INDUSTRIAL ENGINEERING MASTER THESIS

DESIGN OF A METHODOLOGY FOR THE PLANNING OF NEAR-ZERO ENERGY DISTRICTS. CASE STUDY FOR THE UPV'S VERA CAMPUS

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ABSTRACT

Nearly-zero energy districts (NZEDs) are high-performance districts whose near-zero or very low energy needs are largely met by renewable energy sources (RES).

Their proven ability to reduce greenhouse gas emissions, while increasing energy efficiency and the share of renewable energy sources in the building sector, makes their deployment a widely supported strategy for achieving ambitious energy transition targets.

However, NZEDs are still a developing area and, as a result, there is still a lack of a mature methodology with sufficient planning and decision-making tools to support and accelerate their adoption.

This paper consists of the design of a methodology to plan a nearly-ero energy district (NZED).

On this basis, this master's thesis is divided into three parts :

The first deals with the literature research and assessment of existing methodologies, and the choice of the most promising methodology to be adapted.

The second part focuses on the theorical application of this methodology.

Finally, the third part is the validation of the methodology in the Vera campus of the Universitat Politècnica de València (UPV).

In this way, this master's thesis proposes a methodology for NZED planning with the aim of being highly adaptable in different contexts. It will then be applied to the Vera campus of the UPV to demonstrate its feasibility and usefulness. As a result, a plan for the campus to be NZED by 2030 will be proposed.

Keywords : NZED; Low Emission Districts; Energy Planning; Climate Change

RESUMEN

Los distritos de energía casi nula (NZED) son distritos de alto rendimiento cuyas necesidades de energía cercanas a cero o muy bajas se satisfacen en gran medida con fuentes de energía renovable (RES).

Su capacidad probada para reducir las emisiones de gases de efecto invernadero, al tiempo que aumenta la eficiencia energética y la proporción de fuentes de energía renovables en el sector de la construcción, hace que su implementación sea una estrategia ampliamente respaldada para lograr ambiciosos objetivos de transición energética.

Sin embargo, los NZED son todavía un área en desarrollo y, como resultado, todavía falta una metodología madura con suficientes herramientas de planificación y toma de decisiones para apoyar y acelerar su adopción.

Este trabajo consiste en el diseño de una metodología para planificar un distrito energético casi ero (NZED).

Sobre esta base, esta memoria científica se divide en tres partes:

El primero trata de la investigación bibliográfica y la evaluación de las metodologías existentes, y la elección de la metodología más prometedora a adaptar.

La segunda parte se centra en la aplicación teórica de esta metodología.

Finalmente, la tercera parte es la validación de la metodología en el campus Vera de la Universitat Politècnica de València (UPV).

De esta forma, esta memoria científica propone una metodología para la planificación NZED con el objetivo de ser altamente adaptable en diferentes contextos. Posteriormente se aplicará al campus Vera de la UPV para demostrar su viabilidad y utilidad. Como resultado, se propondrá un plan para que el campus sea NZED para 2030.

Palabras clave : NZED ; Distritos de bajas emisiones; Planificación Energética; Cambio Climático

RESUM

Els districtes d'energia gairebé zero (NZED) són districtes d'alt rendiment les necessitats energètiques gairebé zero o molt baixes dels quals es cobreixen en gran part amb fonts d'energia renovables (FER).

La seva capacitat demostrada per reduir les emissions de gasos d'efecte hivernacle, alhora que augmenta l'eficiència energètica i la proporció de fonts d'energia renovables en el sector de la construcció, fa que el seu desplegament sigui una estratègia àmpliament recolzada per assolir objectius ambiciosos de transició energètica.

Tanmateix, els NZED encara són una àrea en desenvolupament i, com a resultat, encara falta una metodologia madura amb suficients eines de planificació i presa de decisions per donar suport i accelerar-ne l'adopció.

Aquest treball consisteix en el disseny d'una metodologia per planificar un districte energètic quasi ero (NZED).

Sobre aquesta base, aquesta memòria científica es divideix en tres parts:

El primer tracta de la recerca bibliogràfica i l'avaluació de les metodologies existents, i l'elecció de la metodologia més prometedora a adaptar.

La segona part se centra en l'aplicació teòrica d'aquesta metodologia.

Finalment, la tercera part és la validació de la metodologia al campus Vera de la Universitat Politècnica de València (UPV).

D'aquesta manera, aquesta memòria científica proposa una metodologia de planificació NZED amb l'objectiu de ser altament adaptable en diferents contextos. Després s'aplicarà al campus Vera de la UPV per demostrar la seva viabilitat i utilitat. Com a resultat, es proposarà un pla perquè el campus sigui NZED el 2030.

Paraules clau: NZED; Districtes de baixes emissions; Planificació Energètica; Canvi Climàtic.

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ACRONYMS

CapEx	Capital expense / Capital expenditure
CFC	Chlorofluorocarbure
CO2	Carbon dioxyde
EED	Energy Efficiency Directive
ECM	Energy conservation measure
EDA	Exploratory Data Analysis
EDM	Energy demand management
EDRM	Energy demand reduction measure
EEM	Energy efficiency measure
EIS	Energy Independence and Security
EMP	Energy master planning
EMS	Energy management system
EPBD	Energy Performance of Buildings Directive
ESM	Energy saving measure
GHG	Greenhouse Gas Protocol
H2020	Horizon 2020
H2O	Monoxyde dihydrogène
ha	Hectare
HFC	Hydrofluorocarbure
HOMER	Hybrid Optimization Model for Electric Renewables
HVAC	Heating, ventilating, and air-conditioning
IEA	International Energy Agency
Kg	Kilogram
KPI	Key performance indicator
Kw	Kilowatt

LCC	Library Control Card
LMGI	Load match(ing) and grid interaction
m	Meter
M&V	Measurement and verification / Monitoring and verification
m2	Square meter
MS	Member State
nBL	n-bottom line
NZEB	Net zero-energy building
NZEC	Net zero-emission community
NZED	Net zero-energy district
NZEXD	Net zero-exergy district
PED	Positive Energy District
PFC	Perfluorocarbonos
PV	Photovoltaïque
RES	Renewable energy source
RE-SIZED	Research Excellence – Solutions and Implementation of Net Zero Energy City Districts
RET	Renewable energy technology
RI	Return on investment
RTD	Research and technological development
SECAP	Sustainable Energy and Climate Change
SECAP	Social, Environmental and Climate Assessment Procedures
SWOT	Strengths, Weaknesses, Opportunities and Threats
UPV	University Polytechnic of Valencia
UV	Ultraviolet energy
WFH	Work-from-home
WOS	Web of Science
Yr	Year

GUILLAUME Dylan

VALENCIA 2021

DESIGN OF A METHODOLOGY FOR THE PLANNING OF NEAR-ZERO ENERGY DISTRICTS.

CHAPTER 1. INTRODUCTION

This chapter presents and positions the research problem in a broader context to justify the relevance of this master's thesis. It also specifies the research questions that the dissertation seeks to answer and provides an overview of the methodology for doing so.

1.1. Background

1.1.1. Historical

Given the growing demand for energy in the world, the lack of energy resources in underdeveloped countries[1], the increasing cost of operating and maintaining conventional energies, as well as the impact of energy on the environment, encourages us to develop other energy sources that address these problems.

Several studies have been conducted in this context to answer these different questions. For example, one source of energy that could ensure this energy transition would be renewable energies. For this, the conversion chain must be efficient and obtain a high yield for a low cost.

Therefore, it is necessary to extract the maximum power from renewable energies. This is conceivable if renewable energy and renewable energy technology (RET) sources are maintained at their maximum efficiency. However, the maximum power point varies depending on several factors such as solar radiation, wind speed, the amount of rainwater, etc. These types of fluctuations are random, unstable, and therefore difficult to control effectively.

1.1.2. Political commitment and action plan

United Nations International Legislative Framework

According to the Intergovernmental Panel on Climate Change, human activity is responsible for a 1°C increase in global temperature from pre-industrial levels, and another 1.5°C increase is projected between 2030 and 2050, if current trends continue [47].

Reversing the current trend of climate change requires reducing greenhouse gas (GHG) emissions. Several agreements, initiatives and programs support the work needed to change the global situation. The main one, the Paris Agreement[2], concluded in 2015, that the goal is to limit global warming below 2 degrees Celsius above pre-industrial levels. As a result of this scientific awareness and the proposed action plan, measures and decisions have been taken by the United Nations world body.

This decision calls on each state and nation to gather their strength and knowledge to establish a carbon neutrality that will thus make it possible to fight against global warming.

European and state legislative framework

Responsible for 10% of global greenhouse gas emissions, the European Union is a world leader in the transition to a low-carbon economy, setting a roadmap for 2050 from 2009, with a reduction in emissions from 1990 of at least 20% by 2020, at least 40% by 2030, and up to 80-95% by 2050. In terms of energy,

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[1] We are talking about countries under-developed and under-development of a country when the health and economic situation is very bad.

[2] Is an international treaty on global warming adopted in 2015.

the current target is to improve energy efficiency by 32.5% and increase the consumption of renewable energy to around 32% of total energy consumption by 2030.

As a result, initiatives such as the EU Climate Contracts, Positive Energy Districts, the Climate Action Plan (C40) and the Covenant of Mayors have been launched or scaled up, focusing specifically on the transition of urban areas to low-carbon economies.

The role of municipal governments and the case of Valencia in particular

As a member of the Convention, and the Covenant of Majors, the City of Valencia is committed to achieving the European Union's 2030 targets by developing the Action Plan for Sustainable Energy and Climate Change (SECAP). This document includes a historical inventory of consumption, emissions and waste generated since 2007, as well as an assessment of the city's risks and vulnerabilities related to climate change.

Valencia City Council, as the promoter of the initiative, is responsible for following the plan and designing strategies to convert the city into a long-term model.
Long-term objectives are set in addition to those set by the European Commission and the Covenant of Mayors. As a result, two major strategic initiatives have been established simultaneously: climate justice and energy democracy.
Thus, both sides are working to reduce socio-economic inequalities and natural imbalances caused by climate change.

1.2. Theme

1.2.1. Definition of GHGs

Greenhouse gases are gaseous components that absorb infrared radiation emitted by the Earth's surface and thus contribute to the greenhouse effect. The increase in their concentration in the Earth's atmosphere is the principal factor causing the global warming.

1.2.2. Cause of GHGs

The different causes of GHGs are:

Water vapor, carbon dioxide (CO2), methane, nitrous oxide, ozone from the lower atmosphere, fluorinated gases (CFCs, HFCs, PFCs).

Those emissions come from massive use of fossil fuels (coal, gas, oil) for transport, buildings, agriculture, industry produce large quantities of GHGs that are concentrated in the atmosphere.

Thus, CO2 is an emission that we can control because we produce it ourselves. This emission accounts for three-quarters of GHG emissions related to human activities.

- 85.5% by hydrocarbons (coal, oil, gas).
- At 14.5%, by the destruction of forests to burn wood and cultivate land.

We will then focus mainly on carbon emissions from hydrocarbons.

1.2.3. Zero carbon

Positive energy district, net zero energy building and Net Zero Energy District

On the one hand, there are several scales to focus on: world, country, city, neighborhood.

On this dissertation, we will focus on the scale of the neighborhood because of the time allotted to carry it out with the most precision and rigor possible.

At this scale, three main terms must be defined:

Firstly, the positive Energy District (PED) is short for "positive energy district". It is a concept proposed by the European Commission with the aim of contributing to the achievement of the objectives of the Paris Agreement, strengthening European capacities and broadening knowledge on the creation of sustainable neighborhoods and cities.
This is achieved by supporting and encouraging localized efforts to mitigate climate change while improving the quality of urban life.

Moreover, le net zero energy building (NZEB) is the total amount of energy used by the building, on an annual basis, equals the amount of energy generated on-site.

Finally, the Net Zero Energy District (NZED), which is a higher level than the NZEB, involves a larger area with a variety of uses, spaces and energy consumption. They involve more variables to achieve the common goal of reducing consumption while increasing distributed renewable generation.

These communities have a common goal: to achieve carbon neutrality, and they work together to achieve this by sharing their strategies and adapting them to their unique characteristics.

The different scopes of carbon emissions

Scopes are used to identify the source of gas emissions from a product organization.

- Scope 1 includes all greenhouse gas emissions that are directly related to the manufacture of the product. These emissions are said to be direct because they come from fuels used in buildings, transport, and industry.
- Le scope 2 gathers the greenhouse gas emissions related to energy consumption during the manufacture of the product. All emissions related to secondary energy consumption are counted in scope 2. Indirect emissions related to energy consumption are called indirect emissions.
- Scope 3 encompasses all other greenhouse gas emissions that are not directly related to the manufacture of the product, but rather to other stages of the product's life cycle (supply, transportation, use and disposal). These indirect emissions, linked to the life cycle of the product, are accounted for in scope 3. They are referred to as other indirect emissions.

Energy-neutral district design methodology

The first step for this energy plan is to find (or design) a methodology that achieves a Nearly Zero Energy District.

Several neighborhoods show great results thanks to a methodology that has worked.

Thus, through the study of its different methodologies, we will design the methodology that will allow us to arrive at a nearly carbon-neutral neighborhood for the Vera campus of the Polytechnic University of Valencia.

1.3. Problem

1.3.1. Research question

Commissioned by the chair of urban energy transition at the polytechnic university of Valencia, this study was proposed in the form of a master's thesis.

We will thus answer the following problem: what methodology to apply for a transition to a nearly zero energy district of the Vera campus of the Polytechnic University of Valencia?

1.3.2. Objective

This master’s thesis aims to find the most effective and appropriate method for measuring emissions at the district level. To do this, it considers existing research and methods for carbon inventories at national and municipal levels and adapts them to achieve this objective.

1.4. Plan

This master's thesis is structured in five chapters:

Chapter 1 - Introduction
Presents and positions the research problem in a broader context to justify the relevance of this master's thesis. It further specifies the research questions that this master's thesis seeks to answer and provides an overview of the methodology for doing so.

Chapter 2 – State-of-the-Art
Traces the ideation of NZED methodologies and synthesizes the research and practices that have been conducted in the field so far. This chapter serves to justify the novelty of this master's thesis and offers the theoretical foundations for chapter 3.

Chapter 3 – Deployment of the methodology
Presents the main contribution of this scientific dissertation and concerns the conceptual framework and methodology for renovating existing residential areas and transform them into near NZED. This chapter dissects each step of the planning and decision-making process and explains how and why the framework is designed as such.

Chapter 4 – Validation. Case study for the UPV’s Vera campus

Presents and analyzes the case study selected to determine the applicability of the conceptual framework of the methodology proposed in Chapter 3.

Chapter 5 – Conclusion

Summarizes the results of this master's thesis and proposes courses of measures to be taken for the continuity of this work.

CHAPTER 2. STATE-OF-THE-ART

This chapter traces the ideation of NZED carbon emission methodologies and synthesizes the research and practices that have been conducted in the field so far. This chapter serves to justify the novelty of this master's thesis and offers the theoretical foundations for chapter 3.

2.1. Search for resources

2.1.1. Research Method

First, a methodology is a particular type of knowledge within an area. The following picture classifies the types of knowledge based on its universality (higher at the top) and the amount of more specific concepts and cases (higher at the bottom).

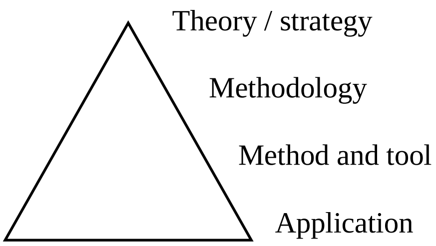


Figure 1 Types of Knowledge.

There are several different concepts and methodologies used to determine how to measure carbon emissions in a neighborhood. The extent to which to use it depends on the criteria for the energy planning of the Vera campus and on the time and cost of setting up the methodology.

An inventory of existing methodologies is therefore an essential accounting tool to have a global panel of what exists and to be able to choose.

We focused our research through these documents on the different possible methodologies for measuring carbon emissions in a neighborhood and planning NZED.

The subject of this research master's degree being to establish a methodology to plan a NZED for the Vera campus, we have made an inventory of the different existing methodologies through the documents that we have rigorously chosen. (See **Appendix 1**)

We have considered in each text as well, the following points:

1. Objective
2. Methodology and structure
3. Resources
4. Schedules

The documents deal with a net-zero energy district planning. Various means are put in place in these reports to achieve this result.

We can mention, for example, the integrated modeling of the construction and distribution system, all the indicators for the diagnosis and for the identification of their needs and priorities....

To answer the research questions, a review in two different stages was conducted.

First, the literature review and second, the implementation of a methodology specific to the Vera campus.

Document analysis was conducted as a research method. For this, a specific literature review was carried out.

The research focused on three main data areas:

1. Net Zero-Energy District
2. Positive Energy District
3. Nearly Zero energy neighborhoods

2.1.2. Document analysis

The review of the specific literature began with the search for previous studies of the state of the art. This work has helped us to understand the research done, the importance of carbon emission measurements in current approaches and applications.

Based on these early articles, search terms were chosen, and search equations were developed. As the so-called "grey" sources (blogs, news, seminars, etc.) were considered unsuitable for the objectives, the focus was solely on scientific databases.

In those databases we find peer-reviewed articles, competitive book chapters and deliverables of publicly funded projects, even if the latter are not peer-reviewed and are commonly referred to as "grey literature".

As we searched for specific articles, we applied search equations to each database, paying particular attention to the title, keywords, and summary fields.

Web of Science (WOS), Scopus, Science Direct and Google Scholar were the data sources (although only the title could be chosen in this case, and only a few papers were found).

After analyzing the preliminary results, the initial keywords and equations were examined, resulting in those listed in Table 1.

Outcomes of the literature review.

	Equation Query:	**WOS**	**Scopus**	**Science Direct**	**Scholar Google**
1	"Net Zero-Energy District" OR "Net Zero Energy District" OR "Net Zero Emissions District" OR "Net Zero-Emissions District" "Nearly zero-energy district" OR"Nearly zero-energy districts"	7	13	46	11
2	"Positive Energy Districts" OR"Positive Energy District"	2	6	9	56
3	"Nearly zero-energy district"	2	5	43	34
4	"Zero energy neighbourhoods" OR "Nearly Zero energy neighbourhoods"	4	12	34	111
5	"Net zero emissions"	54	110	277	62
6	"Energy district"	79	152	283	277
7	"Net-zero energy communities"	8	27	30	206
Title	**Total (with report and duplicates)**	149	325	722	757

Table 1 Keyword search for all documents found on carbon neutral neighborhoods.

Subsequently, the total number of publications peaked to 1,953. These are mainly articles, but also book chapters, guidelines, and project reports. As noted earlier, we then conducted a relevance check, which resulted in the elimination of several documents unrelated to the topic as well as many duplicates.

The resulting trimmed list has been further condensed by deleting publications for one of the following reasons:

- The book is too theoretical and does not help in the implementation of the author's proposals (if any).
- The publication coincides with others that provide more relevant information for research.
- The article is almost twenty years old and cannot include the most recent tools and proposals (for parts of the memory).

Ultimately, the analysis of the document included a final set of 39 articles and reports. They were read in their entirety and analyzed according to the research questions. Each of these documents, address the issues on how to make the country, city or district concerned neutral in carbon or nearly zero energy.

2.2. Observation of resources

2.2.1. Finding of the literature review

As noted, we were able to see terms combining "Positive Energy Districts" or similar terms with "Net Zero-Energy District", "Nearly zero-energy district" returned few documents.

The results of this research provide most of the final publications studied, among the articles, project deliverables and book chapters, linked to the terms "positive energy districts (PED)" and "net zero energy (NZED)".

2.2.2. Analysis of projects and actors

The online search using the terms "nearly zero energy" and similar terms combined with "projects" yielded a list of projects and some project databases.

After submitting them to research questions and using Snowball sampling, a group of 12 projects was selected.

Most of the projects discovered were Horizon 2020 (H2020) projects, which is expected given the novelty of the NZED and the clear support it enjoys in the final stages of that program.

Project Name	**Actor of the project**
THE MAKING-CITY PROJECT	Coordinator = CARTIF Technology Center
r2cities: Residential Renovation towards nearly zero energy CITIES	Coordinator = CARTIF Technology Center
Workshop Amsterdam bilbao citizen driven smart cities	Founder = Frans Verspeek Coordinator = City of Amsterdam
CityxChange (Positive City Exchange)	Founder = European Union's Horizon 2020 research and innovation program. Host and leader = Norwegian University of Science and Technology (NTNU), Lighthouse Cities Trondheim and Limerick
GrowSmarter: transforming cities for a smart, sustainable Europe	Founder = European Commission's in the first call for 'Smart cities and communities' under the Horizon 2020 funding stream.

IRIS Smart Cities Co-creating smart and sustainable cities	Co-founder = Horizon 2020 Framework Programme of the European Union Coordinator = Eva Edman Pavic
Matchup	Founder = European Union's Horizon 2020 research and innovation program
mySMARTLifeTransition of EU cities towardsa new concept of Smart Life and Economy	Founder = European Union's Horizon 2020 research and innovation program Coordinator = CARTIF Technology Centre + 27 partners from 6 countries are collaborating to make sustainable cities
Peña Station NEXT: Visualizing a Net-Zero Energy District	Coordinator = Engineers and computer scientists at NREL have created an immersive planning environment at the laboratory's Insight Center
SINFONIA project: Low Carbon Cities for Better Living	Coordinator = Bolzano and Innsbruck Founder = European Union's Horizon 2020 research and innovation program
ZenN project: Nearly Zero Energy Neighborhoods	Coordinator = Fundacion tecnalia research & innovation
El proyecto europeo Pocityf contribuye a la creación de edificios y distritos de energía positiva	Founder = European Union's Horizon 2020 research and innovation program

Table 2 Table listing the different projects of the application project on nearly zero energy and carbon neutrality.

Other projects were not selected as examples for a variety of reasons, the most important of which are:

- The main objective of the project is to educate people about NZED.
- The aim is to involve all stakeholders in NZED, but at a strategic level rather than at a tactical level that is not intended for practice.

- The objective is to follow the evolution of NZED, but not to plan them.

- Their proposals were not deemed detailed or concrete enough to help R&I teams apply them to their work.

- The project is still in its infancy and has not yet produced any results at the time of writing this master's thesis.

In summary, the project includes a database of "key documents", some of which have been identified as relevant and for a long-term viability.

2.3. Choice of methodology

Through different research papers aimed at addressing the issue of carbon neutrality, we found different methodologies that could be applied to the Vera campus.

2.3.1. Methodology Selection Strategy

After selecting the documents, we proceed by elimination.

- A first draft on our need by the said methodologies.

Neighborhood and campus-based documentation

New methodology (because they include the new data and are already based one the old ones)

- A second draft on the analysis of the chosen methodology.

The quality of the information transmitted

The details, figures and number of documents consulted to establish the said methodology

The date of publication of the scientific document

2.3.2. Selection of methodology

First draft – Need of the methodology

We were thus able to see that the documents: [26], [27], [29], [30], [31], [32], [33], [34], [35],[36], [37] (see **Appendix 1**), do not meet the criteria mentioned above.

Second draft – Precision of the chosen methodology

We have thus seen that the documents: [38], [39], [40],[41],[42],[43], [44], [45] (see **Appendix 1**), do not meet the criteria mentioned above.

Through these criteria, we were able to select the methodology that corresponded the most: document [46] (see **Appendix 1**).

Energy master planning for net-zero emission communities: State of the art and research challenges [46]

Despite the high quality of this study, we have made changes to the methodology. These modifications have made it possible to enrich the proposed basis in relation to the said study [46].

- More precisely these changes concerned the names of the phases.
- These names and the orders of certain steps.
- The enrichment of the content by new scientific studies updated since.

Initially, we changed the name of the phases to make it more coherent on the progression of the methodology: "Actor and outcome", "Current situation", "Strategy and action plan". Also, we made changes due to the inconsistency for phases "data collection and analysis" which itself includes the "calculates energy need and emissions" part, so we merged them.

Ina second step, we noticed that some steps can be "merged" and renamed. We have merged the stage "community actor" and "political actor" because their common points concerned both to bring together the actors. We have also placed the stage "selection of indicators", in the new phase named “Current situation”, because are contained concerns the design. And we've renamed the entire chapter 3 with progressive and more coherent terms.

In a third step, we have enriched the entire content with scientific studies (see **Appendix 1**) in Chapter 3.

2.4. The chosen methodology

In this part we will make a global summary of the scientific document [46], in order to define and explain some important terms and concepts for part 3.

2.4.1. Neighborhood wide methodology

An NZED refers to any group of buildings (e.g., city districts, communities, villages, groups of buildings or a university campus) with the objective of achieving a net or positive energy balance, which produces less energy than it consumes and whose reduced energy demand is met by renewable energy produced on or near the spot [9] [1], [11].

Energy Plan

The novelty of NZED as an area of research is highlighted by a significant proportion of articles found in the literature that offer new frameworks, methods, and tools, which serve as a theoretical basis for the transition to NZED [2].

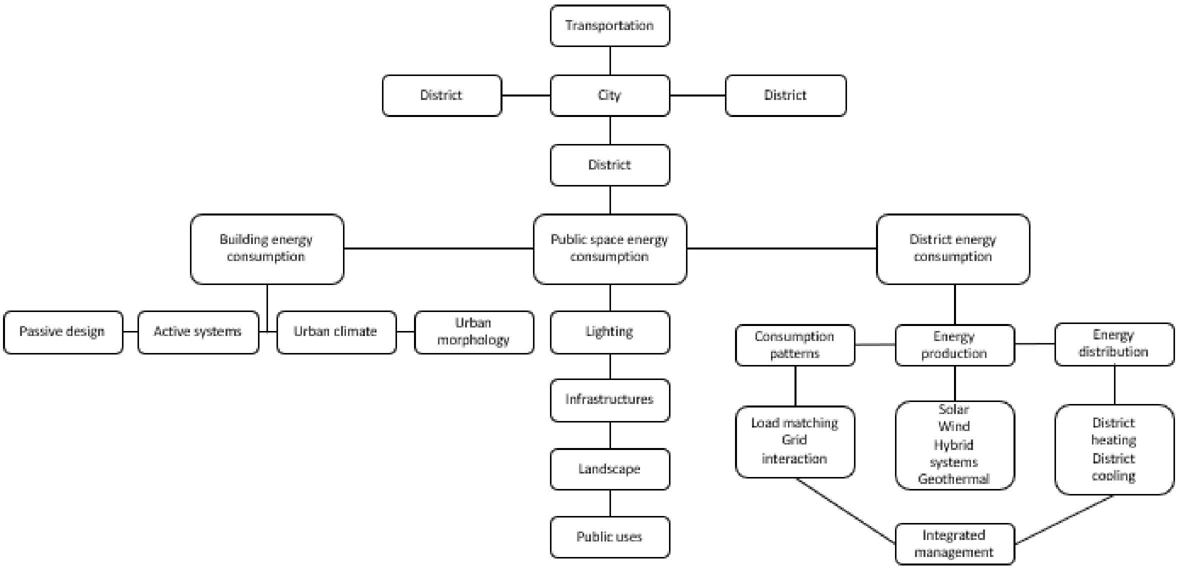


Figure 2 Methodology to achieve nearly zero energy and carbon neutrality in the city scale.

These suggestions were developed for the following purposes:

- Define and classify.
- Quantify and calculate their demand and/or energy balance.
- Evaluate the performance and/or energy effects of the district.

This conceptual framework of the NZED methodology allows decision-makers to define their own NZED strategy, choose the appropriate KPIs, and set goals for each KPI based on the context in which the neighborhood is located.

To achieve a balance close (for NZED) or equal (for NZED and PED) to zero, it has been established in theory and practice to reduce the energy demand of a district to the absolute minimum before providing the maximum amount of renewable energy that local energy generation systems can provide.

In this regard, we examine [3] the mathematical formula of the NZED objective as follows:

$$min \sum f_{Demand} \leq max \sum f_{offer}$$

Where demand matches the overall energy needs of the neighborhood, and supply represents the total amount of renewable energy that can be supplied. Energy demand reduction can be achieved through a variety of energy demand reduction measures (and combinations thereof) applied at different scales.

The following table and diagram explain that the maximization of renewable energy supply occurs at two levels, with renewable energy sources on site having priority over renewable energy sources off site.

Option number	**Supply-side options**	**Examples**
0	Reduce the site's energy consumption with energy-efficient construction technologies	Natural lighting, high-efficiency HVAC equipment,natural ventilation, evaporativecooling, etc.
On-site procurement options		
1	Use the SER available in the construction footprint	PV, solar hot water, and wind located on the building
2	Use the SER available on the site	PV, solarhotwater, low-impact hydropower and wind located on-site, but not on-site building.
Off-site procurement options		
3	Use off-site SER to generate on-site energy	Biomass, wood pellets, ethanol or biodiesel that can be imported from off-site, or waste streams from on-site processes that can be used on-site to generate on-site electricity and heat
4	Buy off-site SER	Wind, photovoltaics, emissions, or other “green” purchase options based on utilities. Hydropower is sometimes considered.

Figure 3 Overview of off-site of on production location and source

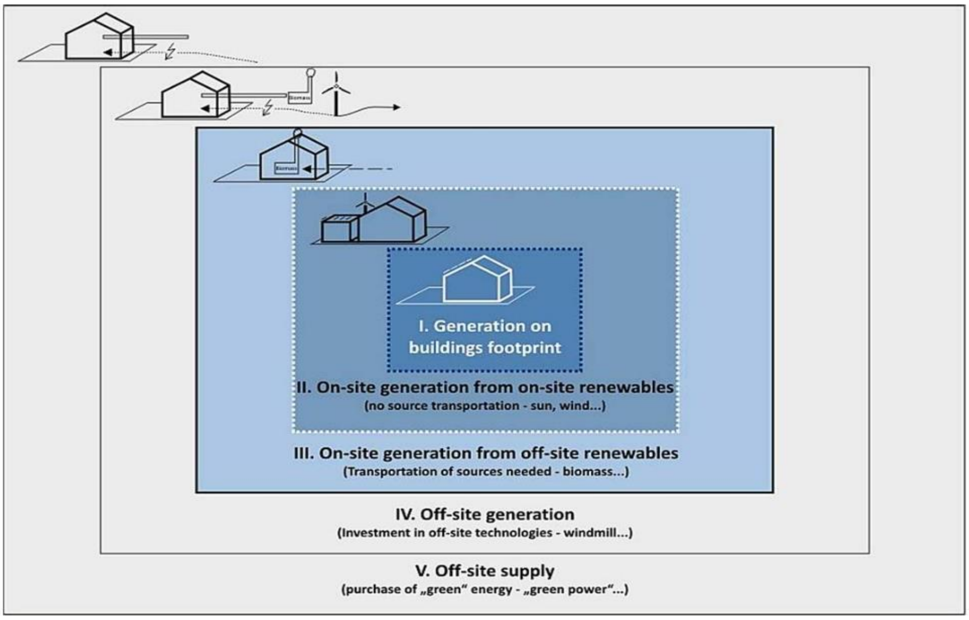


Figure 4 Overview of possible RES options based on production location and source [49]

Although these measures are only applicable to buildings, they must be preserved in the district because the main objective remains the reduction of the load of the largest energy consumers by sector (generally in Spain):

The energy consumption is: Building 18,3%, industry 24,8%, transport 39,8%, agriculture 3%, and fishing 0,4%, according to national data from the international energy agency (IEA) for Spain [48].

In this scheme, energy demand reduction measures (EDRMs) are classified as energy saving measures (MSEs), "active" energy saving measures (ESMs) and must be prioritized accordingly.
These intervention scales can be adapted to illustrate the ideal process of reducing energy demand in districts. In this representation, EDRMs are classified as (1) Energy saving measure (ESM), (2) Energy efficiency measure (EEM), or (3) Energy conservation measure (ECM) and should be prioritized accordingly [10].

Instead, it distinguishes between passive (ESM) and active (EEM) solutions that apply at the building level and uses the "systems" scale to refer to the neighborhood (e.g., energy, water, and waste systems).

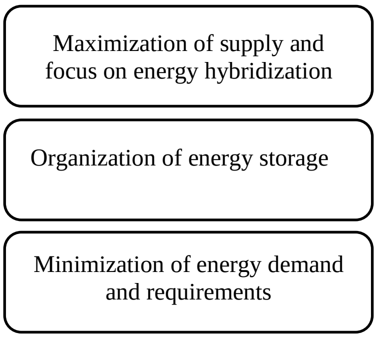
Scale of intervention

		Urban	**Building**	**Systems**	**Occupants**
EDRMs	**ECMs**			**5°**	**6°**
	EEMs		**3°**	**4°**	
	ESMs	**1°**	**2°**		

Table 3 Energy demand by scale of intervention to minimize the energy demand on the districts. Numbers indicate priority

On the other hand, the maximization of renewable energy supply takes place at two levels, with on-site renewable energy sources having priority over off-site renewable energy sources for the reasons mentioned above.

This strategy, or "pillar of action", must also work in tandem with the organization of energy storage devices to ensure the energy independence of the district and security (EIS).



It is also necessary to pay particular attention to the match between supply and demand to minimize network responsibilities and maximize the efficiency of the NZED network [12].

With "smart" systems and technologies (e.g., smart meters, ESM, etc.), which facilitate the interaction between demand and supply and thus help to optimize the flexibility and autonomy of the entire district energy system.

2.5. Summary

2.5.1. Zero energy

Due to the promising technologies and economic and social benefits of NZED over NZEB, the neighborhood-based approach to achieving a zero-energy goal has recently attracted the attention of researchers and policymakers.

2.5.2. Methodology chosen

After establishing the following criteria:

1. The quality of the information transmitted.

2. The accuracy, figures and number of documents consulted to establish that methodology.

3. The date of publication of the scientific document.

We have deduced the methodology that will serve as a basis for our development.

2.5.3. Methodology for zero energy district

The basic technical strategies to achieve zero energy balance in districts follow this order:

1. Minimization of energy demand.
2. Maximizing the supply of renewable energy.
3. Optimization of the flexibility and autonomy of the system.

The first and second core strategies focus on demand and supply respectively, while the third strategy focuses on the interaction between the two. The relationship between these strategies is based mainly on the "three pillars of action" described in [3], with the addition of a digital layer that encompasses all pillars (or strategies).

CHAPTER 3. DEPLOYMENT OF THE METHODOLOGY

This chapter presents the main contribution of this scientific dissertation and concerns the conceptual framework and methodology for renovating existing residential areas and transform them into near NZED. This chapter dissects each step of the planning and decision-making process and explains how and why the framework is designed as such.

3.1. Background

First, let's redefine the concept of methodology. The methodology is the study of all scientific methods. It can be considered the science of the method, or even the "method of methods".

Before the implementation of a project methodology, the project itself takes the following reflection:

Preliminary	**Methodology**	**Realization**
Decision to start the project	Project definition	Project plan implementations

Table 4 Major phase of the NZED project.

The skeleton of the methodology selected in the state-of-the-art section was chosen by defined criteria. However, many changes have been made with the help of scientific documents which have made it possible to enrich the proposed base and adapt it to the Vera campus.

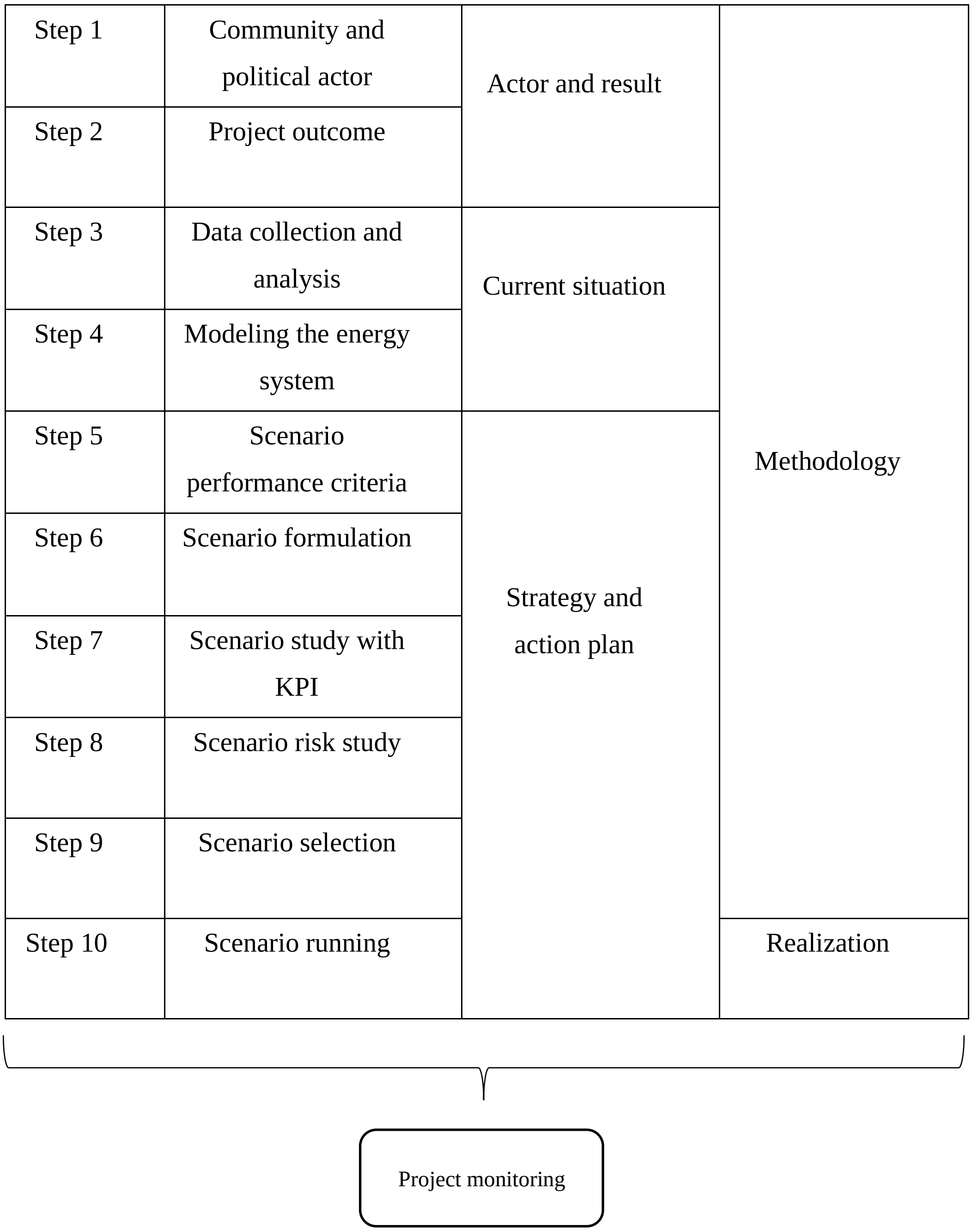
The methodology for designing a carbon-neutral neighborhood hereby presented consists of 10 steps arranged in two phases (figure 4):

- The methodology (with 9 steps)
- The realization (with 1 step)

This master focuses only on the planning section, which has three sub-phases:

- Actor and outcome
- Current situation
- Strategy and action plan

As the project progresses towards execution, the level of performance uncertainty decreases [6], and the energy master plan (EMP) evolves from conceptual to more detailed.



Step 1	Community and political actor	Actor and result	Methodology
Step 2	Project outcome		
Step 3	Data collection and analysis	Current situation	
Step 4	Modeling the energy system		
Step 5	Scenario performance criteria	Strategy and action plan	
Step 6	Scenario formulation		
Step 7	Scenario study with KPI		
Step 8	Scenario risk study		
Step 9	Scenario selection		
Step 10	Scenario running		Realization

Figure 5 Detailed steps of the methodology for the design of NZED.

3.2. Methodology

3.2.1. Actor and outcome

Strategic planning, in the general sense of the term, consists of establishing an overall development scheme (as opposed to tactical planning that focuses on specific activities) with the aim of achieving a set of pre-defined objectives.

This step concerns the organizational management activities that provide guidance to stakeholders and the district renewal project by establishing agreement on common objectives, expected results and ways to achieve them [15].

Step 1: Community and political actor

- Community actor

The involvement of all relevant stakeholders was considered essential at all stages of the planning process.
In addition, given that "effective communication and awareness-raising initiatives strengthen local support for the project, which can contribute to strengthening the project's business case" [13], it is strategic to identify and communicate with all stakeholders involved from the outset of the NZED renovation project. It is necessary to maintain the efforts and to exchange regularly with the stakeholders so that they follow the project in its progress.

- Political actor

Given that the transition to NZED is largely influenced by international and local policies, the review of these policies is the first step to provide all parties[3] involved with a holistic view of the project [3].
We arrive at the notion of project at the end of the chain "distant causes-next causes-problem-issue-actor-project" in the politic field.

In addition, international and local policies are adopted and detailed in planning and building regulations, where mandatory requirements and constraints help shape the goals and objectives of the project [6] (see step 5).

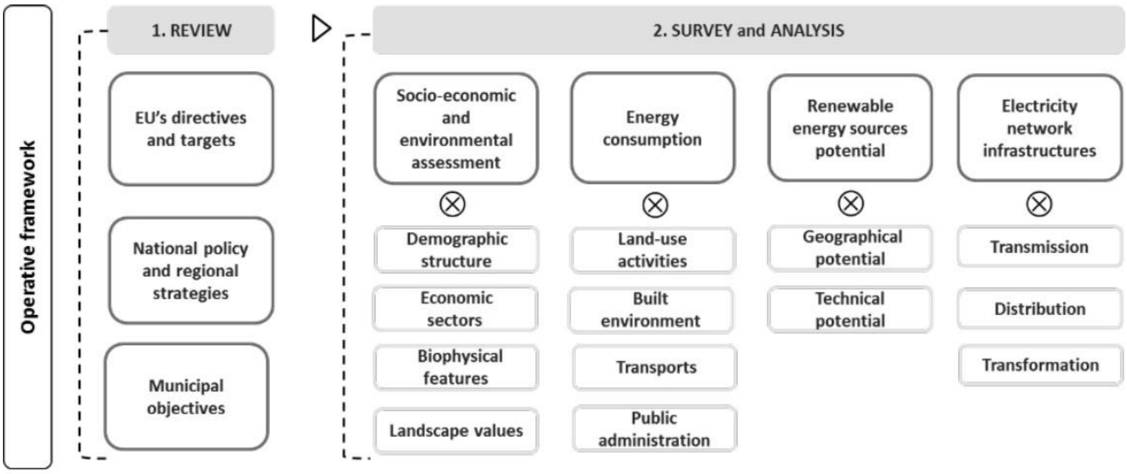


Figure 6 Operational framework of the SMART RURAL model. Source: Poggi et al. [8].

This figure describes the operating framework of the smart rural model. More precisely, it is divided into two sections "review" and "investigation and analysis" :

- The review section lists the different political and intervening actors in the project in descending order (EU, national, municipal).

- The survey and analysis part lists in four sections the energy supply and demand on a rural scale. Its four sections are themselves divided into sub-sections on actors playing a role in energy supply / demand (such as transport, economy, electricity distribution).

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[3] Who is interested in its object in its entirety.

Step 2: Project outcome

We must then give meaning to the project by defining an objective and a need that aims to promote our actions.

So we have to define the location of the project and the KPIs of what we want to measure to arrive at the objective.

3.2.2. Current situation

Creating the baseline scenario for a district requires a detailed representation of the entire system (energy system, built and unbuilt environment, on-site resources, etc.) to identify current demand and available supply. The accuracy of this representation, however, depends on the quantity and quality of the data collected, as well as the methods and tools used to collect and process it.

Step 3: Data collection and analysis

Data analysis also known as exploratory data analysis or Exploratory Data Analysis (EDA) is a type of statistical method whose main characteristics are to be multidimensional and descriptive[4].

Several methods, most of which are geometric in nature, help identify possible relationships between various data sets and extract statistical information that allows for a more succinct description of the main content of the data. There are other ways to group the data.

Other strategies help organize data in a way that makes it stand out, making it more consistent and easier to understand.
Data analysis makes it possible to work with many data sets and extract the most interesting features of their structure.

According to the analysis [3], the most important element in determining a district's baseline scenario is the collection and analysis of data, which makes it easier to identify opportunities and constraints of the site.
However, getting a complete set of data is time-consuming and not always feasible, especially in the early stages [6].

According to the observation [5], the data collection procedure presents three major challenges:

- The type of data to be collected.
- The minimum level of detail required to ensure validity and reliability.
- The stakeholders who would benefit from this data.

For example, during the analysis process, data are continually reviewed and supplemented to the extent possible. If there is already on-site energy production, it will be determined from which sources it comes, as well as the schedules, circumstances, and power it produces.

A difference will be made between thermal and electrical demand in the classification of consumption.

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[4] Which concerns several levels, several dimensions of experience, knowledge.

In addition, data on consumption characteristics and temporal data will be collected over a year to conduct simulations.

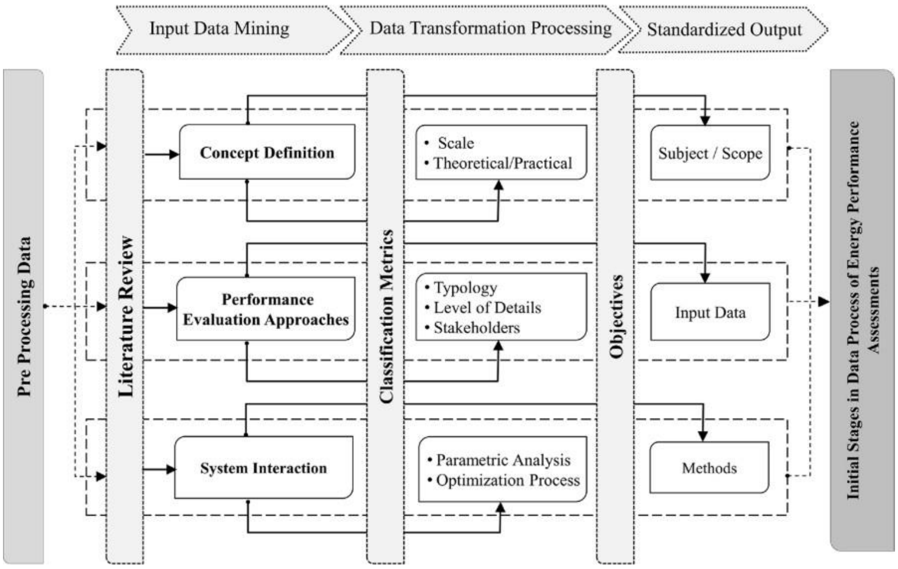


Figure 7 Data processing for data collection.
Source: Aghamolaei et al. [1].

Several sectors are primarily responsible for carbon emissions around the world. It is for this reason that we have focused our system into four macro-areas of interest :

- Transport
- Residential
- Energy
- Waste management

With this macro areas, we reunify all the data (who depend on the project: campus, house district…) who permit to design a nearly zero energy district.

➢ *Calculation of the energy balance*

Finally, it is necessary to provide a detailed description of energy use (key indicators that allow where to act) during the data collection and analysis phase.
What makes a district an NZED is the respect of the NZE balance and, therefore, a method of calculating the balance sheet that must be included in the data collection phase.
The list of variables that will be used in the next calculation method can be found below.

Variable	**Parameter**	**Unit**
E_D	Total energy demand	kWh/year
E_S	Total supply of electrical energy	kWh/year
z	Minimum unmet demand (acceptable for NZED)	kWh/year
d	Energy consumption per capita	kWh/inhabitant/year
n	Population	#
E_{D_0}	Base energy demand	kWh/year
I	Scenario number	#
E_X	Total energy savings through energy demand reduction interventions	kWh/year
j	Number of interventions reducing energy demand	#
X	Energy saving per intervention	kWh/year
k	RES intervention number	#
S	Energy produced by RES intervention	kWh/year

Table 5 Table with variables for energy calculation.

The NZED balancing principle for this work.

$$ED = ES \quad (12)$$

Before the calculation of the balance can proceed, the following parameters are required: the current population (n), the energy consumption per capita (d), and the minimum energy demand that is not met by renewable energies (z). With all this, the base energy demand can now be determined using equation (13):

$$E_{D_0} = nd \quad (13)$$

For each scenario (i), the total reduced energy demand of each intervention shall be calculated as follows:

$$E_{X_i} = \sum_j X_j \quad (14)$$

before subtracting it from equation (13) to determine the new total energy demand for this scenario (EDi), described as:

$$E_{D_i} = E_{D_0} - E_{X_i} \quad (15)$$

The RES supply options are then reviewed and proposed to match the value obtained from equation (15). The total energy of energy in the supplied form is then calculated as follows:

$$E_{S_i} = \sum_k S_k \quad (16)$$

If the ZED balance, expressed as:

$$\text{ZED balance} = E_{D_i} - E_{S_i} \qquad (17)$$

satisfies the condition described in equation (18):

$$z \leq \text{ZED Balance} \leq 0 \qquad (18)$$

then, this scenario passes the NZED assessment and can proceed to the evaluation of the district according to the performance criteria defined at the stage selection of the KPIs and establishment of the objectives.

Step 4: Modeling the district energy system

The main objective of modelling a district's energy system is to provide an accurate estimate of the district's baseline energy demand, which serves as a starting point for the next stage of performance criteria for scenario and setting targets. The scientific literature is full of methods for estimating the energy demand of neighborhoods, with top-down and bottom-up approaches being the most common.

Regarding the top-down approach, energy demand in neighborhoods is estimated from initial data, which are collected through economic (e.g., energy prices and incomes) and technological (e.g., application ownership trends) correlations [16].

- Firstly, they model an urban block as an entity based on its general characteristics and are therefore not able to explicitly account for the energy consumption of each building [18].
- Moreover, the distinction can be used to describe the mode of animation and steering of a procedure as a participatory (bottom-up) steering, in which the facilitator's file begins with the perceptions and initiatives of the lowest (hierarchical) or lowest (operational) level to be examined, rejected, and considered by the higher levels.

Regarding the bottum-up approach, that calculate the energy consumption of each building before extrapolating the results to represent the entire district [17], top-down methods calculate the energy consumption of each building before extrapolating the results to represent the entire district.

- Firstly, they reconstruct the behavior of an urban block from the individual behaviors of its constituents, where the total energy demand is the sum of the energy demands of each building [18]. As a result, we have a better understanding of the methods for estimating the demand of available neighborhoods.
- Moreover, the difference can be used to refer to the mode of animation and control of a procedure as a directive (descending) control, while the hierarchy controls the thread of the animation. The "subordinate" levels are responsible for formatting, executing, delegating, and improving the prescribed instructions.

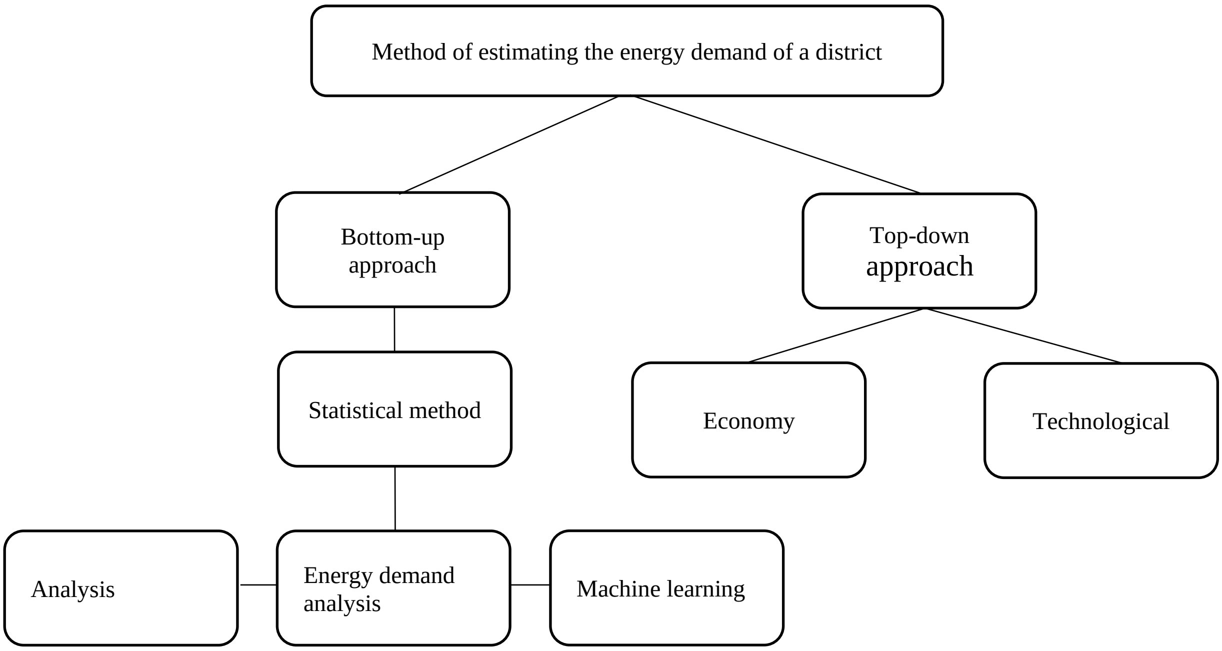


Figure 8 Classification to estimate the energy demand of a district.

As we can see, this diagram describes the method of estimating energy demand of a district according to two distinct approaches: bottom-up and top-down.
It is important to note that this research brief lists the options available to estimate the district's energy demand. Depending on the time and resources available, the desired level of accuracy, and the technical know-how of the simulators, decision-makers in a renovation project may use one of these methods [7].

Therefore, these tables provide a comparative overview of these methods, which can guide decision-makers in choosing the most appropriate method to assess the district's energy consumption.

3.2.3. Strategy and action plan

Step 5: Scenario performance criteria

KPIs are a predetermined value that allows us to monitor and measure the performance of its site or application. It is possible to evaluate the effectiveness of an action or set of marketing activities.

Project goals and desired effects are translated into problem-solving objectives, which are frequently classified as environmental, economic, or social [19]. In addition, based on the analysis [6], we can add that the technical performance of a district can also be called "n-bottom lines" (nBL).
Among these four objectives, economic objectives predominate in practice [6], [19], while also being verified for compliance with regulatory and technical constraints [6].

Decision-makers should establish performance criteria to facilitate the assessment of a scenario at the risk assessment stage and the assessment of a district's progress towards the NZED target during and after the implementation stage. The following formula [6] is used to break down the composition of a performance criterion:

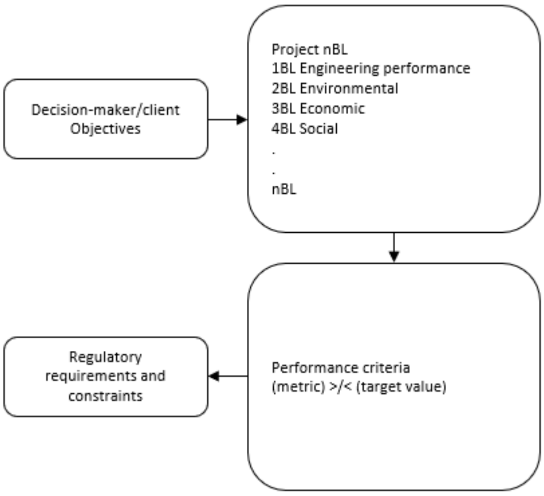


Figure 9 Performance criterion election.
Source: Aghamolaei et al. [1].

This diagram allows us to make decisions based on performance criteria and to deduce requirements and constraints.

In which the process of selecting performance criteria is shaped by decision-makers' objectives and regulatory constraints. The table below lists the evaluation criteria used for each n-bottom row.

Economical	**Environmental**	**Social**	**Engineering Performance**
Discounted cost	CO2emissions	Job creation	Energy resilience
CapEx	GHG emissions	Social acceptance	Energy consumption
Operating expenses	Refrigerant emissions	Productivity	Reliability
LCC Card	Water use	Security	Energy efficiency directive (DSI)
Return on investment (RI)	Waste generation	Welfare	The IEQ
Recovery time	Embodied carbon	Participation	Thermal comfort
WINNOW	Air quality	Aesthetic	Interaction with the grid
Annual cost of energy	Depletion of natural resources	Human health	Load match and grid interaction (LMGI)
Maintenance cost	Land use	Social equity	Lifespan
Incentives	Biodiversity	Education	Loss of energy
Tax	Ecotoxicity of materials, mobility	Confidence	

Table 6 KPI performance indicator related to energy measurement.
Source: Aghamolaei et al. [1].

So after having seen the diagram on the performance criteria, this diagram lists an example of a key performance indicator included in each performance criterion.

In addition, decision-makers can assign a weighting factor to each KPI based on internal or external motivations. However, this work does not promote a set of performance criteria or a corresponding scoring system, instead leaving the selection to the decision-makers of the renovation project.

This is the last stage of the design and modelling phase, and it is at this stage that a solution is formulated and proposed to be implemented in the execution phase. The chosen action plan, together with a detailed explanation of the actions and a detailed description of the guidelines on how to implement it, are integrated into a broader and definitive plan which will then guide the implementation of the NZED modernization project at the implementation stage.
Thus, formulating solutions allows objectives to move from ideas to solutions, to evaluate, strengthen and select the most suitable solutions.

Step 6*: Scenario formulation*

We know that the process of developing a strategy involves setting goals, or a desired outcome that organizations' activities must enable them to achieve. The definition of objectives is therefore linked to future forecasting as well as operational reforms.

Specifically, the scenario includes strategies to achieve the objectives set in the step 5. This is a key that will guide in a general view. The specific view will be formulated in the step 10 (action plan), for the execution of the project.

Generally, each scenario must include these criteria (who permit to quantify the project):

- Technical, which focuses on engineering solutions
- Financial/Economics, which concerns financing programs
- Policy and strategic, which focuses on the
- Resource, which deals with resource mobilization (e.g., people, equipment, etc.). However, this work covers only strategies in the technical field.

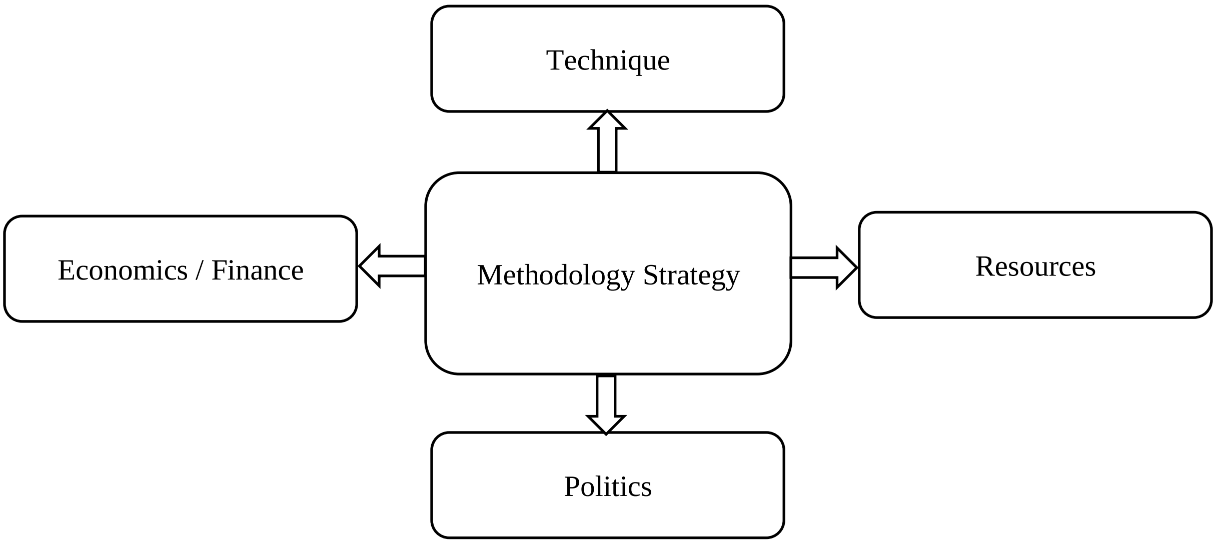


Figure 10 Strategic areas of methodology.

Precisely, each scenario has to respect the following criteria (who guide in the final objective to design a near-zero energy district):

ENERGETIC	DIGITAL
S1: Minimizing energy demand	
S1A1: Renovation of the building envelope (e.g., thermal insulation, glazing, etc.) S1A2: Modernization of active systems (e.g., HVAC, lighting, energy-efficient appliances, etc.)	S1A3: Smart Technologies
S2: Maximizing the supply of renewable energy	
S2A1: On-site RES S2A2: Off-site RES	S2A3: Smart Grids S2A4: Energy Optimization
S3: Optimization of the flexibility and autonomy of the system	
S3A1: Energy Storage	

Table 7 Technical action to design a NZED.

This table presents the different actions from an energy and digital point of view. Each action is numbered, and this is intended to meet three main criteria to reach the NZED (Minimizing energy demand, maximizing the supply of electrical energy, optimize system autonomy and flexibility).

Due to varying constraints depending on the context, not all these measures could be realistically implemented in all modernization projects. Thus, decision-makers can choose from a variety of combinations of these elements based on what best suits their needs.

The table below shows all possible combinations, called "sets of action plans", from which decision-makers can choose. However, there is a minimum criterion that must be met to meet the definition of the NZED ("basic minimum" package), and failure to meet this criterion does not qualify for an NZED.

Set of action plans	**Actions**
Basic minimum	S1A1 + S1A2 + S2A1
Smart Minimum	S1A1 + S1A2 + S2A1 + S1A3 + S2A3
Autonomous minimum	S1A1 + S1A2 + S2A1 + S3A1
Intelligent autonomous minimum	S1A1 + S1A2 + S2A1 + S1A3 + S2A3 + S3A1
Minimum optimized	S1A1 + S1A2 + S2A1 + S1A3 + S2A3 + S2A4
Optimized standalone minimum	S1A1 + S1A2 + S2A1 + S1A3 + S2A3 + S2A4 + S3A1
Basic maximum	S1A1 + S1A2 + S2A1 + S1A3 + S2A2
Smart Maximum	S1A1 + S1A2 + S2A1 + S1A3 + S2A2 + S2A3
Maximum autonomy	S1A1 + S1A2 + S2A1 + S1A3 + S2A2 + S3A1
Intelligent autonomous maximum	S1A1 + S1A2 + S2A1 + S1A3 + S2A2 + S2A3 + S3A1
Maximum optimized	S1A1 + S1A2 + S2A1 + S1A3 + S2A2 + S2A3 + S2A4
Optimized standalone maximum	S1A1 + S1A2 + S2A1 + S1A3 + S2A2 + S2A3 + S2A4 + S3A1

Table 8 Advanced Modernization Strategy.

Each action is therefore classified by the criteria set in this table, which makes it possible to obtain the above result.

Step 7: Scenario study with KPI

Firstly, in this step we study all the formulated KPIs (in step 2), depending on the scenario. That permit to know if the scenario selecte is better than an other scenario the answer at the final result of the project (because the KPIs are based to measure the final result).

Moreover, the results of the quantitative modeling are presented and discussed. The scenarios are compared by their demand, their production and finally by their performance within the KPIs.

Step 8: Scenario risk study

The study of the risks of the scenarios is important. This involves a review of information about the project itself, energy projects, geopolitical information, and previous projects. Some examples of information gathering techniques used to identify risks are:

- Brainstorming
- Interviews with experts
- SWOT Analysis [9]

It may be interesting to use one or more of the tools mentioned above (who permit to cross again the result to precise the final answer).

Step 9: Scenario selection

This part becomes much simpler in view of the work carried out on the table of actions and criteria and the study of the risks of the scenarios.

All scenarios that pass the risk assessment stage will be subject to a final selection procedure by the decision-makers.

We recall the set of criteria for choosing the scenario:

- Scenario study with KPIs
- Scenario risk study

Moreover, it is possible in this part to precise more the data with the software (for example: QGIS, HOMER…), who permit to select more precisely the good scenario.

Before starting the action plan associated with the final stage of the methodology, a single scenario is chosen based on the collectively established and validated priorities.

Step 10: Scenario running

The chosen action plan and the detailed explanation of the guidelines on how to implement it, are incorporated into the final with an energy management system (EMS) which will then guide the implementation of the NZED modernization project until the execution phase.

- *Execution*

After the selection of the scenario, we do an action plan who will permit to guid the team who execute. This action plan will be presented in the form of a table containing the results formulated in the chosen scenario but with more precision because it will also include "what", "who," where "," when ".

After the approval of the final energy plan, the NZED modernization project is launched. However, regular monitoring is necessary to ensure the validity of the expected results of the final energy master plan.

Project deliverables are delivered throughout the execution phase of the project. Therefore, it is the phase that uses the most energy and resources. During this phase, a variety of tasks and methods are used to solidify the project concept and achieve its objectives.

- *Project monitoring*

We know that verification is an essential step in a project because it allows you to adjust the plan to achieve the project result.

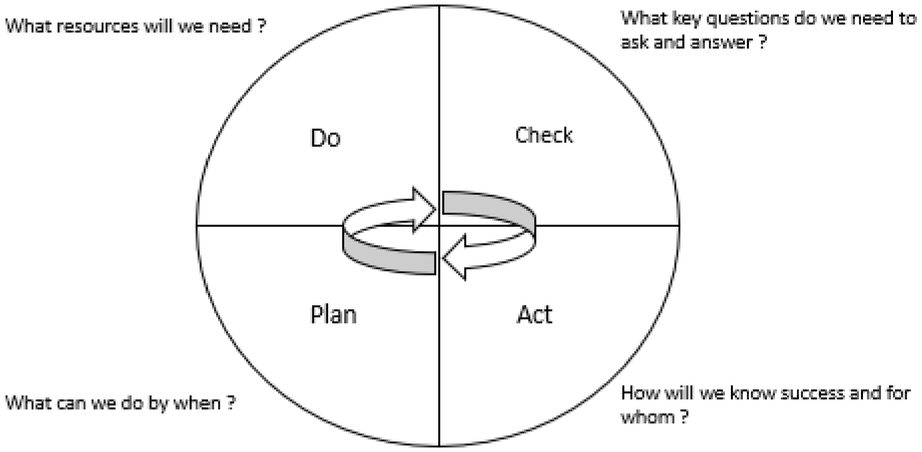


Figure 11 Verification of a project in continuous improvement mode.
Source: PDCA, 2014. Project monitoring and verification [21]

William Edwards Deming formalized and popularized this methodology based on the Plan-Do-Check-Act continuous improvement logic, and it can be applied to a variety of other methodologies.

The verification phase is essential because it allows to evaluate the results of the next phase, as well as to determine whether the objective is achieved and whether corrective or preventive action is necessary.

- Verification is about ensuring that things are done in accordance with what has been defined using key indicators (see step 5).
- Validation is about ensuring that the desired results have been achieved.

We do this verification with the KPIs formulate in the step 2.

3.3. Summary

The initial goal is to design NZED neighborhoods to achieve a goal of carbon neutrality by 2050. This goal is itself set with the aim of responding to the major problem of the 21st century, global warming.

This part therefore presents the development of the methodology for planning and predicting different scenarios to carry out the design of a neighborhood or campus in NZED.

The initial phases of the methodology are to bring together the different actors useful to the project, diagnose and design the NZED transition, and formulate a strategy and action plan for the execution of the methodology.

As we have seen, the definition of the main objectives of an energy strategy is influenced by technical, economic, social, and administrative factors.

The development of strategic scenario alternatives facilitates this decision-making. Between advantage and disadvantage, decision-making is quantified, which makes it possible to have the most accurate answer possible in relation to the most suitable scenarios for a given situation.

Once the strategies are proposed and simulated, a risk analysis is carried out to minimize the uncertainty of the project and to facilitate the decision on the strategy to be followed.
This analysis highlights the differences between the scenarios and makes it possible to definitively choose the most adapt and the least risky to execute it.

CHAPTER 4. VALIDATION. CASE STUDY FOR THE UPV’S VERA CAMPUS.

This chapter presents and analyzes an example of a case study selected to determine the applicability of the conceptual framework of the methodology proposed in Chapter 3. Hence, this case study intends to be a “validation” of the methodology.

4.1. Background

In terms of the use of public space and long-term viability, the Polytechnic University of Valencia (Campus of Vera) is very active.
Its goal is to transform itself into a shared green place for its students. A place that weaves links between tradition and innovation through culture, where entrepreneurship and education meet sport and international research.

This strategy aims to serve as an example for other campuses and neighborhoods. It launches the university into a phase focused on the sustainability issues that have become so crucial in recent years. Since then, the University of Valencia has been studying the possibilities of spatial sustainability through sustainability reports and impact reduction studies.

We can cite several previous studies conducted by this laboratory aimed at reducing the carbon footprint of the university by calculating the carbon footprint of this institution.

A case study will permit to validates the chosen methodology, based on real life data using primary data collection.
The application of the methodology (formulate in the chapter 3) will be followed to the letter, thus demonstrating the effectiveness and capacity of the methodological framework through its ability to determine if and how the context affects the results, allowing for greater generalization [20].

4.2. Methodology

First, we know that case study is a method used in qualitative studies but can be used to validate a methodology.

4.2.1. Actor and outcome

Step 1: Community and political actor

Firstly, the primary action is to define a list of actors who permit to help to realize the project.

After that, we have to schedule a meeting to discuss with the actor about the project.

The purpose of the meeting is thus to propose solutions concerning the development of the Vera campus towards the near energy district. The various issues discussed with actors will focus on carbon emissions at the level of transport, residences, and energy (we will exclude waste management because it is not included in this master’s thesis). The central question of this meeting will be the help that these actors can bring in this project and the problems mentioned.

- Community actor

The renovation of the Vera campus in NZED begins with a meeting with all stakeholders (or with their key representatives) for their initial preparatory meeting regarding the project.

The stakeholders of each project, as well as their key actors, are identified and listed. The categorization of stakeholders is adapted from the IEA [14], as shown in the table.

Stakeholder	**Actor**
Users	Referent student, professor, staff, (company = bars, shop, student staffs)
Investors	Public administration, UE junior, Spanish government, company (pay research, laboratory)
Political actors	City of Valencia, regional government, ministerial education
Actors related to the district	Neighbors of the campus, mobility suppliers, highschool systeme of students...
Energy Network Solution Providers	Retail companies (buy/sell energy) = gas retail companies
Renovation solution providers	Retrofiting companie, energy equipment companies, mobility companies
Other intermediaries	Media, other universities

Table 9 Different stakeholders and actors related to the project.

These actors can all contribute to the nearly zero carbon evolution of the Vera campus.

Let us take the example for the referring students.

We could consider a meeting to decide what actions they can take for the campus. This could be for example the daily use of the bicycle with a reward system every time he uses it. It will also be a sensitization to change the mentality concerning the use of their university accommodation (water, electricity ...).

We can also take the example of investors and more specifically the Spanish government.

We could arrange a meeting to present them the situation on our campus and send them a costed and realistic plan to make it nearly zero carbon, in order to benefit from their help.

In addition, we can take the example of actors linked to mobility.

Indeed, we could plan a partnership including an award ceremony that will encourage students and staff entering and leaving the Vera campus to take public transport rather than the car, the motorbike …

Finally, take the example of energy equipment companies.

We could solicit their help for the installation of solar panel in order to extend this renewable energy on the whole of the campus.

- Political actor

Stakeholders should then review all political actor relevant to the project, which are listed in the table below depending on the administrative level that issued them.

Stakeholder	**Actor**
EU	Horizon Europe funding program
National	Minister of education
Regional	Regional department of education
Municipal	City of Valencia

Table 10 Different stakeholders and actors related to the project at the global level.

Take the example of the actor (City of Valencia).

We could consider some help from them for the partnership and a price reduction with "valenbisi" to encourage even more students and staff entering and leaving the Vera campus to take the bicycle rather than carbon emission transport.

Finally, we can solicit all the strategic players (EU, national, regional, and municipal).

Who permit to help finance the Vera campus for the development of nearly zero carbon.

Step 2: Project outcome

Firstly, we fix the territorial result boundaries of the entire district of the Vera campus and the demarcations of the area covered by the renovation project (marked by the shaded layer).

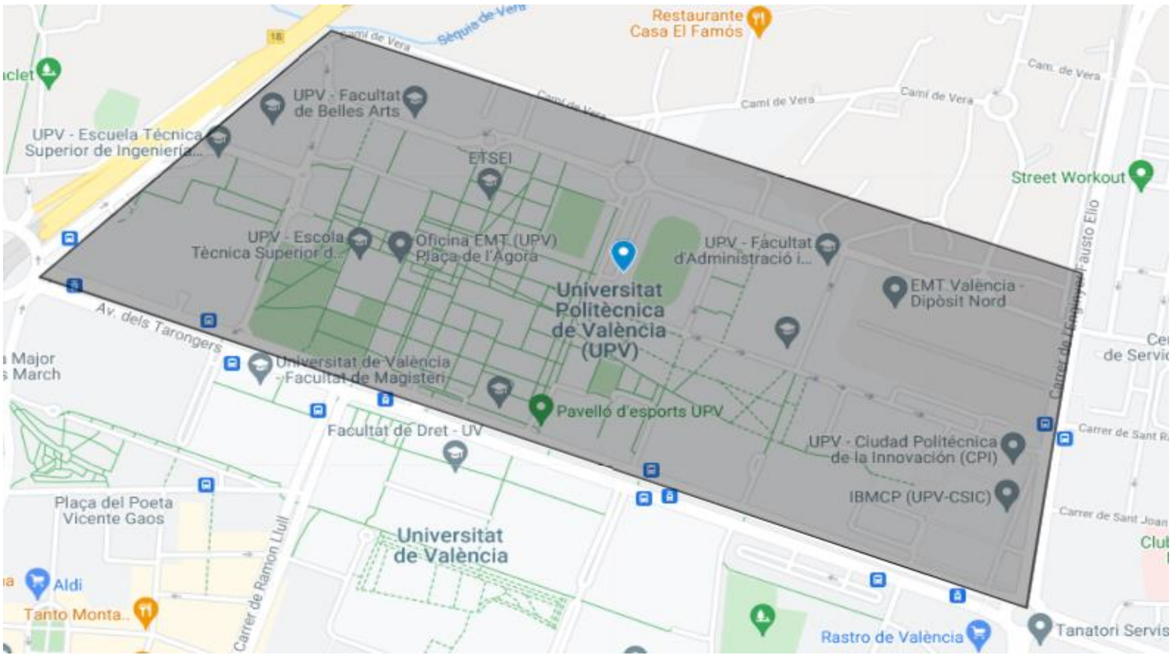


Figure 12 Satellite photography of the Vera campus.

Moreover, the criteria result for the Vera campus is the following:

Criteria of the project	**KPI**	**Unit**
Nearly zero primary energy	Light savings Mobility savings HVAC savings	GWh
Electric autonomy	On-site PV Wind power Geothermal Biomass Underground	GWh
Nearly zero carbon energy	Transport (car, bus) Residential (heating, hot water, oven, stove), Energy (CO2)	GWh
Economic performance	Cost of each equipment and materials buy for the project	Euros

Table 11 NZED definitions for the Vera campus.

More generally, we choose these criteria because in the scientific study [46], it is mentioned that these criteria permit to answer at how design a near-zero energy district.

4.2.2. Current situation

Step 3: Data collection and analysis

In the proposed roadmap, this step (Data collection and analysis) is intended to cover only the methods and tools for data collection and analysis and is considered separate from those used in modeling the district system which is covered in Step 5.

However, this case study analysis reveals that the methods and tools used for data collection and analysis may also be the same ones used for modeling the district system.

The step « district energy system modeling » may occur simultaneously with the collect data. The first finding may be attributed to the rapid development of complex simulation software, whose high versatility has allowed them to perform several functions at the same time.

This, in turn, will permit the district system to be modeled while collecting and analyzing data to gradually increase its accuracy.

Step 4 : Modeling of the district energy system

Here we will therefore use a top-down approach, we start from the whole, breaking down into ever more detailed elements, to lead to a “total dissection”, an inventory of the studied object.

We chose this approache because this project must be very precise because we must arrive at almost zero energy.

We proceed by macro-domain and we will subsequently cut out these macro-domains on a case-by-case basis.

Several sectors are primarily responsible for carbon emissions around the world. It is for this reason that we have focused our system into four macro-areas of interest:

- Transport
- Residential
- Energy
- Waste management (we will don’t use this because it is not in subject of this thesis).

- Transport data

The UPV is located between Av. De Catalunya, Carrer de Enginyer Fausto Elio Road and Avenue dels Tarongers which give the district quick access to downtown Valencia by private car or public bus :

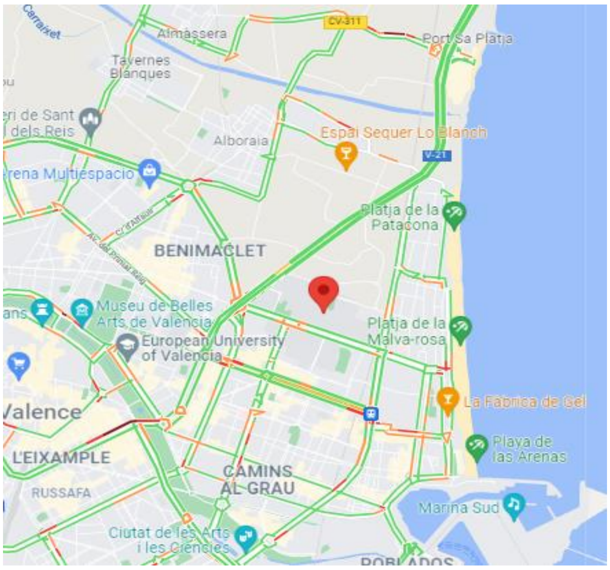


Figure 15 Truck drivers around the Vera campus.

Moreover, a quarter of those who arrive at the Campus of Vera walk or ride their bikes, while nearly 40% use public transportation. Metrovalencia and EMT Bus, in particular, are responsible for urban routes, whereas Renfe Train and MetroBus are responsible for interurban routes. Private transportation, such as cars and motorcycles, makes up the final quarter (see figure 14).
The Campus de Vera provides ample parking for these occupants, with over 5000 spaces. The majority of them are regulated by a system of stationing barriers, to which only employees and students with special needs, such as those who live in remote areas or in special circumstances, are allowed access (Universitat Politècnica de València, 2015).

The following diagram summarizes the many types of transportation :

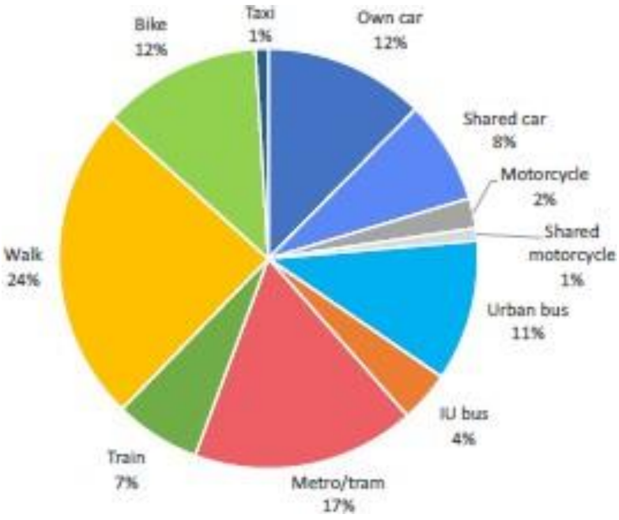


Figure 13 Transportation methods for residents of the Vera campus (doglianipietro, "Towards a Smart and Sustainable Campus of Vera," Universitat Politecnica de Valencia).

- ***Residential data***

The Vera Campus spans 558 306 m² and is home to 105 buildings with a total built-up area of 480 199 m². Since its inception, the campus has grown steadily, through many phases of building.

Figure 14 Buildings highlighted on the Vera campus. Source : UPV, 2021. Map of the Polytechnic of Valencia, campus vera [23]

It is also important to know the number of floors per building. These data will be very important for the rest of the calculations and the steps because they make it possible to know precisely the interventions that must be carried out for each floor of the building(s) concerned :

.

Orange	**Brown**	**Light green**	**Purple**	**Dark green**	**Red**	**Yellow**	**Pink**
5D = 2	6A=1	4M=3	2F=3	7H=1	1B=1	2E=3	5J=3
5I = 2	6F=1	4H=3	2B=3	7K=1	1E=3	3A=3	5H=3
5M=2	6E=1	4E=3	2G=3	7C=2	1G=3	3F=3	5F=3
5F=2	6B=6	4A=3	2D=3	7G=6	1F=3	3Q=1	5O=3
5E=2	6C=5; 3	4I=3	2C=3	7F=6	1C=3	3P=3	5P=1
5D=1	6G = 5; 3	4Q=3	2A=3	7J=6		3M=5	5Q=1
5A=1	6D= 5; 3	4J=2		7A=6		3K=3	5M=3
8H=2		4L=4		7J=4		3J=3	5K=3
8K=2		4K=4		7I=4		3H=3	5N=4
8N=1		4G=3		7E=4		3D=1	5I=2
8F=3		4D=4		7B=4		3C=3	5G=3
8D=3				7L=4		3B=3	5B=3
8C=3							5C=3
8A=3							5D=3
8I=1							5E=3
8J=1							5R=3
8P=3							5S=2
8B=7							
8E=7							

Figure 15 Number of floors per building on the Vera campus.

In addition, it is necessary to know the typology of each building. This is an essential variable when taking into account the NZED renovation.

Figure 16 Typology of buildings highlighted on the Vera campus.

Finally, we needed to know the evolution of each structure in order to do an extention of PV pannel for example.
To do so, we used Google Maps and cataloged every sort of building on campus. Our findings back up the work of (doglianipietro, "Towards a Smart and Sustainable Campus of Vera," Universitat Politecnica de Valencia).

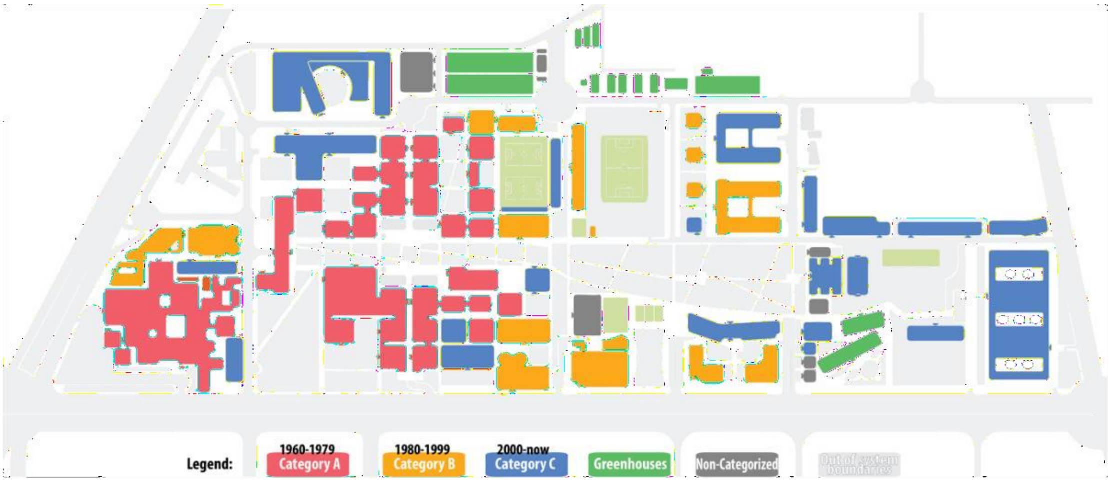


Figure 17 Evolution of each building on campus vera [50].

- *Energy data and calculation of the energy balance*

This case study is based on an ascending "bottom up" method for calculating their overall energy use. As a result, for this ascending method, we will prioritize the sense in which one departs from the details, from the "bottom," that is, the lowest echelon, in order to consolidate and operate a synthesis.

In fact, this method is far superior when attempting to synthesize a scenario in order to gather data on the ground, which is then used to return to the original path.

The goal of this section is to calculate and evaluate the Vera campus's energy consumption and output. To be more specific, it would be necessary to know what sort of energy is being used. As a result, we'll be able to provide a scenario that includes this element in order to get to a NZED.

The following data shows the base energy demand and renewable energy potential of the Vera campus (doglianipietro « towards a smart and sustainable campus de vera », universitat politecnica de valencia).

The built environment is assumed to be solely responsible for energy consumption in the geographic limit of the campus with a demand for :

- Electricity = 38 GWh.
- Gas = 8.3 GWh.
- Diesel = 0.2 GWh.

Energy demand = Electricity + Gas + Diesel

This translate into a primary energy consumption of 82 GWh.

Current situation	**Result**
Energy demand	82 GWh

Table 12 Energy demand of the campus of Vera in 2021

The heating, ventilation, and air conditioning system, in particular, accounts for 18% of overall electricity use (HVAC).
With the use of an internal and private memory dedicated to this topic [50], we were able to extract data that might be included in this report.

More specifically, the energy consumption by building evolution is as follows:

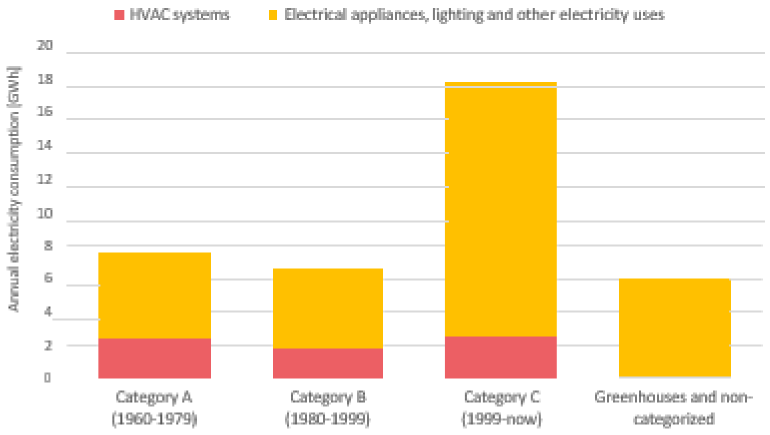


Figure 18 Energy consumption by evolution and building category in the Vera campus [50].

For this, the values and thicknesses of typical building envelope elements (for example, walls, roofs, and windows) are shown in the following table, which is organized by construction year. A more detailed overview of the various components may be found here:

Element	**EXT. WALL**			**ROOF**			**FLOOR**			**WINDOW**		
Category	A	B	C	A	B	C	A	B	C	A	B	C
Thickness [mm]	150	285	265	492	492	688	390	390	610	4-12-4	4-12-4	4-12-4
U-value [W/m^2/k]	0.67	0.51	0.69	0.49	0.64	0.41	1.16	1.20	0.62	5.7	3.4	3.4

Table 13 Detailed description of the building components of the Vera campus [50].

In addition, regarding the energy supply of the Vera Campus, it depends almost entirely on energy imports of electricity, gas and diesel. Its electricity requirement is supplied by the national grid, whose production mix in 2019 is shown in the following figure.

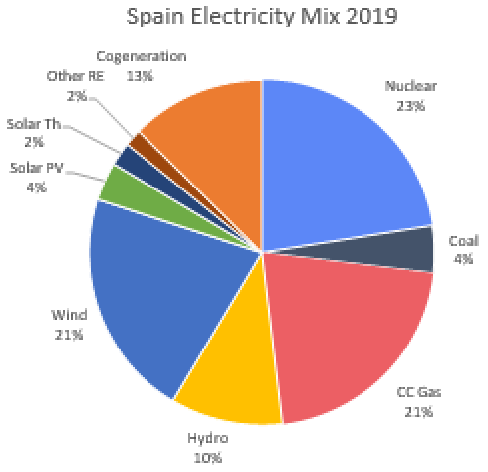


Figure 19 Spanish electricity mix in 2019 (Red Eléctrica de España, 2020)

Only 0.05% of the electricity consumed is produced on campus, with solar installations contributing 21 MWh (Martí Barranco et al., 2020).

Current situation	**Result**
Energy production	0,05/100 * 82 = 0,041 GWh

Nonetheless, solar radiation availability on the Vera Campus is high : the average annual solar radiation for Valence is between 4,6 and 5 kWh/m2 per day (Fernández-González et al., 2020), much above the average, with excellent weather conditions throughout the year.

However, as we get further out from the city, the availability of eolic energy increases, since there are more places that are conducive to eolic production (Global Wind Atlas, s.d.).

4.2.3. Strategy and action plan

Step 5: Scenario performance criteria

We establish the performance criteria to facilitate the assessment of a scenario at the risk assessment stage and the assessment of a district's progress towards the NZED target during and after the implementation phase.

After using the performance criterion selection scheme (Figure 10). We have selected the following criteria:

Economical	**Environmental**	**Social**	**Engineering Performance**
Discounted cost	CO2emissions	Productivity	Energy resilience
Annual cost of energy	Water, electricity use	Security	Energy efficiency
Maintenance cost	Building	Comfort	Interaction with renewable energy
Incentives	Biodiversity	Education	Loss of energy
Tax	Ecotoxicity of mobility	Confidence	

Table 14 Performance criteria related to energy measurement for campus of Vera.

The macro-domains below include the criteria formulated above. It offers the most important solutions. These solutions will then be distributed by scenarios with a precise action to achieve this result.

- *Transport : Reducing CO2 expenditure in transportation*

The basic case assumes that the mobility goals and long-term relationships of various external actors are met. These players include both public transportation companies and government agencies (EMT Bus, Renfe ferroviaire, Ministerio de la Transición Ecológica y el Reto Demográfico, and the Spanish Government).

- *Residential: Increasing energy efficiency through isolation*

Various solutions were investigated, but only one have been chosen, the windows.

The replacement of windows has the advantage of reducing thermal losses while also providing a better passive control of solar radiation. The double-glazed windows with improved thermal resistance are envisaged in two configurations : with and without low emissivity covering.

- *Energy : Increase the use of renewable energy sources.*

The implementation of energy production systems must be considered in order to meet the predetermined. Solar photovoltaics and biodigesters are two renewable energy technologies being investigated.

We will propose 2 scenarios which bring together the above solutions. The scenarios mentioned are also specific but not operable, we will see that after with the action plan.

Step 6: Scenario formulation

- *Scenario 1*

To formulate each scenario, we take into account the following criteria tables :

In scenario 1, the UPV plays a more active role in planning aspects of mobility and coordinating the actions of the different actors.

- Firstly, for the transport part, the intelligent management of the campus allows better programming of activities, allowing a reduction in the number of travel days per week.
    - We can for example for that do a deployment of parking fees for internal combustion engine (ICE) vehicles could help push students and UPV staff even more to use public transport, cycling, walking, etc.
    - We can for example use the fees in all of the parking of the campus of Vera. More over we can develop an application who permit to take a picture when the vehicul is not ICE, this app for student and staff of the university will permit to have in return money…
    - Also, to reduce travel, we can do 3 days of TVwork and 2 days of school for the formation where it’s possible (for example computing…).
    - Increase the bicycle parking to facilitate to take bike.

  - Do a partner with Valenbici and provide 6 Valenbici bicycle parking spaces around the Vera campus.
  - Make a partnership with EMT bus and metro valencia to give a price reduction and encourage students to use public transport

- Secondly, for the energy part, the addition of photovoltaic solar modules to the Vera Campus is proposed with a little bit more extension over the entire campus.
  - Create project groups in each training course to help the energy part of the Vera campus (engineering : construction of solar panel, mini wind turbine / IT: application for centralization of energy data from the campus shared on the UPV website. ..).

- Finally, for the residential part, would be to replace windows with high thermal loss by double glazed windows.
  - Create project groups in each training to help the residential part of the Vera campus (architecture : replacement of windows / engineering : project management ....).

- And, we have also to influence the behavior of the student and the personal of the UPV campus of Vera with for example :
  - Publicity paper or screen at the entry of the university.
  - Game formation with impactful images for all the formation at UPV.
  - Student associations helping the implementation of the nearly zero energy campus of Vera project.
  - Create project groups in each training course to help the communication part of the Vera campus (IT : creation of communication applications on the right actions to follow for a nearly zero energy campus / communication : impactful information to stimulate on the networks social, the UPV site, the screens of the Vera campus ....).

- *<u>Scenario 2</u>*

In scenario 2, the UPV plays a more active role in renewable energy and building isolation.

- Firstly,for the mobility,
  - In the transport sector, the scenario 2 does not propose any significant mobility plan. Therefore, it only relies on external actors, that achieve their 2030 goals, and on a change in commuter behavior.
- Secondly, for energy
  - In order to achieve the KPI Net Zero Energy, a substantial deployment of photovoltaic solar modules is proposed, utilizing the **maximum** available surface area.
  - At the same time, a biodigester is also introduced. Their implementation follows the UPV's will to add renewable energy production on campus, as proven by the financing of a viability study in 2018 by the Environmental Unit (Cerveró Albert et al., 2019).
  - Create project groups in each training course to help the energy part of the Vera campus (engineering : construction of solar panel, mini wind turbine / IT: application for

centralization of energy data from the campus shared on the UPV website. ..).

    - Aiming at the Electricity Autarchy KPI, the BESS, coupled with the production in loco, diminishes the dependence of the campus of Vera on the national grid.

- Finally, for the residential portion, the methods presented in scenario 1 will also work in this scenario.
    - As would the isolation of the roofs of the buildings.
    - With regards to the building envelope, the windows of buildings of category A and B are replaced with new, low- emissive components, while the roof insulation is implemented only in category A buildings.
    - Circular economy of materials, object (sorting and recycling)

- And, we have also to influence the behavior of the student and the personal of the UPV campus of Vera like the scenario 1.

Step 7: Scenario study with KPI

By pressing the basic data of the report [50], for each scenario, we specify the exact results by macro domain according to the KPIs

- *Scenario 1*

The scenario 1 that we formulate is approximately the same than the scenario 3 of [50]. So, we use the general data, and we include the specific data of our scenario to formulate it.

Nearly zero primary energy

Firstly, based on the specific composition of the technologies on the demand and production side, the primary energy is estimated to be around **43%**.

Moreover, to calculate we use the following formula [50]:

Net Primary Energy [%] =

$$\frac{\text{PV production} + \text{WT production} - \text{El. losses}}{PEFgrid\ Grid\ Electricity\ Purchased + PV\ production + PEFtransport\ Transport\ consumption}$$

Finally, to calculate this formula, we collected the basic data of the UPV in document [50] and we included the specific data from our scenarios (the fixed result to be achieved as mentioned before).

Electric autonomy

Firstly, based on the any installed energy storage system, only a value of **80%** can be achieved. This contribution to electricity comes from the hours in which Campus de Vera is consuming its own photovoltaic power.

Moreover, to calculate we use the following formula [50]:

$$Electric\ autonomy\ [\%] = 1 - \frac{\mathbf{Grid\ Electricity\ Purchased}}{\mathbf{Electrical\ consumption}}$$

Finally, to calculate this formula, we collected the basic data of the UPV in document [50] and we included the specific data from our scenarios (the fixed result to be achieved as mentioned before).

Nearly zero carbon energy

Firstly, the carbon in the campus of Vera can be reduce to **90%** in this scenario.

Moreover, to calculate we use the following formula [50]:

$$Net\ CO2\ Emission\ Rate\ [\%] = 1 - \frac{CO2\ (Scenario\ total\ emissions)}{CO2\ (Current\ account)}$$

With, Scenario total emissions = Transport + Grid

Finally, to calculate this formula, we collected the basic data of the UPV in document [50] and we included the specific data from our scenarios (the fixed result to be achieved as mentioned before).

Economic performance

Firstly, the chosen set-up results in total net present costs equal to **16 M€.**

Moreover, to calculate we use the following formula [50]:

We used the criteria (demand side, production, grid, and economic performance) and the cost database [50].

Finally, to calculate this formula, we collected the basic data of the UPV in document [50] and we included the specific data from our scenarios (the fixed result to be achieved as mentioned before).

- *Scenario 2*

The scenario 2 that we formulate is approximately the same than the scenario 1 of [50]. So, we use the general data, and we include the specific data of our scenario to formulate it.

Nearly zero primary energy

Firstly, based on the specific composition of the technologies on the demand and production side, the primary energy is estimated to be around $\mathbf{1\%}$.

Moreover, to calculate we use the following formula [50]:

Net Primary Energy [%] =

$$\frac{\text{PV production} + \text{WT production} - \text{El. losses}}{PEFgrid\ Grid\ Electricity\ Purchased + PV\ production + PEFtransport\ Transport\ consumption}$$

Finally, to calculate this formula, we collected the basic data of the UPV in document [50] and we included the specific data from our scenarios (the fixed result to be achieved as mentioned before).

Electric autonomy

Firstly, based on the any installed energy storage system, only a value of **3%** can be achieved. This contribution to electricity comes from the hours in which Campus de Vera is consuming its own photovoltaic power.

Moreover, to calculate we use the following formula [50]:

$$Electric\ autonomy\ [\%] = 1 - \frac{\boldsymbol{Grid\ Electricity\ Purchased}}{\boldsymbol{Electrical\ consumption}}$$

Finally, to calculate this formula, we collected the basic data of the UPV in document [50] and we included the specific data from our scenarios (the fixed result to be achieved as mentioned before).

Nearly zero carbon energy

Firstly, the carbon in the campus of Vera can be reduce to $\mathbf{50\%}$ in this scenario.

Moreover, to calculate we use the following formula [50]:

$$Net\ CO2\ Emission\ Rate\ [\%] = 1 - \frac{CO2\ (Scenario\ total\ emissions)}{CO2\ (Current\ account)}$$

Our data for:

Scenario total emissions = Transport + Grid

Finally, to calculate this formula, we collected the basic data of the UPV in document [50] and we included the specific data from our scenarios (the fixed result to be achieved as mentioned before).

Economic performance

Firstly, the chosen set-up results in total net present costs equal to **7 M€.**

Moreover, to calculate we use the following formula [50]:

We used the criteria (demand side, production, grid, and economic performance) and the cost database [50].

Finally, to calculate this formula, we collected the basic data of the UPV in document [50] and we included the specific data from our scenarios (the fixed result to be achieved as mentioned before).

KPI	Scenario 1	Scenario 2
Nearly zero primary energy	43%	1%
Renewable energy	80%	3%
Nearly zero carbon energy	90%	50%
Economic performance	16M. euros	7M. euros

Table 15 All the results of the scenario compare to the KPI

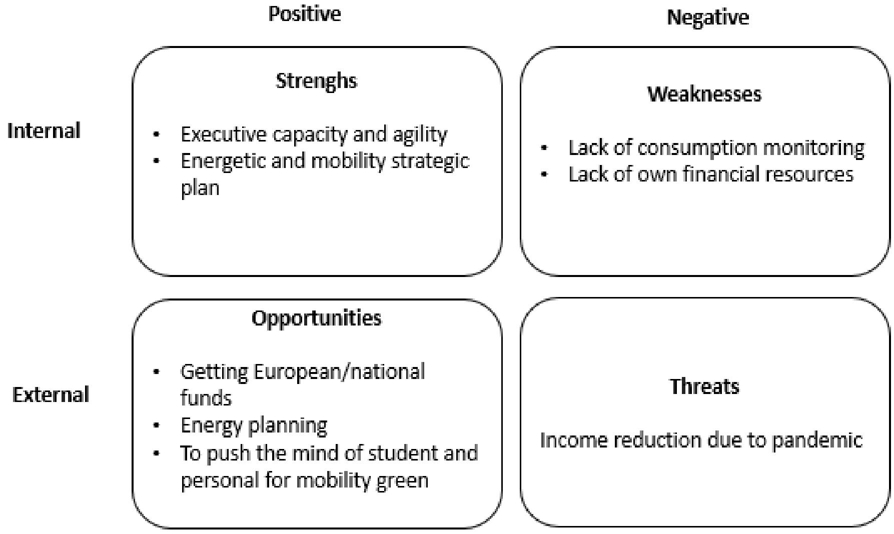
Step 8: Scenario risk study

For this part, we choose the SWOT analysis because in the procedure of the rédaction of this report, I could not interviw experts or do a brainstorming with some people rely in this project.

The SWOT analysis, and the risk assessment are some of the most important aspects of the methodology, which are based on strategic project planning.

The SWOT analysis allows for an overall business development by combining two sorts of data : internal and external. Internal information will be used to determine the company's strengths and weaknesses. When it comes to external data, it will be about local threats and opportunities.

- *Scenario 1 :*

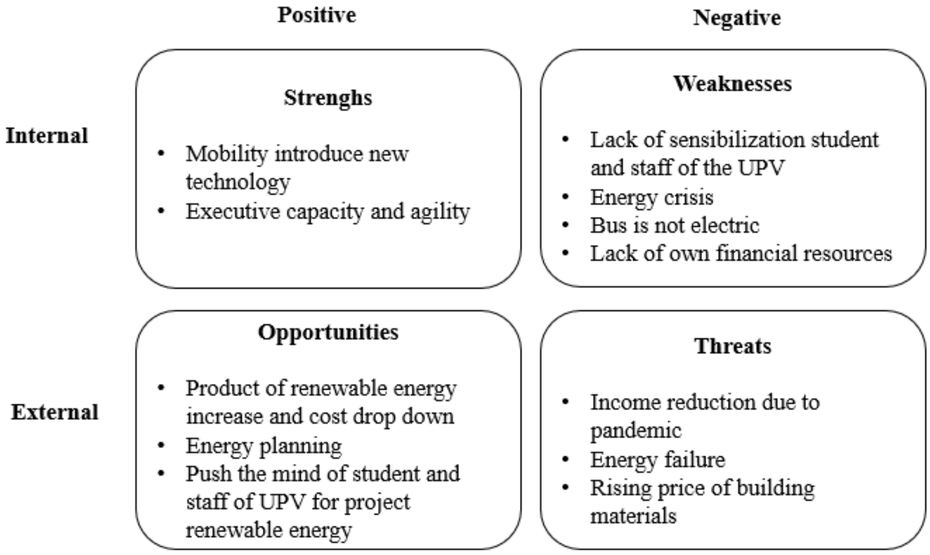


	Positive	Negative
Internal	**Strenghs** • Executive capacity and agility • Energetic and mobility strategic plan	**Weaknesses** • Lack of consumption monitoring • Lack of own financial resources
External	**Opportunities** • Getting European/national funds • Energy planning • To push the mind of student and personal for mobility green	**Threats** Income reduction due to pandemic

Figure 20 SWOT analysis for scenario 1

We deduce for scenario 1, three possible opportunities and strengh. One threats and two weaknesses.

- *Scenario 2 :*



	Positive	Negative
Internal	**Strenghs** • Mobility introduce new technology • Executive capacity and agility	**Weaknesses** • Lack of sensibilization student and staff of the UPV • Energy crisis • Bus is not electric • Lack of own financial resources
External	**Opportunities** • Product of renewable energy increase and cost drop down • Energy planning • Push the mind of student and staff of UPV for project renewable energy	**Threats** • Income reduction due to pandemic • Energy failure • Rising price of building materials

Figure 21 SWOT analysis for scenario 2

We deduce for scenario 2, three opportunities but also four weakness and three threat.

Explanation of the wording of the risk analysis
This part allows to see from a general point of view the risks of each scenario.
For example, scenario 1 being more accentuated on mobility, will present less threat in relation to the evolution of the cost of solar panels than scenario 2 (focused on energy).

Step 9: Scenario selection

This part becomes much simpler in view of the work carried out on the table of actions and criteria and the study of the risks of the scenarios.

All scenarios that pass the risk assessment stage will be subject to a final selection process by decision makers.

In the proposed methodology, Step 8 allows decision-makers to choose only one scenario from those pre-selected in Step 7.

Remember that we took in place 2 table of criteria in this document (which arises from the parts before):

- Firstly, the result and KPI criteria (table 14).
- Secondly, the SWOT risk analysis (figure 20).

We decide to choose the scenario 1 because in terms of numbers it is significantly better. And by the risk analysis, it presents less negative aspect and more positive aspect.

Step 10: Scenario running

- *Execution*

Concerning the execution step. This step is outside the scope of this master's thesis and is, therefore, excluded from the analysis.

Nevertheless, we can formulate an action plan for the smooth running of the project.

To follow scenario 1 to the letter, we recommend performing the results in macro domains:

- Transport
- Energy
- Residential
- Behavior

Each part contains an action plan specific to scenario 1. We recommend the following execution plan (limited to the general result only):

- Transportation

What	How	Who	Where
Deployment of an application to help respect the rules of ICE cars that have not paid the fees (take a photo of the license plate with the offense committed)	- Build the application on a code platform. - Learn about the legal data related to this application	UPV student class (engineering and computer science)	Campus of Vera (phone)
Deployment of parking fee payment terminal for ICE vehicle	- Pay company to install parking meter. - Contact legal department of the municipality of valencia to have their agreement.	The company : Estacionamientos y Servicios (FCC)	The parking already present in the campus of Vera
Deployment of TVwork 3 days per week for the formation where it’s possible	- Find out about the rules and possibilities of the national education ministry. - Adapt students 'and teachers' time schedules accordingly.	- University director - Ministry of Education	Home
Deployment of bicycle parking	- Creation of a student group to set up the bicycle parking lot - Purchase of the elements constituting the parking lot from a company	- The company : Vadebike - UPV student	Campus of Vera (building C and D)
Deployment of valenbici parking around Vera campus and price reduction	- Agreement with the Municipality of Valencia - Plan the construction of parking lots	Municipality of Valencia	Campus of Vera (on each principal door of the campus)

	around the campus		
Deployment of parternership rice reduction for EMT bus and metro Valencia	- Communication for the price reduction negotiation for campus students - Communication on this award ceremony for students	Metro and EMTbus company Valencia	Campus of Vera

Table 16 Action plan for the transport part

- Energy

What	How	Who	Where
Addition photovoltaic solar modules	Contact the company for the purchase of additional solar panel and for the management of the installation	The company: Solar Montroi	Campus of Vera (Building without solar panel)
Create student project to help the energy part of the campus of Vera	Ask teachers to organize engineering projects: construction of solar panel, mini wind turbine / IT: application for centralization of energy data from the campus shared on the UPV website	Professor in class of engineering and IT	Campus of Vera (on the classroom concerning)

Table 17 Action plan for the energy part

- Residential

What	How	Who	Where
Replace windows with high thermal loss by double glazed windows	- Ask teachers to organize projects architecture: replacement of windows / engineering: project management - Purchase of windows and help with dangerous installation from a company	Professor in class of architecture The company : Ademuz	Campus of Vera (Building without wondows double glazed)

Table 18 Action plan for the residential part

- Behavior

What	How	Who	Where
Publicity screen	Ask the university management to display a message impacting respect for the environment for the achievement of the nearly zero energy campus of Vera	Direction of university	On all display panel on the campus of Vera
Game formation	Ask the programming of a game for each class in the Vera campus to raise awareness of the change of the campus and the individual role of each	Professor and direction of the university	Campus of Vera (on the classroom concerning)
Student association helping implementation of			

the nearly zero energy campus of Vera project			

Table 19 Action plan for the behavior part

Concerning the « When », that depend of decision take about this action and the duration of the professional for example the installation of the solar panel.

With the duration and the decision to begin it is possible to fixe the period « When » and to put a deadline for each result. This should be done following the meeting on the analysis of the action plan with the director of the university.

- ***Project monitoring***

This step applies only in the phase of exectution (who is not in this document).

We apply the following form who permit to correct and to grow the project from the result.

We remember :

- Verification is about making sure that things are done in accordance with what has been defined using key indicators (see step 5).
- Validation consists of ensuring that the desired results have been achieved.

Since the proposed performance evaluation algorithm is based mainly on the energy balance calculation method, it can no longer be applied to the case study.

Finally to check the progress of the project, we must measure it. For this, it is essential to use the KPIs used to achieve the result (table 12).

In addition, we can also add some additional indicators who allow us to understand why we are achieving the objectives or not :

Criteria	**KPI**
Energy quality of buildings (PEB certificate)	• The heat needs of the home • The performance of the heating system • The performance of the domestic hot water installation • The presence of a ventilation system • The use of renewable energies)

Table 20 Secondary KPI to understand why we are achieving our goals

4.4. Summary

The comparative analysis carried out reveals that the methodology can work for the Vera campus.

This means that the methodology provides precise guidance for planning modernization projects towards the NZED objective.

For example, the third and fourth steps can be merged since data collection and analysis can be done at the same time as modeling the district's energy system. The same goes for steps 7 and 8.

In this respect, the detailed step-by-step instruction provided by the methodology can be reduced and simplified to its three basic subphases (actor and outcome, current situation, strategy, and action plan). Moreover, this methodology is even more easily applicable when data is limited.

On the other hand, the methodology works even better when all relevant data is readily available. As such, its applicability would be better tested in a case study designed specifically for it.

The proposed calculation method and, therefore, the performance evaluation algorithm (which is mainly based on the calculation method) could work if data on the population and its current and foreseen future energy consumption per person were available.

Overall, the conceptual framework of the proposed method has a high potential for application.

Finally, the execution will follow the final formulated plan of step 9 (the previous steps only served to formulate this plan, but could also serve as content and precision for the execution phase)

Thanks to this methodology, the execution part will therefore have a precise plan that meets an important need and leads to a quantified result.

CHAPTER 5. CONCLUSION

This chapter summarizes the results of this research dissertation and proposes lines of action to be taken for the continuity of this work.

5.1. Research Summary

Achieving a zero-energy balance in the built environment has been widely regarded as an effective way to cut both GHG emissions and energy consumption of the largest, energy consuming sector. The move from ZEBs to ZEDs has been triggered by the technical, economic, and social advantages that the latter have over the former and, thus, have gained more attention in recent years.

In this regard, this master's thesis proposes a comprehensive and context-adaptive methodologique to design districts (verify with the case of campus de Vera) to aid in the dissolution of barriers to the energy transition in the building sector, particularly in the residential sector.Based on the case study, the methodology has the potential to work in different contexts given that sufficient data is available.

5.2. Recommendations

One of the major obstacles that the Vera campus will face while implementing the proposed solution is financing capital-intensive technology and initiatives. To reduce financial burden on the Vera campus, it is recommended that the power generation systems be outsourced.

Energy contracting may also be applied to photovoltaics and battery storage systems. However, because of the cheap operational expenses and levelized power rates for PV, it should be considered keeping that system on the campus de Vera.

When looking at the Net Primary Energy KPI, it's evident that travelling to and from campus consumes a substantial amount of energy. Furthermore, the Vera campus can only regulate a portion of the sector's carbon footprint. To achieve an effective transition to sustainable mobility to school, Vera's campus should engage with nearby public and shared transportation providers.

Commuting's carbon footprint might be further reduced through joint pilot programs. It should be noted that Campus de Vera does not have to fully account for the required energy generation in public transportation since, if public transportation enterprises follow the UPV's lead, Net Zero Primary Energy will be achieved on a macro-scale.

Campus de Vera is encouraged to launch awareness efforts in order to hasten the adoption of more sustainable behavior patterns among employees and students. The results would be substantially better than predicted because behavioral changes on campus were not taken into consideration when calculating the KPIs.

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APPENDICES

Appendix 1: Inventory of scientific reports proposing an NZED design methodology

Title	Methodology (summary)	Title	Methodology (summary)
Towards a net-zero energy district design in the other through integrated modelling of buildings and distribution systems [25]	*"First of all, individual buildings in the neighborhood are modeled in URBAN opt, neighborhood-level modeling, tool developed on OpenStudio.35,36* *The main 296 advantage of using URBAN opt over a more detailed building energy modeling tool such as BEopt37 or Open Studio is that the level of input detail required by URBAN opt»*	Techno-economic analysis of a hybrid renewable energy system with solar district heating for a net-zero energy community [26]	*"The Primary Energy Saving Index (PSE) and greenhouse gas emissions general CO2 emissions were used to compare the energy and environmental impacts of the proposed system compared to the conventional system»*
Towards positive energy communities at high latitudes [27]	*"The development of a NZED theoretical model is introduced as a decision-making support approach towards a city's strategies for zero energy planning in its neighborhoods. The methodology was deployed in several phases. Each phase ensured an effective dialogue between all stakeholders and urban planners in the city to build confidence in this direction. The NZED phased approach. »*	Methodology of positive energy districts and its potential for replication [29]	*"City-level indicators are used to show the extent to which overall policy objectives have been achieved. In the process of becoming a smart city, establishing a reliable measure is a key point to help cities identify strengths and weaknesses and, therefore, set priorities for action.* *For this reason, a set of indicators at city level are established for the diagnosis and for the identification of their* needs and *priorities. These indicators are grouped under energy and environment, mobility, governance and areas of society and citizens. »*
An urbanization algorithm for neighborhoods with minimized emissions based on urban planning and gray energy towards net-zero energy goals [30]	*"This paper resumes the method of research work in which a perspective of the multidimensional energy system* *assess the condition of an NZEXD target as well as urban density, increase in buildings and building materials. »*	Towards Net-Zero Energy Communities: A Study of Design Strategies and Seasonal Collection and Storage of Net-Zero Energy Solar Energy [31]	*"This research is being carried out on a large area of 64 ha, for mixed use, to study the design and implementation potential of solar thermal collection and storage. This is accompanied by efforts to design a high-energy efficiency district.* *This hypothetical mixed-use neighborhood is designed, based on various considerations. The pilot location of the study is Calgary (Alberta, Canada; 52°N), which represents a medium-high latitude level, cold climate zone. This neighborhood has been the subject of previous research*

			technological development (RTD) related to energy efficiency and environmental impact (Hachem et al., 2015; Hashem, 2016). A summary of the design *The process for this neighborhood is presented below, followed by a presentation of the survey used in this study. It has the potential to design and* implement *a solar thermal capture and storage system.* *This is combined with efforts to design a high-energy efficiency neighborhood."*
The idea of zero energy in neighborhoods: application of a methodological approach to a case study from Epinlieu (Mons) [32]	*"Development of a NZED theoretical model is introduced as a decision-making support approach to a city's strategies for zero energy planning in its neighborhoods. The methodology was deployed in several phases. Each phase ensures an effective dialogue between all stakeholders and urban planners in the city to build trust* *to that direction. »*	Optimal sizing and operation of electrical and thermal storage in a net-zero multi-energy system [33]	*"The methodology used to estimate the annual energy demand for electrical, thermal and (electric) transmission loads. In this study, the NZES concept was developed by the electrification of the heat and transport sectors. In NZES the planning tool has been developed according to three main steps. »*
Towards the Development of an Approach to Assessing Net-Zero Energy Neighborhoods: A Review of Sustainable Assessment Approaches and Tools [34]	*"A considerable part of the articles included presented a new methodology-ologies, frameworks or tools (58 publications or 40.3%) which shows that the field is still quite new and that a lot of preparatory work is underway.* *The second most widely used method (52 papers or 36.1%) was numerical and mathematical modelling, often in relation to the presentation of a new methodology,* *frame or tool (14 times) .-* *More than half (87 or 60.4%) of the 144 studies reviewed applied their research to case studies.* *The case studies were localized in Norway and 11 in China, followed by Italy with 10, Belgium with 9, Germany with 8, and Sweden and Spain with 7.* • *NMM Numeric, mathematical,* modeling • *Techno-economic,* analysis *and feasibility*	Define and operationalize the concept of positive energy neighborhood [35]	*"In addition, for the EPN concept to give impetus to the design of net positive energy in the building environment, it is necessary to have a method to clearly communicate the 'energy positivity level' of a neighborhood. To enable this, an "energy positivity label" is proposed in Section 4. This pro-label provides a clear and easy-to-understand method to visualize the energy performance of a neighborhood.* *The first KPI is the one used to measure the balance between energy demand and renewable energy supply from all energy sources in a neighborhood.* *Annual Mismatch Report (AMRx) to measure the amount of energy imported into the vicinity for each type of energy, per year.* *Maximum hourly surplus (MHSx) to measure what is the maximum value of the local renewable hourly supply (for each type of energy) higher than the demand during that hour*

	- *Interview, survey, experience* - *Methodology, framework, tool, presentation* - *Revision, a social aspects and other methods not captured by previous categories »*		*(per year).* *Maximum hourly deficit (MHDx) to measure the maximum value of the maximum value of hourly local demand relative to local supply renewable during that hour (per year) Monthly ratio of peak hourly demand to lowest hourly demand (RPLx) to measure the magnitude of peak electricity demand »*
New design support methodology based on a multi-criteria decision analysis approach for energy-efficient neighborhood renovation projects [36]	*"Overcoming these barriers requires establishing systemic methods that can help stakeholders implement better approaches to collaborate and make more informed decisions. This methodology is based on the evaluation of a set of sustainability indicators while proposing an improved integrated method of project implementation.* *Communications between stakeholders and, therefore, the decision-making process. Multi-criteria business intelligence (MCDA) that considers multiple criteria in decision-making environments »*	Planning the transition to energy for net-zero energy districts [37]	*"The document sets out the measures and decision support tools that will be introduced. Overall, supply integration options and demand-side measures are assessed against the desired objective. »*
Analysis of the energy system of a net-zero exergy pilot district [38]	*"A total of five scenarios were developed, including an original input based on the method provided.* *Main framework of the scenario construction process for the No index.* *The quantitative basis of the given analytical framework begins with a key MMER parameter, w Ri, which measures the level of correspondence between supply and demand for exergy dem (i) and e sup (i). Eq. (1) »*	Unified model for optimal management of a prosumer's electrical and thermal equipment in a disaster recovery environment [39]	*"There are four potential markets for residential or commercial prosumers.* *The first is the so-called micro-generation (intelligent) network.* *Micro-generators do not have priority self-sufficiency services, but, by definition, self-consumption cannot be granted.* *The third type of market is the interconnection of different microgrids: prosumers (perhaps organized into small groups) access a network of limited expansion (which includes many microgrids, with a regional geographical scope). The situation of prosumers connected to separate microgrids (i.e. to a particular grid disconnected from the conventional electricity grid) is defined"*

Economic valuation of near-zero energy cities [40]	*"This document provides* an *overview of existing assessment tools and methods.* *In addition, it offers an evaluation methodology for this function, based on the availability of geometry, construction standards and usable data. »*	Evaluation of urban energy planning tools	*"After gathering information on the different tools from previous review studies and online research, 17 tools for assessing energy systems at the scale of an urban area and/or neighborhood with various energy system services/conversions and a detailed description and easily accessible documents were selected for this review study. »*
An Investigation on the Feasibility of Near-Zero and Positive Energy Communities in the Greek Context	*"First, the technical analysis is conducted using appropriate software to determine the energy flows at the building and district level. Suitable KPIs are then identified to evaluate the results obtained. In the following paragraphs, the selection process of the suitable assessment criteria used, and the appropriate software are presented »*	Decision making for sustainable urban energy planning: an integrated evaluation framework of alternative solutions for a NZED (Net Zero-Energy District) in Turin	*"According to EBPD recast methodology, the first step of the analysis consists in the definition of the case study characteristics (form, envelope, system and operation), and proceed with the estimation of its current thermal and electrical energy consumption. To simplify the calculation, the buildings were clustered in few typologies, hypothesizing that the constructions with the same features could be characterized by comparable consumptions. Consequently, the district buildings were clustered in five typologies, according to their geometrical and thermo-physical features and their construction period using the TABULA database. »*
From traffic data to GHG emissions: A novel bottom-up methodology and its application to Valencia city [44]	*"The methodology uses data from the urban traffic control and monitoring systems as a baseline to calculate emissions"*	Overview and future challenges of nearly zero energy buildings(NZEB) design in Southern Europe [45]	*"Guidelines establishing a methodology framework for calculating cost-optimal levels of minimum energy performance requirements. For calculation of primary energy with primary energy factors, EN15603 presents explicit formulas, with degrees of flexibility for MS. For example, in Italy a NZEB definition »*
Energy master planning for net-zero emission communities: State of	*"As a result, a PEM conceptual framework has been proposed to support performance-based decision-making by different stakeholders in the design and planning of*	Towards the development of a net-zero energy district	*Districts have a significant role in achieving the principles of sustainability. Within the past decades, a great variety of assessment tools and methodologies has*

the art and research challenges [46]	*NZECs. »*	evaluation approach: A review of sustainable approaches and assessment tools	*been developed in an effort to 'translate' the sustainability criteria into applied cases. There is an increasing interest in this contribution scaled up the assessment to larger territorial analysis and urban agglomerations. Notwithstanding, developing an assessment tool with sustainable standards requires strategic approaches to incorporate the theoretical framework to their implementation of city districts by measuring their performance in a consistent manner in respect of multiple criteria. Among these issues, energy efficiency and the zero energy objectives are significant for European policies. This study aims to provide an overview of the existing assessment tools and methods comparing their criteria and key parameters. As a second step, it introduces a simplified methodological assessment theoretical tool (U-ZED) by focusing on the commitment towards the zero energy targets in a future district. In a more general perspective, the study deals with the challenge of the development of a tool from building to district with the main concern to define the context of sustainable and long-term districts dealing with the challenges of 2050 horizon.*
Decision making for sustainable urban energy planning: an integrated evaluation framework of alternative solutions for a NZED (Net Zero-Energy District) in Turin	*The European Union issued several directives in the field of energy efficiency which impact on the building sector in order to avoid a further increase of energy consumption and to mitigate climate change. In particular, the recast of the European Energy Performance of Buildings supports the improvement of buildings energy performance and introduces a new target, the Nearly Zero-Energy Building (NZEB) concept. Nowadays, the European Commission is shifting attention towards the district level and post-carbon cities and Net Zero-Energy District (NZED) targets are emerging. In order to evaluate alternative strategies for the*	The zero-energy challenge in districts. Introduction of a methodological decision-making approach in the case of the district of Cuesmes in Belgium	*Transforming cities with the aim of achieving cleaner energy targets is a major bet worldwide, dealing with the immense stress of the rapid urbanisation, the depletion of natural resources, the climate change and its impacts during the post-industrialised period. Struggling with this problematic, in this work we develop a horizontal and cross-sectoral process as an integral part of the city planification towards the energy transition.*

	construction of NZED, according to a socio-economic point of view, different aspects and impacts have to be considered. This paper studies the NZED concept and proposes an evaluation method developed from the Cost-Benefit Analysis (CBA) in order to include extra-economic benefits generated by the project. The proposed approach is applied on a real case concerning the energy requalification of a NZED in Turin (Italy).		
The Zero-Energy Idea in Districts: Application of a Methodological Approach to a Case Study of Epinlieu (Mons)	*Rapidly increasing global energy demand has raised concerns about the exhaustion of energy resources and the consequent heavy environmental impact. Improving energy efficiency in cities comprises an initial measure for addressing these phenomena. Within the current context of globalization, EU initiatives and policy targets have been proposed in order to revise urban development strategies and motivate its member states (MSes) toward "zero-energy objectives". Providing a methodological approach with a simulation district analysis, the present article summarizes how this challenge was analyzed in an existing district in Belgium. This study contributes to the scientific discussion by analyzing the applicability of a holistic approach to zero-energy objectives on a larger scale.*	Zero energy concept at neighborhood level: A case study analysis	*The concept of zero energy has emerged as the flagship for the achievement of energy conservation and CO2 emissions reduction in the built environment. The implementation of the concept beyond single buildings offers the potential of expanding the scale of zero energy performance while overcoming the limitations of single buildings related to building use, size, on-site renewable energy availability and cost.* *Literature to date has discussed the zero energy concept at neighborhood scale mostly by looking at theoretical and simulated cases, including both existing and new developments. All types of energy use can be considered for achieving a zero energy balance at neighborhood scale or only the building related component. Often research focuses on Renewable Energy sizing and management for achieving the balance. The present paper analyses the real data obtained from the first year of monitoring of a pilot Zero Energy Neighborhood.*
Smart and sustainable urban development in Egypt: the case of Nabta Smart Town	*Nabta Smart Town (NST), in New Borg el Arab, close to Alexandria, is an ambitious project under planning that includes residential and commercial facilities, in combination with high quality "Educational Magnets" capable of creating a dynamic community and generating all*	Decision making for sustainable urban energy planning: an integrated evaluation framework of	*The European Union issued several directives in the field of energy efficiency which impact on the building sector in order to avoid a further increase of energy consumption and to mitigate climate change.*

	sorts of interesting activities. Therefore, the uniqueness of NST is building a fully integrated and inclusive neighbourhood – Educational Magnet, Residential, Commercial (shopping, leisure and entertainment), with Administrative Offices (including high-end security). *The initial conceptualization of NST by the local promoters envisions a culture that protects, maintains and recycles within the community. The collaboration of VTT Technical Research Centre of Finland Ltd. (VTT) was sought to ensure that the Master Plan (MP) and the buildings of the University, as well as the Residential and Commercial facilities of NST comply with the standards of a modern EcoCity adapted to the Egyptian context. The first phase of the work focuses mainly on carrying an EcoCity Energy Efficiency Feasibility Assessment. Specific methodologies and tools developed by VTT have been used to ensure adaptation of the solutions proposed to the local conditions.*	alternative solutions for a NZED (Net Zero-Energy District) in Turin	*In particular, the recast of the European Energy Performance of Buildings supports the improvement of buildings energy performance and introduces a new target, the Nearly Zero-Energy Building (NZEB) concept. Nowadays, the European Commission is shifting attention towards the district level and post-carbon cities and Net Zero-Energy District (NZED) targets are emerging. In order to evaluate alternative strategies for the construction of NZED, according to a socio-economic point of view, different aspects and impacts have to be considered. This paper studies the NZED concept and proposes an evaluation method developed from the Cost-Benefit Analysis (CBA) in order to include extra-economic benefits generated by the project. The proposed approach is applied on a real case concerning the energy requalification of a NZED in Turin (Italy).*
Energy master planning for net-zero emission communities: State of the art and research challenges	*Aiming to achieve net-zero operational greenhouse gas emissions at the community level is a valuable endeavour because of synergies and efficiency gains through mixed energy uses, the economy of scale, and a broader range of technological options. Nevertheless, there are several challenges in the planning and design process of the energy infrastructure towards this goal for whole communities.* *The preponderance of the zero emission concepts at community scale, including unclear definitions of key terms, the availability of supporting tools, and the energy planning approaches could affect the design and decision-making process of stakeholders.* *In this paper, the state of the art and the state of practice of*	The idea of zero energy in neighborhoods: application of a methodological approach to a case study from Epinlieu (Mons)	*"Development of a NZED theoretical model is introduced as a decision-making support approach to a city's strategies for zero energy planning in its neighborhoods. The methodology was deployed in several phases. Each phase ensures an effective dialogue between all stakeholders and urban planners in the city to build trust to that direction. »*

	energy master planning of net-zero emission communities are critically reviewed in order to identify the key research challenges and opportunities to enhance decision-making and hasten their wider adoption. Energy master planning approaches.		
A top-down control method of nZEBs for performance optimization at nZEB-cluster-level	*Nearly zero energy buildings (NZEBs) are considered as a promising solution to the mitigation of the energy problems. A proper control of the energy system operation of the nZEB cluster is essential for improving load matching, reducing grid interaction and reducing energy bills. Existing studies have developed many demand response control methods to adjust the operation of energy systems to improve performances. Most of these studies focus on optimizing performances at individual-nZEB-level while neglecting collaborations (e.g. energy sharing and battery sharing) between nZEBs. Only a few studies consider the collaborations and optimize the system operation at nZEB-cluster-level, yet they cannot take full advantage of nZEB collaborations as optimization is conducted in a bottom-up manner lacking global coordination.* *This paper, therefore, proposes a top-down control method of nZEBs for optimizing performances at the cluster level. The top-down control method first considers the nZEB cluster as 'one' and optimizes its energy system operation using the genetic algorithm (GA), and then it coordinates the operation of every single nZEB inside the cluster using non-linear programming (NLP).*	Overview and future challenges of nearly zero energy buildings(NZEB) design in Southern Europe	*"Guidelines establishing a methodology framework for calculating cost-optimal levels of minimum energy performance requirements. For calculation of primary energy with primary energy factors, EN15603 presents explicit formulas, with degrees of flexibility for MS. For example, in Italy a NZEB definition »*
Optimal sizing and operation of electrical and thermal storage in a net-zero multi-energy system	*"The methodology used to estimate the annual energy demand for electrical, thermal and (electric) transmission loads. In this study, the NZES concept was developed by the electrification of the heat and transport sectors. In NZES the planning tool has been developed according to three main steps. »*	Life cycle assessment of a renewable energy generation system with a vanadium redox flow battery in a NZEB	*Buildings are responsible for a significant part of the global energy consumption. Besides the need to improve their energy efficiency, new buildings also need to generate their own energy, preferably from renewable sources, to become more sustainable. As renewable*

		household	*energy generation is strongly dependent on the climatic conditions, energy storage must be considered when designing such a system. In this study, a cradle-to-grave life cycle assessment (LCA) study of a renewable energy generation system with a prototype Vanadium flow battery integrated in a Near Zero Energy Building (NZEB) is performed.* *A combined grid-connected PV and a solar thermal system generates the energy, and it was dimensioned to supply the annual energy needs of a household in Porto, Portugal considering the local climatic conditions. As an end of life scenario, it is assumed that the battery is dismantled and most of the materials are recycled. A functional unit of 1 kWh of supplied energy to the system was considered, and study results show that environmental impacts are reduced when the energy is produced onsite and the battery components are recycled or reused. A sensitivity analysis was conducted changing the household's geographic location.*

Appendix 2: Table of projects related to the design of net zero energy district

	Duration	Project	Aim	Web Link	"Positive energy districts" OR "Net-zero energy (emissions) districts"
1		THE MAKING-CITY PROJECT	In the context of the Conference of the Parties (COPs) and the Paris Agreement, MAKING-CITY is an answer to urban transformation.	http://makingcity.eu/the-project/	Positive energy districts
2		r2cities: Residential Renovation towards nearly zero energy CITIES	Develop and demonstrate replicable strategies for designing, constructing and managing large scale district renovation projects for achieving nearly zero energy cities	http://r2cities.eu/	Net-zero energy (emissions) districts
3		ATELIER AmsTErdam BiLbao cItizen drivEn smaRt cities	ATELIER is an EU-funded Smart City project aiming to create and replicate Positive Energy Districts (PEDs) within two Lighthouse Cities and six Fellow Cities.	https://smartcity-atelier.eu/	Positive energy districts
4		CityxChange (Positive City ExChange)	Thus, not all types of stakeholders have the same opportunity to participate in the implementation of positive energy blocks in their districts and cities. +CityxChange is situated in the process of this transition and aims at providing new evidence-based and replicable solutions in the urban environment.	https://cityxchange.eu/	Positive energy districts

5	1 January 2015 and ran until 31 December 2019	GrowSmarter: transforming cities for a smart, sustainable Europe	In a rapidly urbanising world cities need to become smarter to respond to citizen needs and to reduce their environmental footprint. GrowSmarter brought together cities and industry to integrate and demonstrate '12 smart city solutions' in energy, infrastructure and transport, to provide other cities with valuable insights on how they work in practice and opportunities for replication.	https://grow-smarter.eu/home/	
6		IRIS Smart Cities Co-creating smart and sustainable cities	Demonstrate solutions at district scale integrating smart homes and buildings, smart renewables and closed-loop energy positive districts Demonstrate smart energy management and storage solutions targeting Grid flexibility	https://irissmartcities.eu/content/objectives-ambition	Positive energy districts
7		MAtchUP	MAtchUP will design and implement a palette of innovative solutions in the energy, mobility and ICT sectors that will serve as a model of urban transformation for other cities in Europe and beyond.	https://www.matchup-project.eu/	
8		mySMARTLife Transition of EU cities towards a new concept of Smart Life and Economy	The mySMARTLife project aims at making the three Lighthouse Cities of Nantes, Hamburg and Helsinki more environmentally friendly by reducing the CO2 emissions of cities and increasing the use of renewable energy sources.	https://www.mysmartlife.eu/mysmartlife/	Net-zero energy (emissions) districts
9		Peña Station NEXT: Visualizing a Net-Zero Energy District		https://www.nrel.gov/news/program/2018/planning-a-city-virtually.html	Net-zero energy (emissions) districts

10		SINFONIA project: Low Carbon Cities for Better Living		http://www.sinfonia-smartcities.eu/	Positive energy districts
11	2014	ZenN project: Nearly Zero Energy Neighborhoods		http://www.zenn-fp7.eu/ournetworkmysmartcitydistrict.4.21d4e98614280ba6d9e5fc9.html	Net-zero energy (emissions) districts
12		El proyecto europeo Pocityf contribuye a la creación de edificios y distritos de energía positiva	POCITYF is an EU-funded smart city project that will help historical cities to become greener, smarter and more livable while respecting their cultural heritage. By implementing and testing Positive Energy District in its cities, POCITYF will support Europe in the race to become the first Carbon Neutral Continent by 2050.	https://pocityf.eu/	Positive energy districts

Appendix 3: Methods and tools found in literature to support the study of the district scale

	Topic or Field	Objectives	Methods/Tools	Scale	References
1	**Net-Zero Energy District (NZED's)**	Definition proposal for **NZED**	Hierarchical and qualitative approach	District	(Carlisle et al., 2009; Sornes et al., 2014)
		Assessment of e**xtending NZEB concept to the neighborhood scale**	Dynamic simulations	District	(Marique & Reiter, 2014)
		Development of a methodological approach for evaluating **NZED**	Simplified energy demand calculation	District	(Koutra et al., 2018)
		Evaluation of alternative strategies for the construction of **NZED's**	Multicriteria decision analysis (PROMETHEE)	District	(Becchio, Bottero, Corgnati, & Dell'Ana, 2017)
		Optimization of energy systems design towards a **NZED**	Genetic algorithm (MOBO)	District	(Wang, Kilkis, Tjernström, Nyblom, & Martinac, 2017)
2	**Sustainability assessment tools**	Analysis of existing sustainability assessment tools in a community perspective	Comparative analysis of criteria and data	District	(Haapio, 2012; Sharifi & Murayama, 2013)
		Analysis of existing sustainability assessment tools in a community perspective	Comparative analysis of criteria and data	Urban	(Ameen et al., 2015)
		Analysis of existing sustainability assessment tools in a community perspective	Top-down and bottom-up models	District	(Huang et al., 2015)
3	**Solar potential**	Development of residential solar blocks with high passive solar potential	Development of solar envelope with dynamic simulation (EnergyPlus)	Urban	(Vartholomaios, 2015)
		Analysis of urban morphology for increasing solar potential in **neighborhoods**	Statistical data	District	(Sarralde et al., 2015)

		Analysis of compactness indicators related to solar potential in **neighborhoods**	Dynamic simulations (CitySim)	District	(Mohajeri et al., 2015, 2016)
		Relationships between urban forms, density and solar potential	Dynamic simulations	Building/District	(Cheng et al., 2006; Kanters & Horvat, 2012)
		Analysis of the potential of urban roofs and façades for active and passive solar heating, energy production and daylighting	Numerical simulations	Building/District	(Compagnon, 2004)
		Analysis of solar photovoltaic potential in urban context	Combination of GIS with parametric modeling (Rhinoceros) and simulation (Ecotect)	Urban	(Amado & Poggi, 2012, 2014)
		Investigation of design parameters for increasing solar potential in **neighborhoods**	Simulation of alternative configurations in EnergyPlus		(Hachem et al., 2013)
		Analysis of urban morphology parameters and buildings' envelopes materials for maximizing solar potential	DIVA-for-Rhino	District	(Lobaccaro et al., 2017)
4	**Urban microclimate**	Impact of urban microclimate in buildings' energy performance	Dynamic simulations (EnviBatE, SOLENE-Microclimate)	District	(Gros, Bozonnet, Inard, & Musy, 2016)
		Impact of urban patterns in wind flows at urban level	Computational Fluid Dynamics (CFD)	Urban	(Liu, Xu, Chen, Zhang, & Li, 2015; Mochida & Lun, 2008)
		Inclusion of Urban Heat Island effect on buildings performance simulation	Combination of GIS with simulation (TRNSYS)	Urban	(Palme et al., 2017)
5	**Urban/district design**	Analysis of **neighborhood properties influencing energy and airflow**	CFD	District	(Srebric et al., 2015)
		Analysis of **interrelationship between energy use in buildings and in transportation**	LT method	Urban	(Steemers, 2003)

		Analysis of the impact of **design parameters of neighborhood** on environmental performance	Dynamic simulations (EnergyPlus)	District	(Hachem, 2016)
		Analysis of the impact of design parameters of neighborhood on energy demand for heating and cooling	Dynamic simulations (EnergyPlus)	District	(Hachem et al., 2012)
		Analysis of the impact of **urban context** on buildings thermal performance	Generative design; simulation; optimization algorithms	District	(Rodrigues et al., 2015a)
		Understanding the **concept of sustainable neighborhoods**	Qualitative analysis	District	(Choguill, 2008; Koch & Girard, 2011; Luederitz et al., 2013)
		Analysis of urban form and energy use for transportation	Data analysis	Urban	(da Silva et al., 2007)
		Analysis of the impact of urban form on buildings' energy demand	Urban Energy Index for Buildings (UEIB); LT method	Building/Urban	(Rodríguez-Álvarez, 2016)
		Analysis of urban energy lifecycle	Data analysis; simulation	Urban	(Davila & Reinhart, 2013)
		Assessment of energy demand and supply options in urban planning competitions	Automated procedure; simulation	Urban/District	(Eicker, Monien, Duminil, & Nouvel, 2015)
		Application of parametric design and optimization into urban design	Optimization algorithms (Grasshoper, ANSYS CFX)	Urban	(Taleb & Musleh, 2015)
6	**Energy systems**	Analysis of load matching and grid interaction in NZEB's role	Data analysis	Buildings	(Salom et al., 2011; Salom, Marszal, Widén, Candanedo, & Lindberg, 2014; Voss et al., 2010)
		Analysis of the lower temperature a **district heating** can be without losing efficiency and comfort levels	Simulations (IDA-ICE)	District	(Brand & Svendsen, 2013)

		Evaluation of available energy sources to implement a **district heating system**	Multicriteria decision analysis (PROMETHEE)	District	(Ghafghazi, Sowlati, Sokhansanj, & Melin, 2010)
		Modeling and optimization of **energy supply and demand at district scale**	Genetic algorithm	District	(Best, Flager, & Lepech, 2015)
		Optimization of urban energy systems	Mixed integer linear program	District	(Morvaj, Evins, & Carmeliet, 2016)
7	**Urban energy modeling**	Impact of neighborhood location in energy consumption	Comparative analysis of energy consumption data	District	(Rey et al., 2013)
		Optimization of a district heating system	Linear program (LP) model	District	(Huang & Yu, 2014)
		Impact of urban texture on buildings' energy consumption	LT model; analysis of digital elevation models (DEM)	Urban	(Ratti et al., 2005)
		Characterization of consumption patterns in urban district buildings	Dynamic simulation coupled to a GIS platform	District	(Fonseca & Schlueter, 2015)
		Development of a technical scenario for a 100% renewable energy city	EnergyPLAN analysis model	Urban	(Ostergaard & Lund, 2011)
		Analysis of the impact of district heating systems in renewable energy systems	EnergyPLAN analysis model	Urban/District	(Lund, Möller, Mathiesen, & Dyrelund, 2010)
8	**Computer tools**	Solar access support decision processes focusing on sustainable urban design	3D urban information system coupled with solar assessment	Urban	(Teller & Azar, 2001)
		Simulation of energy flows for sustainable urban planning	Simulation (CitySim)	Urban/District	(Robinson et al., 2009)
		Urban layout optimization to maximize solar potential	Simulation and optimization	Urban	(Kämpf & Robinson, 2010; Vermeulen et al., 2013, 2015)
		Analysis and optimization of energy systems in **neighborhoods**	City Energy Analyst (CEA)	Urban	(Fonseca et al., 2016)
		Urban energy simulation and **modeling for energy use in neighborhoods**	Simulation (OpenStudio)	Building/District	(Polly et al., 2016)
			Simulation (UMI)	Urban/District	(Reinhart et al., 2013)

		Evaluation of building **energy consumption in the district context**	Combination of Canopy Interface Model and simulation (CitySim)	Building	(Mauree et al., 2017)
9	**Review of available tools**	Evaluation tools for the integration of renewables in diverse energy systems	Review of available tools	Urban/District	(Connolly et al., 2010)
		Tools for modeling solar radiation and assessing solar potential in **urban scenarios**	Review of available tools	Urban	(Freitas et al., 2015)
		Evaluation tools for electricity grids, microgrids and off-grid energy systems	Review of available tools	Urban/District	(Allegrini et al., 2015; Keirstead et al., 2012; Markovic et al., 2011; Mendes et al., 2011)
		Support tools for solar systems design	Review of available tools	Urban/District	(Horvat & Wall, 2012; Kanters, Wall et al., 2014)

Appendix 4: Literature on districts energy performance parameters and calculation.

	Objectives	Method	Metrics/Type of Energy	Units	Parameters considered	Ref
1	Development of a methodology for evaluating **Net-Zero Energy District (NZED's)**	Function of Users, Buildings, Infrastructure, Industrial Activities, Mobility, Other requirement	/	kWh	Buildings: heating, cooling, appliances, DHW	(Koutra et al., 2018)
2	Evaluation of energy consumption of different **neighborhood** scenarios	Dynamic simulations (ENVI-met)	Electricity use for cooling	kWh	Urban layout pattern, street width, street orientation	(Sosa et al., 2018)
3	Development of a methodology for evaluating **Net-Zero Energy District (NZED's)**	Dynamic simulations (URBANopt)	Electricity use for heating and cooling	kWh	Buildings: orientation, window-to-floor ratio, envelope characteristics, airtightness Solar potential: orientation, roofs slopes, avoid building-tobuilding shading	(Polly et al., 2016)
4	Evaluation of overall energy demand of existing **neighborhoods**	Buildings: Energy Performance Index for each building + Transportation: transport energy indicator + Outdoor lighting: electric energy consumption per unit area of public space	Primary energy for heating	kWh/m^{2}y	Buildings: opaque and transparent envelope surfaces Transportation: distance, means of transportation, number of trips Outdoor lighting: number and type of lamps	(Fichera et al., 2016)
5	Analysis of the impact of design parameters on energy performance of **neighborhoods**	Dynamic simulations (EnergyPlus)	Total annual electrical energy use	GWh	Buildings' energy performance level (local statistics), density, district	(Hachem, 2016)

					typology, CBD relative location, streets’ design	
6	Assessment of the impact of urban form on **districts’** energy needs	Buildings: sum of energy consumption for heating, cooling, ventilation, appliances, cooking, DHW + Transportation: Energy consumption for daily mobility	Primary energy	kWh/m^{2}y	Buildings: heating, cooling, ventilation, appliances, cooking, DHW Transportation: distance, means of transportation, relative consumption rate	(Marique & Reiter, 2014)
7	Study of energy demand for heating and cooling of **neighborhoods** according to housing units’ shape	Dynamic simulations (EnergyPlus)	Total annual energy use	kWh/y	Buildings’ shape, density, site layout	(Hachem et al., 2012)

Appendix 5: <u>Typology of vera campus buildings</u>

Figure 22 Typology of buildings on the Vera campus on google earth