Building Science Atlas

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Preface

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1 Introduction

Welcome to the **Building Science Atlas**.

This collaborative repository compiles the current state of sustainability analysis for building science and urban analysis. We explore key questions from a systems and complexity perspective.

Our goal is to cover workflows, code, and theory—from the simplest ballpark estimates to complex simulation models.

2 Energy Demand

What is the energy demand of a building? This is one of the most common questions in building science.

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2.1 Simple Ballpark Estimates

To start, we look at the simplest way to get a ballpark number. This might involve looking at historical energy use intensity (EUI) for similar buildings in the same climate zone.

> “A good estimate is better than a precise error.” - Anonymous Building Scientist

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Table 2.1: Typical Building Metrics

Building Type	Typical EUI (kWh/m2/yr)	Peak Load (W/m2)
Residential	100 - 150	40 - 60
Office	150 - 250	60 - 100
Retail	200 - 300	80 - 120

2.2 When to Attempt a Simulation

If a simple estimate is insufficient, a simulation may be necessary. We detail the different levels of complexity involved in simulating energy demand, starting from basic RC models.

2.2.1 RC Models (e.g., R51C)

RC (Resistance-Capacitance) models provide a simplified dynamic representation of a building's thermal behavior.

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2.2.2 Full Energy Balance

A full energy balance model considers all heat flows, internal loads, and HVAC system interactions.

The general heat balance equation can be expressed as:

$$Q_{load} = Q_{solar} + Q_{internal} + Q_{conduction} + Q_{ventilation} \pm Q_{storage} \tag{2.1}$$

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3 Simulation Workflows

If simulation is the goal, what are the different levels of complexity? We explore workflows for setting up and running building energy and urban simulations.

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3.1 Tools and Platforms

We rely on several open-source and widely-used tools in our field, such as:

- Eddy3D
- Urbano
- EnergyPlus

Each topic in this section will go from the most simple to the most complex analysis, describing what is involved to set it up.

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The calculation of mean radiant temperature (T_{mrt}) is crucial in many of these tools:

$$T_{mrt} = \left[\sum_{i=1}^{n} F_{p-i} T_i^4 \right]^{1/4} \tag{3.1}$$

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Figure 3.1: Simulation Workflow Overview

4 Neural Nets in Building Science

When classical simulation models reach their computational limits—such as in complex urban microclimates or real-time control applications—machine learning approaches offer a powerful alternative.

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This chapter covers the application of Artificial Neural Networks (ANNs) in building science.

> “AI is the new electricity, and data is the new oil.” - Common ML Proverb

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A standard feedforward neural network layer can be expressed mathematically as:

$$h_{l+1} = \sigma(W_l \cdot h_l + b_l) \tag{4.1}$$

where h_{l+1} is the output, σ is the activation function, W_l are the weights, and b_l is the bias.

4.1 Physics-Informed Neural Networks

How can we embed the laws of thermodynamics into a neural network to predict energy consumption or indoor temperatures faster than an EnergyPlus run?

We will explore state-of-the-art physics-based deep learning approaches to these problems.

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Table 4.1: Common Hyperparameters for Building Energy Prediction

Hyperparameter	Typical Range	Description
Learning Rate	$10^{-4} - 10^{-2}$	Step size for gradient descent
Batch Size	32 - 256	Number of samples per update
Hidden Layers	2 - 5	Depth of the neural network
Units/Layer	64 - 512	Width of each hidden layer

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5 Summary

In conclusion, this repository represents an ongoing effort by students and researchers to document building science workflows.

By looking at particular questions from a systems and complexity perspective, we hope to provide a structured, curated guide for our field (Knuth 1984).

References

Knuth, Donald E. 1984. "Literate Programming." *Comput. J.* 27 (2): 97–111. https://doi.org/10.1093/comjnl/27.2.97.