TECHNISCHE UNIVERSITÄT WIEN

Building renovation passports: an instrument to bridge the gap between building stock decarbonisation targets and real renovation processes

Iná MAIA, Lukas KRANZL

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Energy Economics Group

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Introduction

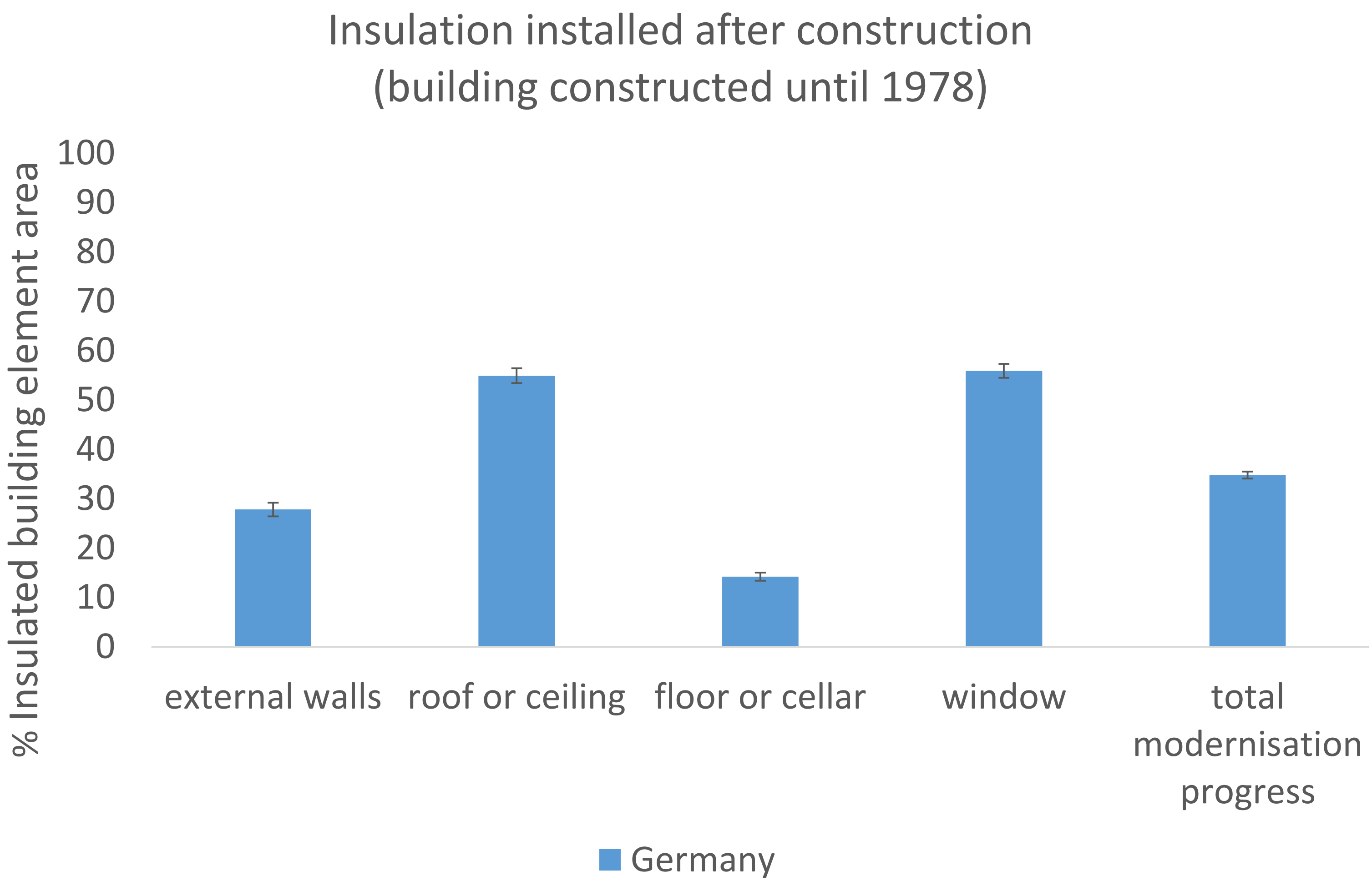
- Building renovation passports: what is it?
    - Energy Performance of Buildings Directive (EPBD) 2018/844/EU introduced in Article 19a:

  "complementary document providing a **long-term** and **step-by-step** renovation roadmap for a specific building"

    - This document should guide and help building owners through the renovation process

- Why can it bridge the gap between building stock decarbonisation targets and real renovation processes?
    - In **real life**, many renovation processes are performed step-by-step
    - But, most deep renovation **modelling focus** on single stage deep renovation

Introduction



Source: adapted from Diefenbach N. and Cischinsky H., 2016, Datenerhebung zu den energetischen Merkmalen und Modernisierungsraten im deutschen und hessischen Wohngebäudebestand (Table 124)

Research question

- What is the potential role of step-by-sep renovation measure sequence to achieve ambitious decarbonisation targets in the German residential single family house building stock?

Research question

- In the step-by-step approach, how to determine the time step of each renovation measure?

- How does each building type‘s energy demand develop during the period from the construction year until 2050?

- Pre-analysis:
  - What happened with each building type in the past?
  - When did it happen?
  - What does is represent for the „building history“ until now?

Method

1st step

- **Target: determine a step-by-step approach**
- literature review
- definition of reference buildings: single family houses building stock (DE)
- data collection
- synchronization between the databases: Tabula and material life time

Setting a step-by-step approach

2nd step

Energy demand development in the step-by-step concept

- **Target: analyse space heating demand development over whole building's lifetime until 2050 – since construction year**
- plausibility proof of the first assumptions
- first analysis regarding possible renovation cycles

3rd step

- **Target: compare the results in at building stock level**
- setting the conditions of a single stage deep renovation approach
- comparison of both approaches

Upscale and comparison with single stage concept and Invert/EE-Lab

Invert-EE/Lab (SET-Nav scenario)
reduction scenario: 77 % CO_2-Emission

Pre-analysis

- Relevant parameters: building element‘s material and it‘s lifetime

Y=yes, the building element has the corresponding building material

N=no, the building element does not have the corresponding building material

Building element	Building material	Material's lifetime [yr]	until 1918	1919-1948	1949 - 1957	1958 - 1968	1969 - 1978	1979 - 1983	1984 - 1994	1995 - 2001	2002-2009
windows	multi glazing	25	y	y	y	y	y	y	y	y	y
floor	insulation	30	n	n	n	y	y	y	y	y	y
external wall	insulation	30	n	n	n	n	y	n	n	y	y
roof	insulation	30	n	n	n	y	y	y	y	y	y
floor	wood (load bearing)	60	y	n	n	n	n	n	n	n	n
external wall	cement	70	n	n	n	n	n	n	y	n	n
external wall	wood	70	n	n	n	n	n	n	n	n	n
windows	single glazing	80	n	n	n	n	n	n	n	n	n
external wall	brick (load bearing)	90	y	y	y	y	n	y	n	n	n
roof	cement reinforced	100	n	n	n	n	n	n	n	n	n
floor	natural stone (load bearing)	100	n	y	y	n	n	n	n	n	n
roof	wood chairs	120	y	y	y	n	n	n	n	n	n

Table 1: Characterization of the reference buildings - building elements, building material and material lifetime (for each building vintage, a reference buildings for single family houses in Germany).
Source: *own table, based on* (TABULA and EPISCOPE project, 2016) *and* (Pfeiffer et al., 2010)

Pre-analysis

- Building elements’ renovation cycle until 2017:

Construction period	until 1918		1919-1948		1949 -1957		1958 -1968		1969 -1978		1979 -1983		1984 -1994		1995 -2001	
Construction year	1875	1918	1919	1948	1949	1957	1958	1968	1969	1978	1979	1983	1984	1994	1995	2001
Building age until 2017	142	99	98	69	68	60	59	49	48	39	38	34	33	23	22	16
Roof	1	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0
Floor	3	2	2	0	0	0	1	1	1	1	1	1	1	0	0	0
External wall	2	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0
Window	5	3	3	2	2	2	2	1	1	1	1	1	1	0	0	0

Table 2: Building elements’ renovation cycle until 2017, for each building vintage. Source: *own table*

- Buildings with building element‘s life cycle, therefore building stages
- Renovation cycles don‘t mean energy performance improvement
- Windows replacement is the most frequent measure
- Renovation only happens, if material’s end-of-life is achieved

Other relevant assumptions

- Minimum requirement of heat protection standards for new buildings as orientation basis for existing buildings

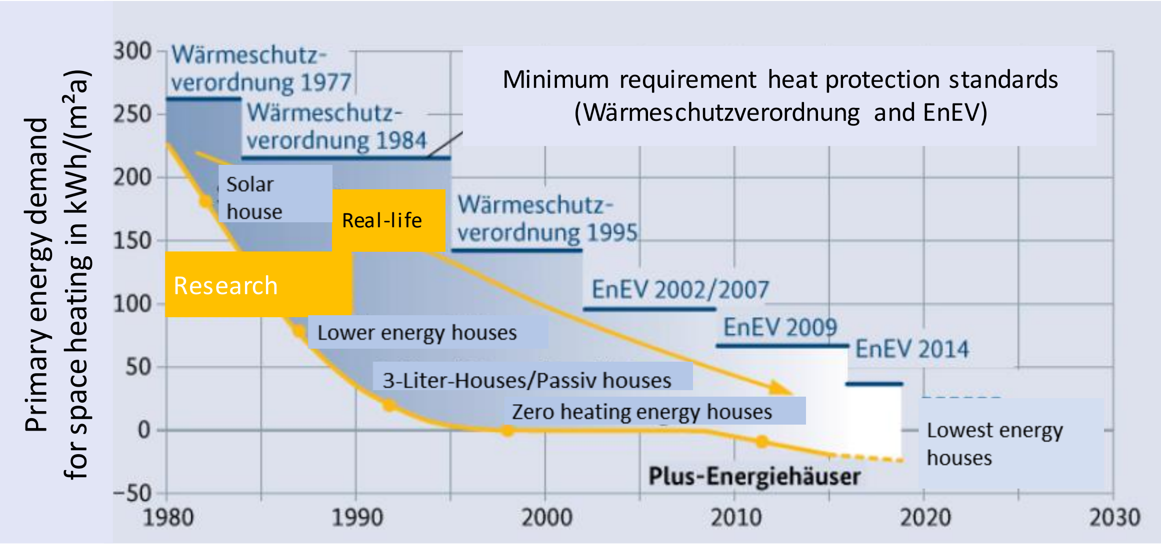
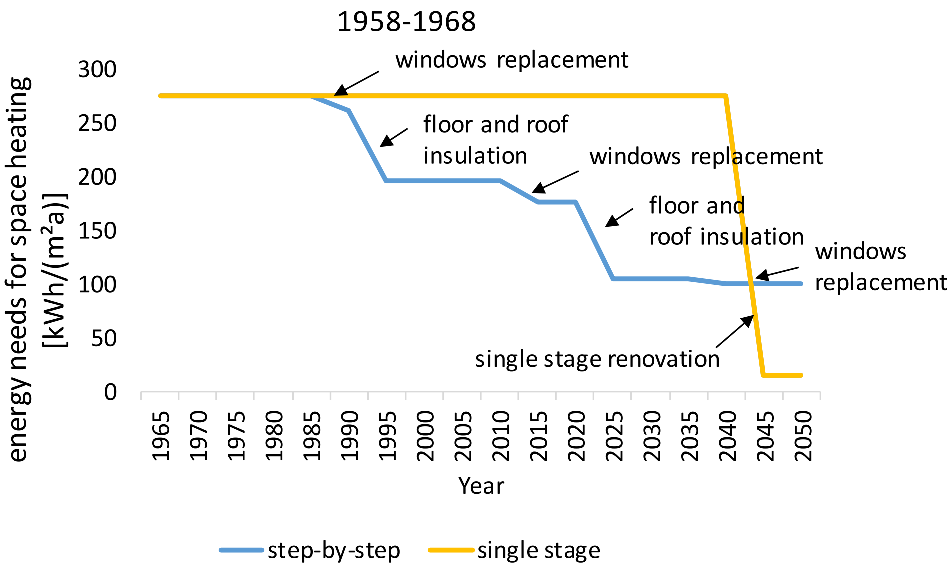


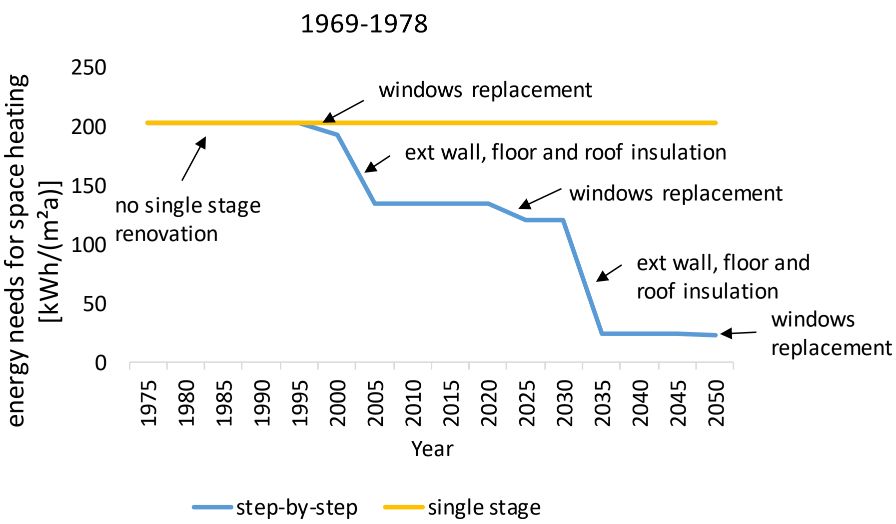
Figure 1: Development of German energy efficiency building codes. Source: adapted from BMUD, 2016

- Single stage approach: constant time step frequency of 80 years

Results

- Development of energy needs for space heating (concepts step-by-step and single stage)
- Examples: Construction vintages 1958-1969 and 1969-1978





Results

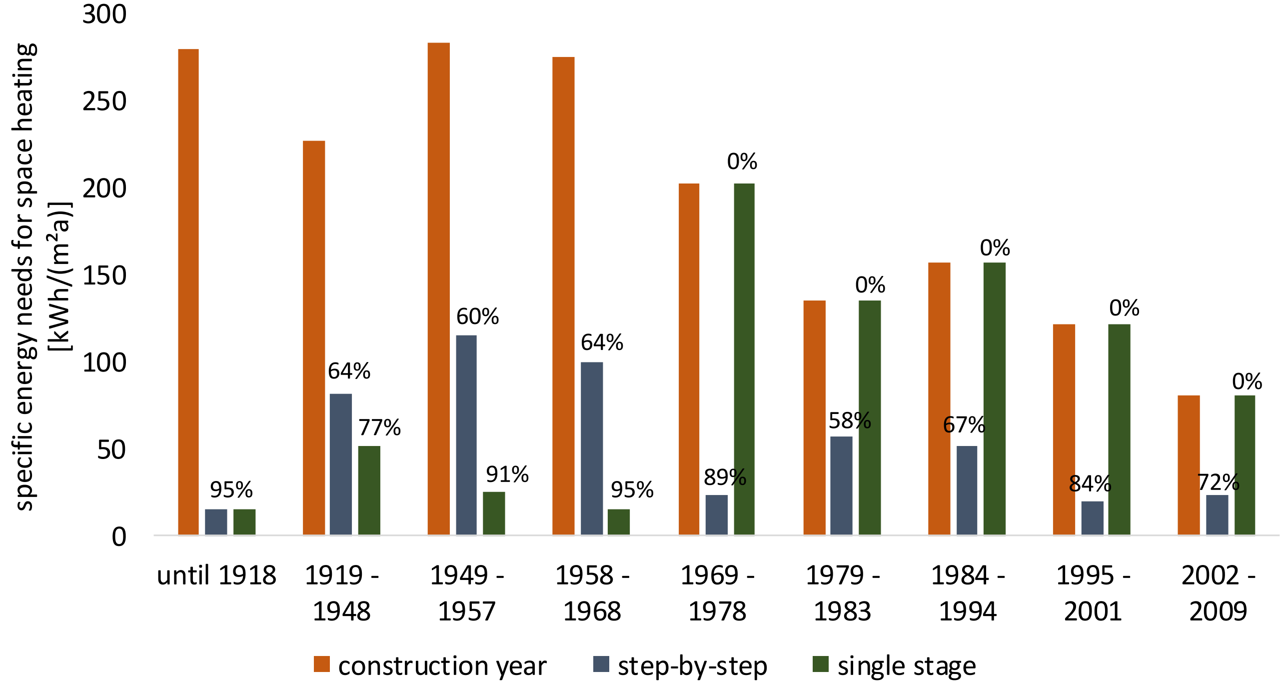
- Year of the last renovation step (step-by-step and single stage concept)

Building vintage		until 1918	1919 - 1948	1949 - 1957	1958 - 1968	1969 - 1978	1979 - 1983	1984 - 1994	1995 - 2001	2002 - 2009
Construction year of reference building		1890	1935	1955	1965	1975	1980	1990	2000	2005
Step-by-step	Roof	2040	no renovation	no renovation	2025	2035	2040	2050	2030	2035
	Floor	2040	2035	no renovation	2025	2035	2040	2050	2030	2035
	External Wall	2040	2025	2045	no renovation	2035	2050	no renovation	2030	2035
	Window	2040	2035	2030	2040	2050	2030	2040	2050	2035
Single stage	all building elements	2050	2015	2035	2045	no renovation	no renovation	no renovation	no renovation	no renovation

Table 3: Last renovation year

Results

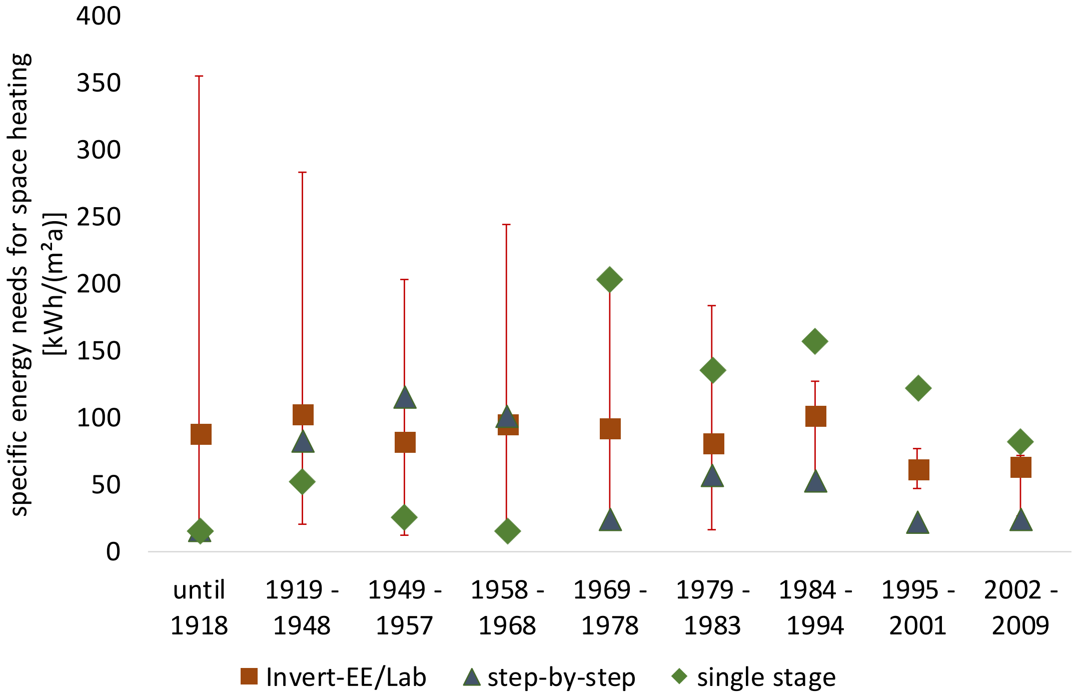
- Specific energy needs in kWh/(m²a) of the construction year and after renovation: step-by-step and single stage concepts (for each building vintage)
- Energy savings (%) based on the energy demand in the construction year



Graph 2: Energy needs (before and after renovation) and energy savings according to both step-by-step and single stage concept, for each building vintage

Results

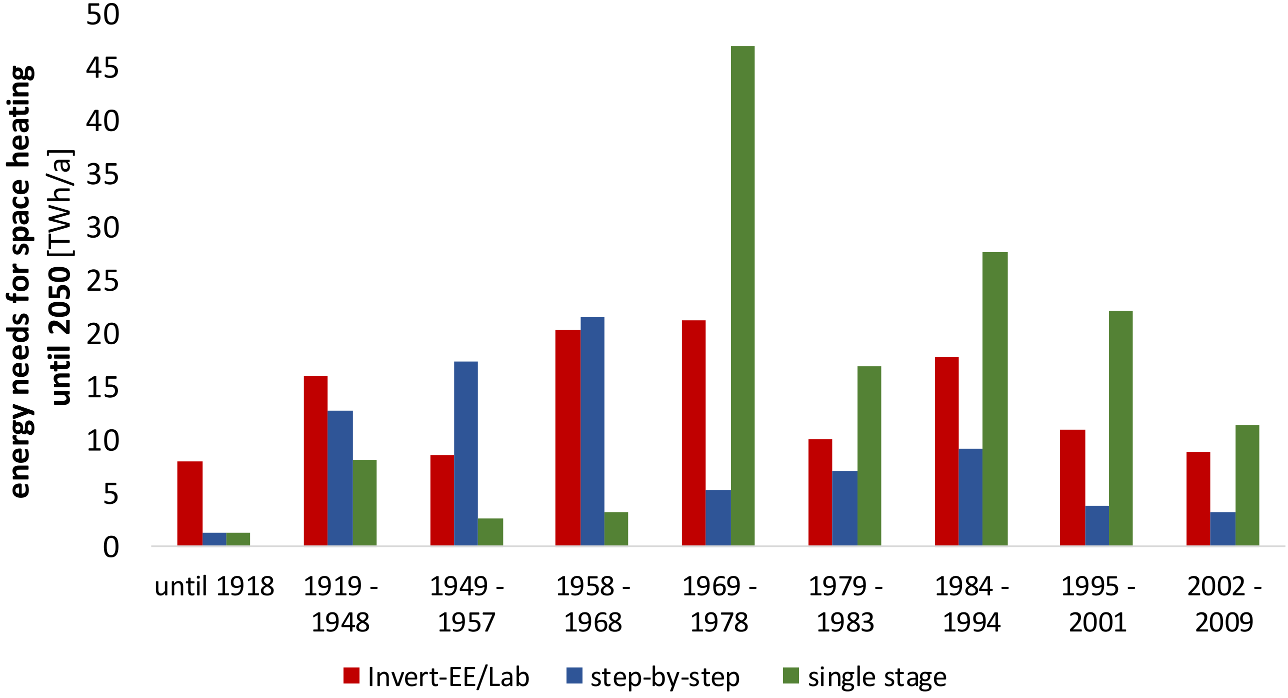
- Specific energy needs for space heating in kWh/(m²a) with step-by-step concept, single stage concept and model Invert/EE-Lab
- Reference building based on the construction year



Graph 3: comparison of specific energy needs for space heating in kWh/(m²a) between step-by-step concept, single stage concept and Invert/EE-Lab model, for a reference building of each building vintage (before 1918 until 2009)

Results

- The total energy needs for space heating in TWh/a in 2050:
  - 122 TWh/a (Invert-EE/Lab)
  - 81 TWh/a (step-by-step)
  - 140 TWh/a (single stage)



Graph 4: comparison of total energy needs for space heating TWh/a between step-by-step concept, single stage concept and Invert/EE-Lab model, for each building vintage

Conclusion

- **Period of time to complete first renovation cycle according to materials lifetime:**
  - non-insulated building elements need longer period to perform the first renovation cycle-> because of insulation lifetime (25-30 years)
  - after the first renovation cycle was completed, the subsequent renovation cycles happen more frequently

- **Comparison between both concepts:**
  - step-by-step concept: faster adaptation of the building elements to the building code in force as insulated building elements need shorter period of time to perform the next renovation cycle than non-insulated ones
  - single stage concept: building element might not have reached its end-of-life by the time of renovation and building's energy performance remains constant over a longer period of time

- **Upscale and comparison with Invert-EE/Lab (SET-Nav Scenario):**
  - distribution of buildings, in terms of number of buildings and their different energy needs, becomes a relevant parameter
  - step-by-step and single-stage present plausible results when compared to the Invert-EE/Lab Model
  - the step-by-step approach resulted in lower energy demand than the single stage approach (comparison until 2050)

Limitations and next steps

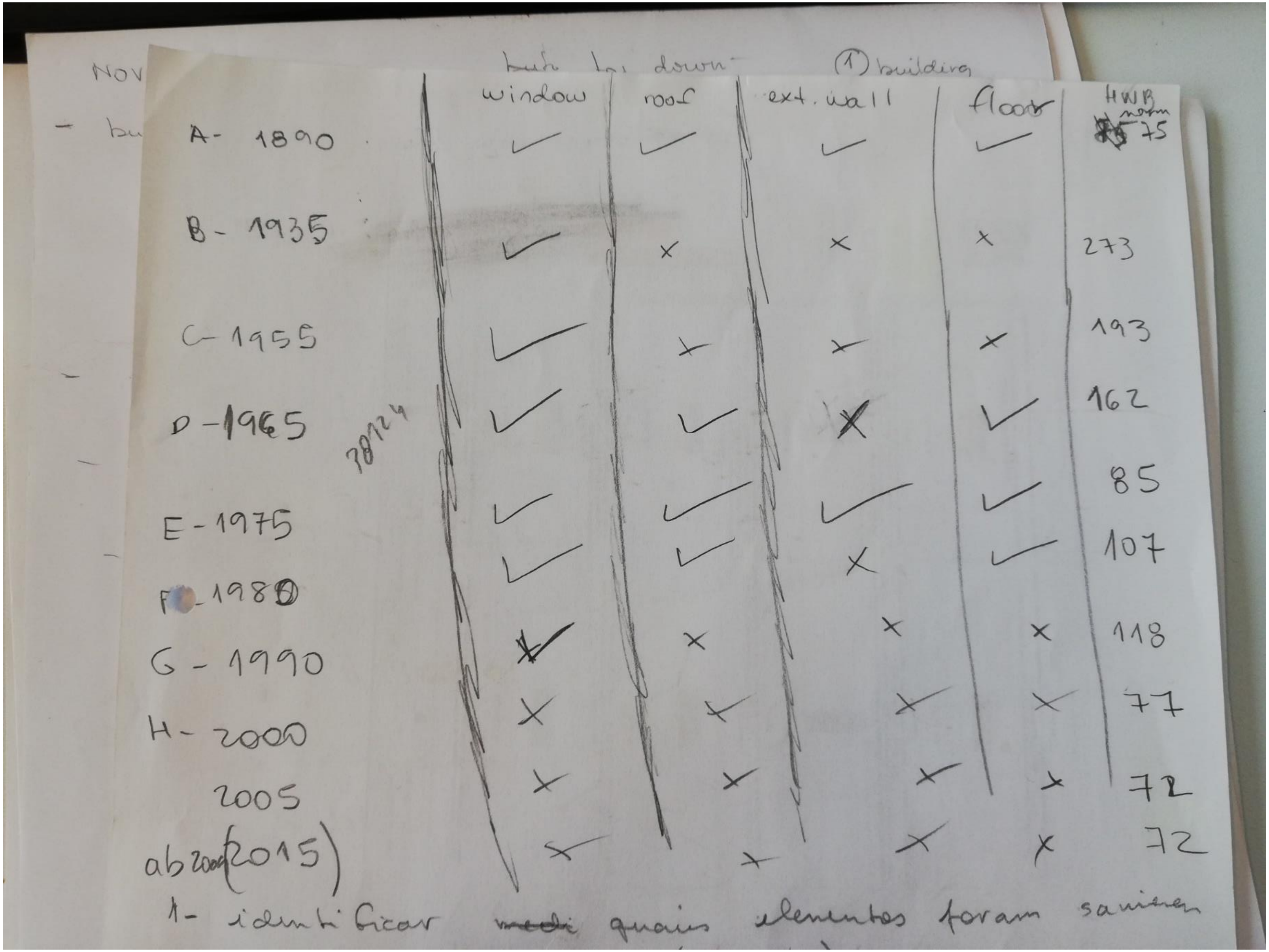
- Limitations
  - reference buildings (described according to the chosen database)
  - further: sensitivity analysis
    - reduced or increased time intervals between renovation in the single-stage concept
    - limited information in old building codes for existing buildings
    - we assume that in the future, benchmarks for existing buildings will follow the same threshold as for new buildings
  - choice of the step-by-step renovation measures -> renovation packages
- Next steps
  - integration of replacement of heating systems with hot water preparation;
  - considering a more realistic distribution of the building elements´ lifetimes, e.g. by using a Weibull distribution (as also done in the model Invert/EE-Lab);
  - empirical evaluation of the historical renovation cycles;
  - economic assessment:
    - include accurate estimation of investment costs
    - include investment costs as decision parameter for a deep renovation
    - economic consequences of not reaching materials end-of-life should be taken into account (rest-value of material)

Thank you for your attention!

Iná Maia

maia@eeg.tuwien.ac.at

Orig. Photo: Patrick Stargardt



	window	roof	ext. wall	floor	HWB norm
A - 1890	✓	✓	✓	✓	~~85~~ 75
B - 1935	✓	×	×	×	273
C - 1955	✓	×	×	×	193
D - 1965	✓	✓	×	✓	162
E - 1975	✓	✓	✓	✓	85
F - 1980	✓	✓	×	✓	107
G - 1990	~~✓~~ ×	×	×	×	118
H - 2000	×	×	×	×	77
2005	×	×	×	×	72
ab ~~2009~~ (2015)	×	×	×	×	72

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1- identificar ~~modi~~ quais elementos foram saniert

Building vintage		until 1918	1919 - 1948	1949 - 1957	1958 - 1968	1969 - 1978	1979 - 1983	1984 - 1994	1995 - 2001	2002 - 2009
construction year	[kWh/(m²a)]	280	227	284	275	203	135	157	122	81
step-by-step	[kWh/(m²a)]	15	82	115	100	23	57	52	20	23
single stage	[kWh/(m²a)]	15	52	25	15	203	135	157	122	81
Energy savings step-by-step	[%]	95	64	60	64	89	58	67	84	72
Energy savings single stage	[%]	95	77	91	95	0	0	0	0	0