Assignment 1: Component 2 – High Performance Building Case Study

UCSI University

School of Architecture and Built Environment UCSI University

Master of Architecture
AM523 Computer Aided Modelling & Simulation
July 2023

Lecturer:
Dr. Taki Eddine Seghier

Prepared by:
Koon Si Qi 1002266298
Low Cheok Wing 1001437419
Danny Loh Chin Her 1001747644

Helsinki Energy & Climate Atlas

Helsinki

Case Study 1: Performance in the Urban Scale

Helsinki 3D

Main Objective for Case Study

Objectives that make use of Helsinki 3D

Helsinki City Strategy Objectives

Pleasant and safe
We will make Helsinki safer and more pleasant.

Sound and healthy
Well-being and health for all Helsinki residents.

Minds the wellbeing of children and young people
We will take care of the well-being of children and youth, as well as prevent marginalization.

Athletic and active
The physical activity of residents will be promoted.

Functional urban structure
The development of the City structure will take accessibility and functionality into account.

Vital
The appeal and vitality of Helsinki will be increased.

Diverse nature
We will secure the diversity of urban nature and sea nature.

Carbon neutral
We will develop Helsinki to become an ecologically sustainable and carbon-neutral city.

Resident-oriented and engaging
Helsinki will be developed in a resident-focused and open manner.

Digital
We will take advantage of digitalization opportunities.

Learning
We will enable lifelong learning.

Business-friendly
Helsinki's focus on business will be developed.

Responsible leadership
Helsinki will be managed responsibly, and the well-being of staff will be looked after.

Financially sustainable
The economy of Helsinki will be managed responsibly, sustainably and profitably.

City of Helsinki (2017) "The Most Functional City in the World: Helsinki City Strategy 2017-2021"

1.0 Introduction

Helsinki 3D+

The 3D model of Helsinki is a digital twin of the city in a virtual environment, displaying the city's environment, operations and changing circumstances. The digital twin combines information technology services, open data and updating information that is accessible by the public.

The digital twin is used to achieve the city's strategy objectives, such as developing the urban model to understand the urban morphology, measuring the urban buildings (volume, elevation, distances and surface areas).

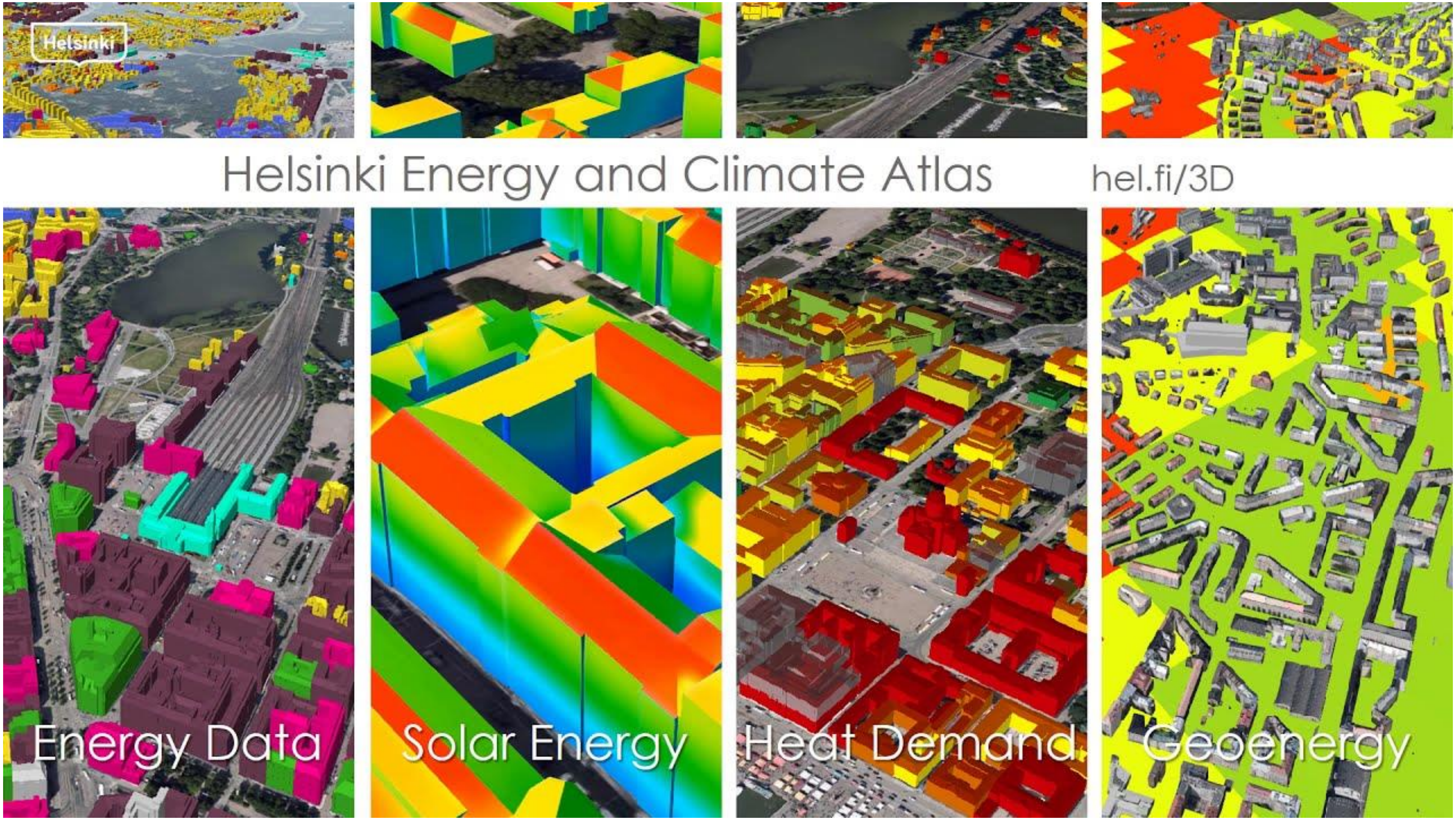
The digital twin also stores information about individual buildings, terrain and geographical elevations, simulation results and many more. The twin also simulates environments that are imagined by past architects such as Eliel Saarinen's design from 1915.

The digital twin and its accompanying information and simulations aid the government in the decision making for the future of the city.

The model is publicly available, so the general user is able to access the information for their own use and use the data to inform their own decision making.

Helsinki

Helsinki 3D. (2023) City of Helsinki. Retrieved July 22, 2023, from https://www.hel.fi/en/decision-making/information-on-helsinki/maps-and-geospatial-data/helsinki-3d#energy-and-climate-atlas



Store measured energy data of each building in the city

Evaluate areas with solar energy potential for photovoltaic panel installation

Store measured and simulated heating demand of each building in the city

Evaluate areas with the largest potential for geothermal energy

4 Main Uses

Helsinki

1.0 Introduction

City of Helsinki. (n.d.). *Helsinki Energy and Climate Atlas*. Retrieved July 21, 2023, from https://kartta.hel.fi/3d/atlas/#/

Carbon neutral

To calculate the city's energy demands to achieve the carbon-neutral goal

To evaluate energy consumption on a city-wide scale

To predict future heating and energy demands of the city in the face of climate change

To identify areas of potential for high-impact renovations to reduce carbon emissions

To evaluate future energy demands and simulate different renovation scenarios

To calculate the heating-demand-saving potential in the city

2.0 Performance Goals of the Simulation

Simulation Scenarios

Type of Scenarios / *Performance Metrics* / *Type of Simulations*	**Business As Usual (BAU)** *Allowing daily urban life and businesses to run as usual with minimal refurbishment* *Refurbishment rate: 1%*	**Rapid Development (RD)** *Allowing daily urban life and businesses to run as usual with minimal refurbishment* *Refurbishment rate: 3% + improvement to district heating network*
Heating Demand Simulating the heating demand and energy demand of the city	Baseline: *Heating Demand of the current measured year* *(case study year: 2019)* Performance Metrics: • *Heating demand of individual buildings (MWh)* • *Heating demand of the city (TWh)*	
CO_2 Emissions Simulating the CO_2 emissions of the city as measured against the emissions from 1990	Baseline: CO_2 emissions from the 1990 Performance Metrics: - CO2 emissions (kilotonnes) - Percentage reduction in carbon emissions as compared to 1990 (%)	

Data Preparation

3D Model Preparation

3D City Model
Software: City GML

+

Attributes in City GML
Year built, building function etc

+

Energy Application Domain Extension (Energy ADE) Attributes
Software: 3DCityDB
Total floor area, usage area, no. of occupants

3D Model Preparation

Building Typologies

Physics Library
Construction year
Building type
Construction elements
Thermal transmittance (u-value)

Usage Library
Function, Occupancy, Ventilation, Heating Profile, Hot water consumption, Electricity Consumption

Energy Library
Efficiency of heating and hot water systems, CO emission factors

Simulation

Simulation
Software: Simstadt by HFT Stuttgart

Heating Demand Simulation

CO_2 Emission Simulation

Simulation of different refurbishment scenarios

Business As Usual (BAU) scenario
1% refurbishment rate

Rapid Development (RD) scenario
3% refurbishment rate & improvement to district heating network

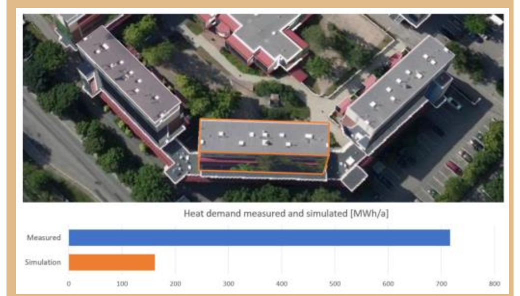
Evaluation

Validation of Results

Comparing measured data (heating demand of the measured year 2019)

against

simulation data of the same year (2019)



Verification and adjustment of simulation based on results to get the most accurate results

Result Visualisation

Converting simulated results and data into 3D tiles for visualisation in the 3D City Model

Software: Cesium 3D Tiles

Displaying of simulation results in the 3D City Model on an online platform

Software: Virtual City Systems

Data from the simulation is fed back to the 3D model for future simulations

Helsinki

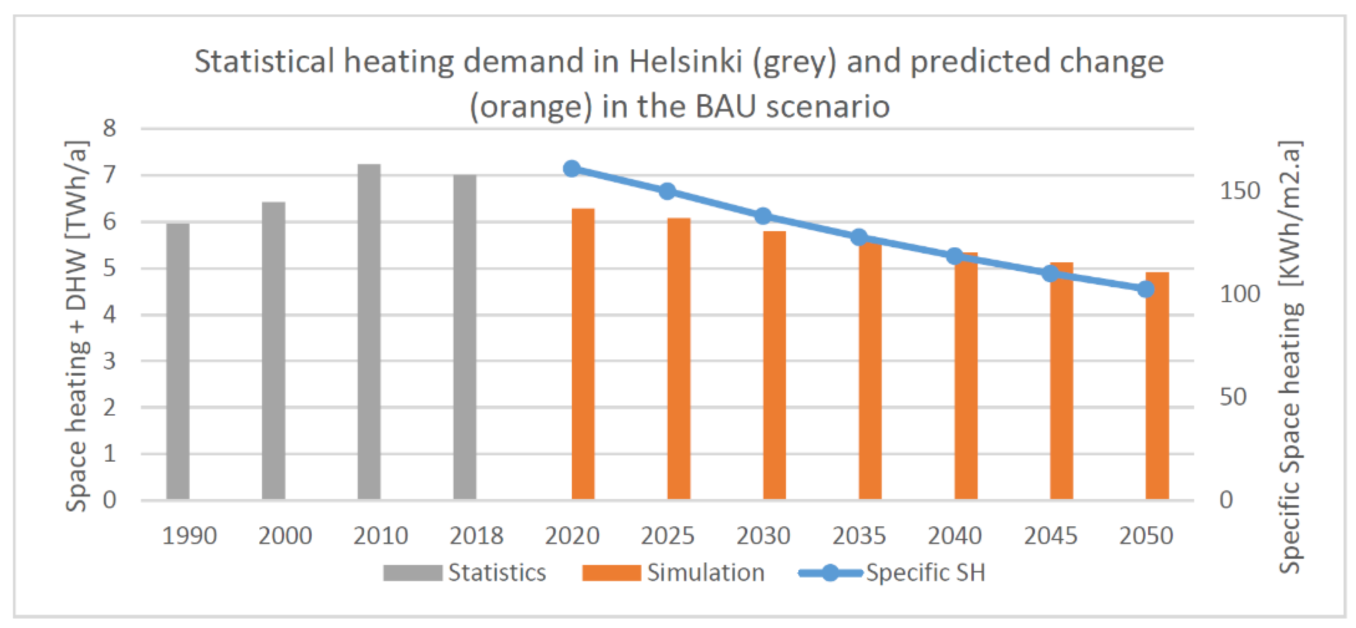
4.0 Tools, Software and Techniques

Rossknecht, M., & Airaksinen, E. (2020). Concept and Evaluation of Heating Demand Prediction Based on 3D City Models and the CityGML Energy ADE—Case Study Helsinki. *ISPRS International Journal of Geo-Information 2020, Vol. 9, Page 602*, *9*(10), 602. https://doi.org/10.3390/IJGI9100602

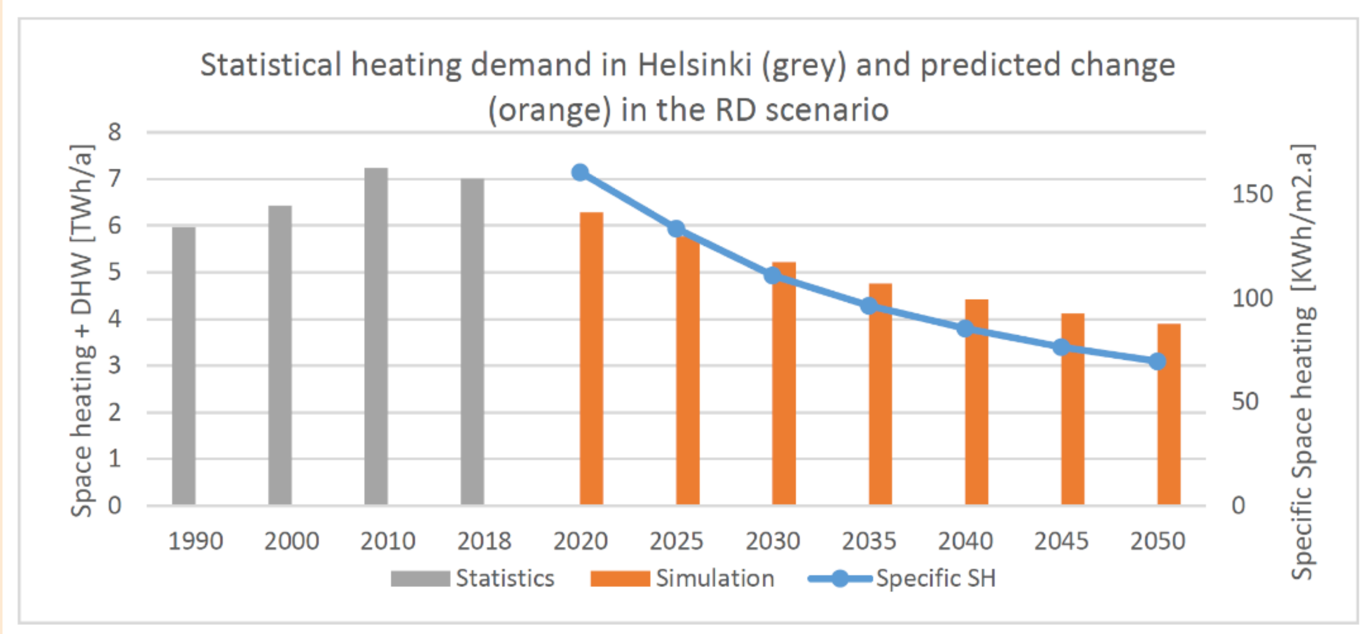
BAU Scenario *(1% refurbishment rate)*

RD Scenario *(3% refurbishment rate)*

Heating Demand Simulation Results

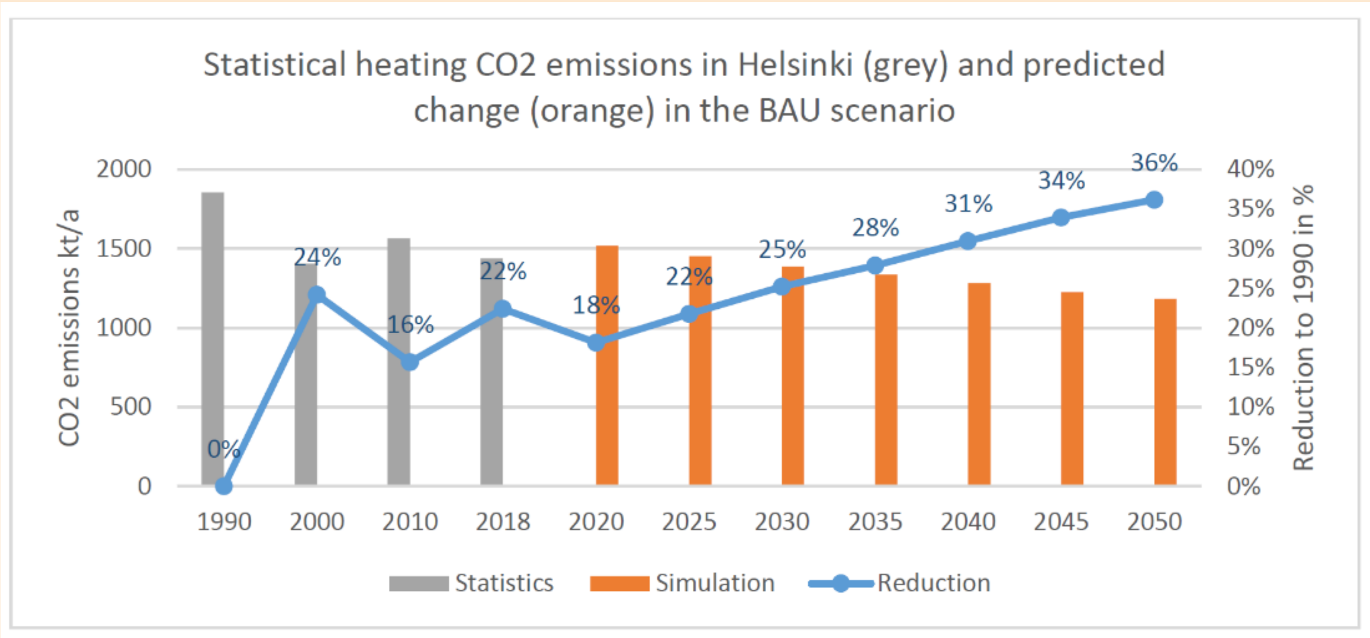


2035: decrease 0.71 TWh
2050: decrease 1.37 TWh

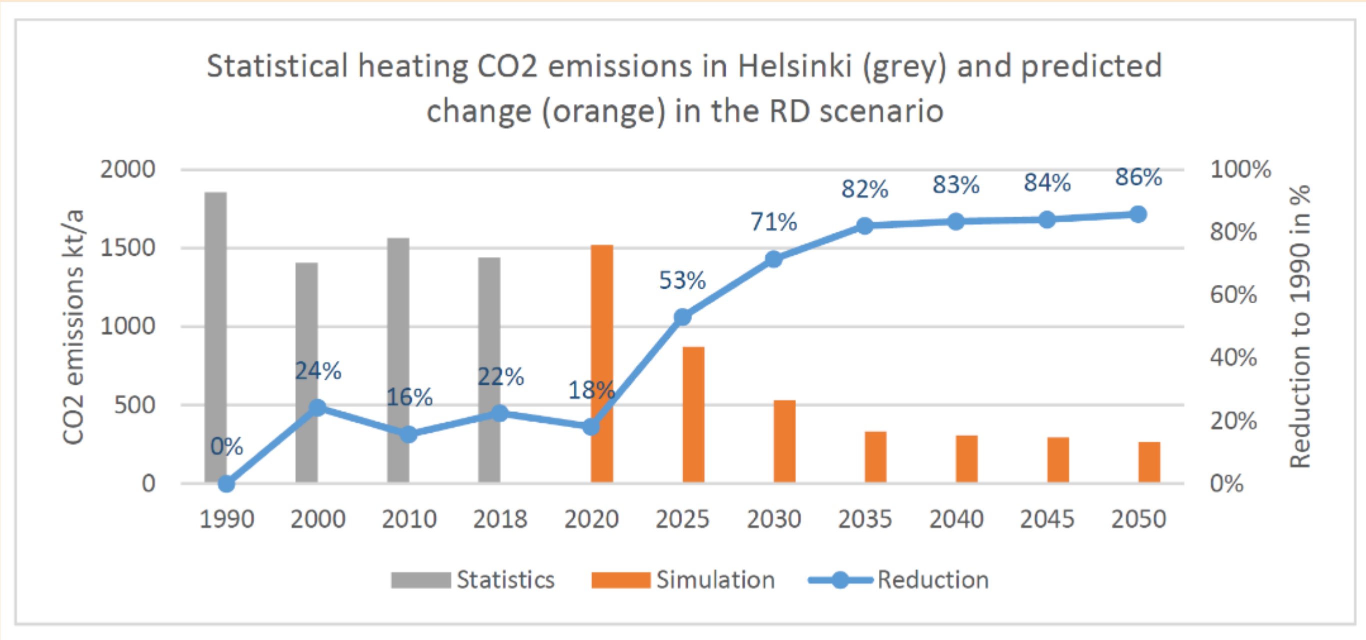


2035: decrease 1.5 - 4.76 TWh
2050: decrease 2.4 - 3.89 TWh

CO_2 Emissions Simulation Results



2035: decrease 25%
2050: decrease 36%

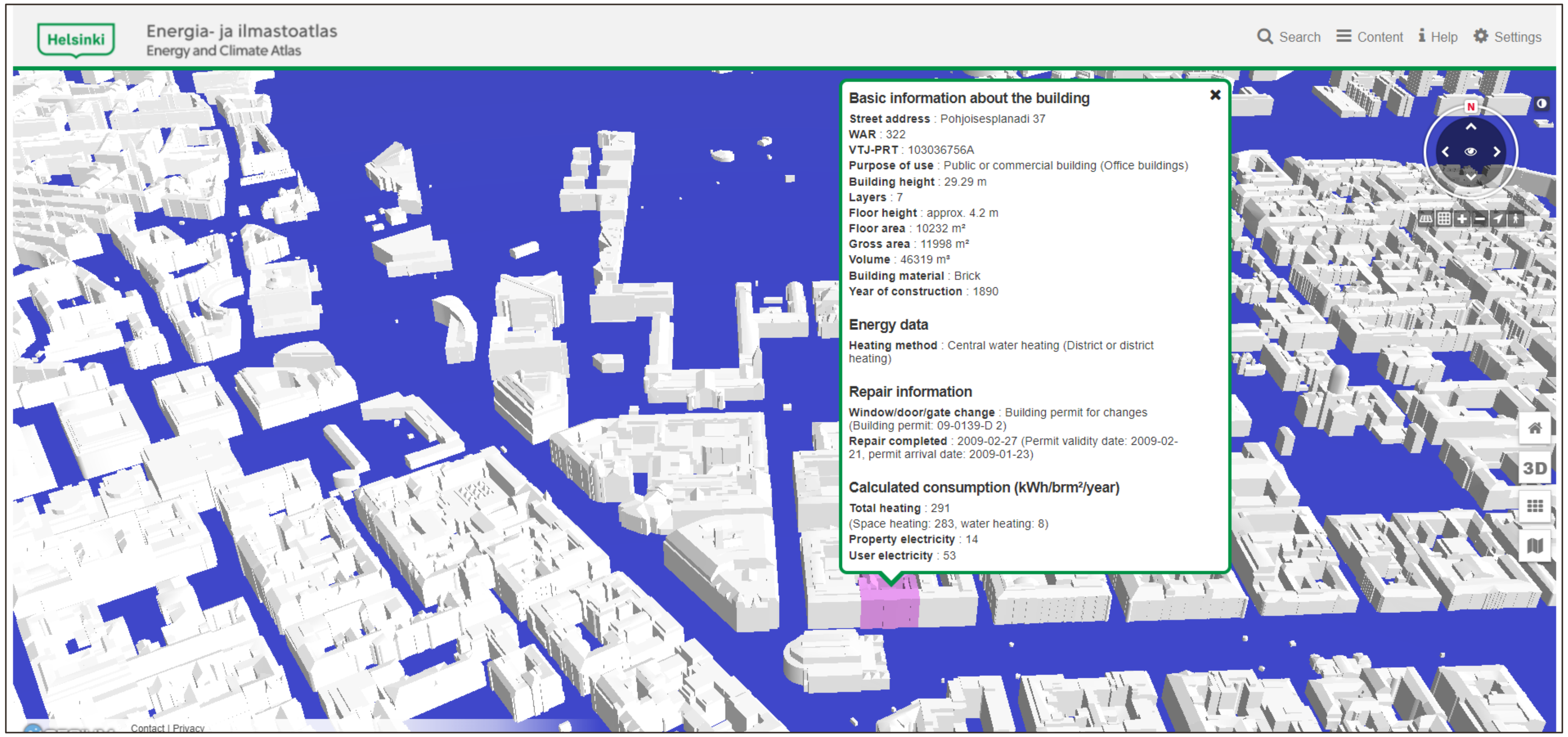


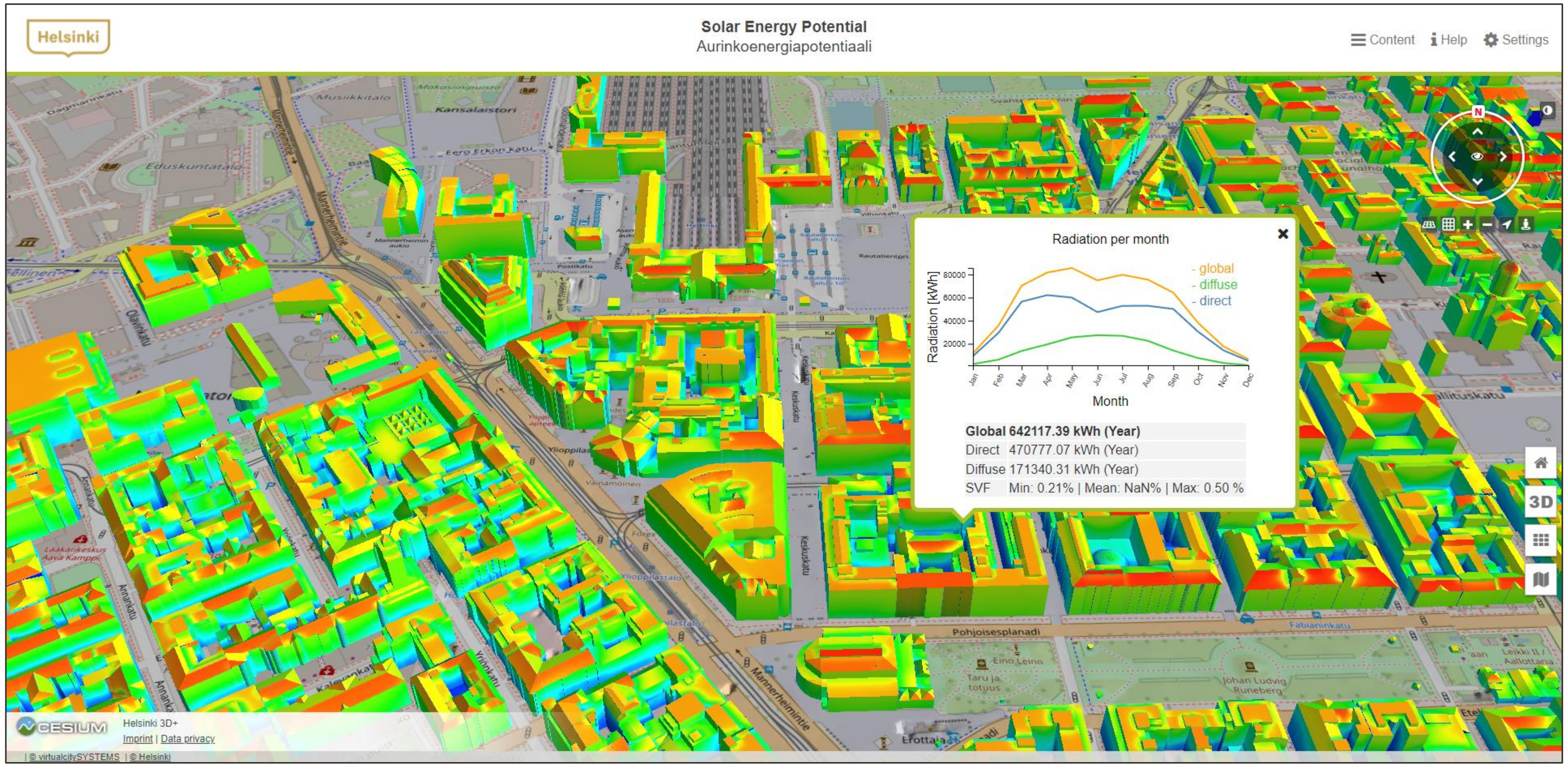
2035: decrease 82%
2050: decrease 86%

Helsinki

5.0 Computer Simulation and Results

Rossknecht, M., & Airaksinen, E. (2020). Concept and Evaluation of Heating Demand Prediction Based on 3D City Models and the CityGML Energy ADE—Case Study Helsinki. *ISPRS International Journal of Geo-Information 2020, Vol. 9, Page 602*, *9*(10), 602. https://doi.org/10.3390/IJGI9100602





Results Visualisation

The results are shown in the 3D City Model that is available online for the public to use.

The public is able to see the energy data, calculated energy consumption and refurbishment information on the Energy and Climate Atlas webpage.

The solar potential is found on the Solar Energy Potential webpage which shows the amount of radiation and the surface with the highest radiation.

Helsinki Energy and Climate Atlas. (n.d.). City of Helsinki. Retrieved July 22, 2023, from https://kartta.hel.fi/3d/atlas/#/

Helsinki Solar Energy Potential. (n.d.). City of Helsinki. Retrieved July 22, 2023, from https://kartta.hel.fi/3d/solar/#/

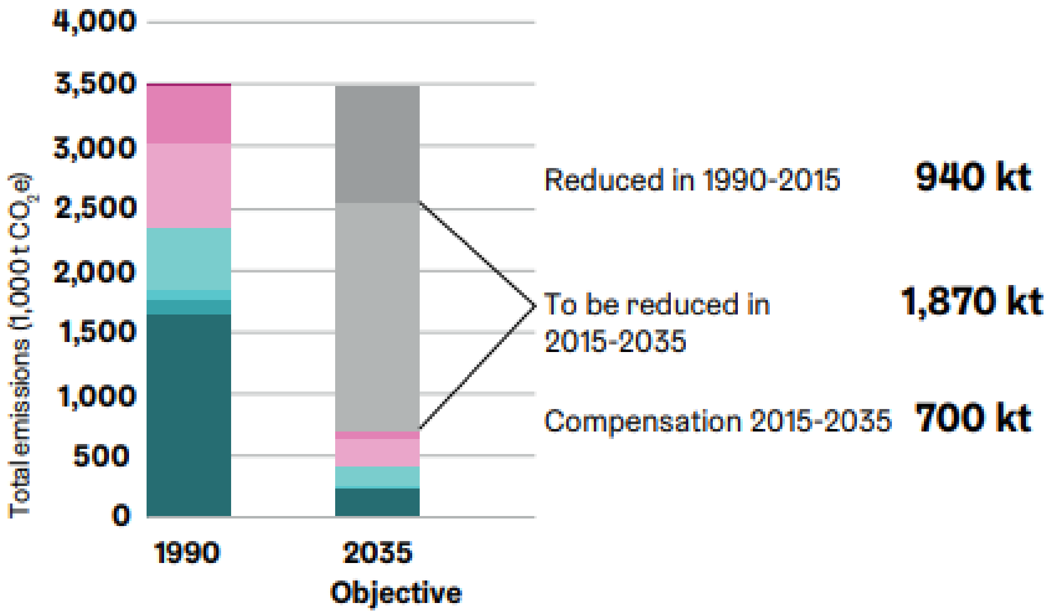


Figure 7. Emission reduction required to reach carbon-neutrality by 2035. (HSY 2017)

The estimated proportions of the various sectors and actions of the emissions reductions required for the 80-per-cent reduction are presented in Figure 8.

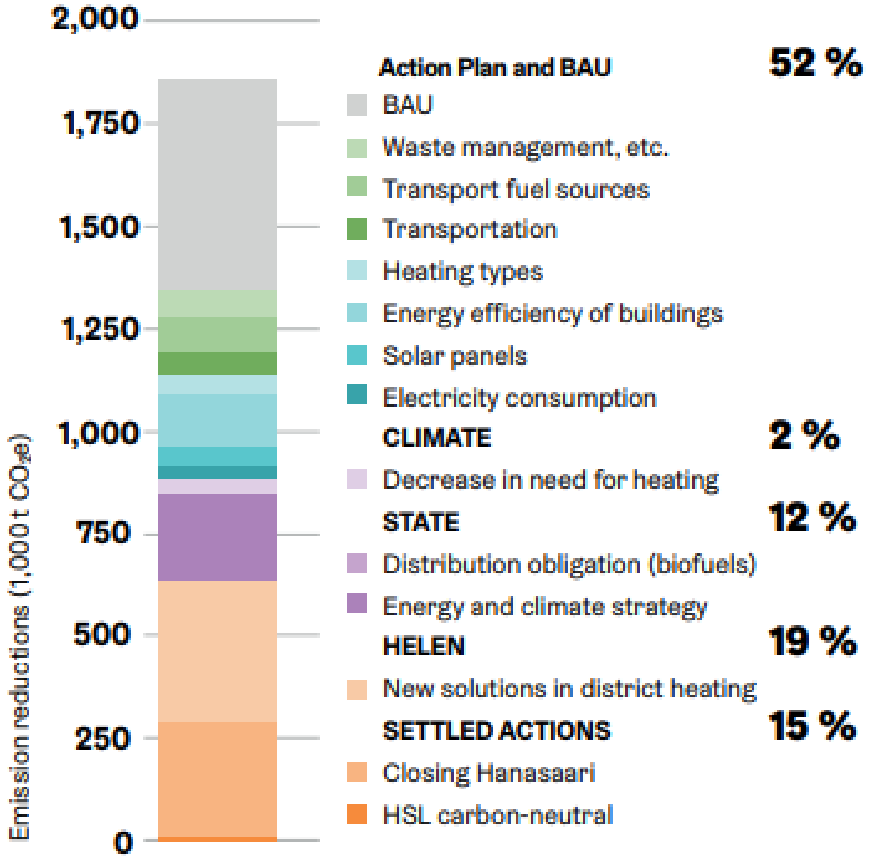


Figure 8. Emission reduction required to reach carbon-neutrality by 2035. In the calculation principle used, the impact of the energy efficiency actions for buildings has been calculated first, the changes in heating methods second, modernisations in energy production third, and the reduction in the need for heating caused by global warming fourth. The proportion of traffic amounts to 377 kt CO_2e and that of buildings amounts to 576 kt CO_2e, including the related BAU actions (Table 2). (HSY 2017)

The information from the simulation has helped to inform the action plan needed to taken to achieve its goal. It is clear that a BAU scenario is not enough to achieve the carbon neutral goal.

A rapid development scenario with a 3% refurbishment rate is the lowest minimum rate needed to reach the carbon neutral goal.

The simulation has helped to inform the government's action plan and future policies regarding heating demand and energy use. The simulation has helped to identify the overall portion of CO emission reductions required across different fields.

The public are also able to access the data to makes decisions for themselves and work together with the government in achieving the carbon neutral goal together.

Helsinki

6.0 How Did It Assist in Improving the Performance of the Project

City of Helsinki (2018) "The Carbon-neutral helsinki 2035 Action Plan" Retrieved July 22, 2023, from http://carbonneutralcities.org/wp-content/uploads/2019/06/Carbon_neutral_Helsinki_Action_Plan_1503019_EN.pdf

Shenzhen Bayview Tower

Case Study 2: Performance in the Building Scale

The profile and silhouette of the building draws inspiration from the undulating natural forms of the surrounding Nanshan Mountains and the Shenzhen Bay. Both the mountains and the water are important symbols and physical characteristics of the Shenzhen landscape. By borrowing inspiration from these natural forms, the building creates a direct relationship to its context and becomes an architectural manifestation. From across the bay, the tower appears as a new peak located between the water and the mountains and a beacon of light that anchors the entrance into the bay.

The form of the tower was developed using a holistic approach to the notion of efficiency. This means that the building efficiency is not solely measured in its floor plate, but also in its structure and environmental system performance. By combining efficiency and comfort with the aerodynamic form, the building is more cost effective, user friendly, and easier to maintain.

1.0 Introduction

Adrian Smith + Gordon Gill Architecture. (n.d.). Retrieved July 30, 2023, from http://smithgill.com/work/shenzhen_bayview_tower/

Sustainable goals

High Performance

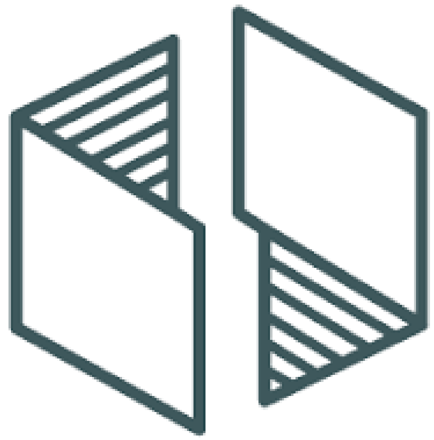
A high performing environmentally, socially, and economical building.

Adaptable

A building that is adaptable to the future and can change with the demands of the real estate sector

Power Generating

A building that generates a significant proportion of its own electricity



Flexible

An efficient and flexible building that promotes the ability for spaces to easily be changed and adapt to

Energy Efficiency

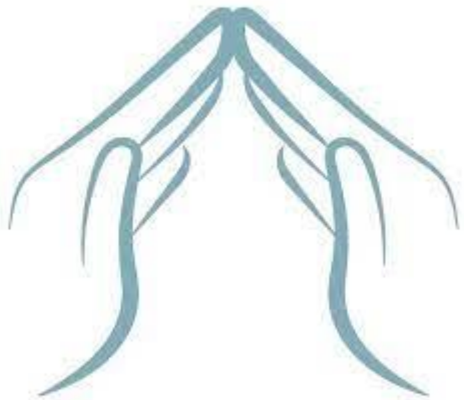
A Regional benchmark for uncompromising energy efficiency

Resilient

A building that is resilient to climate change

Net Zero Water

A building with Net Zero Water consumption



Wellness

A building that is designed to enhance the health and wellness of its occupants

A S
G G

Adrian Smith + Gordon Gill Architecture. (n.d.). Retrieved July 30, 2023, from http://smithgill.com/work/shenzhen_bayview_tower/

To assist in the massing of the building at the early stages of design

To find the most suitable form for efficiency and comfort

To reduce wind forces on the high-rise building by experimenting with form and wind slots

A S
G G

2.0 Performance Goals of the Simulation

Corner Streams

Floor plate efficiency (ratio of usable floor area to gross floor area)

User Comfortability

Total force magnitude

Wind Pressure (Pa)

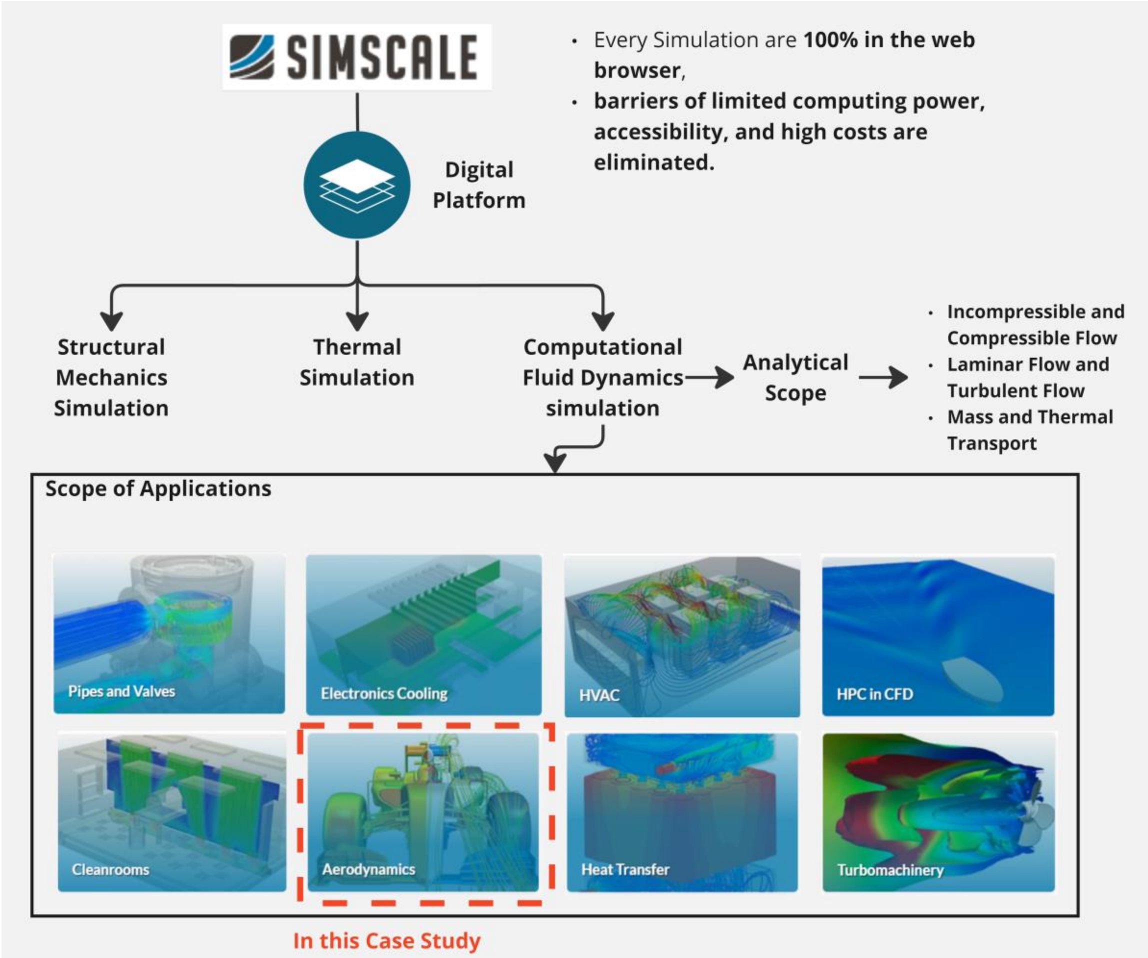
Wind Speed / Velocity (m/s)

Selected metrics for case study discussion

3.0 Selected Performance Criteria and Metrics

Software

1



Developer:
Numeric Systems GmbH, Pacefish®

Nature:
Cloud-Based Digital simulation Platform

Type of Simulation:
Computational Fluid Dynamics(CFD)

Selling Point:
Intergration of Lattice Boltzmann method (LBM)

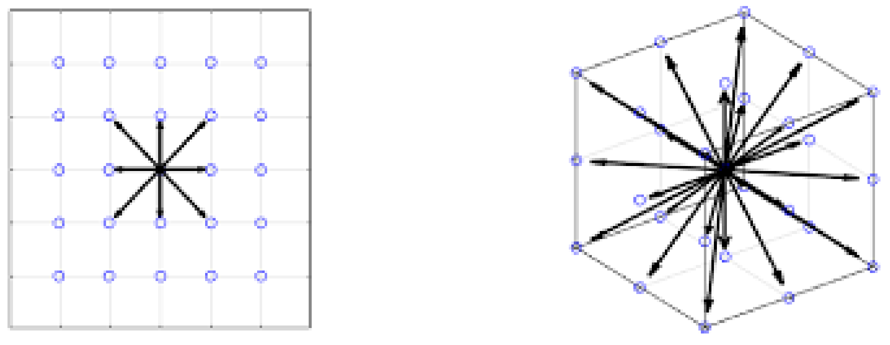
- tailored to the **massively-parallel architecture of GPUs.**
- **20-30 times Shorter** turnaround **time** than traditional methods

2

Aerodynamic Analysis: This involves the use of computational fluid dynamics (CFD) to **analyze the flow of air** around an aircraft or other aerospace vehicle. This analysis can be **used to optimize the design** of the vehicle for **improved performance, fuel efficiency, and safety**

Software

3



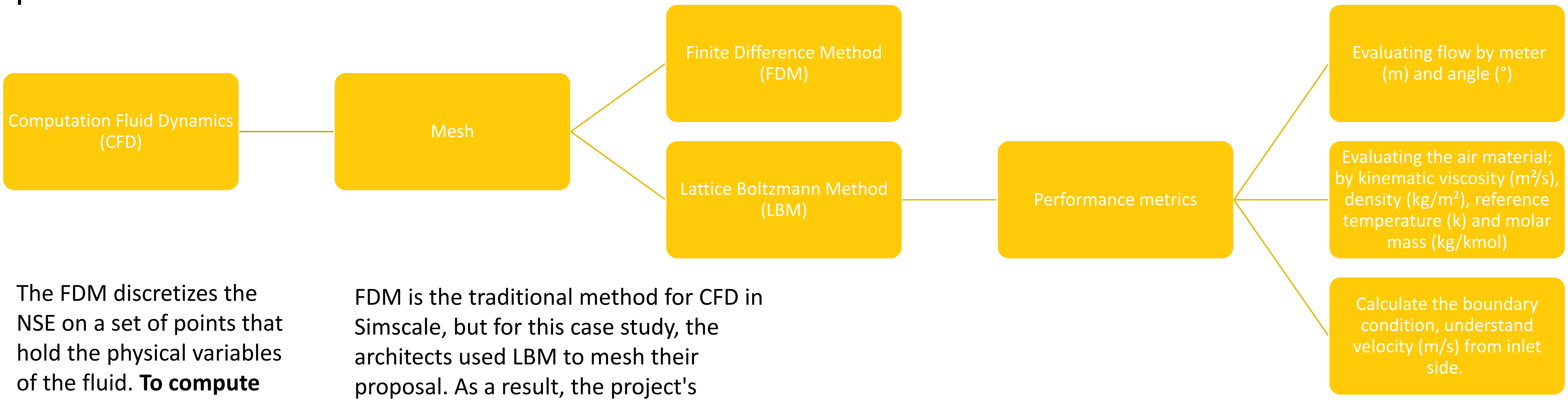
(a) (b)

A promising alternative to traditional CFD approaches is represented by the Lattice Boltzmann method. In this method, the **Boltzmann equation is used to approximate macroscopic fluid phenomena as mesoscopic shock events** of fictitious particles.

It consists of just two steps:

- **Step 1:** streaming, each cell exchanges their fictitious particles with all of their neighboring cells
- **Step 2:** collision, new mesoscopic quantities are computed based on the particles that were streamed in before

4



The FDM discretizes the NSE on a set of points that hold the physical variables of the fluid. **To compute the derivative at a node, a Taylor expansion is utilized**

FDM is the traditional method for CFD in Simscale, but for this case study, the architects used LBM to mesh their proposal. As a result, the project's timeframe for developing its proposal has been shortened.

Computational Fluid Dynamics Methods Explained. (n.d.). Retrieved July 30, 2023, from https://www.dive-solutions.de/blog/cfd-methods

Aerodynamics and aerospace applications in industry and CFD. (n.d.). Retrieved July 31, 2023, from https://www.mr-cfd.com/industries/aerodynamic-and-aerospace-engineering/

Method

CAD Preparation and analysis type selection

Importing the model into the software.

Simulation Setup

Insert the data and metrics
- External Flow Domain
- Material
- Boundary Conditions
- Simulation Control
- Result Control

Meshing

-Discretization of the simulation domain
-Split up a large domain into multiple smaller domains and solve equations for them
-Based on the lattice Boltzmann method (LBM)

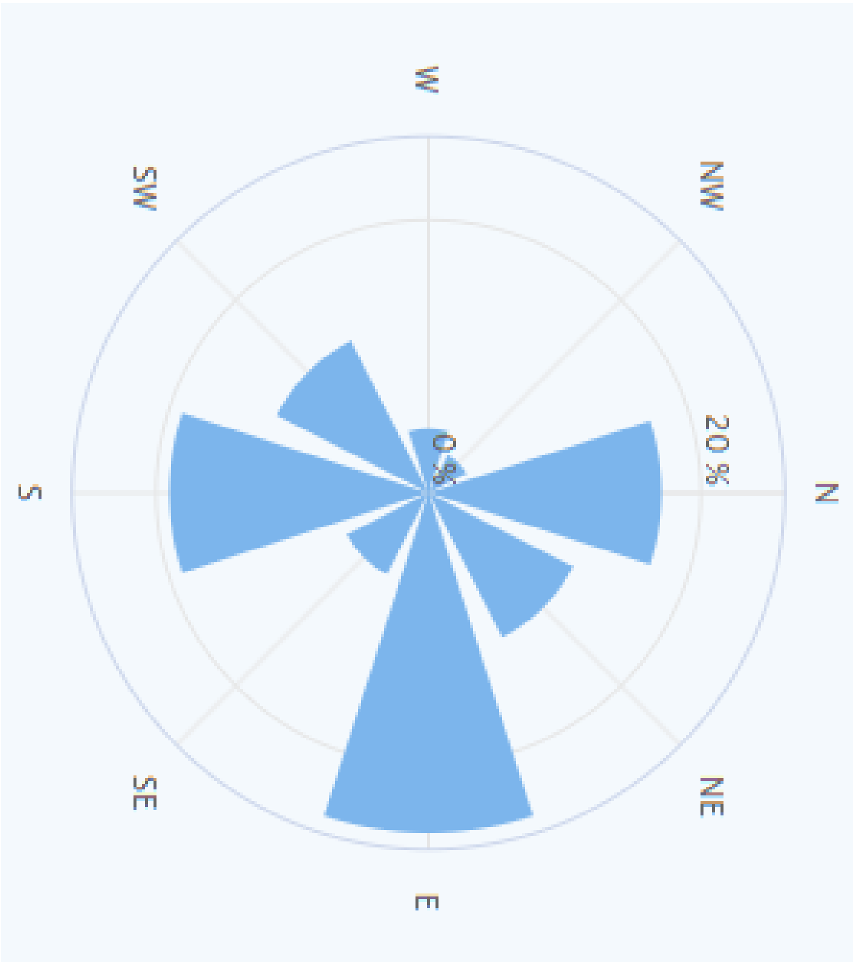
Simulation and Result

-Run the simulation
-Post-processing

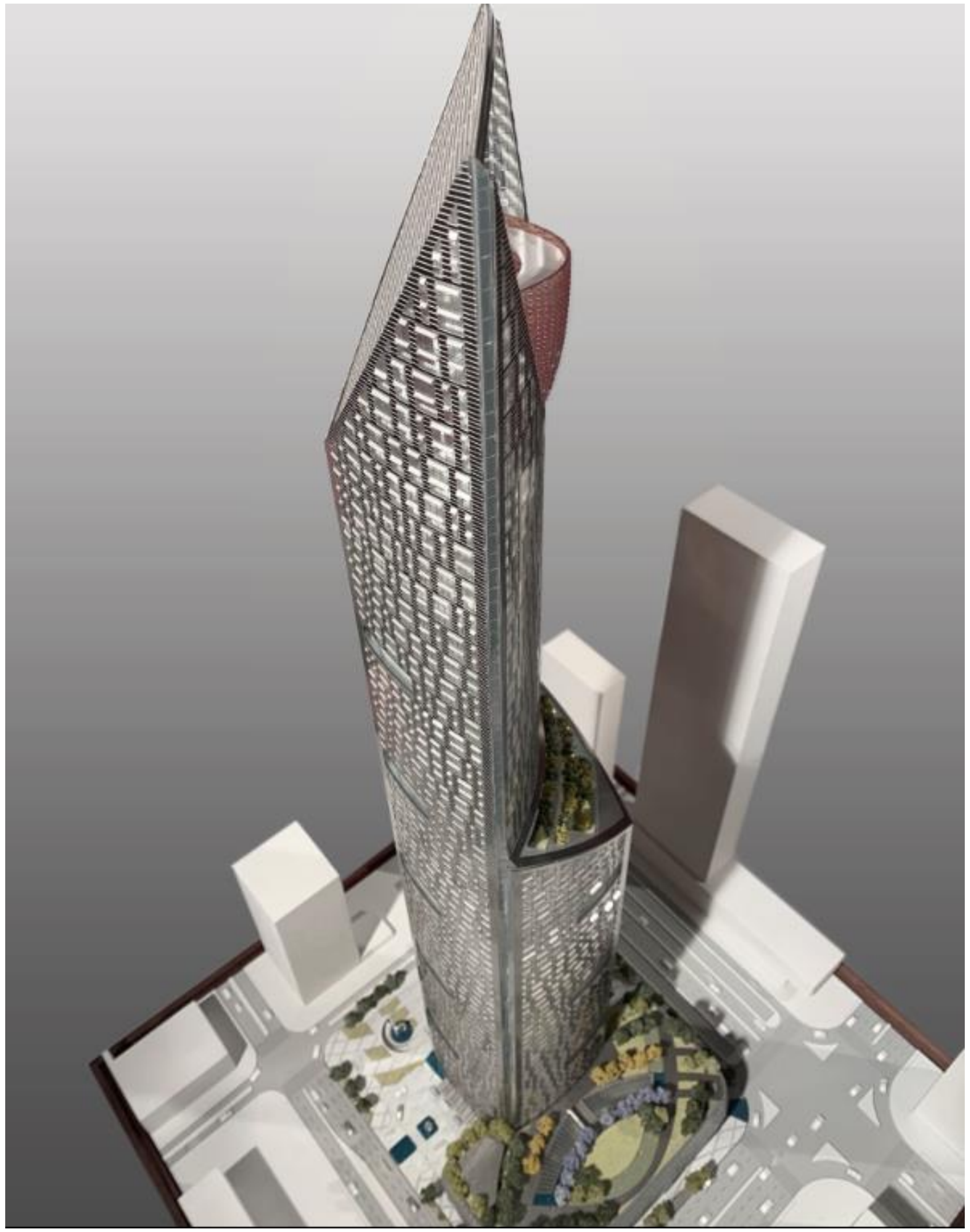
Wind Analysis using LBM (Lattice Boltzmann) | Tutorial | SimScale. (n.d.). Retrieved July 30, 2023, from https://www.simscale.com/docs/tutorials/wind-analysis-using-lbm-solver/

ncompressible (LBM) | Analysis Types | SimScale. (n.d.). Retrieved July 30, 2023, from https://www.simscale.com/docs/analysis-types/incompressible-lbm/#mesh

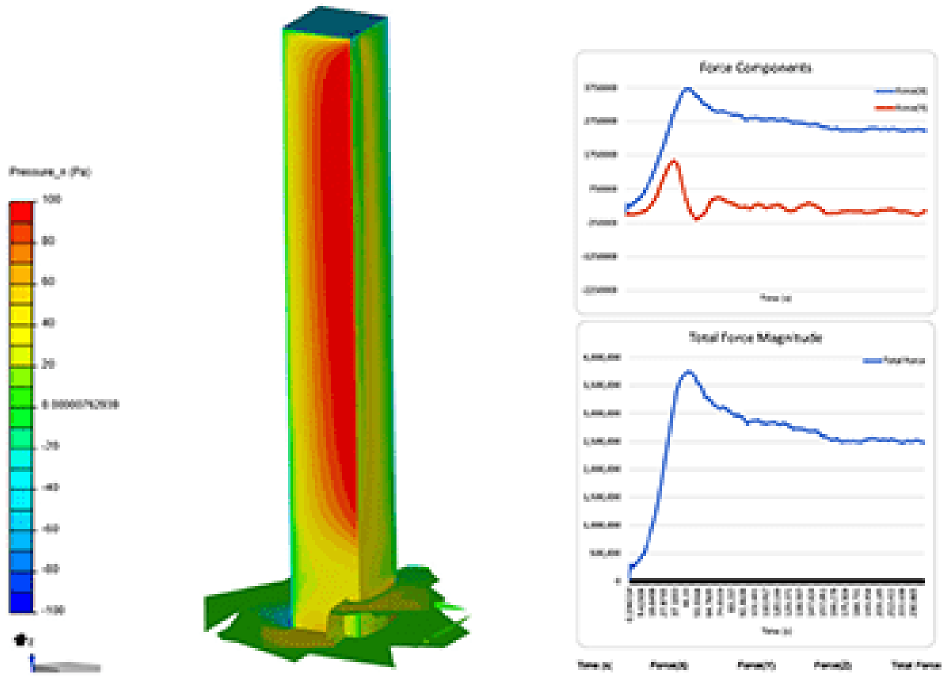
Weather Data



N ▼ Northern	NE ◢ Northeastern	E ◀ Eeastern	SE ◥ Southeastern	S ▲ Southern	SW ◤ Southwestern	W ▶ Western	NW ◣ Northwestern
17.1%	11.9%	24.9%	6.7%	19%	12.5%	4.7%	3.1%

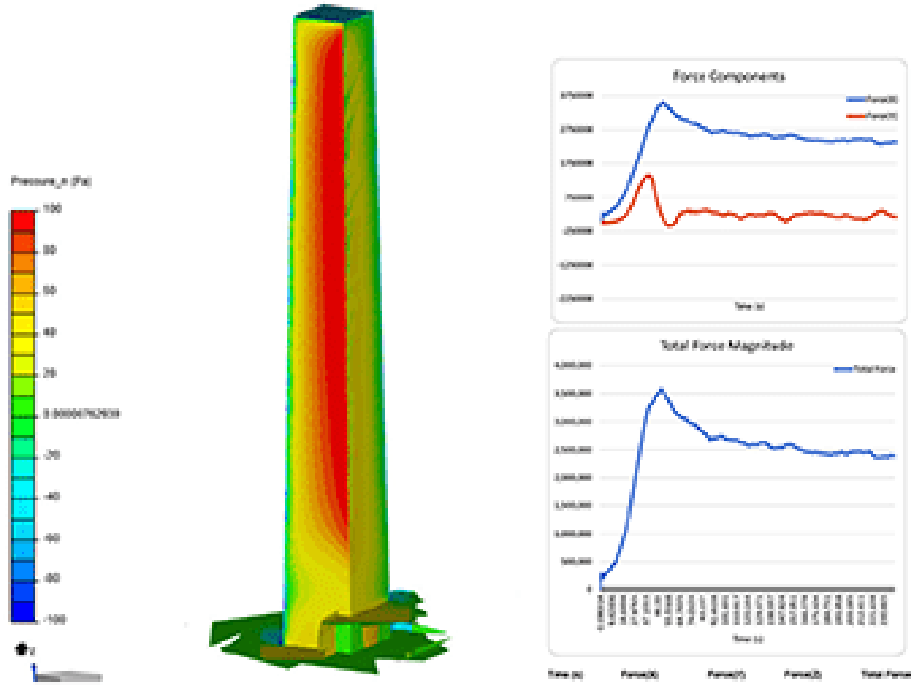


Weather Archive in Shenzhen, World Weather. (n.d.). Retrieved July 30, 2023, from https://world-weather.info/archive/china/shenzhen/#t2



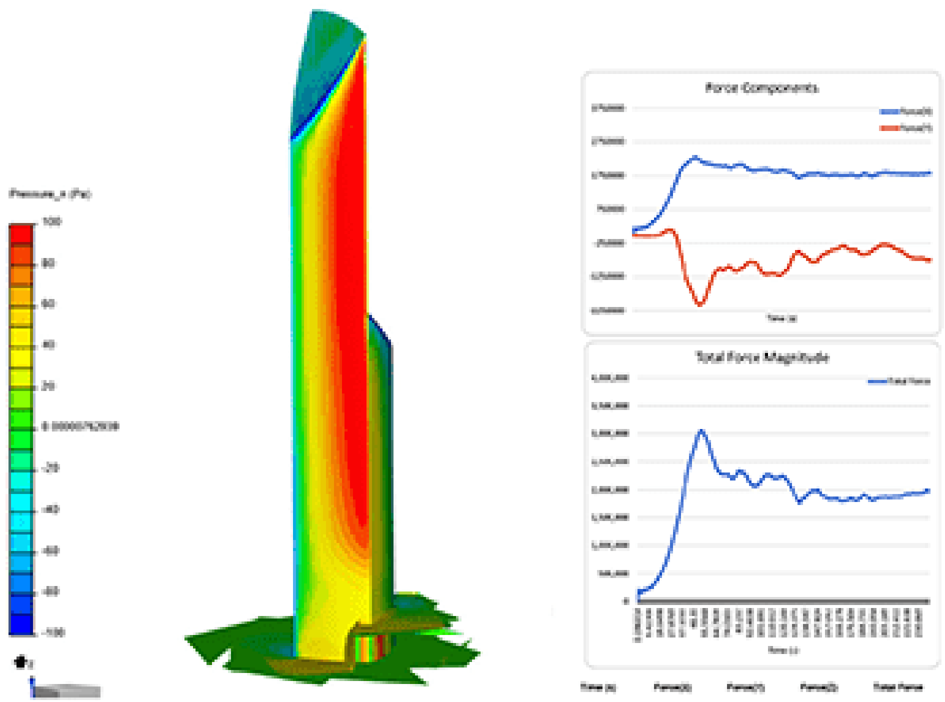
拉伸
Extrusion
基准
Baseline

01



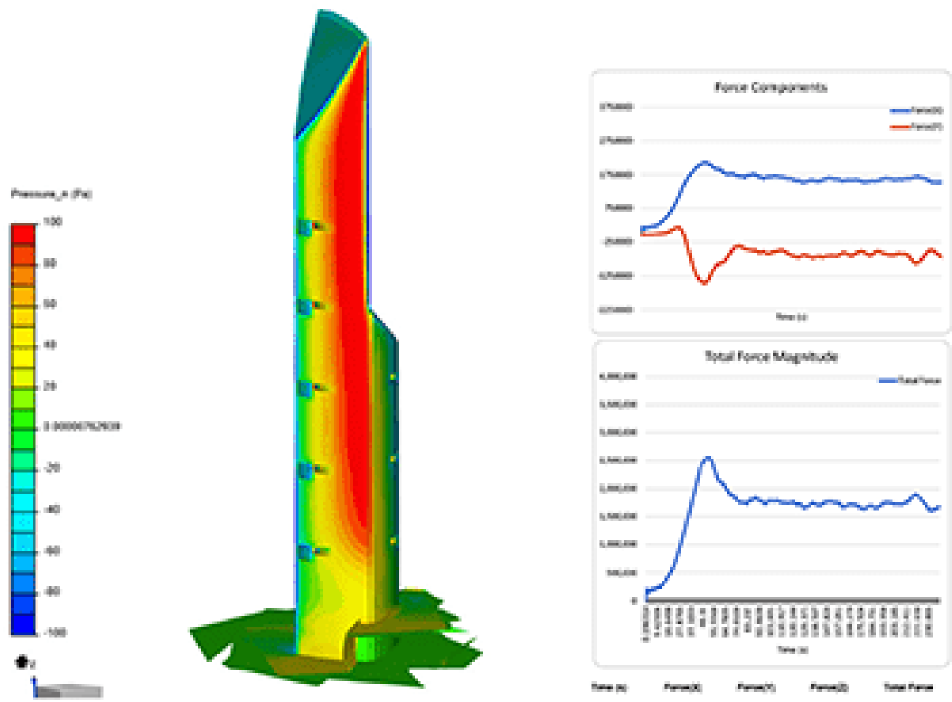
逐渐收分
Tapered
比基准减少:
Reduction from baseline: 4.54%

02



分层
Stepped
比基准减少:
Reduction from baseline: 25.86%

03



分层凹口
Stepped Notched
比基准减少:
Reduction from baseline: 34.85%

04

01 Simple Extrusion

Preliminary analysis indicated this particular site, reducing the mass of the top of the building by stepping back the form was more effective at mitigating the wind loads than if they were to taper the building, a fact that was revealed through the design iteration and simulation process.

02 Tapering Shape

Using a baseline rectangular extrusion, the various tapered versions produced an approximate reduction of 5% of the total force magnitude whereas a stepped version reduced the total force magnitude by 26%.

03 Rear profile reduction

A further reduction was made at a detailed level by utilizing wind relief slots that mitigate forces developed due to vortex shedding.

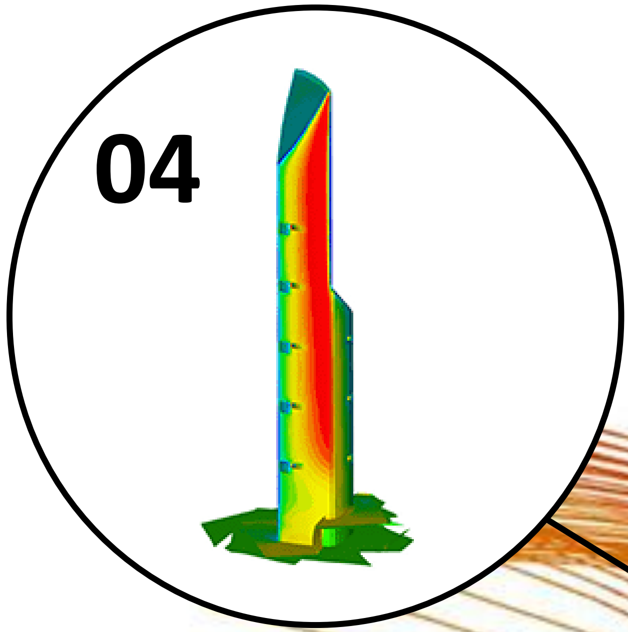
04 Notched Opening

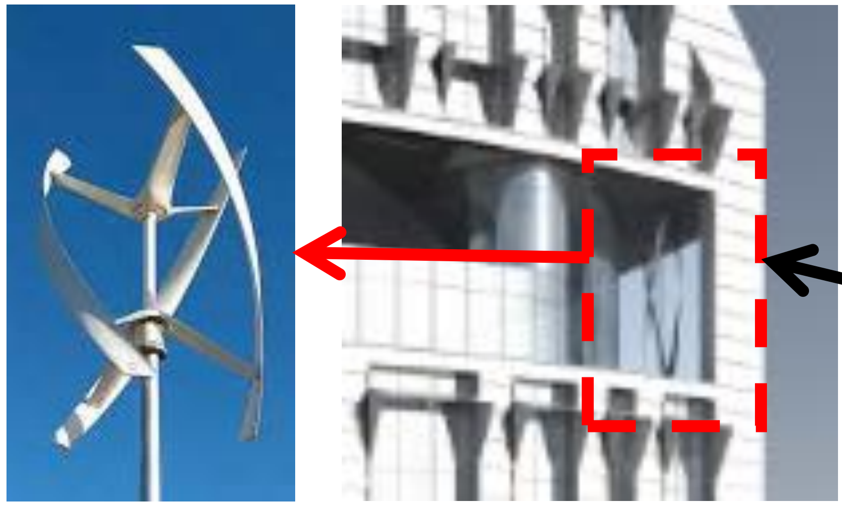
Incorporates 16 wind turbines located on the AOR floors at points where wind vortices are maximum.

5.0 Computer Simulation and Results

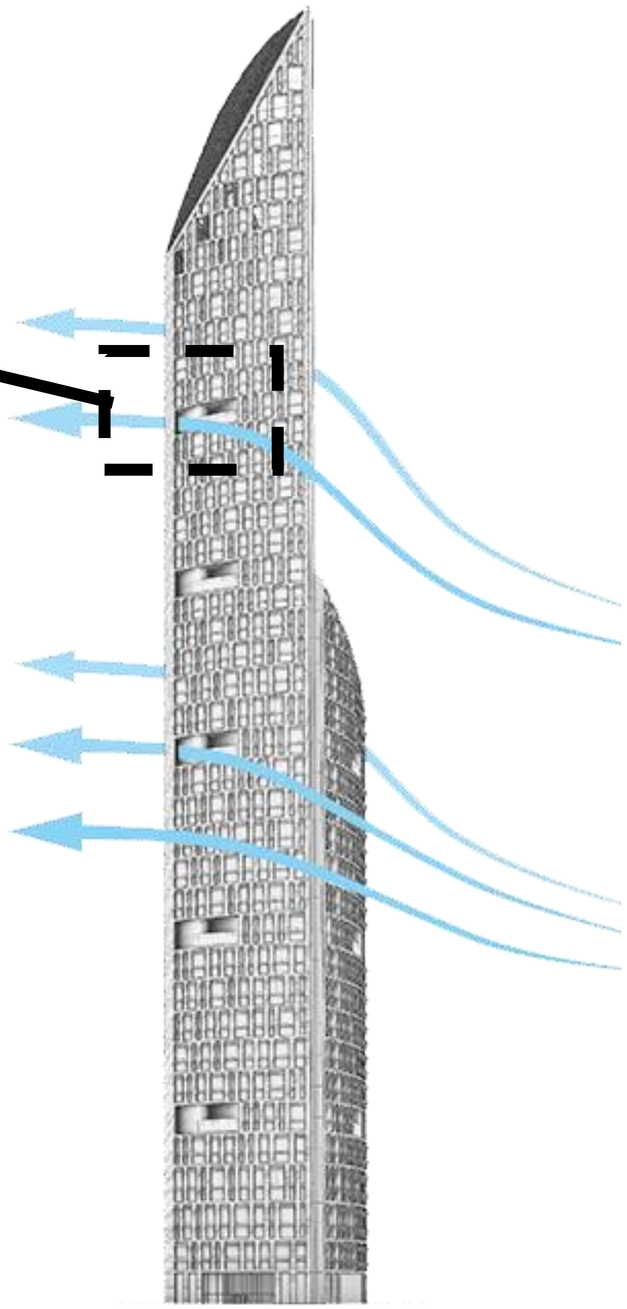
Adrian Smith + Gordon Gill Architecture PWC Case Study | SimScale. (n.d.). Retrieved July 30, 2023, from https://www.simscale.com/customers/adrian-smith-gordon-gill-architecture/

Result Visualisation

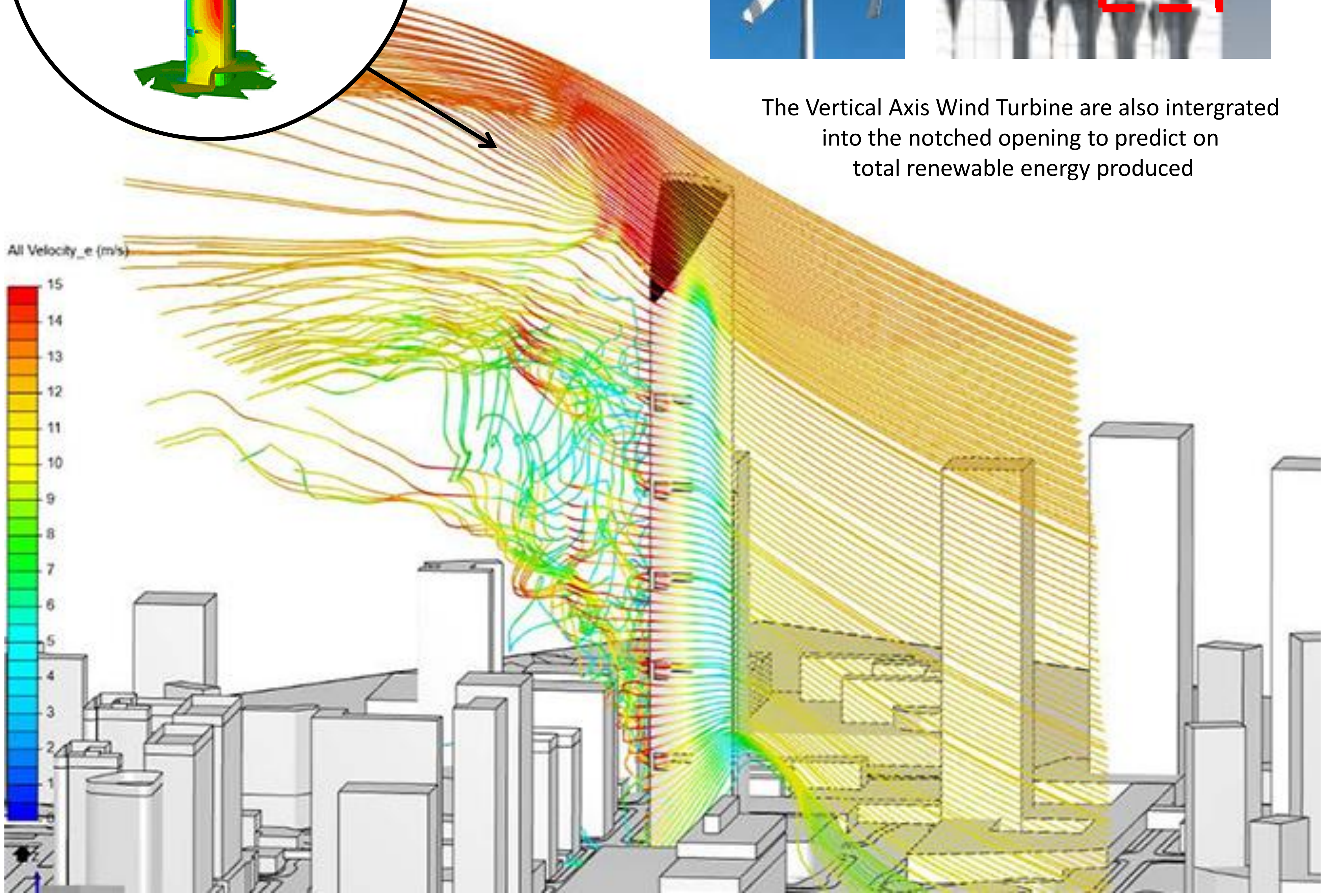




The Vertical Axis Wind Turbine are also intergrated
into the notched opening to predict on
total renewable energy produced



The Pressure and Wind Velocity parameter are one
of the key factor to determine the type of wind
turbine could be used for the tower



A More Detailed Simulation result on
Velocity magnitude field from the side of the building

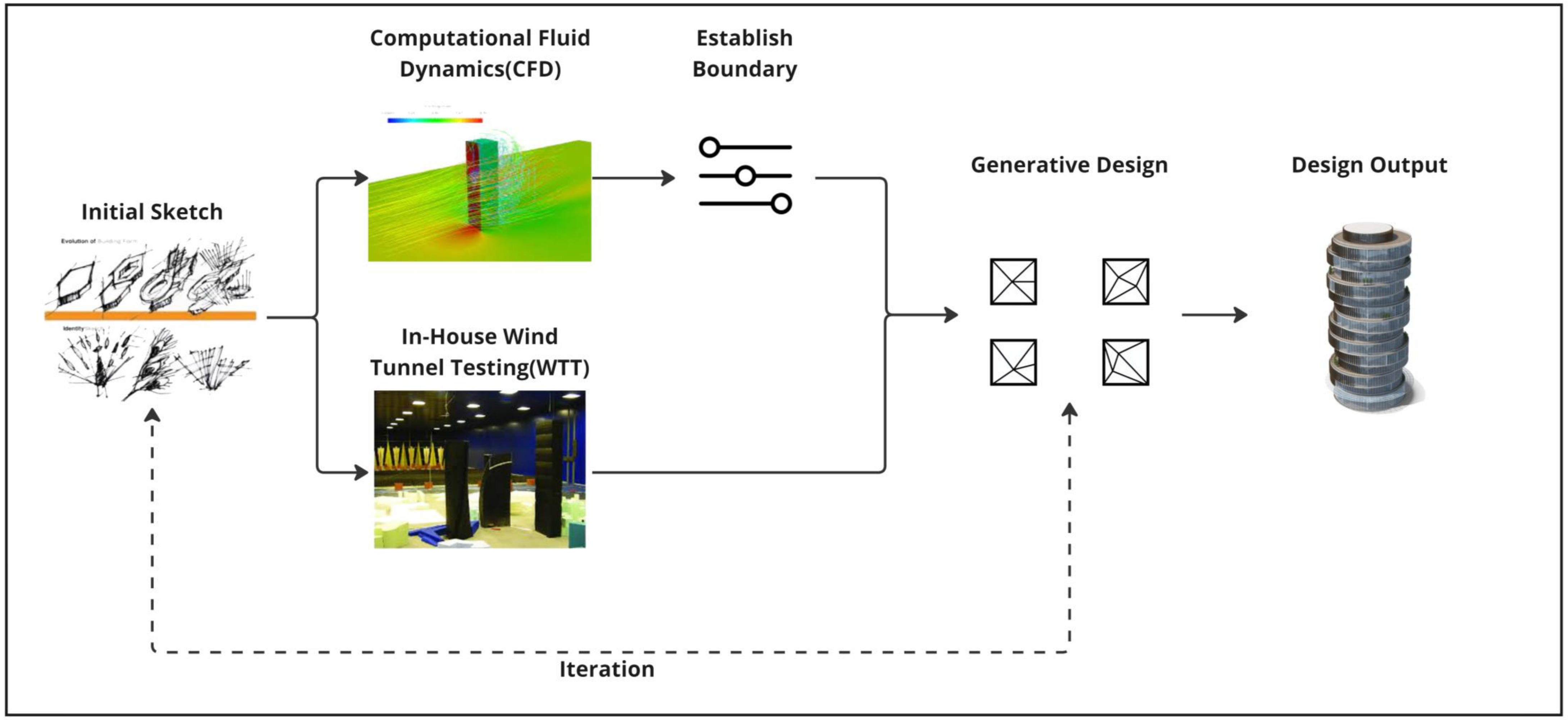
The total renewable energy produced from **wind is estimated to be 1.8% of the total building's annual energy consumption.**

A | S
G | G

5.0 Computer Simulation and Results

Adrian Smith + Gordon Gill Architecture PWC Case Study | SimScale. (n.d.). Retrieved July 30, 2023, from https://www.simscale.com/customers/adrian-smith-gordon-gill-architecture/

Implementation of CFD in Architectural BIM Workflow



Summary of CFD in Architecture Design

In the current era, there are two ways to simulate on Aerodynamic process which is CFD and In-House Wind Tunnel Testing(WTT). Using the conventional and traditional way to implement Aerodynamic simulation could be disruptive towards the architect's design process.
Newer software and platform are develop to bridge and allow more efficient design through real time modification and simulation using the digital model.

Optimize Workflow

- SimScale allow Cloud-based Real-Time Simulation to **reduce more time** in **production of generative design** for complex building.

Generative Design
Reduced Wind Forces by 35%

- The software result approximate **reduction of 5% of the total force magnitude and total force magnitude by 26%.**

Green Energy Prediction

- Generate data to **predict the total renewable energy produced from wind** is estimated to be 1.8% of the total building's annual energy consumption.

Computational Fluid Dynamics in Building Design Practice ABSTR ACT. (n.d.).