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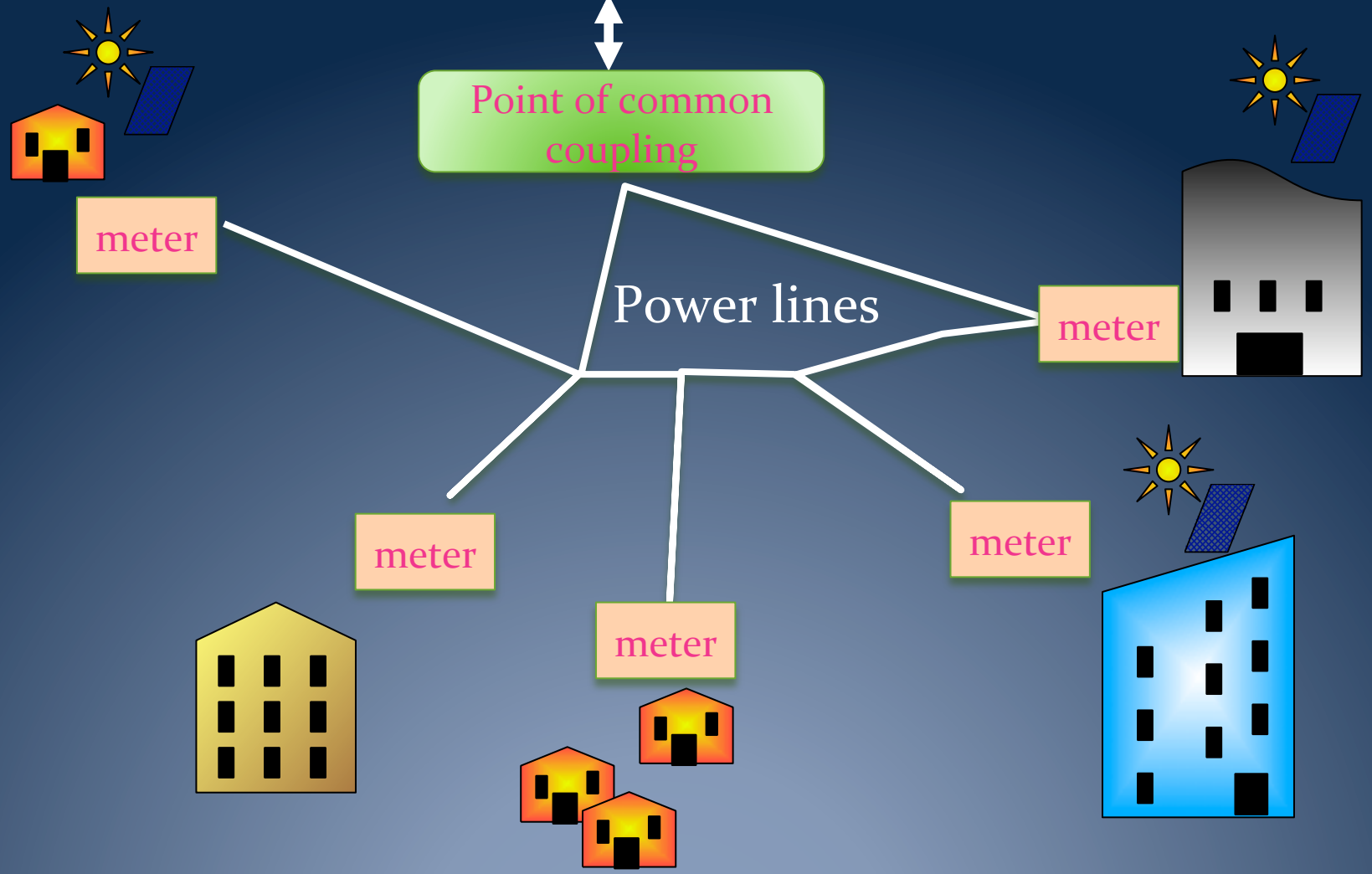
Current grid structure



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Current grid structure

- Households, buildings, factories are connected to a local grid via "dumb" meters
- Energy can be purchased from different suppliers (ENEL, Sorgenia, etc..)
- Ownership and maintenance of power lines are decoupled from energy vendors
- Each neighbors or group of consumers is connected through the low-voltage residential grid via a point of common coupling (PCC)
- Most nodes are passive (consumers only).
- Few nodes are also producers, mainly PV. Energy vendors are required by law to buy all PV energy produced.
- No node is intelligent , i.e. no control is allowed at the node level.
- No energy storage is available in these local grids.

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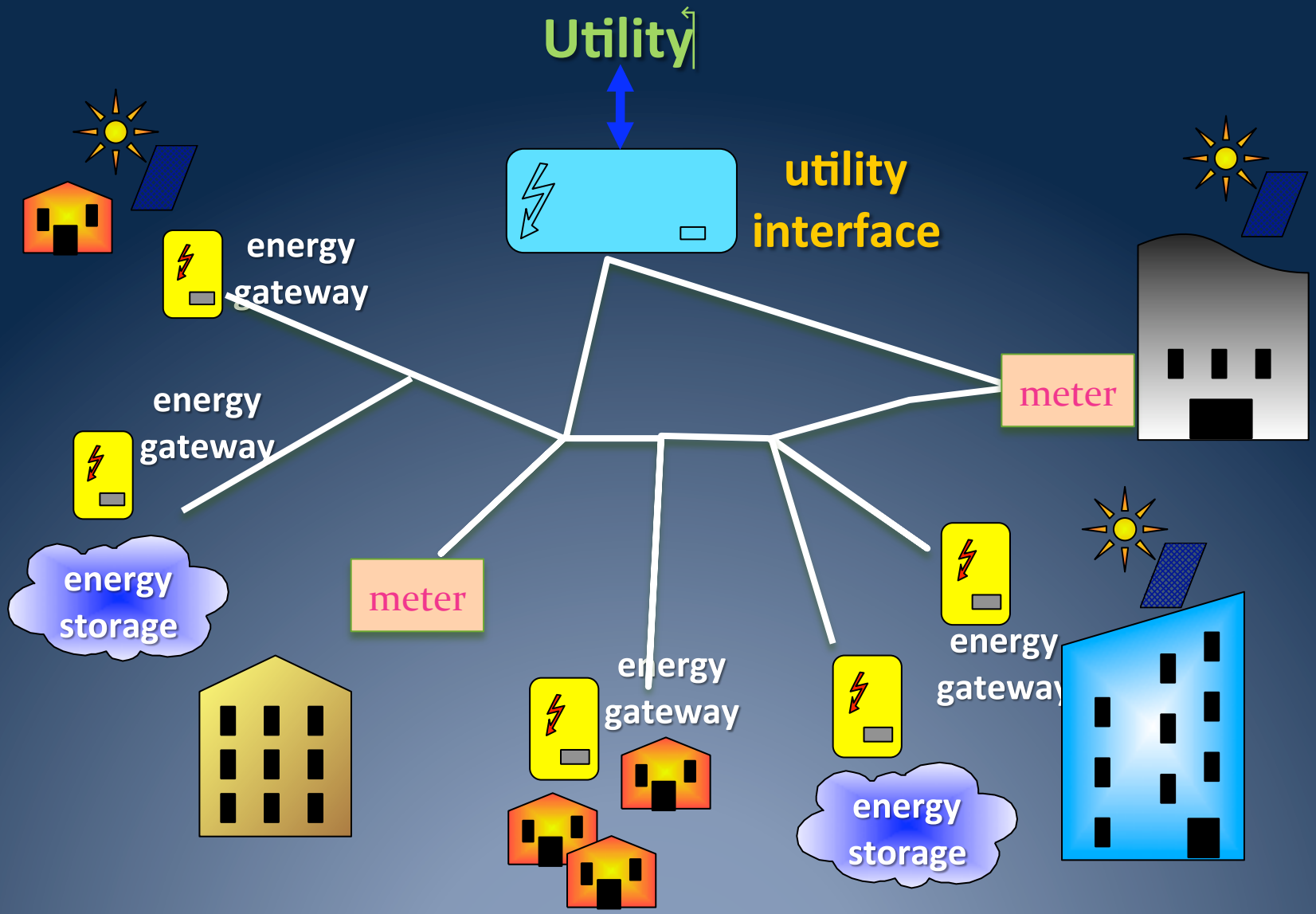
Future grid: Smart Micro-grid



Future grid: Smart Micro-grid (I)

- **The power lines and physical infrastructure will not be changed.**
- Many houses will be provided with green energy production (PV, wind, biomass) and energy storage.
- **Some households, buildings, factories will remain connected to the micro grid via a "dumb" meter (non controllable nodes).**
- **Many dumb meters will be substituted by smart meters called energy gateways.**
- **PCC will be provided with an smart device called Utility Interface.**

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Future grid: Smart Micro-grid (I)

- **Energy gateways** are electronic devices capable of
  - **Measure** physical quantities (active/reactive power, voltage amplitude, relative phase, etc..)
  - **Communicate** with other energy gateways and with utility interface
  - **Control** of local power production/consumption/storage within the nodes
  - **Optimize** load balancing and other grid-wide objectives
- The **Utility Interface** is an electronic device capable of
  - **Measure** physical quantities (active/reactive power, voltage amplitude, relative phase, etc..)
  - **Communicate** with energy gateways of the micro grid and with utility interface units of other micro grids.
  - **Coordinate (directly or indirectly)** energy gateways to achieve grid-wide objectives
  - **Forecast** grid-wide energy demand and production

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Future grid: Smart Micro-grid (III)

- Communication can occur via the power lines (PLC) or via traditional means (Ethernet, Internet, Wifi).
- The communication network topology does not necessarily coincide with the power network topology .

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Scientific challenges & benefits

Challenge	Potential benetifs
Real-time sensing and sychronization	Coordinated and optimized grid management
Desing of standardized interfacing for EG and UI and interoperability	Plug&Play system structure for easing the deployment and tuning phase
On-line grid parameter identification and self-configuration	Adaptation to time-varying grid and units features
Distributed estimation and control	Scalability and Robustness to components failures
Grid-wide supply/demand energy forecasting	Better use of the grid and of the renewable energy sources
Grid Stability with inverter based sources	Islanded operation

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Drivers of our project

- Provide a **distributed market-based architecture** for the control and management of the Smart Micro Grids providing a business model of the proposed system architecture
- Provide a **distributed design paradigm** so that Energy Gateways (EGs) are self-configurable, have automatic discovery of neighbors EGs, can identify local parameters of the smart-grid
- Provide a **retrofitting strategy** so that the physical power network does not need to be changed, but EGs can provide additional capabilities to optimize energy production/consumption both at the node level and at the grid-level
- Provide a design using **off-the-shelf HW ~~and SW(?)~~ technology**. The novelty will be totally in the ICT development
- Provide a **standardized interface** suitable to **plug-and-play.** In this way EGs can be produced, installed and managed by potentially different operators and energy vendors.

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Project strengths

- **Market-based** design paradigm for a **business** oriented system architecture
- **Distributed** design paradigm for the control, estimation optimization and grid identification for a **scalable** system architecture
- **Standard** based design paradigm for a **plug and play** system architecture
- **Off-the-shelf** technology and **retrofitting** for increasing (strengthening?) the impact of the proposed system architecture

Energy gateway - functional diagram

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Battery pack

PV system

Home Appliances

Power Flows

Power Electronics

DC/DC

DC/DC

Inverter

Power lines

µ GRID

On board ICT

Sensing

Estimation

Local control of power converters

Micro grid distributed control

Micro grid supervision/policies

Communication

Communicat ion network

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Utility Interface - functional diagram

Three phase distribution infrastructure

Energy Storage

Power Electronics

System Policies:

- Aggregator (enabling distributed customers Energy management & Demand Response)
- Managing Islanded Operation
- Ancillary Services to Grid
  - In a mature Smart Grid scenario: key player to mediate between customers and market

I/O INTERFACE

Communication with µ-Grid and main utility

µ GRID

energy gateways

Concept idea: micro-grid to appear as an 'ideal' programmable load

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Retrofitting existing plants