BERGISCHE UNIVERSITÄT WUPPERTAL

Leibniz Institute of Ecological Urban and Regional Development

IWU

90th EUROCONSTRUCT Conference
23-24 November 2020, Munich

Approach to an Unknown: Representative Sample Survey to Explore the Non-residential Building Stock in Germany - Methods and first Results -

Michael Hörner
Institut Wohnen und Umwelt
Darmstadt

KFW

Energy Performance Analysis is being carried out using VSA 2.0, a tool provided by IWU with funding of KfW Group.

ENOB:dataNWG, a Research Project
funded by the Research Initiative
Research for Energy Optimised Buildings (EnOB)
within the Framework of the
6th Energy Research Programme of the Federal Government
Reference Number 03ET1315

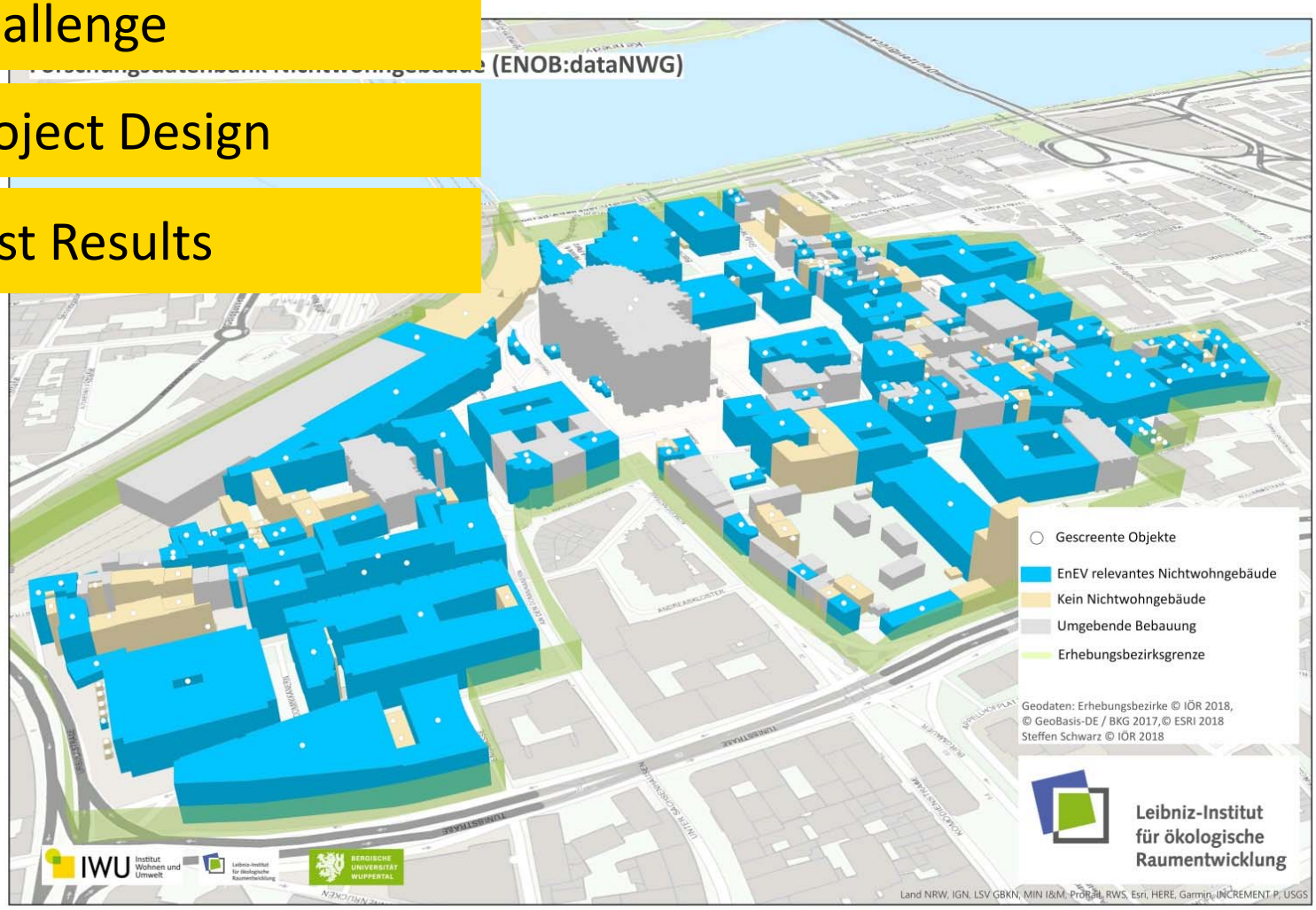
Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

Research Database Non-residential Buildings
(ENOB:dataNWG)

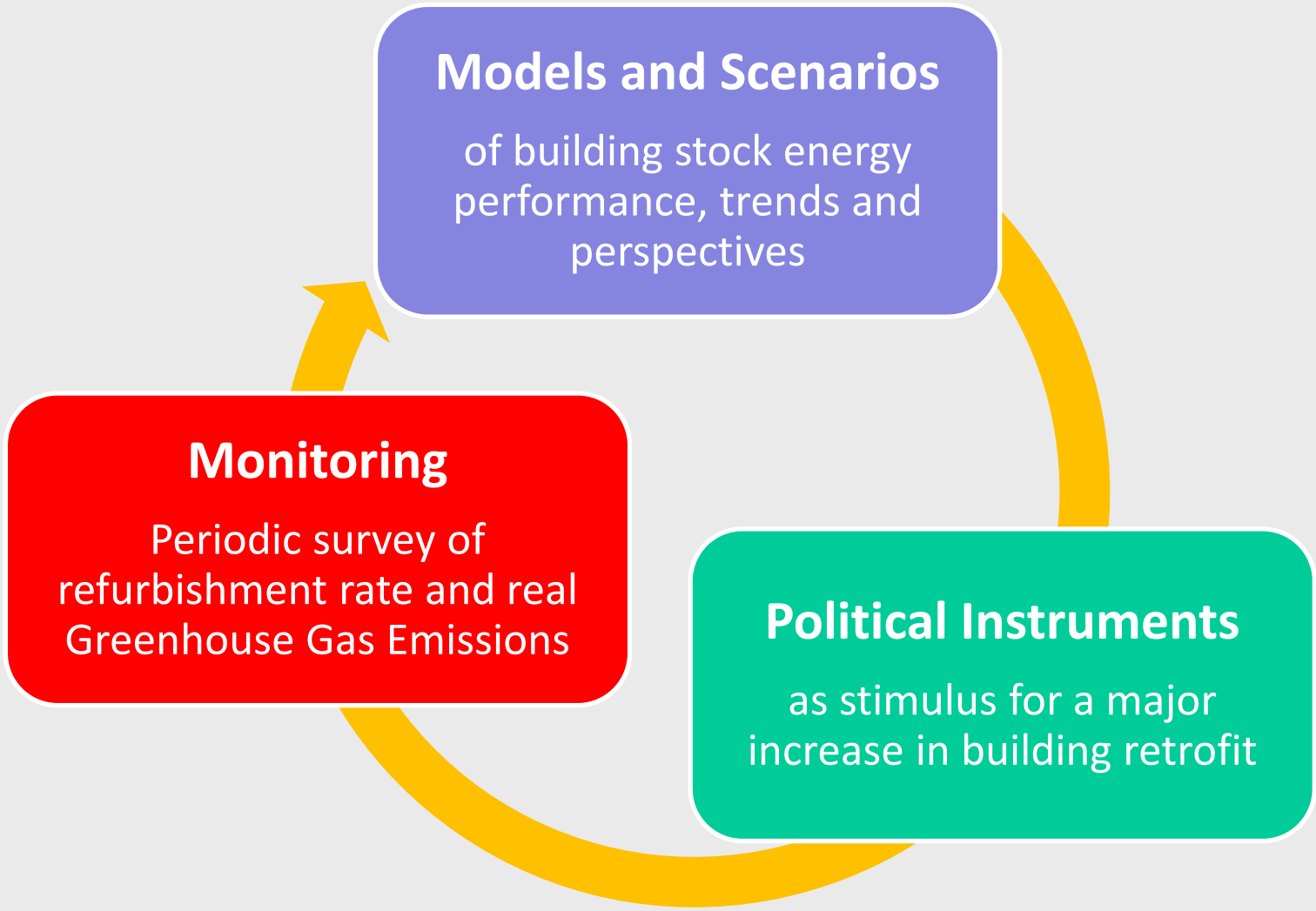
1 Challenge

2 Project Design

3 First Results

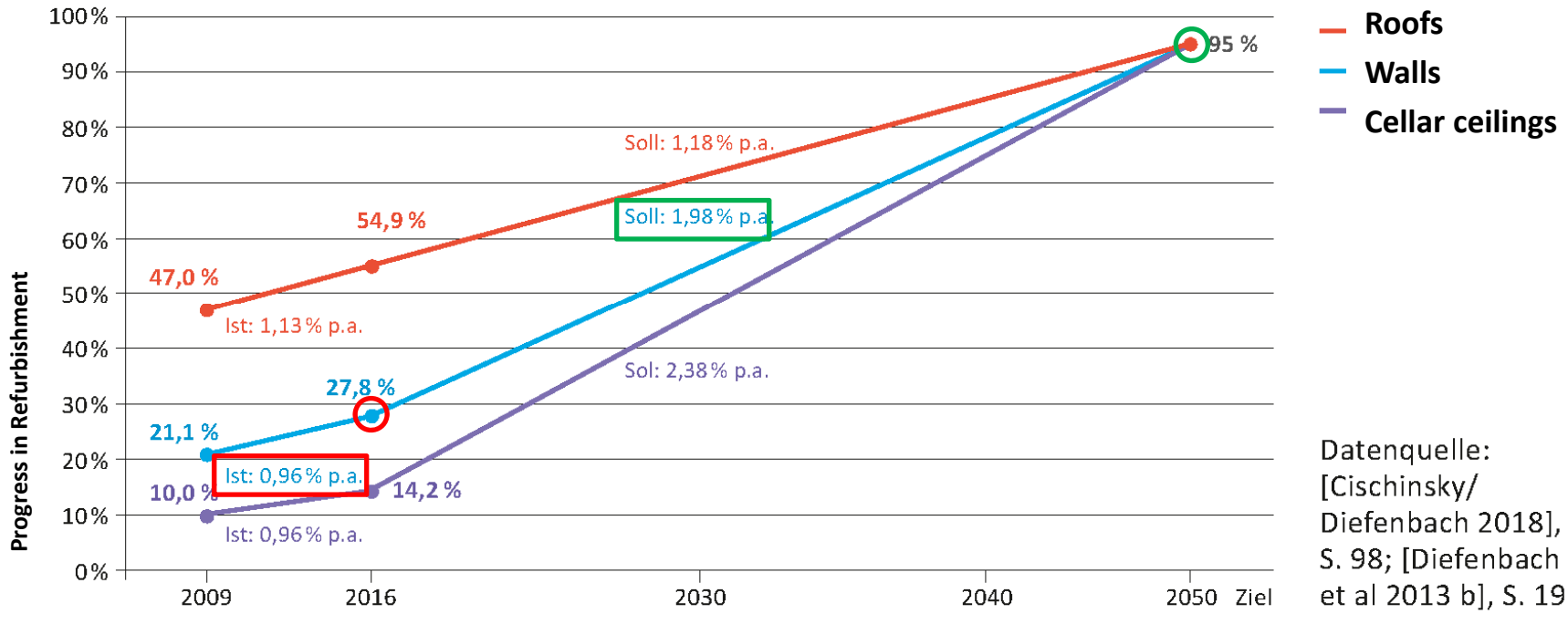


1.1 Make the Building Stock Paris aligned ...



ENOB:dataNWG, euroconstruct 2020, online

1.2 Energy-related Refurbishment in the Residential Building Stock



Datenquelle: [Cischinsky/ Diefenbach 2018], S. 98; [Diefenbach et al 2013 b], S. 19

Refurbishment Progress

Actual percentages of building envelope area (built before 1978) already refurbished in 2009 and 2016 and target value 2050.

Net Refurbishment Rate

Actual percentage of building envelope area refurbished every year and target values

ENOB:dataNWG, euroconstruct 2020, online

1.3 Challenge of Non-residential Buildings

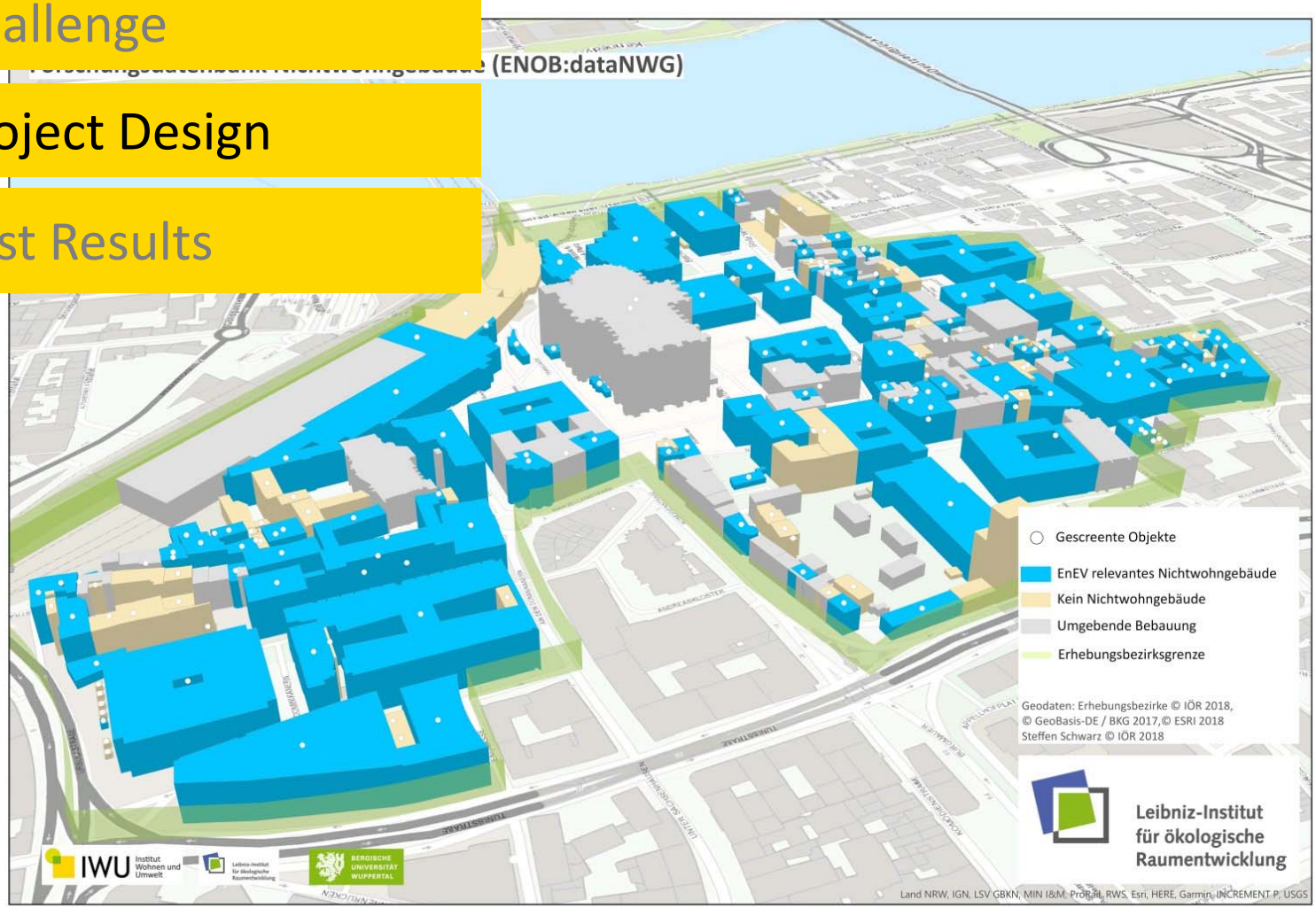
- The **Target Population** is unknown.
  - There is no **National Building Register** in Germany with owners‘ contact information.
  - **Statistics of Construction Activity** covers new construction activities mainly, no reliable conclusions regarding the quality of the non-residential building stock in Germany possible.
  - Official statistical data from the **Census on Buildings and Housing** is available for the residential building sector only. Official data on the stock of non-residential buildings is not available.
- Previous Primary Data Elicitation and Research towards non-residential buildings focused on **Archetype Approaches** or the analysis of given **Subsets** of the building stock leading to **descriptive Statistics** only, no extrapolation to the whole stock possible.
- A **Census**, i.e. a full survey, is out of reach in terms of time and expense.
- A **Sample Survey** on non-residential Buildings seems conceivable provided an appropriate **Sampling Frame** can be found.

Research Database Non-residential Buildings
(ENOB:dataNWG)

1 Challenge

2 Project Design

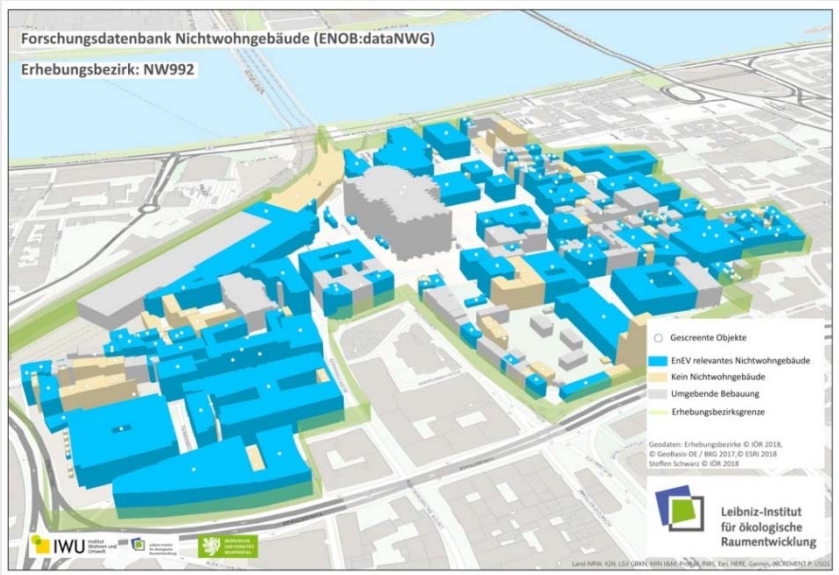
3 First Results

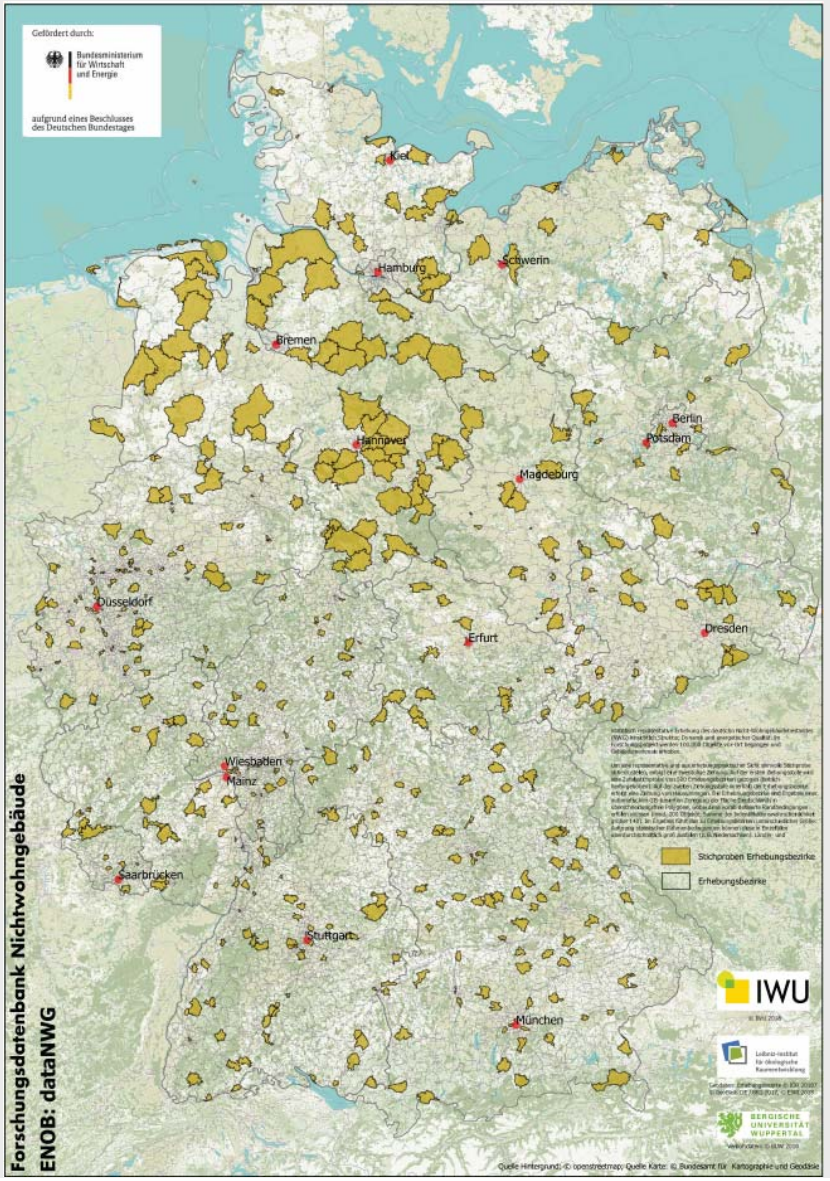


2.1 Frame of Sampling Units

Geospatial Data are our choice for a Sampling Frame, they are available for all buildings in Germany from Surveying Authorities.

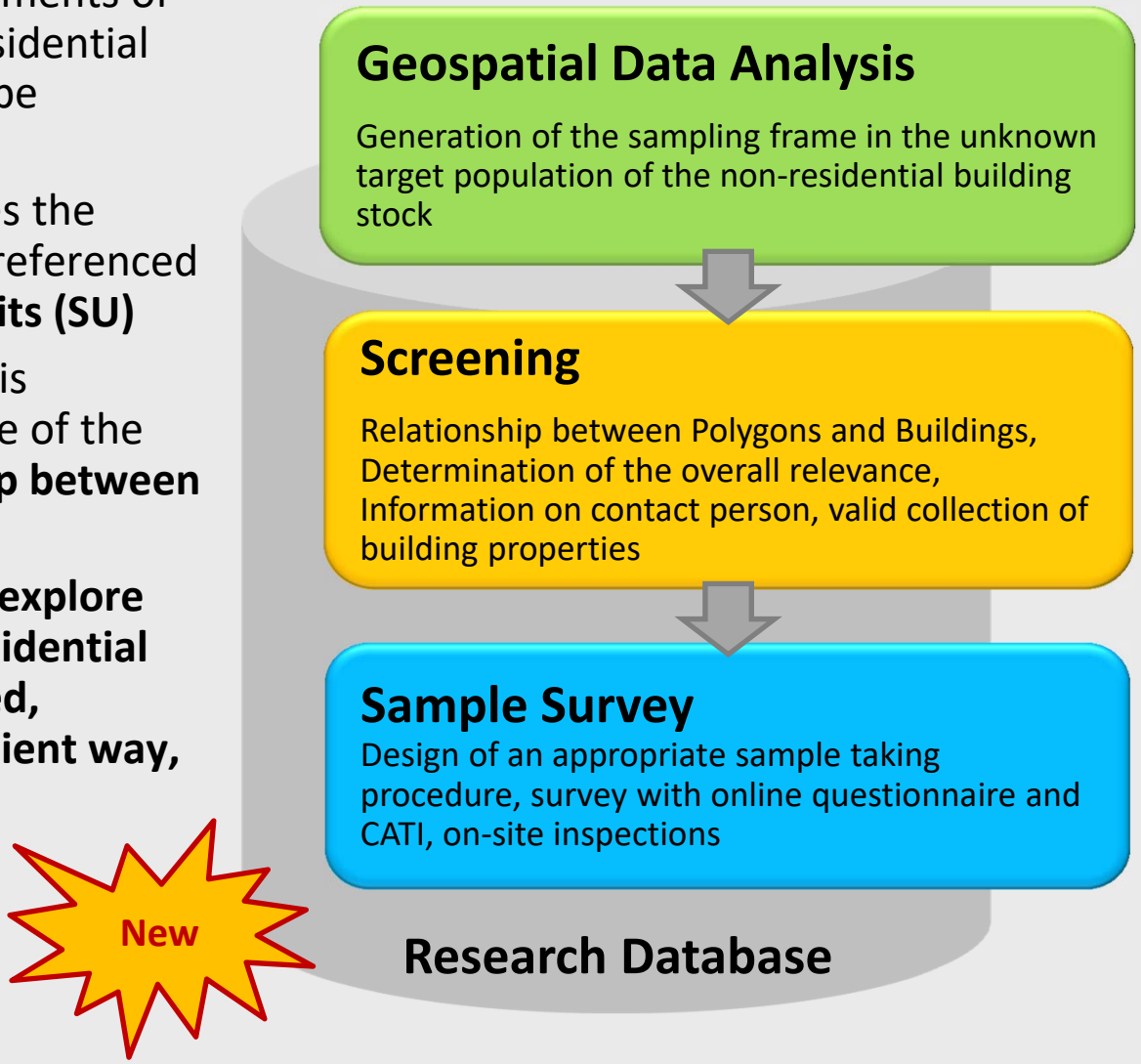
- Official Building Polygons (HU-DE)
  + Official 3D Building Models (LoD1-DE)
- Two-stage Stratified Sample Taking
  - Survey Districts as Primary Sampling Units (PSU)
  - Building Polygons as Secondary Sampling Units (SSU)





2.2 From Sampling Units to Research Objects

- **Research Objects (RO)** are the elements of the Target Population, i.e. non-residential buildings, which are supposed to be investigated in a Sample Survey.
- Geospatial Data Analysis generates the Sampling Frame based upon geo-referenced building polygons as **Sampling Units (SU)**
- **Screening** of the buildings on site is necessary to identify the relevance of the SU and to establish the **relationship between the SU and the RO**.
- **This new approach enables us to explore the sector of the German non-residential buildings in a statistically unbiased, regionally balanced and cost efficient way, for the first time.**



ENOB:dataNWG, euroconstruct 2020, online

2.3 Project Design

1. Analysis of Geospatial Data

- Processing of 52 Mio. building polygons
- Adding building function and about 40 further attributes

2. Sample Taking

- Two-stage stratified sample
- 500 Districts per 200 Building Polygons each

3. Screening

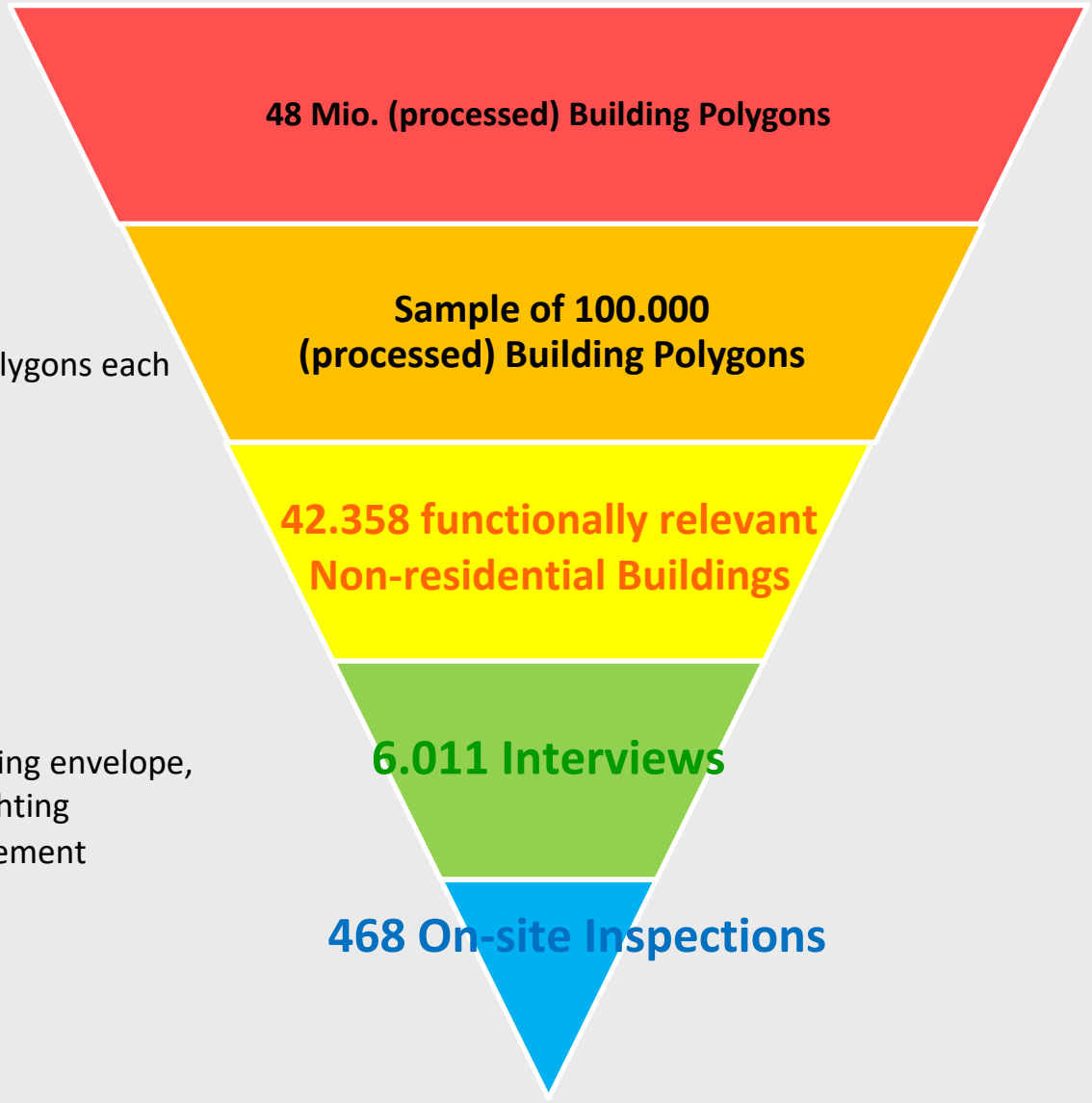
- Presumable relevance
- Relation Polygons : Buildings
- Owners‘ adresses
- Basic building attributes

4. Interviews

- Structural attributes
- Energy-related attributes: Building envelope, heating, cooling, ventilation, lighting
- Owner category, facility management

5. On-site Inspections

- Measured consumption
- Calculated demand
- usage

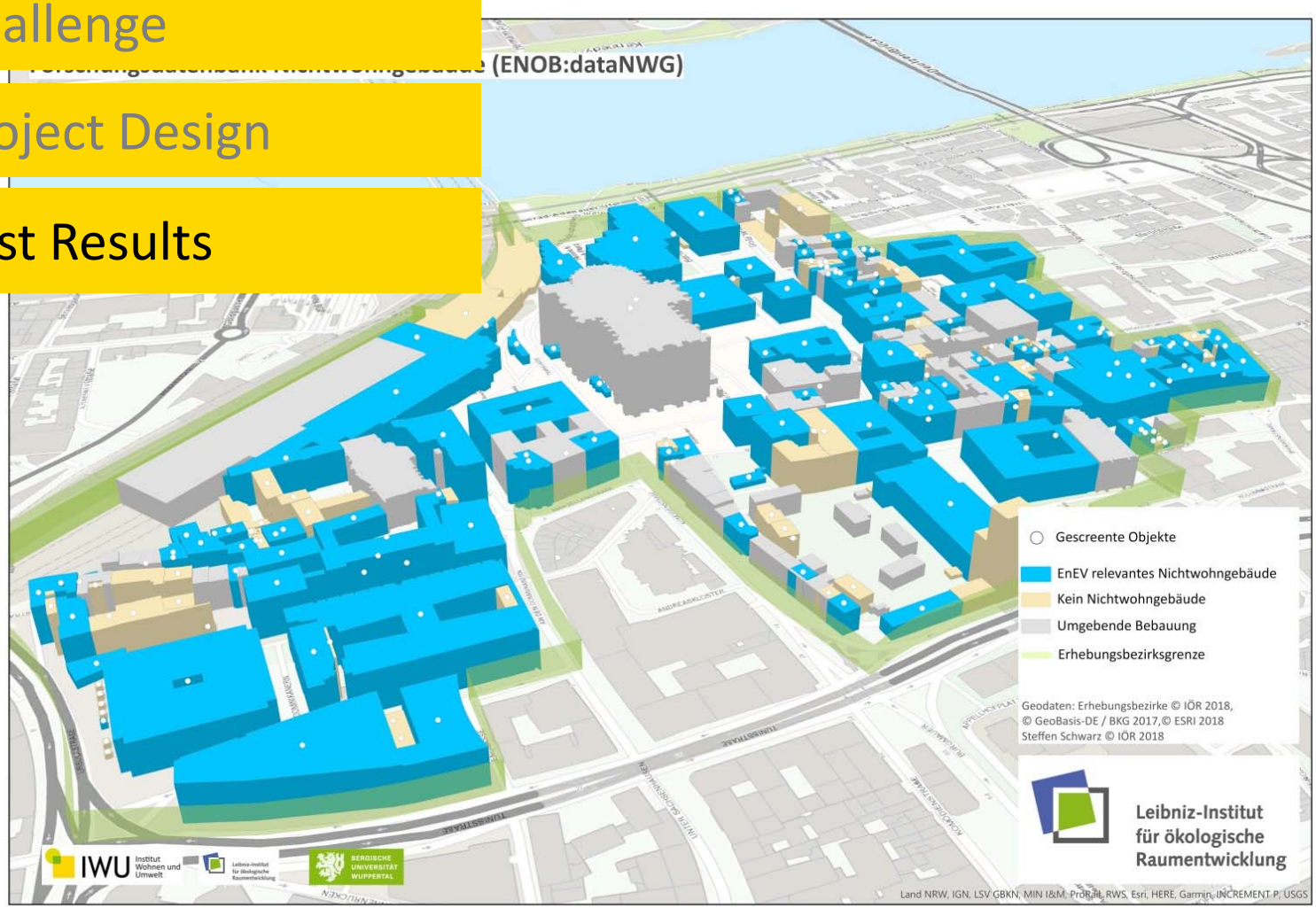


Research Database Non-residential Buildings
(ENOB:dataNWG)

1 Challenge

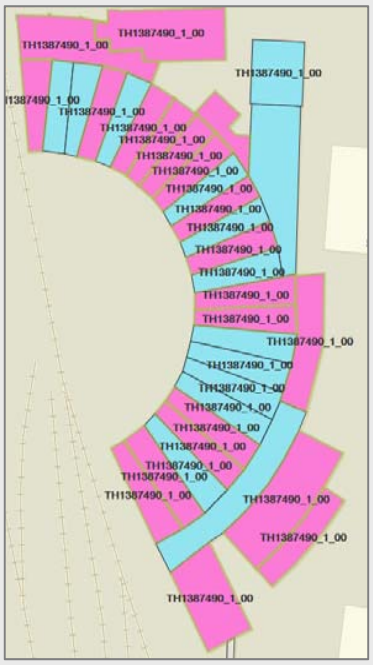
2 Project Design

3 First Results



4.1 What is a "single building"?

- **Buildings** are independently usable, covered structures that can be entered by people and are suitable or intended for the protection of people, animals or property. (General Building Regulation / Musterbauordnung))
- **Non-residential Buildings (NRBs)** are dedicated to non-residential uses on more than 50% of their net floor area. (Statistics of Construction Activity / Bautätigkeitsstatistik)
- **<u>Single</u> Buildings** are detached buildings as well as those buildings which consist of building parts having been built at the same time based upon an integrated architectural design plus subsequently added building parts which cannot be used independently and which are to be assigned to the building for functional reasons with regard to development and use.
  All building parts must be structurally connected on the ground.
  In case of doubt, realisability is another criterion for determining which parts belong to a single building.



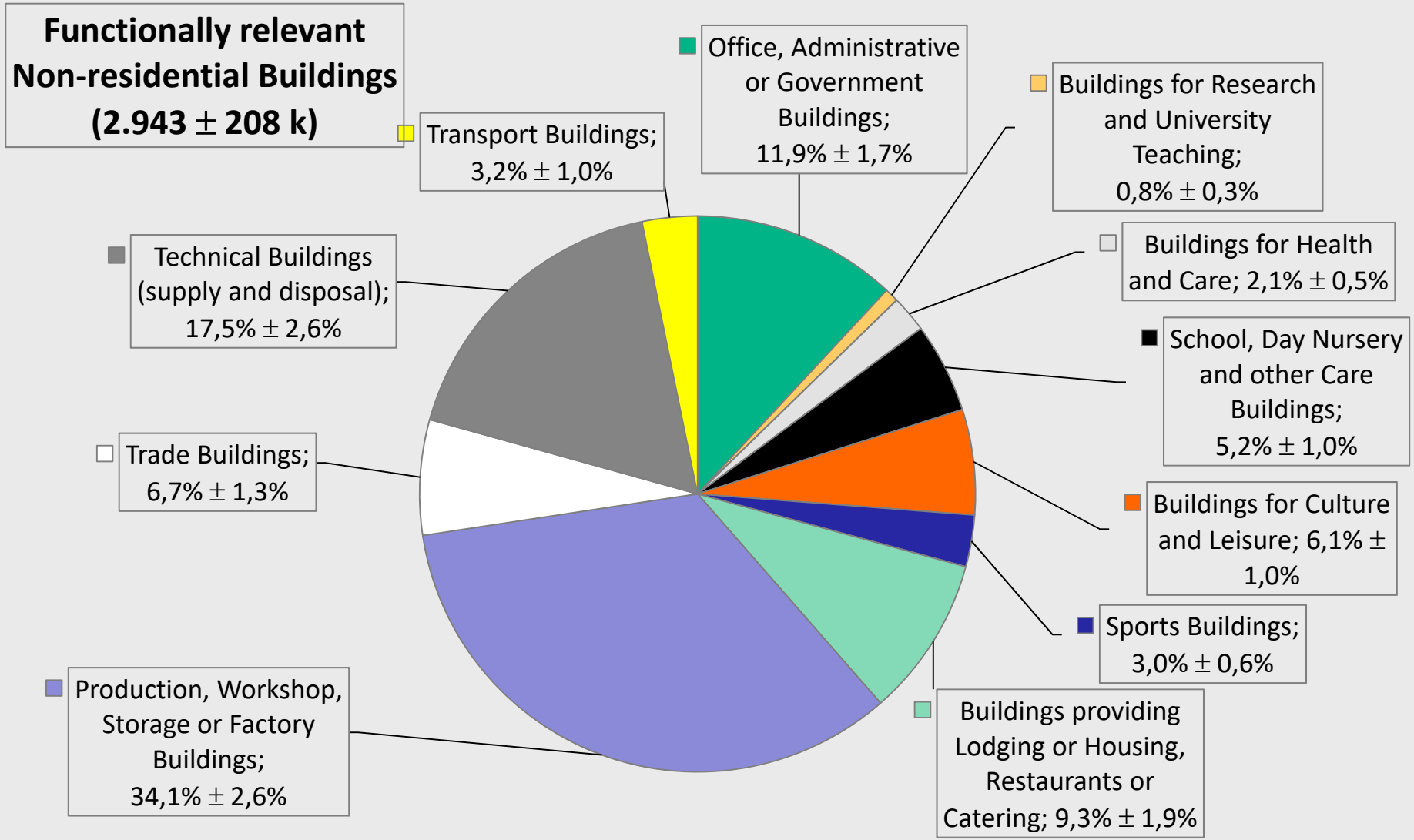
4.2 Decomposition of the Building Stock

Non-residential Buildings (NRB) in Germany by type of building	Number in 1.000	absolute Standarderror in 1.000	relativ Standarderror in %
Non-residential Buildings	21.124	445	2,1%
... of which thermally relevant NRB	... 2.172	168	7,7%
... of which fully GEG-relevant NRB	... 1.981	152	7,7%
... of which thermally low-conditioned NRB	... 0.192	47	24,7%
...of which other, thermally conditioned NRB	... 4.166	170	4,1%
...of which thermally not conditioned NRB	... 14.786	375	2,5%
Functionally relevant NRB	2.943	208	7,1%
... of which fully GEG-relevant NRB	... 1.981	152	7,7%
... of which thermally low-conditioned NRB	... 192	47	24,7%
... of which thermally not conditioned NRB	... 771	111	14,3%

- **Functionally relevant**: Fully GEG-relevant and thermally low-conditioned NRBs as well as those NRBs which have a relevant building function within the scope of the Building Energy Act (GEG §2), f.i. a storage building, but which, according to the respondents of the survey, are not thermally conditioned.
- **Thermally relevant**: Functionally relevant and thermally conditioned, i.e. heated and/or cooled NRBs that are subject to GEG §2 Abs. (1).
- **Other**: Functionally not relevant NRBs.

ENOB:dataNWG, euroconstruct 2020, online

4.3 Building Function



ENOB:dataNWG, euroconstruct 2020, online

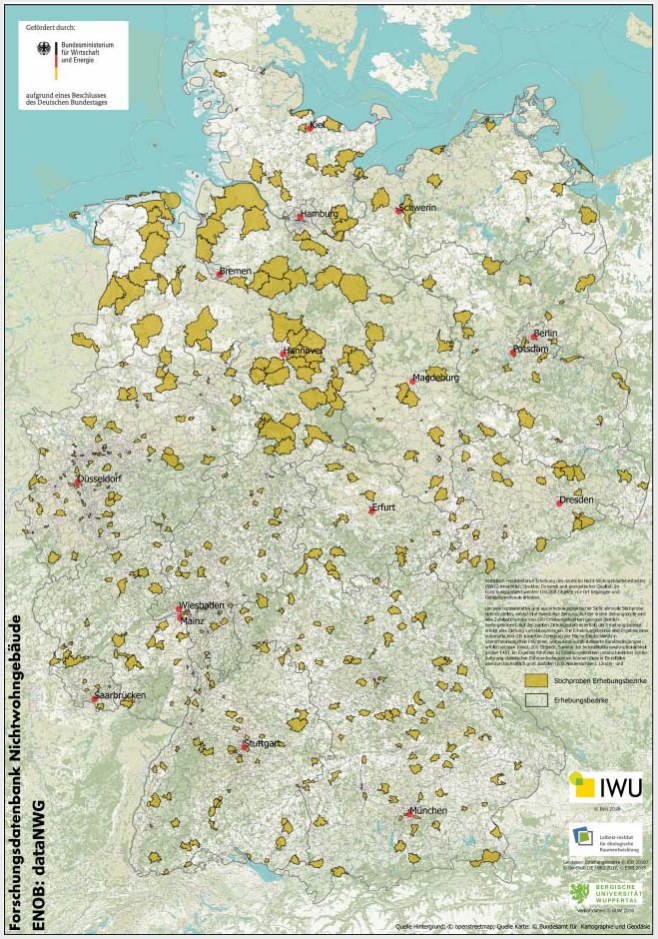
4.6 Age Bands

1.1.9.	Fully GEG-relevant NRBs 1.981 ± 152 k			
Age Bands	Relative Frequency in %	Age Bands	Relative Frequency in %	Relative Standard-error in %
Old Buildings before 1. TIO(*)	57,9%	<= 1859	3,2%	28,5%
		1860 - 1918	10,4%	16,2%
		1919 - 1948	6,2%	18,6%
		1949 - 1957	7,5%	22,4%
		1958 - 1968	15,3%	16,3%
		1969 - 1978	15,2%	15,9%
Old Buildings after 1. TIO(*)	38,2%	1979 - 1983	5,0%	22,6%
		1984 - 1994	14,2%	17,2%
		1995 - 2001	9,3%	15,3%
		2002 - 2009	9,7%	21,4%
New Buildings	3,9%	2010 - 2014	3,1%	22,6%
		>= 2015	0,8%	40,9%

(*) 1. Thermal Insulation Ordinance

4.4 Federal State

In the case of evaluations specific to the federal states, it is to be expected that the cluster effect will increase the standard error.



Thermally relevant NRBs in Germany	Number in 1.000	relativ Standarderror in %
Schleswig-Holstein	61	36%
Free and Hanseatic City of Hamburg	27	44%
Lower Saxony	282	15%
Free Hanseatic City of Bremen	3	49%
North Rhine-Westphalia	504	22%
Hesse	127	27%
Rhineland-Palatinate	115	28%
Baden-Wuerttemberg	274	17%
Free State of Bavaria	379	19%
Saarland	31	71%
Berlin	32	33%
Brandenburg	65	31%
Mecklenburg-Western Pomerania	54	31%
Free State of Saxony	103	39%
Saxony-Anhalt	62	34%
Free State of Thuringia	54	46%
Germany	**2.172**	**8%**

ENOB:dataNWG, euroconstruct 2020, online

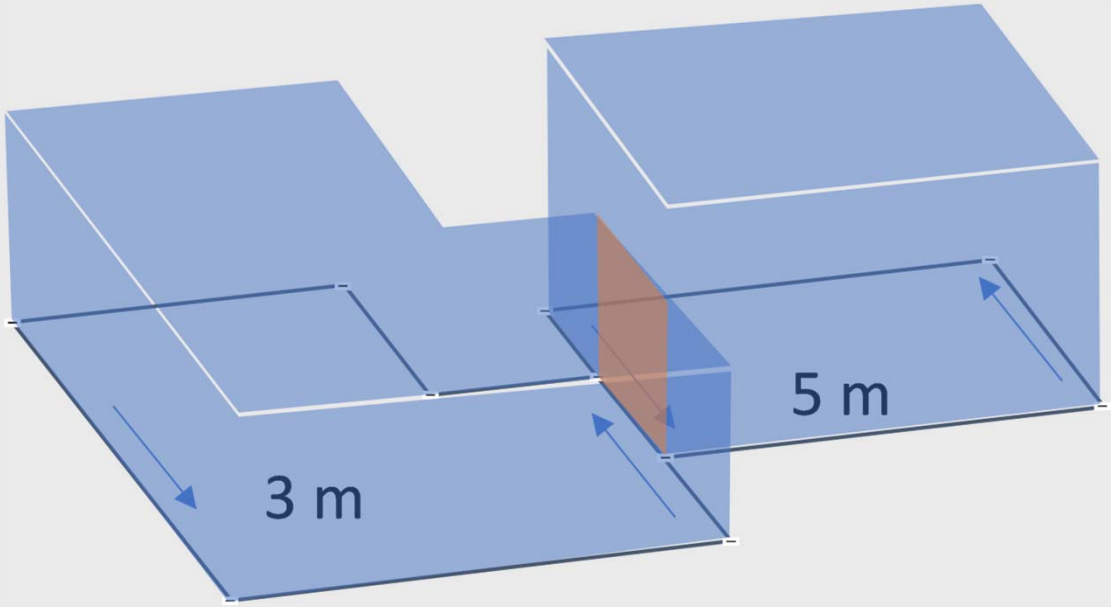
4.5 Geospatial Data and Building Envelopes

The population of non-residential buildings in Germany is unknown. In ENOB:dataNWG for the first time basic geospatial data were used to create a sampling frame to draw a representative sample and to conduct a survey.

Geoinformatic methods were then applied to calculate geometric properties for all buildings in the sample:

- floor areas,
- façade areas
  (by main compass directions),
  and
- volume.

Areas and volume of the entire building stock in Germany can be estimated unbiasedly.



4.6 Floor Areas, Volume and Envelope Surface Area

Geometrical Characteristics of Fully GEG-relevant NRBs (1.981 ± 152 k)	**Mean** [1]		**Sum** [1]	
Gross Volume	9.181	[m³]	18.182.367	[1.000 m³]
Gross Floor Area	1.771	[m²]	3.507.081	[1.000 m²]
Façade Area	962	[m²]	1.905.495	[1.000 m²]
… of which Window Area [2]	398	[m²]	787.815	[1.000 m²]
… of which External Wall Area against ambient Air [2]	593	[m²]	1.173.684	[1.000 m²]
Roof Area	927	[m²]	1.836.828	[1.000 m²]

[1] Estimation of standard errors in progress

[2] Preliminary estimation according to Screening data

4.7 Building Typology ...

Mean Gross Floor Area [m²] (*) of Fully GEG-relevant NRBs (1.981 ± 152 k)	Old Buildings before 1. ESO	Old Buildings after 1. ESO	New Buildings	Total
Office, Administrative or Government Buildings	2262	1806	1006	2060
Buildings for Research and University Teaching	4301	3170	1769	3562
Buildings for Health and Care	4469	2965	2621	3516
School, Day Nursery and other Care Buildings	2636	1291	856	2024
Buildings for Culture and Leisure	1152	1109	578	1105
Sports Buildings	1691	1816	703	1672
Buildings providing Lodging or Housing, Restaurants or Catering	888	957	2639	915
Production, Workshop, Warehouse or Factory Buildings	1349	2125	1100	1654
Trade Buildings	3352	2709	2116	3020
Technical Buildings (supply and disposal)	722	436	251	504
Transport Buildings	1085	932	224	977
Total	1767	1838	1166	1771

(*) Evaluation 1.3.1, Estimation of standard errors in progress

4.8 Further Research Questions

- Sample Survey
  - **Structural attributes** of the non-residential building stock (spatial distribution, building types, total number, total area, building envelope areas etc.)
  - **Energy-related attributes** of building envelopes and technical installations of relevant non-residential buildings in the stock. Refurbishment progress and annual refurbishment rates of building parts and technical installations
  - Underlying conditions of **decision making processes** in building refurbishment in the non-residential building stock
  - **Calibration** of reduced order energy performance simulation tools by measured consumption data
- Geo-spatial Data Analysis:
  - Calibration of **geoinformatic recognition algorithms** of non-residential buildings based upon building polygons and 3D building models
- Scenarios
  - Relevance of energy-related measures in the non-residential building stock in Germany to the **achievement of climate protection objectives in 2030 and 2050**

Summary: The Sampling Design works!

- **Geospatial data constitute a suitable sampling frame** for a representative sample survey to explore the formerly unknown stock of non-residential buildings in Germany.
- **Two-Stage, stratified Sampling** with 500 Survey Districts as PSUs with 200 Building Polygons as Secondary Sampling Units (SSU) each make a good sample design concerning both, sample theory and survey practice.
- **Screening on site is necessary** to relate building polygons as sampling units (SU) to buildings as research objects (RO) and to get information on the owner and adresses.
- **Response rates in the interview phase of 14%** turn out to be sufficient in order to do meaningful statistics with reasonable sample sizes. About 50% of the respondents in the interviews were interested in an on-site inspection.
- A survey with this sampling design can be carried out **in all of the EU** since in 2007 the Commission started the **INSPIRE**(*) Initiative to create a european infrastructure for geospatial data.
- However, the importance of the building sector actually requires the establishment of a **National Register of Buildings**. A sample survey would thus be considerably simplified and should be carried out regularly.

(*) INSPIRE: Infrastructure for Spatial Information in the European Community

Research Database Non-residential Buildings

(www.dataNWG.de)

The unknown Continent of
Non-residential Buildings in Germany
has been surveyed.