Template (Italy)

Action 4.1.1: National Frameworks

Author: Giovanni Minelli – EU-IMP
Laura Pandolfi – EU-IMP
Chiara Jacini – EU-IMP
Nicola Galli – AGIRE
Roger Tonetti – AOSTA
Andrea Tampieri – AOSTA
Gabriele Grea – Gruppo Clas
Alessandro Maghella – ALOT

Work Package Responsible
University of Liechtenstein
Professor Peter Droege and Team

Lead Partner
B.A.U.M. Consult
Ludwig Karg, Patrick Ansbacher, Dr. Michael Stöhr
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List of acronyms and abbreviations

ACER  Agency for the Cooperation of Energy Regulators
AEEG  Authority for Electric Energy and Gas
APEA  Energy facilities productive area
AVERE European Association for Battery, Hybrid and Fuel Cell Electric Vehicles
CAES  Compressed Air Energy Storage
CCTG  Cycle Turbine Generator Plants
CEER  Council of European Energy Regulators
CEI   Italian Electrical Committee
CHP   Combined Heat and Power
CSP   Concentrating Solar Power
CSPs  Charging Service Providers
DER   Distributed Energy Resources
DG    Dispersed Generation
DSO   Distribution System Operators
ENTSO-E agency European Network of Transmission System Operators for Electricity
ESS   Energy Storage System
EVs   Electric Vehicles
FER   Renewable Energy Sources
GSE   Energy Systems Manager
IPS   Interface Protection System
MGP   Day-Ahead Market;
MI    Intra-Day Market
MPE   Spot Electricity Market
MSD   Ancillary Services Market
MTE   Forward Electricity Market
NHC   Nodal Hosting Capacity
P2G   Power-to-Gas
PCM   Phase Change Material
PLC   Power-line carrier
PV    Photovoltaic
RE    Renewable Energies
RES   Renewable Energy Sources
RIA   Regulatory Impact Analysis
SEN   National Energy Strategy
TSO   Transmission System Operator
TABs  Thermally activated building system
VPS   Virtual Power System
VRB   Vanadium Redox Batteries
WACC  Weighted Average Cost of Capital
1. Summary

In recent years the Italian national framework on energy storage systems and on the electric system has been changing swiftly. In the storage sector different technologies and projects have been developed and implemented to different extents, however, none of them has yet gained a key position on the market. The technology of pump storage power plants is actually the only practiced way in Italy for large power storage. In the near future, stationary electrochemical batteries and EVs may play a key role for the stability of the grid.

The electric system has been abruptly changed by the growth of small size DG, which has been mainly related to the construction of RES power plants, largely from solar (FV) and wind source. The rise in RES installed power has been a direct consequence of the incentives granted by the government and has forced the network to start an evolution towards an “active” behaviour. In this context, policy initiatives and legislation play a critical role. On the production side, the recent technical standards and regulation concerning DG power plants are gradually charging the DSOs with the active management of their plants connected to the MV/LV grids. On the demand side the Italian smart metering system allows the application of a Time-of-Use electricity price for 30 million customers. In the electric mobility sector the Italian regulatory authority decided that DSOs should not have an exclusive role in developing recharging infrastructures; hence CSPs are expected to build and operate an EV public recharge systems.

The contribution and the priority input in the grid of RES power plants has also made the Italian electricity market inconstant and quickly changing. Large size energy producers are now suffering the competition from RES power plants; the implementation of storage systems could limit the daily range of price and, in future, create the condition for the RES power plants to remain on the market with the other electricity producers.

1.1 The Italian scenario: storage resources role

Actually, in the European context, towards the achievement of EU climate change and energy policy targets for 2020 and beyond, a paradigm shift is on-going: The whole electric system management is going to be changed, requiring a progressive re-engineering of the networks: electricity grids need to become smarter and stronger, exploiting new technologies, e.g. decentralized storage devices, power electronics components, information and communication technology (ICT) solutions to keep the whole electric system reliable at affordable costs. Innovative approaches are required through automation of control of generation and demand (in addition to other forms of demand response) to ensure balancing of supply and demand. Storage could help maximizing electricity system stability in case of any sudden drop/surge due to the variability of most RES generation plants. In the past only Pumped Hydro Storage has been feasibly implemented, today many other technologies are promising, but there are still technical and mostly regulatory issues to be faced. Moreover, new actors are rising their footprint in this picture, in particular electric based mobility solution (e-car, e-bike, e-bus) could be the most promising and interesting resource in order to have an elastic behaviour from the electric load, i.e. the ability to shift (in the time) and move (in the space) the electric load in order to better fit the energy availability (generation). In a nutshell the keyword is Flexibility, i.e. the capability of a power system to maintain reliable
supply by modifying production or consumption in the face of rapid and large imbalances, such as unpredictable fluctuations in demand or in variable generation. In terms of regulatory issues, open questions are related to which players (private market operators contributing to system optimization or regulated operators) shall own and manage storage facilities. Looking at storage devices for Alpine Space scenario, it could be said that a few candidate technologies fit the needs from a technology standpoint. However, there exist some barriers related to costs, constraints on sites, technology costs, industry standards and protocols, regulatory issues.

Focusing on the Italian scenario a very particular situation has to be identified in order to correctly evaluate the picture: a huge deployment of RES generators on the distribution grid was recorded between 2010 and 2011 (figure 1). Such a violent development has been driven by a particular favourable RES incentive structure (feed-in tariffs), resulting in a scenario unimaginable only few years ago. European Union’s ambitious renewable energy targets for 2020, at least for wind and photovoltaic resources, are now no more ambitious: actually Italian policy makers are increasing the national targets for the renewables penetration. On the other side a very critical situation has been detected on the electric grid, requiring a fast and deep revision of the technical regulation of the energy sectors. New technical rules and new market regulation structures have been quickly introduced. Finally, Pilot projects have been proposed in order to evaluate Smart Grid and Storage solutions effectiveness for the efficiency and security of the system. Today, the Italian industrial sector is hardly working in order to develop new apparatus/control structures for the Pilot applications, similarly, Policy Makers are particularly interested on the capability of this new solutions to be effective in the management of the new scenario, looking for the security of supply, from one side, and for the market efficiency (i.e. economic efficiency) on the other.

Last but not least, the social problem is clearly rising, providing a correct information results to be a mandatory target in many contests in order to build up a correct awareness on the problem and on the possible solutions.

Figure 1: Wind and Photovoltaic penetration [MW] in the Italian electric grid
2. Storage technology checklist

2.1 Market and local future options

2.1.1 Biogas digesters and storage tanks

Market availability / number of units in operation:

A biogas plant is generally organized in two different sections: the anaerobic digestion section to produce biogas and the cogeneration section to produce heat and power from the biogas. On the top of the digester(s) and eventually on the side, there is a biogas storage unit, to guarantee the right flow of biogas to the cogenerator, the modulation capability and to give the needed operating autonomy. This biogas storage unit usually allows about 4 hours autonomy at the cogenerator rated power. But it is suggested to have at least 8 hours autonomy (need to increase the storage size). The usual size is $1 \div 2.5$ m$^3$ biogas per kW (electric power) with a pressure of $1.5 \div 5$ mbar. The lower calorific value of biogas is about $5$ kWh/m$^3$. The number of plants in Italy at the end of 2011 was 819 with 773.4 MW (year 2011) of installed electric power (55% from agricultural activities and 45% from waste and sludge). It means $1.652$ m$^3$ of average storage capacity with a total amount of energy of $6,700$ MWh ($1,350,000$ m$^3$). The gasometers have variable volume and low (generally constant) pressure. They can be of different kinds:

- rigid: mainly used in the past, dry or water seal;
- flexible: most common, they are made of coated fabric canvas. They can be built with a simple membrane, double membrane, triple membrane or bag. The advantages are: the possibility of installing the biogas storage unit directly on the top of the digesters, without a new structure and space consumption; easier accessibility; adaptability to existing geometry.

Local future options:

Another way to store energy is the biomass storage unit beside the plant that allows an average autonomy of $3 \div 12$ months to the cogenerator. Obviously this energy needs more time to be ready to be used (20 $\div$ 50 days is the retention time to obtain the whole quantity of biogas from the stored biomass). Italian power production from biogas by agricultural activities in 2011 was 1,450 GWh (total 3,405 GWh): it can be conservatively assumed that the biomass storages (trenches) can store 805 GWh in terms of primary energy (considering an average power efficiency of 45% a 3 months autonomy on side of the plants).

Local future options:

The previous data lead to a comment: the biogas storage, also considering the possibility of doubling, as order of magnitude, is not significant for assuring the Italian energy supply: for example the 6,7 GWh of national stored biogas will be consumed in a few hours by a single gas turbine plant. The interesting point of biogas storage is the possibility of controlling the power produced by a biogas plant, setting the cogenerator and using the gasometer to store the excess biogas. This solution is particularly interesting in order to manage local energy production of programmable (biomass) and not programmable (solar, wind) renewable energy sources,
also considering the opportunity to use the stored biogas for other uses (sustainable mobility as for agricultural biogas vehicles, and/or input into the gas grid), and the opportunity to connect the plant through a Virtual Power System with other kinds of energy storage (as mobile or stationary batteries).

2.1.2 Power-to-Gas (methane in the gas grid)

Market availability / number of units in operation:
In Italy the input of biomethane into the gas grid is still not allowed. The law decree n. of 3th March 2011 with the article 20 paragraph 1 established that in 3 months since the release the Italian Energy Authority for power and gas issues specific directives about the technical and economic conditions for the provision of the connection service of the biomethane production plants with the natural gas grid. The grid operators have the obligation to connect third parties. The Authority has not yet issued the directives, so it’s still not possible to apply the law and supply the natural gas grid with biomethane. All the Italian biogas working plants are now connected to cogenerators or local methane users.

Local future options:
The possibility of connecting the biomethane plants directly with the natural gas grid is very important for many reasons:
- the Italian natural gas grid is very wide and well distributed;
- the cogenerator is the main critical part of a biogas plant (cost, life, reliability);
- the possibility of using the grid as gas storage in order to increase local control of the renewable energy through a Virtual Power System.

2.1.3 Power-to-Gas (hydrogen in the gas grid)

Market availability / number of units in operation:
Not available, since there is no legislation framework. The only hydrogen grid developed in Italy is in the gold district of Arezzo (Tuscany), where there are: a 4000 Nm³ storage at 200 bar pressure with 1 km conduit that connect the artisans that use hydrogen directly in gold processing and also to produce heat and power with CHP.

Local future options:
The experience of Arezzo is increasing with the APEA (energy facilities productive area) that will extend the existing hydrogen grid to 2.450 m in the San Zeno productive area.
Other:

An important project named Power-to-Gas\(^*\) (P2G) involves the development of technologies and demonstration plants to increase the conversion of renewable fuels into gas to be fed into the natural gas distribution network. Two main lines will be pursued:

- organic conversion of primary sources (biomass, landfill gas, waste) in gas sources such as bio-methane and bio-hydrogen;
- conversion of peak electrical power from renewable sources (wind, solar) into synthetic gases (hydrogen, synthetic methane) to be injected into the distribution network for natural gas.
The project has a total of 24 partners with a whole budget of 12 M€. Coordinator is Asja (Torino), involving research institutions of primary importance (the Polytechnic of Turin, the Polytechnic of Milan and the University of Bologna).

2.1.4 Power-to-Gas (hydrogen local)

**Market availability / number of units in operation:**

There are different ways to store hydrogen: vehicle fuel tanks and stationary fuel tanks as fuel stations or industrial storage.

In Italy the number of hydrogen cars and vehicles is very small: only a few prototypes such as the 2 Fiat Panda developed by the ZeroRegio Project and managed by LabterCrea and the Comune of Mantova. There are four fuel stations owned by ENI in the whole of Italy (Collesalvetti – Tuscany; Mantova and Milano – Lombardy; Rome – Lazio). Industrial storage is more important and better developed: there are industries specialized in hydrogen production, the most important is Sapio, with seven factories located in different Italian regions, that produce mainly hydrogen from natural gas. Other companies use (and store) hydrogen for chemical processes: for example it’s used by refineries to desulfurize Diesel fuel. Other companies produce hydrogen as a result of their chemical processes, as in the dehydrogenation of polystyrene.

Regarding H₂ storage with metal hydrides, the Hydrostore project is in the implementation phase, funded by the Ministry of Economic Development under the call "Energy Efficiency - Industry 2015", with the objective of developing innovative technologies for hydrogen storage with the technology of metal hydrides, both in mobile (vehicles) and stationary application. Partners in the project, with a total budget of 12 M€ are ENEL, ENEA, CSGI, RSE, the University of Padova, the University of Roma, the University of Genova, ACTA, Giacomini, SOL, TPA and SGS.

In the field of small stationary fuel tanks two Italian companies, Electro Power Systems S.p.A. and Giacomini S.p.A., produce two interesting systems, named respectively ElectroSelf and H₂ydroGEM Box, powered on board with an electrolyser to produce H₂ form RES, H₂ tanks and a fuel cell to reconvert H₂ into Power. At the moment there are few units in operation in Italy like the one in Cellarengo (Monferrato area – Piedmont) that implement a grid-connected ElectroSelf system powered with a PV and micro wind plant at service of a Wi-Max antenna that brings Broadband Internet to the Monferrato rural area.

**Local future options:**

Hydrogen is a very interesting energy carrier, with strong potentiality both for stationary and mobile applications, in particular considering the possibility of producing it by and generating power with fuel cells. The main problems that need to be solved are:

- the high pressure of the hydrogen stored inside vehicles tanks (danger);
- the need of rare materials (platinum) that implies high costs.

Sapio is developing many projects regarding hydrogen storage and application:
• A hydrogen bus project in Turin (mobile storage of 9 cylinders with 200 barG pressure to feed a 60 kW fuel cell).
• Hysy_Labj: laboratory within the Environment Park of Turin to study hydrogen production, storage and applications.
• Zero Regio: a hydrogen production chain in Mantova. Production from natural gas, distribution with new hydrogen fuel service station, application with two FIAT Panda cars with fuel cells (hydrogen storage pressure 350 barG).
• Hydrogen parkk: in Marghera, to develop R&D on hydrogen as an energy carrier.
• NEO Fuel Cell Daily: fuel cell van
• Hydrogen produced by biomass and polyethylene gasification (2,500 kg/h).

Figure 4: Hydrogen production by biomass gasification: the TWR process (Source: SAPIO)

2.1.5 Chemical storage systems (zeolite etc.)

*Market availability / number of units in operation:*

Actually there are no relevant chemical storage units in operation in Italy. Regarding Zeolite technology special gas absorption heat pumps are available on the market, (zeoTHERM manufactured by Vaillant and Vitosorp produced by Viessmann), for applications limited to the small scale residential sector. In these systems the zeolite does not carry out a real function of energy storage, but acts as adsorbent material for the cycle of the heat pump. These systems are not interconnected with the electrical chain.

2.1.6 Compressed air storage systems
Market availability / number of units in operation:

At the moment there are no units in operation in Italy. Different research projects are in development, like the RSE one that considers the possibility of storing compressed air in the sea inside balloons that use hydrostatic pressure to increase efficiency.

Figure 5: The bathymetry project offshore near Milazzo (Source: RSE – Ricerca Sistema Elettrico)

Figure 6: Examples of air storage in the sea (Source: RSE – Ricerca Sistema Elettrico)
Local future options:

CAES could become a good option in the future with the following particular aspects:

- to reduce the peak power required in the power supply by performing the peak-shaving option;
- to perform the so-called “spinning reserve”;
- to support the production of reactive power.

Furthermore, these systems are perfectly integrated with the production of electricity from intermittent renewable sources like wind and solar.

Another affordable usage of compressed air is the use of the same as it was for pneumatic drives in production lines for different requirements and generally for automatisms. Practically all production units require a ring of compressed air, normally at a pressure less than 12 bar. Thus it is possible to use compressed air produced at night or during renewables peaks.

Regarding transport there is an interesting option in the prototyping stage: vehicles powered by compressed air. Actually they still have some technological problems, like the fall of air temperature during the expansion phase, and the energy efficiency of the chain. In fact, it can be seen that the efficiency of the energy chain in the case of an EV is much more advantageous because the AV has to bear the mechanical efficiency of the compressor and the expander that do not exceed 70% and have a negative impact on the overall performance of chain.

Other:

Considering that the main disadvantage of CAES is the dependence on geological formations which limits the possibility of installation of the equipment only to certain areas, especially in a country that is geologically sensitive like Italy, it’s interesting to highlight the project “AG Mini-A-CAES/2-TES” that stands for “Above Ground Compressed Air Storage 1 to 10 MW combined with a two-level Thermal Energy Storage at the University of Rome. The AG Mini A-CAES/2 TES concept provides:

- Above Ground (“AG”) compressed air storage (not underground cavern, but steel tanks).
- Medium-Small Size (“Mini”) i.e. 1 to 10 MW, about 8 hrs charge / 2 hrs discharge (it can be modified).
- Adiabatic (“A-CAES”): heat produced during compression stored/used to heat air before expansion Two-level thermal energy storage (“2 TES”), molten salt and pressurized hot water.

2.1.7 Pump storage systems (regional in Alpine Space)

Market availability / number of units in operation:

The technology of pump storage power plants is actually the only practiced way in Italy for large power storages. Their function is basically to pump the water during the night with a lower cost of electrical energy and to provide power during the day in peak hours.

At present there are 22 pump storage power plants operating in Italy, almost all owned by ENEL, for a total power installed of 7,659 MW. The majority of these plants are installed in the north of Italy with 15 plants for a power installed of 5,137 MW, the rest in the south with 7 plants and a power of 2,522 MW.

The major pump storage power plants in Italy are listed below:
### Main pump storage power plants in Italy

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Power [MW]</th>
<th>Max Storage generation [h]</th>
</tr>
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<tbody>
<tr>
<td>Chiotas</td>
<td>Piedmont</td>
<td>1,065</td>
<td>16</td>
</tr>
<tr>
<td>Delio</td>
<td>Lombardy</td>
<td>1,040</td>
<td>17</td>
</tr>
<tr>
<td>Presenzano</td>
<td>Campania</td>
<td>1000</td>
<td>7</td>
</tr>
<tr>
<td>Edolo</td>
<td>Lombardy</td>
<td>978</td>
<td>5</td>
</tr>
<tr>
<td>Anapo</td>
<td>Sicily</td>
<td>500</td>
<td>8</td>
</tr>
<tr>
<td>Suviana</td>
<td>Emilia Romagna</td>
<td>330</td>
<td>8</td>
</tr>
<tr>
<td>Taloro</td>
<td>Sardinia</td>
<td>240</td>
<td>52</td>
</tr>
<tr>
<td>Rovina</td>
<td>Piedmont</td>
<td>125</td>
<td>16</td>
</tr>
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Table 1: Main pump storage power plants in Italy°

Considering the estimated annual energy capability of these plants, close to 8,000 GWh/year, the last few years they have been heavily underutilized as showed in the following graph.

This situation, which might seem to conflict with the simultaneous sharp increase of energy produced from wind and solar (see also chapter 3), is indeed closely linked to this evolution. In fact, this rapid increase, together with the start up of the electricity market, resulted in an overcapacity of the Combined Cycle Turbine Generator plants (CCTG) and generated a crush in the differential price of the full/empty hours. In this condition the CCTG plants are more competitive than the pump storage power plants in tracking the absorption peaks, thus fulfilling a sort of virtual storage function.

- By this analysis it’s evident that the pump storage power plants are not yet used as systems for the storage of the energy produced from renewable energy sources, in particular wind and solar.
Local future options:

The pump storage power plants play a key role for the stabilization of the grid, with particular regard to the centre and south of the country, which is characterized by the presence of large wind and solar power plants with large grid deficiencies.

The National Energy Strategy (SEN) indicates, among the priority actions for the development of infrastructure and the electricity market, the reinforcement, in the long term, of storage capacity with the adoption of pump storage power plants and batteries.

Finally, considering the Italian geography, surrounded by sea and mainly mountainous, the development of marine pump storages is interesting, such as the Japanese prototype in Okinawa.

![Figure 7: Okinawa pilot plant (Source: RSE – Ricerca Sistema Elettrico)](image)

Other:

According to a study of the Joint Research Centre of the EU (JRC) to increase pumping in Europe, instead of building new plants it may be convenient to convert the hydroelectric plants already in operation, instead of constructing new ones.

Currently no data are available on the real potential of pumping in Europe. The study "Pumped-hydro energy storage: potential for transformation from single dams", realized by the JRC in collaboration with the University College of Cork (Ireland) therefore proposes a new method for assessing the potential of the cost-effective technology based on the technical and environmental hydroelectric power plants in operation. It focuses on two case studies (Croatia and Turkey), the evaluation of which leads to the assumption that the growth potential of pumping systems in Europe is very high.

In Croatia, for example, the electricity pumping potentially achieved by altering existing plants is in fact about 3 times that available today, while in the case of Turkey the study of JRC evaluates a potential of 3.8 billion kWh per year, compared to generation currently zero.

2.1.8 Pump storage systems (Scandinavia etc.)
**Market availability / number of units in operation:**

Actually in Italy there are no pump storage systems in operation that perform the wider spatial strategy applied in the Norwegian storage capacity.

**Local future options:**

The Italian pump storage power plants are typically largely away from areas of higher concentration and production of power from wind and photovoltaic. In fact, as mentioned in the previous section, most of the pumping stations are located in the north, while most of the wind farms are located in the south. So, as done by the Scandinavian pump storage plants, a possible future option might be to use the north Italian storage capacity for the south Italian wind power in a wider spatial context.

2.1.9 Thermal energy storage systems – High temperature

These systems are based on the possibility of realizing an interconnection between the electrical and the thermal chain by using thermal and cooling generators powered by electricity, which typically use the technology of heat pumps. These, when properly sized and equipped with heat/fridge storage capabilities - even with phase change -, can be used to store electrical energy as heat/cold that can be used later according to requirements of the load. These systems are very interesting because they use storage units that are already connected to the load requirements, however they require that the load can be controlled.

**Market availability / number of units in operation:**

The applications of HTTESS are mainly related to the production of heat processes in the industrial sector. It's difficult to quantify the units in service and these ones are not always interconnected with the electrical chain.

**Local future options:**

In the field of the Concentrating Solar Power (CSP) technology, ENEA has developed an innovative technology based on the use of a mixture of molten salts with the double function of heat transport and thermal storage. This technology solution allows an increase in the operating temperature in comparison with thermal oil and brings significant benefits to functionality, economy, safety and the environmental compatibility of the system. Other important benefits derive from the ability to integrate this type of solar thermal power plants with conventional thermoelectric plant and to store the thermal energy efficiently, thus reducing the discontinuity of solar energy.

The first industrial plant based on the ENEA solar technology was realised by ENEL in the Priolo Gargallo thermoelectric plant (Sicily). The Archimedes Project, currently in the demonstration phase, opened in 2010. The new solar system is able to concentrate, by means of linear parabolic collectors (SEGS), direct sunlight. The energy obtained, thanks to the properties of the fluid composed of salts, is stored and made available at a high-temperature (550 °C) at any time of the day, avoiding the discontinuity typical of other renewable sources.
The thermal energy produced is used to produce steam at high temperature (535 °C) and high pressure (110bar) suitable for placing in the steam turbine of a combined cycle. The “solar array” consists of 72 parabolic collectors, with a total area of about 40,000 square metres active. The solar concentrators, fully integrated with the thermodynamic cycle and with the facilities and services existing in the plant, increase the power of the plant of about 5 MW for an energy production of approximately 10 GWhe/year. The German study MED-CSP assessed the Italian economically exploitable potential of solar CSP in 7,000 GWh/year.

2.1.10 Thermal energy storage systems – Low temperature

**Market availability / number of units in operation:**

The applications of latent heat thermal energy storage systems are mainly based on the properties of the Phase Change Material (PCM – Solid to liquid & Liquid to solid phase change) and are typically related to the production of heat and cold in the domestic and in the tertiary sector. Possible applications of these systems are:

- Storage of cold for cooling systems (with operating temperatures from 5 °C to 18 °C);
- Accumulation of heat for heating (temperature around 55 °C - 60°C);
- Accumulation at high temperature for applications in solar cooling (over 80 °C);
- Walls of buildings with materials encapsulated PCM (operating temperatures around 22 °C - 25 °C, which may, however, vary depending on the climate and the needs of heating or cooling);

It’s difficult to quantify the units in service - typically are very innovative/pilot systems - and they are not always interconnected with the electrical chain, except in the case of the production of heat and/or cold through electric power generation systems (such as heat pumps).

**Local future options:**

The development of these technologies, with respect to sensible heat storage, is very interesting because they allows better energy performance in addition to significant reduction of volumes related to the storage. At present their high cost does not justify their wide adoption, in addition to the complications related with the sizing and design of these systems.

2.1.11 Thermal energy storage systems - Water

**Market availability / number of units in operation:**

In the last few years, with the diffusion of solar thermal, biomass and heat pump heating systems, the market of water storage systems, both for applications in the field of production of domestic hot water and heating, has seen a veritable explosion, especially in the residential sector.
Regarding the solar thermal market, 3,073,930 m$^2$ with a thermal capacity of 2,151,751 kWth are installed in Italy. Considering an average installation of about 6 m$^2$, we can evaluate an approximate 500,000 storage water storage systems actually in operation in Italy. Also in this case these systems are not always interconnected with the electrical chain, except in the case of the production/integration of heat and/or cold through electric power generation system (like compression heat pumps).

Another important sector for water storage systems is represented by district heating, where large storage systems (over 1,000 m$^3$) are used to support, typically, the CHP functioning. There are also the first examples of district heating powered with big compression heat pump systems (between 2 and 20 MW). One of these plants is under construction in the Aosta Valley for the heating district of Aosta: the system is powered with a compression heat pump of 17.6 MW and provides heat recovery from an industrial steel production process.

**Local future options:**

In consideration of the 20-20-20 EU targets for the all above-mentioned systems further growth is foreseen. Of particular interest for the electric grid are the systems based on compression heat pumps, a strategic sector for Italy also from the industrial point of view.

### 2.1.12 Thermal energy storage systems - Salt

**Market availability / number of units in operation:**

These systems are discussed in the section dedicated to the HTTESS applied in the Concentrating Solar Power (CSP) plants.

### 2.1.13 Thermal energy storage systems – Materials like concrete, stones or sand

**Market availability / number of units in operation:**

The storage and thermal inertia properties of stone and especially concrete are exploited in the field of the air-conditioning of buildings, in particular in the services sector, for the so-called thermal activation of the mass (Thermally activated building system – TABS). At the moment it is not possible to quantify the TABS in operation.

Some research projects in the field of Concentrating Solar Power (CSP) systems consider stones and concrete for the storage of heat and the production of steam.

**Local future options:**

The thermal activation of the mass applications are currently still under-used but, being typically powered by compression heat pumps, could be a good potential in term of power storage, thus realizing a perfect interconnection between the electrical and thermal chain.
2.1.14 Flywheels (small-sized)

**Market availability / number of units in operation:**

Actually there are different manufacturers on the market (Riello UPS, Beacon Power, Caterpillar, Piller Power Systems, Socomec) that propose small-sized flywheels dedicated to UPS, power quality and frequency regulation functions. One Italian manufacturer, the Riello UPS company® (part of the Riello Elettronica group), constructs UPS flywheel-based for special application like the datacentre, hospitals and industry. Usually these systems work in assistance to batteries UPS or diesel oil gensets. There is no information about flywheels as storage systems as a support to the grid. Different research centres and universities in Italy have R&D projects in which they develop flywheels for common energy storage.

**Local future options:**

No information at the moment.

2.1.15 Flywheels (large-sized)

**Market availability / number of units in operation:**

Different research centres and university in Italy has R&D projects in which they develop flywheels for common energy storage.

**Local future options:**

No information at the moment.

2.1.16 Mobile batteries (electric vehicles)

**Market availability / number of units in operation:**

Available electric cars on the Italian market: electric traction only with lithium-polymer battery with autonomy of up to 100-150 km:

- i-MIEV Mitsubishi, iOn Peugeot, C-Zero Citroen, 47 kW.
- Nissan Leaf, 80 kW.
- Renault Twizy, 15 kW, Zoe, Fluence, 70 kW, Kangoo, 55-80 kW (rental batteries).
- Smart Fortwo Electric Drive, 55kW (rental batteries)
- Tazzari Zero, 15 kW
Mild Hybrid - vehicles with small electric motors that help the main combustion engines in starting and acceleration with nickel batteries charged by electric brakes. This system reduces consumption and emissions especially in urban use.

- Prius 1 e 2 from ’97 to 2009.
- Honda Insight, Jazz e CR-Z.
- Mercedes-Benz Class E BlueTEC, Class S 400 Hybrid.
- BMW Serie 3, 5, 7, X6 Active Hybrid.
- Audi Q5, A8.
- Volkswagen Touareg Hybrid (245 kW total).
- Porsche Cayenne, Panamera S Hybrid.

Full Hybrid - Electric motor and combustion engine have the same power and the batteries (nickel-metal hydride to contain costs for small and medium cars) allow only electric. running at low speed 2-3 km

- Toyota Yaris, PriusC, Prius+, Atkinson cycle 1,5 l. and electric 70 kW total.
- Toyota Prius 3, Auris, Lexus 200, Atkinson. 1,8 l and electric 100 kW total.

Lexus CT, IS, GS, RX, LS (from 226 to 327 kW total).
- Prius Plug-in with additional lithium battery pack to obtain an electric autonomy of 20 km at 100 km/h.

Volvo V60 Plug-In

Full Hybrid Diesel.
- Peugeot 3008 and 508, Citroen C5 and DS5 with diesel engines 118 kW front wheel drive, and electric rear wheel drive, 147 kW total. High performance, low consumption also on the motorway, all-wheel drive.

Extended range - Electric Vehicles with lithium batteries and combustion power generators to increase autonomy.
- GM Volt and Opel Ampera con electric motor 111 kW and lithium batteries for 60 km autonomy and combustion power generator for 500 km autonomy.

2.1.17 Stationary batteries

**Market availability / number of units in operation:**

In Italy the main activities regarding stationary batteries are developed by the large grid operators: Terna (transmission – largest high voltage grid manager) and Enel (distribution – biggest medium and low voltage grid manager). Also RSE and Enea are studying and testing different electrochemical storage systems.

They are looking for different applications. Energy intensive storage systems are useful for adjustments in terms of hours (they can help the integration of the not programmable renewable energy sources on the National electric system in order to use their energy production when the market needs and demands more energy): Sodium-Sulfur NaS batteries and Flow batteries ZrBr and VRB are the kind of electrochemical storage
systems applicable for energy intensive purposes. Power intensive storage systems are useful for adjustment in terms of seconds and minutes: they need to constantly balance the energy production and consumption and maintain the grid stable. This is very important also considering that the increase of the renewable energy production means a reduction of the operation of the conventional fossil plants and the primary power reserve connected with them (by law). Lithium ion Li-Ion batteries are the most interesting electrochemical storage systems for power intensive regulation.

![Electrochemical storage systems](image)

**Figure 8: Electrochemical storage systems (Source: STES)**

TERNA: In the 2011 Development Plan the integration of the not programmable energy sources with the National Transmission Grid are included, as foreseen by the Law n. 28/2011 to increase, a first phase of installation of batteries for 35 MW (240 MWh). They will be placed in critical areas, especially located in South Italy (Puglia, Molise, Campania), where the impact of wind and solar plants is higher. Another project is dealing with the power intensive technologies for the main islands (40 MW).
Figure 9: Energy storage systems in TERNA’s 2011 development plan (Source: TERNA)

RSE: Energy System Research, is a private company, owned by GSE (Energy Service Manager), a private company owned by the Italian Economic Development Ministry. They are testing lithium-ion batteries, active filters with supercapacitors, VRB batteries (45 kW – 90 kWh) and they are also developing components for Na-S batteries.
FIAMM, the Italian leader in lead acid batteries production for automotive and industrial sectors, has focused its R&S efforts in recent years on the development of technology of sodium/nickel chloride batteries with the brand “FIAMM SONICK” and with the creation of the division “FIAMM Energy Storage Solutions”. In 2011 FIAMM realized, in collaboration with Elettronica Santerno, Terni Energia and Galileia, a pilot system based on sodium/nickel chloride batteries - 10 modules of 23 kW each for a total of 230 kWh installed - coupled to a 180 kWp photovoltaic plant. The system is designed to store the energy produced in excess by the PV plant, with respect to the local load, shifting energy in times of increasing demand or insufficient PV production. Also Terna introduced the technology of sodium/nickel chloride batteries in its “storage lab” (see also chapter 8) for the realization of, at least, 2 test storage plants with a power of 1 MW. The programme of Terna is to realize, if the experimentation is positive, 110 MW (of 240 MW) of storage plants with this technology in the context of the resolution 288/2012/R/EEL of the Italian Authority for Electric Energy and Gas.

Local future options:

Other private companies (PV plants producers and installers) offer the possibility of storing energy with stationary batteries to their clients, in order to increase the economic benefits of PV plants. From the end of August 2012, the new incentive law for PV systems provides higher tariffs for the self-consumed energy with respect to the tariff for the energy fed into the grid. For example for small plants (1 kW ≤ P ≤ 3 kW) installed on the roof of a building the tariff for the energy fed into the grid is 208 Euro/MWh (all inclusive), while the tariff for the self-consumed energy is 126 Euro/MWh that is to add to the saving achieved (from 150 to 200 Euro/MWh depending by the supply contract). The self-consumed energy is economically 3/2 of the energy exchanged with the grid and this is stimulating the development of storage systems (batteries) included in PV plants.
### 2.2 Technology Comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>Market availability</th>
<th>Storage period</th>
<th>Storage volume</th>
<th>Response Time</th>
<th>Local future Option</th>
<th>Power/Energy</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas digestion and storage systems</td>
<td>+++</td>
<td>weeks</td>
<td>++</td>
<td>medium</td>
<td>++</td>
<td>+/-</td>
<td>+</td>
</tr>
<tr>
<td>Power-to-Gas (methane in gas grid)</td>
<td>--</td>
<td>weeks</td>
<td>--</td>
<td>quick</td>
<td>++</td>
<td>+++/+++</td>
<td>+</td>
</tr>
<tr>
<td>Power-to-Gas (hydrogen in gas grid)</td>
<td>--</td>
<td>weeks</td>
<td>--</td>
<td>quick</td>
<td>--</td>
<td>+++/+++</td>
<td>0</td>
</tr>
<tr>
<td>Power-to-Gas (hydrogen local)</td>
<td>--</td>
<td>days</td>
<td>--</td>
<td>quick</td>
<td>-</td>
<td>+/-</td>
<td>0</td>
</tr>
<tr>
<td>Chemical storage systems (zeolite etc.)</td>
<td>+</td>
<td>days</td>
<td>o</td>
<td>slow</td>
<td>o</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Compressed air storage systems</td>
<td>+</td>
<td>weeks</td>
<td>o</td>
<td>medium</td>
<td>o</td>
<td>+/-</td>
<td>+</td>
</tr>
<tr>
<td>Pump storage systems (regional in AS)</td>
<td>+++</td>
<td>days</td>
<td>+++</td>
<td>quick</td>
<td>++</td>
<td>+++/+++</td>
<td>+++</td>
</tr>
<tr>
<td>Pump storage systems (Scandinavia etc.)</td>
<td>+++</td>
<td>weeks</td>
<td>---</td>
<td>quick</td>
<td>++</td>
<td>+++/+++</td>
<td>+</td>
</tr>
<tr>
<td>Thermal energy storage systems – high temperature</td>
<td>+</td>
<td>weeks</td>
<td>+</td>
<td>medium</td>
<td>++</td>
<td>No data</td>
<td>+</td>
</tr>
</tbody>
</table>
## National Frameworks: The case of …

### Table 3: Technology examples

<table>
<thead>
<tr>
<th>Technology</th>
<th>Market availability</th>
<th>Storage period</th>
<th>Storage volume</th>
<th>Response Time</th>
<th>Local future Option</th>
<th>Power/Energy</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal energy storage systems – low temperature</td>
<td>o</td>
<td>days/weeks</td>
<td>o</td>
<td>medium</td>
<td>o</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Thermal energy storage systems – water</td>
<td>+++</td>
<td>days</td>
<td>+++</td>
<td>quick</td>
<td>+++</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Thermal energy storage systems – salt</td>
<td>+</td>
<td>weeks</td>
<td>+</td>
<td>medium</td>
<td>++</td>
<td>No data</td>
<td>+</td>
</tr>
<tr>
<td>Thermal energy storage systems – lithic material</td>
<td>o</td>
<td>hours</td>
<td>o</td>
<td>Very slow</td>
<td>o</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>flywheels (small-sized)</td>
<td>++</td>
<td>minutes</td>
<td>--</td>
<td>very quick</td>
<td>+++</td>
<td>+/-</td>
<td>++</td>
</tr>
<tr>
<td>flywheels (large-sized)</td>
<td>--</td>
<td>weeks</td>
<td>--</td>
<td>very quick</td>
<td>o</td>
<td>+/-</td>
<td>++</td>
</tr>
<tr>
<td>mobile batteries (electric vehicles)</td>
<td>++</td>
<td>hours</td>
<td>o</td>
<td>very quick</td>
<td>+++</td>
<td>o/o</td>
<td>++</td>
</tr>
<tr>
<td>stationary batteries</td>
<td>+++</td>
<td>days</td>
<td>o</td>
<td>very quick</td>
<td>+++</td>
<td>+/+</td>
<td>++</td>
</tr>
</tbody>
</table>

### Explanation

Market availability, storage volume, local option: +++ (best), ++, +, o (neutral), -, --, --- (worst)
Storage period: minutes, hours, days, weeks, months
Response time: very quick, quick, medium, slow, very slow
3. Renewable energy status: sources, supplies, network, market

One of the biggest changes of the electrical distribution system is related to the development of dispersed generation; this new phenomena permits a higher efficiency of energy process, increases the renewable energy exploitation and decreases gas emissions. From here onwards, Dispersed Generation (DG) is defined as a set power plans with rated power lower than 10 MW and connected to the distribution network, both Medium Voltage (MV) and Low Voltage (LV); the DG location is usually uncertain and power injections are unpredictable. Whereas, Small Dispersed Generation (SDG) is a set of power plants for electrical energy production, including cogeneration systems, with sizes up to 1 MW (this is a subset of DG).

The development of DG in Europe is due also to the EU 2020 strategy of 20-20-20:
- to produce 20% of renewable energy of the total EU energy demand;
- to achieve a 20% decrease of EU energy consumption in respect to the forecast for 2020;
- to achieve a 20% decrease in gas emissions in respect to the emissions of 1990.

Some of these aims can be achieved by DG. Because of the novelty of this phenomenon, there is no common definition of DG in the different countries (not only European). DG definitions all around the world are reported in a survey conducted by the CIRED 1999.

Nowadays, the growth of dispersed generation in the electrical system, and mainly in the distribution system, leads to an evolution of networks from "passive" to "active"; this evolution is forcing an upgrade in protection systems and the networks management and control systems.

Focusing on the Italian system, Figure 11 highlights the generation portfolio evolution over the last fifty years. The figure clearly depicts the rapid development of renewable resources over the last few years. But, in order to correctly evaluate the "electric" scenario in Italy a wider picture has to be evaluated: actually electric power grids are interconnected all over Europe and they are associated in the so called ENTSO-E agency (European Network of Transmission System Operators for Electricity). Recently, ETSO-E presented the 2013 Winter report regarding electric system adequacy, depicting a quite interesting index: the remaining generation capacities if all countries would solely have to rely on their own generation resources. Figure 12 point out the results for a severe condition scenario: when a country is in violet, it has a negative remaining capacity, whilst it is blue if the remaining capacity is less than 10% of peak load, and green if it is higher. Actually, Denmark, Sweden, Finland, Latvia and Poland all appear as non-green as they rely on imports to meet the demand during severe conditions. Moreover, Belgium and France have an energy deficit under severe conditions and therefore require considerable amounts of energy to be imported from other countries; the margin in Germany is very low, whilst the Netherlands has a large amount of surplus energy that could be exported. The reports demonstrate that Italy could export energy to border countries inverting its own energy rule if compared with the current energy scenario. Actually, this scenario is due to a curious combination of factors. During the night, Italy imports energy from France, but only because of convenience due to the lower price of French energy. As a matter of fact, Italy has a strong energy surplus, even excessive with respect to the energy load requirement. The power capability of Italian power plants is higher than 100 thousand MW in face of half of peak power demand. These data
demonstrate the Italian electric system to be very strong with respect to the energy demand, i.e. able to correctly guarantee a reliable energy supply for the coming years. Figure 13 details the Italian generation portfolio at the end of 2011, while Figure 14 points out the energy flows across the grid. As previously stated, due to economic reasons Italy typically imports energy from France and Germany, consequently the grid has to support a power flow from the North to the Middle of the Country. On the other side the South of Italy has very poor energy consumption and, simultaneously, a very rich availability of power plants using renewable (and non-renewable) resources; such a scenario leads to a power flow from the south to the middle of Italy. The national electric transmission grid is the highway that makes such flows possible, ensuring the reliability of the energy supply (figure 15).

Figure 11: Maximum capacity of electric power plants in Italy at 31 December 2011 (source TERNA)

Figure 12: Remaining generation capacity vs load for 1013 winter severe condition scenario (source ENTSO-E)
Figure 13: Components (%) of Electricity Supply Side (source TERNA)

Figure 14: Italian balance of physical exchange of electricity – 2011 data – [GWh] (source TERNA)
Looking at the distribution grid, i.e. to the “local scenario”, it’s possible to have a picture about the penetration level of distributed generation (a quite complex picture due to the huge number of generators involved) in the Italian electricity system by analysing data collected by the Authority for Electricity and Gas. On this matter, the Authority conducts an annual analysis of the development of this form of generation in Italy; the study mainly focuses on the impact of DG on the electrical network, the energy mix, the sustainable development and the use of marginal sources. Below, a survey concerning the last monitoring of distributed generation in Italy for the year...
2010, published in 2012, is reported. The gross production of electricity from GD in 2010, in Italy, amounted to 19.8 TWh (about 6.6% of the national production of electricity), an increase of 3.4 TWh compared to 2009. It can be concluded that in recent years GD production has increased; also the percentage of DG production on the global gross energy production has increased. The number of DG plants is equal to 159,876, with a gross efficient power of 8225 MW (about 7.5% of the national gross efficient power); while in 2009 the in-service power plants were 74,188, with a gross efficient power of 5644 MW (about 5.4% of the national gross efficient power). The increase in the number of GD plants is mainly due to solar power plants (in detail, photovoltaic plants increased from 71,258 in 2009 to 155,977 in 2010); with regards to other energy sources: hydroelectric power plants increased from 1,904 in 2009 to 2,385 in 2010, thermal power plants increased from 902 in 2009 to 1,224 in 2010 and wind farms from 124 in 2009 to 290 in 2010.

In 2010, a rated power equal to 2299 MW of hydroelectric plants were installed, they produced 9.4 TWh (47.3% of production from GD), 2191 MW of thermal power plants which produced 7.8 TWh (39.5% of production by GD), 458 MW of wind farms that produced 0.8 TWh (3.9% of output by GD) and 3277 MW of photovoltaic plants which produced 1.9 TWh (9.3% of output by GD). Note that the FV statistic does not take into account the shift in time between the commissioning date (that is when the installed power is accounted) and the energy production period. In the following table 5, the number of power plants, the gross efficient power installed, the gross energy production and the net energy production are reported for each power plant technology; a distinction between the energy locally produced and energy injected to the grid is also indicated.

The data reported in the table shows a small number of hydroelectric and thermoelectric power plants compared to the photovoltaic ones, but their energy production is much higher, it’s due to the higher power plant size of these technologies compared to the photovoltaic ones, which is usually smaller. Furthermore, thermoelectric power plants have the certainty of primary energy supply which allows to have equivalent hours of operation at rated power higher than those obtained by renewable sources.

Of particular interest is the analysis of the mix of energy sources used for the production of electricity from GD, this is significantly different from the typical mix of the Italian generation system. In particular, in 2010 the 74.6% of the electricity produced by GD was from renewable sources (Figure 16); the main renewable energy source, as already noticed in previous years, is hydroelectric production with an amount of 47.4% of the total DG production. Focusing on the total Italian energy production (Figure 17), there is a quite different scenario, in fact the 74.6% of production (including production from pumping hydroelectric power plants) is from non-renewable sources. Considering the renewable energy sources, water is the most used with an incidence of 16.9%. This difference is due to the type of primary energy sources used in the conversion into electrical energy; in fact, the low energy density of renewable sources doesn’t encourage the production in power plants with higher size whereas only small size plants spread along the network are used. The non-renewable sources allow a higher efficiency in case of larger power plant sizes.

Another relevant aspect is related to the voltage level connection of DG; in the following graphs the analysis is reported and a distinction between the number of plants (Figure 18) and power size (Figure 19) is also carried out. In figure 20 the amount of energy injected is reported as a function of the voltage level in which it is connected.
<table>
<thead>
<tr>
<th>Country</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Connected to the distribution network (up to 132 kV) which is capable of supplying customer load directly</td>
</tr>
<tr>
<td>Austria</td>
<td>Usually up to 10 MW, connected to the MV system</td>
</tr>
<tr>
<td>Belgium</td>
<td>Not considered in the co-ordination production</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>Connected to the distribution network (up to 110 kV) and up to a limited power rating.</td>
</tr>
<tr>
<td>Denmark</td>
<td>Not subordinated to regional load despatch centres</td>
</tr>
<tr>
<td>Finland</td>
<td>By voltage level (20 kV and 0.4 kV)</td>
</tr>
<tr>
<td>France</td>
<td>Connected to the distribution network capable of supplying customer loads directly. Generation connected to the following voltage levels (0.4 kV, 15 kV, 20 kV)</td>
</tr>
<tr>
<td>Germany</td>
<td>No strict definition, mainly sun, wind and small hydro (connection up to 20 kV, 110 kV for wind parks)</td>
</tr>
<tr>
<td>Greece</td>
<td>Connected to the distribution system, not centrally planned or despatched</td>
</tr>
<tr>
<td>India</td>
<td>New renewable energy sources (connection up to 11 kV)</td>
</tr>
<tr>
<td>Italy</td>
<td>Connected to the distribution system (0.4 kV up to 150 kV)</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Owned by utilities, industry or combination but not active in national production optimisation (up to 150 kV)</td>
</tr>
<tr>
<td>Poland</td>
<td>Not dispatched and connected at up to 110 kV</td>
</tr>
<tr>
<td>Portugal</td>
<td>Power limit 10 MW (except CHP). Co-gen or renewable energy source. Any voltage level.</td>
</tr>
<tr>
<td>Spain</td>
<td>Connected to the distribution system</td>
</tr>
<tr>
<td>UK</td>
<td>Connected to the distribution system (up to 132 kV) – may be dispatched.</td>
</tr>
</tbody>
</table>

*Table 4: GD definition for different EU countries (source CIRED)*
Table 5: GD power plants in Italy (source AEEG Resolution 129/2013/I/eel, 28 March 2013, data refers to December 2011 scenario)

<table>
<thead>
<tr>
<th>Source of Energy</th>
<th>N. Plants</th>
<th>Gross efficient power (MW)</th>
<th>Gross production (MWh)</th>
<th>Net production (MWh) - local consumption</th>
<th>Net production (MWh) - in the net</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrotic</td>
<td>2.549</td>
<td>2.448</td>
<td>8.553.823</td>
<td>399.540</td>
<td>8.011.020</td>
</tr>
<tr>
<td>Biomass, Biogas, Bioliquid,</td>
<td>1.088</td>
<td>1.005</td>
<td>3.788.948</td>
<td>316.225</td>
<td>3.243.570</td>
</tr>
<tr>
<td>Urban solid waste</td>
<td>37</td>
<td>120</td>
<td>441.331</td>
<td>85.630</td>
<td>299.612</td>
</tr>
<tr>
<td>No - Renewable resources</td>
<td>872</td>
<td>1.499</td>
<td>5.208.036</td>
<td>3.440.387</td>
<td>1.600.522</td>
</tr>
<tr>
<td>Hybrid</td>
<td>17</td>
<td>45</td>
<td>93.365</td>
<td>36.879</td>
<td>48.711</td>
</tr>
<tr>
<td>Total thermal</td>
<td>2.014</td>
<td>2.669</td>
<td>9.531.680</td>
<td>3.879.122</td>
<td>519.415</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wind energy</td>
<td>587</td>
<td>539</td>
<td>805.841</td>
<td>89</td>
<td>796.637</td>
</tr>
<tr>
<td>TOTAL</td>
<td>335.318</td>
<td>17.911</td>
<td>29.237.583</td>
<td>6.716.967</td>
<td>21.789.381</td>
</tr>
</tbody>
</table>

Data reported in the graphs show the high number of small power plants connected to LV systems (figure 19). Although the high number of power plants connected to the LV network, a further comparison of the data highlights that the installed power and the energy injected by these plants is low because of the lower equivalent hours of operation of PV plants than other technologies.

An analysis of DG photovoltaic plants shows an exponential increase of the number of photovoltaic plants in 2011. In the same way, the installed power has increased (from 3.277 MW in 2010 to 12.255 MW in 2011) and the energy has increased (from 1.853 GWh in 2010 to 10.346 GWh in 2011). In the same way, the installed power has increased (from 1.143 MW in 2009 to 3.277 MW in 2010) and the energy has increased (from 676 GWh in 2009 to 1.853 GWh in 2010). In 2011 325,081 photovoltaic power plants were connected to the network with a total power of 12685 MW and a total energy production of 10.9 TWh.

From the graphs reported, the photovoltaic development of recent years is evident; this evolution increased the ratio between the DG power installed and the number of power plants (i.e. the average power per power plants): from 1.53 MW/plant in 2006 to 0.14 MW/plant in 2008, up to 0.05 MW/plant in 2010. The ratio between the gross electrical production of DG and the number of power plants (i.e. the average energy production per power plant) decreased from 5.13 MW/plant in 2006 to 0.44 MW/plant in 2008, up to 0.12 GW/plant in 2010.

These indices show a further decrease during the two-year period 2011-2012 because of the considerable increase of photovoltaic plants. This phenomena highlights the current passage from a scenario with a few big
power plants to a scenario with a lot of small size power plants. In particular, a particularly favourable feed-in tariff incentive scheme, brought a huge increase of photovoltaic DG power plant connection (figure 21) in 2011.

Figure 16: Net energy production for Renewable DG plants (source AEEG Resolution 98/2012/I/eel, 22 March 2012)

Figure 17: Italian 2010 energy generation scenario (source AEEG Resolution 98/2012/I/eel, 22 March 2012)
Figure 18: GD plants “number” classified with respect to the voltage level of the point of common coupling with the main grid (source AEEG Resolution 98/2012/l/eel, 22 March 2012)

Figure 19: GD plants “power” classified with respect to the voltage level of the point of common coupling with the main grid (source AEEG Resolution 98/2012/l/eel, 22 March 2012)
Figure 20: GD plants “production” classified with respect to the voltage level of the point of common coupling with the main grid (source AEEG Resolution 98/2012/I/eel, 22 March 2012)

Figure 21: Photovoltaic production rise in recent years
<table>
<thead>
<tr>
<th>Type</th>
<th>2010</th>
<th>2011</th>
<th>var %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n°</td>
<td>kW</td>
<td>GWh</td>
</tr>
<tr>
<td>Hydro P &lt; 1 MW</td>
<td>2.729,0</td>
<td>17.876,169,0</td>
<td>51.116,8</td>
</tr>
<tr>
<td>P &lt; 1 MW</td>
<td>1.727,0</td>
<td>523.491,0</td>
<td></td>
</tr>
<tr>
<td>1 MW &lt; P &lt; 10 MW</td>
<td>700,0</td>
<td>2.210.451,0</td>
<td></td>
</tr>
<tr>
<td>P &gt; 10 MW</td>
<td>302,0</td>
<td>15.142.227,0</td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>487,0</td>
<td>5.814.281,0</td>
<td>9.125,9</td>
</tr>
<tr>
<td>Solar</td>
<td>155.977,0</td>
<td>3.469.880,0</td>
<td>1.905,7</td>
</tr>
<tr>
<td>Geothermal</td>
<td>33,0</td>
<td>772.000,0</td>
<td>5.375,9</td>
</tr>
<tr>
<td>Bioenergies</td>
<td>669,0</td>
<td>2.351.545,0</td>
<td>9.440,1</td>
</tr>
<tr>
<td>Biomass</td>
<td>142,0</td>
<td>1.242.659,0</td>
<td>4.307,6</td>
</tr>
<tr>
<td>- urban waste</td>
<td>71,0</td>
<td>797.929,0</td>
<td>2.048,0</td>
</tr>
<tr>
<td>- other biomass</td>
<td>71,0</td>
<td>444.730,0</td>
<td>2.259,6</td>
</tr>
<tr>
<td>Biogas</td>
<td>451,0</td>
<td>507.704,0</td>
<td>2.054,1</td>
</tr>
<tr>
<td>- from waste</td>
<td>228,0</td>
<td>341.338,0</td>
<td>1.414,8</td>
</tr>
<tr>
<td>- from sludges</td>
<td>47,0</td>
<td>14.569,0</td>
<td>28,2</td>
</tr>
<tr>
<td>- from zootechnc</td>
<td>95,0</td>
<td>41.371,0</td>
<td>221,0</td>
</tr>
<tr>
<td>- from agriculture</td>
<td>81,0</td>
<td>110.426,0</td>
<td>390,2</td>
</tr>
<tr>
<td>Bioliquids</td>
<td>97,0</td>
<td>601.182,0</td>
<td>3.078,4</td>
</tr>
<tr>
<td>- vegetable oil</td>
<td>86,0</td>
<td>510.016,0</td>
<td>2.681,6</td>
</tr>
<tr>
<td>- other bioliquids</td>
<td>11,0</td>
<td>91.166,0</td>
<td>396,8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>159.895,0</td>
<td>30.283.875,0</td>
<td>76.964,4</td>
</tr>
</tbody>
</table>

Table 6: Power and Energy produced by renewable sources in 2010 and 2011 (source: SIMERI)
4. Institutional framework

- **The Ministry of Economic Development**
  The Ministry of Economic Development is responsible for a wide variety of policies, including energy. Recently the National Energy Strategy has been presented and is currently under discussion. Among the priorities of action there is the developing of the electricity market and infrastructure.
  The strategy being pursued has three main objectives: to align electricity prices and costs to European standards; to ensure Italy's full integration with the European market; and to maintain and develop a free market fully integrated with energy produced from renewable sources, gradually removing all distortions and absorbing current surplus production capacity.
  In order to eliminate the cost differential the Government will:
  - *Develop the electricity grid*, to reduce congestions and bottlenecks between market zones and constraints on the full exploitation of the most efficient production capacity.
  - *Limit market inefficiencies and distortions*. More specifically, the “other system charges” in electricity bills, which account for about 4% of the cost of electricity, will be carefully reviewed.
  - *Review the special conditions granted to specific categories of users*.

In addition to the Ministry of Economic Development the two main public institutions in charge of regulation in the areas of energy production, distribution, consumption, storage and electromobility are the Italian Regulatory Authority for Electricity and Gas and the Italian Electrical Committee.

- **Regulatory Authority for Electricity and Gas (Aeeg) [www.autorita.energia.it]**
  The Regulatory Authority for Electricity and Gas (Aeeg) is the independent body which regulates, controls and monitors the electricity and gas markets in Italy. It was established by the law November 14th 1995, n.481 with the purpose of protecting the interests of users and consumers, promoting competition and ensuring efficient, cost-effective and profitable nationwide services with satisfactory quality levels. The Aeeg mission includes defining and maintaining a reliable and transparent tariff system, reconciling the economic goals of operators with general social objectives, and promoting environmental protection and the efficient use of energy. It provides an advisory and reporting service to the government and parliament, and formulates observations and recommendations concerning issues in the regulated sectors of electricity and gas.

With the law November 2011, n. 214, Aeeg has now competences also in regulating, controlling and monitoring water services. The mentioned law provides that: "with respect to the national Agency for both regulation and vigilance of water services, the functions of regulation and control of water services are assigned to the Authority making use of the same powers given by the law November14th 1995, n.481"
Aeeg recovers its entire costs from the companies it regulates. One of Aeeg’s principal guidelines, is transparency: the main Legal Acts are published on a website Bulletin and its general decisions are also published on the official website (an English summary is generally made available for the most important acts). The Authority involves its own stakeholders (consumers, system operators, market participants, trade unions and industrial associations) in the decision-making process, through public consultations and auditions; some of its most relevant decisions are submitted to application of Regulatory Impact Analysis (RIA).

Aeeg maintains bilateral relations with all the European regulators and in particular those belonging to countries sharing a border with Italy. Furthermore, AEEG collaborates with many non-EU Regulators to exchange best practices and share experiences.

Aeeg takes part in the regulatory board of the Agency for the Cooperation of Energy Regulators (ACER), the EU body established in 2009 to assist National Regulatory Authorities in exercising, at EU level, the regulatory tasks that they perform in the Member States and to coordinate their action on regulatory aspects of cross-border energy trade.

Aeeg is a founder member of the Council of European Energy Regulators (CEER), the non-for-profit association established on a voluntary basis to promote cooperation, exchange best practices among national regulators and to facilitate the creation of a single, competitive, efficient and sustainable EU internal energy market. CEER also maintains numerous contacts with new regulators or those currently being set up, especially in countries that have applied for EU membership and other European transition countries.

In the field of electromobility, Aeeg’s activities are devoted to the development of the network, providing relevant contributions to regulation and standards. Moreover, the authority is financing and monitoring six pilot projects on public charging, in order to test different models and options and promote the development of charging infrastructure across the territory.

- Italian Electrical Committee (CEI) www.ceiweb.it

CEI, Comitato Elettrotecnico Italiano, founded in 1909, is the Italian Institution, formally recognized by the Italian Government and by the European Union in charge of standardization and unification in the electrical, electronic and telecommunications fields in Italy. CEI technical standards define the best practices, i.e., the set of requirements enabling the design and construction of electric and electronic components, equipment, machines as well as installations, on the basis of defined safety principles, evolving in parallel with technological progress.

CEI’s duty is not only to publish technical standards, but also to promote and spread technical-scientific culture and electrical safety in particular. Therefore, CEI performs a number of standardization and pre-standardization activities, including: the publication of technical standards at national level and the endorsement of those harmonized according to European Directives; co-ordination actions, research & development, communication and training activities in co-operation with the other parties involved in the standardization process at a domestic, European and international level.

A special commission inside CEI is CIVES (Commissione Italiana Veicoli Elettrici Stradali a Batteria, Ibridi e a Celle a combustibile), in charge of electromobility issues. CIVES is the Italian branch of AVERE (European Associaton for Battery, Hybrid and Fuel Cell Electric Vehicles), established in 1978 by the EC in order to study and promote the use of electric vehicles. CIVES aggregates operators of the electromobility sector both with
reference to the supply side (automotive and component manufacturers, energy suppliers, research bodies, etc), and on the demand side (fleet managers, transport operators, associations, etc. Moreover, several public entities such as ministries, local authorities, municipalities and local agencies are members. CIVES promotes the knowledge of electric vehicles and stimulates the development of public initiatives for the sector, and acts as a round table for joint activities among its members and other stakeholders of electromobility.

Moreover several grid companies are today very active in the areas of energy storage and electromobility:

- **Italian TSO (TERNA) [www.terna.it](http://www.terna.it) and the new company TERNAPLUS (www.ternaplus.it)**
  Terna Plus is the company within the Terna Group responsible for developing new business in Italy and abroad. Terna Plus’ expertise goal is to grasp the business opportunities deriving from technological innovation: on the one hand, developing systems and solutions for energy efficiency and on the other, introducing widespread storage systems that allow safely managing renewable energy plants and systems.

- **Enel Distribuzione (Enel)**
  ENEL DISTRIBUZIONE is the main DSO in Italy. The ENEL group is active in all areas of electric power, ranging from Smart Grid projects to Smart Cities studies up to Storage pilot plants. Moreover, with EnelDrive, Enel has developed an innovative charging infrastructure, based on advanced technologies like Enel’s electronic meter.

- **FIAMM [http://www.fiamm.com](http://www.fiamm.com)**
  Finally, Italy has one big company, active in the battery manufacturing sector. FIAMM is the largest Italian battery manufacturer (probably the only one strong enough to have an active role in the worldwide scenario), in particular the energy storage solutions range from the traditional technologies to the new lead-free sodium nickel SoNick batteries, patented by the company.
5. Policy initiatives and plans

The advent of smart grids, smart meters and electromobility is creating new challenges not only in terms of technological innovation but also in terms of economic and technical regulation. The Italian case is interesting for a number of reasons, that go beyond its well-known leadership position in the area of smart metering and the related mandatory introduction of Time of Use pricing for a large share of consumers. Italy is facing a dramatic increase in RES (Renewable Energy Sources) penetration: several regulatory developments were introduced to favour the integration of intermitted generation and the transformation of distribution grids in active networks, capable of accommodating DG (Dispersed Generation) units.

Indeed, the management of energy production/consumption covers a central role especially in those power systems (as the Italian one) with a huge penetration of non-programmable renewable resources. In this context, the intermittent power production from RESs requires suitable management of both the generation and consumption resources across the grid, in order to ensure the safe operation of the system (power balance) in all operational conditions. To this purpose, the recent evolutions in Italian regulation and technical rules for the connection of DG power plants are remarkable: the Annexes A.70 and A.72 to the TSO’s Grid Code\(^a\), the Resolution 84/12/R/eel\(^b\) and the Standards CEI 0-16 \(^c\)and CEI 0-21\(^d\) are the first implementations towards a full RES dispatch. With the aim of dealing with the increasing penetration of DG in the national power system, they require the DERs power plants to be able to supply ancillary services, such as their disconnection on the basis of an order given in advance by the TSO (in some case an excess of power production w.r.t. load is forecasted), or the monitoring/forecasting of DG power injections to be carried out by DSOs, or the need to keep the DG safely connected to the grid during perturbations involving the HV network.

Moreover, the recent Resolution 281/2012/R/efr\(^e\), starts a revision process of the dispatching service for DG units from non-programmable DERs: it charges active users with the costs caused by the imbalances between forecasting and actual DG production, which so far impacted on the overall system. The aim of the Italian Authority is to make users aware of the effective forecast of their power injections.

Another example of the worth of effective generation/load dispatching is the implementation of pilot Projects for electrochemical distributed energy storage systems (batteries) within the transmission system with the purpose of supplying ancillary services to the system. Devices as expensive as batteries are used for several reasons: first of all, the need to compensate the reduction in the number of power plants able to regulate frequency caused by the increasing of FER power plants (which are not required to supply primary frequency regulation); furthermore, the need to avoid/limit congestion on branches of HV network or to improve the voltage profile across the transmission system.

It is relevant to point out that the Annex A.70 to the Grid Code sets the bases for a distributed monitoring of generation and load resources connected at the MV/LV level (for simplicity, the DSOs must provide the data about DG and load power exchanges, measured and predicted, to the TSO in an aggregated way).
Moreover, Resolution ARG/elt 198/11\textsuperscript{2} of the Italian Authority defines new standards for the Quality of Service. In particular, it sets more severe indicators for the continuity of service w.r.t. the previous regulation (number/duration of interruptions); moreover, it establishes new measures for the advanced monitoring of the voltage quality on MV/LV systems. In particular, it requires that: on the MV level, by December 2014, the number and amplitude of voltage dips by all the HV/MV primary substations will be monitored; on the LV level, the distribution network could be subjected to spot measurements, for the monitoring of voltage variations at the Point of Common Coupling of users.

The Italian regulation makes clear the benefits which could be achieved through a widespread monitoring system on the MV/LV network. Equipping active and passive users with an Energy Management System able to exchange data in real time with the TSO/DSO will make possible the collection of data (e.g. power exchanges; voltage quality) useful for the operation of the network, and also for planning and for regulatory purposes. Despite the fact that currently DSOs are not required to dispatch the load/generation resources underlying their grids, in the future this service could be requested from them. In this context, we underline the recent evolutions in the technical standards and regulation concerning DG power plants (Annexes A.70 and A.72 to the TSO’s Grid Code, Resolution 84/12/R/eel, Standards CEI 0-16 and CEI 0-21) gradually charging the DSOs with the active management of DG plants connected to the MV/LV grids.

Looking at the more technical side of the problem, and, focusing on the electric protection scheme for DG, the previously introduced A70 annex aims to give the minimum requirements concerning:

- Voltage and frequency operation ranges;
- Production Control;
- System needs for protection;
- Regulations.

TERNA establishes that all the production power plants and their equipment has to be designed and has to operate connected with the main grid even in case of emergency and grid reconnection. In particular, the power plants, in case of loading, have to be able to remain connected to the MV and LV network when the voltage is in the range 85% Vn≤V≤110% Vn. Furthermore, power plants have to stay connected to the mains for a short time period if voltages is in the range between 110% and 115%.

Concerning the frequency operation values, power plants have to stay connected to the main grid permanently when frequency oscillations fall into the range 47.5 Hz≤f≤51.5 Hz.

In order to satisfy the national electrical system needs, together with the needs of the distribution utilities, the active users (protection of the equipment) and the needs of the final customers (quality of supply) it is necessary to adopt protection schemes which can select thresholds and operation time of the frequency relays according to two different events:

- Local fault,
- Frequency oscillations due to global events on the transmission system.

The protection system should be able to select the events and disconnect DG units only for local faults on the MV and LV system, whereas DG has to remain connected in case of global frequency transients.

The two thresholds of the maximum frequency relay have to be set, according to the CEI standards, as follows:

- low frequency setting 50.3 Hz (0.1 s tripping time),
- high frequency setting 51.5 Hz (4.0 s tripping time);

Concerning the minimum frequency thresholds, the settings are:
low frequency setting 49.7 Hz (0.1 s tripping time),
high frequency setting 47.5 Hz (4.0 s tripping time);
the use of two separate settings remotely controlled by means of a communication signal are enough so that the Interface Protection System (IPS) works well in both cases.
In fact, a global event (frequency oscillations in all electrical system with load surplus or generation surplus) is a slow frequency oscillation phenomena with symmetric voltages. An event which involves the global system, the low frequency settings (49.7 Hz – 50.3 Hz) should remain disabled and the DG tripping has to occur for high frequency setting violation (47.5 Hz – 51.5 Hz). Vice versa, for local events (faults in the distribution network and tripping of the current protection located in the primary substation) the DSO can remotely switch the IPS to the low frequency settings and favour the DG disconnection. In case of lack of a communication system (the current scenario of the distribution system) the threshold commutation is not possible; a protection system is necessary, which operates only according to local information with the intent to discriminate between local events and global ones. The A70 attachment suggests the following protection functions to enable the low frequency settings (49.7 Hz – 50.3 Hz):
- zero sequence overvoltage protection (59.N);
- negative-sequence overvoltage protection (59.V2);
- positive-sequence undervoltage protection (27.V1).
The protection system logic which includes the voltage unlock is shown in figure 23. According to this, the IPS installed in the active users network is able to detect frequency oscillations due to the tripping of the circuit breaker located in the primary substation or due to the tripping of the switch disconnector located along the feeders. These actions guarantee a fast disconnection of the DG units and before the first fast automatic reclosure in order to avoid an out of phase reconnection.
It’s possible to combine with local voltage measurements the remote signals which can enable the low frequency settings or directly control the system protection interface, making it possible to perform different operation modes.

Figure 22: IPS operation logic scheme
6. Legislation

Discussing the Italian case, the regulatory authority has introduced a series of input-based incentives, in the form of an increase in the Weighted Average Cost of Capital (WACC), aimed at promoting strategic investments, in electricity transmission first, then in electricity distribution and finally in gas infrastructures as well. In general terms, with the regulatory policies designed so far, the Italian regulator was focusing on extracting most of the benefits from liberalisation: passing cost savings in operating expenses to final consumers, ensuring an efficient level of investments in the networks, stimulating competition at the wholesale and retail level, as well as increasing the level of service quality. As a result, for instance, the Italian distribution networks present an extremely high level of automation (on average, three secondary stations out of five are remotely controlled), mainly because of the incentives provided by service quality regulation. The reward and penalty scheme for continuity of supply was firstly introduced for the regulatory period 2000-03 for distribution networks only, and then regularly renewed every four years, as well as progressively enlarged to the transmission system. The significant level of energy injected by RES has already impacted the Italian system, both from a technical and from a regulatory standpoint. Nevertheless, the impact on the operation of the transmission network has been managed properly by the TSO, by means of special requirements in the national Grid Code, with the support of the regulating authority. For the sake of simplicity, it can be stated that the transmission network (thanks to a meshed topology, and to the presence of a complete and state-of-the-art control system) has already an active behaviour. Nevertheless, high RES penetration, especially in distribution networks (where almost all the PV plants are connected, more than 99% of the total number of units), requires changes on several fronts of the technical and economic regulation, in order to efficiently integrate this production in the network. AEEG started addressing the issue a few years ago (between 2007 and 2008) with a research project focused on the Nodal Hosting Capacity (NHC) of Italian distribution networks at medium voltage (MV) level. This research was commissioned by the regulatory authority to the Politecnico di Milano (Energy Department), and was based on a large sample of data on distribution network characteristics (detailed per single bus), created by means of a formal information request specifically made by the AEEG to the Italian Distribution System Operators (DSO). The project results were later published as part of AEEG Resolution ARG/elt 25/09.

- **Smart Grid Pilot Projects**

The Italian Authority has started an important Pilot application program for Smart Grid projects: the approach to the demonstration phase is designed around an input-based incentive scheme, to be awarded, on the basis of a competitive process, only to a limited number of projects. According to AEEG Resolution ARG/elt 39/10, selected smart grid demonstration projects can benefit from an extra remuneration of capital cost (a 2% extra WACC in addition to the ordinary return) for a period of 12 years. The incentive is funded through the network tariff and it was awarded to eight proponents (table 7). The selection of these projects (currently all running) was conducted, on behalf of the regulatory authority, by a committee of experts. In particular, in order to participate in the selection process, demonstration projects had to meet three main requirements, defined by AEEG: • in the electricity distribution area covered by the demonstration project, a reverse powerflow must occur for at least 1% of the time in a year; • all possible solutions are to be tested on real MV networks with both end-users and active users (loads and generators); •
only open and non-proprietary communication protocols are to be used for any communication applications involving network users.

The eight selected projects have common characteristics (innovative Interface Protection Relays, voltage control in presence of reverse flow, standard protocols), and specific features with respect to the type of environment (urban, rural): Table 8.

After this demonstration phase, the next phase will be a smart grid deployment program: the Italian regulator is motivated to move towards an output-based regulation. The regulator’s first thoughts on an output-based incentive scheme for full deployment of smart grids are outlined in a recent AEEG consultation document.

Table 7: Performance indices for the Smart Grid pilot projects selection (AEEG Resolution ARG/elt 39/10)

<table>
<thead>
<tr>
<th>Position rank</th>
<th>Primary Substation (PS) involved in the pilot</th>
<th>P_{smart} [MW]</th>
<th>Project Benefit (A)</th>
<th>C [k€]</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A2A - PS Lambrate</td>
<td>53170.69</td>
<td>65</td>
<td>773</td>
<td>4715</td>
</tr>
<tr>
<td>2</td>
<td>ASM Terni</td>
<td>16176.47</td>
<td>68</td>
<td>800</td>
<td>1375</td>
</tr>
<tr>
<td>3</td>
<td>A2A - PS Gavardo</td>
<td>3701.00</td>
<td>65</td>
<td>755</td>
<td>663</td>
</tr>
<tr>
<td>4</td>
<td>ACEA Distribuzione</td>
<td>44934.25</td>
<td>73</td>
<td>4970</td>
<td>660</td>
</tr>
<tr>
<td>5</td>
<td>ASSM Tolentino</td>
<td>6211.44</td>
<td>66</td>
<td>689</td>
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Table 8: Italian selected Smart Grid Projects (AEEG Resolution ARG/elt 39/10)

- **Smart Metering and Demand Response**

It is well accepted that in the Smart Grid picture, one of the most important “bricks” is the “smart metering” function. Actually, the Italian smart metering system is one of the largest in the world, gathering more than 30 million users. In its present configuration, the remote control system is composed of two parts: first, each MV/LV transformer station is equipped with a concentrator that collects all data coming from meters, via a power-line carrier (PLC), and it is capable of sending instructions to individual meters; second, from the concentrator upwards, communication is mainly based on the public TLC network (GSM/GPRS). This means that the present configuration does not allow a real time control of the end-point meters. Indeed, this was not among the
objectives that guided Enel’s decision to develop a smart metering system. At that time (around the year 2000) Enel’s objectives were four: remote meter reading, both periodical or on request; remote control of operations such as connection and disconnection of customers or setting the maximum available capacity; reduction of thefts, thanks to alarms installed in the end-point meters and (iii) energy balance on the LV network below the concentrator. Nonetheless, in terms of exploiting the value of the smart metering system, the most important regulatory decision was the mandatory introduction of a Time-of-Use (ToU) electricity price for all LV customers (in fact, to those who are served in the “universal supply regime”, i.e., household and small business customers who have not yet switched to a different retailer). This requirement has been in place since July, 1st 2010, has been fully phased-in by end-2011, and probably represents the largest experiment in the world of time-of-use pricing. The aim of the initiative is for small users to be exposed to cost-reflective prices, and to provide them with information on the economic value of the choices they make about electricity use. With these regulatory decisions, Italy is again aligned with European Commission objectives. The European Directive 2009/72/EC for the internal market in electricity (a component of the so called Third Energy Package) indicates smart metering as a necessary measure to extend the benefits of retail liberalisation to all users. The next steps in regulation will thus continue to focus on demand response and customer services; a recent consultation envisages further demonstration projects for standard interfaces on the smart meter, open to all retail suppliers wishing to offer innovative solutions to their customers, equipped with visual displays or load management devices.

- Electromobility

Moving on to the new forms of energy exploitation, the electromobility area is probably one of the most interesting. Although at the moment the amount of power that will be absorbed by those vehicles remains extremely difficult to predict, the advent of mobile electricity consumers poses a number of challenges to the design and functioning of power systems and electricity markets as well. The new, mobile consumers will be entitled with the freedom to choose their own supplier, just like the more traditional electricity consumers; moreover, they will uncover a new electricity need: access to recharging facilities, not only in private locations but also in public places or, at least, in places open to the public.

It is a shared view among national regulatory authorities in Europe that a competitive market should develop for PEV recharge. This might also allow a multi-vendor approach, where PEV-consumers choose their electricity supplier at the recharging station, provided that the recharging infrastructure ensures open access to electricity suppliers, through non-proprietary protocols. The Italian regulatory authority took an official position that developing PEV public recharging infrastructure is not part of a DSO’s licence. Consequently, DSOs should not have an exclusive role in developing recharging infrastructures, apart from the connection (the infrastructure is simply another network user). Moreover, the costs of building the infrastructure should not be included in the Regulatory Asset Base (RAB). This approach acknowledges the need to balance competition in the PEV recharging activity and competition in the electricity retail market, as well as the need for preliminary tests to analyse and understand the behaviour of mobile electricity consumers.

Coming after a long consultation process, AEEG decision ARG/elt 242/10 is probably the first regulatory action taken on electromobility development in Europe. Essentially, AEEG launched a call for demonstration projects which, differently from the call for smart grids, is open to both DSOs and other operators. In fact, the call is for Charging Service Providers (CSPs), who are expected to build and operate an EV public recharge system. DSOs can undertake this task but under an unbundling constraint: this activity must remain separated from regulated activities.
Table 9: Performance indices for the Electromobility pilot projects selection (AEEG Resolution ARG/elt 242/10)

- **Storage the grid**

Last but not least, the Italian Authority proposed the same incentive scheme adopted for the Smart Grid Pilot Applications (increase in the Weighted Average Cost of Capital - WACC) also for Pilot Storage Applications on Transmission Grid (Resolution 288/2012/R/EELii). The selection of the Pilot projects is currently underway. In particular, a new incentive scheme for Pilot Storage Applications on the Transmission Grid is proposed. A detailed description of technical requirements is also provided. In the following section a short summary is reported:

- The incentives are provided to all storage systems connected to the transmission system (high voltage network). A storage system has to balance the energy injected by renewable power sources and others not predictable power plants. This system has to be complementary to the on-line network control systems.
- The incentives are provided for up to three projects.
- In order to run for this call, each pilot project must include a suitable technical and economic analysis to demonstrate the fulfillment of the requirements.
- Only electrochemical storage systems are allowed for this call.
- For each pilot project, economic indices based on the cost/benefit ratio are calculated along the established conventional time period of 12 years. The cost/benefit indices take into account the increase of power injection produced by renewable power plants thanks to the storage systems. Other technical parameters are considered for the final ranking of the call.
- Every six months of the first two years of the conventional time period (12 years), the owners of the three award-winning pilot projects have to present the results of the experimentation to the Authority. At the end of the two year period a final report has to be carried out in order to summarise the experimentation results. Afterwards, the owners have to submit an annual report including the
cost/benefit indices. Then, results concerning the behaviour of the storage system and its effectiveness must be published.

Minimum requirements are detailed in terms of:

- The incentive is provided only if the project achieves the benefits in term of power production increase of at least 50% in the two firsts years.
- Overcoming of temporary critical network operations.
- The first goal is the decrease the lack of energy production of not predictable power plants due to network congestions.
- The portion of the network under analysis must include equipment to establish the dynamic thermal rating as a function of the meteorological conditions in order to maximise the lines capacity.
- Voltage control along lines by exploiting reactive power regulation of the inverters located in the storage systems; these control strategies have to be coordinated with the voltage control systems of the network.
- The storage system must guarantee the primary frequency regulation for every operation condition and supply ±5% of the rated power for at least 15 minutes.
- Rated capacity lower or equal to 40 MWh.
- The storage system must decrease the lack of energy produced by not predictable power plants of a multiple of its capacity.
- The global storage system can be made up by more different independent storage systems, with different technologies and they can be installed in several nodes of the network portion under analysis.
- The project can include systems to forecast the energy production of not predictable power plants.
- The project can include systems to measure, forecast and collect weather data in the renewable power plants. These data can be exploited to forecast the production of these plants and the lack of production due to network constraints.

Moreover, it is proposed that, in some critical conditions, the storage system can operate only with the goal of regulating the electrical frequency.
7. Market

List and describe overall current market conditions and economic activities related to energy storage. This should include a discussion on using stationary and mobile storage systems as buffers in Smart Grids.

- Electricity market
The Italian energy market is very complicated after the measures of liberalisation on one side, and the policy for incentivising renewable energy sources on the other side. The international economic crisis and the relative drop in consumption have further contributed to an inconstant, uncertain and highly variable trend, in particular for the electricity market. The high contribution of the renewable energy plants, in particular photovoltaics, concentrated in specific places (Southern Italy) and times (summer, daytime), together with the decrease in consumption, have drastically reduced, sometimes, the request for power from fossil fuels power plants, creating high instability in the energy market, together with the other problems as the balance of the grid, the reduced working hours and production of quite new CCGT plants with economic problems to respect their business plans and the reduction of power reserve available when these plants are working. The priority input in the grid for the electricity produced by renewable sources, established by the Law 387/03, and that is fundamental for their growth and promotion, penalise the effort for regulation and storage by the renewable energy sources plants owners. The change in the electricity market is clear looking at the trend of the average monthly prices by band: the F1 peak price [€/MWh], was generally highest with respect to the F2 mid-level price and the F3 off peak price. Starting in 2011 and for most of all 2012, during the summer the F2 price is constantly higher than F1.

![Figure 23: Average monthly prices by band [€/MWh] (data source: GME)](image-url)
An extreme condition occurred on the 9th April 2012 in the Sicily market, during a public holiday: the electricity price from 2 pm till 4 pm was 0 €, because the PV production was enough to satisfy the demand, with a maximum price of about 120 €/MWh between 8 pm and 9 pm.

The implementation of storage systems could limit the daily range of price and, in future, create the condition for the RES plants to remain on the market with the other electricity producers.
The Decree 28th March 2011, that implements the DIR 2009/28/CE, establishes criteria and incentives to adapt the national transmission grid and to implement storage systems in order to facilitate the input of the renewable energy into the grid.

- **Feed-in scheme**

The new incentive system for renewable power plants moves in the same direction: the fifth feed in-scheme (Ministerial Decree 5th July 2012) for solar photovoltaic power generation and the new Ministerial Decree 6th July 2012 for the other renewable sources power generation (not yet applicable because of the lack of technical definitions) and the old green certificates system. The electricity produced by renewable sources receives the same tariff regardless of the instant in which it is produced. Only the third feed-in scheme (Ministerial Decree 6th August 2010) considered a bonus (+20% on the tariff) for the electricity produced by a foreseeable load profile system: a local system of photovoltaics, other RES plants and users able to respect the energy output (balance) announced the day before. In this case the energy storage should be useful for the system in order to respect the expected energy balance and obtain the economic benefit. But this article of the third feed-in scheme was never applied, because the Energy Authority considered its introduction and definition too expensive and difficult. Later feed-in schemes did not propose this kind of bonus anymore.

Unlike the previous support schemes, the 5th feed-in scheme grants an all-inclusive feed-in tariff to the share of net electricity injected into the grid and a premium tariff to the share of net electricity consumed on site. The premium tariff added to the savings obtained through the self-consumption become overall higher than the feed-in tariff. This condition should stimulate on site consumption, and the installation of storage systems to increase it.

The following description shows the characteristics of the main Italian energy markets as reported on the websites of the responsible bodies.

- **Italian electricity market**

The Italian Electricity Market arises from Legislative Decree no. 79 of 16 March 1999 (Legislative Decree 79/99), which transposed the European Directive on the internal market in electricity (96/92/EC) into the National legislation. As in other international experiences, the creation of a market responds to two specific requirements:

- promoting competition in electricity generation, sale and purchase, under criteria of neutrality, transparency and objectivity, through the creation of a marketplace;
- ensuring the economic management of an adequate availability of ancillary services.

The Electricity Market consists of the Spot Electricity Market (MPE), of the Platform for physical delivery of financial contracts concluded on IDEX (CDE) and of the Forward Electricity Market (MTE).
The Spot Electricity Market consists of:

- **Day-Ahead Market** – MGP (energy market);
- **Intra-Day Market** - MI (energy market);
- **Ancillary Services Market** - MSD.

The **Day-Ahead Market (MGP)** hosts most of the electricity sale and purchase transactions.

- In the MGP, hourly energy blocks are traded for the next day.
- Participants submit offers/bids where they specify the quantity and the minimum/maximum price at which they are willing to sell/purchase.
- The MGP sitting opens at 8 a.m. of the ninth day before the day of delivery and closes at 9:15 a.m. of the day before the day of delivery. The results of the MGP are made known within 10:45 a.m. of the day before the day of delivery.
- Bids/offers are accepted under the economic merit-order criterion and taking into account transmission capacity limits between zones. Therefore, the MGP is an auction market and not a continuous-trading market.
- All the supply offers and the demand bids pertaining both to pumping units and consumption units belonging to foreign virtual zones that are accepted in the MGP are valued at the marginal clearing price of the zone to which they belong. This price is determined, for each hour, by the intersection of the demand and supply curves and is differentiated from zone to zone when transmission capacity limits are saturated.
- The accepted demand bids pertaining to consumption units belonging to Italian geographical zones are valued at the “Prezzo Unico Nazionale” (PUN – national single price); this price is equal to the average of the prices of geographical zones, weighted for the quantities purchased in these zones.
- GME acts as a central counterpart.

The **Intra-Day Market (MI)** allows Market Participants to modify the schedules defined in the MGP by submitting additional supply offers or demand bids. The MI takes place in four sessions: MI1, MI2, MI3 and MI4.

- The sitting of the MI1 takes place after the closing of the MGP. It opens at 10:45 a.m. on the day before the day of delivery and closes at 12:30 p.m. on the same day. The results of the MI1 are made known before 1:00 p.m. of the day before the day of delivery.
- The sitting of the MI2 opens at 10:45 a.m. on the day before the day of delivery and closes at 2:40 p.m. on the same day. The results of the MI2 are made known before 3:10 p.m. of the day before the day of delivery.
The sitting of the MI3 opens at 4:00 p.m. on the day before the day of delivery and closes at 7:30 a.m. on the day of delivery. The results of the MI3 are made known before 8:00 a.m. of the day of closing of the sitting.

The sitting of the MI4 opens at 4:00 p.m. on the day before the day of delivery and closes at 11:45 a.m. on the day of delivery. The results of the MI4 are made known before 12:15 p.m. of the day of closing of the sitting.

Supply offers and demand bids are selected under the same criterion as the one described for the MGP.

Unlike in the MGP, accepted demand bids are valued at the zonal price.

GME acts as a central counterpart.

The Ancillary Services Market (MSD) is the venue where Terna S.p.A. procures the resources that it requires for managing, operating, monitoring and controlling the power system (relief of intra-zonal congestions, creation of energy reserve, real-time balancing). In the MSD, Terna acts as a central counterpart and accepted bids/offers are valued at the offered price (pay-as-bid).

The MSD consists of a scheduling stage (ex-ante MSD) and of the Balancing Market (MB). The ex-ante MSD and the MB take place in multiple sessions, as specified in the dispatching rules.

The ex-ante MSD consists of three scheduling substages: MSD1, MSD2 and MSD3. The sitting for bid/offers submission into the ex-ante MSD is a single one. It opens at 3:10 p.m. on the day before the day of delivery and closes at 4:40 p.m. on the same day. The results of the MSD1 are made known before 8:40 p.m. of the day before the day of delivery. GME notifies Market Participants of the individual results of the MSD2 session (as specified in the dispatching rules) concerning the bids/offers accepted by Terna before 10:00 a.m. of the day of delivery. GME notifies Market Participants of the individual results of the MSD3 session (as specified in the dispatching rules) concerning the bids/offers accepted by Terna before 2:15 p.m. of the day of delivery. In the ex-ante MSD, Terna accepts energy demand bids and supply offers in order to relieve residual congestions and to create reserve margins.

The MB takes place in different sessions, during which Terna selects bids/offers in respect of groups of hours of the same day on which the related MB session takes place. At present, the MB consists of 5 sessions. The first session of the MB takes into consideration the valid bid/offers that Participants have submitted in the previous MSD session. For the other sessions of the MB, all the sittings for bid/offers submission open at 11:00 p.m. on the day before the day of delivery (and anyway not before the results of the previous session of the ex-ante MSD are made known) and close 1 and a half hours before the first hour which may be negotiated in each session. In the MB, Terna accepts energy demand bids and supply offers in order to provide its service of secondary control and to balance energy injections and withdrawals into/from the grid in real time.

The Forward Electricity Market (energy market) is the venue where forward electricity contracts with delivery and withdrawal obligations are traded.

- All Electricity Market Participants are automatically admitted to the MTE.
- Trading in the MTE takes place on a continuous basis.
- In the MTE, the tradable contracts are of the following types: Base-Load and Peak-Load, with monthly, quarterly and yearly delivery periods. ([Technical Rule no. 01 rev 4 MTE](#)). The contracts with quarterly and yearly delivery periods are regulated by the “cascading” mechanism.
- Market Participants submit orders where they specify the type and period of delivery of the contracts, the number of contracts and the price at which they are willing to purchase/sell.
- After the trading period, the contracts with monthly delivery are registered as corresponding transactions onto the PCE, after the adequacy verifications that are referred to in the PCE Rules.
- Also OTC contracts may be registered in the MTE.
- GME acts as a central counterpart.

The sessions take place from Monday to Friday, from 09:00 to 17:30, except on the next-to-the-last day of open market of each month, when the closing time is brought forward to 14:00 for operational reasons.

The sessions of the MTE are held every day except on:
- all Saturdays;
- all Sundays;
- 1 January;
- Friday before Easter;
- Monday after Easter;
- 1 May;
- 15 August;
- 24 December;
- 25 December;
- 26 December;
- 31 December;

- **Simplified Purchase and Resale Arrangements for small renewable energy plants**

GSE has offered simplified purchase & resale arrangements (ritiro dedicato) to small producers since 1 January 2008. Under these arrangements (AEEG's Decision 280/07), producers sell the electricity generated and to be injected into the grid to GSE, instead of selling it through bilateral contracts or directly on IPEX.

An agreement is entered into between the producer and GSE, whereby GSE:

- purchases and resells the electricity to be fed into the grid at the zonal price or at a minimum guaranteed price;
- on behalf of the producer, transfers the fees for the use of the grid (dispatch and transmission fees) to distributors and to the TSO.

Eligible parties are the producers with:
- plants having a nominal apparent power of less than 10 MVA: RES plants or hybrid plants for the portion of electricity generated from RES;
- plants of any capacity using the following RES
  - wind;
  - solar;
  - geothermal;
  - waves;
  - tides;
  - hydro (run-of-river only);
• plants with a nominal apparent power of less than 10 MVA: non-RES plants or hybrid plants for the portion of electricity generated from non-RES;
• plants having a nominal apparent power greater than or equal to 10 MVA: plants using RES other than wind, solar, geothermal, waves, tides and hydro (run-of-river only), provided that they are owned by a self-producer (as defined in article 2, para. 2, Legislative Decree 79/99).

The price applied to the electricity purchased by GSE and injected into the grid is the "average zonal price", i.e. the average monthly price per hourly band which is set on IPEX for the market area to which the plant is connected. Producers with small-sized plants (with a nominal electrical capacity of up to 1 MW) benefit from “guaranteed minimum prices” for the first 2 million kWh per year and they may get more if the hourly zonal prices prove to be more advantageous. The guaranteed minimum prices are updated annually by AEEG. At the end of each year, GSE makes adjustments for plants in respect of which the revenue associated with the hourly zonal prices proves to be higher than the one resulting from the application of the minimum guaranteed prices.

The simplified purchase & resale arrangements are not compatible with net metering (scambio sul posto), with the all-inclusive feed-in tariff.

• Net Metering for small renewable energy plants

Since 1 Jan. 2009, AEEG (Decision ARG/elt 74/08, as subsequently amended and supplemented by Decision ARG/elt 186/09) has assigned to GSE the management of the net metering service (scambio sul posto). This service is activated at the request of interested parties. Under the service, the electricity generated by a consumer/producer in an eligible on site plant and injected into the grid can be used to offset the electricity withdrawn from the grid. GSE pays a contribution to the customer based on injections and withdrawals of electricity in a given calendar year and on their respective market values.

Under AEEG’s Decision ARG/elt 74/08, GSE has the role of managing net metering and paying the related contribution, which covers part of the charges incurred by the customer for withdrawing electricity from the grid. GSE determines the contribution taking into account: the characteristics of the plant, the contractual conditions between the customer and his/her supplier and the data that grid operators and suppliers are required to periodically report to GSE. To know more about the calculation of the net metering contribution, refer to AEEG’s Decision ARG/elt 74/08.

Eligible plants
Owners of one of more of the following plants may apply for the net metering service:
• RES-E plants with a capacity of up to 20 kW;
• RES-E plants with a capacity of up to 200 kW (commissioned after 31 Dec. 2007);
• high-efficiency CHP plants with a capacity of up to 200 kW.

Net metering is not compatible with the simplified purchase & resale arrangements (ritiro dedicato) and with the all-inclusive feed-in tariff (tariffa onnicomprensiva).
• **Feed-in scheme**

The feed-in scheme is the programme which *grants incentives* for electricity generated by photovoltaic (PV) plants connected to the grid.

Italy introduced this support scheme in 2005 (Ministerial Decree of 28 July 2005 – 1st feed-in scheme).

The Ministerial Decree of 5 Jul. 2012 (published in “Gazzetta Ufficiale” no. 159 of 10 Jul. 2012) - the so-called 5th feed-in scheme - redefines the rules on support for solar photovoltaic power generation.

The 5th feed-in scheme will cease to have effect 30 calendar days after reaching an indicative cumulative cost of incentives of € 6.7 billion per year (including costs allocated for plants whose position in the relevant Registries does not exceed the applicable cost limit). Based on the data reported by GSE through its Photovoltaic counter, AEEG will determine the cessation of the scheme.

The tariffs of the 5th feed-in scheme are granted to the following types of plants:

- PV plants, divided by type of installation (art. 7, Ministerial Decree of 5 Jul. 2012);
- BIPV plants with innovative features (art. 8);
- CSP plants (art. 9).

Under the above-mentioned Decree, the plants eligible for feed-in tariffs may be new, upgraded, or totally renovated.

**The tariffs of the 5th feed-in scheme are alternative to net metering, simplified purchase & resale arrangements and sale of electricity in the market (only for plants with a capacity of up to 1 MW).**

Unlike the previous support schemes, the 5th feed-in scheme grants an *all-inclusive feed-in tariff* to the share of net electricity injected into the grid and a *premium tariff* to the share of net electricity consumed on-site.

In particular, without prejudice to AEEG’s Decisions on dispatching, GSE will award the following tariffs under the 5th feed-in scheme:

- for the share of net generation injected into the grid
- by plants with a nominal capacity of up to 1 MW, an all-inclusive tariff based on the capacity and type of plant; this tariff is granted to PV plants, BIPV plants with innovative features and CSP plants;
- by plants with a nominal capacity of above 1 MW, the difference (if positive) between the all-inclusive tariff and the hourly zonal price; if the hourly zonal price is negative, this difference will not exceed the amount of the all-inclusive tariff applicable to the plant, depending on its capacity and type, as well as on the reference half-year. The electricity generated by plants with a nominal capacity of above 1 MW will remain available to the producer. The monthly hourly zonal prices will be posted on the website of GME.
- for the share of net generation consumed on site, a premium tariff.

Thus, if a plant generates electricity for self-consumption, the applicable tariff will be given by the sum of the all-inclusive tariff for the share of net generation injected into the grid and of the premium tariff for the share of net generation consumed on-site.

**PV plants** with a nominal capacity of **below 20 kW** which i) are only used for supplying **direct-current** consumers, ii) are connected to the power grid, and iii) do not inject electricity into the grid, will only get a premium tariff for the net electricity consumed on site.
As established by the Ministerial Decree of 5 Jul. 2012, the values of the two tariffs (all-inclusive and premium) will progressively decrease in the half-years of application of the 5th feed-in scheme, beginning on 27 Aug. 2012.

The **tariff** will be the one applicable upon the date of commissioning of the plant and will be paid over a period of 20 years beginning thereon.

The **value of the feed-in tariff will remain constant** throughout the support period, after deducting periods of outage, if any, required by grid security or due to disasters (as determined by the relevant authorities).

- **Electromobility**

Although the sector can be considered at a very early stage of development, understanding the trends in the electric vehicles market is very important in order to define the related potential demand of energy storage systems, not only in terms of volume but especially of characteristics of the network and connections with transport infrastructure and territory.

The market trends for BEV and PHEV in Italy haven’t shown relevant increases in recent years, although a rise in interest among potential demand is increasing for several reasons such as environment awareness, fuel costs, technology, etc. and despite main obstacles such as purchasing cost, range anxiety, availability of charging infrastructure. Moreover, an increased attention has been reported in the field of fleet management, due to positive expectations in terms of total cost of ownership as well as in terms of new business models for private mobility (innovative car-sharing options, last-mile mobility, micro-mobility, etc.)

According to recent surveys, main relevant issues for the Italian market are represented by higher expectations in terms of range, and quality/cost ratio. Charging infrastructure, although relevant, is not perceived as the main issue since the first requirement is represented by an extended range. Moreover, customers expect the development of new car concepts not simply derived from traditional ICE models but highly innovative, and last but not least a key element of success for the market is perceived to be the development of a new and more competitive market for batteries, in order to lower the price and raise the potential performance of e-vehicles.

In order to help market development for e-mobility, a long (and still ongoing) debate at political level resulted in 2012 in a range of measures included in the Legislative Decree 22.06.2012 n° 83 (so called “Decreto Sviluppo”). The main relevant ones deal with the simplification of rules for the development of a charging network, the establishment of a national infrastructure plan for electric vehicles charging infrastructure (defining the guidelines for the development of the network), and incentives for the purchasing of low emission vehicles. In particular, this last point may result in ambiguous effects on the development of the market, since it may strengthen the competitiveness of alternative fuels such as CNG and LPG, already quite strong on the automotive market in the last few years.

Concerning energy tariff for electromobility, this is regulated according to the already mentioned AEEG decision ARG/elt 242/10 for public charging, while for private charging (business or domestic) the AEEG decision ARG/elt 56/10 considers it in the “other uses” tariff category.

On private charging, commercial offers have now been developed in strong collaboration between energy and charging service providers and vehicles suppliers. An interesting experience is provided by B2B energy providers including in their offers e-vehicle fleets and dedicated charging infrastructure, in order to provide better market conditions for the take-off of electromobility.
Concerning public charging, AEEG decision ARG/elt 242/10 establishes a common network tariff, expressed in c€/kWh, in order to avoid an equal distribution of fixed distribution costs. Moreover, special conditions for the demonstration project awarded were set, in terms of a common tariff including network costs and charging infrastructure costs (14,3294 c€/kWh for 2011).

The demonstration projects selected by AEEG and currently ongoing are the following:

- Enel Distribuzione-Hera SpA, (distribution model), 100 charging points;
- A2A SpA (service provider, monovendor), 165 charging points;
- Comune di Parma (service provider, monovendor);
- Enel Energia SpA (service provider, multivendor), 6 charging points;
- Class Onlus (service provider, multivendor), 25 charging points.

Moreover, other public charging infrastructure development projects are being developed across the territory at different levels, for which a complete overview is not available at national level. The main relevant ones are being developed by Enel (e-mobility) and A2A (e-moving) with the collaboration of municipalities and automotive players.

In general, the market for public charging infrastructure is at an early stage in Italy, although several initiatives are under development. The establishment of an European Electromobility Observatory expected for 2013 will help to provide a more detailed picture, gathering relevant information on development projects in different regions.
8. R&D

- **TERNA “Storage Lab”**
  In its “Strategic Plan 2012-2016” TERNA provides, in addition to € 4.1 billion for the security and the modernisation of the HT electricity grid, about € 1 billion for the construction of battery-powered storage systems for total power installed of 240 MW. These investments will be approved on condition of obtaining a fair return, as provided by the resolution 288/2012/R/EEL of the Italian Authority for Electric Energy and Gas in case of approval of the TERNA pilot project.

  In this context, the Storage Lab (TBD) is a project conceived by TERNA and aimed at providing a privileged observatory on the state of the art technology for the realisation of energy storage systems, that are becoming increasingly necessary with the great development of renewable energy that affects Italy. The vast majority of technological solution storage systems currently available, in fact, require an appropriate experimentation before being judged suitable.

  In particular, the project Storage Lab aims to identify:
  - the right mix of technologies to optimise the cost/benefit ratio to mitigate the technological risks;
  - actions to be followed to ensure the safety of the electrical system;
  - the characteristics of each of proven technologies (useful life, time of realization, efficiency, performance, etc.);
  - possible solutions associated to each “Smart Grid” technology.

- **RSE**
  In the context of storage systems, the R&D activities conducted by RSE regards mainly:
  - the characterisation of lithium batteries;
  - the design of a storage system;
  - the definition of a procedure for characterisation of the batteries.

  In the field of the Zebra batteries RSE developed a control system for the optimal management of the charging of several batteries Zebra in parallel within a storage system connected to the LV network.

  On lithium batteries and battery Zebra RSE led dynamic stress tests to analyze the behavior of the storage systems used in a typical vehicular application.

  With regards to electrochemical storage RSE realized a test station for the experimental characterisation of sodium-sulphur and sodium-nickel-chloride cell in order to evaluate the behaviour from the point of view of heat exchange (as well as electrochemical).

  RSE carries out research and development also in the field of Hydrogen storage (see also chapter 3 – Hydrostore project) and on the impact of EV on the National Electric System.

- **ENEA**
  Similarly to RSE, ENEA undertakes R&D in the field of energy storage technologies with particular regards to Li-ion batteries and supercapacitors for industrial and service sectors.

  In particular, in the period 2011-2012, the activities were related to:
- research on materials and processes to improve the performance of the cathode and anode elements;
- construction and testing of finished cells from the laboratory;
- design, implementation and testing of control technologies and power interface significant (10-20 kW) of the storage system with the network and with particular uses;
- experimental validations of a house with mixed storage strategies (thermal and electrical) in a logic of "active house";
- definition and evaluation of test profiles to verify the extension of the "second life" of lithium batteries used in electric vehicles;
- investigation of potential applications in the national electricity grid storage systems alternative to the electrochemical systems such as new water pumping and the storage of compressed air (CAES).

- **ENEL Distribuzione**

Enel Distribuzione is developing some projects regarding smart grids, provided with storage, Enel Distribuzione have 6 pilot projects to test the ESS functions for the distribution network. ESS connected to HV/MV substation can contribute to reducing costs for power reserve for the electrical system. In the case of positive pilots Enel Distribuzione identified 46 further installations for the coming years.

**ISERNIA SMART GRID**

The objective of the Isernia Project is to combine the generation from distributed energy resources with a reliable and safe management of the system under real operating conditions. The Isernia project, approved by the city of Isernia in the Molise region (Italy), will test, in the field, an innovative model for the protection, automation and management of power generation in the distribution network according to the principles of smart grids. The geography and climate of Isernia offers the perfect setting to fully exploit solar, hydroelectric and biogas efficiently integrate renewable energy sources into the distribution network. The Isernia project has recently won a competition-based procedure launched by the Italian regulator (AEEG) granting incentives to innovative smart grids pilot projects. The project offers a new approach to distributed generation management which monitors the active involvement of both distributors and customers, recognized as prosumers (producer-consumers) of energy. Monitoring occurs through a broadband connection, based on a Wi-Max communication protocol and a fibre optics communications infrastructure which depends on the remote management system implemented across the territory with the electronic meter. The project will be developed around the primary cabin in Carpinone and will include the installation of nearly 8,000 ‘Smart Info’ devices for customers connected to the low voltage grid. The devices will supply information about changes in the price of energy based on time slots, promoting efficient use and increasing active customer participation in the management of the system. The project also includes the installation of a charging station to power a fleet of five electric vehicles, integrated with a photovoltaic plant and a multi-functional storage system. The storage system may also be used for the management of medium voltage lines, or peak shavings and load profiling, and will be able to replace the charging system or receive energy directly from the photovoltaic plant.
Figure 27: Isernia Smart Grid project (source: Enel Spa – Infrastructure and Network Division)

- **Project period:** 3 years, from 2011 to 2014
- **Investment:** nearly 7 million euro.
- **ESS main characteristics:**
  - Battery technology: Li-ion
  - Max power: 1 MVA
  - Energy capacity: 500 kWh
  - Number of cycles: 2000
  - Efficiency: 85%
  - Installation area: 90 m²

Figure 28: Isernia smart grid architecture (source: Enel Spa – Infrastructure and Network Division)
GRID4EU PROJECT

The goal of the GRID4EU project is to carry on demonstration pilots of Smart Grid solutions on a large-scale basis. The project involves 27 partners in 12 EU countries; it is coordinated by ERDF, the main French distribution company, and has its technical management belonging to Enel. The initiative will implement 6 demonstration projects in 6 EU countries (Italy, France, Germany, Sweden, Spain and the Czech Republic), to be integrated into a single one. It proposes solutions that go beyond the existing limits for electricity networks through the large-scale integration of distributed generation, the improvement of energy efficiency, the enabling and integration of active demand and new electricity uses.

In this framework Enel will perform a project focused on the integration into the distribution grid of energy production from renewable sources through advanced control systems; the budget for the Enel project amounts...
to 8.2 million Euro. It will be carried out in the Forlì-Cesena area, together with other 4 partners (Ricerca sul Sistema Energetico - RSE, Selta, Siemens, and Cisco). Activities in the region of Romagna will be performed in two high and medium voltage substations and the corresponding medium voltage network.

The core of the project is an advanced control system, which will communicate through a broadband communication system with the renewable generators and with all the relevant facilities of the medium voltage network, including a storage device. The resulting system will therefore be able to control power flows and voltage levels to properly integrate distributed generation in the network, as well as testing energy storage to enhance network operations. In particular, thanks to this particular installation it will be possible to “move” the storage in different feeders depending of the results of an optimization procedure (ESS optimal location).

- **Investment**: 54 million euro
- **Project period**: 4 years, from 2011 to 2015
- **Partners**: 27, including 6 Electricity energy distributors: Enel, Cez, Rwe, Erdf, Iberdrola, Vattenfall.
- **ESS main characteristics:**
  - Battery technology: Elettrochemical
  - Max power: 1 MVA
  - Energy capacity: 1 MWh
  - Number of cycles: 2000
  - Efficiency: > 80%

**VENTOTENE PROJECT**

On the Ventotene island an ESS will be installed by Enel Prodotuzione for renewable energy integration and network stabilization. The network is a MV microgrid not connected to the Italian transmission/distribution system, where electrical energy is supplied by a diesel generator and several other dispersed generators. The goal is to increase the hosting capacity of the grid allowing the connection of new renewable sources. Moreover, the installation of the storage system will optimize the load curve of the diesel generator (enabling cost reductions) and stabilize the network.

- **ESS main characteristics:**
  - Battery technology: Li-ion
  - Max power: 1 MVA
  - Energy capacity: 500 kWh
  - Number of cycles: 2500
  - Efficiency: 85%

- **Ventotene scenario:**
  - Load: 0.15 MVA ÷ 1.15 MVA
  - Not renewable installed power: 4 Diesel generators for total 2.7 MVA
  - Renewable installed power and new request: 76 kW today, new request for 74 kW
  - Min Load = Max renewable generation → NO hosting capacity without ESS
INTERREGIONAL OPERATIONAL PROGRAM (POI)xx
The Interregional Operational Program (POI), approved in 2007 by the European Commission and to be completed by 2013, aims to increase energy consumption produced by renewable sources and to promote local development opportunities by enhancing energy efficiency.
Focal points of POI are the so-called Italian “convergence regions”, namely Campania, Calabria, Puglia, and Sicily, which are working with Enel on the network’s reinforcement and innovation. Each region has a pilot program to increase the availability of medium voltage network, with direct benefits for both distributor and consumers, whether private or company. POI projects will improve voltage regulation, preventing unwanted effects of momentary interruptions, and will help to better connect renewable plants.
In order to improve the development and implementation of distributed generation, the POI will develop a broadband communication network between the medium voltage network and substation, generators and loads. The Programme also helps to improve remote control systems, the Remote Terminal Unit used across the grid-controlled area and control systems for the so-called “prosumers”, meaning those consumers who own renewable plants and communicate with the network as central distributed generation players.
Three ESS will be used to reduce the variability of the power flow in the parts of the network with high penetration of RES, alleviating fast power flow variations in case of wind gusts or passage of clouds. In particular, the ESS will be used to control energy exchange profiles between the HV/MV substations and the National Grid to make them more predictable (1h - 24h ahead).

- Project duration: 2007-2013
- Funds: 77 million Euro (part of which dedicated to Smart Grids technologies)
- Project partners: Enel, the Regional Government of Campania, Calabria, Puglia and Sicily
- ESS main characteristics:
  - Battery technology: Li-ion
  - Max power: 2 MVA
  - Energy capacity: 1 MWh (2), 2 MWh (1)
  - Number of cycles: 2000 ÷ 4000
  - Efficiency: 85%
- Max installation area: 200 m²/MWh

Figure 32: POI Regions (source: Enel Spa – Infrastructure and Network Division)
APPENDIX and supplementary material

Index

a. Review of existing sources and literature
b. Key contacts and resources
c. Other material
d. Review of existing sources and literature

- Statistical Report 2011 Renewable Energy sources power plants – *GSE Gestore Servizi Energetici*
- Statistical data on electricity in Italy in 2011 – *TERNA S.p.A.*
- Energy storages: ongoing projects and initiatives – *Dott. Enrico Senatore Responsabile Battery Storage – Terna Plus*
- ENEL plans for storage introduction in Italian distribution network - *Christian Noce Network technologies system manager Enel SpA – Infrastructure and Network division*
- Electric storage: pump systems and CAES – *Antonio Negri RSE Ricerca Sistema Elettrico*
- Elettrochemical energy storage: projects and initiatives by Terna – *Ing. Angelo Ferrante Direzione Regolatorio, Commerciale e Pianificazione rete TERNA*
- Annual Report 2011 – *GME Gestore Mercati Energetici*
- Electricity storage – *RSEview Reflections on Energy – Il Melograno Editore*
- The root of the electric devolution – *RSEview Reflections on Energy – Editrice Alkes*
- The power and energy storage contribute to the improvement of the distribution network quality and efficiency – *C. Bossi, S. Grillo, R. Lazzari, E. Micolano, E. Tironi – RSE SpA, Dipartimento Sistemi di Generazione; Politecnico di Milano, Dipartimento di Elettrotecnica*
b. Key contacts and resources

- Autorità per l’energia elettrica e il gas (Energy Authority) - [www.autorita.energia.it](http://www.autorita.energia.it) - Piazza Cavour, 5 - 20121 Milan - tel. +39 02 655651 - fax +39 02 65565266
- Enel S.p.A. - [http://www.enel.it](http://www.enel.it)
- Terna S.p.A. - Rete Elettrica Nazionale – [www.terna.it](http://www.terna.it) - Roma - Viale Egidio Galbani, 70 – 00156 tel. +39 06 8313 8111 mail: info@terna.it
- Gestore dei Servizi Energetici – GSE S.p.A. – [www.gse.it](http://www.gse.it) - V.le Maresciallo Pilsudski, 92 – 00197 Roma tel +39 06.8011.1 mail: info@gse.it
- Gestore dei Mercati Energetici S.p.A. – [http://www.mercatoelettrico.org/En/Default.aspx](http://www.mercatoelettrico.org/En/Default.aspx) - largo Giuseppe Tartini, 3/4 00198 Rome Italy ph: +39 06 8012 1 fax: +39 06 8012 4524 mail: info@mercatoelettrico.org PEC: gme@pec.mercatoelettrico.org
- SAPIO Srl - [http://www.grupposapio.it/](http://www.grupposapio.it/) - Via Silvio Pellico 48 20052 Monza Tel +39(039)83981 fax +39(039)836068 mail: gruppo@sapio.it
- FIAMM – [http://www.fiamm.com](http://www.fiamm.com/)
c. Other material
d. Endnotes

a GESTORE SERVIZI ENERGETICI, Rapporto Statistico 2011 Impianti a fonti rinnovabili, p. 5

b GESTORE SERVIZI ENERGETICI, Rapporto Statistico 2011 Impianti a fonti rinnovabili, p. 10

c ALPSTORE PARTNERS, Virtual Power Systems White Book version n.4


e ZERO REGIO PROJECT, http://www.zeroregio.com

f HYDROSTORE PROJECT, http://www.progetto-hydrostore.it/

g ELECTRO POWER SYSTEMS, http://www.electropowersystems.com/

i HYSY LAB PROJECT, http://www.envipark.com/

j HYDROGEN PARK, http://www.hydrogenpark.com/


l VIESSMANN, http://www.viessmann.it/it/service/area_stampa/comunicati_di_prodotto/VItosorp_200-F.html

m FEDERICO SANTI, UNIVERSITÁ LA SAPIENZA DI ROMA, Presentation at the Energy storage forum 2012 in Rome

n ENEL, http://energyviews.enel.it/data

o Terna, Annuario statistico Terna 2011 – Sezione Produzione

p M. FALCHETTA, A. MACCARI, ENEA, Calore ad alta temperatura dal sole per produrre elettricità e idrogeno

q ESTIF (European Solar Thermal Industry Federation), Trends and market statistics 2011

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u AUTORITÁ DI GESTIONE, http://www.autorita.energia.it/it/docs/12/084-12.htm

v AUTORITÁ ENERGIA, http://www.autorita.energia.it/it/docs/08/033-08arg.htm

w CEIWEB, http://www.ceiweb.it/struttura/body-news-notizia1.html

x AUTORITÁ ENERGIA, http://www.autorita.energia.it/it/docs/12/281-12.htm


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**cc** AUTORITÁ ENERGIA, http://www.autorita.energia.it/it/docs/10/039-10arg.htm

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**hh** AUTORITÁ ENERGIA, http://www.autorita.energia.it/it/docs/12/242-10arg.htm

**ii** AUTORITÁ ENERGIA, http://www.autorita.energia.it/it/docs/10/242-10arg.htm


**ll** GME - Gestore Mercati Energetici, http://www.mercatoelettrico.org/En/Mercati/MercatoElettrico/IlMercatoElettrico.aspx

**mm** GSE - Gestore Servizi Energetici, http://www.gse.it/en/ridssp/SimplifiedPurchaseandResaleArrangements(RID)/Pages/default.aspx


**oo** DELOITTE, Osservatorio auto elettrica 2012, 2012

**pp** ANGELO FERRANTE, TERNA, Accumulo elettrochimico dell’energia Progetti ed iniziative

**qq** RSE, http://www.rse-web.it/temi/sottotema/19?objId=5

**rr** ANTONIO NEGRI, RSE, L’accumulo di energia elettrica: pompaggio e CAES


**tt** ENEA, http://www.enea.it/it/Ricerca_sviluppo/ricerca-di-sistema-elettrico/accumulo-di-energia-elettrica

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