Sustainable Urban Planning in Toledo: A case of study through a holistic energy approach

Introduction

In Spain, urban environments contemplate high energy consumption, with the residential-service sector responsible for at least 27% of total energy consumption [1]. The challenge is to reach European global energy consumption reduction goals of 9% in 2016 [2], and the Kyoto Protocol goals regarding greenhouse effect gas emissions.

Several initiatives exist for energy consumption reduction in buildings, ranging from a new regulatory framework (Código Técnico de la Edificación - Technical Code in Building, CTE [3]), to economic initiatives (Energy Saving and Performance Plan 2008-2012 [4]). However, many of the possible intervention alternatives are thwarted from the start due to the non-existence of a global approach to planning, design and execution of energy efficient urban communities (on a suburban scale).

This article attempts to contribute to improving the energy performance of new urban planning developments through a holistic and global methodology that helps urban planners to design urban communities. This methodology has been applied to the design of a new urban community in Toledo.

1. Methodology

To define an urban planning scenario from the energy performance point of view, the first step that should be followed is compiling data to do with the siting such as land surveying, climate, nearby supply networks, etc. These parameters affect the two central aspects of an energetically efficient community: minimization of demand and optimization of energy generation.

This methodology is developed at two levels, the first on an urban development planning level and the second on an energy planning level. Urban planning mainly affects the suburb's demand and energy planning of the generation and storage of energy.

The following table shows the factors born in mind in the urban planning phase, in terms of minimizing its energy demand.

Urban planning	Regulations Climate Uses	Other urban elements	Public roads Open spaces
Buildings	Building typologies Plot Distance between buildings Percentage of gaps Shading devices	Construction solutions	Facades Roofing Flooring Glazing Vegetation

Table 1 - Factors that affect an EcoCommunity's energy performance

Some indicators have been developed for each section that help to obtain a more efficient community.

After the suburb's demand has been minimized, the next step is to optimize energy generation. This optimization of generation is carried out in two phases. The first is to size the energy installations and the second consists of demarcating areas and technically-economically analysing each one.

2. Case study determinants

The methodology has been validated applying it to a case study located in the province of Toledo. This is a 46 ha plot, where residential (multi-family and one-family), tertiary, equipment and green spaces uses are planned. To the north it runs along side a mountainous area, to the south along a high-speed railway track, to the east along an existing urban area, and to the west along a rural area.

The following tables show the climatic and urban planning determinants in the case study.

Plot surface area	46 ha
Transfer for infrastructures	12%
Built-up area	21%
Green Space Area	46%
Mineral Area	7%
Housing Building Area	45%
Office Building Area	16%
Equipment Building Area	15%
Shopping Building Area	24%

Table 2 - Urban planning determinants

Location	Calipo	
Province	Toledo	
Temperatures (ºC)	Temperate Continental	
	Maximum temperature	26.5
	Minimum temperature	6.1
	Mean temperature	15.5
Minimum humidity (%)	43	
Maximum humidity (%)	78	
Mean humidity (%)	61.75	
Altitude (m)	660	
Latitude	N 40° 14´	
Minimum solar radiation (kWh/m^2)	2.18 (December)	
Maximum solar radiation (kWh/m^2)	9.06 (June)	
Wind speed (m/s)	5 m/s	
Max precipitation (mm)	74.51	
Min precipitation (mm)	7	

Table 3 - Climatic determinants

3. Application to the case study

3.1. Minimization of demand

Solutions in different phases and times in the urban planning-building process

Considering the variety of solutions from the urban planning phase to the building, the methodology allows for choosing the best alternatives for minimizing the energy demand in the case study. According to the previously defined study factors (Table 1), the methodology, applied to the case study, obtains a group of indicators, shown in the following sections. The optimum values of these indicators have been obtained from good practice manuals [5] and from the results of the simulations specifically carried out with the case study's specific determinants, using EnergyPlus software.

The modelling exercise first bears in mind each parameter individually (volumetrics, shape, dimensions and orientations, distances between buildings, percentage of glazed surfaces and shading devices, permeability, the albedo, material conductivity and emissivity, etc.), to subsequently combine them, generating a group of alternatives to direct the planner towards the EcoCommunity's energy performance.

The following table includes the values of the indicators for the case study.

Urban planning	1. Distribution between activities and residence	40%
	2. Proximity to daily activities	11%
	3. Housing density	54.12
	4. Knowledge-based areas	21%
	5. Access to equipment and basic services	<300 m
	6. Minimum reserve for council housing	40%
	7. Percentage of green spaces (including green roofs)	52%
Building	8. Optimum typologies	Optimum typology (width 8-12 m) = 91% no. build rest = 9%
	9. Form factor	m^2 Buildings in the optimum factor = 63%
	10. Orientation of the longitudinal facades	N-S: 87% Rest: 13%
	11. Optimum plot shapes	Rectangular
	12. Distance-height ratio	1.5
	13. Percentage of gaps in facade	Residential: S 50%, N 5%, E-W 10% Offices: S 50%, N 20%, E-W 30%
	14. Type of shading devices depending on the orientation	South: Horizontal East-West: Vertical
	15. Size of projections depending on orientation	0.5-1.5

Other urban elements	16. Public roads designed for private vehicles and public transport in area	14%
	17. Public roads designed for pedestrians and other uses of the public space	86%
	18. Proportion of closed condominiums	0%
	19. Trees in the public roads	38.02 m^2/pers (green spaces) + 3.15 m^2/pers (flower beds, trees on pavement)
	20. Access to public transport stops	300 m
	21. Access to bicycle track	300 m
	22. Access and equipping of car parks for private vehicles	300 m 2.2 spaces/house Area= 312.05 spaces Underground= 5043.02 spaces Mineral Surface= 148.11 spaces
	23. Equipping parking area for bicycles	2 space/hous 2500 m^2 allocated for bicycle parking
	24. Accessibility for persons with reduced mobility	> 3 m of pavement
	25. Permeability index	39%
	26. Access to green spaces	> 1000 m², < 200 m > 5000 m², < 750 m > 1 ha, < 2 km > 10 ha, < 4 km
Construction solutions	27. Inertial mass - insulation ration in facades	Ufacade= 0.57 W/m^2K
	28. Inertial mass - insulation ratio in roofing	Uroof= 0.38 W/m^2K Uroof.plant= 0.34 W/m^2K
	29. Insulation in flooring	Uflooring= 0.43 W/m^2K
	30. Type of glass depending on the orientation	RESIDENTIAL: Double-glazing OFFICES: Low emissivity double-glazing
	31. Transmittance – solar factor	Uglass= 2.9 W/m^2K g = 0.76 W/m^2K

Table 4 - Case study indicators

Minimization and calculation of the energy demand

The final urban planning proposals for the case study (Figures 1, 2) uses passive design for maximising the solar gain of open spaces and buildings, enabling natural ventilation and lighting of the building, and restricting the energy demand with compact buildings. Figure 3 represents the energy demand (electricity, heat and air-conditioning) of the case study.

Figure 1 - Case study in Toledo

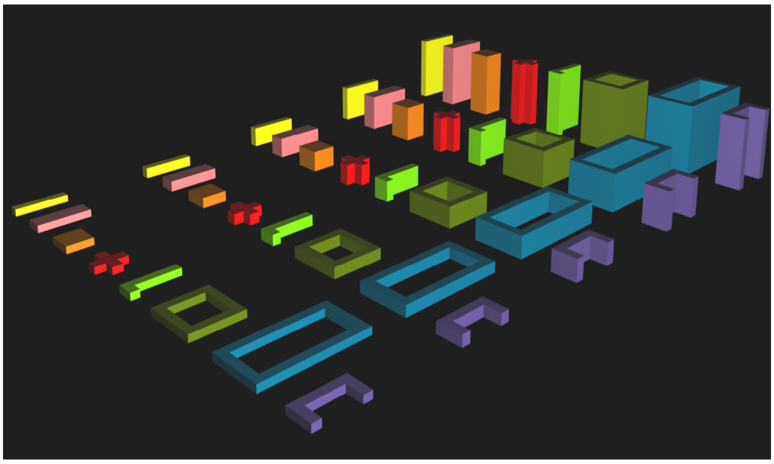

Figure 2 - Analysed volumetrics

To calculate it, we have used our own CEEM-U (Cálculo Económico y Energético de Microrredes Urbanas - Economic and Energetic Calculation of Urban Micronetworks) software. This software has been designed to plan electric and thermal generation and storage solutions and to design micronetworks. This software is validated with the results obtained by EnergyPlus [6].

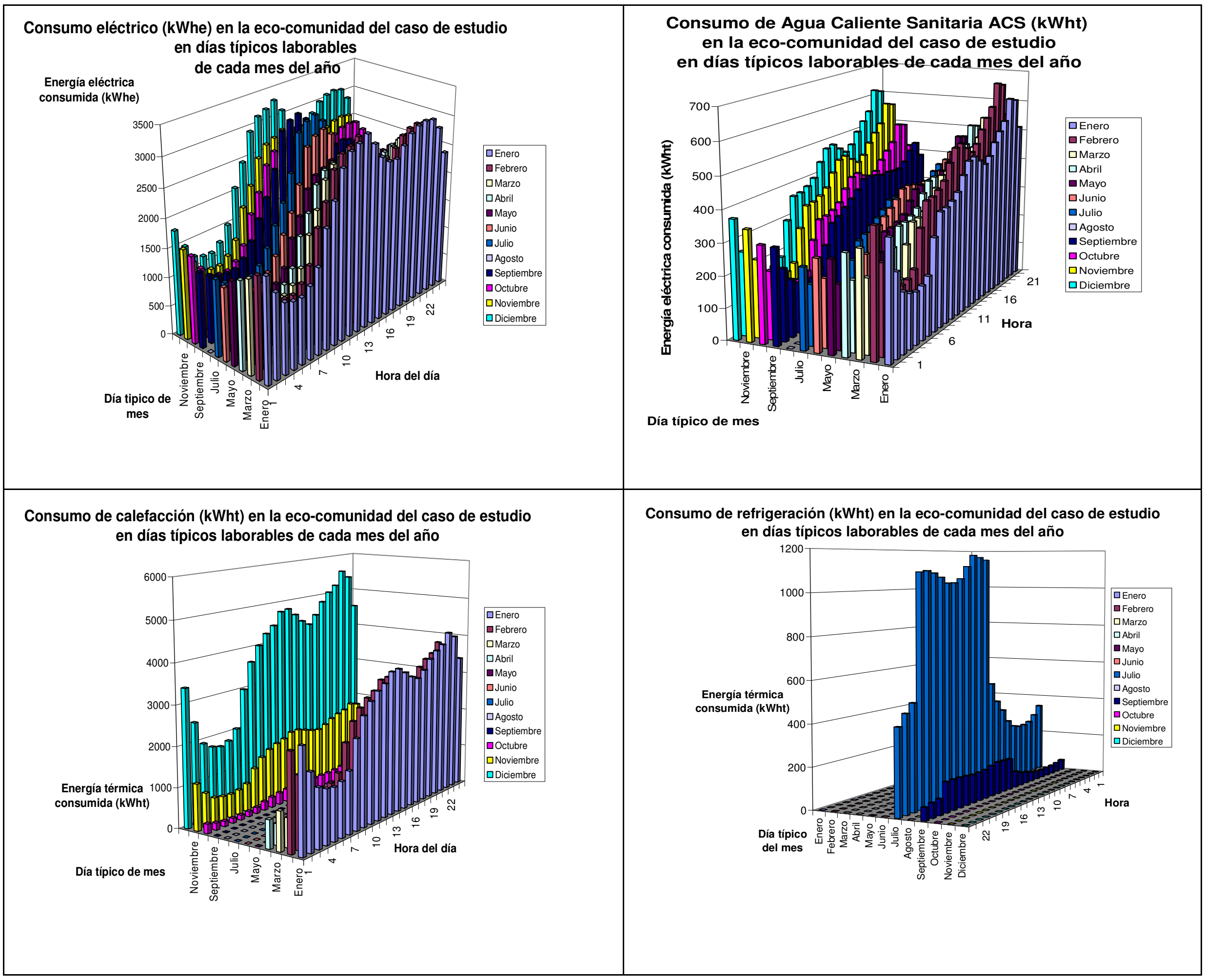

Figure 3 - Energy demand (electric and thermal) in the case study

3.2. Optimization of energy generation

As regards the analysis of the generation potential to supply the electric and thermal demand, and the sizing of the electric and thermal generation and storage sources, the methodology proposes two phases. A technical-economical viability study is carried out in both of them, based on parameters such as Net Present Value at 20 years (NPV) or the Equivalent Electric Efficiency (EEE) of the high energy performance generation sources (co and trigeneration).

- The first phase considers sizing the energy installations (powers, space availability) for the entire case study. The choice of the following generation mix results from this phase: photovoltaic electric energy with 10,000 m² of panels, thermal solar energy with a total area of 1,000 m² of panels, low temperature geothermal technology totalling 375 kW for 25 buildings.

It also assesses the possibility of including a cogeneration machines (also called CHP, Combined Heat and Power), to burn different raw materials: natural gas, biomass or biogas obtained from biomass (the latter two considered as renewable).

- The second phase considers demarcating areas inside the case study and technically-economically analysing each area. Specifically, two areas have been considered for demarcation (Figure 4**Error! Reference source not found.**):

- The Southern area includes the aforementioned cogeneration source and most of the photovoltaic panels in a micronetwork [7], where most of the office and shopping buildings are.
- The rest of the energy supply sources (all of the thermal solar and geothermal sources and 3,000 m^2 of the photovoltaic sources) operate separately in what is called Distributed or Dispersed Renewable Generation (rest of the plot in the case study, that is not the micronetwork).

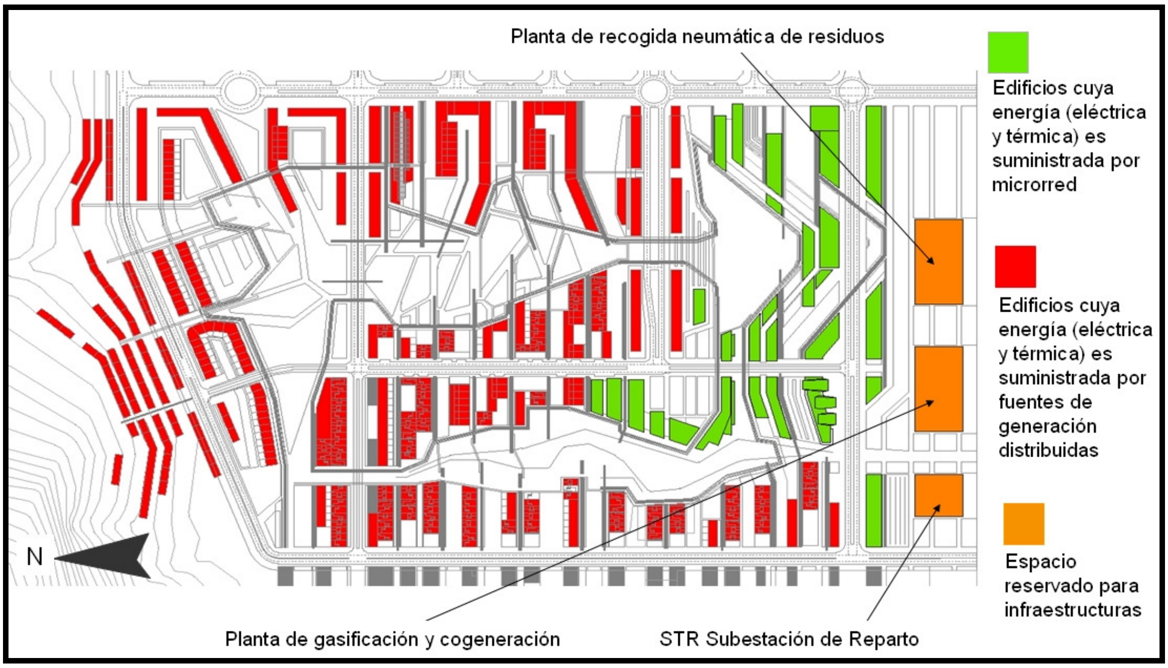

Figure 4 - Generation potential. Energy Plan. Area demarcation

A separate viability study is carried out on each area with the same aforementioned technical-economic criteria. Figure 5 and Figure 6 show the cogenerator sizing study to supply the thermal demand (heat and air-conditioning) of the Southern area.

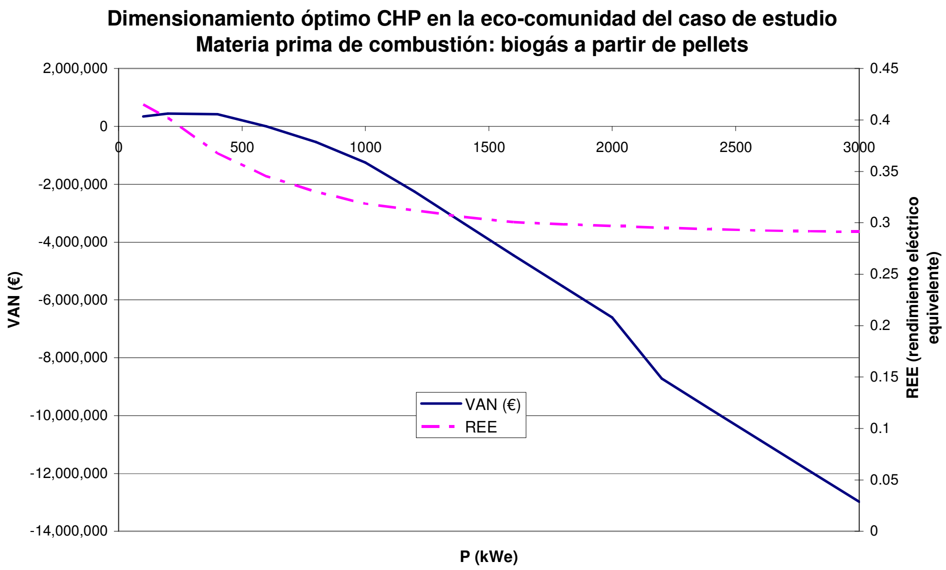

Figure 5 - Optimum generator sizing. Combustion raw material: biogas from pellets. Net Present Value compared to and Equivalent Electric Efficiency compared to cogenerator power

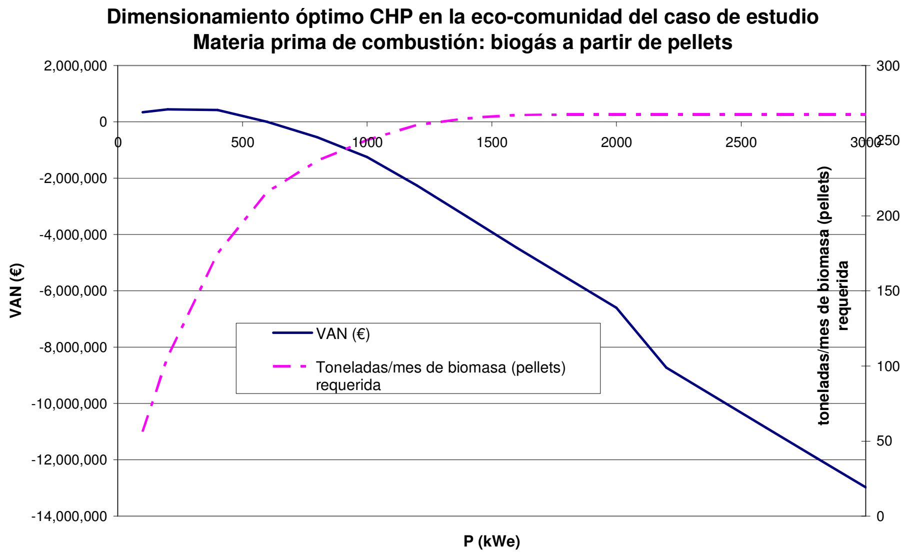

Figure 6 - Optimum generator sizing. Combustion raw material: biogas from pellets. Net Present Value compared to and tonnes of required biomass (pellets) compared to generator power

The CEEM-U software documented in [6], [7] is used. It is considered that the cogenerator will have the support of an absorption machine for air-conditioning. Market investment, operating and maintenance costs of the technologies considered (photovoltaic, cogeneration and urban heating and air-conditioning) are born in mind, as well as electricity rates [8] (these rates, incentives, etc., may have been slightly changed, updated by a Royal Decree published when this paper was being written and published, without detriment to the general conclusions intended for the reader).

It is assumed that the electricity generated by the generator, which operates following thermal instructions, is sold charging the incentives [9]. The electricity generated by the 7,000 m^2 of photovoltaic panels to be installed in the Southern area (of the total 10,000 m^2 in the EcoCommunity) is also sold at a rate [10].

It is observed that for the Southern area of the case study (yearly thermal demand of 5 thermal GWh), only cogenerators with an electric power of up to 600 kWe (with performances of 1289 kWe and 1567 kWt per tonne of biomass) are minimally profitable (the NPV at 20 years is equal to -€1,200). In the analysis, together with the cogenerator, the option of purchasing, installing and running a 600 kWt absorption machine with a COP (Coefficient Of Performance, kWcold/kWhheat) of 0.7, and 1,350 kWt of boilers), has been considered. It is also advisable to look at other technical parameters such as the EEE that for the technology considered, biogas cogenerator, obtained from biomass in the form of pellets, requires at least 0.3 (30% for biomass included in the b.6 groups according to RD 661/2007 [11]) and the supply of pellets (for the aforementioned 600 kWe machine and the thermal demands that have to be supplied. These parameters are: EEE equal to 0.345 and need for 216 tonnes of pellets a month.

Conclusions

The case study's results suggest that using energetically efficient design guidelines from the early stages of the planning process considerably improves the energy budget of the resulting urban communities. Public and private development companies are considered as possible users of this project, and the diversification of their interventions as Energy Service Companies is proposed, to work in the global energy management on a suburban scale. Large landowners and heritage managers in charge of exploiting it are also potential users. In general, the benefits for the administration consist of making the building sector and general public aware of the introduction of more sustainable practices and the establishment of regulatory mechanisms. The end users will enjoy higher quality and better equipped buildings and urban spaces, designed taking into consideration the entire urban-planning-building process; from the design of the suburb to the details in the building.

As a conclusion to the energy supply planning study, the following should be highlighted:

- Investment return periods are relatively long (20 and 30 years). It should be noted that additional financing has not been considered (subsidies currently exist to the order of 30% of the low temperature geothermal capturing and cogeneration system installation).
- Sustainability of the solution (set out in the framework of an EcoCommunity): the global energy supply based on renewable energy sources on the EcoCommunity's energy consumption is 40%. Photovoltaic energy and cogeneration cover 12% and 22%, respectively, of the electric demand. Geothermal energy covers 7% of the heating demand (4% of the global thermal demand). Thermal solar energy covers 43% of the demand for Sanitary Hot Water (9% of the total thermal demand). Cogeneration covers 31% of the total thermal demand. The micronetwork should be operated and run by a ESCo (Energy Service Company).

References

1. Eurostat. (2008), *Energy Yearly Statistics 2006*, Edition: 9, 149..., Luxemburgo, Eurostat Statistical Books, Office for Official Publications of the European Communities.
2. Comisión Europea.(2007).
3. RD 314/2006.
4. Plan de Ahorro y Eficiencia Energética 2008-2012.
5. http://www.sevilla.org/urbanismo/plan_indicadores/
6. Perea, E., Rodríguez, R., Turienzo, E., Madina, C., Romero, A., Zabala, E. (2008), "Micro-redes, una solución sostenible para un suministro energético integral a eco-comunidades", DYNA. Número 9, Volumen 83: 550-560, Bilbao.
7. Perea, E. (2008), *La microrred una alternativa de futuro para un suministro energético integral*, Derio, Edición de TECNALIA, ISBN 978-84-612-7972-2.
8. Orden ITC/3860/2007.
9. Orden ITC 1857/2008.
10. RD 1578/2008.
11. RD 661/2007.

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