District energy choices: More than a monetary problem. a SDSS approach to define urban energy scenarios

District energy choices: more than a monetary problem. A SDSS approach to define urban energy scenarios

Francesca Abastante, Isabella Maria Lami*, Patrizia Lombardi*, Jacopo Toniolo**

key words: milticriteria anlyses (MCDA), cost analysis (CA), spatial decision support system (SDSS), DIMMER projects

Abstract

The article illustrates a piece of research concerning the development and application of display platforms (Spatial Decision Support System - SDSS) able to integrate assessment methods of financial and economic nature. The aim of the proposed SDSS platform is to support the development of urban scenarios focusing attention on improving energy conditions at district level in service of public and private policies. The platform, known as the Dashboard, was developed as part of the European DIMMER project (2013-2016) with the aim of obtaining real time data on user attitudes towards the use of energy through sensors and direct feedback from users.

In this specific context, the choice of a methodological approach able to compare different heating options of buildings is complex, considering, above all, a district vision. The article therefore proposes a framework based upon a Cost Analysis (CA) and Multi-Criteria Analysis (MCA) integrated in a SDSS display platform. To test the tool, we used a case study located in Turin (Italy).

1. INTRODUCTION

The development of an energy improvement strategy on a district/urban scale is being seen increasingly as a political and environmental decision rather than a technical and financial issue (Head, 2008). Firstly, European Directive 2010/31/EU dated 19 May 2010 (European Parliament, EPBD2010/31/EU) requires European Union Member States to adjust energy generation systems to new standards of control of individual consumption. However, Italian legislation on the matter has delayed transposing that Directive (Italian Legislative Decree 141, 2016) due to strong social resistance by the population in installing new energy consumption control systems. Secondly, adjusting existing buildings to new European standards is not only a problem of financial nature but also an environmental challenge, as different heat generation systems give rise to polluting emissions at local and global level which may differ significantly based upon the system adopted.

Both aspects, already complex in themselves, also involve a series of difficulties in terms of implementation and evaluation, requiring the comparison of different energy transition scenarios on an urban scale. In this sense, the article offers an innovative methodological framework which integrates three different approaches: a spatial approach through the Spatial Decision Support System (SDSS) platforms, an economic-financial approach through the Cost Analysis (CA) and a qualitative-quantitative approach supported by Multi-Criteria Analyses (MCA).

In particular, the SDSS platform used, known as the Dashboard, was developed as part of the European DIMMER project (District Information Modelling and Management for Energy Reduction - dimmerproject.eu) with the aim of analysing public and private buildings. To make the Dashboard efficient, a CA was applied to estimate the financial and economic costs relating to different measures of energy redevelopment. Therefore, the analysis is not limited to the assessment of financial and monetary costs, but it includes also environmental, social and technical aspects.

The CA is therefore the SDSS database. Finally, to manage the decision-making process effectively, the SDSS was applied in support of an MCA.

The article reports the initial results obtained from applying the tool to the urban district of Turin known as "Crocetta".

After the introduction, the article is organised as follows: section 2 indicates the methodological framework used, focusing on the joint use of SDSS, CA and MCA; section 3 illustrates the application to the DIMMER case study while section 4 concludes the article, providing some reflections on the future development of the work.

2. METHODOLOGICAL FRAMEWORK

2.1 The Spatial Decision Support System (SDSS) tool

SDSSs are display instruments based upon Geographic Information System (GIS) technology. SDSSs can support assessments and decision-making processes at urban scale, facilitating the integration of different sub-systems and databases and enabling the management of complex strategic scenarios (Arciniegas *et al.*, 2011). They are therefore extremely useful in resolving semi-structured problems of spatial nature (Sprague and Carlson, 1982).

In the energy field, SDSSs are proving particularly useful in supporting decision-making processes in real time, helping decision-makers/stakeholders to define urban energy scenarios. SDSSs can in fact display in real time the areas subject to intervention using coloured interactive maps (Chalal *et al.*, 2016) which become "visual indicators" dynamically changing in line with the preferences expressed by stakeholders (Jankowski *et al.*, 2001; Abastante *et al.*, 2017; Lombardi *et al.*, 2017).

The purpose of the Dashboard developed ad hoc as part of the DIMMER project is to provide a visual support to stakeholders during focus groups/workshops, helping them to understand how the trade-off between different decision-making criteria may evolve based upon the modification of some parameters in real time (Chakhar and Martel, 2004).

The Dashboard (Figure 1) can therefore be considered an SDSS as, thanks to its graphical interface, it allows for the interactive exchange of information between stakeholders and the tool itself, supporting the different phases of the decision-making process using maps and qualitative-quantitative indicators (Malczewski, 1999).

Operatively, the Dashboard was developed from the partnership of the DIMMER project and, in particular, by the Polytechnic of Turin, thanks to the technical support of Consorzio sui Sistemi Informativi (CSI-Piedmont) which implemented the platform in terms of functionality based upon the QuantumGIS open source software (QGIS - Hugentobler, 2008) and the CESIUM virtual globe (cesiumjs.org).

As part of the DIMMER project, the "Crocetta" (Turin) district was used as a pilot case study. After careful census work on the district, the Dashboard therefore contains numerous different levels of information of all buildings (Figure 1) to allow for energy, technical, spatial and social analyses as required by the DIMMER project.

The Dashboard also enables real time queries in relation to the buildings registry through the insertion of pop-up cards (Figure 2) indicating the most important information on the selected building.

Unlike a simple GIS model, which contains and displays data of spatial nature, one of the main strengths of the Dashboard is its ability to acquire, store and manage geo-referenced and non-geo referenced data at the same time. In this way, the Dashboard facilitates the analysis of spatial problems, considering simultaneously a broad spectrum of decision-making criteria.

To enable those functions considering real data, a Cost Analysis (CA) was done in line with the specific requirements of the DIMMER project and focused on the possible energy redevelopment solutions of the buildings and heat generation systems (Mittler, 2016).

2.2 The Cost Analysis (CA)

The CA developed and presented in this article considers economic and financial costs referring to different alternatives of possible redevelopment of existing buildings in terms of construction systems and heat generation plants. The DIMMER project in fact focuses on improving the existing building heritage rather than on creating new buildings for numerous reasons: on one side, it considers the scarcity of land available for constructing new buildings; on the other, it focuses on sustainable development because, as stated by Elefante (2007), "*the greenest building is the one that is already built*".

Figure 1 - *Example of Dashboard interface*

Figure 2 - *Example of pop-up card*

In particular, the CA developed considers:

1. redevelopment interventions of the building envelope of existing buildings, such as improving the thermal insulation performances of the vertical and horizontal walls and replacing the windows and doors;
2. replacing the heat generation systems, considering the connection to the district heating network, the installation of latest generation condensing boilers, the installation of photovoltaic panels, air heat pumps.

Due to the peculiarities of the territory, it was not possible to consider a broader spectrum of energy redevelopment technologies as, on the other hand, suggested in literature (Pahio *et al.*, 2013). The indications of existing legislation on heat generation do not, in fact, allow for the installation of some methods of heat generation in the considered territory such as, for example, water heat pumps which require the water table to be easily accessible to the system and which are therefore located, if possible, on the surface.

Operationally, in line with (Mattinen *et al.*, 2014), the CA was structured based upon the following sources: i) study of the industry's scientific literature (Burton and Hubacek, 2007; Pahio *et al.*, 2013; Patti *et al.*, 2015; D'Alpaos and Bragolusi, 2018); ii) Regional Price List of the Piedmont Region (regione.piemonte.it, 2017); iii) local empirical investigations to verify the costs in the city of Turin.

The illustrated analysis considers the costs charged to the end user (inhabitants) while the potential costs that may be borne by the heat management companies are not considered.

Based upon the considered literature, the CA therefore considers the following cost items: i) annual cost of fuel for heating; ii) annual system maintenance and management costs; iii) costs of investing in different energy redevelopment technologies; iv) net energy consumption for the heating system; v) environmental costs relating to local and global CO_2 emissions.

The annual cost of fuel for heating was calculated based upon monitoring the real consumption data collected in 2015 for the 200 considered buildings (Patti *et al.*, 2015). That value was multiplied by the price of fuel considering different energy sources and the market performance in the year of reference. The general formula for calculating the annual cost for heating is the following:

$$CCgb = \alpha(Q)$$

Where:

CCgb = cost of fuel [€]

α = parametric cost of fuel [€/kWh]

Q = energy required for heating [kWh]

That operation was performed for different sources of heat generation using the appropriate parametric costs inferred from the current energy market.

The same approach was also used to calculate the maintenance and management costs of the heat generation system.

The investment costs relating to energy redevelopment technologies were calculated, on the other hand, based upon the parametric costs codified in the Price List of the Piedmont Region (2017) mediated by market surveys performed locally in Turin. The general formula for calculating the investment costs of energy redevelopment technologies is the following:

$$(RefWR)C = \sum cf * p(V)$$

Where:

(RefWR)C= Investment cost [€]

$\sum$cf = Sum of fixed costs relating to energy redevelopment technology [€]

p = Corrective coefficient

V= Volume of buildings affected by the intervention [mc]

That same operation was performed for the different energy redevelopment technologies considered, after having estimated the respective energy costs.

It should be emphasised that the parametric investment costs included in the CA consider the following cost items: design, safety and regulations, documents for the Public Administration, scaffolding installation costs, cost of materials and labour.

The energy redevelopment alternative that involves the possibility for the buildings to connect to the district heating network constitutes an exception to that approach from the perspective of calculating the necessary investment cost. In fact, since those costs are not attributable to an individual building but cover an urban area, the district heating management company in Turin (IREN) was contacted to ascertain the necessary costs empirically.

To estimate the items relating to local and global CO_2 emissions, the official national emission factors published in (Patti *et al.*, 2015) were consulted, with the exception of emissions relating to the district heating network which, not being codified at national level, were provided directly by the energy company IREN.

The estimated cost items were then entered into an economic-financial database of the Dashboard enabling the development and comparison of different urban energy scenarios. The combination between the CA and the Dashboard in fact produces a dynamic analysis of the different cost items required to achieve a set target by the interested stakeholders. The financial and economic savings and the Payback Period (PBP) of the hypothesised interventions can also be calculated.

The Dashboard, thus configured, was used as a support during the focus group illustrated in paragraph 3.2.

2.3 The Multi-Criteria Analysis (MCA)

In general terms, the MCA are a family of consolidated and broadly used approaches able to support the decision-maker in taking decisions in a structured and intuitive manner (Figueira *et al.*, 2005; Abastante *et al.*, 2019). MCAs are considered to be powerful instruments for the decision-maker in situations of multiple decision-making criteria or in the presence of multiple alternatives. In addition, over the years, MCAs have proved to be particularly useful in territorial and urban planning which is often characterised by the simultaneous presence of different aspects and where the stakeholders involved have different and often conflicting aims (Huang *et al.*, 2011; Abastante and Lami, 2013; Lami and Abastante, 2014; Abastante, 2016; Abastante *et al.*, 2018).

Among the numerous MCA methods, the MCA methodology known as "Measuring Attractiveness by a Categorical Based Evaluation Technique" (MACBETH) plays an important role (Bana and Costa and Vansnick, 1997; Bana and Costa *et al.*, 2010).

The MACBETH method is based upon the additive method and requires qualitative judgments in terms of value differences to help an individual, a group or an entity in the respective quantification in terms of attractiveness between actions/alternatives or decision-making criteria. Based upon the qualitative judgments required from the stakeholders involved, MACBETH enables the construction of quantitative values, supporting a learning process and reducing cognitive "*discomfort*" (Fasolo and Bana e Costa, 2014) which can occur when direct numerical judgments are required from the stakeholders (Bana and Costa *et al.*, 2004).

The application of the method can be summarised in three phases: structuring of the model, assessment and analysis of the results (Abastante and Lami, 2018).

Structuring of the model: the main problems to be addressed in the decision-making process (decision-making criteria) and the options (or alternatives) are identified and structured in the form of a tree (known as *value tree*) in order to provide a visual panoramic of the aspects of the analysed problem.

Assessment: the stakeholders are asked to respond to a series of pair comparisons, specifying the difference in attractiveness between the various alternatives with respect to the decision-making criteria, using the semantic categories codified by the model (Table 1).

Analysis of results: the method provides clear results in the form of a ranking identifying the importance of the criteria and the alternatives using the dedicated M-Macbeth software (m-macbeth.com).

From the various multi-criteria methods suited to the structuring of decision-making problems, we decided to use MACBETH for various reasons: i) it is a simple and comprehensible methodology even for those who are not experts in the field of decision-making processes; ii) the technical parameters on which the method is based are robust and recognised by the scientific community; iii) the results provided by the methodology can constitute a basis for comprehensible discussion in the subsequent phases of the process; iv) the M-Macbeth software and the interaction protocols involved in the model provide clear results even for non-expert stakeholders.

Table 1 - *Semantic categories of the methodology*

SEMANTIC CATHEGORIES	
Extreme	Extreme difference among two elements
Very strong	Very strong difference among two elements
Strong	Strong difference among two elements
Moderate	Moderate difference among two elements
Weak	Weak difference among two elements
Very weak	Very Weak difference among two elements
NO	No difference among two elements

3. CASE STUDY

The decision-making process reported in this paper pursues different objectives: i) to test the utility of the Dashboard for supporting stakeholders in making decisions; ii) to discuss the possible decision-making criteria to be considered and their importance within the examination; iii) to discuss and analyse different energy redevelopment scenarios with a view to reducing energy consumption and polluting emissions.

The district subject to the decision-making process and used as part of the DIMMER project is "Crocetta" in Turin, selected on the basis of a series of architectural and urban characteristics. It is a largely residential district with buildings constructed mainly in the 1960s: they represent the most widespread type in Italian cities, as well as the properties that most require energy redevelopment. The presence of public and private use buildings also allows for analyses and reasoning to be developed observing the behaviour of users in different situations of social use.

Given the complexity of the problem, the information available and the requirements of the DIMMER project, it was decided to limit the analysis to 200 buildings located in the district based upon the building heritage mapped in the Dashboard and shown in Figure 1.

Error. The reference origin is not found. Despite the analysed sample limiting the study to only a portion of the urban fabric of the district, the 200 buildings considered represent the architectural and energy situation of the district and are different in terms of orientation, size, use, technology and construction materials (Figure 3). This sample corresponds to about 4,000 end users, making the analysis reliable even though it does not consider the entire district.

The decision-making process, lasting about one year, was structured into the following phases: firstly, a group of experts in MCA, energy, territorial planning and economic valuations structured the decision-making model, using the MACBETH methodology, defining the decision-making criteria and some hypotheses of urban energy transformation scenarios. An initial focus group was then organised in the presence of stakeholders active in the territory in order to validate the decision-making model. Finally, during a second focus group, the decision-making model MACBETH was applied, supported by the Dashboard, to assist the stakeholders in identifying the best urban energy scenario for the considered district.

Figure 3 - *The 200 buildings considered*

More specifically, the article indicates the results of the second focus group; the stakeholders involved in that group were represented by the Association of Constructors of Turin and the Public Administration, Entrepreneurs, designers and experts/academics in the field of energy and economic valuations.

3.1 Definition of decision-making criteria and alternatives

Considering the industry's literature (Pahio *et al.*, 2013), the data available from local sources, the data estimated through the CA and the indications received from the stakeholders involved during the validation phase of the model, five fundamental decision-making criteria were identified:

- investment costs, meaning the capital necessary to launch the energy redevelopment operations (Becchio *et al.*, 2016);
- Payback Period (PBP) measured in number of years necessary to compensate the initial investment (Volva iovas *et al.*, 2013);
- reduction of CO_2 emission which each scenario is able to achieve in percentage terms (Beccali *et al.*, 2003);
- reduction of energy demand in percentage terms. That criterion refers to the improvement of the building's energy performances after the redevelopment (Wang *et al.*, 2009);
- resilience of the energy system meaning the capacity to absorb knocks and/or to suffer interruptions without affecting the energy supply.

Based upon the decision-making criteria, three hypotheses of scenarios for the urban energy development of the "Crocetta" district were produced.

The scenario hypotheses consider a timeframe of 15 years, within which all buildings not connected to the district heating network or without a condensing heat generation system must be modified (Italian Legislative Decree 141, 2016) in line with existing regulations. It is also hypothesised that the buildings currently connected to the district heating network will not change the heat generation method within the considered timeframe (Italian Legislative Decree 141, 2016). The district heating network is in fact considered an energy supply system of so-called *lock-in* nature. Interrupting the connection to the district heating network is in fact possible in theory but presents considerable technical and economic difficulties which constitute a disincentive to that practice.

Table 2 provides a summary description of the scenario hypotheses considered and the performances with respect to the decision-making criteria considered.

It must be emphasised that the alternative scenarios proposed constitute simplifications of the possible future developments in energy terms and their intention is to stimulate the comparison between different future visions in line with (Cassen *et al.*, 2015).

In particular, scenario 1 (Increase of district heating) can be defined as a strategy of "*top-down Centralized ENergy*

Transition (CENT)" nature promoted by central policies pursued without considering in detail the requirements of inhabitants of the specific district. In this sense, the CENT strategy is often preferred by Public Administrations as it enables greater control in terms of safety of the system and polluting emissions (Cassen *et al.*, 2015). This is despite that strategy demonstrating some problems particularly linked to the *lock-in* system (Scott and Pollitt, 2010) which incentivises energy monopoly and reduces system resilience. It is also worth noting that scenario 1 has the lowest investment cost among those hypothesised as it considers the investment costs that would have to be paid to inhabitants but does not consider the costs relating to the district heating network and stations.

Scenario 2 (Conservative) can be defined as "*business as usual*". In this scenario, it is assumed therefore that the current heat generation system and the building components are redeveloped due to obsolescence and economic/regulatory requirements.

Scenario 3 (Extreme) reflects the strategy known as "*bottom-up Societal Energy Transition (SET)*" in which market decisions are applied at building/district level. That strategy is able to consider a long-term economic perspective, in view of the requirements of inhabitants of the district. As shown in Table 2, that scenario presents high investment costs, which can be recovered in the short-term, as emerges from the PBP.

The scenario hypotheses were therefore integrated in the Dashboard to stimulate the discussion with the stakeholders, helping them to align their points of view (Vennix, 2006) and to have a collective vision (Andersen and Richardson, 1997) of the problem at issue.

3.2 The DIMMER focus group

After having defined and validated the decision-making criteria and the scenario hypotheses, the decision-making model was able to be structured through the MACBETH methodology. A focus group was therefore organised with the stakeholders involved in the transformation with a view to discussing the importance of the criteria and the scenarios.

In line with the MACBETH methodology, the stakeholders were asked questions on both the decision-making criteria and the scenarios, such as:

- *In your experience, order the decision-making criteria and the transformation scenarios, from the most important to the least important, considering the transformation in question;*
- *After having ordered the criteria, indicate which you believe to be a more important criterion than another, using the MACBETH scale;*

Table 2 - *Alternative scenarios and performance of criteria*

ALTERNATIVE SCENARIOS			DECISION-MAKING CRITERIA				
			Investment costs	Simple Payback Period (SPBP)	Reduction of CO_2 emissions	Reduction of energy demand	System resilience
1	Increase of district heating	Involves: - 87% of district hearing and 13% of condensing boilers; - 10% of buildings redeveloped with external insulation.	€ 8.700.000	30 years	30%	10%	Low
2	Conservative	Involves: - 65% of district hearing and 35% of condensing boilers; - 20% of buildings redeveloped with external insulation.	€ 12.600.000	20 years	25%	17%	Medium
3	Extreme	Involves: - 52% of district hearing and 23% of condensing boilers; - 50% of buildings redeveloped with external insulation.	€ 30.400.000	10 years	55%	50	Medium/high

Example: the "Investment Costs" are much more important than the "SPBP" criterion while the "SPBP" criterion is a little more important than the "System Resilience".

Each stakeholder present at the focus group responded individually to the questions provided by the method.

After obtaining the responses from the individual stakeholders, a discussion was stimulated among the attendees supported by the Dashboard with the aim of allowing the opinions to converge and to reach agreed solutions.

In this phase, the Dashboard played a fundamental role in helping the decision-makers to view information in real time. The possibility of "seeing" the geo-referenced scenarios in the territory, supported by precise and/or aggregated numerical data estimated with the CA, allowed the stakeholders to increase their knowledge of the problem, the territory in question and the energy and economic performances of the considered scenarios (Figure 4).

Figure 4 constitutes an example of geo-referenced information on performances in terms of annual maintenance costs for the 200 considered buildings: the lightest buildings have the best energy performance in terms of maintenance costs (i.e. they have the lowest maintenance costs) while the darker buildings have the worst performances.

At the end of the discussion, it emerged that, for some pairs of questions, it was extremely difficult to reach a response that satisfied all stakeholders. In these cases, therefore, the judgments attributed by the individual stakeholders were aggregated during the focus group following the logic of the "majority method" (Bouyssou *et al.*, 2001; Lami *et al.*, 2014; Lami, 2014). Preference was therefore attributed to the criterion/alternative that obtained the highest number of votes and from these the arithmetic average was determined, as suggested in literature by (Aczèl and Saaty, 1983).

The final ranking resulting from the analysis in terms of decision-making and alternative criteria is reported in Table 3.

When considering Table 3 it emerges that the criterion deemed most important for the transformation of the "Crocetta" district is the "Investment Costs" (30%) followed by the "PBP" (27%) and the "Reduction of energy demand" (23%). The difference of importance in percentage terms between these criteria is minimal and mainly reflects a strategy of short-term private profit. The

Figure 4 - *Visualisation of the maintenance costs for some of the considered buildings*

Table 3 - *Final ranking of criteria and alternatives*

Criteria Order	Weights (%)	Scenarios Order	Weights (%)
Investment costs	30	Scenario 3	47.50
PBP	27	Scenario 2	29.03
Reduction of energy demand	23	Scenario 1	23.46
Reduction of CO_2 emissions	18		
System resilience	2		

criterion "Reduction of CO_2 emissions" (18%) is not considered to be fundamental in view of energy redevelopment at district level while the "System Resilience" (2%) is rather negligible. During the focus group, in fact, it emerged that CO2 emissions and the resilience of the energy system still do not constitute a concern perceived by the inhabitants.

From the point of view of the scenario, in line with the responses provided during the focus group, the best energy redevelopment scenario for the "Crocetta" district was found to be Scenario 3 (Extreme, 47.50%) with a view to incentivising the autonomy of choice of the district's inhabitants.

This result is coherent with the importance attributed to the criteria since, despite the stakeholders having attributed the greatest importance to the criterion of "Investment Costs", they considered as fundamental also the criteria "PBP" and "Reduction of energy demand", whose performances are better in Scenario 3. In that sense, Scenario 3 is able to maximise those aspects at the same time in a long-term perspective, considering the preferences above all of private investors. In addition, Scenario 3 would allow for environmental sustainability objectives to be pursued, as suggested in the focus group by the public stakeholders since CO2 emissions would be reduced thanks to the use of clean energy. Scenario 3 would therefore appear to be able to conciliate aspects usually in antithesis.

Conversely, the stakeholders present at the focus group considered Scenario 2 (Conservative, 29.3%) to be less interesting than Scenario 3 as, despite being financially more accessible, it does not achieve the required performances in terms of CO2 emissions. Finally, Scenario 1 (Increase of district heating, 23.46%) was found to be less interesting despite the excellent performance of the "Investment Costs". The stakeholders, in fact, replied that a CENT type strategy is not feasible from the environmental and energy perspective. In addition, the energy monopoly inherent in Scenario 1 is not aligned with the idea of profit and development of private investors.

Thanks to the results obtained through the MACBETH method (Table 3) during the focus group an interesting discussion was triggered between the stakeholders as to the fact that the alternative scenarios proposed and compared were only some of the possible solutions that could be pursued for the energy redevelopment of the district. The stakeholders therefore developed some opinions not linked to the alternatives proposed but supported by the Dashboard, which enables the comparison of data of different buildings in graphic and tabular terms.

The stakeholders, in fact, were able to simulate alternative energy development scenarios defined as *what-if* based upon the parameters provided by the Dashboard.

The participants therefore used the tool in an interactive way, selecting in the table groups of buildings, modifying their type of heat generation system and choosing the redevelopment technologies from the following options: installation of heat pumps and photovoltaic panels, connection to the district heating network, installation of latest generation condensing boilers, replacement of windows and doors and/or insulation of vertical and horizontal walls (Figure 5).

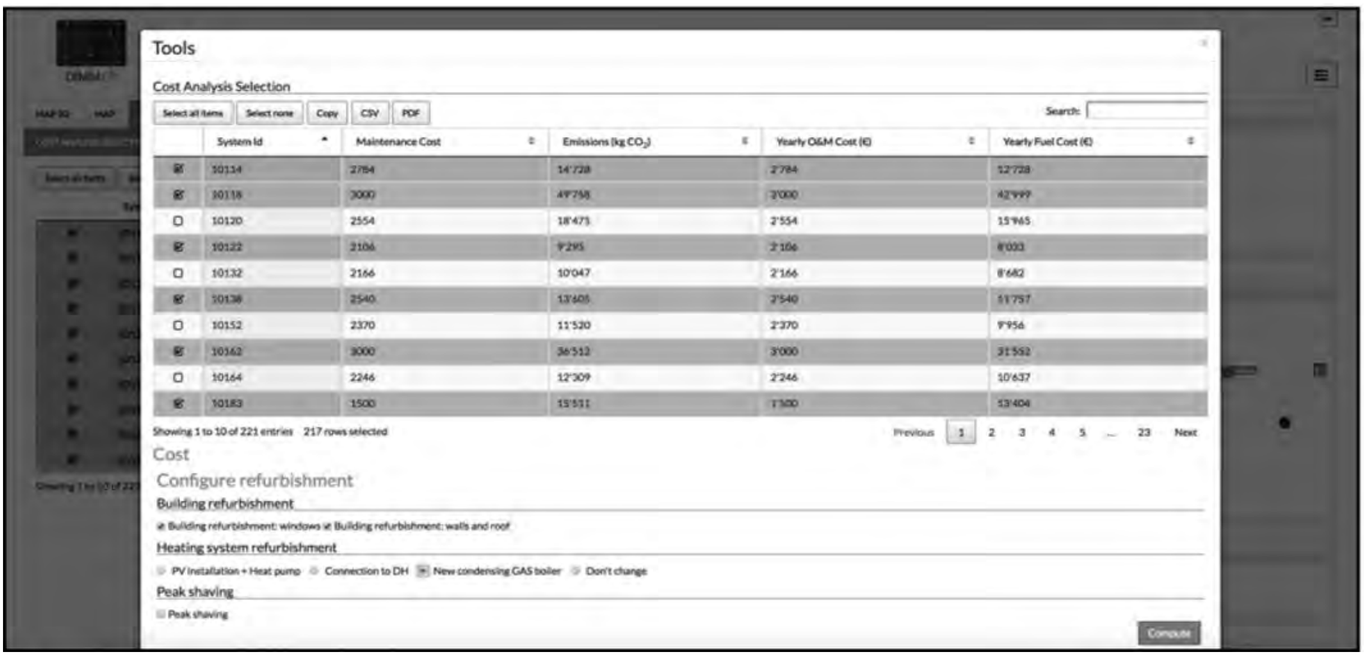

Figure 5 - *Alternative scenarios simulation: choice of the parameters*

Based upon the decisions made by the stakeholders in real time during the focus group, the Dashboard produced the performances of the hypothesised scenarios (Figure 6). The first two graphs show the differences between the current energy situation and that simulated in terms of energy consumption (kWh) and CO_2 emissions; the pie chart shows in percentage terms the heat generation systems hypothesised in the simulated scenario.

This functionality was found to be extremely interesting for the private and public stakeholders. The private stakeholders in fact had the opportunity of viewing different energy redevelopment alternatives in order to acquire information in terms of private economic interests. The public stakeholders, on the other hand, acquired greater awareness in terms of the environmental protection of the territory.

4. CONCLUSIONS

The article reports an experience of a decision-making process in the energy field structured thanks to the joint use of different tools and methods: an SDSS instrument, a CA and a MCA.

In particular, the article demonstrates some of the possible contributions that can be obtained from the joint use of traditional assessment methods and display tools to move from a building perspective to one of the district, supporting district energy policies including quantitative and qualitative analyses.

In the illustrated case, the CA constituted the database integrated into the Dashboard, estimating financial, economic and environmental cost values that are key elements in urban energy transformations. This allowed for different activities during the focus group, such as: the display of geo-referenced and non-geo referenced data, the consultation of aggregate and precise information on the performances of the scenario hypotheses, the definition in real time of new *what if* scenarios based upon the preferences of the stakeholders.

The Dashboard was found to be extremely useful in supporting the structured decision-making process thanks to the MACBETH multi-criteria method as it allowed for assessments to be developed of integrated nature and helped to achieve consensus (AbuSada and Thawaba, 2011) considering simultaneously long-term and short-term effects, conflicting interests and prospects of socio-economic development (Wang *et al.*, 2009) and providing an order of priority of criteria and design alternatives.

The future developments of the work involve: the application of the assessment framework to the entire "Crocetta" district or other districts in order to expand the territorial scale of analysis; the estimate of variables of social nature, such as the registry of inhabitants on a statistical basis to gain a better understanding of the considered buildings; to integrate the MCA into the SDSS tool.

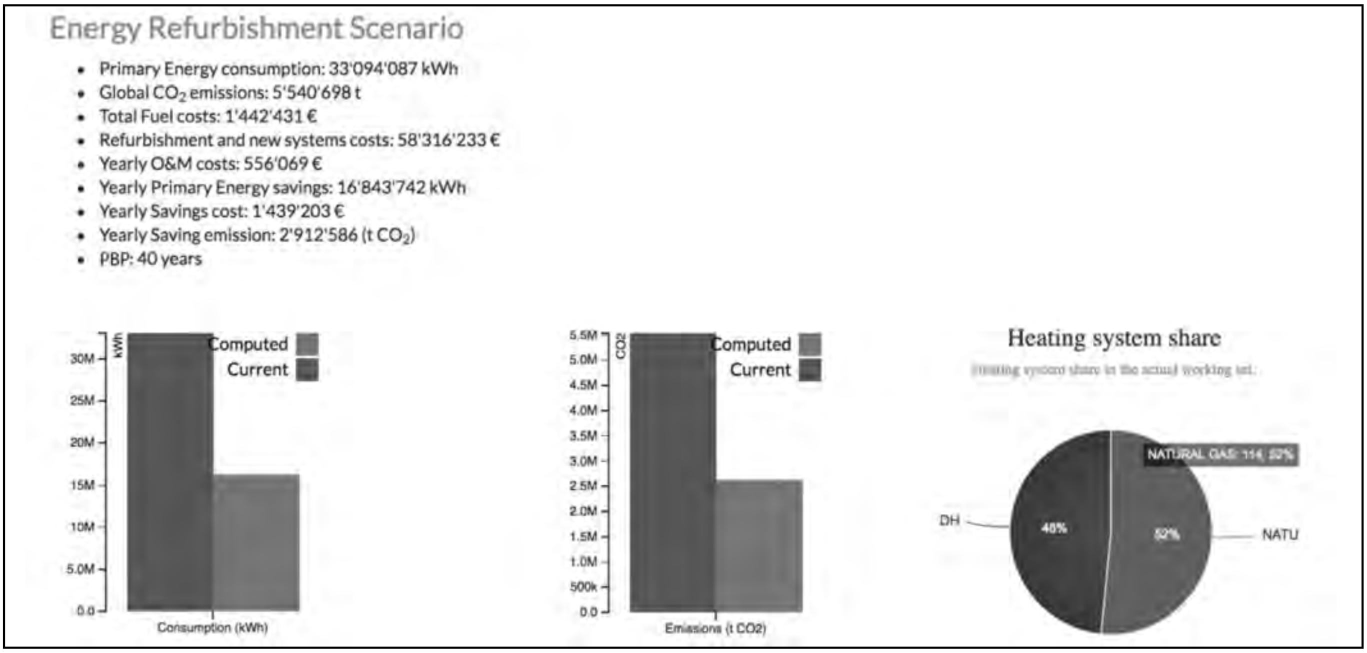

Figure 6 - *Alternative scenarios simulation: final graphs of the results*

* **Francesca Abastante, Isabella Maria Lami, Patrizia Lombardi, Jacopo Toniolo,** *InterUniversity Department of Regional and Urban Studies and Planning (DIST). Politecnico di Torino, 39 Viale Mattioli, 10125 Turin, Italy.*

e-mail: *francesca.abastante@polito.it; isabella.lami@polito.it; patrizia.lombardi@polito.it; jacopo.toniolo@polito.it*

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