

# Renewable energy sources and the electric network in Italy: Some basic considerations and evolution scenarios

The ambitious European and National targets for de-carbonization demand for a significant increase in electric power generation from Renewable Energy Sources in the next future in Italy, particularly in the medium-long term (2030-2050). A large penetration of Renewable Energy Sources could be regarded as a quite natural evolution from recent years: at the same time, significant consequences are expected in terms of conventional (fuel-fired) operation, that will need to be more flexible, and of grid structure and management, both at the transmission and distribution levels, with an increasing importance of storage. Last but not least, the importance of the environmental impact of Renewable Energy Sources and its metrics (how the impact is evaluated) is going to increase in the decision processes

DOI 10.12910/EAI2014-72

■ Massimo Falchetta

**T**he penetration of Renewable Energy Sources (RES) in the Italian electric network has recently surpassed some of the most ambitious expectations of those who advocated their development in the last decades of the 20th century or at the same time – even recently – questioned on the possibility of implementing a significant RES contribution to the overall electricity consumption. This fact of course is not limited to Italy; it can be said that RES are now an established set of energy technologies, and this is demonstrated by the significantly increasing interest on RES technologies by the major financial and investing groups operating in the globalized market. Of course, still a greater progress is expected from R&D, namely a further increase in RES competitiveness in the various markets, reducing the need of any specific public support mechanism.

“Objective” of this paper, specifically focused only on grid-connected (electrical) RES, is not discussing the

economic trends of RES in the energy sector, but rather introducing some basic considerations on Italy’s near-future expectations as to the relationship among RES and the electric network, with a further glance to the medium-long term (2030-2050). Indeed the paper is a résumé of a more comprehensive report recently edited by ENEA on the same subject [1].

The scenario presented here does not claim to be exhaustive, predictive or economically optimized, but simply tries to indicate a “typical trend” arising from the given input data, also useful to better focus on the R&D actions

■ Massimo Falchetta  
ENEA

Contact person: Massimo Falchetta  
massimo.falchetta@enea.it

to be needed; so let's start from the input, the European and National Targets.

## European and national targets

It is useful to briefly summarize the official European and National targets involving grid-connected RES; these are considered the “input data” to the scenario:

- the “20-20-20” European climate and energy package, introduced in 2008, aiming at producing 20% of the European primary energy from RES by 2020, [2]
- the more recent European platform proposal on climate and energy for 2030, presented on January 2014 [3] and more recently discussed by the European Parliament, targeting a RES contribution to energy production by 30% by 2030,
- the long term scenario (2050) of the Energy Roadmap 2050 [4] setting 75% of gross energy consumption from RES, with a 97% target specific to electrical production.

Regarding the viability of such targets and their practical consequences, it is worth noting that a number of studies from R&D Institutions and Universities have recently assessed the feasibility of achieving a 100% quota of Renewable Production over the electrical consumption (see e.g. [5]), while the recent R&D HORIZON2020 programme is particularly focused on the 2020 EU targets, particularly as to supporting the R&D effort needed to implement those targets. The European targets are also seriously taken into account by many major industrial operators, e.g. Audi in Germany.

In Italy, the national targets on RES contribution have been first fixed in the 2010 National Action Plan (NAP), based on the binding commitment to reach a 17% energy production from RES by 2020, defining the subsequent targets for the different technologies; it is worth noting that the NAP target for photovoltaics (PV) was already met in 2011, only a year after issuing the NAP, that is 9 years in advance with respect to its target.

More recently, the National Energy Strategy (NES) [6], issued in 2013, set a target for the RES quota - by 2020 - equal to 23% of the gross energy consumption, with a 35-38% electric quota (120-130 TWh<sub>e</sub>/y), and included targets similar to the European Energy Roadmap by 2050, namely a 75-90% RES quota in the electricity

production. At the same time, a significant increase in transports and heating (by heat pumps) electrification duties is predicted by the NES.

## The current situation in Italy

In 2012, 45.4% of the RES contribution to electricity production in Italy came from the Hydro source, totalling 42 TWh/y, that has long been the major source of RES contribution; indeed, last century before the '60s, hydro-electricity has been the major source of electricity production ever. In the last 20 years the so called “new” RES, like Wind and Solar Power, have become mature with a significant quantum leap in PV installations in the last three years only; almost 15 GW of new PV plants were added in 2010-2013, now reaching roughly 18 GW; summing all contributions, electricity production from RES totalled 93 TWh/y in 2012, with a trend that shows how the 2020 target is very close and will be easily surpassed (Figure 1, taken from [6]).

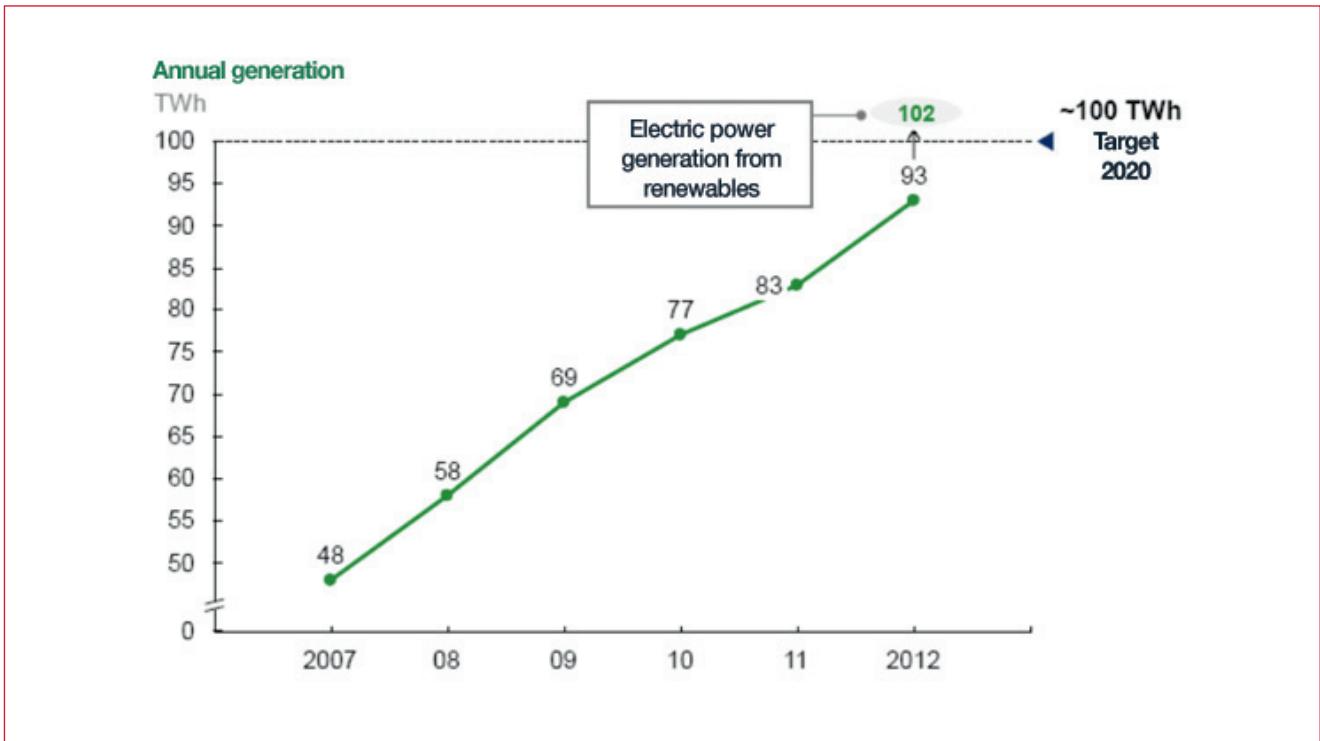
Another interesting picture (Figure 2, taken from [7] by the Italian TSO Terna) illustrates the recent increase in Wind and Solar Power capacity, showing how the NAP 2020 target set in 2010 had actually been surpassed in 2011, as said above.

## Some consequences and challenges for the generation, transmission, and distribution system

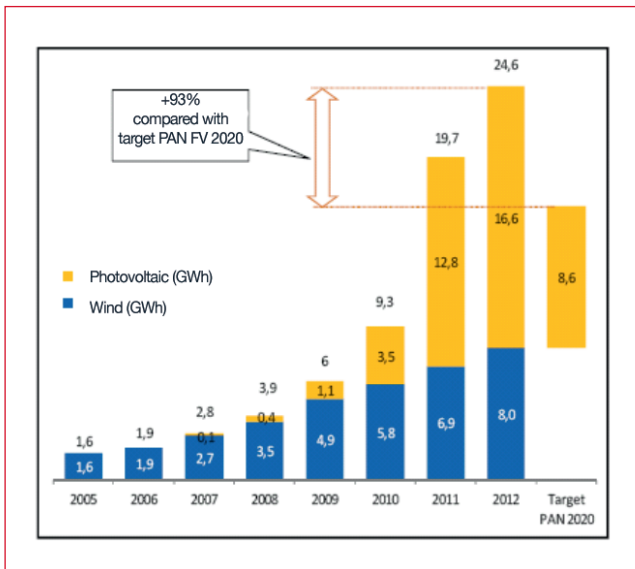
The recent significant trend in turn represents a significant challenge for the whole electricity generation and transmission/distribution system.

A first consequence is that the Capacity/Energy ratio of the production assets is expected to increase, as actually happened; correspondently, defining as  $h_G$  the “equivalent operative hours per year” of a given plant - simply calculated as the ratio Yearly Energy Yield (GWh)/Capacity (GW) - the average  $h_G$  value of all plants is expected to decrease. The global reduction in  $h_G$  is primarily due to the addition of plants, like Wind and PV, that typically operate with an  $h_G$  value ranging from 1000 to 2000 hours/y, in the Italian situation.

Since these plants have also a “dispatching priority” - correctly, at least from the author's point of view, due to their environmental value - this fact in turn reflects



**FIGURE 1** Trend of Renewable Energy Sources electric power generation in Italy with respect to the 2020 target<sup>6</sup>



**FIGURE 2** Recent evolution of Wind and Solar capacity<sup>7</sup>

in an  $h_G$  reduction also for fuel-fired power stations, actually mostly equipped with gas-fired CCGT groups, the only ones that can be used in a flexible way.

Such trend has been augmented by the reduction in global domestic electric consumption experienced in the last years (328 TWh/y in 2012 with respect to 340 TWh/y in 2007), due to the combined effects of economic crisis and efforts in energy savings.

As a result,  $h_G$  values of CCGTs decreased ([8]) from 5100 to 3100 in 2006-2011; currently, expectations for CCGTs are in the range of 1000-2000 h/y ([9]), therefore similar to those of Wind and PV plants. In other words, CCGT groups are going to operate more and more as a “RES back-up” rather than as Baseload or even Mid-merit units, as they were conceived, and are also called to significantly increase their flexibility (start-stops; partial load; variable load...).

Another challenge regards the electrical Network; the increasing Capacity/Energy ratio is going to stron-



gly influence ancillary and dispatching services; on the one hand there is an increasing need by the TSOs (Terna in Italy) of dispatching services, on the other a growing need to increase the dynamic performance of these services, with shorter reaction times. A typical effect is the increase in the so-called residual load that must be covered by fully dispatchable plants (pumped hydro, hydro w/reservoir, CCGT) in summer afternoons as the PV contribution decreases, at present requiring rates of 10-12 GW of residual load in 2 hours ([7]). This situation will become ever demanding as more “Non-Dispatchable RES” plants are going to be added.

In turn, also the Distribution network will have to become more “controllable” and “bidirectional” as the Transmission network actually is, in order to allow a greater inclusion of “distributed” production from small-medium size RES, normally feeding the low-voltage or medium-voltage sections of the grid, according to the so-called “smart-grid” paradigm. A description of the relevant requirements and trends can be found in [8]. Last but not least, the importance of storage, both at the transmission (e.g., large pumped-hydro units) and at the distribution levels (e.g., electric batteries) will increase. Indeed, there is a worldwide strong R&D effort in battery technologies, with a number of start-ups developing or re-considering a number of electrochemical processes.

In this regard, Italy has a tradition on pumped-hydro (since the ‘30s of the last century); these plants are now totalling 7,659 MW in 22 major units, as in 2010; on the other hand, such plants are actually not fully utilized, since the energy sent to pumping stations decreased from 10.65 TWh/y in 2002 to 2.7 TWh/y in 2012. More recently, Terna, Enel and other Distribution System Operators (DSO) have begun to explore the possibility of including a battery storage system; one of the major projects is the Terna project for 6 units equipped with Na-S batteries, for a total of 35 MW/232 MWh, permitting 6-7 hours of storage with a round-trip efficiency of 75%.

### Simplified scenario

As stated above, the significance of the scenario that is going to be presented here is only indicative of

the “foreseeable trend” that arises from the fulfilment of the RES “targets”, therefore being not a prediction nor an energy or socio-economic optimization, but rather the quantification of the “order of magnitude” of the challenges. The main driver normally adopted, and still assumed here, is the evolution of the electric demand. In Italy such demand was significantly increasing during the “economic boom” years; now it is practically flat or even decreasing. The most recent Terna report ([7]) is assumed here as a reference; indeed such a report predicts a moderate increase in the electricity demand. In [1], or better in [7], more details on the evolution of demand can be obtained; here only the final data input to an “average” scenario are shown, listed in Table 1.

The proposed demand evolution corresponds to intermediate values with respect to Terna predictions up to 2030, with a substantial stabilization from 2030 to 2050; the rationale is the reduction in energy intensity and increase in energy efficiency on the one side, the increase in electrification on the other.

Further hypotheses on the RES contribution quota are based upon:

- 1650 h/y for Wind Power, 1300 h/y for PV, 2000-3000 h/y for CSP w/storage
- an increase in Wind Power, substantially in accordance with Terna assumptions, with a limit to 25 GW for environmental reasons (visual impact)
- a moderate increase in Solar Thermodynamic (CSP) plants; all equipped with storage
- a moderate increase of Hydro Power, with a 60 TWh/y limit, quite close to the maximum estimate for Italy, that corresponds to 65 TWh/y
- a moderate increase in geothermal and marine contribution
- a substantial increase in the Biomass energy yield, with a rate of 7.5 TWh/y of increment per decade in 2020-2050. It is worth noting that “Biomass” covers a number of technologies and is subject to a number of constraints, so the estimate is approximate
- since its wide applicability to a number of different situations, PV evolution has been simply calculated as the difference between the RES target and the contribution of “other RES”; in other words, the amount needed to meet the target.

	2012	2020	2030	2050
Demand (TWh/y)	328	367	415	420
Renewable share (%)	28.4	35.4	52	85
Renewable production (TWh/y)	93	130	216	357
Hydro (TWh/y)	49.4 <sup>a</sup>	52.5	55	60
Geothermal (TWh/y)	5.6	6	7.5	10
Marine Energy (TWh/y)	0	0.1	0.2	1
Solar Thermodynamic (CSP) (TWh/y)	0	0.6	1.5	4.5
Biomass (TWh/y)	12.5 <sup>b</sup>	20	27.5	42.5
Wind Power (TWh/y)	13.1	20	33	41
Photovoltaic (TWh/y)	19.2	30.8	91.3	198
Wind+PV+Marine (Non Dispatchable) <sup>c</sup>	32.3	50.9	124.5	240
<b>Ratio "Non-Dispatchable Input"/Demand (%)</b>	<b>9.85</b>	<b>13.86</b>	<b>30.0</b>	<b>57.14</b>

<sup>a</sup> Mean of years 2008-2012  
<sup>b</sup> Estimation  
<sup>c</sup> All the Hydro contribution has been assumed as "dispatchable", overlooking the run-of-the-river contribution

**TABLE 1** Hypothetical scenario for the evolution of the electricity demand and Renewable Energy Sources generation

	2012	2020	2030	2050
Demand Peak (GW)	54	65	73	75
Wind Power Capacity (GW)	8	12.1	20	25
PV Capacity (GW)	16.6	23.7	70.2	152.3
Wind Power "rate"	0.15	0.186	0.274	0.33
PV "rate"	0.31	0.364	0.998	2.03
<b>"Non-dispatchable rate"</b>	<b>0.46</b>	<b>0.55</b>	<b>1.273</b>	<b>2.36</b>

**TABLE 2** Evolution Load Peak and Capacity of "non-dispatchable Renewable Energy Sources"

### Capacity implications

What I will try to point out now is some of the implications of Table 1. First of all a distinction has to be made among "dispatchable" and "non-dispatchable" RES. "Dispatchable" basically means that the instantaneous output power of the unit can be "significantly controlled", whereas "non-dispatchable" means that its instantaneous output power cannot be controlled (apart from eventually reducing or cutting it in the case of overgeneration). Indeed, such distinction is in a way arbitrary, since any power station is not fully dispatchable (e.g., when subject to programmed or non-programmed faulty outages); on the other hand even the output of non-dispatchable RES is normally predictable, indeed generally more predictable than the consumer load that the grid must supply.

In any case, for the following discussion, "dispatchable RES" include:

- hydro
- geothermal
- biomass
- solar thermodynamic w/storage.

"Non-dispatchable RES" include:

- wind power
- photovoltaics
- marine energy.

At this point, the Peak Load of the grid must be introduced; this number is, for a given country, normally connected to the Yearly Load demand by the simple formula:

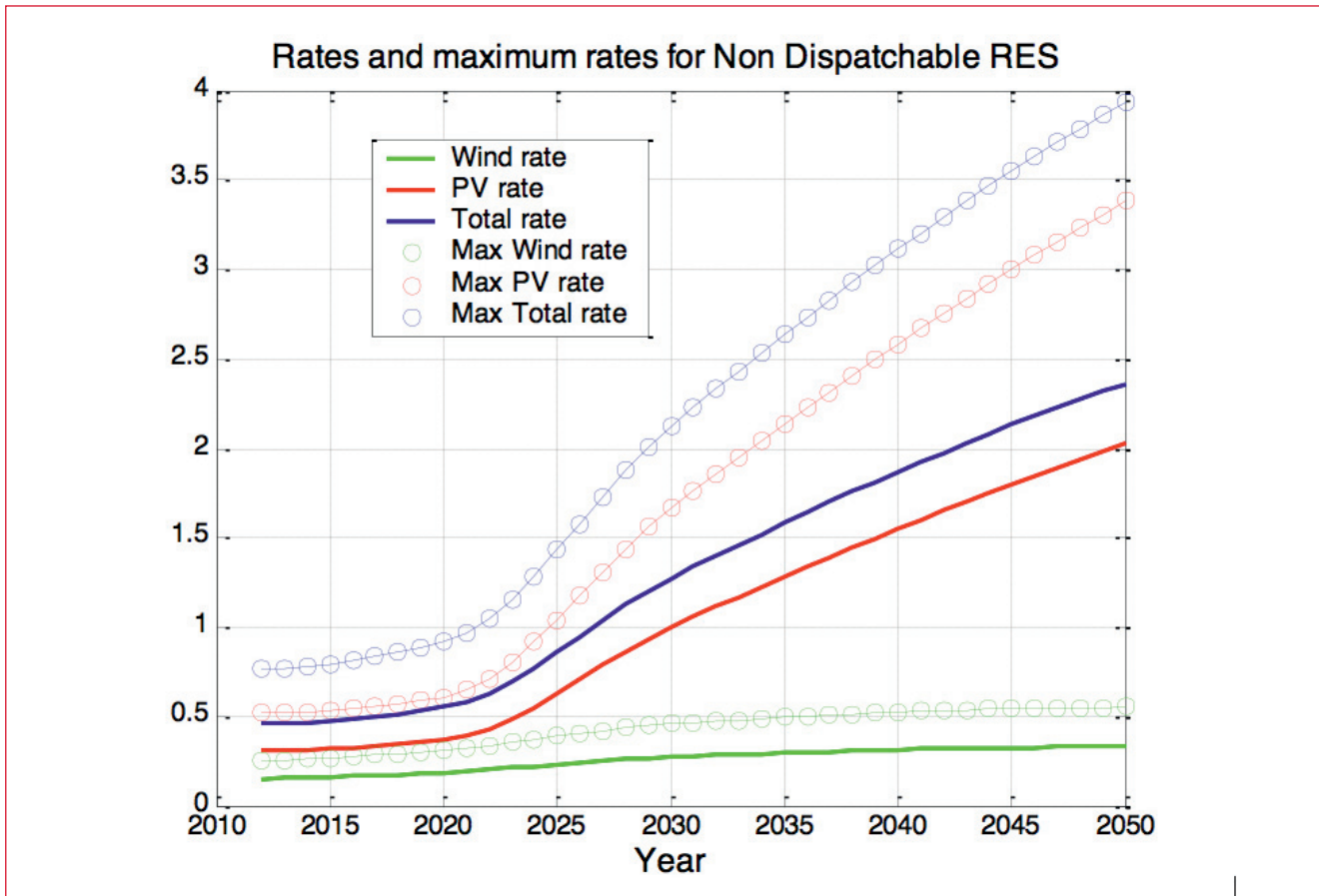
$$\text{Peak Load (GW)} = \frac{\text{Yearly Demand (GWh)}}{h_L}$$

where  $h_L$  is the number of average equivalent operative hours of the grid Load; for Italy such number was in the order of 6000 hours, in 2012.

From Table 1, with the assumptions better described in [1], the situation of Table 2 can be derived, where the Peak Demand and Capacities of the major "non-dispatchable RES" are shown.

A figure named "rate" has been introduced here, simply meaning the ratio between Capacity and Load; such rate gives a measure of how the Installed "non-dispatchable RES Capacity" can affect the grid operation, characterized by its Peak Load. As the rate approaches or even surpasses the unit, the "stress" on the grid becomes evident, meaning that the probability for the Load to be fed only by "non-dispatchable RES" becomes high, while dynamic frequency and voltage stability margins decrease due to the loss of rotating mass, normally supplied by the fuel-fired groups that have to be put out of service in order not to incur in overgeneration. The situation is even worse taking into account the "minimum daily peak of the year" (not the minimum load of the year, that is even lower), which typically happens during a summer holiday; such a peak in 2008-2011 ranged from 48% to 69% of the yearly peak, averaging 60%. The corresponding rate is here called "maximum rate".

Such rate data are shown in Figure 3. Summing up, starting from 2020 the ratio of "non-dispatchable RES" to Load will tend to grow up quickly and reach values well over the unit (up to 4 in the case of the "maximum rate", corresponding to the "minimum peak load", by 2050); these numbers give a rough idea of the problems that



**FIGURE 3** Non-dispatchable Renewable Energy Sources rates

will affect the grid and the complex of generation assets in the medium and long term in relation to the targets. Technical improvements will therefore have to be introduced in order to cope with this situation, so as to ensure that targets be really achieved:

- Transmission grid enforcement, increase in transnational balancing flows, smart-grid introduction at the distribution level
- improvements in forecasts; load management at various levels
- increase of flexibility of “conventional” plants
- progressive introduction of peak (minutes to h) and energy (1-5 hours) storage at various levels; in the medium-long term, also long-term energy storage (by RES-generated hydrogen, or methanation), in order to

avoid the progressive loss of generated RES energy due to “overcapacity” and balance the seasonal variations in RES supply.

Since now in general, R&D efforts will have to be applied to render all the RES “more dispatchable”, e.g. by introducing storage systems directly at the RES production level.

### Environmental impact

The last but not least important implication of the scenario is its environmental impact. Indeed, as RES become significant in quota, also their impact on the environment (e.g., visual impact on Landscape in case of Wind Power or large solar fields, pollution or conflicts with agricultu-

Estimate of the impacted areas (km <sup>2</sup> )	2012	2020	2030	2050
Area of Wind Power visual impact	8500	12250	19200	21300
Area interested by PV (Land and/or roofs)	200	284.4	842.4	1827.6
Land for energetic cultivations	1250	2000	2750	4250

**TABLE 3** Evaluation of land areas impacted or affected

re in case of Biomass, ...) becomes potentially significant. As a matter of fact, such conflicts did already arise - e.g. the visual impact large solar fields, and of Wind Turbines (the best wind sites being usually located on cliffs or coastal areas with high "Landscape value"); local pollution and possible stench in the case of biomass plants; and so on. Treating such problems would demand much more insight, here only the order of magnitude of areas affected and/or needed is presented (more details on how the numbers were evaluated can be found in [1]). Evaluation of land areas impacted or affected.

Some brief explanations of the numbers:

- the evaluation of any "visual impact" is subject to a number of "highly questionable" assumptions, e.g. individual attitudes and expectations; the numbers therefore represent a quite subjective (by the author) rough order of magnitude
- the PV area is calculated assuming approximately 8 m<sup>2</sup>/kW of active area and an average ratio of land to active area equal to 1.5; the visual impact is not considered
- for biomass, the assumption is 50% coming from residuals and waste, while 50% from cultivated biomass;

of the latter, only 40% is assumed to be directly cultivated in Italy.

## Conclusions

Renewable Energy Sources, especially those producing electricity, have recently had a significant development in Italy; at the same time either European and National commitments demand for further increase, that according to the official targets could reach an 85% quota of electric consumption by 2050. Applying these targets to a comprehensive scenario shows both the electrical network and the structure of the complex of generation assets as a whole will need a sort of revolution in order to cope with the task. Namely: grid enforcement; smart-grid approach for distribution; increased flexibility; energy storage at various levels. In addition, also the environmental impact of RES will become a significant factor to be taken into account in decision-making; such a factor and its evaluation/mitigation will be an important aspect not to be neglected when it comes to technical and economic considerations.

The long-term alternative to properly face the challenges posed by a significant domestic development of RES is either to reduce the commitment targets or to resort to renewable energy imports, namely wind and solar electricity or "fuels from RES", e.g. from North Africa or the Balkan region.

**Massimo Falchetta**

ENEA, Technical Unit for Renewable Energy Sources

## bibliografia

- [1] M. Falchetta, Fonti Rinnovabili e Rete Elettrica in Italia, RT/2014/8/ENEA <http://hdl.handle.net/10840/4931>
- [2] The climate and energy package - <http://ec.europa.eu/clima/policies/package/>
- [3] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A policy framework for climate and energy in the period from 2020 to 2030, Brussels, 22.1.2014 – COM(2014) 15 final [http://ec.europa.eu/energy/doc/2030/com\\_2014\\_15\\_en.pdf](http://ec.europa.eu/energy/doc/2030/com_2014_15_en.pdf)
- [4] Tabella di Marcia per l'energia 2050 – Comunicazione della Commissione al Parlamento Europeo, al Consiglio, al Comitato economico e sociale europeo e al comitato delle regioni COM(2011) 885, 15/12/2011 <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0885:FIN:IT:PDF>
- [5] M. Z. Jacobson, M. A. Delucchi, Providing all global energy with wind, water, and solar Power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials, Energy Policy 39 (2011) 1154-1169; Part II: Reliability, system and transmission costs, and policies, Energy Policy 39 (2011) 1170-1190
- [6] Strategia Energetica Nazionale: per un'energia più competitiva e sostenibile, Ministero dello Sviluppo Economico, marzo 2013 [http://www.mise.gov.it/images/stories/normativa/20130314\\_Strategia\\_Energetica\\_Nazionale.pdf](http://www.mise.gov.it/images/stories/normativa/20130314_Strategia_Energetica_Nazionale.pdf)
- [7] Terna – Piano di Sviluppo 2013 (Terna Development Plan 2013) <http://www.terna.it/LinkClick.aspx?fileticket=gw0JzJRpz4l%3d&tabid=6345>
- [8] M. Delfanti, V. Olivieri – Sviluppo delle smart grid: opportunità per le aziende italiane del settore - Politecnico di Milano, Dipartimento di Energia, dicembre 2013.
- [9] M. Di Carlo, L. Michi, A. Camponeschi - Gli impianti CCGT nel nuovo contesto di mercato e del sistema elettrico - L'Energia Elettrica 35, novembre-dicembre 2013.