Historic buildings and city centres – the potential impact of conservation compatible energy refurbishment on climate protection and living conditions

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ABSTRACT

Is it reasonable to invest - thoughts and money - in the energy refurbishment of historic buildings? This paper quantifies the potential impact in terms of climate protection and enhanced living conditions – looking not only at exemplary listed buildings, but more generally historic "cityscapes". Statistics reveal that 14% of EU-27 building-stock dates before 1919, other 12% between 1919 and 1945 (with considerable national differences), corresponding to 30 resp. 55 million dwellings and 120 million Europeans living there. With information on climatic regions and building performance a heating-demand of 855 TWh corresponding to more than 240 Mt CO_2 can be estimated. Refurbishment can save 180 Mt CO_2 within 2050 (3.6 % of 1990's EU-27-emissions), while bringing indoor comfort increases (higher surrounding temperatures, less draughts, ...) and energy-costs decrease. Finding conservation-compatible solutions enhances therefore long-term-conservation and sustainable management of our towns.

KEYWORDS

Energy refurbishment, old town, housing statistics, energy refurbishment, indoor comfort, CO_2 emission

INTRODUCTION

The main question behind the herein presented analysis is, whether it is reasonable to invest – thoughts and money – in the energy refurbishment of historic buildings?

Energy demand in buildings contributes 40% of the final energy demand in Europe. Within the last decade Europe has joined forces to explore the huge saving potential [1] in this sector, with a variety of measures on different levels, e.g. the European Energy Performance in Buildings Directive [2]. The latter, however, both in its first version [3] and in the recast [2] allows the implementing member states not to apply the requirements to buildings and monuments officially protected as part of a designated environment or because of their special architectural or historic merit if this would unacceptably alter their character or appearance (Art.4 §3 resp. §2). While this position is very understandable for the definition of general minimum requirements, it seems to lead to a general not-consideration of historic buildings when talking about energy refurbishments.

Even if the definition of historic buildings is not restricted to "protected" or "listed" buildings, the energy refurbishment of them should be subject to particular attention, both as regards conservation and aesthetical [4, 5] as well as structural and building physics related issues [6]. Interventions need interdisciplinary collaboration and more effort, as “standard solutions” cannot be defined.

This paper quantifies the potential impact in terms of climate protection and enhanced living conditions – looking not only at exemplary and listed buildings, but more generally at historic “cityscapes” concentrating on the residential sector.

METHOD

Definition of the scope

The analyses in this paper are focused on dwellings. EU-27 countries are considered and reference year 2001 is chosen. Two periods for construction usually used for national housing statistics are considered as possible categories of historic buildings:

(i) buildings built before 1919 and
(ii) buildings built between 1919 and 1945.

Housing

Main data source for the numbers of dwellings by period of construction is the “Bulletin of Housing Statistics for Europe and North America 2004” [7] which is published regularly by the United Nations Economic Commission for Europe (UNECE). Specifically, table pubHB03.xls reporting the aggregated values by country and period of construction was used. Values are given in percentage of dwellings dating from the single construction period. Absolute numbers of dwellings were calculated by multiplying this percentage with the total number of dwellings for the specific year of reference, which is reported by UNECE in the same table.

For five countries, i.e. Belgium, Czech Republic, Germany, Greece and Poland, information was retrieved from table pubHB06, which reports the size of dwellings by period of construction. In these cases the information from the column “Total occupied dwellings”, which reports the total percentage of dwellings for this period of construction was taken.

For Italy and United Kingdom, accounting with 27’269 (2001 value, from ISTAT) resp. 25’456 (2001 value, from UNECE) dwellings for 24.9 % of dwellings of EU-27, the numbers were retrieved from national statistics. For Italy data is available related to reference year 2001 from the population census (table “Abitazioni in edifice ad uso abitativo per epoca di costruzione – Italia – Censimento 2001” [8]). For UK reference is made to three different tables from the national housing statistics [9]: table 110, reporting the dwellings stock by period of construction for England (reference year 2007), table 104 reporting the historical series of total dwelling stock in England (from 1991 to 2007) and table 101 reporting the historical series of total dwelling stock in UK (from 1991 to 2007). From this information the distribution of dwellings by period in construction for UK with reference to 2001 was estimated (see Table 1).

Data for Malta and Sweden are missing. The latter accounts with. 4’307 (2001 value, UNECE) dwellings for 2 % of EU-27 dwellings. For the calculation of total dwellings from a specific period of construction in Europe, the European average distribution based on the other countries was applied also to Sweden. For Malta no data is reported by UNECE, error for not-consideration is however estimated to be low.

Table 1. Estimation of dwellings' distribution to periods of construction in UK (in % resp. thousand dwellings)

Table 110 describes the distribution of dwellings by period of construction, total number 21'989 thousand

-1852	1852-1918	1919-1944	1945-1964	1965-1984	1985-1994	1995 or later
4%	15%	19%	22%	24%	7%	9%

Table 104 reports for 2006 21'990 thousand dwellings in England
Table 101 reports for the same year 26'418 thousand dwellings in UK
distributing the total dwellings in UK to the construction periods reported for England results in the following numbers

1'057	3'963	5'019	5'812	6'340	1'849	2'378

adaptation to reference year 2001 (25'462 thousand dwellings in UK according table 101) results in

1'057	3'963	5'019	5'812	6'340	1'849	1'422

these numbers are finally rearranged to meet the UNECE periods as follows

-1852	1852-1918	1919-1944	1945-1964	1965-1984	1985-1994	1995 or later

before 1919	1919-1945	1946-1970	1971-1980	1981-1990	1991-2000	2001
5'020	5'020	7'714	3'170	2'378	2'161	
19.7%	19.7%	30.3%	12.5%	9.3%	8.5%	

Reference time and periods

Reference year 2001 is available for all countries except (i) Germany, where reference is 1998, (ii) Hungary, reference 1997, (iii) Netherlands, reference 1997, (iv) Poland, reference 2002, (v) Portugal, reference 1997, (vi) Romania, reference 1993. As regards the absolute numbers of dwellings in the two categories considered for historic building evaluation, no error is caused by the difference in reference year. The percentages in whole building stock might however vary slightly especially for countries with high number of new buildings between reference year and 2001.

Furthermore the construction periods are not defined identically in the single countries. How data for UK were adapted to the UNECE categories is described in Table 1. For France and the Netherlands differing periods are reported in the UNECE bulletin [7]. The influence on the analysed construction periods should however be small, since the difference is only few years in relation to quite long periods. Some specific deviations as described in [7] are, for completeness also reported in Table 2.

Population

Population figures were taken from the same sources as housing information [7, 8, 9]. An even distribution of the population to dwellings irrespectively of period of construction is assumed for the calculation of people living in "historic buildings".

Estimation of Energy Consumption and related CO_2 Emissions

For the estimation of the energy consumption of the "historic buildings", an average demand of 170 kWh/m²a is applied. This amount is consistent both with the average calculated from a sample of 193 audited buildings by Balaras & al. in [10] and with the average for EU-27 retrievable from data reported by Uihlein & Eder in [11]. The CO_2 emission factor for EU-27of 0.28 in 2000 connected to this energy consumption was also taken from data provided by Uihlein & Eder in [11].

An average dwelling size of 90 m² was revealed from the UNECE bulletin [7]. Table pubHA042006 reports size classes of which the weighted average was determined from the mean sizes (resp. upper or lower limit for first and last class) weighted with the number of dwellings for Germany, France, Italy and Poland, representing in sum 50% of total dwellings in EU-27. This value is also consistent with the figure reported by Balaras & al. in [12] for EU-15.

Evaluation of Saving Potential

The estimation of the energy saving potential of energy refurbishment interventions in protected or listed buildings is based on the analysis of realised cases, referring mainly to two sources of information: IEA SHC Task 37 “Advanced Housing Renovation with Solar and Conservation” and the online archive for innovative energy project of BINE information service.

RESULTS

In EU-27 the building stock built before 1919 amounts to 14.3% - in absolute numbers more than 30 million dwellings and 65 million Europeans living there. The share varies however considerably from country to country with a minimum of 1.7 in Finland and a maximum of 22.8 in France. Noticeably in three of the five countries with highest dwelling number in EU-27, the value is about 20% or higher. Also in Denmark (20.9 %), Austria (19.1 %), Hungary (15.6 %), Slovenia (15 %) and Italy (14.3 %) the share is above European average. Certainly the big part of this

Table 2. Dwellings’ distribution to periods of construction in U-27 (in %)

country	year	total	before 1919	1919 -1945	before 1945	1946 -1970	1971 -1980	1981 -1990	1991 -2000	2001 & later
Austria	2001	3'284	19.1	8.6	27.6	27.9	16.2	13.0	15.3	…
Belgium[*]	2001	4'084	11.5	12.7	24.2	22.3	11.8	7	4.8	4.9
Bulgaria	2001	3'686	2.4	11.0	13.5	36.8	22.6	19.8	7.2	0.2
Cyprus[*]	2001	293	…	7.4	7.4	16.9	20.7	27.4	25.0	…
Czech Rep.	2001	4'336	10.9	14.7	25.6	26.3	22.7	16.4	8.2	
Denmark	2001	2'523	20.9	17.8	38.6	29.8	16.4	9.4	5.2	0.6
Estonia[†]	2001	622	9.4	14.2	23.7	30.0	21.4	24.9[‡]	…	…
Finland[*]	2001	2'544	1.7	9.2	10.9	30.8	23.5	20.1	12.4	1.1
France[*]	1999	28'702	22.8	12.1	34.9	31.4	12.4	11.0	10.3	
Germany	1998	37'050	8	6	14.0	57.9	10.2	3	7.5	
Greece	2001	3'532	2.3	6.4	8.7	34.1	26.1	18.3	12.7	
Hungary	1997	4'011	15.6	13.9	29.4	27.2	21.4	17.5	4.0	
Ireland	2001	1'337	10.7	8.5	19.1	17.1	18.2	16.8	28.8	
Italy	2001	27'269	14.3	9.9	24.2	36.8	18.9	12.2	7.9	
Latvia	2002	942	11.0	14.0	25.0	28.0	22.0	21.3	3.6	0.1
Lithuania	2001	1'292	6.2	23.4	29.6	33.2	17.6	13.5	5.8	0.3
Luxembourg[*]	2001	172	11.9	14.8	26.7	27.0	14.9	11.6	17.1	…
Malta					0.0					
Netherlands	1997	6'441	9.9	12.8[§]	22.7[§]	28.4	19.6	18.3	10.9	
Poland[*]	2002	11'633	10.1	13	23.1	26.9	18.3	20.9	7.7	1.1
Portugal[**]	1997	4'771	12.1	8.8	20.9	28.3	19.5	31.2[‡]	…	
Romania[**]	1992	7'682	6.7	11.2	17.9	39.5	25.1	16.8	0.7	
Slovakia[*][**]	2001	1'712	3.4	6.6	10.0	35.1	25.6	21.0	6.8	…
Slovenia[*]	2001	719	15.0	6.8	21.8	26.9	22.8	27.1	…	…
Spain	2001	20'823	22.0	16.9	38.9	12.9	15.6	32.5	…	
Sweden										
UK	2001	25'462	19.7	19.7	39.4	30.3	12.5	9.3	8.5	
EU-27			**14.3**	**12.1**	**26.4**	**34.4**	**15.7**	**14.1**	**7.2**	

[*] Difference of percentage totals from 100% due to dwellings with unknown built date
[†] Recalculation based on census 2000
[‡] 1981 and later
[§] Before 1944
[**] Percent to occupied dwellings and not to total dwellings

Table 3. Dwellings' distribution to construction periods in U-27 (in thousands).

country	year	total	before 1919	1919 -1945	before 1945	1946 -1970	1971 -1980	1981 -1990	1991 -2000	2001 & later
Austria	2001	3'284	627	281	908	915	533	427	501	…
Belgium*	2001	4'084	470	519	988	911	482	286	196	200
Bulgaria	2001	3'686	90	406	496	1'357	832	731	264	6
Cyprus*	2001	293		22	22	49	61	80	73	…
Czech Rep.	2001	4'336	476	642	1'118	1'148	991	716	358	
Denmark	2001	2'523	527	448	975	751	413	238	132	15
Estonia†	2001	622	59	89	147	187	134	155		…
Finland*	2001	2'544	44	233	277	783	599	512	315	29
France*	1999	28'702	6'539	3'481	10'020	9'024	3'546	3'168	2'944	
Germany	1998	37'050	2'964	2'223	5'187	21'452	3'779	1'112	2'779	
Greece	2001	3'532	81	226	307	1'204	922	646	449	
Hungary	1997	4'011	624	557	1'181	1'090	857	704	161	
Ireland	2001	1'337	143	113	256	228	243	225	385	
Italy	2001	27'269	3'894	2'705	6'599	10'041	5'143	3'325	2'161	
Latvia	2002	942	104	132	235	264	207	201	34	1
Lithuania	2001	1'292	80	302	382	428	228	175	75	4
Luxembourg*	2001	172	20	25	46	46	26	20	29	…
Malta										
Netherlands	1997	6'441	637	824	1'461	1'830	1'265	1'181	704	
Poland*	2002	11'633	1'175	1'512	2'687	3'129	2'129	2'431	896	128
Portugal**	1997	4'771	578	422	999	1'352	930	1'489		
Romania**	1992	7'682	513	862	1'375	3'036	1'928	1'290	53	
Slovakia* **	2001	1'712	59	113	172	601	438	359	117	…
Slovenia*	2001	719	108	49	156	193	164	194		…
Spain	2001	20'823	4'581	3'519	8'100	2'686	3'248	6'767		
Sweden										
UK	2001	25'462	5'019	5'019	10'039	7'714	3'170	2'378	2'161	
SUM		204'951	29'408	24'725	53'015	70'421	32'267	28'808	14'788	382
EU-27		**211'623**	**30'366**	**25'530**	**55'933**	**72'714**	**33'317**	**29'746**	**15'270**	**395**

building stock makes part of the cultural heritage of European countries und gives identity to European cities, villages and public spaces.

Including also buildings built between 1919 and 1945, the percentage rises to 26.4% and more than 55 million dwellings as well as 120 million Europeans living there. In four European countries the share exceeds 1/3 of the building stock: UK (39.4 %), Spain (38.9 %), Denmark (38.6 %) and France (34.9 %). Only Finland, Slovakia, Greece and Cyprus do have shares which are less than half the European mean. Even if much less buildings from this latter epoch than from the building stock before 1919 are listed, they form a part of the city-centre and cityscape and retrofit interventions should take account of the specific demands in terms of aspect preservation.

While the share of historic dwellings in total building stock as shown in Figure 1 pronounces the importance of the issue for the single country, the amount of dwellings in absolute values as illustrated in Figure 2 shows the areas of major interest and concern in Europe.

The examples of energy refurbishments in Europe reported in Table 4 illustrate well, that assuming an energy reduction potential of Factor 4 is not exaggerated.

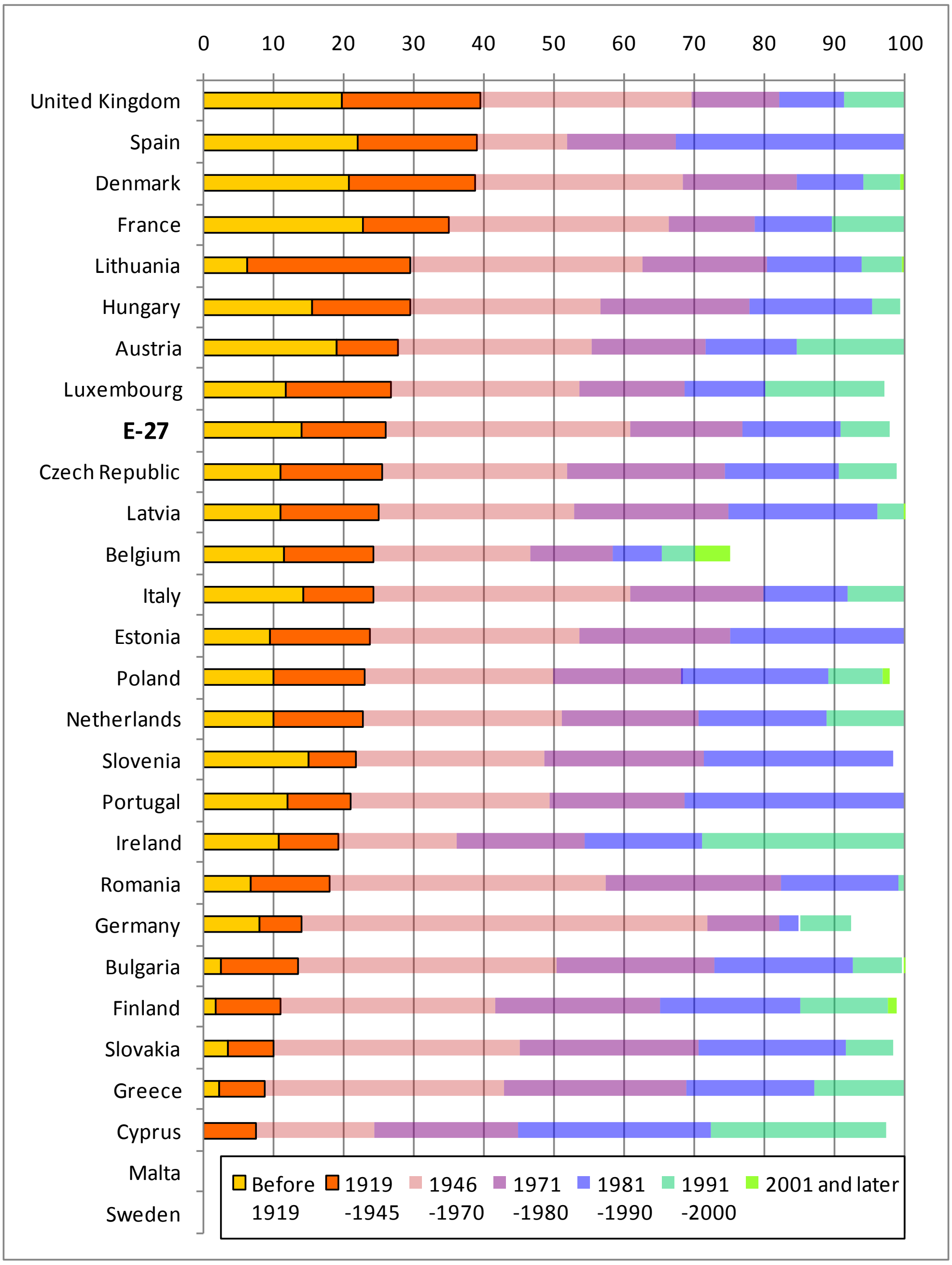

Figure 1. Share of dwellings in classes for periods of construction for EU-27, reference year 2001, ordered by share of buildings built before 1945. See also note* on 1th page of this paper.

Estimation for energy demand of the buildings built before 1945 is about 855 TWh, corresponding to a CO_2 emission of more than 240 Mt. Considering, that the vision of the European Construction Technology Platform expects by 2030 30% of the building stock to be retrofitted, by 2050 even the whole buildings stock [13], it is evident how important a significant intervention is: Factor 4 reduction corresponds to 180 Mt less CO_2 emission reduction per year! This is equivalent to 3.6 % of the total EU-27 CO_2 emissions in 1990.

While saving energy by simply heating less and living in twilight would considerably worsen living conditions, energy saving achieved with retrofit measures does on the

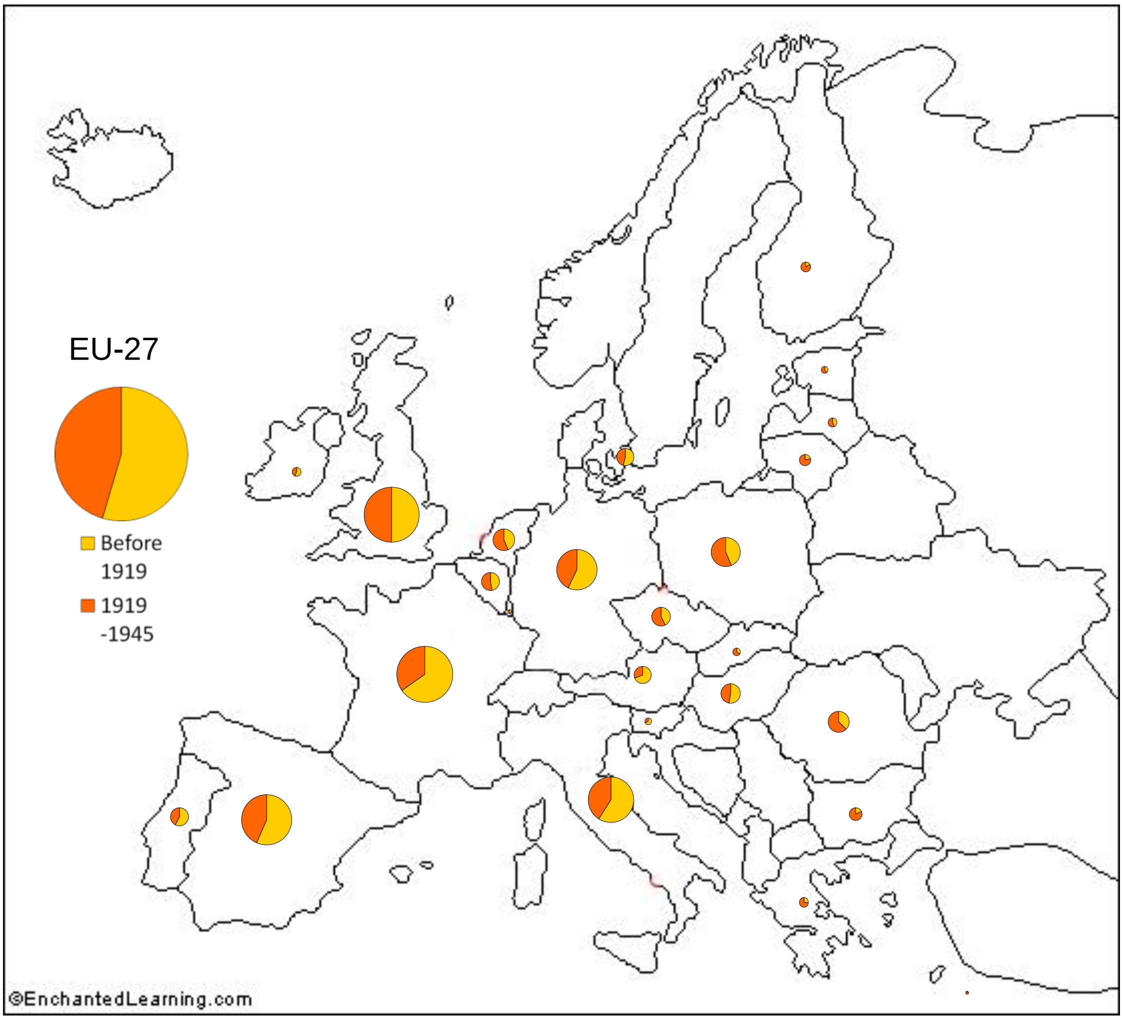

Figure 2. Dwellings built before 1919 and between 1919 and 1945 for EU-27. The area of the circle is proportional to number of dwellings.

contrary improve the indoor comfort for the occupants: Higher surrounding wall temperatures increase the perceived temperature, airtight and isolating windows avoid air draught and irradiative losses, repaired thermal bridges decrease the risk of mould grow, small energy demands allow for more comfortable low-temperature heating systems, extensive daylight use improves health and well-being.

The energetic retrofit is even an insurance for living comfort, especially for a socially vulnerable group, who might not be able to pay the energy bill any more due to rising oil-price.

Furthermore it can be sustained, that with the increased comfort demand of our society, the revitalisation of historic towns and its socioeconomic impact can be positively affected by the energy efficiency in these buildings [25].

DISCUSSION

The number of formally protected buildings in Europe is significantly lower than the herein considered buildings (dating before 1919 or from 1919 -1945). For Germany Grunewald & Will [26] report 4-5% for Germany and 10% (residential buildings in

Table 4. Realised energy refurbishments in Europe (not exhaustive list!). Reduction factor given for Heating demand (HD) and/or Primary Energy (PE).

Description	Demand after intervention kWh/m²a	Reduction factor
Baroque building in Görlitz (Germany): refurbishment to near passive house standard: combination of insulation plaster and interior (diffusion open) insulation for the street facing facade, high efficiency windows according historic appearance, ventilation system. Detailed monitoring system [14]	20 (HD)	>10 (HD)
Orangerie of Ansitz Kofler in Bolzano (Italy): listed building from 17th century; S/V 0.8(!); internal and external insulation, windows, ventilation. Detailed energy and hygrothermal monitoring [15]	30 (HD)	>10 (HD)
„Gründerzeit“ buildings “Kleine Freiheit” in Hamburg (Germany)Interior insulation for ornamented street facing facade (diffusion open), exterior insulation towards the courtyard. Solution for beam end restoration tested. Special issue: Air tightness [16]	60 (HD)	5 (HD)
“Jugendstilhaus” in Nürnberg (Germany): listed building from 1912, internal insulation and vapour barrier (6 cm→0.28 W/m²K), refurbishment of old box type windows (3 →1.1 W/m²K), ventilation with heat recovery; ecological materials, rain water for toilets and garden. Monitoring [17]	109 (HD)	2.5
Passivhaus in the city wall of Günzburg (Germany): listed building from the 18th century; external and partitions’ insulation (not visible timber frame); windows restoration and integration with 3-pane windows; insulation of basement (“underpinning the exterior wall); heat pump using exhaust air for domestic hot water preparation. Issue: air-tightness of the intrinsically flexible construction. [18]	15	>10
Schlacht- und Viehhof in Nürnberg (Germany): new utilization as kinder garden. Internal and external insulation (insulating plaster), major effort put in reduction of thermal bridges, decisions on thicknesses and materials based on hygrothermal simulations [19]	45 (HD) 56 (PE)	4 (HD) 5 (PE)
“Jugendstil” villa (Germany) from 1905, refurbished conserving the specific Jugenstil elements, CO_2 emission reduced by 40kg/m²; internal insulation with adaptive vapour barrier and special solution for decorative glazing with lead glass [20]		
Historic Building in Modena (Italy): primary energy reduction of factor 5 with insulation measures, improved windows and solar thermal collectors. [21]	70 (PE)	5 (PE)
Apartment building from 1898 in Zürich (Switzerland): primary energy reduction of factor 4 with insulation, new windows, heat recovery system, pellets boiler and solar collectors [22]	40 (PE)	4 (PE)
Rowhouse, Henz-Noirfalise in Eupen (Belgium): refurbishment to passive house standard (reduction of 95%) with internal insulation, triple glazed windows, heat recovery and solar thermal collectors [23]	12 (PE)	>10
Renewable Energy House (Belgium): No fossil fuel needed at all! Insulation of façade and roof, Low emission, sun protective glazing, Highly-efficient lighting systems, Efficient mechanical ventilation system, Pellet heating system, Solar thermal heating and absorption cooling system, Geothermal heating and cooling system, Electricity production with PV [24]	0 (PE)	

this case) for Saxony, for Austria the number was estimated to be around 2% [27]. The wider approach is however in line with a development towards integrated and active conservation, e.g. followed in Denmark, where besides the ~9000 listed buildings, more than 300’000 where defined “worthy of preservation” [28]. Within SAVE project in 6 municipalities all buildings built before 1940 were documented [29]. As another example the City of Bologna is cited: 65% of the 3600 buildings in the city centre date before 1919, 80% before 1945. As an instrument to preserve the character of the old town, the concept besides the “listed” buildings the preservation category “building of documentary value” was introduced, including all buildings built before 1949 [30, Art. 57].

Applying a heating energy demand of 170 kWh/m²a implies that historic buildings – in average – do neither consume more nor less than the average building stock. There is however also some more detailed data reported by Balaras et.al. [12], which from the audit of 193 buildings in different European countries calculates average heating demands for 15-year periods: ~40 kWh/m²a (>1990), ~135 kWh/m²a (1975-1989), ~185 kWh/m²a (1960-1974), ~200 kWh/m²a (1945-1959), ~230 kWh/m²a (1930-1944) and of 170 kWh (<1930). The herein applied value might thus underestimate the heating consumption.

The saving potential, as outlined by the examples in Table 4, is pointing higher than the finally applied "Factor 4" reduction for the impact estimation. This underlines, that an average reduction of "Factor 4" (i.e. to 25% of the demand before intervention) is well achievable with market available techniques and solutions – keeping however in mind, that this is not necessarily true for each single historic building, where a specific solution has to found case by case.

There are a number of ongoing initiatives and projects, both on national and international level, which aim at giving guidance and providing solutions for typical issues met when refurbishing historic buildings. One example presented by the author within this conference is the FP7 project 3ENCULT, where a multidisciplinary team including conservation, technical and urban development experts, industry partners and stakeholder associations, develop passive and active energy-retrofit-solutions as well as diagnosis, monitoring and control instruments [31].

CONCLUSION

The wider interpretation of historic buildings, as discussed above, takes into consideration all buildings, which have been built before 1945. Even if only a reduced number of these buildings are formally protected and listed buildings, they do form a part of Europe's typical city-centres and the "cityscape", and retrofit interventions should take account of the specific demands in terms of preservation aspect.

With regard to the above interpretation a heating-demand in historic buildings and old towns of 855 TWh corresponding to 240 Mt CO_2 has be estimated. Energy refurbishment can save 180 Mt CO_2 within 2050 (3.6 % of 1990's EU-27-emissions). At the same time indoor comfort increases, since the energy refurbishment also results in higher surrounding temperatures and less draughts, and energy-costs decrease.

Finding conservation-compatible solutions for the energy refurbishment of historic buildings enhances therefore long-term-conservation and sustainable management of our towns.

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