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Environmental Benchmarks for buildings:
Needs, challenges and solutions
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Benchmarks for environmental impact of housing in Europe: definition of archetypes and LCA of the residential building stock

Monica Lavagna . Politecnico di Milano . ABC Dept

average environmental impact of current housing stock in Europe

The aim of the research is to quantify the **average environmental impacts related to current residential building stock in Europe** (which constitutes 60% of Europe's overall building stock) and to define reference values (**baseline scenario**) for policies development.

Hence, the Life Cycle Assessment (LCA) method is applied to 24 **statistically-based representative models of dwellings** (multi-family house and single-family house), representative of the **EU housing stock in 2010**.

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Benchmarks for environmental impact of housing in Europe: Definition of archetypes and LCA of the residential building stock

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ABSTRACT

This study describes the results of Life Cycle Assessment (LCA) applied to 24 statistically-based dwelling archetypes, representative of the EU housing stock in 2010. The aim is to quantify the average environmental impacts related to housing in Europe and to define reference values (baseline scenario) for policies development. The average environmental impacts have been calculated taking into consideration the number of dwellings (clustered per typology, year of construction and climate zone) related to each representative model. System boundaries include production, construction, use (energy and water consumption), maintenance/replacement, and end-of-life phases of each dwelling. The environmental life cycle impact assessment was carried out using the ILCD method. EU average annual environmental impact per person, per dwelling, and per m^2 were calculated. Results show that the average life cycle greenhouse gases emissions related to housing per person per year are 2.62 t CO_2eq and related to a representative dwelling per year are of 6.36 t CO_2eq. The use phase (energy and water consumption) is the most relevant one, followed by the production and the maintenance/replacement phases. Single-family houses are responsible for the highest share of impacts related to housing in Europe. The same type of building has different impacts in different climatic zones, due to the differences in the need for space heating. In general, electricity use and space heating are the activities that contribute more to the overall impacts. The final results could be used as a baseline scenario for testing eco-innovation scenarios and setting targets toward impact reduction.

1. Introduction

The built environment is one of the main drivers of environmental impacts in Europe and represents one of the most important areas of intervention for reducing emissions and consumptions of resources.

In recent years, several European policy initiatives, such as the Europe 2020 Strategy and the Resource-efficient Europe flagship [1], identified the built environment as one of the strategic areas. As a result, there are many guidelines and European directives on the construction sector, in particular those related to the reduction of energy consumption in the use phase of buildings (which contributed to 41% of EU energy consumption in 2010). These directives aim to reduce the overall environmental impacts of buildings. However, the main policies tend to focus only on the most impacting phase (use phase) and on the most known drivers of impacts (such as energy and CO_2 emissions) without checking the effects of the promoted strategies on the entire life cycle of the impacts and considering a variety of environmental impacts. The risk, in fact, is to create burden shifting among the life cycle phases and among the different impacts.

During the years, several requirements were defined to improve the energy performance of buildings (e.g. increase of thermal resistance), through the 2002 and 2010 Energy Performance of Buildings Directive (EPBD) [2–4] and the 2012 Energy Efficiency Directive [5]. Nonetheless improving the energy performance of buildings toward Zero Energy Buildings, the impacts derived from the production of building materials and equipment can overcome the impacts related to the use phase. It should be emphasized that not all the energy efficiency strategies, including the regulatory ones, lead to an overall reduction of the environmental impacts. In fact, while in old buildings the ratio of impacts between the production of materials and the impact of energy consumption on the use phase is 1:10, in low-energy buildings the embodied energy can represent the 45% of the lifecycle energy [6,7].

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Basket of products: average impacts of representative products

The objective of the JRC research is to **provide the environmental impacts of 3 key consumption categories (food, housing and mobility)**, as well as the **impacts of representative products within each consumption category**.

The objective is to identify, through representative products, **the environmental impact of an average citizen in EU-27 in 2010**.

The environmental impact related to the **basket-of-products** are developed in order to help policy makers to monitor and evaluate the progress towards the reduction of the lifecycle environmental impacts of European consumption, including helping focus eco-innovation and other different policy activities.

Benchmark definition

The meaning of benchmark adopted in this research is therefore a **reference value of the current state of the existing building stock**.

The goal of the research is therefore **not to define targets** to be included in the tools that are used by designers for environmental certification of buildings (GBRS), **but to define the current situation of impacts**.

Knowledge of the environmental performances of the building stock is of fundamental importance to establish effective policies and priority actions.

A top-down approach based on statistical data was combined with a bottom-up approach based on the LCA of representative products, statistically based.

Adapted from (Lützkendorf et al., 2012).

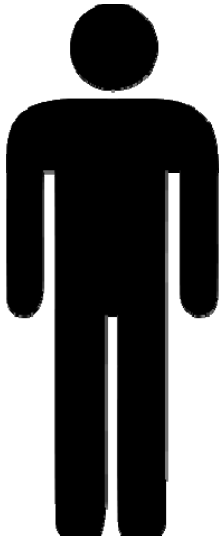
Benchmark type	Possible source for values
Target value	National/government targets Technical optimum Financial optimum
Best practice value	Best practice Statistical analysis of data (Upper quartile)
Reference value	Statistical analysis of data (Median)
Limit value	Legal minimum Prescriptive minimum

Reference value

Statistical analysis of data not of new buildings but of what already exist (a picture of current scenario)

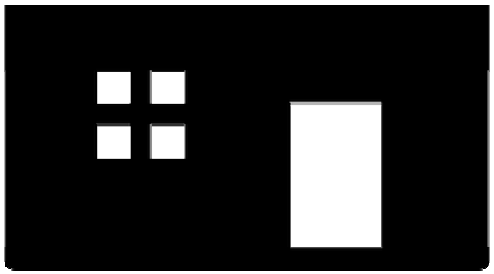
functional units and reference study period: 100 years

Functional Unit 1



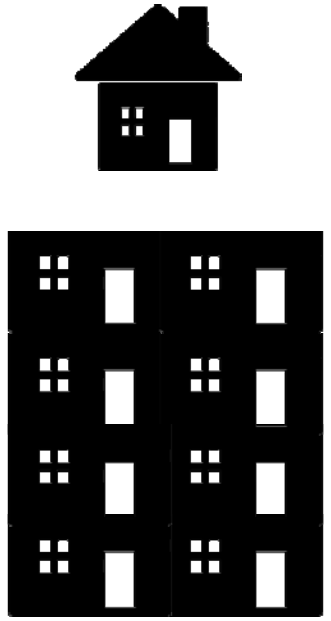
average environmental impact of housing per person per year in EU-27 in 2010

Functional Unit 2



average environmental impact of housing per dwelling per year in EU-27 in 2010

Functional Unit 3



average environmental impact of housing per dwelling type per year in EU-27 in 2010

Methodology

– **analysis of the features** of the current European housing stock through the gathering of **statistics** relating to size, type, period of construction, technical characteristics and energy consumption;

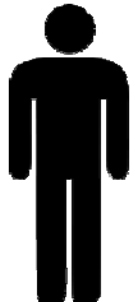
– **cluster-based subdivision** of the European residential building stock (according to **type, climate zone, period of construction**), establishment of **representative models** for each cluster and detailed profiling of the typological and construction characteristics of each representative building, based on statistical data and the scientific literature;

– **calculation of the environmental impact from cradle to grave** of the different representative types of dwelling using the LCA method **and scaling up** of the results in order to assess overall European environmental impacts;

– **establishment of benchmark LCA values** in relation to the average annual environmental impact of a European dwelling (these data have also been expressed in terms of the average annual impact of a European citizen and of one square metre of living space);

– identification of critical aspects and priorities for action.

The impacts are showed per year (reference study period: 2010) and per person



average environmental impact of housing per person per year in EU-27 in 2010

TOT impacts of the dwelling

- Production phase
- Construction phase
- Use phase Replacement
- Use phase Energy
- Use phase Water
- EOL phase

*n. dwelling by categories / service life / EU population

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Sources of statistical data

Eurostat

European researches Intelligent Energy Europe:

- IEE Project TABULA
  "Typology Approach for Building Stock Energy Assessment"
- IEE Project EPISCOPE
  "Energy Performance Indicators for Building Stocks"
- IEE Project ENTRANZE
  "Policies to Enforce the TRAnsition to Nearly Zero Energy buildings in the EU-27 "
- IEE Project ODYSSEE database
  "Energy Efficiency Indicators in Europe"

BPIE Data Hub (Buildings Performance Institute Europe)

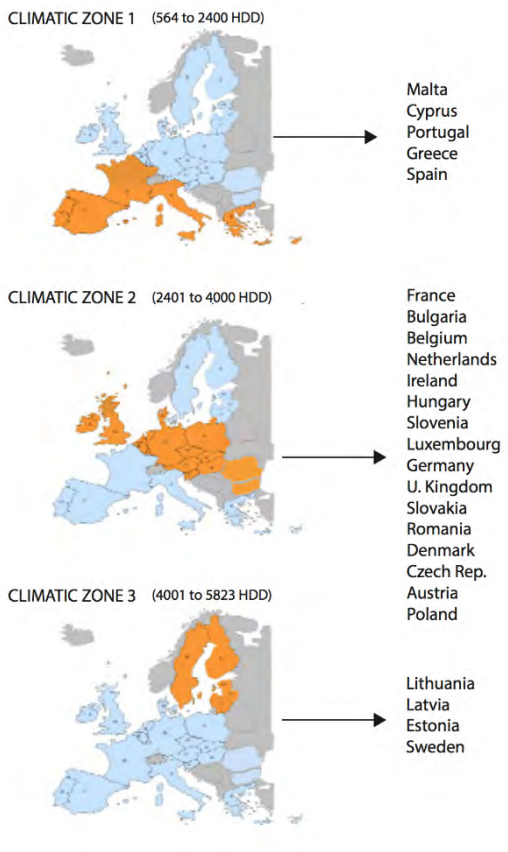
Critical points:

- deviations between the different data sources
- very few reports cover all information needed
- different way of aggregate data from country to country = different classification

Cluster-based subdivision

Assumption:
select characteristics according to which it is possible to find statistical data of the consistency of housing stock

DWELLING TYPE	AGE	CLIMATE
Single family house	<1945	Warm
	1945-1969	
	1970-1989	Moderate
Apartment in multifamily house	1990-2010	Cold



From the intersection of these characteristics we can define 24 representative products.

Breaking down structure of the total European dwelling to define the 24 clusters

SFH 49.74%	WARM 15.72%	<1945	24.98%
		1945-1969	24.66%
		1970-1989	31.48%
		1990-2008	18.88%
	MODERATE 80.20%	<1945	23.38%
		1945-1969	26.68%
		1970-1989	30.52%
		1990-2008	19.43%
	COLD 4.08%	<1945	27.41%
		1945-1969	27.08%
		1970-1989	30.33%
		1990-2008	15.18%
MFH 50.26%	WARM 34.86%	<1945	15.54%
		1945-1969	30.67%
		1970-1989	34.44%
		1990-2008	19.35%
	MODERATE 59.64%	<1945	21.04%
		1945-1969	27.01%
		1970-1989	32.41%
		1990-2008	19.53%
	COLD 5.50%	<1945	23.48%
		1945-1969	27.98%
		1970-1989	32.42%
		1990-2008	16.12%

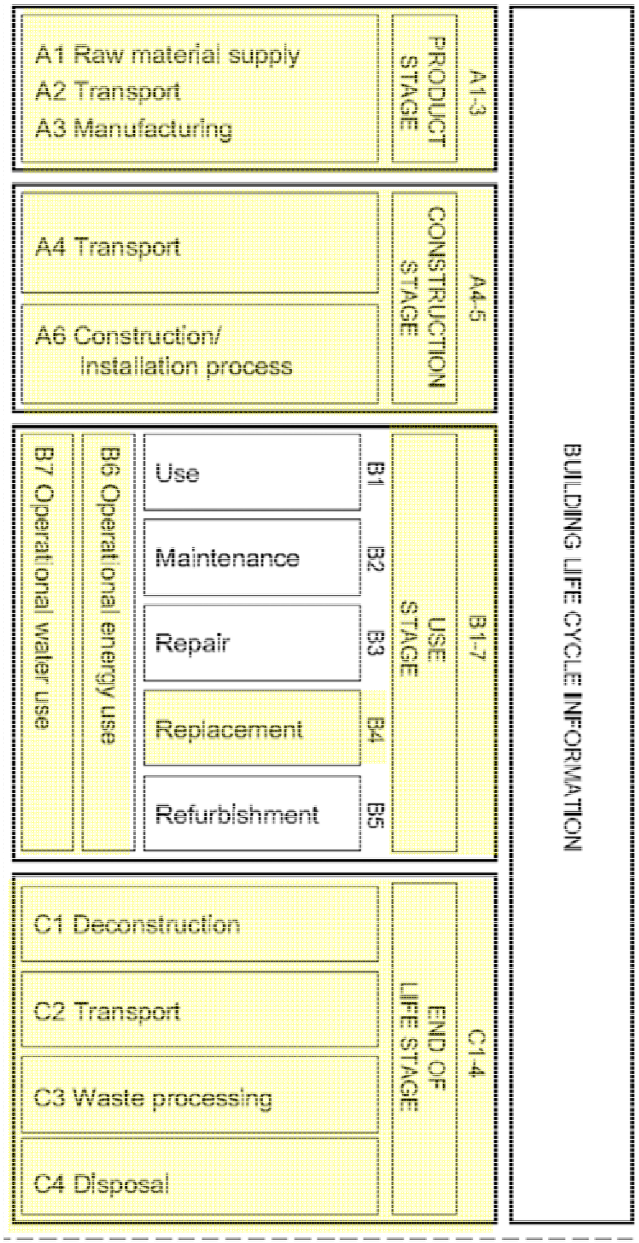
Main features of the representative dwellings chosen for the Single Family House group

Dwelling type	Single Family House											
	SFH_warm_ < 1945	SFH_warm_1945-69	SFH_warm_1970-89	SFH_warm_1990–2010	SFH_moderate_ < 1945	SFH_moderate_1945-69	SFH_moderate_1970-89	SFH_moderate_1990–2010	SFH_cold_ < 1945	SFH_cold_1945-69	SFH_cold_1970-89	SFH_cold_1990–2010
Building typology	Detached House											
Number of dwelling	1											
Number of floors	2											
Lifetime of the building	100 years											
Climate	warm				moderate				cold			
HeatingDegreeDays	500–2300				2301–4000				4001–6000			
Year of construction	1945–1969	1945–1969	1970–1989	1990–2010	1945–1969	1945–1969	1970–1989	1990–2010	1945–1969	1945–1969	1970–1989	1990–2010
Model dwelling size (m^2)	100			130	90		100		100		120	
Number of inhabitants	3.43				2.71				2.83			
Internal height (m)	2.7				2.5				2.5			
Surface/Volume	0.92			0.85	0.98			0.95	0.92		0.87	
Window-to-wall ratio	0.29			0.31	0.30		0.32	0.32	0.30		0.28	
Constructive technology	heavy				heavy				light, dry assembly			
Foundations	reinforced concrete curb											
Underground retaining walls	reinforced concrete											
Load bearing elements	masonry in brick				masonry in brick				timber frame			
Floors (structure)	reinforced concrete/bricks				reinforced concrete				timber frame + board			
Stairs	reinforced concrete				reinforced concrete				timber frame			
External walls	masonry brick (25 cm)			masonry brick (25 cm)	masonry brick (32 cm)	masonry brick (38 cm)	masonry brick (30 cm)	masonry brick (32 cm)	timber frame		timber frame	timber frame
Insulation	no insulation			insulation (2 cm)	no insulation	no insulation	no insulation	insulation (5 cm)	insulation (4 cm)		insulation (5 cm)	insulation (6 cm)
External walls finishes	plaster				plaster				wood			
Windows	wood frame single glass				wood frame single glass			PVC frame double glass	wood frame single glass		wood frame double glass	wood frame triple glass
Roof Insulation	pitched no insulation			flat insulation (2 cm)	pitched insulation (2 cm)		pitched insulation (5 cm)	pitched insulation (10 cm)	pitched insulation (4 cm)			pitched insulation (7 cm)
Bottom floor	no insulation		insulation (1 cm)	insulation (1 cm)	insulation (1 cm)			insulation (2 cm)	insulation (7 cm)		insulation (8 cm)	insulation (11 cm)
Roof finishes	brick tiles				brick tiles				cement tiles			
Internal walls	hollow brciks				wood frame				wood frame			
Internal walls finishes	plaster				plasterboard				plasterboard			
Flooring	ceramic tiles				ceramic tiles				wood			
U-value walls	1.71		1.47	0.82	1.54		0.98	0.5	0.64		0.52	0.39
U-value roof	2.32		2.19	1.18	1.38		0.72	0.35	0.75		0.71	0.47
U-value windows	4.00		3.45	3.00	3.65		2.65	1.84	2.30		2.01	1.87
U-value bottom floor	1.76		1.71	1.48	1.63		1.16	0.49	0.49		0.43	0.33
Heating energy consumption	108	102	76	62	220	184	151	100	190	175	150	115
Heating systems	boiler				boiler				electricity			
Heating terminal unit	radiators			radiant floor	radiators			radiant floor	convector heaters			
Tot nr. of dwellings in EU-27	3,990,078	3,940,268	5,029,842	3,015,954	19,053,376	21,741,474	24,874,549	15,835,402	1,137,005	1,123,212	1,258,137	629,666
Tot nr. of people living in the dwelling EU-27	54,801,521				221,050,717				11,733,022			

Main features of the representative dwellings chosen for the Multi Family House group

Dwelling Type	Multi-Family House											
	MFH_warm_-<1945	MFH_warm_1945-69	MFH_warm_1970-89	MFH_warm_1990–2010	MFH_moderate_<1945	MFH_moderate_1945-69	MFH_moderate_1970-89	MFH_moderate_1990–2010	MFH_cold_<1945	MFH_cold_1945-69	MFH_cold_1970-89	MFH_cold_1990–2010
Building typology	Low-rise > 10 apartment											
Number of dwelling	16											
Number of floors	4											
Lifetime of the building	100 years											
Climate	warm				moderate				cold			
HeatingDegreeDays	500–2300				2301–4000				4001–6000			
Year of construction	1945–1969	1945–1969	1970–1989	1990–2010	1945–1969	1945–1969	1970–1989	1990–2010	1945–1969	1945–1969	1970–1989	1990–2010
Model dwelling size (m^2)	90				60				60			
Number of inhabitants	2.03				2.05				1.67			
Internal height (m)	2.7				2.5				2.5			
Surface/Volume	0.55				0.65				0.65			
Window-to-wall ratio	0.22				0.26				0.26			
Constructive technology	heavy				heavy				light, dry assembly			
Foundations	reinforced concrete curb											
Underground retaining walls	reinforced concrete											
Load bearing elements	reinforced concrete frame											
Floors (structure)	reinforced concrete/bricks				reinforced concrete				reinforced concrete			
Stairs	reinforced concrete											
External walls	hollow bricks (30 cm)			hollow bricks (30 cm)	hollow bricks (30 cm)		hollow bricks (20 cm)		hollow bricks 8 cm			
Insulation	no insulation			insulation (2 cm)	no insulation		insulation (2 cm)	insulation (4 cm)	insulation (3 cm)			
External walls finishes	plaster				plaster				facing bricks (12 cm)			
Windows	wood frame single glass		aluminium frame double glass		wood frame double glass		PVC frame double glass		wood frame single glass		wood frame double glass	alum frame double glass
Roof	flat			flat	flat		flat	flat	pitched		pitched	pitched
Insulation	no insulation			insulation (2 cm)	insulation (2 cm)		insulation (4 cm)	insulation (10 cm)	insulation (4 cm)		insulation (5 cm)	insulation (8 cm)
Bottom floor	no insulation	no insulation	insulation (1 cm)		insulation (1 cm)		insulation (2 cm)	insulation (7 cm)	insulation (5 cm)		insulation (6 cm)	insulation (9 cm)
Roof finishes	bitumen				bitumen				cement tiles			
Internal walls	bricks				wood frame				wood frame			
Internal walls finishes	plaster				plasterboard				plasterboard			
Flooring	ceramic tiles				ceramic tile				wood			
Uvalue walls	1.76		1.47	0.81	1.55		0.98	0.54	0.71		0.54	0.58
Uvalue roof	2.25		2.11	1.16	1.42		0.75	0.39	0.79		0.73	0.48
Uvalue windows	4.80		4.90	3.75	3.81		2.90	1.93	2.20		2.04	1.97
Uvalue bottom floor	1.81		1.73	1.52	1.67		1.16	0.51	0.57		0.51	0.38
Heating energy consumption	101	98	63	52	182		133	98	158	168	148	129
Heating systems	boiler				boiler				electricity			
Heating terminal unit	radiators			radiant floor	radiators			radiant floor	convector heaters			
Tot nr. of dwellings in EU-27	5,563,385	10,977,814	12,326,198	6,923,950	12,883,862	16,543,072	19,849,947	11,961,082	1,326,949	1,580,981	1,831,829	910,548
Tot nr. of people living in the dwelling EU-27	72,640,110				125,289,263				9,463,779			

System boundary: from cradle to grave (+ recycling benefits)



EN 15978
Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method

System boundary

DATASET single family house				
lifetime: 100 years				
number of inhabitants: 2,4 (average household size)				
m^2: (average area of a dwelling unit: 92 m^2)				
PRODUCTION PHASE				
raw materials- transports-manufacturing of building's materials				
			building's materials:	
	undergroud structure	foundations	reinforced concrete	
		undergroud	reinforced concrete	
	structure	pillars	reinforced concrete	
		floors	reinforced concrete	
	envelope	walls	brick	
			insulation	
		windows	wood	
			glass	
		roof	insulation	
			membrane	
		first floor	insulation	
			membrane	
	finishes	plaster	plaster	
		pavement	ceramic	
	systems	heating/cooling	steel	
		wiring	copper	
		VMC	steel	
		plumbing system	lead /copper / PVC	
		sanitary appliances	ceramics	
		smart systems		
	household equipment	cooker / oven		
		refrigerator		
		washing machine		
		television		
		dish washer		
	furnishing		particle board	
			XPS	
CONSTRUCTION PHASE				
transport to site				
construction	land excavation			
	debris			
	energy	electricity		
		fuel		
	water			
	scaffolding			
	construction waste			
USE PHASE				
energy	heating			
	cooling			
	lighting			
	cooking			
	appliance (electricity)			
water	consumption			
wastewater				
waste				
refurbishment	substitution of	insulation	30 years	
		windows	30 years	
		systems	25 years	50%
		waterproofing	20 years	
		finishes	30 years	50%
		furnishing	20 years	50%
		household equipment	10 years	
refurbishment waste				
END OF LIFE				
deconstruction				
transport				
EOL scenario for each material				

Calculated (related to specific building products)

PRODUCTION PHASE

underground structure	foundations	gravel
	foundations	reinforced concrete curb (50 cm)
	underground retaining walls	reinforced concrete (20 cm)
structure	pillars	timber frame (20 cm x 20 cm)
	floors	timber frame (16 cm x 30 cm) wood board (2 cm + 2 cm)
	stairs	timber frame
envelope	external walls	wood frame insulation (4 cm)
	windows	wood frame triple glass
	roof	roof battens insulation (7 cm)
	bottom floor	insulation (11 cm)
internal walls	internal walls	wood frame
finishes	external walls internal walls	wood cladding
	flooring	wood light concrete screed
	roof	cement tiles
systems	convector heaters	steel
	wiring	copper
	plumbing system	steel PVC
	sanitary appliances	ceramic

System boundary

DATASET single family house				
lifetime: 100 years				
number of inhabitants: 2,4 (average household size)				
m^2: (average area of a dwelling unit: 92 m^2)				
PRODUCTION PHASE				
raw materials- transports-manufacturing of building's materials				
			building's materials:	
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		undergroud	reinforced concrete	
	structure	pillars	reinforced concrete	
		floors	reinforced concrete	
	envelope	walls	brick	
			insulation	
		windows	wood	
			glass	
		roof	insulation	
			membrane	
		first floor	insulation	
			membrane	
	finishes	plaster	plaster	
		pavement	ceramic	
	systems	heating/cooling	steel	
		wiring	copper	
		VMC	steel	
		plumbing system	lead /copper / PVC	
		sanitary appliances	ceramics	
		smart systems		
	household equipment	cooker / oven		
		refrigerator		
		washing machine		
		television		
		dish washer		
	furnishing		particle board	
			xps	
CONSTRUCTION PHASE				
transport to site				
construction	land excavation			
	debris			
	energy	electricity		
		fuel		
	water			
	scaffolding			
	construction waste			
USE PHASE				
energy	heating			
	cooling			
	lighting			
	cooking			
	appliance (electricity)			
water	consumption			
wastewater				
waste				
refurbishment	substitution of	insulation	30 years	
		windows	30 years	
		systems	25 years	50%
		waterproofing	20 years	
		finishes	30 years	50%
		furnishing	20 years	50%
		household equipment	10 years	
refurbishment waste				
END OF LIFE				
deconstruction				
transport				
EOL scenario for each material				

Literature generic assumptions
Transport to site: average 100 km
On site construction: 10% of production impacts

CONSTRUCTION PHASE		
transport to site	50 km 100 km	Lorry 16-32 t Lorry 3.5-7.5 t
energy	electricity	2% embodied energy of production
construction waste		4% production

System boundary

DATASET single family house				
lifetime: 100 years				
number of inhabitants: 2,4 (average household size)				
m^2: (average area of a dwelling unit: 92 m^2)				
PRODUCTION PHASE				
raw materials- transports-manufacturing of building's materials				
			building's materials:	
	undergroud structure	foundations	reinforced concrete	
		undergroud	reinforced concrete	
	structure	pillars	reinforced concrete	
		floors	reinforced concrete	
	envelope	walls	brick	
			insulation	
		windows	wood	
			glass	
		roof	insulation	
			membrane	
		first floor	insulation	
			membrane	
	finishes	plaster	plaster	
		pavement	ceramic	
	systems	heating/cooling	steel	
		wiring	copper	
		VMC	steel	
		plumbing system	lead /copper / PVC	
		sanitary appliances	ceramics	
		smart systems		
	household equipment	cooker / oven		
		refrigerator		
		washing machine		
		television		
		dish washer		
	furnishing		particle board	
			XPS	
CONSTRUCTION PHASE				
transport to site				
construction	land excavation			
	debris			
	energy	electricity		
		fuel		
	water			
	scaffolding			
	construction waste			
USE PHASE				
energy	heating			
	cooling			
	lighting			
	cooking			
	appliance (electricity)			
water	consumption			
wastewater				
waste				
refurbishment	substitution of	insulation	30 years	
		windows	30 years	
		systems	25 years	50%
		waterproofing	20 years	
		finishes	30 years	50%
		furnishing	20 years	50%
		household equipment	10 years	
refurbishment waste				
END OF LIFE				
deconstruction				
transport				
EOL scenario for each material				

Average statistical data and literature assumption

USE PHASE energy and water

energy	heating	natural gas
	water heating	oil
	cooling	wood
	lighting	district heat
	appliance (electricity)	coal electricity
water	consumption wastewater treatment	

USE PHASE maintenance

substitution of	insulation	30 years
	wood frame external walls	50 years
	wood frame internal walls	30 years
	windows	30 years
	finishes	30 years
		50 years
	systems	50 years
transport	50 km	Lorry 16-32 t
	100 km	Lorry 3.5-7.5 t
replacement waste	window frame, wall frame, finishes	
	glass	
	plasterboard insulation	

zone 1	MFH	1990-2008					
kWh/y		Space heat	DHW	Cooking	Cooling	Lighting	Appliances
14,59	Coal	11,15	3,44	0,00			
1094,71	Oil	656,22	241,13	197,35			
3267,77	Gas	2378,29	620,05	269,43			
155,31	Heat	151,87	3,44	0,00			
1783,00	Renewable	1593,89	94,73	94,39			
2791,27	Electricity	416,58	263,52	209,37	208,06	504,64	1189,09
9106,65	TOT	5208,00	1226,31	770,54	208,06	504,64	1189,09
	%	57,19	13,47	8,46	2,28	5,54	13,06

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System boundary

DATASET single family house				
lifetime: 100 years				
number of inhabitants: 2,4 (average household size)				
m^2: (average area of a dwelling unit: 92 m^2)				
PRODUCTION PHASE				
raw materials- transports-manufacturing of building's materials				
			building's materials:	
	undergroud structure	foundations	reinforced concrete	
		undergroud	reinforced concrete	
	structure	pillars	reinforced concrete	
		floors	reinforced concrete	
	envelope	walls	brick	
			insulation	
		windows	wood	
			glass	
		roof	insulation	
			membrane	
		first floor	insulation	
			membrane	
	finishes	plaster	plaster	
		pavement	ceramic	
	systems	heating/cooling	steel	
		wiring	copper	
		VMC	steel	
		plumbing system	lead /copper / PVC	
		sanitary appliances	ceramics	
		smart systems		
	household equipment	cooker / oven		
		refrigerator		
		washing machine		
		television		
		dish washer		
	furnishing		particle board	
			XPS	
CONSTRUCTION PHASE				
transport to site				
construction	land excavation			
	debris			
	energy	electricity		
		fuel		
	water			
	scaffolding			
	construction waste			
USE PHASE				
energy	heating			
	cooling			
	lighting			
	cooking			
	appliance (electricity)			
water	consumption			
wastewater				
waste				
refurbishment	substitution of	insulation	30 years	
		windows	30 years	
		systems	25 years	50%
		waterproofing	20 years	
		finishes	30 years	50%
		furnishing	20 years	50%
		household equipment	10 years	
refurbishment waste				
END OF LIFE				
deconstruction				
transport				
EOL scenario for each material				

Average statistical data and literature assumption

END OF LIFE		
deconstruction		
transport		
sorting plant	reinforced concrete	
	steel	
	glass	
	gravel, mortar, screed	
	plasterboard	
	insulation	
	wood	
	PVC	
transport to sorting plant	50 km	Lorry 3.5-7.5 t

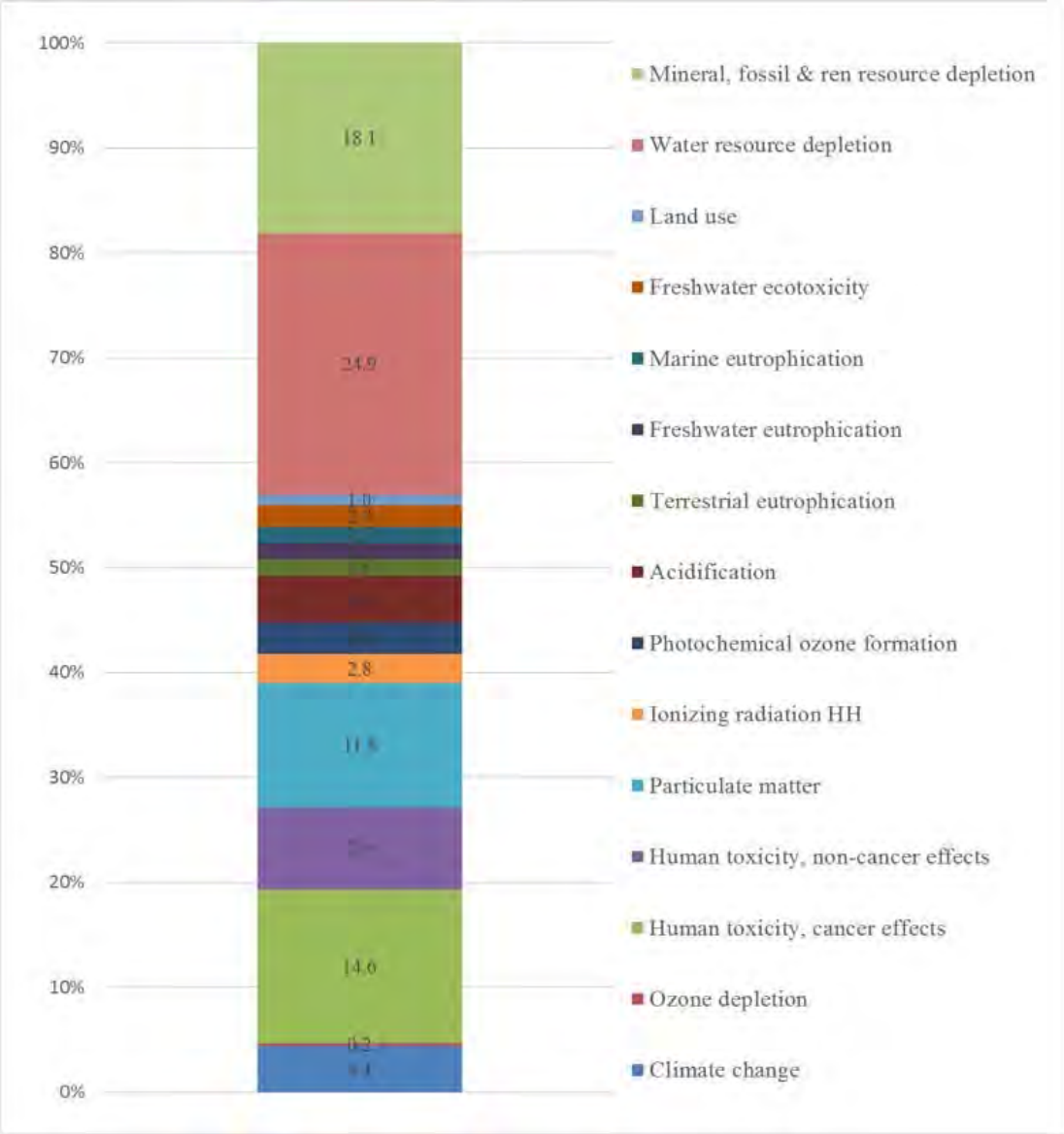
Final results: ILCD method impact categories

Total annual (related to 2010) EU-27 LCA impacts in relation to housing.

Impact category	Unit	Housing
Climate change	kg CO_2 eq	1.24E+12
Ozone depletion	kg CFC-11 eq	1.57E+05
Human toxicity, non-cancer effects	CTUh	1.29E+05
Human toxicity, cancer effects	CTUh	1.68E+04
Particulate matter	kg $PM_{2.5}$ eq	1.39E+09
Ionizing radiation, effects on human health (HH)	kBq U^{235} eq	9.71E+10
Photochemical ozone formation	kg NMVOC eq	2.91E+09
Acidification	molc H^+ eq	6.37E+09
Terrestrial eutrophication	molc N eq	8.79E+09
Freshwater eutrophication	kg P eq	7.04E+07
Marine eutrophication	kg N eq	8.00E+08
Freshwater ecotoxicity	CTUe	5.46E+11
Land use	kg C deficit	2.31E+12
Water resource depletion	m^3 water eq	7.18E+10
Resource depletion	kg Sb eq	5.69E+07

Contribution of the different life cycle phases

Results of the normalisation of average annual impacts for an EU-27 citizen



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Average annual environmental impact of a dwelling in EU

Annual environmental impact of a dwelling in EU. Results are reported per each dwelling type. A colour code is applied from lower impact (in green), to higher impact (in orange). colour scale.

Impact categories		SFH_ warm	SFH_ moderate	SFH_ cold	MFH_ warm	MFH_ moderate	MFH_ cold	Average SFH	Average MFH	**EU housing average**
Climate change	kg CO_2 eq	5.94E+03	7.79E+03	8.61E+03	3.91E+03	5.05E+03	4.97E+03	7.53E+03	4.65E+03	6.08E+03
Ozone depletion	kg CFC-11 eq	6.72E-04	9.66E-04	1.93E-03	4.44E-04	6.18E-04	1.06E-03	9.59E-04	5.82E-04	7.70E-04
Human toxicity, non-cancer effects	CTUh	6.80E-04	7.40E-04	1.39E-03	5.08E-04	4.84E-04	7.80E-04	7.57E-04	5.08E-04	6.32E-04
Human toxicity, cancer effects	CTUh	7.82E-05	9.61E-05	1.64E-04	6.17E-05	6.88E-05	1.06E-04	9.61E-05	6.84E-05	8.22E-05
Particulate matter	kg $PM_{2.5}$ eq	7.32E+00	8.07E+00	1.53E+01	5.33E+00	5.10E+00	8.20E+00	8.24E+00	5.35E+00	6.79E+00
Ionizing radiation HH	kBq U^{235} eq	5.32E+02	5.52E+02	1.13E+03	3.35E+02	3.79E+02	6.46E+02	5.73E+02	3.79E+02	4.75E+02
Photochemical ozone formation	kg NMVOC eq	1.35E+01	1.78E+01	2.78E+01	9.00E+00	1.17E+01	1.56E+01	1.76E+01	1.10E+01	1.42E+01
Acidification	molc H^+ eq	2.82E+01	3.94E+01	6.03E+01	1.83E+01	2.64E+01	3.40E+01	3.85E+01	2.40E+01	3.12E+01
Terrestrial cutrophication	molc N eq	4.39E+01	5.22E+01	9.48E+01	2.91E+01	3.42E+01	5.32E+01	5.27E+01	3.35E+01	4.30E+01
Freshwater eutrophication	kg P eq	3.79E-01	3.99E-01	8.10E-01	2.42E-01	2.80E-01	4.67E-01	4.13E-01	2.77E-01	3.45E-01
Marine eutrophication	kg N eq	3.99E+00	4.75E+00	8.70E+00	2.64E+00	3.12E+00	4.88E+00	4.79E+00	3.05E+00	3.92E+00
Freshwater ecotoxicity	CTUe	2.54E+03	3.27E+03	5.13E+03	1.87E+03	2.18E+03	3.06E+03	3.23E+03	2.12E+03	2.67E+03
Land use	kg C deficit	1.14E+04	1.38E+04	2.57E+04	7.93E+03	8.68E+03	1.31E+04	1.39E+04	8.66E+03	1.13E+04
Water resource depletion	m^3 water eq	3.93E+02	4.09E+02	7.59E+02	2.41E+02	2.89E+02	4.75E+02	4.21E+02	2.82E+02	3.51E+02
Mineral, fossil & ren resource depletion	kg Sb eq	2.75E-01	3.00E-01	5.00E-01	3.28E-01	2.02E-01	3.34E-01	3.04E-01	2.53E-01	2.78E-01

Average annual environmental impact per person in EU

Average annual environmental impact of an EU citizen. Results per person are related to each representative dwelling. A colour code is applied from lower impact (ir green), to higher impact (in orange).

Impact categories		SFH_warm	SFH_moderate	SFH_cold	MFH_warm	MFH_moderate	MFH_cold		Average SFH	Average MFH	EU housing average
Climate change	kg CO_2 eq	1.73E+03	2.87E+03	3.04E+03	1.93E+03	2.47E+03	2.97E+03		2.66E+03	2.30E+03	2.51E+03
Ozone depletion	kg CFC-11 eq	1.96E-04	3.56E-04	6.83E-04	2.19E-04	3.02E-04	6.35E-04		3.39E-04	2.88E-04	3.18E-04
Human toxicity, non-cancer effects	CTUh	1.98E-04	2.73E-04	4.92E-04	2.50E-04	2.36E-04	4.66E-04		2.68E-04	2.52E-04	2.61E-04
Human toxicity, cancer effects	CTUh	2.28E-05	3.54E-05	5.81E-05	3.04E-05	3.36E-05	6.34E-05		3.40E-05	3.39E-05	3.39E-05
Particulate matter	kg $PM_{2.5}$ eq	2.13E+00	2.97E+00	5.41E+00	2.63E+00	2.49E+00	4.89E+00		2.91E+00	2.65E+00	2.80E+00
Ionizing radiation HH	kBq U235 eq	1.55E+02	2.04E+02	4.00E+02	1.65E+02	1.85E+02	3.85E+02		2.02E+02	1.87E+02	1.96E+02
Photochemical ozone formation	kg NMVOC eq	3.95E+00	6.57E+00	9.81E+00	4.43E+00	5.71E+00	9.30E+00		6.20E+00	5.43E+00	5.88E+00
Acidification	molc H^+ eq	8.21E+00	1.45E+01	2.13E+01	9.03E+00	1.29E+01	2.03E+01		1.36E+01	1.19E+01	1.29E+01
Terrestrial eutrophication	molc N eq	1.28E+01	1.93E+01	3.35E+01	1.44E+01	1.67E+01	3.17E+01		1.86E+01	1.66E+01	1.78E+01
Freshwater eutrophication	kg P eq	1.10E-01	1.47E-01	2.87E-01	1.19E-01	1.37E-01	2.79E-01		1.46E-01	1.37E-01	1.42E-01
Marine eutrophication	kg N eq	1.16E+00	1.75E+00	3.08E+00	1.30E+00	1.52E+00	2.92E+00		1.69E+00	1.51E+00	1.62E+00
Freshwater ecotoxicity	CTUe	7.41E+02	1.21E+03	1.81E+03	9.23E+02	1.06E+03	1.82E+03		1.14E+03	1.05E+03	1.10E+03
Land use	kg C deficit	3.34E+03	5.10E+03	9.08E+03	3.91E+03	4.24E+03	7.81E+03		4.93E+03	4.29E+03	4.66E+03
Water resource depletion	m^3 water eq	1.15E+02	1.51E+02	2.68E+02	1.19E+02	1.41E+02	2.83E+02		1.49E+02	1.40E+02	1.45E+02
Resource depletion	kg Sb eq	8.02E-02	1.11E-01	1.77E-01	1.62E-01	9.85E-02	1.99E-01		1.08E-01	1.25E-01	1.15E-01

Remarks: average data versus min-max data (homogeneity versus differences)

	AVERAGE FLOOR AREA OF DWELLING											
	Single family house						Multy family house					
	unit	<1945	1945-1969	1970-1989	1990-2008	average floor	unit	<1945	1945-1969	1970-1989	1990-2008	average floor
Malta	m2/dwelling	99.00	99.00	99.00	99.00		m2/dwelling	85.00	85.00	85.00	85.00	
Cyprus	m2/dwelling	n.a.	n.a.	n.a.	n.a.		m2/dwelling	n.a.	n.a.	n.a.	n.a.	
Portugal	m2/dwelling	86.58	89.57	119.18	149.71		m2/dwelling	77.50	86.72	95.77	107.32	
Greece	m2/dwelling	61.22	64.21	76.27	86.50		m2/dwelling	88.37	83.78	93.46	100.23	
Spain	m2/dwelling	94.72	95.16	108.16	136.93		m2/dwelling	87.41	73.16	86.84	95.10	
Italy	m2/dwelling	123.54	109.40	94.98	106.85		m2/dwelling	90.80	90.80	90.80	90.80	
total by period	m2/dwelling	109.92	97.73	100.03	129.00		m2/dwelling	89.72	85.69	90.01	95.18	
total by climate zone	m2	1,715,847,520.19				107.40	m2	3,208,367,279.95				89.64
France	m2/dwelling	58.79	111.62	104.36	86.41		m2/dwelling	54.04	65.92	63.83	n.a	
Bulgaria	m2/dwelling	64.78	63.16	64.91	60.63		m2/dwelling	64.48	64.48	64.48	64.48	
Belgium	m2/dwelling	73.00	73.00	73.00	73.00		m2/dwelling	113.91	113.91	114.00	114.00	
Netherlands	m2/dwelling	129.34	111.14	107.29	113.13		m2/dwelling	41.72	32.86	30.92	32.40	
Ireland	m2/dwelling	99.03	97.52	114.23	135.89		m2/dwelling	50.00	50.00	69.24	71.26	
Hungary	m2/dwelling	93.15	93.15	93.15	93.15		m2/dwelling	46.73	46.73	46.73	46.73	
Slovenia	m2/dwelling	89.02	90.21	100.38	104.41		m2/dwelling	56.06	46.85	61.26	64.42	
Luxembourg	m2/dwelling	80.45	83.01	97.09	95.89		m2/dwelling	83.18	86.08	86.94	86.08	
Germany	m2/dwelling	100.24	100.15	111.15	119.12		m2/dwelling	n.a.	66.04	58.80	64.05	
U. Kingdom	m2/dwelling	101.09	77.24	73.31	82.04		m2/dwelling	55.20	51.67	48.45	45.47	
Slovakia	m2/dwelling	86.40	91.22	102.32	112.45		m2/dwelling	64.07	58.66	48.85	53.96	
Romania	m2/dwelling	72.58	72.58	71.46	72.58		m2/dwelling	55.36	45.68	46.53	74.46	
Denmark	m2/dwelling	136.35	124.07	137.84	151.36		m2/dwelling	82.04	89.10	59.80	57.20	
Czech Rep.	m2/dwelling	86.56	94.65	104.10	129.12		m2/dwelling	64.07	58.66	61.25	62.61	
Austria	m2/dwelling	111.27	111.37	126.03	131.88		m2/dwelling	70.96	65.72	77.58	73.83	
Poland	m2/dwelling	76.32	79.16	113.10	111.61		m2/dwelling	52.24	43.78	51.85	59.34	
total by period	m2/dwelling	89.84	91.19	95.80	101.53		m2/dwelling	58.54	60.98	57.07	59.97	
total by climate zone	m2	7,684,970,507.84				94.29	m2	3,613,041,661.08				59.00
Lithuania	m2/dwelling	72.43	84.58	104.06	178.09		m2/dwelling	18.60	49.17	62.68	85.06	
Latvia	m2/dwelling	96.00	96.00	96.00	96.00		m2/dwelling	52.00	52.00	52.00	52.00	
Estonia	m2/dwelling	86.11	86.11	86.11	80.10		m2/dwelling	47.80	47.80	47.80	47.80	
Sweden	m2/dwelling	125.00	125.00	125.00	125.00		m2/dwelling	67.00	67.00	67.00	67.00	
Finland	m2/dwelling	70.68	73.88	113.70	118.62		m2/dwelling	56.00	56.00	56.00	56.00	
total by period	m2/dwelling	102.05	99.93	116.92	124.82		m2/dwelling	55.47	59.61	60.25	64.36	
total by climate zone	m2	449,404,127.87				108.34	m2	331,407,734.50				58.65

Reworking (aggregated data). Data source: ENTRANZE

Thank you for attention

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