Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 101 (2016) 1064 – 1071

Energy Procedia

71st Conference of the Italian Thermal Machines Engineering Association, ATI2016, 14-16 September 2016, Turin, Italy

Solar energy technologies in Sustainable Energy Action Plans of Italian big cities

Benedetto Nastasi [a,b]*, Umberto Di Matteo [a,b]

[a] *Department of Sustainability Engineering, Guglielmo Marconi University, Via dei Banchi Vecchi 58, Rome 00186, Italy*
[b] *International Solar Energy Society ISES – Italy branch, Via dei Banchi Vecchi 58 – 00193 Rome, Italy*

Abstract

Cities, accounting for more than 3/4 of global final energy consumption, are equipping themselves with governance tools to improve energy efficiency. In Europe, urban energy policy has adopted, only recently and voluntarily, the Sustainable Energy Action Plans (SEAP), following the European Strategy 20-20-20. Italy, country most sensitive among European ones, accounts for 53% of SEAPs signatories. In order to evaluate how urban energy system in Italy can match sustainability European goals, it is necessary to analyse the technological options promoted by the energy policies for the urban environment. The paper presents the state-of-art of Urban Energy Planning in Italy, focusing on the implementation of Solar Energy technologies, and their role in new urban energy strategy instruments, i.e. SEAP, to promote renewables deployment. Carbon emission avoidance interventions planned by Italian big cities were analysed, highlighting the chosen Solar Energy technology.
The aim of this paper is to discuss and evaluate the differences of solar energy harvesting in Italian urban scenarios, taking into account geographical and morphological constraints, and to compare the forecasts for 2020 and 2030 scenarios, in accordance with European and National laws in force.

Peer-review under responsibility of the Scientific Committee of ATI 2016.
Keywords: solar energy; urban energy systems; Sustainable Energy Action Plan SEAP; carbon emissions; sustainable policy.

* Corresponding author. Tel.: +39 320 8069101
E-mail address: benedetto.nastasi@outlook.com

Peer-review under responsibility of the Scientific Committee of ATI 2016.
doi:10.1016/j.egypro.2016.11.136

1. Introduction

Sustainability is the keyword to broad current energy scenarios to future ones, more environmentally-friendly. To achieve targets set by EU and subsequent National adoption, city play a crucial role. Currently, urban environment is the most lived context and its compatibility to human life is strictly connected to its sustainability.

Changes in urban policies by means of law-driven Renewable Energy Sources (RES) deployment deal with infrastructural and architectural constraints. So, high care should belong to any policy and act which affects urban special areas such as natural zones, protected areas, cultural heritage or, simply, existing and well-established built-up areas [1-3]. Promising RES solutions could be installed in cities, but they require specific morphological conditions as well as architectural integration. For instance, wind energy appliances such as horizontal or vertical turbines could be effective if equipped with stators [4] but, in other zones their integration is not possible due to landscaping constraints which entail further design requirements [5].

Referring to solar energy integration, a shock on the market happened from 2007 to 2012 since incentive schemes as well as feed-in-tariff drove its development. Photovoltaics was the most profitable RES application so as to reach rapidly the so-called Grid parity, i.e. a production cost comparable with the National Grid supply due to the mature and established equipment on the market. Indeed, current research lines address high penetration of RES even if high-income incentives are reduced. They demonstrated an important role played by RES to achieve sustainable energy and decarbonization goals set by EU 20-20-20 from a convenient economic perspective [6]. Another interesting challenge to face is related to the acceptability and reliability of urban energy systems at RES share increasing, especially in district and regional perspective [7,8]. To avoid unnecessary stress to those well-proven Grid architecture, contemporary, local energy efficiency programs were developed as well as monitoring methodology linked to heating systems [9].

Further reduction in energy consumption was promoted by the adaptation of urban color plan and material list in municipal regulations, addressing the increasing of green areas [10], the use of cool materials in outdoor spaces [11] as well as relative wellbeing improvement [12], and in replacing damaged buildings even if under strict restoration requirements [13].

All the aforementioned initiatives were taken into urban policies based on own initiatives or when financial opportunities were made available by Region or National Government. Few situations promote a proper energy planning act. Actually, great part of first interventions followed the EPBD Directive obligations at building scale rather to be part of a city level strategy [14]. A first attempt to plan all those interventions along with a defined framework to attract economic resources as well as interested stakeholders is the Covenant of Mayors (CoM) [15].

Within this agreement, the Municipality has to design a plan, the so-called Sustainable Energy Action Plan (SEAP). The plan must contain a clear outline of the strategy and relative actions to be taken by the local authority to reach its commitments in 2020, in terms of sustainability goals set by EU 20-20-20. Two key aspects are mandatory:

- The long-term strategy and goals until 2020, including firm commitments in specific areas: Transport; Buildings, equipment, facilities & industries; Local energy production (electricity & heat/cold); Land use planning; Working with the citizens and stakeholders.

- Detailed measures for the initial period of 3-5 years to translate the long-term strategy and goals into planned actions. For each one, it is required to provide: a description; the department or a person responsible; the time-schedule such as start-end and major milestones; a cost estimation and foreseeable financing/source; the estimated energy saving and/or increased RES production as well as associated carbon dioxide (CO_2) reduction.

Hence, the authors provide an outlook of current undertaken actions under the agreement of three SEAPs focusing on solar technologies. The analyzed SEAPs belong to the three big Italian Cities: Rome, Milan and Naples. The analyzed solar technologies were presented along with their role and share in energy mixes to achieve CO_2 reduction goals. The 2020 targets are discussed together with the foreseeable projections to reach EU 2030 targets.

Nomenclature

BEI	Baseline Emissions Inventory	PV	Photovoltaics
CoM	Covenant of Mayors	PV/T	Photovoltaics and Thermal
CO_2	Carbon dioxide	RES	Renewable Energy Sources
CSP	Concentrated Solar Panel	SEAP	Sustainable Energy Action Plan
GHG	Greenhouse gas	ST	Solar Thermal

2. Solar technologies

Solar energy plays a central role in achieving sustainability of Mediterranean Cities, especially for those ones are located in Countries where PV production reached the Grid Parity. At the same time, solar thermal production is increasing where it is coded as a minimum production share for new buildings and by new research lines related to Concentrated Solar Panel and their optimal utilization [16]. A brief outline of the solar energy technologies considered in the SEAP guide is presented below.

2.1. Photovoltaic electricity generation

PV modules convert solar radiation to electricity by means of solar cells. The electricity produced has to be changed from direct current to alternating one thanks to an electronic inverter. As the primary energy used is the solar radiation, this technology is considered not emitting CO_2 to the atmosphere. Typical PV solar collectors´ lifespan is estimated at between 25 and 30 years [17]. During the lifetime of the modules the potential for CO_2 reduction in Europe sites ranges from 12.1 t_{CO2}/kWp for Norway location to 30.7 t_{CO2}/kWp in the case of Greece in roof-top installations and from 7.2 to 18.6 t_{CO2}/kWp in façade installations for the same extreme locations, respectively [18].

Its efficiency is calculated as the percentage of solar radiation converted to useful electricity. Many simplified methods are studied due to the large use of PV in feasibility study. High importance belongs to methods which allow people without technical background to provide quite accurate performance value as in [19].

From the life-cycle point of view, the associated CO_2 emissions per kW of power is estimated to be from 90 to 300 times lower than any fossil fuel equipped with clean cutting-edge technologies [20].

The integration of solar modules is determinant in urban environments as well as needed to be funded by National incentive schemes in many European Countries.

2.2. Solar thermal production

Solar thermal modules convert solar radiation to thermal energy by heating up an energy carrier. This technology brings a significant CO_2 reduction as it entirely substitutes fossil fuels. Solar thermal collectors can be used for domestic and commercial hot water, heating spaces, industrial heat processes and solar cooling.

The amount of energy produced by this technology varies based on its location. This option may be taken into account in most of the European Countries due to the increase of fossil fuels and decrease of solar collector prices. Its performance is calculated as the percentage of solar radiation converted to useful heat.

Considering the positive effect on the profitability of low solar fraction and the effect of economies of scale in large plants, ST installations can be implemented in swimming pools, district heating and cooling, laundries, car washing and industries, among others [21]. The ST integration is similar to PV while, the water tank replaces the inverter need. The first one is often bigger than the second device and its location is obliged to the ST layout. This is the reason why ST is less flexible in applications for existing buildings with architectural constraints or protected areas with landscaping values [22]. Yet, similar considerations are related to devices harnessing tidal energy [23,24].

Further development is related to the hybrid configuration PV/T, a panel able to produce electricity and equipped with a heat recovery system consisting in a bottom layer to produce hot water. This solution can be indicated as the solar panel in cogeneration mode. It could be another weapon to greenhouse gas (GHG) reduction challenge.

3. Italian big cities

Having said, the SEAPs of the selected three Italian Cities, i.e. Rome, Milan and Naples, were analyzed. The preparatory phase of the CoM plan is the Baseline Emission Inventory (BEI). Starting from its definition, the values calculated for each urban context were reported in Table 1 and 2.

3.1. Baseline Emission Inventory

The SEAP is elaborated based on an informed current state of the local situation in terms of energy consumption and associated GHG emissions. Therefore, the first step requires an assessment of the current energy use for sector as well as its GHG emitting value. The establishment of a CO_2 baseline emission inventory is a crucial start for CoM commitment. The BEI has to be included in the SEAP as the first section.

The BEI and subsequent inventories are essential numerical tables to allow the local authority to have a clear overview and to prioritize the action per sector. In order to evaluate the impact of the measures and determine the progress towards the target achievement, a correct estimation is required.

The BEI involves five sectors, the same of the declared objective of the SEAP. Data collection and management within the administrative territory of the local authority is the core of BEI reporting. The methodology and data sources should be consistent through the years and they can consider utility bills, on-site surveys and geographical database. The main sectors which represent significant CO_2 emission sources are: residential, municipal and tertiary buildings and facilities, transport, energy production. The data source has to be indicated and attached to SEAP submission documentation.

Since a comprehensive overview of the situation is required, the Reference year chosen for BEI report is at least 4-5 years old compared to the time of SEAP drafting. A further advantage of this choice is that the older the reference year the higher the amount of CO_2 baseline due to the imposed reduction of emissions since the Kyoto Protocol's signatory. In Table 1 the reduction targets were reported by highlighting the two crucial sectors: buildings and transport. Then, in Table 2 the base year and the expected decarbonization costs are provided. Furthermore, an annual carbon avoidance cost was calculated based on the analyzed SEAP [25-27].

Table 1. Details of Sustainable Energy Action Plans of Rome, Milan and Naples. Source: [25-27] and authors' elaborations.

	Rome	Milan	Naples
Date of Signature	18/06/2009	18/12/2008	06/05/2009
Surface in km²	1,287	182	117
Population	2,638,842	1,262,101	959,052
Reduction CO_2 Target %	-20%	-20%	-26%
Reduction CO_2 Target % pro capita in Buildings	-22%	-20%	-29%
Reduction CO_2 Target % pro capita in Transport	-25%	-43%	-21%

Table 2. Reduction targets and associated costs of Rome, Milan and Naples SEAPs. Source: [25-27] and authors' elaborations.

	Rome	Milan	Naples
Base year	2003	2005	2005
Base year level [t_{CO2}]	10,999,517	7,046,000	2,913,434
Target [t_{CO2}]	8,799,607	5,637,000	2,188,548
Reduction CO_2 Target	2,199,910	2,397,000	724,886
Amount of investments [€]	5,000,000,000	187,896,000	2,340,029,210
Annual carbon avoidance cost [€/t_{CO2}]	2,273	78	3,228

3.2. CO_2 Emissions per sector and governance

The sectorial carbon emission reduction is reported in Table 3. Local urban policies addressed differently the sustainability targets, focusing on an equal distribution of decarbonization role or identifying a sector as the driver to achieve EU 20-20-20 goals.

The authors paid attention to the local energy production and the role played by solar technologies in this sub-task. In Rome and Milan SEAPs, it allows to reach 25% of the forecasted target, which is a reduction of 20% CO_2 emission by 2020. While, in Naples SEAP, local energy production contributes for 10% of the total reduction, which in this case is a more competitive target, i.e. a reduction of 26% compared to the reference year. Subsequently, in Naples building sector plays the main role in decarbonization, being the 50% of the interventions outcome. Similar primary role is played by buildings in Rome SEAP but, it is about 37% of the reduction.

Table 3. Emission inventory for each sector defined by Covenant of Mayors.

An example of a column heading	Rome	Milan	Naples
Transport	1,027,000	862,000	160,000
Buildings, equipment, facilities & industries	1,474,000	421,000	336,852
Local energy production (electricity & heat/cold)	**973,700**	**554,000**	**72,042**
Land use planning	308,000	n.a.	90,000
Working with the citizens and stakeholders	140,000	112,000	10,000
Total	3,922,700	1,949,000	668,894

In Rome, the relevant RES supply is caused by a large municipal surface, able to host different RES installations not limited to building integrated solutions. Furthermore, the huge amount of building stock provides the challenge of energy retrofitting in existing buildings, listed ones and even cultural heritage. The big dimension allows to consider agricultural-derived biomass sources. In smaller contexts, a research project demonstrated the benefits coming to citizens and authority when efficient urban lighting project are designed as other sustainable policy tool [28]. In those metropolitan contexts, the transport and commuting traffic management could be highly beneficial but, the deep analysis required to prepare a relative sustainable plan moved public administration to consider transport in terms of minimum requirements in SEAP rather the decarbonization pillar, as shown in Figure 1.

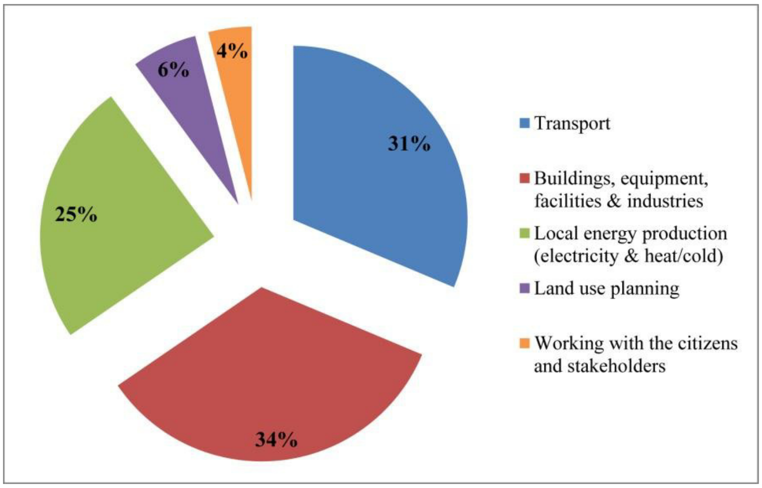

Fig. 1. Percentage distribution of total estimated emissions in the tree Italian big cities.

3.3. Climatic conditions and solar energy

Within the solar energy framework and its harnessing as sustainable measure, climatic conditions due to geographical, orographic and morphological features are fundamental to plan a feasible intervention. Sometimes, the confusion with weather data can change a strategy. It can be the case of Milan SEAP, where a very small contribution is provided by solar technologies. Indeed, as depicted in Figure 2, although Milan has the lowest monthly average temperature per day, it has similar performance in terms of direct normal irradiation. This latter is the key parameter to preliminary design of PV and ST production.

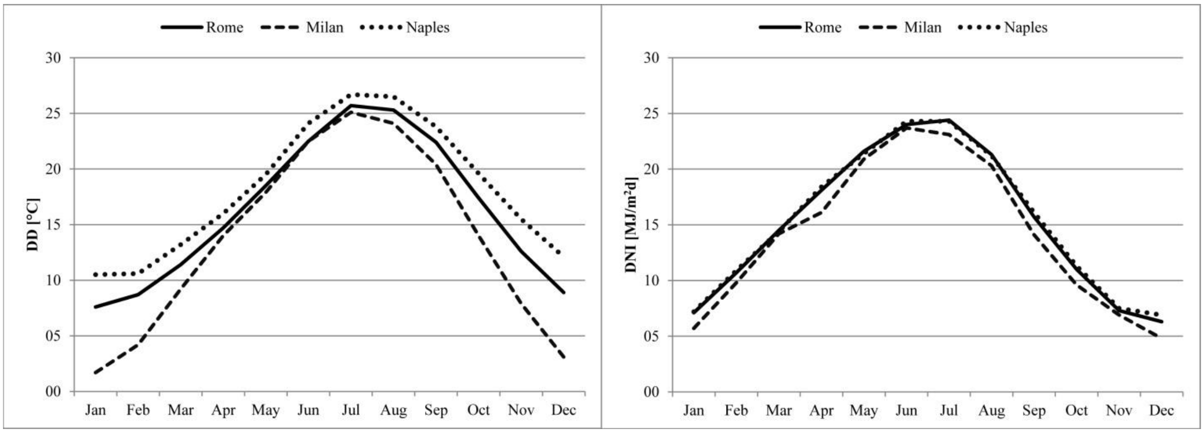

Fig. 2. (a) Average daily Direct Normal Irradiation per month [29] and (b) monthly average temperature trend in Rome, Milan and Naples.

As previously mentioned, in Table 4 the PV foreseeable installations in each city were reported along with the expected renewable energy contribution and associated CO_2 avoided emissions. The high value for Rome SEAP covers 73% of the decarbonization from local energy production while 18% of the total 2020 target. In Milan, where 13,406 kW are already installed in 2013, only further 4,200 kW were expected to be installed so as to provide a negligible amount of saved GHG emissions compared to the total local energy target equal to 121,000 t_{CO2}.

Table 4. Photovoltaics installation and relative energy output and CO_2 savings.

An example of a column heading	Rome	Milan	Naples
Installed Photovoltaic Panels [kW]	1,094,000	4,200	24,600
Energy from PV [MWh]	1,422,000	4,600	34,440
CO_2 reduction from PV [t_{CO2}/y]	708,700	1,868	14,176

In Table 5, the ST installations are presented along with produced energy and associated avoided carbon emissions. It is noteworthy that ST is not explicitly mentioned in Rome SEAP, even if it has favorable climatic conditions as well as large space in municipal territory to be dedicated also to big scale power plant.

Table 5. Solar Thermal installation and relative energy output and CO_2 savings.

An example of a column heading	Rome	Milan	Naples
Installed Solar Thermal Panels [m^2]	-	1,200	6,600
Energy from ST [MWh_{th}]	-	836	6,600
CO_2 reduction from ST [t_{CO2}/y]	-	313	2,478

3.4. The road to 2030 targets

The easy and huge attention paid to PV by Rome SEAP did not involve ST solutions. This latter has more strict requirements of auxiliaries in terms of dimension and location of water tank. It can be obstacle for building integration due to its bigger size if compared to the PV equipment, i.e. the inverter. The performance of solar technologies taken into account in the three SEAPs is different because of climatic conditions. Indeed, the PV production shows 1,400 equivalent operation hours in Naples preliminary sizing, 1,300 in Rome ones and 1,100 in Milan case. A similar difference can be found for ST efficiency. The technical committee of Naples SEAP considered an average production of 1,000 kWh/m^2y while the calculation in Milan SEAP used 700 kWh/m^2y as performance indicator.

The projections to 2030 scenarios can be done mainly in two ways: focusing on the new 40% CO_2 reduction target or on the 27% RES share in local energy mix. A simple doubling of provided installations for 2020 to the future 2030 scenarios can be feasible for Rome SEAP. A supplementary 1 GW of new PV allows to reach more than 2 GW of installed power. So doing, the summer electricity peak in Rome, about 2 GW [25], can be totally covered by the highest PV production that happens in this period of the year. As regards the Milan case, this projection does not provide any advantage. So, if 40% would be reached thanks to PV, further 3 GW are required. Under the same hypothesis, Naples will see the installation of 700 MW of PV panels. Since the current Naples SEAP set 26% as decarbonization target at 2020, only further 14% of reduction needs. It can be totally covered by new PV. Furthermore, interesting projections should take into account higher level planning as well as further RES such as hydro-power to be implemented in urban environment [30] or specific adjustments in listed cultural heritage [31].

Referring to ST potential, Rome SEAP set an indirect target, i.e. decarbonizing completely the domestic hot water supply. So, to cut the estimated 2,500 kt_{CO2} related to total heating sector to 1,900 kt_{CO2}, 600 kt_{CO2} can be avoided if entire hot water supply will be provided by 1,598,062 m^2 of ST. While, in Milan case possible development could be associated to spreading of district heating infrastructure fed by ST or CSP technologies.

4. Conclusions

The authors reviewed the current targets signed by three Italian Cities during the SEAP submission. The role played by solar technologies was highlighted. Important differences were founded especially in the concentration on only one technology, like PV for Rome, or quite neglected as the case of Milan. In Naples, a balance between PV and ST is present, although it is noticed that local energy production plays a secondary role compared to building and transport sectors. For 2030 projections, strong efforts should be made to find a coherent energy policy to carry on the extension of 2020 targets. Since the scale of expected installations is very different between Rome, Milan and Naples, a clear estimate is currently difficult. PV development, if Rome 2020 targets will be reached, could be a feasible perspective whereas, in Milan ST would show better performance due to the contemporary strong commitment at European level for district heating infrastructures which will benefit from ST zero carbon heating supply. A milestone will be the first Monitoring phase in the next two years to realize if the promised targets will be achieved soon and in the expected way. To sum up, solar energy can be the sustainable tool but energy policy support result fundamental for PV, PV/T and ST integration in urban energy systems together with associated GHG emission reduction benefits.

References

[1] Nastasi B. Pianificazione energetica e rigenerazione urbana. Urbanistica Informazioni 2015;263:68-69.

[2] Cumo F, Astiaso Garcia D, Calcagnini L, Rosa F, Sferra AS. Urban policies and sustainable energy management. Sustainable Cities Soc 2012;4(1):29-34.

[3] Astiaso Garcia D, Cumo F, Sforzini V, Albo A. Eco friendly service buildings and facilities for sustainable tourism and environmental awareness in protected areas. WIT Trans Ecology Environment 2012;161:323-330.

[4] Burlando M, Ricci A, Freda A, Repetto MP. Numerical and experimental methods to investigate the behaviour of vertical-axis wind turbines with stators. J Wind Eng Ind Aerodyn 2015;144:125-133.

[5] De Santoli L, Albo A, Astiaso Garcia D, Bruschi D, Cumo F. A preliminary energy and environmental assessment of a micro wind turbine prototype in natural protected areas. Sustainable Energy Technologies and Assessments 2014;8:42-56.

[6] Prina MG, Garegnani G, Moser D, et al. Economic and environmental impact of photovoltaic and wind energy high penetration towards the achievement of the Italian 20-20- 20 targets. Proceedings of 10th International Conference on Ecological Vehicles and Renewable Energies, EVER 2015 11 June 2015, Article number 7112993.
[7] Nastasi B. The eco-fuels in the transition within energy planning and management at building, district and national scale towards decarbonization scenarios. PhD dissertation defended with Honors, Sapienza University of Rome, Rome, 2015, Italy.
[8] Salata F, Vollaro ADL, Vollaro RDL, Mancieri L. Method for energy optimization with reliability analysis of a trigeneration and teleheating system on urban scale: A case study. Energy Build 2015;86:118-136.
[9] Aste N, Buzzetti M, Caputo P, Manfren M. Local energy efficiency programs: A monitoring methodology for heating systems. Sustainable Cities Soc 2014;13:69-77.
[10] Salata F, Golasi I, Vollaro ADL, Vollaro RDL. How high albedo and traditional buildings' materials and vegetation affect the quality of urban microclimate. A case study. Energy Build 2015;99:32-49.
[11] Rossi F, Morini E, Castellani B, et al. Beneficial effects of retroreflective materials in urban canyons: Results from seasonal monitoring campaign. J Physics: Conf Series 2015;655(1):012012.
[12] Rossi F, Anderini E, Castellani B, Nicolini A, Morini E. Integrated improvement of occupants' comfort in urban areas during outdoor events. Build Environ 2015;93(P2):285-292.
[13] Pisello AL, Rosso F. Natural Materials for Thermal Insulation and Passive Cooling Application. Key Engineering Materials 2016;666:1-16.
[14] Nastasi B. Pianificazione energetica (e) urbana in Italia. Urbanistica Informazioni 2014;251:71-72.
[15] Covenant of Mayors Initiatives. Available at http://www.covenantofmayors.eu
[16] Rovense F. A Case of Study of a Concentrating Solar Power Plant with Unfired Joule-Brayton Cycle. Energy Procedia 2015;82:978-985.
[17] Larsen K. End-of-life PV: then what? Renew Energy Focus 2009;10(4):48-53.
[18] International Energy Agency. The IEA Photovoltaic Power Systems Programme IEA PVPS Annual Report 2015. Available at http://www.iea-pvps.org/index.php?id=6&eID=dam_frontend_push&docID=3195
[19] Aste N, Del Pero C, Leonforte F, Manfren M. A simplified model for the estimation of energy production of PVsystems. Energy 2013;59:503-512.
[20] Fthenakis VM, Hyung CK, Alsema E. Emissions from photovoltaic life cycles. Environ Sci Technol 2008;42(6):2168-2174.
[21] Schnitzer H, Brunner C, Gwehenberger G. Minimizing greenhouse gas emissions through the application of solar thermal energy in industrial processes. J Clean Prod 2007;15(13-14):1271-1286.
[22] Cumo F, Astiaso Garcia D, Stefanini V, Tiberi M. Technologies and strategies to design sustainable tourist accommodations in areas of high environmental value not connected to the electricity grid. Int J Sustainable Dev Plann 2015;10(1):20-28.
[23] Barbarelli S, Amelio M, Castiglione T, Florio G, Scornaienchi NM, Cutrupi A, et al. Analysis of the equilibrium conditions of a double rotor turbine prototype designed for the exploitation of the tidal currents. Energy Convers Manage 2014;87:1124-1133.
[24] Barbarelli S, Florio G, Amelio M, Scornaienchi NM, Cutrupi A, Lo Zupone G. Transients analysis of a tidal currents self-balancing kinetic turbine with floating stabilizer. Appl Energy 2015;160:715-727.
[25] Sustainable Energy Action Plan of Rome. Available at http://www.covenantofmayors.eu/about/signatories_en.html?city_id=741&seap
[26] Sustainable Energy Action Plan of Milan. Available at http://www.covenantofmayors.eu/about/signatories_en.html?city_id=261&seap
[27] Sustainable Energy Action Plan of Naples. Available at http://www.covenantofmayors.eu/about/signatories_en.html?city_id=895&seap
[28] Cellucci L, Burattini C, Drakou D et al. Urban lighting project for a small town: Comparing citizens and authority benefits. Sustainability 2015;7(10):14230-14244.
[29] ENEA. SolarItaly - Atlante italiano della radiazione solare. Available at: http://www.solaritaly.enea.it
[30] de Santoli L, Berghi S, Bruschi D. A schematic framework to assess mini hydro potentials in the Italian Regional Energy and Environmental Plans. Energy Procedia 2015;82:615-622.
[31] Nastasi B, Di Matteo U. Innovative use of Hydrogen in energy retrofitting of listed buildings. Energy Procedia.