# Evaluating the impact of local wind microclimate on stacked emergency power generators in a hyperscale data centre

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**SUMMARY**
This work presents a high fidelity CFD study evaluating the external aerothermal environment of a data centre campus located in Santana de Parnaíba (Brazil), with a focus on the performance of vertically stacked emergency power generators. The analysis quantifies how wind-driven flows, terrain effects, and buoyancy from hot exhausts influence the intake temperatures of the generators across various operating scenarios. Simulations covering multiple wind directions, two wind speed conditions, and a no-wind case reveal that hot air recirculation and exhaust entrainment frequently drive intake temperatures close to or above the 50 °C operational limit of the generators for the initial campus design. The simulations identified North winds as the dominant critical condition, since the approaching flow interacted with the buoyant exhaust plume in a way that advected the hot discharge from the rear of the generators around the equipment and back into their intake openings, promoting sustained hot-air re-ingestion.

*Keywords: Data Centre, Computational Fluid Dynamics, Thermal Assessment, Power Generator, Wind Analysis*

## 1. INTRODUCTION

Modern large scale data centres increasingly rely on power generators for redundancy and uninterrupted power supply. These installations typically involve rows of vertically stacked equipment operating outdoors, where their performance becomes sensitive to external wind flow, terrain-induced effects, and thermal interactions between units (B. Rogié et al, 2020; EOLIOS Engineering, 2024).

The present study aims to assess whether the current campus geometry and equipment arrangement ensures safe generator operation for realistic meteorological conditions. The Power Generator Unit (PGU) considered in the current study has a maximum allowable intake temperature of 50 °C. Such threshold can be easily reached depending on weather conditions and local flow topology, especially if strong recirculation occurs. The main goal of the study is thus to:

- quantify wind-driven flow patterns around a multi-block campus with nearly installed generators in a vertical assembly,
- evaluate critical wind directions associated with hot-air backflow,
- assess the effectiveness of proposed design modifications.

## 2. METHODOLOGY

The study was conducted using the HELYX® CFD software (version 4.4.1) (Engys, 2026). A set of steady-state RANS simulations were carried out using a pressure-based block-coupled solver with energy solution and species transport. The k-ω Shear Stress Transport turbulence model was used in the analysis. The numerical model accounted for natural and forced convection heat transfer mechanisms, terrain-influenced atmospheric boundary layer, vegetation effects, and exhaust species and thermal operational conditions for the generator equipment. The methodology combines detailed geometry reconstruction from satellite data for the site and surrounding ambient, high-resolution meshing, and physically consistent boundary conditions.
All simulations were conducted in a High-Performance Computing (HPC) environment on 256 cores (4 nodes - AMD EPYC 9354 2x32 Core Processor with 384 GB RAM available per node).

### 2.1. Geometry Preparation

The campus buildings and generator models were provided by MarkData, the consultancy company responsible for the design of the site. The chiller units were modelled based on the supplier's chiller equipment datasheet. Terrain and surrounding structures were reconstructed from satellite data using the Global Building Atlas with model LoD1 (X. X. Zhu, 2025) and a 3D CAD model created, as shown in Figure 1.

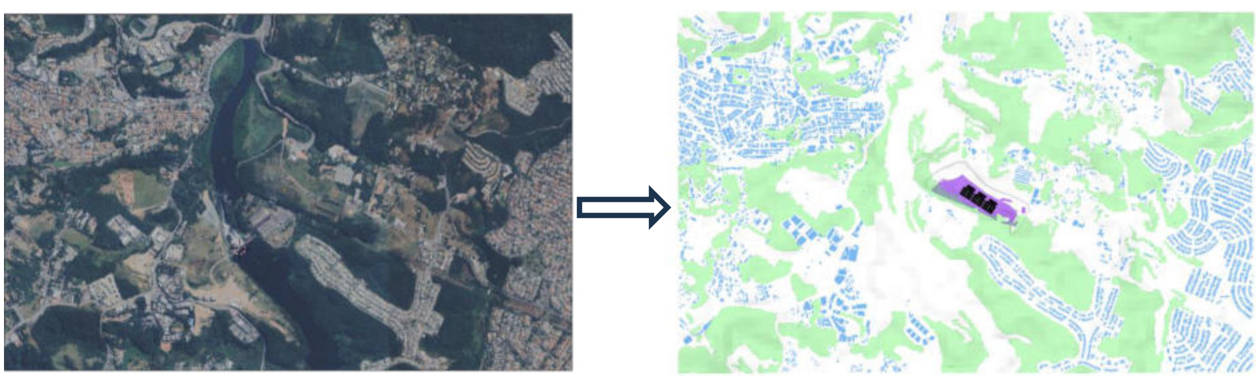

**Figure 1.** Satellite view and resulting 3D CAD model.

### 2.2. Computational Domain

A 2000 m x 2000 m domain was used to fully accommodate all the flow characteristics surrounding the data centre campus location. At the far-field, a base mesh spacing of 40 m was adopted, with local surface and volumetric refinements used in the developed area to capture geometry and flow features around the data centre buildings as well as generators and chillers. The smallest cell size was 40 mm. To better capture the flow gradients near the wall, 4 prism layers were used on ground, buildings, chillers and generator surfaces. The vegetation, highlighted in green in Figure 1, are modelled as Dalpé & Masson (B. Dalpé and C. Masson, 2008) canopy for momentum and turbulence sources.
The resulting mesh, shown in Figure 2, consists of approximately 190 million cells. Average time to mesh each case was 1.56 hours.

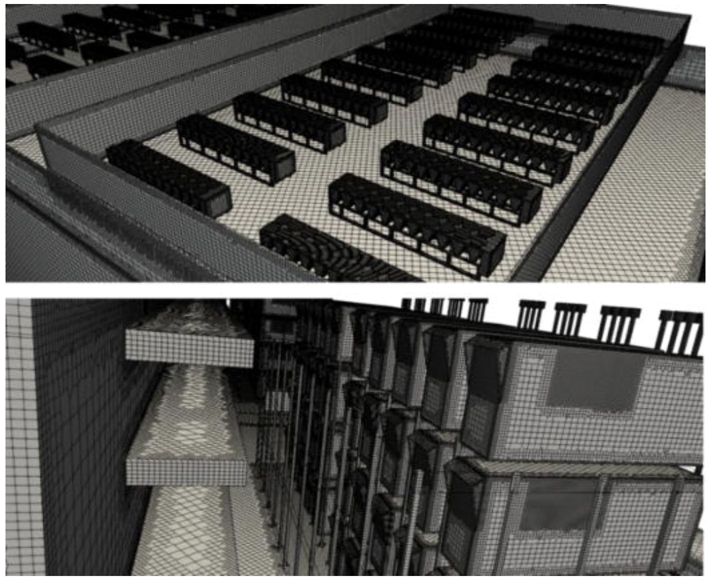

**Figure 2.** Computational mesh. Chillers (top) and Generators (bottom).

## 2.3.Generators and Chillers Modelling

Each of the 120 generators, see Figure 3, accounts for detailed airflow, heat rejection, and exhaust specifications. The procedure proposed by B. J. McBride et al (B. J. MacBride et al, 2002) was used to compute the thermodynamic properties of the multi-species exhaust gas. The generator building floors were modelled as porous media to mimic flow resistance. For the chillers, a prescribed temperature drop between the inlet and outlet was applied to represent the removed thermal load at the operating flow rate.

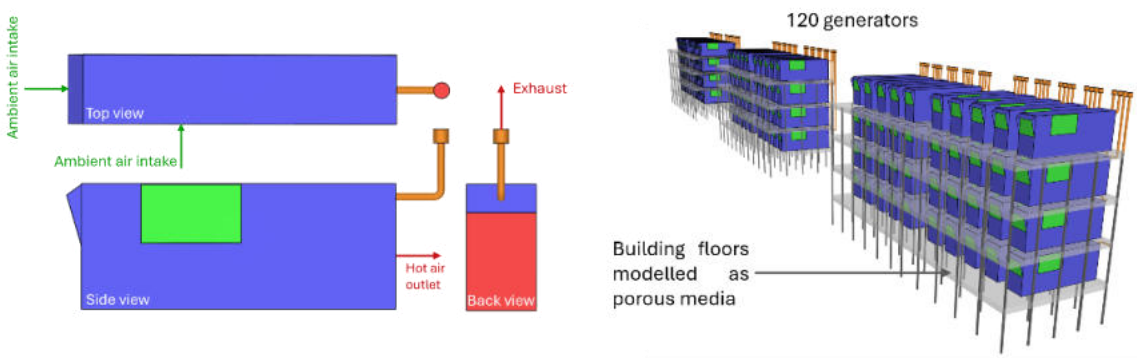


**Figure 3.** 3-D visualization of the generators (left) and installed equipment (right).

## 2.4.Meteorological Boundary Conditions

Wind and temperature statistics were obtained from Global Wind Atlas (Global Wind Atlas, 2025) and INMET (INMET, 2025). Atmospheric data were taken over 10 years period, and a wind rose was calculated, see Figure 4. The atmospheric boundary layer wind profile by Richard & Hoxey was set at the inlet of the domain and magnitudes of 4.5 m/s and 10.0 m/s at reference height of 10 m analysed. A total of 6 wind directions were considered for the analysis, as well as an additional scenario without wind.

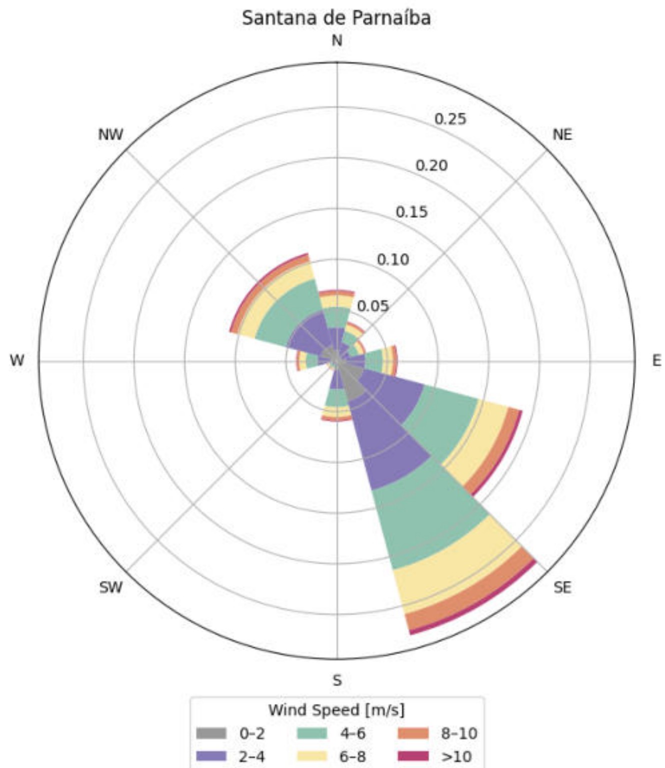


**Figure 4.** Wind Rose generated for the Data Centre area.

Wind directions were chosen following qualitative engineering input from MarkData and Tecto, focusing on scenarios likely to produce critical recirculation and elevated generator intake temperatures, and guided by the prevailing wind directions from the wind rose.

Similarly, wind speed magnitudes were selected according to local historical records, with 10 m/s taken as the upper bound since higher velocities are associated with brief gust events, during which the generators would experience only short exposure.

In the context of this paper, only results for the worst-case scenario with wind coming from North at 10 m/s are shown. The ambient temperature for the worst-case scenario was set to 38.7 °C, based on the maximum temperature for the last 10 years according to ASHRAE meteorological database (ASHRAE, 2026).

## 3. RESULTS

Across all equipment buildings, most of the generators exhibited intake temperatures ≥49 °C, with North and North-west winds producing the worst performance. The air temperature of the equipment surrounding area is shown in Figure 5 for all 4 floors of the building for wind coming from the North.

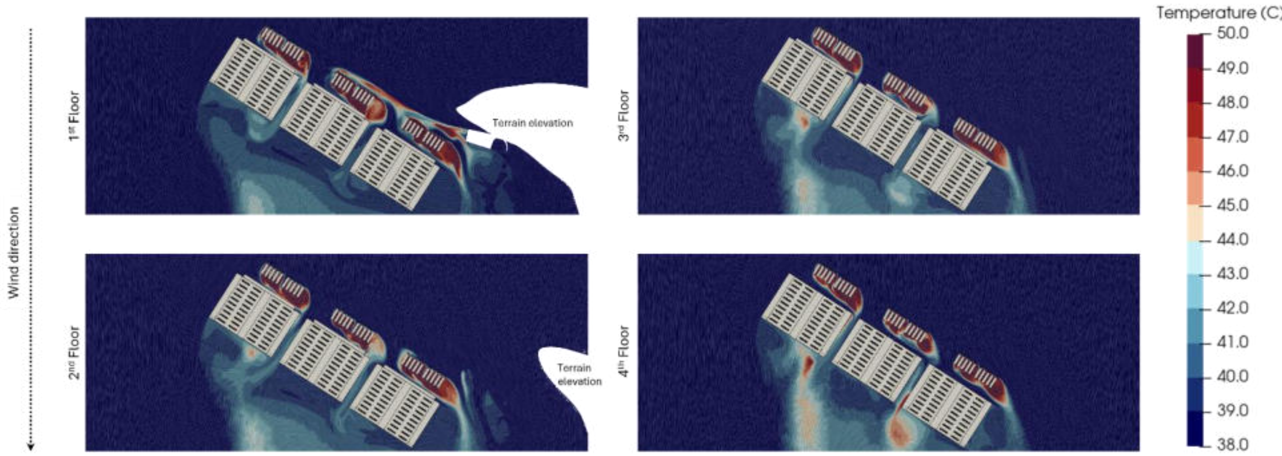


**Figure 5.** Temperature field and LIC in the surrounding area of the subject equipment.

To quantify the intake temperature of each unit, monitors were placed at the equipment inlets, and the average temperature was computed and reported for every generator. The resulting heat map is shown in Figure 6.

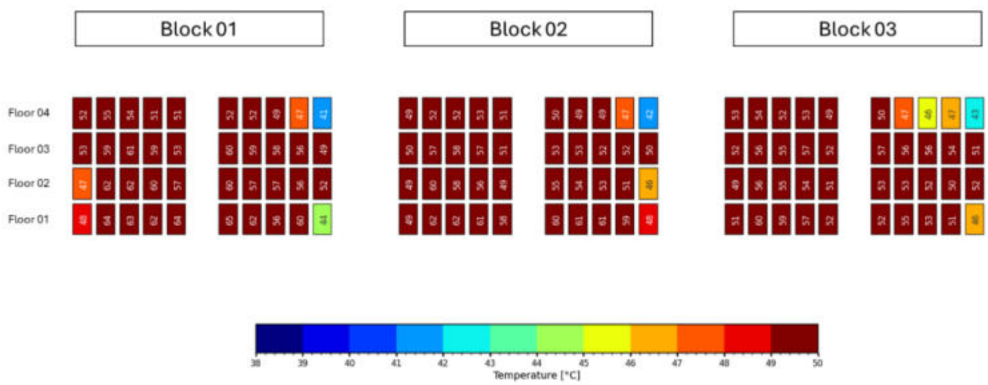


**Figure 6.** Equipment-wise average air intake temperature heatmap.

## 4. PRELIMINARY REMARKS

The baseline configuration results in recurrent thermal limit exceedances for all wind directions. The simulations identified North winds as the dominant critical condition, since the approaching flow interacted with the buoyant exhaust plume in a way that advected the hot discharge from the rear of the generators around the equipment and back into their intake openings, promoting sustained hot-air re-ingestion.

## 5. DESIGN CHANGES ASSESSMENT

Following on the initial assessment of the baseline design, two design changes are considered to evaluate the impact on the intake temperatures of the generators: i.) ducting lateral inlets of the generators to direct the flow to the front side only, and ii.) installing metallic back plates on the back of the generators to prevent the hot at the discharge from the back to be re-directed to the front side of the equipment. The analyses of the proposed mitigation changes are ongoing, and results will be presented in due course.

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