Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 82 (2015) 615 – 622
Energy Procedia

ATI 2015 - 70th Conference of the ATI Engineering Association

A schematic framework to assess mini hydro potentials in the Italian Regional Energy and Environmental Plans

Livio De Santoli[a], Saverio Berghi[b], *, Daniele Bruschi[b]

[a]*Interdisciplinary Centre for Landscape, Building, Environment (CITERA), Sapienza University of Rome, Via A. Gramsci 53, Rome 00197, Italy*
[b]*Department of Astronautical, Electrical and Energy Engineering (DIAEE), Sapienza University of Rome, Via Eudossiana 18, Rome 00184, Italy*

Abstract

In compliance with EU legislation (Directive 2009/28/EC, that establishes for each Member State a target calculated according to the share of energy from renewable sources in its gross final consumption to 2020) and Italian regulatory framework (DM 15/03/12- Burden Sharing, that defines the regional objectives regarding renewable sources), each Italian Region must develop its own Regional Energy and Environmental Plan (PEAR). In order to promote the renewable energy sources (RES) production and to achieve a better energy efficiency use, the $PEAR_S$ should propose to adopt a distributed multi generation (DMG) strategy.

The main aim of this paper is a preliminary assessment of mini hydro potential and perspectives (P <1 MW) in Italian $PEAR_S$. Mini hydro is a mature and developed technology in Italy, and it represents a valiant opportunity for both local territories and the whole national system. Furthermore, thanks to its small size (low economic investment and environmental impact) and its versatility, it has the characteristics for a long-term development with direct industrial implications (i.e. energy cooperative and short supply chain). Specifically, the $PEAR_S$ of four Regions were analysed, identifying the different information about mini hydro and comparing characteristics and potential.

The results obtained are summarized in a schematic framework useful to draw a preliminary $PEAR_S$ guideline that indicates strategies and policies, harmonizing public and private initiatives and structuring a local-scale economy through a mini hydro based DMG.

Peer-review under responsibility of the Scientific Committee of ATI 2015

Keywords: RES; Mini hydro; Distributed multi generation; Burden sharing; Energy plan.

* Corresponding author. Tel.: +39 06 49918607; fax: +39 06 49918607.
E-mail address: saverio.berghi@uniroma1.it

Peer-review under responsibility of the Scientific Committee of ATI 2015
doi:10.1016/j.egypro.2015.12.009

1. Introduction

Nowadays, Italy experiences important social and economic changes that decisively affects the energy and the environment sectors and which required an adequate structure of sustainable growth on a global scale.

Since 1997 with Kyoto Protocol, in order to mitigate climate changes, world community has strongly related human activities of developed countries to the environmental sustainability of long-term planning goals and joint actions. With regard to the developing countries, which are characterized by a significant increase in energy demand and exploitation of energy sources, the energy supply is still large based on fossil fuels [1]. While, as regards the OECD countries, a reduction of energy demand with massive investments in renewable energy sources (RES), energy efficiency and carbon savings technologies (i.e. CHP plants, hybrid systems, etc.) is almost achieved[2-9].

European Union is a leader by drawing a decarbonised future and an unified market (Energy Union Package, COM-2015-80 final). The Climate and Energy Package (specifically Directive 2009/28/EC on the promotion of the use of RES) looking at the 2020 mid-term, focuses on energy saving, on greenhouse gases emissions (GHG) and on RES development, setting the stage to the Roadmap to 2050. Italy is characterized by lack of infrastructures due to the cost gap (brake on growth), the security of energy supply and the financial crisis of national energy utilities. Nonetheless, the recent legislation (DM 08/03/2013 National energy strategy – NES) encourages a turnaround by applying the breakdown of the objectives according to the subsidiarity principle (i.e. Burden Sharing and PEAR) andby supporting RES (incentives for not photovoltaic RES, DM 06/07/2012), in the supply chains and the national energy mix.

In this context, the Italian Regions are called to play a key role to the participation and regionalization process of European environmental and energy policies. Peculiar instrument to achieve these goals is represented by the Regional Energy and Environmental Plan (PEAR). In addition to the commitments actuations under the DM 15/03/2012 (Burden Sharing), the Regions have to program the use of the Structural Funds 2014-2020 and to establish targets and actions for energy efficiency according to Directive 2012/27/EU (Italian Legislative Decree 102/2014).

In Europe, the hydroelectric sector has a consolidated tradition. In 2013, while large sizes (in order of relevance Norway, France, Italy, Spain and Sweden) are well-established [10], small power sizes offer interesting prospects [11]. On the other hand, emerging economies led by China (with a net power increase of about 28.7 GW only in 2013), Turkey, Brazil, Vietnam and India, are characterized by significant investment in that sector [12]. Italy, with an installed capacity equal to 22.4 GW (pumped storage included) [13], has developed expertise at high level, both in terms of technologies and management measures. Since the 19th century and until the economic boom of the '60s, hydropower has been the backbone of the country production capacity, representing still today the main renewable source and the one more reliable and manageable. As in the rest of Europe, also in Italy the large plants ($P > 1$ MW) have reached the highest value of their capacity. Mini hydro plants($P < 1$ MW) show in Italy interesting perspectives (645.2 MW of installed capacity by 2013 with 2,130 plants up to 1 MW) [14] highlighted by geographical information system (GIS) mapping [15] and educational local systems [16]. Hydroelectric development in Italy [17], for the 2014-2015 period was set at 70 MW of new capacity (90% of that is represented by mini hydro), but strongly influenced by future incentive policies not allowing to hypothesize national scenarios in 2020 (see Table 1).

The main aim of the paper is to provide a preliminary framework to arrange the PEAR considering a proper planning of the regional mini hydro plants ($P <1$ MW). The methodology, focused on the analysis of the PEAR in force, in order to provide guidelines to homogenize the different approaches and standards used to draw up the various PEAR$_S$. To test the methodology, PEAR of four Italian Regions(where hydroelectric resource has a strategic relevance) were analysed: the Autonomous Region of Valle d'Aosta (whose energy is almost produced from hydropower), the Lombardia Region (about 27.6% of the National hydroelectric production), Abruzzo Region (the first Region of Central and South of Italy having 5.5% of the national hydroelectric production and with significant perspectives for mini hydro [18]) and Molise Region (where hydraulic source represents 20.7% of total electric RES production [14]). Specifically, those documents were analysed by marking a comparison in the different considered aspects. The obtained results were analysed for developing a preliminary framework useful to support the implementation of new $PEAR_S$ and/or the periodic updates of the existing ones. This would be a tool for the main contents and issues (regulatory constraints, zoning of not suitable areas, evaluation and prediction of climate change, water uses and permissions, etc.).

The schematic framework provided is the first step to plan an organic and multi-criteria management of the regional mini hydro plants able to consider a sustainable enhancement of local RES (versatility and concurrent uses) towards MDG model (development of green economy and supply chains).

2. Materials and methods

The first methodological step is the analysis of the $PEAR_S$ of Autonomous Region of Valle d'Aosta, Abruzzo, Lombardia and Molise Regions. In this context, the drivers and factors which affect the mini hydro sector were highlighted. In Table 1, the main characteristics of hydroelectric sector for each Region were reported.

2.1. Autonomous Region of Valle d'Aosta

Table 1. Hydroelectric characteristics in 2013 (not normalized production, pumped storage not included) and potential perspectives to 2020.

Region	Plants(n)	Gross power at 2013(MW)	Average power (MW/n)	Gross production at 2013 (GWh)	Gross power increase to 2020(MW)	Gross production increase to 2020(GWh)
Autonomous Region of Valle d'Aosta [13-14, 19]	117	934.9	8.0	3,534.5	13.6	110.0
Abruzzo Region [13-14, 20]	58	1,002.7	17.3	2,101.4	15.3	100.0
Lombardia Region [13-14, 22]	462	5,056.7	10.9	11,023.3	100.0	N/A
Molise Region [13-14, 25]	30	87.2	2.9	271.1	21.9	68.8
Italy [13-14]	3.250	18,365.9	5.7	52,773.4	-	-

The PEAR [19], approved in 2014, promotes the transition to a distributed generation system from RES aimed at achieving the regional objectives of Burden Sharing. With 117 plants (gross power equal to 934.9 MW) and a gross production of 3,534.5 GWh, hydroelectric sector represents 98.9% of gross electric production of the Region [13-14]. This PEAR identifies potential scenario to 2020 using the following indicators: historic data on the regional hydroelectric plants (total production since 1990), granted concessions and still under review (from 2001 to 2010), requirements of environmental flow (EF) in compliance with the legislation in force (Water Protection Plan DCR 1788/2006). The carried out projections refer to the average energy production of hydroelectric plants and do not provide reliable information for future production because they do not take into account climate change effects (trend of temperatures, rainfall, snowmelt). Furthermore, they do not provide an organic program of operation and maintenance. Finally, the testing and calibration phase of EF release entails a substantial reduction in the production (between 100 and 430 GWh per year) and it still limit the issue of derivation concessions (DGR 1253/2012). The regional potential exclusively concerns with re-powering measures of existing plants and with building new ones. In fact, the transition stage envisaged for the experimental consolidating of the environmental flows implies restrictions on the concessions issue. By the end of 2015, derivation concessions for hydroelectric use will be given only for those presented before 2012 (except for plants below 50 kW that serve specific types of users). The analysis of the 97 applications of concession granted from 2001 to 2010, compared with 251 applications submitted, highlights the mini hydro potential, which represents 91.5% of the total potential (61 concessions for power less than 100 kW and 25 concessions for power between 100 and 1,000 kW).

2.2. Abruzzo Region

Approved in 2009, PEAR [20] provides an estimate of electricity potential from RES by 2015. The regional hydroelectric plants (58 plants for a power capacity of 1,002.7 MW and an average size of 17.3 MW) in 2013 produced about 62% of RES regional electricity production [11-12]. The factors used for the estimation only affect the potential of the waterway network based on a local survey in the province of Teramo. The results are related only to energy recovery from aqueducts and indicate the expected potential in 2015 equal to 20 MW (new gross power installed).

By considering the Water Management Plan (WMP), PEAR provides a comprehensive picture of the regional hydrography (shared by provinces and catchment basins) not including any information about the structure of the regional derivation concessions for hydroelectric use. Furthermore, it does not consider the management plans of the plants in operation, and the EF regulation postponed to a different specific paper [21]. In addition, the PEAR, written before DM 15/03/2012 does not contextualize the development of water resources within the regionalization strategy of the European objectives to 2020. The estimated hydroelectric potential in the PEAR concerns the repowering of existing plants and small hydro plants (P <3 MW) for new installations. The selected application fields aim at recovering unused jumps from: local aqueduct, industrial effluents, wastewater treatments and drainage/irrigation canals. The estimated value for the real potential of mini hydro in Abruzzo Region is equal to 15.3 MW (100.2 GWh of annual gross production).

2.3. Lombardia Region

To achieve the European objectives on RES and energy efficiency, in 2014, Lombardia Region has adopted a new PEAR [20]. In 2013, the regional hydroelectric system, about 21% of the national system, consists of 462 plants (gross power of 5,056.7 MW and an average plant size of 10.9 MW) and it produced electricity for 11,023.3 GWh. Furthermore, it is the first renewable source in the region (65%) producing 25.4% of the regional electricity gross production [13-14]. PEAR specific annex [23]defines a development scenario of hydroelectric resources considering the climatic factors (time series and projections of the average temperature, rainfall, snowmelt, etc.) and environmental restrictions (environmental and landscape impacts, ecosystem continuity, criteria of plants insertion, etc.). While, few attention was given to Water Protection Plan (WPP) and to the EF regulation. Considering the release of derivation concessions, the exploitable potential by 2020 is estimated equal to 230 MW. According to DM 10/03/2010, PEAR identifies the areas not suitable for the plants installation for RES production. In addition, considering the environmental characteristics and restrictions (natural protected area, areas with high landscape or agriculture value, etc.), it designs the best implementation strategy of the mini hydro plants. In conclusion, the estimation about mini hydro potential is equal to 100MW (not including irrigation canals and residual hydraulic heads potential).

2.3. Molise Region

Up to date, Molise Region has a PEAR in force since 2006 [24]. In 2015, a preliminary document for a new one was published [25]. This transition process drives Molise Region by an energy strategy based on RES development, energy efficiency and low carbon emissions to 2020. In 2013, regional hydroelectric system (with 30 plants and a gross power of 87.2 MW) produced 271.1 GWh, representing about 9.4% of regional gross electricity production [13-14]. This preliminary document for the new PEAR considers resources and characteristics of the regional hydrology and reports a summary of the different catchment basins. Furthermore, a complete survey of standing by concessions, potentials of aqueducts and the three regional land reclamation authorities, designs a framework of exploitable hydraulic source. A Roadmap to 2020, according to Burden Sharing amount, establishes for each strategic field (aqueducts, land reclamation authorities and other plants), goals about gross power and gross production expected. Finally, proposals for a regional insertion of hydro plants by suggesting criteria and strategic fields and indicating the need of a regional hydraulic regulation were developed.

3. Results and discussion

Performed comparison and analysis are related to PEARs (adopted by Autonomous Region of Valle d'Aosta, Abruzzo, Lombardia and Molise Region) by considering different regional policies for the mini hydro development. This research consists in a preliminary case study to verify utilized methodology that will be improved at large scale further. The general criteria of this preliminary assessment process are listed below:

- Dynamic framework: PEAR is characterized by a multidisciplinary approach about environment and energy. It is appropriate to monitor policy strategies and to update Roadmap through specific tools. To monitor different regional databases (hydraulic concessions submitted and granted, survey of regional mini hydro plants) it provides a periodical update about the mini hydro regional scenario potential (Roadmap to 2020);
- End users orientation: subsidiarity principle established in Maastricht Treaty (1992) to promote and encourage initiative of local communities. In this direction, the schematic framework supports private investors and local authorities in developing regional mini hydro potentials (by composing GIS based map of insertion and surveying not suitable areas for mini hydro);
- Climatic changes: the framework for mini hydro faces to current global warming process and its effects on climate. In addition to regional sharing of European 2020 targets (control policies about greenhouse gas emissions - GHG), must be introduced adaption policies to climate change. The framework considers a regional climate modelling (mid-term assessment of average temperature and precipitations) able to draw future scenarios.

Figure 1 shows elements and their links such as in the schematic framework design. Multidisciplinary elements which determines the process, assessment of mini hydro potentials, dynamic tools for monitoring, updating and scoring of goals were included.

First of all, the schematic framework, to a standardized mini hydro guidelines, relates different variables about regional hydraulic overview evaluating different potentials: natural, real and scenario. Then, efficient tools are defined to achieve development targets (by updating Roadmap each year) and to drive and promote local initiatives (by supplying GIS based maps for local end users).Variables associated to ongoing global climate changes (which imply direct modification to final energy consumption and to hydroelectric capacity) were examined within regional climate models. These elements evaluate, within hydrological and morphological facts (statistical surveys and GIS referred maps database), and for each catchment basin, natural hydraulic potential.

Subsequently, real potential was estimated as result of a gross evaluation of the effective exploitable energy for hydraulic use. This assessment was achieved by subtracting from natural potential the share related to local restriction (environmental and landscape restrictions, hydro geological instability, high value areas) and current measurements of protection of waters (priority uses of water and EF rates according to regional authorities provisions).

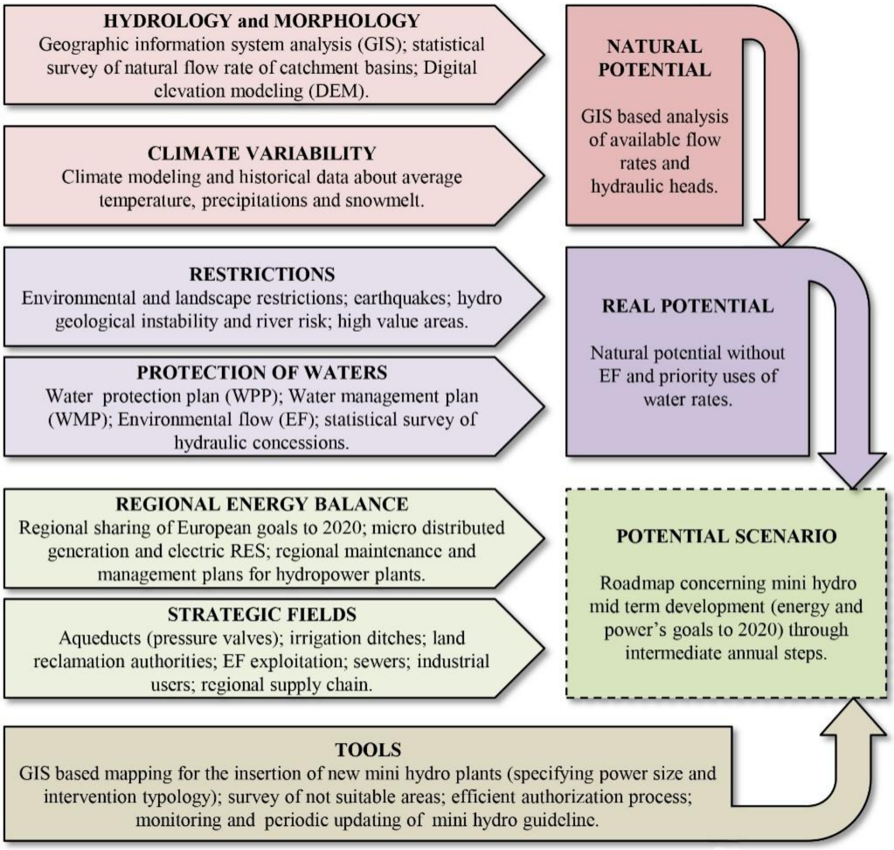


Fig. 1. Schematic framework for supporting $PEAR_S$ assessment activities.

Hence, a potential scenario was developed starting from the real potential by considering local energy policy (regional energy balance, Burden Sharing targets, DMG and electric RES trend) and strategic fields (aqueducts, irrigation ditches and land reclamation authorities, sewers and industrial users, EF exploitation and local supply chain). This scenario defines the exact amount of exploitable hydraulic resource and according to mid-term Roadmap 2020 with yearly capacity and production expected by mini hydro.

Agreeing to potential scenario, specific measurements were introduced. They regard periodic upgrading of the mini hydro Roadmap and end users oriented tools. Communities, local authorities and privates will be attracted in investing in mini hydro thanks to innovative GIS based maps for its insertion (indicating power size and intervention typologies), and a survey of not suitable areas and standardized authorization process (transparent and efficient).

4. Conclusion

The originality of this paper consists in having developed, through the comparison of different $PEAR_S$, a preliminary multidimensional framework for the mini hydro at regional scale. Unlike the analysed PEAR formulation and orientations, the schematic framework proposes an organic structure: starting from different variables, it assesses potentials, proposes a Roadmap and defines efficient tools. In this regard, the tools includes a periodic updating of the guidelines and a GIS database for the insertion of new plants. This approach, transferring subsidiarity and flexibility principles, is an accelerator for local communities and private investors. According to the Italian $PEAR_S$, the next research step will be to test the schematic framework methodology. The goal will be to produce a reference tool for the evaluation of mini hydro defining standardized regional policies.

References

[1] U.S. Energy Information Administration - EIA. International Energy Outlook 2013. 2013. Available at: www.eia.gov

[2] 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.

[3] De Santoli L, Lo Basso G, Bruschi D. A small scale H2NG production plant in Italy: Techno-economic feasibility analysis and costs associated with carbon avoidance. International Journal of Hydrogen Energy 2014; 39(12): 6497-6517.

[4] 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. International Journal of Sustainable Development and Planning 2015; 10(1): 20-28.

[5] De Santoli L, Lo Basso G, Bruschi D. Hybrid system with an integrated CHP plant fueled by H2NG blends: Theoretical energy-environmental analysis and foreseeable optimizations. Energy and Buildings 2014; 71: 88-94.

[6] Astiaso Garcia D, Cumo F, Giustini F, Pennacchia E, Fogheri AM. Eco-architecture and sustainable mobility: An integrated approach in Ladispoli town. WIT Transactions on the Built Environment 2014; 142: 59-68.

[7] Salata F, Nardecchia, F, De Lieto Vollaro A, Gugliermetti F. Underground electric cables a correct evaluation of the soil thermal resistance. Applied Thermal Engineering 2015; 78: 268-277.

[8] Lo Basso G, de Santoli L, Albo A, Nastasi B. H2NG (hydrogen-natural gas mixtures) effects on energy performances of a condensing micro-CHP (combined heat and power) for residential applications: an expeditious assessment of water condensation and experimental analysis. Energy 2015; 84: 397-418.

[9] de Santoli L, Mancini F, Nastasi B, Piergrossi V. Building Integrated Bioenergy Production (BIBP): economic sustainability analysis of Bari airport CHP (combined heat and power) upgrade fuelled with bioenergy from short chain. Renewable Energy 2015; 81: 499-508.

[10] International Hydropower Association - IHA. IHA hydropower report 2013. 2013. Available at: www.hydropower.org

[11] Punys P, Pelikan B. Review of small hydropower in the new Member States and Candidate Countries in the context of the enlarged European Union. Renewable and Sustainable Energy Review 2007; 11: 1321-1360.

[12] Renewable Energy Policy network for the 21st century - REN21. Renewables 2014 Global status report. 2014. Available at: www.ren21.net

[13] Terna Spa. Dati statistici sull'energia elettrica in Italia 2013, 2013. Available at: www.terna.it

[14] Gestore dei Servizi Elettrici - GSE. Rapporto statistico energia da fonti rinnovabili 2013. 2013. Available at: www.gse.it

[15] Peviani M, Menga R, Garofalo E, Grasso F, Stella G. Risultati del censimento del potenziale mini-idro e realizzazione del sistema informativo territoriale. CESI Ricerca Spa; 2006

[16] Alterach J, Postiglione D, Vergata M, Elli A. Sviluppo del mini-idro: valutazione del potenziale effettivo e nuovi strumenti di supporto alla pianificazione e alla progettazione. ENEA - Ricerca sul Sistema Elettrico Spa; 2010.

[17] Energy & Strategy Group. Renewable energy report 2015. Dipartimento di ingegneria gestionale del Politecnico di Milano; 2015. Available at: www.energystrategy.it

[18] Pierguidi F, Carapellucci R, Giordano L. Il piccolo idroelettrico nella Regione Abruzzo, La Termotecnica 2013; 11:55-58.

[19] Regione Autonoma Valle d'Aosta. Piano energetico ambientale della Regione Autonoma Valle d'Aosta (approvato con DCR 727 del 25.09.2014). 2014. Available at: www.regione.abruzzo.it

[20] Regione Abruzzo. Piano energetico della Regione Abruzzo (approvato con DGR 470/C del 31.08.2009). 2009. Available at: www.regione.abruzzo.it

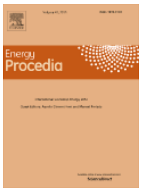
[21] Regione Abruzzo. Studio a supporto della programmazione regionale in materia di risorse idriche destinabili alla produzione di energia idroelettrica (approvato con DGR 495 del 14.09.2009). 2009. Available at: www.regione.vda.it

[22] Regione Lombardia. Piano energetico ambientale regionale (approvato con DGR 2577 del 31.10.2014). 2014. Available at: www.reti.regione.lombardia.it

[23] Regione Lombardia. Allegato 3 - Adattamento del sistema energetico e delle infrastrutture energetiche della Lombardia agli impatti del cambiamento climatico. In: Regione Lombardia. Piano energetico ambientale regionale (approvato con DGR 2577 del 31.10.2014). 2014. Available at: www.reti.regione.lombardia.it

[24] Regione Molise. Piano energetico ambientale regionale (approvato con DCR 117 del 10.07.2006). 2006. Available at: www.regione.molise.it

[25] Regione Molise. Documento preliminare al Programma Energetico Ambientale Regionale 2015. 2015. Available at: www.regione.molise.it



Biography

Saverio Berghi
PhD Student saverio.berghi@uniroma1.it

Civil Engineer. PhD Student in "Energy and Environment", at Department of Astronautical, Electrical and Energy Engineering (DIAEE), Sapienza University of Rome and member of the Italian indoor air quality and refrigeration Association (AiCARR). His research is focused on electric renewable resources, energy plans and governmental supporting policies.