Proceedings of the 8th Conf. Int. Forum Urban., B002, doi:10.3390/ifou-B002.

True Smart and Green City?
8th Conference of the
International Forum on Urbanism

Conference Proceedings Paper

Sustainable Urban Design: A Study in the Emissions Impact Related to the Choice of Urban Typologies and Construction Process

Antonio Ángel Rodríguez Serrano[1], Santiago Porras Álvarez[2,*]

1 Colegio Oficial de Arquitectos de Jaén, C/ Almenas nº 1, Jaén 23001, Spain
2 Department of Architecture, Korea University, Anam Dong, Seongbuk-gu, Seoul 136-713, South Korea

* Author to whom correspondence should be addressed; Tel.: +82-10-8966-5561; Fax: +82-2-921-7947; E-mail: santiago@korea.ac.kr

---

Abstract: While there is an international trend to develop zero or near zero emissions building solutions by 2020, and there are also countless studies on how to optimize building envelope and energy systems to achieve it during the building useful life, few studies take into consideration the enormous impact of the emissions resulting from the urbanization and construction activities, previous to the building use. This research studies in detail the whole emissions balance (and how they can be related or not to the energy efficiency) in a real project of newly built residential clusters in Mancha Real (Jaén, Spain), and the influence resulting from the choice of the different urban typologies. For comparison, single family row houses and low density four floor multi-family housing alternatives have been studied, as they are among most popular housing solutions in Spain. The detailed life-cycle analysis, energy efficiency and emissions have been calculated with the help of a sophisticated and popular commercial software (CYPE). Also the research has been done under the current emissions and energy regulations in Spain, all under the EC general policy framework. Even though the local and very specific character of this study, the methodology can be applied to any other typology and geographical area. After careful choice of building and systems alternatives and their comparison, the study concludes that the major emissions impact and energy cost of the urbanization and building activity occurs during the construction, while the later savings due to the reductions of the building use emissions are very modest in comparison. Therefore, more study is suggested to improve the efficiency in the urban design and typological solutions, and in the construction process itself, for a really reduced emission footprint of the built environment.

Keywords: Economical life cycle analysis of buildings and/or infrastructures from neighborhood to city level, green urban economies, sustainable urban design strategies..

1. Introduction

1.1 Background

While there is an international trend to develop zero or near zero emissions building solutions by 2020, and there are also countless studies on how to optimize building envelope and energy systems to achieve it during the building useful life, few studies take into consideration the enormous impact of the emissions resulting from the urbanization and construction activities, previous to the building use [1]. Even though the real estate bubble burst in Spain has slowed down the frantic construction activity of the 2000‘s, the experts reports are detecting more market confidence which may be encouraging new residential construction to be built in the near future [2, 3, 4]. While the housing before the bubble was designed with criteria from the late 1990‘s, whatever we do from now on must follow at least the 2020 objectives [5], which introduce us in a radically different world of design and building criteria. The debate now is what to do from the perspective of design and planning for more sustainable results, while keeping as possible the character of the local urban culture.

In order to avoid general and abstract discussion, this research tries to draw conclusions from a real case, and studies in detail the whole emissions balance (and how they can be related or not to the energy efficiency) in a project of newly built residential clusters in Mancha Real (Jaen, Spain), and the influence resulting from the choice of the different urban typologies, so conclusions can be derived to enrich the information pool designers have to take decisions for future planning and construction. For comparison, single family row two floor houses and low density four floor multi-family housing alternatives have been studied, as they are among most usual housing solutions in Spain. The study covers the whole urbanization and construction process, plus the use and exploitation of the buildings and urbanization in their first ten years of life.

1.2 Specific objectives of the study

a. To analyze the energy consumption during preparation and construction process, during the periods of production, infrastructure and construction, plus the energy consumption resulting from the usage.
b. To compare two very used urban typologies, single family row housing and low density multi-family housing, in terms of their sustainability especially related to their energy impact and CO_2 emissions.
c. To expand the sustainability study of both typologies over the first ten years of use, which is the legal period for design and construction warrantee in Spain, and the moment in which most renovations and improvements by the owners start taking place.

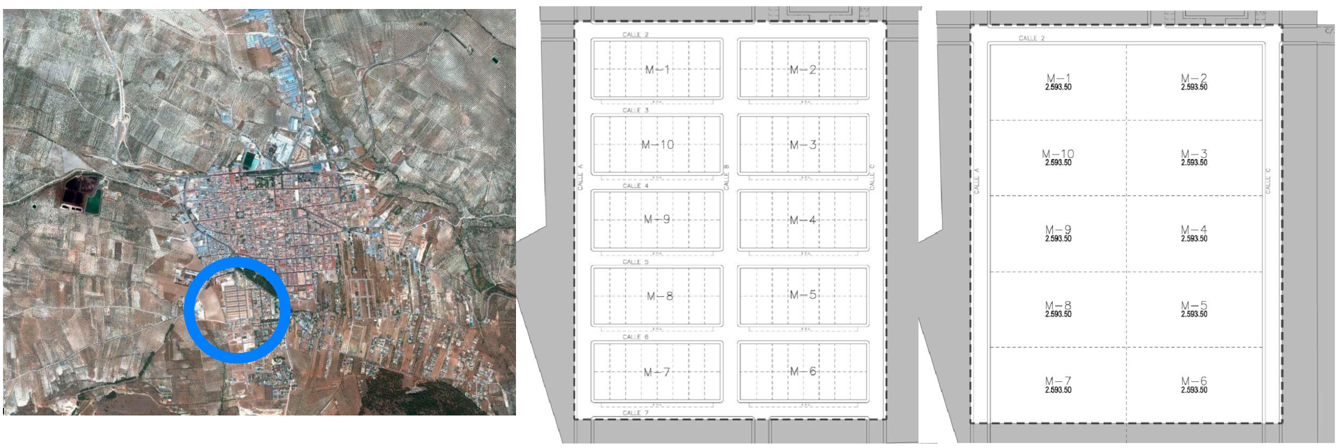
d. To include efficiency comparison as a new decision criterium for urban design decision making, and provide the necessary data for it.
e. To provide conclusions on sustainability criteria regarding typology planning, resource consumption in the urbanization process, land occupancy and provision of free and green spaces, construction and infrastructure costs comparison.
f. It is important to remark that this is a comparative study. Although it has been done with care and rigor, rather than precise calculations of absolute results, a reliable comparison between alternatives has been its main objective.

2. Methods

2.1. Site and urban considerations

The site is a newly developed area in the South of the town of Mancha Real (Jaen, Spain). We concentrated on the housing blocks, letting out of the study the common facilities and park areas. In planning the total area of the polygon is 31,300m^2, with a total of 160 housing units. Although we keep the main guidelines of the existing planning and construction, to make comparison easier we slightly retouched the blocks, to have a total of ten identical clusters of sixteen houses houses each. Since density impact is not a purpose of this study, and to make comparison possible, we kept the same number of housing units. Apart from that, Spanish planning traditionally fixes the housing units per hectare (1Ha = 10,000m^2). To change this parameter is possible, but needs a long legal process as it a basic principle and has to be approved by the autonomic government **[6]**. On the other hand, changing only the building typology while keeping density can be done through a much faster and easier process, and can approved directly by the municipality, so it is realistic to consider this a realisitc alternative in short term planning decisions.

Figure 1. (a) Satellite site view. **(b)** Row houses planning. **(c)** Multi-family housing planning.

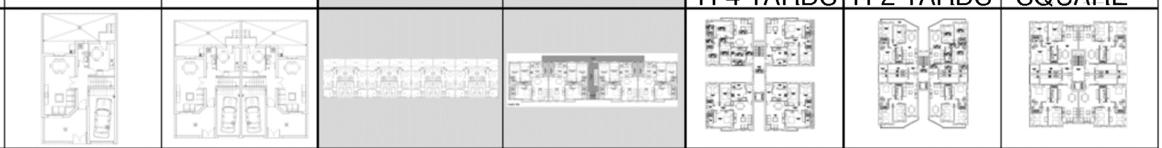


2.2. Typology choices and definition

To establish realistic and clear terms to compare, we started from the existing one family row housing. For future solutions we compared possible alternatives, as isolated housing, paired housing and row housing, concluding this last one is the most efficient (less land use and more compactness, defined as the result of dividing the building volume in cubic meters by the envelope area in square meters). This typology was extremely popular in the 1980's, as it broke the image of impersonal and cheap high rise constructions of post-war and latter economical developing period of the 60's and 70's, providing a more classy, individual and "civilized" dream house. Still most Spanish towns keep in their urban planning considerable areas dedicated to this typology, so the choice is relevant for future planning revisions. This is part of a real project designed in 1999. Part of it was finished between 2000 and 2009, when building activity stopped, leaving some phases on the hold. The alternative studies presented in this paper were elaborated during 2013.

We kept the original design and program, although for this study we updated all the heating/cooling systems as well as envelope quality and performance to today's standards. The unit's size and program is three bedroom and a bath in the upper floor, and living-dining room with kitchen and a small toilet in the lower floor, for a total of 108m^2 of built area. Additionally they all have their parking space of about 19m^2 in the ground floor. This size and program is usual for this kind of housing, in the more economical and affordable versions. We kept it as it is familiar and easy to manage in our calculations, and as for comparison terms size and program have not special relevance. Therefore we did not enter into discussions about innovating typologies (new and more efficient programs for new ways of life) or reducing built area, although it could be the subject for further study. The houses are grouped in pairs of rows of eight units, to configure the planned cluster of sixteen units. We called this Typology A.

Figure 2. Comparison of one family housing (left side) and multi-family housing typologies (right) in terms of their compactness.

	SINGLE FAMILY				MULTI FAMILY		
TYPOLOGY	INIVIDUAL	PAIRED	ROW	OPEN-LINE	H-4 YARDS	H-2 YARDS	SQUARE
PLAN							
FLOORS	2	2	2	4	4	4	4
ENVELOPE (m2)	313,58	421,59	1.863,69	2.283,44	2.756,00	2.202,00	1.919,00
VOLUME (m3)	342,25	675,01	3.571,43	4.726,56	4.944,00	4.932,00	5.232,00
COMPACTNESS	1,09	1,60	1,91	2,07	1,79	2,24	2,73
			ALT A	ALT B			

WE COMPARE ALTERNATIVES A and B, with closest COMPACTNESS

The alternative typology chosen for comparison is a low density, 4 floor multi-family building. To have comparable elements, the housing units are similar in size and program to their counterparts. The car spaces are provided in a common semi-underground parking, half a floor deep, with the ground floor half a floor over ground level. Parking spaces are between 20 to 25m^2 per car. Several alternatives of our floor blocks with four units per floor typologies were studied, as H-shaped block with four open yards, H-shaped block with 2 open yards, compact square block, and open linear block. Among them we finally chose the last one, as it provides cross ventilation and similar orientation of all units for an optimum sunlight planning, and its compactness factor is the closest to the row houses solution we are comparing with. We called this Typology B.

2.3. Study criteria and analytic tools

The research has been done under the current emissions and energy regulations in the Spanish Building Code (CTE, Código Técnico de la Edificación), all under the EC general policy framework. The envelope specifications are according to the CTE documents for energy efficiency **[7]**. Two interior climate systems alternatives have been checked to compare their different impact in both costs and emissions:

I. Air-air heat pump for heating and cooling.
II. a and II.b Biomass heating with radiators with air-water heat pump system for cooling

The sanitary water heating is done by solar panels in the roof, with either electrical back-up by joule effect (I and II.a) or biomass boiler (II.b), depending on the alternatives used for heating. The two alternatives are analyzed in order to find their energy and emissions efficiency classification (with A best classification, and E worst) **[8]**. The life cycle analysis is based in the guidelines of UNE-EN ISO 14040-14044 **[9]**. This study includes the analysis of the lifecycle production period (A1, to A3) and construction period (A4 to A5) . For this period both embodied energy, energy consumption and CO_2 emissions are detailed, together with the economic cost of the urbanization and construction. The following period of the life cycle is the usage (B1) and maintenance (B2). The present study comprises both for a duration of ten years, for the reasons stated in 1.2 above, calculating both the costs of use and maintenance, and the energy consumption along the CO_2 emissions.

The tools used are the life cycle analysis simulation tool included in the complete architectural engineering software package by CYPE Ingenieros S.A **[10]**. With the input of the geographical data and the precise dimensions and specifications of the urbanization, infrastructure and building units and their equipment, the program calculates the economic costs, climatic needs and ecologic burdens for the life cycle up to ten years of use, from an extensive and permanently updated proprietary data base. For the purposes of this study, local data from the region (Central Andalusia) of the year 2012 were used, as with the economic slowdown numbers have barely changed in recent years.

3. Results and Discussion

3.1. Energy and emissions study

With all the data above, the results of the calculations for energy consumption (embodied energy) and carbon emissions of infrastructure and building construction (stages A1 to A5 of LCA), and for the first years of infrastructure and building operation (stages B1 to B2 of LCA) are displayed in table 1 below.

Table 1. Comparative study of Embodied Energy and Carbon Emissions of typologies A and B

TYPOLOGY	**SINGLE-FAMILY** HOUSING		**MULTI-FAMILY** HOUSING	
ALTERNATIVES	TYPOLOGY **A**		TYPOLOGY **B**	
Toral Built Area (m^2)	20.003		22.227	
	per m^2 of building	total	per m^2 of building	total
URBAN-INFRA				
Embodied Energy (kWh)	447	8.941.341	238	5.290.026
CO_2 emissions (Kg)	166	3.320.498	55	1.222.485
BUILDING CONSTRUCTION				
Embodied Energy (kWh)	2.429	48.587.287	1.577	35.051.979
CO_2 emissions (Kg)	727	14.542.181	504	11.202.408
10 YEARS USE				
ALT I. COOLING AND HEATING W/ HEAT PUMP air-air, , HOT WATER (SOLAR + JOULE)				
EMISSIONS LABEL	C		D	
Primary Energy Use (kWh)	766	15.322.298	518	11.513.586
CO_2 emissions (Kg)	169	3.380.507	130	2.889.510
INFRA+BUILD+10 YEARS USE				
TOTAL ENERGY kWh	3.641	72.830.923	2.333	51.855.591
TOTAL CO_2 emissions Kg	1.062	21.243.186	688	15.292.176
10 YEARS USE (choosen alternative)				
ALT II.a BIOMASS HEATING, HEAT PUMP COOLING, HOT WATER (SOLAR + JOULE)				
EMISSIONS LABEL	B		B	
Primary Energy Use (kWh)	1.068	21.363.204	675	15.003.225
CO_2 emissions (Kg)	53	1.060.159	49	1.089.123
INFRA+BUILD+10 YEARS USE				
TOTAL ENERGY kWh	3.943	78.871.829	2.490	55.345.230
TOTAL CO_2 emissions Kg	946	18.922.838	607	13.491.789
10 YEARS USE				
ALT II.b BIOMASS HEATING, HEAT PUMP COOLING, HOT WATER (SOLAR + BIOMASS)				
EMISSIONS LABEL	A		A	
Primary Energy Use (kWh)	1.095	21.903.285	840	18.670.680
CO_2 emissions (Kg)	15	300.045	27	600.129
INFRA+BUILD+10 YEARS USE				
TOTAL ENERGY kWh	3.970	79.411.910	2.654	58.990.458
TOTAL CO_2 emissions Kg	908	18.162.724	585	13.002.795

The first part of the table is straightforward, and the results are not surprising. Even though multi-family typology calls for about 10% more of built area, due to its compactness and reduced needs of urban infrastructure (streets and services, 13,576m^2 in the case of typology A, and 5,365m^2 in the case of typology B), the energy and emissions impact is considerably smaller than for the single family construction. In the urbanization stage the differences are very considerable. Typology A consumes almost 70% (x1,7) more energy, and emits an enormous 170% (x2,7) CO_2 more than typology B. In the Building stage the differences are also remarkable, although less dramatic. Typology A consumes almost 40% more energy, and emits almost 30% CO_2 more than typology B. The 10 years maintenance in this part includes all operation and maintenance costs, with the exception of cooling, heating and sanitary hot water, that are studied in the following paragraphs.

The 10 years energy use needed more study, as there are many alternatives for heating and cooling systems. The building envelope was defined based on the legal standards for lower thermal loads, as for comparison terms the important thing is that both typologies have similar solutions. Thermal loads (heating and cooling) are not detailed here in order to keep the text as concise as possible, and the table 1 provides only the results of the total primary energy used and total carbon emissions for each climate system alternative (I and II) described in the paragraph 2.3 above. Hot water needs study is based on the users, and therefore are the same in both typologies. Solar heat collection with either electrical backup (joule effect) in the alternative I and II.a, or biomass boiler in the alternative II.b were studied. Even though the hot water energy demands are very modest related to heating a cooling, the backup proved to have a great impact in the total primary energy and especially carbon emissions.

The table 1 provides the results of the 10 year use energy consumption and carbon emissions, and adds them to the infrastructure and construction impact to have three different totals for each A and B typologies. The first alternative (Alt I) proved counter intuitive, as being the most energy efficient resulted in a very mediocre emissions mark (C for single family, with over 169Kg of CO_2 per m^2 of building, and D for multi-family, with 130Kg of CO_2 per m^2 of building in 10 years). With a most efficient energy use, due to the electricity production in Spain which in spite of its modernization efforts still heavily relies in thermal centrals, has as a result a more mediocre primary energy efficiency than expected (even so better than the other alternatives), and the worst carbon emissions results of all. When comparing typologies, not surprisingly B is always more efficient than A, in both consumption and emissions.

Alternative II.a with biomass boiler resulted in a better emissions mark (B for both, with a greatly reduced 53Kg of CO_2 per m^2 of building in single family typology, and 130Kg of CO_2 per m^2 of multi-family building in 10 years). However the improvement, due to the being able to reach only B and not A mark, we studied the way to further reduce emissions with alternative II.b. At this stage, even the very modest energy consumption of the sanitary hot water was what caused the B results. Changing the electrical backup in the hot water tank for a biomass boiler backup, the emissions mark A was reached, with a carbon emission near ideal (15Kg of CO_2 per m^2 of building in single family typology, and 27Kg of CO_2 per m^2 of multi-family building in 10 years). However, when compared with the alt. II.a results, we found the savings of CO_2 did not compensate for the higher energy consumption, and decided to choose the Alt II.a to complete the comparative studies, with the economic cost analysis.

The discussion above has been put in the figures 3 and 4 below, to make it more visual. It is easy to observe that in the alternatives studied, energy and carbon efficiency are not related (actually inversely related in the three alternatives chose), although results may vary for more alternatives or other countries with different electricity production systems. Apart from the improvements of energy use of the building use in 10 years, it became very patent that the largest energy and emissions impact occurs during the infrastructure and building construction process. In our example, only changing the typology brought energy and emissions benefits of 334Kg of CO_2 per m^2 of multi-family building, much larger that those that can be obtained in the 10 years (or many more years) of very efficient operation (as in the 22Kg of CO_2 per m^2 of building saved in typology B when changing from Alt II.a to Alt II.b). Furthermore, larger gains in operation efficiency will bring very modest benefits, while construction and urbanization still have a large room for improvement.

Figure 3. Comparison of energy use (left column) and CO_2 emissions (right column) in the phases of Infrastructure Construction, Building, and 10 year operation under three alternatives. In blue the value for Typology A, and in green the value for typology B. Numbers are total absolute values in kWh and Kg of CO_2, for the 10 years operation of the 160 housing units.

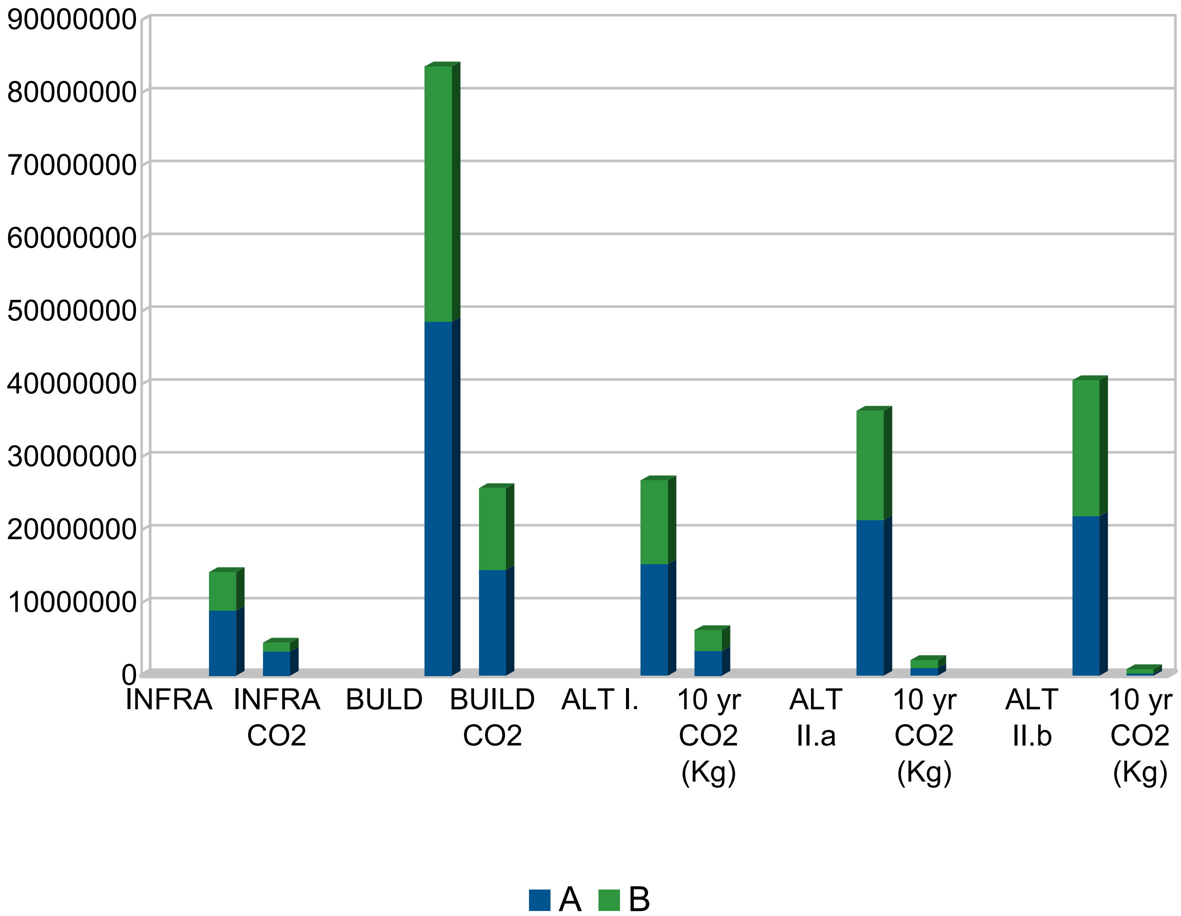
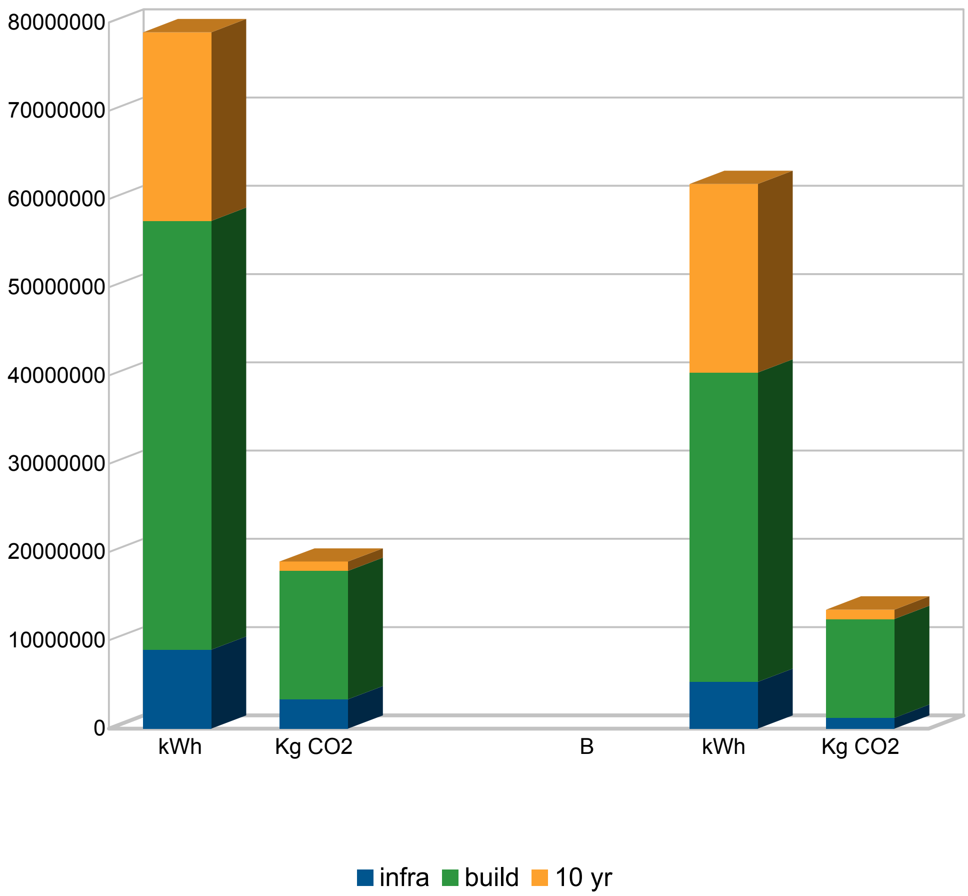


Figure 4. Comparison of energy use and CO_2 emissions, for the urbanization, construction and operation phases, typology A on the left, and typology B on the right side. Graph simplified for the alternative II.a. Numbers are total absolute values in kWh and Kg of CO_2. It becomes clear the larger impact of the building construction period, especially related to carbon emissions.



3.2. Economic study

The total monetary cost in Euro has been calculated for the chosen alternative II.a in both typologies. The summary is in the table 2 below.

Table 2. Comparative total costs of both typologies, in Euro.

TYPOLOGY	**SINGLE-FAMILY** HOUSING		**MULTI-FAMILY** HOUSING	
ALTERNATIVES	TYPOLOGY **A**		TYPOLOGY **B**	
Toral Built Area (m^2)	20.003		22.227	
	per m^2 of building	total	per m^2 of building	total
URBAN+INFRA A1 to A5 (€)	59,56	1.191.378,68	20,49	455.431,23
URBAN+INFRA B1 to B2 (10 yr) (€)	10,52	210.431,56	3,68	81.795,36
BUILDING A1 to A5 (€)	830,55	16.613.491,65	610,87	13.577.807,49
BUILDING B1 to B2 (10 Yr) (€)	215,74	4.315.447,22	142,14	3.159.345,78
TOTAL COSTS (€)	**1.116,37**	**22.330.749,11**	**777,18**	**17.274.379,86**

As expected, costs for typology B are more contained, with the largest difference in infrastructure (with a ratio close to 3 to 1) and a considerable difference in building construction and maintenance, being typology A on average over 41% more expensive than typology B when comparing unitary costs, and near 30% when comparing total costs.

The energy costs of heating and cooling and hot water are included in the totals in last line of the table, B1 to B2 life cycle period. It is remarkable that the biomass equipment is considerably more expensive than the more simple heat pump system. In the case of typology A, the total cost increase was estimated on 190,000€ (almost 3,5 times more expensive), and for typology B 94,000€ (2,25 times higher). However, even when the energy efficiency of the biomass boilers is smaller, the difference of price between electricity and biomass fuel accounted for considerable savings (almost 25,000€ per year in typology A, and 13,500€/year in typology B). If the relative price difference stays over time, the over cost of the heating system can pay back before the end of 10 year period studied (we calculated around 7,5 and 7 years respectively). Lower operation cost can be an additional incentive, together with the lower carbon emissions, we only need both developers and users to think on the long term, not the immediate upfront costs, which is not easy in a strained market.

3.3.- Other considerations.

Besides the clear ecological benefits of the small collective housing over the individual single family row houses, there are more variables to be taken into account for making final planning decisions.

Below are the images of one block of row houses and one block of multi-family houses, to compare the resulting house and urban space definitions.

Figure 5. Resulting floor plan of a block of 16 row houses. In green open spaces, all private.

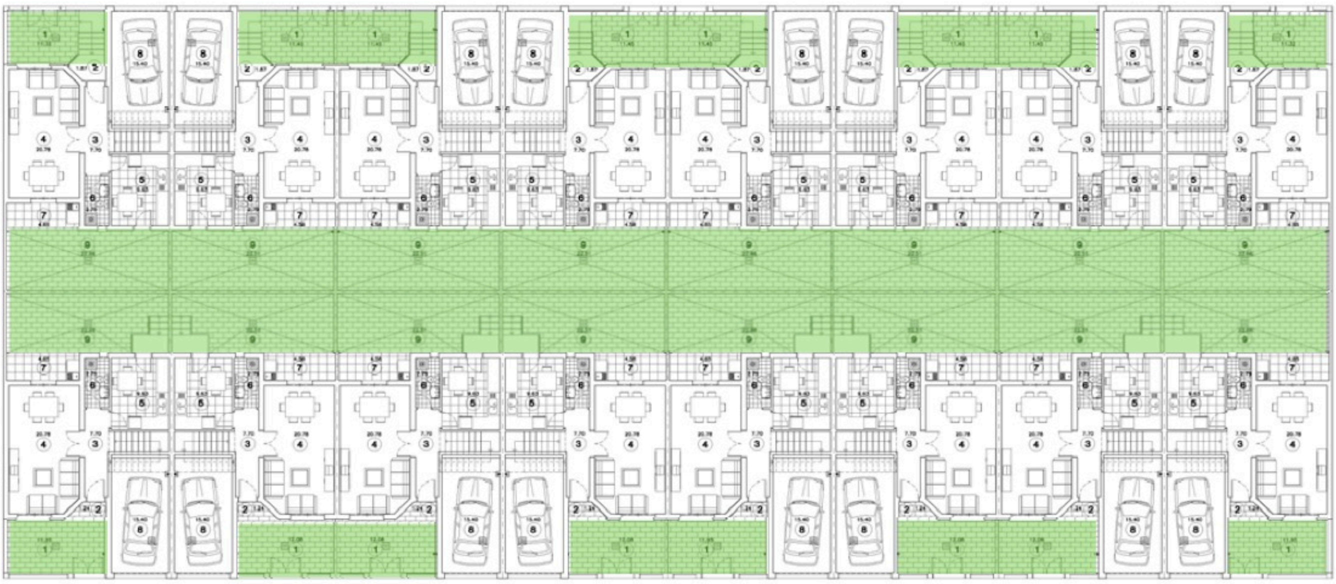
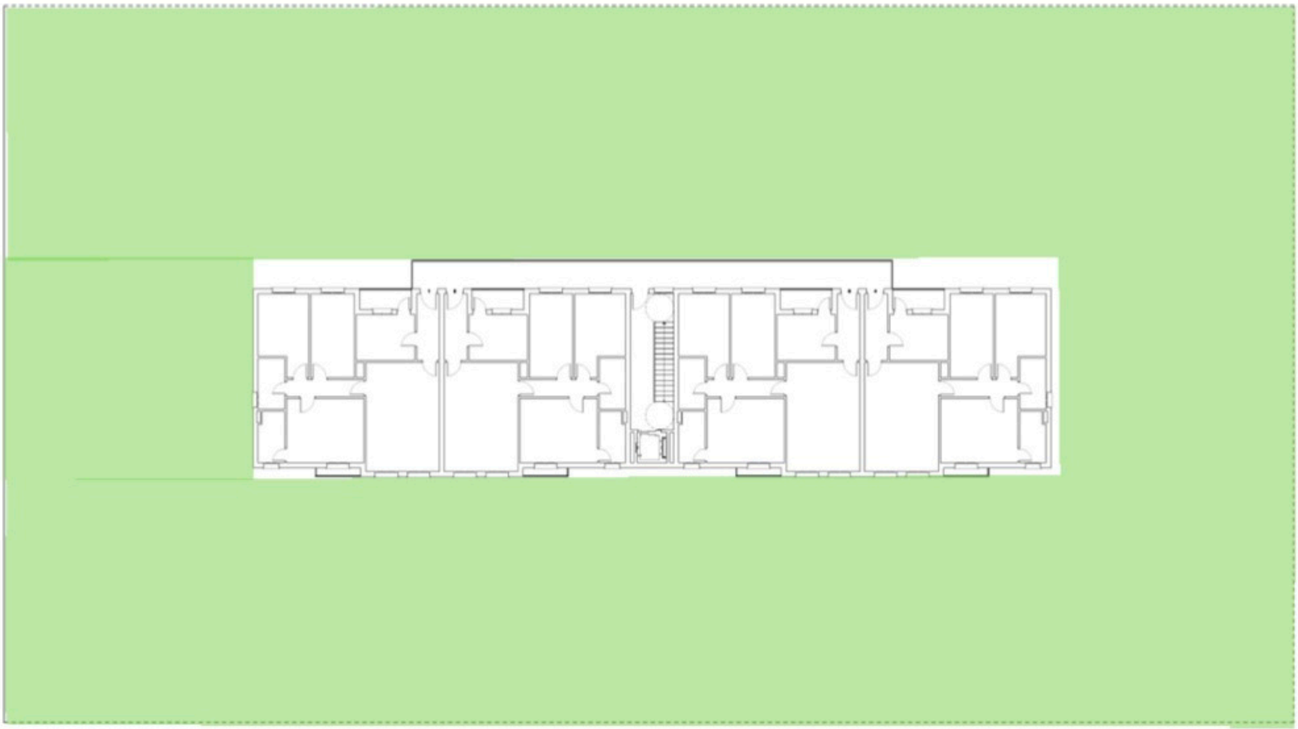


Figure 6. Resulting floor plan of a building of 16 units. In green open spaces, all collective.



The images above are to be considered diagrammatic, as we did not intend to make an ideal design, just a well defined typological object enough for the study here. Good design can produce acceptable results in any of the typologies, but we did not enter in that discussion.

Comparing both plans we can see the advantages of typology A, which still make it popular. The possibility to live straight over the ground and have total ownership of the building and land, direct access form the street and individual parking space, without depending on elevators or common stairs still are popular features. The negative side is the narrowness of the open spaces, the absolute absence of communal green areas, the relative lower privacy resulting of having neighbors windows very close, and the limitations in design as the space is so tight that there are very little possible variations in massing or building disposition. Regarding accessibility, the second floor is always limited as there is only possible access trough a stair.

Collective housing gives an obvious relief to the open spaces, with more distance from streets and safer, wider pedestrian and communal green areas. The abundance of space provides plenty of freedom to change the block design and position to adapt to topography or other circumstances. The existence of elevator makes all floors accessible, and more distance between windows provides more privacy between buildings. On the negative side are the shared ownership with permanent negotiation on costs and management, the added cost of maintaining large green spaces, the privacy problems of having many surrounding neighbors, and the sense of isolation as one must choose between being outside the building on the open space, or confined inside the apartment.

4. Conclusions

Table 3 summarizes the basic numbers of the study. From the study it becomes clear the advantage of multi-family housing typologies over single family row housing typologies, in terms of both economic and ecologic costs. The multi-family typology also brings more opportunities for communal activity and shared spaces, which also account as desirable social sustainability features. Therefore we consider advisable the consideration of adopting this typology in existing planned areas where short or midterm decisions have to be taken without changing the densities established by law. If demand for row housing still exists, we would suggest to keep a small proportion of these in order to provide variety, but informing the users clearly on the impact an costs this typology has.

Table 3. Summary of the comparative ecologic and economic costs of both typologies.

TYPOLOGY	**SINGLE-FAMILY** HOUSING		**MULTI-FAMILY** HOUSING		COMPARISON	
ALTERNATIVES	TYPOLOGY **A**		TYPOLOGY **B**		**(ALT A) / (ALT B)**	
	per built m^2	total	per built m^2	total	per built m^2	total
Toral Built Area (m^2)	20.003		22.227		0,90	
Green Space (m^2)	0,3	6.001	0,96	21.338	0,31	0,28
Total energy (10 years, kWh)	3943	78.871.829	2490	55.345.230	1,58	1,43
CO_2 emissions (10 years, Kg)	908	18.162.724	585	13.002.795	1,55	1,40
Cost (10 years, €)	1135,75	22.718.407,25	753,02	16.737.375,54	1,51	1,36

A second important finding is the necessity to study energy saving systems in detail for each alternative, and the need to know also the real impact of the primary energy produced. In this case the results have been counter intuitive. We were surprised to see that less energy consumption produced more CO_2 emissions, when we would thing both numbers are directly correlated. Different countries or even regions, and different times may change completely the results, especially in what electricity is concerned. In the case of Spain, even with the effort of recent years, still electricity production is done greatly by dirty and low efficient means, producing disappointing results, even with the implementation of the most modern and efficient climate control systems.

Finally an unintended but surprising finding was the extremely high impact of construction in the context of the whole life cycle analysis. The correct typology choice greatly reduced the ecologic impact of the urbanization and construction phases. However, the embodied energy and emissions of this phase is enormous, accounting for the equivalent of 20 or more years of use. While we support the progressive improvement of the building operation costs, we see the gains we may make over what already has been achieved is relatively modest compared with the huge impact of the construction activity still has. We see most training in schools and professional associations concentrating in the efficiency of the operation phase, while still we need much more study on the energy and emissions impact of the urbanization and construction phases.

Acknowledgments

The authors want to acknowledge the expert advice of Prof. José Carlos Claro Ponce, of UNIA (Andalusia International University).

Also the Colegio Oficial de Arquitectos de Jaen (COAJaen, Jaen's Architect's Professional Association) for their support in presenting this communication.

Conflict of Interest

The authors declare no conflict of interest.

References and Notes

1. Insituto Para al Diversificacion y Ahorro de la Energía IDAE, *Guía del planeamiento urbanístico energéticamente eficiente*, IDAE y Insitut Cerdà, Madrid, 2007. ISBN: 978-84-96680-05-0. Online version http://www.idae.es/uploads/documentos/documentos_10528_Guia_Planeamiento_urbanistico_2ed_07_2bb4de9e.pdf last accessed 29 April 2014. As an example, the above reference is the last updated official publication form the Spanish Government, with recommendations for sustainable urban planning concentrating on design issues, mainly aimed at an efficient use and exploitation of the city and buildings. Although some strategies are common sense for a more sustainable construction, it does not provide any specific tool or guideline for a detailed study of the embodied energy and emissions impact of the urbanization and construction activities.
2. Sociedad de Tasación S.A., *Informe Trimestral de ST Sociedad de Tasación, Tendencias del Mercado Inmobiliario, 2015 1er Trimestre*, 2015; Online version in http://www.stvalora.com/ext/pdf/tendencias/informe_tendencias_2015_1T.pdf last accessed 2015/04/29
3. Official statistics of new building permits published mark a regular rhythm of around 200,000 new units per year in the 1990's, being 1995 the start of an increase sharply raising after 1998 with its peak in 2006 reaching near 740,000 units. 2012 marks the lowest point, with less than 60,000 units. Although we have not official statistics beyond that point, several reports (see next reference) indicate a reactivation of the activity . At any rate, the new construction even at a rate of 60,000 units per year is still a considerable activity to be seriously considered in terms if its environmental impact. Data source: Instituto Nacional de Estadística (INE), http://www.ine.es last accessed 2015/04/29
4. Luis A. Torralba, *La reactivación en España del sector inmobiliario es (casi) una realidad,* Valencia plaza.com, 22 November 2014. This press article provides more recent statistics and graphs showing a clear reactivation of the building activity. http://www.valenciaplaza.com/ver/143240/la-reactivacion-en-españa-del-sector-inmobiliario-es-casi-una-realidad.html last accessed 2015/04/29
5. UE objectives for 2015, where energy efficiency and emissions control is stated as the third of the main objectives to achieve by 2020. http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/targets/index_es.htm last accessed 2015/04/29
6. As an example, the recent update of Andalusia Law on Urban Planning still keeps the housing density parameter as one of the basis of planning. *Junta de Andalucía, Ley 2/2012, de 30 de enero, de modificación de la Ley 7/2002, de 17 de diciembre, de Ordenación Urbanística de*

Andalucía, BOJA, vol 26, 2012; Online version in http://www.juntadeandalucia.es/boja/2012/26/1.html, last accessed 2015/04/29
7. Ministerio de Fomento de España, Documento Básico HE Ahorro de Energía, *BOE-A-* 2013-9511; Online version in http://www.boe.es/diario_boe/txt.php?id=BOE-A-2013-9511, last accessed 2015/04/29
8. Instituto para la Diversificación y Ahorro de la Energía IDAE, *Escala de calificación energética. Edificio de nueva construcción*, Madrid, May 2009. http://www.idae.es/uploads/documentos/documentos_CALENER_07_Escala_Calif_Energetica_A2009_A_5c0316ea.pdf
9. The terminology follows the Spanish version of the Standards UNE-EN ISO 14040-14044, summarized in http://gestion.cype.es/impacto_ambiental_analisis_ciclo_de_vida.htm#indice last accessed 2015/04/29
10. *Impacto ambiental. Análisis de ciclo de vida*. CYPE software, environmental impact and LCA online handbook, pp. 9-17. http://gestion.cype.es/ampliadas/impacto_ambiental_04.htm last accessed 2015/04/29