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ENSLIC CASE STUDIES

1 CASE STUDY 1: PARCEL 12 SECTOR 89/4 VALDESPARTERA – ZARAGOZA (SPAIN)

1.1BUILDING DESCRIPTION

On March 13 2001 Zaragoza City Council and the Ministry of Defence signed an Agreement about Valdespartera's former army barracks affecting a total amount of 243,2 hectares of land returned to the city to promote its town planning development by the building of council flats along with facilities and other uses. Thus, Zaragoza City Council is promoting the construction of a new and modern residential area south of the city with around 9.500 council flats.

Figura 1.1. Valdespartera Urban Planning www.valdespartera.es

Once Valdespartera´s land was registered as Building Land, Zaragoza City Council drew up the corresponding Partial Plan for the town planning development of such land. The Partial Plan, eventually approved by the Corporation on November 29 2002, establishes a building capacity of 9,687 flats (97% of which belong to council) as well as tertiary uses.

12 Parcel/ 89 Sector makes part of this plan and is composed of three similar blocks of buildings, sharing the garage. The building under study is called the Southern Block. This building comprises six floors with a total habitable floor space of 4842.94 m^2, 60 apartments and 235 occupants.

Figura 1.2. From left to right, up and down: North façade; South façade; Greenhouse detail; solar collectors on top of the roof.

The garage has a total of 160 parking spaces (69 belong to Southern Block) and 100 storage rooms (40 belong to Southern Block). The ground floor has 10 apartments (5 dwellings of 80 m^2 and another 5 of 60 m^2). Plants 1 to 5 are similar, and consist of 10 apartments of 80 m2, while 6th floor features 26 storage rooms and common boiler.

Flour	Area (m^2)	Height (m)	Volume (m^3)
Garage	1645.3	3.75	6169.9
Ground Flour	922	2.9	2673.8
1st Flour	922	2.9	2673.8
2nd Flour	922	2.9	2673.8
3th Flour	922	2.9	2673.8
4th Flour	922	2.9	2673.8
5th Flour	922	2.9	2673.8
6th Flour	463.89	2.7	1252.5
TOTAL	7641.19	-	23465.2

Tabla 1.1. Building's description.

1.2 METHODOLOGY

The *functional unit* considered is the Southern Block of Parcel 12/ Valdespartera during 50 years lifespan, considering design conditions, thermal comfort, etc.. present in Spain in 2006 (year of construction).

The selection of *impact categories* analyzed in this study considers the current energy and environmental concerns at European level. In this regard it is worth recalling the objectives set by the European Union by 2020: reducing emissions by at least 20% below 2005 levels, 20% energy savings over consumption of 2005 and increased participation of renewable energy in primary energy consumption from the current 7% to 20% in 2020.

Therefore, the impact categories used are embodied energy (expressed in equivalent Megajoules: MJ-Eq) calculated according to the impact assessment methodology "Cumulative Energy Demand (CED)" and global warming potential (in kilograms carbon dioxide equivalent: kg CO2-Eq) calculated according to the methodology of the Intergovernmental Panel on Climate Change (IPCC).

The CED methodology has been used since the 70s to analyze energy systems. The CED provides total energy demand, expressed in terms of primary energy associated with the entire life cycle of a product or service. The CED approach distinguishes between primary renewable energy (hydro, biomass, wind, solar and geothermal) and non-renewable primary energy (fossil and nuclear). For this study we used the version 1.05 of the CED method implemented in the SimaPro v 7.1.8.

The greenhouse effect caused by anthropogenic emissions associated with human activities may be expressed in terms of their global warming potential of CO2 equivalent. For this study we used 1.01 version of the method implemented in SimaPro v 7.1.8, based on the characterization factors given by IPCC for 2007 and taking into account a time horizon of 100 years .

All data related to electricity consumption have been previously adapted to the ***electric mix of production*** in Spain in 2008, as shown in the next table.

Ecoinvent Module	kWh
Electricity, hard coal, at power plant/ES U	0.217
Electricity, lignite, at power plant/ES U	0.03
Electricity, oil, at power plant/ES U	0.02
Electricity, natural gas, at power plant/ES U	0.232
Electricity, industrial gas, at power plant/ES U	0.003
Electricity, hydropower, at power plant/ES U	0.11
Electricity, hydropower, at pumped storage power plant/ES U	0.01
Electricity, nuclear, at power plant/ES U	0.20
Electricity, production mix PV, at power plant/ES U	0.002
Electricity, at wind power plant/ES U	0.1
Electricity, at cogen ORC 1400kWth, allocation exergy/ES U	0.01
Electricity, at cogen with biogas engine, allocation exergy/ES U	0.006
Electricity, natural gas, allocation exergy, at micro gas turbine 100kWe/ES U	0.06

Tabla 1.2. Technosphere resources for the production of 1 kWh in Spain.

The reference ***database*** used for the LCA is Ecoinvent v2.0 (2007) and the ***software*** SimaPro v7.1.8; eventhough this application is not specifically designed to carry out LCA in buildings, the quantity and quality of databases and impact assessment methodologies incorporated make it suitable for this purpose.

The LCA is performed using a series of ***simplifications*** as specified:

- Initially we considered 4 stages in the life cycle of a building: production, construction, use and end of life according to the recommendations made by the Technical Committee "Sustainability of construction works" CEN / TC 350. With this method only production and use are taked into account.

- Production stage is limited to the manufacture of building structure and building envelope.
- Building use phase is limited to the final energy consumption required for heating, cooling, DHW and lighting.

Finally, the software used to estimate *final energy demand and consumption* is CALENER VYP. This software is the official tool developed in Spain for the Energy Efficiency Certification of buildings according to RD47/2007 (see: http://www.mityc.es/energia/desarrollo/EficienciaEnergetica/CertificacionEnergetica/ProgramaCalener). CALENER VYP calculation engine uses a dynamic simulation hourly basis similar to LIDER, both fully developed at the University of Sevilla (Spain).

CALENER VYP calculates the energy efficiency rating from A to G and provides some results such as the energy demand for heating and cooling based on the definition of the building envelope and the local climate. Then it estimates the final energy consumption for heating, cooling and hot water, calculated as the ratio of energy demand and the seasonal efficiency of facilities. This efficiency calculation is based on the atmospheric conditions and performance curves of these facilities, which are mathematically modeled on the basis of certain variables, such us external temperature and workload.

The CALENER calculation engine is validated through tests of the International Energy Agency (BESTEST-Building Energy Simulation Test). Therefore, the results are generally in the same order of magnitude than those obtained with other existing tools for building energy simulation.

To confirm this point, the energy demand is also calculated through the commercial application DesignBuilder. The results are similar as shown in the table below.

DesignBuilder		Lider	
Heating kWh/m^2 year	Cooling kWh/m^2 year	Heating kWh/m^2 year	Cooling kWh/m^2 year
9.12	15.51	11.2	15.1

Tabla 1.1. Energy demand for heating and cooling.

According to the Working Project, solar heat input is able to cover 40% of hot water annual consumption. This contribution is deducted from the final energy consumption associated to DHW.

In terms of final energy consumption for lighting, the calculation has been done considering the power of lamps installed in each room and the estimation of working time. It has been considered 2.5 h / day of operation for living room, 1 h / day for kitchen and bathroom and 0.5 h / day for other rooms. In the common areas 4 hours per day for the garage, 3 h / day for entrances, 1 h / day for stairs and 0.5 h / day for the boiler room.

The final energy consumption for lighting the building is 27.987.1 kWh / year, representing 5.8 kWh / m ^{2} / year with a total of 1399.36 MWh over the lifetime of the building.

1.3INPUT DATA

1.3.1 Production Phase

Structure

We will consider that the building structure is composed of basement retaining walls in the garage and pillars, since other materials making part of basement floor, slabs… are included in the building envelope.

Both pillars and retaining walls are built of reinforced concrete HA-25 N/mm^2, Tmax. 20 mm under NTE-EHS and EHD standards.

	Volume (m^3)	Material	Concrete (t)	Steel (t)	Total (t)
Pillars	126	Reinforced concrete HA-25, 106 kg/m^3 of steel	289.044	13.356	302.400
Garage Pillars	26.59	Reinforced concrete HA-25, 106 kg/m^3 of steel	61.006	2.818	63.824
Retaining Walls	180.3	Reinforced concrete HA-25, 150 kg/m^3 of steel	404.950	27.050	432.000
		TOTAL	755	43.224	798.224

Tabla 1.2. Structure materials

Building Envelope

Working Project includes the composition of different walls, according to this documentation and density specified in LIDER[1] , the weight of the different materials is obtained. Results are shown in the table below.

Enclosure	Surface(m^2)	Material	Volume (m^3)	Density (kg/m^3)	Weight (kg)
Exterior Walls	2752.90	Fiberglass insulation (I Type)	137.27	125.00	17158.65
		Concrete Block 15 cm (no steel)	160.15	685.00	109700.97
		Plasterboard plate	34.32	1040.00	35689.99
		Galvanized steel plate, thickness: 2 mm	6.86	7500.00	51475.95
South Exterior Walls	616.40	Coating	6.16	1250.00	7705.00
		Lightweightclay Thickness: 24 cm	147.94	920.00	136101.12
		Plasterboard plate	92.46	900.00	83214.00
Interior Walls	6266.25	Plasterboard plate	449.87	900.00	404878.50
		Fiberglass	154.31	125.00	19288.13

[1] Spanish official program to ensure minimum insulation of buildings

		insulation (I Type)			
Slabs	6317.00	Ceramic tiles	101.44	2000.00	202875.00
		Cement morter	101.44	1525.00	154692.19
		Slab "Farlap" (25+5)	2028.75	670.00	1359262.50
		Rockwool isolating morter	38.88	40.00	1555.20
		Plasterboard plate	86.86	900.00	78171.75
Basement Floor	1527.21	Reinforced concrete	218.70	1850	404595.00
Roof	1069.00	Grave	534.50	1450	775025.00
		Extruded polystyrene	53.45	38	2031.10
		Water`proof membrane	5.35	1100	5879.50
		Morter	16.04	900	14431.50
		Slab "Farlap" (25+5)	320.70	670	214869.00
		Plasterboard plate	16.04	900	14431.50
			Surface (m^2)	Density (kg/m^2)	Weight (kg)
Doors	705.6	Wood made interior doors	705.6	27.60	19474.56
Windows	2427.02	Double glass climalit	795.01	27.50	21862.67
		Simple glass 5 mm (greenhouse)	1412.06	12.50	17650.80
		Aluminium Frame (10% windows surface)	219.95	50.70	11151.47
				TOTAL WEIGHT (kg)	4163171.03

Tabla 1.3. Inventory of materials belonging to the building envelope.

The total weight of the building envelope is 4163.17 tons. The concrete-based materials, mainly used in floors and roofs, account for the 45% of total weight, followed by the grave, representing 18.6% of total weight.

To assess the impact of these enclosures, Ecoinvent inventories v2.0 (2007) have been adapted modifying predefined values. In "Farlap" slab the amount of steel present in the compression layer and joists accounts for 2.5 kg/m^2 which, considering a thickness of 0.3 m, makes 8.3 kg steel/m^3. In the basement floor the amount of steel present in the reinforced concrete is 60 kg/m^3.

1.3.2 Use Phase Phase

Within this section final energy consumption needed to meet heating, cooling, DHW and lighting demand is calculated, as well as the contribution of renewable energy systems.

	Average maintained illuminance (lm/m²)	Surface (m²)	Installed capacity (W)	Final Energy (kWh/year)
Bedroom	150	1872.13	23401.6	4270.8
WC-Bathrooms	150	390.05	2574.3	939.6
Lounge	300	1258.04	16606.1	15153.0
Hall	100	552.11	2429.3	443.3
Kitchen	150	446.31	1046.0	381.8
Stairs	100	1042.50	4587.0	1674.3
Portal	200	201.00	1768.8	1936.8
Parking	75	1645.30	1928.1	2815.0
Boiler room	100	463.80	2040.7	372.4
TOTAL	-	7871.23	56381.9	27987.1

Tabla 1.4. Calculation of the final energy consumption for lighting

The following table shows all final energy consumption including solar contribution.

	kWh/m² year*	kWh/occupant year	kWh/year	kWh
Heating	13.40	276.15	64895.40	3244769.80
Cooling	8.90	183.41	43102.17	2155108.30
DHW	10.90	224.63	52788.05	2639402.30
Lighting	5.78	119.09	27987.12	1399356.11
SUBTOTAL	38.98	803.29	188772.73	9438636.51
Solar termal contribution	-4.36	-89.85	-21115.22	-1055760.92
TOTAL	34.62	713.44	167657.51	8382875.59

*Tabla 1.5. Final energy consumption of the buiilding. * Climatized surface is considered*

To assess the impact of the consumption of cooling and lighting it has been used Ecoinvent v2.0 (2007) inventories for low voltage power supply, while consumption for heating, hot water and solar thermal input are based on the inventories for gas consumption in boilers.

1.4RESULTS

1.4.1 Primary energy requirement.

The following table presents the key ratios related to the Primary energy requirement in the building.

	Total Primary Energy Requirement			
	MJ-Eq	MJ-Eq/year	MJ-Eq/occupant year	MJ-Eq/m² year
Building production	42.079.276	841.585	3.581	173
Building use	61.760.026	1.235.201	5.256	255
TOTAL	103.839.302	2.076.786	8.837	428

Tabla 1.6. Primary energy requirement ratios in the stages of the building life cycle

The primary energy is mainly from fossil fuels (78%) and nuclear (15%). The contribution of renewable energies reaches only 8%.

Below it is a detailed description of the contribution of the different aspects analyzed in the two stages of life of the building (production & use) to the Primary energy requirement.

			Primary Energy Requirement	
			GJ-Eq	%
Building Production	Construction Materials	Structure	1.465,4	1,4%
		Enclosures	40.613,8	39,1%
		- Walls	7.849,0	7,6%
		- Interior walls	3.372,1	3,2%
		- Slabs	22.181,6	21,4%
		- Roofs	3.467,8	3,3%
		- Windows and doors	3.743,4	3,6%
		SUBTOTAL PRODUCTION	*42.079,3*	*40,5%*
Building use	Operation	Final Energy Consumption	61.760,0	59,5%
		- Heating consumption	13.958,6	13,4%
		- Cooling consumption	24.851,9	23,9%
		- DHW consumption	11.354,4	10,9%
		- Lighting consumption	16.136,9	15,5%
		- Renewable energy contribution	-4.541,7	-4,4%
		SUBTOTAL USE	*61.760,0*	*59,5%*
		TOTAL	103.839,3	-

Tabla 1.7. Primary energy requirement in the stages of the building life cycle

Finally, the following table breaks down the impact on primary energy associated with the manufacture of various building materials (production phase). It is remarkable the high impact of the concrete used in slabs and galvanized plate that covers the building's exterior walls.

Enclosures	Material	GJ-Eq	%
Structure	Concrete, normal, at plant/CH U reinforced pilares *	486	1.2%
	Concrete, normal, at plant/CH U reinforced pilares *	102	0.2%
	Concrete, normal, at plant/CH U reinforced muros contenc *	877	2.1%
Exterior Walls	Glass wool mat, at plant/CH U*	864	2.1%
	Concrete block, at plant/DE U *	93	0.2%
	Gypsum plaster board, at plant/CH U*	212	0.5%
	Tin plated chromium steel sheet, 2 mm, at plant/RER U*	5428	12.9%
	Cement mortar, at plant/CH U *	12	0.0%
	Light clay brick, at plant/DE U *	747	1.8%
	Gypsum plaster board, at plant/CH U*	493	1.2%
Interior Walls	Gypsum plaster board, at plant/CH U*	2401	5.7%
	Glass wool mat, at plant/CH U*	971	2.3%

Slabs	Ceramic tiles, at regional storage/CH U *	3017	7.2%
	Cement mortar, at plant/CH U *	237	0.6%
	Lightweight concrete block, polystyrene, at plant/CH U**	17781	42.3%
	Rock wool, at plant/CH U *	35	0.1%
	Gypsum plaster board, at plant/CH U*	463	1.1%
	Concrete, sole plate and foundation, at plant/CH U**	647	1.5%
Roof	Gravel, round, at mine/CH U*	46	0.1%
	Polystyrene, extruded (XPS), at plant/RER U*	188	0.4%
	Bitumen sealing VA4, at plant/RER U*	314	0.7%
	Cement mortar, at plant/CH U *	22	0.1%
	Lightweight concrete block, polystyrene, at plant/CH U**	2811	6.7%
	Gypsum plaster board, at plant/CH U*	86	0.2%
Windows & doors	Glazing, simple, U=5.7 W/m2K, at plant/RER U*	311	0.7%
	Glazing, double (2-IV), U<1.1 W/m2K, at plant/RER U*	374	0.9%
	Window frame, aluminium, U=1.6 W/m2K, at plant/RER U *	1804	4.3%
	Door, inner, wood, at plant/RER U*	1255	3.0%

Tabla 1.8. Primary energy requirement for the production of the building materials

1.4.2 Global Warming Potential.

The following table presents the key ratios related to the global warming potential of the building.

	Global warming potential			
	kg CO_2-Eq	kg CO_2-Eq /year	kg CO_2-Eq /occupant year	kg CO_2-Eq /m^2 year
Building production	3.019.968	60.399	257	12
Building use	3.163.608	63.272	269	13
TOTAL	6.183.576	123.671	526	25

Tabla 1.9. Global warming potential ratios in the stages of the building life cycle

Below it is a detailed description of the contribution of the different aspects analyzed in the two stages of life of the building (production & use) to the global warming potential.

			Global warming potential	
			t CO_2-Eq	%
Building production	Construction material	Structure	149,8	2,4%
		Enclosures	2.870,1	46,4%
		- Walls	409,9	6,6%
		- Interior walls	184,2	3,0%
		- Slabs	1.875,3	30,3%
		- Roofs	289,3	4,7%
		- Windows and doors	111,4	1,8%
		SUBTOTAL PRODUCTION	3.019,9	48,8%
Building use	Operation	Final Energy Consumption	3.163,6	51,2%
		- Heating consumption	797,5	12,9%

		- Cooling consumption	1.198,6	19,4%
		- DHW consumption	648,7	10,5%
		- Lighting consumption	778,3	12,6%
		- Renewable energy contribution	-259,5	-4,2%
		SUBTOTAL USE	3.163,6	51,2%
		TOTAL	6.183,58	-

Tabla 1.10. Global warming potential in the stages of the building life cycle

Again, this table brakes down the global warming potential associated with the manufacture of various building materials.

Enclosure	Material	t CO_2-Eq	%
Structure	Concrete, normal, at plant/CH U reinforced pilares *	52	1,7%
	Concrete, normal, at plant/CH U reinforced pilares *	11	0,4%
	Concrete, normal, at plant/CH U reinforced muros contenc *	86	2,9%
Exterior Walls	Glass wool mat, at plant/CH U*	40	1,3%
	Concrete block, at plant/DE U *	13	0,5%
	Gypsum plaster board, at plant/CH U*	12	0,4%
	Tin plated chromium steel sheet, 2 mm, at plant/RER U*	32	10,6%
	Cement mortar, at plant/CH U *	2	0,1%
	Light clay brick, at plant/DE U *	-8	-0,3%
	Gypsum plaster board, at plant/CH U*	28	0,9%
Interior Walls	Gypsum plaster board, at plant/CH U*	138	4,6%
	Glass wool mat, at plant/CH U*	45	1,5%
Slabs	Ceramic tiles, at regional storage/CH U *	163	5,4%
	Cement mortar, at plant/CH U *	32	1,1%
	Lightweight concrete block, polystyrene, at plant/CH U**	1589	52,6%
	Rock wool, at plant/CH U *	2	0,1%
	Gypsum plaster board, at plant/CH U*	27	0,9%
	Concrete, sole plate and foundation, at plant/CH U**	61	2,0%
Roof	Gravel, round, at mine/CH U*	2	0,1%
	Polystyrene, extruded (XPS), at plant/RER U*	20	0,7%
	Bitumen sealing VA4, at plant/RER U*	7	0,2%
	Cement mortar, at plant/CH U *	3	0,1%
	Lightweight concrete block, polystyrene, at plant/CH U**	251	8,3%
	Gypsum plaster board, at plant/CH U*	5	0,2%
Windows and doors	Glazing, simple, U=5,7 W/m2K, at plant/RER U*	14	0,5%
	Glazing, double (2-IV), U<1,1 W/m2K, at plant/RER U*	18	0,6%
	Window frame, aluminium, U=1,6 W/m2K, at plant/RER U *	105	3,5%
	Door, inner, wood, at plant/RER U*	-27	-0,9%

Tabla 1.11. Global warming potential for the production of the building materials

1.5ANNEX: SIMPLIFIED VS DETAILED METHOD

In section 1,3 the simplified method is presented assuming the removal of two stages of lifecycle of the building (construction and end of life) and some aspects related with the two stages taked into account (production and use), The justification of these decisions is described in this Annex where the results of a detailed method of LCA are presented,

Primary energy requirement

Following figure shows Primary energy impact of the four stages of life cycle, It is easy to find out that construction and end of life may be rejected compared with production and use of the building,

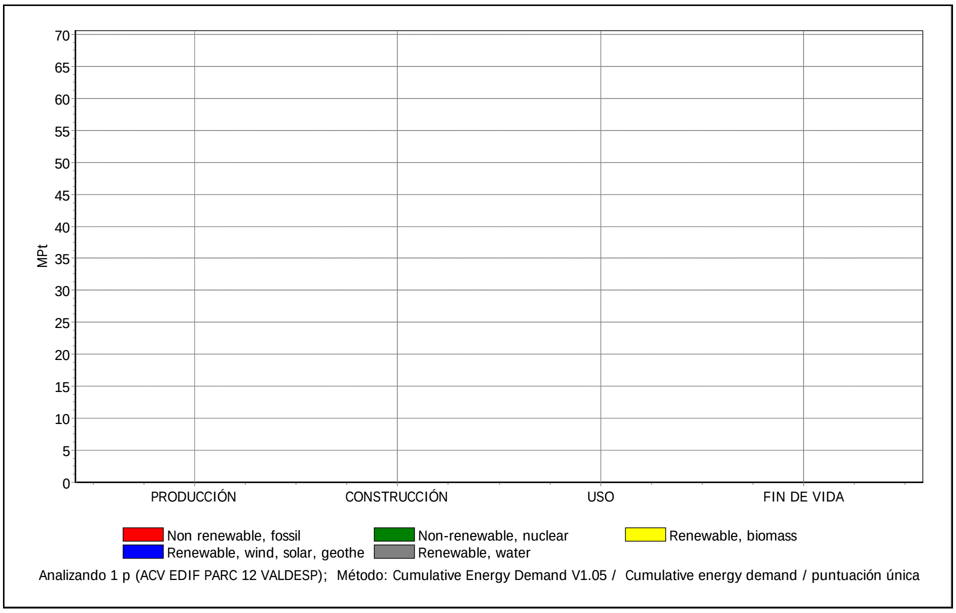

Figura 1.3. Primary energy results considering the four stages of life cycle (production, construction, use and end of life) according to the recommendations made by the Technical Committee "Sustainability of construction works" CEN / TC 350

The following table presents the key ratios related to the Primary energy requirement in the building,

	Total Primary Energy Requirement			
	MJ-Eq	MJ-Eq	MJ-Eq	MJ-Eq
Building production	42997747,31	859954,95	3659,38	177,57
Building construction	1879481,48	37589,63	159,96	7,76
Building use	70568985,66	1411379,71	6005,87	291,43
Building end-of-life	1643657,18	32873,14	139,89	6,79
TOTAL BUILDING	117089871,62	2341797,43	9965,10	483,55

Tabla 1.12. Primary energy requirement ratios in the stages of the building life cycle

Below it is a detailed description of the contribution of the different aspects analyzed in the four stages of life of the building to the Primary energy requirement,

			Primary Energy Requirement	
			GJ-Eq	%
Building production	Construction materials	Structure	1465,4	1,3%
		Enclosures	40613,8	34,7%
		- Walls	7849,0	6,7%
		- Interior walls	3372,1	2,9%
		- Slabs	22181,6	18,9%
		- Roofs	3467,8	3,0%
		- Windows and doors	3743,4	3,2%
		Furniture	0,0	0,0%
		SUBTOTAL	42079,3	35,9%
	Energy systems	Heating and DHW	582,4	0,5%
		Cooling	245,4	0,2%
		Lighting	6,6	0,0%
		Renewable systems	84,1	0,1%
		SUBTOTAL	918,5	0,8%
		SUBTOTAL PRODUCTION	*42997,7*	*36,7%*
Building construction	Transport plant-building	Construction materials	1620,2	1,4%
		Energy sysstems	0,7	0,0%
		SUBTOTAL	1620,9	1,4%
	On-site construction processes	Machinery energy consumption	237,9	0,2%
		Waste	20,7	0,0%
		SUBTOTAL	258,6	0,2%
		SUBTOTAL CONSTRUCTION	*1879,5*	*1,6%*
Building use	Operation	Final Energy Consumption	61760,0	52,7%
		- Heating consumption	13958,6	11,9%
		- Cooling consumption	24851,9	21,2%
		- DHW consumption	11354,4	9,7%
		- Lighting consumption	16136,9	13,8%
		- Renewable energy contribution	-4541,7	-3,9%
		Water consumption	2520,6	2,2%
		Mobility of occupants consumption	0,0	0,0%
		Wastewater treatment	1562,1	1,3%
		SUBTOTAL	65842,8	56,2%
	Maintenance	Replacement of building materials	3766,3	3,2%
		Replacement of energy systems	959,9	0,8%
		SUBTOTAL	4726,2	4,0%
		SUBTOTAL USE	*70569,0*	*60,3%*
Building end-of-life	Construction materials	Structure	265,1	0,2%
		Enclosures	1375,4	1,2%
		Furniture	0,0	0,0%
		SUBTOTAL	1640,5	1,4%
	Energy systems	Heating and DHW	0,3	0,0%
		Cooling	0,6	0,0%
		Lighting	1,4	0,0%
		Renewable systems	0,9	0,0%

		SUBTOTAL	3,2	0,0%
		SUBTOTAL END-OF-LIFE	*1643,7*	*1,4%*
		TOTAL BUILDING	117089,9	-

Tabla 1.13. Primary energy requirement in the stages of the building life cycle

Global Warming Potential

As in previous section, the impact in global warming potential associated to construction and end of life is very small compared with the construction and use of the building,

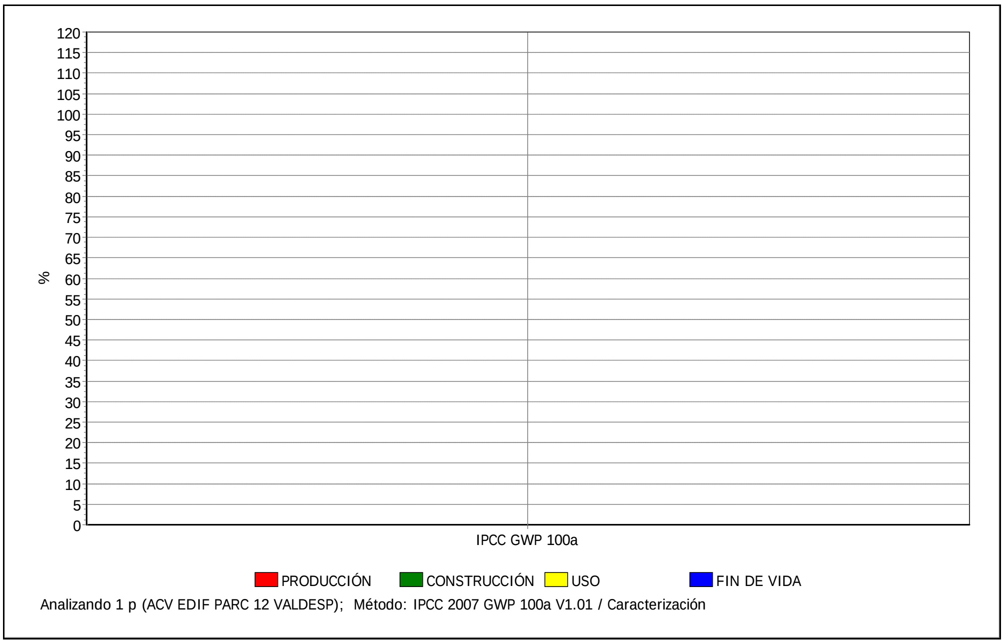

Figura 1.4. Global Warming Potential results considering the four stages of life cycle (production, construction, use and end of life) according to the recommendations made by the Technical Committee "Sustainability of construction works" CEN / TC 350

Key ratios related to the global warming potential of the building are presented bellow,

	Global warming potential			
	kg CO_2-Eq	kg CO_2-Eq /year	kg CO_2-Eq /occupant year	kg CO_2-Eq /m^2 year
Building production	3080405,41	61608,11	262,16	12,72
Building construction	111822,70	2236,45	9,52	0,46
Building use	3619812,38	72396,25	308,07	14,95
Building end-of-life	232239,64	4644,79	19,77	0,96
TOTAL BUILDING	7044280,13	140885,60	599,51	29,09

Tabla 1.14. Global warming potential ratios in the stages of the building life cycle

Next table contains a detailed description of the contribution of the different aspects analyzed in the four stages of life of the building to the global warming potential,

			Global warming potential	
			t CO_2-Eq	%
Building production	Construction materials	Structure	149,88	2,1%
		Enclosures	2870,09	40,7%
		- Walls	409,95	5,8%
		- Interior walls	184,19	2,6%
		- Slabs	1875,27	26,6%
		- Roofs	289,26	4,1%
		- Windows and doors	111,42	1,6%
		Furniture	0,00	0,0%
		SUBTOTAL	3019,97	42,9%
	Energy systems	Heating and DHW	33,79	0,5%
		Cooling	21,64	0,3%
		Lighting	0,40	0,0%
		Renewable systems	4,61	0,1%
		SUBTOTAL	60,44	0,9%
	SUBTOTAL PRODUCTION		*3080,41*	*43,7%*
Building construction	Transport plant-building	Construction materials	95,82	1,4%
		Energy sysstems	0,04	0,0%
		SUBTOTAL	95,86	1,4%
	On-site construction processes	Machinery energy consumption	14,63	0,2%
		Waste	1,34	0,0%
		SUBTOTAL	15,97	0,2%
	SUBTOTAL CONSTRUCTION		*111,82*	*1,6%*
Building use	Operation	Final Energy Consumption	3163,61	44,9%
		- Heating consumption	797,53	11,3%
		- Cooling consumption	1198,58	17,0%
		- DHW consumption	648,73	9,2%
		- Lighting consumption	778,26	11,0%
		- Renewable energy contribution	-259,49	-3,7%
		Water consumption	130,77	1,9%
		Mobility of occupants consumption	0,00	0,0%
		Wastewater treatment	149,77	2,1%
		SUBTOTAL	3444,15	48,9%
	Maintenance	Replacement of building materials	112,78	1,6%
		Replacement of energy systems	62,88	0,9%
		SUBTOTAL	175,66	2,5%
	SUBTOTAL USE		*3619,81*	*51,4%*
Building end-of-life	Construction materials	Structure	12,41	0,2%
		Enclosures	157,82	2,2%
		Furniture	0,00	0,0%
		SUBTOTAL	170,23	2,4%
	Energy systems	Heating and DHW	0,02	0,0%
		Cooling	60,76	0,9%

		Lighting	0,31	0,0%
		Renewable systems	0,91	0,0%
		SUBTOTAL	62,01	0,9%
	SUBTOTAL END-OF-LIFE		*232,24*	*3,3%*
TOTAL BUILDING			7044,28	-

Tabla 1.15. Global warming potential in the stages of the building life cycle

As we can see, both Primary Energy and Global Warming Potential Analysis point out the fact that in the use stage, the highest impact is associated to the energy consumption for cooling, lighting and heating, while in the production stage the enclosures manufacturing, especially the slabs and building's walls, cause the most relevant impact, This is the reason why these are the only stages considered in the simplified method.

2 CASE STUDY 2: PARCEL 24 SECTOR 89/4 VALDESPARTERA – ZARAGOZA (SPAIN)

2.1BUILDING DESCRIPTION

On March 13 2001 Zaragoza City Council and the Ministry of Defence signed an Agreement about Valdespartera's former army barracks affecting a total amount of 243,2 hectares of land returned to the city to promote its town planning development by the building of council flats along with facilities and other uses. Thus, Zaragoza City Council is promoting the construction of a new and modern residential area south of the city with around 9.500 council flats.

Figura 1.5. Valdespartera Urban Planning www.valdespartera.es

Once Valdespartera´s land was registered as Building Land, Zaragoza City Council drew up the corresponding Partial Plan for the town planning development of such land. The Partial Plan, eventually approved by the Corporation on November 29 2002, establishes a building capacity of 9,687 flats (97% of which belong to council) as well as tertiary uses.

24 Parcel/ 89 Sector makes part of this plan and is composed of three similar blocks of buildings, sharing the garage. The building under study is called the Southern Block. This building comprises six floors with a total habitable floor space of 4458,6 m^2, 60 apartments and 230 occupants.

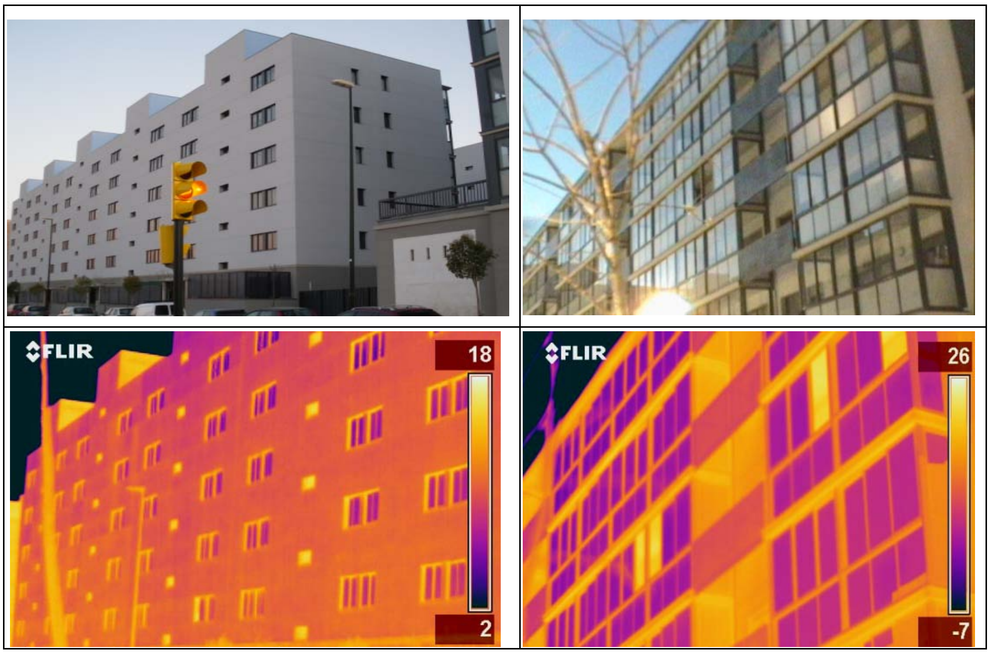

Figura 1.6. From left to right, up and down: North façade; South façade; thermographic picture of North and South façades.

The building includes two basement floors of 1527 m2, one more with respect to Parcel 12. The ground floor has 10 apartments (5 dwellings of approximately 80 m^2 and another 5 of 60 m^2). Plants 1 to 5 are similar, and consist of 10 apartments of 80 m2, while 6th floor includes the common boiler room.

Flour	Area (m^2)	Height (m)	Volume (m^3)
Basement - 2	1527,21	2,65	4047,11
Basement - 1	1527,21	3,85	5879,76
Ground Flour	925,45	2,65	2452,44
1st Flour	925,45	2,5	2313,62
2nd Flour	925,45	2,5	2313,62
3th Flour	925,45	2,5	2313,62
4th Flour	925,45	2,5	2313,62
5th Flour	925,45	2,5	2313,62
TOTAL	8607,12	21,65	23947,41

Tabla 1.16. Building's description,

2.2 METHODOLOGY

The *functional unit* considered is the Southern Block of Parcel 24/ Valdespartera during 50 years lifespan, considering design conditions, thermal comfort, etc,, present in Spain in 2006 (year of construction),

The selection of *impact categories* analyzed in this study considers the current energy and environmental concerns at European level, In this regard it is worth recalling the objectives set by the European Union by 2020: reducing emissions by at least 20% below 2005 levels, 20% energy savings over consumption of 2005 and increased participation of renewable energy in primary energy consumption from the current 7% to 20% in 2020,

Therefore, the impact categories used are embodied energy (expressed in equivalent Megajoules: MJ-Eq) calculated according to the impact assessment methodology "Cumulative Energy Demand (CED)" and global warming potential (in kilograms carbon dioxide equivalent: kg CO2-Eq) calculated according to the methodology of the Intergovernmental Panel on Climate Change (IPCC),

The CED methodology has been used since the 70s to analyze energy systems, The CED provides total energy demand, expressed in terms of primary energy associated with the entire life cycle of a product or service, The CED approach distinguishes between primary renewable energy (hydro, biomass, wind, solar and geothermal) and non-renewable primary energy (fossil and nuclear), For this study we used the version 1,05 of the CED method implemented in the SimaPro v 7,1,8,

The greenhouse effect caused by anthropogenic emissions associated with human activities may be expressed in terms of their global warming potential of CO2 equivalent, For this study we used 1,01 version of the method implemented in SimaPro v 7,1,8, based on the characterization factors given by IPCC for 2007 and taking into account a time horizon of 100 years ,

All data related to electricity consumption have been previously adapted to the *electric mix of production* in Spain in 2008, as shown in the next table,

Ecoinvent Module	kWh
Electricity, hard coal, at power plant/ES U	0,217
Electricity, lignite, at power plant/ES U	0,03
Electricity, oil, at power plant/ES U	0,02
Electricity, natural gas, at power plant/ES U	0,232
Electricity, industrial gas, at power plant/ES U	0,003
Electricity, hydropower, at power plant/ES U	0,11
Electricity, hydropower, at pumped storage power plant/ES U	0,01
Electricity, nuclear, at power plant/ES U	0,20
Electricity, production mix PV, at power plant/ES U	0,002
Electricity, at wind power plant/ES U	0,1
Electricity, at cogen ORC 1400kWth, allocation exergy/ES U	0,01
Electricity, at cogen with biogas engine, allocation exergy/ES U	0,006
Electricity, natural gas, allocation exergy, at micro gas turbine 100kWe/ES U	0,06

Tabla 1.17. Technosphere resources for the production of 1 kWh in Spain,

The reference *database* used for the LCA is Ecoinvent v2,0 (2007) and the *software* SimaPro v7,1,8; eventhough this application is not specifically designed to carry out LCA in buildings, the quantity and quality of databases and impact assessment methodologies incorporated make it suitable for this purpose,

The LCA is performed using a series of *simplifications* as specified:

- Initially we considered 4 stages in the life cycle of a building: production, construction, use and end of life according to the recommendations made by the Technical Committee "Sustainability of construction works" CEN / TC 350, With this method only production and use are taked into account,

- Production stage is limited to the manufacture of building structure and building envelope,
- Building use phase is limited to the final energy consumption required for heating, cooling, DHW and lighting,

Finally, the software used to estimate *final energy demand and consumption* is CALENER VYP, This software is the official tool developed in Spain for the Energy Efficiency Certification of buildings according to RD47/2007 (see: http://www,mityc,es/energia/desarrollo/EficienciaEnergetica/CertificacionEnergetica/ProgramaCalener), CALENER VYP calculation engine uses a dynamic simulation hourly basis similar to LIDER, both fully developed at the University of Sevilla (Spain),

CALENER VYP calculates the energy efficiency rating from A to G and provides some results such as the energy demand for heating and cooling based on the definition of the building envelope and the local climate, Then it estimates the final energy consumption for heating, cooling and hot water, calculated as the ratio of energy demand and the seasonal efficiency of facilities, This efficiency calculation is based on the atmospheric conditions and performance curves of these facilities, which are mathematically modeled on the basis of certain variables, such us external temperature and workload,

The CALENER calculation engine is validated through tests of the International Energy Agency (BESTEST-Building Energy Simulation Test), Therefore, the results are generally in the same order of magnitude than those obtained with other existing tools for building energy simulation,

To confirm this point, the energy demand is also calculated through the commercial application DesignBuilder, The results are similar as shown in the table below,

DesignBuilder		Lider	
Heating kWh/m^2 year	Cooling kWh/m^2 year	Heating kWh/m^2 year	Cooling kWh/m^2 year
11,21	12,25	12,7	11,9

Tabla 1.18. Energy demand for heating and cooling,

According to the Working Project, solar heat input is able to cover 40% of hot water annual consumption, This contribution is deducted from the final energy consumption associated to DHW,

In terms of final energy consumption for lighting, the calculation has been done considering the power of lamps installed in each room and the estimation of working time, It has been considered 2,5 h / day of operation for living room, 1 h / day for kitchen and bathroom and 0,5 h / day for other rooms, In the common areas 4 hours per day for the garage, 3 h / day for entrances, 1 h / day for stairs and 0,5 h / day for the boiler room,

The final energy consumption for lighting the building is 28,064,3 kWh / year, representing 6,3 kWh / m ^{2} / year with a total of 1403,22 MWh over the lifetime of the building,

2.3INPUT DATA

2.3.1 Production Phase

Structure

We will consider that the building structure is composed of basement retaining walls in the garage and pillars, since other materials making part of basement floor, slabs… are included in the building envelope,

Both pillars and retaining walls are built of reinforced concrete HA-25 N/mm^2, Tmax, 20 mm under NTE-EHS and EHD standards,

	Volume (m^3)	Material	Concrete (t)	Steel (t)	Total (t)
Pillars	87	Reinforced concrete HA-25, 106 kg/m^3 of steel	199,578	9,222	208,800
Garage Pillars	75,9	Reinforced concrete HA-25, 106 kg/m^3 of steel	174,1146	8,0454	182,160
Retaining Walls	522	Reinforced concrete HA-25, 150 kg/m^3 of steel	1174,5	78,300	1252,800
		TOTAL	1548,193	95,567	1643,760

Tabla 1.19. Structure materials

Building Envelope

Working Project includes the composition of different walls, according to this documentation and density specified in LIDER[2] , the weight of the different materials is obtained, Results are shown in the table below,

Enclosure	Surface(m^2)	Material	Volume (m^3)	Density (kg/m^3)	Weight (kg)
Exterior Walls	3272,54	Cork	71,43	115	8213,91
		Lime mortar	10,86	1125	12221,43
		Lightweight clay: 24 cm	621,78	920	572039,26
		Gypsum	32,73	900	29452,82
South Exterior Walls	706,77	Lime mortar	4,59	1250	5742,51
		Lightweight clay: 24 cm	169,62	920	156054,82
		Gypsum	14,14	900	12721,86
Interior Walls	6371,50	Gypsum plasterboard	509,72	900	458748,00
		Brick	892,01	630	561966,30
Slabs	7290	Ceramic tile	63,18	2000	126360,00
		Cement mortar	218,70	1250	273375,00
		Expanded clay slab	2187,00	1090	2383830,00
		Gypsum	145,80	900	131220,00
		“Forel” slab	583,20	1929	1124992,80

[2] Spanish official program to ensure minimum insulation of buildings

Basement Floor	1527,21	Reinforced concrete	229,08	1850	423800,78
Roof	1069,00	Expanded clay slab	320,70	1090	349563,00
		Extruded Polystyrene	53,45	38	2031,10
		Gypsum	21,38	900	19242,00
			Surface (m^2)	Density (kg/m^2)	Weight (kg)
Doors	806,40	Wood made interior doors	806,40	27,60	22256,64
Windows	2019,37	Double glass climalit 5-10-6	664,29	27,50	18268,04
		Simple glass 5 mm (green house)	1153,14	12,50	14414,22
		Aluminium frame (10%)	201,94	50,70	10238,19
				TOTAL WEIGHT (kg)	6716752,66

Tabla 1.20. Inventory of materials belonging to the building envelope,

The total weight of the building envelope is 6716,75 tons, The concrete-based materials, mainly used in floors and roofs, account for the 63,8% of total weight, followed by the grave, representing 10,8% of total weight,

To assess the impact of these enclosures, Ecoinvent inventories v2,0 (2007) have been adapted modifying predefined values, In "Farlap" slab the amount of steel present in the compression layer and joists accounts for 2,5 kg/m^2 which, considering a thickness of 0,3 m, makes 8,3 kg $steel/m^3$, In the basement floor the amount of steel present in the reinforced concrete is 60 kg/m^3,

2.3.2 Use Phase

Within this section final energy consumption needed to meet heating, cooling, DHW and lighting demand is calculated, as well as the contribution of renewable energy systems,

	Average maintained illuminance (lm/m^2)	Surface (m^2)	Installed capacity (W)	Final Energy (kWh/year)
Bedroom	150	1963,6	24545,0	4479,5
WC-Bathrooms	150	363,1	2396,2	874,6
Lounge	300	1117,4	14749,0	13458,5
Hall	100	419,4	1845,3	336,8
Kitchen	150	531,4	1245,4	454,6
Stairs	100	562,4	2474,3	903,1
Portal	200	236,9	2084,3	2282,3
Parking	75	3064,0	3590,6	5242,3
Boiler room	100	40,7	179,1	32,7
TOTAL	-	8298,7	53109,2	28064,3

Tabla 1.21. Calculation of the final energy consumption for lighting

The following table shows all final energy consumption including solar contribution,

	kWh/m^2 year*	kWh/occupant year	kWh/year	kWh
Heating	14,60	283,02	65095,56	3254778,00
Cooling	7,00	135,70	31210,20	1560510,00
DHW	8,40	162,84	37452,24	1872612,00
Lighting	6,29	122,02	28064,30	1403214,88
SUBTOTAL	36,29	703,58	161822,30	8091114,88
Solar thermal contribution	-4,20	-81,42	-18726,12	-936306,00
TOTAL	32,09	622,16	143096,18	7154808,88

*Tabla 1.22. Final energy consumption of the building, * Climatized surface is considered*

To assess the impact of the consumption of cooling and lighting it has been used Ecoinvent v2,0 (2007) inventories for low voltage power supply, while consumption for heating, hot water and solar thermal input are based on the inventories for gas consumption in boilers,

2.4RESULTS

2.4.1 Gross energy requirement,

The following table presents the key ratios related to the gross energy requirement in the building,

	Total Gross Energy Requirement			
	MJ-Eq	MJ-Eq/year	MJ-Eq/occupant year	MJ-Eq/m^2 year
Building production	48.975.542,50	979.510,85	4.258,74	219,69
Building use	52.206.130,20	1.044.122,60	4.539,66	234,18
TOTAL	101.181.672,70	2.023.633,45	8.798,41	453,87

Tabla 1.23. Gross energy requirement ratios in the stages of the building life cycle

The primary energy is mainly from fossil fuels (78%) and nuclear (15%), The contribution of renewable energies reaches only 8%,

Below it is a detailed description of the contribution of the different aspects analyzed in the two stages of life of the building (production & use) to the gross energy requirement,

			Primary Energy Requirement	
			GJ-Eq	%
Building Production	Construction Materials	Structure	3.167,2	3,1%
		Enclosures	45.808,3	45,3%
		- Walls	4.717,5	4,7%

		- Interior walls	4.285,4	4,2%
		- Slabs	31.008,1	30,6%
		- Roofs	2.140,8	2,1%
		- Windows and doors	3.656,5	3,6%
		SUBTOTAL PRODUCTION	***48.975,5***	*48,4%*
Building use	Operation	Final Energy Consumption	52.206,1	51,6%
		- Heating consumption	14.001,6	13,8%
		- Cooling consumption	17.995,2	17,8%
		- DHW consumption	8.055,7	8,0%
		- Lighting consumption	16.181,4	16,0%
		- Renewable energy contribution	-4.027,9	-4,0%
		SUBTOTAL USE	***52.206,1***	*51,6%*
TOTAL			**101.181,6**	-

Tabla 1.24. Gross energy requirement in the stages of the building life cycle

Finally, the following table breaks down the impact on primary energy associated with the manufacture of various building materials (production phase), It is remarkable the high impact of the concrete used in slabs and galvanized plate that covers the building's exterior walls,

Enclosures	Material	GJ-Eq	%
Structure	Concrete, normal, at plant/CH U reinforced pilares *	335,52	0,7%
	Concrete, normal, at plant/CH U reinforced pilares *	292,71	0,6%
	Concrete, normal, at plant/CH U reinforced muros contenc *	2538,99	5,2%
Exterior Walls	Cork slab, at plant/RER U *	418,84	0,9%
	Lime mortar, at plant/CH U*	44,17	0,1%
	Light clay brick, at plant/DE U *	3139,20	6,4%
	Gypsum plaster board, at plant/CH U*	174,66	0,4%
	Cement mortar, at plant/CH U *	8,82	0,0%
	Light clay brick, at plant/DE U *	856,39	1,7%
	Gypsum plaster board, at plant/CH U*	75,44	0,2%
Interior Walls	Gypsum plaster board, at plant/CH U*	2720,40	5,6%
	Brick, at plant/RER U *	1565,05	3,2%
Slabs	Ceramic tiles, at regional storage/CH U *	1879,22	3,8%
	Cement mortar, at plant/CH U *	419,73	0,9%
	Lightweight concrete block, expanded clay, at plant/CH U**	12536,85	25,6%
	Gypsum plaster board, at plant/CH U*	778,14	1,6%
	Lightweight concrete block, polystyrene, at plant/CH U**	14716,24	30,0%
	Concrete, sole plate and foundation, at plant/CH U**	677,92	1,4%
Roof	Lightweight concrete block, expanded clay, at plant/CH U**	1838,39	3,8%
	Polystyrene, extruded (XPS), at plant/RER U*	188,26	0,4%
	Gypsum plaster board, at plant/CH U*	114,11	0,2%
Windows & doors	Glazing, simple, U=5,7 W/m2K, at plant/RER U*	253,74	0,5%
	Glazing, double (2-IV), U<1,1 W/m2K, at plant/RER U*	312,37	0,6%
	Window frame, aluminium, U=1,6 W/m2K, at plant/RER U *	1656,06	3,4%

	Door, inner, wood, at plant/RER U*	1434,34	2,9%

Tabla 1.25. Gross energy requirement for the production of the building materials

2.4.2 Global Warming Potential,

The following table presents the key ratios related to the global warming potential of the building,

	Global warming potential			
	kg CO_2-Eq	kg CO_2-Eq /year	kg CO_2-Eq /occupant year	kg CO_2-Eq /m^2 year
Building production	3.483.309,39	69.666,19	302,90	15,63
Building use	2.678.416,69	53.568,33	232,91	12,01
TOTAL	6.161.726,08	123.234,52	535,80	27,64

Tabla 1.26. Global warming potential ratios in the stages of the building life cycle

Below it is a detailed description of the contribution of the different aspects analyzed in the two stages of life of the building (production & use) to the global warming potential,

			Global warming potential	
			t CO_2-Eq	%
Building production	Construction material	Structure	317,9	5,2%
		Enclosures	3.165,3	51,4%
		- Walls	-24,1	-0,4%
		- Interior walls	279,6	4,5%
		- Slabs	2.635,2	42,8%
		- Roofs	181,4	2,9%
		- Windows and doors	93,2	1,5%
		SUBTOTAL PRODUCTION	***3.483,3***	***56,5%***
Building use	Operation	Final Energy Consumption	2.678,4	43,5%
		- Heating consumption	800	13,0%
		- Cooling consumption	867,9	14,1%
		- DHW consumption	460,3	7,5%
		- Lighting consumption	780,4	12,7%
		- Renewable energy contribution	-230,1	-3,7%
		SUBTOTAL USE	***2.678,4***	***43,5%***
		TOTAL	**6.161,7**	**-**

Tabla 1.27. Global warming potential in the stages of the building life cycle

Again, this table brakes down the global warming potential associated with the manufacture of various building materials,

Cerramiento	Material	t CO_2-Eq	%
Enclosure Structure	Concrete, normal, at plant/CH U reinforced pilares *	36,19	1,0%
	Concrete, normal, at plant/CH U reinforced pilares *	31,57	0,9%

	Concrete, normal, at plant/CH U reinforced muros contenc *	250,18	7,2%
Exterior Walls	Cork slab, at plant/RER U *	-5,64	-0,2%
	Lime mortar, at plant/CH U*	7,66	0,2%
	Light clay brick, at plant/DE U *	-32,82	-0,9%
	Gypsum plaster board, at plant/CH U*	10,10	0,3%
	Cement mortar, at plant/CH U *	1,19	0,0%
	Light clay brick, at plant/DE U *	-8,95	-0,3%
	Gypsum plaster board, at plant/CH U*	4,36	0,1%
Interior Walls	Gypsum plaster board, at plant/CH U*	157,29	4,5%
	Brick, at plant/RER U *	122,36	3,5%
Slabs	Ceramic tiles, at regional storage/CH U *	101,60	2,9%
	Cement mortar, at plant/CH U *	56,73	1,6%
	Lightweight concrete block, expanded clay, at plant/CH U**	1052,14	30,2%
	Gypsum plaster board, at plant/CH U*	44,99	1,3%
	Lightweight concrete block, polystyrene, at plant/CH U**	1315,51	37,8%
	Concrete, sole plate and foundation, at plant/CH U**	64,25	1,8%
Roof	Lightweight concrete block, expanded clay, at plant/CH U**	154,29	4,4%
	Polystyrene, extruded (XPS), at plant/RER U*	20,52	0,6%
	Gypsum plaster board, at plant/CH U*	6,60	0,2%
Windows and doors	Glazing, simple, U=5,7 W/m2K, at plant/RER U*	11,98	0,3%
	Glazing, double (2-IV), U<1,1 W/m2K, at plant/RER U*	15,15	0,4%
	Window frame, aluminium, U=1,6 W/m2K, at plant/RER U *	97,19	2,8%
	Door, inner, wood, at plant/RER U*	-31,13	-0,9%

Tabla 1.28. Global warming potential for the production of the building materials

2.5ANNEX: SIMPLIFIED VS DETAILED METHOD

In section 1,3 the simplified method is presented assuming the removal of two stages of lifecycle of the building (construction and end of life) and some aspects related with the two stages taked into account (production and use), The justification of these decisions is described in this Annex where the results of a detailed method of LCA are presented,

Gross energy requirement

Following figure shows gross energy impact of the four stages of life cycle, It is easy to find out that construction and end of life may be rejected compared with production and use of the building,

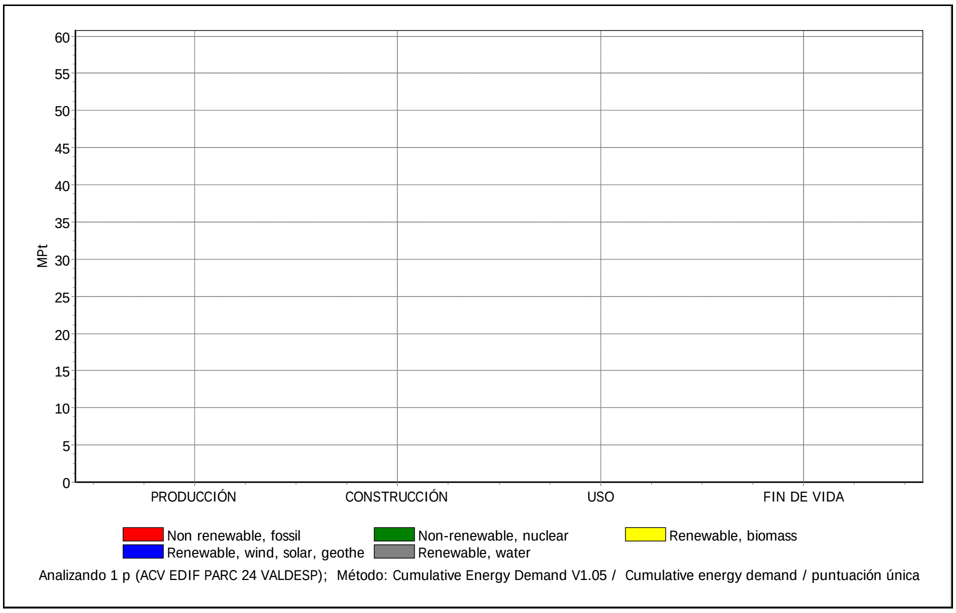

Figura 1.7. Gross energy results considering the four stages of life cycle (production, construction, use and end of life) according to the recommendations made by the Technical Committee "Sustainability of construction works" CEN / TC 350

The following table presents the key ratios related to the gross energy requirement in the building,

	Total Gross Energy Requirement			
	MJ-Eq	MJ-Eq	MJ-Eq	MJ-Eq
Building production	49730962,78	994619,26	4324,43	223,08
Building construction	3075927,14	61518,54	267,47	13,80
Building use	60758689,26	1215173,79	5283,36	272,55
Building end-of-life	2726197,40	54523,95	237,06	12,23
TOTAL BUILDING	116291776,58	2325835,53	10112,33	521,65

Tabla 1.29. Gross energy requirement ratios in the stages of the building life cycle

Below it is a detailed description of the contribution of the different aspects analyzed in the four stages of life of the building to the gross energy requirement,

			Gross Energy Requirement	
			GJ-Eq	%
Building production	Construction materials	Structure	3167,2	2,7%
		Enclosures	45808,3	39,4%
		- Walls	4717,5	4,1%
		- Interior walls	4285,4	3,7%
		- Slabs	31008,1	26,7%
		- Roofs	2140,8	1,8%
		- Windows and doors	3656,5	3,1%
		SUBTOTAL	48975,5	42,1%
	Energy systems	Heating and DHW	395,2	0,3%
		Cooling	245,4	0,2%
		Lighting	9,7	0,0%
		Renewable systems	105,1	0,1%
		SUBTOTAL	755,4	0,6%
		SUBTOTAL PRODUCTION	*49731,0*	*42,8%*
Building construction	Transport plant-building	Construction materials	2730,2	2,3%
		Energy sysstems	0,8	0,0%
		SUBTOTAL	2731,0	2,3%
	On-site construction processes	Machinery energy consumption	321,1	0,3%
		Waste	23,8	0,0%
		SUBTOTAL	344,9	0,3%
		SUBTOTAL CONSTRUCTION	*3075,9*	*2,6%*
Building use	Operation	Final Energy Consumption	52206,1	44,9%
		- Heating consumption	14001,6	12,0%
		- Cooling consumption	17995,2	15,5%
		- DHW consumption	8055,7	6,9%
		- Lighting consumption	16181,4	13,9%
		- Renewable energy contribution	-4027,9	-3,5%
		Water consumption	2504,9	2,2%
		Mobility of occupants consumption	0,0	0,0%
		Wastewater treatment	1553,2	1,3%
		SUBTOTAL	56264,3	48,4%
	Maintenance	Replacement of building materials	3677,8	3,2%
		Replacement of energy systems	816,6	0,7%
		SUBTOTAL	4494,4	3,9%
		SUBTOTAL USE	*60758,7*	*52,2%*
Building end-of-life	Construction materials	Structure	546,0	0,5%
		Enclosures	2176,7	1,9%
		SUBTOTAL	2722,6	2,3%
	Energy systems	Heating and DHW	0,3	0,0%
		Cooling	0,6	0,0%
		Lighting	1,5	0,0%
		Renewable systems	1,2	0,0%

		SUBTOTAL	3,6	0,0%
		SUBTOTAL END-OF-LIFE	*2726,2*	*2,3%*
		TOTAL BUILDING	116291,8	-

Tabla 1.30. Gross energy requirement in the stages of the building life cycle

Global Warming Potential

As in previous section, the impact in global warming potential associated to construction and end of life is very small compared with the construction and use of the building,

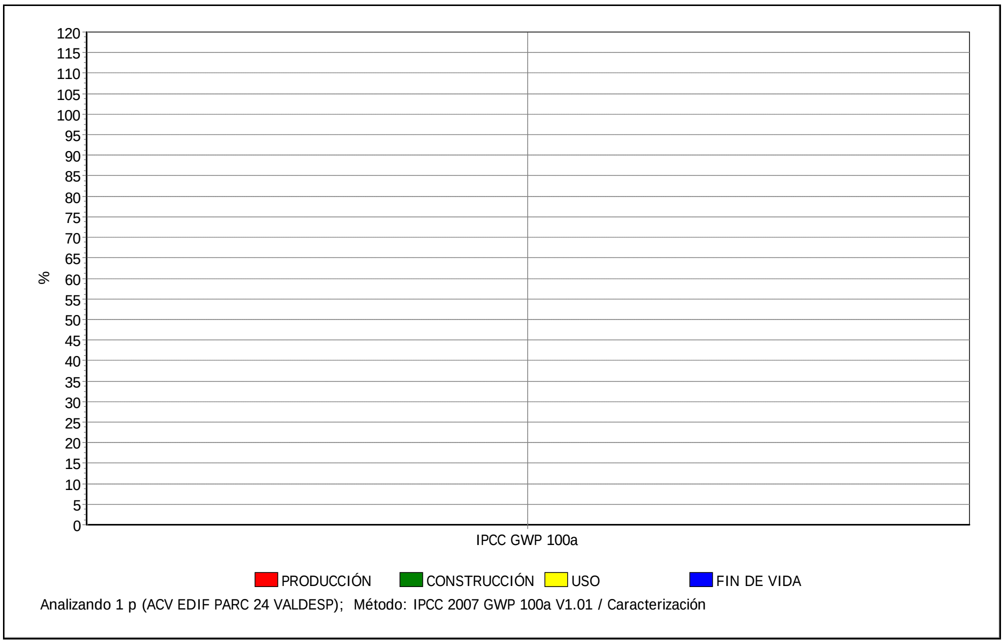

Figura 1.8. Global Warming Potential results considering the four stages of life cycle (production, construction, use and end of life) according to the recommendations made by the Technical Committee "Sustainability of construction works" CEN / TC 350

Key ratios related to the global warming potential of the building are presented bellow,

	Global warming potential			
	kg CO_2-Eq	kg CO_2-Eq /year	kg CO_2-Eq /occupant year	kg CO_2-Eq /m^2 year
Building production	3534241,41	70684,83	307,33	15,85
Building construction	182786,28	3655,73	15,89	0,82
Building use	3106350,75	62127,01	270,12	13,93
Building end-of-life	287401,88	5748,04	24,99	1,29
TOTAL BUILDING	7110780,32	142215,61	618,33	31,90

Tabla 1.31. Global warming potential ratios in the stages of the building life cycle

Next table contains a detailed description of the contribution of the different aspects analyzed in the four stages of life of the building to the global warming potential,

			Global warming potential	
			t CO_2-Eq	%
Building production	Construction materials	Structure	317,94	4,5%
		Enclosures	3165,37	44,5%
		- Walls	-24,09	-0,3%
		- Interior walls	279,65	3,9%
		- Slabs	2635,22	37,1%
		- Roofs	181,40	2,6%
		- Windows and doors	93,19	1,3%
		SUBTOTAL	3483,31	49,0%
	Energy systems	Heating and DHW	22,93	0,3%
		Cooling	21,64	0,3%
		Lighting	0,59	0,0%
		Renewable systems	5,77	0,1%
		SUBTOTAL	50,93	0,7%
	SUBTOTAL PRODUCTION		*3534,24*	*49,7%*
Building construction	Transport plant-building	Construction materials	161,46	2,3%
		Energy sysstems	0,05	0,0%
		SUBTOTAL	161,51	2,3%
	On-site construction processes	Machinery energy consumption	19,74	0,3%
		Waste	1,53	0,0%
		SUBTOTAL	21,28	0,3%
	SUBTOTAL CONSTRUCTION		*182,79*	*2,6%*
Building use	Operation	Final Energy Consumption	2678,42	37,7%
		- Heating consumption	799,99	11,3%
		- Cooling consumption	867,89	12,2%
		- DHW consumption	460,27	6,5%
		- Lighting consumption	780,41	11,0%
		- Renewable energy contribution	-230,13	-3,2%
		Water consumption	129,96	1,8%
		Mobility of occupants consumption	0,00	0,0%
		Wastewater treatment	148,92	2,1%
		SUBTOTAL	2957,29	41,6%
	Maintenance	Replacement of building materials	94,45	1,3%
		Replacement of energy systems	54,61	0,8%
		SUBTOTAL	149,06	2,1%
	SUBTOTAL USE		*3106,35*	*43,7%*
Building end-of-life	Construction materials	Structure	25,56	0,4%
		Enclosures	199,53	2,8%
		SUBTOTAL	225,09	3,2%
	Energy systems	Heating and DHW	0,04	0,0%
		Cooling	60,76	0,9%
		Lighting	0,38	0,0%
		Renewable systems	1,14	0,0%
		SUBTOTAL	62,31	0,9%

	SUBTOTAL END-OF-LIFE	*287,40*	*4,0%*
TOTAL BUILDING		7110,78	-

Tabla 1.32. Global warming potential in the stages of the building life cycle

As we can see, both Gross Energy and Global Warming Potential Analysis point out the fact that in the use stage, the highest impact is associated to the energy consumption for cooling, lighting and heating, while in the production stage the enclosures manufacturing, especially the slabs and building's walls, cause the most relevant impact, This is the reason why these are the only stages considered in the simplified method.

3 CASE STUDY 3: CIRCE BUILDING – ZARAGOZA (SPAIN)

3.1BUILDING DESCRIPTION

CIRCE building is new house of CIRCE School of Energy and Research Institute of the UNIVERSIDAD DE ZARAGOZA. From the very beginning CIRCE building has been projected as a model of bio-construction and sustainability in order to establish scientific bases for the development of Zero Emissions Buildings.

So CIRCE Building is an R&D project and we plan to experiment, interact and learn from it. A Zero Emission Building is more ambitious than a Zero Energy Building, since LCA methodology is used in order to estimate and compensate the emissions associated with the construction, use, maintenance and final disposition of the building. Our aim is also to extend and promote energy efficiency in the building sector, developing an Innovative Centre for the Transfer of the Research Results and the Demonstration in-situ of the more advanced energy technologies.

The building is located in Actur Campus of the University of Zaragoza and will be financed by the University and the Aragón Regional Government, by means of FEDER Funds for Scientific and Technological Infrastructure. The total budget is 2.4 Million Euros.

Figura 1.9. South current view of CIRCE Building.

The construction started in November 2008 and it has been nearly finished by October 2009; just the furniture is missing at the moment and we expect it will be ready in a couple of months.

The total volume is about 9500 cubic meters; the built surface is about 2000 square meter; and the useful surface is 1.700 square meter distributed in two floors.

As you can see in the images, there are three main elements: The central Core, the Offices and the Labs. The Labs Area was designed as a rectangular barrier against the cold north-west wind called “Cierzo”.

Figura 1.10. From left to right, up and down: General view of the building project; Building section; View of constructed building from south façad ;First flour slab in construction.

CIRCE building includes a number of bio-climatic and bio-construction techniques as follows:

- Use of natural materials such as natural cork, wood, and natural paintings.
- Exterior side of the main walls composed of Light weight clay blocks.
- Green roof with native plants reducing inner temperature oscillations.
- Greenhouse in South façade to preheat the inner air in winter. In summer, vertical windows can be opened and the top windows are shaded from the sun by special blinds.
- Double glazing .with 16mm air chamber
- Optimized insulation for each thermal zone of the building using natural cork, expanded clay, etc.
- Wood frames in doors and windows.
- Flooring composed of natural linoleum in offices and corridors, and local natural stone in greenhouse and main entrance.

3.2METHODOLOGY

The *functional unit* considered is the Circe building during 50 years lifespan, considering design conditions, thermal comfort, etc.. present in Spain in 2009 (year of construction).

The selection of *impact categories* analyzed in this study considers the current energy and environmental concerns at European level. In this regard it is worth recalling the objectives set by the European Union by 2020: reducing emissions by at least 20% below 2005 levels, 20% energy savings over consumption of 2005 and increased participation of renewable energy in primary energy consumption from the current 7% to 20% in 2020.

Therefore, the impact categories used are embodied energy (expressed in equivalent Megajoules: MJ-Eq) calculated according to the impact assessment methodology "Cumulative Energy Demand (CED)" and global warming potential (in kilograms carbon dioxide equivalent: kg CO2-Eq) calculated according to the methodology of the Intergovernmental Panel on Climate Change (IPCC).

The CED methodology has been used since the 70s to analyze energy systems. The CED provides total energy demand, expressed in terms of primary energy associated with the entire life cycle of a product or service. The CED approach distinguishes between primary renewable energy (hydro, biomass, wind, solar and geothermal) and non-renewable primary energy (fossil and nuclear). For this study we used the version 1.05 of the CED method implemented in the SimaPro v 7.1.8.

The greenhouse effect caused by anthropogenic emissions associated with human activities may be expressed in terms of their global warming potential of CO2 equivalent. For this study we used 1.01 version of the method implemented in SimaPro v 7.1.8, based on the characterization factors given by IPCC for 2007 and taking into account a time horizon of 100 years .

All data related to electricity consumption have been previously adapted to the *electric mix of production* in Spain in 2008, as shown in the next table.

Ecoinvent Module	kWh
Electricity, hard coal, at power plant/ES U	0.217
Electricity, lignite, at power plant/ES U	0.03
Electricity, oil, at power plant/ES U	0.02
Electricity, natural gas, at power plant/ES U	0.232
Electricity, industrial gas, at power plant/ES U	0.003
Electricity, hydropower, at power plant/ES U	0.11
Electricity, hydropower, at pumped storage power plant/ES U	0.01
Electricity, nuclear, at power plant/ES U	0.20
Electricity, production mix PV, at power plant/ES U	0.002
Electricity, at wind power plant/ES U	0.1
Electricity, at cogen ORC 1400kWth, allocation exergy/ES U	0.01
Electricity, at cogen with biogas engine, allocation exergy/ES U	0.006
Electricity, natural gas, allocation exergy, at micro gas turbine 100kWe/ES U	0.06

Tabla 1.33. Technosphere resources for the production of 1 kWh in Spain.

The reference *database* used for the LCA is Ecoinvent v2.0 (2007) and the *software* SimaPro v7.1.8; eventhough this application is not specifically designed to carry out LCA in buildings, the quantity and quality of databases and impact assessment methodologies incorporated make it suitable for this purpose.

The LCA is performed using a series of *simplifications* as specified:

- Initially we considered 4 stages in the life cycle of a building: production, construction, use and end of life according to the recommendations made by the Technical Committee "Sustainability of construction works" CEN / TC 350. With this method only production and use are taked into account.
- Production stage is limited to the manufacture of building structure and building envelope.
- Building use phase is limited to the final energy consumption required for heating, cooling, DHW and lighting.

Finally, the software used to estimate *final energy demand and consumption* is CALENER GT. This software is the official tool developed in Spain for the Energy Efficiency Certification of Office and Commercial buildings according to RD47/2007 (see: http://www.mityc.es/energia/desarrollo/EficienciaEnergetica/CertificacºionEnergetica/ProgramaCalener). CALENER VYP calculation engine uses a dynamic simulation called DOE 2.2 v4.2a.

CALENER GT calculates the energy efficiency rating from A to G and provides some results such as the energy demand for heating and cooling based on the definition of the building envelope and the local climate. Then it estimates the final energy consumption for heating, cooling, lighting and hot water, calculated as the ratio of energy demand and the seasonal efficiency of facilities. This efficiency calculation is based on the atmospheric conditions and performance curves of these facilities, which are mathematically modeled on the basis of certain variables, such us external temperature and workload.

The CALENER calculation engine is validated through tests of the International Energy Agency (BESTEST-Building Energy Simulation Test). Therefore, the results are generally in the same order of magnitude than those obtained with other existing tools for building energy simulation.

To confirm this point, the energy demand is also calculated through the commercial application TSBI (Danish Building Institute, Kjeld Johnsen & Karl Grau, 1994). The results are similar as shown in the table below.

TSBI		CALENER GT	
Heating kWh/m^2 year	Cooling kWh/m^2 year	Heating kWh/m^2 year	Cooling kWh/m^2 year
27,92	7,51	27,33	4,38

Tabla 1.34. Energy demand for heating and cooling.

To assess the impact of building materials have adapted some Ecoinvent inventories v2.0 (2007) to fit existing materials. For concrete, steel weight is 80 kg/m3, Compacted Gravel Basement is comoposed of 60% of rounded gravel, 15% sand and 25% clay. For some materials not available in Ecoinvent, other databases have been used. For example, natural linoleum data have been extracted from IVAM v 4.06 (2004) and IDEMAT (2001).

In terms of the impact caused by the fabrication of energy appliances to supply heating, DHW, cooling, renewable energies and lighting, again Ecoinvent inventories v2.0 (2007) have been used with the following approaches:

Heating and Domestic Hot Water

- Viessmann condensing boiler, 160 kW nominal heating power with a combustion efficiency of 98%.
- DHW electric tank of 4 kW with a volume of 80 liters.

We assume the impact of a gas boiler is similar to a diesel boiler and apply a scale factor of 0,13 in order to adjust the real volume of the tank to volume of tanks included in Ecoinvent v2.0 (2007).

Cooling

- CLIVET WRHN-202 geothermal heat pump with 54,8 Kw nominal cooling capacity. which runs through electric compressor with a yield in cold mode (EER) of 4.5. Additionally, this pump can also be used as heating service support (66.4 kW).

We again apply a scale factor of 5,5 to adjust the available cooling power of the equipments present in Ecoinvent v2.0 (2007).

Renewable Energies

- PV: Following table includes the different PV technologies that will be integrated in the new building.

Brand	Model	Technology	Power per unit (Wp)	Voc (V)	Isc (A)	Surface per unit (m^2)	Rendimiento (%)	Units	Total Power (kWp)
Wurth	WS 11007/75	CIS	75	22	5,19	0,73	10,56	10	0,75
Kanela	GEA 60	Silicio amorfo	60	91,8	1,19	0,95	6,39	12	0,72
Solarfun	120-18	Policristalino	120	22	7,37	1,01	15	8	0,96
Solarfun	080-18	Mono-cristalino	80	21,8	5	0,67	15,9	8	0,64
Solarwind	MSW 100/40	Bifacial mono-cristalino	140	25	5,5	0,89	15	10	1,4
Unisolar	ES-124	Silicio amorfo, triple capa	124	42	5,1	1,95	6,36	7	0,868
							TOTAL	55	5,338

Tabla 1.35. PV panels projected to be installed in the building.

- Solar thermal: 4 high efficiency vacuum pipe water solar heaters of VIESSMAN VITOSOL 200 of 3 m3 each.

- Eolic: small wind-turbine BORNAY INCLIN 6000 of 6 Kw. A scale factor of 0,2 was used to introduce the available data of the smallest wind-turbine in Ecoinvent v2.0 (2007).

Lighting

This study includes interior and exterior lighting of the building. The necessary number of lamps was obtained from the working project as follows:

		Power (W)	Installed lamps
GROUND FLOOR	Exterior lamps 80 W	1840	23
	"Massana" Lamp 80W	1120	14
	Fluorescent lamps 12x 58W	2505,6	43
	Compact lamp appliance 26 W	1300	50
	Compact lamp 2x26 W	1768	68
	Incasdencent lamp 60 W	1560	26
	Fluorescent lamps 2x36 W l	10368	288
	Fluorescent lamps 2x36 W	1166,4	32
	Fluorescent lamps 2x58 W	10440	180
	Emergency lamps	150	3
	TOTAL GROUND FLOOR	32218	727
FIRST FLOOR	Compact lamp appliance 26 W	624	24
	Compact lamp appliance 36W	252	7
	Compact lamp 2x26 W	520	20
	Incandescent lamp 60 W	720	12
	Fluorescent lamps 2x36 W	8553,6	238
	Fluorescent lamps 2x58 W	1252,8	22
	Fluorescent lamps 2x36 W	388,8	11
	Ceiling lamps 100W (20)	2000	20
	Emergency lamps	300	6
	TOTAL FIRST FLOOR	14611,2	360
TOTAL POWER		46829,2	1087

Tabla 1.36. Lamps installed in the building.

Since Ecoinvent 2.0 (2007) does only include impact data for low consumption and incandescent lamps; then we assume that the impact of halogen and incandescent lamps are similar, and same with fluorescent and low consumption technologies.

3.3INPUT DATA

3.3.1 Production Phase

Due to the geometric complexity of the building, the calculation of the volume/weight of each material of the building (including envelops and structure) is based on the budget included in the Working Project.

These data were filtered and grouped, introducing the materials density obtained from CALENER GT program. The results obtained after this process are shown in the table below.

Tipo de material	Material	Volume (m^3)	Density (kg/m^3)	Weight (kg)
Reinforced Concrete	Reinforced concrete	1.026,33	1.700	1.744.762,70
	Concrete (no iron)	175,41	1.525	272.114,03
	Cement	-	-	127.930,96
	Lime	-	-	71.999,00
	Compacted Gravel Basement	-	-	10.427.596,00
	Glue mortar	0,96	1.250	1.195,12
	Lime mortar	130,73	1.250	163.417,20
	Cement mortar	0,01	1.250	12,50
	Gravel	62,52	1.450	125.210,00
	Sand	192,98	2.000	1.410.034,00
	Soil	1.626,38	2.000	3.252.800,80
	Expanded clay	70,70	538	38.038,75
	Polypropylene granúlate	-	-	43,99
Isolants	Cork granúlate	-	-	24.993,42
	Cork slab	44,39	115	5.105,33
	Wood wool	42,28	50	2.113,86
	Expanded clay	414,53	538	223.016,60
Metals	Zinc	0,66	7.200	4.740,66
	Steel	-	-	69.668,75
	Rolled steel	-	-	8.672,98
	Steel tubes	-	-	696,60
	Steel nails	-	-	834,02
Wood	Pannel OSB	21,90	600	13.139,51
	Pine Wood	30,39	570	17.324,29
	Glued laminated timber	116,97	550	64.333,50
Envelops	Gypsum plasterboard	3,51	900	3.412,23
	Ceramic tiles	5,30	2.000	10.598,95
	Lime stone	2,80	1.895	5.302,97
	Natural Linoleum	1,70	1.200	2.040,42
	EPDM	2,83	1.150	3.257,41
	Geotextil Sheets	-	-	940,91
	Kraft paper	-	-	78,82
	Brick	339,93	1.220	414.711,75
	Light brick	73,23	920	67.368,23

	Lightweight clay	365,93	910	332.997,82
		Surface (m^2)	Density (kg/m^2)	Weight (kg)
Windows and Doors	Wood frame in windows (20% surface, except for the greenhouse with a 30%)	60,31	80,20	4.836,58
	Simple glass (includes 6+6 with no air chamber in greenhouse)	150,31	12,50	1.878,90
	Double glass	109,21	27,50	3.003,22
	Wood doors	121,11	27,60	3.342,64
	Wood-glass doors	45,47	36,50	1.659,66
	Steel doors	42,30	62	2.622,60
	Steel-glass doors	33,14	58	1.922,12
TOTAL WEIGHT (kg)				18.929.769,79

Tabla 1.37. Inventory of materials belonging to the building envelope and structure.

The total weight of the building envelope is 18929,77 tons. The Compacted Gravel Basement is 55.1% of total weight, followed by 17.2% of soil and 9.2% of concrete.

With regard to the energy appliances, they were introduce as described in previous section 3.2.

3.3.2 Use Phase

Within this section final energy consumption needed to meet heating, cooling, DHW and lighting demand is calculated, as well as the contribution of renewable energy systems.

The following table shows all final energy consumption as means of CALENER GT software.

	kWh/m^2 year	kWh/occupant year	kWh/year	kWh
Heating	27,3	736,3	47.863,7	2.393.185
Cooling	4,3	118,1	7.676,1	383.805
DHW	0,1	2,3	152,7	7.635
Lighting	13,7	371,3	24.128,7	1.206.435
TOTAL	45,5	1.288,0	79.821,2	3.991.060

Tabla 1.38. Final energy consumption of the buiilding.

The production of renewable energy appliances was calculates as follows:

- PV: Climatic data of the location were extracted from Metenorm, and used as input of the PvSyst 4.37 for the simulation of the PV modules. Following table shows the results of this estimation:

Fabricante	Modelo	Tecnología	Producción (kWh/kWp)	Potencia total (kWp)	Producción (kWh/año)
Wurth	WS 11007/75	CIS	1416	0,75	1062
Kaneka	GEA 60	Silicio amorfo	1455	0,72	1047,6
Solarfun	120-18	Policristalino	1301	0,96	1248,96
Solarfun	080-18	Mono-cristalino	1324	0,64	847,36
Solarwind	MSW 100/40	Bifacial mono-cristalino	1324	1,4	1853,6
Unisolar	ES-124	Silicio amorfo, triple capa	1455	0,868	1262,94
				TOTAL	7322,46

Tabla 1.39. Electriciy production of PV Panels.

Total electric production amounts to 7322.46 kWh/year, which covers 16.52% of the electricity consumption of the building.

- Solar Thermal: for the solar thermal production we use F-CHART method (Klein, Duffie and Beckman, 1976-77). With the 4 vacuum tube collectors could be covered 10.48% of energy for heating the building, obtaining an energy saving of 3702 kWh / year.
- Eolic windturbine: considering wind data of the nearest weather station (Zaragoza airport, dist:10Km) and the turbine power curve, the potential electricity to be produced by the wind turbine is 13465 kWh / year.

As a summary:

	Contribution (%)	Use	kWh/m^2 year*	kWh/ occupant and year	kWh/year	kWh/lifespam
Solar thermal	10,48	Heating	2	56	3.702	185.100
PV	16,52	Electricity	4	112	7.322	366.123
Eolic wind turbine	30,37	Electricity	8	207	13.465	673.250
TOTAL	30,68	-	14	376	24.489	1.224.473

Tabla 1.40. Contribution of renewable energy equipments to energy production.

3.4RESULTS

3.4.1 Primary energy requirement.

The following table presents the key ratios related to the Primary energy requirement in the building.

	Total Primary Energy Requirement			
	MJ-Eq	MJ-Eq/year	MJ-Eq/occupant year	MJ-Eq/m^2 year
Building production	17.217.304,02	344.346,08	5297,63	196,63
Building use	15.939.345,60	318.786,91	4904,41	182,04
TOTAL	33.156.649,6	663.132,99	10202,03	378,67

Tabla 1.41. Primary energy requirement ratios in the stages of the building life cycle

Below it is a detailed description of the contribution of the different aspects analyzed in the two stages of life of the building (production & use) to the Primary energy requirement.

			Primary Energy Requirement	
			GJ-Eq	**%**
Building Production	**Construction Materials**	Structure and envelopes	17.217	51,9%
		- Concrete	5.619	16,9%
		- Isolates	1.827	5,5%
		- Metals	2.129	6,4%
		- Wood	3.011	9,1%
		- Envelopes	3.831	11,6%
		- Windows and doors	800	2,4%
		SUBTOTAL PRODUCTION	*17.217*	*51,9%*
Building use	**Operation**	Final Energy Consumption	15.939	48,1%
		- Heating consumption	10.295	31,1%
		- Cooling consumption	4.426	13,3%
		- DHW consumption	88	0,3%
		- Lighting consumption	13.912	42,0%
		- Renewable energy contribution	-12.782	-38,6%
		SUBTOTAL USE	*15.939*	*48,1%*
		TOTAL	33.157	-

Tabla 1.42. Primary energy requirement in the stages of the building life cycle

Finally, the following table breaks down the impact on primary energy associated with the manufacture of various building materials (production phase). It is remarkable the high impact of the concrete used in slabs and galvanized plate that covers the building's exterior walls.

Groups	Material	GJ-Eq	%
Concrete	Concrete, normal, at plant/CH U reinforced INV*	3.347,1	19,4%
	Concrete, normal, at plant/CH U *	258,5	1,5%
	Cement, unspecified, at plant/CH U *	460,4	2,7%
	Limestone, milled, packed, at plant/CH U*	55,5	0,3%
	Gravel, unspecified, at mine/CH U****	585,1	3,4%
	Adhesive mortar, at plant/CH U*	29,5	0,2%
	Lime mortar, at plant/CH U*	590,5	3,4%
	Cement mortar, at plant/CH U *	0,0	0,0%
	Gravel, unspecified, at mine/CH U**	12,6	0,1%
	Sand, at mine/CH U*	84,7	0,5%
	Tierra*	13,1	0,1%
	Expanded clay, at plant/DE U*	179,0	1,0%
	Polypropylene, granulate, at plant/RER U	3,3	0,0%
Isolates	Raw cork, at forest road/RER U	475,4	2,8%
	Cork slab, at plant/RER U *	260,3	1,5%
	Wood wool, u=20%, at plant/RER U *	41,7	0,2%
	Expanded clay, at plant/DE U*	1.049,4	6,1%
Metals	Zinc, primary, at regional storage/RER U*	297,6	1,7%
	Reinforcing steel, at plant/RER U *	1.595,1	9,3%
	Reinforcing steel, at plant/RER U *	1.98,6	1,2%
	Cast iron, at plant/RER U*	17,0	0,1%
	Cast iron, at plant/RER U*	20,4	0,1%
Wood	Oriented strand board, at plant/RER U *	469,3	2,7%
	Sawn timber, paraná pine (SFM), kiln dried, u=15%, at sawmill/BR U	668,5	3,9%
	Glued laminated timber, indoor use, at plant/RER U *	1.873,5	10,9%
Enclosures	Gypsum plaster board, at plant/CH U*	20,2	0,1%
	Ceramic tiles, at regional storage/CH U *	157,6	0,9%
	Limestone, milled, packed, at plant/CH U*	4,1	0,0%
	Linoleum*	103,8	0,6%
	Synthetic rubber, at plant/RER U*	293,7	1,7%
	Glass fibre reinforced plastic, polyester resin, hand lay-up, at plant/RER U*	77,2	0,4%
	Kraft paper, unbleached, at plant/RER U*	4,8	0,0%
	Brick, at plant/RER U *	1.154,9	6,7%
	Brick, at plant/RER U *	187,6	1,1%
	Light clay brick, at plant/DE U *	1.827,4	10,6%
Windows and doors	Window frame, wood, U=1.5 W/m2K, at plant/RER U*	278,9	1,6%
	Glazing, simple, U=5.7 W/m2K, at plant/RER U*	33,1	0,2%
	Glazing, double (2-IV), U<1.1 W/m2K, at plant/RER U*	51,4	0,3%
	Door, inner, wood, at plant/RER U*	215,4	1,3%
	Door, outer, wood-glass, at plant/RER U*	78,9	0,5%
	Door, outer, steel, at plant/RER U*	79,6	0,5%
	Door, outer, steel-glass, at plant/RER U*	62,4	0,4%

Tabla 1.43. Primaryenergy requirement for the production of the building materials

The figure below shows the building materials that have a larger fraction of renewable energy incorporated in their Primaryenergy demand.

Figura 1.11. Materials with larger fraction of reneable energy incorporated.

3.4.2 Global Warming Potential.

The following table presents the key ratios related to the global warming potential of the building.

	Global warming potential			
	kg CO_2-Eq	kg CO_2-Eq /year	kg CO_2-Eq /occupant year	kg CO_2-Eq /m^2 year
Building production	888.678	17.773	273	10
Building use	853.336	17.067	262	9
TOTAL	1.742.014	34.840	536	19

Tabla 1.44. Global warming potential ratios in the stages of the building life cycle

Below it is a detailed description of the contribution of the different aspects analyzed in the two stages of life of the building (production & use) to the global warming potential.

			Global warming potential	
			t CO_2-Eq	**t CO_2-Eq**
Building Production	**Construction Materials**	Structure and envelopes	889	51,0%
		- Concrete	697	40,0%
		- Isolates	30	1,7%
		- Metals	133	7,6%
		- Wood	-83	-4,8%
		- Envelopes	107	6,2%
		- Windows and doors	3,5	0,2%
		SUBTOTAL PRODUCTION	*889*	*51,0%*
Building use	**Operation**	Final Energy Consumption	853	49,0%
		- Heating consumption	588	33,8%
		- Cooling consumption	213	12,3%
		- DHW consumption	4	0,2%
		- Lighting consumption	671	38,5%

		- Renewable energy contribution	-624	-35,8%
		SUBTOTAL USE	*853*	*49,0%*
		TOTAL	1.742	-

Tabla 1.45. Global warming potential in the stages of the building life cycle

Again, this table brakes down the global warming potential associated with the manufacture of various building materials.

Groups	Material	t CO2-Eq	%
Concrete	Concrete, normal, at plant/CH U reinforced INV*	388,5	43,7%
	Concrete, normal, at plant/CH U *	47,6	5,4%
	Cement, unspecified, at plant/CH U *	100,5	11,3%
	Limestone, milled, packed, at plant/CH U*	2,2	0,2%
	Gravel, unspecified, at mine/CH U****	34,6	3,9%
	Adhesive mortar, at plant/CH U*	1,3	0,1%
	Lime mortar, at plant/CH U*	102,4	11,5%
	Cement mortar, at plant/CH U *	0,0	0,0%
	Gravel, unspecified, at mine/CH U**	0,7	0,1%
	Sand, at mine/CH U*	4,9	0,5%
	Tierra*	0,9	0,1%
	Expanded clay, at plant/DE U*	13,5	1,5%
	Polypropylene, granulate, at plant/RER U	0,1	0,0%
Isolates	Raw cork, at forest road/RER U	-42,4	-4,8%
	Cork slab, at plant/RER U *	-3,5	-0,4%
	Wood wool, u=20%, at plant/RER U *	-3,4	-0,4%
	Expanded clay, at plant/DE U*	79,4	8,9%
Metals	Zinc, primary, at regional storage/RER U*	18,2	2,1%
	Reinforcing steel, at plant/RER U *	100,3	11,3%
	Reinforcing steel, at plant/RER U *	12,5	1,4%
	Cast iron, at plant/RER U*	1,0	0,1%
	Cast iron, at plant/RER U*	1,2	0,1%
Wood	Oriented strand board, at plant/RER U *	-12,5	-1,4%
	Sawn timber, paraná pine (SFM), kiln dried, u=15%, at sawmill/BR U	1,3	0,1%
	Glued laminated timber, indoor use, at plant/RER U *	-72,0	-8,1%
Enclosures	Gypsum plaster board, at plant/CH U*	1,2	0,1%
	Ceramic tiles, at regional storage/CH U *	8,5	1,0%
	Limestone, milled, packed, at plant/CH U*	0,2	0,0%
	Linoleum*	-0,8	-0,1%
	Synthetic rubber, at plant/RER U*	8,4	0,9%
	Glass fibre reinforced plastic, polyester resin, hand lay-up, at plant/RER U*	4,6	0,5%
	Kraft paper, unbleached, at plant/RER U*	-0,1	0,0%
	Brick, at plant/RER U *	90,3	10,2%
	Brick, at plant/RER U *	14,7	1,7%

	Light clay brick, at plant/DE U *	-19,1	-2,1%
Windows and doors	Window frame, wood, U=1.5 W/m2K, at plant/RER U*	-2,6	-0,3%
	Glazing, simple, U=5.7 W/m2K, at plant/RER U*	1,6	0,2%
	Glazing, double (2-IV), U<1.1 W/m2K, at plant/RER U*	2,5	0,3%
	Door, inner, wood, at plant/RER U*	-4,7	-0,5%
	Door, outer, wood-glass, at plant/RER U*	2,9	0,3%
	Door, outer, steel, at plant/RER U*	2,1	0,2%
	Door, outer, steel-glass at plant/RER U*	1,7	0,2%

Tabla 1.46. Global warming potential for the production of the building materials