Linking the European housing demand to sustainable wood construction materials

Monserrat Budding-Polo Ballinas, Lesly García Chávez

PUBLIC

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Linking the European housing demand to sustainable wood construction materials.

Wooden Housing Prototype

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Contents

Abstract

This research is part of the project Negative GHG emissions and long-time sequestration through the development of new C-based product (KB-34-012-001/KB-3D-1) which focuses on long-term storage of carbon in bio-products (>25 years) and substitution of fossil-based products, with the aim to reduce atmospheric greenhouse gas concentration and contribute to fight against climate change. This report also adds to the research developed for assessing the GHG balances and potential impacts for long lifespan products for a forestry case study where structural timber is used as construction material.

Literature review was done to have a better understanding on the kind of housing needed to develop the prototype house. Information was gathered on the European residential floor standards, size of housing and household size, household composition, housing demand and supply, and on wooden housing and its function as carbon sink. Based on the secondary data findings, a housing prototype has been developed to estimate the m^3 of structural wood that might be required per housing unit. The housing prototype is a step towards the evaluation for structural timber used in European housing systems as means to store carbon and foster wood as a sustainable construction material.

This housing prototype is based on a wooden or timber building design, which is fundamentally different from those buildings designed with steel and/or concrete materials on their structural and spatial layout. The following assumptions were considered for the design, dimensions and materials of the housing prototype using the data found from the Netherlands (2020) as a reference point: i) the model meets the dimensions for social housing taking the average floor space of 104 m^2 where 96 m^2 are constructed area and 8 m^2 of veranda; ii) the average household size considered is 2.1 persons; iii) the targeted households are: single-person household, (married/unmarried) couples without children, (married/unmarried) couples with one child, and single-parent households; iv) the design takes into account the traditional European construction methods of a log cabin which meets the technical building regulations in European Union (EU) countries; v) the typology could be used for detached and semi-detached dwellings; vi) the wall insulation considers the dimensions needed for the miscanthus in insulation panels (as thermal insulation); the European wood/timber materials (softwood and hardwood) are included and vii) to support on the carbon storage function provided by wooden buildings, the prototype includes a higher volume of wood per area compared to other types of buildings that contain more concrete and steel instead.

The European Social, Cooperative and Public Housing providers aim at building and refurbishing 400,000 homes per year or 4 million homes between 2020 and 2030. It was estimated that around of 1.8 million (1,795,630) of new social housing was completed in the period 2013-2020 in Europe with an average European percentage of total social housing of 13%. With this information an estimation of a total European housing demand was made. The hypothetic housing supply is 3.1 million houses per year in the coming 10 years resulting in a total number of 31 million houses by 2030.This information drops a hypothetic increase of 78.21% of new social housing to be built or refurbished every year in Europe. Another interesting finding is that approximately 17.8 m^3 of timber is needed to build a prototype wooden house using European wood such as pine, oak, or beech. The future increase on the demand of wood in Europe as construction material, raises concerns regarding legal and illegal deforestation. Therefore, it is important to regulate the production and extraction of timber to ensure that it is sourced from responsibly managed forests.

Keywords: European Housing, Long-term carbon sequestration, Housing demand and supply, Housing Prototype, Structural timber, Wooden construction materials.

Introduction

This research is part of the project Negative GHG emissions and long-time sequestration through the development of new C-based product (KB-34-012-001/KB-3D-1) which focuses on long-term storage of carbon in bio-products (>25 years) and substitution of fossil-based products, with the aim to reduce atmospheric greenhouse gas concentration and contribute in the fight against climate change. Many examples are available for substitution of materials, chemicals and energy sources with biobased alternatives. However, there is still a lack of integrated insights in the potential reduction of greenhouse gas emissions and the potential scale of applications with long-term carbon storage, as well as their environmental, social and economic effects.

Biobased products can contribute to reducing climate change. This potentially could be achieved either through long-term storage of carbon in these biobased products and/ or through substitution of other products with high greenhouse gas emissions. The net carbon balance of these production systems, however, needs to be determined. There are many ideas for replacing materials, chemicals and energy sources with biobased alternatives, but there is a lack of understanding of the potential scale of application and long-term effects and consequences are unknown. Three different cases at European level are studied:

1. Wood-based products using forest biomass
2. Products based on (ligno-) cellulose from perennial crops
3. Products made from marine biomass (such as shellfish)

The benefits of renewable materials are that their biomass source can be regrown within the foreseeable future and they contribute to photosynthetic or biological CO_2 fixation. Depending on their use, the biobased materials need some specific treatment (e.g. thermal or chemical modification, impregnation or coating). These treatments increase the durability and applications of the biobased products, but also bring environmental impacts. For more efficient and sustainable production of biobased materials, it is also desirable that the products have a long lifespan or at least a lifespan that agrees with the biomass rotation periods. In order to accelerate biobased economy, the development of products based on renewable resources need to have high quality and high technical performance, to be competitively priced and of course to show tangible environmental benefits.

This report supports mainly the first research objective to develop an appropriate carbon accounting approach for long term carbon sequestration (afforestation/reforestation/soil carbon) and carbon storage in sustainable construction materials for future European housing, which have the goal of achieving negative GHG emissions. Likewise, it contributes to the bio-based House components of structural frames/columns based on wood. This report also adds to the research developed in WP1: Analytical Framework for assessing the GHG balances and potential impacts for long lifespan products, and to WP2: Forestry Case Study. Structural timber as construction material.

On the following chapters, literature review reflects information gathered on the European residential floor standards, size of housing and household size, household composition, housing demand and supply, and on wooden housing and its function as carbon sink. Based on the secondary data findings, a housing prototype has been developed to estimate the m^3 of structural wood that might be required per housing unit. The housing prototype is a step towards the evaluation for structural timber used in European housing systems as means to store carbon and foster wood as a sustainable construction material.

1 Residential floor standards in Europe

According to the European Commission (2011), The floor area per dweller is one of the key indicators of dwelling comfort. It is the result of the size of dwelling (m^2 floor area) and the number of persons living in the dwelling. The average floor area per person in EU 28 is 42,56 m^2 per person. This indicator is dedicated only to housing and shows the average floor area per person (dweller) according to the type of building in division to family houses and apartment buildings. In most member states this indicator is below the average in EU 28, but rather close to it.

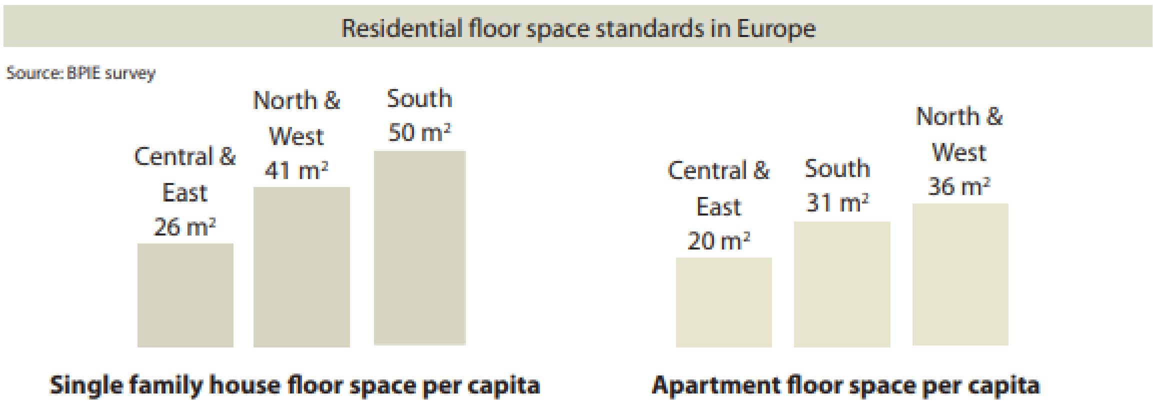
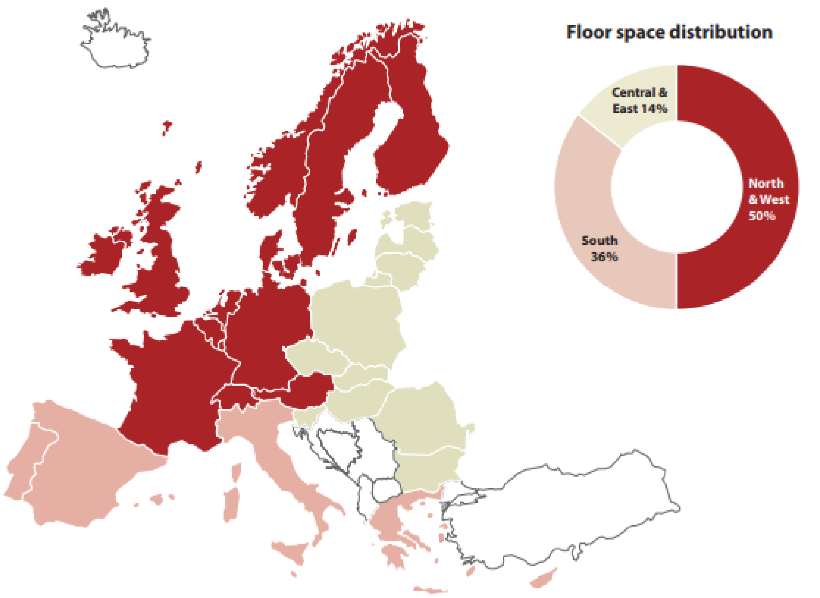


Figure 1 Residential floor space standards in Europe. Source: Economidou, 2011

Economidou (2011), has categorized the European countries based upon climatic, building typology and market similarities into three regions: North & West, South, and Central and East. Space standards (expressed through the floor area per capita) are the highest in countries in the North & West while the countries of Central & Eastern Europe have the lowest residential space standards both in single family houses and apartment blocks (Figure 1). Economic wealth, culture, climate, scale of commerce, increased demand for single occupancy housing are some of the factors affecting the size of spaces we live and work in. The difference between the highest value of the indicator (in Cyprus) and the lowest one (in Romania) is rather huge, about 45 m^2 per person. Also in the countries with rather large population, such as the Netherlands, France and Germany the values of average floor area per person are above the EU average (Economidou, 2011).

Each European region divided in the study from Economidou (2011), consists of the countries shown in the table and map of Figure 2. It should be noted that half of the total estimated floor space is located in the North & West region while the remaining 36% and 14% are contained in the South and Central & East regions, respectively. The floor space breakdown per country is shown in Figure 3. The five largest countries (in terms of population: France, Germany, Italy, Spain and the UK) account for approximately 65% of the total floor space. This comes as no surprise since the corresponding share of population in these countries is equal to 61% of the total. As explained above, the relationship between population and building floor area is in fact a complex one which is influenced by a range of factors including economic wealth, culture, climate, scale of commerce, increased demand for single occupancy housing and many others (Economidou, 2011).

The floor space standards have been analyzed by estimating the floor space per capita for each country. From the analysis made by Economidou (2011), it appears that countries in the North & West region have higher total floor area per person than in the South and Central & East regions. Upon closer examination, the countries of Central & Eastern Europe tend to have lower space standards in terms of dwellings with a floor space of around 25 m^2 /person in comparison to the Northern and Southern European countries, which have space standards typically of around 40 m^2 /person. On the other hand, non-residential floor space per capita is nearly double in the North compared to other regions, which may suggest a link between non-residential floor space and economic wealth.



North & West	AT, BE, CH, DE, DK, FI, FR, IE, LU, NL, NO, SE, UK	Population: 281 million
Central & East	BG, CZ, EE, HU, LT, LV, PL, RO, SI, SK	Population: 102 million
South	CY, GR, ES, IT, MT, PT	Population: 129 million

Figure 2 ***European countries and regions considered with equivalent population and floor space figures. Source: Economidou, 2011***

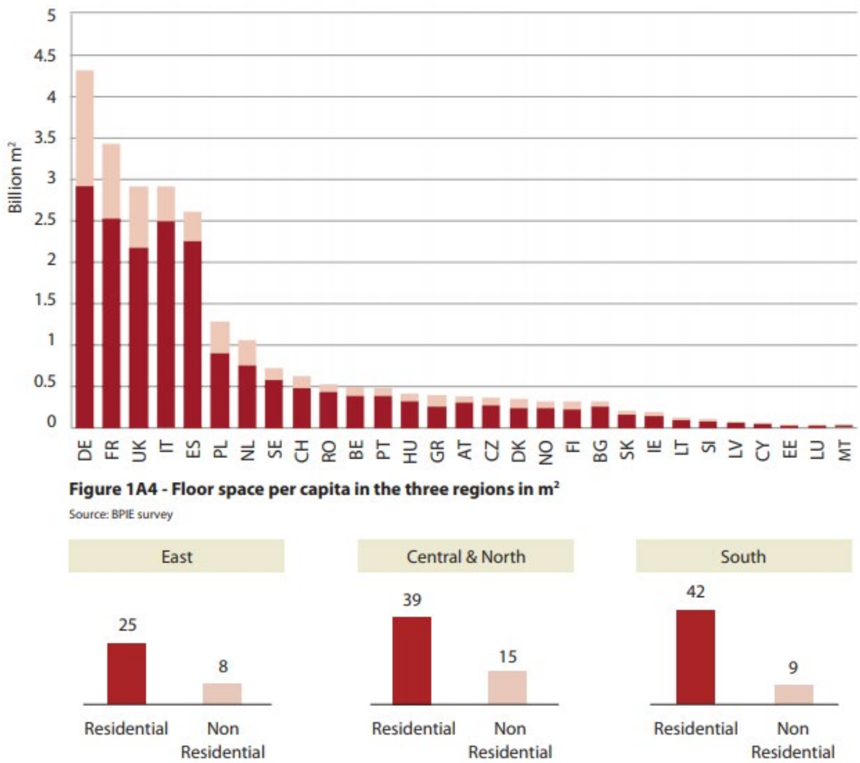


Figure 3 ***Floor space distribution per country. Source: Economidou, 2011***

The residential stock is the biggest segment with an EU floor space of 75% of the building stock (Figure 4). Within the residential sector, different types of single family houses (e.g. detached, semi-detached and terraced houses) and apartment blocks are found. Apartment blocks may accommodate several households typically ranging from 2-15 units or in some cases holding more than 20-30 units (e.g. social housing units or high rise residential buildings). An analysis of this data made by Economidou (2011), indicates that across the focus countries, 64% of the residential building floor area is associated with single family houses and 36% with apartments.

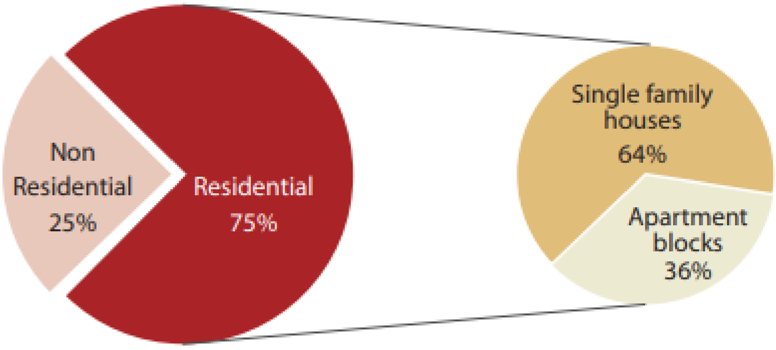


Figure 4 ***Residential floor space for European countries. Source: Economidou, 2011***

The split between the two main types of residential properties varies significantly from country to country. Austria, Bulgaria, Czech Republic, Germany, Lithuania, Poland, Sweden and Switzerland could be said to hold more even portfolios with similar floor areas for single family houses and apartments. Greece, Ireland, Norway and the UK have the smallest proportion of floor area of apartments in the residential building stock, whilst Estonia, Latvia and Spain have the highest (Economidou, 2011).

An apartment block in Europe

A typical single family house in Europe

Figure 5 ***Difference between an apartment block and a single family house in Europe. Source: Economidou, 2011***

In terms of floor space per capita, the Central & East countries are among the countries with the lowest residential space in terms of both single family houses and apartment blocks (Figure 5). North & West countries have the highest residential floor areas per capita compared to other regions. Countries in the South have the highest single family house floor space per capita which perhaps indicates the frequency of holiday houses in those countries. It is interesting to note that in all regions, the floor space standards in apartments are lower than in single family houses, a trend which perhaps reinforces the link between floor space and wealth conditions (Economidou, 2011).

2 Size of housing and household size

According to Eurostat (2020), The size of housing can be measured as the average number of rooms per person: there were on average 1.6 rooms per person in the EU in 2019. Among the Member States, the largest number was recorded in Malta (2.2 rooms per person), followed by Belgium and Ireland (both 2.1 rooms). At the other end of the scale were Croatia, Poland and Romania, all with 1.1 rooms on average per person (Figure 6).

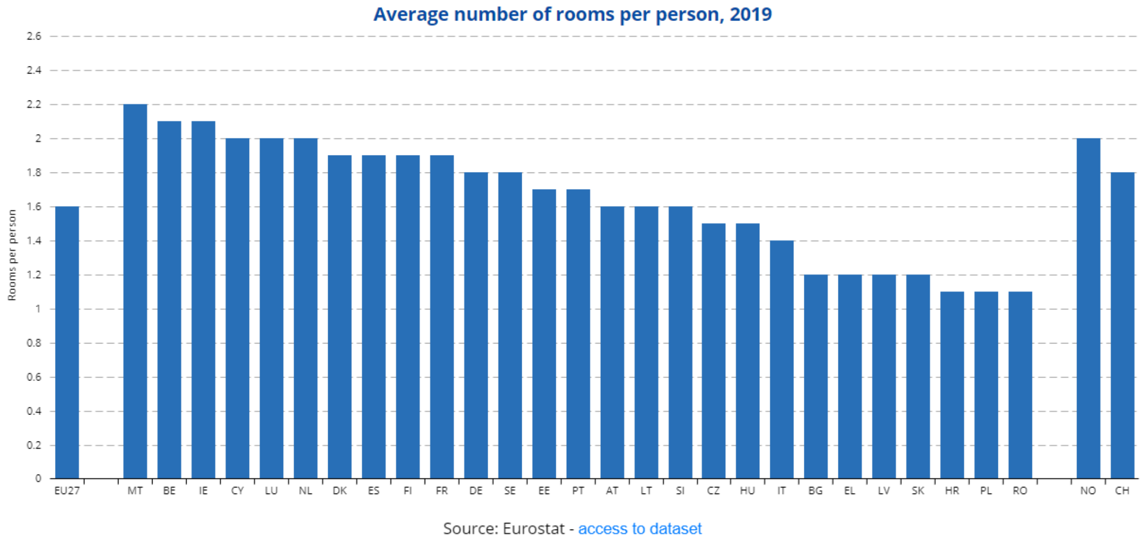


Figure 6 ***Average number of rooms per person in European housing in 2019. Source: Eurostat, 2020***

A related indicator is the number of persons per household. There were on average 2.3 persons per household in the EU in 2019. Among the Member States, this number ranged from 2.9 persons in Slovakia, 2.8 in Poland and 2.7 in Cyprus and Croatia down to 2.0 persons in Germany, Denmark, Finland and Sweden (Eurostat, 2020).

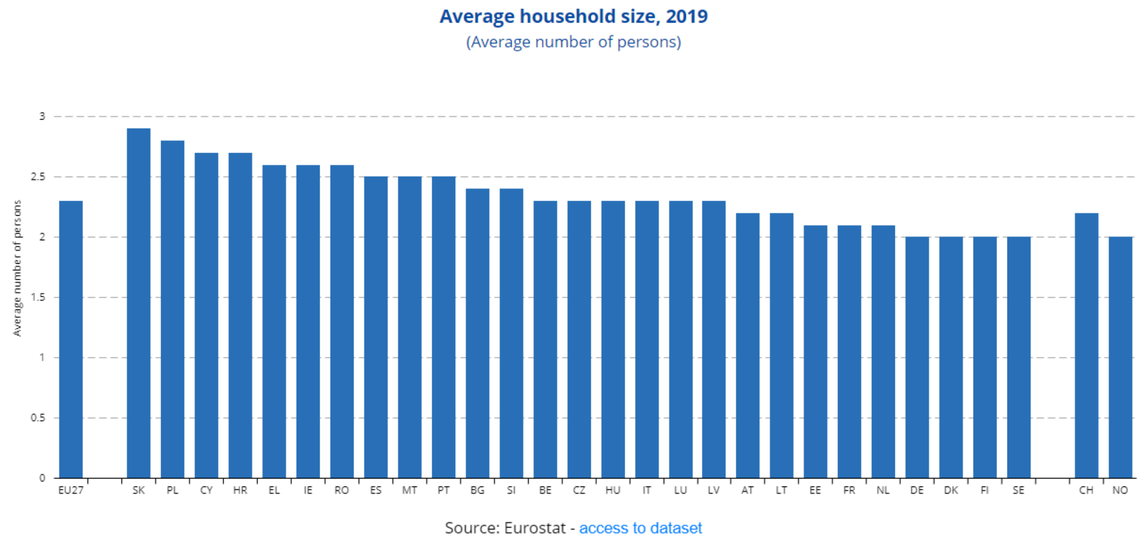


Figure 7 ***Average household size in 2019. Source: Eurostat, 2020***

The average household size based on the Eurostat (2021) report, mentions a similar numbers from 2014 to 2019 of 2.3 persons for the Member States (EU 27) (Figure 7). There is no available data for 2020 yet, though there is a probability that due to the COVID-19 pandemic these numbers might vary. The highest average households size registered in 2020 are Croatia (2.7 persons), Greece and Romania (2.6 persons) and Slovenia (2.5 persons). The countries with a smaller household size registered in 2020 are Denmark, Finland and Sweden (2.0 persons).

Dataset: Average household size - EU-SILC survey [ILC_LVPH01$DEFAULTVIEW]
Last updated: 01/07/2021 23:00

Time frequency [FREQ]: Annual [A]
Unit of measure [UNIT]: Average [AVG]

GEO (Codes)	GEO (Labels) \ TIME	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
EU	European Union (EU6-1958, EU9-1973, EU10-1	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3 e	:
EU27_2020	European Union - 27 countries (from 2020)	2.4 e	2.4 e	2.4 e	2.3 e	2.3 e	2.3 e	2.3 e	2.3 e	2.3 e	:
EU28	European Union - 28 countries (2013-2020)	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3 e	:
EU27_2007	European Union - 27 countries (2007-2013)	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3 e	:
EA	Euro area (EA11-1999, EA12-2001, EA13-2007	2.3 e	2.3 e	2.3 e	2.3 e	2.3 e	2.3 e	2.3 e	2.3 e	2.2 e	:
EA19	Euro area - 19 countries (from 2015)	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.2	:
EA18	Euro area - 18 countries (2014)	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.2	:
BE	Belgium	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3 b	2.3 b
BG	Bulgaria	2.9	2.8	2.7	2.6	2.5	2.5 b	2.4	2.4	2.4	2.4
CZ	Czechia	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	:
DK	Denmark	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
DE	Germany (until 1990 former territory of the FR	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	:
EE	Estonia	2.3	2.2	2.2	2.2 b	2.2	2.2	2.2	2.2	2.1	2.1
IE	Ireland	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	:
EL	Greece	2.6	2.6	2.6	2.5	2.6	2.6	2.6	2.6	2.6	2.6
ES	Spain	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	:
FR	France	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.1	:
HR	Croatia	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.7	2.7 p
IT	Italy	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	:
CY	Cyprus	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.7	2.7	:
LV	Latvia	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	:
LT	Lithuania	2.4	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	:
LU	Luxembourg	2.5	2.4	2.5	2.4	2.4	2.5 b	2.5	2.3	2.3	:
HU	Hungary	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3
MT	Malta	2.7	2.7	2.6	2.6	2.6	2.5	2.5	2.5	2.5	:
NL	Netherlands	2.2	2.2	2.2	2.2	2.2	2.2 b	2.2	2.2	2.1	2.1 p
AT	Austria	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2
PL	Poland	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	:
PT	Portugal	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.5	:
RO	Romania	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6
SI	Slovenia	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4	2.5
SK	Slovakia	2.8	2.8	2.9	2.8	2.8	2.8	2.8	2.9	2.9	:
FI	Finland	2.1	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0
SE	Sweden	2.1	2.1	2.0	2.0	2.0	2.0	2.1	2.0	2.0	2.0
IS	Iceland	2.4	2.4	2.5	2.5	2.5	2.4	2.3	2.3	:	:
NO	Norway	2.1	2.1	2.1	2.1	2.0	2.0	1.9	2.0	2.0	:
CH	Switzerland	2.3	2.3	2.3	2.2 b	2.2	2.2	2.2	2.2	2.2	:
UK	United Kingdom	2.3	2.3 b	2.3	2.3	2.3	2.3	2.3 b	2.3	:	:
ME	Montenegro	:	:	3.3	3.3	3.3	3.3	3.0	3.3	3.3	:
MK	North Macedonia	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	:
AL	Albania	:	:	:	:	:	:	3.7	3.7	3.7	:
RS	Serbia	:	:	2.9	2.9	2.9	2.9	2.9	2.9	2.9	:
TR	Turkey	3.7	3.6	:	3.5	3.5	3.5	3.4	3.4	3.3	:
XK	Kosovo (under United Nations Security Counc	:	:	:	:	:	:	:	6.0	:	:

Figure 8 Average household size in the Member States (EU 27). Source: Eurostat, 2021

There is another updated information from the report of Eurostat (2021) on the average size of dwelling by household type in total (all degrees of urbanization). Among the Member States (EU 27), the average size of dwelling is 90.7 m^2, for a single person is 72.3 m^2, for a household with two adults the size of dwelling is 96.1 m^2, households without dependent children is 85.6 m^2 and households with dependent children is 103.1 m^2 on average (Figure 8). The biggest size of dwelling reported are in Cyprus (141.4 m^2), Luxembourg (131.1 m^2), Iceland (130.4 m^2), Belgium (124.3 m^2), Norway (122.7 m^2) and Denmark (118.1 m^2) to mention a few. The Netherlands and Portugal are around the same size with 106.7 m^2 and 106.4 m^2 respectively. The smallest dwelling size are reported in Romania (43.9 m^2), Latvia (62.5 m^2), Lithuania (63.2 m^2), Estonia (66.7 m^2), among others.

Dataset: Average size of dwelling by household type and degree of urbanisation [ILC_HCMH02__custom_1237669]
Last updated: 20/06/2019 23:00

Time frequency [FREQ]: Annual [A]
Unit of measure [UNIT]: Average [AVG]
Degree of urbanisation [DEG_URB]: Total [TOTAL]
Time [TIME]: 2012

	HHTYP (Codes)	TOTAL	A1	A2	HH_NDCH	HH_DCH
GEO (Codes)	GEO (Labels) \ HHTYP (Labels)	Total	Single person	Two adults	Households without dependen	Households with dependent ch
EU	European Union (EU6-1958, EU9-1973, EU10-1981, EU12-198	96.4 e	76.8 e	100.5 e	90.7 e	110.2 e
EU27_2020	European Union - 27 countries (from 2020)	90.7 e	72.3 e	96.1 e	85.6 e	103.1 e
EU28	European Union - 28 countries (2013-2020)	96.4 e	76.8 e	100.5 e	90.7 e	110.2 e
EU27_2007	European Union - 27 countries (2007-2013)	96.5 e	76.8 e	100.7 e	90.8 e	110.4 e
EA	Euro area (EA11-1999, EA12-2001, EA13-2007, EA15-2008, E	97.1 e	75.8 e	102.1 e	91.0 e	111.2 e
EA19	Euro area - 19 countries (from 2015)	96.5 e	75.4 e	101.6 e	90.5 e	110.6 e
EA18	Euro area - 18 countries (2014)	96.9 e	75.6 e	101.9 e	90.8 e	111.0 e
BE	Belgium	124.3	97.7	132.2	115.6	143.4
BG	Bulgaria	73.0	61.8	71.9	70.7	77.1
CZ	Czechia	78.0	61.1	75.9	72.7	88.7
DK	Denmark	118.1	88.8	131.5	106.7	149.1
DE	Germany (until 1990 former territory of the FRG)	94.3	69.4	103.3	86.7	118.4
EE	Estonia	66.7	51.8	69.6	61.1	78.9
IE	Ireland	: u	: u	: u	: u	: u
EL	Greece	88.6	67.5	85.5	83.2	99.4
ES	Spain	99.1	87.7	98.8	96.7	103.6
FR	France	93.7	73.0	101.9	88.0	106.5
HR	Croatia	81.6	64.6	76.3	75.9	92.2
IT	Italy	93.6	80.8	94.5	90.2	101.2
CY	Cyprus	141.4	98.9	127.0	122.3	171.7
LV	Latvia	62.5	48.8	62.6	58.2	70.9
LT	Lithuania	63.2	52.7	66.2	59.7	70.1
LU	Luxembourg	131.1	101.4	140.2	121.6	149.5
HU	Hungary	75.6	61.8	76.2	71.5	84.4
MT	Malta	: u	: u	: u	: u	: u
NL	Netherlands	106.7	81.0	117.0	98.8	126.0
AT	Austria	99.7	73.9	102.8	91.5	120.6
PL	Poland	75.2	54.6	69.5	67.6	87.6
PT	Portugal	106.4	86.4	100.3	99.2	118.8
RO	Romania	43.9	36.5	43.1	41.4	47.8
SI	Slovenia	80.3	59.3	79.2	72.7	93.4
SK	Slovakia	87.4	72.4	85.2	82.9	94.5
FI	Finland	88.6	60.9	96.2	78.1	119.9
SE	Sweden	99.7	72.2	111.4	90.5	125.7
IS	Iceland	130.4	89.6	137.8	115.3	152.5
NO	Norway	122.7	88.4	133.5	107.9	156.9
CH	Switzerland	117.2	88.2	124.0	110.3	134.1
UK	United Kingdom	: u	: u	: u	: u	: u

Figure 9 Average size of dwelling by household type in total (all degrees of urbanization in EU27). Source: Eurostat, 2021

Eurostat (2021), also reports the average size of dwelling by degree of urbanization: Cities, Towns & Suburbs, and Rural Areas. In the Member States (EU 27), the average size of dwelling in cities is 80.8 m^2, for a single person is 65.3 m^2, for a household with two adults the size of dwelling is 85.9 m^2, households without dependent children is 76.3 m^2 and households with dependent children is 92.2 m^2 on average (Figure 9). The biggest size of dwelling in urban areas reported are in Cyprus (138.4 m^2), Belgium (110.4 m^2), Luxembourg (104.6 m^2), Iceland (125.0 m^2) and Norway (116.1 m^2). Switzerland reported 98.1 m^2, Denmark 94.8 m^2, and The Netherlands 94.3 m^2. The smallest dwelling size in cities are in Romania (41.7 m²), Estonia (58.1m²), Lithuania (57.4 m²), Latvia (55.1 m²) and Poland (61.5 m²).

Dataset: Average size of dwelling by household type and degree of urbanisation [ILC_HCMH02__custom_1237669]
Last updated: 20/06/2019 23:00

Time frequency [FREQ] Annual [A]
Unit of measure [UNIT] Average [AVG]
Degree of urbanisation [DEG_URB] Cities [DEG1]
Time [TIME] 2012

GEO (Codes)	HHTYP (Codes) / HHTYP (Labels) / GEO (Labels)	TOTAL Total		A1 Single person		A2 Two adults		HH_NDCH Households without dependen		HH_DCH Households with dependent ch	
EU	European Union (EU6-1958, EU9-1973, EU10-198	89.4	e	72.9	e	91.5	e	83.9	e	102.6	e
EU27_2020	European Union - 27 countries (from 2020)	80.8	e	65.3	e	85.9	e	76.3	e	92.2	e
EU28	European Union - 28 countries (2013-2020)	89.4	e	72.9	e	91.5	e	83.9	e	102.6	e
EU27_2007	European Union - 27 countries (2007-2013)	89.5	e	72.9	e	91.7	e	84.0	e	102.8	e
EA	Euro area (EA11-1999, EA12-2001, EA13-2007, E	86.0	e	68.0	e	91.5	e	80.8	e	98.9	e
EA19	Euro area - 19 countries (from 2015)	85.5	e	67.7	e	91.0	e	80.4	e	98.3	e
EA18	Euro area - 18 countries (2014)	85.8	e	67.9	e	91.2	e	80.6	e	98.6	e
BE	Belgium	110.4		88.9		120.1		102.1		131.0	
BG	Bulgaria	72.1		61.8		70.6		70.1		75.4	
CZ	Czechia	68.3		56.2		68.5		63.9		78.1	
DK	Denmark	94.8		75.3		108.8		86.1		125.2	
DE	Germany (until 1990 former territory of the FRG)	77.4		60.4		89.7		72.5		99.4	
EE	Estonia	58.1		44.6		60.7		53.1		69.9	
IE	Ireland	:	u	:	u	:	u	:	u	:	u
EL	Greece	82.9		65.1		81.8		78.2		92.3	
ES	Spain	90.0		80.4		89.6		87.9		94.2	
FR	France	81.5		63.4		90.7		76.1		94.4	
HR	Croatia	73.3		58.1		69.3		69.4		81.2	
IT	Italy	88.3		77.2		90.0		85.2		95.2	
CY	Cyprus	138.4		100.6		129.2		124.0		164.0	
LV	Latvia	55.1		44.5		54.7		51.2		63.9	
LT	Lithuania	57.4		45.7		60.7		54.1		63.5	
LU	Luxembourg	104.6		86.1		114.7		98.5		121.9	
HU	Hungary	64.7		53.1		65.7		60.8		75.9	
MT	Malta	:	u	:	u	:	u	:	u	:	u
NL	Netherlands	94.3		72.8		106.1		86.2		116.6	
AT	Austria	75.9		62.4		83.9		71.6		89.4	
PL	Poland	61.5		48.9		60.6		57.2		70.5	
PT	Portugal	100.5		82.5		94.4		94.6		110.3	
RO	Romania	41.7		35.1		40.0		39.7		45.2	
SI	Slovenia	72.1		58.7		74.3		67.7		82.6	
SK	Slovakia	72.9		60.8		71.4		69.7		77.8	
FI	Finland	75.2		54.8		78.3		65.3		104.9	
SE	Sweden	84.2		61.1		93.4		75.1		106.9	
IS	Iceland	125.0		84.5		130.5		107.9		150.2	
NO	Norway	116.1		83.7		124.3		100.5		151.6	
CH	Switzerland	98.1		76.7		106.0		91.2		117.6	
UK	United Kingdom	:	u	:	u	:	u	:	u	:	u

Figure 10 Average size of dwelling by household type in European Cities (EU27). Source: Eurostat, 2021

In Towns & Suburbs, the Eurostat (2021) reports the average size of dwelling among the Member States (EU 27), of 96.5 m², for a single person is 77.7 m², for a household with two adults the size of dwelling is 101.7 m², households without dependent children is 91.6 m² and households with dependent children is 107.9 m² on average (Figure 10). The biggest size of dwelling in towns and suburbs are reported in Cyprus (141.3 m²), Belgium and Norway (129.3 m²), Denmark (125.1 m²), Luxembourg (120.8 m²), Switzerland (120 m²) and The Netherlands (117.5 m²). Portugal (109.9 m²), Spain (105.3 m²), and Germany (101.1 m²) range around the same size. The smallest size of dwelling in towns and suburbs are found in Romania (45.1 m²), Lithuania (57.6 m²), Latvia (60.9 m²) and Estonia with (64.2 m²).

Dataset: Average size of dwelling by household type and degree of urbanisation [ILC_HCMH02__custom_1237669]
Last updated: 20/06/2019 23:00

Time frequency [FREQ] Annual [A]
Unit of measure [UNIT] Average [AVG]
Degree of urbanisation [DEG_URB] Towns and suburbs [DEG2]
Time [TIME] 2012

GEO (Codes)	HHTYP (Codes) / HHTYP (Labels) / GEO (Labels)	TOTAL Total		A1 Single person		A2 Two adults		HH_NDCH Households without dependen		HH_DCH Households with dependent ch	
EU	European Union (EU6-1958, EU9-1973, EU10-	99.4	e	79.9	e	103.2	e	93.5	e	113.3	e
EU27_2020	European Union - 27 countries (from 2020)	96.5	e	77.7	e	101.7	e	91.6	e	107.9	e
EU28	European Union - 28 countries (2013-2020)	99.4	e	79.9	e	103.2	e	93.5	e	113.3	e
EU27_2007	European Union - 27 countries (2007-2013)	99.5	e	79.9	e	103.3	e	93.6	e	113.4	e
EA	Euro area (EA11-1999, EA12-2001, EA13-200	102.7	e	81.3	e	107.2	e	96.8	e	115.7	e
EA19	Euro area - 19 countries (from 2015)	102.5	e	81.1	e	107.1	e	96.6	e	115.4	e
EA18	Euro area - 18 countries (2014)	102.6	e	81.2	e	107.2	e	96.8	e	115.6	e
BE	Belgium	129.3		103.6		135.9		121.1		146.9	
BG	Bulgaria	74.4		63.7		74.2		73.6		75.7	
CZ	Czechia	75.9		59.6		73.9		70.9		86.2	
DK	Denmark	125.1		99.3		137.0		115.3		147.0	
DE	Germany (until 1990 former territory of the F	101.1		75.2		109.0		93.6		122.9	
EE	Estonia	64.2		49.2		69.9		59.7		74.1	
IE	Ireland	:	u	:	u	:	u	:	u	:	u
EL	Greece	98.2		68.4		91.5		89.2		112.2	
ES	Spain	105.3		97.2		103.9		104.1		107.1	
FR	France	95.4		77.1		102.5		90.5		106.4	
HR	Croatia	84.8		65.4		78.6		76.9		97.1	
IT	Italy	98.2		84.1		97.8		94.8		105.1	
CY	Cyprus	141.3		92.3		123.1		116.6		172.9	
LV	Latvia	60.9		45.2		57.7		52.8		73.4	
LT	Lithuania	57.6		43.4		58.3		49.6		70.9	
LU	Luxembourg	120.8		94.4		133.6		113.0		134.8	
HU	Hungary	75.6		63.9		76.7		72.3		82.0	
MT	Malta	:	u	:	u	:	u	:	u	:	u
NL	Netherlands	117.5		92.7		124.3		111.0		131.2	
AT	Austria	99.3		76.7		102.1		91.2		119.4	
PL	Poland	76.1		53.9		72.0		68.4		87.5	
PT	Portugal	109.9		91.5		105.7		104.0		119.0	
RO	Romania	45.1		37.4		45.3		42.6		48.7	
SI	Slovenia	80.7		59.3		79.9		73.5		92.0	
SK	Slovakia	89.8		74.1		84.7		84.4		98.4	
FI	Finland	82.2		58.8		88.7		73.1		113.6	
SE	Sweden	99.5		72.1		109.2		88.8		126.8	
IS	Iceland	0.0		0.0		0.0		0.0		0.0	
NO	Norway	129.3		91.2		141.3		115.1		163.7	
CH	Switzerland	120.0		92.5		125.7		113.7		134.3	
UK	United Kingdom	:	u	:	u	:	u	:	u	:	u

Figure 11 Average size of dwelling by household type in European Towns & Suburbs (EU27). Source: Eurostat, 2021.

For Rural Areas, the Eurostat (2021) reports the average size of dwelling among the Member States (EU 27), of 100.1 m^2, being bigger than in cities and towns and suburbs. For a single person is 79.7 m^2, for a household with two adults the size of dwelling is 104.5 m^2, households without dependent children is 94.7 m^2 and households with dependent children is 112.0 m^2 on average (Figure 11). The biggest size of dwelling in towns and suburbs are reported in Luxembourg (150.3 m^2), Cyprus (148 m^2), Iceland (140.5 m^2), Belgium (136.4 m^2), Denmark (135.4 m^2), Switzerland (135.0 m^2), Norway (131.0 m^2) and The Netherlands (126.2 m^2). Austria (121.9 m^2), Spain (112.2 m^2) and France (110.8 m^2) have a medium-size of dwelling followed by Portugal (111.9 m^2), Sweden (105.4 m^2) and Italy (96.9 m^2). The smallest size of dwelling are Romania (45.1 m^2), Lithuania (69.7 m^2), Latvia (71.2 m^2), Bulgaria (73.2 m^2) and Estonia (77.4 m^2).

Dataset:	Average size of dwelling by household type and degree of urbanisation [ILC_HCMH02__custom_1237669]
Last updated:	20/06/2019 23:00
Time frequency [FREQ]	Annual [A]
Unit of measure [UNIT]	Average [AVG]
Degree of urbanisation [DEG_URB]	Rural areas [DEG3]
Time [TIME]	2012

	HHTYP (Codes)	TOTAL		A1		A2		HH_NDCH		HH_DCH	
	HHTYP (Labels)	Total		Single person		Two adults		Households without dependen		Households with dependent ch	
GEO (Codes)	GEO (Labels)										
EU	European Union (EU6-1958, EU9-1973, EU10-	104.9	e	80.8	e	110.4	e	99.5	e	117.2	e
EU27_2020	European Union - 27 countries (from 2020)	100.1	e	79.7	e	104.5	e	94.7	e	112.0	e
EU28	European Union - 28 countries (2013-2020)	104.9	e	80.8	e	110.4	e	99.5	e	117.2	e
EU27_2007	European Union - 27 countries (2007-2013)	105.2	e	81.0	e	110.7	e	99.8	e	117.5	e
EA	Euro area (EA11-1999, EA12-2001, EA13-200	110.2	e	86.6	e	112.5	e	103.2	e	124.3	e
EA19	Euro area - 19 countries (from 2015)	109.1	e	85.7	e	111.7	e	102.3	e	123.0	e
EA18	Euro area - 18 countries (2014)	109.7	e	86.3	e	112.2	e	102.8	e	123.8	e
BE	Belgium	136.4		104.7		139.4		127.1		153.5	
BG	Bulgaria	73.2		60.9		72.0		69.6		80.5	
CZ	Czechia	89.1		70.1		84.5		83.3		99.2	
DK	Denmark	135.4		100.9		143.3		122.7		166.3	
DE	Germany (until 1990 former territory of the F	113.5		84.9		115.9		104.9		132.0	
EE	Estonia	77.4		61.4		80.0		71.1		89.7	
IE	Ireland	:	u	:	u	:	u	:	u	:	u
EL	Greece	92.8		71.4		87.8		87.6		104.1	
ES	Spain	112.2		96.8		113.2		109.3		117.4	
FR	France	110.8		89.6		115.2		105.1		122.1	
HR	Croatia	85.7		69.0		80.4		79.9		96.8	
IT	Italy	96.9		83.4		98.6		92.7		108.0	
CY	Cyprus	148.0		99.9		125.1		122.7		185.4	
LV	Latvia	71.2		55.3		73.0		67.8		77.3	
LT	Lithuania	69.7		60.3		72.3		66.5		76.3	
LU	Luxembourg	150.3		117.5		156.4		139.5		169.9	
HU	Hungary	86.4		71.5		87.6		82.9		92.5	
MT	Malta	:	u	:	u	:	u	:	u	:	z
NL	Netherlands	126.2		99.7		129.9		118.9		142.1	
AT	Austria	121.9		89.0		117.5		112.1		143.4	
PL	Poland	90.1		65.7		80.4		81.0		101.8	
PT	Portugal	111.9		87.6		103.7		101.4		133.9	
RO	Romania	45.1		37.2		44.8		42.4		49.5	
SI	Slovenia	84.2		59.8		81.3		75.0		98.8	
SK	Slovakia	93.9		77.4		93.2		89.2		101.5	
FI	Finland	96.7		65.0		105.4		85.6		128.2	
SE	Sweden	105.4		76.5		117.4		96.3		133.4	
IS	Iceland	140.5		101.1		149.4		129.3		156.9	
NO	Norway	131.0		96.1		143.7		117.3		162.9	
CH	Switzerland	135.0		100.4		138.1		127.9		151.9	
UK	United Kingdom	:	u	:	u	:	u	:	u	:	u

Figure 12 ***Average size of dwelling by household type in European Rural Areas (EU27). Source: Eurostat, 2021.***

3 Household composition in Europe

The average household in the EU has been shrinking in recent decades. This pattern may be attributed to a range of factors, including: a rising share of people living independently; an increase in the share of the elderly living alone; declining fertility rates; higher divorce rates; and a shift in household structures away from extended families living together under the same roof towards more households being composed of 'nuclear' families, single-parent families and people living alone (Eurostat, 2018).

The Eurostat (2021a) 'Household Composition Statistics' report, presents information on the development of households in the European Union (EU) and in the EU Member States during the past decade. It also reports at European level on the evolution of men and women living either as a couple, alone or in another type of household. The presence of children in households is also given special attention. Furthermore, the report focuses on the changes in young people's living situations between 2019 and 2020. The statistics presented by Eurostat (2021a), are based on the European Union Labour Force Survey (EU-LFS), which is one of the largest European household sample surveys.

A private household is defined as a person living alone or a group of people who live together in the same private dwelling and share expenditures, including the joint provision of the essentials for living. A household-dwelling unit consists of the permanent occupants of a dwelling collected on the basis of 'usual residence', in other words, the place where a person normally lives (aside from temporary absences for the purposes of recreation, holidays, visits to friends and relatives, business, medical treatment or religious pilgrimage). An institutional household comprises persons who have board, lodging, care or nursing at an institution. Institutional households include, for example, student halls of residence, old people's homes, nursing homes, military barracks, prisons or religious institutions; the data presented in this research generally focuses exclusively on private households (Eurostat, 2018).

The main highlights of the Eurostat (2021a) report is that during the decade 2010-2020, the total number of households in the EU increased by 7.2%, and as mentioned in the section above, the average of members per household is 2.3 persons. Also, there is an increase of single adult households (e.g. households consisting of only one adult, living with or without children) increased much faster, namely by 19.5 % in 2010-2020. With regard to single adults, both men and women recorded a higher number of people living alone for all age groups in 2020 compared to 2010 (Figure 13) (Eurostat, 2021a).

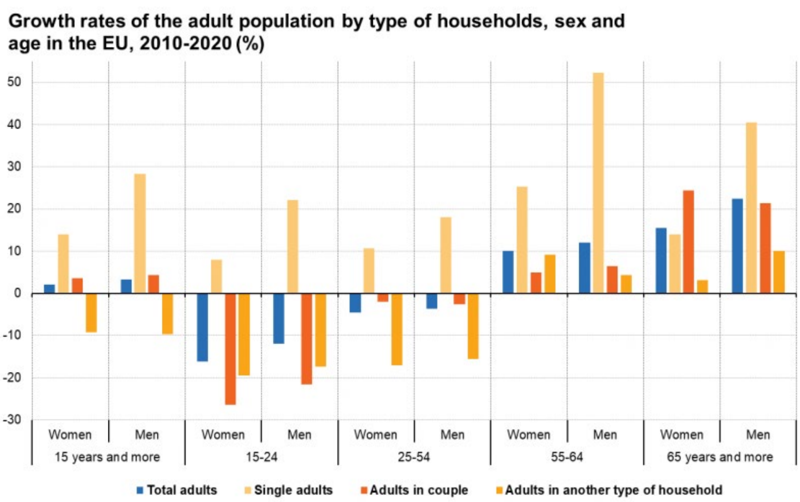


Figure 13. Growth rates of the adult population by type of households, sex and age in the EU, 2010-2020 (%). Source: Eurostat, 2021a.

The growth is higher than 10% for all categories except for young women aged 15-24. For both men and women, the proportion of single adults increased faster than that of adults living in a couple. This last finding is observed for men and women of all age groups, apart from women aged 65 and more for whom a higher increase was recorded for those living in a couple. In terms of gender, male adults living alone increased more steeply than female adults living alone, regardless of age group. Men aged 55-64 experienced the greatest increase in the period 2010-2020, with a 52.2% increase. For comparison, women in the same age category recorded an increase of 25.2% since 2010. Older men aged 65 and over living alone increased by 40.5% in 2020 compared to 2010. The corresponding increase for women was 14.0% (Eurostat, 2021a).

In 2020, the EU recorded an increase of 11.2% in households without children and a decrease of 1.4% in households with children, compared with the situation in 2010. At national level, all countries, with the exception of Bulgaria which showed no change, recorded an increase between 2010 and 2020 in households without children, ranging from +67.6% in Malta, +54.0% in Sweden*, +34.6% in Luxembourg and +26.2% in Cyprus to +1.1% in Croatia, +4.2% in Denmark and +4.6% in Germany. Turkey also recorded a sharp increase (68.4%) in households without children. Regarding households with children, the development is relatively disparate among the Member States: the number of households with children decreased in 17 EU Member States, with the largest decrease in Lithuania (-21.3%). It remained stable in Spain, however, and increased in 9 EU Member States, including Luxembourg and Malta, where it increased by more than 15% (+15.1% and +35.4%, respectively) (Eurostat, 2021a).

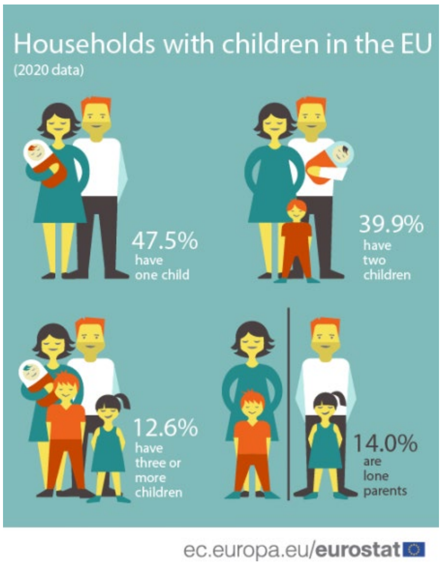


***Figure 14** Households with children in the EU. Source: Eurostat, 2021a.*

More than two thirds of households with children consisted of couples (68.7%). In some countries, it is by far the most common type of household with children: in Finland and Greece, couples represent 83.9% and 79.2% respectively of the total number of households with children, while the lowest share in the EU is observed in Latvia (46.6%). In Serbia and North Macedonia, less than half of the households with children are couples (48.2% and 40.9%). These two candidate countries have the highest share of households consisting of two (not being a couple) or more adults and that include children (46.3% in Serbia and 57.2% in North Macedonia). They are followed by the two EU Member States Croatia and Romania, as well as Turkey, where more than one-third of households with children include two (who are not a couple) or more adults. At EU level, these households accounted for 17.3 % of households with children, while this percentage is below 10% in Estonia, Finland, Denmark and Sweden. In these countries except Finland (e.g. Estonia, Denmark and Sweden) but also in Latvia, Lithuania and France, single parents represent more than 20% of households with children. In the whole European Union, single parents accounted for 14.0% of households with children. Romania and Croatia had the lowest proportions of single parents, as did Serbia, Turkey and North Macedonia (all recording a percentage less than 7%). In 2020, in the EU, almost half of the households with children included one child (47.5%). Portugal, Lithuania and Latvia showed the highest shares of households with one child, i.e. ranging between 55% and 57%. At EU level, four in ten households with children (39.9%) included two children in 2020. Households with two children or more were most frequent in Ireland, Sweden, the Netherlands, Slovenia, Croatia and in North Macedonia. In the EU, 12.6% of the households with children in 2020 consisted of households with three or more children. Ireland, Finland, Belgium, France, the Netherlands, Sweden and Croatia recorded the highest share of households with three children or more, all above 15.0%; this was also the case of North Macedonia (Figure 14) (Eurostat, 2021a).

4 Housing demand in Europe

Living in a house or a flat differs among the Member States, and also varies depending on whether people live in a city or the countryside. In the EU in 2019, 53% of the population lived in a house, while 46.1% lived in a flat (1% lived in other accommodation, such as houseboats, vans etc.) (Figure 15). Just over one third (34.8%) of the population lived in detached houses and almost one fifth (18.5%) lived in semi-detached or terraced houses. Ireland (92%) recorded the highest share of the population living in a house, followed by Croatia and Belgium (both 78%) and the Netherlands (75%) (Eurostat, 2020; Eurostat, 2021b).

Houses are most common in two thirds of the Member States. The highest shares for flats were observed in Latvia (66%), Spain (65%), Estonia (61%) and Greece (59%). In terms of different levels of urbanization, it was reported that in cities 72% of the EU population lived in a flat and 28% in a house (Figure 16). For towns and suburbs, the proportions were 58% for flats and 42% for houses (Figure 17), while for rural areas, 82% of the population lived in a house and only 18 % in a flat (Figure 18) (Eurostat, 2020).

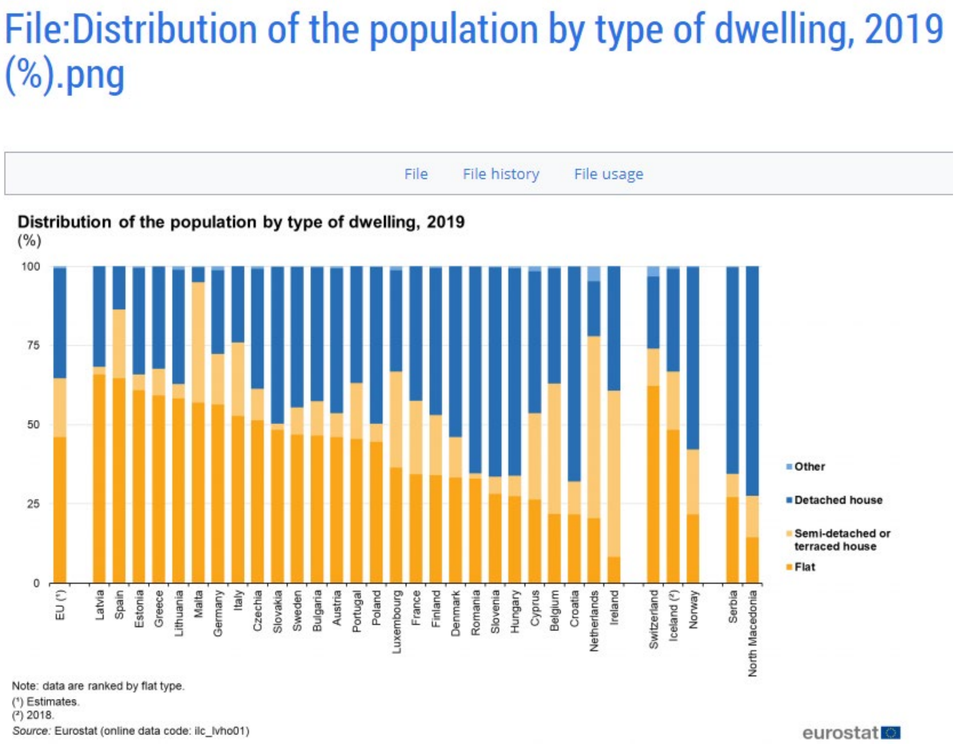


Figure 15 ***Distribution of the EU population by type of dwelling. Source: Eurostat, 2021b***

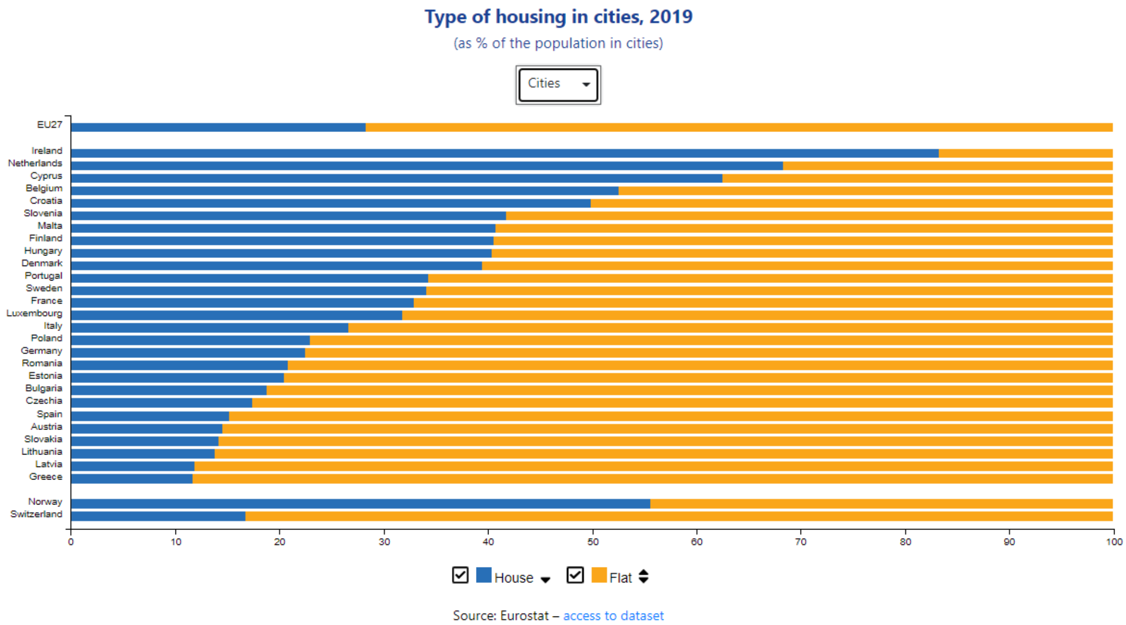


Figure 16 ***Type of housing in EU cities. Source: Eurostat, 2020.***

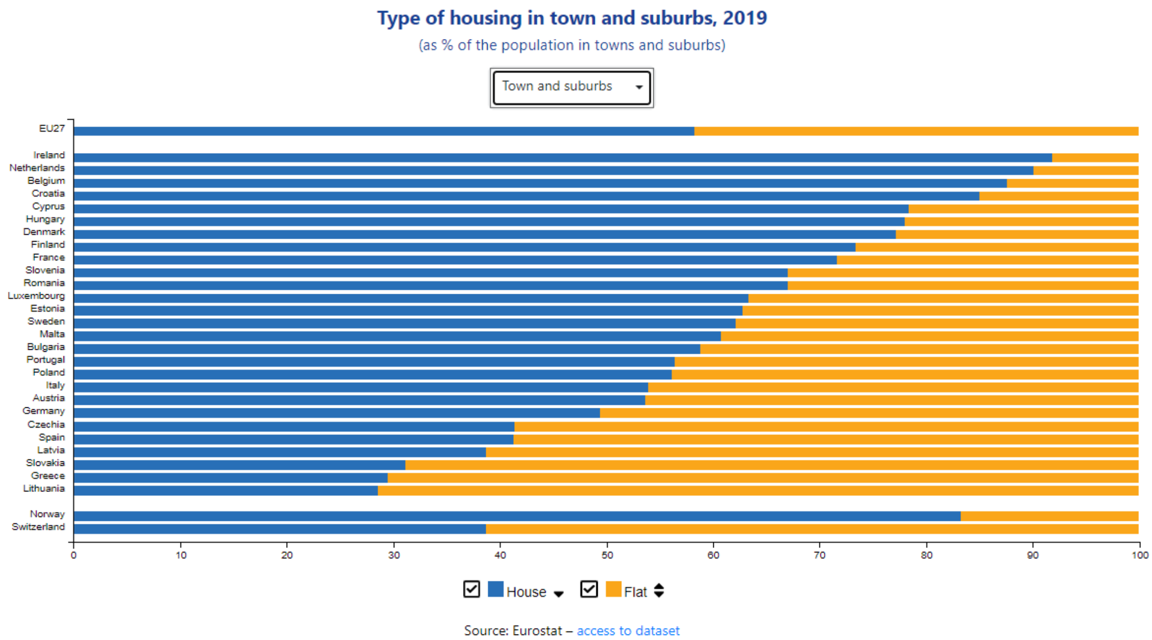


Figure 17 ***Type of housing in EU towns and suburbs. Source: Eurostat, 2020.***

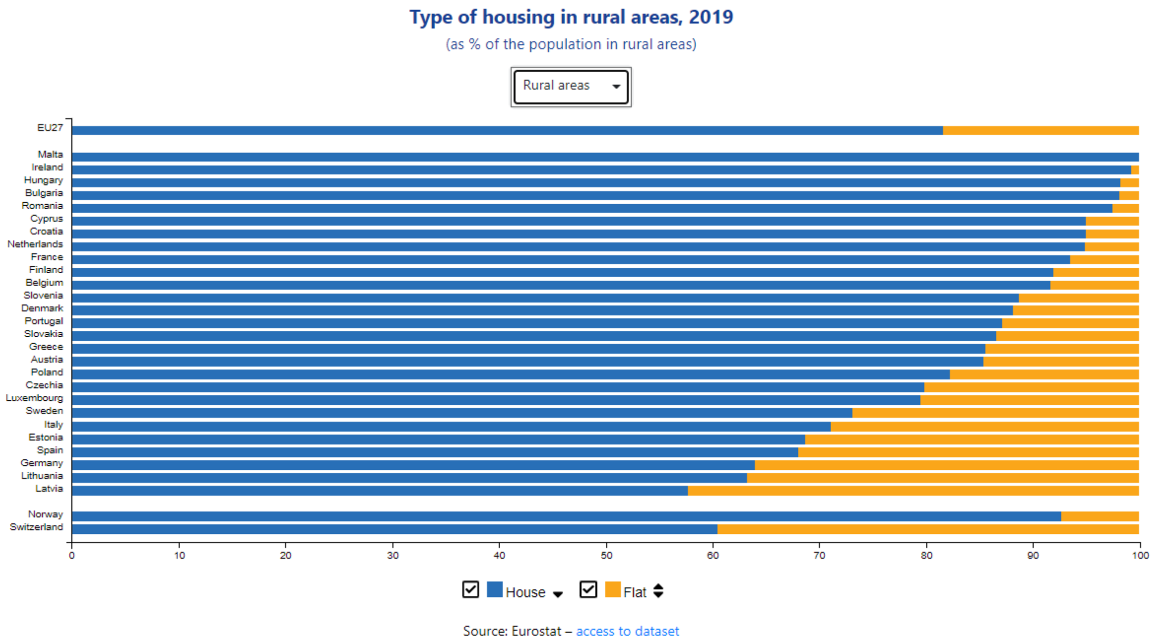


Figure 18 Type of housing in rural areas. Source: Eurostat, 2020

The Housing Europe (2021) 'State of Housing 2021' report provides a first analysis of the impact the COVID-19 crisis that had on public, cooperative, social housing and EU communities. It illustrates the alarming housing reality in 21 countries and offers concrete policy recommendations on how to overcome substantial challenges to decent, sustainable, inclusive, affordable housing. The vital need for shelter from the COVID-19 storm has made the essential role of decent and affordable housing even more explicit, reinforcing the strong link between adequate homes and health. Various analyses show that inadequate housing has an impact on well-being, mental health, school performance and the possibility to work remotely. Previous editions of 'State of Housing' have been drawing attention to Eurostat figures that report for nearly 10% of the EU population experiencing housing cost overburden and over 17% of Europeans living in overcrowded homes, making social distancing a particularly challenging task.

While housing markets have recovered from the Global Financial Crisis in 2009, average house prices in the EU's private sector have increased by over 30% in the past decade and rents have gone up by almost 15%. Unbearable housing costs coupled with growing unemployment rates due to COVID-19 will result in higher demand for social and affordable housing according to the OECD. Higher demand comes on top of already large unmet needs. Council housing waiting lists in England already count 1.1 million households and risk to nearly double to 2 million households in a year from now. One out of four tenants in Czechia in 2020 fear that they will have to leave their current home in the next 12 months. In Italy, the share of tenant households with debts on rent payment in the private rental sector has jumped from less than 10 to 24% since the start of the pandemic (Housing Europe, 2021).

In 2020, most governments across Europe have taken fast, effective emergency policy measures in supporting incomes or temporarily banning evictions. However, there is not yet a sustained trend in long-term investment in social or affordable housing. There is a need of a mix of political decisions that could create a unique opportunity for Member States and the EU to invest in social, cooperative housing: The EU Stability and Growth Pact has been put on hold, allowing EU Member States to use debt to invest in both emergency measures and recovery plans. The EU has also made monetary policies more accommodating to face the pandemic. Eventually the European Pillar of Social Rights, which acknowledges the essential role of social housing in a modern European welfare state, is meant to be the compass of the European Commission to ensure that EU policies will support social progress, also in the field of housing (Housing Europe, 2021).

4.1 Housing and living conditions demand in Europe

In the 'Living conditions in Europe' report (Eurostat, 2014), mentions that in the context of material living standards and well-being, housing is a fundamental aspect. People's ability to afford adequate housing of decent quality in a safe environment is a matter of importance for meeting basic needs and a key determinant of well-being. Housing quality covers a wide range of aspects, which are related not only to the dwelling itself, but also to the broader residential area where people live in. Structural problems of the dwelling (damp walls, leaking roof, etc.), overcrowding and space shortage, housing deficiencies and lack of basic amenities (e.g. affording an adequately warm home) are key elements for assessing housing quality. At the same time, living in a noisy area, being exposed to pollution and grime or feeling unsafe in the residential area where the home is situated, while based on subjective perspectives, denote perceived housing problems with regard to the quality of the dwelling environment (Eurostat, 2014).

Overall, 17% of the Europeans (EU-28) lived in an overcrowded household in 2012. Despite the sharp differences among countries, overcrowding is more prevalent in Southern and Eastern Europe. Cross-country comparisons reveal that densely-populated areas were associated with the highest overcrowding rates in almost all countries, with a few exceptions. Shortage of adequate housing is a long-standing problem in most European countries. The overcrowding rate describes space problems, defined on the basis of the number of rooms available to the household, the household's size, as well as its members' ages and family situation (Eurostat, 2014).

4.2 Sustainable housing demand: Example of The Netherlands

On average, a Dutch person has 65 m^2 of living space. There are large differences between regions and also between the available living space by type of household. In the Randstad the average living area per person is generally smaller than outside the Randstad. In the larger cities the living area is on average the smallest. In Amsterdam, per person average is 49 m2 (CBS, 2018).

The Real Estate Market Outlook 2021 (CBRE, 2021) mentions that the major Dutch banks are increasingly financing sustainable and socially responsible projects. The result is that instead of owner-occupied homes in the top segment, sustainable mid-market rental homes or housing for seniors is being more eagerly financed. This involves the reduction of CO_2 emissions or energy efficiency. Inner-city redevelopments are not necessarily green but easily become sustainable by redevelopment and improving the socio-economic structures of the city. Banks are certainly prepared to bear the higher risk of redevelopment if that results in new homes.

Sustainability stopped being a priority for several years during the global financial crisis. However, during the COVID-19 pandemic, this topic remains a priority; in some part because of the Paris Agreement and government goals to emit 49% less greenhouse gasses before 2030 than in 1990. To achieve this goal, the rate of reduction will have to double according to the Netherlands Climate and Energy Outlook 2020 published by the Netherlands Environmental Assessment Agency. In addition, institutional investors are raising the bar every year through the Global Real Estate Sustainability Benchmark rating (GRESB). Also, more attention is given for sustainability certifications like BREEAM and LEED at building level. Investors are realizing that the only way to contribute to the reduction goals, as well as to make their portfolio future-proof, is through making their real estate more sustainable (CBRE, 2021).

The Dutch multifamily market remains popular among domestic and international investors. Many investors have been allocating capital to Dutch multifamily real estate for years due to stable rents and reduced chances of vacancy due to the structural housing shortage – a trend that was accelerated by the COVID-19 pandemic. The multifamily share is also increasing within many mixed-use funds and more and more specialized multifamily funds are being established (CBRE, 2021).

Affordability in the rental market has become even more important over the past year. Purchase options are declining for part of the population due to the COVID-19 pandemic, partly due to reduced income security. Many of those home seekers are not eligible for social housing, which means that there is even more demand for the mid-market segment. There is an increased interest from investors in affordable rental homes in secondary locations in the Randstad Region over the course of 2020. This is also expected to remain a popular investment product in 2021 (CBRE, 2021).

In the Netherlands, the demand from expats has almost completely disappeared. Nevertheless, the social problem of the Dutch residential market remains, given the increasing shortage of approximately 330,000 homes, according to ABF Research – with no prospect of substantial growth. This is expected to put upward pressure on rents in the longer term. It is not expected an urban exodus, despite the coronavirus pandemic. Students and particularly young professionals head to the city for development opportunities in a creative and social environment. Young families are more likely to step outside that environment, which has been an ongoing trend. Space shortages and a lack of green space are usually mentioned as reasons for relocation, according to the most recent Netherlands' Housing Survey by the Ministry of the Interior and Statistics Netherlands. The volume and type of homes added to urban stock will ultimately determine if this trend continues. Cities will remain popular with more supply (CBRE, 2021).

5 Housing supply in Europe

In most EU countries, public investment in the supply of new homes doesn't seem adequate to respond to the growing demand. Despite widespread recognition of an urgent need to invest in both new construction and rehabilitation, and the increasing availability of data on affordable housing in Europe and beyond, the lack of knowledge on the actual needs and related investment in social and affordable housing is striking. First of all, there is little comparable information on how much investment is currently feeding into housing, and more specifically affordable and social housing. If data on public expenditure related to the different policy measures in place are fragmented and hardly comparable (partly due to the variety of support mechanisms in place), information on private investment is almost completely lacking. Secondly, there are huge discrepancies across countries in terms of the availability of official estimates of housing needs (Housing Europe, 2019; Housing Europe, 2021).

In France for instance the current government objective is to provide 110,000 new social housing units each year. Instead, according to a recent report by the French Court of Auditors, social housing companies had to decrease their overall investment in recent years after reforms adopted by the government in 2018 led to a significant decrease in revenues. As a consequence, only about 90,000 units were started in 2020, and investment in housing maintenance decreased by 7%. On a positive note, though, one particularly innovative example of policy adaptation is the French 'Alliance Européenne pour un logement social durable et inclusive', which brings together the French social housing federation USH, the public Banque des Territoires (former Caisse des Depots et Consignations), the European Investment Bank, and the Council of Europe Development Bank to facilitate access to European financing for social housing providers (Housing Europe, 2021).

In the Netherlands, with parliamentary elections having been announced for March 2021, an unprecedented national coalition of 34 key stakeholders from all aspects of the construction, social care and financing of housing, including and initiated by the social housing federation Aedes, came together in February 2021 to outline the 'Actieagenda Wonen' (Housing Action Agenda). Their unified "offer" to the next government to tackle housing challenges currently being faced in the Netherlands. However, this will require the government to reform many aspects of the current housing system, as well as providing additional supports (Housing Europe, 2021).

Worth mentioning as a positive example is the Draft Budget 2021-22 of the Welsh government, which allocates an additional €44.2 million (£36.8 million) for new social housing supply, bringing the total to almost €233 million (£200 million) and marking the highest budget ever announced for social housing in Wales. At the same time, the Belgian Walloon Region has also seen unprecedented support for social housing over the past two years, with €1.2 billion allocated for the renovation of 25,000 units over 4 years and a long-terms objective to renovate 55,000 by 2030. The regional government is also supporting the supply of an additional 3,000 units by 2024, and has recently launched additional programmes to increase aesthetics, innovation and sustainability in public housing. Last, but not least, the Irish budget for 2021 includes a €110 million allocation towards affordable housing and delivery of a brand new cost-rental scheme which will provide 400 homes by Approved Housing Bodies in Ireland (Housing Europe, 2021).

The European Union has made the Green Deal its guiding principle and the fair energy transition and decarbonisation of the building stock should have a central place. Social, cooperative and public housing providers are already frontrunners in the fair energy transition in most countries. Indeed, in many cities and regions the average energy performance of their homes is better than in any other segment of the housing market, whilst also managing to provide housing for low-income families, ensuring comfort at an affordable price. Fundamentally, social, cooperative and public housing providers' main objective for the renovation wave and the fair energy transition is to create and maintain sustainable communities with a high level of quality of life and an affordable cost of living (Housing Europe, 2021).

Before the COVID-19 pandemic, social, cooperative and public housing providers intended to spend €35bn per year on the development of new homes and around €23bn for renovation and maintenance activities - upgrading about 400,000 housing units every year. In order to renovate the entire social, cooperative and public housing stock in Europe by 2050 to at least level B (60 to 120 kwh/m²/year) or A (below 50kwh/m²/ year), contributing substantially to the decarbonisation of the building stock and a CO_2 neutral Europe, it is needed to increase this number by at least 200,000 per year, whilst also increasing the scope of the average renovation. This would require at least an extra €10bn per year until 2050. This would only cover the building envelope and not the decarbonisation of the heating systems (Housing Europe, 2021).

The Renovation Wave will be an important milestone for the EU push towards a carbon neutral Europe by 2050. It will also be a complex piece of policy-making, since the energy performance of homes cannot be regulated in the same way as energy efficiency of appliances or cars. The observation of the results of measures on energy efficiency in buildings shows that there is no single route towards decarbonisation of the building stock. Indeed, there is no correlation between one specific set of policies in one country and the average performance of the building stock. The Renovation Wave should therefore promote a flexible and integrated approach to energy efficiency in buildings, aiming at preserving affordability and quality of life for residents and communities. In particular, the Renovation Wave will promote an innovative approach regarding area-based interventions: "In order to guarantee that local social housing projects have access to all necessary technical capacity, the Commission will launch the Affordable Housing Initiative. It will pilot 100 lighthouse renovation districts in a smart neighbourhood approach and provide blueprints for replication, setting liveability and latest innovations at the forefront. It will mobilise cross sectoral project partnerships linking them to local actors, including from the social economy, to promote efficient, circular and modular processes, social engagement models to empower residents, inclusive and accessible developments and cultural innovation" (Housing Europe, 2021).

To bring the stock of social, cooperative and public housing in to Energy Performance Certificate Label B and A by 2050, on top of the yearly €23 billion dedicated to renovation and maintenance in a business-as-usual scenario, the sector would need an extra €13 billion every year until 2050. The Climate Action Social Facility size will determine by the expected revenues from the auctioning of emissions units. At the end of 2020, Housing Europe announced its 4 million renovated homes by 2030 with the aim to decrease the energy consumption of the refurbished housing units on average by 50% by 2030, cut emissions with at least 50% and save up to €700 per year on average to each resident. Their main goal is to live in a climate-neutral continent and deliver decent, healthy, adequate housing to next generations (Housing Europe, 2021a).

According to the European Housing Report (Re/Max, 2021), in many countries across Europe, the COVID-19 pandemic has caused shifts in both market activity and buyer preference. Many city dwellers are now looking for more space, seeking out larger properties in rural areas. This is partly due to Europeans working from home and wanting more space to accommodate a home office. For some Europeans (35%), the COVID-19 pandemic has made them more interested in buying or selling. This sentiment is strongest in Turkey (60%) and Spain (56%). Approximately, 37% of Europeans have considered moving to a more rural community since March 2020. This sentiment is strongest in Spain (58%), Portugal (50%) and Turkey (43%), and the trend has been evident in countries like Austria, Italy and Finland (Re/Max, 2021).

5.1 Estimation of housing supply in Europe

As mentioned by the European Social, Cooperative and Public Housing (Housing Europe, 2020), providers aim at building and refurbishing 400,000 homes per year or 4 million homes by 2030. The Table 1 presents a summary on the estimation of housing stock and new social housing units built per year in different European countries (average values between 2013 and 2021). According to the literature review, it was estimated that around of 1.8 million (1,795,630) of new social housing was completed in the period 2013-2021 in Europe with an average percentage of social housing of 13% (see Table 2, Annex 1).

For some countries like the Netherlands where the pressure on the housing market remains unprecedentedly high. In 2021, there is a shortage totals nearly 300,000 homes. If more cooperation can be created and building permit procedures can be accelerated, then they can build more than 35,000 affordable rental homes annually (this is around 12% of the current housing shortage) (Capital Value, 2021).

Table 1 Hypothetic housing supply for the period 2020-2030.

Period	2013-2020 (8 years)	2020-2030 (10 years)	Increase of last period target per year to reach the new period target
Total new social housing (EU+E)	1,795,630 (built)	4,000,000 (to be built)	
New social housing built per year (EU+E)	224,454	400,000	224,454 + **175,546= 400,000**
			Increase of 78.21% of new social housing per year

An estimation of a total European housing demand was made, knowing that Europe expects to build around 400,000 social houses every year in the period from 2020 to 2030 and assuming that the average percentage of social housing at European level will remain at 13% during this period. The hypothetic housing supply is 3.1 million houses per year in the coming 10 years resulting in a total number of 31 million houses by 2030 as shown in Table 3.

Table 3 Hypothetic European housing supply estimated for the period 2020-2030 in Europe.

Period	Number social houses to be completed per year in Europe	Estimated number of houses to be completed per year in Europe
2020-2030	400,000	3,100,000
Total Period	4,000,000	31,000,000

6 Wooden housing and CO_2 storage

The anticipated growth and urbanization of the global population over the next several decades will create a vast demand for the construction of new housing, commercial buildings and accompanying infrastructure. The production of cement, steel and other building materials associated with this wave of construction will become a major source of greenhouse gas emissions (Churkina, et al., 2020). In Europe alone, about 190 million square meters of housing space are built each year, mainly in the cities, and the amount is growing quickly at the rate of nearly 1% a year. A recent study Aalto University (2020) and the Finnish Environment Institute shows that shifting to wood as a building construction material would significantly reduce the environmental impact of building construction. The results show that if 80% of new residential buildings in Europe were made of wood, and wood were used in the structures, cladding, surfaces, and furnishings of houses, all together the buildings would store 55 million tons of carbon dioxide a year. That's equivalent to about 47% of the annual emissions of Europe's cement industry (Aalto University, 2020).

The construction of new buildings is a significant source of emissions. These are caused by the processing, manufacturing, and transportation of building materials. Concrete and steel productions in particular are responsible for a large share of global emissions. However, it is possible to transform this source of emissions into a tool to mitigate climate change. Combined with sustainable forestry, wood construction could increase the carbon sinks of cities beside forests. Several authors have proposed using wooden buildings for climate mitigation, and numerous cities have committed to achieving carbon neutrality in the coming years. Buildings can provide long-term carbon storage, especially if they are located in urban areas where there is a growing demand for real estate; and thus, old wooden buildings do not become obsolete but are retrofitted instead of being demolished or left to decay (Amiri, et al., 2020).

One way of reducing initial embodied emissions is to use building materials that can be produced with less energy and fewer emissions. Wooden buildings seem to expel the least GHG emissions over their life cycle. Thus, while wooden buildings are beneficial for the planet insofar as they generate fewer emissions during manufacturing, the carbon storage of wooden buildings is an additional mitigation option in both the short and the long term. While wood is considered as an environment friendly material, one should bear in mind that unsustainable use of wood supplies might result into further loss of endangered forests. Although developed regions (Europe, Oceania and North America) have been successful of keeping their forest area stable from 1990 to 2010, developing regions (Asia, Africa and South America) have lost 135 Mha of their forest area (Amiri, et al., 2020).

The carbon storage capacity of buildings is not significantly influenced by the type of building, the type of wood or the size of the building but rather by the number and the volume of wooden elements used in the structural and non-structural components of the building. The amount of wood used in structural, non-structural, and installed products plays a major role in determining the amount of carbon stored by the building. Neither building type nor wood type has much influence on carbon storage (Amiri, et al., 2020).

Based on the research developed by Amiri, et al (2020), low-rise buildings, including attached and detached houses, seem to be more homogenous. This may be due to current construction practices used for these houses and their higher number of wooden components. Construction companies have less experience in higher-rise wooden buildings and the technical details are needed for their design and construction. There appears to be more variation in higher-rise buildings, which is likely due to the current trend to use non-wooden components, especially for non-structural parts. The size of buildings may have a small impact, whereby larger buildings store a little less carbon on average.

Wooden non-structural elements clearly increase the carbons stock of a building. Local building regulations affect the amount of wood used, which, in turn, affects a building’s carbon storage. For example, strict regulations about fire safety might result in the use of thicker or extra layers of wood. In locations such as Japan, where earthquake regulations significantly influence the structural parts of buildings, greater amounts of wood are used in buildings’ structures (Amiri, et al., 2020).

In the results of the analyses from Amiri, et al (2020) of the four scenarios relating to wood construction in Europe, wood construction is estimated to account for 5%, 10%, 45%, and 80%, respectively, of total construction in Europe for the period 2020 to 2040. For each scenario, it was tested how wooden buildings with different carbon storage levels—level 100 (low), level 200 (mid) and level 300 (high)—would influence the outcome. The carbon storage levels are presented in kg CO_2 per m2. Figure 19(a) shows the results for the 5% scenario, where the cumulative amount of captured CO_2 for levels 100, 200, and 300 is 0.022 Gt, 0.044 Gt, and 0.067 Gt, respectively. The values for the 10% scenario (figure 19(b)) are 0.044 Gt, 0.089 Gt, and 0.133 Gt respectively. The cumulative values for the 45% scenario (figure 19(c)) are 0.2 Gt, 0.4 Gt, and 0.6 Gt, while those for the 80% scenario (figure 19(d)) are 0.356 Gt, 0.712 Gt, and 1.067 Gt. When considering the results for the various scenarios, it is worth noting that if steel and concrete were used for new buildings, with an average floor area per capita of 30 m^2 , the cumulative emissions for Europe during the 20 year period would be 0.195 Gt; the figure for the world would be 10.819 Gt.

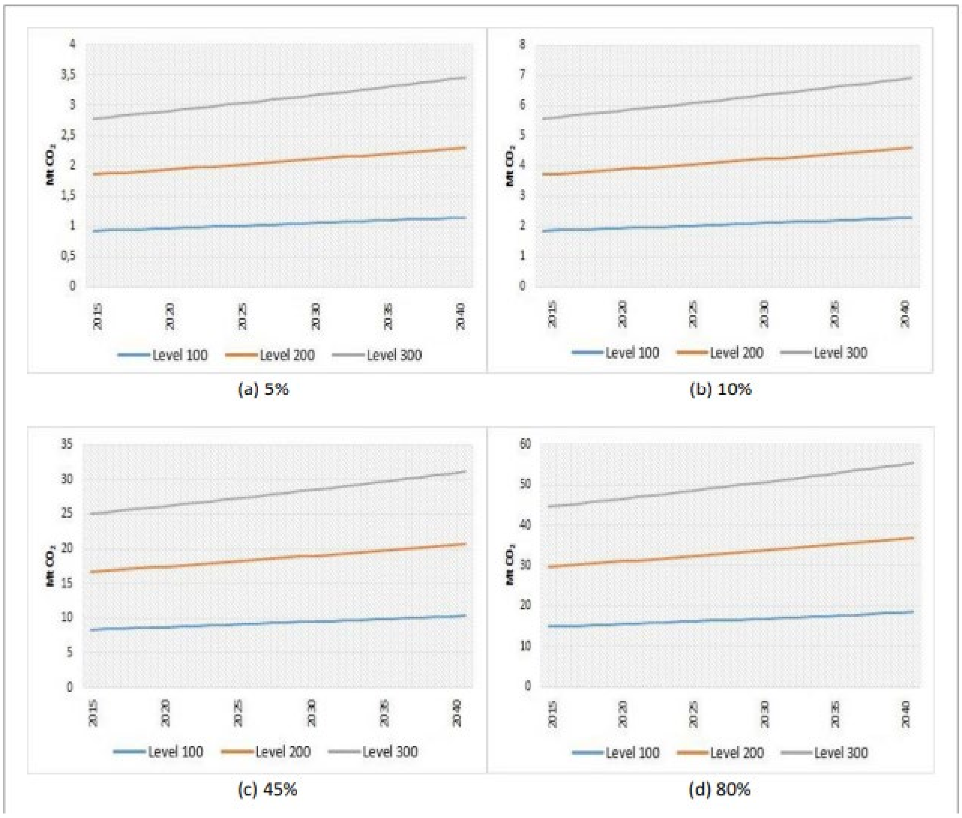


Figure 19 Annual carbon storage potential for (a) 5%, (b) 10%, (c) 45% and (d) 80% wooden buildings of different levels. Source: Amiri, et al., 2020.

The environmental concerns together with the increasing demand of building construction make it necessary to find building materials which not only produce less emissions during their production but also serve as carbon sequestration solution to mitigate climate change. As a widely available material in Europe, wood is a considerable option. There are two factors that affect the total amount of carbon storage provided by wooden building construction: (1) the volume of wood per area of the building and (2) the percentage of wooden buildings compared to other types of buildings, such as concrete and steel. European decision makers need a gradual plan of switching to wooden building with focus on both options. There is a carbon storage capacity equal to 1 and 47% of European cement industry CO_2 emissions if new buildings construction in Europe is planned to be wooden (Amiri, et al., 2020).

6.1 Wooden construction materials in Europe

As trees grow, they bind the carbon (C) of carbon dioxide (CO_2) in the wood and release the oxygen component (O_2). Each cubic meter of wood binds about 250 kg of carbon – this is the amount of carbon contained in one ton of CO_2. Forests and their wood are therefore natural carbon sinks and thus support in the climate crisis. When used in furniture, bridges or buildings, wood will continue to store the carbon for its entire life span. Therefore, the bigger the timber building (more volume, storeys), the more CO_2 it can store. When building in timber, our climate benefits twice: Forests remove CO_2 from our atmosphere. And the use of wood, e.g. in multi-storey buildings, avoids emissions from the production of substituted, more emission-intensive materials (Build in wood, 2021).

Timber for construction is one of the many forest products used around the world. It is used in buildings both large and small scale. Construction-grade timber and engineered forest products are some of the highest value products from trees. This suggests that structural use is important for economies that rely on forestry. Furthermore, following primary use as structure, there are many secondary or tertiary uses for timber construction waste that retain its value (Ramage, et al., 2017).

The EU woodworking industries include the production of sawn wood, wood-based panels, and wooden construction materials and products. About 70% of the wood in the EU is used in construction and furnishings. The harvested wood products retain the carbon gathered by trees. Processing wood to make these often requires much less energy than those derived from other materials, so wood has a smaller carbon footprint than other materials. Around 97% of the raw wood processed in the EU comes from sustainably managed EU forests; the rest is imported. Although not mandatory, evidence of sustainable forest management (SFM) is often provided on a voluntary basis through "chain-of-custody" certification schemes that link wood products back to sustainable sources. In line with the EU "Timber Regulation" (Regulation 995/2010), all wood and wood products placed on the EU market must come from verifiably legal sources. Many wood-based materials, such as wood-based panels and wood-based building products, use adhesives. Many of these are based on compounds containing formaldehyde, which is becoming classified as a carcinogen. Replace these with safer but still affordable adhesives is a big challenge. (European Commission, n.d.)

The European building sector represents a significant material stock for wood-based construction materials. In the 1950s and 1960s, 5.2 million tonnes of conventional wood-based construction materials (mainly sawn wood) were consumed on average every year. Between 1990 and 2010 this number was 6.4 million tonnes. The increased use of solid wood and timber panel constructions began to expand at the end of 1980s in the western European countries, such as the UK, Austria, Italy and Germany. In the last two decades the technical innovations of engineered timber products and their production processes, as well as the newly adopted building regulations e.g. fire protection regulations, have facilitated growth in the construction of multi-storey buildings made of wood. At the same time, the overall construction of and permits for new buildings decreased significantly after the financial crisis in 2007.In the decade from 2000 to 2010 the number of building permits were 1.7 to 2.5 times higher than in 2010 and even faced a further decrease of around 10% in the five years up until 2015 (Hildebrandt, et al., 2017).

A related market demand for wood-based construction materials, such as engineered wood products (EWP), in the building sector is expected for the construction of new residential buildings (one and two-family houses, multi-family houses and other types of dwellings) and for energetic renovation and retrofitting of old buildings, i.e. within urban built infrastructures. In terms of the total production volume of EWP, the ecological construction industries have been able to maintain constant growth rates of 2.5% to 15%, for example, in the production of wood fibre insulation boards (WFIB), cross-laminated timber products (CLT), laminated veneer lumber (LVL) and glulam products in recent decades. At the same time they have created added value by having a lower environmental impact and higher emissions efficiency than reference production systems (Hildebrandt, et al., 2017).

Even though EWPs have superior technical properties, such as high bending moments, high flexural and compressive strength and time-efficient prefabrication, as well as ecological advantages such as low carbon intensity the fossil-based industries and mineral-based construction materials are more effective in playing out their competitive advantages. Considering the expected climate effectiveness of wood construction in residential buildings, both the retrofitting and the new constructions are regarded as a way to meet the European climate targets of decreasing CO_2 emissions by 88–91% by 2050 (Hildebrandt, et al., 2017).

In defining a future scenario for the most plausible development of wood construction quotas by 2030, construction quotas and trade balances in the northern European exporting countries are expected to remain high at around 75–85%. In contrast, the trend towards more domestic consumption in trading countries such as Austria, Germany, Italy, and France will slightly increase from around 5–10% to 15–20% (Hildebrandt, et al., 2017).

Aside from dimensional sawn timber, softwoods are also processed into structurally optimised building materials known as 'engineered timber' seen in Figure 20. The benefits of these wood composites – manufactured from laminated timbers, adhesives and other materials, include increased dimensional stability, more homogenous mechanical properties and greater durability. Families of these materials include (Ramage, et al., 2017):

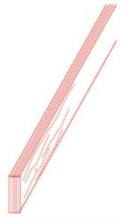
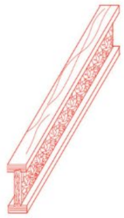
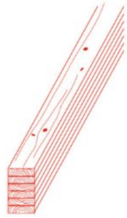
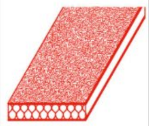
Engineered Timber Product	Parallel Strand Lumber (PSL)	Laminated Veneer Lumber (LVL)	I-Joist	Glulam	Structural Insulating Panel (SIP)	Cross Laminated Timber (CLT)	Brettstappel
Typical Detail							
Application	• Beams • Columns	• Beam • Columns • Cord	• Joist • Beam	• Beam (Long span) • High Loading	• Roof • Wall • Floor	• Roof • Wall • Floor	• Roof • Wall • Floor
Usage	Interior	Interior	Interior	Interior / Exterior	Interior	Interior/ Exterior	Interior/ Exterior

Figure 20 Common structural engineered timber products in Europe.

- **Glulam:** Defined as a structural timber member composed by at least two essentially parallel laminations which may comprise of one or two boards side by side having finished thicknesses from 6 mm up to 45 mm [BS EN 14080:2013]. These are typically used to fabricate curved and long beams limited only by methods of transport. Glulam is allocated to specific strength classes defined in BS EN 14080:2013 (Ramage, et al., 2017).
- **Laminated Veneer Lumber (LVL):** A reconstituted dimensional timber that is commonly twice the strength of dimensional timber of the same species manufactured from rotary peeled veneers of spruce, pine or douglas fir of 3 mm thickness. Commonly the veneer grain is oriented in a single direction but cross-grained sections are also manufactured to offer tailored mechanical properties. Lengths of short veneer are jointed end-to-end with a scarf joint allowing limitless dimensional lengths (Ramage, et al., 2017).
- **Structural Veneer Lumber (SVL)**: Consists of outer plies of LVL laminated together to form linear structural components. Douglas fir veneers of 2.5 mm laminated in the direction of grain parallel to the longitudinal direction of the board or beam is common (Ramage, et al., 2017).
- **Cross-Laminated Timber (CLT)**: Timber panels that are made of a minimum of three layers of sawn softwood stacked on top of one another at right angles and glued to form a thickness in the range 50–500 mm suitable for floor, wall and roof elements of up to 13.5 m in length (Ramage, et al., 2017).
- **I-Joists**: Whilst these are more expensive and deeper than solid timber joists for an equivalent strength and stiffness, composite I-Joists are more dimensionally stable due to their homogeneous OSB web and the relatively small dimension of the solid timber or LVL flanges (Ramage, et al., 2017).
- **Structural Insulating Panels (SIPs)**: Structural prefabricated sandwich panels consisting of an insulation layer encased between two skins of fiber or oriented strand board (Ramage, et al., 2017).
- **Brettstapel**: Also known as 'dowellam', these solid wood panels are manufactured from softwood planks connected by hardwood dowels. Hard wood dowels are driven into the panels at 8% moisture content. With the softwood planks at 12–15% moisture content the hardwood dowel swells to find equilibrium, fixing the panels tight without the need for glue (Ramage, et al., 2017).

Many engineered panel products are also combined with dimensional timber frame constructions to add bracing and shear strength including Plywood, Oriented Strand Board (OSB, Medium Density Fiber Board (MDF) and Fiber board. Although engineered timber products have superior structural properties as compared to dimensional timber, the necessity for adhesives use, negatively impacts the embodied energy burden of these products (Ramage, et al., 2017).

7 Wooden housing prototype

On a previous analysis in 2020 of this KB project (KB-34-012-001/KB-3D-1), it was identified the potential availability of wood harvest from forests for 10 regions in Europe (Southwestern Ireland, Lochaber (UK), York (UK), the Netherlands, Vosges (France), Haute-Loire (France), Bayern (Germany), Nordrhein-Westfalen (Germany), Catalonia (Spain) and Smaland (Sweden)). As well, it was identified 20 different hardwood and softwood species according to the European standards as acceptable raw material to produce structural wood. For 2021, these two sources of information were combined to start an evaluation of opportunities for more structural timber use in houses in Europe. Therefore, a housing prototype is needed to estimate the m^3 of structural wood that will be required per house in a further analysis.

It is important to mention that this housing prototype is based on a wooden or timber building design, which is fundamentally different from those buildings designed with steel and/or concrete materials on their structural and spatial layout. Based on the literature review done in the previous chapters, the following assumptions were considered for the design, dimensions and materials of the housing prototype using the data found from the Netherlands (2020) as a reference point:

- This model meets the dimensions for social housing taking the average floor space of 104 m^2 where 96 m^2 are constructed area and 8 m^2 of veranda.
- Average household size considered is 2.1 persons.
- Targeted households are: single-person household, (married/unmarried) couples without children, (married/unmarried) couples with one child, and single-parent households.
- The design takes into account the traditional European construction methods of a log cabin which meets the technical building regulations in European Union (EU) countries.
- The typology could be used for detached and semi-detached dwellings.
- The wall insulation considers the dimensions (e_f =25 cm) needed for the miscanthus in insulation panels (as thermal insulation).
- The European wood/timber materials (softwood and hardwood) are included.
- To support on the carbon storage function provided by wooden buildings, the prototype includes a higher volume of wood per area compared to other types of buildings that contain more concrete and steel instead.

To figure out the volume of sawn wood (dry and planed) that is needed to build a wooden house, a rough estimate of the amount of wood that might be needed was made. Information from literature review of wooden housing construction companies were compared. The following Table 4 shows some findings:

Table 4 Comparison of construction companies for wooden housing.

	House Design [1]	House Design [2]	Average
Type of wood	Caribbean Walnut (hardwood)	Pine Tree (softwood)	
Timber (m^3)	15.6	38.7	17.3
House area (m^2)	96.0	241.5	137.3
15% extra timber accounted for losses or mistakes (m^3)	2.34	5.80	2.60
Amount of timber per house surface area (m^3/m2)	0.187	0.183	0.185
Amount of timber for a prototype house (m^3)	17.9	17.7	17.8
Amount of timber (sawn wood dry) to cover European housing per year[3] (Million m^3)	57.4	56.5	57.0

1 Sosa, 2021: 15.6m^3 of timber is needed for a 96m2 house (68.7 board feet per 1m^2 house) of hardwood, (including framing, floor and walls).

2 The House Designers, 2021. At: https://www.thehousedesigners.com/articles/how-many-trees-does-it-take-to-build-a-house.asp. (Mature Pine tree, according to the Census Bureau, the average American home built in 2013, the average American home of 2,600 ft^2, would have required 16,380 board feet of timber).

3 Considering 32 million houses /year (not only social housing)

It is relevant to mention that the exact amount of wood that is required to build every wooden house varies depending on the house design and on the construction industry as well. A detailed calculation for the amount of timber for a 104 m2 (96 m^2 constructed area and 8 m^2 of veranda) wooden house can be found in Table 5 (see Annex 2).

Based on some calculations from The House Designers (2021a), they provide an example on the amount of trees needed to build a wooden house. The consider a mature pine with a height of 24.4 m and a diameter of 0.61 m. The lumber yield is about 754 board feet. If it is required 16,380 board feet to build the average home, that means that almost 22 mature pines are needed to fill that demand. This calculation pertains only to the trees required for the framing of a house and not any of the extras. Hardwood floors, cabinets, etc. could easily double the number of trees needed to complete a home. It takes decades to produce that amount of lumber sustainably.

7.1 Wooden housing design

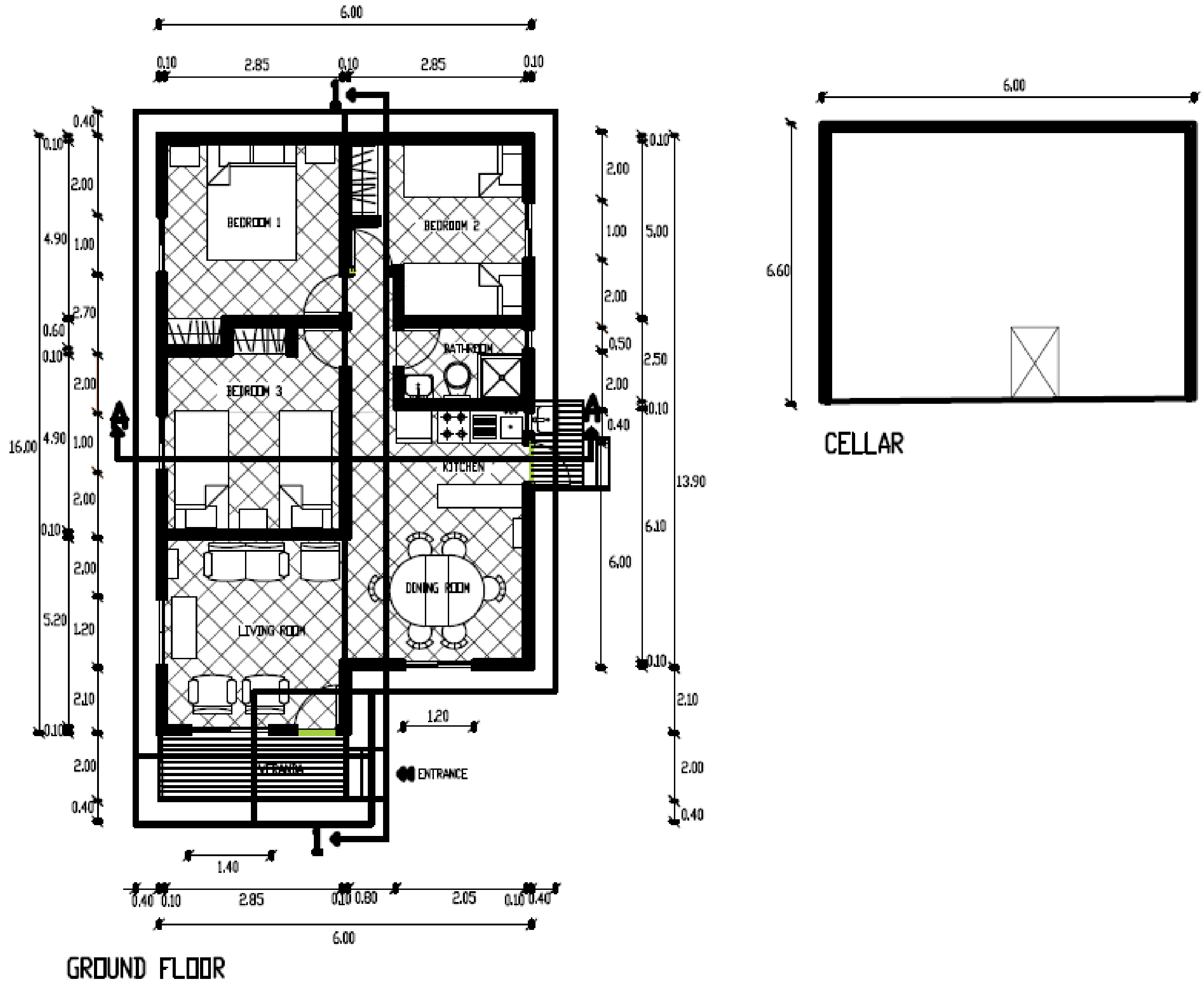


Figure 21 ***Floor plan. Living area 96 m^2 (6.00 m x 16 m), Veranda 8 m^2 (2.00 x 4 m)= Total size 104 m^2.***

Figure 22 Front elevation and Right side elevation.

Figure 23 Rear elevation and Left side elevation

Figure 24 Sectional elevation A-A and Sectional elevation 1-1

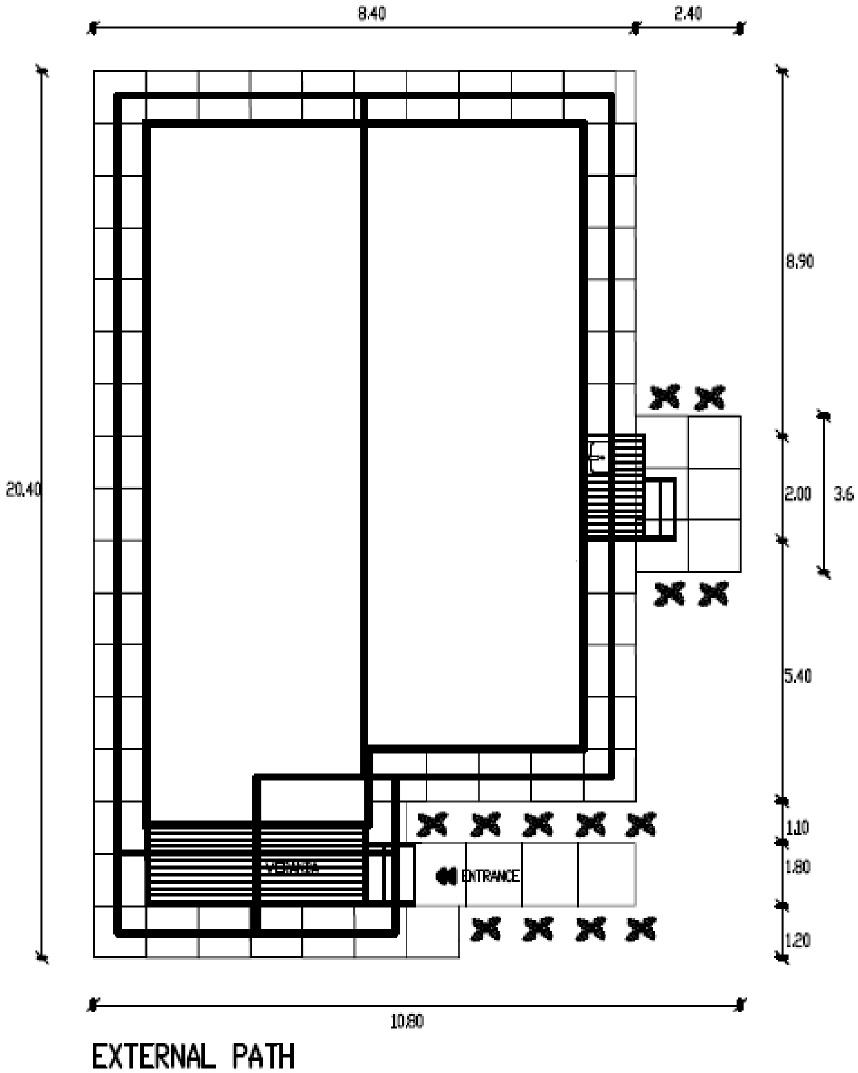


Figure 25 External path.

8 Conclusions and recommendations

Housing is currently an urgent topic in the agenda of European policy makers, mainly due to high pressure to supply inclusive and affordable housing after the high demand since the financial crisis of 2008 and the COVID-19 pandemic faced during the last years. Next to this, the housing renovation wave strategy from the European Commission aims to improve the resource- and energy-efficiency of construction materials, as well to enhance sustainability and circular economy within the building sector to help deliver the European Green Deal and contribute against climate change.

The high demand of housing could be embraced as an opportunity to contribute to sustainable urbanization in Europe using construction materials such as wood and other long-term storage of carbon bio-products, to substitute fossil-based industries and mineral-based products in the European building sector. A rising demand of wood and bio-based construction materials could provide incentives to expand and sustainably manage forests and at the same time increase innovation in the building sector to provide higher quality of buildings and living environments. Sustainable urbanization will impact European cities and communities to become more resilient to social and environmental challenges.

To contribute to the estimation of m^3 of structural wood that might be required per housing unit. A wooden housing prototype was developed based on secondary data gathered for public/social housing as this information was available on European reports. Little or almost none information was available on the amount of new construction or refurbishment of private housing (residential and middle-income housing). Therefore, it is recommended to continue future research for private housing as this sector is also relevant for the sustainable market development of wood buildings and the reduction of GHG emissions from the building sector.

The European Social, Cooperative and Public Housing providers aim at building and refurbishing 400,000 homes per year or 4 million homes between 2020 and 2030. It was estimated that around of 1.8 million (1,795,630) of new social housing was completed in the period 2013-2020 in Europe with an average percentage of total social housing of 13%. This information drops an hypothetic increase of 78.21% of new social housing to be built or refurbished every year in Europe.

The average size of housing in Europe (EU27) is 90.7 m^2. However, the size of dwelling varies on the household size and composition. For the wooden housing prototype, the floor space considered was 104 m^2 where 96 m^2 are constructed area and 8 m^2 of veranda with a household size of 2.1 persons. In Europe there are different household compositions identified, for which the average dwelling size varies from 72.3 m^2 for a single person household up to 103.1 m^2 for households with dependent children. In the Netherlands the average size ranges between 106 m^2, while in Cyprus the average size is 141.4 m^2 and in Estonia is 66.7 m^2. Based on the literature review, the central and eastern countries in Europe are among the ones with the lowest residential space in terms of both single family houses and apartment blocks, while in countries in the north and western Europe, the floor areas are the highest per capita and in the south of Europe some countries have the highest single family house floor space per capita which perhaps indicates the frequency of holiday houses.

The housing prototype keeps a simple traditional European construction method for log cabins to meet the technical building regulations within this assignment and can be used for detached and semi-detached (or terraced) dwellings. For the wall (thermal) insulation, the calculation of wood materials includes the dimensions needed to introduce the miscanthus insulation panels. The European wood (softwood and hardwood) thought for the structure and panels are pine, oak and beech. An approximation of the amount of timber needed for a housing unit is 17.8 m^3.

The future increase on the demand of wood in Europe as construction material, raises concerns regarding legal and illegal deforestation. Therefore, it is important to regulate the production and extraction of timber to ensure that it is sourced from responsibly managed forests.

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10 Annexes

10.1 Annex 1

Table 2. Housing stock and new social housing in European countries (2013-2021).

Country	Housing stock	Social housing	Private rental	Owner-occupier	Other/ Unknown	Total social housing (%)	Year	New social housing units	Deep renovations/ rehabilitations	Housing Completion per year
European Union										
Austria	3,949,900 2019-primary residence	930,900 (24%)	1,165,400 (30%)	1,477,200 37%)	376,300 (9%)	24%	2013 2014 2015 2016 2017 2018 2019 2020	13,400 15,200 18,000 14,560 16,000 14,900 16,100 17,000	13,230 11,200 10,100 8,000 9,200 8,100 7,100 7,400	55,000 (2017)
Belgium	5,514,332 2019	299,775 (5.4%)	-	-	-	5.4%	2013 2014 2015 2016 2017 2018 2019 2020	3,276 4,888 5,138 4,095 4,556 4,182 4,050 -	- - - - - - - -	50,419 (2017)
Bulgaria	3,951,000 2017	-	-	-	-	2.6%	2017	59	-	2,205 (2017)
Croatia	-	-	-	-	-	-	-	-	-	3,639.000 (2019)
Cyprus	452,000 2017	-	-	-	-	2.8% (2017)	2017	84	-	2,993 (2017)

Country	Housing stock	Social housing	Private rental	Owner-occupier	Other/ Unknown	Total social housing (%)	Year	New social housing units	Deep renovations/ rehabilitations	Housing Completion per year
Czechia	4,104,635 (occupied)	9.4%	22.4%	55.9%	Other: 4.5% Unknown: 7.8%	9.4%	2013 2014 2015 2016 2017 2018 2019 2020	25,240 23,950 25,090 27,320 28,570 33,850 36,410 34,430	- - - - - - - -	28,575 (2017)
Denmark	2,719,974 2020 (occupied)	558,761 (21%)	711,155 (26%)	1,326,304 (49%)	114,044 (4%)	21%	2013 2014 2015 2016 2017 2018 2019 2020	4,655 2,419 2,211 2,972 2,112 2,470 3,885 2,700	16,456 5,774 13,905 11,802 8,756 14,472 10,814 39,900	24,519 (2017)
Estonia	730,000 2019	Public rental housing: 8,030 Cooperative apartment associations: 22,600 (Buildings)	-	-	-	70%	2016 2017 2018 2019 2020	125 125 125 125 125	- - - 400 300 (Renovations of cooperative housing buildings)	5,890 (2017)
Finland	2,734,219 2019	Public rental: 308,953 (11%) Right of Occupancy: 47,288 (2%)	613,608 (22%)	1,710,877 (63%)	53,493 (2%)	11%	2017 2018 2019 2020	8,560 8,627 7,441 9,000	- - - -	317,000 (2017)
France	33,721,040 2019	5,329,720 (16%)	7, 451,710 (16%)	17,321,240 (51%)	Secondary residences:	16%	2013 2014	81,769 89,256	120,000 105,000	135,000 (2017)

Country	Housing stock	Social housing	Private rental	Owner-occupier	Other/ Unknown	Total social housing (%)	Year	New social housing units	Deep renovations/ rehabilitations	Housing Completion per year
					3,618,370 (11%)		2015 2016 2017 2018 2019 2020	92,076 86,194 78,225 80,403 76,026 -	125,000 110,000 135,000 150,000 111,000 -	
Germany	41,400,000 2018	Social housing: 1,120,000 (3%) Cooperative housing: 1,886,000 (5%) Municipal housing: 2,083,000 (5%)	18,611,000 (45%)	17,700,000 (43%)	-	3%	2013 2014 2015 2016 2017 2018 2019 2020	9,874 12,517 14,653 24,550 26,231 27,040 25,565 -	79,300 52,600 53,000 53,400 54,200 78,900 79,700 -	275,350 (2017)
Greece	3,949,900 2019	0%	24.6%	75.4%	-	No Social Rental Housing Sector	Trends in tenure 2014 2015 2016 2017 2018 2019	Owner 74% 75.1% 73.9% 73.3% 73.5%75.4%	Rented 26% 24.9% 26.1% 26.7% 26.5% 24.6%	6,125 (2017)
Hungary	-	-	-	-	-	-	-	-	-	28,208 (2020)
Ireland	2,049,000 2019	Social housing: 177,000 (9%) Cooperative housing: 5,500 (0.3%)	324,000 (16%)	-	Other: 1,542,500 (75%)	9%	2013 2014 2015 2016 2017	757 642 5,312 5,185 6,530	- - - - -	17,800 (2017-20219)

Country	Housing stock	Social housing	Private rental	Owner-occupier	Other/ Unknown	Total social housing (%)	Year	New social housing units	Deep renovations/ rehabilitations	Housing Completion per year
							2018 2019 2020	7,334 8,606 -	- - -	
Italy	24,611,766 2011 (occupied)	954,161 (3.8%)	3,468,141 (14%)	17,691,895 (72%)	2,468,993 (10%)	3.8%	2013 2014 2015 2016 2017	- 4,557 - 1,111 1,204	- 11.423 / 4.999 - 3.437/ 1.174 6.578/ 1.578	235,000 (2017)
Latvia	-	-	-	-	-	-	-	-	-	2,970 (2018)
Lithuania	-	-	-	-	-	-	-	-	-	11,040 (2018)
Luxemburg	233,675 2020	2,217 (1%)	-	-	-	1%	2013 2014 2015 2016 2017 2018 2019	9 45 75 21 79 23 84	- - - - - - -	
Malta	-	-	-	-	-	-	-	-	-	12,000 (2019)
Netherlands	7,891,786 2020	2,294,219 (29.1%)	1,047,799 (13.3%)	4,517,921 (57.2%)	31,847 (0.4%)	29.1%	2013 2014 2015 2016 2017 2018 2019	36,566 20,678 24,821 19,612 21,405 19,069 19,926	- 29,400 - 50,800 39,600 - -	67,000 (2017-2019)

Country	Housing stock	Social housing	Private rental	Owner-occupier	Other/ Unknown	Total social housing (%)	Year	New social housing units	Deep renovations/ rehabilitations	Housing Completion per year
							2020	-	-	
Portugal	5,968,00 2019	Social housing: 130,000 (2%) Cooperative housing: 200,000 (3%)	-	-	-	2%	2017	284	-	14,190 (2019)
Poland	-	-	-	-	-	8%	2017	1,155	-	14,439 (2017)
Romania	-	-	-	-	-	-	-	-	-	20,000 (2021)
Slovakia	1,994,897 2017	-	-	-	-	3%	-	-	-	2,793 (2020)
Slovenia	680,000 2018 (occupied)	39,800 (6%)	12,800 (2%)	549,440 (81%)	77,960 (11%)	6%	2016 2017 2018 2019 2020	2 150 25 46 91	- - - - -	3,165 (2017-2019)
Spain	25,793,323 2020	290,000 (1.1%)	-	-	-	1.1%	2017 2018 2019 2020	12,209 17,094 19,111 12,379	126,335 73,401 112,583 47,397	54,610 (2017)
Sweden	4,978,239 2019	Social housing: 827,449 (17%) Cooperative housing: 1,184,576 (24%)	686,027 (14%)	2,044,356 (41%)	Other: 235,831 (5%)	17%	2013 2014 2015 2016 2017 2018 2019 2020	4,233 5,978 6,933 9,697 8,927 8,896 10,718 -	14,197 15,008 18,084 16,977 14,472 18,208 13,110 14,350	34,830 (2017)
							Subtotal European	**1,493,983**		

Country	Housing stock	Social housing	Private rental	Owner-occupier	Other/ Unknown	Total social housing (%)	Year	New social housing units	Deep renovations/ rehabilitations	Housing Completion per year
							Union			
					Europe					
Armenia	863,307 2017	-	-	92%	-	-	-	-	-	-
Norway	2,475,000 2020 (occupied)	Municipal housing: 110,000 (4%) Cooperative housing: 340,000 (14%) Apartment associations: 320,000 (13%) Non-commercial rent: 50,000 (2%)	345,000 (14%)	1,240,000 (50%)	Other: 70,000 (3%)	14%	2013 2014 2015 2016 2017 2018 2019 2020	2,662 2,503 4,592 5,017 5,093 4,298 4,113 -	- - - - - - - -	532,000 (2017)
Switzerland	3,804,777 2019 (occupied)	Cooperative housing: 172,885 (5%) Public rental 105,552 (3%)	2,015,524 (53%)	1,384,241 (37%)	125,466 (3%)	5%	2013 2014 2015 2016 2017 2018 2019 2020	2,500 2,495 3,614 2,238 3,135 3,873 - -	- - - - - - - -	2,760 (2018)
UK- England	24,414,000 2019 (primary residence)	590,000 (17%)	4,725,000 (19%)	15,581,000 (64%)	42,000 (0%)	17%	2013 2014 2015 2016 2017 2018 2019 2020	22,430 24,960 31,770 26,530 29,030 30,240 34,220 -	- - - - - - - -	169,000 (2017-2019)
UK- Northern Ireland	808,000 2020	590,000 (24%)	121,000 (15%)	566,000 (70%)	-	24%	2013 2014	1,967 1,658	- -	

Country	Housing stock	Social housing	Private rental	Owner-occupier	Other/ Unknown	Total social housing (%)	Year	New social housing units	Deep renovations/ rehabilitations	Housing Completion per year
							2015	1,209	-	
							2016	1,387	-	
							2017	1,507	-	
							2018	1,682	-	
							2019	1,626	-	
							2020	-	-	
UK- Scotland	2,495,623 2019 (primary residence)	590,000 (24%)	340,000 (14%)	1,540,000 (62%)	30,000 (1%)	24%	2013	4,403	-	
							2014	3,315	-	
							2015	4,008	-	
							2016	3,836	-	
							2017	3,880	-	
							2018	4,998	-	
							2019	5,909	-	
							2020	-	-	
UK- Wales	1,437,567 2020	229,902 (16%)	204,955 (14%)	1,002,709 (70%)	-	16%	2013	1,862	218	
							2014	1,850	81	
							2015	1,923	103	
							2016	2,322	138	
							2017	2,533	130	
							2018	1,876	78	
							2019	2,583	141	
							2020	-	-	
							Subtotal Europe	**301,647**		
					Average social housing in EU+E (%)	**13%**	**Total EU+E**	**1,795,630**		

Sources: Housing Europe, 2021; Housing Europe 2019; Statistics Poland, 2017; Global Property Guide, 2021; Romania Business Review, 2021; Hungarian CSO, 2021; Malta Independent, 2019; Worldakkam, 2021.

10.2 Annex 2

Table 5. Detailed calculation for the amount of timber for a 104 m2 (96 m^2 constructed area and 8 m^2 of veranda) wooden house.

Structural calculation for wooden house 104m2

Number	Type	Concept	Unit	Amount	Height (meters)	Thickness (meters)	Thickness (inches)	Thickness B (Meters)	Thickness B (inches)	Volume per unit (m3)	Volume per concept (m3)	Volume (board-foot)	Volume Conversion (m3)	Type of wood	Height (feet)	New volume (board-foot)	Conversion (m3)
1	Wall	External wall	Board-foot	302	2.5	0.00		0.00		0.02	6.04	2559	6.04		8.20		0
2	Wall	Internal wall	Board-foot	42.5	2.5	0.00		0.00		0.02	0.85	360	0.85		8.20		0
3	Foundation	Posts	Piece	35	1.6	0.15	6	0.15	6	0.04	1.30	525	1.24	Oak Strenght class D40 Mean density 700 kg/m3	5.25	525	1.239
4	Foundation	Floor beams	Piece	7	8	0.06	2.5	0.10	4	0.05	0.36	140	0.33	Oak Strenght class D40 Mean density 700 kg/m3	26.25	140	0.3304
5	Foundation	Floor joists	Piece	5	12	0.06	2.5	0.10	4	0.08	0.39	150	0.35	Oak Strenght class D40 Mean density 700 kg/m3	39.37	150	0.354
6	Structure	Load-bearing post	Piece	54	2.5	0.05	2	0.25	10	0.03	1.74	720	1.70	Beech D35 Strenght class D35 Mean density 670kg/m3	8.20	720	1.6992

7	Structure	Load-bearing post	Piece	29	2.5	0.05	2	0.08	3	0.01	0.28	116	0.27	Beech D35 Strenght class D35 Mean density 670kg/m 3	8.20	116	0.27376
8	Structure	Load-bearing post	Piece	4	8	0.05	2	0.25	10	0.10	0.41	1.6	0.00	Beech D35 Strenght class D35 Mean density 670kg/m 3	26.25	1.6	0.003776
9	Structure	Load-bearing post	Piece	4	12	0.05	2	0.25	10	0.15	0.62	240	0.57	Beech D35 Strenght class D35 Mean density 670kg/m 3	39.37	240	0.5664
10	Structure	Load-bearing post	Piece	14	1.2	0.05	2	0.25	10	0.02	0.22	28	0.07	Beech D35 Strenght class D35 Mean density 670kg/m 3	3.94	28	0.06608
11	Structure	Load-bearing post	Piece	2	2	0.05	2	0.08	3	0.01	0.02	6	0.01	Beech D35 Strenght class D35 Mean density 670kg/m 3	6.56	6	0.01416
12	Structure	Load-bearing post	Piece	6	1	0.05	2	0.08	3	0.00	0.02	9	0.02	Beech D35 Strenght class D35 Mean density 670kg/m 3	3.28	9	0.02124
13	Structure	Load-bearing post	Piece	9	0.4	0.05	2	0.08	3	0.00	0.01	9	0.02	Beech D35 Strenght class D35 Mean density 670kg/m 3	1.31	9	0.02124

14	Structure	Load-bearing post	Piece	1	1.8	0.05	2	0.08	3	0.01	0.01	3	0.01	Beech D35 Strenght class D35 Mean density 670kg/m 3	5.91	3	0.00708
15	Internal structure	Load-bearing post	Piece	2	3.4	0.05	2	0.08	3	0.01	0.03	8	0.02	Beech D35 Strenght class D35 Mean density 670kg/m 3	11.16	8	0.01888
16	Internal structure	Load-bearing post	Piece	2	3.45	0.05	2	0.08	3	0.01	0.03	11	0.03	Beech D35 Strenght class D35 Mean density 670kg/m 3	11.32	11	0.02596
17	Internal structure	Load-bearing post	Piece	2	3	0.05	2	0.08	3	0.01	0.02	9	0.02	Beech D35 Strenght class D35 Mean density 670kg/m 3	9.84	9	0.02124
18	Internal structure	Load-bearing post	Piece	2	2.6	0.05	2	0.08	3	0.01	0.02	8	0.02	Beech D35 Strenght class D35 Mean density 670kg/m 3	8.53	8	0.01888
19	Internal structure	Load-bearing post	Piece	2	3	0.05	2	0.08	3	0.01	0.02	9	0.02	Beech D35 Strenght class D35 Mean density 670kg/m 3	9.84	9	0.02124
20	Internal structure	Load-bearing post	Piece	2	0.95	0.05	2	0.08	3	0.00	0.01	3	0.01	Beech D35 Strenght class D35 Mean density 670kg/m 3	3.12	3	0.00708

21	Internal structure	Load-bearing post	Piece	2	3	0.05	2	0.08	3	0.01	0.02	9	0.02	Beech D35 Strenght class D35 Mean density 670kg/m3	9.84	9	0.02124
22	Roof	Scissors trusse/ Strut	Piece	24	4.82	0.05	2	0.30	12	0.07	1.79	720	1.70	Beech D35 Strenght class D35 Mean density 670kg/m3	15.81	720	1.6992
23	Roof	Scissors trusse/ King post	Piece	24	1	0.03	1	0.10	4	0.00	0.06	24	0.06	Beech D35 Strenght class D35 Mean density 670kg/m3	3.28	24	0.05664
24	Roof	Scissors trusse/ King post	Piece	24	1.4	0.03	1	0.10	4	0.00	0.09	40	0.09	Beech D35 Strenght class D35 Mean density 670kg/m3	4.59	40	0.0944
25	Roof	Scissors trusse/ King post	Piece	12	1.15	0.05	2	0.10	4	0.01	0.07	32	0.08	Beech D35 Strenght class D35 Mean density 670kg/m3	3.77	32	0.07552
26	Roof	Scissors trusse/ King post	Piece	12	8.5	0.05	2	0.10	4	0.04	0.53	208	0.49	Beech D35 Strenght class D35 Mean density 670kg/m3	27.89	208	0.49088
27	Subfloor	Loft beams	Piece	18	8	0.06	2.5	0.10	4	0.05	0.93	360	0.85	Oak Strenght class D40 Mean density 700 kg/m3	26.25	360	0.8496
28	Roof	Rafters	Piece	8	12	0.03	1	0.10	4	0.03	0.25	32	0.08	Beech D35 Strenght class D35 Mean	39.37	32	0.07552

														density 670kg/m 3			
29	Roof	Purlins	Piece	2	12	0.01	0.5	0.20	8	0.03	0.06	32	0.08	Beech D35 Strenght class D35 Mean density 670kg/m 3	39.37	32	0.07552
30	Floor	Flooring	Square meter	96		0.02	0.7	0.00		0.02	1.92	864	2.04	Beech D35 Strenght class D35 Mean density 670kg/m 3	0.00	864	2.03904
31	Interior trim	Solid wood	Square meter	154	250	0.01	0.5	0.01	0.5	0.01	1.54	1483	3.50	Beech D35 Strenght class D35 Mean density 670kg/m 3	820.25	1483	3.49988
32	Interior trim	Loft flooring	Piece	33	2.44	0.03	1.2	0.01	0.5	0.00	0.03		0.00		8.01		0
33	Interior trim	Wooden ceiling	Piece	33	2.44	0.03	1.2	0.01	0.3	0.00	0.02		0.00		8.01		0
34	Interior trim	Loft wooden ceiling	Piece	48	2.44	0.03	1.2	0.01	0.3	0.00	0.03		0.00		8.01		0
35	Frame	Wooden door frame- Room 1	Piece	4	0.8	0.04	1.5	0.06	2.5	0.00	0.01	4	0.01	Beech D35 Strenght class D35 Mean density 670kg/m 3	2.62	4	0.00944
36	Frame	Wooden door frame- Room 1	Piece	4	2.1	0.04	1.5	0.06	2.5	0.01	0.02	6	0.01	Beech D35 Strenght class D35 Mean density 670kg/m 3	6.89	6	0.01416
37	Frame	Wooden door frame- Room 2	Piece	4	0.8	0.04	1.5	0.06	2.5	0.00	0.01	4	0.01	Beech D35 Strenght class D35 Mean density 670kg/m 3	2.62	4	0.00944

38	Frame	Wooden door frame- Room 2	Piece	4	2.1	0.04	1.5	0.06	2.5	0.01	0.02	6	0.01	Beech D35 Strenght class D35 Mean density 670kg/m 3	6.89	6	0.01416
39	Frame	Wooden door frame- Room 3	Piece	4	0.8	0.04	1.5	0.06	2.5	0.00	0.01	4	0.01	Beech D35 Strenght class D35 Mean density 670kg/m 3	2.62	4	0.00944
40	Frame	Wooden door frame- Room 3	Piece	4	2.1	0.04	1.5	0.06	2.5	0.01	0.02	6	0.01	Beech D35 Strenght class D35 Mean density 670kg/m 3	6.89	6	0.01416
41	Frame	Wooden door frame- Bathroom	Piece	6	0.7	0.04	1.5	0.06	2.5	0.00	0.01	6	0.01	Beech D35 Strenght class D35 Mean density 670kg/m 3	2.30	6	0.01416
42	Frame	Wooden door frame- Bathroom	Piece	6	2.1	0.06	2.5	0.04	1.5	0.01	0.03	9	0.02	Beech D35 Strenght class D35 Mean density 670kg/m 3	6.89	9	0.02124
43	Veranda	Veranda posts	Piece	8	1.6	0.30	12	0.30	12	0.15	1.19	576	1.36	Oak Strenght class D40 Mean density 700 kg/m3	5.25	576	1.35936
44	Veranda	Veranda beams	Piece	3	4	0.06	2.5	0.10	4	0.03	0.08	30	0.07	Oak Strenght class D40 Mean density 700 kg/m3	13.12	30	0.0708

45	Veranda	Floor beams	Piece	4	2	0.06	2.5	0.10	4	0.01	0.05	20	0.05	Oak Strenght class D40 Mean density 700 kg/m3	6.56	20	0.0472
46	Veranda	Flooring	Square meter	8		0.00		0.00		0.02	0.16	72	0.17	Beech D35 Strenght class D35 Mean density 670kg/m 3	0.00	72	0.16992
47	Veranda/ Handrail	Handrail posts	Piece	1.1	3	0.08	3	0.61	24	0.14	0.15	18	0.04	Beech D35 Strenght class D35 Mean density 670kg/m 3	9.84	18	0.04248
48	Veranda/ Handrail	Frame	Piece	4	1.5	0.08	3	0.05	2	0.01	0.02	9	0.02	Beech D35 Strenght class D35 Mean density 670kg/m 3	4.92	9	0.02124
49	Veranda/ Handrail	Frame	Piece	4	4	0.08	3	0.04	1.5	0.01	0.05	9	0.02	Beech D35 Strenght class D35 Mean density 670kg/m 3	13.12	9	0.02124
50	Veranda/ Handrail	Balaustrade	Piece	60	0.95	0.03	1	0.08	3	0.00	0.11	45	0.11	Beech D35 Strenght class D35 Mean density 670kg/m 3	3.12	45	0.1062
									Total A	**1.2**	**14.8**	**6623.6**	**15.6**		**1352. 2**	**6623.6**	**15.63**

Concept	Unit	Amount	Hight (meters)	Width (inches)	Thickness (inches)	Width (meters)	Thickness (meters)	Volume per unit (m3)	Volume per concept (m3)
Bedroom 1 door trim	Piece	4	2.1	31.5	0.2	0.80	0.01	0.009	0.034
Bathroom 1 door trim	Piece	6	2.1	27.5	0.2	0.70	0.01	0.007	0.045
Bedroom 2 door trim	Piece	4	2.1	31.5	0.2	0.80	0.01	0.009	0.034
Bathroom 2 door trim	Piece	6	2.1	27.5	0.2	0.70	0.01	0.007	0.045
Bedroom 3 door trim	Piece	4	2.1	31.5	0.2	0.80	0.01	0.009	0.034
Bathroom 3 door trim	Piece	6	2.1	27.5	0.2	0.70	0.01	0.007	0.045
							Total B	**0.048**	**0.237**
								Total A + Total B	**15.02**

Concept	Unit	Amount	Length (meters)	Width (meters)	Area m2	Area m3
Wood veneer	Piece	24	4.27	1.1	4.697	112.728

Source: Sosa, 2021.

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