

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

KFW

Energy Performance Analysis
is being carried out using
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Research Database Non-residential Buildings (ENOB:dataNWG)

1 Challenge

2 Approach

3 Project Design

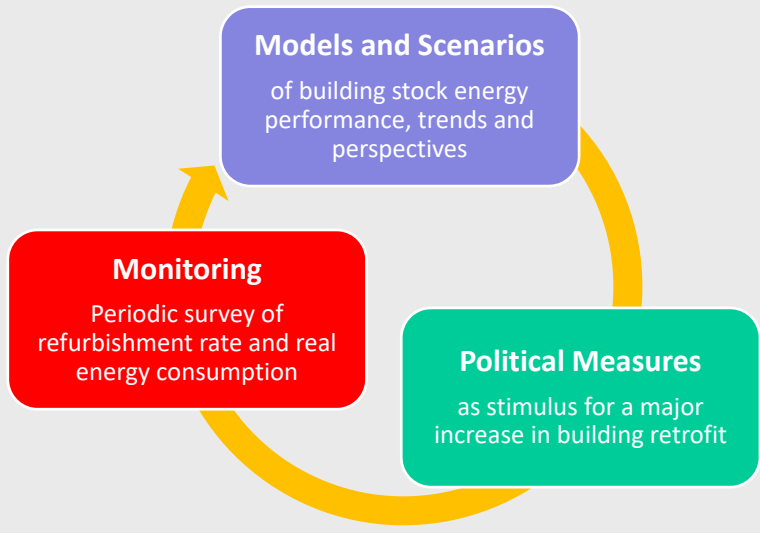
4 First Results



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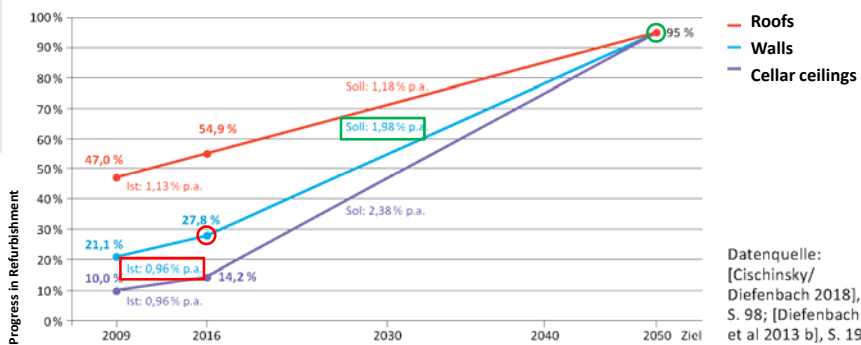
1.4 Instruments to Upgrade the Building Stock



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2.6 Residential Building Stock



Refurbishment Progress

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

Net Refurbishment Rate

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

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1.4 Challenge on non-residential Buildings



- The **Target Population** is unknown.
 - There is no **National Register** of buildings in Germany with owners' contact information.
 - **Statistics of Building 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 a given **Subsets** of the building stock leading to **descriptive Statistics** only, limited to the scope of the building set analysed.
- A **Census**, i.e a full survey, of the national non-residential building stock seems far out of reach in terms of time and expense.
- A **Sample Survey** on non-residential Buildings seems conceivable if an appropriate **Sampling Frame** can be found.

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2.1 Approach

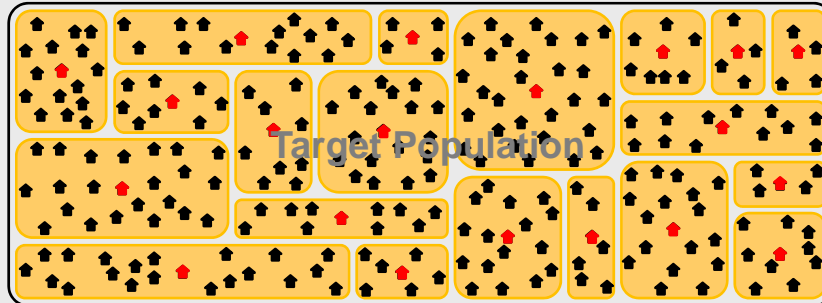


- Define what are the **Research Objects**.
- Find an appropriate **Sampling Frame**.
 - Since the target population is not known a sampling frame may be established that associates the elements of the population with the sampling units of the frame.
 - How is the relation to be established?
- Design an appropriate **Probability Sample** and a **Survey** meeting these requirements
 - Unbiasedness in a statistical sense
 - Quantification and minimization of the sampling error
 - Appropriate regional representation
 - technical feasibility with reasonable costs
- Define an appropriate **Sample Size** and **Variables of Study** to get information about unknown population characteristics or parameters (like totals, means, ratios of totals, regression slopes etc.)
- Establish all prerequisites for **inductive Statistics**, i.e. conclusions on the target population can be made.

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2.6 Inductive Statistics



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

then unbiased conclusions from a sample to the corresponding target population may be drawn.

Mean annual refurbishment rate for heating insulation of all residential buildings **in the sample** between 2010 and 2016: $0.99\% \pm 0.04\%$ p. a
The true, but unknown value **in the target population** lies between 0.95% and 1.03% with a probability of 68%.

2.2 Definition of the Research Objects

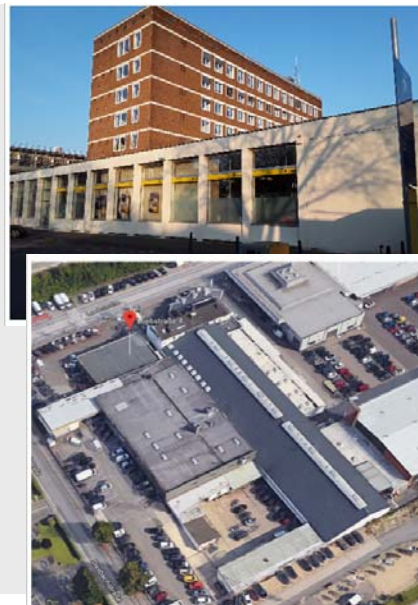
Non-residential Buildings are dedicated to non-residential uses on more than 50% of their useful floor area.

Single Buildings are detached buildings as well as those that consist of building parts having been built based upon an integrated architectural concept at the same time plus retrofitted parts that are to be assigned regarding access and function, because they cannot be used independently.

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.

Relevance: Thermally conditioned, i.e. heated and/or cooled, non-residential buildings that are subject to the Energy Savings Ordinance.



2.3 Frame of Sampling Units

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

- Official Building Polygons of Germany (HU-DE)
- Official 3D Building Models in "Level of Detail 1" (LoD1-DE)

Solutions to the deficits of this frame

- Processing of the Building Polygons is necessary
 - Elimination of overlap
 - Elimination and/or merger of very small presumably irrelevant polygons
- On-site verification is necessary.
 - Building Polygons do not necessarily encircle Buildings but only parts of them!
 - Building function might have changed without the land register having been informed
 - Owner information is not included



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2.4 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 the **relationship between the SU and the RO**. Furthermore contact information of the building owner or user has to be collected.
- This approach enables us for the first time to explore the sector of the German non-residential buildings in a statistically unbiased, regionally balanced and cost efficient way.**

Geospatial Data Analysis

Geo-informatic generation of the sampling frame in the unknown target population of the non-residential building stock

Screening

Determination of the overall relevance, information on contact person, valid collection of building properties, verification of the geo-informatic selection algorithms

Sample Survey

Design of an appropriate sample taking procedure, survey with online questionnaire and CATI, on-site inspections

Research Database



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3.1 Sample Design and Sample Size

Sample Size fixed at 100,000 Building Polygons

- Target of **10,000 Interviews** in order to measure the presumed 1%-effect of energy-related refurbishment in the building stock
- Assumed response rate of 20% requires 50,000 relevant non-res. Buildings

Two-stage Stratified Sample Taking

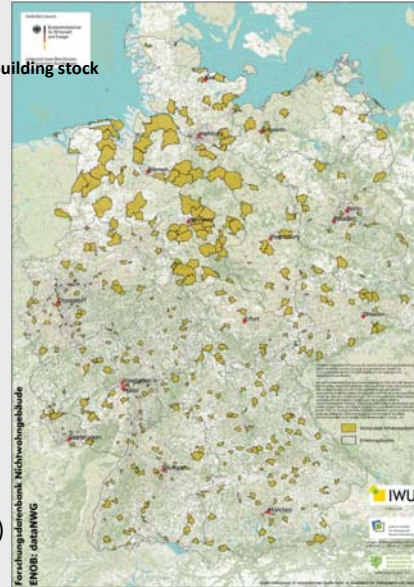
- A relevance probability is attributed to each building polygon by a binary logistic regression analysis
- Deficits of the sampling frame require a **check of relevance on site** of a sufficiently great number of building polygons to focus interview expenses
- Cost and limited mobility of personnel require concentration on survey districts

Survey Districts as Primary Sampling Units (PSU)

- Breakdown, nationwide and without overlap, into 7,465 survey districts with at least 200 building polygons and a sum of relevance probability ≥ 140
- Sample of 500 districts proportionally stratified by states and planning regions (Raumordnungsregionen)

Building Polygons as Secondary Sampling Units (SSU)

- 200 Building Polygons per district, disproportionately stratified by 5 relevance probability classes



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3.2 Project Design

1. Geodata Analysis

- 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

3. Screening

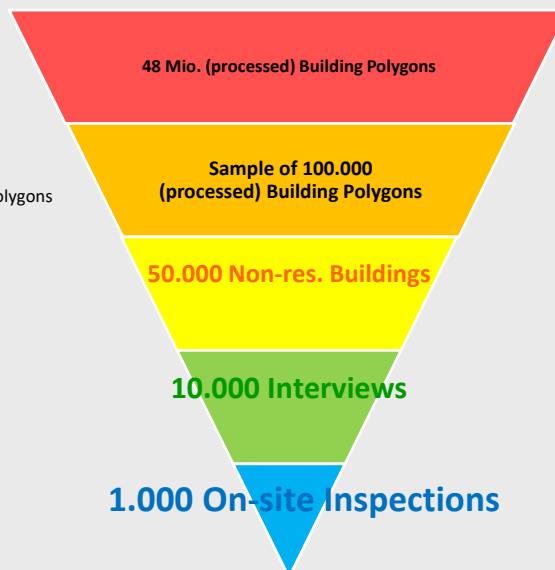
- Relevance: at least 50.000
- Relation Polygons - Buildings
- Owners' Adresses
- Basic Building Attributes

4. Interviews

- Structural Attributes
- Energy-related Attributes,
- Owner Category
- Facility Management

5. On-site Inspections

- Measured consumption
- Calculated demand
- usage



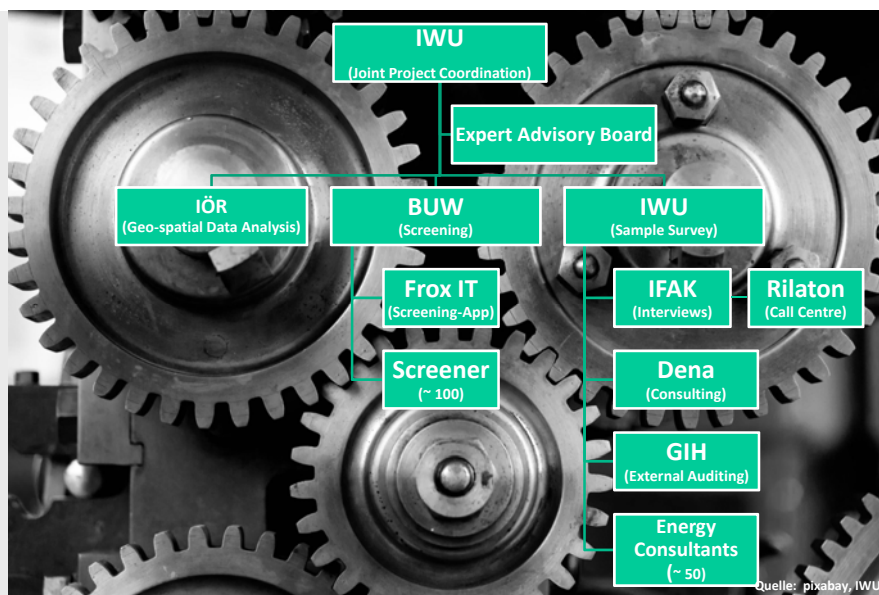
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3.3 Research Questions

- Sample Survey
 - **Structural parameters** of the non-residential building stock (spatial distribution, building types, total number, total area, building envelope areas etc.)
 - **Energy-related parameters** 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 combined with image processing and machine learning 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**

3.4 Research Consortium



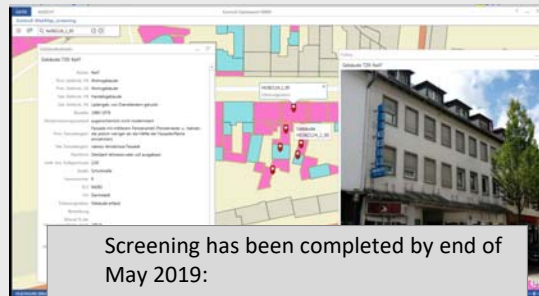
4.8 Screening Results

Building Profiles:

- Site plan
- Fotos
- Building Function
- Age Band
- Refurbishment Status
- window to wall ratio
- Number of floors

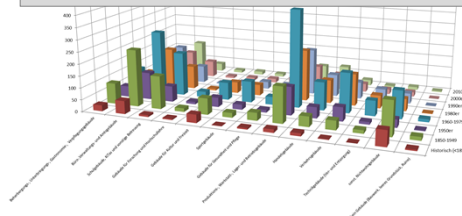
Non-residential Building Typology

- Building function
- Age bands
- Frequencies
- ...



Screening has been completed by end of May 2019:

- Screened Buildings: 100,000
- Relevant Buildings: 48,600



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4.10 Interviews

- Address validation
 - From Screening data find contact data of building owner
- Contact Qualification
 - Find person in the organisation of the building owner, who is competent enough and willing to take part in an interview on energy-related subjects of the building
 - No expert but satisfactory knowledge of the building history
- Interview
 - CATI or Online Questionnaire
 - Method Change allowed
 - Online link may be forwarded to different respondents
 - 30 to 45 minutes duration
- Six building-related subjects addressed
 - Basics (function, area, age, owner, ...)
 - Façade, windows and walls
 - Roof and cellar
 - Heating, solar thermal and photovoltaic installations
 - Ventilation, Cooling
 - Lighting

by end of May2019:

- Interviews: ~3,000
- Response Rate: ~ 15%

Exemplary Interview question on construction method of the predominant part of the facades

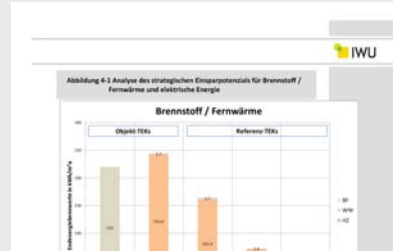
Quelle: IFAK

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4.11 On-site Inspections

- On average 3 hour inspection
 - Certified Energy consultant
 - Accompanied by owner's delegate
- Measured Consumption
 - Fuel / District Heat
 - Electricity
- Actual Usage
 - Usage zones
 - Room Temperature
 - Appliances
 - Internal heat gains
- Calculated Demand
 - Supposed U-Values
 - Types of generators



by end of May2019:

- On-site inspections: ~ 200
- Response Rate: ~ 50% of Interviews



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.
- Screening on site is a necessary step to relate building polygons as sampling units (SU) to buildings as research objects (RO).
- Two-Stage, stratified Sampling with 500 Survey Districts as PSUs with 200 Building Polygons as Secondary Sampling Units (SSU) each make a good sample.
- Response rates in the interview phase turn out to be sufficient in order to do meaningful statistics with reasonable sample sizes
- About 50% of the respondents in the interviews are interested in an on-site inspection.
- The Sampling Design works! It can be transferred to other countries with a similar geospatial data stock.*

(*) Unless there is a building register already, the set up of which we strongly recommend for Germany also.

Research Database Non-residential Buildings

(www.dataNWG.de)

The Expedition into the
unknown Continent of non-residential Buildings
is on the way ...



Quelle: AdobeStock