



# Pan-European open building footprints: analysis and comparison in selected countries

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# Introduction

# Context – Technology

- Building footprints (from now on buildings) are key geospatial datasets for several **use cases**
  - city planning, demographic analyses, modelling energy production/consumption, disaster preparedness/response, digital twins
- Traditionally produced, curated & updated by **governmental organisations**
  - National Mapping/Cadastral Agencies responsible for Spatial Data Infrastructures (SDIs)
- Recent technological trends have seen **other players** become producers of building datasets
  - private sector, research/academia, citizen-generated data initiatives

# Non-governmental open building footprints

- From **citizen-generated data** initiatives

- OpenStreetMap (OSM)



- From **private** initiatives

- Microsoft Global ML Building Footprints



- Google Open Buildings  Google Research

- Overture Maps  OVERTURE MAPS FOUNDATION



- From **academia/research** institutions

- EUBUCCO  MCC  
Mercator Research Institute on  
Global Commons and Climate Change



- Digital Building Stock Model (DBSM)



# Experiment

# Objective

- Select 4 building datasets
  - from **non-governmental organisations** of different type
  - available (at least) **in the EU**
  - accessible under an **open license**
  - downloaded in January 2024
- Assess the similarity/difference between the datasets
  - only based on their **geometry** (no attributes)
  - in a limited number of EU countries
  - considering the **degree of urbanisation**

# Building datasets (1/2)

- OpenStreetMap (OSM)
  - **crowdsourcing** project, 2M+ contributors
  - **ODbL**-licensed
  - digitalisation of satellite imagery + import of datasets with ODbL-compatible license
  - **global** coverage
  - updated on a **continuous** basis
  - extracted from GeoFabrik (*building=\**)
  - <https://www.openstreetmap.org>



- EUBUCCO 
  - produced by a **research** team in Berlin
  - mostly licensed under **ODbL**
  - governmental datasets for countries where they are openly available, OSM otherwise
  - coverage: **EU27 + Switzerland**
  - released in **2022**
  - <https://eubucco.com>

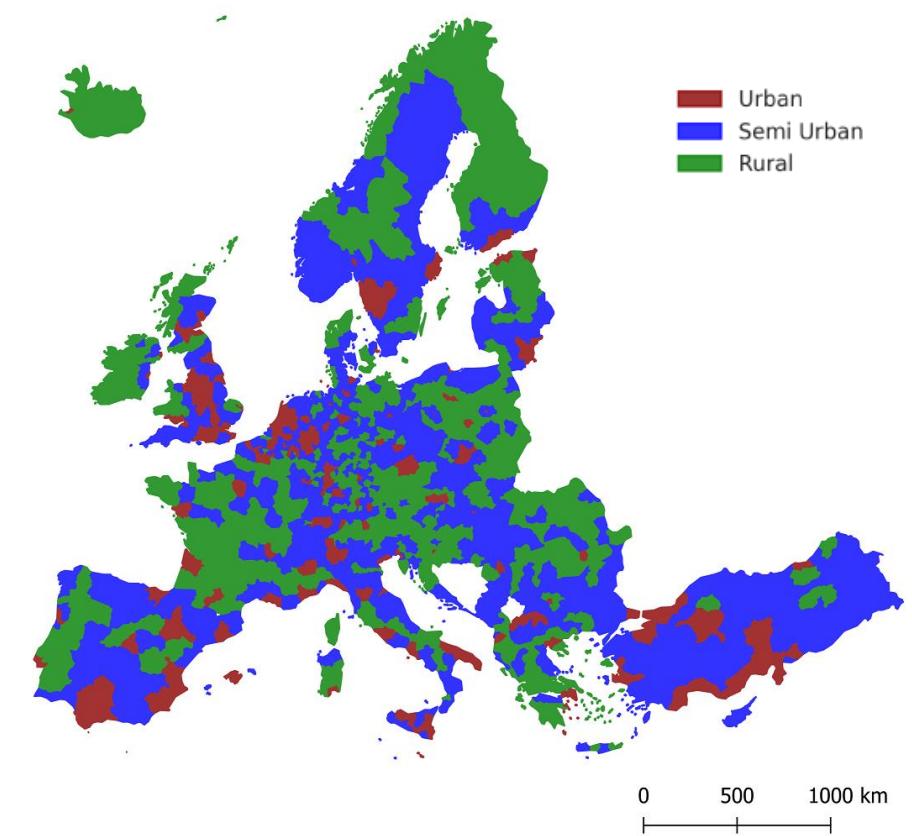
# Building datasets (2/2)

- Microsoft Global ML Building Footprints (MS)
  - **private**-led initiative
  - **ODbL**-licensed
  - machine learning on Bing Maps high-res imagery from 2014 to 2023
  - **global** coverage
  - **regularly** updated
  - <https://github.com/microsoft/GlobalMLBuildingFootprints>
- Digital Building Stock Model (DBSM)
  - produced by a JRC **research** team
  - **ODbL**-licensed
  - hierarchical conflation of OSM, MS, European Settlement Map
  - coverage: **EU27**
  - released in **2023**
  - <https://europa.eu/!W9YJqy>



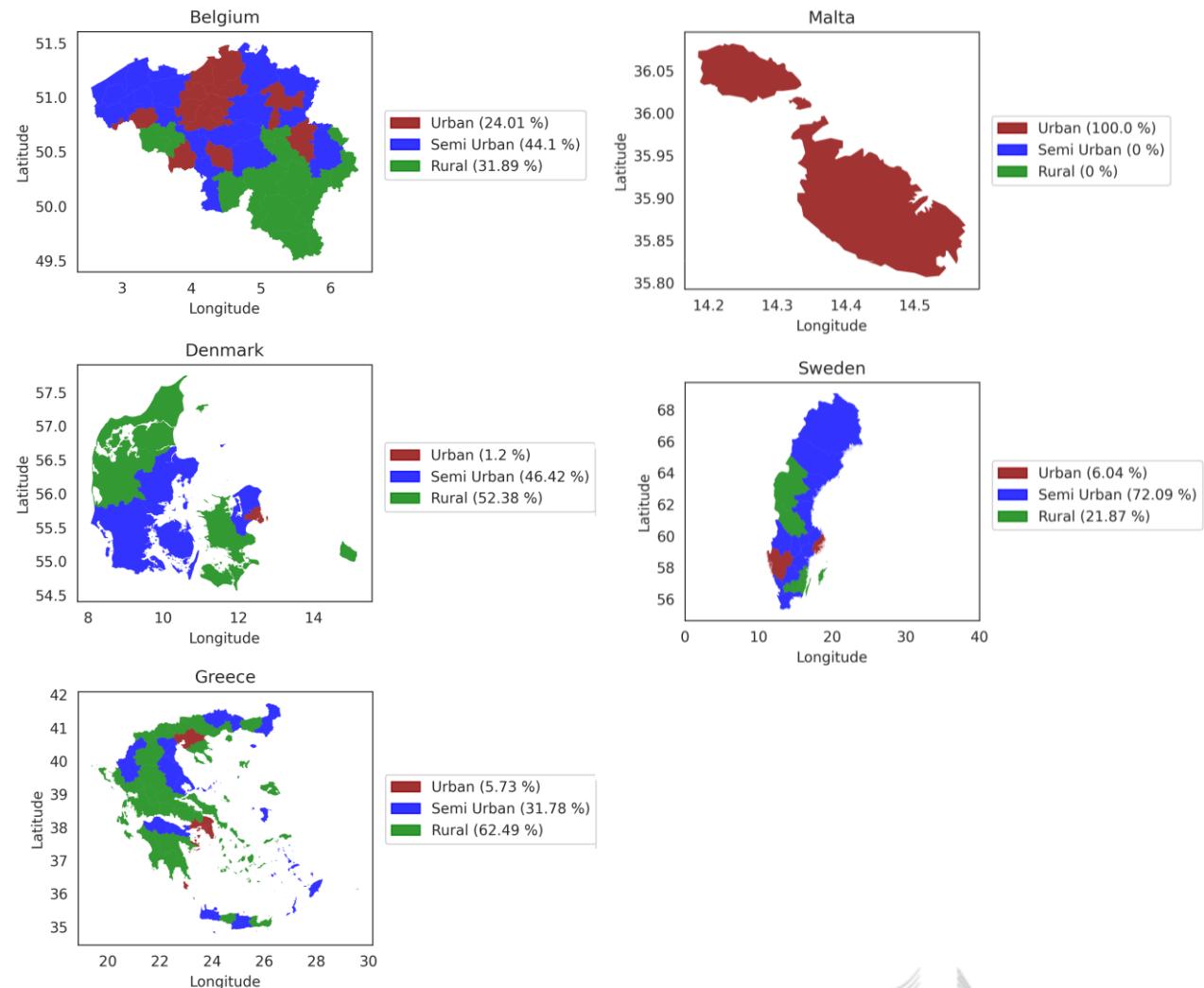
# Degree of urbanisation

- Analysis performed (also) according to the degree of urbanisation
  - using the smallest EU administrative areas (**NUTS3**) – municipalities or counties with a population of 150,000-800,000 inhabitants
  - classification into: **urban, semi-urban, rural**



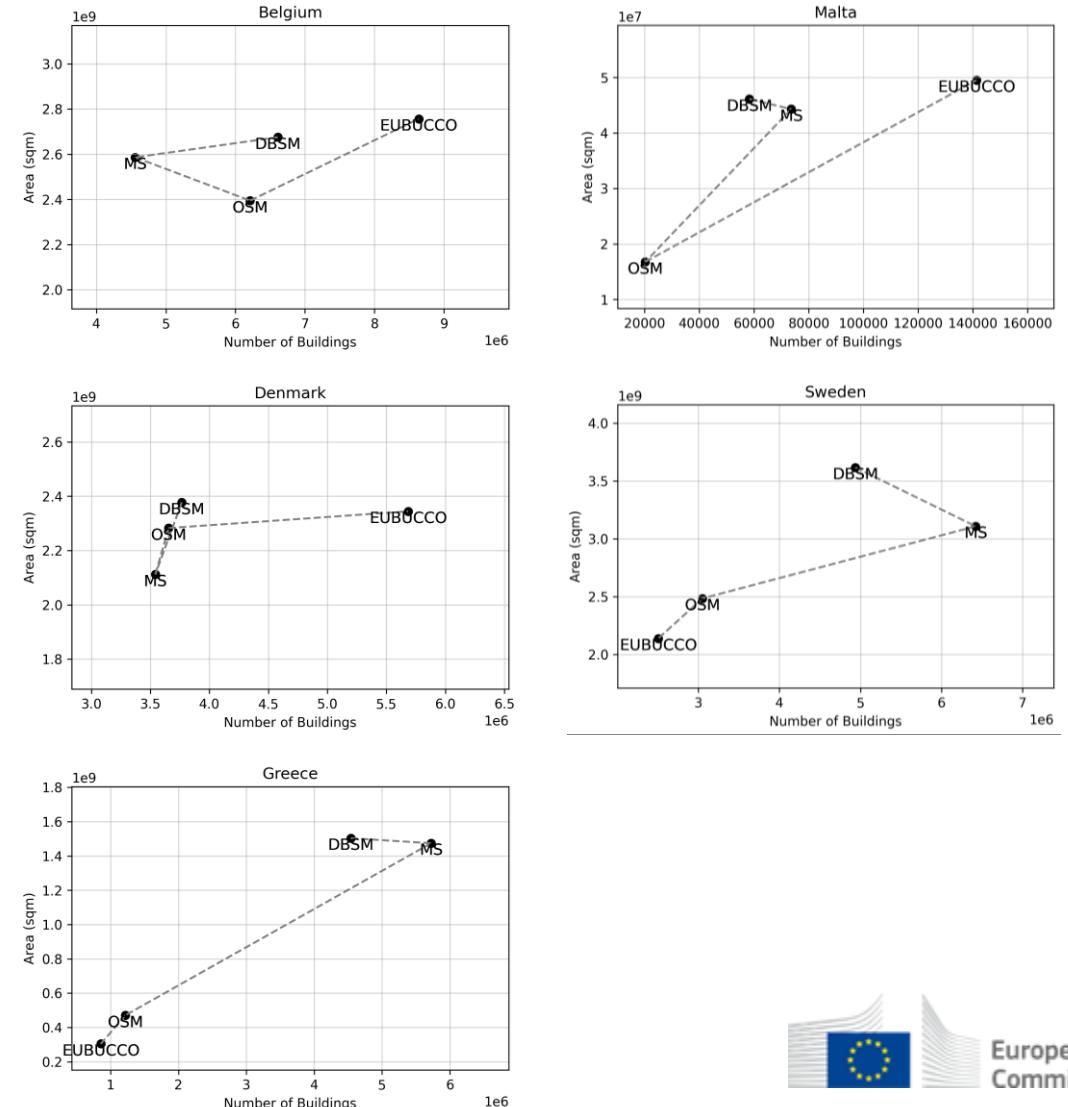
# Study areas

- **5 EU countries:** Belgium, Denmark, Greece, Malta, Sweden
  - of **different size** and **geographically distant** from each other
  - having **different fractions** of urban, semi-urban and rural areas
  - having a **different data source** in **EUBUCCO**: governmental dataset (Belgium, Denmark, Malta) & OSM (Greece, Sweden)



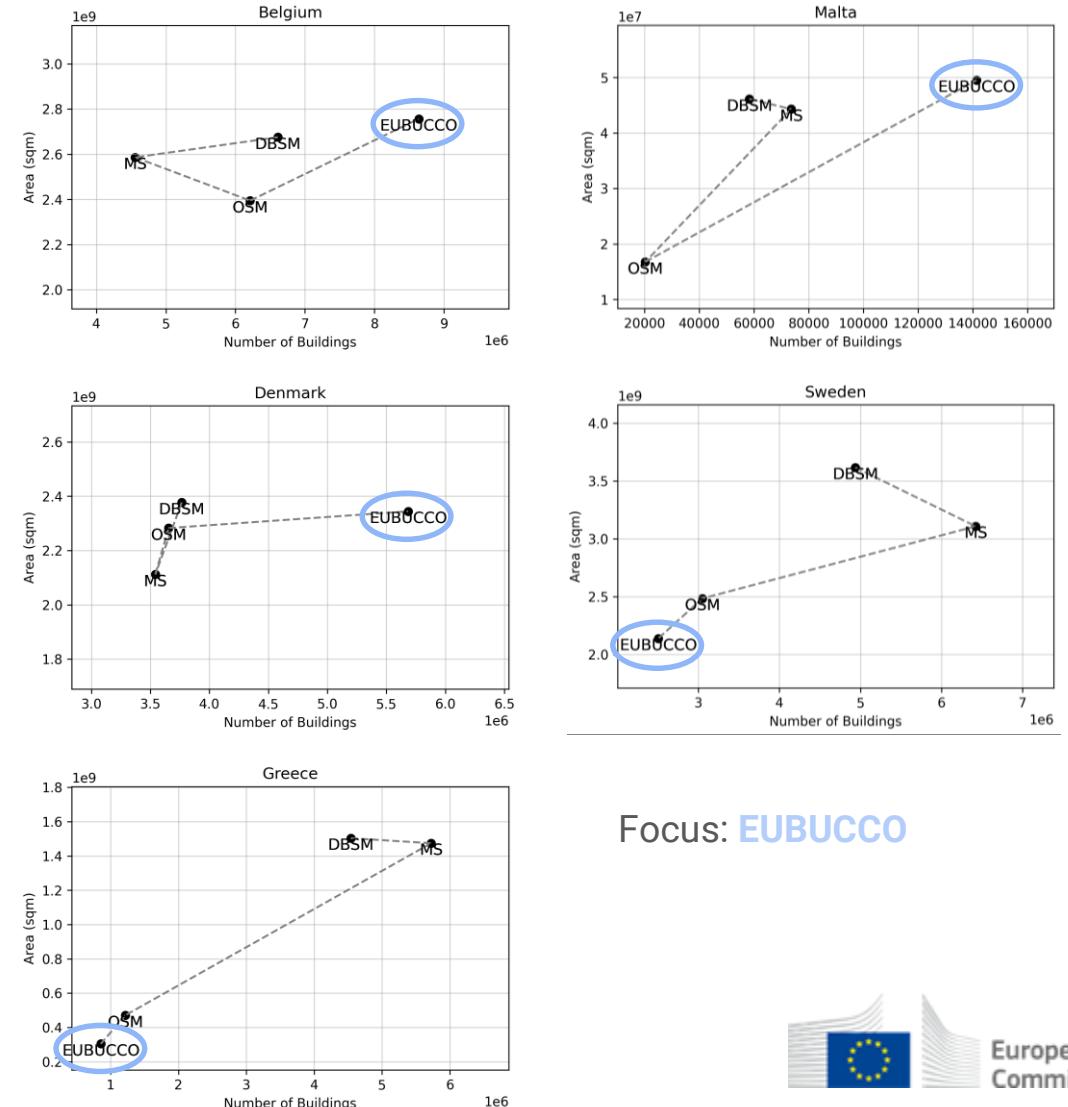
# Total number & total area of buildings

Dataset	Country	Number of buildings	Area of buildings [ $10^8 \text{ m}^2$ ]
EUBUCCO	Belgium	8,636,114	27.56
	Denmark	5,684,734	23.44
	Greece	856,140	3.04
	Malta	141,329	0.49
	Sweden	2,504,961	21.38
OSM	Belgium	6,211,451	23.94
	Denmark	3,654,875	22.82
	Greece	1,217,547	4.71
	Malta	20,225	0.16
	Sweden	3,050,667	24.84
DBSM	Belgium	6,610,034	26.75
	Denmark	3,765,255	23.76
	Greece	4,540,228	15.03
	Malta	58,247	0.46
	Sweden	4,936,573	36.16
MS	Belgium	4,557,403	25.86
	Denmark	3,541,845	21.11
	Greece	5,722,750	14.74
	Malta	73,579	0.44
	Sweden	6,422,594	31.07



# Total number & total area of buildings

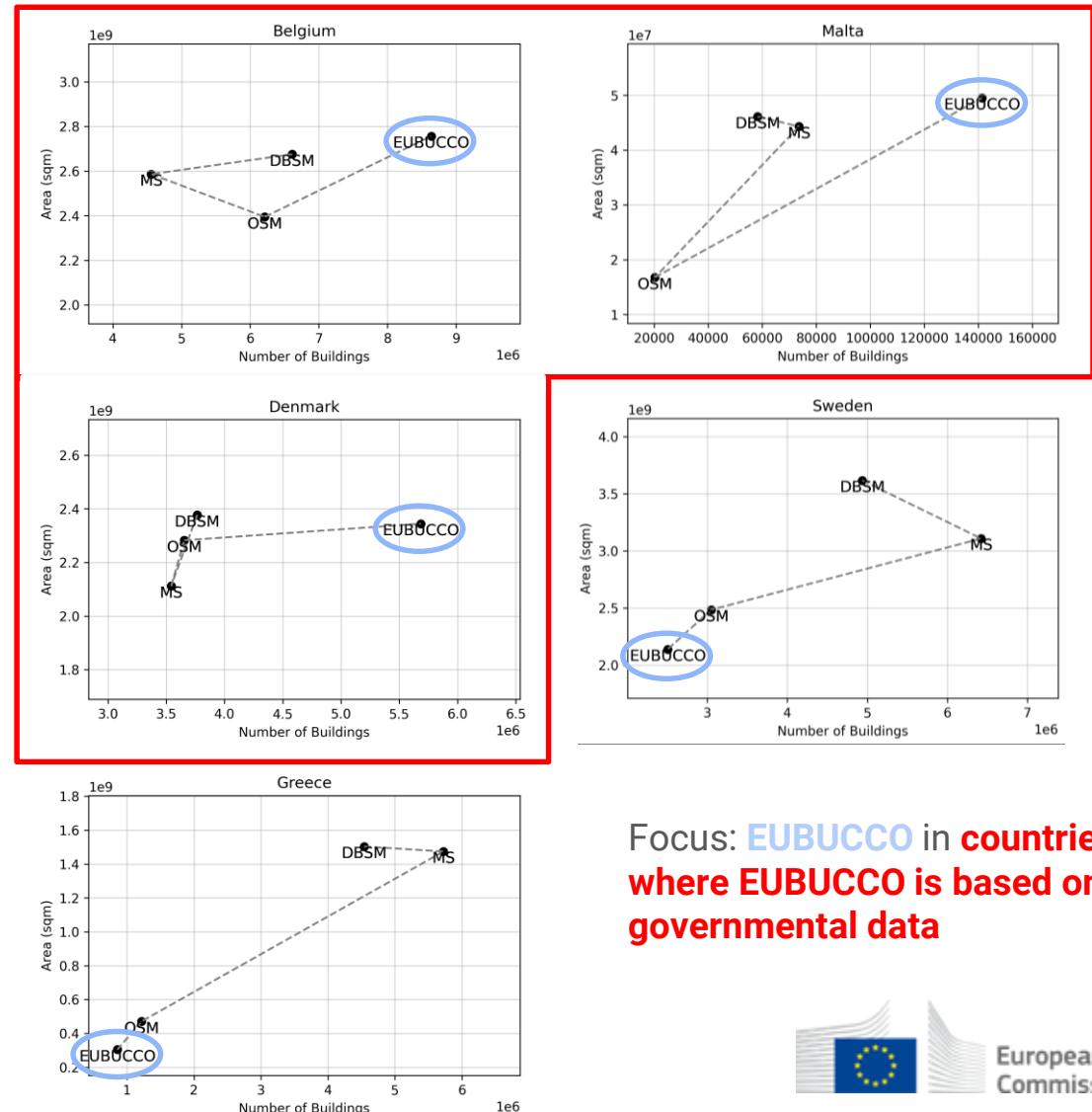
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Focus: **EUBUCCO**

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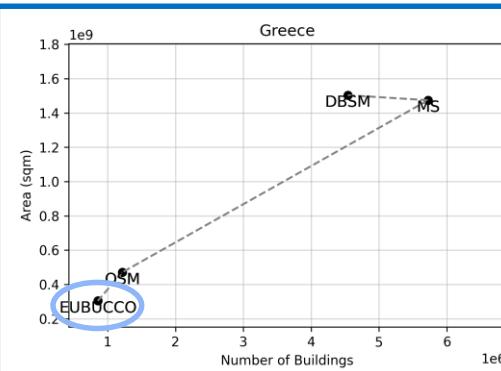
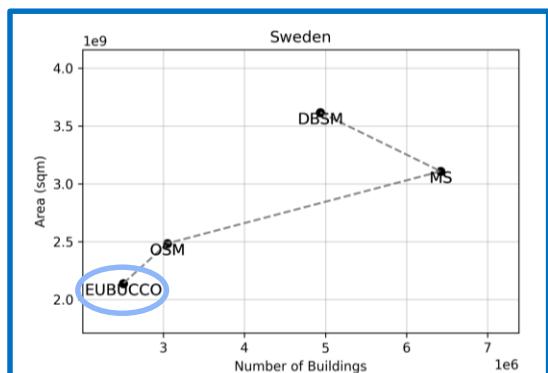
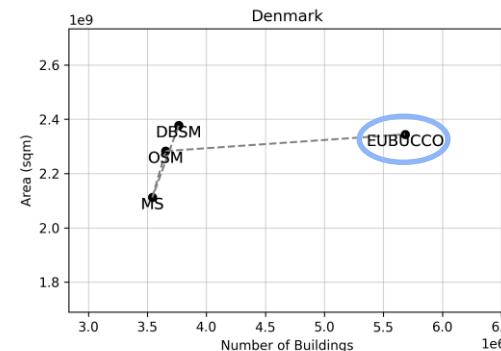
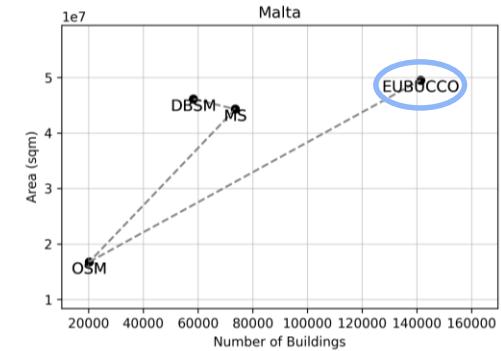
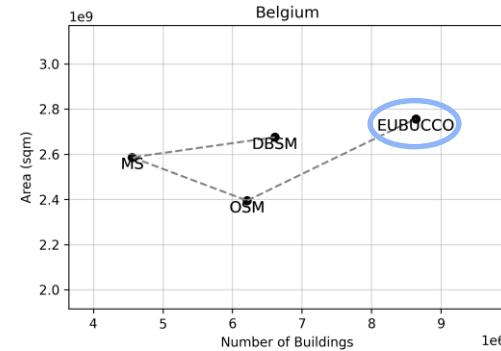
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Focus: **EUBUCCO** in countries  
where EUBUCCO is based on  
governmental data

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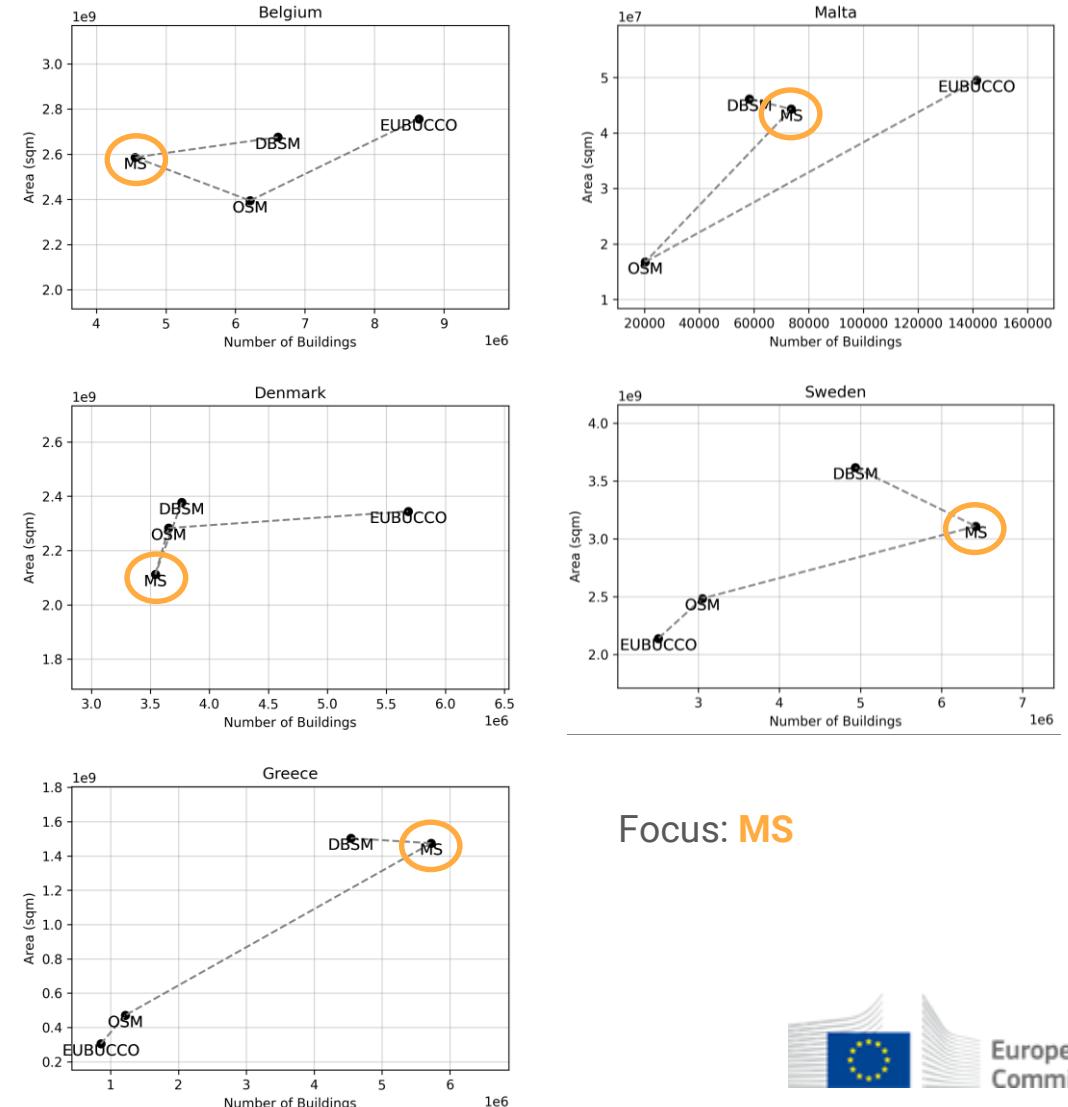
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Focus: **EUBUCCO** in  
countries where EUBUCCO  
is based on OSM

# Total number & total area of buildings

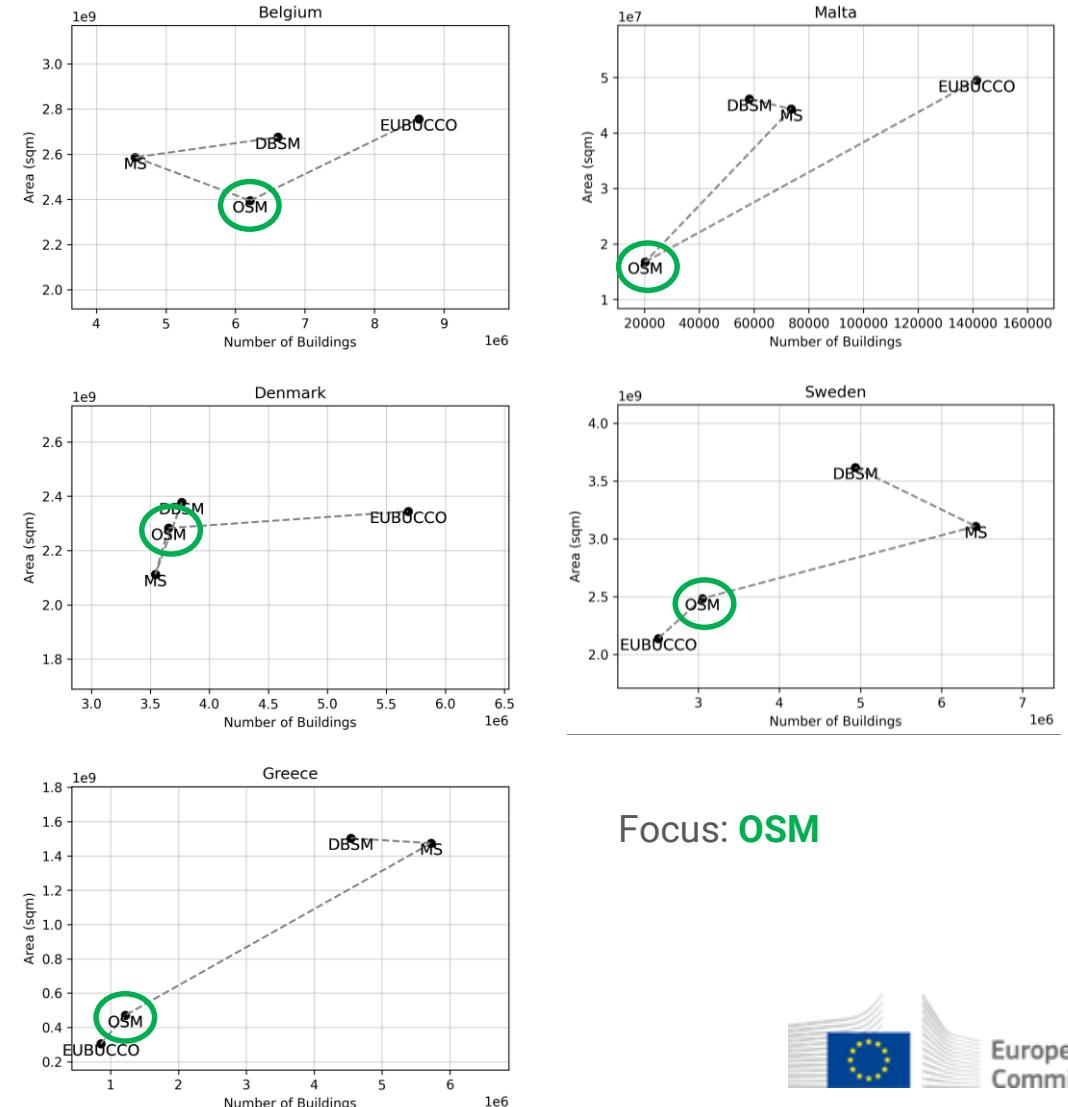
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Focus: MS

# Total number & total area of buildings

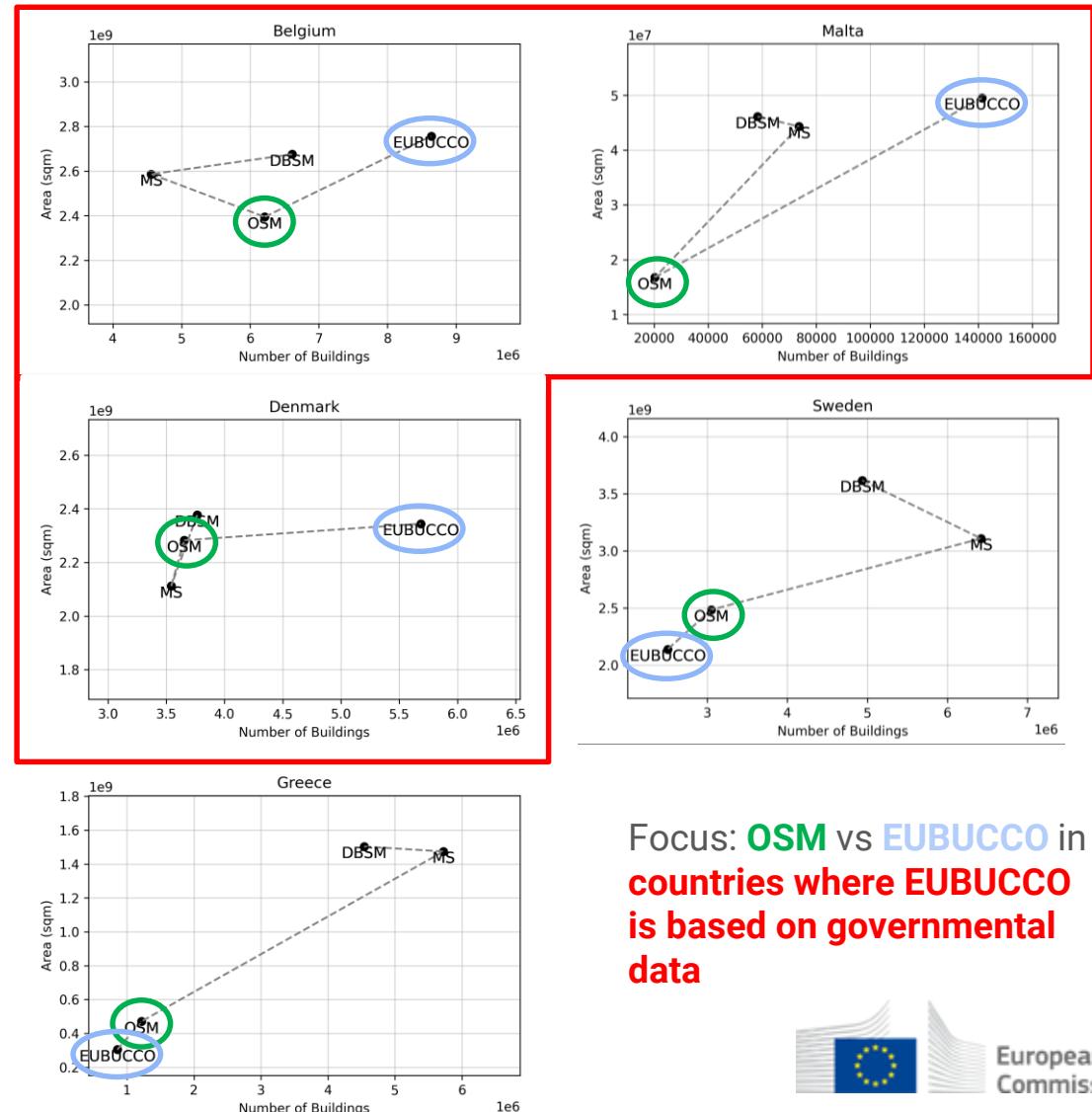
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Focus: OSM

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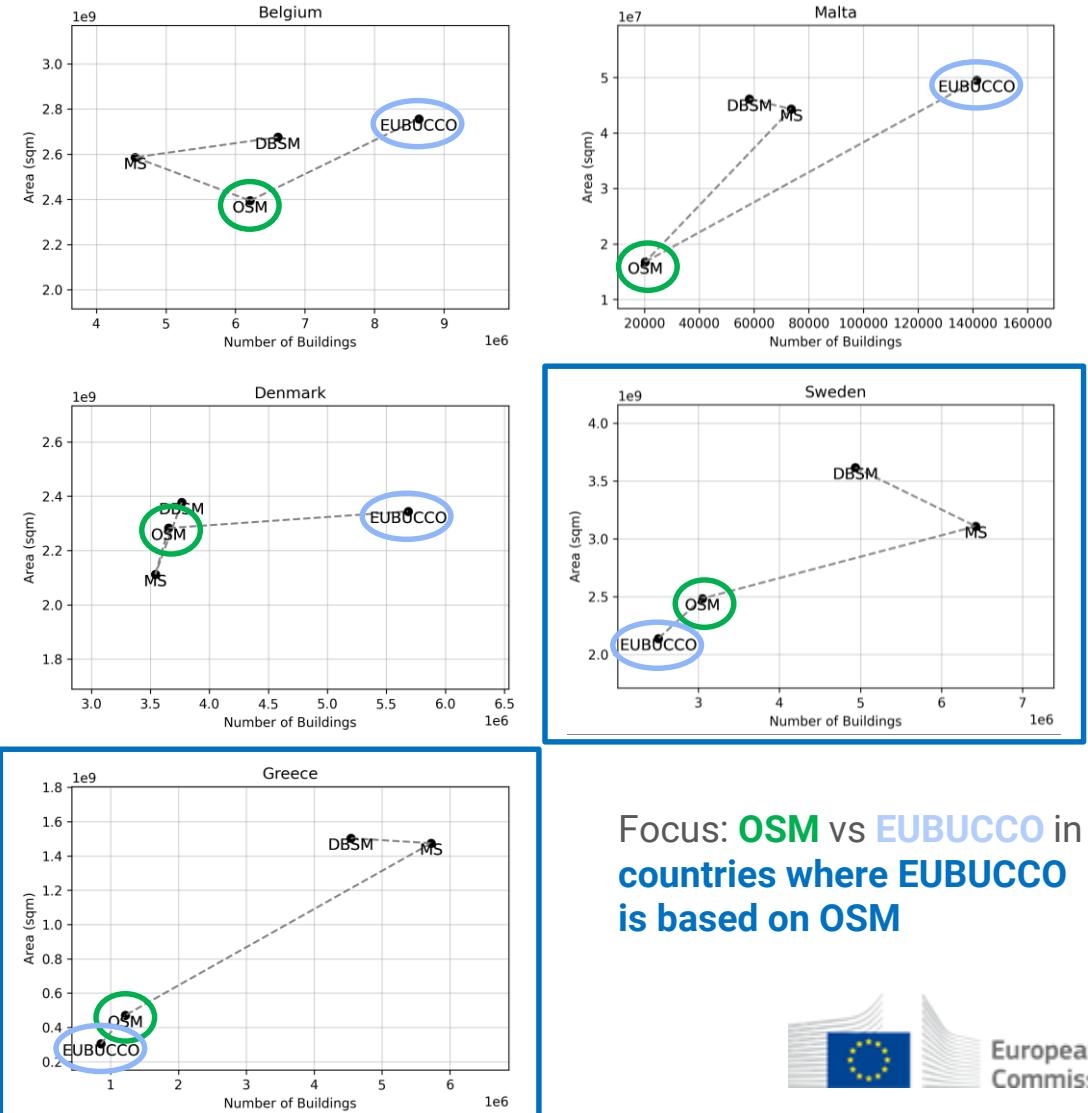
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Focus: **OSM** vs **EUBUCCO** in  
countries where EUBUCCO  
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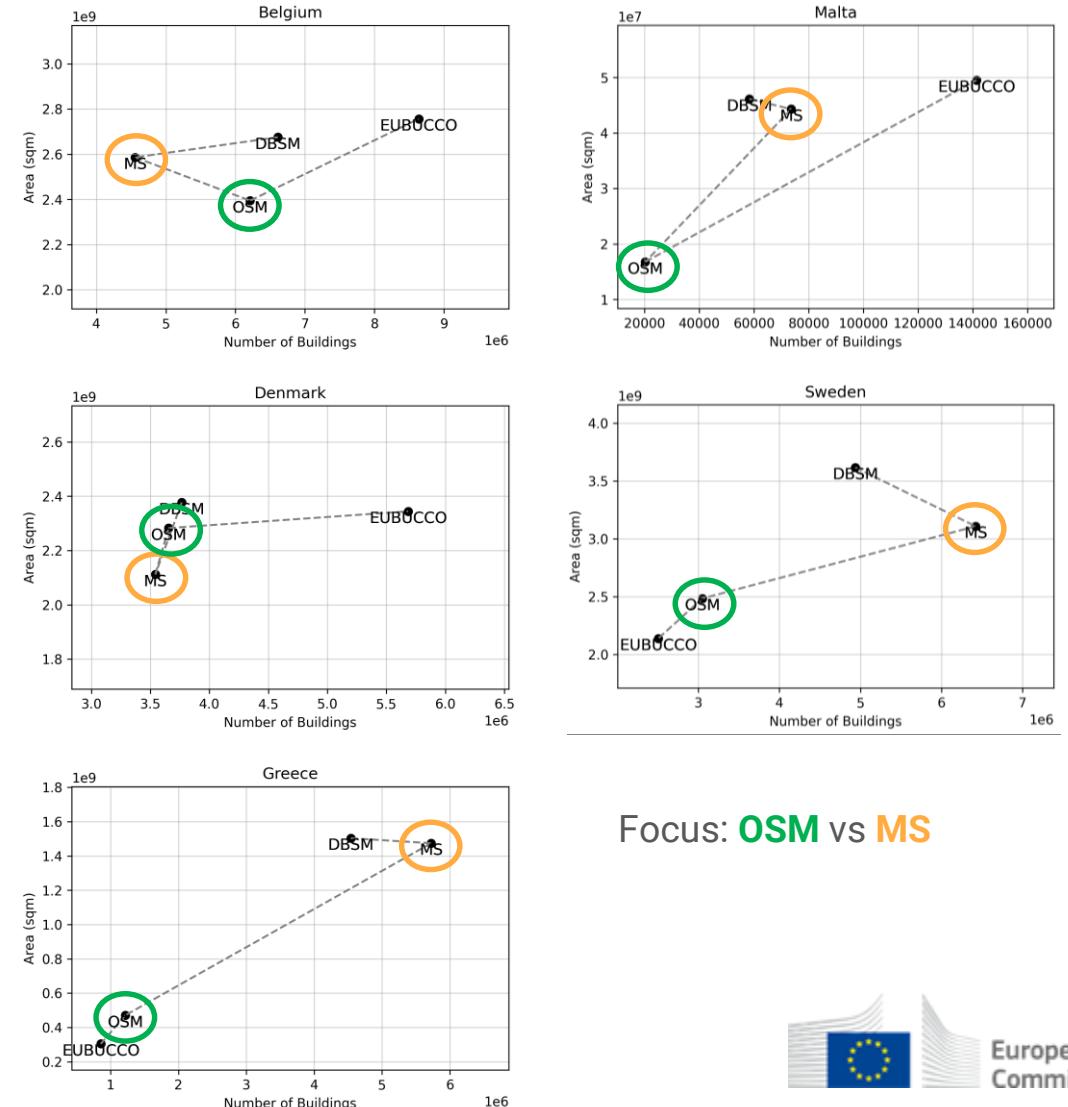
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Focus: **OSM** vs **EUBUCCO** in  
countries where EUBUCCO  
is based on OSM

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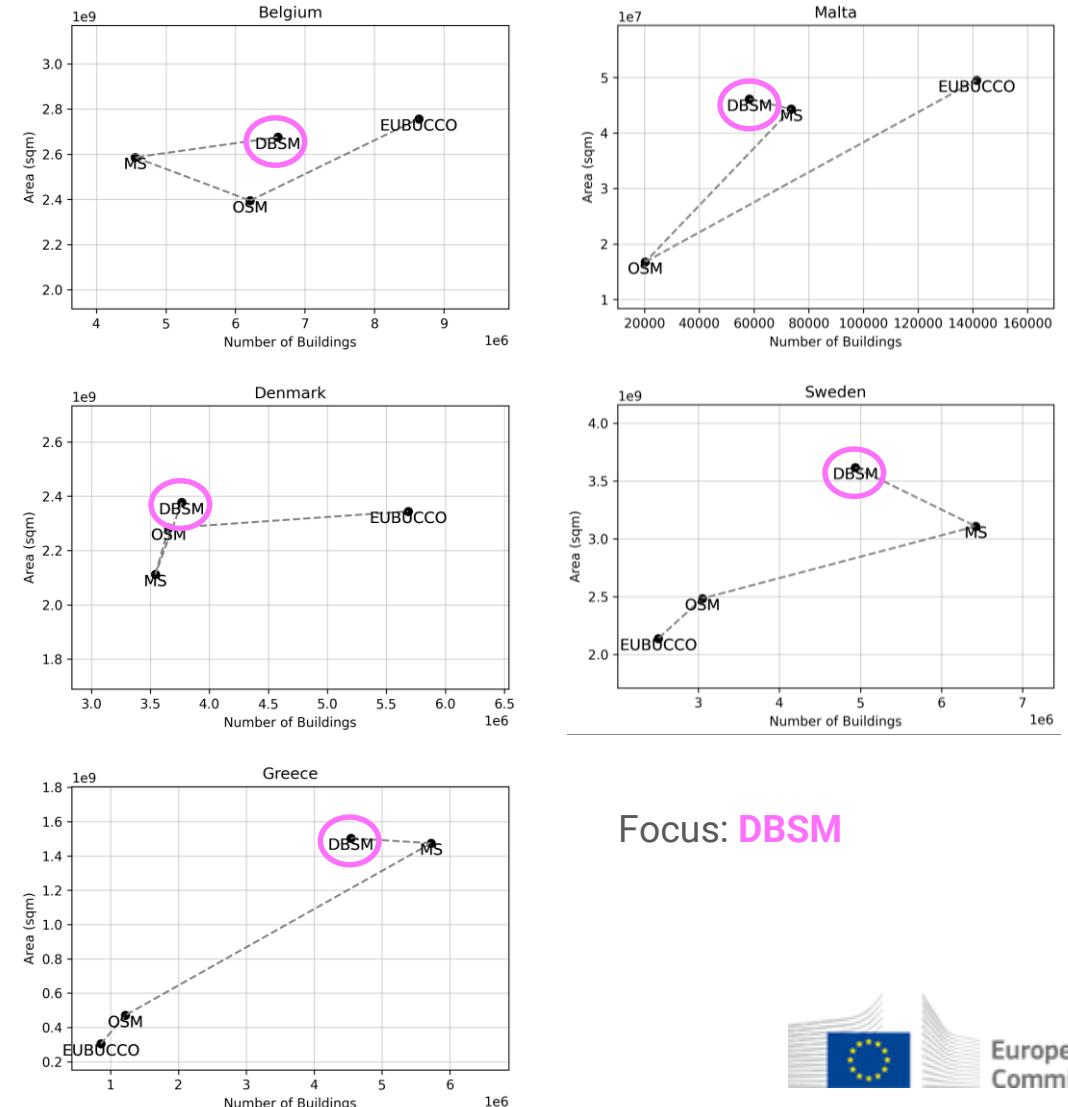
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Focus: OSM vs MS

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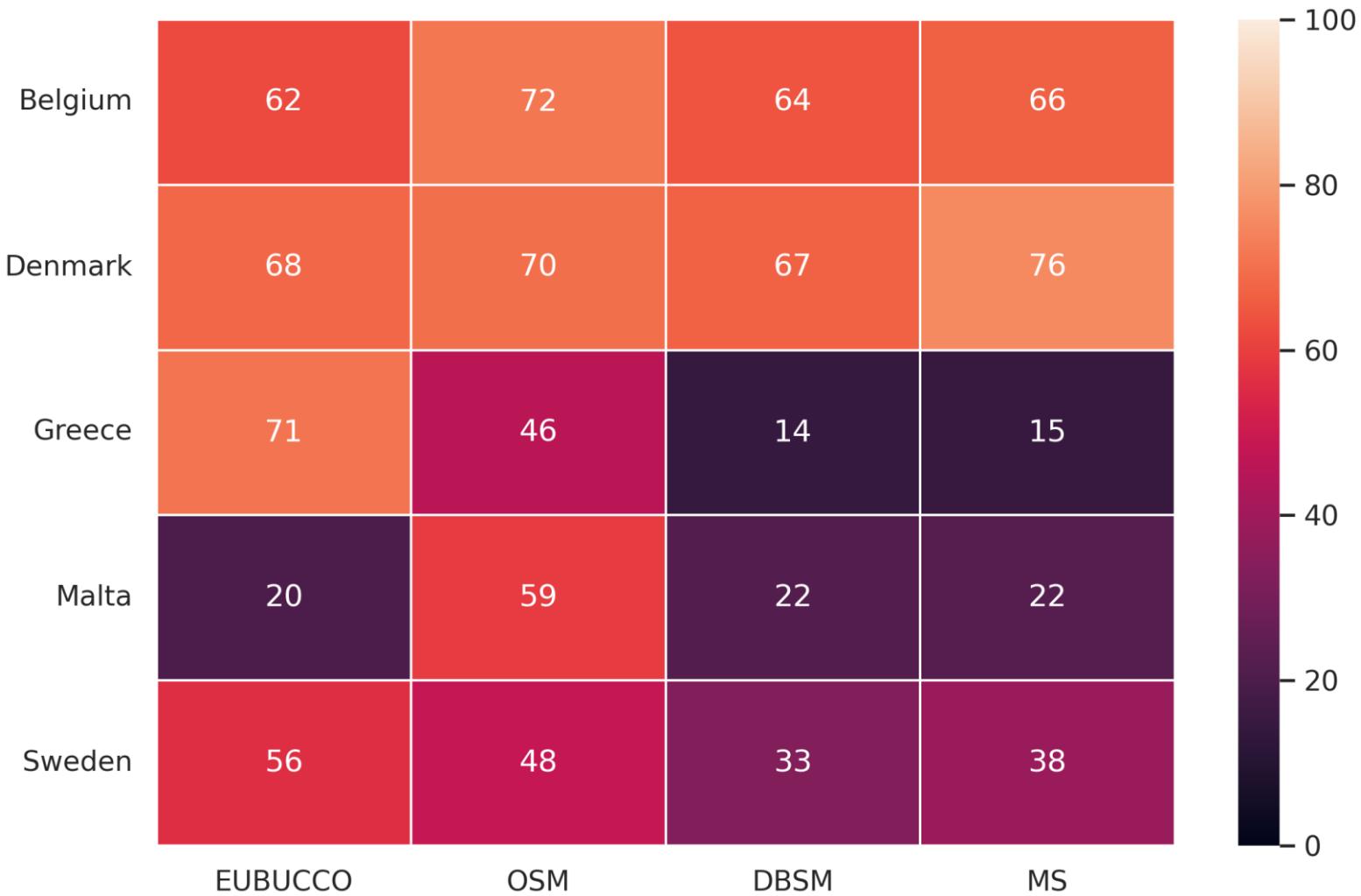
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Focus: DBSM

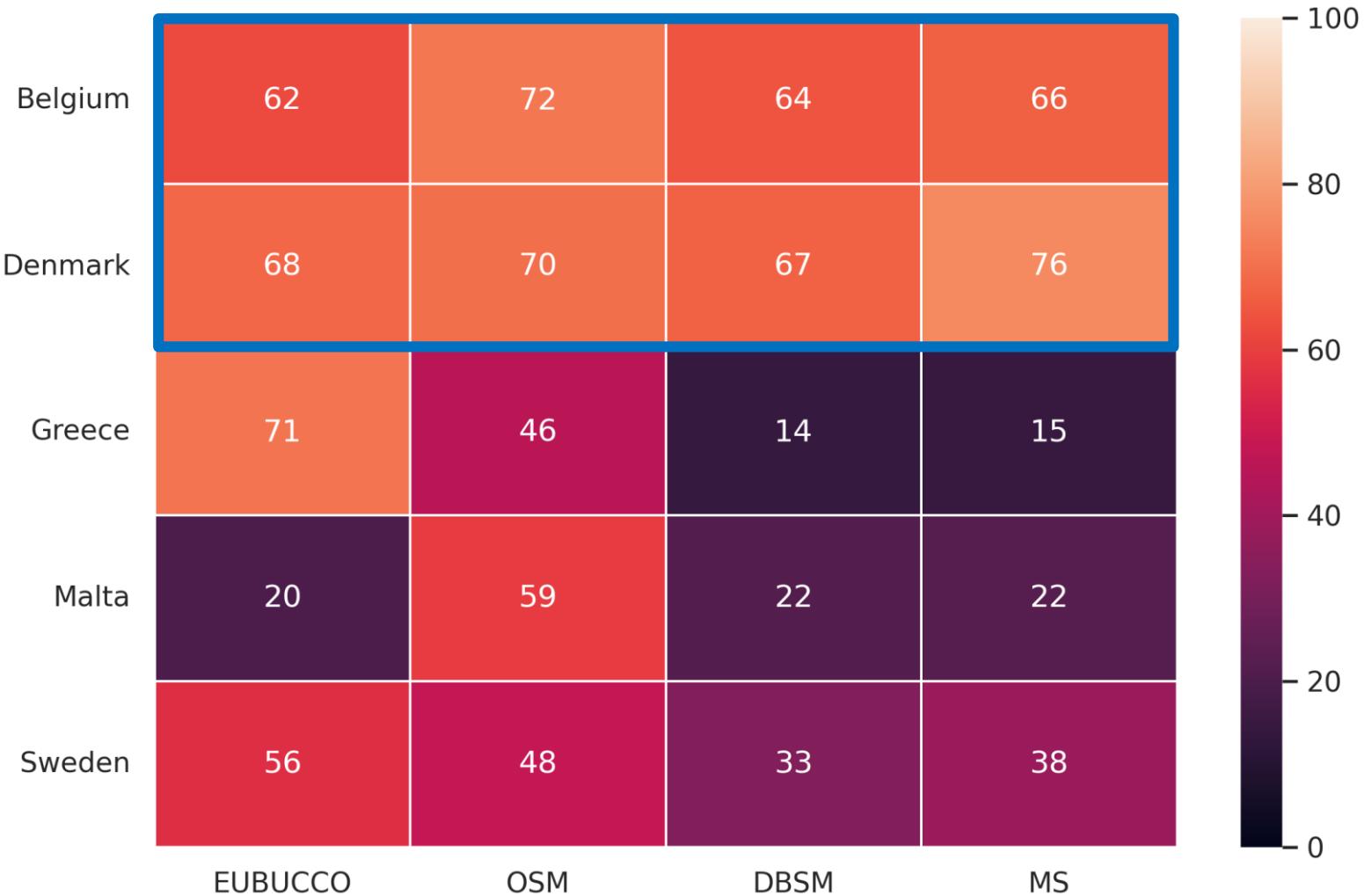
# Similarity of building datasets

- Intersection between all the 4 datasets
  - % of the area of each dataset represented by the area of intersection between the 4 datasets



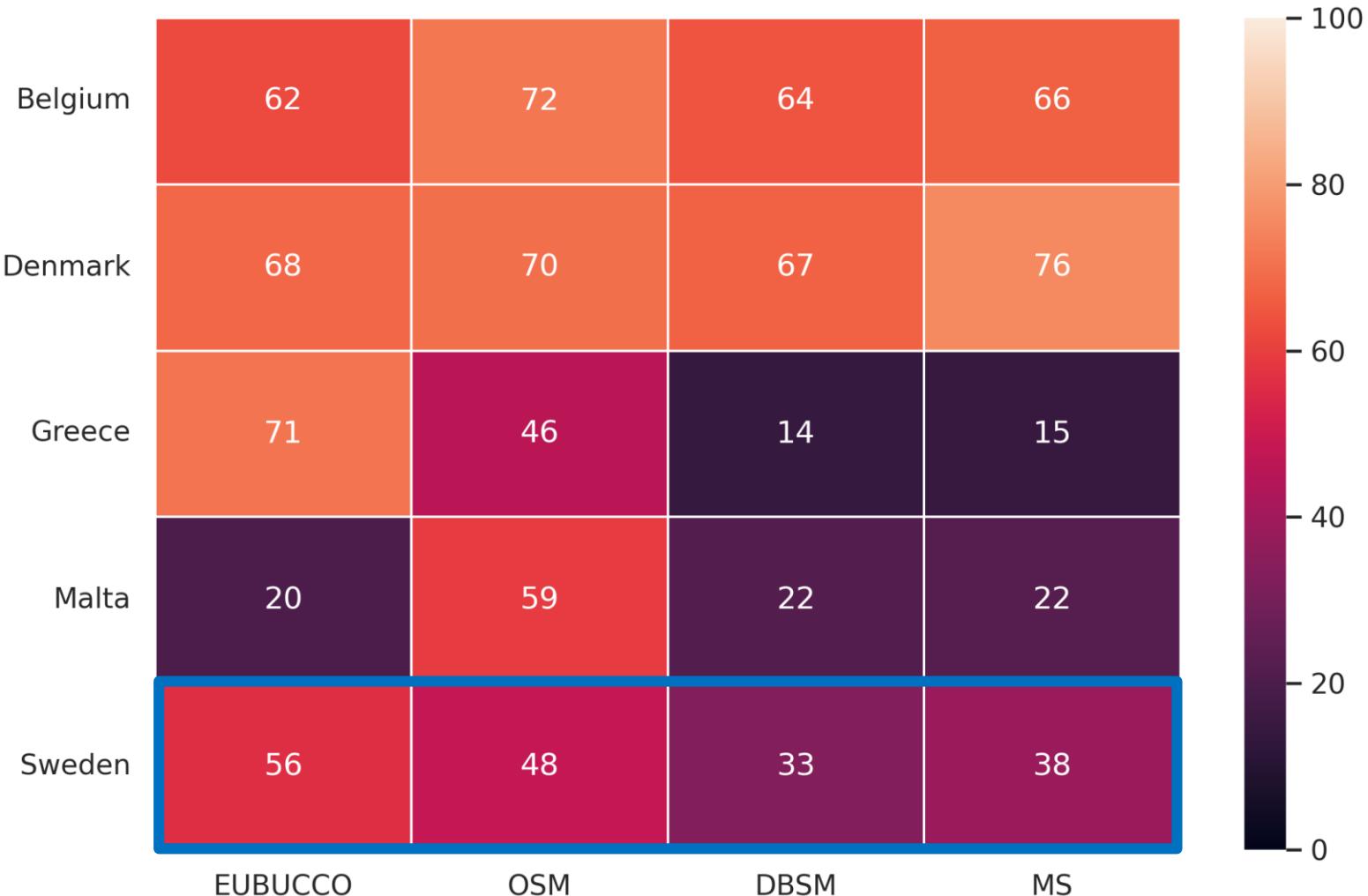
# Similarity of building datasets

- Intersection between all the 4 datasets
  - % of the area of each dataset represented by the area of intersection between the 4 datasets
  - from the **country perspective**



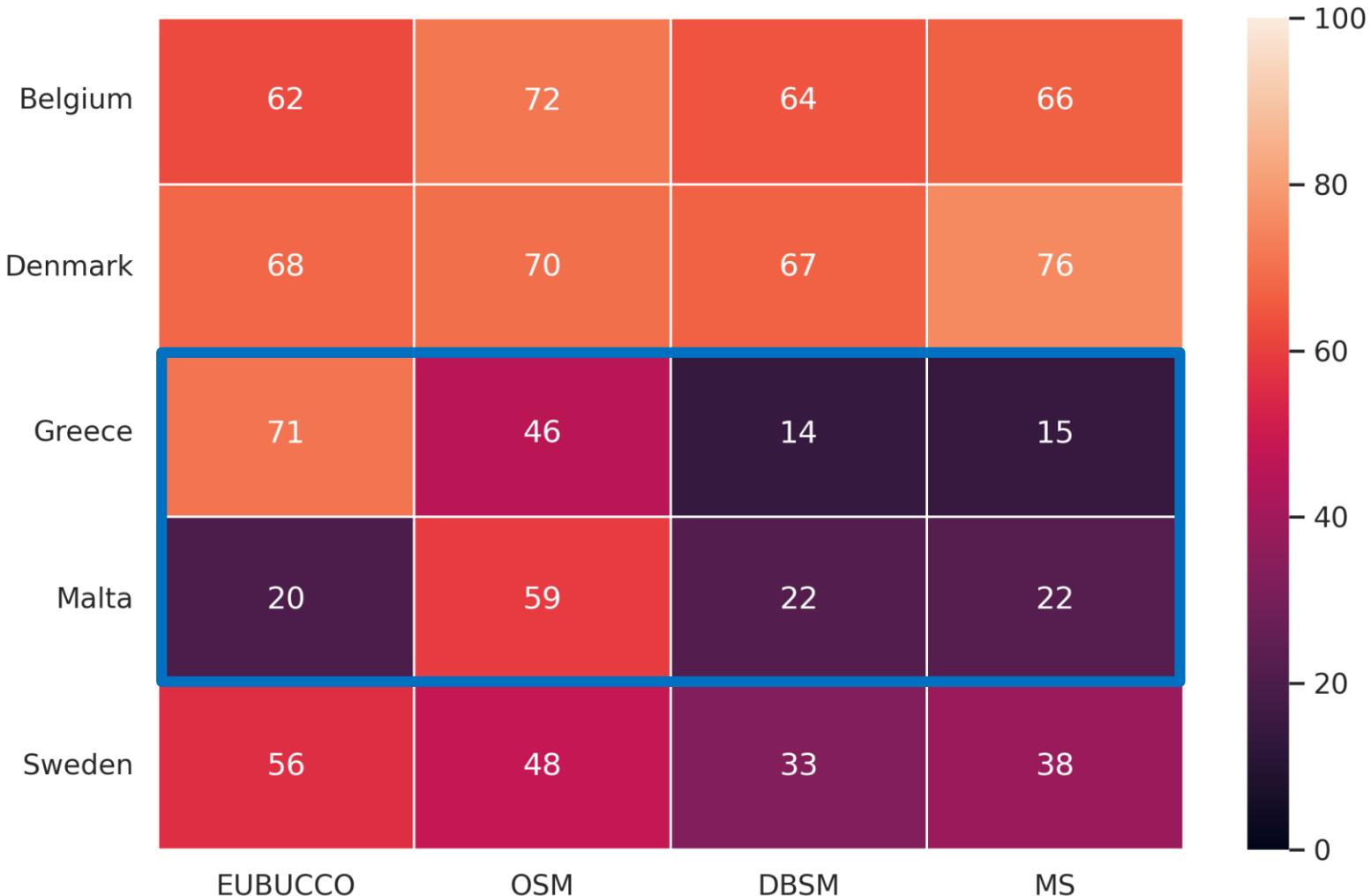
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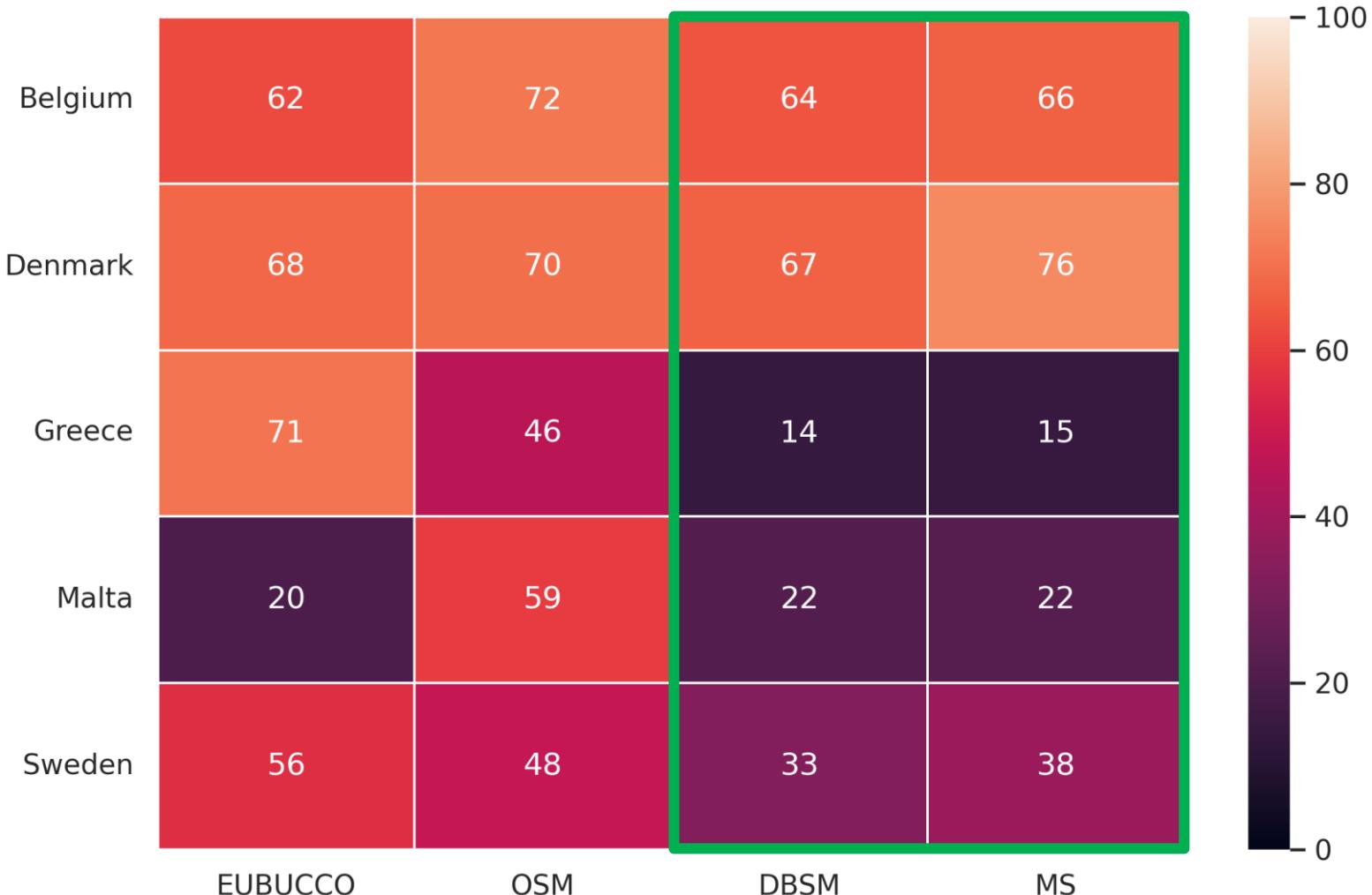
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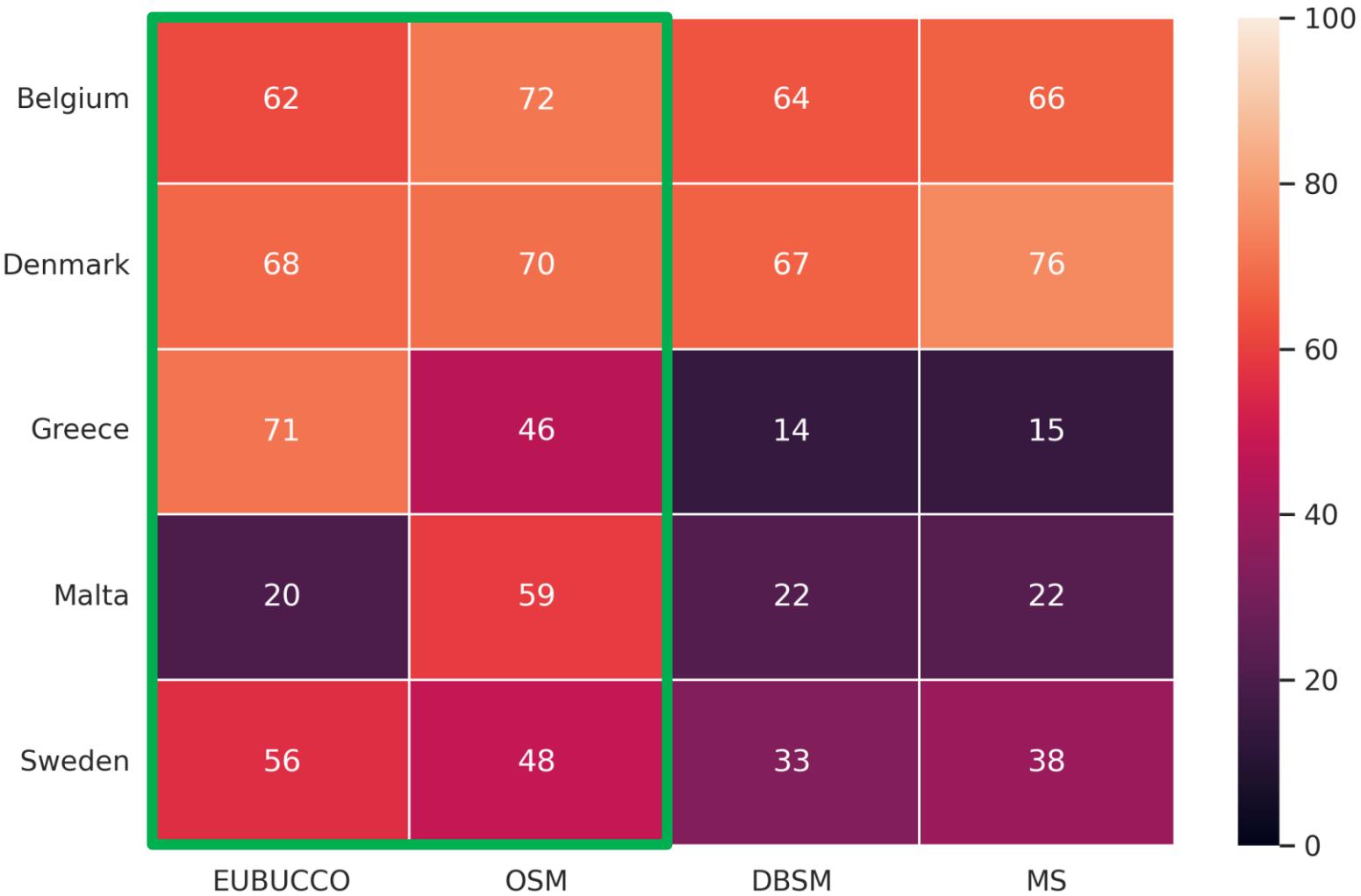
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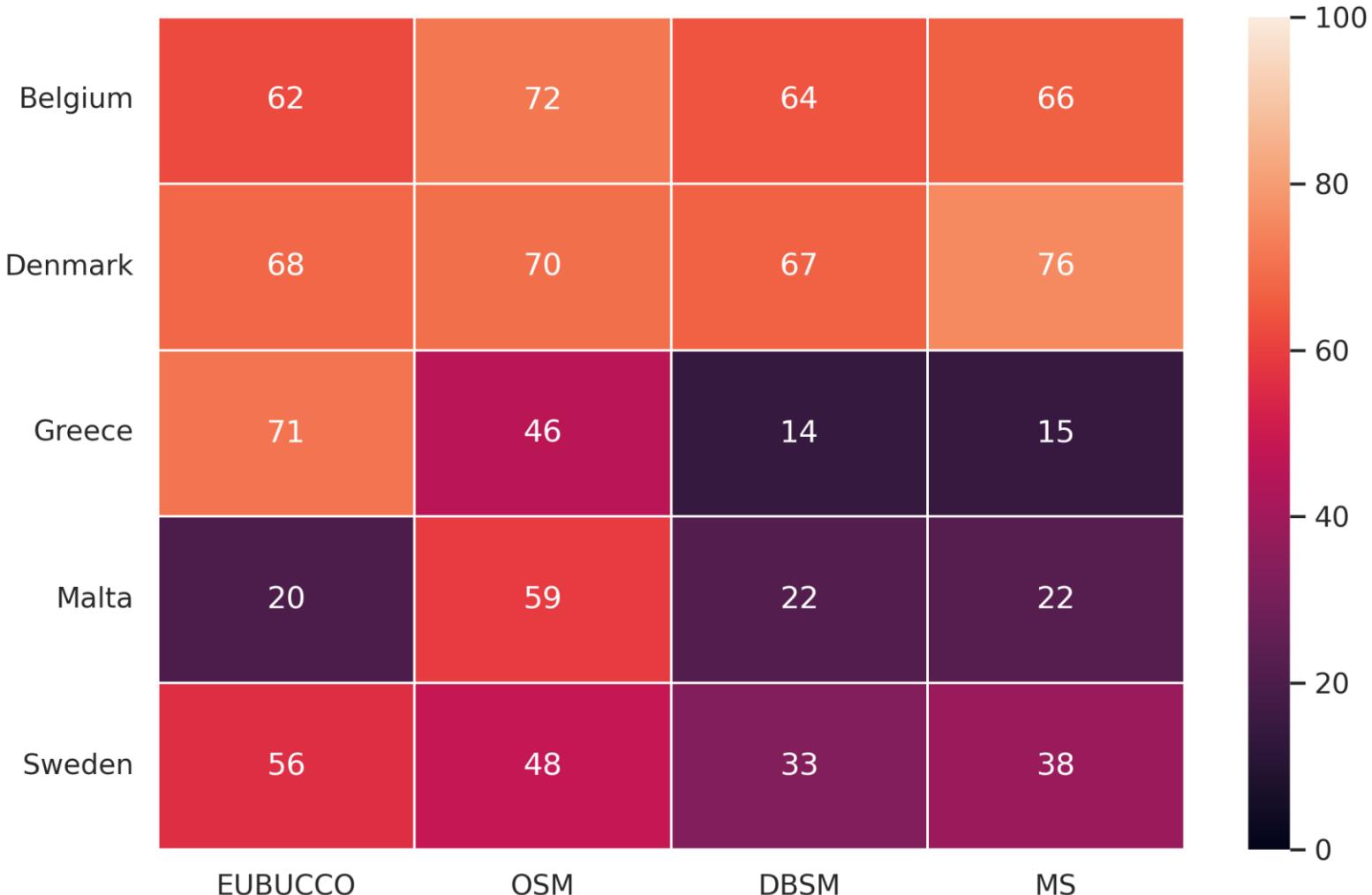
# Similarity of building datasets

- Intersection between all the 4 datasets
  - % of the area of each dataset represented by the area of intersection between the 4 datasets
  - from the **dataset perspective**



# Similarity of building datasets

- Intersection between all the 4 datasets
  - % of the area of each dataset represented by the area of intersection between the 4 datasets
  - % **lower in rural areas** (minimum 7%) and **higher in urban areas** (maximum 79%)



# Similarity of building datasets

- Intersection between each couple of datasets
  - % of the area of the dataset in the row, represented by the area of intersection between the dataset in the row and the dataset in the column

Belgium	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	86	71	81
DBSM	88	100	71	89
MS	76	74	100	69
OSM	94	99	74	100

Denmark	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	94	71	93
DBSM	93	100	70	96
MS	79	79	100	77
OSM	96	100	71	100

Greece	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	99	68	99
DBSM	20	100	88	31
MS	14	89	100	24
OSM	64	98	74	100

Malta	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	69	65	27
DBSM	74	100	86	36
MS	73	90	100	25
OSM	81	98	67	100

Sweden	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	98	57	97
DBSM	58	100	67	70
MS	39	78	100	45
OSM	84	99	56	100

# Similarity of building datasets

- Intersection between each couple of datasets
  - % of the area of the dataset in the row, represented by the area of intersection between the dataset in the row and the dataset in the column

Focus: **OSM vs EUBUCCO** in  
**countries where EUBUCCO is based on governmental data**

Belgium	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	86	71	81
DBSM	88	100	71	89
MS	76	74	100	69
OSM	94	99	74	100

Denmark	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	94	71	93
DBSM	93	100	70	96
MS	79	79	100	77
OSM	96	100	71	100

Greece	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	99	68	99
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OSM	64	98	74	100

Malta	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	69	65	27
DBSM	74	100	86	36
MS	73	90	100	25
OSM	81	98	67	100

Sweden	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	98	57	97
DBSM	58	100	67	70
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  - % of the area of the dataset in the row, represented by the area of intersection between the dataset in the row and the dataset in the column

Focus: DBSM vs EUBUCCO and MS vs EUBUCCO in countries where EUBUCCO is based on governmental data

Belgium	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	86	71	81
DBSM	88	100	71	89
MS	76	74	100	69
OSM	94	99	74	100

Denmark	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	94	71	93
DBSM	93	100	70	96
MS	79	79	100	77
OSM	96	100	71	100

Greece	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	99	68	99
DBSM	20	100	88	31
MS	14	89	100	24
OSM	64	98	74	100

Malta	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	69	65	27
DBSM	74	100	86	36
MS	73	90	100	25
OSM	81	98	67	100

Sweden	EUBUCCO	DBSM	MS	OSM
EUBUCCO	100	98	57	97
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  - % of the area of the dataset in the row, represented by the area of intersection between the dataset in the row and the dataset in the column

Focus: **EUBUCCO vs OSM** in  
**countries where EUBUCCO is based on OSM**

Belgium	<b>EUBUCCO</b>	<b>DBSM</b>	<b>MS</b>	<b>OSM</b>
<b>EUBUCCO</b>	100	86	71	81
<b>DBSM</b>	88	100	71	89
<b>MS</b>	76	74	100	69
<b>OSM</b>	94	99	74	100

Denmark	<b>EUBUCCO</b>	<b>DBSM</b>	<b>MS</b>	<b>OSM</b>
<b>EUBUCCO</b>	100	94	71	93
<b>DBSM</b>	93	100	70	96
<b>MS</b>	79	79	100	77
<b>OSM</b>	96	100	71	100

Greece	<b>EUBUCCO</b>	<b>DBSM</b>	<b>MS</b>	<b>OSM</b>
<b>EUBUCCO</b>	100	99	68	99
<b>DBSM</b>	20	100	88	31
<b>MS</b>	14	89	100	24
<b>OSM</b>	64	98	74	100

Malta	<b>EUBUCCO</b>	<b>DBSM</b>	<b>MS</b>	<b>OSM</b>
<b>EUBUCCO</b>	100	69	65	27
<b>DBSM</b>	74	100	86	36
<b>MS</b>	73	90	100	25
<b>OSM</b>	81	98	67	100

Sweden	<b>EUBUCCO</b>	<b>DBSM</b>	<b>MS</b>	<b>OSM</b>
<b>EUBUCCO</b>	100	98	57	97
<b>DBSM</b>	58	100	67	70
<b>MS</b>	39	78	100	45
<b>OSM</b>	84	99	56	100

# Similarity of building datasets

- Intersection between each couple of datasets
  - % of the area of the dataset in the row, represented by the area of intersection between the dataset in the row and the dataset in the column

Belgium	EUBUCCO	DBSM	MS	OSM
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Focus: OSM vs MS

# Similarity of building datasets

- Intersection between each couple of datasets
  - % of the area of the dataset in the row, represented by the area of intersection between the dataset in the row and the dataset in the column
  - similarity higher in urban areas & lower in rural areas** (OSM vs MS: maximum 84-82%, minimum 68-75% in Denmark)

Belgium	EUBUCCO	DBSM	MS	OSM
<b>EUBUCCO</b>	100	86	71	81
<b>DBSM</b>	88	100	71	89
<b>MS</b>	76	74	100	69
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<b>OSM</b>	84	99	56	100

# Code: <https://github.com/eurogeoss/building-datasets>

- Written in **Python**, **parallelised** & available as Jupyter Notebooks
- Main **libraries**
  - Pandas, GeoPandas, Dask-GeoPandas, Shapely, Plotly, Seaborn
- **License:** EUPL v1.2

README EUPL-1.2 license

## building-datasets

The repository contains code for importing and analyzing European building data.

0-[functions]-0\_methods.ipynb The notebook contains common functions for loading raw data, loading data enriched with NUTS information using the dask\_geopandas library, a function for spatial join executed in parallel to calculate the area of each building, the number of vertices, an aggregation function for the results obtained from the spatial join, and a function for drawing the map of provinces of each input country with respect to the degree of urbanization.

1-[data\_processing]-0\_mapping\_buildings\_to\_nuts.ipynb: This notebook contains the code for processing raw data and mapping each building to the province (NUTS 3 LEVEL) in which it is located.

1-[data\_processing]-1\_compute\_overlapping\_area\_among\_datasets.ipynb: The code performs intersection between pairs of datasets to measure the degree of overlap of building geometries. Additionally, an intersection is performed across all datasets to measure the common area. Also, some images showing individual intersections between pairs of datasets are generated as output.

2-[data\_analysis]-0\_dataset\_comparison.ipynb: This notebook contains the code used to compute statistics for comparing various datasets.

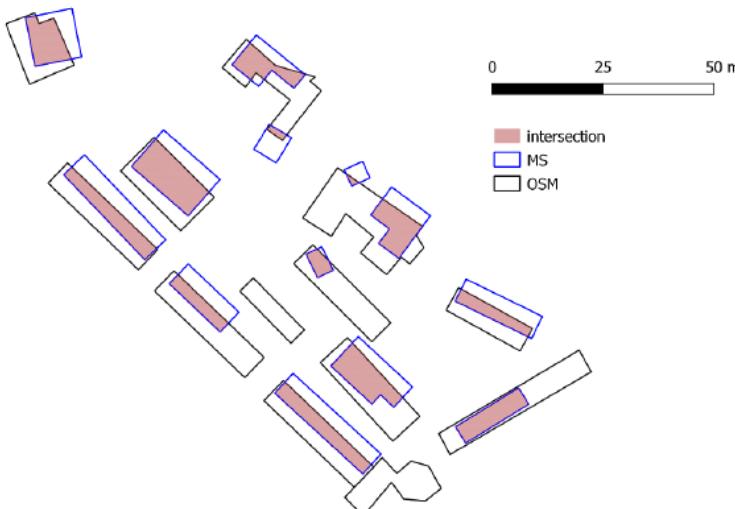
# Conclusions

# Discussion

- First comparison of (some) non-governmental open building datasets
- Relative **comparison** (not quality assessment) of datasets is the way to go
  - **different sources**: governments, citizens, private companies
  - **different production/update approaches**: digitalisation, machine learning, conflation

# Discussion

- First comparison of (some) non-governmental open building datasets
- Relative **comparison** (not quality assessment) of datasets is the way to go
  - **different sources**: governments, citizens, private companies
  - **different production/update approaches**: digitalisation, machine learning, conflation
  - **variability** with countries & regions



# Discussion

- Pros, cons & recommendations in using the 4 datasets
  - **OSM**: quality depends on the presence of an active community & imports; completeness increases from rural to urban areas; using the latest ‘version’ is always recommended
  - **EUBUCCO**: governmental datasets represent a reliable source, but may be outdated; OSM changes quickly and this is not captured
  - **MS**: heterogeneous results – appears as a complete dataset, but position accuracy is sometimes questionable
  - **DBSM**: combining multiple datasets overcomes their issues and maximises completeness

# Future work

- Extend the study to **validate results**
  - to additional **countries/areas** (e.g. EU27)
  - to additional **datasets** (e.g. Google Open Buildings & Overture)
  - to **attributes**
- Complement the study with a **qualitative analysis** of the datasets
  - usability: licensing, accessibility, reliability
  - quality: coverage, granularity, QA/QC mechanisms
  - governance: decision-making process, community, sustainability

# Thank you!

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