REPORT
DELIVERABLE 2.1

OutPHit WP2
Reliable Deep renovation Systems

An overview on qualities and requirements

Darmstadt, 10.10.2022,

D2.1_CATALOGUE WITH CATEGORIES OF EXISTING CONSTRUCTION PROTOTYPES (TASK 2.1)

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BUILDING TYPOLOGIES AND RELIABLE DEEP RENOVATION SYSTEMS

THE BUILDING STOCK IN GERMANY - POTENTIAL FOR SERIAL REFURBISHMENT

Building Typology

In Germany, single-family homes (SFH) are the most common building type with 55%, followed by terraced houses with 28%. Apartment buildings or multi-family houses (MFH) are in third place with 17% [see Table 4-IWU 2015]. Looking at the construction activities of the past decades, most of the housing units were built between 1958 and 1968, i.e. 50 to 60 years ago. Looking at the typical life cycles of the building envelope, it is clear that many of these building components are due for refurbishment.

PART OF THE BUILDING SHELL	AVERAGE AGE
OUTSIDE RENDERING	≥ 45 YEARS
OUTSIDE COLOURING	≥ 20 YEARS
ROOF TRUSSES (THE BEARING CONSTRUCTION)	≥ 50 YEARS
FLAT ROOFS (THE BEARING CONSTRUCTION)	≥ 50 YEARS
FLAT ROOF WATERPROOFING	30 - 40 YEARS
ROOFING	≥ 50 YEARS
WINDOWS	40 – 50 YEARS

The evaluation of [Data base of 2010] shows that 5% of old German buildings (built before 1978) are fully or partially listed [IWU 2015]. In the case of these buildings, it can be assumed that a refurbishment measure from the outside is not possible or only possible in parts.

Building law issues for buildings with a small boundary distance

In the best case, renovating the building envelope according to EnerPHit means applying thermal insulation 15 to 25 cm thick on the outside. For free-standing buildings with a large distance to the property boundary, this is usually not a problem.

However, if a building is located on the boundary or at a short distance from the public space, then an exemption is usually required because distance areas are not being observed or even the additional thermal insulation protrudes into the street space. These approvals of exceptions are now usually given by the building authorities without further ado, because the energetic refurbishment is considered valuable and sensible and a weighing of interests usually permits the reduction of the boundary distances to the necessary extent. In general, however, this must be applied for individually for each building project. In addition, the relevant regulations in Germany are the responsibility of the individual federal states and differ therefore from here to there.

If a building is located directly on the border with a private neighboring property, as is the case with terraced houses, for example, then the express consent of the neighbor must also be obtained in addition to the regulations of public building law.

Particularly in the case of terraced houses that are offset or buildings that are located on narrow paths with rights of way, there is regularly the problem that, in the worst case, a piece of wall to the neighboring property cannot be insulated or can only be insulated from the inside.

In terms of construction practice, this purely legal problem can only be solved by the neighbor ceding a part of his land, in the area of the length of the wall in question times the thickness of the insulation, which will then protrude over the land. However, such a transaction is legally possible only by mutual consent. There are very few cases so far where courts have ordered a corresponding transfer or sale of part of a plot of land. In this respect, private law regulations or exceptions are therefore far more difficult to clarify than exceptions concerning public building law. A legally binding statement on these issues can expressly not be made within the scope of this text.

Property law issues in multi-family houses of WEG

In the case of apartment buildings owned by so-called condominium owners' associations (COA), there is the additional problem of decision-making: in principle, every decision that changes something on the outside of the building, i.e. on the common property, must be made by the COA by consensus. In the meantime, decisions on energy refurbishment must be made by a simple majority. Until recently, each individual condominium owner had a quasi-veto right and could also block sensible measures. Again, a legally binding statement on these issues can explicitly not be given within the scope of this text. Moreover, these issues are regulated differently in different countries.

From a legal point of view, however, it is easiest if decisions on refurbishments can only be made by a single owner, i.e. if apartment buildings are rented out. In addition, it is usually easier to communicate and persuade housing associations because they are more aware of the economic benefits and implications than private owners.

The warm rent model

Basically, however, the owner-investor-user dilemma still remains there between the single owner and the tenants: because the owner has to bear the major part of the investment costs and can only pass them on to the tenants to a limited extent. The tenants, however, enjoy the benefit of lower energy costs after an energy retrofit. These issues have already been solved in individual cases with the warm rent model: because energy costs are very easy to calculate and practically capped after the EnerPHit refurbishment because they are very low, a flat rate for heating costs can be agreed in new leases if necessary. This not only saves administrative costs for consumption billing, but also allows the landlord to include the investment costs of the refurbishment in the warm rent. The warm rent then practically reflects the full life cycle costs (annuity).

Building structure

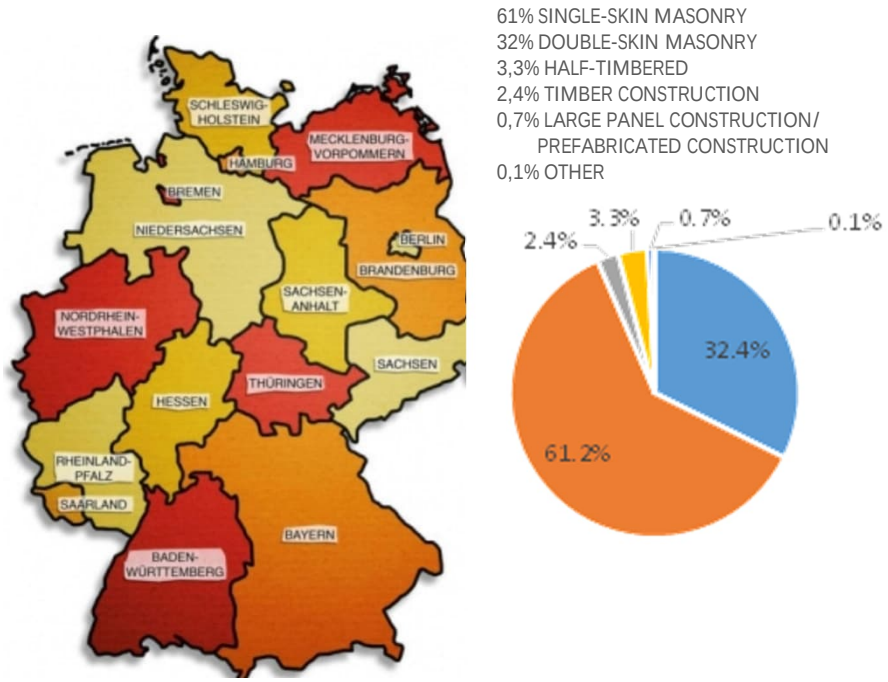

Figure 1: The majority of the existing building stock consists of single-skin masonry followed by double-skin masonry with 32%. Together, masonry constructions have a share of over 90% [IWU 2015]

In the context of refurbishment with prefabricated elements, questions of statics are of particular importance. The weight of the facade construction including windows and sun protection must be transferred to the existing construction or must be able to be supported by the existing construction. While in ETICS the load is transferred to the wall by a large number of dowels and adhesives, in curtain walls it is individual heavy load supports. The load transfer via the masonry and the floor slabs must be ensured accordingly. For this purpose, it is important to know the main wall formers of the existing building.

The figure clearly shows that the majority of the existing building stock consists of single-skin masonry. This is particularly favorable for the installation of curtain walls, as the loads can be transferred directly to the supporting structure. Double-skin masonry is particularly common in northern and northwestern Germany and presents a challenge in two respects at once. On the one hand, the load of the curtain wall must be transferred through the facing brickwork into the supporting structure. The moment to be transferred is greater because of the longer lever action, and the supports are correspondingly more massive. On the other hand, double-skin wall systems already have a high wall thickness (about 40 cm). With a highly insulating curtain wall, at least another 20 cm are added. In addition, the cavity between the supporting structure and the facing wall must be filled to prevent convection. Otherwise, the thermal insulation measure risks becoming ineffective. Another problem is that the cavities in the intermediate space are often already partially filled with rubble and are therefore no longer available as a heat-insulating layer.

CONSTRUCTION PROCESSES OF THE REFURBISHMENT

Usually, the refurbishment of existing buildings is carried out by different trades (roofers, painters and plasterers, shell construction companies, etc.) who are accompanied and coordinated by architects and energy consultants (architects and energy consultants).

Serial renovation, on the other hand, is characterized by a standardized construction process in which one company, e.g. as a general contractor (total solution provider), combines all the trades as well as the planning. The components and designs do not have to be conceived for each building, but rather put together according to a construction kit. It is not absolutely necessary that all components are industrially prefabricated – it can make sense to carry out parts of the refurbishment or even the complete refurbishment on site in the usual craftsman's way. The main differences lie in the standardization of the work steps and the execution as well as in the fact that the responsibility for the entire refurbishment is borne by a single provider:

Work packages / steps:	Tasks / Responsible:
• Definition of the objective	→ Energy consulting / as-built data collection
• Planning	→ architectural and engineering services
• Awarding of contracts	→ construction industry / manufacturer
• Execution	→ GU (all trades under one roof)
• Commissioning	→ Interface between architecture, engineering and contractors
• Optimization of operation and maintenance	→ Service provider

The most important precondition for successful refurbishment in this context is that the heating requirements of buildings must be drastically reduced in order to achieve a climate-neutral building stock. In [OutPHit-Key Points], it was shown that this objective can be achieved economically by refurbishing the building stock to EnerPHit level [passipedia 2019]. In addition, this opens up greater scope for regenerative energy supply. This is because in the winter half of the year in particular, significantly less renewable energy is available to cover the heating requirements of the existing building stock. Moreover, the seasonal storage of solar energy available in summer is highly lossy. The aim of the renovation is therefore to achieve the lowest possible heating requirement. For the renovation measure, it is therefore necessary to investigate which measures are suitable for achieving the EnerPHit standard. Depending on the nature of the specific building, this can mean different insulation standards for the building envelope and different solutions for the heat supply.

Inventory and energy consulting

In order to standardize the refurbishment process, the existing data is collected and, if necessary, digitized. The focus is on the components of the thermal building envelope as well as the heat generation and, if applicable, the ventilation system. In addition to the energetic qualities, the renewal cycles are important in order to make economically viable decisions regarding sensible renovation measures. Furthermore, it is imperative to collect static data of the existing structures. The static load transfer of the elements must be guaranteed.

In order to obtain meaningful documents for prefabrication, it is necessary to measure the building geometry again. The data is converted into a digital model, e.g. Building Information Modeling (BIM), using a 3D laser scanner, and this data is then used for a detailed energy balance calculation (PHPP). This can then be additionally matched with data on the actual existing energy consumption (energy performance certificate). Based on this, the necessary measures are defined and the energy properties of the components (e.g. U-values) required to achieve the EnerPHit standard are determined.

Planning - Award - Execution - Commissioning

For the building envelope, highly thermally insulated, thermal bridge-free or low thermal bridge and airtight component structures and connection details are required. This requires solutions from system providers for pitched roofs, flat roofs, walls, plinths, etc., as well as standard details for eaves, verges, parapets, dormer joints, window and door installations, balcony connections, etc. The required thermal parameters are described in detail in chapter Fehler! Verweisquelle konnte nicht gefunden werden..

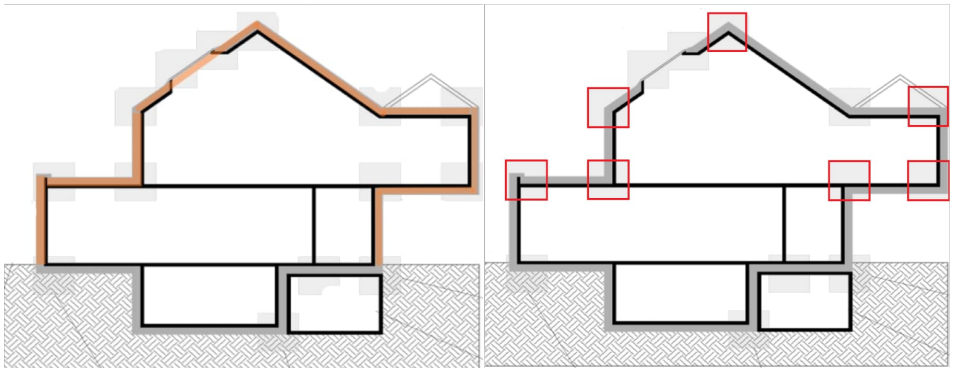

Figure 2: Schematic representation of the various components and connection details for a renovation of the building envelope.

The main challenge in planning is to adapt the standard wall structures and details to the specific object. In addition to the geometric boundary conditions, the condition and load-bearing capacity of the building structure also play a special role. Fa-

cade elements, including window and door elements, are either hung on the exterior wall or loaded on their own foundations. The latter means financially a significantly higher renovation effort. Roof elements either have to be placed on top of the existing roof beams or, for their part, act as new heat-insulating and at the same time load-bearing elements.

The building services can also be prefabricated to a large extent. Particularly in the case of multi-story residential buildings, it is worthwhile to ensure the heat supply of several buildings, e.g. via a local district heating network. The high level of renovation and the good quality of workmanship make it possible to implement economically attractive solutions. If the heating requirement is halved compared to a conventional refurbishment, the number of boreholes required for an energy supply with heat pumps and geothermal probes, for example, is also significantly reduced and the output of the heat pumps can be dimensioned accordingly smaller. The inclusion of regenerative energies, especially PV, promises further economic advantages, which make it possible to implement far-reaching renovations without affecting the rent. Here too, however, the lower the energy demand, the better it can be provided with renewable energies.

Modular and prefabricated solutions are also available as standard for building service technology and can be used reasonably. Heat pumps, hot water tanks and combined systems are often freely scalable and already available prefabricated and coordinated. Particular attention must be paid here to the optimal coordination of the components with each other. At best, the control and regulation of the building services systems should be uniform for all components. The control algorithms should be adapted to the behavior of the building after refurbishment – better thermal insulation – and be designed to be robust. For example, avoid simultaneous or short-term successive heating or cooling on any given day: it is either summer OR winter. Prefabrication and implementation by one supplier makes it possible to realize the existing optimization potential in terms of control and design of the system components. This is also a great advantage when it comes to commissioning as an interface between planning and execution. Unfortunately, essential information is often lost in this process, so that the systems – controlled residential ventilation but also heating systems – are not operated optimally. The planning task consists above all in matching the systems and renovation concepts to the specific object.

System selection for the renovation of the building envelope

Location of the building

Figure 3: Densely built-up inner-city area - delivery and installation of large-area modules difficult or impossible. Source: Google maps

Especially in inner-city areas, the accessibility of the building, the possibilities to carry out construction work with heavy equipment is often very limited. This can affect the execution with prefabricated elements. The following aspects must be considered here:

- Checking the accessibility of the facades and roof areas with vehicles for deliveries
- Checking the possibilities for erecting scaffolding
- Check access possibilities and set-up areas for mobile crane.

Building physics / technical framework

Regulations / Conditions

- Noise protection requirements
- Fire protection requirements
- Thermal insulation requirements
- Requirements for monument protection
- Official requirements (e.g. green roof)
-
- Compulsory connection to district heating
- Use of groundwater / geothermal energy as heat source
- Use of special energy sources possible (biomass, natural gas)

Buildings

- Load-bearing capacity of the facade / floor slabs
- Condition of roof structure / roof truss
- Required energy quality to achieve the EnerPHit standard
- Moisture protection / rising damp
- Space conditions (building services room / decentralized vs. centralized supply solutions)
- Ownership conditions
- Shading (PV use)

This refers to all framework conditions that are set by ordinances, standards, official specifications, building regulations or by the building itself (e.g. statics, wet basement).

SERIAL - MODULAR - CONVENTIONAL

Refurbishment with prefabricated elements and/or concepts should be as highly automated and standardized as possible. With this streamlining of the construction process, not only can the amount of work and time be greatly reduced, but a significantly improved quality assurance can also be achieved. Depending on the object, different degrees of prefabrication can be implemented. In serial refurbishment, complete wall or roof elements are custom prefabricated and installed on site in a short construction time. In this case, it is important to mention the greatly reduced disruption to the residents: a declared goal is that the work that needs to be done within a single apartment should be completed as quickly as possible, i.e. within a week at the most.

Ideally, the elements of the building envelope can also include components of the building services and heat supply (e.g. heating, DHW, ventilation, electrical, sewage). Ventilation equipment, in particular, is best located within the building envelope.

If, due to the nature of the building envelope (cubature), refurbishment with large-format prefabricated elements at the factory is not practical, a combination of serial prefabrication of individual components and assembly on site may be appropriate. Smaller façade or roof modules can be used, or elements can be delivered in parts and assembled on site. It should be noted that prefabrication usually involves thermal bridges in the area of the joints for stability reasons. In addition, each joint involves the risk of minor leaks. Quality assurance must be carried out both in the factory and, to a large extent, on site.

Therefore, a coordinated concept for air tightness is absolutely necessary for any serial refurbishment. Thermal bridge effects must also be thoroughly considered and minimized during planning: however, since planning only needs to be done once in principle and then many elements are 'serially' manufactured, the corresponding planning effort is reduced considerably.

If the modules become too small and the joint lengths too large, conventional refurbishment measures could be useful. As a rule, buildings contain both areas that are suitable for industrially prefabricated elements (e.g. large-format wall surfaces) and areas that require on-site craftsmanship (e.g. balcony niches, plinth areas, eaves connections or other transitions). The key factors here are standardized procedures, prefabricated or ready-made components, and details solved in advance. In this case, renovations carried out by craftsmen on site also offer potential for high implementation speeds. The important thing here is that the implementation is carried out by trained construction teams working hand in hand on the basis of a coordinated concept from a single source (one-stop shops).

Degree of prefabrication Conventional with one-stop stores usual construction practice

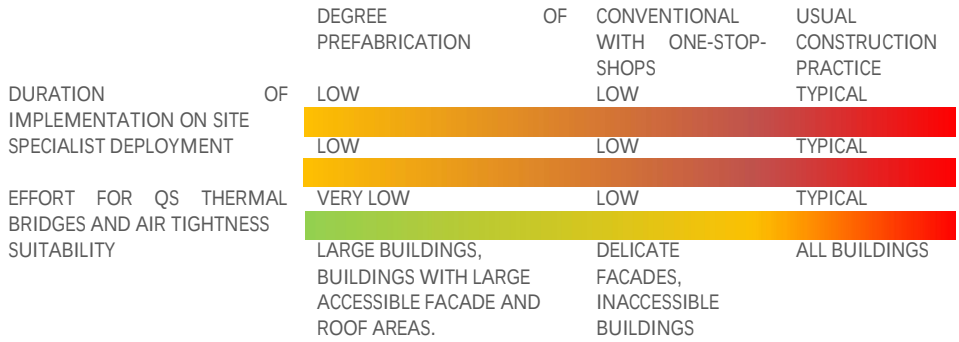

Figure 4: Visualization of the suitability of the different approaches: serial / conventional

One-Stop-Shops

One-stop shops describe a principle that is intended to standardize and shorten communication processes so that the individual work steps can run smoothly. Applied to serial refurbishment, this means that all planning, financial, implementation and bureaucratic steps necessary for the measure are located at a central, responsible point. The establishment of one-stop shops offers great potential for in-depth serial renovation.

Building owners are often reluctant to tackle a complex refurbishment project, including all the necessary issues. Housing associations, on the other hand, have to renovate a large number of buildings quickly in the coming years and sometimes do not have the necessary personnel capacities to do so. The offer to hand over the refurbishment measure to a single contractor who coordinates and is responsible for all tasks can close this gap.

List of sources

[IWU 2015]	https://www.iwu.de/fileadmin/publikationen/gebaeude-bestand/episcope/2015_IWU_LogaEtAl_Deutsche-Wohngeb%C3%A4udetypologie.pdf
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[Data base of 2010]	https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Bauen/Publikationen/Downloads-Bautaetigkeit/baugenehmigungen-baustoff-pdf-5311107.pdf?__blob=publicationFile

APPENDIX

BUILDING QUALITY STRUCTURE IN GERMANY SINCE 1850 UP TO PRESENT

Tab. 4: Wohnflächen und Häufigkeiten im deutschen Wohngebäudebestand / Basis-Typen / Baujahr bis 2009, Stand: Mai 2011 [Diefenbach 2013]

Auswertung der Gebäude- und Wohnungszählung 2011		Baualtersklassen										Summe	Anteil
		bis 1860	1861 - 1918	1919 - 1948	1949 - 1957	1958 - 1968	1969 - 1978	1979 - 1983	1984 - 1994	1995 - 2001	2002 - 2009		
Stichtag: 9.5.2011		A	B	C	D	E	F	G	H	I	J		
Deutscher Wohngebäudebestand Baujahre bis 2009	**EFH**												
	Anzahl Wohngebäude in Tsd.	330	966	1.131	859	1.509	1.507	704	1.160	1.035	775	**9.976**	*55%*
	Anzahl Wohnungen in Tsd.	399	1.213	1.389	1.060	1.948	1.915	881	1.397	1.204	858	**12.263**	*31%*
	Wohnfläche in Mio. m²	46	135	150	116	218	233	110	178	158	119	**1.463**	*41%*
	RH												
	Anzahl Wohngebäude in Tsd.	148	492	710	447	633	611	335	652	619	384	**5.030**	*28%*
	Anzahl Wohnungen in Tsd.	181	617	840	546	749	685	374	722	674	409	**5.796**	*15%*
	Wohnfläche in Mio. m²	19	62	82	52	76	79	45	85	80	52	**633**	*18%*
	MFH												
	Anzahl Wohngebäude in Tsd.	54	442	388	356	586	412	146	309	244	85	**3.023**	*17%*
	Anzahl Wohnungen in Tsd.	214	2.177	1.911	2.003	3.348	2.313	852	1.826	1.390	461	**16.495**	*42%*
	Wohnfläche in Mio. m²	16	163	129	125	225	169	64	133	104	39	**1.168**	*33%*
	GMH												
	Anzahl Wohngebäude in Tsd.	0,6	28,7	7,4	17,3	34,0	50,1	15,0	28,7	20,9	7,6	**210**	*1%*
	Anzahl Wohnungen in Tsd.	11	526	126	308	818	1.366	356	605	408	151	**4.674**	*12%*
	Wohnfläche in Mio. m²	0,7	35,8	7,9	17,0	47,1	86,7	21,9	34,8	25,5	10,4	**288**	*8%*
Anzahl Wohngebäude in Tsd.		**533**	**1.929**	**2.236**	**1.679**	**2.762**	**2.580**	**1.200**	**2.150**	**1.919**	**1.251**	**18.239**	
Anteil		*3%*	*11%*	*12%*	*9%*	*15%*	*14%*	*7%*	*12%*	*11%*	*7%*		
Anzahl Wohnungen in Tsd.		**806**	**4.533**	**4.265**	**3.915**	**6.863**	**6.279**	**2.463**	**4.550**	**3.675**	**1.880**	**39.228**	
Anteil		*2%*	*12%*	*11%*	*10%*	*17%*	*16%*	*6%*	*12%*	*9%*	*5%*		
Wohnfläche in Mio. m²		**82**	**396**	**370**	**309**	**567**	**569**	**240**	**431**	**368**	**220**	**3.552**	
Anteil		*2%*	*11%*	*10%*	*9%*	*16%*	*16%*	*7%*	*12%*	*10%*	*6%*		

Gewählte Zuordnung: EFH: freistehende Ein-/Zweifamilienhäuser; RH: Ein-/Zweifamilienhäuser als Doppelhaushälfte,Reihenhaus oder sonstiger Gebäudetyp
MFH: Mehrfamilienhäuser mit 3-12 Wohnungen, GMH: Mehrfamilienhäuser ab 13 Wohnungen
Die Angaben beziehen sich ausschließlich auf Wohngebäude (ohne Wohnheime, ohne "sonstige Gebäude mit Wohnraum", ohne "bewohnte Unterkünfte")

IWU

Source: https://www.iwu.de/fileadmin/publikationen/gebaeudebestand/episcope/2015_IWU_LogaEtAl_Deutsche-Wohngeb%C3%A4udetypologie.pdf

Bild 7: Deutsche Gebäudetypologie – Häufigkeit von Gebäudetypen unterschiedlichen Baualters

Gebäudetypen*	Baualtersklassen: vor 1918 (A)	vor 1918 (B)	1919 - 1948 (C)	1949 - 1957 (D)	1958 - 1968 (E)	1969 - 1978 (F)	1979 - 1983 (G)	1984 - 1994 (H)	1995 - 2001 (I)	2002 - 2006 (J)	Summe	Anteil
EFH												
Wohnfläche in Tsd. m²	81.503	148.776	168.937	174.251	235.409	223.135	112.631	236.441	255.280	103.208	**1.739.571**	*52%*
Anz. Wohneinh. in Tsd.	916	1.707	2.010	1.915	2.274	1.867	936	2.055	1.994	671	**16.345**	*42%*
RH												
Wohnfläche in Tsd. m²		14.543	31.450	21.993	35.996	61.478	24.503	32.951	33.366	11.675	**267.955**	*8%*
Anz. Wohneinh. in Tsd.		145	326	231	348	517	202	281	285	83	**2.418**	*6%*
MFH												
Wohnfläche in Tsd. m²	31.974	109.337	135.827	117.051	149.881	122.930	61.044	118.019	154.740	24.267	**1.025.070**	*31%*
Anz. Wohneinh. in Tsd.	462	1.501	2.034	1.912	2.210	1.677	821	1.712	2.240	296	**14.865**	*38%*
GMH												
Wohnfläche in Tsd. m²		31.549	10.160	38.936	47.501	46.124					**174.270**	*5%*
Anz. Wohneinh. in Tsd.		448	169	703	784	697					**2.801**	*7%*
HH												
Wohnfläche in Tsd. m²					12.617	12.988					**25.605**	*1%*
Anz. Wohneinh. in Tsd.					198	198					**396**	*1%*
MFH NBL												
Wohnfläche in Tsd. m²				14.324	24.418						**38.742**	*1%*
Anz. Wohneinh. in Tsd.				329	408						**737**	*2%*
GMH NBL												
Wohnfläche in Tsd. m²						22.976	19.899	17.977			**60.852**	*2%*
Anz. Wohneinh. in Tsd.						390	336	305			**1.031**	*3%*
HH NBL												
Wohnfläche in Tsd. m²						16.823	4.230				**21.053**	*1%*
Anz. Wohneinh. in Tsd.						310	67				**377**	*1%*
Wohnfläche in Tsd. m²	**113.477**	**304.205**	**346.374**	**366.555**	**505.822**	**506.454**	**222.307**	**405.388**	**443.386**	**139.150**	**3.353.118**	
Anteil	*3%*	*9%*	*10%*	*11%*	*15%*	*15%*	*7%*	*12%*	*13%*	*4%*		
Anz. Wohneinh. in Tsd.	**1.378**	**3.801**	**4.539**	**5.090**	**6.222**	**5.656**	**2.362**	**4.353**	**4.519**	**1.050**	**38.970**	
Anteil	*4%*	*10%*	*12%*	*13%*	*16%*	*15%*	*6%*	*11%*	*12%*	*3%*		

*) EFH = Einfamilienhaus, RH = Reihenhaus, MFH = Mehrfamilienhaus, GMH = großes Mehrfamilienhaus, HH = Hochhaus, NBL = neue Bundesländer

Source: https://www.iwu.de/fileadmin/publikationen/gebaeude-bestand/2007_IWU_LogaEtAl_Querschnittsbericht-Energieeffizienz-im-Wohngeb%C3%A4udebestand.pdf

Tab. 5: Wandtypen im Wohngebäudebestand nach Regionen, Baualtersklassen und Gebäudetyp / Quelle: [Datenbasis 2010]
Prozentwerte bezogen auf die jeweilige Gebäudeanzahl /
innerhalb einer separaten Spalte summieren sich die Werte zu 100 %

	Deutschland	Nord	Süd	Ost
einschaliges Mauerwerk	61,3% +/- 1,4%	32,4% +/- 2,5%	85,1% +/- 1,3%	63,4% +/- 2,5%
zweischaliges Mauerwerk	29,9% +/- 1,4%	61,2% +/- 2,7%	6,5% +/- 1,1%	21,5% +/- 2,1%
Fachwerk	3,1% +/- 0,3%	2,4% +/- 0,5%	2,9% +/- 0,5%	4,9% +/- 1,1%
Holz-Fertigteile, sonstiger Holzbau	3,7% +/- 0,3%	3,3% +/- 0,5%	4,3% +/- 0,5%	3,2% +/- 0,6%
Betonfertigteile, Großtafelbau, Plattenbau	1,9% +/- 0,3%	0,7% +/- 0,2%	1,0% +/- 0,2%	6,7% +/- 1,6%
Sonstiges	0,1% +/- 0,1%	0,1% +/- 0,0%	0,1% +/- 0,1%	0,2% +/- 0,2%

	Altbau bis 1978	BJ 1979 - 2004	Neubau ab 2005
einschaliges Mauerwerk	63,8% +/- 1,5%	56,0% +/- 2,1%	57,5% +/- 4,2%
zweischaliges Mauerwerk	28,7% +/- 1,5%	32,8% +/- 2,0%	27,8% +/- 3,8%
Fachwerk	4,4% +/- 0,5%	0,4% +/- 0,1%	0,6% +/- 0,6%
Holz-Fertigteile, sonstiger Holzbau	1,5% +/- 0,2%	7,5% +/- 0,7%	13,0% +/- 3,1%
Betonfertigteile, Großtafelbau, Plattenbau	1,5% +/- 0,3%	3,1% +/- 0,8%	0,8% +/- 0,4%
Sonstiges	0,1% +/- 0,0%	0,2% +/- 0,1%	0,2% +/- 0,2%

	alle EZFH	alle MFH	EZFH, Altbau	MFH, Altbau
einschaliges Mauerwerk	60,7% +/- 1,5%	64,0% +/- 2,2%	63,0% +/- 1,6%	67,0% +/- 2,6%
zweischaliges Mauerwerk	30,7% +/- 1,6%	25,7% +/- 2,2%	29,8% +/- 1,6%	24,5% +/- 2,6%
Fachwerk	3,3% +/- 0,4%	2,1% +/- 0,6%	4,8% +/- 0,5%	2,6% +/- 0,7%
Holz-Fertigteile, sonstiger Holzbau	4,4% +/- 0,4%	0,5% +/- 0,2%	1,9% +/- 0,3%	0,2% +/- 0,2%
Betonfertigteile, Großtafelbau, Plattenbau	0,7% +/- 0,2%	7,7% +/- 1,6%	0,4% +/- 0,1%	5,7% +/- 1,2%
Sonstiges	0,1% +/- 0,1%	0,0% +/- 0,0%	0,1% +/- 0,1%	0,0% +/- 0,0%

Erläuterungen:
„Nord": Nördl. Teil Deutschlands in den alten Bundesländern, d. h. Schleswig-Holstein, Hamburg, Niedersachsen, Bremen und Nordrhein-Westfalen
„Süd": Südlicher Teil Deutschlands in den alten Bundesländern, d. h. Hessen, Rheinland-Pfalz, Baden-Württemberg, Bayern und Saarland
„Ost": Neue Bundesländer und Berlin, d. h. Berlin, Brandenburg, Mecklenburg-Vorpommern, Sachsen, Sachsen-Anhalt und Thüringen

Source: https://www.iwu.de/fileadmin/publikationen/gebaeudebestand/episcope/2015_IWU_LogaEtAl_Deutsche-Wohngeb%C3%A4udetypologie.pdf

T2.1 Building Typologies

Paris, 04.11.21,

BUILDING TYPOLOGIES / OUTPHIT PROJECT

Undertake a study that investigates the current state of the different construction typologies all over Europe as well as their technologies and methodologies in order to analyse their capacity of being renovated with prefabricated elements to reduced costs. These construction systems, prefabricated or conventional, will be analysed regarding their ability to support prefabricated modules or on the contrary (=if not possible for various reason) with conventional streamlined approach. The outcome will be a survey report of renovation systems that are suitable for reliable and fast deep retrofits in various European climate zones, specifying various characteristics, like the suitability for the application on certain existing construction types (as identified in Task 2.2), the consideration of step-by-step refurbishments or the implementation of either ventilation or renewable energy systems. Taking figures out of the “French” case, some ideas about the ”best” suitable typologies for OutPhit project can be drawn.

Last updated 04.06.2022 by ProPassif

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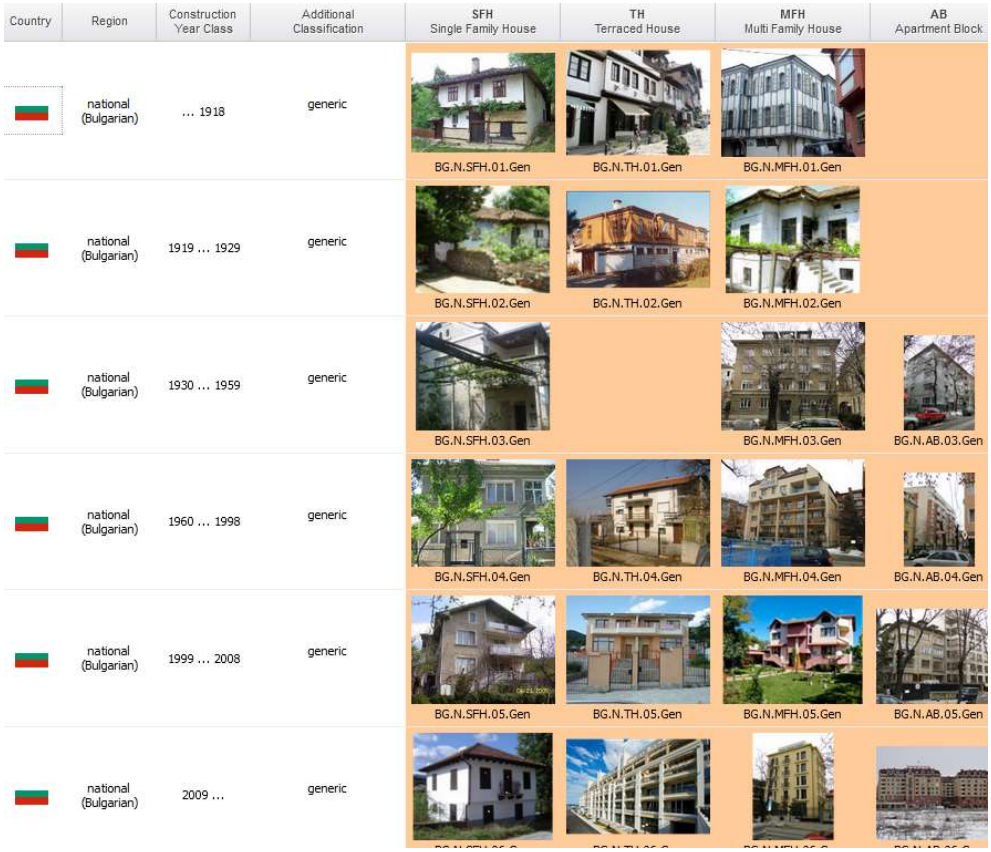
Table des matières

1. BUILDING TYPOLOGIES IN THE LITERATURE:

Building typologies have been described in many different European studies dedicated to the renovation of the existing stock. The most graphical one is project **TABULA / EPISCOPE web tool** **https://webtool.building-typology.eu/**
With exhaustive example for each EU27 countries:

- **Example for Bulgaria:**

From this perspective view, all EU buildings seem very similar in design and conception. Which makes the use of prefab modules everywhere of interest. For each "Construction year class" which describes best the construction:

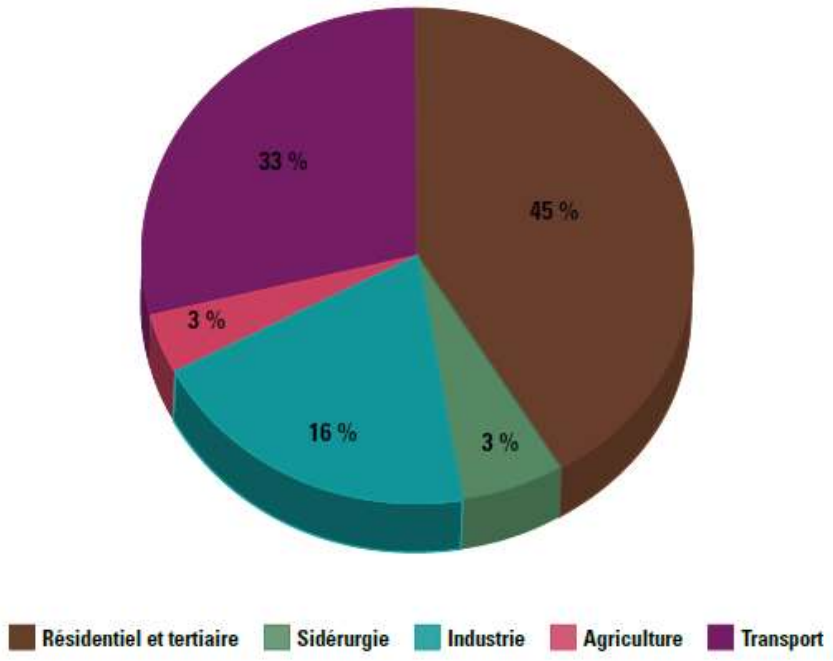


For France, typologies have been more precisely analysed within the "PACTE" Project: « ANALYSE DÉTAILLÉE DU PARC RÉSIDENTIEL EXISTANT », giving lots of quantitative information on energy efficiency of the buildings.

For Germany, typologies have been analysed within the Passivhaus Institute Book "**Altbaumodernisierung mit Passivhaus-Komponenten" S. Anhang:** 9.1 Zeittypische Bauteilaufbauten und U-Werte im Bestand (Deutschland, Alte Bundesländer)

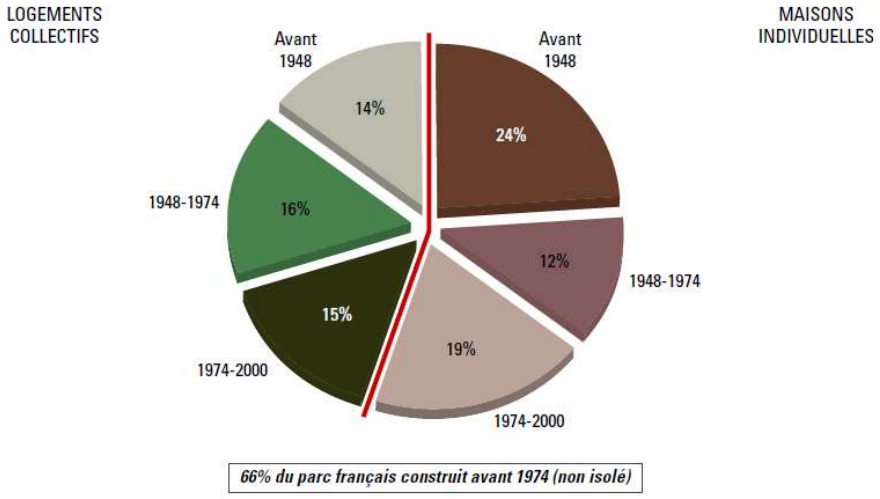
	Average heating demand by building age (kWh/m²a)							
Type	-1918	-1918	1919 -1948	1949 -1957	1958 -1968	1969 -1978	1979 -1983	1984 -1990
SFH	238 (318)	185 (225)	204 (263)	253 (329)	146 (171)	141 (147)	119 (119)	120 (122)
TerracedH	–	203 (249)	166 (205)	163 (219)	160 (211)	156 (187)	121 (121)	94 (94)
Small residential	190 (216)	163 (190)	179 (222)	184 229)	173 (213)	127 (170)	98 (98)	76 (77)
Big residential	–	161 (190)	164 (203)	151 (191)	153 (184)	123 (139)	–	–
high-rise building	–	–	–	–	105 (127)	120 (120)	–	–

Both studies are based on very similar yearly categories: (with minor differences between East and West Europe due to Marshall Plan)



The French housing stock comprises 37 million dwellings (2020) and an annual energy consumption of 476 TWh. (With 12 million dwellings more than in 1982).

Individual housing represents 55%. Collective housing 45% in 2020



Graphique 1: Répartition du parc résidentiel par familles de logements et par périodes de construction (nombre de logements)

• Before 1914 (before WWI):
- Mainly wooden and local "vernacular" architecture
- Development of an urban architecture in the path of industrial revolution

• 1918- 1948 (in-between):
- Bauhaus architecture + Invention of reinforced concrete
- Le Corbusier, Niedermeyer (Brasilia)

• 1948 – 1974 ("30 glorieuses" / "Wirtschaftswunder"):
- Reconstruction Europe (West: Marshall plan)
- Generalized use of reinforced concrete for building rapidly and resorbing slums
- Panel building, etc…

• 1975 – 1981 (Oil crisis):
- Energy efficiency first!
- The Club of Rome publish "The limits to growth"
- Building with insulation and double glazing
- Start of prefabricated buildings!

• 1982 – 1989 (80's):
- First thermal regulations nationwide in Europe: RT, WSchV,..

• 1990 – 2000 (90's):
- First Passive House was built / Renovation with Passive House components
- RT2000, EnEV, etc…

Prefabrication, without revealing too many secrets, is easier to produce in a cubic geometry making it fit for manly straight "flat" façade. Balconies/loggias will be

access later on. High rise buildings have special characteristics for fire protection which make them complex to access.

THIS LEADS TO A 7 POINTS RÉSUMÉ FOR CHEAP AND QUICK RETROFITS:

1. **Collective building**
2. **No High Rise** building: Height less than 28 meters (France):
3. „**Flat facade**“: No balcony or loggia to be preferred
4. **Regularity and repetitiveness** of facades: no waves
5. **Number of units**: between 80 and 100 units
6. **Facade Composition**: no facade having undergone thermal renovation.
7. **Prefabricated buildings are easy** to retrofit: retrofit boxes.

This typology is to be found more easily in 3 ages categories:

1918 – 1948: mainly well built, but no insulation
1948 – 1974: poorly built, no insulation, geometric forms
1975 – 2000: poorly isolated, some prefabrication easily retrofit

Tableau 6 : Indentification des familles d'immeubles collectifs présentes dans le parc résidentiel ([DHUP 2011] – [DHUP 2007])

PÉRIODES	TYPES	DONNÉES SUR LE PARC D'IMMEUBLES COLLECTIFS		
		Nombre de logements du parc d'IC (%)	Consommations énergétiques finales tous usages (%)	Consommations énergétiques de chauffage (*) (kWhef/m².an)
« Ancien » Avant 1948	Immeuble de bourg	11 %	11 %	132
	Immeuble Haussmannien et assimilés	10 %	11 %	143
	Immeuble éclectique	4 %	4 %	171
	Immeuble de type HBM	1 %	1 %	146
« Récent non isolé » 1948 – 1974	Immeuble pastiche	3 %	3 %	139
	Immeuble «bourgeois»	2 %	3 %	213
	Habitat intermédiaire 1968 – 1974	3 %	5 %	187
	Petit collectif divers 1948-1974	20 %	25 %	157
	«Barres» 1948 – 1974	12 %	14 %	140
	Tours 1948 – 1974	< 1 %	< 1 %	150
« Récent isolé » 1975 – 2000	Habitat intermédiaire 1975 – 1981	1 %	1 %	95
	Petit collectif divers 1975 – 1981	5 %	4 %	74
	«Barres» 1975 – 1981	6 %	5 %	120
	Tours 1975 – 1981	< 1 %	< 1 %	74
	Immeubles 1982 – 1989	8 %	5 %	61
	Immeubles 1990 – 2000	11 %	7 %	56

(*) Cf. Consommation énergétique de chauffage pour l'ensemble du parc (résidences principales, résidences secondaires, logements vacants)

The rest of the study analyses the "façade complexity": complex/mean/simple: highlighted are best typologies for our goals

Before 1948: façade complexity :
- « City center » building: Complex
- Hausmannian : Complex
- « Immeuble éclectique » : Mean to complex
- Building type « HBM » : Complex

1948 – 1974 :
- « Pastiche » building : Complex
- « Bourgeois » building : Simple
- Intermediate housing 1968-1974 : Simple
- Small collectives 1948-1974: Complex with balconies
- Panel building 1948-1974: Simple
- High Rise 1948-1974: Simple to mean

1975 – 2000 :
- Intermediate housing 1975-1981: Complex with balconies
- Small collectives 1975-1981: Complex with balconies
- Panel building 1975-1981: flat façade
- High Rise 1975-1981: often flat facades
- Properties 1982 – 1989: mean
- Properties 1990-2000: Simple to mean

Here we have our first "wish-list" for quick and affordable prefab retrofits:

- Intermediate housing 1968-1974: 3% of collective building stock
- Panel building 1948-1981: 18% of collective building stock
- Properties 1990-2000: 11% of collective building stock

2. BUILDING TYPOLOGIES IN THE PRAXIS:

After the building has been selected, a **preliminary study** or **existing situation analysis** should be carried out on the building, clearing its potential and handicap for retrofit with prefabricated modules, clearing different aspects such as:

- **Structural integrity:** capacity of the existing building to bear nonstructural insulation panels
- **Bearing points** have to be inspected carefully in order to obtain a sustainable solution

Apart from those "logical" reasons, there are other criteria depending on the history of the building which may influence the decision to retrofit:

1) **"Old" prefabricated buildings**: prefabrication has been used for a long time since the 50's. Those buildings are extremely simple to renovate by changing the "old" prefabrication to a new one. Many examples already done: Tour Pleyel, Paris; University, Prag; aso.
2) **Pollutants**: subject for retrofitting is the presence/absence of pollutants in the soil/walls of the building. To be taken also into consideration:
   - Water/humidity in the construction:
   - Asbestos in the construction:
   - Oil/petroleum in the soils:
   - Other pollutant: volatile organic compounds?

   In those case the renovation is a must. The pollutants have to be removed first and the rest of the retrofit could be made with the help of the prefabricated modules. (s.CS29)
3) **Acoustics regulations** have to be taken into consideration.
4) **Fire regulations** have to be accessed, before starting the retrofit analysis. Fire place and exhaust is another part of this chapter. Existing one and their future utilisation is a major subject. If no more use is decided they can be used for ventilation ducts (s. OP08)
5) **Balconies** new reinforced concrete techniques made it available on a larger basis in the seventies. "Radiator" balcony is responsible for 10-15% of EU buildings' energy costs. Balcony facades can be cut (if ramshackle), and replaced with self-supporting elements or closed and integrated in the new prefabricated flat façade. Balcony is not a problem, is part of the new solution.
6) **Air pollution:** is since Covid pandemia a real subject for renovating non-residential buildings such as school (s. CS29)

Regulations: last but not least, new regulations change the way stakeholder consider their duties. For France, "**Decret tertiaire**" **for non-residential** aiming at 2030, and for residential building: F and G rated dwellings are prohibited from being rented out as soon as 2023 (Les logements G au DPE sont-ils interdits à la location dès 2023).

3. CONCLUSION:

In this paper we tried to answer the question of „what is the existing building typology best suited for retrofit to reduced costs". We have found an answer out the existing literature available beginning of the 20's of XXIst century and for Europe.

We also addressed the subject from the praxis point of view, featuring there's many more building available for a necessary quick retrofit, that could be also fixed to not so heavy costs. The urgence for those retrofits ease the subvention schema for those buildings.

We see as well in France, the evolution of the regulations pointing out different deadlines for obligatory retrofits for residential and non-residential buildings.

This may foreseen an evolution of the financial environment for the next years, which could be helpful if we want to be online with the Paris agreement in terms of CO2 emission and Fit for 55 as well. Building still represent 40% of energy consumption and 40% of CO2 emission in Europe in 2022.