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Ktirio Urban Building From Building to City-Scale Energy on EuroHPC Systems using Open Data

HiDALGO2 Clustering Event (HLRS)

Pilot-ready research platform —
Map → Mesh → Simulate → City KPIs (energy • comfort • IAQ),
reproducibly on EuroHPC.

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EuroHPC Joint Undertaking

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Introduction: City Scale Energy Simulation

Context

EU buildings impact: 36% of greenhouse gas, 40% of final energy consumption.

Goal

Horizon 2050 target: double annual renovation rates over the next 10 years [2] (≈ 700,000/yr in France).

Method

Shift from **Building Energy Models (BEM)** to **City Energy Models (CEM)**, to assess performance at city scale.

City (policy & planning)

A **rolling EPC-like stock picture**, regularly updated for progress tracking and prioritisation.

Scenario screening for energy demand, peak loads, heat-stress, and IAQ under present & future climate.

Comparable KPIs across districts with transparent assumptions and auditability.

District / tile (microclimate & equity)

Microclimate-aware metrics (radiation, wind, shading, evapotranspiration) to reflect local conditions.

Fair inter-building ranking via microclimate normalisation and clear vulnerability criteria.

Hotspot detection to target refined simulations and interventions (passive & active).

Building (operations & health)

Fast dynamic assessment for shortlisted hotspots (comfort, overheating hours, IAQ trade-offs).

Real vs conventional gap tracking using available measurements (measurement & verification ready).

Ventilation strategies robust to local microclimate and pollution episodes.

Introduction : Ktirio urban building

What is Ktirio ?

A **simulation tool** that analyzes a building or a collection of building as integrated within their environment.

Built on **open-source data**

Designed to **make complex simulations simple**, enabling city simulation in just a few clicks.

Leveraging the power of **high-performance computing** to run ensemble simulations, which helps address problems caused by a lack of data.

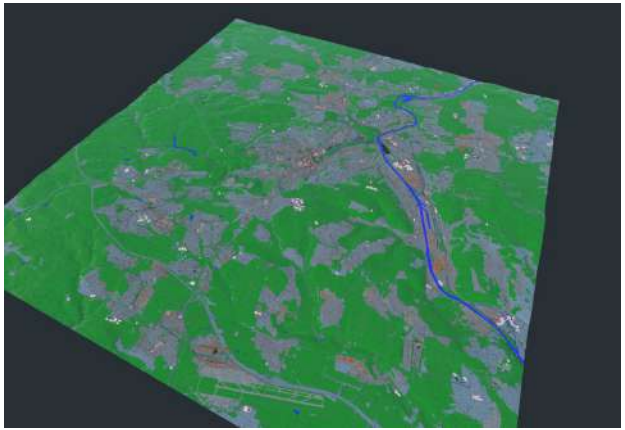
Objectives

To **predict energy consumption, thermal comfort, and indoor air quality**

To provide these predictions at both the individual **building scale** and the much larger **urban scale** (and beyond)

Model relevant building environment to modeling and simulation for energy and air quality

Support large scale computing and **automated workflows**



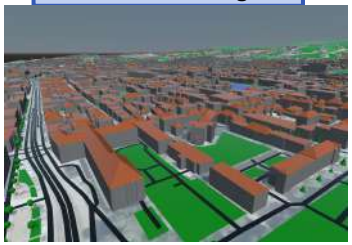
Ktirio Workflow

Multiscale approach to city simulation

From Building

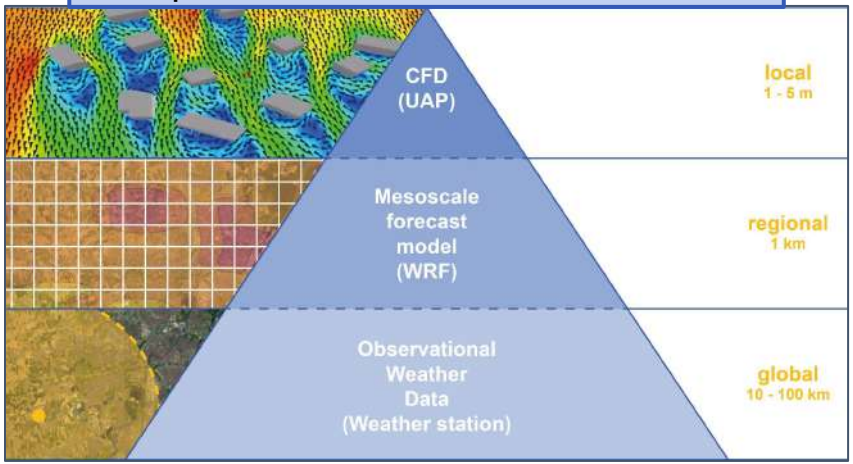
- **From building to city simulation**
  - Quick simulation with **automatic** definition of buildings properties at a large scale using **open data**, to precise simulation with data fed from user in order to zoom on specific hotspot.
- **Two way coupling with microscale model**
  - 1–5 m grid
  - Bidirectional exchange of boundary data at the building façade/roof scale.
- **One way coupling with mesoScale model**
  - 1 km resolution
  - enriches building simulations with regional weather.
- **Point-Based Meteorological Data (e.g., stations, OpenMétéo)**
  - Low spatial resolution

From Building



To City

From sparse sensor data to meso and micro urban climate



Why simulate if we “already know” what to do?

Why simulation on top of field know-how?

- **Scale**:

  from a block to the whole city stock, systematically, same KPIs.
- **Counterfactuals**:

  A/B/C options with comparable assumptions, visible trade-offs.
- **Fair prioritization**:

  budget to highest impact (€/kWh or €/°C·h or IAQ thresholds), not just where issues are loudest.
- **Future-proofing**:

  test heat waves & IAQ scenarios; decide with ranges, not a single number.

Simulation doesn’t replace site expertise — it **targets and sequences** it.

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Ktirio Urban Building
Where we are today

Where we are today

End-to-end flow: area → open-data ingest → **watertight, partitioned mesh** → dynamic **energy + comfort + IAQ (baseline)**.

Scale & ops: up to 300K buildings; **EuroHPC deployment**; containerized runs with **regression tests**.

Evidence: BESTEST-600 alignment; first sensor-based checks on buildings.

Data setup (Open Data)

Location · Weather/AQ · Occupancy/Use

Location & area of interest

Search for **address** or **coordinates** (lat/long); **multiple points** of interest**.**

Define the area: **circle** (center/radius) or **polygon**; include/exclude buildings.

Context: **OSM/cadastre, topography** (DTM), **LOD0/LOD1**; optional imagery.

Weather & Air Quality (AQ)

Open sources (weather API, external AQ); define **time window** (start→end) with **hourly** resolution.

Key variables: T_2m, RH, wind, precipitation, **irradiance**; AQ: **$PM_{2.5}$, NO_2, O_3/AQI**.

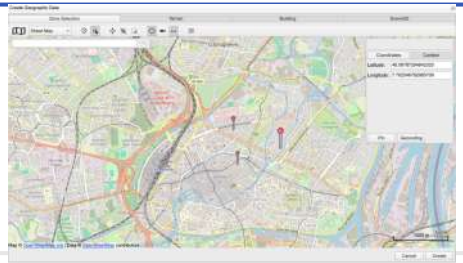
Microclimate normalisation (radiation, wind, shading, evapotranspiration) for **fair ranking** and **IAQ boundary conditions**.

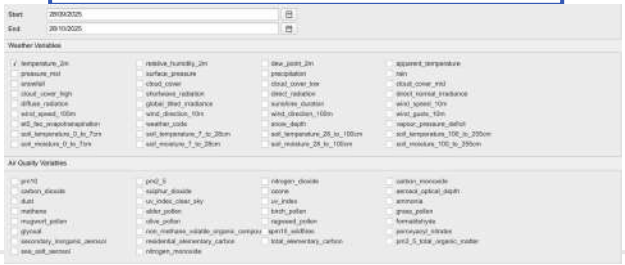
Occupancy / use scenarios

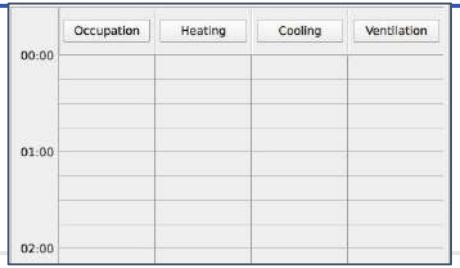
Schedules by typology (hour/day/week; holidays/weekends).

Setpoints and flows: heating/cooling; **ventilation** (ACH); **infiltration/exfiltration**.

Internal gains: appliances + occupants; **per-building exceptions**.



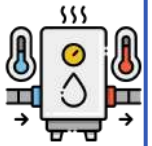




Advanced calculations for greater model precision

Energy model

Dynamic energy simulation.
Automatic power sizing of heating systems.
Comfort indicators (PET, PMV).
BVH calculation for solar mask.
Scenarii with setpoint temperature and heating/cooling season

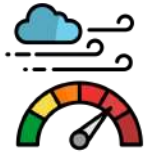


HPC

Benchmark
Distribute terrain, buildings, and vegetation entities efficiently for High-Performance Computing (HPC) applications.

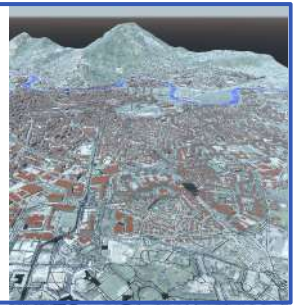
Air pollution model

Multizone air pollution model for indoor air quality.
Track a wide range of pollutant concentration.
Account for deposit, oxidation and filtration.



Mesh

Watertight and refined meshes.
Roads, vegetation, park, body of water.
Different level of detail simple bounding box to multiple polygon extrusion with roof.



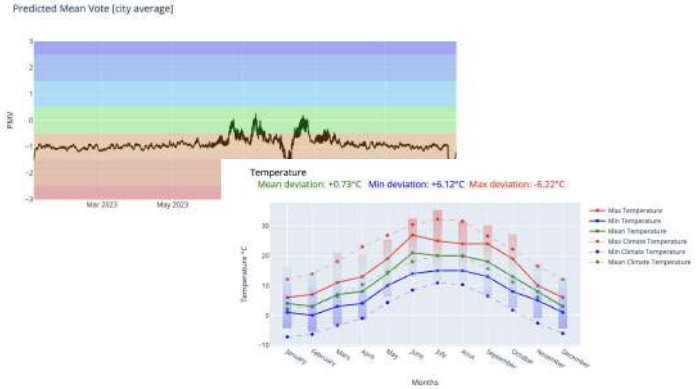
Visualization tools : Simulation reports

City scale comfort indicators

- Time-series and scatter plots, using PMV and PPD metrics at the district level.

Weather analysis

- Temperature trends
- Wind roses
- Solar radiation profiles
- Cloud cover statistics

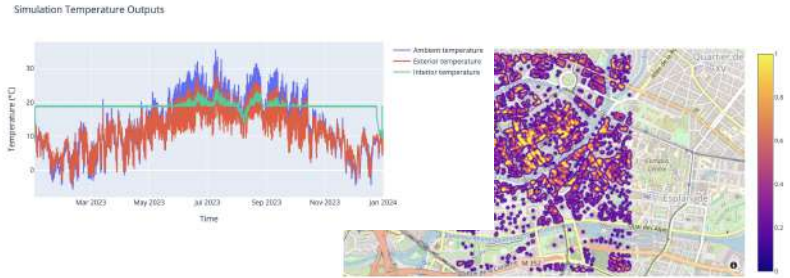


City scale energy consumption

- Plots of ambient vs. interior/exterior temperatures
- Solar shading occlusion factors
- Heat fluxes for heating and cooling
- Total energy demand

Building statistics

- Number of buildings
- Spatial density
- Typology breakdowns
- Distributions of heights and floor areas



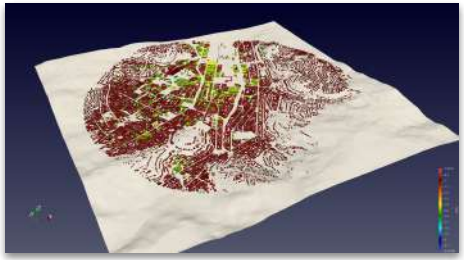
Visualization tools : Spatial visualization

Paraview

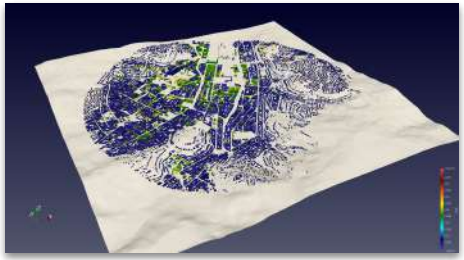
visualisation of output on 3D model
- Comfort indicator,
- heatflow for heating or cooling,
- indoor temperature
- …

Ktirio Gui

- Visualize mesh: LoD0 LoD1 and LoD2
- Navigation modes
- Very fast visualisation with mockup environment (sun, landuse…)

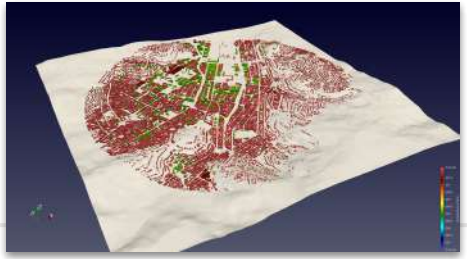


PMV indicator

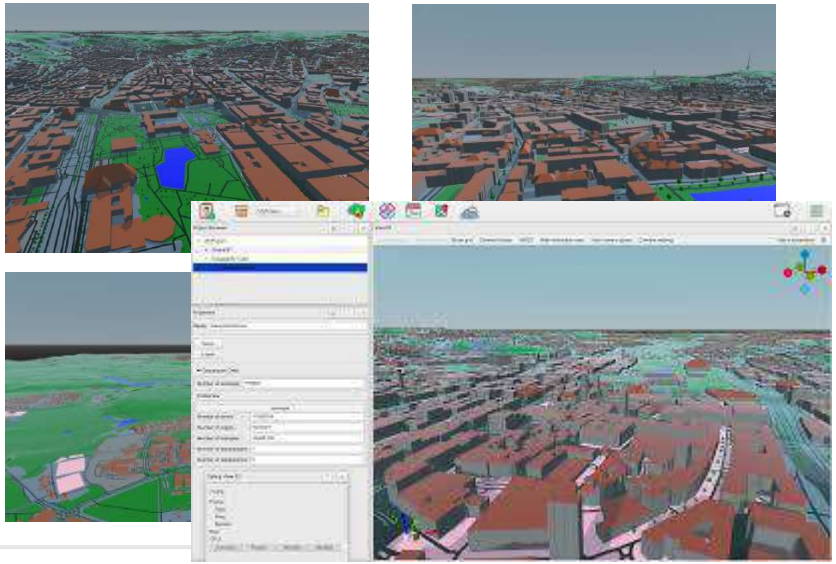


PPD indicator

Heating flow



Interior temperature



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Ktirio Urban Building Outlook and Next Steps

Timeline

Now (M36): city-scale runs; energy & comfort KPIs; GUI workflow; EuroHPC pipeline; initial validation.

Next 1–3 months: IAQ scenarios (ventilation/infiltration, IAQ KPIs); first **ensemble** batches (scenarios × weather years × interventions); **SSO + signed images + scheduled regressions**.

Next 3–6 months: UQ dashboards (ranges, not points); **LOD2 exemplars**; **pilot scorecards** for partners.

Deployment and Workflows

Identity & Federation

SSO (Keycloak): GUI login via federated identities; predefined accounts removed; aligned with site **AAI**.

User-scoped workflows: users bring repos/credentials; jobs run under **user EuroHPC allocations** (no UNISTRA accounts in production).

IAM hardening: staged onboarding, org isolation, least-privilege **OIDC** tokens.

Indicators: SSO adoption; share of user-scoped runs.

Secure Software Supply Chain

Scanning + SBOM + attestations: all releases; **signed images** required for promotion to stable.

Secrets management: OIDC-issued short-lived tokens, rotation, least-privilege scopes.

Release gates & compliance: stable channel requires checks + integration tests on a reference cluster; playbooks refreshed.

Indicators: SBOM/attestation coverage; signature compliance rate.

Reproducibility, Packaging & Benchmarking

Regression & runners: scheduled regression tests across representative scenarios/datasets/architectures; **EuroHPC runners** for early validation.

Packaging & portability: improved **Apptainer/WASM**; pinned toolchains; matrix builds; per-site variants as needed.

Provenance & reporting: automated provenance; cost/performance dashboards;

Indicators: regression pass-rate; CI rebuild reproducibility;time-to-ensemble...

From pilots to platform
safe access, trusted builds, evidence by default.

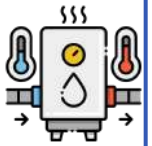
Further improvement on model precision

Energy model

Radiative environment: **SW direct/diffuse + reflections**, **LW 2-flux**; material presets injected as BCs.

Urban effects: morphology-derived **z_0/wind**, **evapotranspiration** for vegetation, simple **runoff/impervious** impacts.

Coupling: **WRF→UBM** forcing and façade/roof **two-way exchange** with UAP/CFD



HPC/Ensemble/UQ

Ensemble engine for **scenarios × weather years × interventions**

UQ: priors/metrics, sensitivity; HPDA post-processing; reproducible benchmarking.

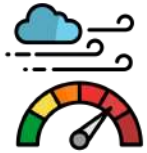
Outputs: delta maps vs baseline, **cost/performance dashboards**, notebooks and datasets.

Indoor Air Quality model

Occupant-behaviour scenarios and emission sources with **per-building exceptions**.

Ventilation/infiltration/exfiltration and **ACH** control; outdoor→indoor AQ boundary conditions.

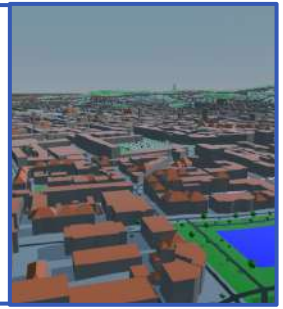
IAQ proxies (**CO_2/PM**) reported alongside comfort/overheating metrics.



Mesh

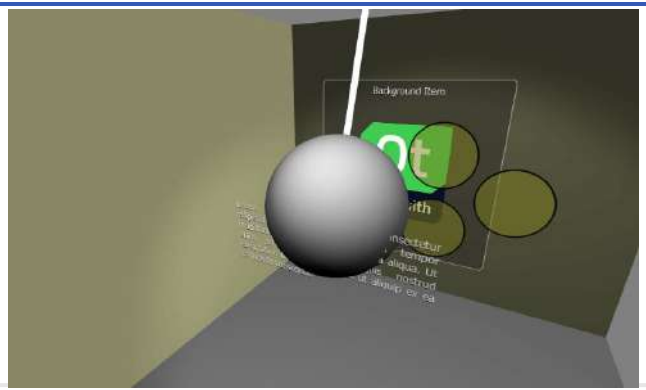
Improved City-scale geometry pipeline. Multi-LoD buildings; improved geometric modeling

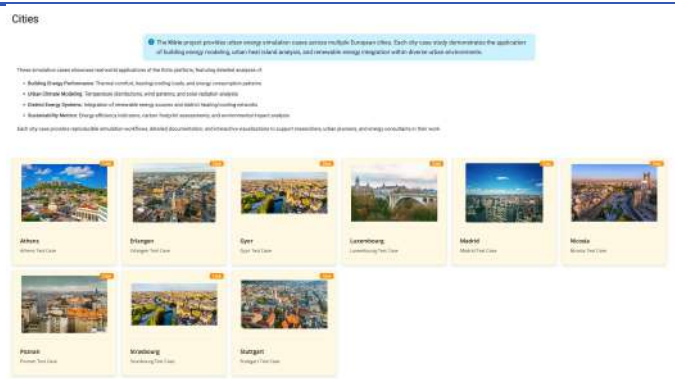
Automated **tiling/merge & HPC partitioning**; reproducible mesh artifacts with provenance.



Visualisation

Ktirio Gui	Ktirio cases
Visualisation through the GUI including ● GIS information ● Energy and IAQ metrics ● 2D Statistics plots/time series with UQ ● Automated initial reports ● City and building dashboards ● EPC proxy maps city/country ● Include uncertainty mappings (hotspots) ● Multiscale visualisation from city to district to buildings	Online Dashboard for buildings, district and cities generated by Ktirio GUI and deployed from Ktirio GUI





Valorisation

Strategic goal: Moves Ktirio from a research tool to the operational City Energy Model (CEM) that enables actors to plan and execute the EU's large-scale renovation goals (Renovation Wave, Horizon 2050) renovation strategies.

- **A hybrid open-core model** A multi-scale (building-to-city, EPC to microclimate) model, leveraging an open-source foundation, to provide actionable energy data to city actors, enabling them to plan and execute large-scale renovation strategies.
- **Validation and deployment**

Real world proof of impact

Use of large-scale demonstrator projects as testbeds for co-development, validating the accuracy and utility of the model in real-world scenarios for city-wide renovation strategies.

Public partners

Targets cities and agencies, using large-scale validation projects as models for adoption.

Industrial partners

Engages with energy, construction, and planning sectors by providing a tool to optimize and de-risk district-level projects.

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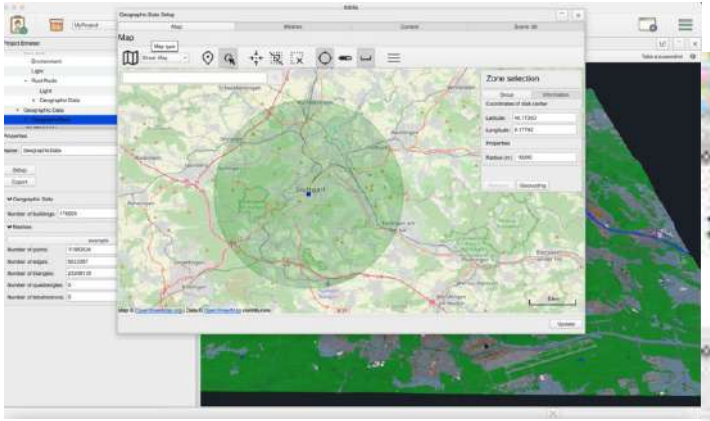
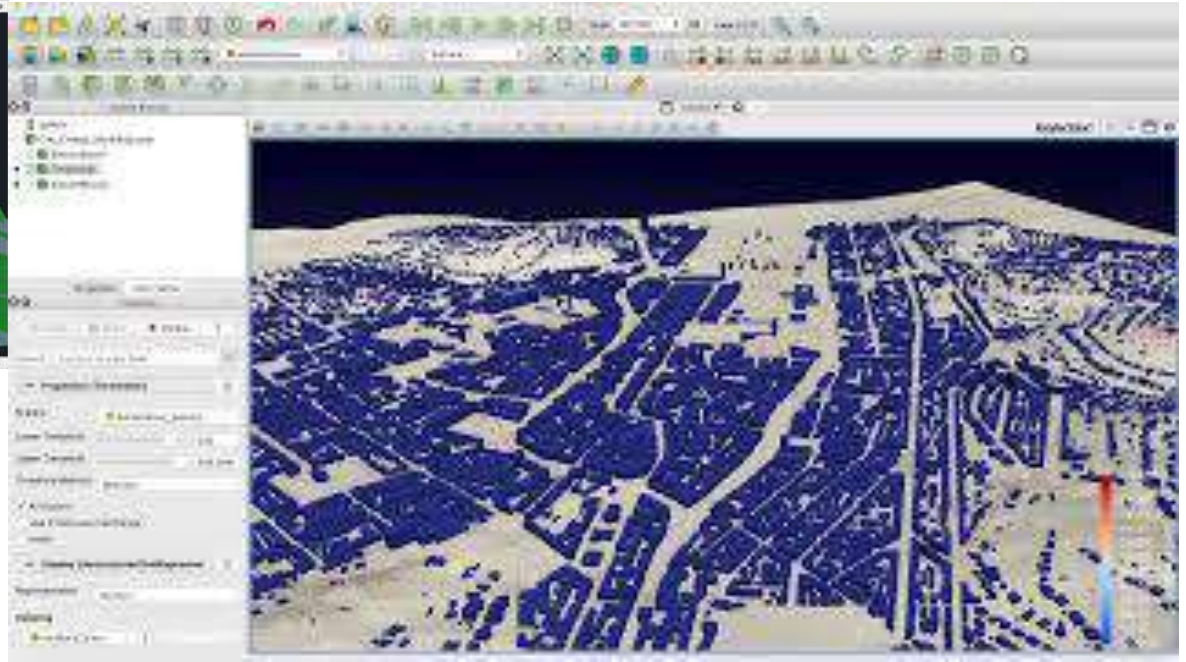
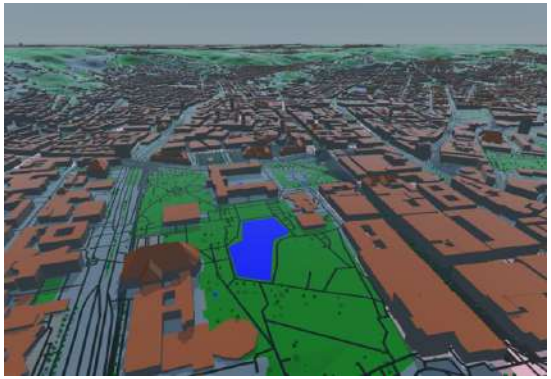
Video

Map → Mesh → Simulate → City KPIs

End to End Video of the Pipeline for Stuttgart 2Km radius







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Thank You

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