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Local energy efficiency programs: A monitoring methodology for heating systems

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ABSTRACT

In recent years, as a result of an important agreement with the Italian Ministry of the Environment, Lombardy Region has promoted and supported numerous measures for energy efficiency and renewable energy sources integration within its territory.

Subsequently, monitoring campaigns have been launched to evaluate the global outcomes of the different calls and programs. Among other types of interventions, the promotion of the replacement of diesel boilers with high efficiency natural gas boilers represents an effective way to reduce primary energy demand and emissions and, more in general, to support the definitive transition from oil derived fuels to less polluting fuels like natural gas.

The research presents the results of the monitoring campaign performed on about 1500 heating system's retrofit interventions subsidized by Lombardy Region within its "Framework Program Agreement in the field of Environment and Energy". Local energy efficiency programs are particularly important today and have to be designed, managed and monitored to clearly identify the real energy, economic and environmental benefits that they produce. The research presented aims to provide a methodology and useful insights for the implementation of such programs along with their monitoring and analysis processes. In particular, the research illustrates the use of indicators to enable a comparison according to multiple criteria and different perspectives, in particular the societal one and the end-user's one.

1. Introduction

The European goals for the years 2020 (European Parliament, Directive 2009/28/EC, 2009) and 2050 (ECF, 2010) along with other European Directives focused on energy efficiency, like the EPBD Recast (European Parliament, Directive 2010/31/EU, 2010) and the Energy Efficiency Directive (European Parliament, Directive 2012/27/EU, 2012), are clear signs of an increasing commitment to energy sustainability at continental level. Italy recently introduced new programs like the National Action Plan for Energy Efficiency (Ministero dell'Ambiente, 2011) and the National Energy Strategy (Parlamento Italiano, D.I. 04/03/2013, 2013). Despite the substantial improvements made at the technological and regulatory level in recent years, a significant potential for energy efficiency remains still unexploited (IEA, 2008a, 2008b).

The statistics regarding energy consumption highlights how buildings in Europe (residential and tertiary) are responsible for about the 40% of the primary energy consumption (BPIE, 2011). New and existing buildings are key components to tackle in view of future energy and environmental goals, because of their very high potential and the general implications related to the efficiency of the built environment (Wilkinson, Smith, Beevers, Tonne, & Oreszczyn, 2007). Italian buildings account for the 35% of the overall national energy balance (ENEA, 2012). Residential buildings represent the 57% of this quantity and space heating alone is responsible for about the 66% of energy consumption in this sector. Despite the large availability of efficient "off the shelf" technologies, the cost of efficiency measures remains, in many cases, one of the most important barriers, as underlined in the EPBD recast (European Parliament, Directive 2010/31/EU, 2010), which states that "energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels". Beside costs, there exist also various types of non-technical barriers, related, for example, to non-uniform regulations between national and local government, rapidly changing requirements, inability to attract investments, management issues, etc. At the policy making level, the importance of the heating sector can be recognized also in the Directive 2009/28/EC on the promotion of the use of energy from renewable sources and in the Directive 2004/8/EC on the promotion of cogeneration. In fact, while at National and

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Nomenclature

Variables and parameters

C	cost
c	cost per unit of energy
DPB	discounted payback
E	energy
f	emission or conversion factor
m	mass
η	efficiency
NPV	net present value
r	discount rate of the investment
v	value
w	relative weight

Subscripts and superscripts

em	emission
$fuel$	fuel
i	index
inv	investment cost
max	maximum
N	project lifetime
$O\&M$	operation and maintenance
th	thermal
y	year

Regional level the more diffuse conventional systems, fossil fuel boilers, have a required minimum performance level (D.G.R., 2007; Parlamento Italiano, D.P.R. 59/2009, 2009), an increasing emphasis should be put on the role of technologies based on renewable energy sources combined with high-efficiency technologies, to meet the heat demand of the built environment more sustainably in the future (Pardo Garcia, Vatopoulos, Krook-Riekkola, Perez Lopez, & Olsen, 2012).

Indeed, policies should be aimed at a synergistic effect (i.e. exploiting systems of efficient technologies as a mean to achieve ambitious goals, specific for different sectors, but clearly quantifiable by means of indicators) and supplemented by continuous planning, monitoring and adjustment. These steps clearly require an interaction among governmental institution, policy makers, construction industry, investors, owners and occupants of buildings. Basically, two fundamental points of view have to be considered, the societal one, encompassing cost of "externalities" (climate change, pollution, etc.), and the end-user's one encompassing reasons that can prevent efficiency investment (technical barriers, lack of information and motivation, risks and uncertainties related to the investment, etc.).

In this framework, the paper aims to describe, by means of a case study, a methodology to monitor and evaluate the results of energy efficiency programs, addressing the following issues:

1. effectiveness of the programs with respect to multiple objectives;
2. relevance of the subsidy mechanism with respect to the objectives considered;
3. simplicity, transparency and ease of implementation of the monitoring and evaluation process;
4. fundamental insights and generalization.

The following section presents more specifically the motivation of the research.

2. Research motivation

Energy policy, among other things, should be aimed at learning effective schemes to enhance the diffusion of efficient technologies and practices. In this sense, national and local governmental institutions have to develop a specific know-how to support effectively the transition towards a more sustainable energy paradigm. Therefore, research and development in the energy sector has to be performed both at the technological level and at the system level. In the building sector, the necessity to accelerate the introduction of innovative technologies is rapidly shifting the focus on global optimality of design strategies and competitiveness of solutions (Aste, Adhikari, & Manfren, 2013; European Commission, 2011a, 2011b; Georges, Massart, Van Moeseke, & De Herde, 2012; KB, 2011; Mahapatra & Gustavsson, 2008; Nässén & Holmberg, 2013).

In any case, the technological and normative development has to be necessarily complemented by a monitoring process and policies have to be adjusted coherently as the characteristics of the reference system evolve (Steinbach et al., 2013). We assisted in recent years at a proliferation of energy efficiency programs at European, Italian and local level. However, programs have to be correctly designed from the beginning in order to ensure consistency with the administrative procedures in terms of information management and ease of implementation, avoiding time consuming and expensive analysis procedures, in particular in the verification and monitoring phases.

For this reason, the results of this research are described by means of environmental, energy and economic performance indicators, in order to address not only the outcomes of local energy policy actions, but also to set the basis for future local policies in which there will be the necessity to compare in a transparent way larger portfolios of technological options and different scales, from single buildings to communities and territories. The case studies presented are existing heating systems which have been retrofitted by substituting the diesel boilers with efficient natural gas boilers and which received a subsidy from Lombardy Region. The details on the case studies and the specific thematic areas and indicators considered are described in detail in Section 3.

3. Monitoring campaign of a local energy efficiency program for heating systems

Lombardy Region in the last years promoted several programs and projects such as "Action Plan of Energy", "Strategic Plan of technologies for Energy Sustainability In Lombardy", "Plan for Sustainable Lombardy", "Factor 20" and "Trend". The monitoring of energy demand and supply, the environmental impact and the degree of achievement of European targets is presented by an information system which stores all the fundamental statistics collected at regional level (Finlombarda S.p.a. CENED; Finlombarda S.p.a. CURIT; Regione Lombardia; SIRENA).

At present, the total primary energy consumption of Lombardy Region is about 29.3 MTEP; this value accounts for the primary energy consumption related to the use of fuels and electricity. If we consider the energy losses related to transformation and transportation processes, it corresponds to about 24.9 MTEP of total energy supply to end-users, able to satisfy the following demands: 10.4 MTEP for the civil sector; 7.6 MTEP for the industrial sector; 6.6 MTEP for transportation and 0.4 MTEP for agriculture. These statistics clearly underline the importance of the built environment in the overall energy balance (Factor20, 2011).

Lombardy Region joined, with the approval of the "Accordo di Programma Quadro in materia di Ambiente e Energia" (Framework Program Agreement in the field of Environment and Energy), a national program launched in 1999 (year of the first call) by