Smart Grids:a slogan,an opportunity or a necessity ?

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1. A global energy view

- World population now 7 billion people: (300000 births/day).
- In the last 10 years: population +12%; primary energy +20%; electricity +30%
- 1.3 billion human beings with no electricity.
- Electric Energy consumption in 2030 will be double quantity of 2007 with 44% of primary energy resources for its production (36% in 2007).

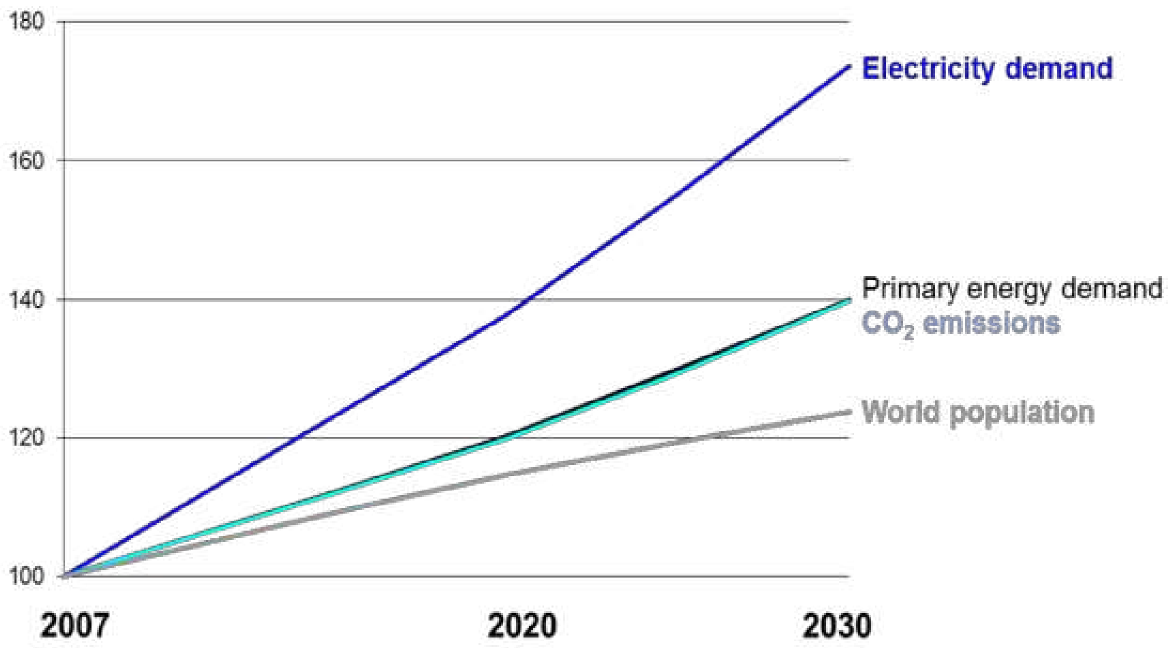
Worldwide 40% of CO_2 emissions connected to energy are caused by production of electricity : 12 billion t/year. EU quota – part now: 14% (8% in 2020); Italy 2% now.

Electricity is more and more important.

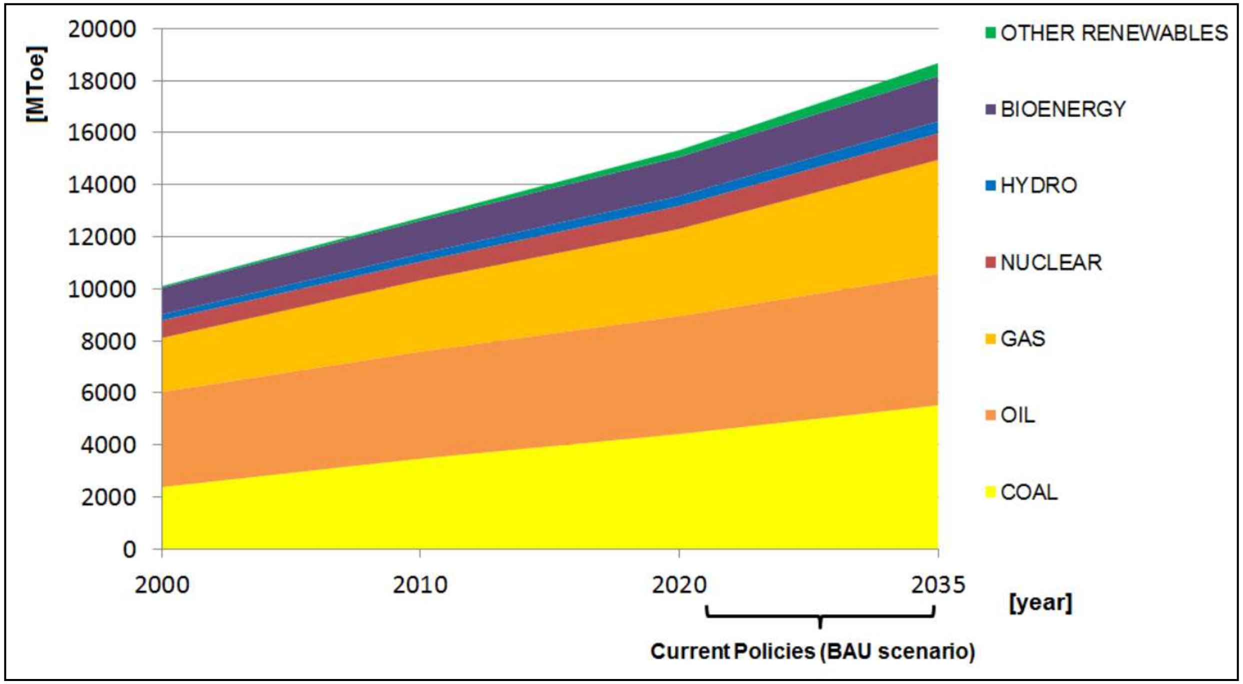
What are the prevailing trends impacting energy?

- Growth in population, increased urbanization/large cities,
- Living standards and demand increase especially in LDC's,
- CO_2 emissions :possible limits

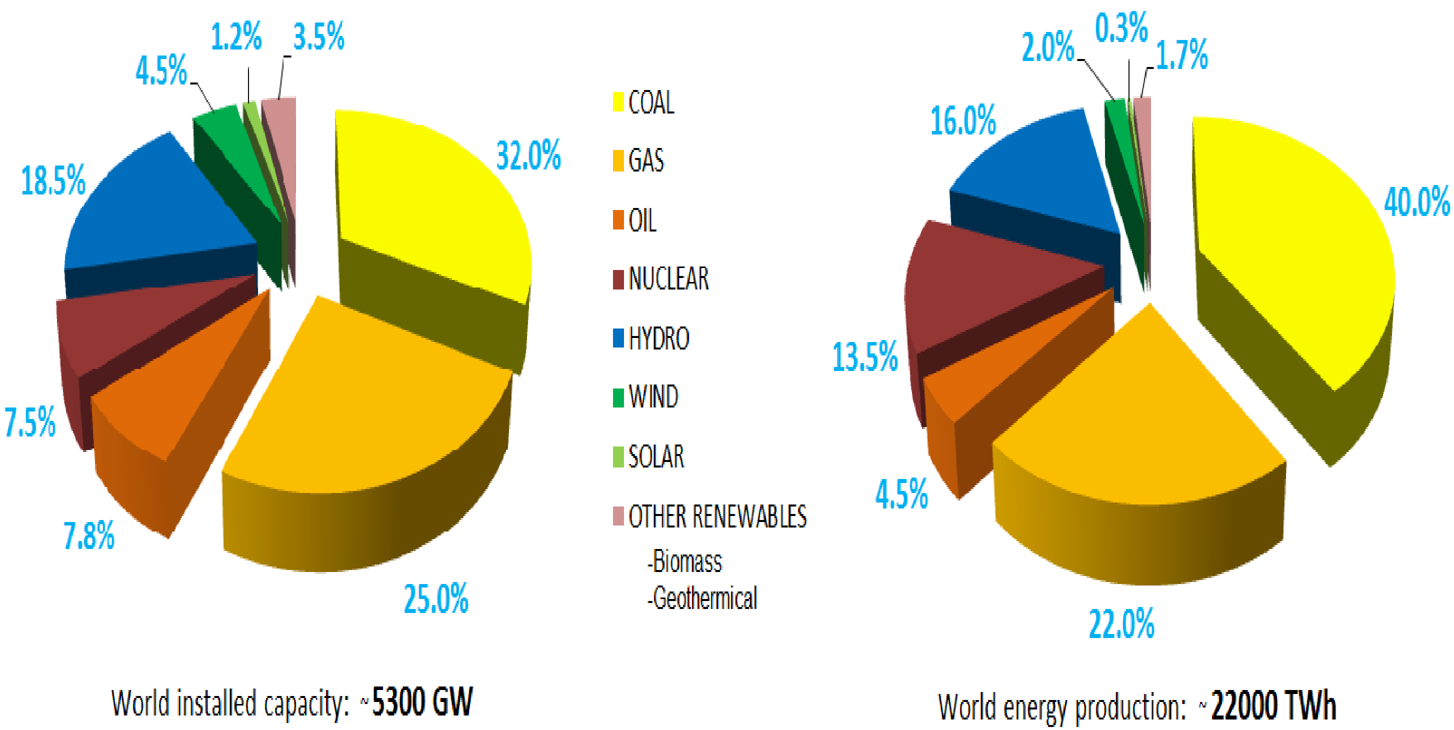
Source: International Energy Agency, Global Insight



Primary energy demand in the world – BAU scenario (source IEA 2012 World Energy Outlook)



Electricity installed capacity and energy production worldwide (source Terna and CESI elaborations)



Trend over the last decade for the power production worldwide from different primary resources (CESI elaborations from IEA data)

	2001		2010	
Coal	38.7%	64.7%	41.7%	66.6%
Oil	7.4%		4.2%	
Natural Gas	18.6%		20.7%	
Nuclear	17.1%		13.4%	
Hydro	16.5%	18.2%	16.2%	20%
Biomass	1.1%		1.5%	
Other Renewable	0.6%		2.3%	

Conventional fossil fuel resources have a reserve (R) to present consumption (C) ratio R/C

200 years for coal,
60 years for natural gas and
40 years for oil.

But the technology developments and the high price of oil at around 100$/barrel make convenient also the use of **huge reserves of unconventional oil and unconventional gas** (see the shale gas revolution in USA) which are around 3 times those of the conventional fuels.

Fossil fuels availability is therefore not a real problem for 200 years; the key issues are:

- their reserves are unevenly distributed between production and consumption areas with the well-known socio-political implications;
- the possible impact on environment for their extraction, production and “burning”.

2. The electrical system

Electricity Around the World

Industrialised nations:

Transformation of the electricity energy system from vertical integration to unbundled situation: generation (market)- transmission / distribution (concessions) - sales (market)

→ Environmental concerns - Market rules - Financing

Growing economies:

Quick development of the electrical system with local/cheap energy sources

→ Making energy available

Poor regions:

Fight against energy poverty

→ Political instability - Financing

An Electrical system ranges from power generation, transmission, distribution to final consumption.

Key issue is the reliable and economic flow of energy at any time from any generating plant to any load.

Deregulation and the opening of markets have pushed for unbundling of:

- Production P
- Transmission T
- Distribution D
- Sales S

and this with proliferation of entities, split responsibilities, different / conflicting interests.

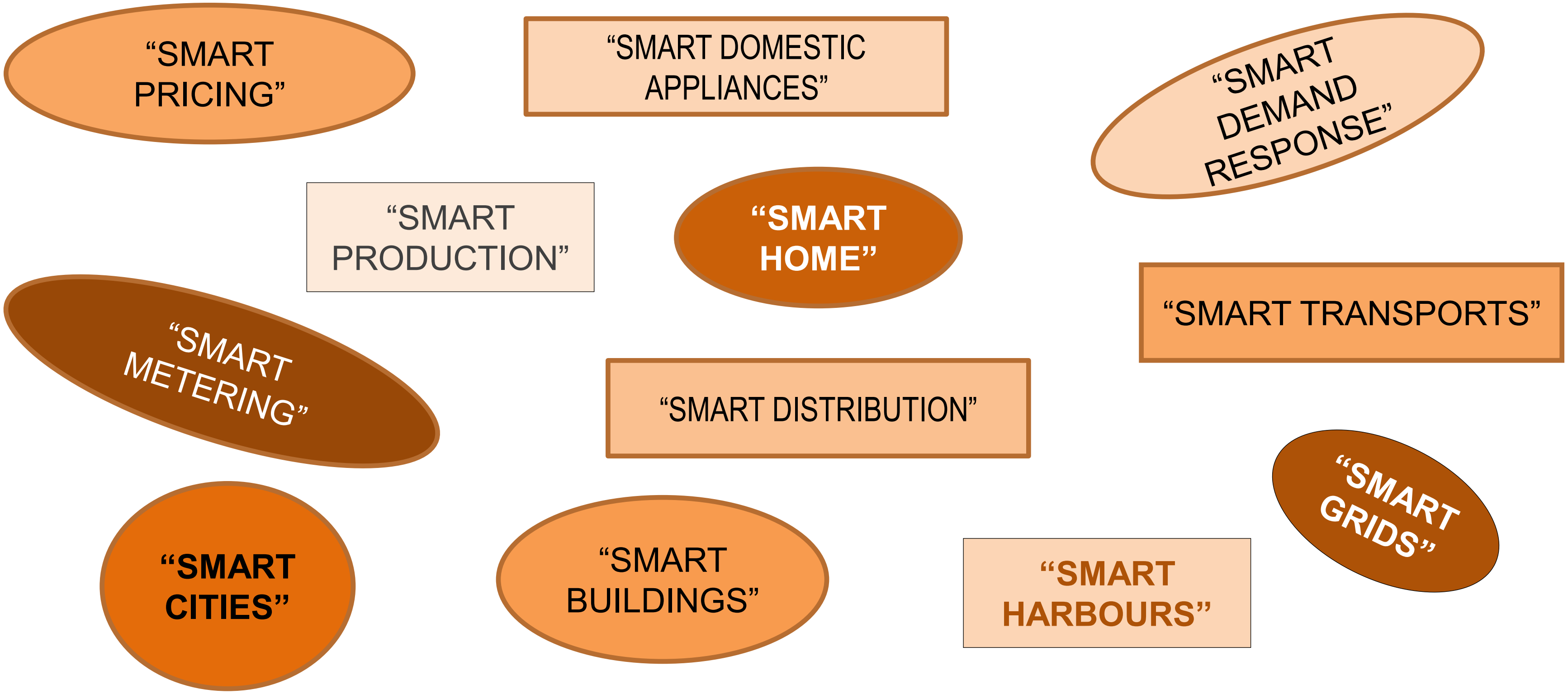
On the other hand:

- Environmental issues.
- Increased of RES penetration (both large/bulk and distributed).
- Increased demand response systems.
- The always increasing difficulty to build new transmission lines and substations.
- The development of Technologies in both the electric “power industry” and in the ICT arena.

are pushing for a better and indispensable integration of the operation of P - T – D and clients/”prosumers”.

3. Smart grids

Everything is becoming "smart". Some titles of newspapers:



Smart… smart… smart…

We are fed up

A smart grid (or better system) is an evolved electrical system from any type of production to consumers that manages the electricity production, transmission, distribution and demand through measuring, communicating, elaborating and controlling all the on line quantities of interest with transparent info accessible to all the involved stakeholders; this to optimize the valorization of assets and the reliable and economic operation allowing adequate global savings with smart sharing of cost and benefits among all the involved.

And who is going to pay is a key issue.

For smart grids:

- Advanced hardware (power system infrastructures)
- Advanced ICT's (and a terrific number of data are involved)

are the key ingredients

ICT is an asset but... without adequate infrastructures does not solve the problem; ICT cannot control the flow of electrons if there are no adequate overhead lines (OHTL's) and substations.

But also vice versa, there is no optimum utilization of power system infrastructures without ICT.

Smart grid concept comprises a lot of interacting “subsystems”.Let us however consider here 3 different subchapters

- Supergrids / Interconnections
- Distribution systems
- Generation fleets

4 .Interconnections/Transmission

Evolution of the role of interconnections

- Reserve capacity sharing, peak shaving and mutual support facing large perturbations
- Energy exchanges on the basis of pre - established contracts (usually long term contracts)
- Cross-border exchanges based on short - mid term contracts
- Mean to foster a higher penetration of RES with consequent reduction of GHG emission

Enhanced profitability of large interconnections when accounting for CO_2 emission costs: optimum use of sustainable resources

FACTS: Flexible Alternating Current Trans. Systems

- A variety of power electronic equipment for application in transmission systems has been developed over the last few decades. The incentive has been the need for:
  - better load flow control;
  - improved system dynamics;
  - and better voltage control.
- FACTS devices help in increasing transport capacity, in avoiding loop power flows,in improving transient and dynamic stability etc

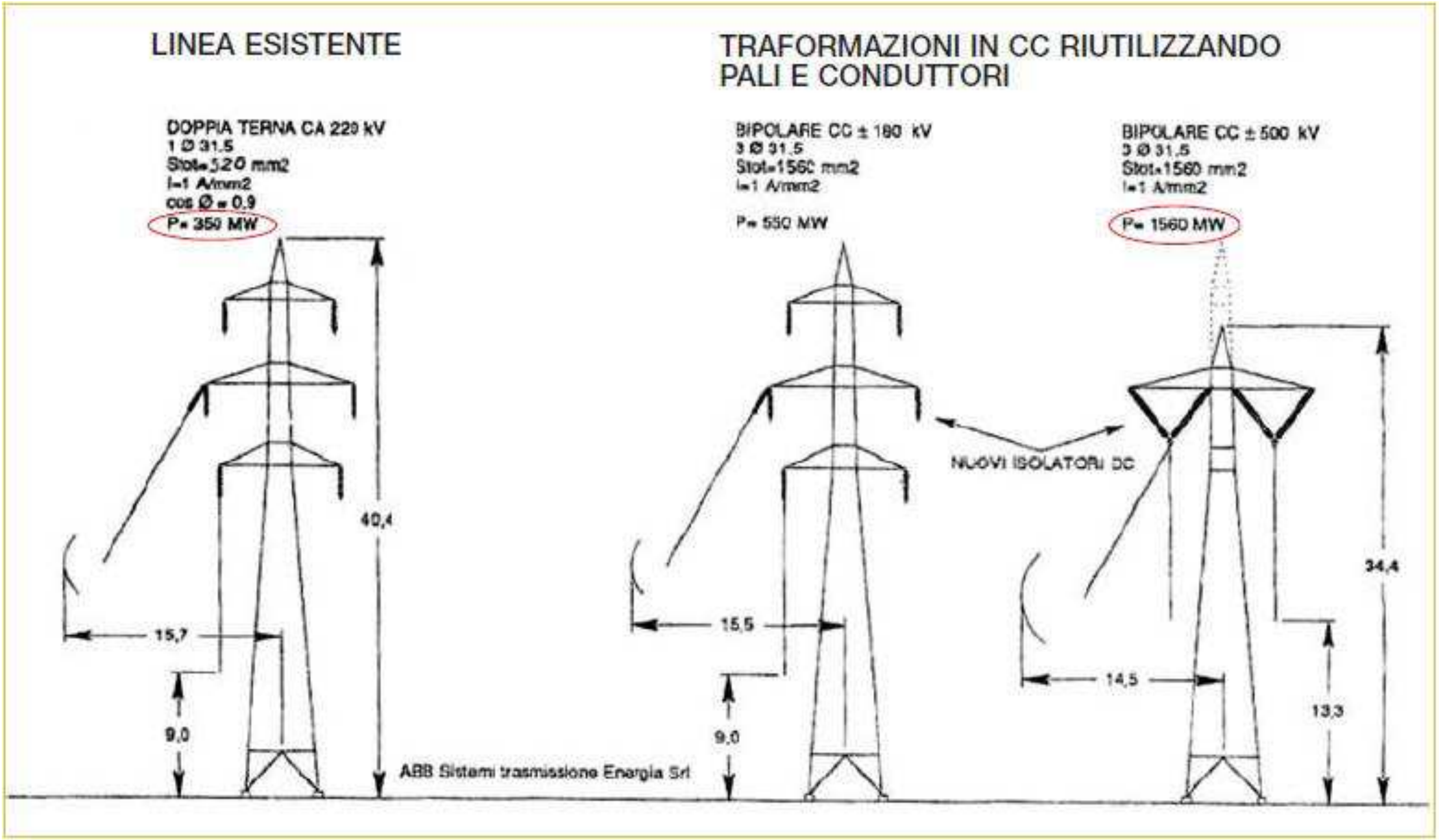
Considering the key bottle neck in electrical power systems is transmission, the quick application of smart grid concepts to transmission should be implemented as soon as possible to maximize the utilization of existing assets.

And smart grid concepts include “smart upgrading” of existing transmission line corridors and optimum utilization of substations with relevant transformers.

For upgrading of existing OHTL corridors, one could adopt:

- New special conductors with higher current capacity and less sags;
- Modification / substitution of an existing AC line with another one at higher voltage;
- Transformation of an AC line to a DC one with substantial power increase.

Possible transformation of Italian 220 kV AC lines to HVDC



Better utilization of existing OHTL's (dynamic loading)

OHTL's have:

- a summer current limit (and consequent power) valid for all the summer months/hours;
- a winter current limit valid for all the winter months/hours.

based on critical / extreme ambient wind / temperature to avoid excessive sags of conductors.

An on line monitoring of conductor current/ temperature, sags and ambient conditions (LTM Line Thermal Monitoring):

- **allows larger transfer capacity in the great majority of hours;**
- **allows an alleviation of N-1 conditions (to be reconsidered)**.

Effect on standards and operating rules

Better utilization of trafos

- Also trafos have pass-through power limits depending from ambient conditions and actual hot spot temperature.
- Trafos are usually working in parallel at 50% of load to avoid overloading of the parallel one in case of a trafo fault.
- **Adequate monitoring and diagnostics systems and control of ambient and winding hot spot temperature would increase the utilization of the machines both in normal and emergency conditions**; this minimizes:
  - Possible consequences on the transmission system from transformer faults;
  - Restrictions of operation for possible overloads that are not overloads in many specific conditions.

Distribution Systems

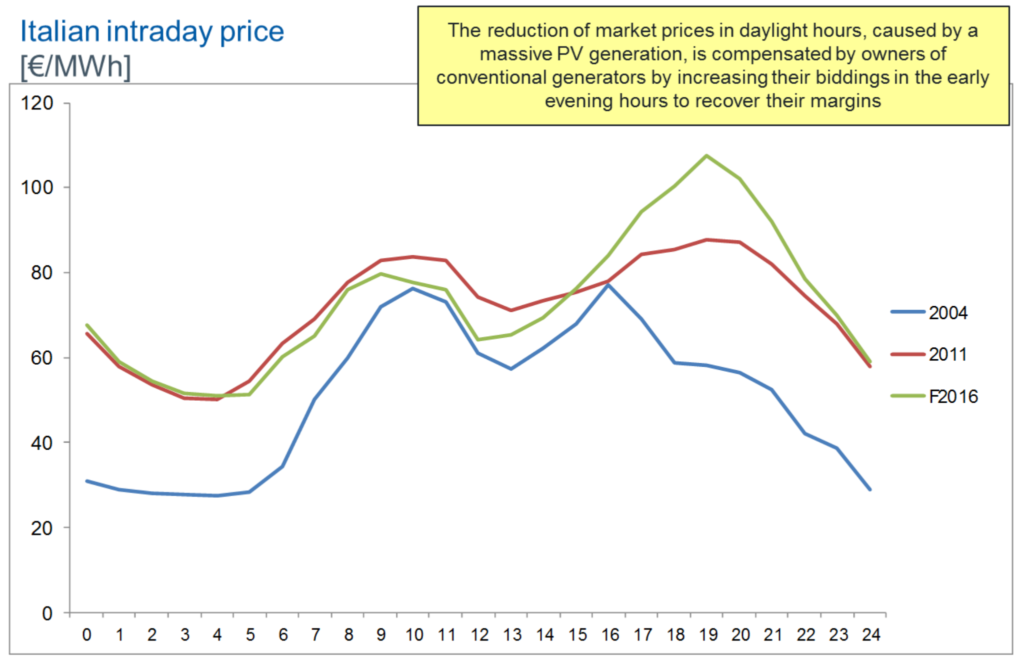
They are strongly affected by the spread of possible important distributed generation.

The “Smart Grid approach” is usually confined to distribution and the majority of talks/theoretical and practical developments are mainly confined to this sector; I do not enter here into details.

5.RES,the market and generation fleet

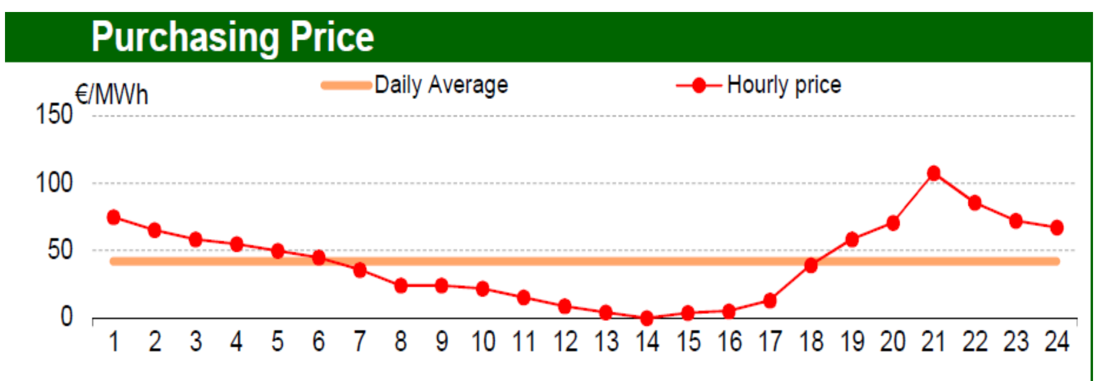
Problems to overcome to enhance generation from non-programmable RES

- **Impact on power markets**

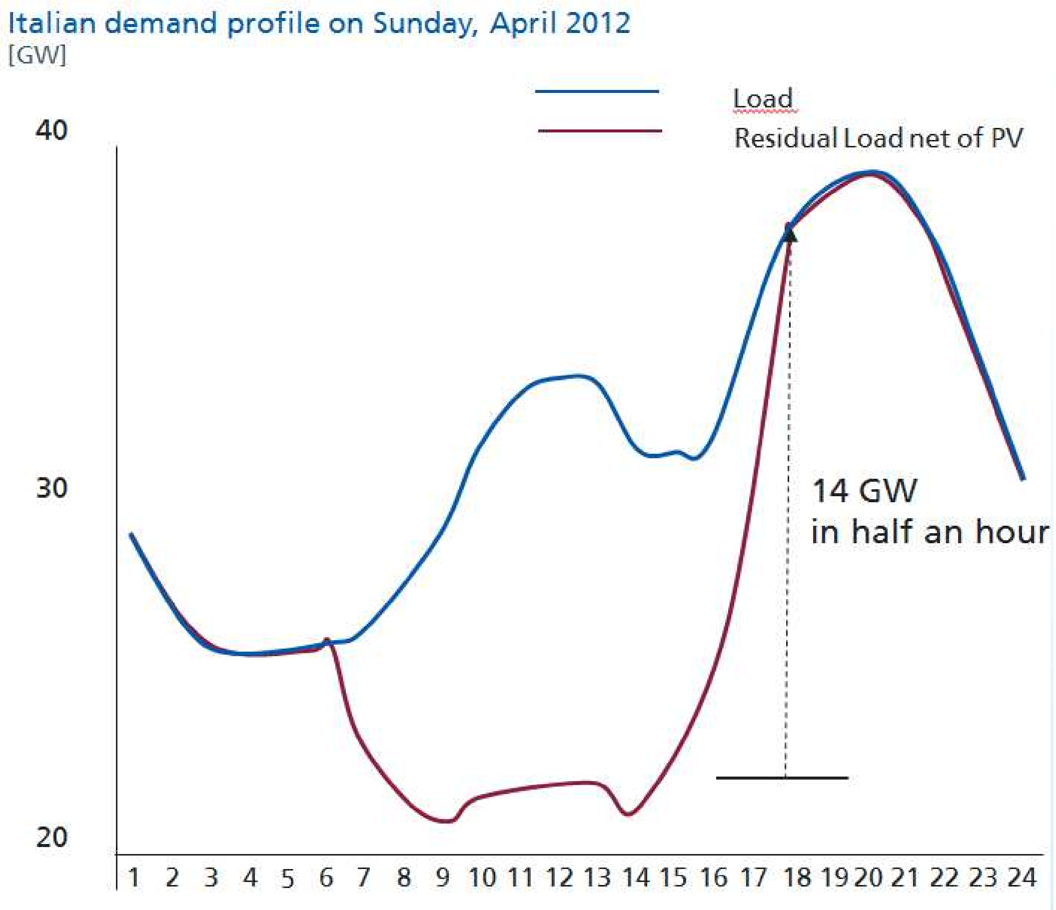


What happened in the Italian day-ahead market on May 1st, 2013:

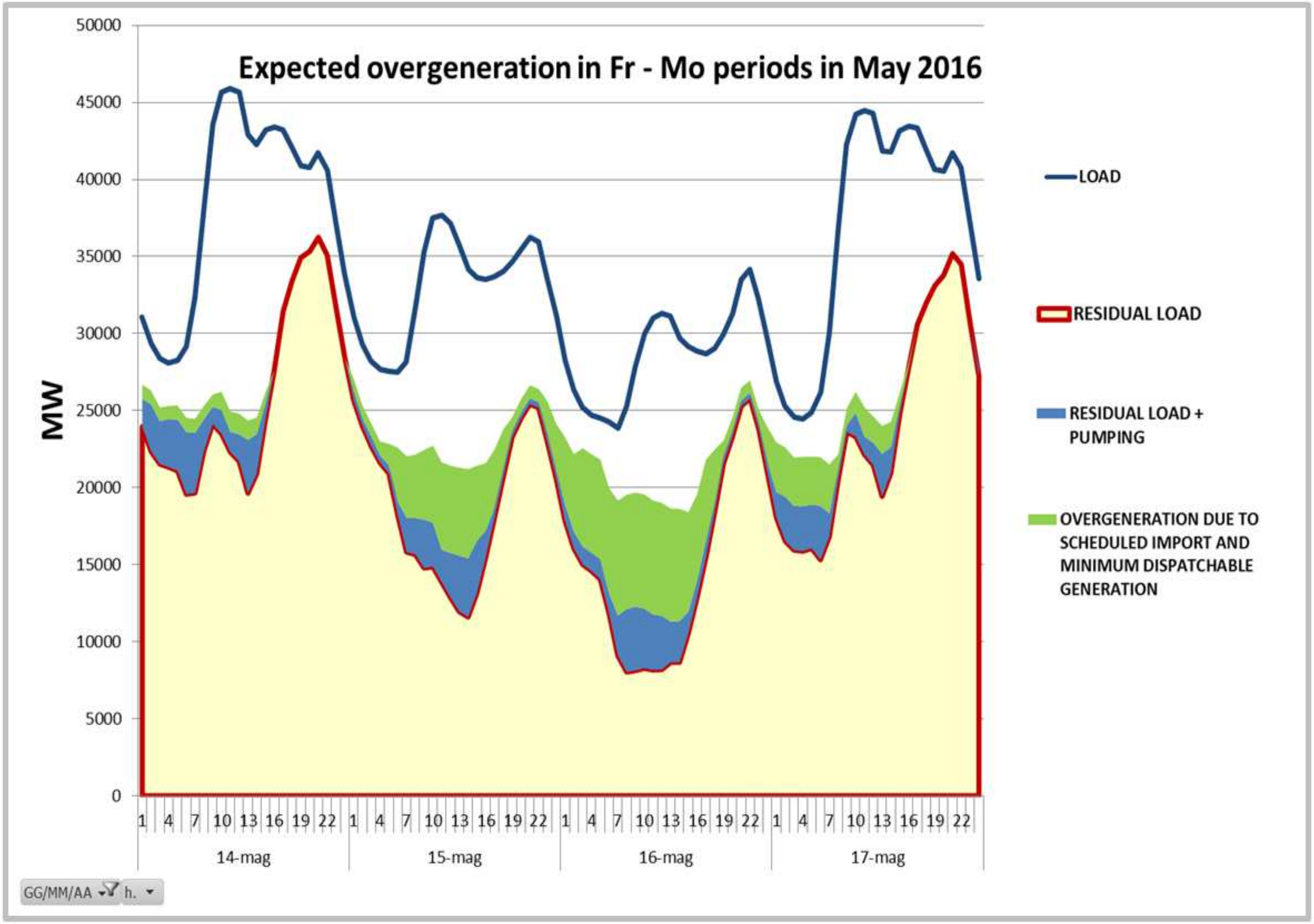
- *Minimum price: 0,1 €/MWh*
- *Maximum price: 107,5 €/MWh (27,2% of offered energy supply by GSE)*



Source GME



Residual load in the Italian system in presence of PV generation



Estimation of "overgeneration" in Italy in 2016

Main impacts of non-programmable RES generation on the power system

- *Impact on the day-ahead power market*
- *Load following*
- *Risk of “overgeneration”*
- *Need for additional reserve*
- *Network congestions*
- *Risk of RES generating unit cascade disconnection*
- *Dynamic stability and quality of supply*

Assessing the maximum penetration of non-programmable RES generation to have an economic and reliable power system should be programmed with appropriate technical and economic approaches to avoid RES to become a problem instead of an asset.

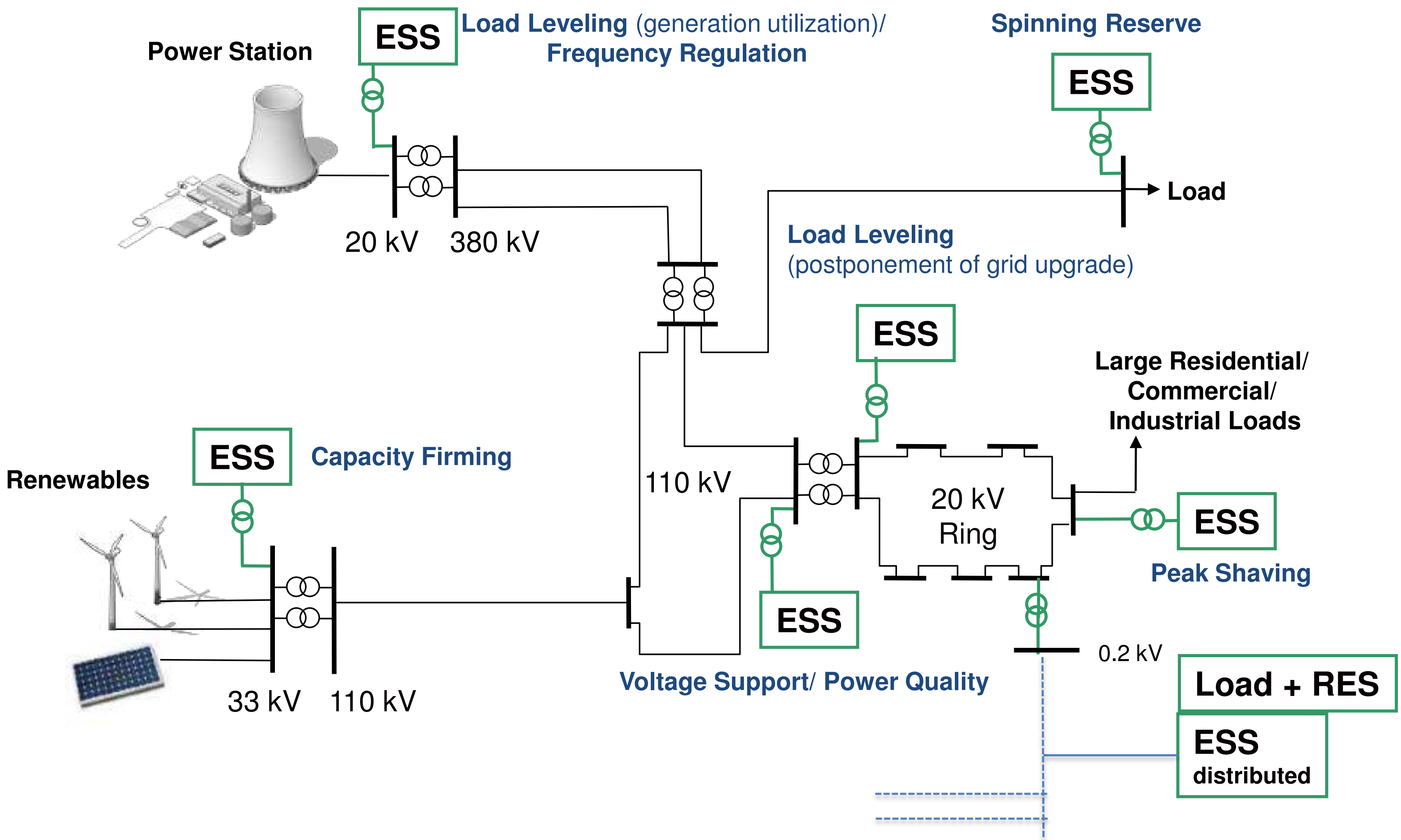
And CESI has developed a sophisticated approach applied in various foreign countries

6.Conclusions

The advantages of emerging technologies within a smart grid approach should be assessed with detailed studies and experiments adequately supported in order to assess their possible global benefits versus global costs ;this without imposing additional long term burdens to the bills of final clients.

A clear example are the energy storage systems (ESS) where detailed analyses on the different types of batteries to be considered and on the interactions between the specific ESS and the power system must be carried out; and also here CESI avails a deep experience

Energy Storage Systems (ESS) Applications



- A correct «smart grid approach» must consider the complete electrical power system,that is : generation,transmission , distribution and the final clients.
- Final scope of a smart grids should be that to optimize the reliable and economic utilization of assets with fare sharing of the benefits and information between the involved stakeholders

For an effective and inherently gradual application of smart grid concepts,a more practical vision is necessary with clear steps of implementations based on detailed technical and economical analyses and financing structures.

Let us stop a lot of bla,bla,bla and an abuse of the term smart

Let us avoid the usual approach of long term incentives using the final clients as a «bancomat»