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A COMPOSITE DECISION SUPPORT SYSTEM FOR ASSESSING TRANSFORMATION SCENARIOS AT THE DISTRICT LEVEL

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Abstract *Urban areas are responsible for almost 75% of overall resource consumption. To avoid a further increase of these values, it is important to implement energy efficiency measures, in order to achieve the target of Post Carbon Cities (PCC). Next to the concept of Post Carbon Cities, the Post Carbon District (PCD) is emerging, becoming the appropriate level to test the different strategies to move towards a more sustainable society. The definition of energy policies at this level shall cover all the sectors of the entire urban system. In addition to the buildings, which become an active part of the energy system, the sectors of water, waste management, public and private mobility, and public lighting come into play. As suggested by the European Commission, the evaluation of alternative strategies at large scale must take into account, not only the energy and economic aspects, but also the environmental and social impacts. The objective of the present paper concerns an investigation of a tool for supporting the decision-making process of alternative scenarios of energy transformation for a district. Starting from the most common approaches used in the field of investment evaluations, an approach that combines the potential of Cost-Benefit and Multi Criteria Analyses is proposed to include financial aspects and intangible impacts generated by urban redevelopment projects.*

1. INTRODUCTION

Nowadays, cities occupy about 2% of the Earth's surface, but they are responsible for 70% of the global primary energy consumption. About 50% of the world's population lives in cities and it is estimated that, in 2050, it can achieve the 75% [1]. Therefore, cities, given their high concentration of people, services and consumption, play a key role in the transition towards a sustainable society. This process, closely linked at the climate change mitigation, represents one of the greatest challenges of the 21st century, as recognised on Paris Agreement.

The role of cities, in the transition to a more sustainable future, is increasingly recognised and testified by the spread of the Post Carbon Cities (PCCs) concept, which is also shifting to a smaller scale of intervention, the district, with the realization of Post Carbon Districts (PCDs). It is something in-between of city and building and is the most appropriate scale for testing the various strategies of the urban system transformation where they may have a significant impact, reducing the size and the risk and making them more manageable [2]. However, it is important to highlight that districts are not the simple sum of its buildings, but the set of all parties that make up the urban system such as buildings, mobility, public lighting, water and waste management systems. The energy policies can lead to various positive social, environmental and economic impacts that can bring an added value for the choice of the alternative strategies. Therefore, new support instruments and criteria for considering these impacts are needed, being fundamental in a complex context like the urban one, where several stakeholders with different interests coexist.

Their inclusion may take place through different assessment systems, such as Life Cycle Cost (LCC), Life Cycle Assessment (LCA), Cost-effectiveness analysis, Cost-Benefit Analysis (CBA), Multi-Criteria Decision Aid (MCDA), Composite Modelling Assessment (COSIMA), and allows comparing various possible scenarios, justifying the decision.

The subsequent sections illustrate a methodological approach for district level assessment, focusing on the choice of transformation scenarios and the proper metrics to measure their impact.

2. METHODOLOGY

The energy efficiency measures (EEMs) need of innovative methodologies in order to be assessed beyond than mere reduction of consumption and investment costs.

The methodological process for the assessment of district transformation scenarios requires a series of steps. First of all, it is necessary to consider the current state of each element of urban system (building, mobility, public lighting, water and waste) as baseline to identify the EEMs and to proceed to the definition and identification of benefits that they can lead. The knowledge of the district can be supported by the use of geographic information system (GIS), an informative system that allows to collect, process and visualize geo-referenced data. As regards building stock, it is not feasible to analyse the energy consumption of each building. As shown by Ballarini et al. [3], on a large-scale analysis, one of the existing approaches is based on the identification of reference buildings (RBs), representing the heterogeneity of the building stock of city dividing it in specific classes. Each class is based on certain features (e.g. age of construction, geometrical and thermo-physical features), and is characterized by specific energy needs and consumptions, expressed in kWh/m^2y, estimated through the modelling of the representative RBs. The real buildings in the district are grouped in clusters according to the classes identified. In this way, it is possible to associate the consumption of RB to the cluster group and estimate the whole buildings and district energy consumption.

Once the state of the art has been identified, the EEMs for each sector need to be set out. Even then an energy assessment shall be carried out to get performance indexes to be compared to the baseline.

In order to compare the alternative scenarios, the last step is the macroeconomic assessment in which economic and extra-economic benefits are considered. First, benefits need to be identified and quantified for each scenario. Secondly, it is necessary to identify an assessment methodology that compares the different scenarios.

One possible support instrument in this phase is COSIMA analysis [4]. It can be briefly explained as an analysis that combines the Cost-Benefit Analysis and the Multi-Criteria Decision Aid. Therefore, it involves co-benefits, expressed in monetary terms (as in the case of CBA), and extra-monetary benefits which are defined through Key Performance Indicators (KPIs) of quantitative and qualitative type. Examples of benefits are shown in Table 1, with the identification of the proper metrics. For the MCDA part, is used the Analytic Hierarchy Process (AHP), which identifies and gives the importance of KPIs. Indeed, contrary to co-benefits, KPIs do not all have the same relevance, but to them is assigned a weight, which allows to support the objective of the stakeholders [5].

Table 1. Examples of monetary and extra-monetary benefits and their metrics

Monetary	**Unit**	**Extra-monetary**	**Unit**
Energy saving	€/kWh	Increase in public transport passengers	passenger/km
CO_2 emission avoided	€/ kg CO_2	Reduction of drinking water usage	l/per capita
PM_{10} emission avoided	€/ gPM_{10}	Covering renewable energy sources	%
Real estate market value	€/m²	Visual impact of EMMs	qualitative scale
Green jobs	€/per new net green job	Reliability of EEMs	qualitative scale
Fuel costs avoided	€/kg or €/l	People acceptance	qualitative scale
External cost	€/kWh		

3. SCENARIOS DESIGN

In this section, the different EEMs which can be taken in a hypothetical district are outlined. The selected actions follow the strategies to fulfil the decarbonisation objectives.

For buildings and mobility, the measures are many and it is necessary to combine them to get the overall strategy. Furthermore, some more efficient measures are designed only for the advanced retrofit level. In the light of the above, 9 EEMs for buildings, 4 for mobility, 3 for water, 2 for waste and 1 for public lighting are outlined. By the union of this, 144 possible scenarios are obtained. If the number of possible scenarios is high, the most significant cases can be selected to proceed to the macroeconomic assessment.

A possible logic, for the choice, shall be as follows: the least intrusive scenario (in green, as shown in Figure 1) and the most invasive one (in orange) are identified. After that, an intermediate scenario (in blue) is defined. Later more scenarios are chosen by modifying some measures from the basic scenarios, including at least once all the measures. In this way, it is possible to evaluate the impact of a measure on results.

Table 2. Examples of energy efficiency measures for all the sectors

Building (B)			**Mobility (M)**		
EEM	***Type***	***Code***	***EEM***	***Type***	***Code***
Plant	District Heating	D	Public transport	Methane buses 50% Electric buses 50%	1
	PV (Only for Envelope Advanced retrofit)	P			
Envelope	Standard Retrofit	S		Electric buses 100%	2
	Advanced Retrofit	A		Buses increase	A
Envelope retrofit coverage	50%	1	Private transport	Zero emission car 25%	1
	70%	2		Zero emission car 50%	2
	100%	3		Car number decrease	A
Water (A)			**Waste (W)**		
EEM	***Type***	***Code***	***EEM***	***Type***	***Code***
New devices	Faucets aerators Dual flush WC	1	Review of waste collection system	Door-to-door waste collection with electric vehicles	1
New devices + rain recovery	Faucets aerators Dual flush WC Rainwater recovery (for WC)	2A	Review of waste collection system + new garbage containers	Underground solution for urban waste (organic, plastic, glass, undifferentiated)	2
New devices + rain recovery + appliances substitution	Faucets aerators Dual flush WC Rainwater recovery (for WC) High efficiency appliances	2B		Door-to-door paper collection with electric vehicles	
Public Lighting (L)					
Lamps substitution	Led lamps	L			

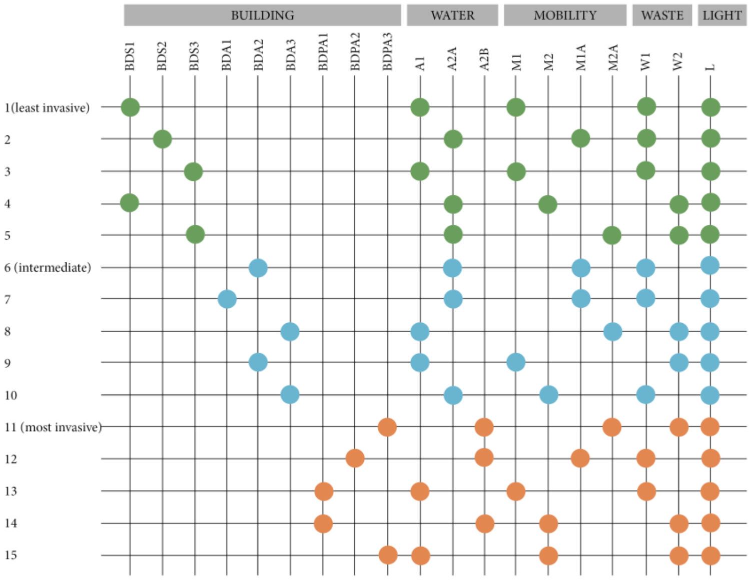

Figure 1. Combination of measures for the selection of scenarios to analyse

4. CONCLUSION AND FUTURE DEVELOPMENTS

The main objective of this article was to set the methodological instruments in supporting the assessment of alternative energy efficiency scenarios for the district scale, taking into consideration co-benefits attained by the project and putting a focus on the identification of the most appropriate metrics. The co-benefits are not always easy to be identified and quantified in monetary terms. Therefore, the use of hybrid assessment instruments, as COSIMA analysis, allows to get a more complete analysis, by combining the strengths of CBA and MCDA. This methodology is being applied in a Turin's district.

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