# BIM and 3D City Models as input for Microclimate Simulation

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# The Microclimate

- What is the microclimate?
  - Small area where climate circumstances deviate from the surrounding climate (i.a. temperature, humidity, wind)
- How is the (urban) microclimate influenced?
  - Geometry, materials, pavements, vegetation, etc.
- Why is the microclimate important to consider?
  - Avoid analyses with wrong information

Image by PIRO4D from Pixabay

# Microclimate simulation

- Uses:
  - Realistic input data for (energy demand) calculations
  - Urban comfort
  - Other analyses
- Microclimate simulation with ENVI-met
  - Complete & adaptive
  - Suitable for research

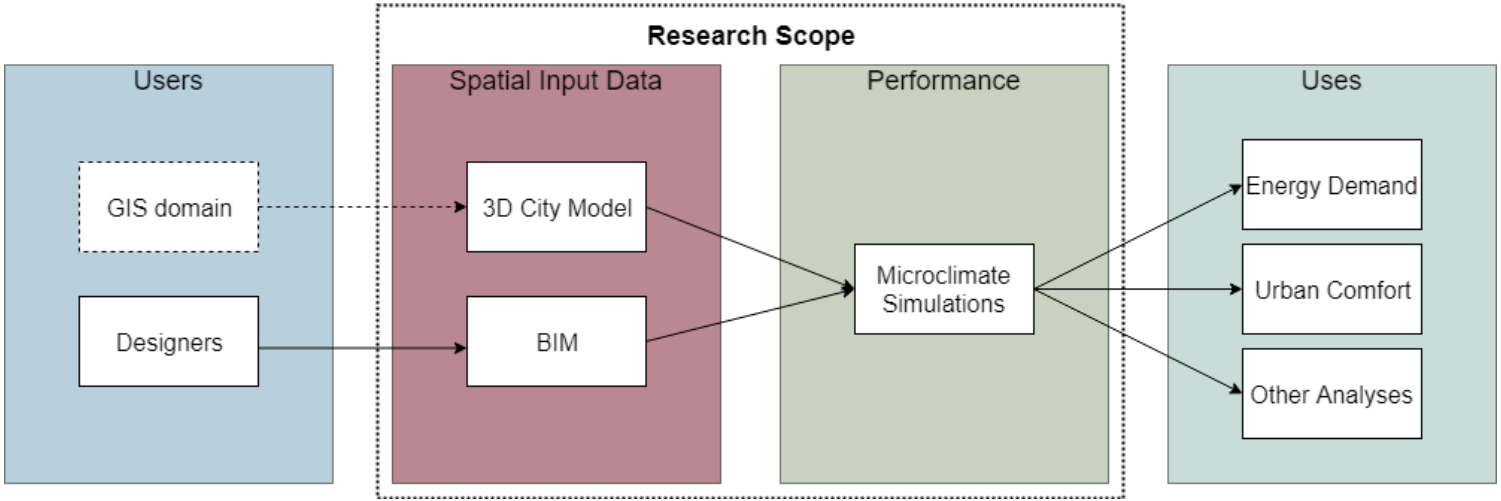
Image from envi-met.com

# 3D models

- 3D City Models
  - CityGML
  - City level
  - Simple correct shapes
- BIM
  - IFC
  - Building level
  - Detailed

Images from delft 3dfier and subzero pavilion

# Research framework



# Research questions

- How can **IFC** and **CityGML** models be used as **input** for microclimate simulation software **ENVI-met**?
  - What **data** is **needed** for microclimate simulation? **Where** can this information be **found** in **IFC** and **CityGML schemas** and data from **practice**?
  - What **characteristics** should the **data** have, in order to allow their suitable use in the process?
  - How to **convert** and **combine IFC** and **CityGML** information effectively into the **ENVI-met** format?

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# Outline

- Theoretical **background** and related work
- **Methodology**
- Data **requirements** for microclimate simulation in ENVI-met
- **Characteristics** of the data
- **Conversion** of IFC and CityGML model data to microclimate simulation software ENVI-met
- **Testing**: resulting products and case study
- **Conclusions**

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# ENVI-met

- Surface-plant-air interactions
- Orthogonal 3d grid (voxels)
- Area input file, simulation file, database

Image from envi-met.com

# CityGML

- GIS domain
- City level
- Classes
  - I.a. Buildings, Relief, Transportation, Vegetation and WaterBodies
- Level of Detail (LOD)
  - LOD2: volumes with extensions and different shaped roofs (e.g. sloped)

Image from delft 3dfier

# IFC

- Building domain
- Building level
- Highly detailed
- Each building element defined as separate entity
  - Supports complex geometry
  - Related information to element
- Multiple interpretations and user error

Image from subzero pavilion

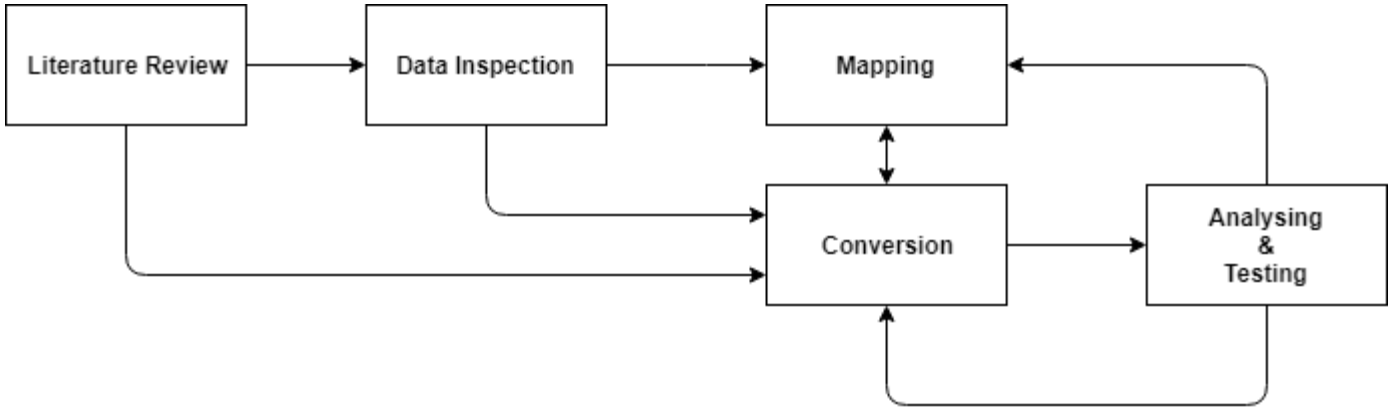
# GeoBIM

- Integrating BIM and GIS
  - Enriching GIS data with detailed BIM data
  - Providing context for BIM data with larger scale GIS data
- Similar challenges and problems:
  - Entity selection, typological errors, working with location data

# Importing existing models in ENVI-met

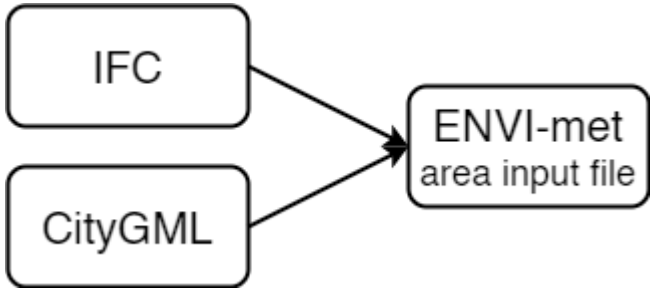
- Importing vector based models (like shapefiles) and worldwide databases (like open street map) into MONDE
- Coupling CityGML with ENVI-met
- 3D models mostly done by hand

# Overview of the methodology

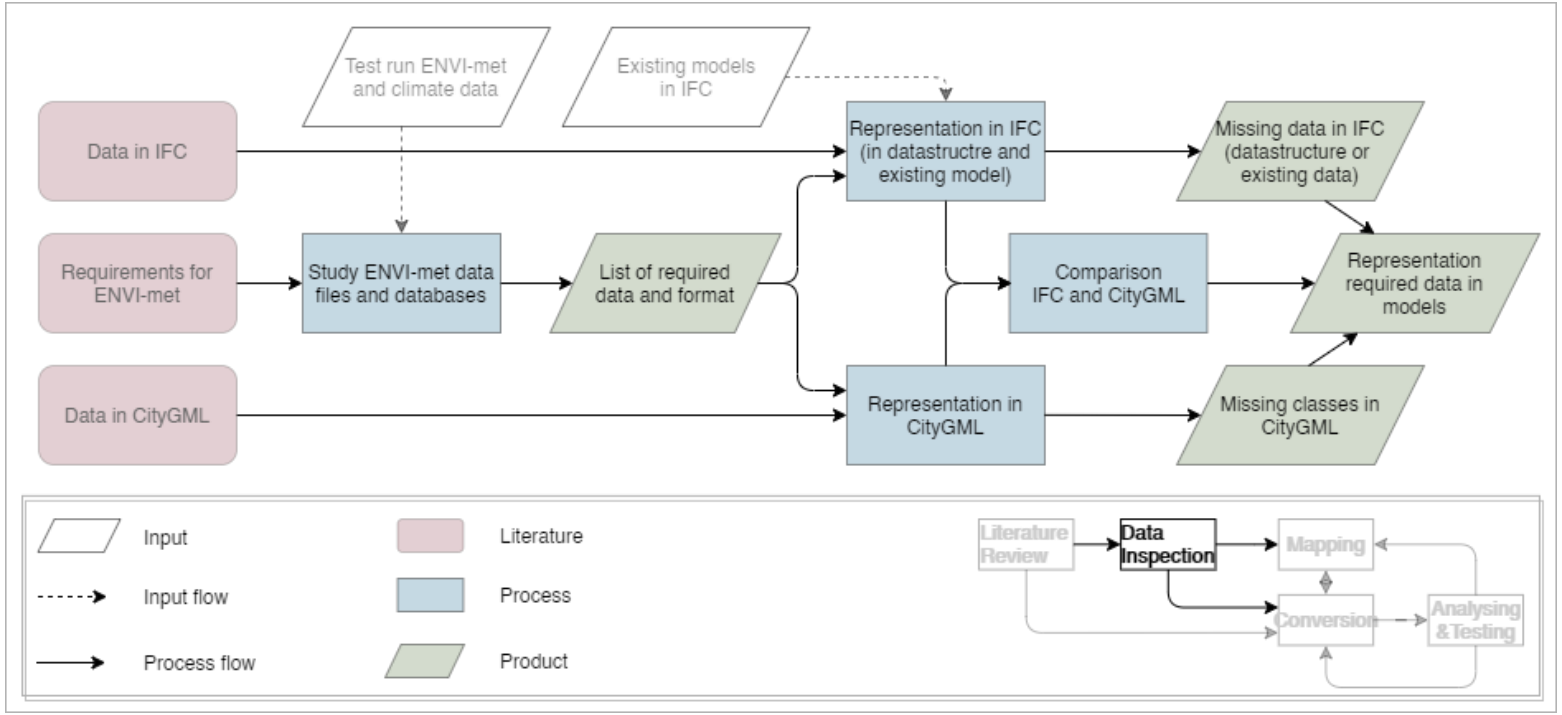


# Conversion approach

- Extract
- Convert
- Combine
- Format



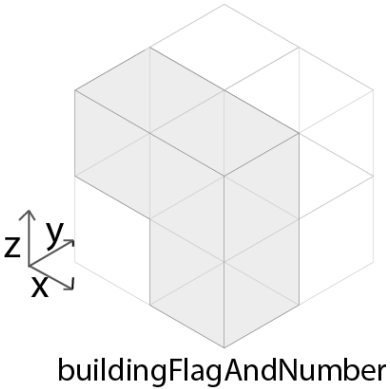
# Data inspection



- Input
  - Area input file (.inx)
  - Simulation file (.simx)
  - Database (.edb)
- Area input file elements:
  - Model geometry, location data, nesting, buildings (2d & 3d), building, single and green walls and roofs, simple and 3d plants, soils, pollution, elevation (2d & 3d)

# Building 3D Example

- Voxel based 3d matrix
- Attribute:
  - Building voxels
  - <buildingFlagAndNumber>
  - List of voxels that contain building
  - Each voxel (I,J,Z,f,nr):
    - Grid location
    - Building flag
    - Building number



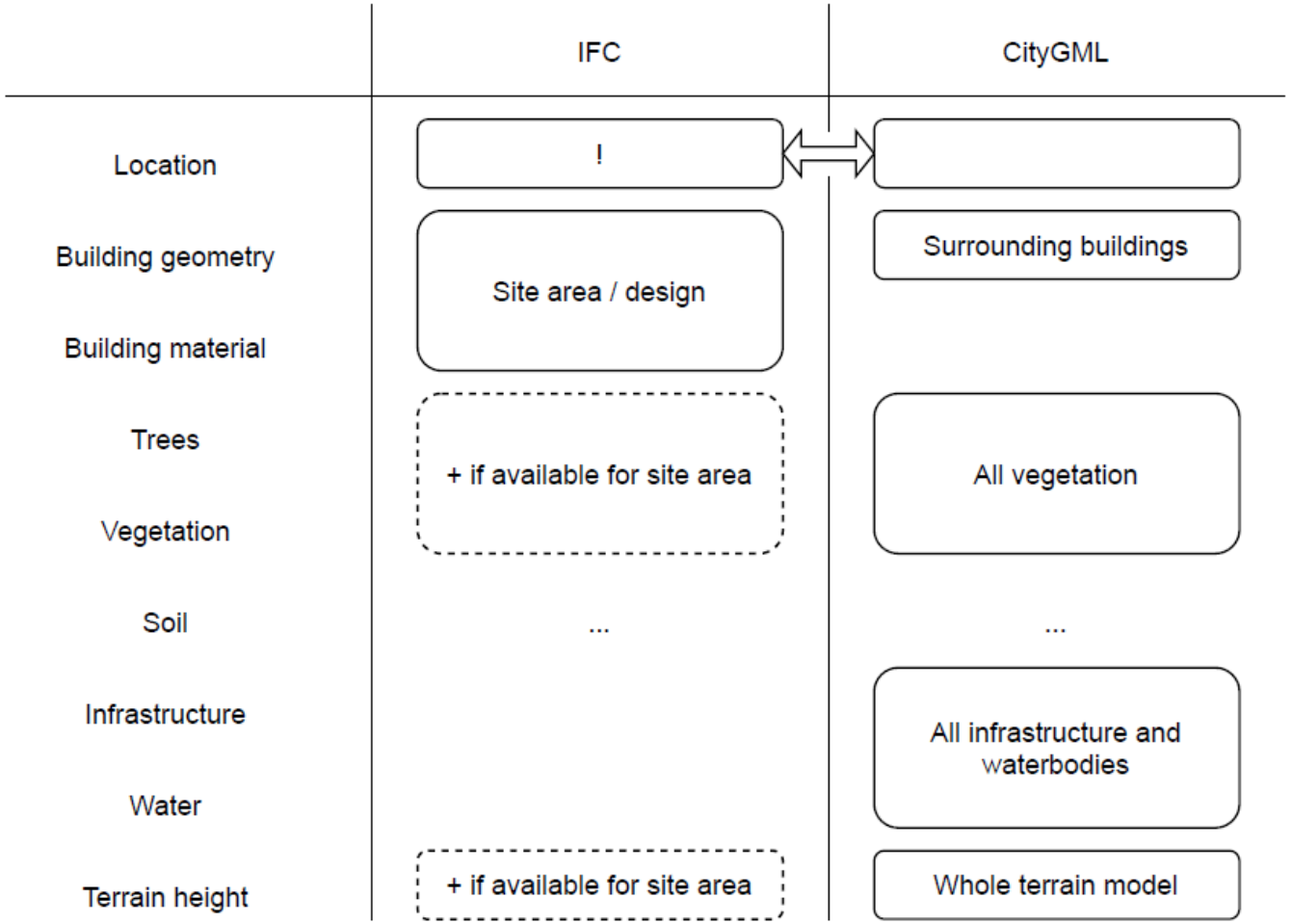

buildingFlagAndNumber

(0,0,1,1,1)
(1,0,0,1,1)
(1,0,1,1,1)

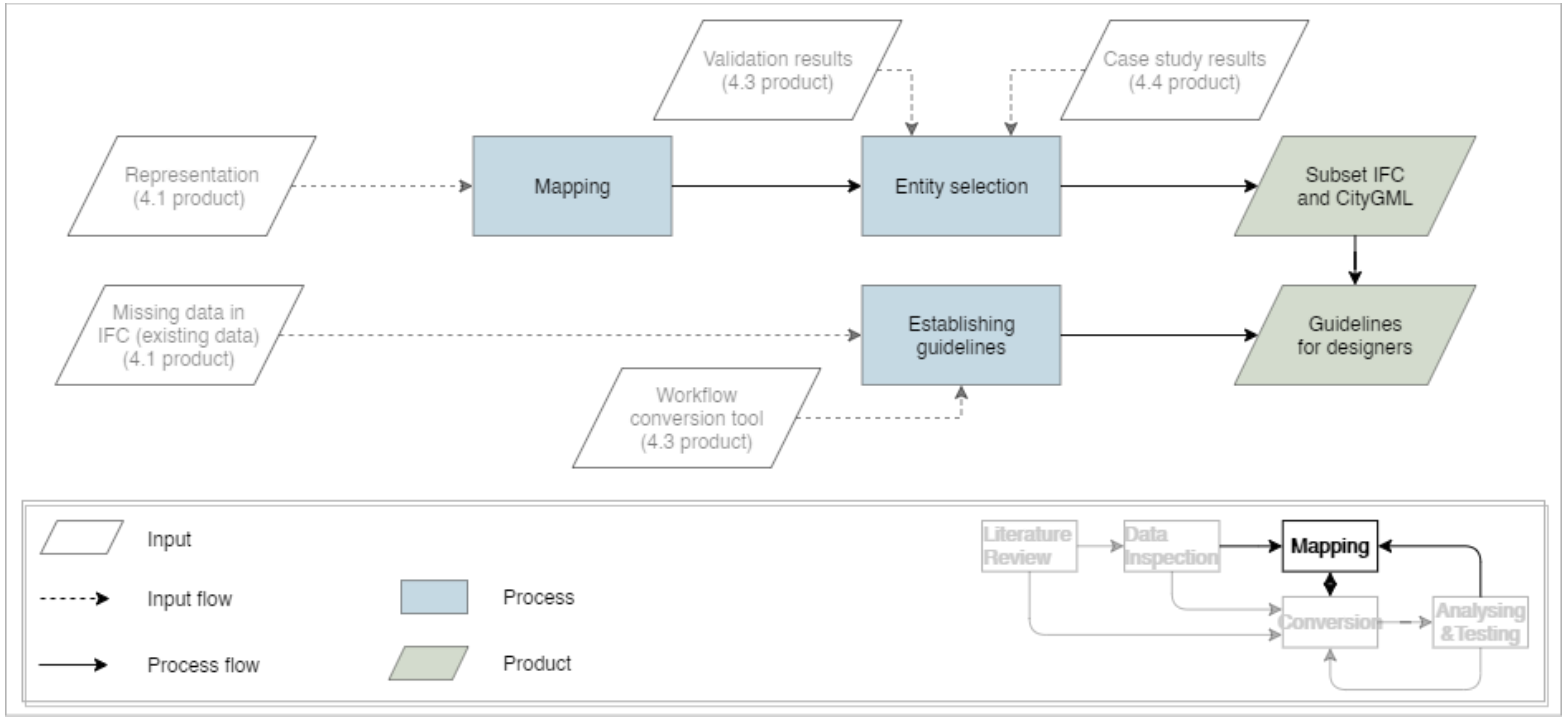
| Required elements | | Representation in IFC schema | Representation in existing IFC data | Representation in CityGML schema | Representation in existing CityGML data |
|---|---|---|---|---|---|
| Location data | | ✓ | ~ | ✓ | ✓ |
| Building 2D/3D | | ✓ | ✓ | ✓ | ✓ |
| Wall/single wall | | ✓ | ✓ | ~ | ~ |
| Greening | | ~ | ~ | X | X |
| 3D Plants | | ✓~ | ~ | ✓ | ~ |
| Simple plants | | ✓~ | ~ | ✓ | ~ |
| Soils | Soils | ✓~ | ~ | ~ | X |
| | Infra | ✓~ | ~ | ✓ | ~ |
| | Water | ~ | X | ✓ | ~ |
| Sources | | X | X | X | X |
| DEM 2D/3D | | ✓ | ~ | ✓ | ~ |

# Building 3d example

- IFC:
  - IfcBuildingElement
  - IfcWall, IfcSlab, etc.
  - Attribute: representation
- CityGML:
  - Class: Building
  - Multisurface
- Comparison:
  - Both contain buildings
  - Level of detail



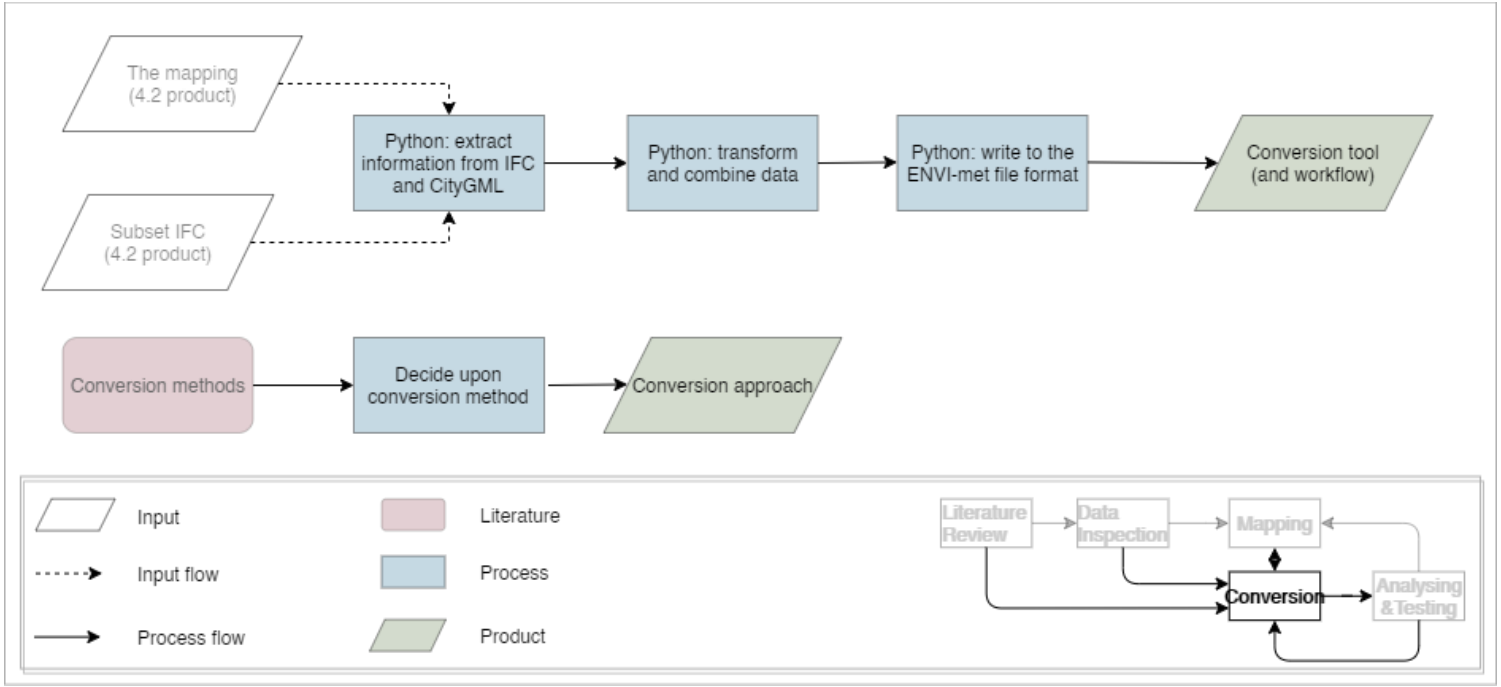
# Mapping



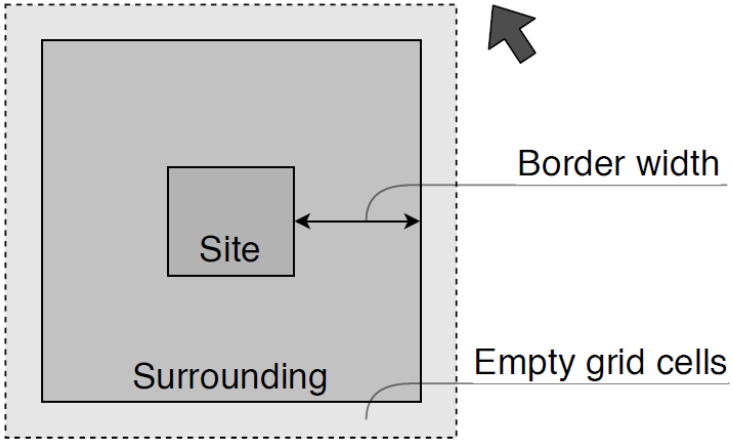
# Building 3d example

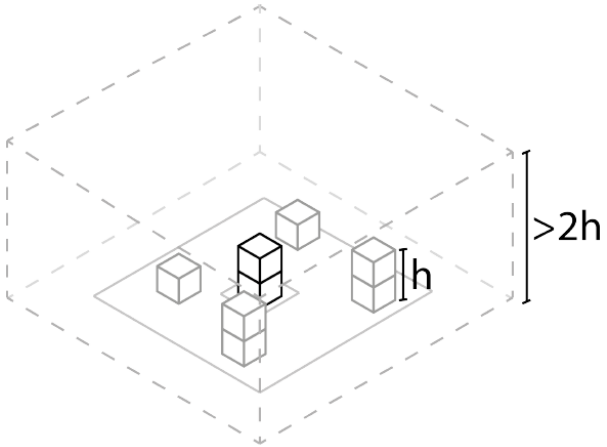
- Mapping:
  - CityGML: Building -> lod2multifurface
  - IFC: IfcBuildingElement -> IfcSlab/IfcWall -> representation
    - Property: isExternal
- Guidelines:
  - CityGML: Buildings Class used, lod2multisurface representation present
  - IFC: One buildings, in mm, IfcSlab used correctly

# Steps within conversion phase



# Model design




- Site (IFC), border(CityGML), empty outer grid
- Model height

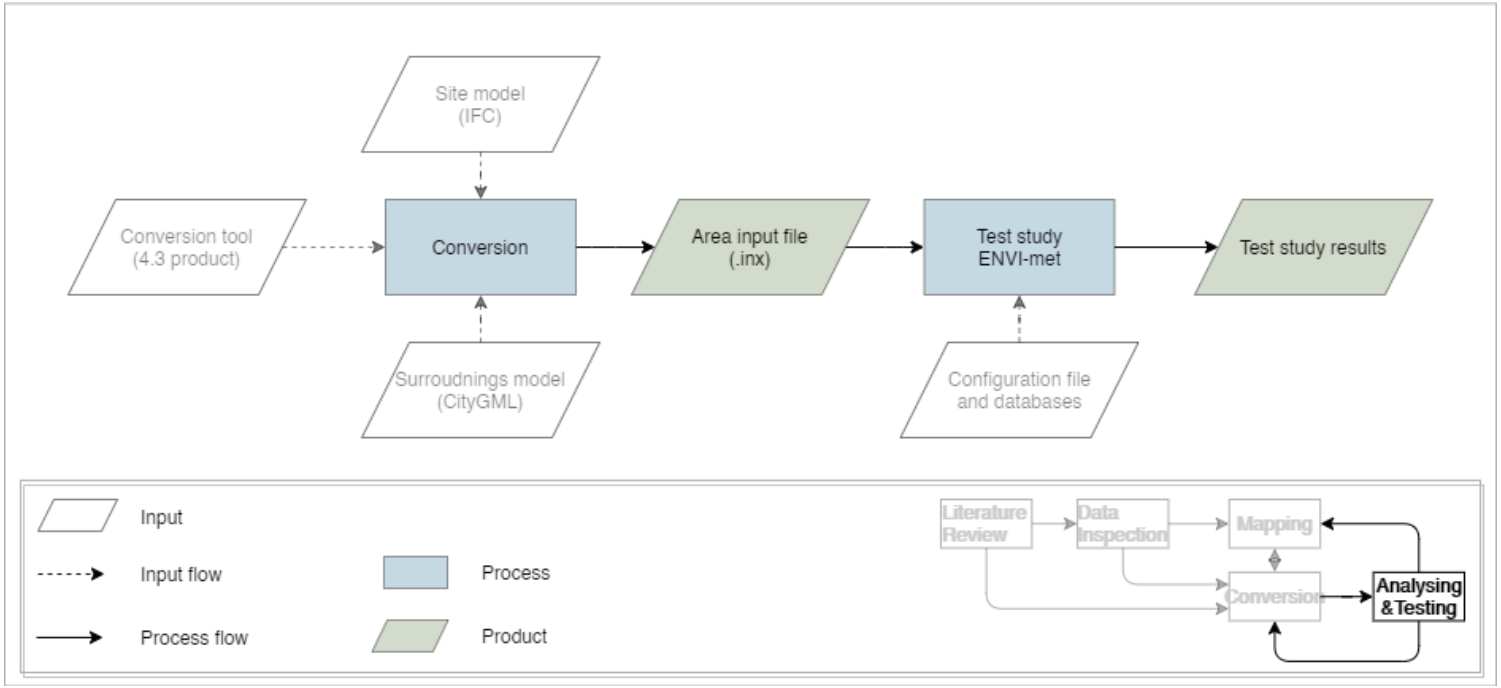
# Transformation & conversion

- Transformation between different reference systems
  - Existing reference system
  - Custom local reference systems
- Conversion between geometry representations
  - From solid and boundary representation to voxel representation

# Conversion building 3d example

- CityGML:
  - Extract multisurface
  - Check if middle of each voxel within bounding box building, lies within building geometry
- IFC (2.5d):
  - Extract all horizontal surfaces from floors and roofs
  - Check from both underneath and top when line crosses these surfaces

# Testing



# User input

- IFC input model
- CityGML input model
- Output file path
- Border width
- Resolution
- Border grid

# Conversion

- Command line tool
- Runs automatic
- Feedback

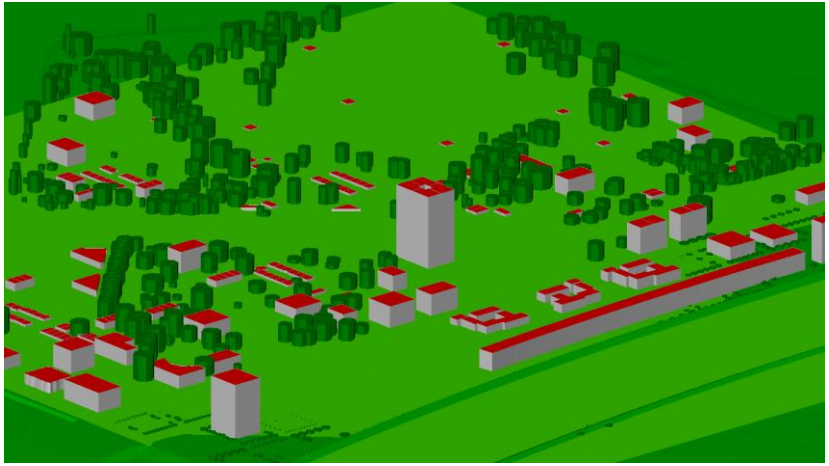
```
loading ifc [input/Myran2.ifc]...
loading citygml [input/floriade.gml]...
input files loaded
calculation parameters...
extracting buildings from input files...
converting IFC building...
converting CityGML building 18 of 18...
extracting and generating dem...
extracting and converting trees...
creating 'ENVI-met area input file'...
writing to file [output/final_reshalf.INX]...
```

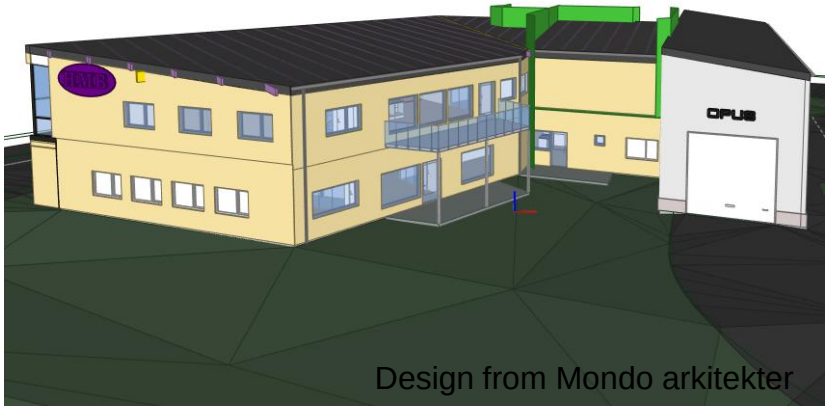
# Verification and editing

- ENVI-met SPACES
  - Deleting buildings
  - Adding extra border grid cells
  - Assigning materials to building walls
  - Adding more elements like trees, infrastructure, etc.

# Input models

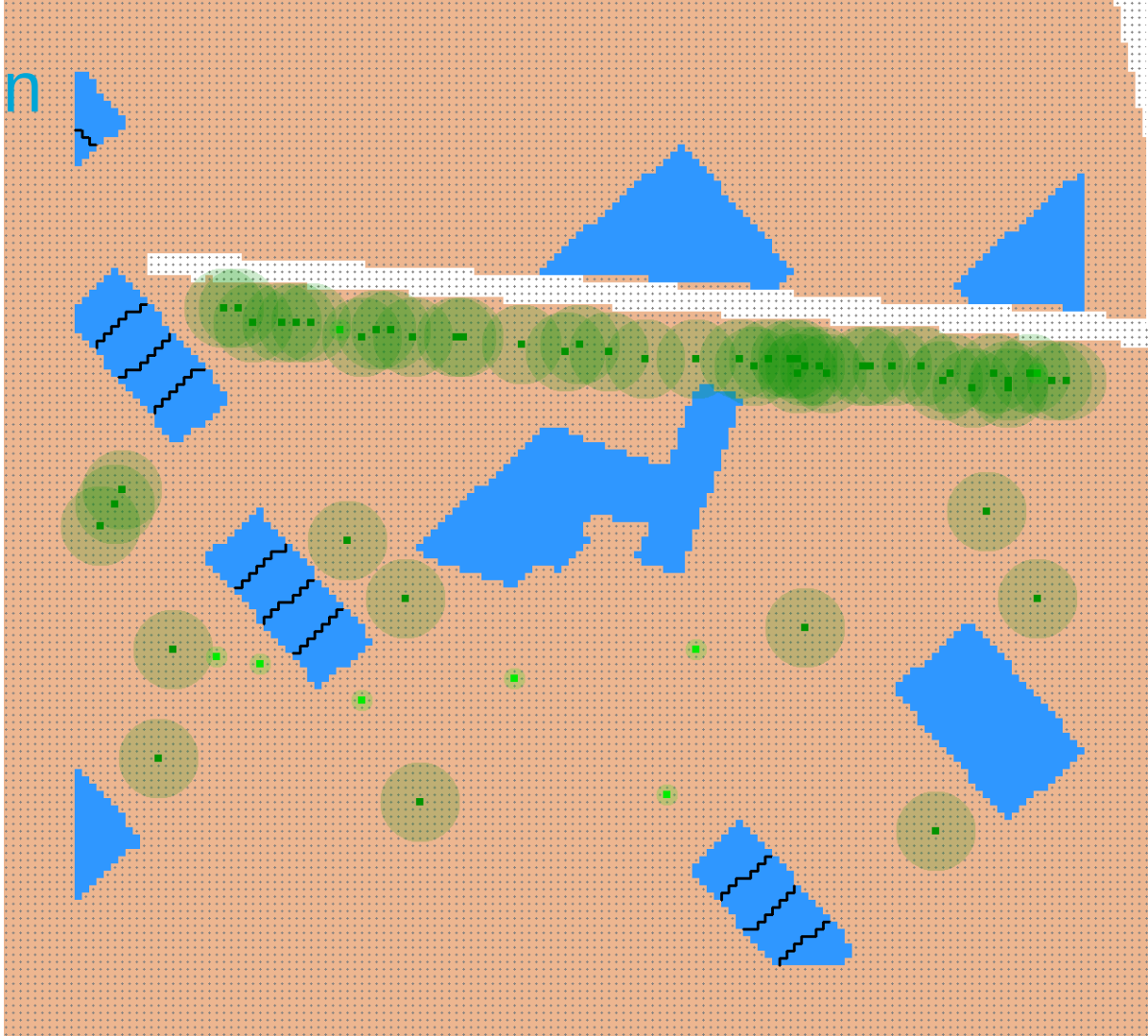
- CityGML:
  - Floriade model
- IFC:
  - Myran model






Design from Mondo arkitekter

# Conversion result 2d



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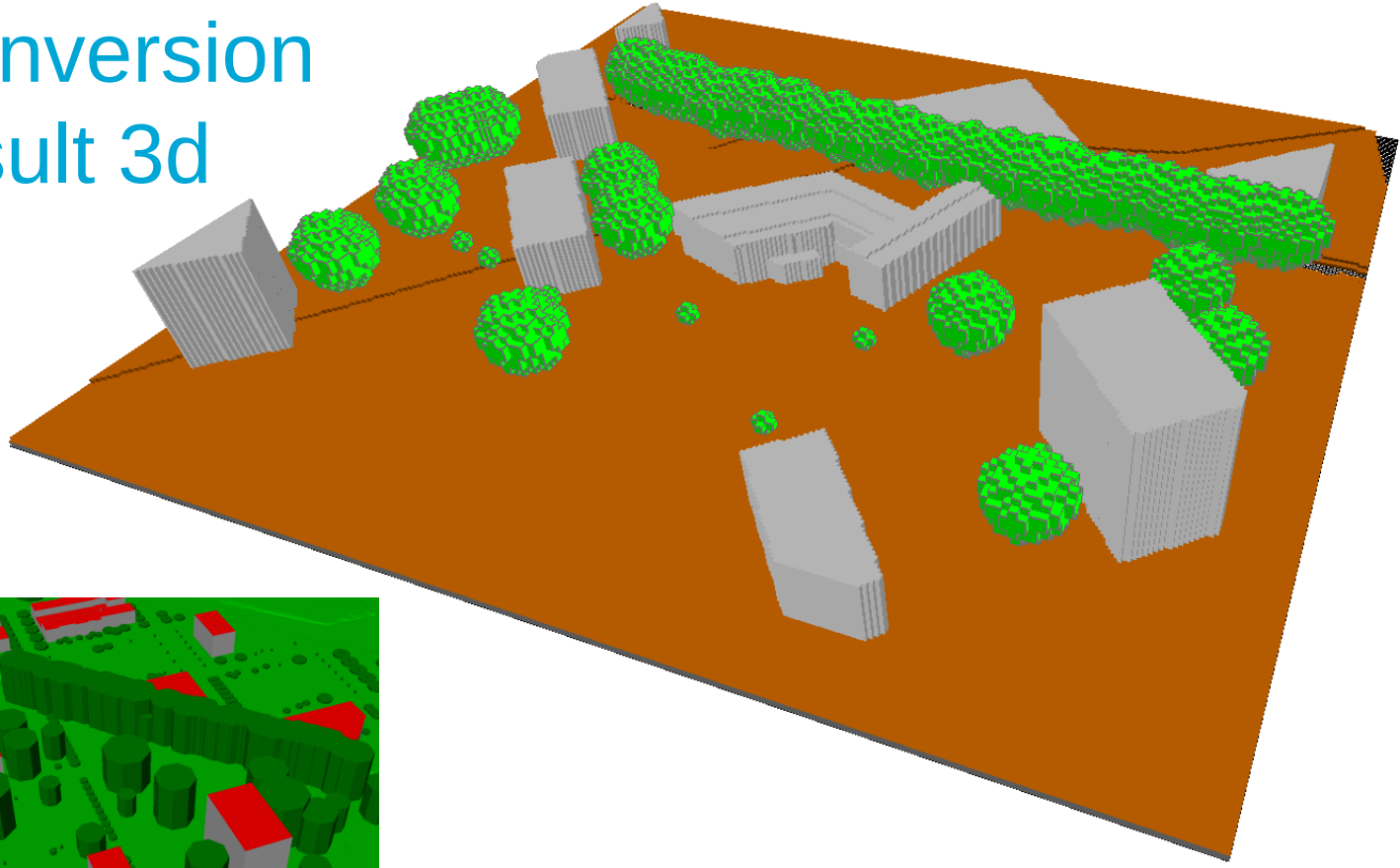
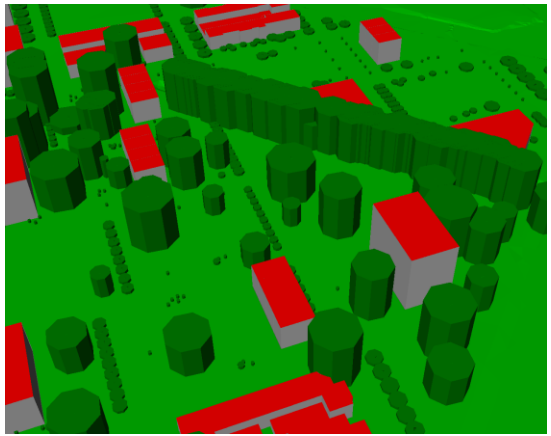
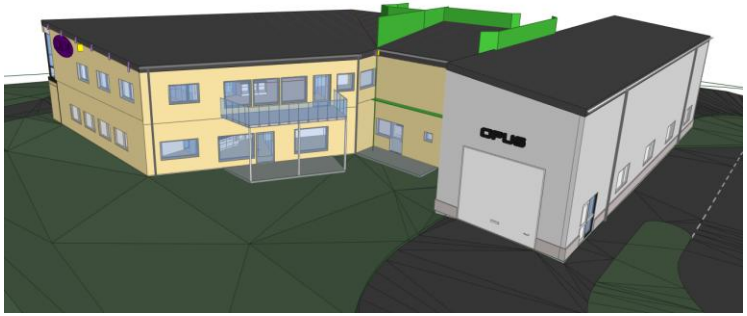
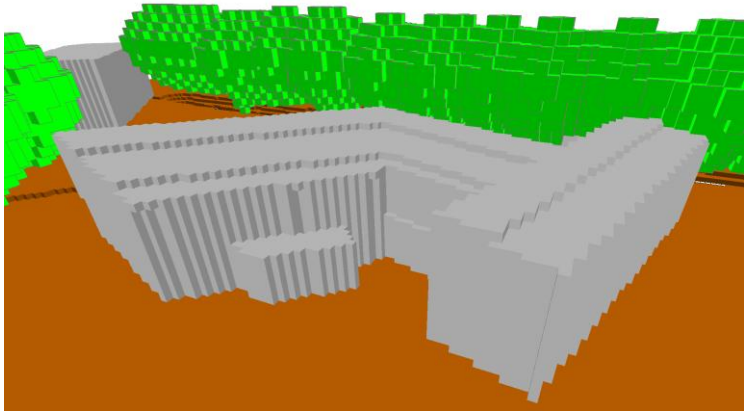
# Conversion result 3d

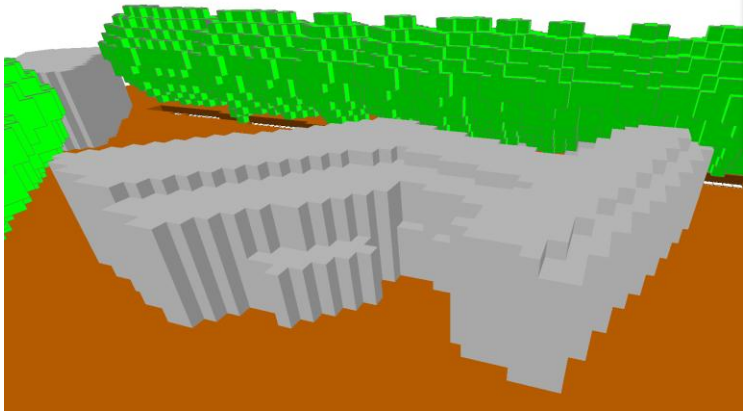


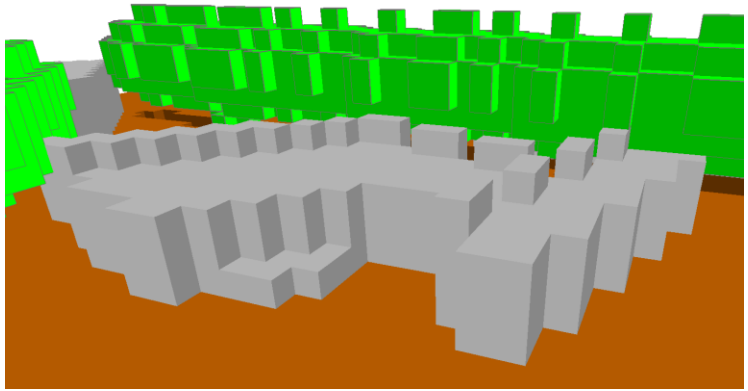


# Result details







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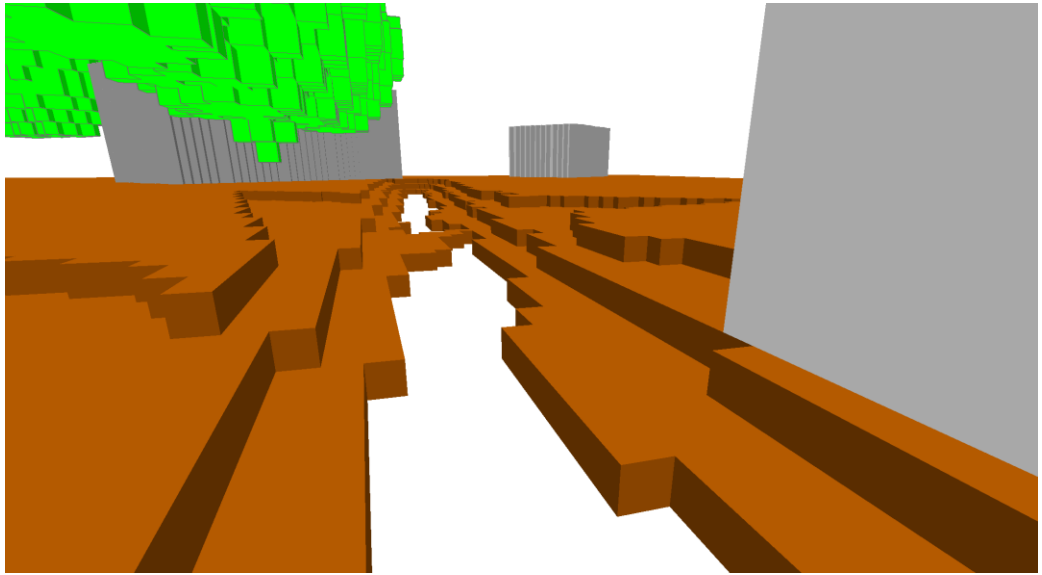
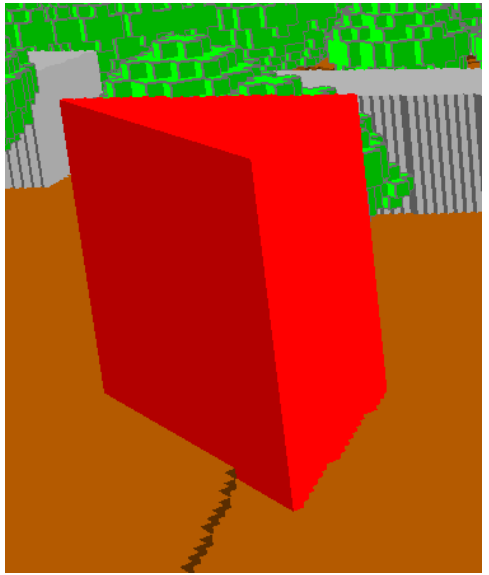
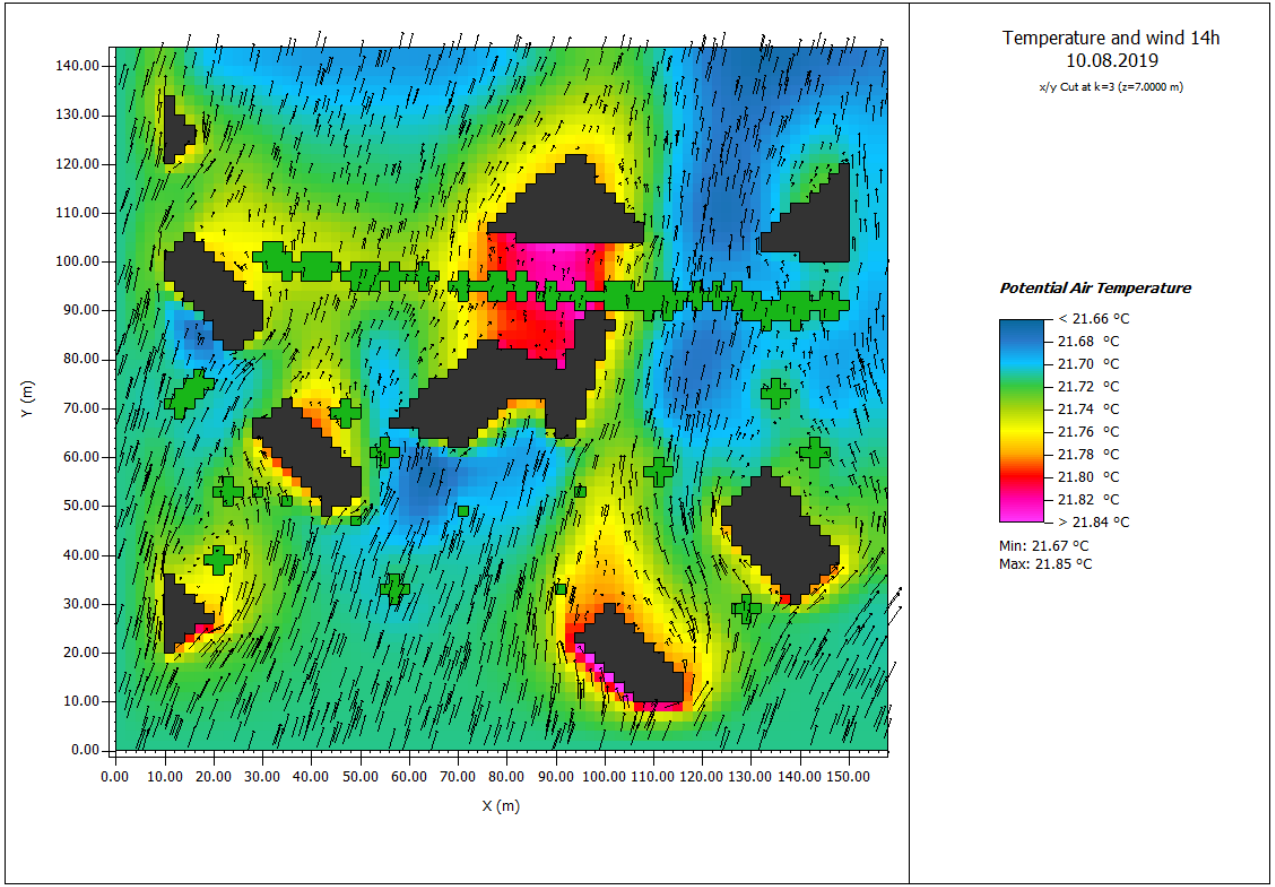




# Simulation results



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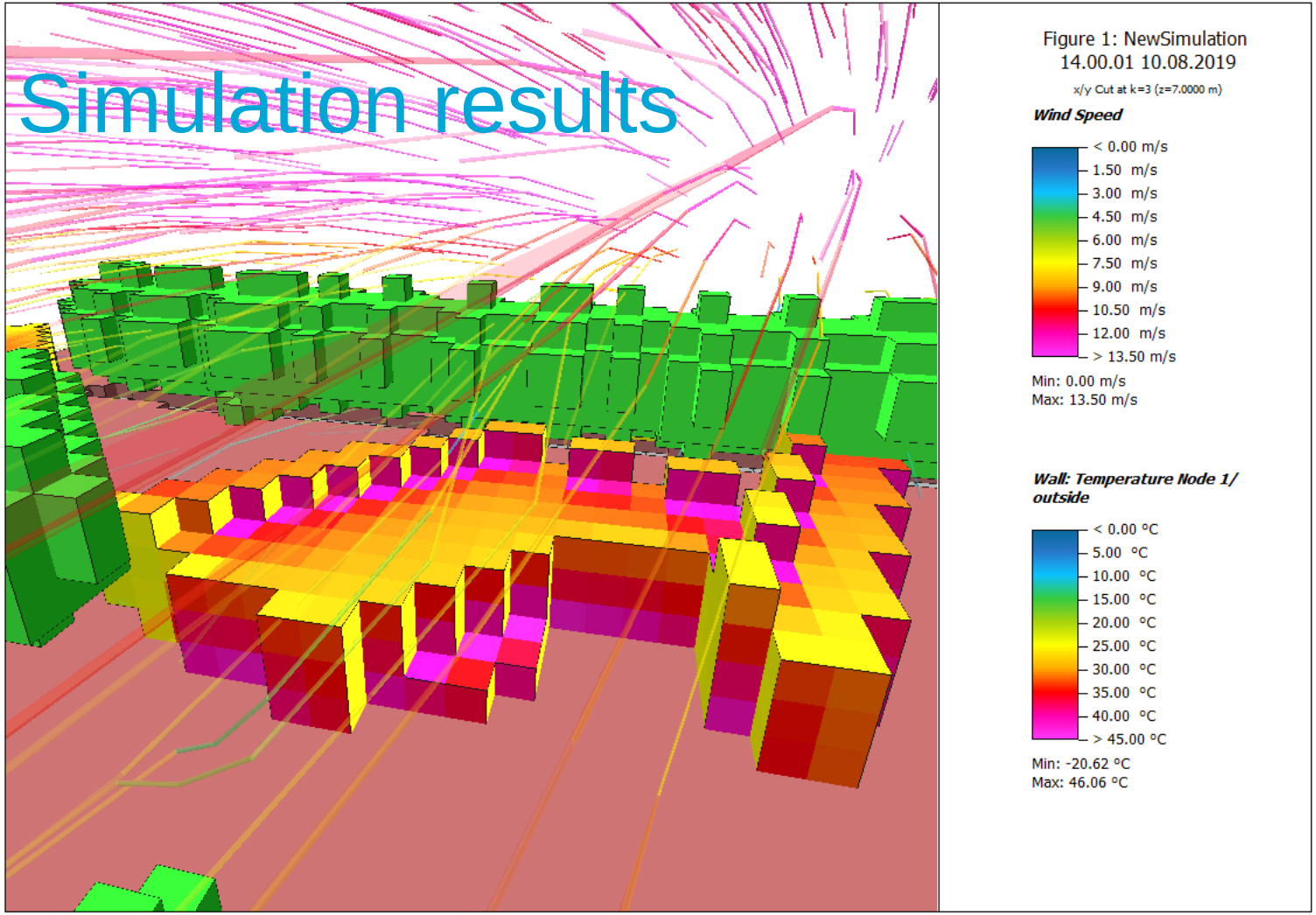


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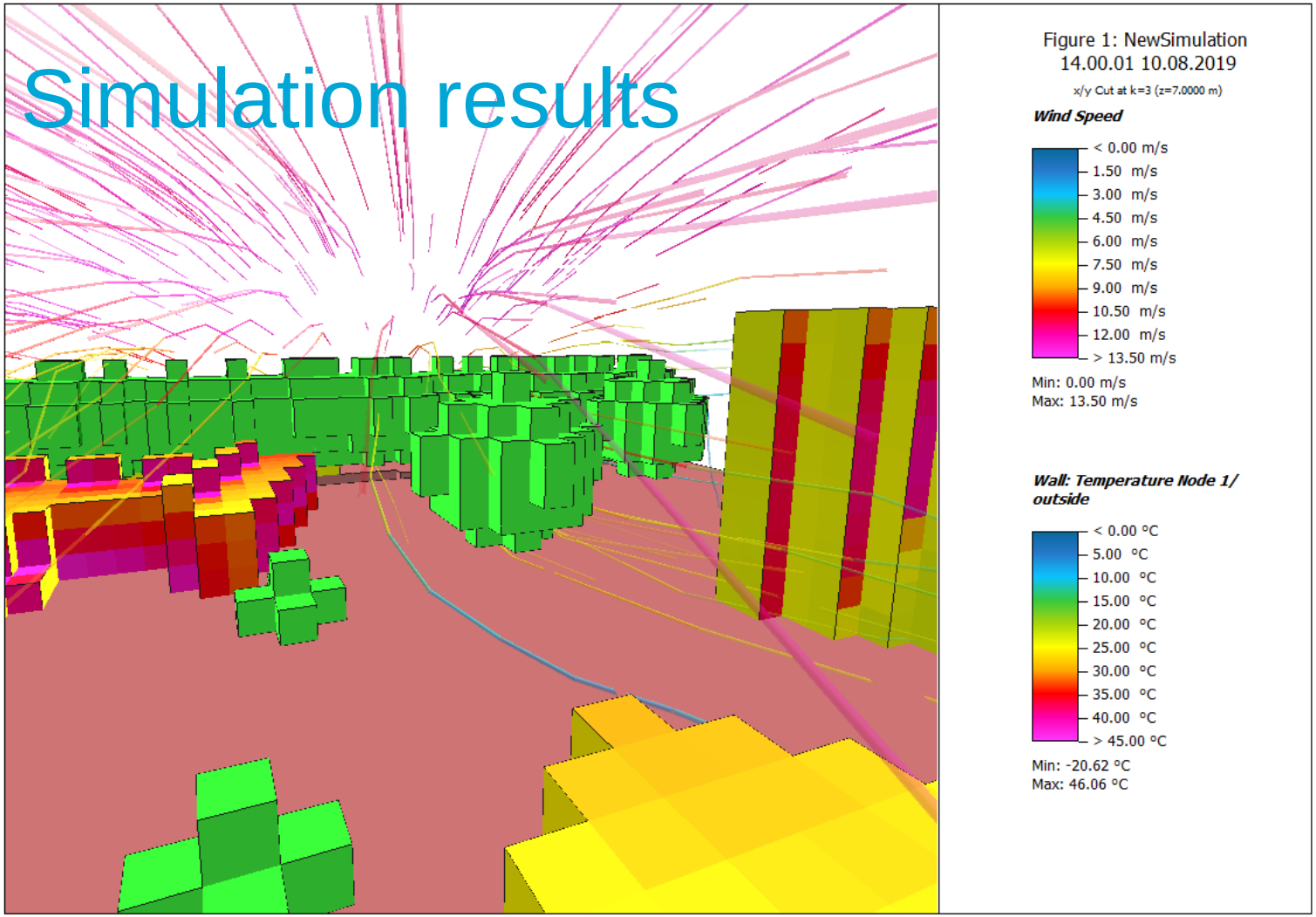


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# Conclusions

- Successfully used IFC and CityGML as input for microclimate simulation
- Proof of concept
  - Does not handle all cases
- Simplifies the use of ENVI-met

# Thank you for your attention

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