Redefining possible.

To Artificial Intelligence and Beyond

The Ever-Expanding Toolkit for Modeling the Physics of Exhaust Dispersion and Design

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Learning Objectives

1. Summarize the basics of fluid flow modeling and wind flow around buildings, including established wind tunnel modeling procedures and evolving computational techniques

2. Explore use cases for computational (CFD and AI) modeling for exhaust dispersion to evaluate laboratory exhausts for re-entrainment risk

3. Understand some of the best practices, potential challenges and exciting opportunities associated with the use of CFD modeling to evaluate atmospheric dispersion for laboratory exhaust stacks

4. Receive insights regarding selection of the most appropriate dispersion modeling tool for a given exhaust dispersion and building scenario

Acknowledgements

Outline

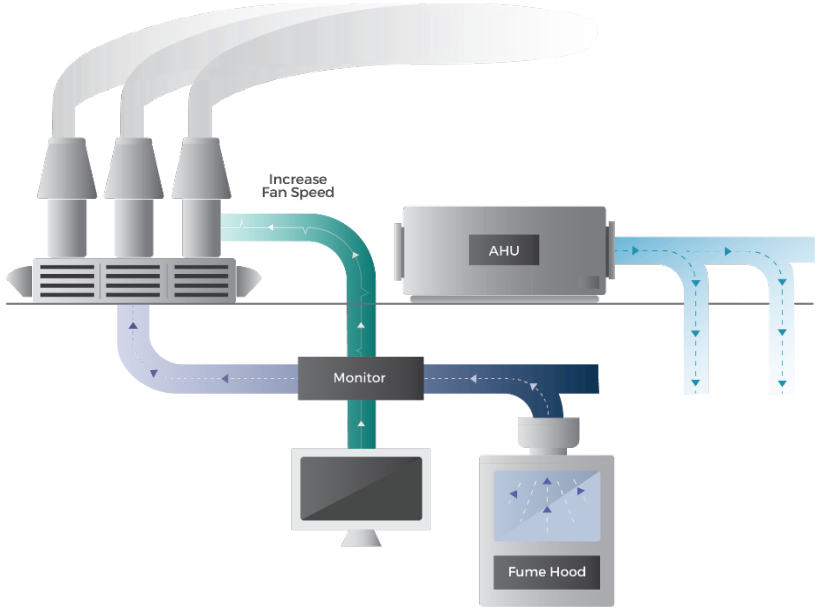
1. Building Performance-Based Design and Tools
2. Artificial Intelligence for Building Performance
3. Case Study for Exhaust Dispersion
4. Summary of Key Takeaways

Why Performance -Based Design?

Prescriptive design can be **easier** : 10 ft. stack height, 3,000 fpm exit velocity

However,

1. Prescriptive design parameters can be excessively **conservative** (or in some cases, may not be conservative enough?)
2. Prescriptive design parameters may **not apply**
3. Performance-based design allows for **innovation** and **energy savings**



Which Tool Do We Use When?

Factors to consider:

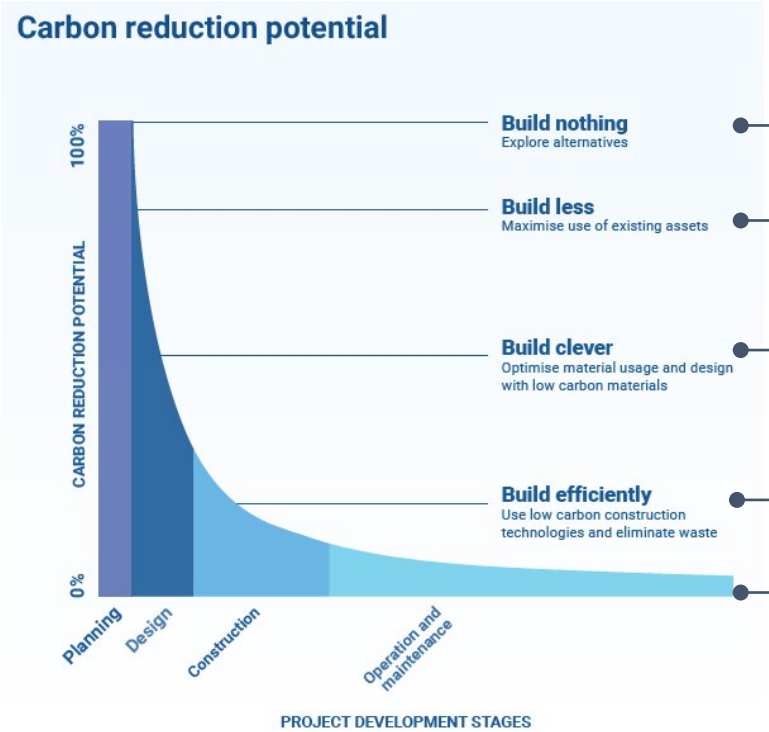
1. **Validation:** Are relevant physics being adequately represented by the tool you are using? What validation work has been done to demonstrate this?

2. **Trust:** Is this methodology accepted/widely used within the industry? Where applicable, do regulatory bodies accept this methodology?

3. **Cost:** Does this methodology maximize value for minimum time and dollar cost? A

4. **Timing:** What is the required level of fidelity for the decisions that need to be made now?

Maximizing Value of Impact



Fantastic! We don't see these!

Re-use is great, but can have subpar performance on operational energy

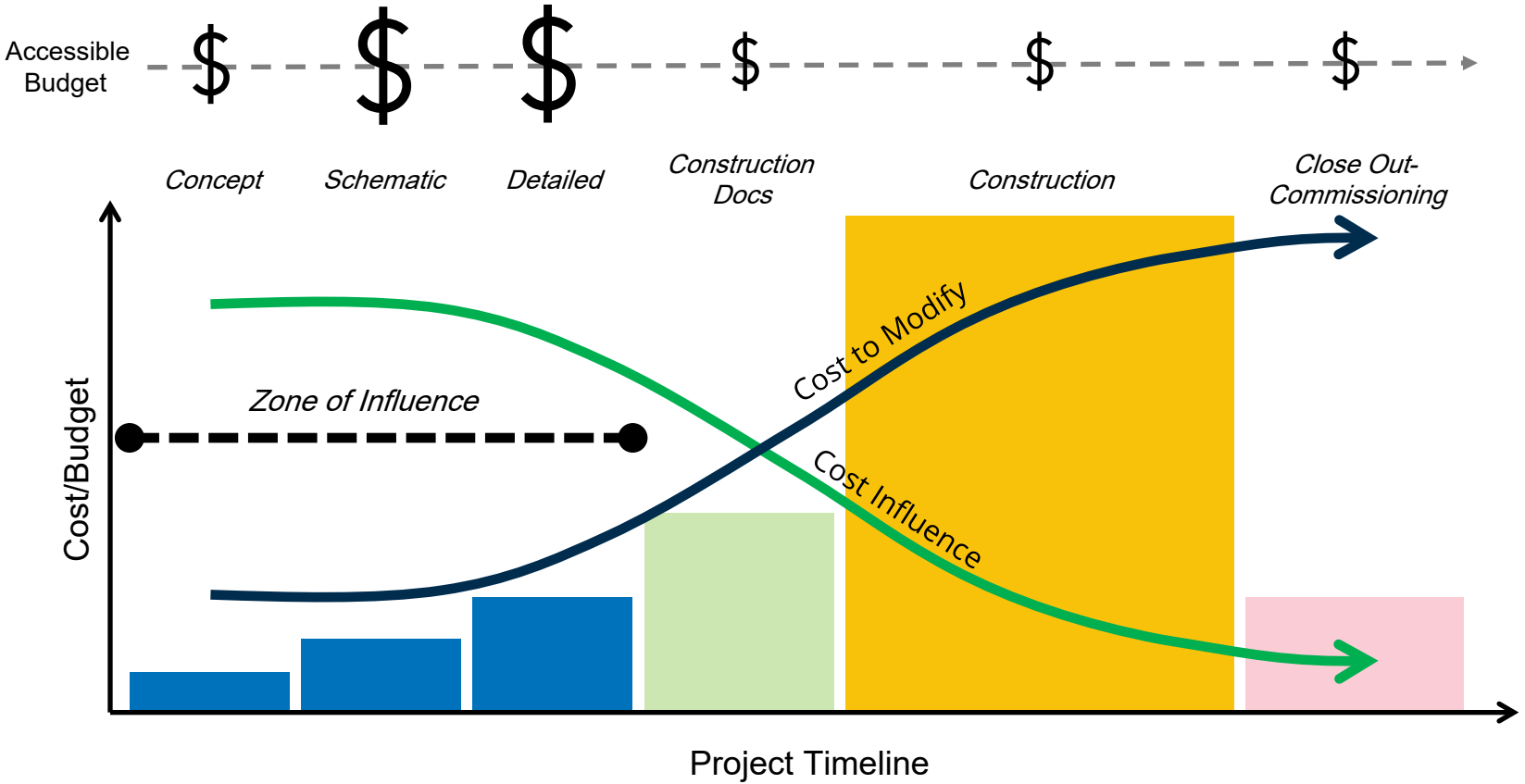
Sweet spot for impact vs cost

Important but too late to bake it into design

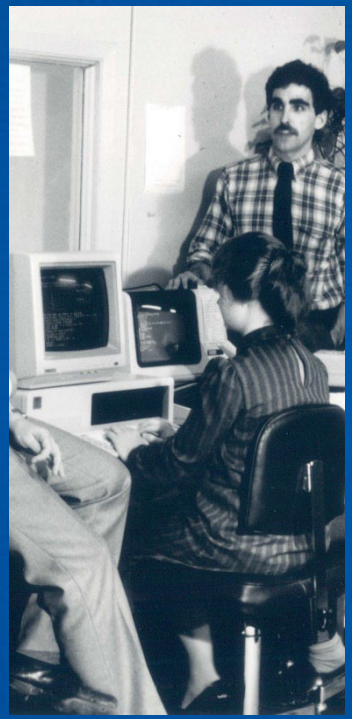
Optimization can't fix a poorly designed/constructed building

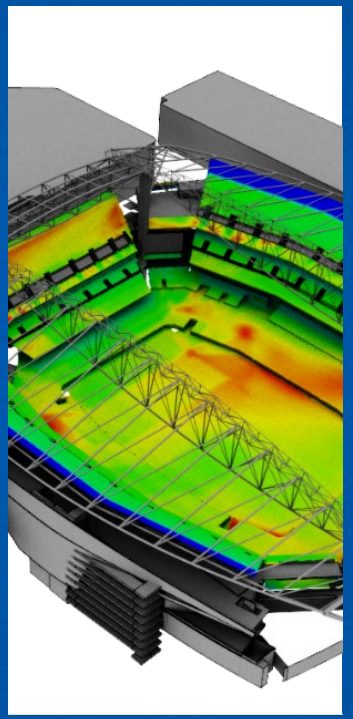
Source: Bringing embodied carbon upfront, World Green Building Council ,2019

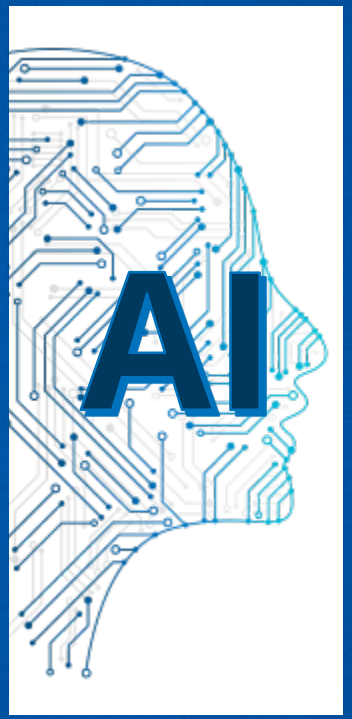
Cost Influence & Budgets



Wind Engineering Tools Have Evolved Tremendously







Tool Applicability

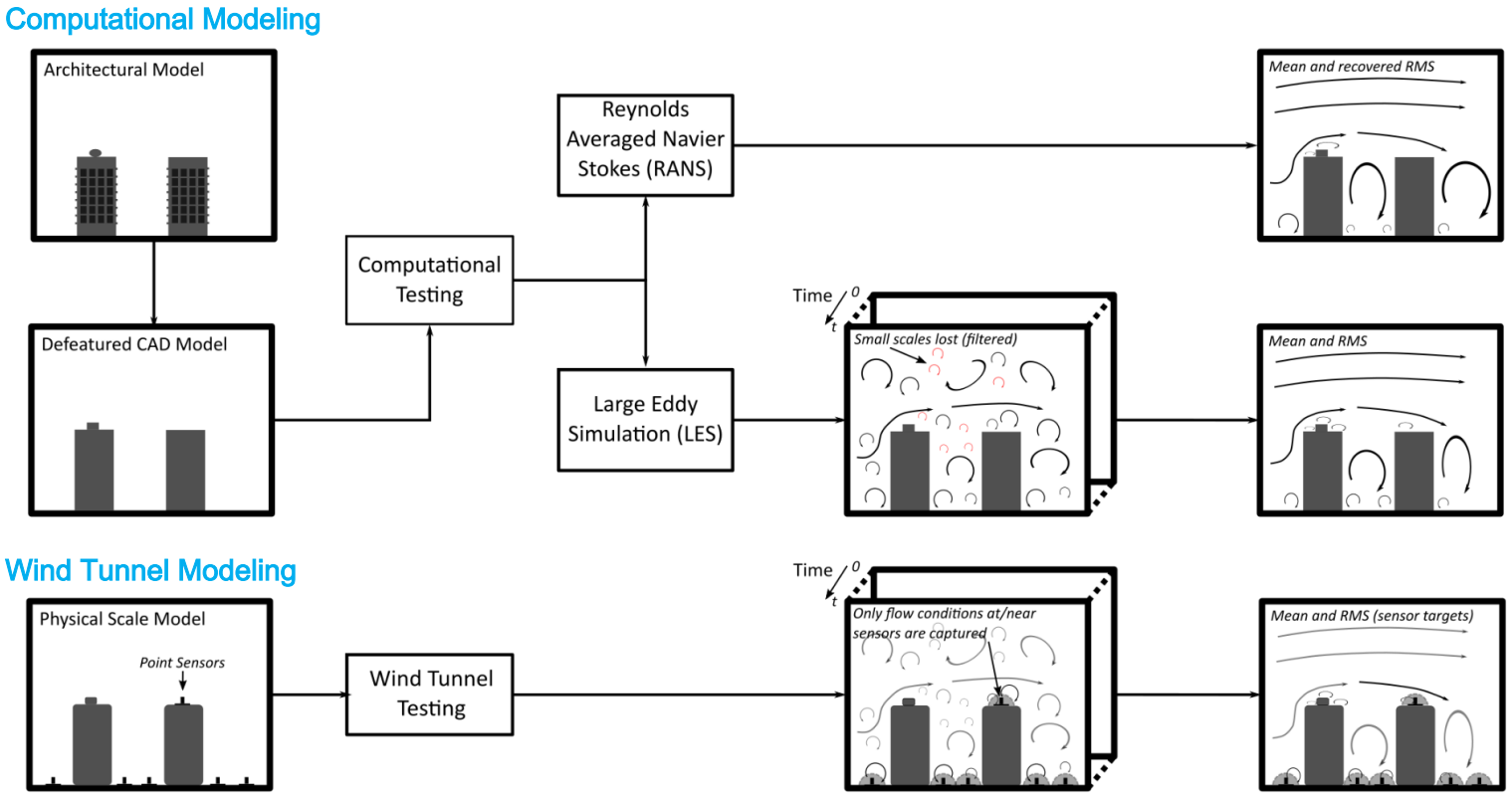
Study Area	Wind Tunnel	CFD - RANS	CFD - LES	AI/ML
Pedestrian Safety/Comfort	✓	✓ - Comfort Only	✓	✓ - Comfort Only
Exhaust Dilution and Dispersion	✓		✓	?
Structural Loads	✓		✓	Simplified Estimates
Cladding Pressures	✓		✓	✓
Mechanical Pressure Loss	*	✓	✓	*
Natural Ventilation	*	✓	✓	*
Dust and Sand Migration		✓	✓	
Building Stack Effect	*			*
Wind-Driven Rain and Snow	Snow in Water Flume	✓	✓	

* Results used as inputs to other modeling tools

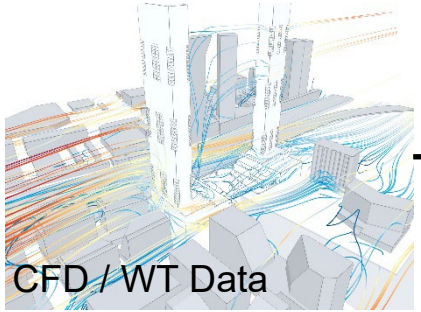
Factors to Consider when making a choice:

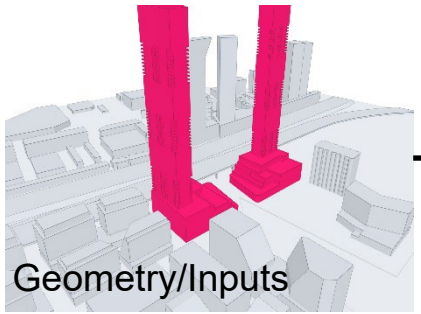
- Level of Validation
- Level of Confidence Required
  - Early vs Late Stage
  - Life Safety
- CFD is heavily dependent on program quality and user choices
- Some approaches are more costly and time -consuming than others

Traditional Modeling Processes

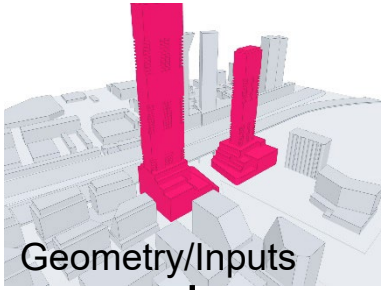


Process for Modeling using AI

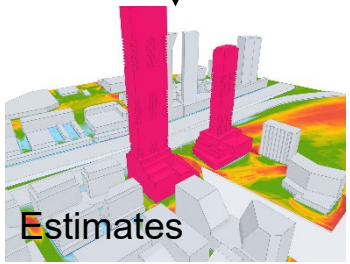


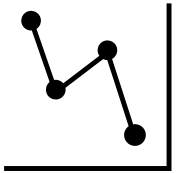


Training



Trained Model





Benchmark for Comparison?

Machine Learning

ML

Physical Testing

Wind Tunnel

WT

CFD Modeling

Out of the Box Steady-State (RANS)

R-OOB

Modifications to input parameters or physics models

R-MODEL

Flow physics aware modifications

R-MOD+

Time-varying (LES)

Model Selection

LES

But how do all these compare with what is happening in real life?

ML Wind Estimator Development

ML Engine Training

100's CFD Projects

Geometry:
Target + Context

Volume Data:
Pressure, Speed, etc.

Volume Data
Speed, Pressure etc.
Trillions of data points

ML Engine

ML Wind Simulation

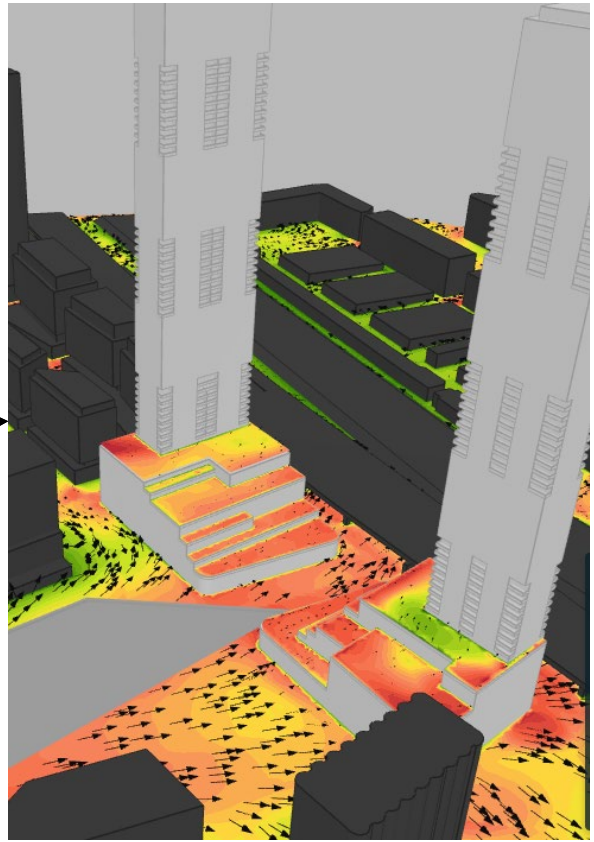
Geometry:
Target + Context

Environmental Info

Wind Speed Info

Climate Data

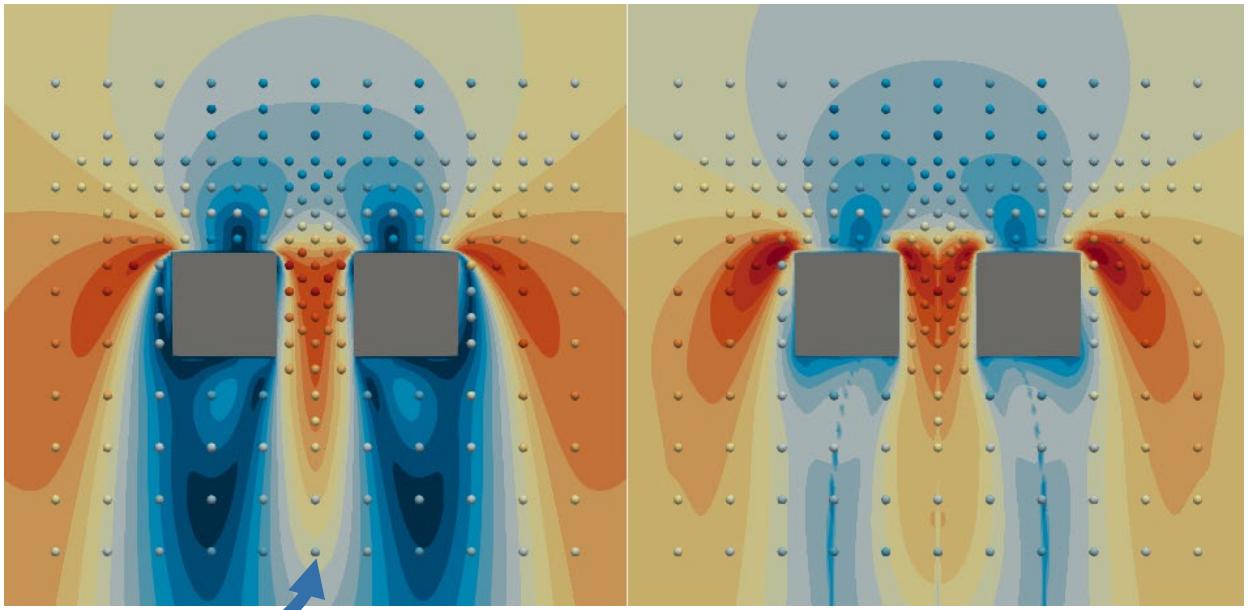
Microclimate Parameters



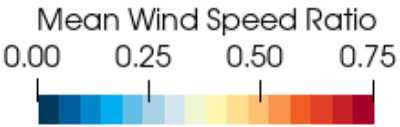
CFD Validation: Wind Flows Around Buildings

CFD - RANS

CFD - LES



WTT

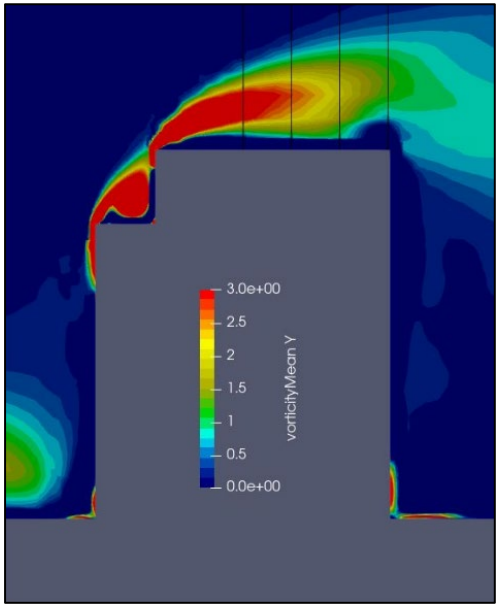


Hypothetical Two Building Case

Simple and provides a variety of interesting flow scenarios:

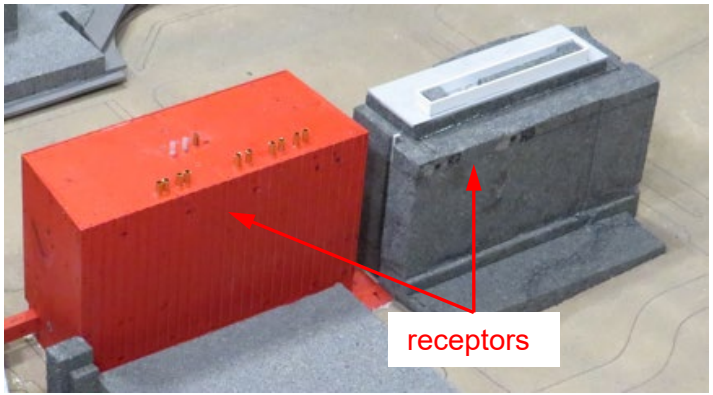
- Stagnation
- Corner accelerations
- Shear layers
- Down -washing
- Wakes
- Channeling
- Deep wake

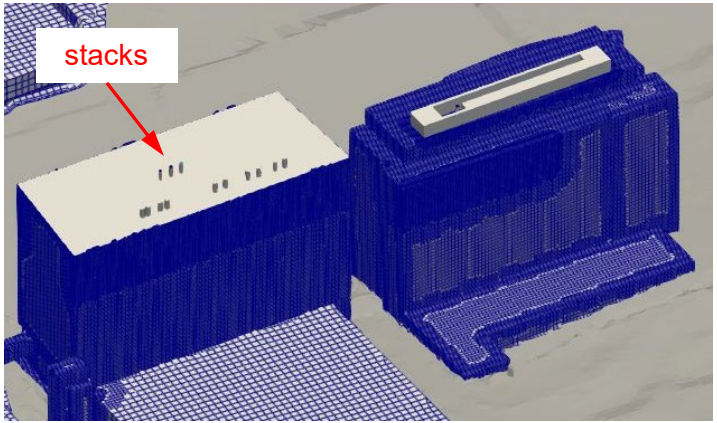
CFD Validation for More Complexity



- Atmospheric boundary layer
- Turbulence Representation (Average vs Time-Varying)
- Rooftop recirculation zones
- Plume dispersion characteristics
- Effects of simple structures (e.g., screen walls)

LES CFD Validation: Case Study

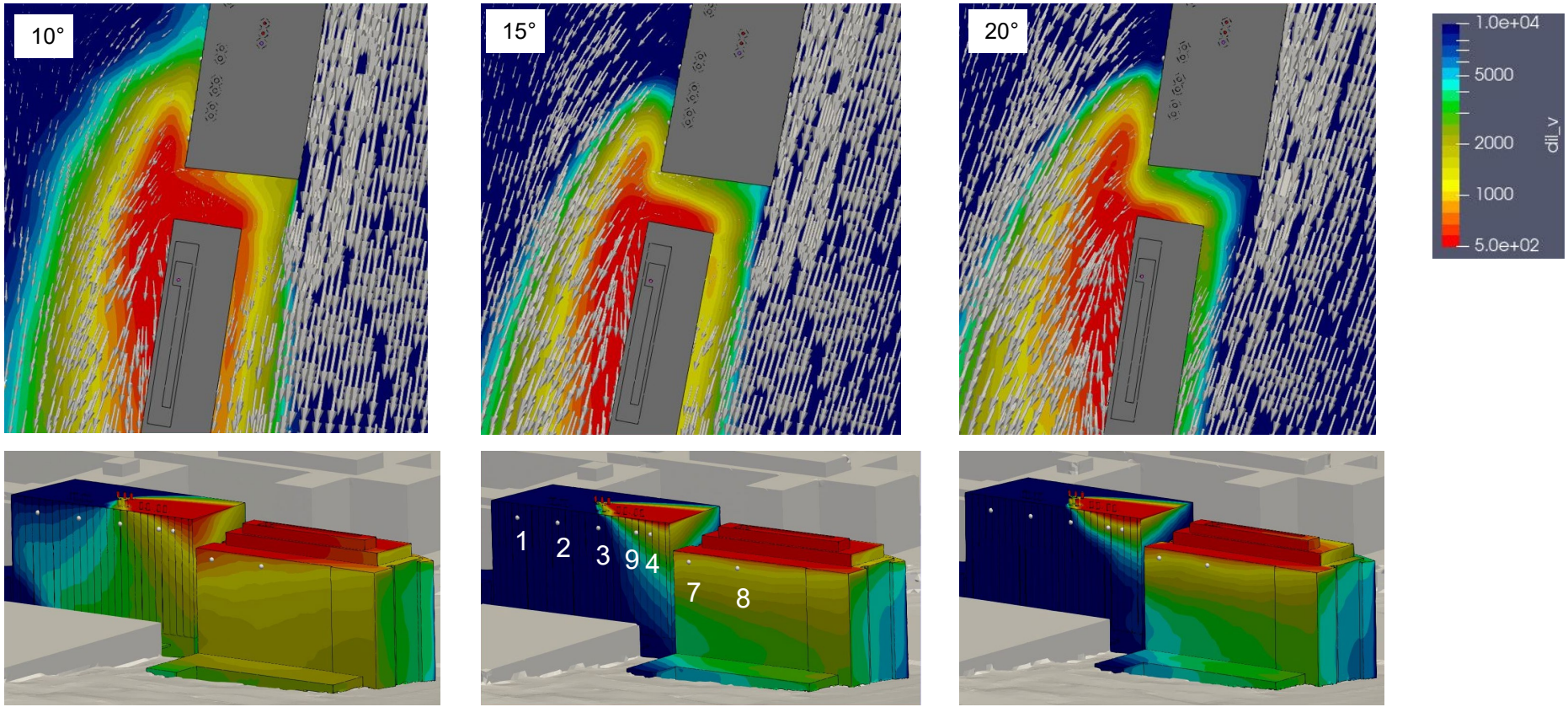




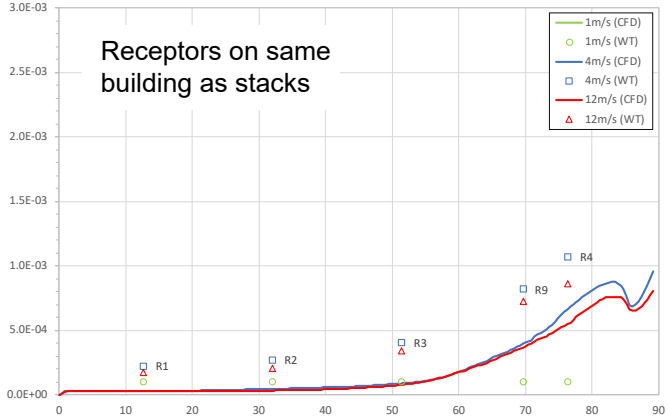
Rooftop Laboratory Exhausts

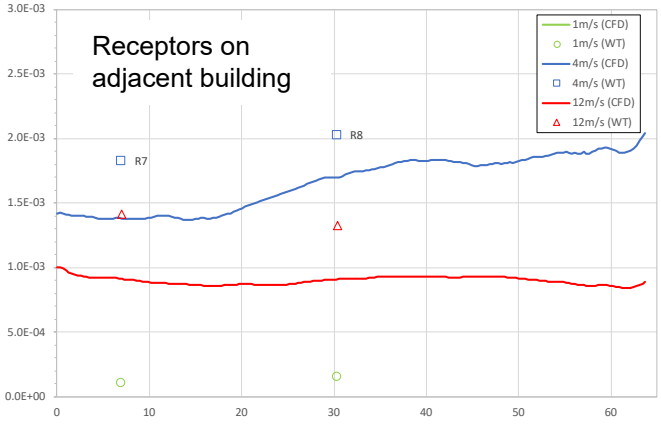
- Approximately 160 -ft tower, relatively simple geometry
- Mid rise urban environment, buildings are 1 -8 stories
- 20,000 cfm rooftop exhausts, 3,000 fpm exit velocity
- Dispersion from stacks considered on multiple buildings
- Moderately windy location

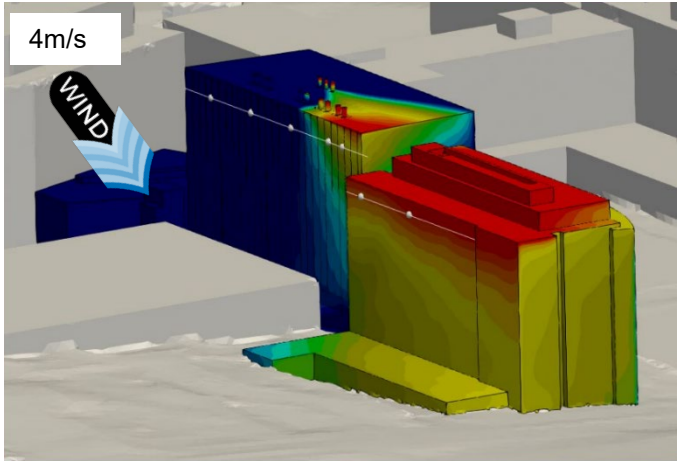
LES CFD Validation: Case Study

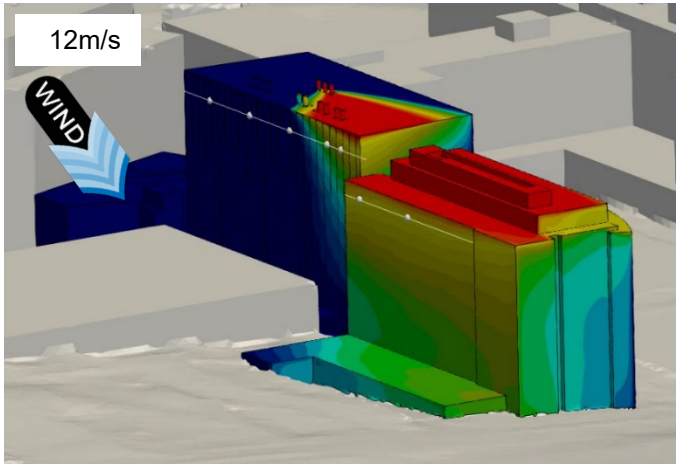


LES CFD Validation: Case Study

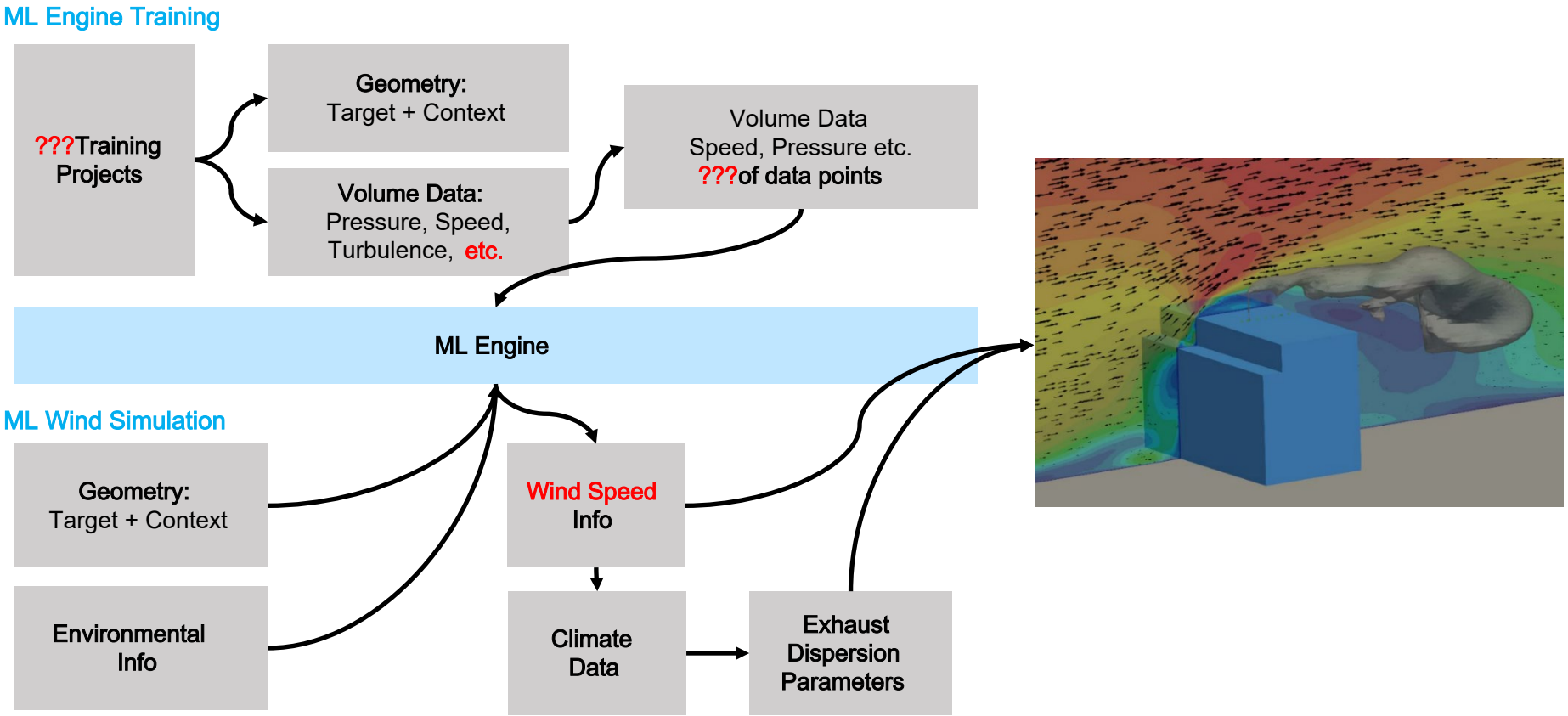






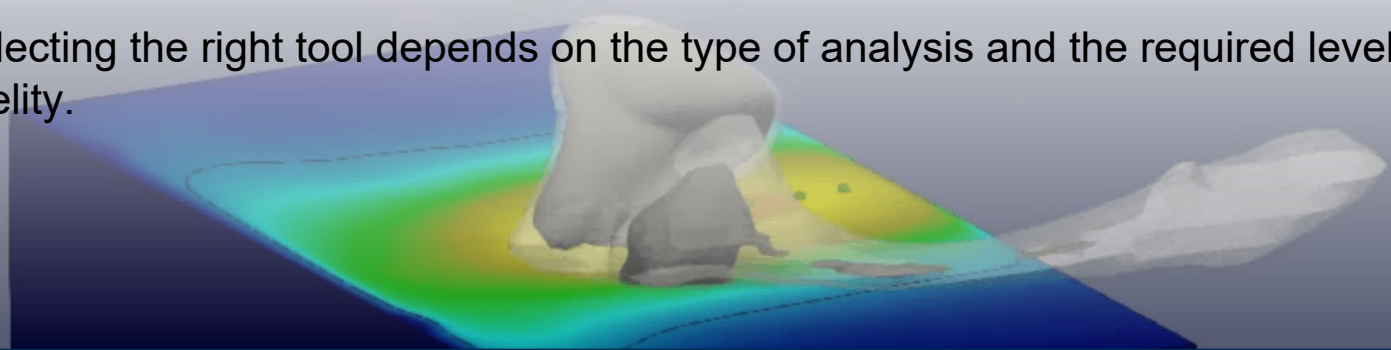


EDD Wind Estimator Development



Summary

- The challenges facing modern buildings are complex, but through collaboration and correct application of technology we can find solutions.
- Expertise can be used to compensate for limitations of modeling tools. Modeling tools cannot be used to compensate for a lack of expertise.
- Extensive validation of the applicability of a tool to a problem is required to bring a tool from its early stages of development to industry acceptance.
- Selecting the right tool depends on the type of analysis and the required level of fidelity.



THANKS FOR YOUR TIME!

Are there any questions?

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