



3RD INTERNATIONAL CONFERENCE ON
**SMART ENERGY SYSTEMS AND
4TH GENERATION DISTRICT HEATING**

COPENHAGEN, 12–13 SEPTEMBER 2017



AALBORG UNIVERSITY
DENMARK



EnergyVille

VERIFYING GEOMETRY IN URBAN BUILDING ENERGY MODELS

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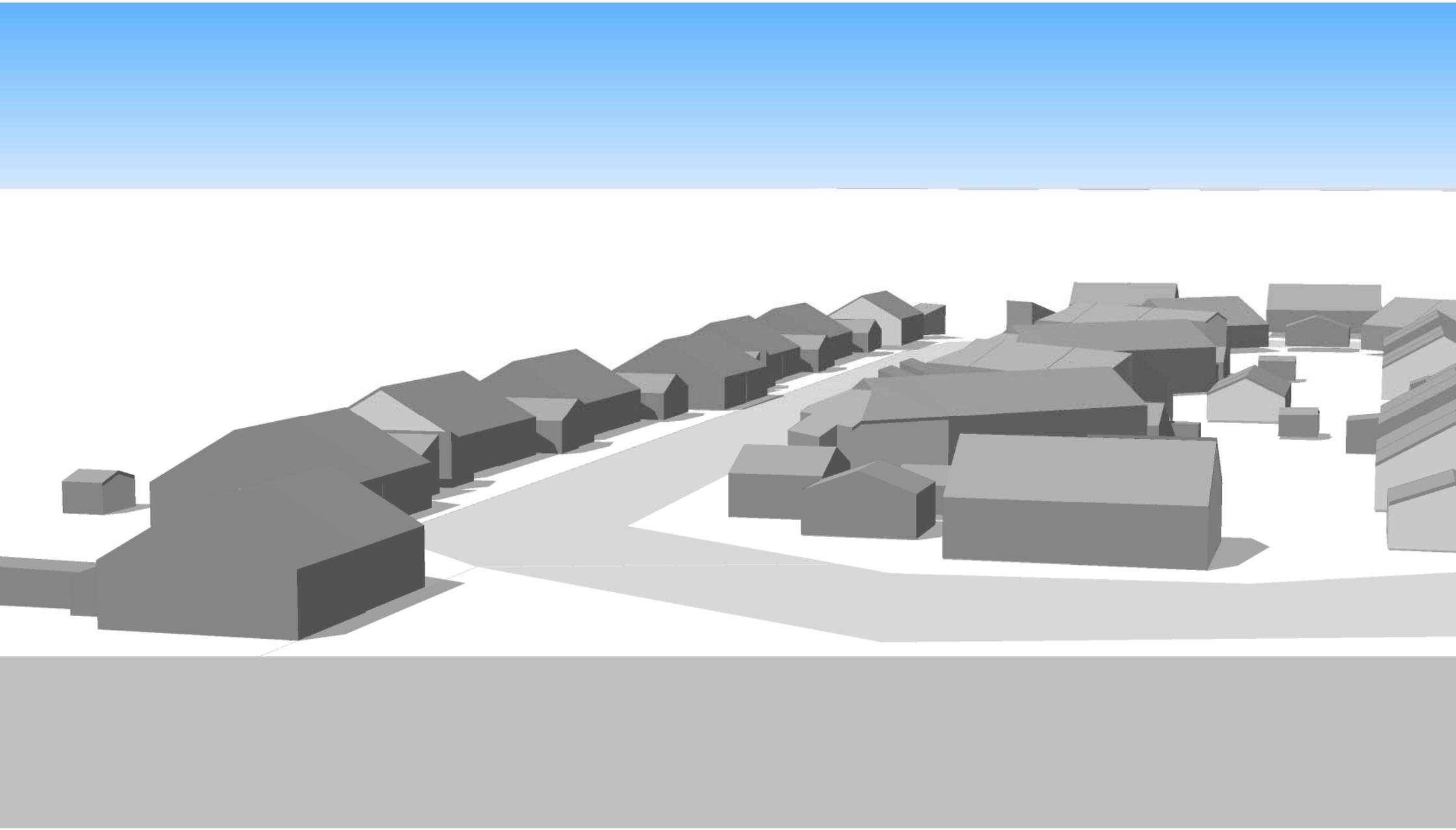
Yixiao Ma ^b

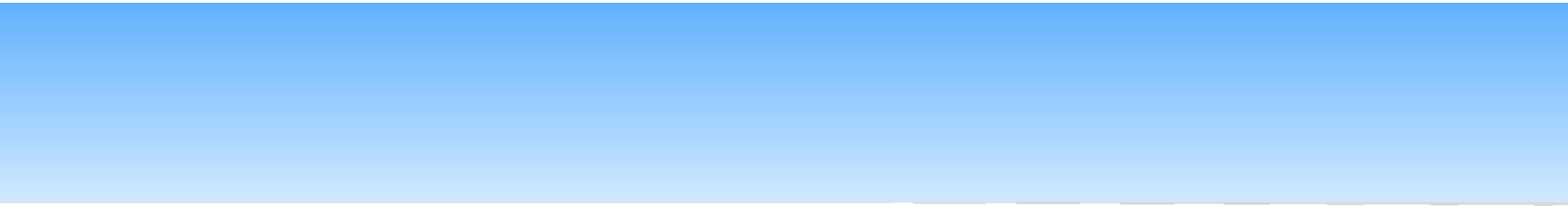
Dirk Saelens ^a

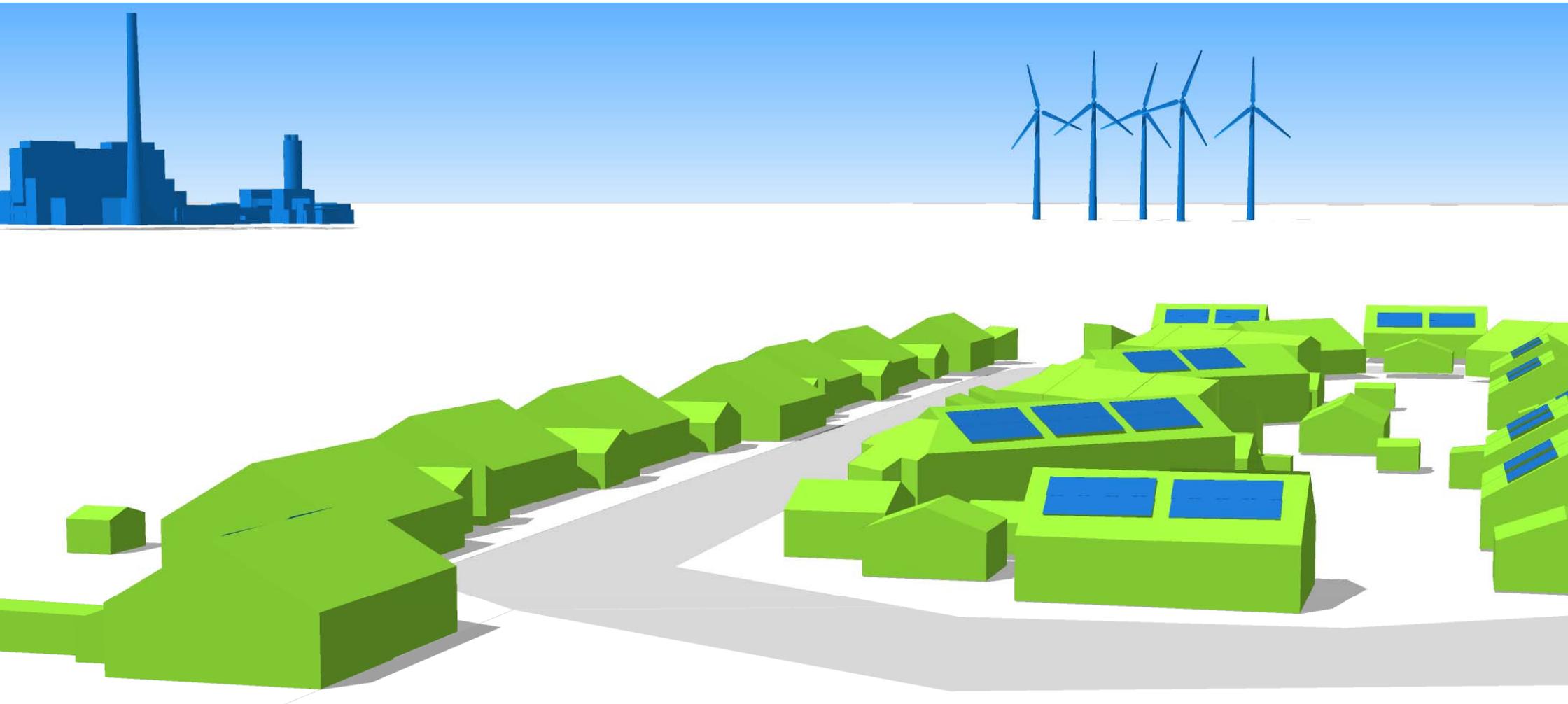
^a KU Leuven, Building Physics Section

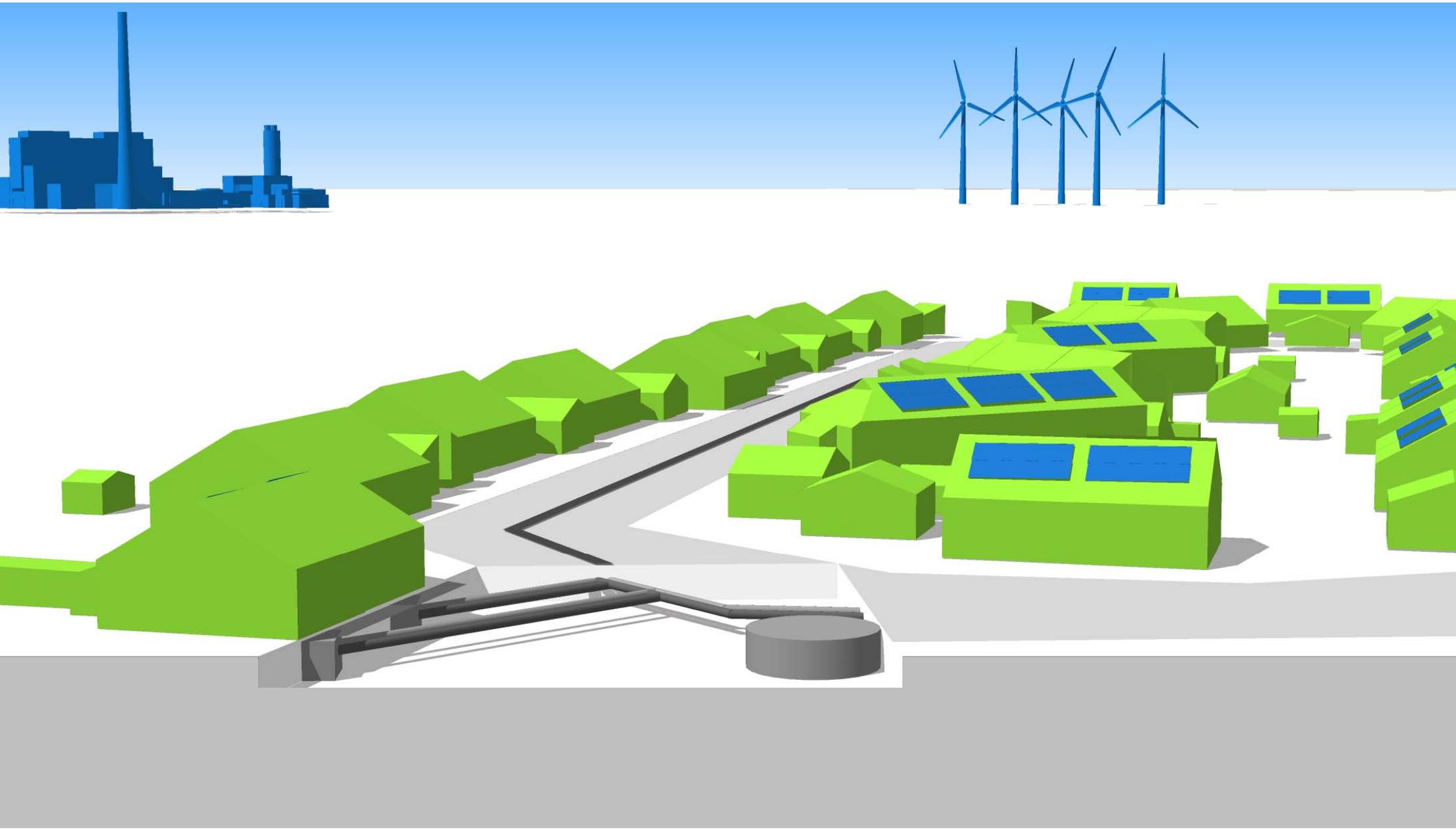
^b VITO, Unit Smart Energy & Built Environment











EFRO-SALK GeoWatt Project

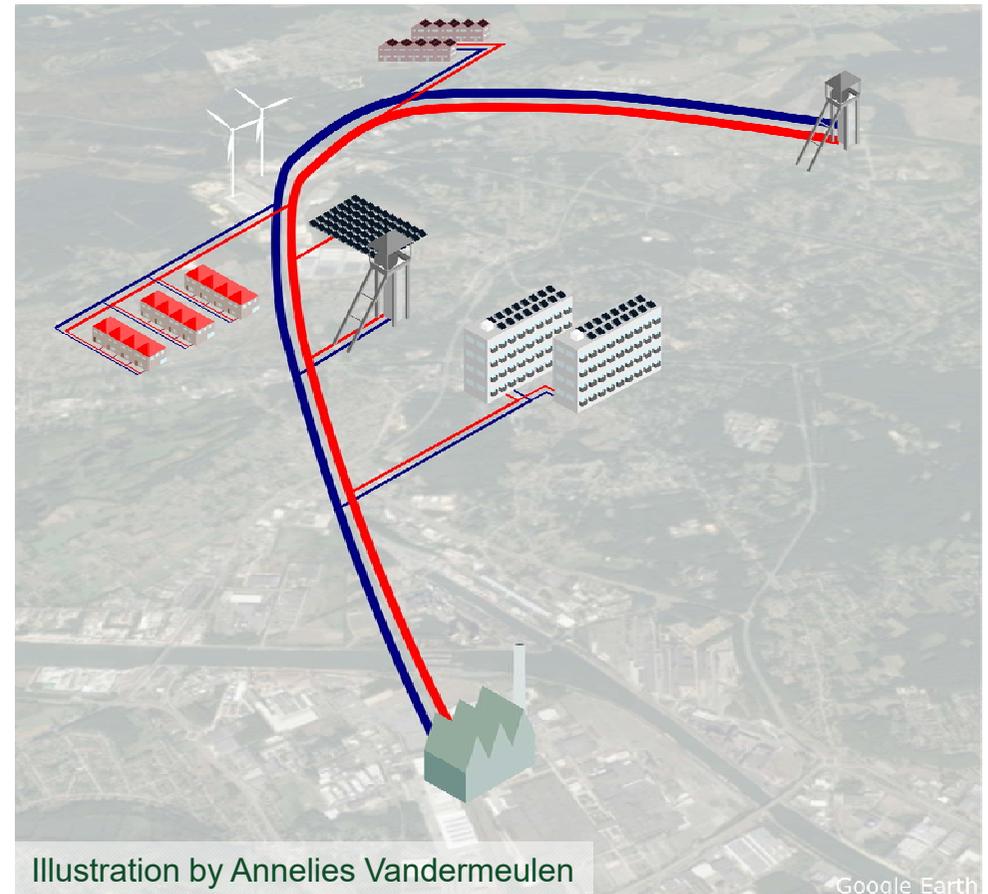
“Towards a Sustainable Energy Supply in Cities”

Research topics

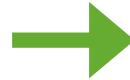
- Building models
- Optimal design
- Thermal network control
- Flexibility
- Geothermal energy
- Fault detection

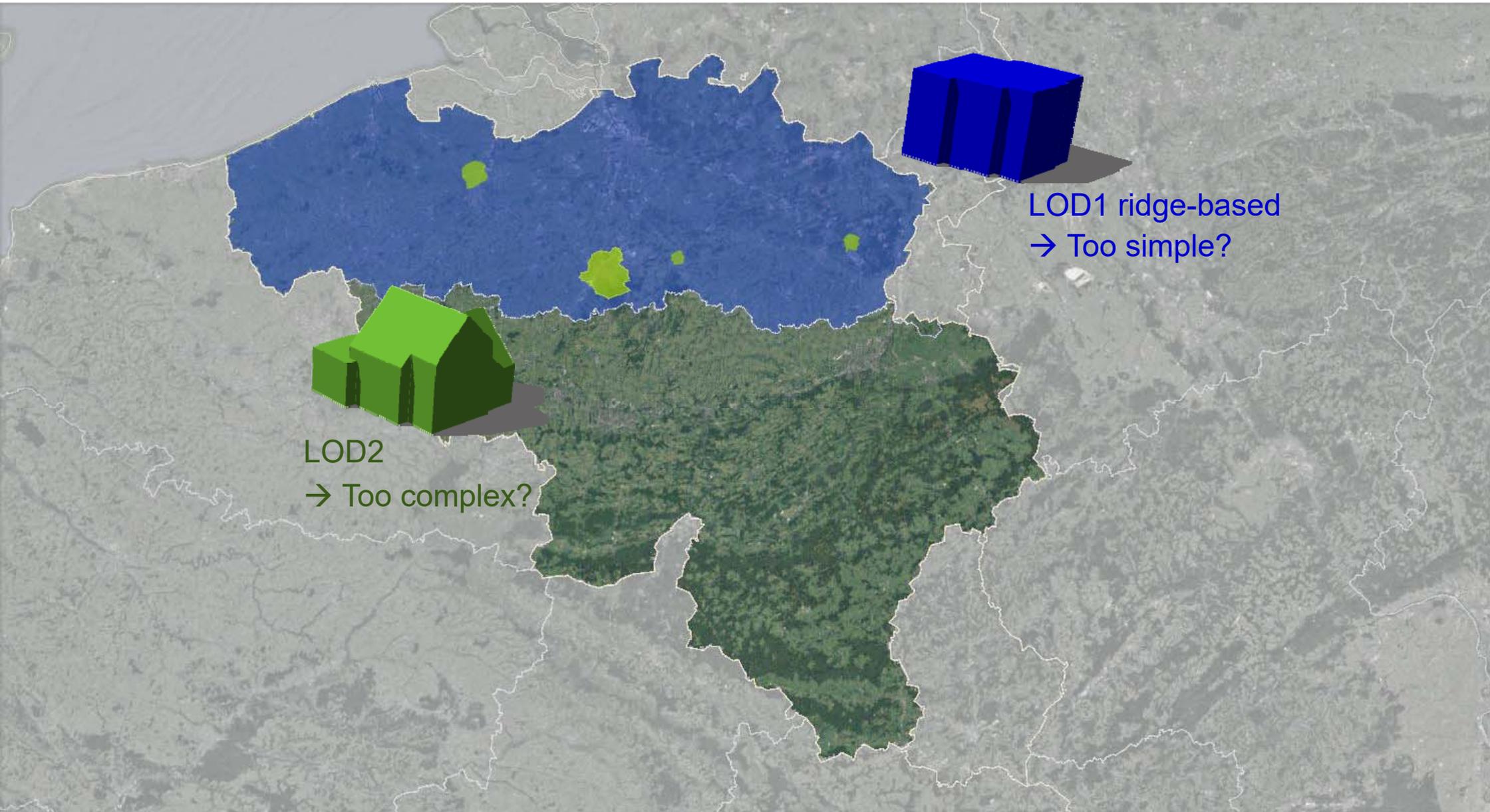
Common case

- City of Genk (B)



Introduction





LOD1 ridge-based
→ Too simple?

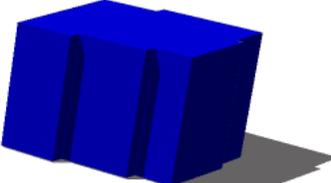
LOD2
→ Too complex?

Introduction

- How does LOD2 differ from LOD1?
 - In terms of geometrical input?
 - In terms of energy simulation outcome?



LOD2

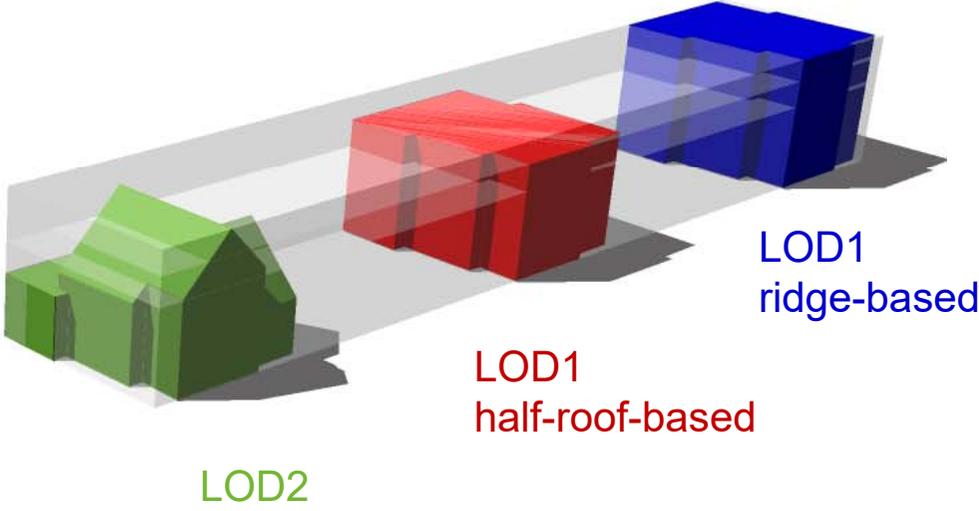


LOD1
ridge-based



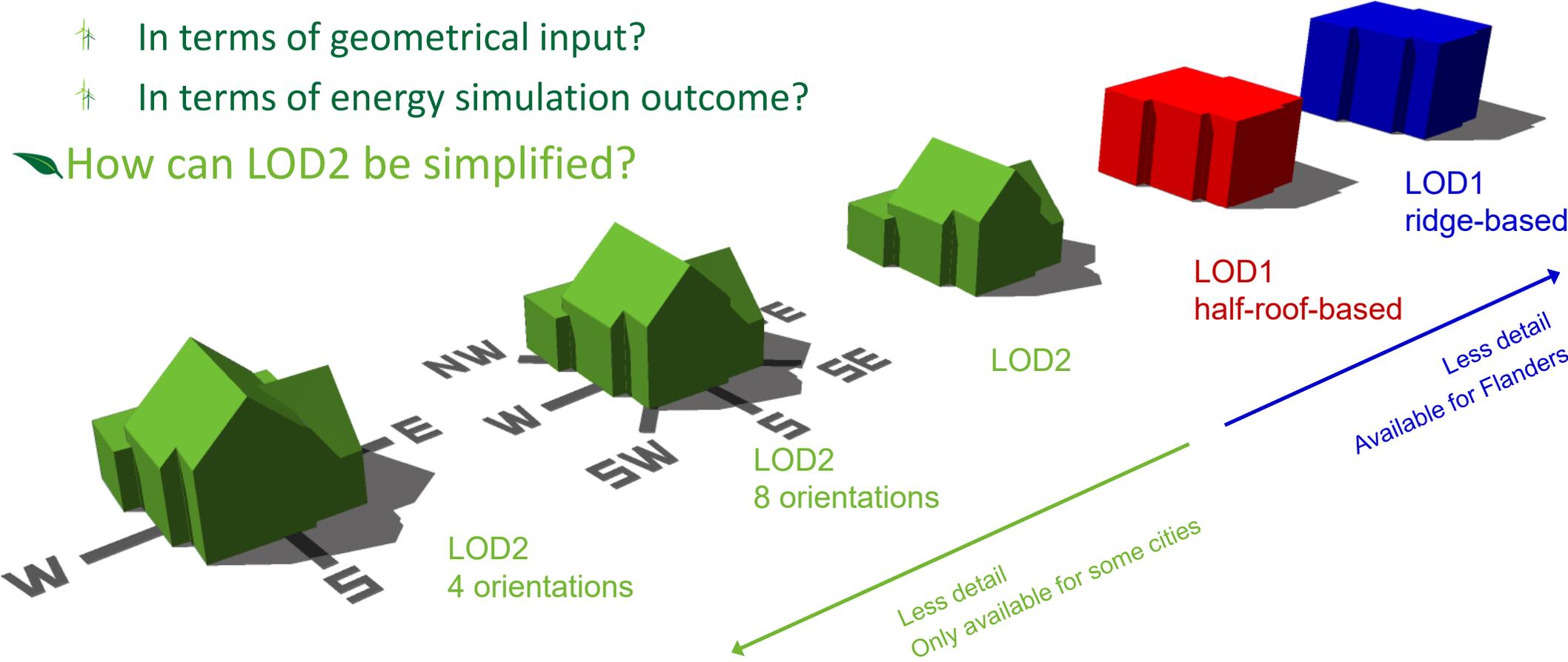
Introduction

- How does LOD2 differ from LOD1?
 - In terms of geometrical input?
 - In terms of energy simulation outcome?

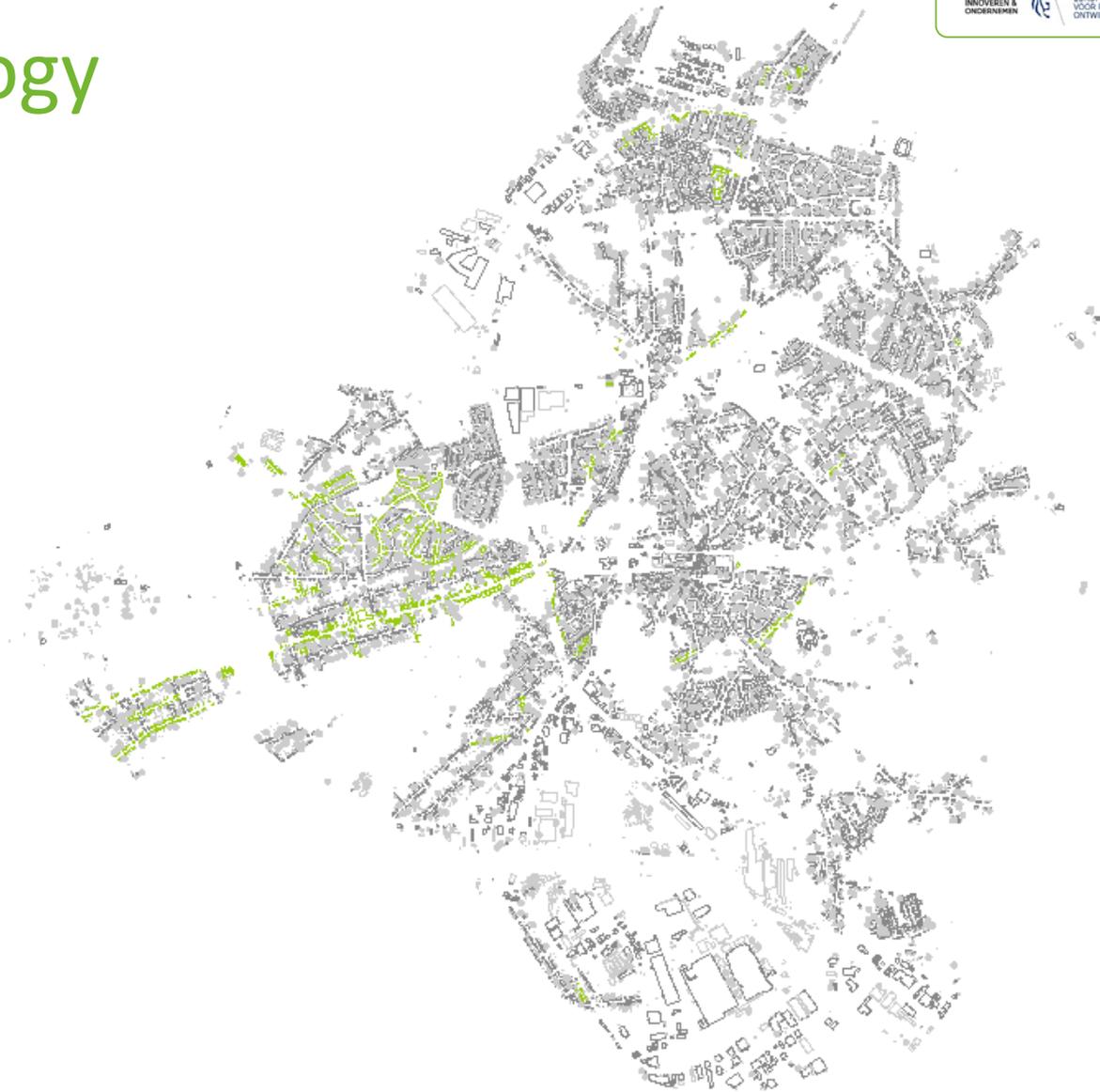


Introduction

- ✦ How does LOD2 differ from LOD1?
 - ✦ In terms of geometrical input?
 - ✦ In terms of energy simulation outcome?
- ✦ How can LOD2 be simplified?



Methodology

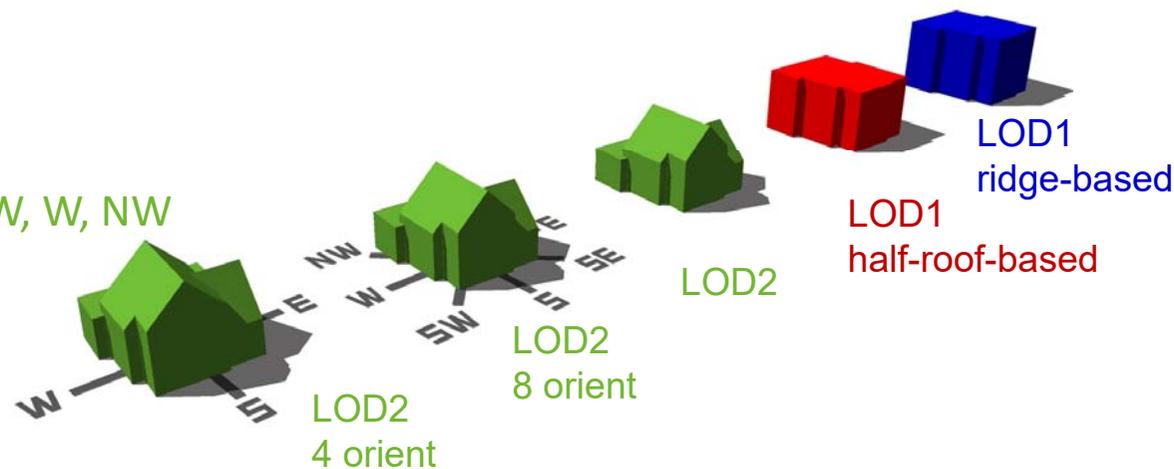


Methodology

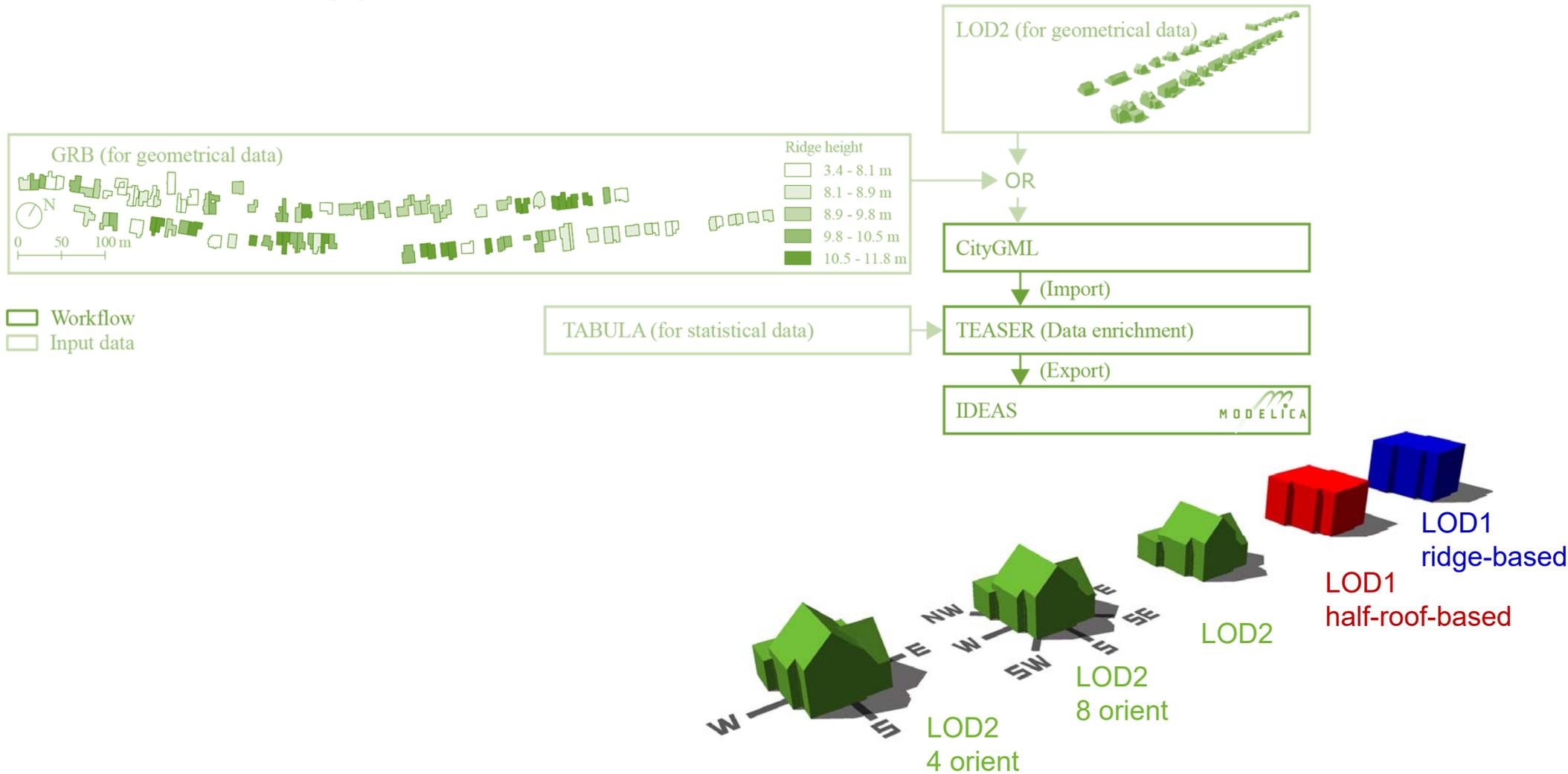


Methodology

- ✦ 5 approaches to model a district:
 - ✦ LOD1 ridge-based approach
 - 🏠 Top = ridge height
 - ✦ LOD1 half-roof-based approach
 - 🏠 Assumption: story is at least 3m high
 - 🏠 Top = ridge height – (story height/2)
 - ✦ LOD 2 approach
 - 🏠 Geometry defined through LiDAR
 - ✦ LOD2 with 8 orientations approach
 - 🏠 Geometry is labelled N, NE, E, SE, S, SW, W, NW
 - ✦ LOD2 with 4 orientations approach
 - 🏠 Geometry is labelled N, E, S, W



Methodology



Methodology

Defined key performance indicators

✦ *Related to geometry:*

- 🏠 Ground floor area [m²]
- 🏠 Heated floor area [m²]
- 🏠 Heated volume [m³]
- 🏠 Total loss surface area [m²]

✦ *Related to energy performance:*

- 🏠 Peak power [kW]
- 🏠 Total energy use [kWh]
- 🏠 Specific energy use [kWh/m²]
- 🏠 Overheating risk of dayzone [Kh]

Methodology

Reporting KPIs

Percentage Error (PE)

$$PE = \frac{Reference - Forecast}{Reference}$$

Mean Percentage Error (MPE)

$$MPE = \frac{1}{n} \sum_{1}^n PE$$

Standard Deviation Percentage Error (σ_{PE})

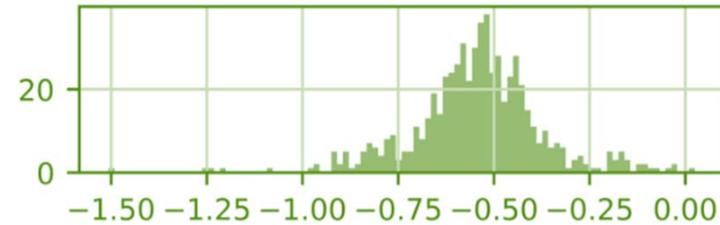
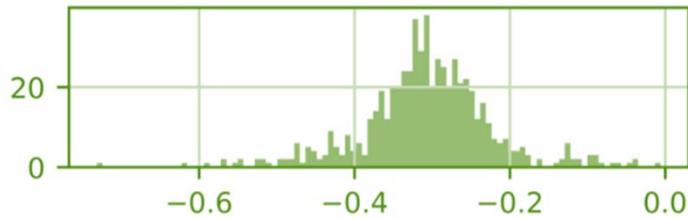
Results

LOD1 vs LOD2 (percentage errors)

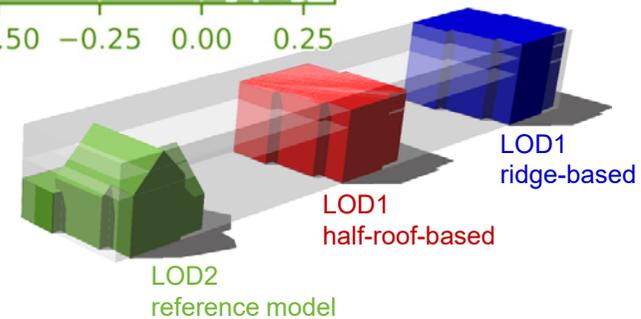
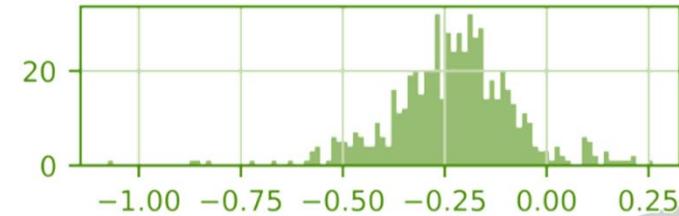
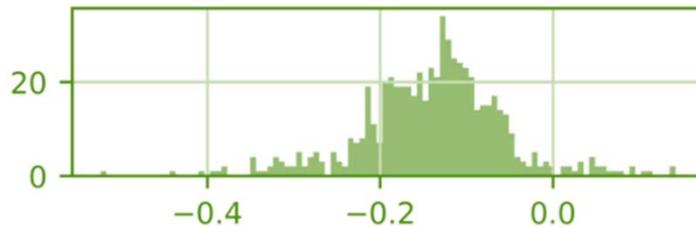
Total loss surface area [-]

Total energy use [-]

LOD1
Ridge-based



LOD1
Half-roof-based



Results

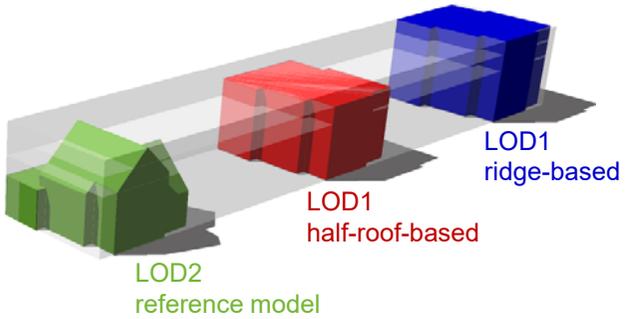
🌿 LOD1 vs LOD2

KPI → APPROACH ↓	Ground floor area [-]		Heated floor area [-]		Heated volume [-]		Total loss surface area [-]		Peak power [-]		Total energy use [-]		Specific energy use [-]		Overheating [-]	
	MPE	σ_{PE}	MPE	σ_{PE}	MPE	σ_{PE}	MPE	σ_{PE}	MPE	σ_{PE}	MPE	σ_{PE}	MPE	σ_{PE}	MPE	σ_{PE}
LOD1 Ridge-based	0.00	0.00	-0.15	0.16	-0.44	0.18	-0.31	0.08	-0.33	0.14	-0.54	0.17	-0.36	0.19	-0.15	0.16
LOD1 Half-roof-based	0.00	0.00	-0.15	0.16	-0.14	0.17	-0.14	0.08	-0.18	0.13	-0.23	0.15	-0.08	0.16	-0.19	0.17

✦ Standard deviation is unneglectable, why do they differ?

🏠 LOD2 approach includes:

- Roof type
- Building extensions

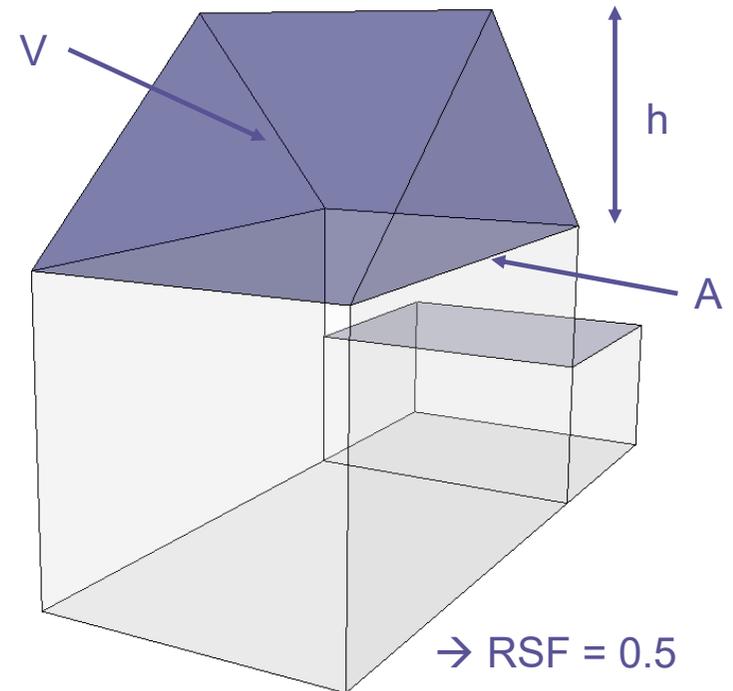


Results

Analysis of the LOD2 model

Main volume and extensions are quantified in terms of:

- 🏠 Ground floor area
- 🏠 Building height (= height of roof edges)
- 🏠 Building volume (= volume below roof)
- 🏠 Roof height
- 🏠 Roof volume
- 🏠 Roof shape factor (RSF)
 - Logic: $V = A * h * RSF$
 - Pitched roof: $RSF = 0.5$
 - Hip roof: $RSF = 0.33$



Results

Analysis of LOD2

Category	Total number	Roof type [%]			Number of extensions [%]					
		Gable	Hip	Flat	0	1	2	3	4	5+
All	12136	84.2	6.7	9.1	32.1	42.5	18.7	5.0	1.2	0.5
Detached	6673	85.0	7.5	7.5	43.4	36.7	14.4	4.1	0.9	0.4
Semi-detached	4248	84.2	5.7	10.1	19.9	48.3	23.7	5.9	1.6	0.5
Terraced	1215	80.2	5.3	14.6	12.4	53.8	24.9	6.8	1.5	0.6
Small	3034	82.0	4.6	13.4	27.9	54.6	15.5	1.8	0.2	0.0
Medium	3034	87.3	5.5	7.2	22.9	48.7	23.3	4.6	0.6	0.0
Large	3034	87.3	6.8	5.9	36.9	35.9	19.4	5.9	1.5	0.4
Extra-large	3034	80.1	9.8	10.1	40.7	30.7	16.7	7.7	2.7	1.5
1 floor	1175	44.2	3.4	52.4	46.7	37.4	12.0	3.3	0.4	0.1
2 floors	4687	85.4	6.9	7.6	41.6	38.3	15.2	3.7	0.9	0.4
3 floors	6030	90.7	7.1	2.1	22.5	46.6	22.5	6.2	1.6	0.6
4 floors	244	92.2	5.3	2.5	17.6	43.4	24.6	10.2	2.9	1.2

Results

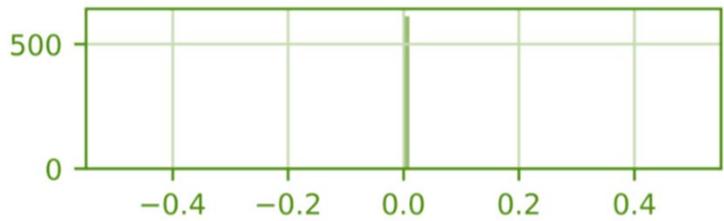
LOD2 with limited orientations vs LOD2

LOD2
4 orientations

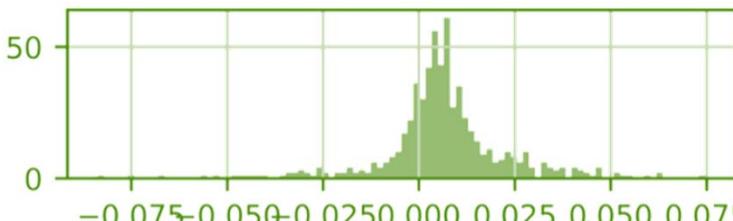
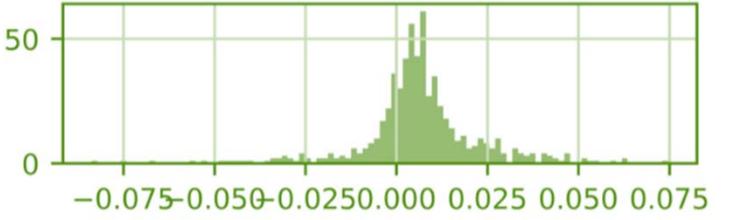
Total loss surface area [-]



LOD2
8 orientations



Total energy use [-]



Results

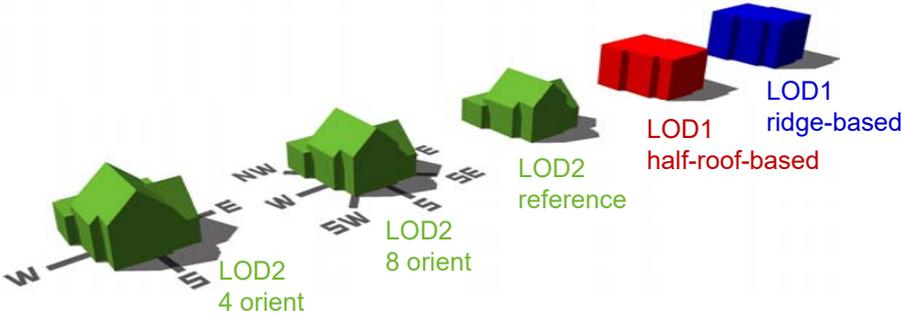
LOD2 with limited orientations vs LOD2

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LOD2 4 orientations	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.03	0.08
LOD2 8 orientations	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.03	0.08

✦ LOD2 with limited orientations favored

🏠 [when focusing on energy use]

✦ No significant differences between 4 and 8



Conclusion

GIS enables to include spatial dimension more accurately within DES

KPI → APPROACH ↓	MPE of Total energy use [-]
LOD1 Ridge-based	-0.54
LOD1 Half-roof-based	-0.23
LOD2 4 orientations	0.01
LOD2 8 orientations	0.01

LOD1 not capable to represent LOD2

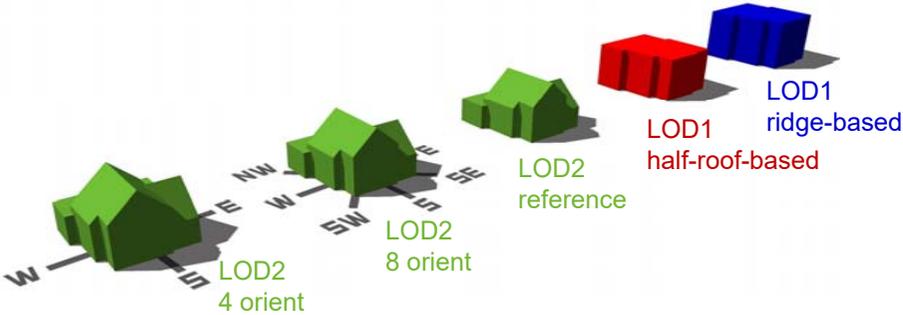
Too simple

LOD2 with all orientations not needed

Too detailed

Future work:

- ✦ Are these 600 buildings representative?
- ✦ Allowable percentage error?



Questions?

Thank you!

Ina De Jaeger

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