REPOWERING EUROPE

Photovoltaics: centre-stage in the power system

Challenges and opportunities in the integration of PV in the electricity distribution networks

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Chair of ETP SmartGrids

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HEDNO

electra
Turn On the Grid of the Future

European Targets for 2030 (agreed 10/2014)

EERA
European Energy Research Alliance
Smart Grids Joint Programme

SEVENTH FRAMEWORK PROGRAMME

	Greenhouse Gas Emissions	Renewable Energy	Energy Efficiency	Interconnection
2020	-20 % Greenhouse Gas Emissions	20 % Renewable Energy	20 % Energy Efficiency	10 % Interconnection
2030	≤-40 % Greenhouse Gas Emissions	≥27 % Renewable Energy	≥27 % Energy Efficiency	15 % Interconnection
2050 ambitions	-80-95 % Greenhouse Gas Emissions	Increased Renewable Energy	Increased Energy Efficiency	

27% renewable energy in 2030: up to 45% renewable electricity

Ph
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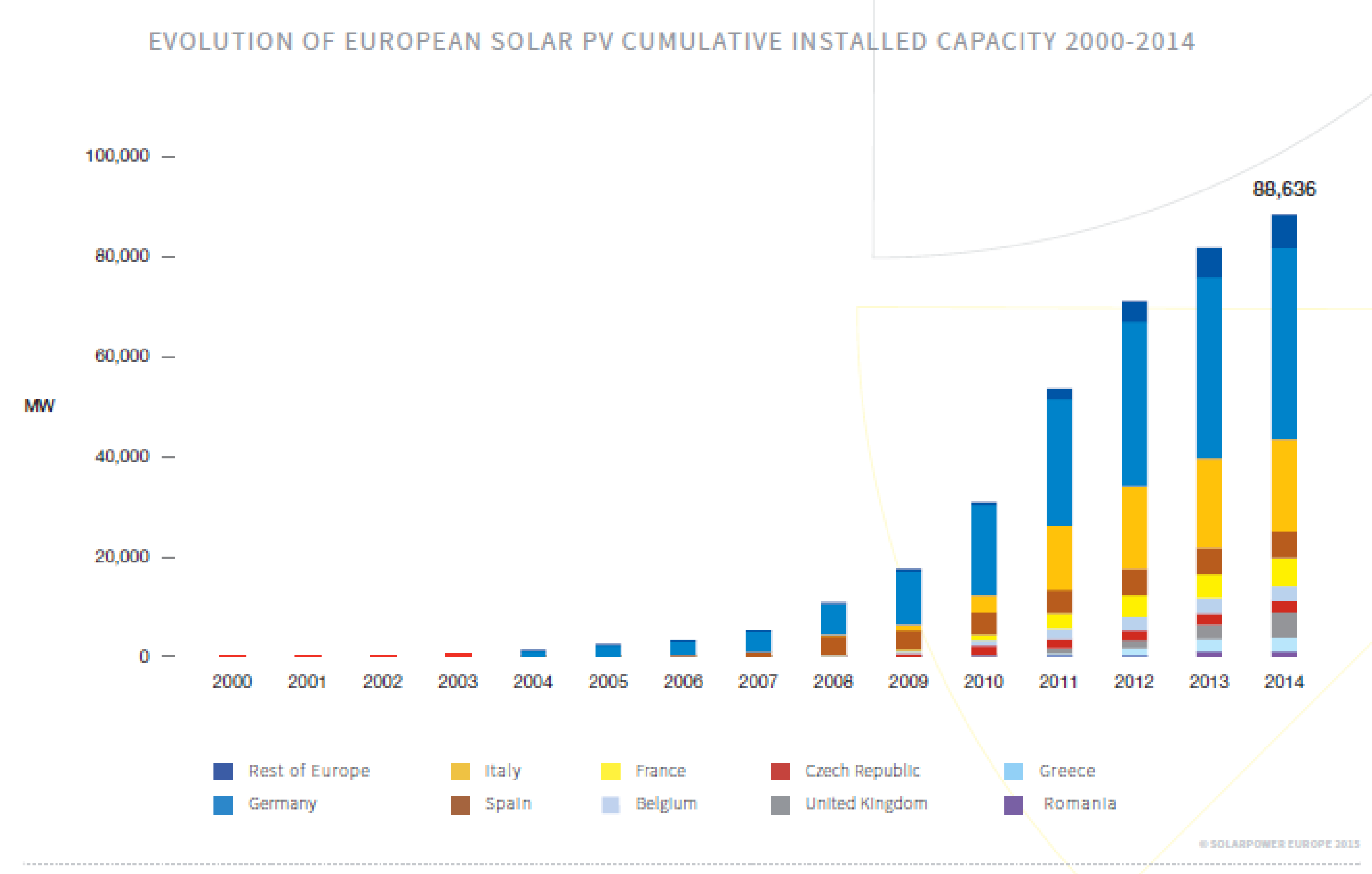
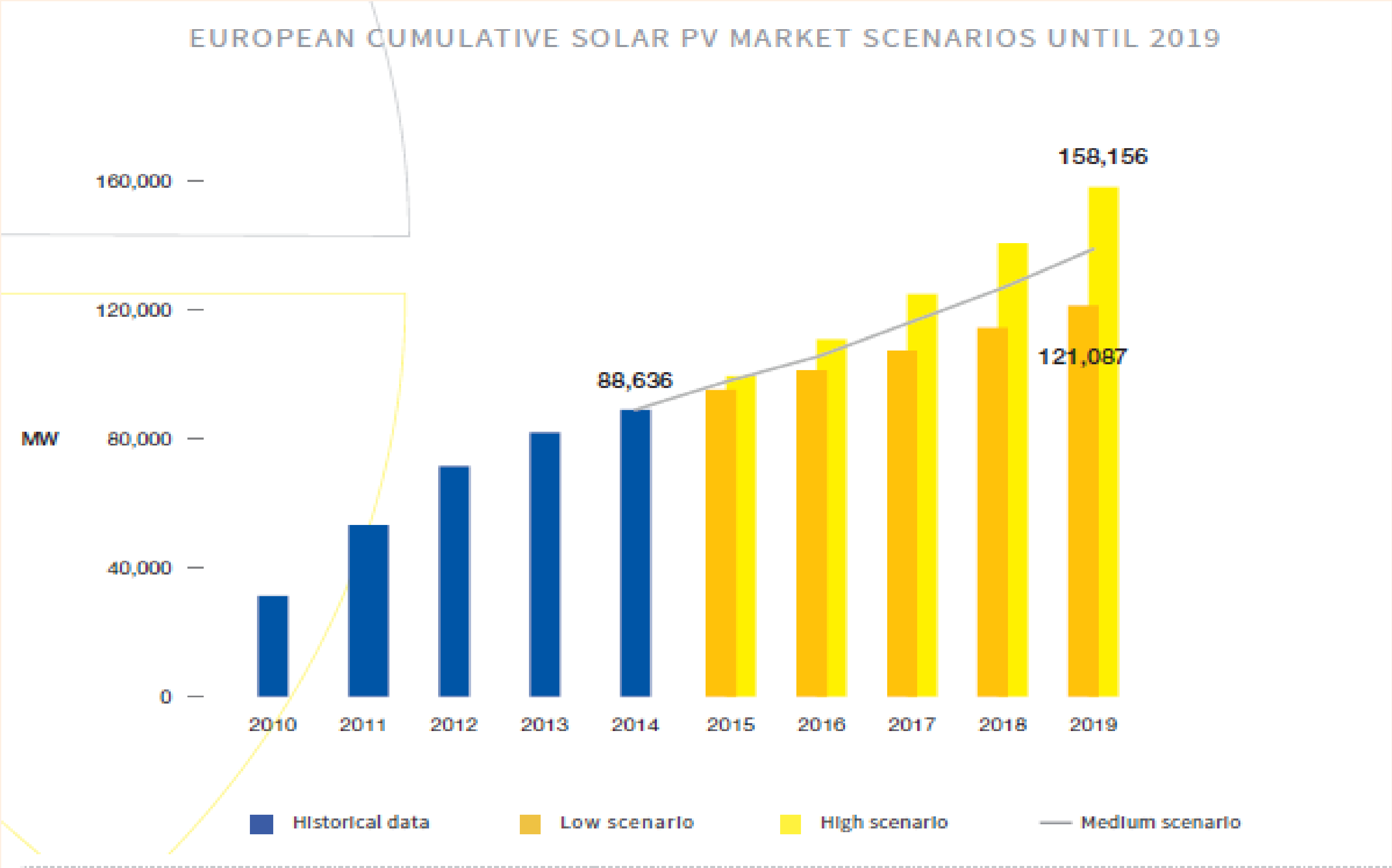
Evolution of EUROPEAN solar PV CUMULATIVE installed capacity 2000-2014



Source: www.solarpowereurope.org

EUROPEAN cumulative solar PV market scenarios



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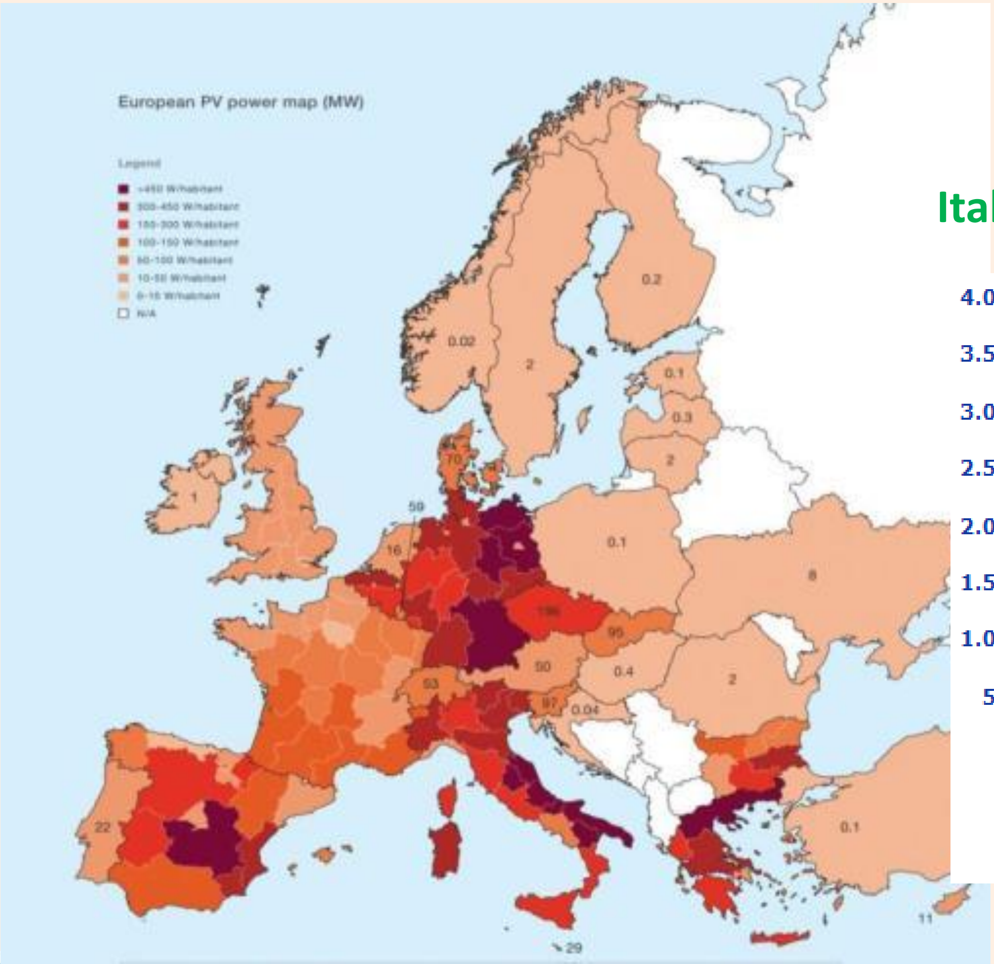
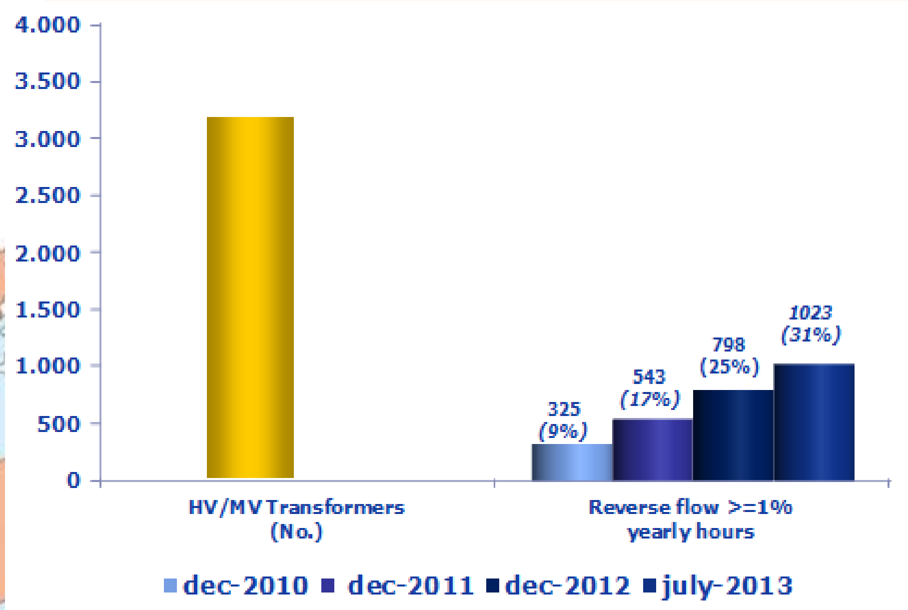
Source: www.solarpowereurope.org

95% of PV capacity is installed at LV (60%) and MV (35%)



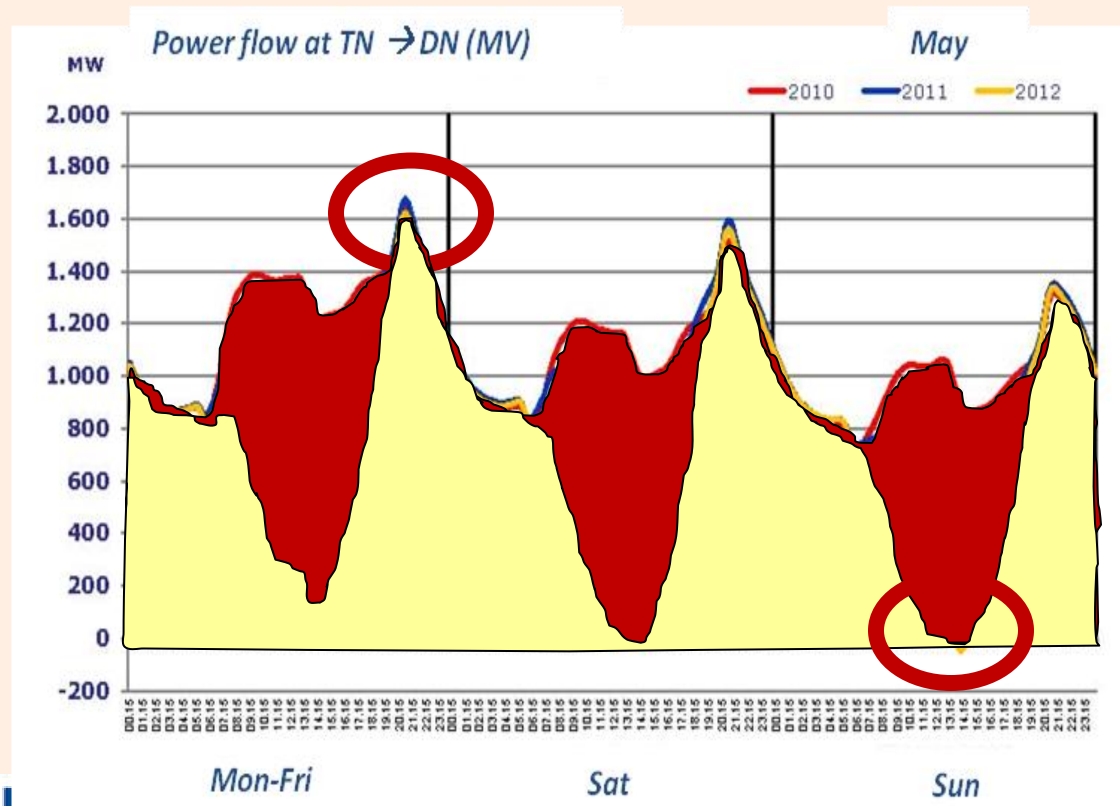
Source: EPIA, 2012

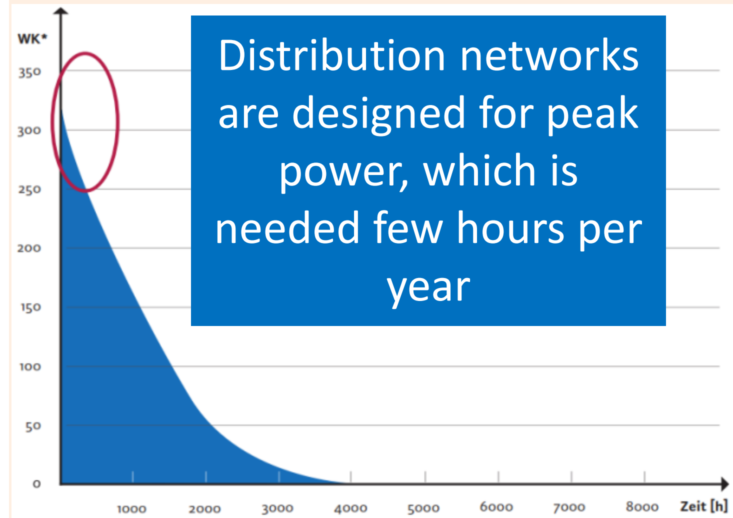
Italy: Energy Flows at TSO-DSO boundary



Source: ENEL, 2013

Use of Network is decreased, but not the need for investments





Distribution networks are designed for peak power, which is needed few hours per year

Power flows between transmission and distribution network in Italy, 2010-2012

Source: Enel Distribuzione

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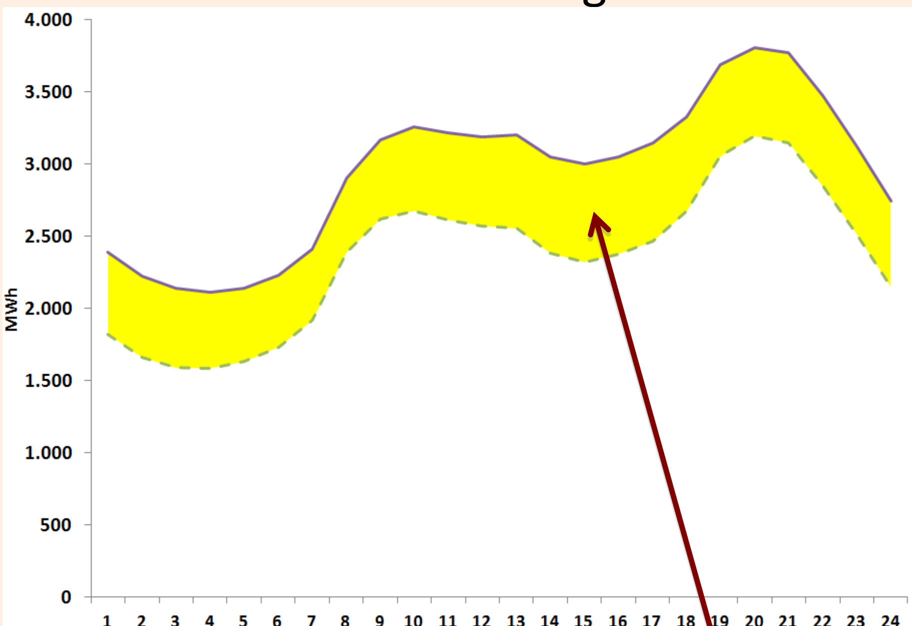
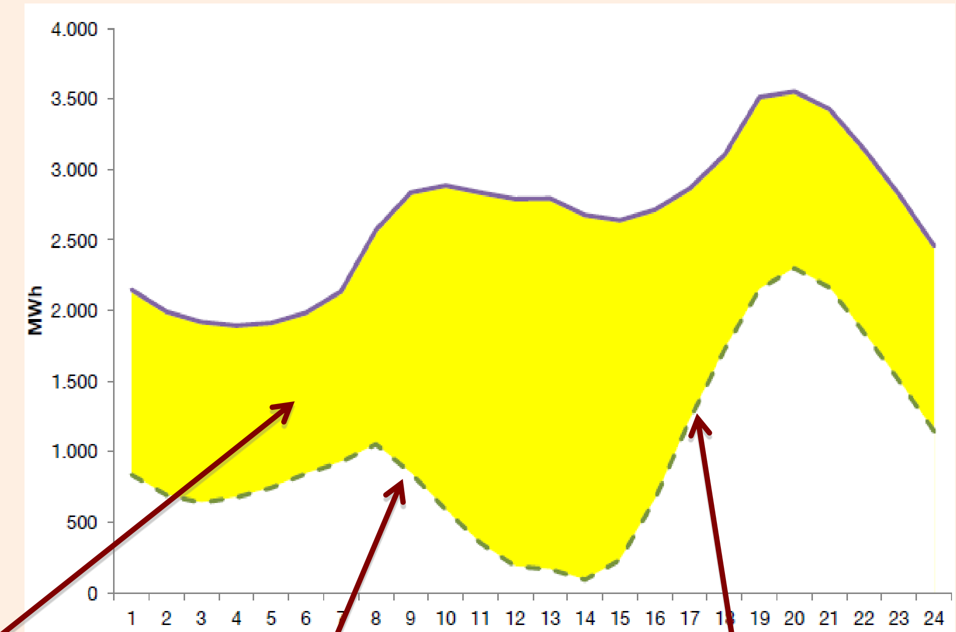
Impact of VRES on distribution networks (1/2)

March 2010 - **Working days**
Southern regions



Hour (h)

March 2013 - **Working days**
Southern regions



Hour (h)

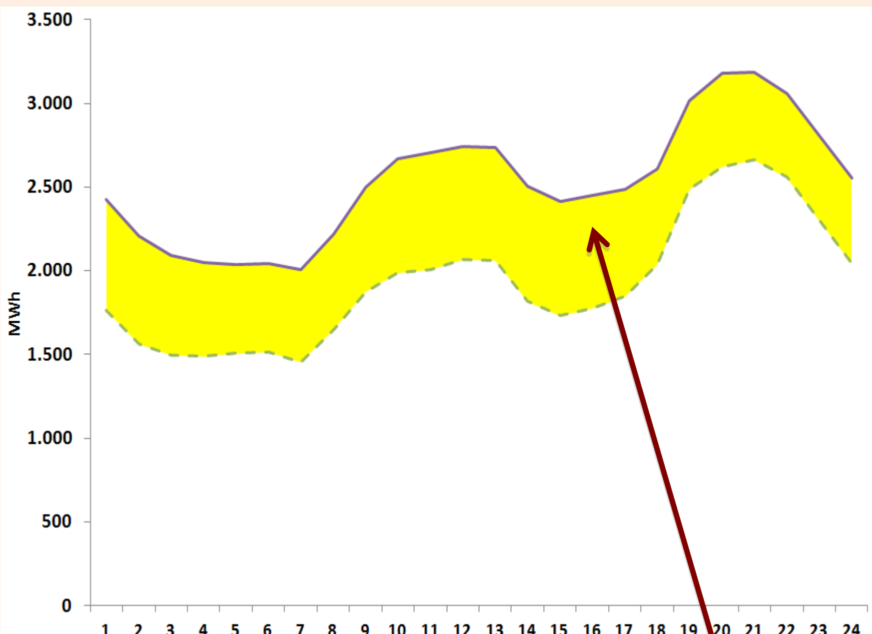
Load covered by
wind and PV

Apparent reduction
in the morning

Steep ramps
in the evening

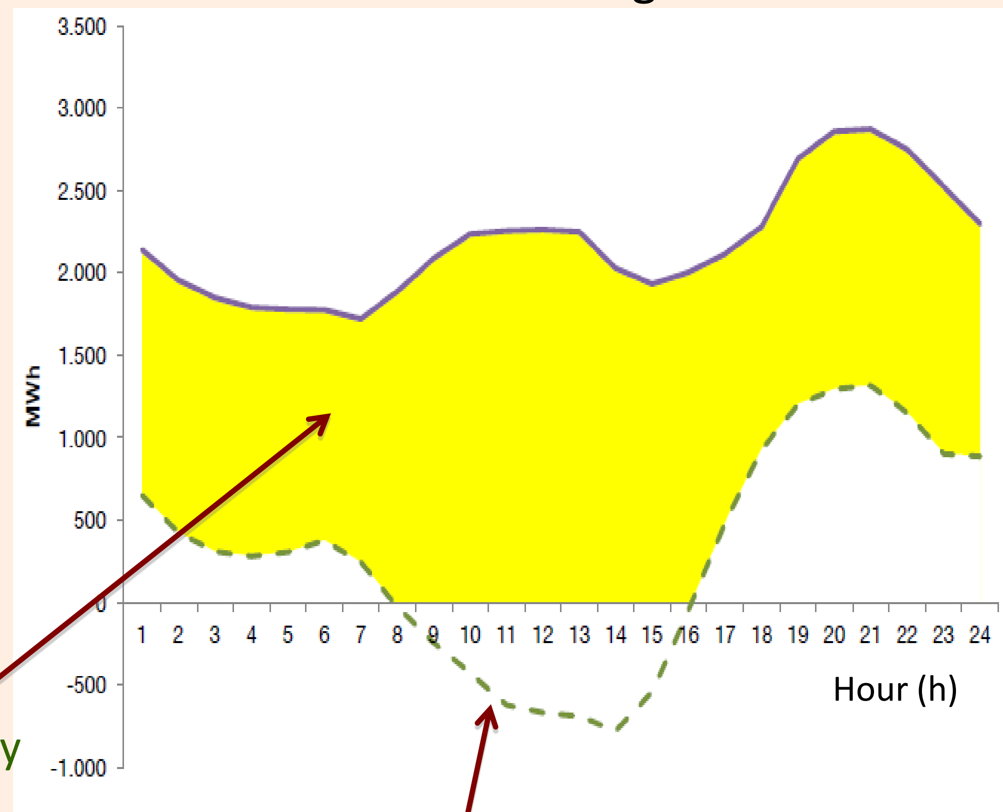
Impact of VRES on distribution networks (2/2)

March 2010 - **Sundays & holidays**
Southern regions



Hour (h)

March 2013 - **Sundays & holidays**
Southern regions



Load covered by wind and PV

Reverse power flow (from MV to HV)

Technical Challenges

- Congestion - Thermal ratings (transformers, feeders etc) especially on:
  - ✓ Low load – max generation situations - unavailability of network elements (N-1 criterion)
- Voltage regulation
  - ✓ Overvoltage (e.g. minL – maxG situation or/combined with high penetration in LV network) - Undervoltage (e.g. large DER after OLTC/VR) - increased switching operation of OLTC/VR
- Short circuit
  - ✓ DER contribution to fault level - compliance with design fault level etc
- Reverse power flows – impact on:
  - ✓ Capability of transformers, automatic voltage control systems (e.g. OLTC), voltage regulation, voltage rise etc
- Power quality
  - ✓ Rapid voltage change, flicker, DC current injection , harmonics, etc
- Islanding – Protection
  - ✓ Personnel/consumers/facilities safety, mis-coordination among protection equipment and reduced sensitivity operation zone

Requirements for DER capabilities in Network Codes

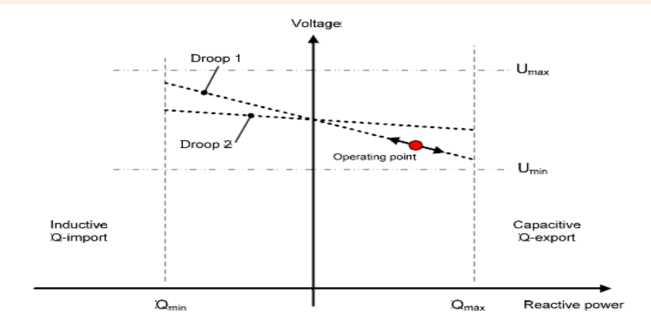
- Expanded operation limits for **voltage and frequency** in normal operation
- **Continuous operation** under low voltage (LVRT or FRT)
- **Voltage support** during faults (injection of reactive current)
- **Frequency support**:
    - Static (droop type, $\Delta P = k \cdot \Delta f$ – mainly for overfrequency)
    - Dynamic (inertial support, $\Delta P = k \cdot ROCOF$)
- Contribution to **Voltage Regulation**:
    - Reactive power control /power factor ($\cos\phi = f(U)$ ή $\cos\phi = f(P)$)
    - Active voltage regulation
- **Monitoring** και power control of DER stations:
    - Active power curtailment
    - Limits of rate of change of power production
    - Provision of spinning reserve

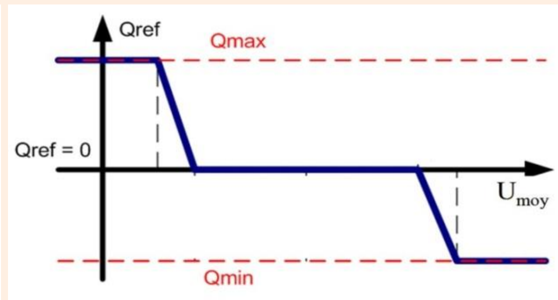
Transmission Services

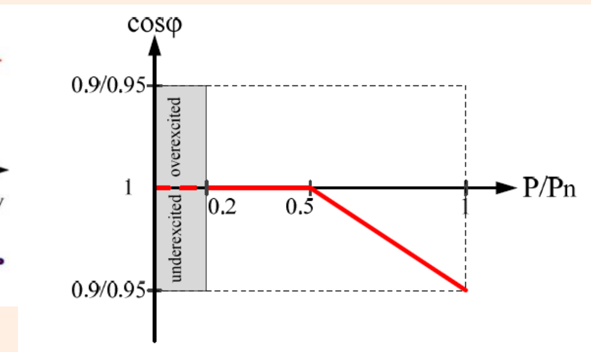
Distribution Services

Requirements for DER Stations in Network Codes

- Control of DER
  - Reactive power control (P-Q, V-Q etc), active power curtailment



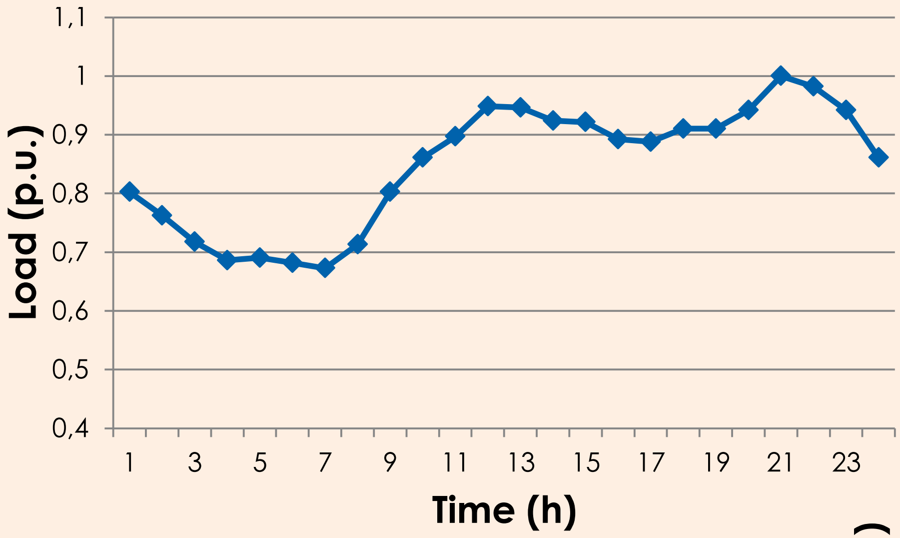


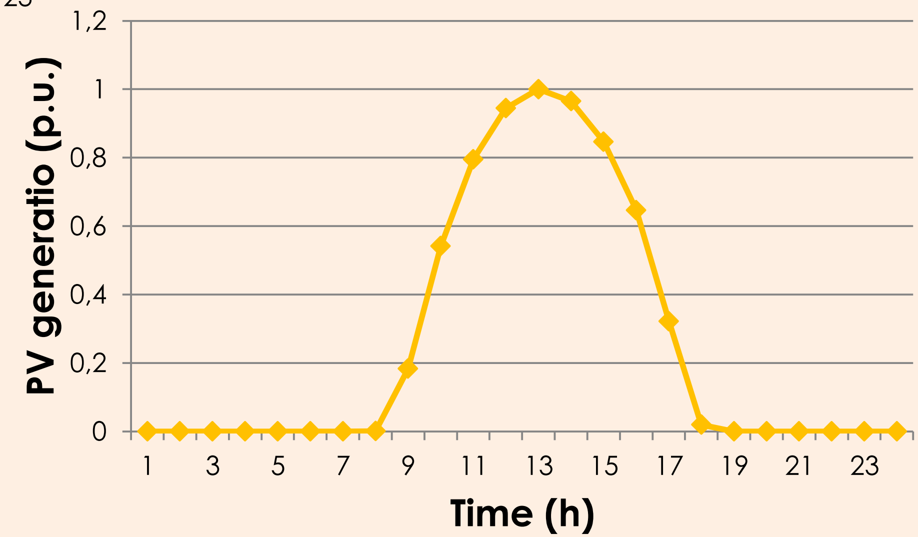


- Future concepts
  - Centralised or decentralised storage for peak saving
  - Coordinated (centralised or decentralised) voltage control
  - Usage of SCADA software or other (smart grids, web-interfaces e.g.)

Coordinated Voltage Control

Daily PV generation and load curves





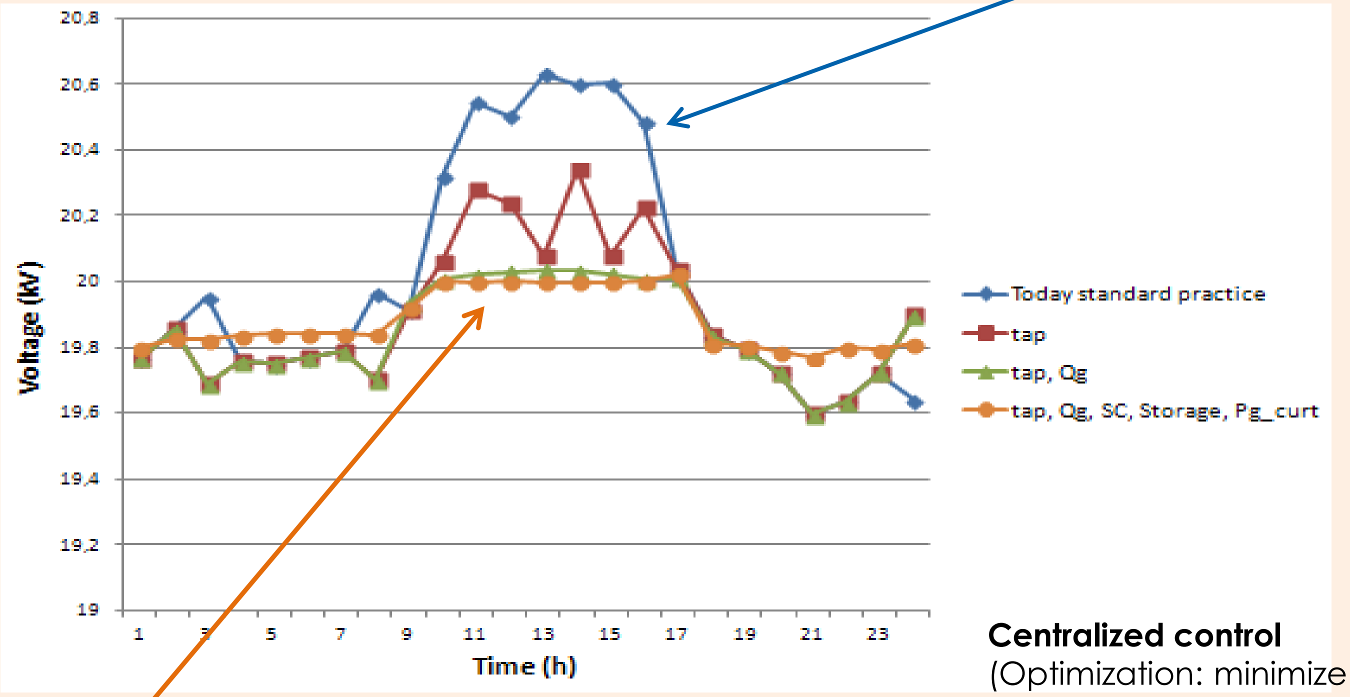
Study Case in Rhodes

Source: EC, FP7 Sustainable Project

Coordinated Voltage Control

Improvement of node voltages (daily variation) by gradual application of control means

3rd Node



Conventional practice

Advanced voltage control

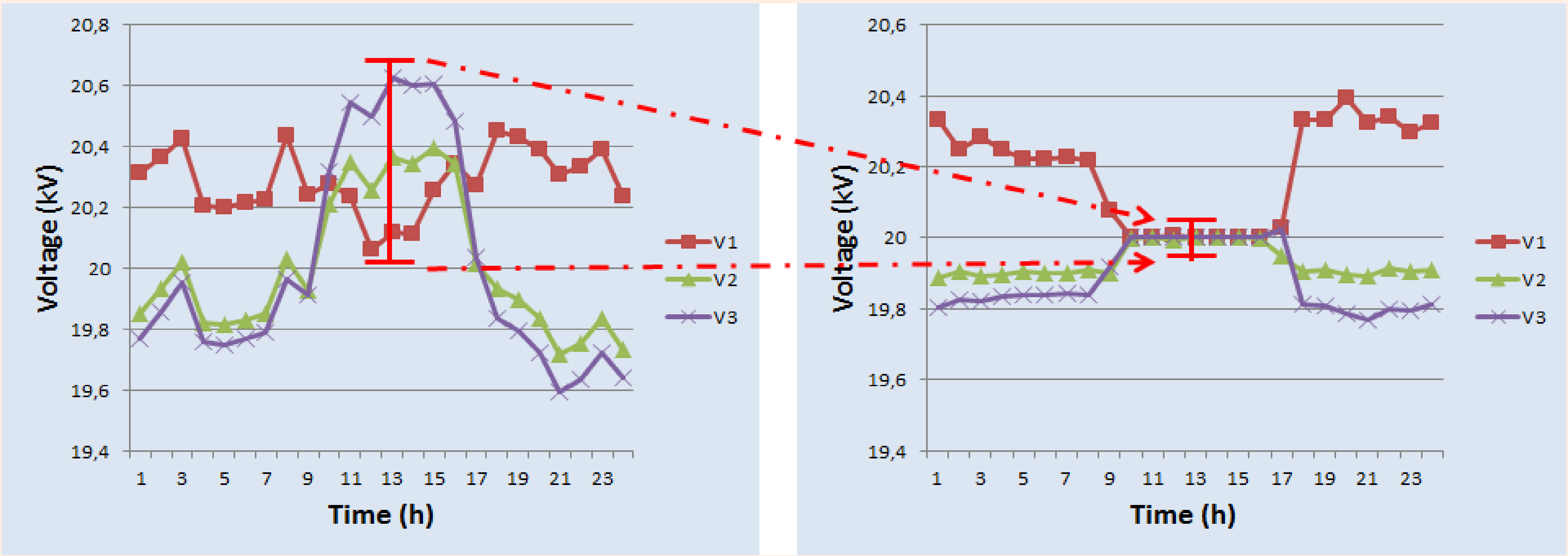
Centralized control
(Optimization: minimize voltage deviations from nominal)

Source: EC, FP7 Sustainable Project

Coordinated Voltage Control

Improvement in voltage variations

Improvement of node voltages (daily variation) by applying advanced controller (Objective: minimize voltage deviations - All available control variables exploited)



Standard practice (typical voltage regulation)

Advanced controller:

$$J = \sum_{t=1}^{24} \left(w_1 * \sum_{i=1}^{N} \left(V_{it} - V_{ref} \right)^2 \right)$$

Source: EC, FP7 Sustainable Project

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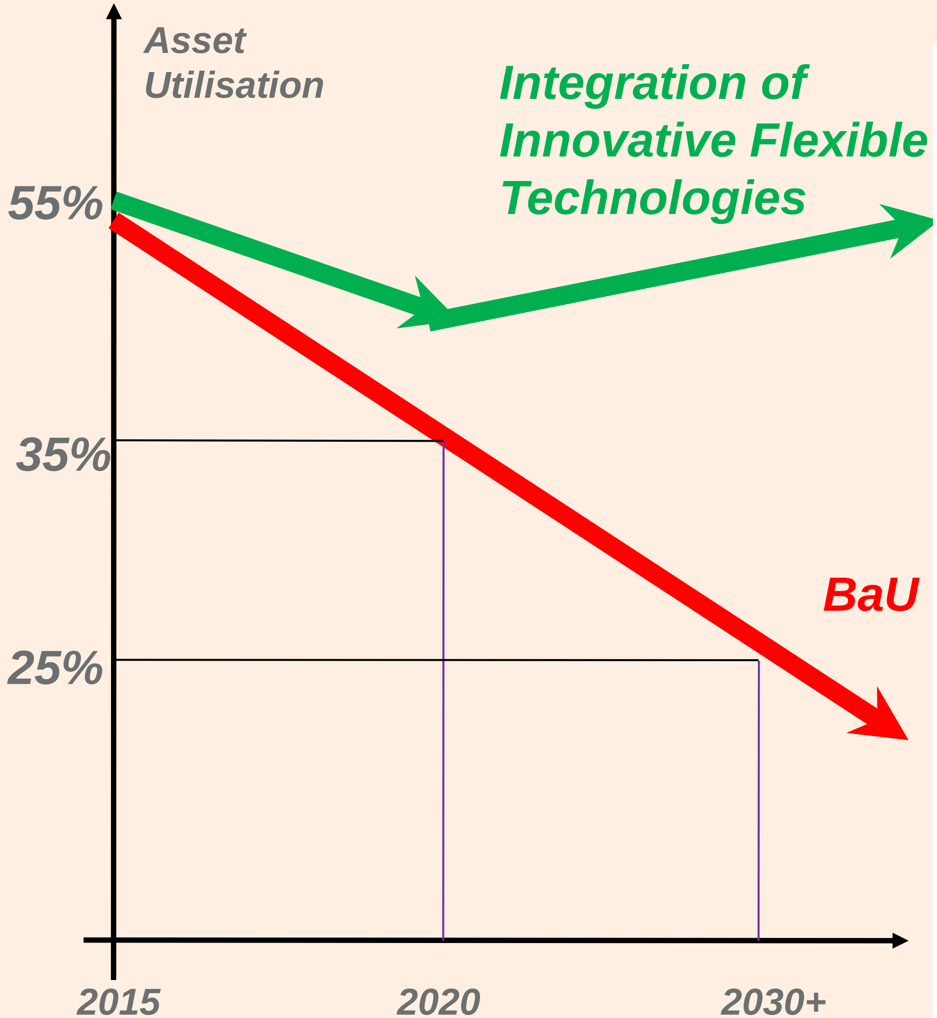
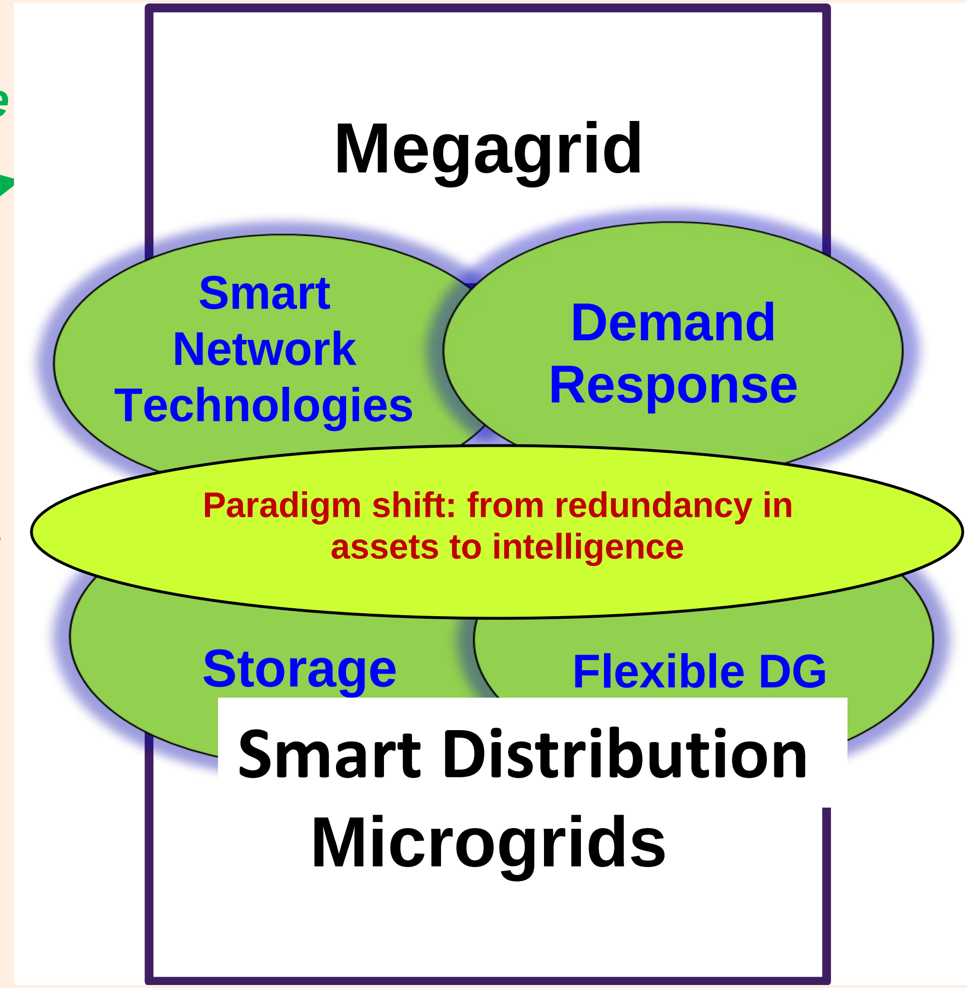
The ETP SmartGrids Vision

http://www.smartgrids.eu

Can we afford silo & non smart?





Value of flexible technologies > €30bn/y

Challenges for 2020

- **Paradigm shift towards smart grid**
  - From redundancy in assets to smart integration of all available resources – fundamental review of standards
- **From Silo to Whole-Systems approach**
  - **Enable interaction across sectors and energy vectors**
- **From Centralised to Distributed Control**
  - **Consumer choices driven development**