Methodology adapted for the implementation of a master plan for the European mission 100 Climate--Neutral cities by 2030. Development of the energy self-sufficiency indicator

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Abstract

In order to make three neighbourhoods in the city of Valencia climate neutral by 2030, a master plan methodology, called Plan.0, has been developed. Plan.0 will be configured by programming a master plan model that is adapted to the specific context for which it is designed but, due to its adaptive nature, can be applied in other neighbourhoods of the city. To this end, we propose an iterative methodology that articulates five tools: Life Cycle Analysis (LCA), Programming Applied to Design, Building Information Modelling (BIM), Ecological Urbanism (EU), and Citizen Innovation (CI).

To achieve the adaptability of the plan.0, the methodology approach is predominantly scientific. For this reason, it will be necessary to transform the data obtained from the physical environment into numerical information, as well as the diagnosis through indicators that allow for objective decision-making and to establish a perfectible methodology divided into six sections: Data collection (GIS, Big Data, iOT); Evaluation and mapping of indicators (EU); Determination of actions (EU); Simulation and optimisation (BIM, LCA, CFD, Evolutionary Solving); Prototyping (CI); Implementation (CI). This methodology will be developed over two years and will remain active until the target is achieved in 2030.

The main objective is to test the methodology and technical tools necessary to develop the urban energy self-sufficiency indicator and the whole Plan.0. This indicator is probably the most important because of its direct impacts on a city's energy consumption and the social contexts related to energy poverty.

1. Introduction

The Sustainable Development Goals [1], SDGs adopted in 2015 by the United Nations, are an opportunity for cities to embark on a new path to improve the lives of all citizens, leaving no one behind. Goal 11 of the SDGs is to promote sustainable cities and communities, specifically to "make cities and human settlements inclusive, safe, resilient and sustainable" [2]. In this context, the European Union is launching "Mission 100 climate neutral cities by 2030: by and for citizens". The mission will support, promote and showcase the transformation of 100 European cities towards climate neutrality by 2030, and turn them into hubs of experimentation and innovation. People will be at the centre of the mission. They will be agents of change through bottom-up initiatives, innovation and new forms of governance [3]. Valencia, being aware of its particular vulnerability to the consequences of climate change, is developing Missions Valencia 2030. A project that establishes a new model of innovation governance in Valencia to create a culture and innovative outlook, strengthen alliances and networks, and boost social and urban innovation in Valencia. Six missions related to six visions made this project: healthy city, sustainable city, shared city, entrepreneurial city, creative city and Mediterranean city [4]. To meet the objectives of the Valencia Neutral City Mission, the first of the six missions launched by the Missions Valencia 2030 project, the Plan.0 will be developed: the driving force behind the Valencia Neutral City Mission.

One of the Plan.0 tools is programming applied to design. This methodology makes it possible to design with adaptive models instead of generating a specific design for each context. The specific design is achieved using parameters and programmed orders using software such as Rhinoceros and Grasshopper developed by the American multinational McNeel, which is involved in the project. There are multiple examples of the implementation of this methodology in the field of urban planning, such as the parametric urban plan in Beijing developed by Guilherme Pinto, Andrea Vieira and Pedro Neto in 2013 [5], or the Masterplan in Vienna implemented by Theresa Fink and Reinhard Koenig in 2019, both published by ECAADE [6].

Furthermore, implementing these methodologies will allow us to develop public viewers for non-professional users. A good example is the Moviga application, promoted by the Xunta Gallega. On this application, any owner can consult the estimated consumption, CO2 emissions or investment cost necessary to rehabilitate the building energetically [7].

2. Objectives and Scope

This work aims to test a methodology to assess the suitability for energy retrofits in urban districts in the Neutral Cites environment. Plan.0 works together with the strategy of the Valencia City Council to apply a get selected in the EU Call: “100 Climate-neutral Cities by 2030 – by and for the Citizens” [3]. The limitation of carbon emissions in cities is a vast problem that needs a solution to mitigate the effects of

Climate Change. As caused by multiple variables, this situation needs a holistic and multifactorial analysis. As settled by the EU on the Introduction of the EPBD: Energy Performance of Buildings Directive Directive 2010/31/UE, the building environment and especially the residential buildings are the second responsible for the carbon emission after the mobility in cities [8]. Another reason to limit our first approach to the energy problem in buildings is that the use of energy in buildings is related to social factors such as energy poverty and access to green energy to vulnerable groups. In every optimization problem, the initial situation is critical to getting an accurate solution and assessing the effect of different measures and policies. The work presented is part of the Plan.0 task and focuses on assessing the suitability for energy retrofits and impact reduction in a complex district of the City of Valencia. An index is defined to assess the benefits of the measures and assign economic resources and policies to the most suitable zones within the district to obtain the maximum impact reduction.

3. Methodology

3.1. Plan.0 methodology. A cycle with three levels of implementation: virtual, partial and complete:

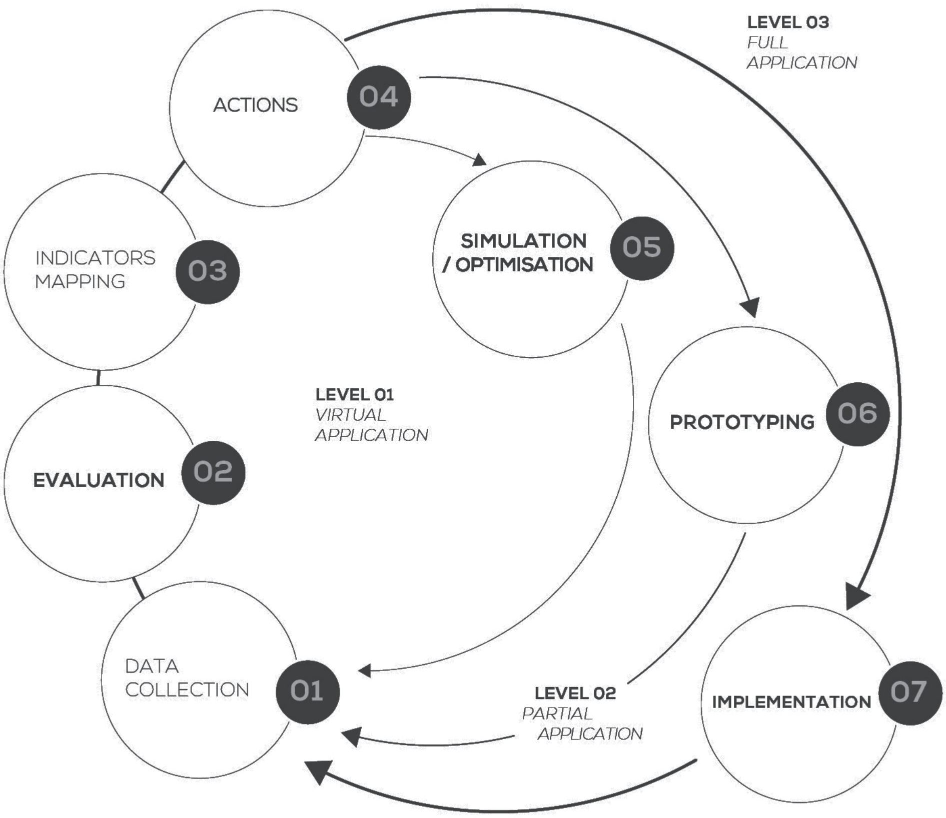

Figure 1
Plan.0 methodology concept map.

The Plan.0 methodology is cyclical and will be implemented from the beginning of the drafting process until the achievement of the Valencia Neutral City Mission in 2030. The majority of urban master plans follow the linear sequence of a single level of the classic urban development instruments (analysis-project-implementation). We propose a cyclical and iterative system with three levels of experimentation. First, a virtual level whose effects and actions on the urban environment and optimises the resources invested are simulated. Afterwards a second level of partial application is where the action prototype is tested. Lastly the third level: the definitive implementation of the actions.

Each action framed in a given temporal context will affect the decision-making of subsequent steps, altering data collection and consequently all next phases: evaluation and mapping of indicators, simulation/optimisation, prototyping and implementation as the end and beginning of a new cycle. The first level of performance is based on the virtual experimentation of the effects of the actions to be implemented on the territory. The energy simulation focused on Life Cycle Analysis (LCA) will allow us to recalculate the indicators used for the diagnosis and determination of actions and thus quantify the impact of the measures to be implemented.

3.2. Data collection and mass processing of information.

The methodology starts with the neighbourhood's current state, taking as information the geographical, architectural and sociological indicators extracted from the data collection phase. This information may be objective (GIS, Big Data, IoT) or result from information gathering procedures through citizen participation processes. In the latter area, it will be necessary to use regulated methods to quantify information of an intangible nature but of enormous relevance in decision-making. All the data will be processed and classified to be evaluated and transformed into indicators in the next phase.

The Plan.0 will draw on data sources from both the public and private spheres and the academic and associative spheres. We rely on the information compiled by the Smart City Office of Valencia City Council, which is dumped on the VLCi platform (open data + scorecard) and information from agents outside the City Council. Some of them have already participated in the project in this proposal phase.

3.3. Assessment and Mapping of Urban Indicators.

The urban indicators, based on the Ecological Urbanism Certification system developed by the Barcelona Urban Ecology Agency [9], constitute a reading of data that will give rise to thematic maps according to ranges previously designed to improve the efficiency of the urban system (people - diversity/energy) through a calculation process. The programming of the calculation of these indicators will allow us to simultaneously evaluate the influence of all of them in the whole territory. Using an IoT ecosystem, while making it possible to handle large amounts of information, allows us to gauge the influence of the actions jointly on all the indicators.

From these indicators, we will obtain a localised diagnosis focused on the achievement of the Valencia Neutral City mission. This diagnosis will allow us to articulate the actions that will be simulated, prototyped and finally implemented in the territory. These indicators follow the following structure of areas of ecological urbanism: Urban morphology; Public spaces, comfort and environmental variables; Mobility and services; Functional diversity and use; Urban metabolism; Urban biodiversity; Social cohesion; Governance and management.

Each of these urban indicators has a direct association with the actions grouped in the different planning instruments: Governance (legislation and municipal by-laws), Mobility (pedestrianisation, E-Mobility, etc.), Water and Energy (SAE, water treatment, leakage control, energy communities), Construction (energy rehabilitation of facades, installations, PV production, etc.), Recycling (recycling management and promotion programmes, etc.) and Urbanisation (PV Pergolas, trees to reduce heat island effects, etc.).

One of the most important indicators to achieve the objective of climate neutrality is the urban self-sufficiency indicator. This is because of its direct impacts on a city's energy consumption and the social contexts related to energy poverty. The main objective of this paper is to test the methodology and technical tools necessary to develop the urban energy self-sufficiency indicator and the whole Plan.0.

3.4. Development of the urban energy self-sufficiency indicator

This indicator consists of a factor showing the level of the external energy dependence of the urban sector under analysis and even individually per building. The calculation process is based on the expression (1).

$$Urban\ Energy\ Self-sufficiency = \frac{Prenewable,sector}{Csector}; \quad (1)$$

Where: Prenewable, sector is the real annual renewable energy production in the emission-free sector; Csector is the total real annual energy consumption in the sector.

The limitation of this study is that the collaboration with the city council of Valencia has not yet started. Consequently, we do not have essential data that cannot be shared due to their confidential nature and application of the data protection law of Spain. For this reason, the approximation and test of the indicator are carried out with renewable energy production and estimated energy consumption, following the data extraction structure described in figure 2.

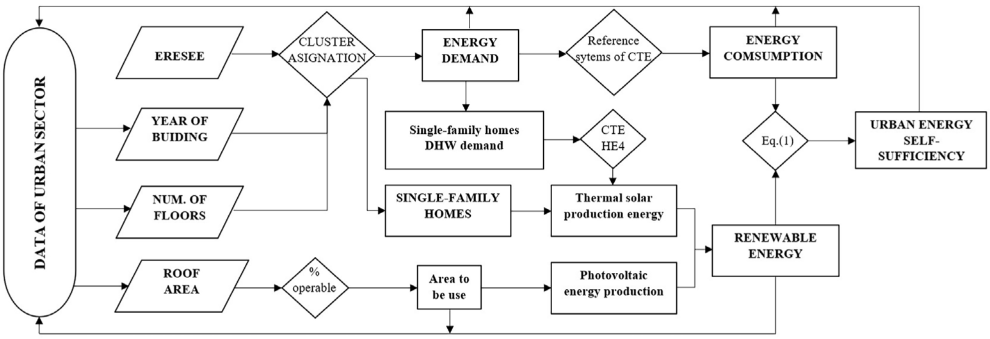

Figure 2
Urban energy self--sufficiency indicator workflow.

3.4.1. Data extraction and processing

The GIS (Geographical Information System) methodology has been used to extract information, specifically the Meerkat Gis tool, a set of tools to generate Grasshopper geometry from GIS shapefiles. The information of Valencia City Council is in .shp format (Shapefile) located in the open data portal developed by the VLCi platform.

From all the available information, we have selected the information related to the alignments fixed by planning and the plots registered in the land registry. From the first data, we obtained the number of heights and the second the year of construction. In order to interrelate data, it has been necessary to detect which plots are included in which alignments and thus attribute both data to the same geometric element: the plot. Intrinsic to the geometry of the plot is its surface area, another piece of information that will later be necessary for the calculation of renewable production.

Figure 3
The year of construction (left) and number of heights per plot (right).

3.4.2. ERESEE and calculation of energy demand.

In 2020, Spain updated the Long-term Strategies for Energy Retrofitting in the Spanish Building Sector (ERESEE 2020) [10] and its supporting documents. These documents are intended to provide technicians with the tools, data and strategies to address the issue of energy refurbishment. We can segment the building stock into clusters by extracting data on heights and year of construction, as described in support document 1 of the ERESEE 2020 [11].

Once the building stock has been segmented into clusters, we can estimate the energy demand for each cluster according to the calculation methodology developed by Helena Coch and Rafael Serra [12] and in ERESEE 2020 Supporting Document 2 [13]. This approach to energy demand is widely tested. In another work, we made a comparison between detailed simulations of actual buildings calculated with EnergyPlus versus approximation calculation. This study shows that the deviations do not exceed 7% individually and 3% collectively [14].

3.4.3. Calculation of energy consumption.

In order to obtain a theoretical energy consumption, the energy demand is divided by the nominal performance values of the reference systems established in table 4.5 of the HE0 of the CTE [15]. With this conversion, we can assign to each cluster an estimated energy consumption in kWh/m2, figure 4, which allows us to evaluate the areas or buildings with the highest consumption.

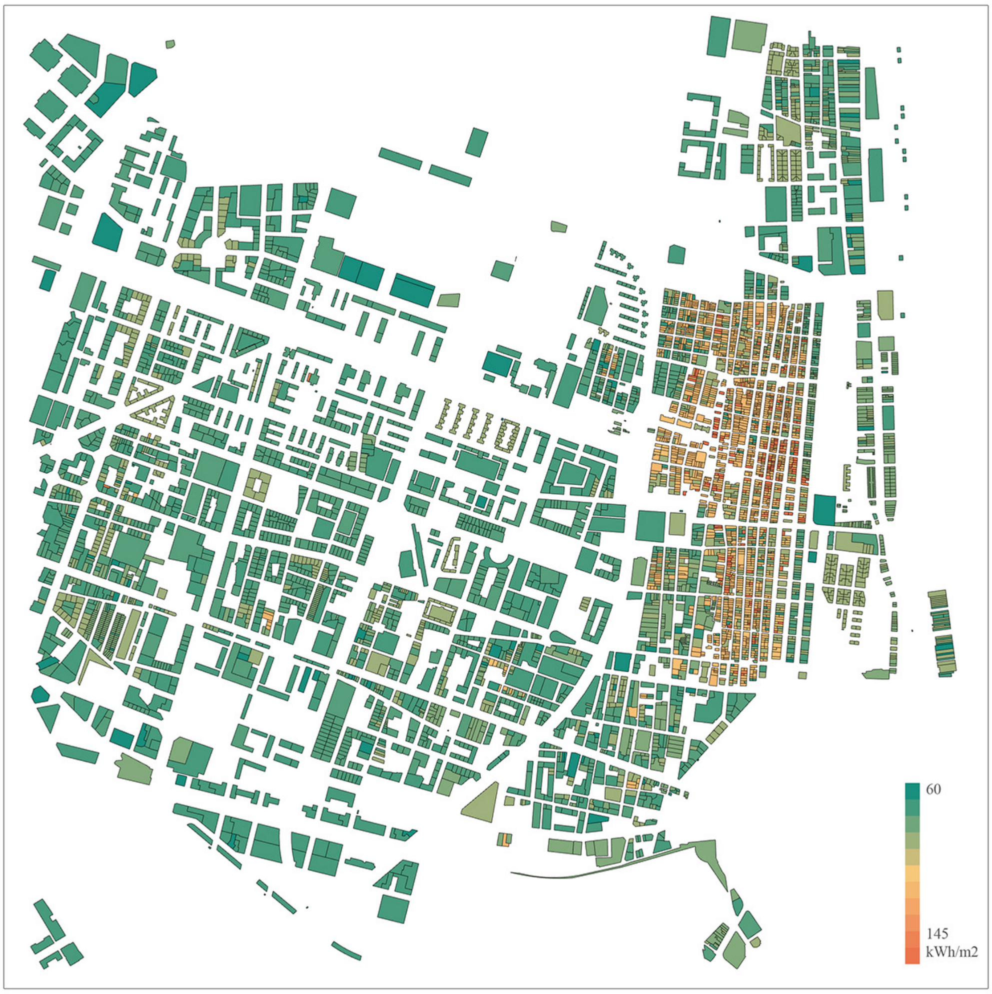

Figure 4
Energy consumption (kWh/m2) estimated from the clusters set by ERESEE.

Estimating renewable energy production in a sector is divided into two components. The first of these components is solar thermal energy dedicated to DHW. This renewable energy is only applied in single-family buildings, given that the logistics required to enable these systems in multi-family buildings would be too costly, considering that most multi-family buildings have individual DHW production systems [16]. The HE4 standard of the CTE [15] states that the minimum contribution of renewable energy to DHW production is 60%. The solar thermal contribution can be estimated through the consumption of DHW us know in before point.

The other component of renewable production is the potential photovoltaic energy production. For the estimation of the production, the available roof area has been considered (considering that 40% is not exploitable due to solar obstructions, chimneys or stairs) and the average production of a solar panel according to the solar radiation of the coordinates of the location.

Among the available eligible renewable energies, wind energy has been discarded due to the difficulties of its urban implementation. Also, possible theoretical renewable contributions from aerothermal heat pump type equipment have been ruled out.

Figure 5
Estimation of the potential capacity of solar energy production by photovoltaic panels (left) and solar collectors ACS (right).

4. Results

With the methodology described above, we can obtain result maps to evaluate the different characteristics of an urban sector. As a result, Figure 6 shows the distribution of the urban self-sufficiency indicator. The results indicate that low-rise single--family or collective dwellings have the highest consumption (mainly due to their low compactness). However, higher-rise dwellings are the most energy dependable as they do not have enough surface area for energy production to compensate for their consumption.

In Figure 5, we can see that the urban energy self-sufficiency indicator is around 0.55, which means that theoretical renewable energy can assume up to 55% of the current demand. The next step of the Plan.0 methodology will be to analyse which buildings need to be retrofitted energetically to compensate for other consumption and idem about the renewable production of solar energy.

Figure 6
Distribution of the Urban Energy Self--Sufficiency Indicator.

5. Conclusions

- The results show that a general implementation of renewable energies cannot absorb the energy consumption of the sector analysed, with a contribution of 55%, with a maximum of 70% and a minimum of 20%. This result means that the energy demand of buildings must be reduced by at least 45%. Therefore, an energy rehabilitation of façades and roofs is necessary, in which thermal insulation is increased.
- The theoretical development of the urban energy self-sufficiency indicator demonstrates that it is possible to develop indicators. In addition, the methodology can analyse these indicators to their prior evaluation and optimise the actions to be carried out through the use of multi-objective evolutionary algorithms such as Wallacei [17].

- This procedure demonstrates the compatibility between GIS methodology, ecological urban planning and programming applied to design.
- Plan.0 sets out several indicators derived from the implementation of green urbanism that needs to be assessed for controllability based on the final available information.
- It is a profound challenge to consolidate the Plan.0, but achievable, and its capacity to adapt to different contexts and cities. In addition, to initiate the automation processes and optimisation of decision making.

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