Digital Twins in the Built Environment

IAQ & Energy Efficiency

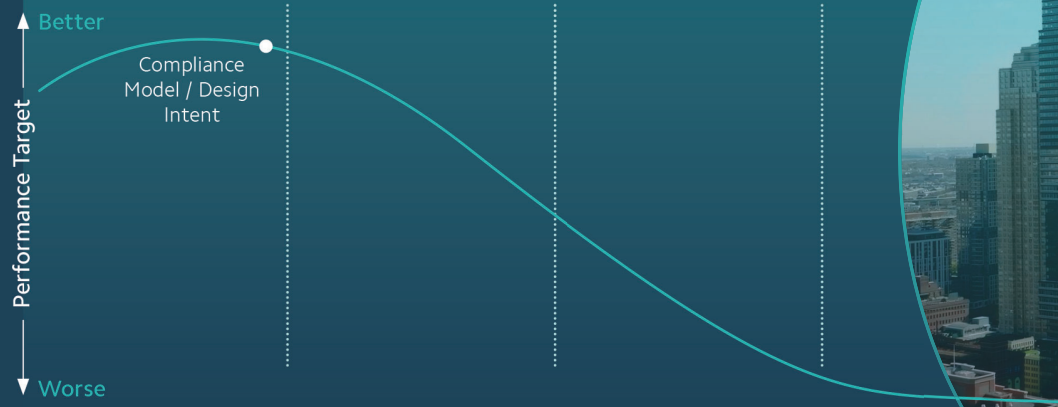
Rohan Rawte, Managing Director, IESVE Singapore Pte Ltd

The Problem with Buildings

- Many have made pledges to decarbonise buildings but few understand how their buildings perform or have concrete plans to improve them at the scale required
- Complex, dynamic assets with shifting requirements that often change daily
- Buildings designed for energy, e.g. A-Rated, LEED Gold, but controlled for comfort
- Lack of clear guidance/policy direction on how to meet Net-Zero targets & other objectives
- Poor performing buildings increase operating costs, CO2 emissions, reduce asset value & impact negatively on health, wellbeing & productivity

The S-Curve

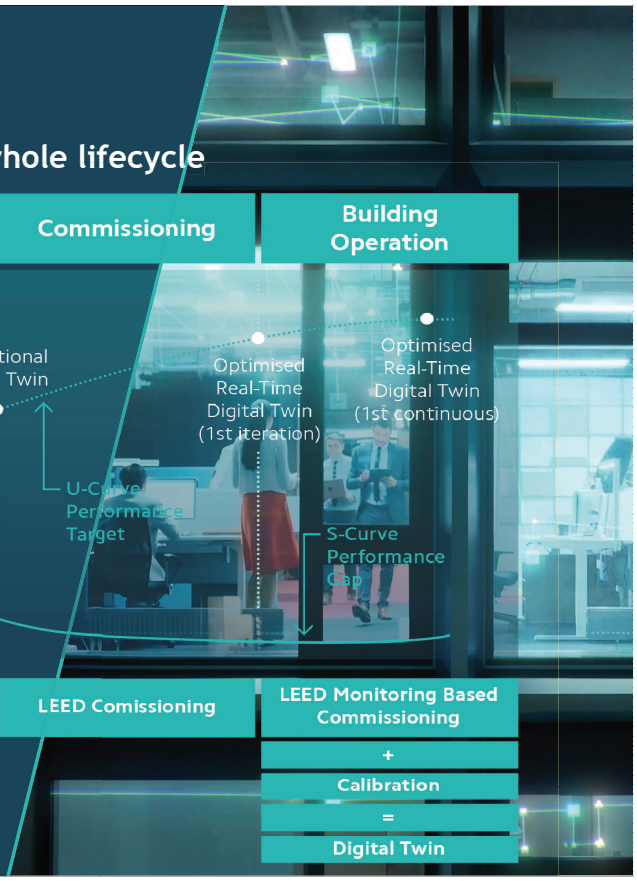
Planning and Initial Design	Detailed Design	Construction	Commissioning	Building Operation



OGC Gateway Review for Programmes & Projects,
https://webarchive.nationalarchives.gov.uk/20100609094113/http://www.ogc.gov.uk/what_is_ogc_gateway_review.asp

The U-Curve

Valuable Asset for improving performance across the whole lifecycle



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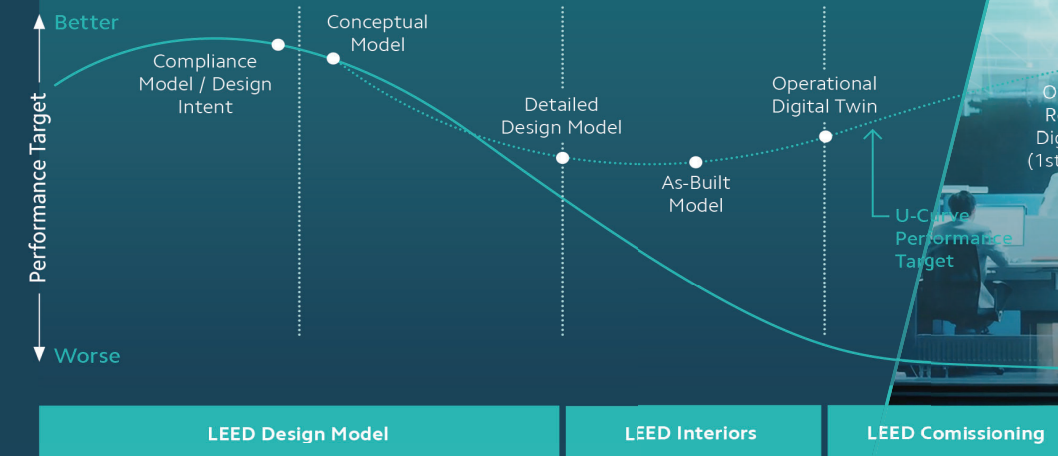


LEED Design Model	LEED Interiors	LEED Comissioning	LEED Monitoring Based Commissioning
			+
			Calibration
			=
			Digital Twin

The IAQ/EE Digital Twin

- A virtual replica which gathers real data and uses physics-based simulations to respond and behave in the same way as its real-world counterpart
- Allows you to analyse how your buildings and associated infrastructure are performing now, gain insights into how they should be performing and explore different scenarios to understand the impacts of future changes
- Provides decision support information to improve asset performance, influence future building design and retrofit and reduce investment risks

The Best of Physics, Data and AI/ML

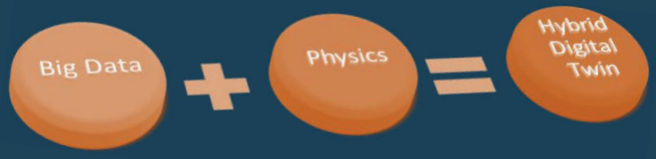
Physics Enabled Simulation
- Based on fundamental physics principles
- Simulates the physics of energy & heat flow

Real & Virtual Sensor Data
- IoT & BMS Data from the Real Building
- Virtual Sensor Data from the Simulation

AI & Machine Learning
- Enables data driven prediction
- Fills data gaps & checks for anomalies

Digital Twin
Leverages the best of both Building Simulation, Sensor Data, AI & Machine Learning

The Best of Physics, Data and AI/ML



Digital Twin Applications

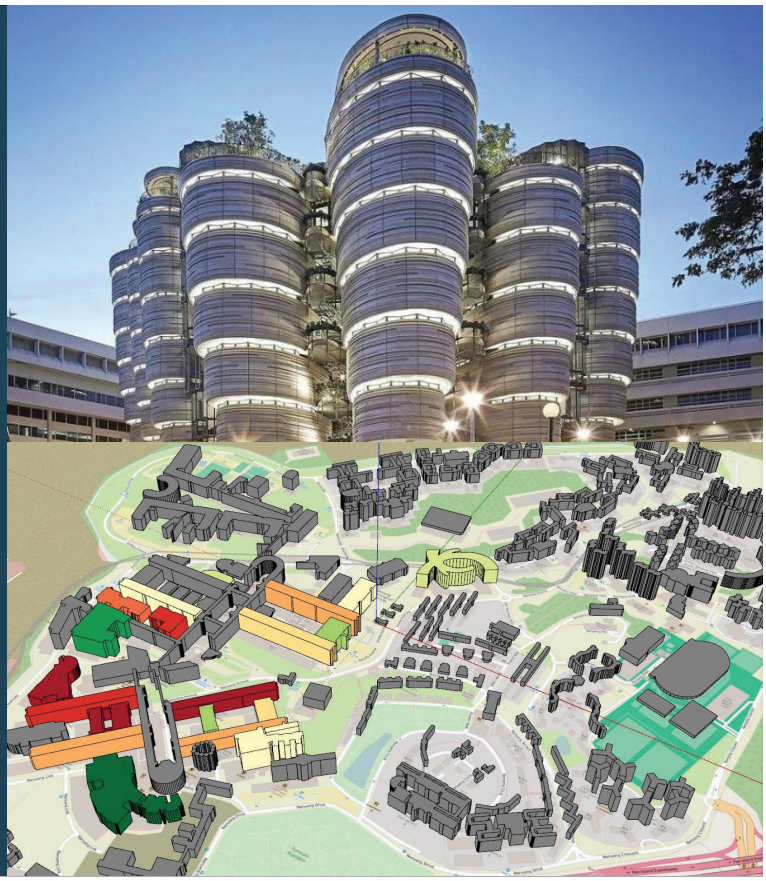
Digital Twins in Action

EcoCampus Masterplanning

Nanyang Technological University (NTU)

Singapore

- 10 million sq.ft built up floor area
- 200 Buildings on Campus
- 31% reduction in Campus Energy
- 9.6kt Carbon Savings
- S$5M in Financial Savings

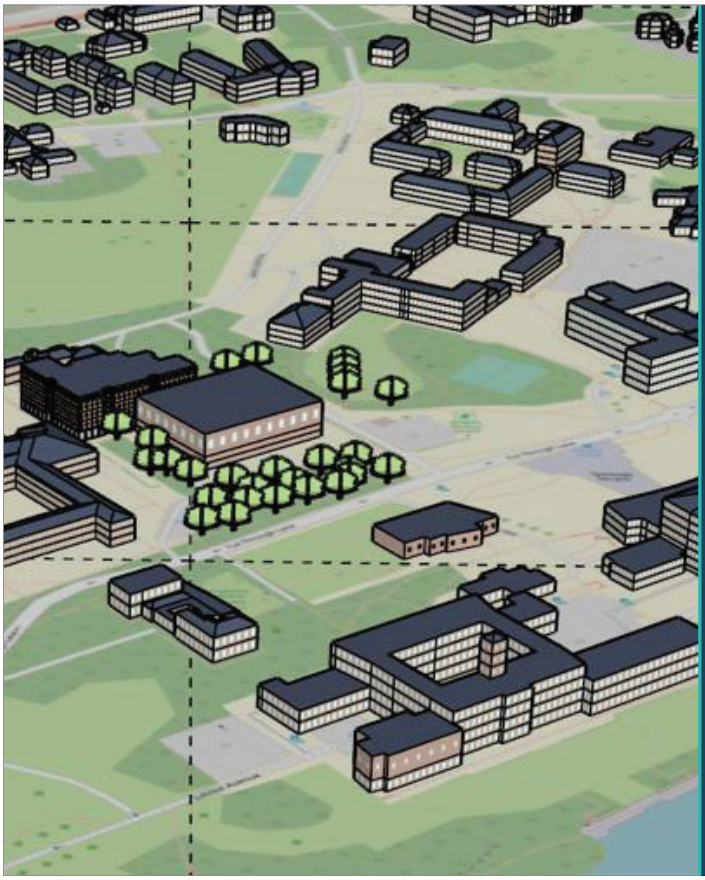


University of Nottingham Digital Twin & Living Lab Partnership

University of Nottingham

Living Lab Partnership

- IES has been working with the University of Nottingham on various projects since 2013
- Created an interactive platform for the Trent Basin low-energy community, enabling real-time visualisation of energy data across 145+ low-energy homes
- Ongoing Living Lab partnership
- Provides students and staff with access to cutting-edge IES digital twin technology
- Enables the Estates team to better manage the campus buildings and plan interventions

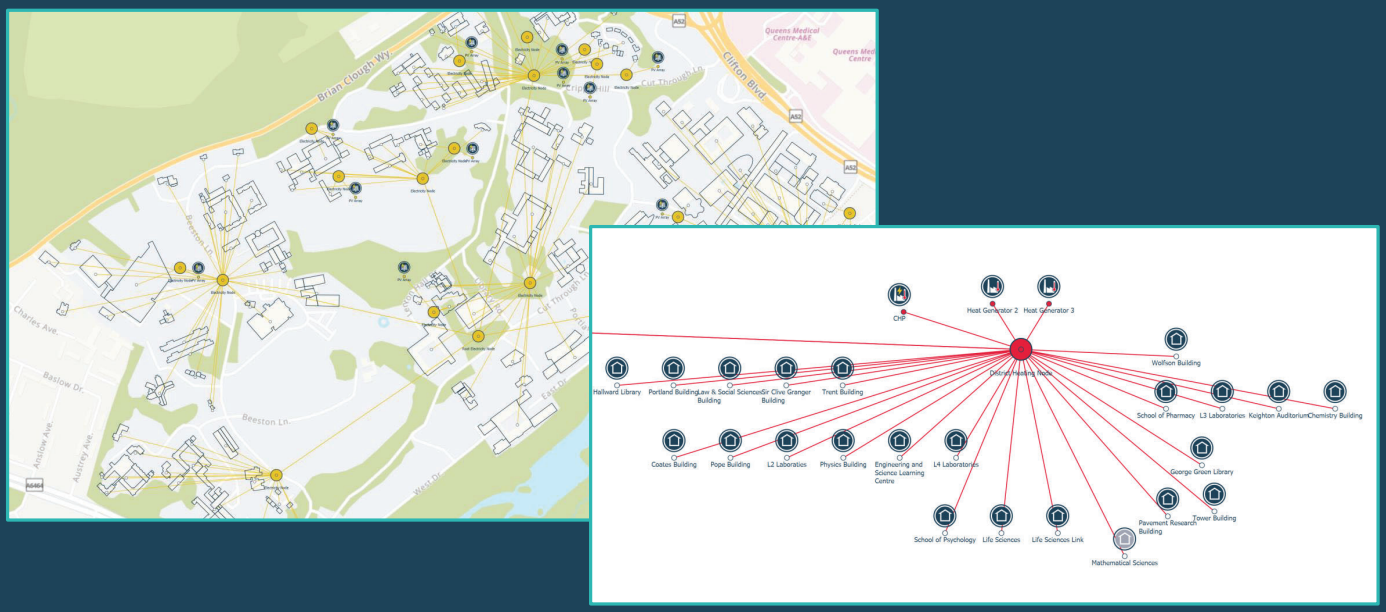


University of Nottingham

Campus Level Digital Twin - University Park

- Digital twin created encompassing 280 buildings
- High level overview of campus performance
- Energy masterplanning & network modelling
- Decarbonisation roadmap
- Campus and building level dashboards will be developed through ongoing collaboration

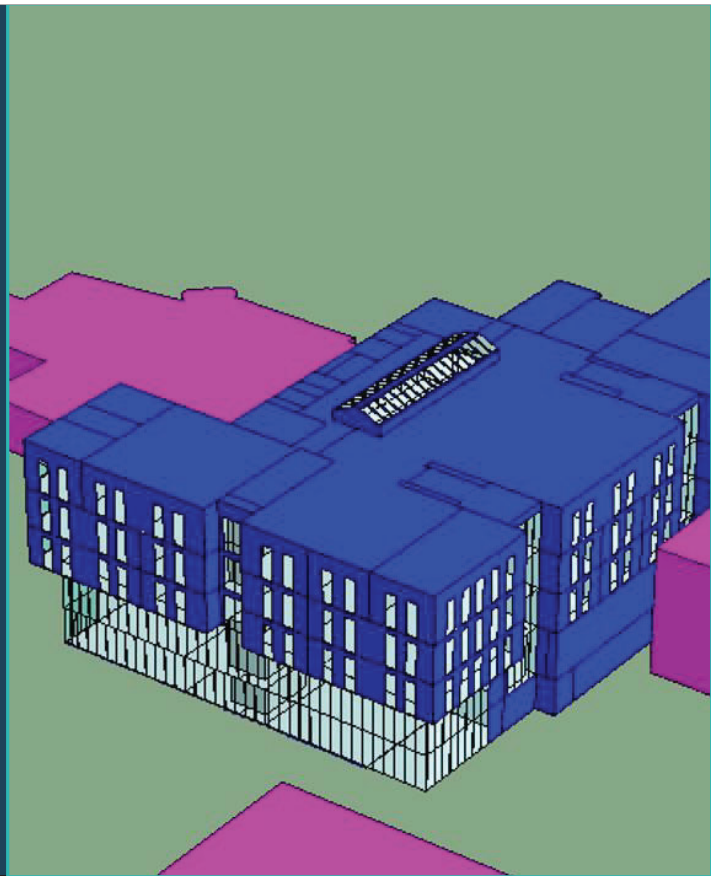
iVN Virtual Network Model
University Park Campus



University of Nottingham

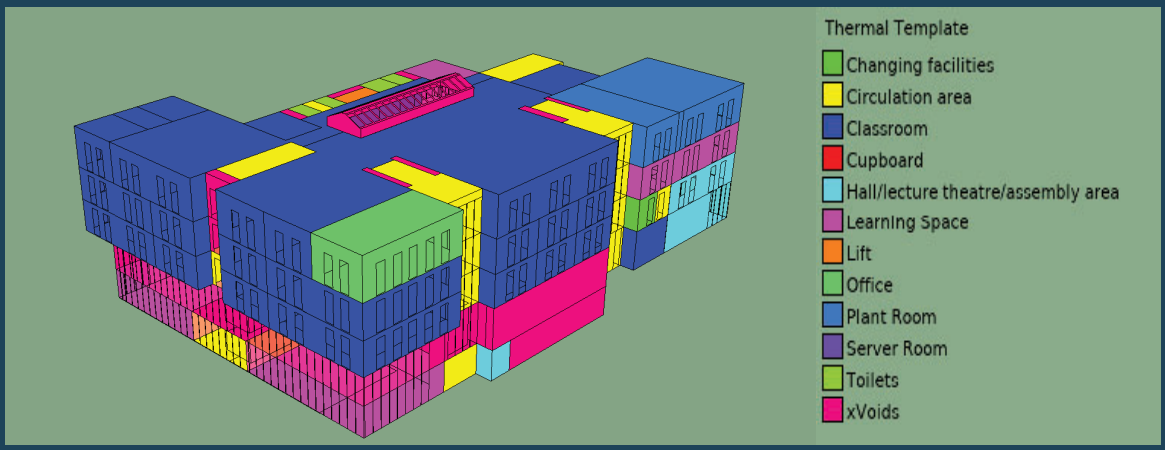
Building Level Digital Twin - Monica Partridge Building

- Building constructed in 2017
- Primarily used for learning & teaching, with some office space
- HVAC systems include Underfloor Heating, Air Handling Units, VRF Units & radiators
- Electricity & Gas data received for the whole of 2022
- Aim of creating a Digital Twin of the building by achieving monthly calibration with the energy data



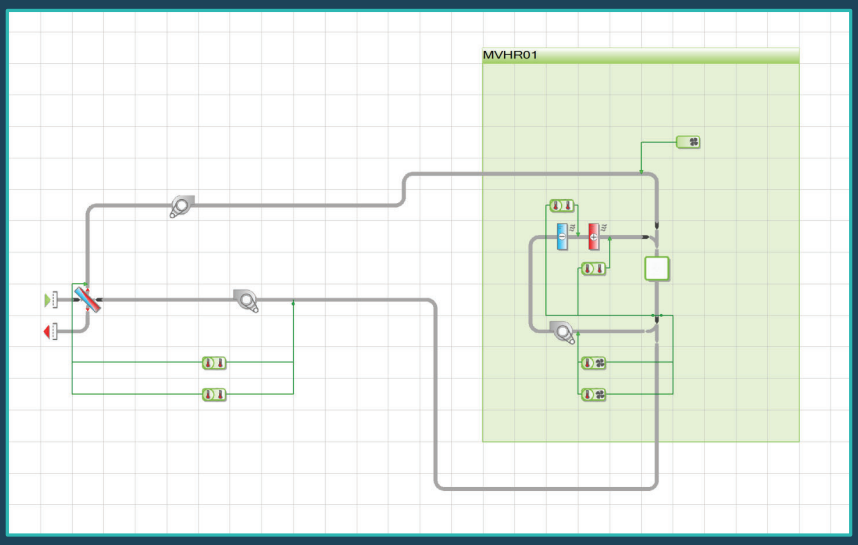
Model Set Up - Geometry

- Geometry was created using drawings provided by the University
- Thermal templates constructed and applied to help define the characteristics of the spaces
- Inputs such as internal gains from lighting and equipment, occupant density and space systems are assigned here



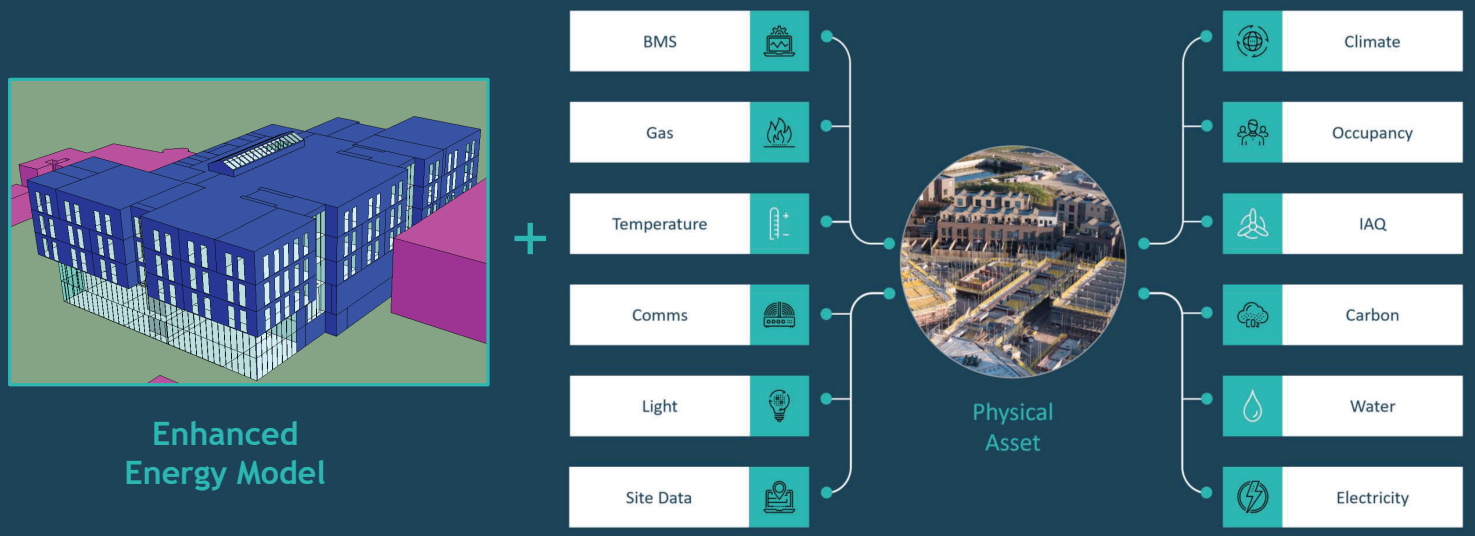
Model Set Up - Systems

- HVAC systems are then set up in the model, with their respective components and controls, to condition the appropriate spaces



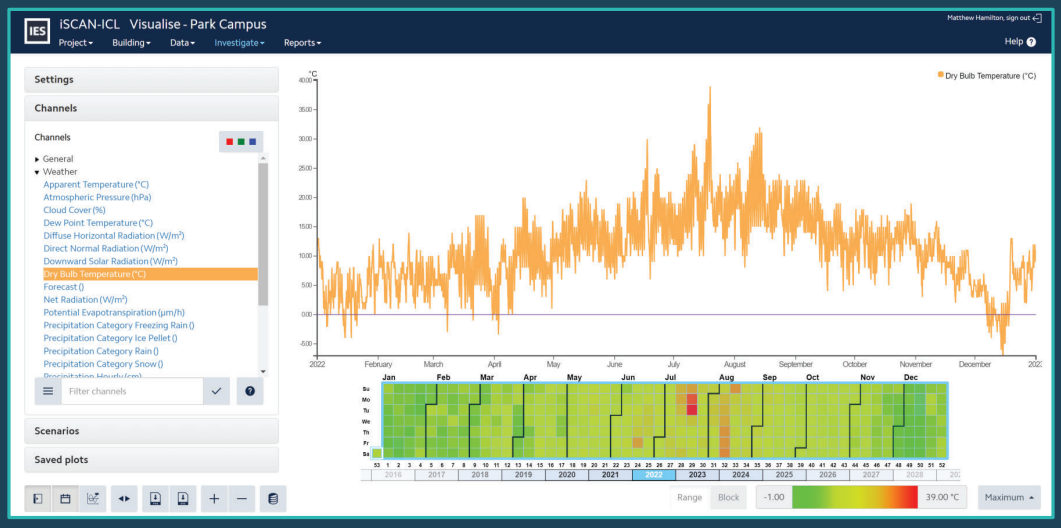
Model Set Up - Data Sources

- The diagram below details the various information sources that are typically used in the creation of a Digital Twin asset



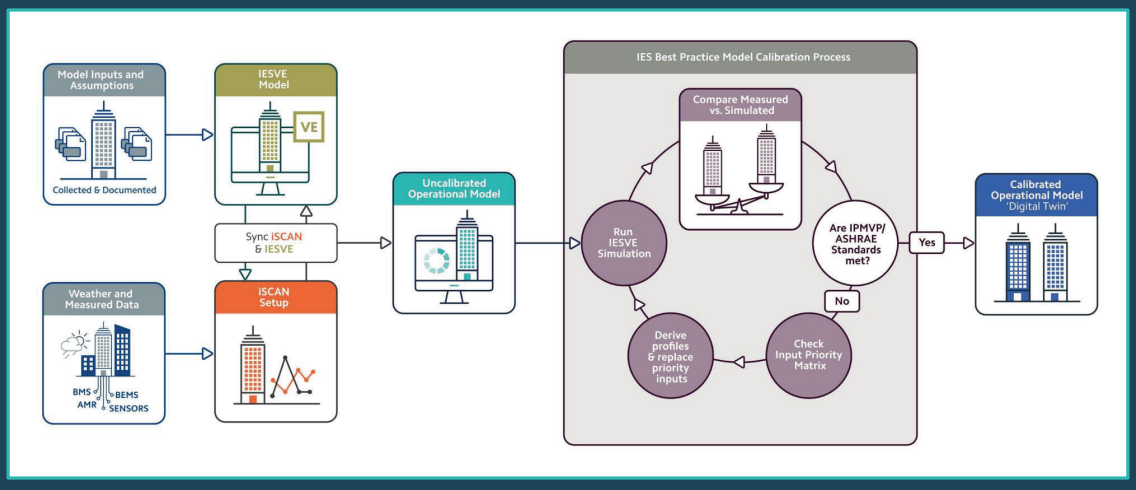
Model Set Up - Weather Data

- Weather data for the site was acquired from the iSCAN data analytics platform for 2022
- This way of obtaining the weather file for the simulation will ensure that the same outdoor parameters are present at each time step of the simulation



Calibration Process

- Once inputs are assigned the calibration process is undertaken, through which results of the physics-based dynamic simulation are compared to actual consumption data
- ASHRAE Guideline 14 has been used as a reference guide to evaluate the accuracy of this calibration on a monthly basis

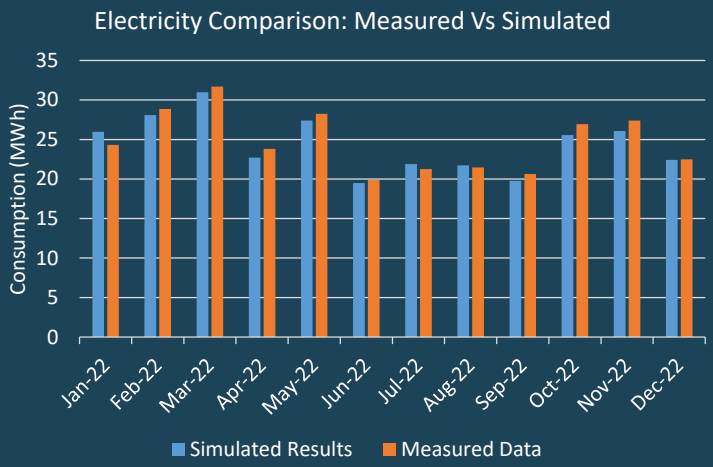


Calibration Metrics

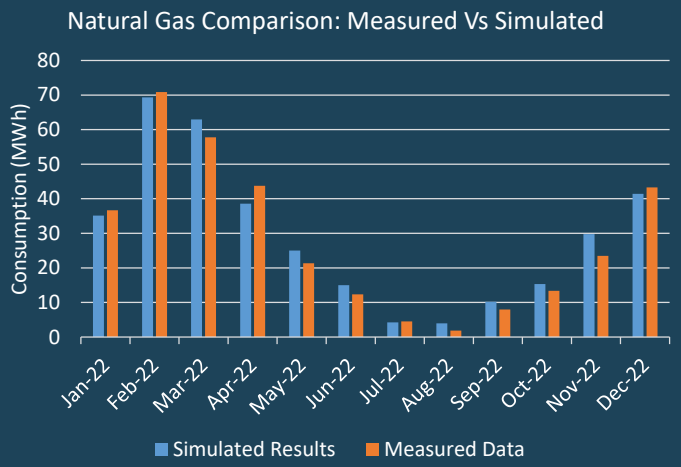
- Energy models are deemed to be calibrated if they meet the defined criteria specified by ASHRAE Guideline 14 for both the Coefficient of Variation of the Root Mean Square Error (CvRMSE) and Normalised Mean Bias Error (NMBE) – the two key metrics which are widely applied for evaluating calibrated models
- The table below details the thresholds for these in both Monthly and Hourly calibrations

Calibration Type	Index	Acceptable Value
Monthly	NMBE	±5%
	CvRMSE	15%
Hourly	NMBE	±10%
	CvRMSE	30%

Calibration Results – Monica Partridge Building



Calibration Metric	ASHRAE Limit	Model Value
NMBE	±5%	1.80%
CvRMSE	15%	4.19%

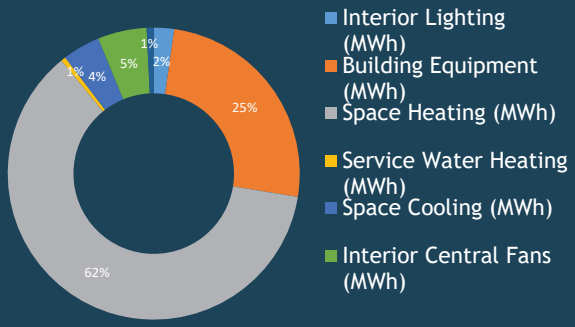


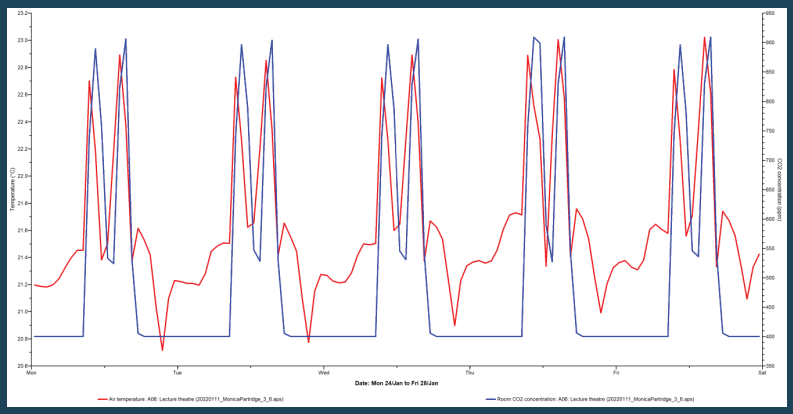
Calibration Metric	ASHRAE Limit	Model Value
NMBE	±5%	-4.39%
CvRMSE	15%	13.07%

Digital Twin Insights

- Once the model is calibrated it can provide various insights into the building behaviour
- Enables identification of operational optimisation strategies to significantly improve energy efficiency and lower carbon emissions without sacrificing IAQ
- Powerful tool for scenario modelling and decarbonisation road mapping
- Understand the impact of different retrofit measures & net-zero investments prior to implementation in the real building

Calibrated Model - Energy Breakdown





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Thank You

Any Questions?

rohan.rawte@iesve.com
+65-9242 2596

www.iesve.com