Large-scale grid integration and storage options

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RES4MED&Africa Executive Seminar

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Agenda

Context

Main highlights of Terna's storage projects

Expected evolution of storage

Introduction (1)

Terna & Northern Africa

Studies carried out by Med-TSO, the association of the Mediterranean TSOs, established in 2012 and hosted by Terna, show that countries in Northern Africa will become more and more interconnected on a commercial basis, **with a total of €20bn of investments foreseen in transmission networks** by 2030.

Terna and STEG (the Tunisian power company) are working on the realization of a **600MW HVDC undersea cable between Italy and Tunisia**. This cable will further **interconnect Northern Africa and the EU electricity system through Italy**, reducing balancing problems and improving security of supply and sustainability on both shores of the Mediterranean.

The project has already **obtained the institutional endorsement of the governments of Germany, France and Malta,** in addition to the governments concerned. The interconnection is listed in ENTSO-e's TYNDP and has received a favorable opinion for being included in the 2017 PCI list and could therefore be eligible to co-funding from CEF.

Introduction (2)

Terna & Eastern Africa Power Pool (EAPP)

A recent study on EAPP conducted by Pöyry in cooperation with Terna and CESI shows that the region's growth in electricity demand can be increasingly covered by RES but has to be accompanied by an increase in interconnection capacity, in order to:

- Integrate RES into power systems
- Better exploit the complementarity between generation mixes and RES potentials across EAPP members
- Reduce energy costs

THE EASTERN AFRICA POWER POOL

ADDIS ABABA

The **key to interconnection development** and maximization of its benefits is **TSO coordination & regional system planning**, including common regulation & market design.

The role of transmission grids & storage

Part of this RES potential will be exploited locally in the form of micro-grids (e.g. in order to electrify rural areas). Yet, this does not eliminate the need for larger electricity grids. Cost-effective RES potential is not always located near industrialized areas and big cities, especially when it comes to wind and hydro, as can for instance be observed in Ethiopia.

The EU's experience in energy transition shows that investments in new RES capacity go hand in hand with transmission grid investments. Recent experience also shows that storage can complement grid development.

Energy transition in Europe and Italy

European Guidelines

Market Efficiency

Security of Supply

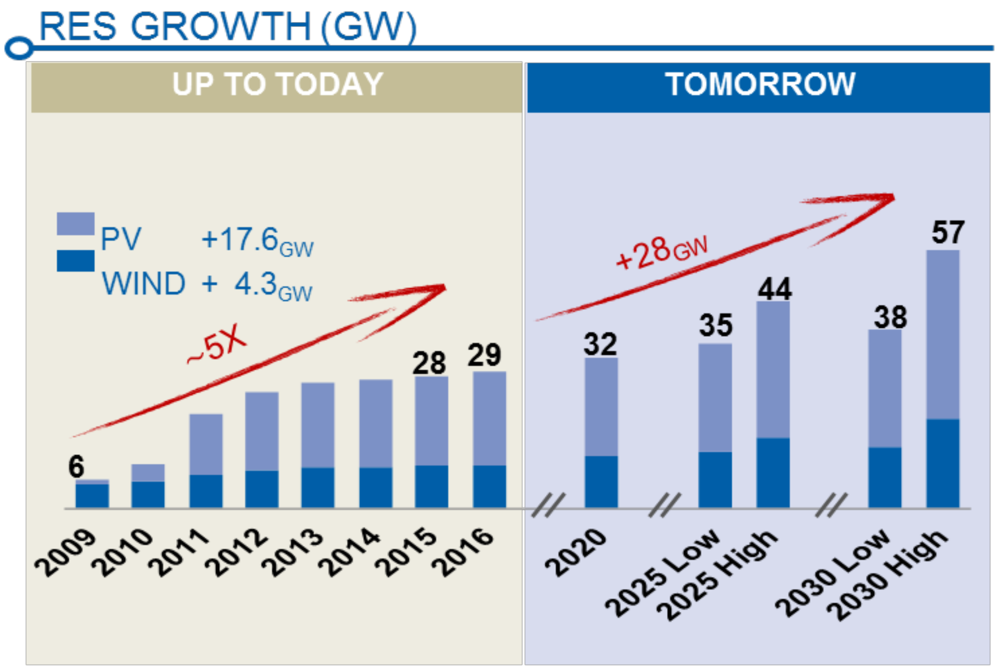
AIMS

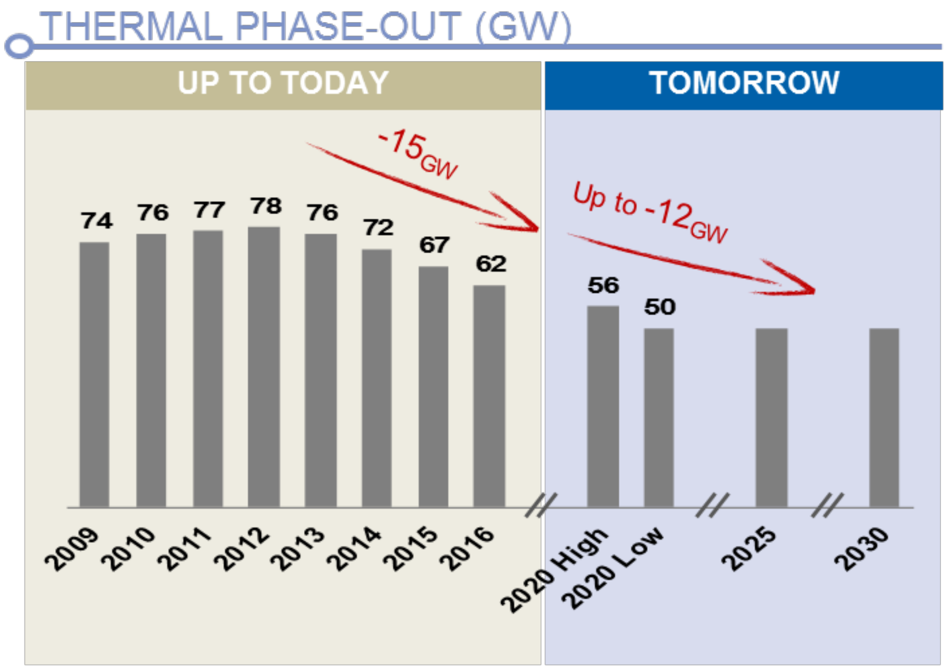
	2020 EU 20-20-20 (EU)	2020 EU 20-20-20 (Italy)	2030 The energy bridge (EU)
Reduction of greenhouse gas emissions	*- 20%*	*- 13%*[1] ✓	*- 40%*
RES share in consumption[2]	*≥20%*	*≥17%* ✓	*27%*
Energy efficiency (vs scenario BAU)	*+ 20%*	*+ 20%*	*+30%*[3]
Interconnection vs. installed capacity	*≥ 10%*[4]	*≥ 10%*[4]	*≥ 15%*[5]

The European guidelines and 2030 objectives ensure a secure, affordable, environmentally friendly and low-carbon energy supply.
The electricity vector is fundamental to reach these goals.

1. *For Italy the goal is defined by ESD (Effort Sharing Decision)*
2. *Renewable energy contribution as a percentage in final energy consumption (transport + electricity + heating & cooling)*
3. *Proposed by Winter Energy Package of the EC (previous target at 27%)*
4. *"Barcelona criterion" 2002 European Council, in Barcelona*
5. *Goal per Member State, being evaluated by the ECc*

Renewables growth and thermal capacity phase-out in Italy

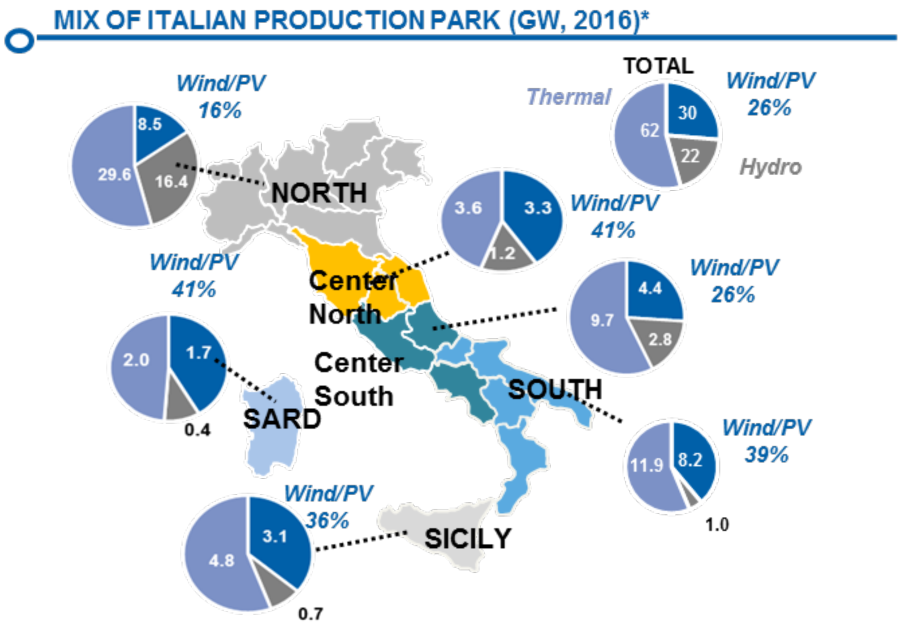




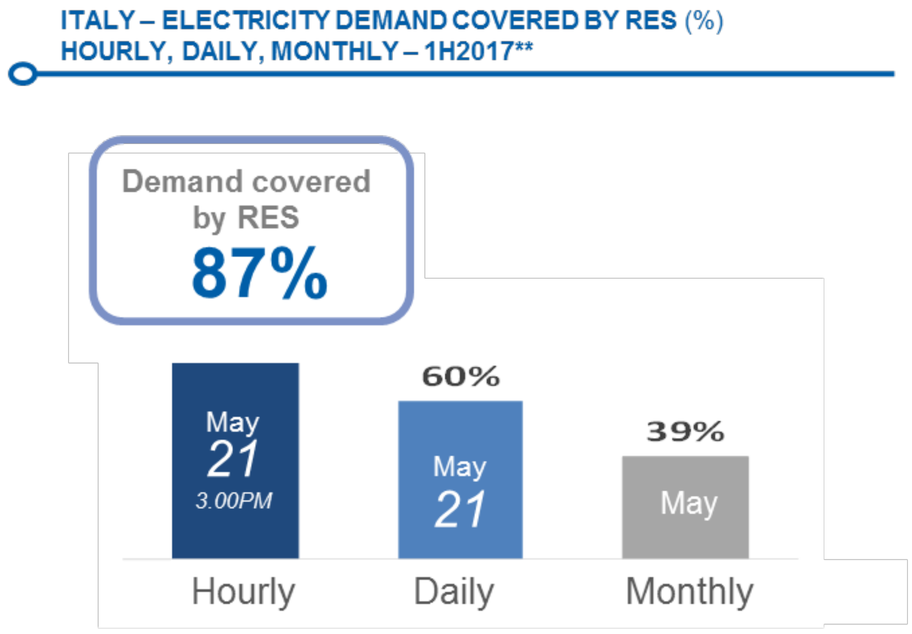
RES targets of 50% defined in SEN3 require stronger deployment than envisioned in the NDP* of at least 51GW of solar photovoltaics and 17GW of wind

NOTE: Terna estimates for Italian Electricity Market
**National Development Plan*

Electricity system evolution



Increase in RES has been inhomogeneous at regional level, focusing mainly on the areas of the highest availability of resources (South and Islands), far away from the major consumption centers



Further increase in peaks of daily demand coverage from intermittent RES production are expected, considering the expected evolution of the installed capacity of wind and solar photovoltaic plants

*Estimated data

** INCLUDES HYDRO-ELECTRIC

Increase in RES penetration: Actions needed

SYSTEM IMPACTS

- Increase in number of **congestion** hours, up to 25% of total hours, in particular between North-Center and Center-South
- Increasing level of **overgeneration** – non-dispatchable generation that cannot be curtailed – 14 TWh in the case of low imports (33 TWh) and 19 TWh in the case of high imports (57 TWh)
- **Integration of ancillary services markets** would contribute to a significant reduction in overgeneration

ACTIONS NEEDED

Network investments

- Operations defined in **National Development Plan** and **National Defense Plan**
- **Network reinforcements** (Dorsal North-Center e Center -South)*

Markets

- **Coupling** with **foreign balancing** markets
- **Opening of MSD** to demand-side, distributed generation and non-dispatchable RES

Generation

- Converting part of the existing CCGTs to allow operation as **OCGT** and realization of new OCGT (triggered by the **capacity market**)

Storage

- **Pumped hydro** (additional 5GW**)
- **Electrochemical batteries**, alternative/combination to pumped hydro

* Expected from the analysis in the NDP 2017
** First simulation results. Resources for voltage regulation are required in the absence of pumping

Enabling factors for the energy transtion

Capacity Market	• Mechanisms to ensure **system adequacy** through long-term price signals
Network Development	• Increase in capacity and intermeshing of the transmission network
Storage	• Deployment of **utility-scale and distributed storage** systems
Demand Response	• Opening the balancing market to the **demand-side**
Smart Grid	• Investments in **FACTS** (Flexible AC Transmission System) and **real time grid management systems**
Market Evolution	• Market structure evolution for the purpose of **participating in new resources** (demand-side, distributed generation and storage)
Data Management	• Full **data availability** of all resources/operator and implementation of a **management platform**

It is necessary to implement a complex mix of interventions including the development of additional storage capacity

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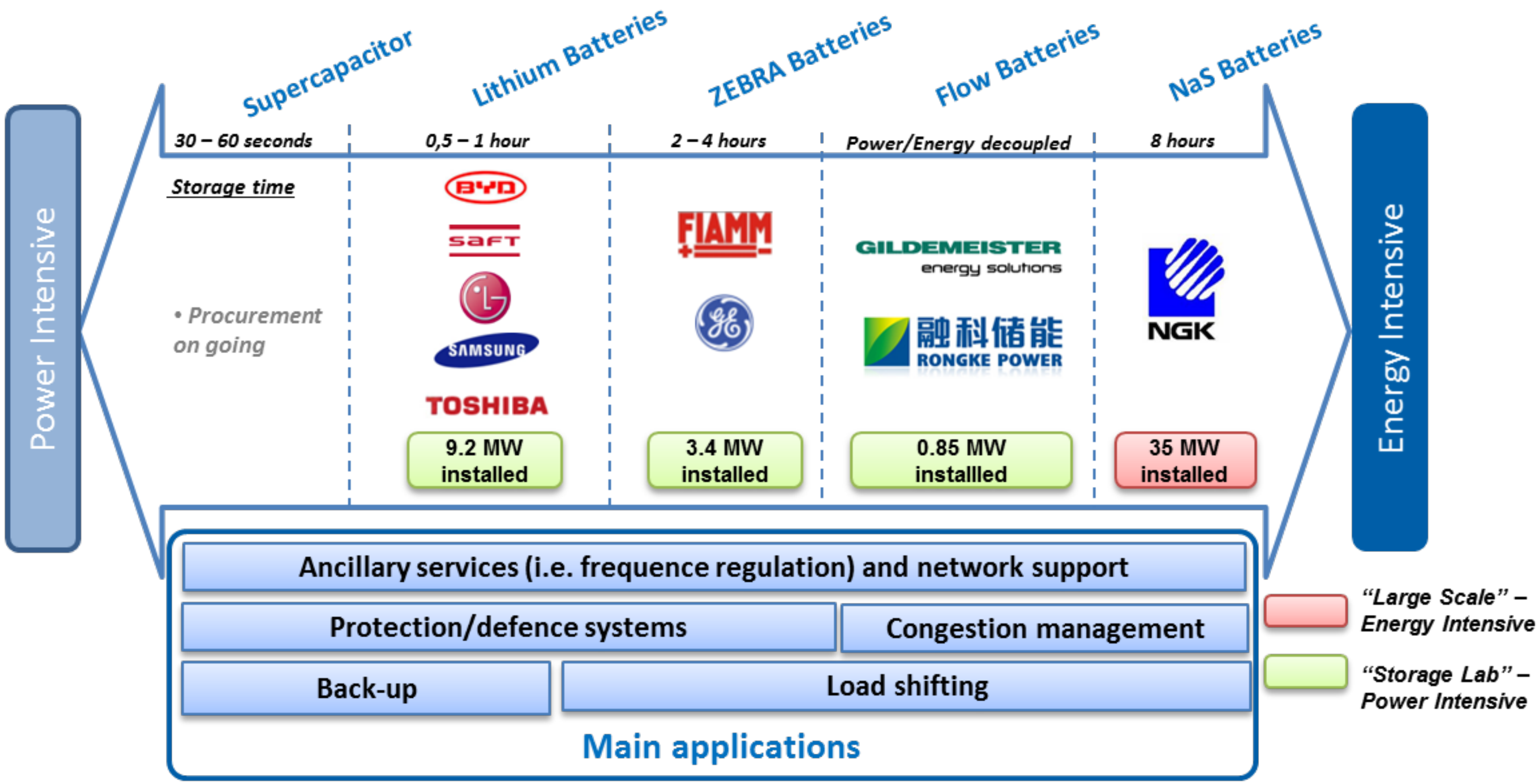
Technological portfolio of Terna



With its storage projects, Terna has covered the full range of applications for storage systems - from strongly power-intensive to mostly energy-intensive solutions

Storage projects of Terna

Storage Lab (Power Intensive)

- **Main goal:** contributing to network security
- **Size (MW):** ≈ 16 MW (Phase I)
- **Solutions:** Li-Ion, Zebra, Flow, other (Supercap...)
- **Number of sites:** 2

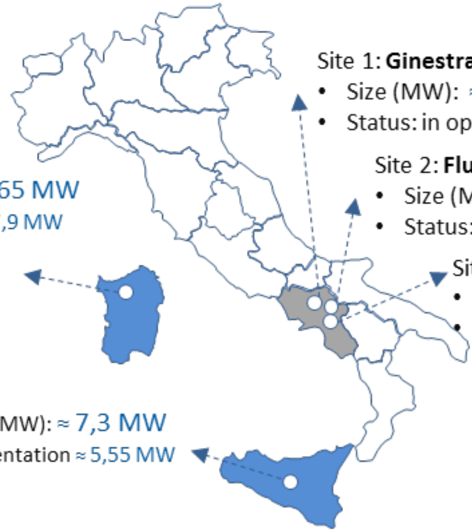
〉 Testing, comparison and evaluation of **different storage technologies**

〉 **Advanced control systems** to manage multi-technology systems

〉 Both **"grid scale"** and **"lab scale"** systems

Sardinia - Codrongianos
- Final planned size (MW): ≈ 8,65 MW
- Status: in experimentation ≈ 7,9 MW

Sicilia - Ciminna
- Final planned size (MW): ≈ 7,3 MW
- Status: in experimentation ≈ 5,55 MW



Large Scale (Energy Intensive)

- **Main goal:** reduction of network congestions (*)
- **Size (MW):** ≈35 MW
- **Solutions:** NaS (Sodium Sulfur)
- **Number of sites:** 3

Site 1: **Ginestra**
- Size (MW): ≈ 12 MW
- Status: in operation

Site 2: **Flumeri**
- Size (MW): ≈ 12 MW
- Status: in operation

Sito 3 **Scampitella**
- Size (MW): ≈ 10,8 MW
- Status: in operation

〉 **Single technology,** with **already stablished solution on the market**

〉 **Large scale plants,** suitable to reduce network congestion

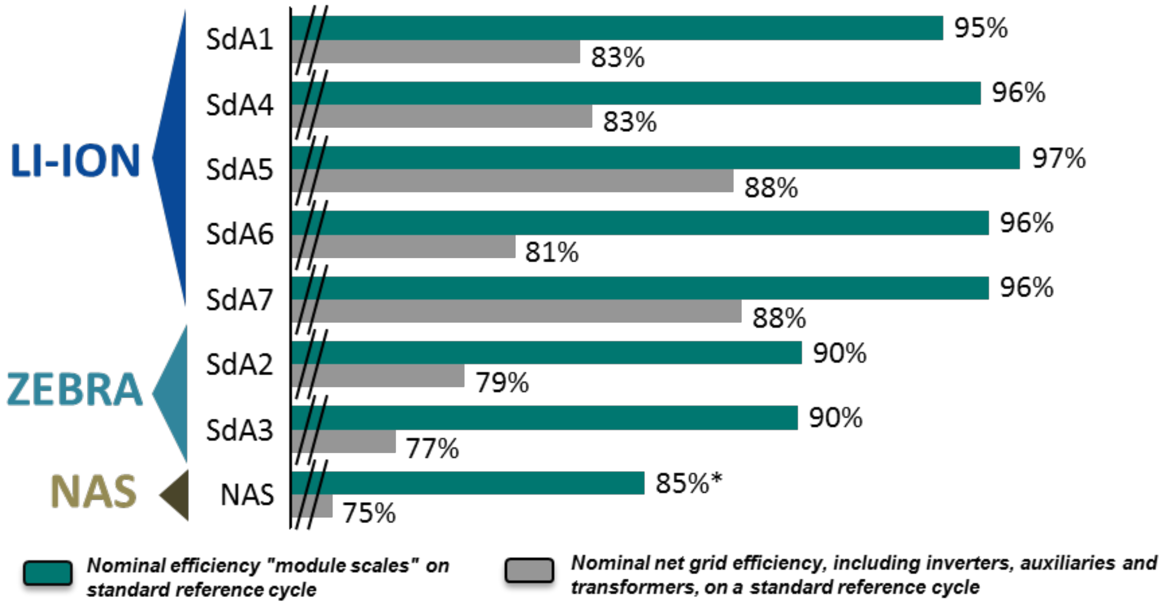
〉 Additional supply of **ancillary services**

Power and Energy Intensive projects have different sizes and purposes, hence the different approach to testing

** There is a remuneration paid to wind power generators in case of curtailment.*

Main findings: Efficiency

Nominal efficiency on reference cycle (cell VS system)



Net efficiency in continuous operation

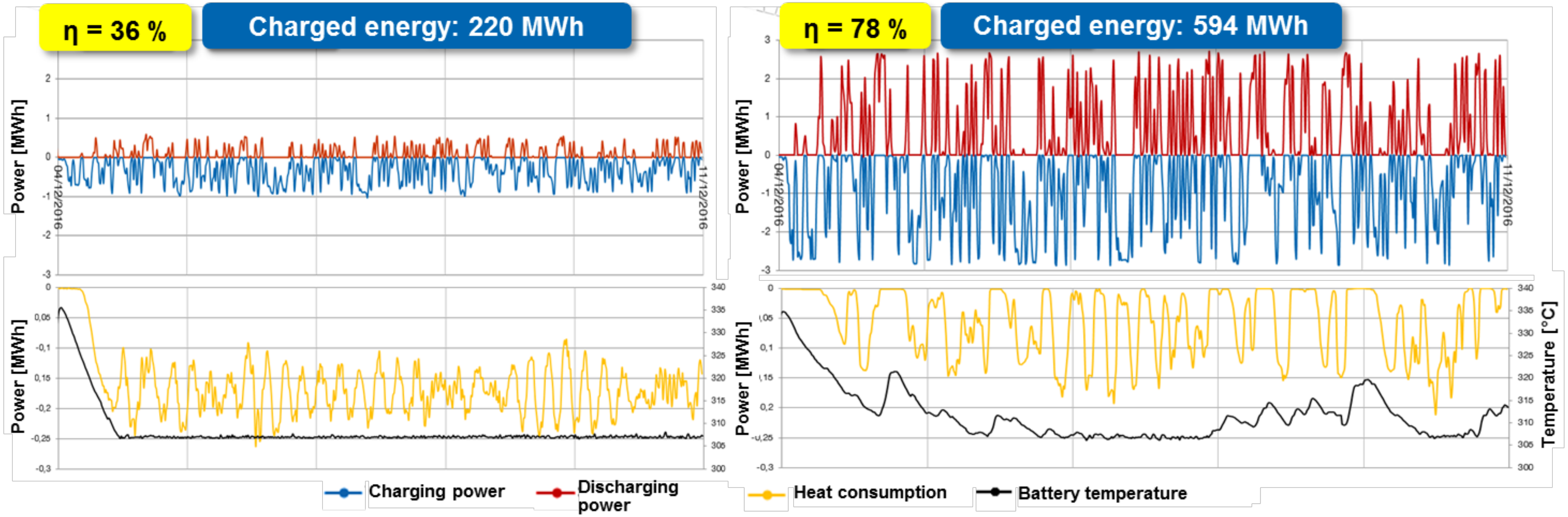
- Net efficiency solely for primary frequency control: **15-30%**
- Net efficiency in in both primary and secondary frequency control: **65-80%**
- **ZEBRA** (average semiannual technologies values)
  Primary frequency control **18%**
  Primary+secondary frequency control **67%**
- **LI-ION** (average semiannual technologies values)
  Primary frequency control **23%**
  Primary+Secondary frequency control **76%**

Installed systems have high efficiencies, in line with technical specifications when used under nominal conditions (i.e. with "standard" charge / discharge cycles). However, the efficiency drops drastically when the utilization cycles foresee lower energy volumes than those of standard cycles

** «grid scale» battery systems*

Main findings: Consumption of auxiliary systems

Energy Intensive plants: energy throughput VS heating consumption



Performance is strongly influenced by usage cycles, as reducing the volume of energy exchanged leads to stronger weight of losses. The consumption of battery heaters is notably affected by the presence of stand-by phases, the number of continuous cycles performed and the average operating power

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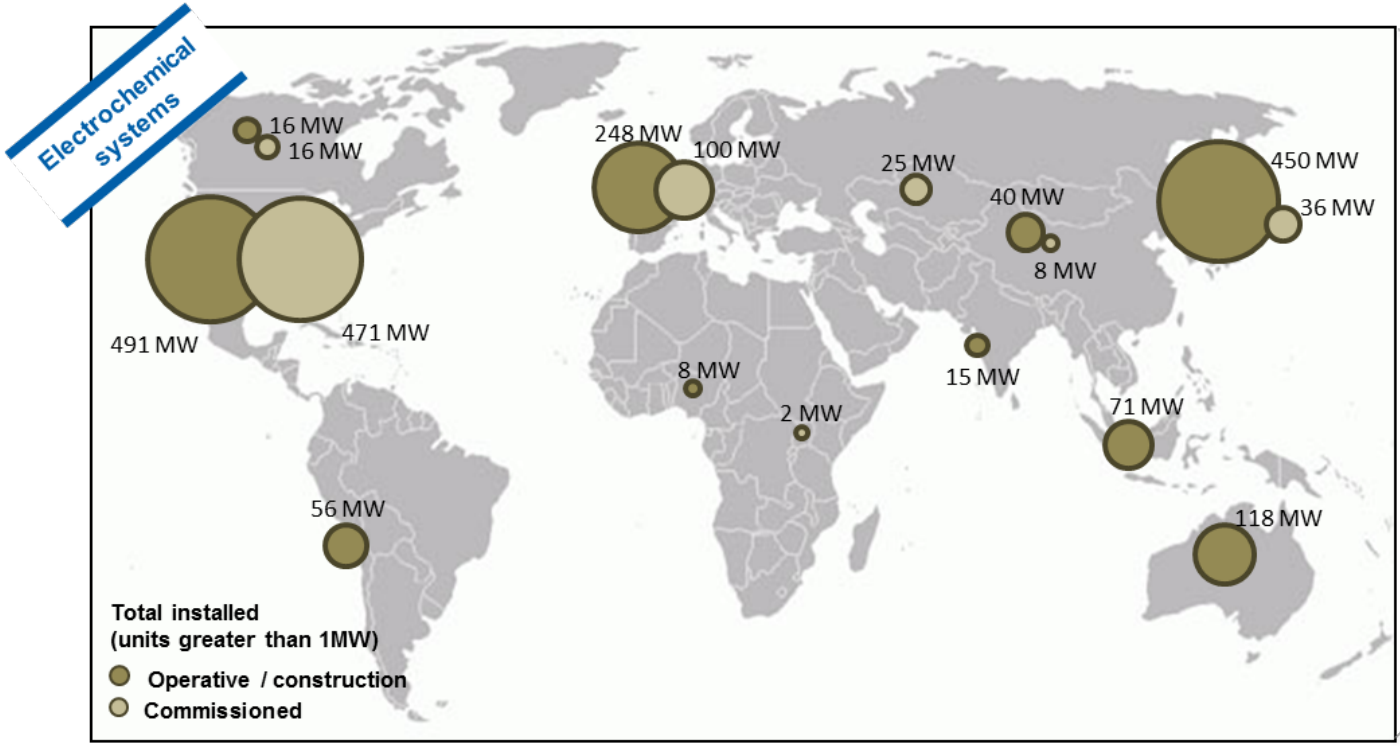
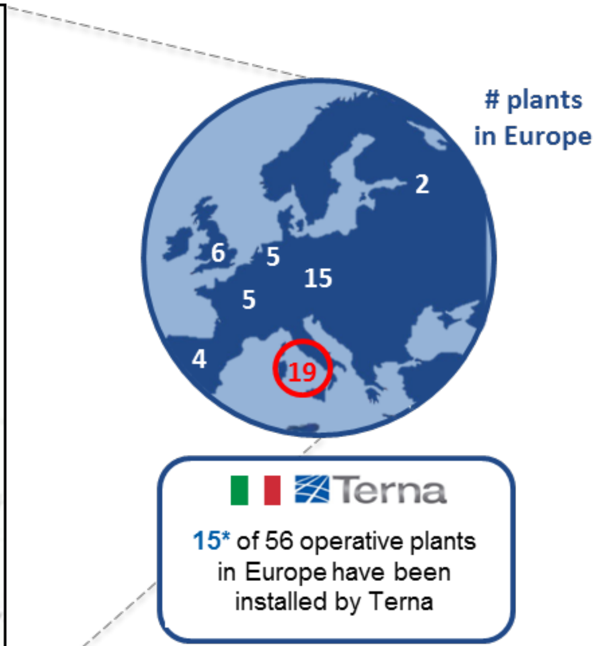
Global distribution of energy storage systems



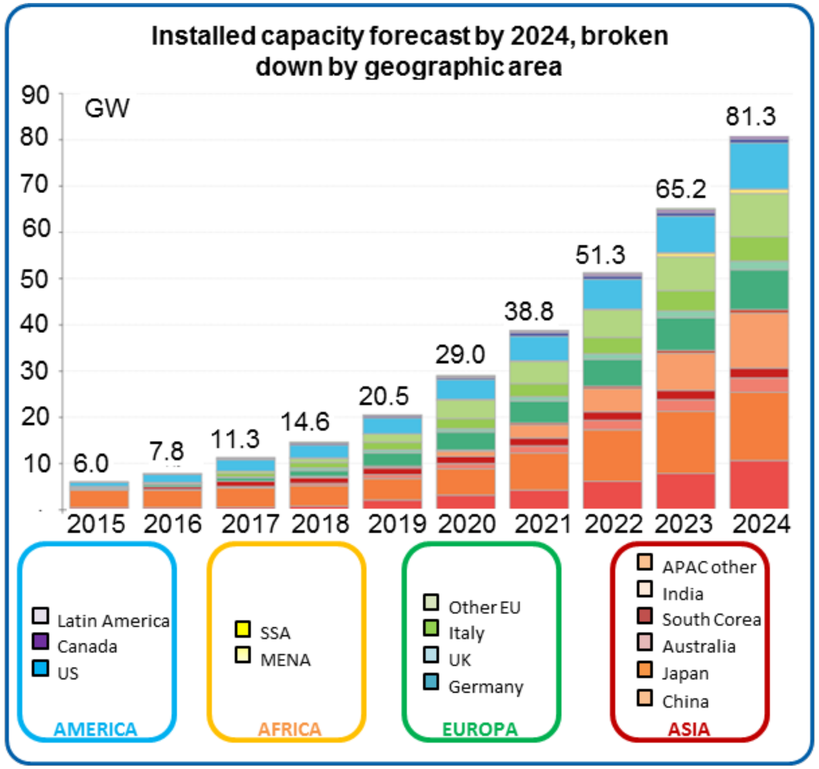


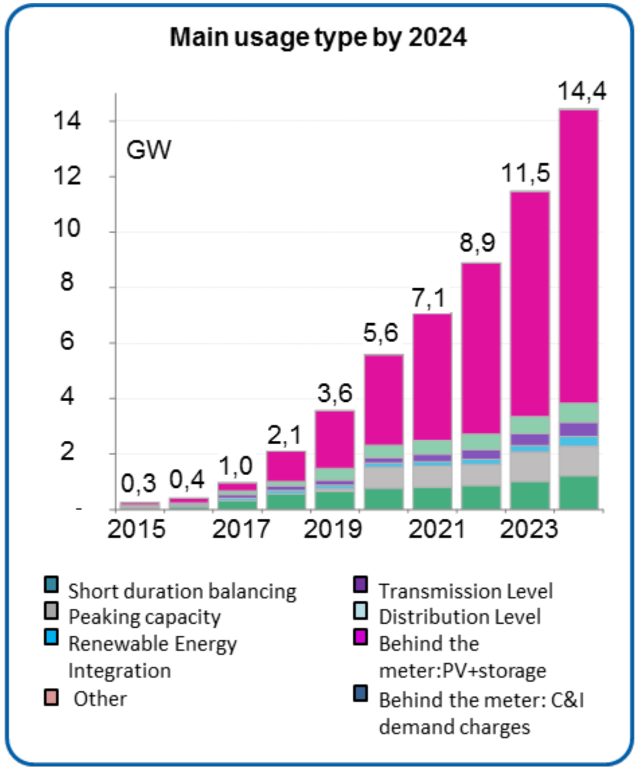
Source: DOE database – February 2017

The United States, Europe and Japan are the driving geographies in the Electrochemical Storage industry. Thanks to Terna's contribution, Italy, together with Germany and England, is one of the most active countries in Europe

**12 battery systems of the Storage Lab (without considering two flow systems) + 3 Energy Intensive plants*

Trends in storage growth and scope of use





In the medium term, the geographies that will continue to drive will be USA, Japan and Europe. Even though behind the meter applications may struggle to develop in the short term, it is expected that these will represent the main usage type in the future

** Source: Bloomberg New Energy Finance, "Global Energy Storage Forecast, 2016-24"*

European use cases: UK

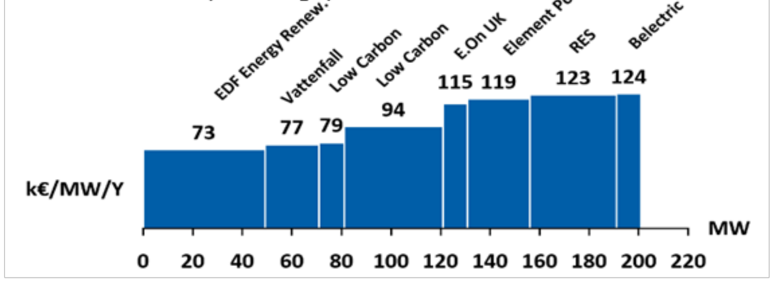
Enhanced Frequency Response - EFR (200MW)

The service requires:

- **Power output within 500ms** from frequency deviation
- **Full output within 1 second**
- Symmetrical adjustment service
- **Resource avalability in 18 months** after being awared a contract
- Mantain full **power for at least 15 minutes**
- Possibility to exchange 9% of nominal power within deadband
- **Contract duration: 4 years**

> 223 offers received (201 storage)

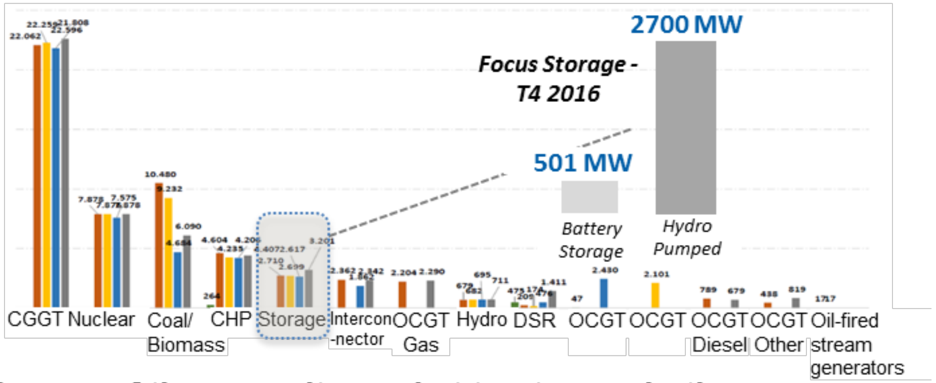
> 8 offers contracted (8 storage)



Capacity Market - CM

- The **Capacity Market** has been introduced in the UK in December 2014. Production, storage or DSR (*Demand Side Response*) plants of more than 2 MW can participate.
- In the auction of **December 2016,** 41 storage facilities were contracted with a total of 3.2 GW, **including 501 MW from 28 newly built battery storage**
- Among 28 battery storage plants, **4 are also winners of the EFR tender and will provide both services**

> **4 battery storage** solutions **will provide both services - EFR and CM**



In the European context, the EFR tender and the opening up of the capacity market to storage in the UK represent an example of the possible role of TSO in the promotion of "market storage"

Key findings: testing of storage systems

- In conditions similar to the reference cycle, the storage technologies tested by Terna are performing in line with nameplate specifications return, with respect to efficiency

- Actual operating performance can be significantly lower than nominal and is strongly dependent on the usage type and consumption of the auxiliary systems

- Batteries can provide services with a much faster response time compared to traditional technologies

- It is not yet possible to give conclusive evidence on the actual technical lifetime of batteries but it is already possible to point out that there are significant differences, also across very similar technologies

- Using a storage system for a sole service may not allow to exploit its full potential. It is therefore appropriate to design an accumulation plant for the provision of a variety of services, while still bearing in mind the technical constraints that characterize accumulation technologies

Thank you

A. Ponti – Director Strategy and Market Analysis

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