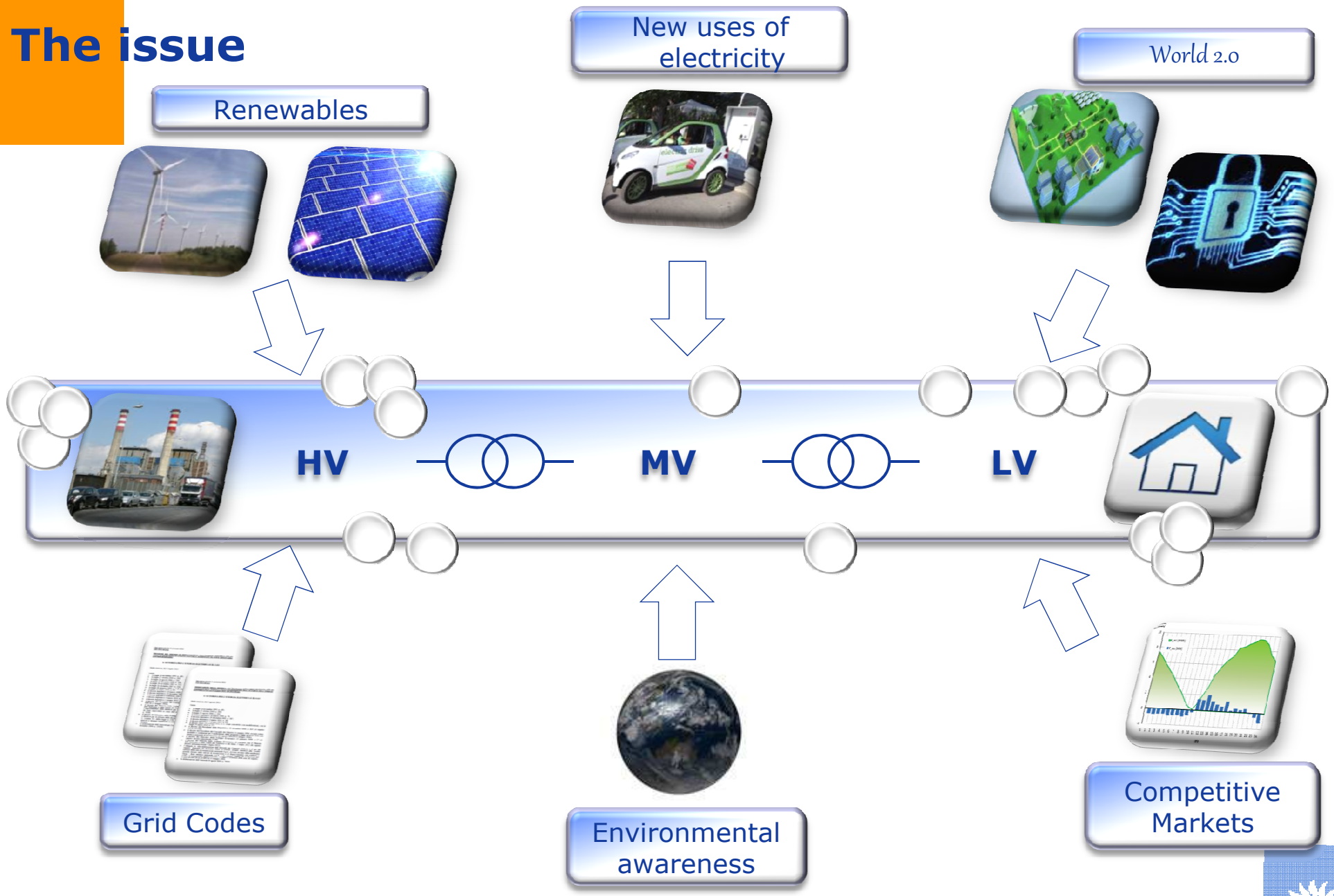
Enel Research

Intelligent use of electricity

Gianluca Gigliucci

Eprice workshop, Pisa, January 28th 2013

The issue



Technologies, rules, people habits are reshaping the electric system

A unique chance to make business…

Communication and Control Technologies

Energy Storage & Power Electronics

LV	MV	HV
Home	District	Substation
Building	Substation	Conventional Plants
E-mobility	REN Plant	REN Plant
Microgrids		

Cybersecurity

Market & Grid codes

Reshaping pressures are inducing a **"rounder" integrated market** with **much softer business opportunities** to be caught through **key enabling technologies**

Active End-Users and Energy Efficiency

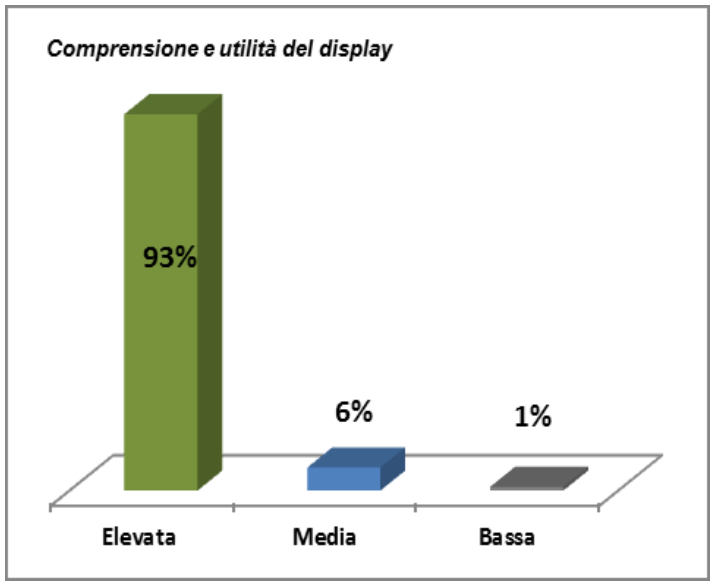
Customer (self)awareness

ComeConsumo Trial (ENEL ENERGIA): Provision of **value added services** tailored for **Residential** and **Small Business** customers

Real Time monitoring: **How much** customers consume

Store and Show Data: **When** and **How** they consume

Provision of services**: Load management**



Ongoing trial on 1200 customers

Feedback on smart technologies at home:

- 93% of customers satisfied by the interface and information

Consumption awareness on own consumptions:

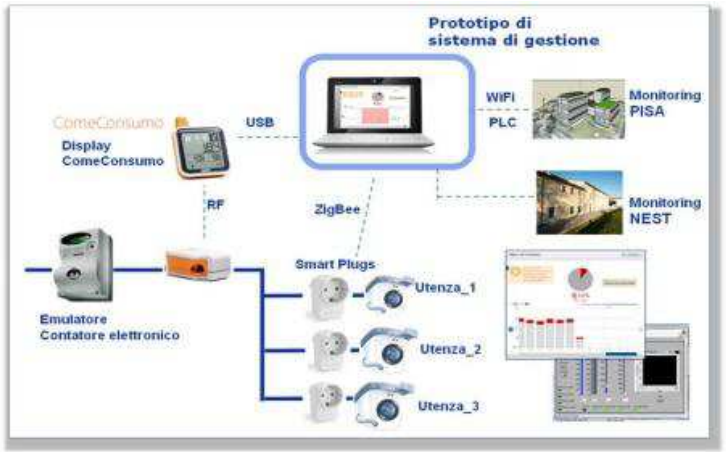
- Before trial: 2%
- After trial: 57%

Active End-Users and Energy Efficiency

DomusLab

DomusLab: assessment and modelling of technologies that may enable more intelligent electricity uses

- **Emulation of different environments**
  - Residential customer level (active)
  - Retailer level (future development)
- **Interoperability of devices**
  - Test of effective integration of different technologies
- **Residential environment simulator**
  - Multiagent modeling of a home automation system (e.g. **storage@home**)
  - Hardware in the loop validations
- **Assessment of appliance "signature"**
  - Measurements of signatures & Validation of Non Invasive Load Monitoring algorithms



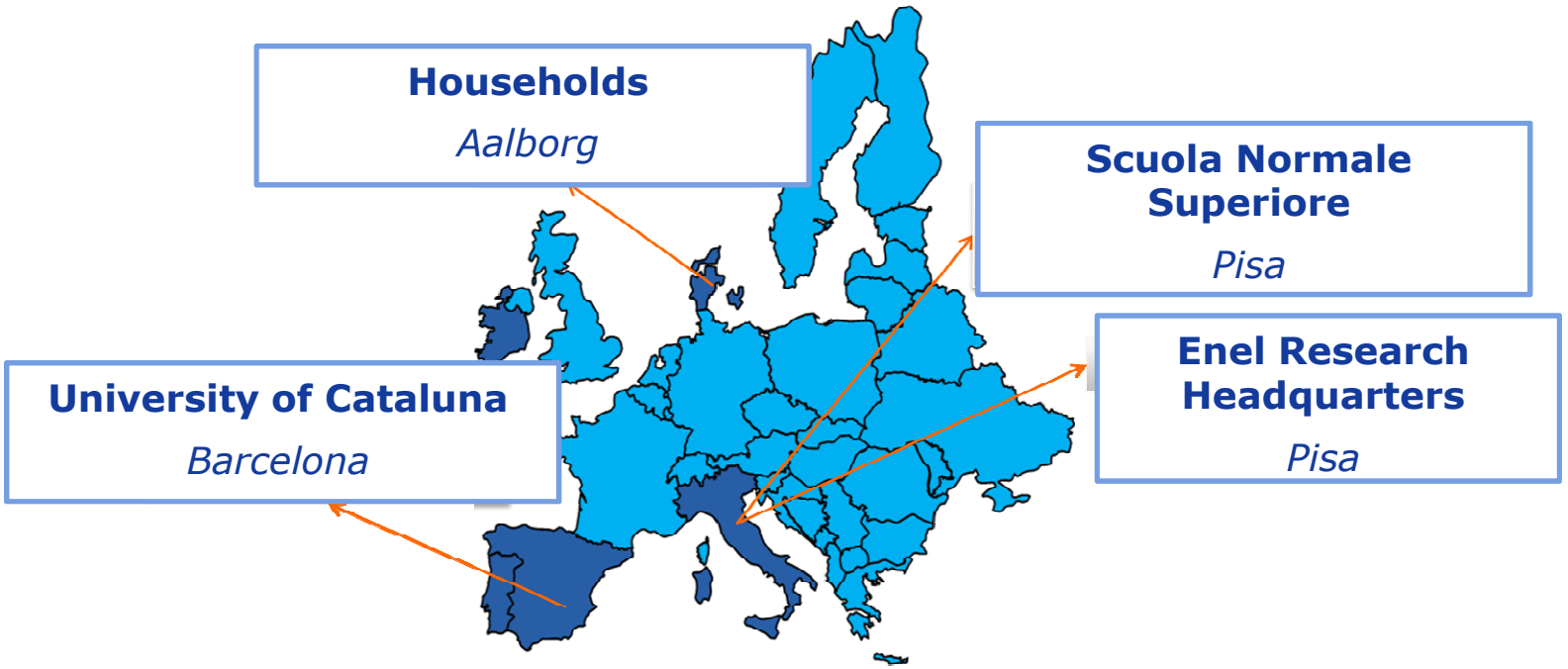
Active End-Users and Energy Efficiency

Smart Buildings

Identification of the **best energy efficiency solution** for **different buildings**: residential, offices, laboratories. Savings are achieved by means of:

- ✓ RES deployment and **building integration**
- ✓ Use of storage systems (thermal and electrical) to optimize consumption/production of energy, **increase revenues and reliability**
- ✓ **Building automation** systems for optimal **management of local loads**

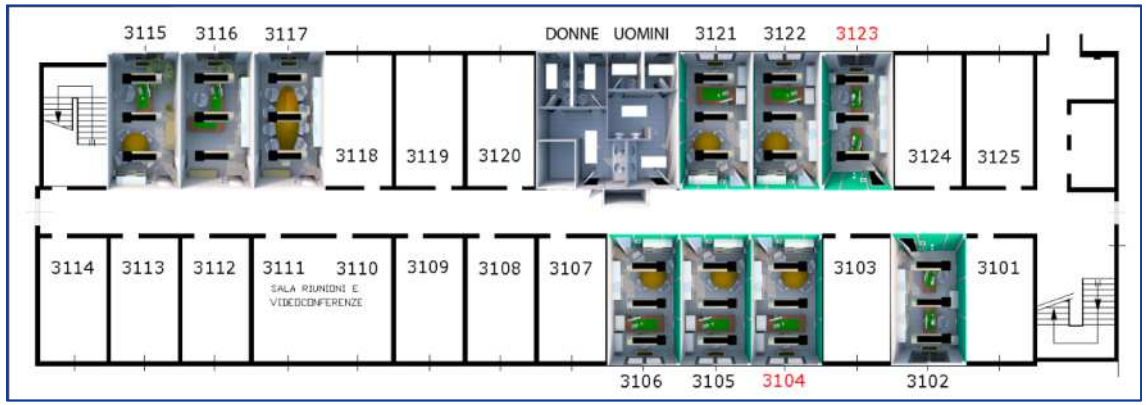
Demo Sites

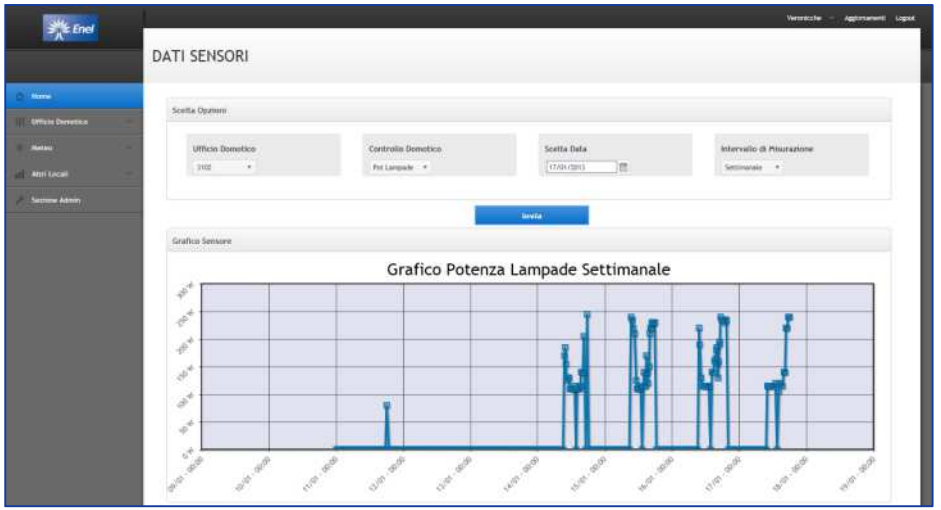


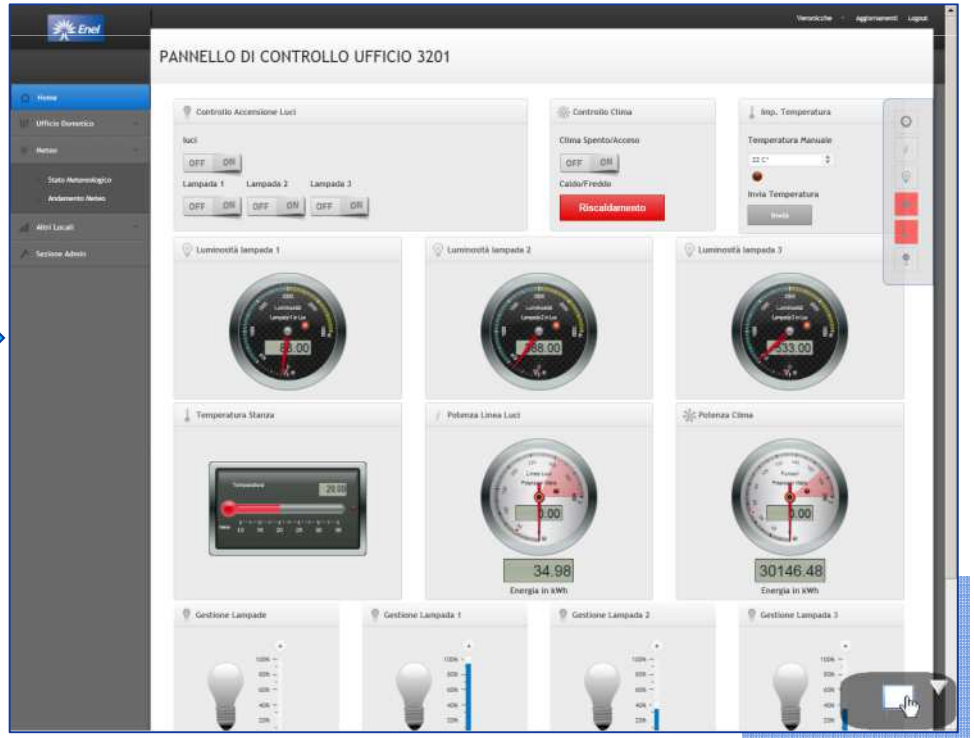
Active End-Users and Energy Efficiency

Smart buildings - Pisa demo

Domotic offices @Pisa E&R HQ







- **Centralised & Distributed appliance control**
- **Comparison of "domotised" vs. standard offices**

Active End-Users and Energy Efficiency

Active buildings – Catania demo

Enel solar lab building

- Designed (’80) to demonstrate building efficiency
- Facades may be replaced to test effects on internal environment

Next innovations

Refurbish the external structure to use the building as a living lab to test:

- **Building integrated renewables** (structural materials, active paintings, etc.)
- **High efficiency appliances** to enhance electricity use instead of gas
- **Domotics**

Autonomous Grids and Districts

Two field tests: Navicelli and Pontlab

Development of management algorithms for district optimisation

- Optimisation of energy exchange with the distribution network
- Maximisation of revenues for the district owner
- Provision of added value services to the Distribution System Operator (DSO): power/frequency, voltage control, active demand

---

Local resources available:

- Renewable generation
- Industrial Loads
- Cogeneration
- Storage (thermal, electric)

Navicelli Demo Site

Autonomous Grids and Districts

Field test – first results

Output: operational set-points for every Distributed Energy Resource (DER) each 15' for the following 24 hours

INPUT

- Electricity purchase/selling prices
- Gas purchase prices
- Value of incentives
- Load curtailment cost
- Operation cost
- Load/Generation forecast
- Load request
- Real time measurement
- Meteorological real-time data
- Weather forecast
- Request of service from DSO/Market

CONSTRAINTS

- Network capability
- DERs capability
- DERs efficiency

Energy Management System

Optimisation Algorithm

- ❑ **Optimization of operation**
- ❑ **Maximization of profits**

OUTPUT: 96 distpatch orders

- ❑ **Dispatch of generating units**
  - Set point of P, Q for generators
  - Set point of heat power
- ❑ **Demand Side Management**
  - Percentage of electric load curtailment
  - Percentage of thermal load curtailment
- ❑ **Energy storage systems**
  - Charge/discharge of electric storage
  - Charge/discharge of thermal storage

First results: cost savings from 30% to 42%

Enel
L'ENERGIA CHE TI A SCELTA.

Autonomous Grids and Districts

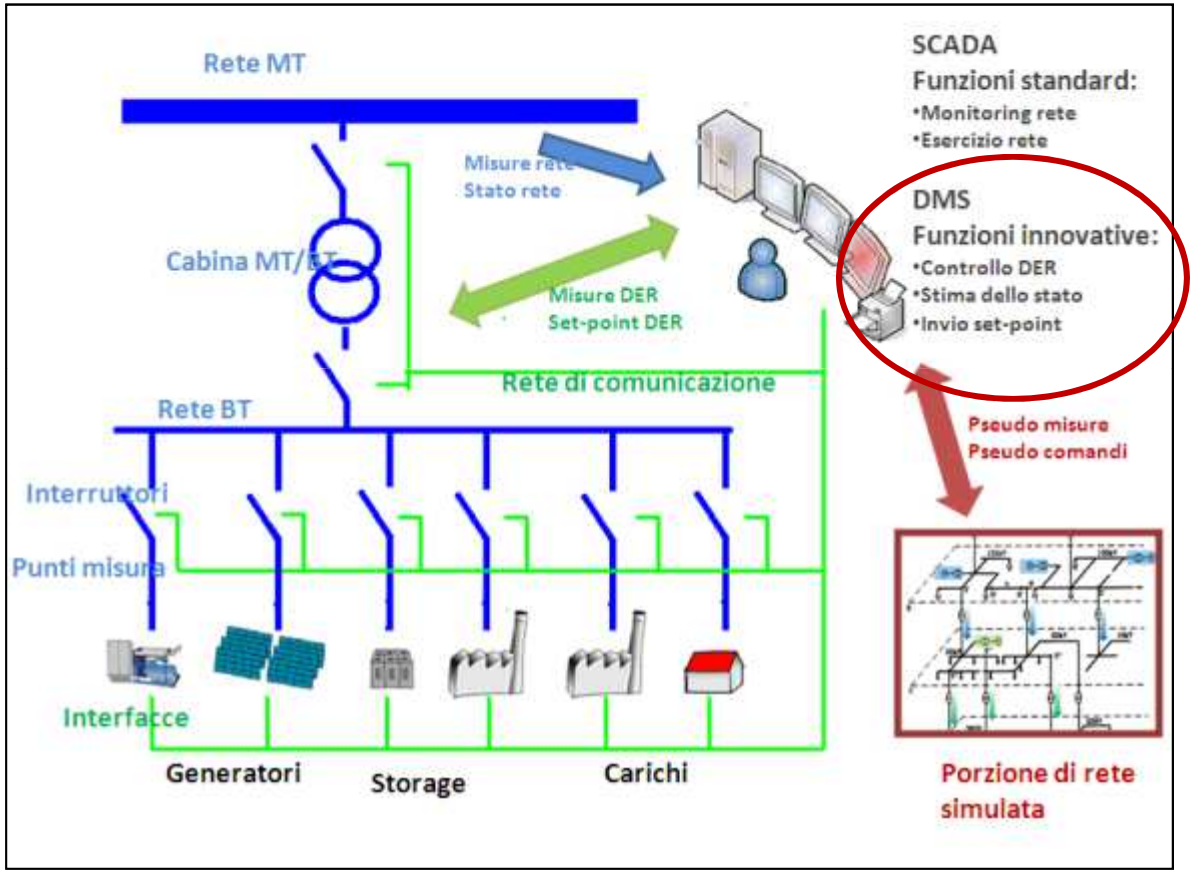
Development of advanced Distribution network Management System

Development and validation of advanced DMS with the following functionalities:

- Optimised integration of Distributed Energy Resources (DER)
- Use of DER to provide added value services to the main distribution/transmission network
- Network state estimation
- Network reconfiguration for minimisation of losses

Livorno Experimental Area

Livorno Test site architecture



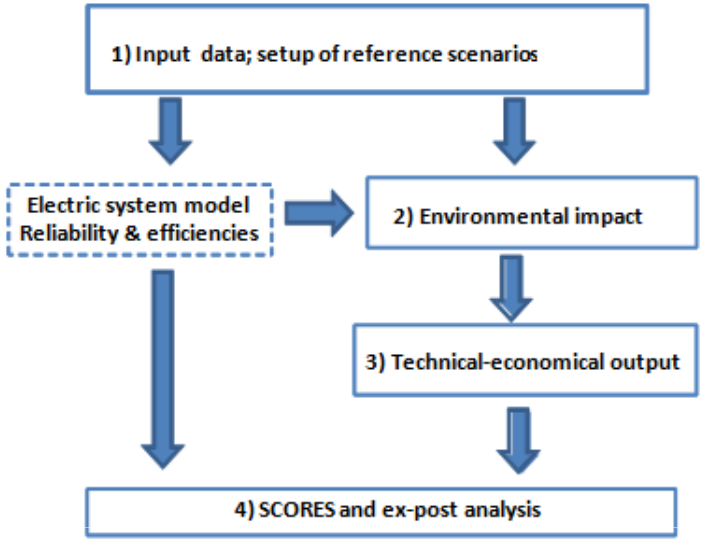
Test to begin by June 2013

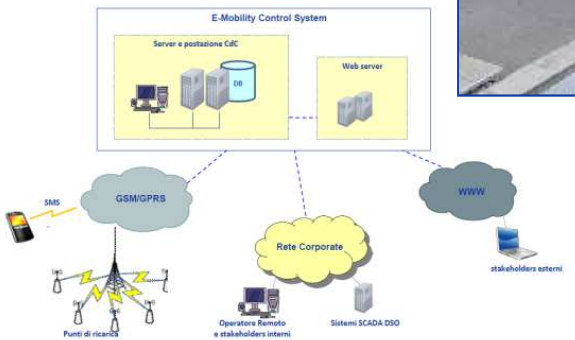
Fostering e-mobility

Impact on the grid and enviromental benefits

Evaluation of the impact of the EV on electric system and definition of the best practices for diffusion

- ✓ **Development of algorithm** to calculate the **benefits** of the use of EVs, comparing and quantifying the efficiency of the energy chain (well-to-wheel), the **emission** of GHG gases and other pollutants, and the **impact** of **EVs** on the bulk **power system**, in terms of reliability and primary energy consumption
- ✓ **Field measurements of pollutants from traffic** in urban environment
- ✓ Data analyses on Pisa, Rome and Milan **e-vehicles** tests (ongoing)





Towards full electric cities

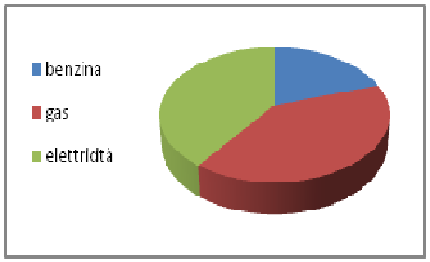
Goals

- Integration of the best technologies to provide **valuable services through electricity**, while **minimizing primary energy consumption and urban pollution**.
- Development and demonstration of the **"ElectriCity" concept**, able to optimize energy management and life quality in whole urbane areas

A methodology towards a full electrified zero emission City

Descriptors of urban context
- Geographic
- Population
- State of buildings
- Public services
- Citizens behavior
- Average km/day with car
- ….

Evaluation of energy consumption

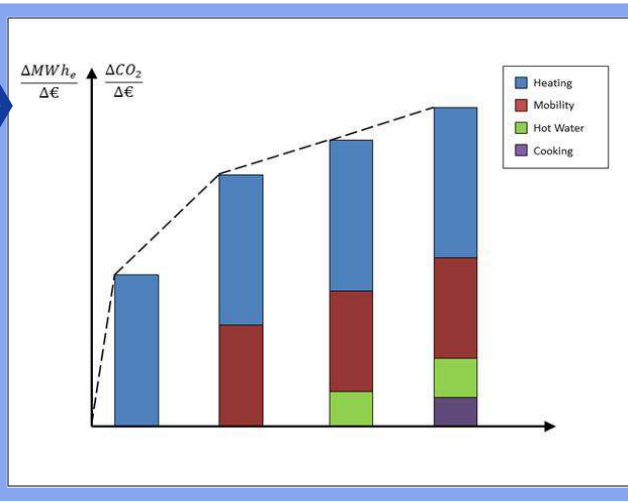


Range of action
Conversion to the electric vector

Implementation of the Action Plan
- Electric vehicles
- Heat pump
- Induction Cooking
- Renewable generation

Development of Business Models
- Definition of targets
- Identification of the drivers (who realizes the Electric city)

Results
Optimal investment portfolio in order to:
- Increase electric vector penetration
- Increase revenues
- Reduce CO2 emissions



Enabling Know-how

Development of a reference archive of distribution networks

Expected results:

- Libraries of models:
  - Typical Configurations of Italian MV/LV Distribution Networks
  - Generation, storage and compensation systems, loads
  - Distribution network components, supplied with a database of technical characteristics
  - Evolution Scenarios of distribution systems, together with case study simulations
- Web Site/Forum for networks, models and results exchange

Benchmark with current state of the art:

- DG and electronic interfaces modeling consolidation
- Stochastic nature representation of intermittent primary resources
- Operation models taking into account price and volume signals

Results achieved so far:

- Identification of key parameters for the characterization of each reference grid
- DMS logics implementation

Average indexes values for the generalized reference networks

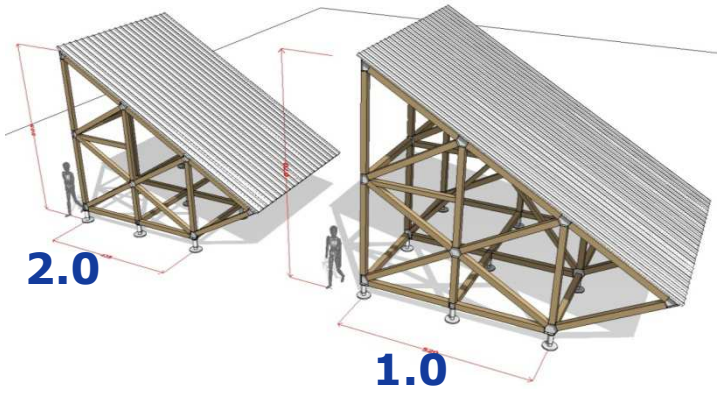
Type	*Load_dens*	*MV/LV*	*Lenght*	*Users_dens*	*Gen*
	[kVA/km]	*[km/km]*	*[km]*	*[1/km]*	*[kVA/km]*
RUR	216.7	0.280	168.1	80.5	35.1
IND	418.6	0.787	104.4	108.1	68.2
URB	771.7	0.592	80.3	208.1	21.0

Average indexes have been calculated for each area in order to provide a generalized classification of reference grids

Enel E&R Patented design

Remote areas

TOB system – energy & services for local use



Internal surface available	1.0	2.0
• Ground floor:	30 m²	20 m²
• Utility room:	10 m²	7m²
Maximum height		
• from ground floor	6mt	5mt

Foundations:

- All terrain screw piles (no concrete bases needed)

PV power production:

• PV roof available surface:	54 m²	37 m²
• Installed power: up to	9 kW	7.5 kW

Average daily energy available:

- 30 kWh*

Energy storage:

- Gel sealed lead acid batteries
- Night time/overcast use, capacity 8 kWh or more

Loads:

- Internal/external LED lightning
- Portable/rechargeable LED lamps
- Notebook
- Electricity plugs for appliances and e-vehicle

Capability to manage appliances and micro-grids:

- 10 kW or more

Transportation:

- 4 fully equipped basic units fit inside a 20ft container

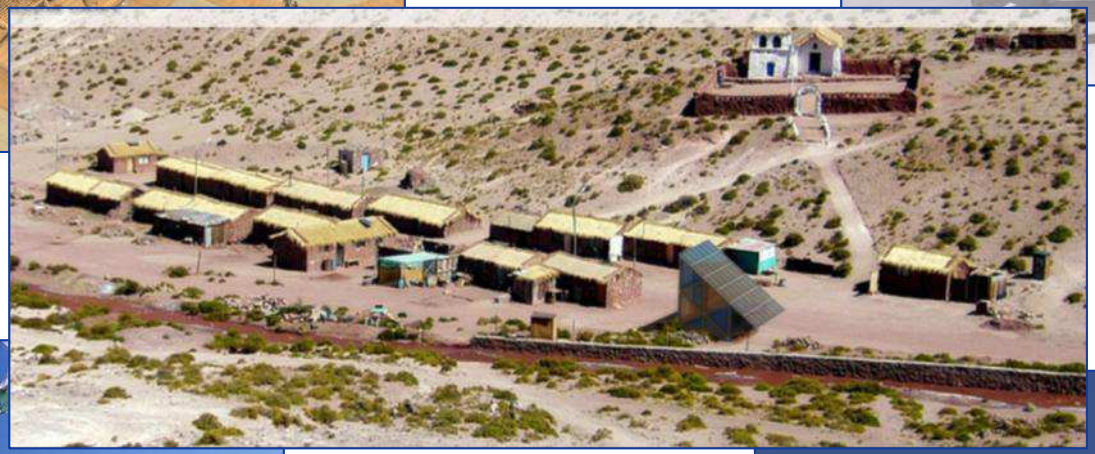
Installation:

- 1 week without heavy tools and specialized workers

* Hypothesis: Annual Global Irradiation 2000 kWh/m²

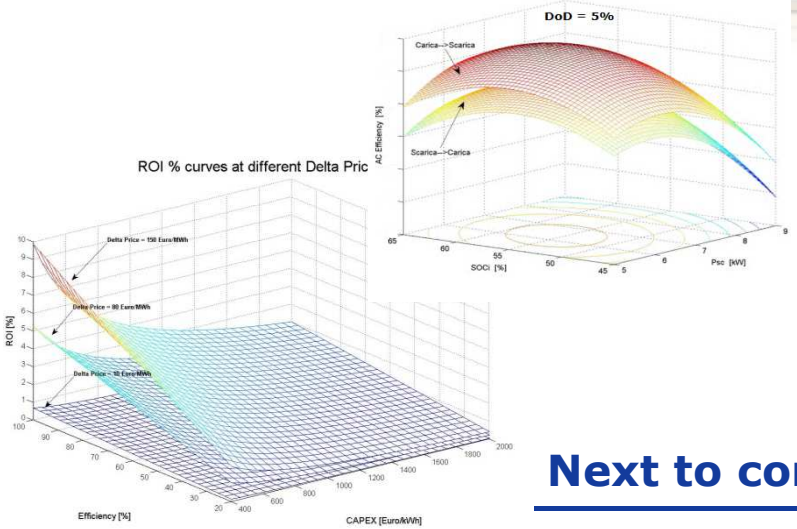
Remote areas

Towards creation of micro-grids



Enabling Technologies

Storage Systems - activities



Modeling and Experimental assessment

- Assess technologies **KPI** (Key Performances Indicators) in different regimes and evaluate **operating readiness for utility applications**
- Develop **guidelines for integration** of components to ensure proper performances
- Develop optimal **control algorithms** for Enel applications
- Address **cradle-to-grave issues** related to the deployment of storage and interconnection to the grid

Technical – economical evaluations

- Evaluate **economic and technical viability** of storage applications (renewable integration, isolated grid management, ancillary services provision, etc.)
- Identification of **business opportunities** and development of **tailored management strategies**

Next to come

- Autonomous operation and islanding capability to support microgrid operation
- Synergic use of energy storage, power electronics, distributed generation and backup engines

Enabling Technologies

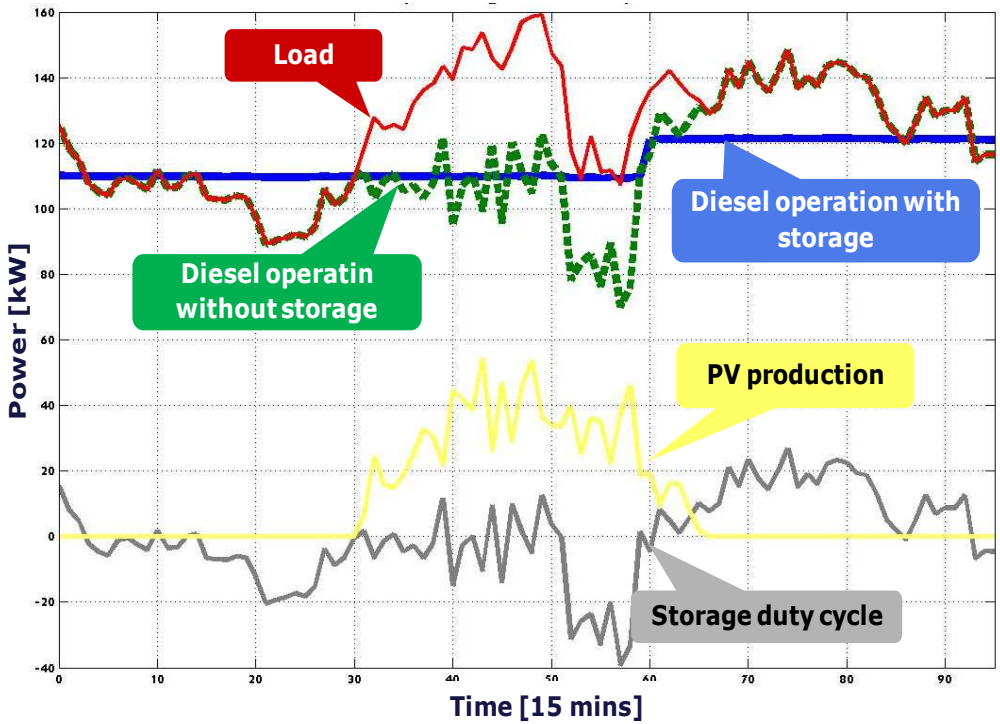
Storage Systems – Ventotene Island Demo

Ventotene today

- Peak load 900÷1200 kW during summer
- **4 diesel engines** (600 kVA each) and a MV distribution ring
- Increase of residential PV plants caused **grid stability problems** (frequency, voltage, etc.)
- Diesel engines operated at **low load factors**

Demonstration Project

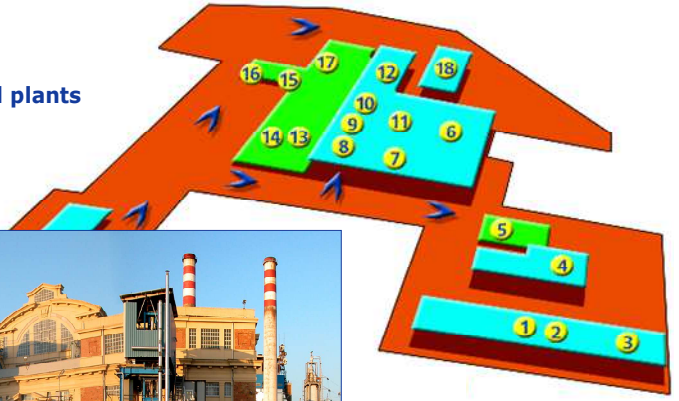
- Integration of a Lithium battery (**300÷500 kW, 600 kWh**) with the diesel power station
- Benefits:
  - Optimize conventional generation operation for **fuel saving** and **emission abatement**
  - Decrease of average cost of electricity
  - Life extension of conventional assets
  - Optimization of reserve assets
  - Increase of renewable **hosting capacity**

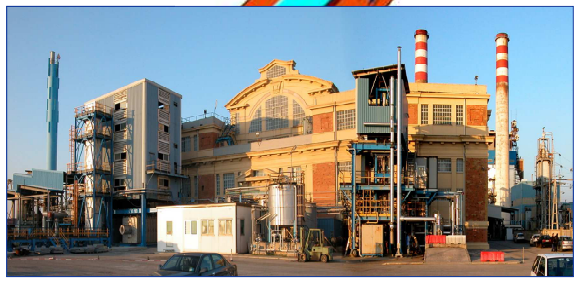


Enabling Know-how

SCADA Cyber-Security Lab

- 16000 m²
- 12 operators
- 18 experimental plants





Dedicated assets

- **Network infrastructure** replica
- **Power plant infrastructure** replica
- **Remote Control system** replica (SCADA, RTU, IEC 104)
- **IDROLab** test plant with **sensors and actuators**
- **Attack and Observer Area** + control room

Next step

- **Smart Power "Prosumer" systems** replica

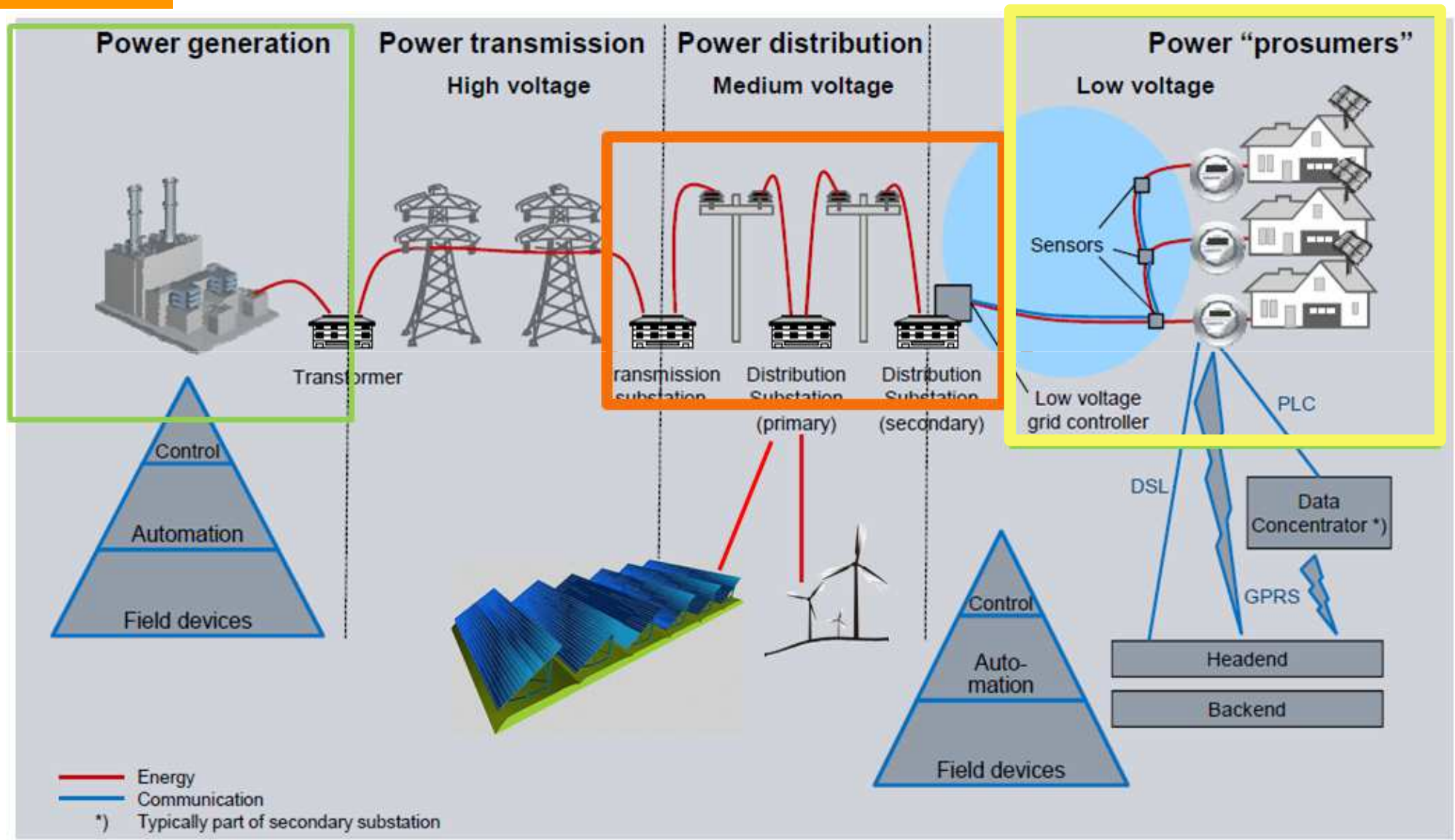
Activities & objectives

- Execution of **Vulnerability & Attack tests**
- Definition and validation of **new security policies and Countermeasures**
- Comparison of security level of **different architectures**
- Continuous monitoring and check of **standards**

Enel SCADA Security Lab is the first laboratory in Europe for ICT security test and analysis of Generation power plants (JRC source)

Enabling Know-how

SCADA Cyber-Security Lab



Reproduced and tested

Ongoing implementation and connection to the Cybersecurity Lab

New fields of investigation

Inverter modeling and testing

Goal:

Assess and develop advanced inverter functionalities to provide grid support

Activity:

Simulation and field validation of inverters (Livorno)

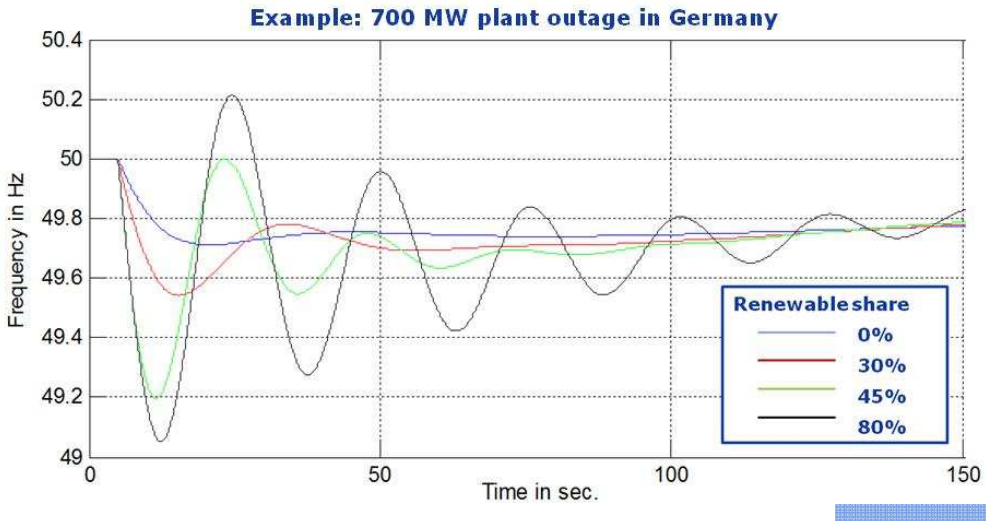
System stability analysis

Goal:

Estimation of variable renewables effects on system stability and identification of business opportunities

Activity:

Stability analysis of the Italian electric system in three different scenarios



Thank you for your attention!