Representative Sample Survey on Building Stock Data

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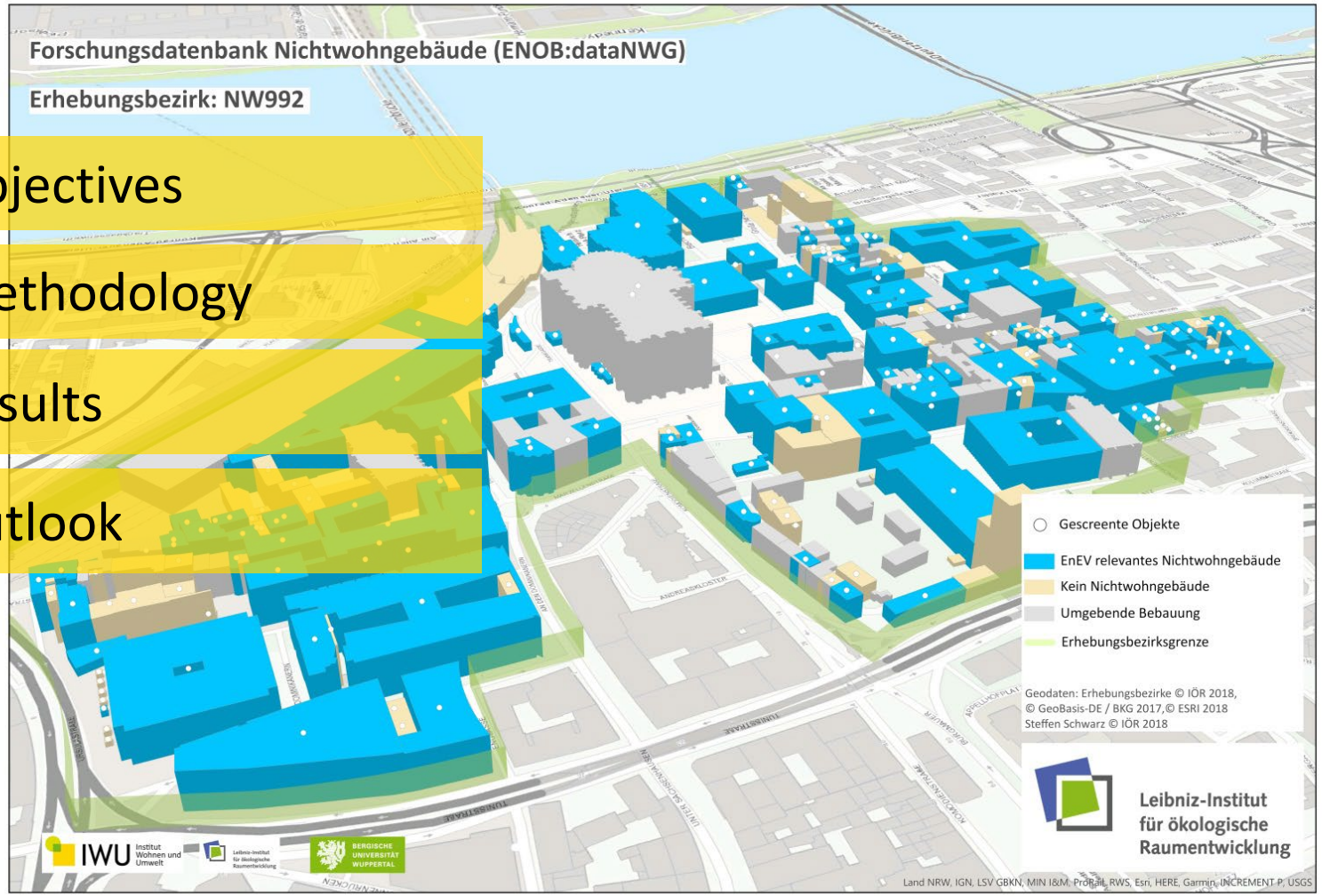


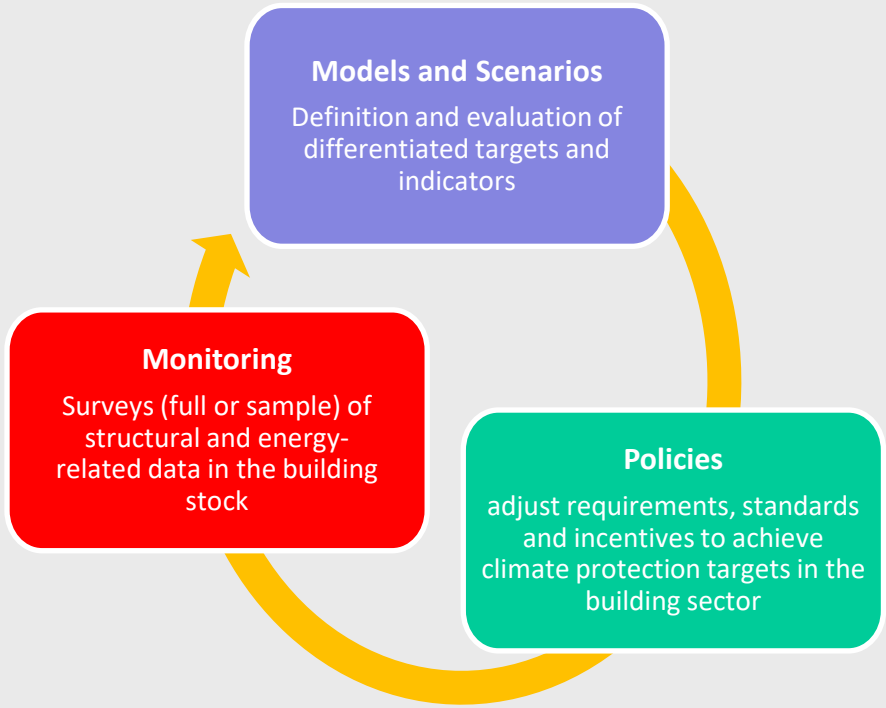
1.1 Objective: Governance of Building Stocks!

Problem

- Unlike residential buildings, non-residential buildings (NRBs) are **not included in the census.**
- **Official statistics** in Germany (destatis) and Europe (eurostat) cover only parts of the NRBS.
- **Building registers** exist only in a few EU MSs, like Austria, Finland and Denmark.
- If at all, some **structural data** on the non-residential building stock is provided, like the number of building permits per year. **Energy-related characteristics** are not available.
- **Owner addresses** are subject to data protection and usually not available for statistical or scientific purposes.
- According to the EPBD, EPCs are to be issued for new buildings and in case of resale or reletting only. Renovation is not necessarily a trigger for the issuance of a new EPC. EPCs are valid for 10 years, regardless of whether an energy-related renovation has taken place or not. Hence, **EPC databases are a highly biased sample and therefore not "representative"**.

Solution

- **Sample survey,** designed strictly according to the well-known rules of inductive statistics.
- **Authoritative Geospatial Data**, like Building Polygons (BP) and 3D building models, based on the cadastres provide a suitable sampling frame.

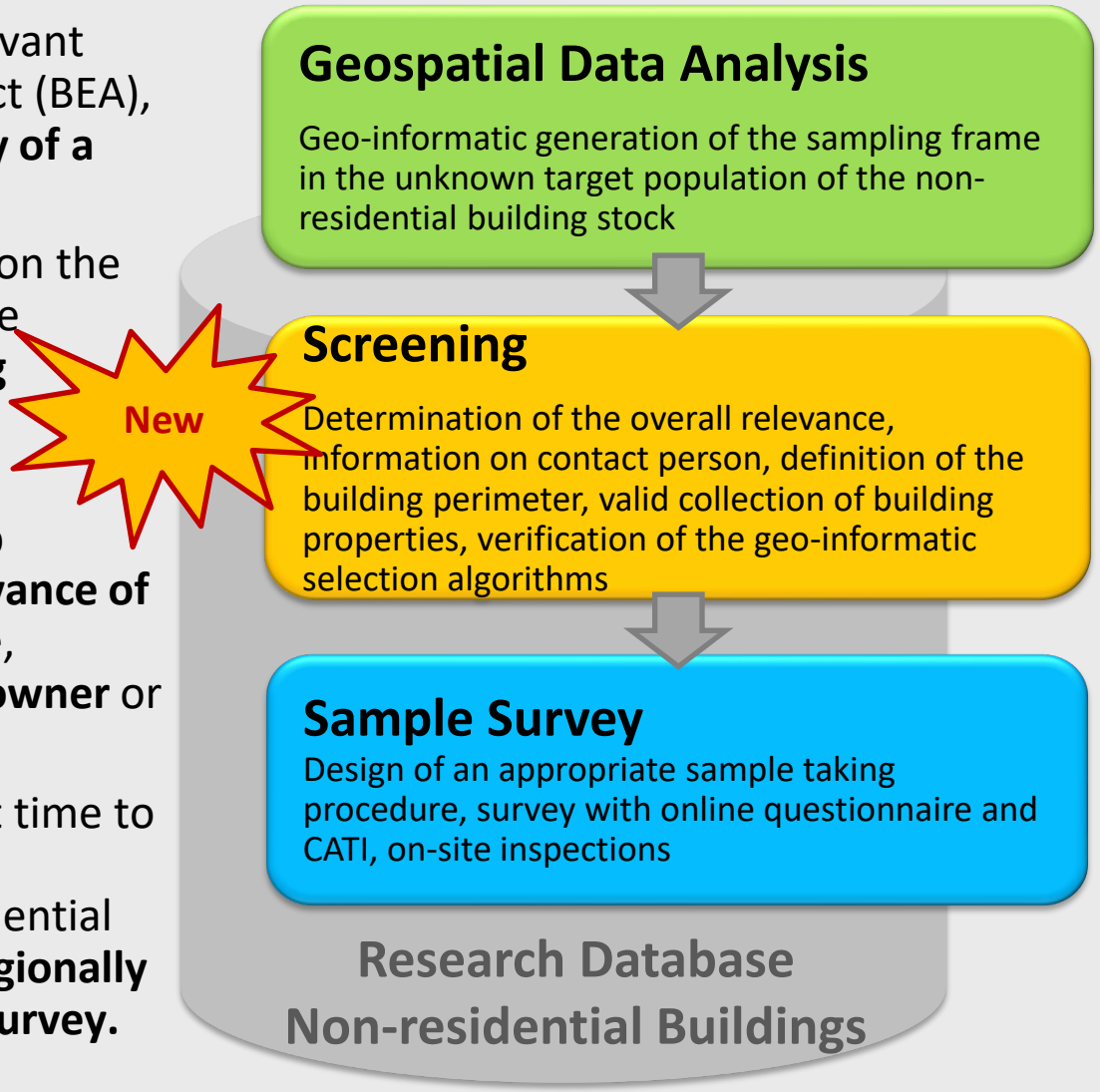


1.2 Objective: Data on Non-residential Buildings

- Building Stock Database
  - **Structural parameters** of the non-residential building stock (NRBS) like spatial distribution, building types, total number, total area, building envelope areas etc.
  - **Energy-related characteristics** of building envelopes and technical installations of relevant non-residential buildings in the stock.
  - **Measured energy consumption** and real usage parameters.
- Building Stock Model and Scenarios
  - **Model-input variables** like renovation progress and annual rates of building parts and technical installations, U-values, heat generators' expenditure factors, calculated energy demand
  - Development of a reduced order **Energy Performance Simulation Tool (DIBS,** available on GitHub: https://github.com/IWUGERMANY**) for building stock modelling** operating with only 35 of these model-input variables.
  - **Calibration** of energy demand calculations by measured consumption data
- MEPS for NRBs
  - **Definition of threshold values** for the chosen indicators based upon a valid, reliable and objective database

2.1 Methodology: Representative Sample Survey

- **Non-residential Buildings (NRB),** relevant under the German Building Energy Act (BEA), are the targeted elements in **a survey of a representative sample**.
- Authoritative geo-spatial data based on the cadastres provide the Sampling Frame consisting of **geo-referenced Building Polygons (BP)**
- **Screening** of the buildings on site is necessary to identify the **relationship between BPs and NRBs** and the **relevance of the NRBs** in the sample. Furthermore, **contact information of the building owner** or user must be collected.
- This approach enabled us for the first time to collect structural and energy-related parameters on the German non-residential building stock in a **representative, regionally balanced and cost-efficient sample survey.**



2.2 From Sampling Units to Research Objects

1. Geodata Analysis

- Processing of 52 Mio. BPs (elimination of micro polygons)
- Adding LoD1 Building Function and 40 geometric and semantic attributes

2. Sampling

- Two-stage, disproportionally stratified sample
- 500 Districts per 200 BPs

3. Screening

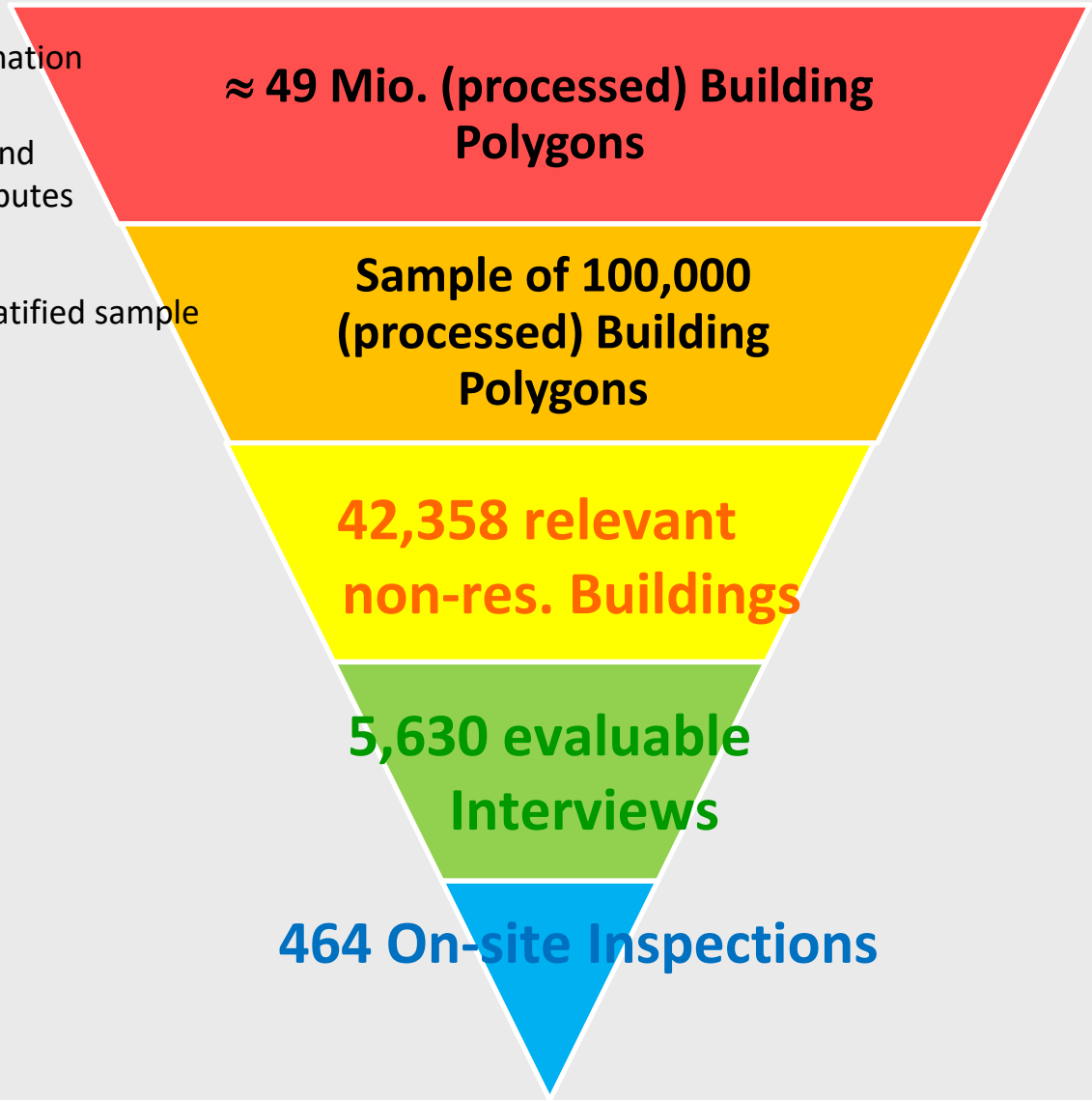
- Relevance
- Relation polygons - buildings
- Owners‘ adresses
- Basic building characteristics

4. Interviews

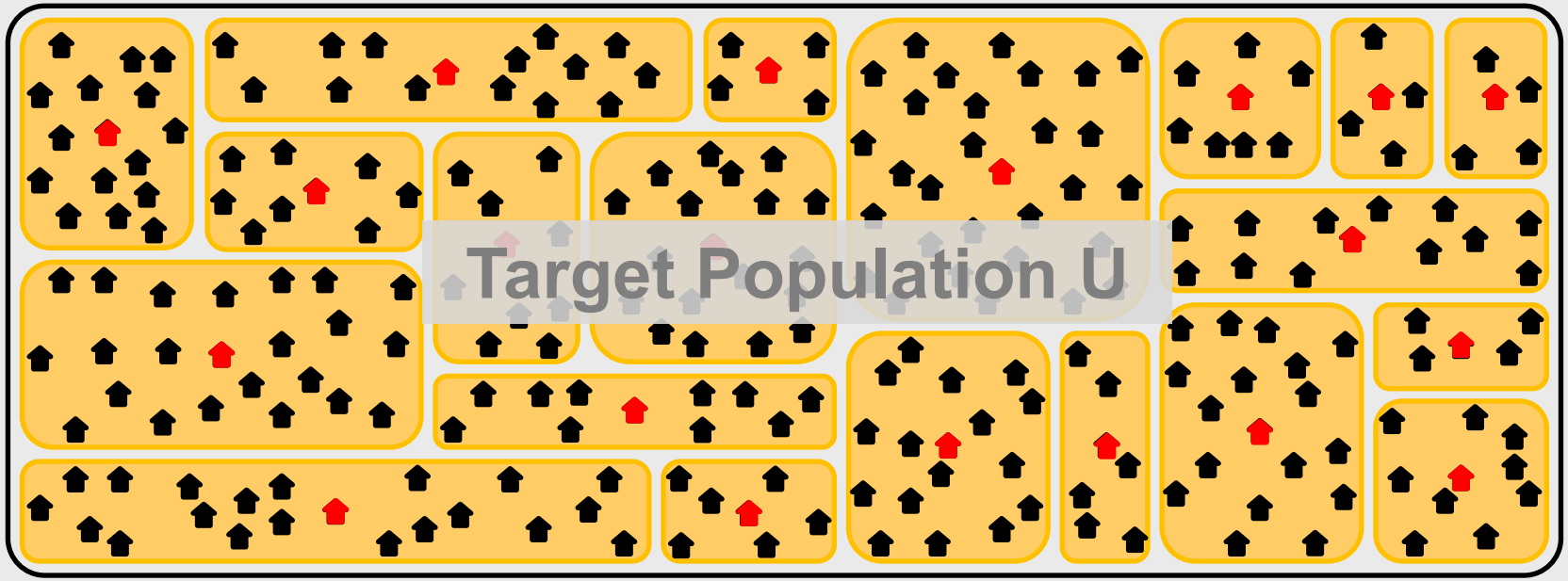
- Structural attributes
- Energy-related attributes,
- Owner characteristics
- Facility Management

5. On-site Inspections

- Measured consumption
- Calculated demand
- Usage parameters



2.3 What is *representativeness*?



1. If **pure chance** decides on the inclusion of a population unit into the **sample s**,
2. (1st order) **inclusion probability** of all sampling units (SU) in the sample is known and
3. **every population unit** has a chance, i.e. a positive inclusion probability, to be included in the sample

then **unbiased result estimates of parameters of the population U from the sample s** with a quantifiable and lowest possible sampling-related uncertainty.

This is what we call a **representative sample** survey in inductive statistics. Authoritative geospatial data products, like HU-DE / LoD1 in Germany, as sampling frame provide all necessary features.

2.4 Asset vs. Operational Rating

Calculated Demand

- DIBS needs 35 monitoring variables as input only to calculate the energy demand
- These can be requested from the owner using an online questionnaire.
- In the projection, the owner can reliably plan his package of measures to comply with the requirements.

Measured Consumption

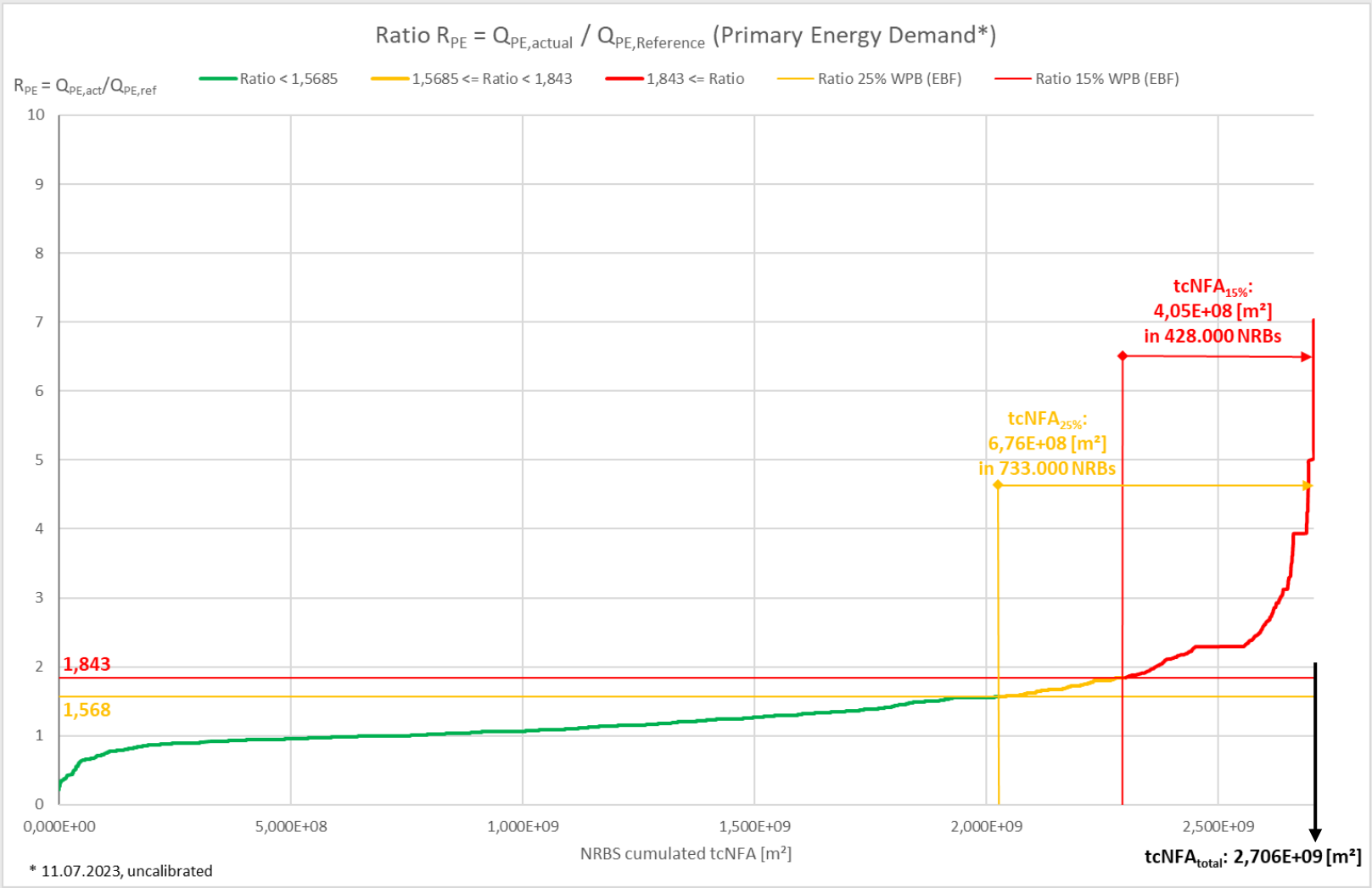
- Is the metered consumption actually that of the building? The meter structure must be clarified!
- Weather adjustment!
- Vacancy adjustment!
- Building category with special uses, efficiency measures already implemented, usable areas, year of construction must be requested from the owner
- Operational optimisation would be included in the assessment

3.1 Key Findings from dataNWG in Germany

- How many are there?
  - 21.124 ± 0.445 Mio. non-residential buildings (NRB)
  - 1.981 ± 0.152 Mio. BEA(1)-relevant NRBs on 3,507 ± 399 Mio. m² GFA(2), thereof 1.146 ± 0.110 Mio. old buildings(3)
  - NRB-Typology differentiated according to building category and construction age classes
- Progress and rate energy-related building renovation in old buildings
  - weighted by the area fractions g_i of the building envelope components(4) : renovation progress 30.3% ± 7.1% of component surface area;
  - corresponding to an average yearly renovation rate in 2010 – 2019 of 0.7%/a ± 0.2%/a
- Missed opportunities
  - Repainting or plaster renewal of outer walls without applying thermal insulation at the same time: 3.2%/a ± 0.5%/a (of all buildings built before 2010).
  - Single measures preferred in 70% ± 5% and 4 or 5 measures (deep renovation?) in less than 10% ± 4% of the renovation cases in 2010 – 2014.
- Heat supply in old buildings
  - Modernisation rate of heat generators: 2.5%/a ± 0.3%/a
  - No fuel switch in 81% ± 6% of gas heating renewals

(1) BEA-relevant: thermally conditioned and relevant under the German Building Energy Act (Gebäudeenergiegesetz (GEG))
(2) GFA: Gross floor area
(3) Old buildings: built before 1978
(4) Components: outer walls, windows, roofs, floor slabs

3.2 Key Findings: MEPS for NRBs



See also final report on the project funded by European Climate Foundation:
https://www.researchgate.net/publication/377296160_Minimum_Energy_Performance_Standards_for_Non-Residential_Buildings_-_EU_requirements_and_national_implementation

4.1 Speeding it up!

1. Geospatial data will remain the most suitable sampling frame: Representative sample of building polygons (BP) with geo-coordinates and data from 3D building models.
2. Applying geoinformatic recognition algorithms developed from dataNWG to distinguish non-residential from residential buildings
3. Online screening to collect crucial building characteristics using aerial photography, Google Street View, Points of Interest …
4. Addressing the owners, two options:

a. Municipalities are obliged to cooperate

- Find building address and parcel number in the online cadastre / land register via geo-coordinate
- Find owner address in the property tax administration via parcel number
- Dispatch of invitations to voluntarily participate in the survey to the owners by address transmission via the property tax offices of the municipalities in compliance with data protection regulations

b. The Building Register already exists.

- Find owner address in the register
- Dispatch of invitations to voluntarily participate in the survey to the owners by address transmission via the register administration in compliance with data protection regulations

5. Online questionnaire including definition of single buildings as research objects from BPs filled in by the owners

4.2 Transfer to other EU MSs

We propose to organise a feasibility study in all EU MSs with the following objectives:

- **Cadastral Data** are presumed to be available everywhere and form the basis of digital geospatial data. With the end of the implementation phase of the **EU INSPIRE Directive** by the end of 2021, all EU MSs should have their authoritative geospatial data infrastructures cross-border compatible and shareable!
- The availability and usability of current **owner addresses** is the key to a cost-effective implementation of the survey. Property tax offices in cities and municipalities have this data. Will they cooperate to make owner addresses usable for statistical purposes, e.g., by means of address transmission, in compliance with data protection requirements?
- In addition to their function in the census, future national **Building Registers** should also be able to serve as a sampling frame for sample surveys in cooperation with municipal property tax offices, for example. When will they be available?

In principle, so it is conceivable to **transfer the survey methodology** described here to other EU MSs and to carry out representative sample surveys in building stocks with reasonable effort and sufficient accuracy on a regular basis.

Exploring an unknown: Representative sample survey on structure and energy-related quality of the non-residential building stock in Germany

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Exploring an unknown: Representative sample survey on structure and energy-related quality of the non-residential building stock in Germany

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ABSTRACT

The non-residential building stock in Germany, as in many other countries, is not fully represented in any official statistics, in contrast to residential buildings. This is surprising given the economic significance of this asset and its importance as a source of greenhouse gases. The knowledge gap was closed in a representative sample survey providing statistically valid data on structural parameters and energy-related characteristics of the non-residential building stock in Germany. This became possible because by December 2014 authoritative building polygons from all German cadastres were available in a national database for the first time. These geospatial data, adjusted for topological inconsistencies and supplemented with owner information in an on-site screening, were used as a sampling frame in the previously unknown population of the non-residential buildings, a new approach in building stock statistics worldwide. While the geometry of all buildings can be derived from the geospatial data, energy-related characteristics and renovation activities have to be obtained by interviews with the owners of the relevant non-residential buildings in the sample. With this methodology, regular monitoring of building stocks at reasonable costs becomes possible. It also can be transferred to other states with similar geospatial data infrastructure, in particular to other EU Member States.

1. Introduction

1.1. The importance of the building sector

The construction industry is an important economic sector in Germany [1], the EU Member States (EU MSs) [2] and worldwide. Its products, buildings in particular, represent a large economic asset [3, p. 8]. As a production factor, buildings are indispensable in all sectors and branches of the economy. Although buildings are not defined as a separate economic sector, they are recorded in Germany in the *official construction statistics* [4], monitoring short-term and structural data of the construction industry as well as the construction activity. Detailed knowledge of current investment processes, supply and demand in the building sector is of great political and economic importance.

Buildings also play a decisive role in energy and climate policy. The Enquete Commission "Protection of Man and the Environment" of the German parliament (Deutscher Bundestag), installed in 1991, already drew attention to the immense importance of material flows in the areas of construction and housing, finally with the publication of [5]. Buildings are run as a separate sector in this policy area including the combustion of fuels in households, commerce and public authorities, defined for example in the German Climate Protection Act (CPA) according to the Common Reporting Format (CRF) of the United Nations Framework Convention on Climate Change (UNFCCC) [6].

For the entirety of the buildings, we here use the term building stock (BS). In the EU-27, the BS was responsible for 35 % of the energy-related greenhouse gas (GHG) emissions in 2019 [7,8]. Globally in 2022, the

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