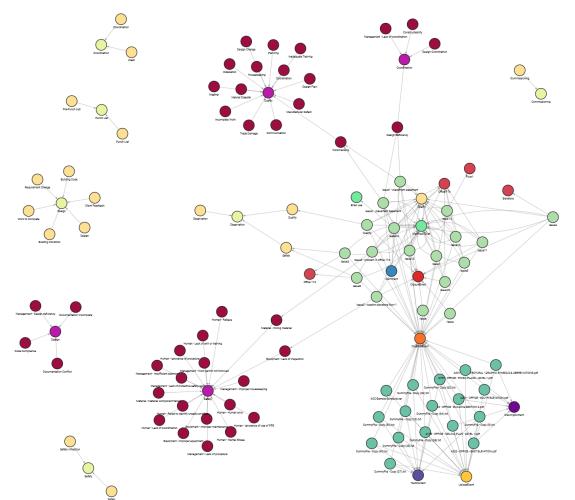


Getting Information

Data Models for Retrieval



VECTOR
DATABASE

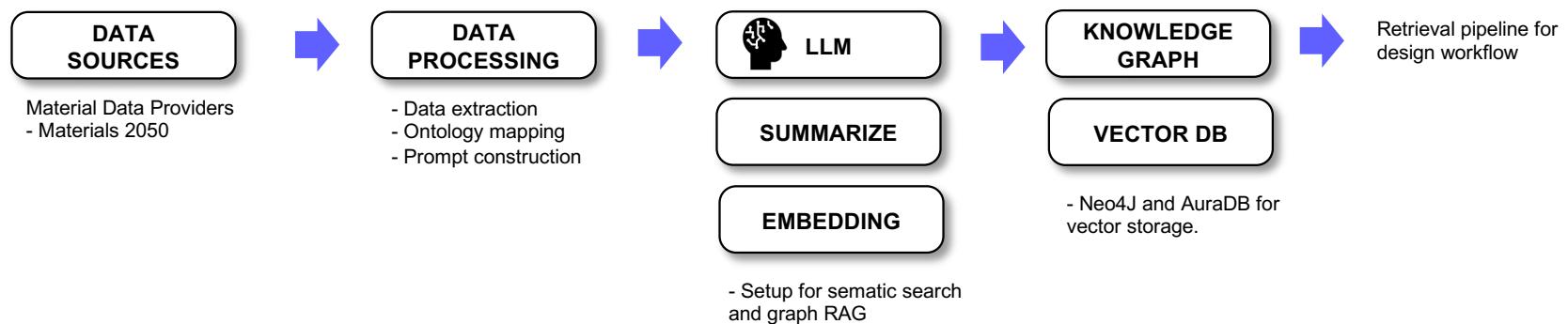
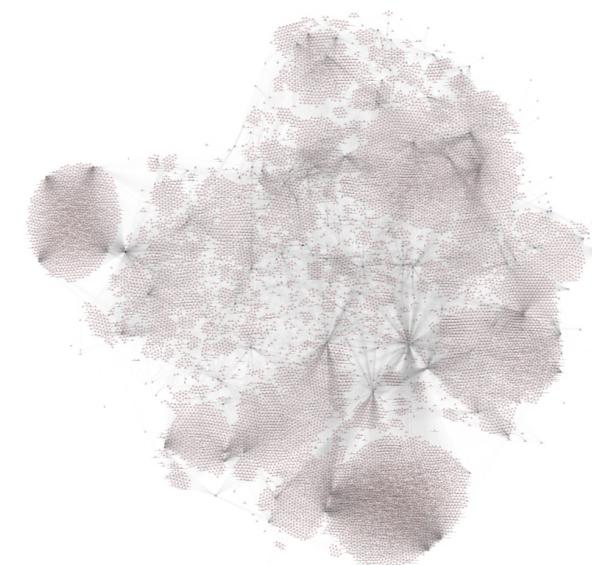
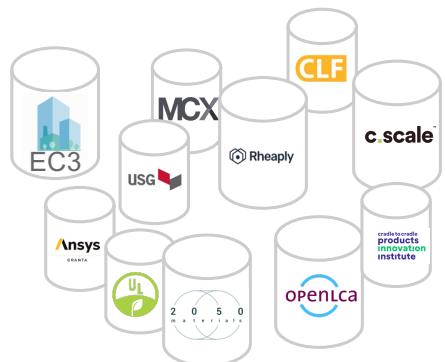


GRAPH
DATABASE



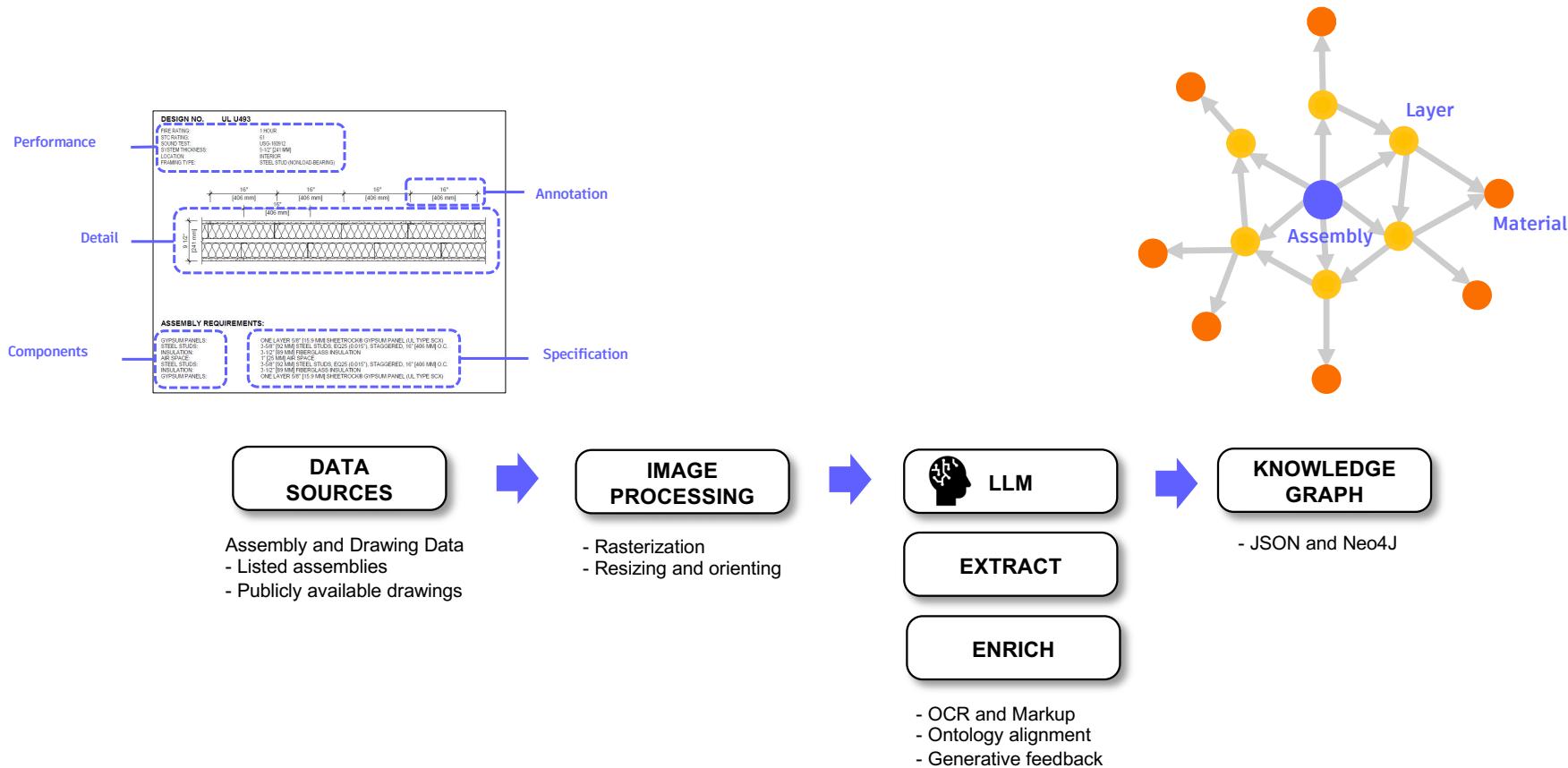
Graph Construction

Materials and Product Data

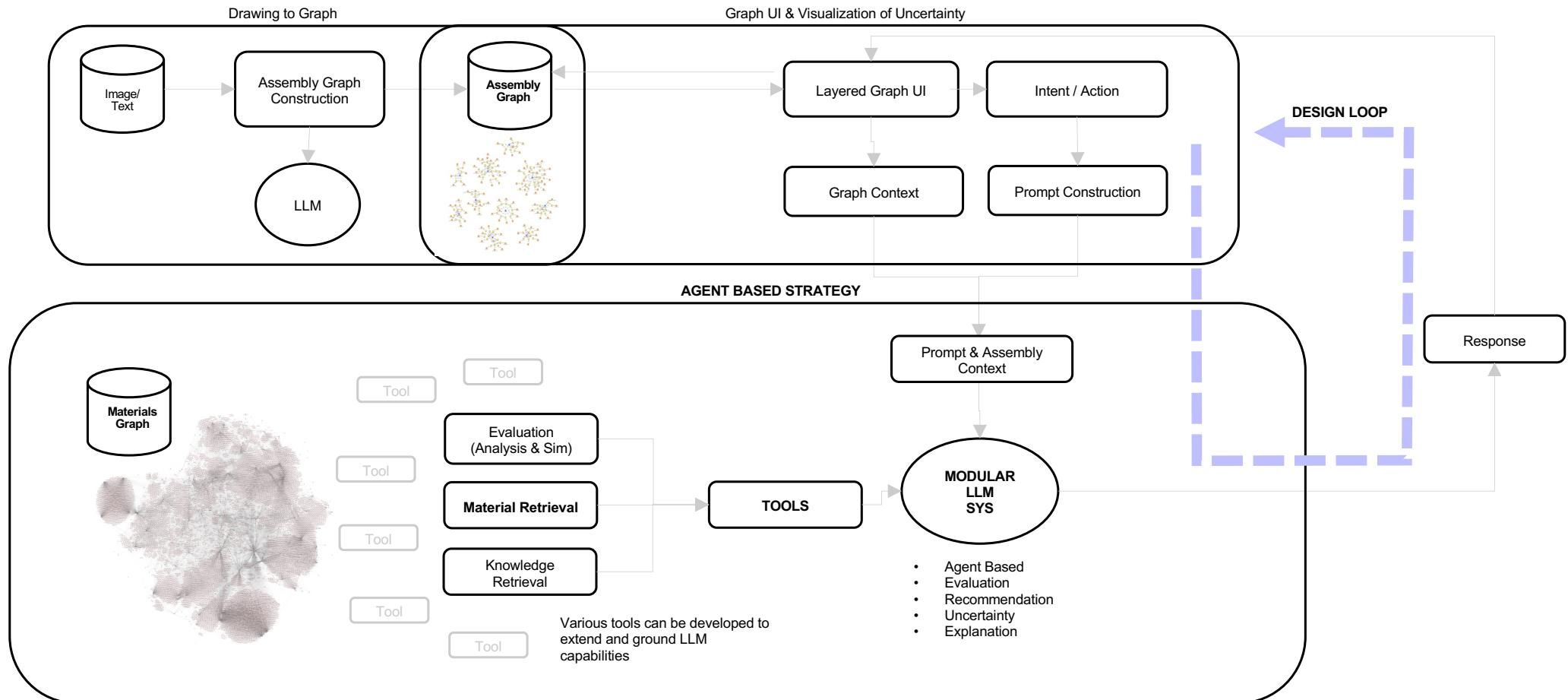


Graph Construction

Assembly Data



A System for Assisted Assembly Design



Experimental Prototype

a. design goal input box

Welcome! This is an experimental AI-powered tool. The goal is to help design AEC assemblies with new materials.

Assembly Outcomes and Goals

- low carbon and 1-hour fire rating wall assembly

Choose an example drawing:

- Example_01.png
- Upload Drawing
- Drag and drop file here
- Limit 20MB per file - JPG, JPEG, PNG

Browse files

b. assembly drawing selection options

- one.
- Extract the Drawing if there isn't already a baseline graph.
- Use the table or graph view to select which layers you would like to find materials for.
- Press the 'Get Materials' button for the selected layers, this may take a minute to complete, try not to select other things while the AI is working!
- Review the resulting suggestions, you can select each material for more details and explanations from the AI agent.
- If you would like to incorporate a material, press the 'Swap Material' button.
- You would like to save the assembly, press the 'Save Assembly' button.

c. assembly drawing view

Drawing View

e. assembly graph view

Graph View : Baseline

f. selected node properties

```

{
  "id": 12738,
  "label": [
    0: "Layer"
  ],
  "properties": {
    "description": "Provides weather resistance and serves as an exterior finish.",
    "name": "Fiber Cement Board Siding",
    "function": "ExteriorFinish",
    "continuity_type": "Continuous",
    "continuity_application_width": null,
    "continuity_gap_width": null,
    "thickness": 0.25
  },
  "user": "Selected exterior finish that withstands weather impact and has a long lifespan."
}
  
```

g. assembly performance metrics

Assembly Metrics

Metric	Value	Uncertainty
GWP (kgCO2e/m2)	10.18	0.40
Fire Resistance Rating (hours)	1	0.50
Acoustic Rating (STC)	50	0.50
Thermal Performance (R-value)	28	0.50

Get Materials

Swap Materials

ExteriorFinish Layer --- id: 12738 --- Optional Additional Design Requirements

Natural Materials

Suggested Materials

Info: This table shows suggested materials for the selected layer. An AI assistant has reviewed a set of products and determined their suitability and relevancy. Select a material to view more information.

ExteriorFinish Layer --- id: 12738

Only Show Suitable

Product Type	Material Type	Name	Suitable	Relevant	GWP (kgCO2e)	Units
Cladding	Softwood	NORD cladding - pressure impregnated	Yes	Yes	1.43	m2
Cladding	Softwood	Thermopine Cladding	Yes	No	2.24	m2
Cladding	Softwood	Panel of spruce / pine, for interior u	Yes	Yes	2.07	m2
Cladding	Softwood	Panel of hot spruce / pine, for interior u	Yes	Yes	2.19	m2
Cladding	Timber (Other)	Thermal ash	Yes	Yes	3.2	m2
Cladding	Engineered wood	Vulcan - Thermally Modified, Finger-Jo	Yes	Yes	2.2	m2
Structural access	Gulam	Vulcan - Thermally Modified, Glulam	Yes	Yes	2.51	m2
Building boards (I) Wood fibre		Colored wood fibers panel Vachromat	Yes	Yes	9.29	m2

Product Information

Product Name: NORD cladding - pressure impregnated spruce

Product Type: Cladding

Material Type: Softwood

Explanation: NORD cladding is a natural softwood product treated for enhanced durability and weather resistance. Its pressure impregnation process may also contribute to fire resistance, aligning with the 1-hour fire rating goal. The material's low carbon footprint supports the assembly's low carbon objective.

Description: NORD cladding provides weather resistance with pressure impregnated class NTR spruce, ensuring durability and longevity.

Metrics

Info: The metrics below are based on actual product data, some values may have required estimation, and are subject to uncertainty.

Metric	Value	Uncertainty
GWP (kgCO2e/m2)	1.43	0.00
Fire Rating Class	B	0.50
Acoustic Rating (STC)	0	0.00
Thermal Performance (R-value)	7	0.00

Links

Product URL

Certificate URL

h. alternative material suggestions

AI-Augmented Design Process



AI-Augmented Design Process



User Study Results

Participant No.	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11
Gender	F	M	M	F	M	M	M	M	F	M	M
Age Group	20-30	40-60	20-30	20-30	30-40	20-30	20-30	20-30	20-30	40-60	30-40
Expertise (years)	3	25	10	5	14	15	8	5	5	25	25

Low Carbon Materials Workflow Study - Akshit...

We are interested in your Material Selection approach. Who can see your viewing activity? cloud, step by step your general approach to finding and selecting appropriate materials for this exterior wall assembly that meets the stated project context.

Design scenario

You have designed an interior wall assembly for a project but now there are some new design requirements and information:

- The project is a 4-story multi-family housing.
- The location is Oakland, California.
- The neighborhood is composed of older single family homes.

Here are the new design requirements and information:

- The project has been rezoned but no regulations.
- The owner is interested in trying new materials that meet their goals.
- Design should be a modern aesthetic and fit in the neighborhood.
- Resource materials and fixtures are presented to you now.

Materials available:

- fiber cement board siding
- air gap
- insulation wrap
- heat channel
- exterior gypsum sheathing
- exterior insulating sheathing
- Zst wood framing
- fiberglass cavity insulation

Dimensions: Mm-mm

Score: 00:00:00 / 00:15:00 Speed: 1.00

Video Player

Audio Transcript Chat Messages

Search transcript EN

and it depends on what kind or paint we are specifying low, low voc is always preferred, but industry has, like a 50/50 balance on it.

But I still see paint not being vocs.

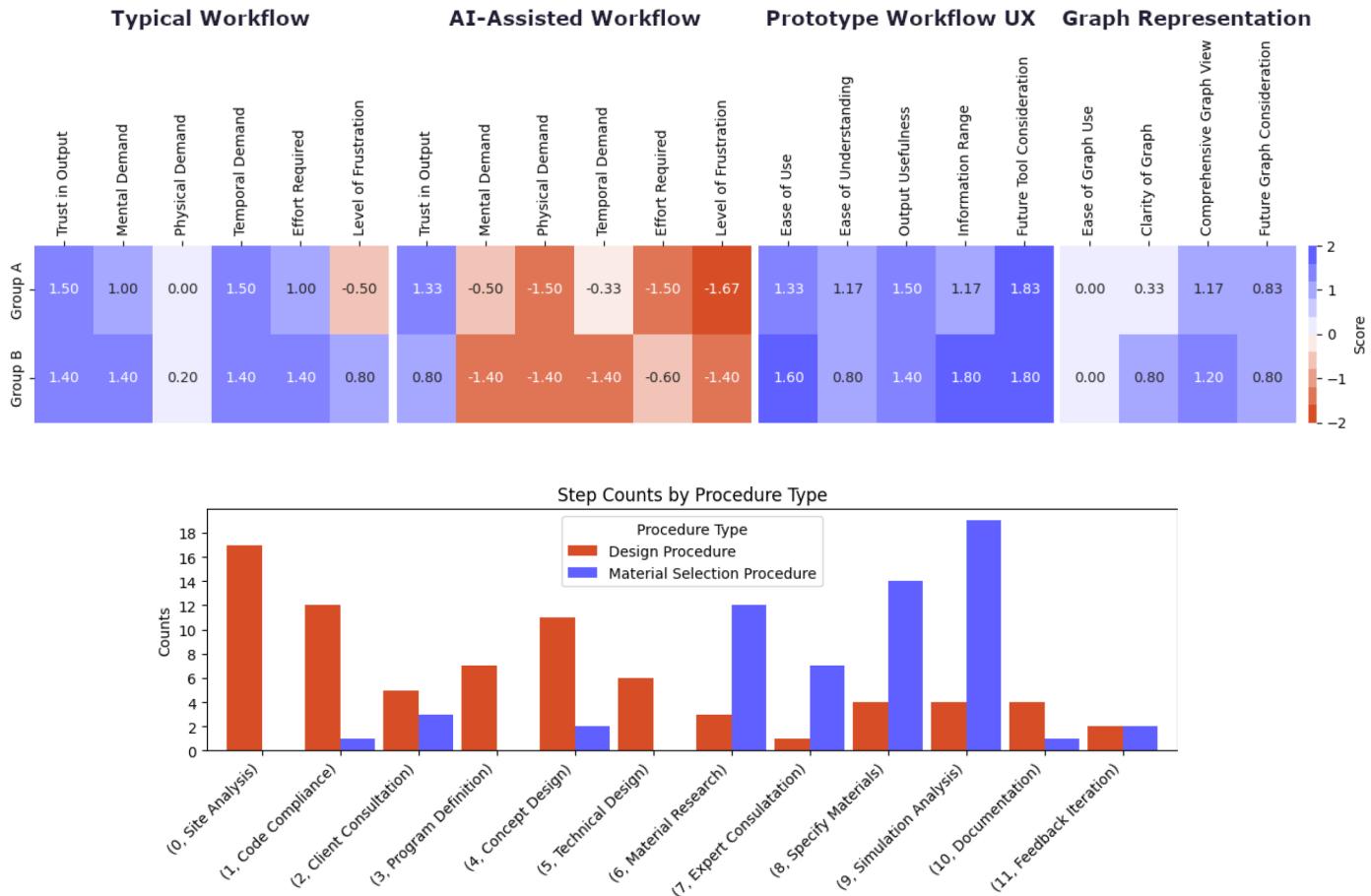
So that would be the second priority that where the design could improve.

Arthur Harusyanakit 00:26:13

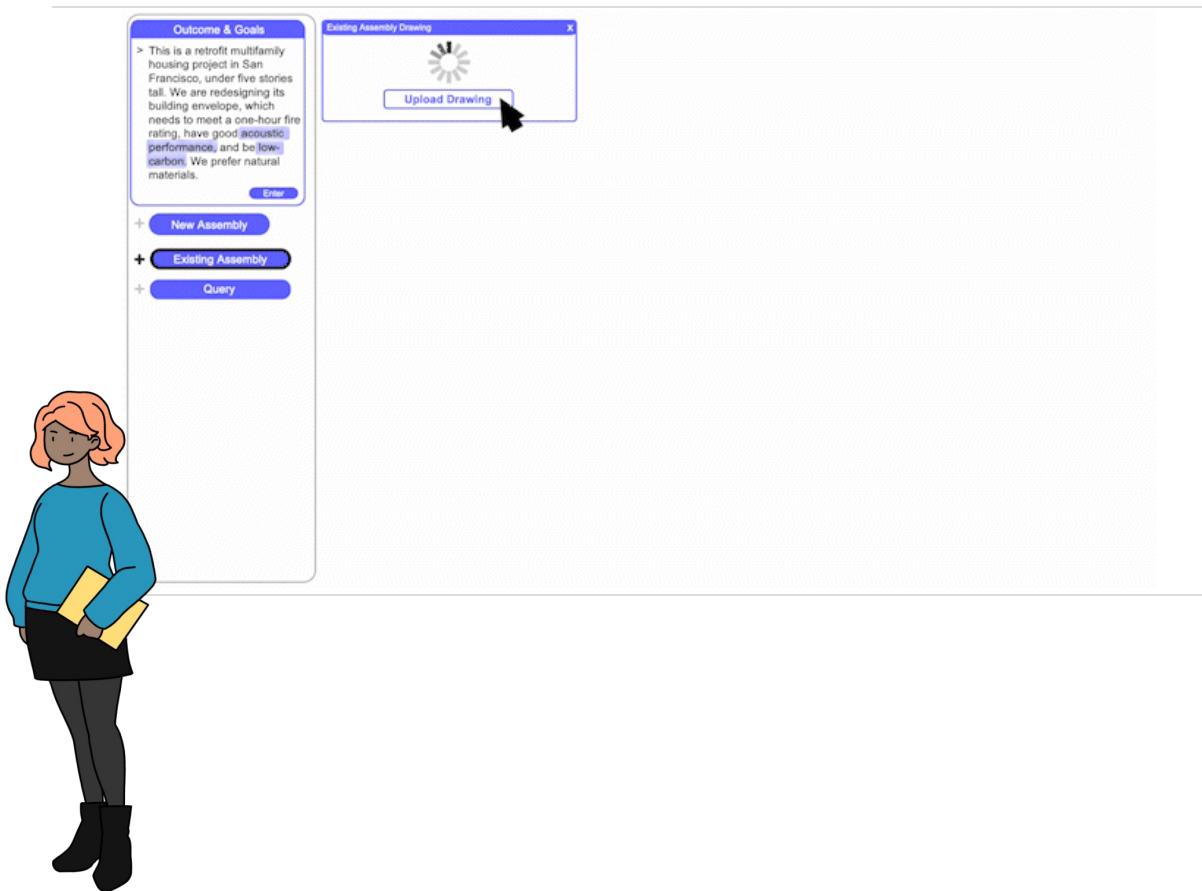
It sounds like you're trying to understand each material in this assembly and its impact.

How do you think you, if you were given this at work like how do you think you would try to understand that like, would you

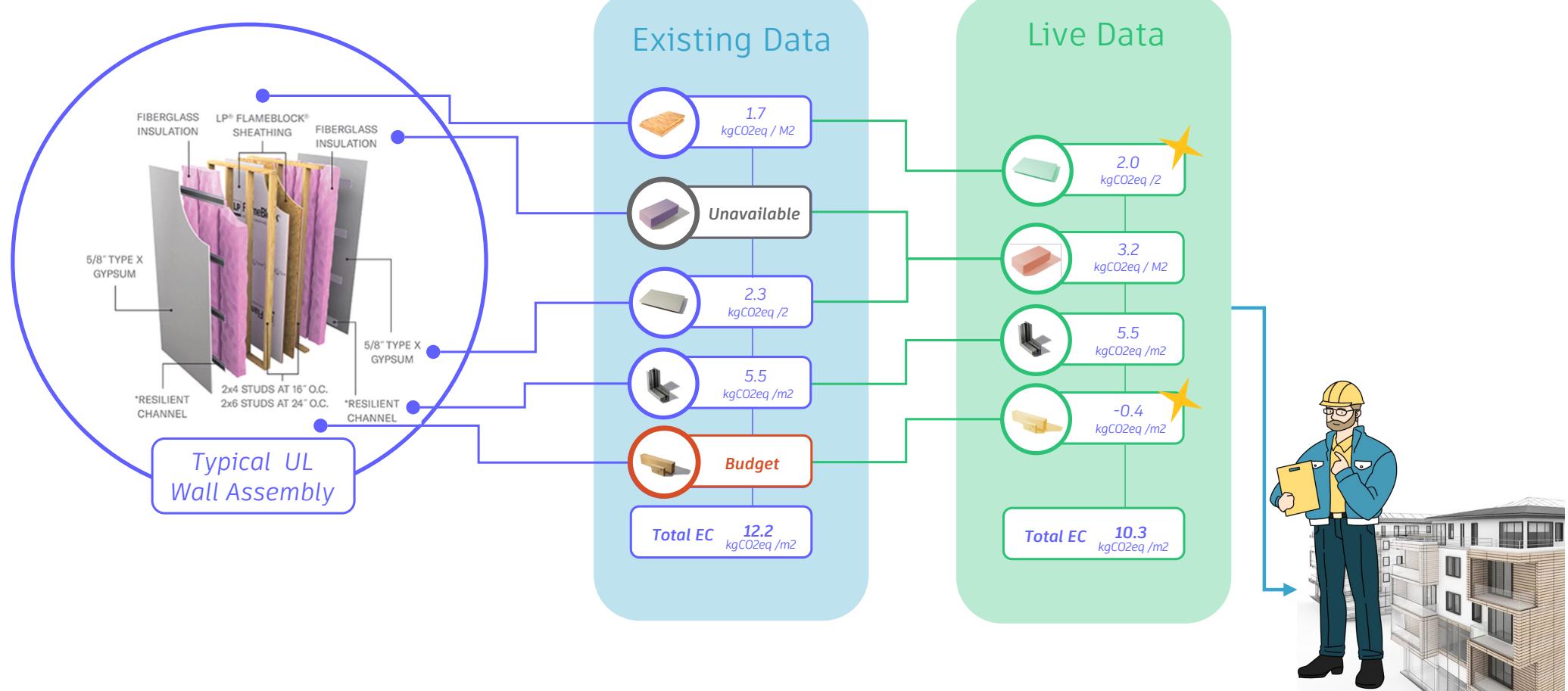
User Study via ARC



Integration with Digital Workflows



Future Potential & Industry Impact



In Summary

The interface shows a detailed architectural cross-section of a wall labeled "FOS BioFRP 1 Hour Wall". Below it is a network graph where nodes represent different materials or components, and edges represent inferred relationships based on the LLM's knowledge. The graph is highly interconnected, showing complex dependencies between various building materials.

Architectural Drawing to Graph

Material Relationships inferred by LLM

This visualization represents a large-scale Materials Knowledge Graph. It consists of numerous nodes (purple circles) connected by a dense web of lines (edges). The nodes are labeled with various material names and properties, such as "Air", "Gas", "Membrane", "Stainless steel", "Masonry", "Drywall", "Framing profiles", and "Framing/stud frame". The graph illustrates the extensive network of relationships between different materials used in construction.

Materials Knowledge Graph

Over 14k materials connected with 2.5million queryable relationships

The interface displays a JSON-like code snippet representing material suggestions. The code defines three main items: M1 (Air), M2 (Tyvek), and M3 (Material2050). Each item has properties like name, type, and material type. The M3 section also includes details about framing profiles and specific product types.

LLM Material Suggestion

Connected to Live Product Data of over 100k unique products

```
tant, Structural support"
Board (OSB)"
rigidity, Wind resistance"
support"
resistance"
intable"
Protective"

Deploy

1 : {
  "id" : "M1",
  "name" : "Air",
  "type" : "Gas",
  "properties" : "Provides ventilation",
  > "material" : []
}

2 : {
  "id" : "M2",
  "name" : "Tyvek",
  "type" : "Membrane",
  "properties" : "Breathable, Water-resistant",
  > "material" : []
}

3 : {
  "id" : "M3",
  "material2050" : [
    {
      "name" : "AADG Stainless Steel Frame (Drywall or Masonry)",
      "norm" : [
        0 : "2.5 - External walls",
        1 : "2.7 - Internal walls and partitions"
      ],
      "material_type" : "Stainless steel",
      "material_type_family" : "Metals",
      "product_type" : "Framing profiles (Cladding/stud frame)",
      "product_type_family" : "Framing profiles",
      > "material_facts" : {
        "data_source" : "Declare Label"
      }
    }
  ]
}
```



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