Quantitative Impact Assessment of SEAP Measures Implementation on Several Districts in the City of Donostia

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ABSTRACT

Nowadays municipalities are facing an increasing commitment regarding the energy and environmental performance of cities. In order to answer this increasing demand, municipalities need integrated methodologies and tools which make possible take into account the specific boundaries, strengths and barriers and assess their impacts (environmental, economic and social) at current stage and allowing the evaluation of low carbon refurbishment scenarios with life cycle approach. Considering these needs, Tecnalia is working by different tool and methodologies, allowing the assessment of direct and indirect environmental, economic and social impact of new and existing districts. Using one of these tools, NEST (Neighbourhood Evaluation for Sustainable Territories) within the research projects ESSAI URBAIN and OptEEmAL, authors of this work have carried out the evaluation of several existing districts in the city of Donostia. This evaluation has firstly consisted in analyzing the baseline scenario in terms of energy performance, environmental and economic impacts; and social “well-being” of these districts. Then, with the objective of improving the energy performance and reducing the global impacts, authors have proposed several refurbishment scenarios based on specific actions from the SEAP (Sustainable Energy Action Plan) of Donostia municipality. This study has been performed in close collaboration with the city of Donostia which enabled the identification and selection of the most relevant and feasible scenarios from social perspectives. Results from this study have been used for comparing theoretical values extracted from the Donostia SEAPs, for developing a critical view of the achieved results and for proposing a prioritization process between different refurbishment strategies.

Keywords: *decision support tool, refurbishment scenarios, environmental impacts*

1. INTRODUCTION

Energy security and climate change are driving a future that will require significant improvements in the energy performance of the building sector. The 28 Member States of the European Union (EU) have set an energy saving target of 20% by 2020, which will need to be reached mainly through energy efficiency measures. The EU has also committed to reduce greenhouse gas (GHG) emissions by 80-95% by 2050, as part of its roadmap for moving to a competitive low-carbon economy in 2050 (Directive 2010/31/EU, 2010).

In order to support the energy transition of Europe towards a low carbon economy, municipalities have a key role to play. Launched the Covenant of Mayors for Climate & Energy brings together thousands of local and regional authorities voluntarily committed to implementing EU climate and energy objectives on their territory. Signatories now pledge to reduce CO_2 emissions by at least 40% by 2030 and to adopt an integrated approach to tackling mitigation and adaptation to climate change and to endorse and support the efforts deployed by local authorities in the implementation of sustainable energy policies. A Sustainable Energy Action Plan (SEAP) is the key document in which the Covenant signatory outlines how it intends to reach its CO_2 reduction target by 2020. It defines the activities and measures set up to achieve the targets, together with time frames and assigned responsibilities. These cities have signed the Covenant of Mayors on a voluntary manner and are committed to implement sustainable energy policies to meet and exceed the EU 20% CO_2 reduction objective through increased energy efficiency and development of renewable energy sources. However, there is a lack of connection between global objectives at city level and the implementation of energy strategies at district level. Specific solutions implemented at district level often ignore global issues, failing in the consideration of mid-term and long-term scenarios. Besides, measures defined at global scale usually underestimate boundaries and barriers at district level.

In order to be effective in their energy and environmental transition, cities need specific tools to coordinate local stakeholders' information, provide detailed and relevant diagnosis of their city; identify boundaries and barriers of each district and their potential for energy measures implementation, considering technical and social issues. Using NEST (Neighbourhood Evaluation for Sustainable Territories) (Yepez, 2011), the authors of this work carried out an environmental and social evaluation of three districts in the city of Donostia. The evaluation firstly consisted of analysing baseline impacts. Then, with the objective of reducing environmental impacts and increasing social well-being, the authors proposed several refurbishment scenarios for the studied districts, in line with Donostia's strategies for energy efficiency.

2. NEST: NEIGHBOURHOOD EVALUATION FOR SUSTAINABLE TERRITORIES

Neighbourhood Evaluation for Sustainable Territories (NEST) was developed through a PhD thesis (Yepez, 2011) in Nobatek and the Groupe Recherche Environnement, Confort (GRECAU) laboratory, and focused on the environmental assessment of eco-neighbourhoods. Currently, the development of this software is carried out between Nobatek and Tecnalia, French and Spanish research centers with extensive experience in assessing environmental, economic and social impacts of buildings and districts. NEST is a plugin for Trimble SketchUp, which is the most used 3D modeler among urbanists and architects. NEST analysis is performed directly on the 3D master plan of the neighbourhood, and performs the assessment of a set of indicators that was developed through a scientific approach to operational urban planning objectives.

In terms of system boundaries, four major neighbourhood components are taken into account by NEST: buildings, land use, infrastructure (public lighting), and daily mobility of neighbourhood users (inhabitants and non-resident workers). Furthermore, NEST is one of the first tools that aims at assessing environmental impacts of neighbourhood scale projects, based on Life Cycle Assessment (LCA) methodology (social impacts currently are not evaluated with the life-cycle approach). NEST is based on the EN15978 (EN, 2011) standard, which defines the evaluation scope of a building's assessment with a life-cycle approach. Based on the conclusions obtained in the study carried out by Oregi (Oregi, 2015), NEST is focused on the assessment of the environmental impact of some of the life-cycle stages. The length of the NEST analysis is 50 years. Regarding the components of the district, the service life of the buildings is 50 years (Malmqvist et al., 2001), of land use is 50 years and of infrastructure is 30 years (Fthenakis et al., 2009).

3. PROJECT

3.1 Goal and scope

The goal of this study is to develop a methodology in order to promote resource conservation, reduction of environmental impacts and also to improve social conditions, adopting a life cycle approach. Using NEST, where studied the historical part of the city ("Parte Vieja"), the centre of the city ("Ensanche Cortazar") and the new part of the city ("Amara district") (see Figure 1). In this paper, we will present and discuss how the NEST tool was used in order to support the decision making process of urban refurbishment projects in order to implement the SEAPs measures into the three districts under study.

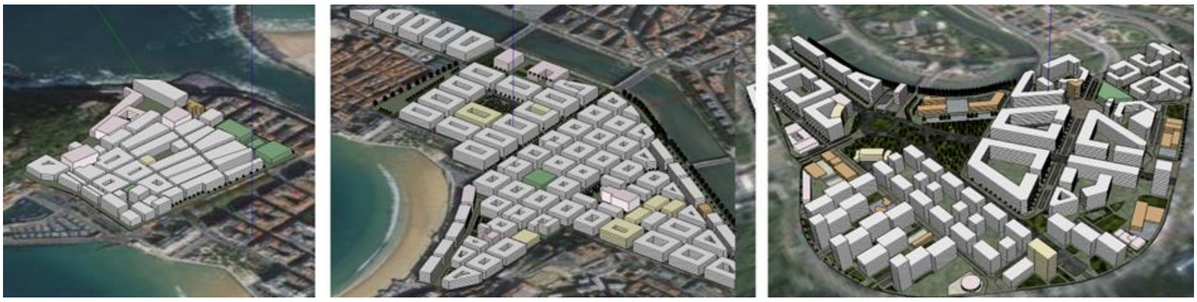

Figure 1: Screenshots of the three areas studied with the ESSAI URBAIN (Essai Urbain, 2009-2013) framework ("Parte Vieja" – "Ensanche Cortazar" – "Amara").

3.2 Case studies: Presentation

The three districts studied (see Figure 1) were chosen for their representativeness of the city of Donostia. As in most European cities, due to urbanism characteristics, construction age, buildings use, thermal properties, mobility infrastructure, building protection level, etc., the improvement potentials and constraints are quite different for each district. The historic centre of Donostia, founded in 1180, is protected by various regulations, reducing the number of conceivable options in terms of refurbishment strategies. The "Ensanche Cortazar" was designed in 1864. The architectural quality of some of these buildings turns them into catalogued or protected buildings, disabling their energy rehabilitation through strategies such as ventilated facades or window replacement. However, due to the high amount of energetically inefficient buildings, the potential of improvement is very high. In the second half of the 20th Century, Donostia city was enlarged and new urban areas had been created to make room for the increasing population ("Amara" district). The use of buildings in Amara is mainly residential and there is no building architecturally or urbanistically protected. Consequently, the energetic improvement potential of this district becomes very.

3.3 Evaluation methodology

A classical LCA process, similar to the one recommended by ISO standards on LCA was implemented beginning in the early stages of the study. To start, the goals and scope of the project were defined. As a result, it was decided that interest in the energy refurbishment strategies selected by the SEAP would be assessed, and would encompass each studied area over several time horizons. Next, the inventory analysis phase was carried out. This stage was critical as well as time consuming, because it required the collection of a large amount of data. The third phase consisted in running assessment calculations.

Primarily, a baseline analysis was done for the three districts. The baseline was defined in 2009, and corresponds to the starting point for Donostia with regard to municipal ordinance implementation (called "eco-ordenanza") (Gipuzkoa, 2014). This ordinance aimed at optimizing energy efficiency of new and renovated buildings. After that, three assessments were performed in order to evaluate the efficiency of the measures taken by the city of Donostia: municipal ordinance, horizon 2020 and horizon 2030. Finally, the results provided by NEST were interpreted and compared to the baseline, taking into account three indicators: Primary Energy (PE), Global Warming Potential (GWP) and Air Quality (AQ). It must be noted that because mobility aspects have already been deeply studied by the municipality, it has been excluded from the calculations.

3.3.1 Baseline

The information obtained in close collaboration with the city of Donostia the definition of a vast majority of the inputs required for modelling the baseline scenario of each of the studied districts. Based on this information, Table 1 shows some of the results obtained after inserting the input data in the tool. Ninety-three percent and 91% of PE and GWP impact, respectively, are related to the impact generated during the operational stage of the buildings. During this stage, 43% of PE and 75% of GWP are related to heating consumption. With regard to the air quality impact and with the exception of the historic district, in which mobility is limited mainly to pedestrians, more than 95% of the AQ impact is related to individual and public transport. In terms of comparison among the three districts, it appears that the Ensanche Cortazar has the highest impacts related to buildings.

This is explained by the significant number of buildings without insulation, as well as by its lower density. With respect to public lighting, the Parte Vieja district has the highest impact due to the relatively low efficiency of its public lighting system. And finally, in terms of mobility, the Amara district has the highest impacts mainly because of the district's transportation model, which relies more on energy-consuming and GHG-emitting transportation modes than the two other districts.

Impact indicator	Sector	Life Cycle Stage	Parte Vieja	Ensanche Cortazar	Amara
PE (MJ/year/user)	Buildings	A1-5, B2, B4, C1-4	0.0E+00	0.0E+00	0.0E+00
	Buildings	B6, B7	4.4E+04	9.7E+04	4.7E+04
	Public lighting	A1-3, B4, B6	1.9E+03	1.5E+03	1.3E+03
	Mobility	A1-4, B6, C1-4	1.2E+00	1.7E+03	2.1E+03

	Buildings	A1-5, B2, B4, C1-4	0.0E+00	0.0E+00	0.0E+00
GWP ($kg_{eq}CO_2$/year/user)	Buildings	B6, B7	2.5E+03	3.4E+03	1.5E+03
	Public lighting	A1-3, B4, B6	1.4E+01	1.1E+01	9.8E+00
	Mobility	A1-4, B6, C1-4	0.4E+00	9.7E+01	1.2E+02
AQ (m^3/year/user)	District		6.6E+03	2.9E+05	6.3E+05

Table 1: Baseline results for each studied district (per year and user)

NEST models also provided the "well-being" profile (see Figure 2) of each district through the social indicator assessment, which provides a better understanding of the district structures, highlighting their main features.

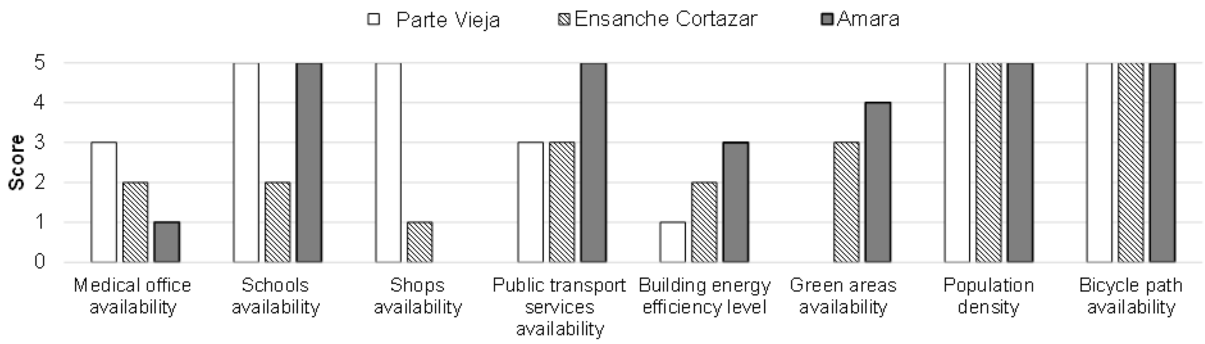

Figure 2: NEST social indicator results assessment of the three baseline scenarios.

3.3.2 Refurbishment scenarios

After evaluating the impacts of the baseline scenario, the second phase of the project was focused on the assessment of different energy refurbishment scenarios. The refurbishment scenarios are divided into three different temporal evaluations:

- Municipal ordinance of energy efficiency (2009-2014 years) (Gipuzkoa, 2014).
- Scenario 2020: Scenario based on the SEAP of Donostia (Minuartia Enea et al., 2011).
- Scenario 2030: Scenario based on Hiri Berdea document (ENEA, 2014).

Based on the information provided by these documents and through direct collaboration with the municipality, Table 2 shows the different energy refurbishment strategies for each aforementioned period.

Refurbishment strategy		**<2009 (Baseline)**	**Eco-ordenanza**	**2020**	**2030**
Public lighting	Luminary	Mercury vapour		Low pressure	LED
Public buildings	Boiler	Natural gas	No improvements		Condensation
	Lighting	No improvements			
	Cooling system	Standard		Efficient	
	Heating reduction	No improvements		15%	15%
Residential buildings (RB) boilers	Oil (PV, EC and A)	20%	10%	0%	0%
	Natural gas (EC)	80%	90%	90%	75%
	Natural gas (A)	80%	90%	90%	60%
	Condensation (PV)	0%	0%	10%	50%
	Condensation (EC)	0%	0%	5%	15%
	Condensation (A)	0%	0%	10%	30%
	Biomass (PV)	0%	0%	0%	0%
	Biomass (EC)	0%	0%	5%	10%
	Biomass (A)	0%	0%	0%	10%
RB replacement	Windows (PV)	No improvements		5%	15%
	Windows (EC)	No improvements		10%	20%
	Windows (A)	No improvements		15%	40%
	Façade (PV)	No improvements		0%	0%
	Façade (EC)	No improvements		5%	10%

Façade (A)	No improvements	20%	40%
RB heating demand reduction	No improvements	4%	7%
Solar thermal (PV)		No improvements	
Solar thermal (EC)	No improvements	970 m^2	2000 m^2
Solar thermal (A)	No improvements	2000 m^2	3500 m^2
Photovoltaic (PV and C)		No improvements	
Photovoltaic (EC)	No improvements	45 m^2	

Table 2: Refurbishment strategies proposed for "Parte Vieja" (PV) – "Ensanche Cortazar" (EC) – "Amara" (A) districts

From Figure 3, it can be seen that results vary among the three districts. The "Ensanche de Cortazar" and "Amara" districts evolve in the same way, with reductions in terms of PE demand and GWP for the three scenarios (between 1% and 28%, depending on the scenario and the indicator).

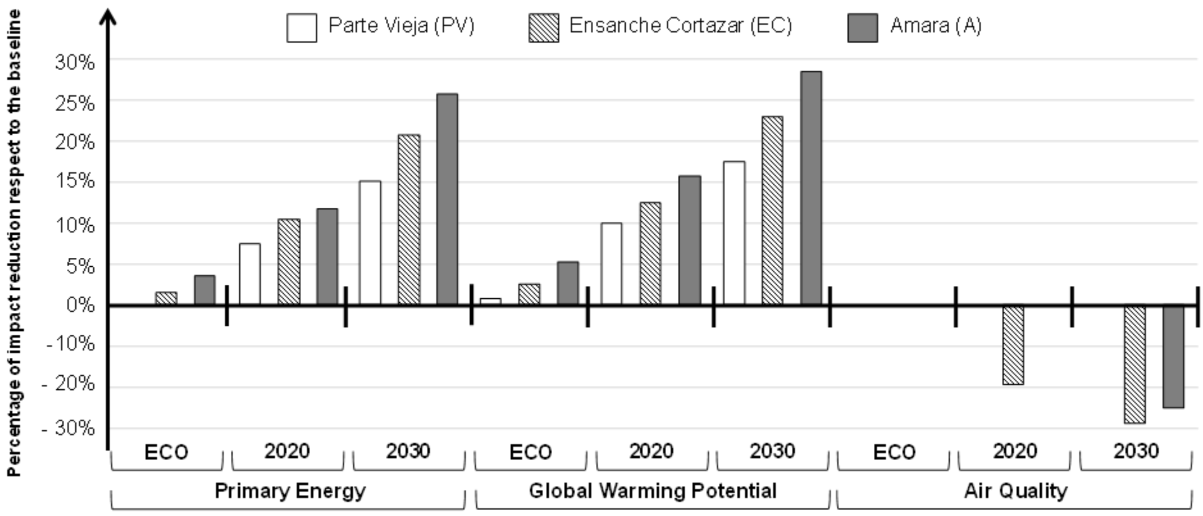

Figure 3: Impact variation (%) for the three districts studied in relation to the baseline.

However, the air quality indicator increases in the 2020 and 2030 scenarios due to the implementation of wood boilers (instead of gas boilers), leading to higher particulate emissions. It must be noted that this analysis should be deeply investigated while the precise type of wood boiler to be implemented is known. For the "Historic city" district, the impact reduction in terms of PE demand and GWP is lower due to historical constraints, which limit the implementation of energy refurbishment strategies. Also, the less frequent use of biomass boilers leads to a reduction in particulate matter, and thus reduces the influence on the air quality indicator.

4. DISCUSSION

Results provided by NEST allow quantifying the performance of the three districts at different time horizons in terms of primary energy demand, GHG emissions and air quality. This evaluation permitted to set the position of the studied districts with respect to the Donostia city objectives in terms of GHG emissions reduction for 2020 and 2030. As indicated in Table 3, results of the simulations show that the envisaged scenarios are not sufficient to reach the city objectives. Consequently, these results shed light on the improvements still needed to reach the defined objectives. However, it has to be noted that the proposed scenarios only tackle the built environment and associated impacts. One of the next possible areas of work in terms of methodology could be related to the influence of historical restrictions in designing energy refurbishment strategies at the city scale. Discovering new paths when designing refurbishment plans for such areas could significantly increase the refurbishment potential of cities.

(Impact indicator: GWP)		**ESSAI URBAIN results** (Essai Urbain, 2007–2013)	**SEAP** (Minuartia Enea *et al.,* 2011) **& Hiri Berdea** (ENEA, 2014)
Eco	Parte Vieja	1%	-
	Ensanche Cortazar	3%	
	Amara	5%	

2020	Parte Vieja Ensanche Cortazar Amara	11% 13% 16%	20,5%
2030	Parte Vieja Ensanche Cortazar Amara	18% 23% 28%	30%

Table 3: Comparison between ESSAIN URBAIN orders of magnitude and the targets to be reached

5. CONCLUSION

As mentioned, the work carried out during this study aimed at positioning the envisaged energy refurbishment scenarios and associated environmental impacts in relation to the city's objectives. The results showed some differences between the three districts studied, and helped the city of Donostia answer some critical questions. First, the assessment performed has allowed for the identification of GHG emissions hotspots in the baseline, and thus for the definition of key areas of action both in terms of geography (which districts) and items (which elements). For instance, it was highlighted that the Historical centre, due to architectural restrictions, will not be able to reach the same performance levels as the Amara or Ensanche districts. Also, building heating has been identified has the main contributor to district GHG emissions in the baseline. Finally, this exercise has provided important information regarding the envisaged energy refurbishment plan and its corresponding role in reaching the city's objectives. This has been particularly useful for the municipality to justify the need for additional efforts to reach their GHG emission objectives.

ACKNOWLEDGEMENTS

Part of this work was developed from results obtained during the ESSAI URBAIN (project number EFA287/13), POCTEFA program and "Optimised Energy Efficient Design Platform for Refurbishment at District Level" (OptEEmAL) project, Grant Agreement Number 680676. Another part of this work was developed with financial support from the French State, managed by the French National Research Agency (ANR) in the frame of the "Investments for the future" Programme ITE for the project INEF4 (ANR-10-IEED-0013).

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