Satellite view of Europe in September 28th, 2003

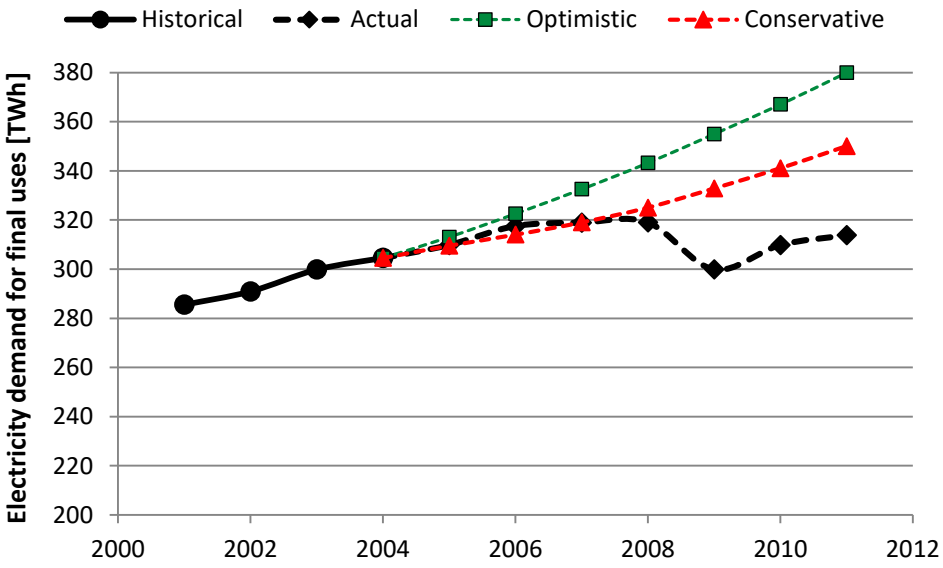
Power supply was restored between 5 hours (in northern Italy) and 19 hours (!!!, in Sicily) after the accidental event …

… very high economic impact, which roughly estimated assuming a Value of Loss Load (VOLL) in the order ot 4000 €/GWh, resulted in the order of 0.06-0.1 % of GDP …

Weakness of national electric system, mainly due to insufficient working capacity of power plants, was identified as one of the main causes …

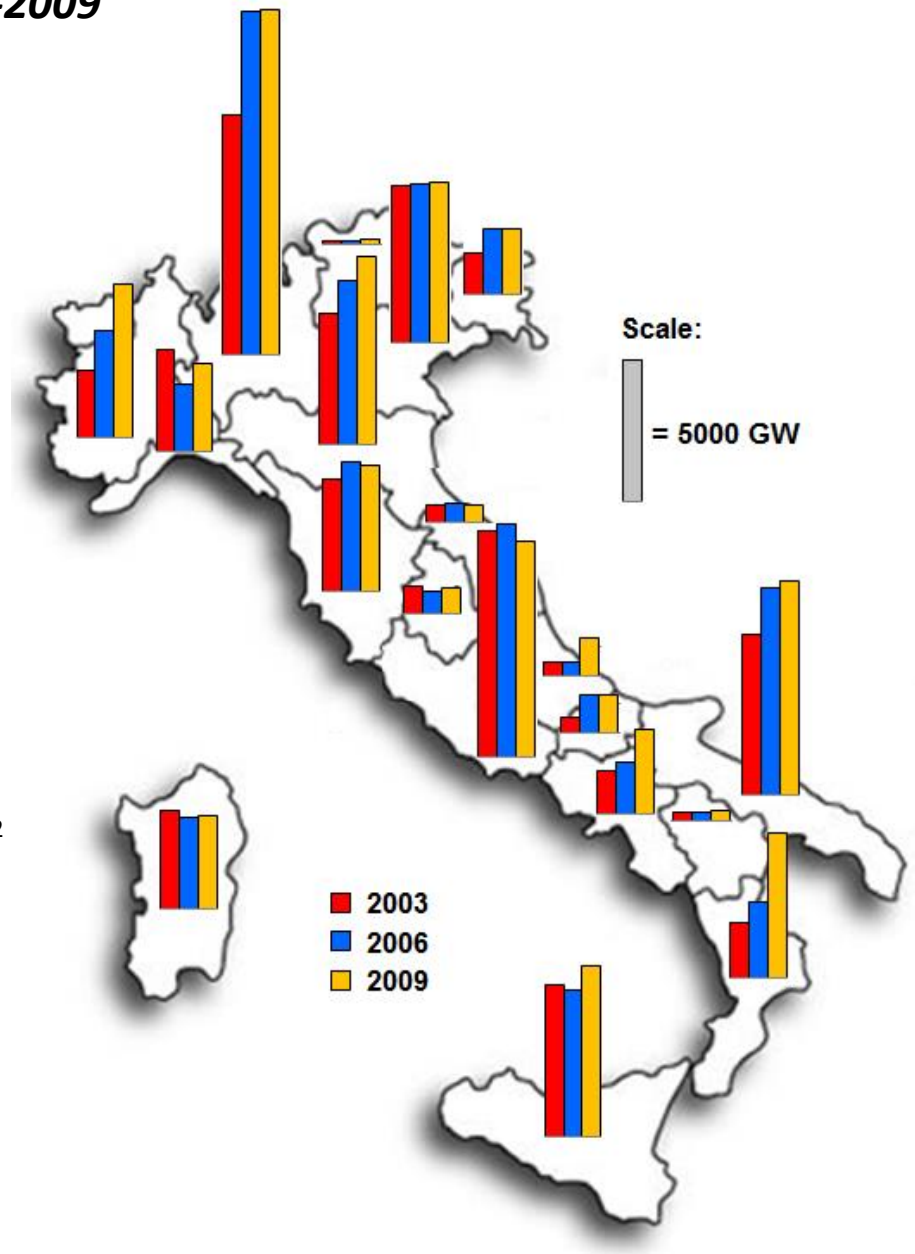
New thermoelectric capacity installed in 2003-2009

Based on the current demand at 2003 and overestimation of future demand …



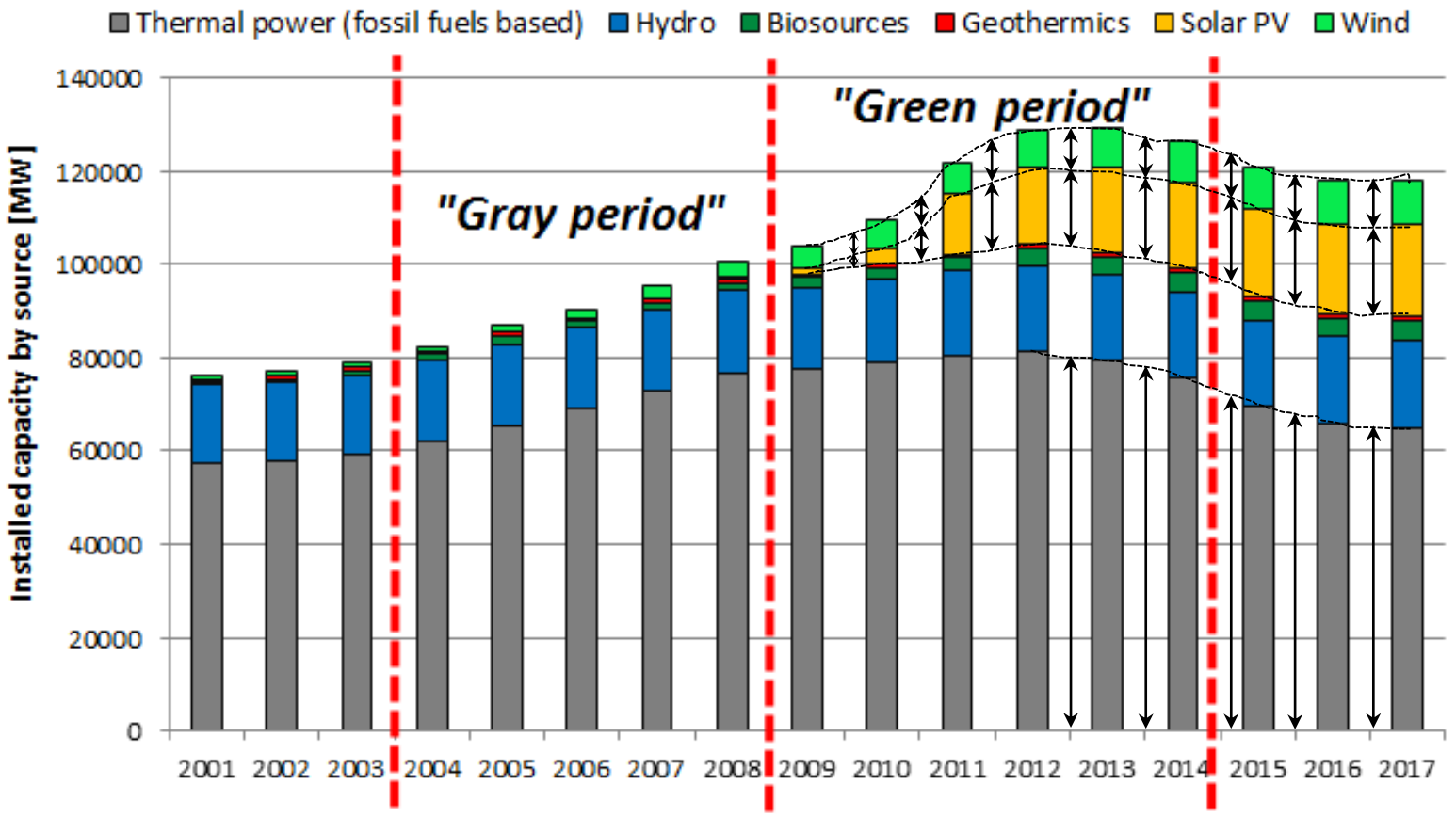
… approximately 20 GW of new capacity by novel power plants (mainly, CCGT) and repowering of old plants were installed

… let us indicate this as **«grey period»**

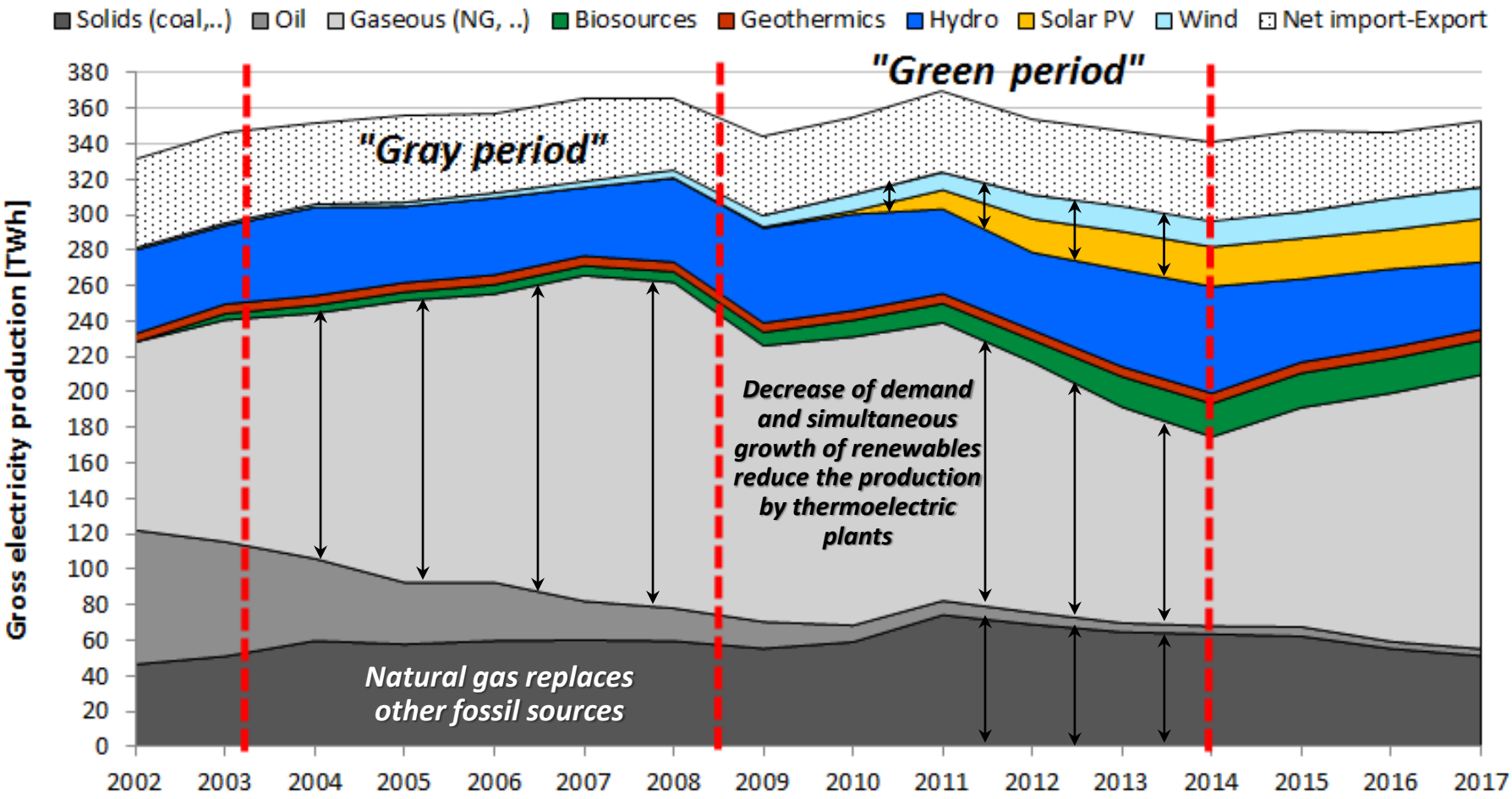


Rapid growth of renewable capacity installed in 2009-2014

Several support mechanisms (Green Certificates for wind, then feed in tariff for wind and biosources, several programmes of feed-in premium for solar PV) have favoured a rapid growth of installed renewable capacity …

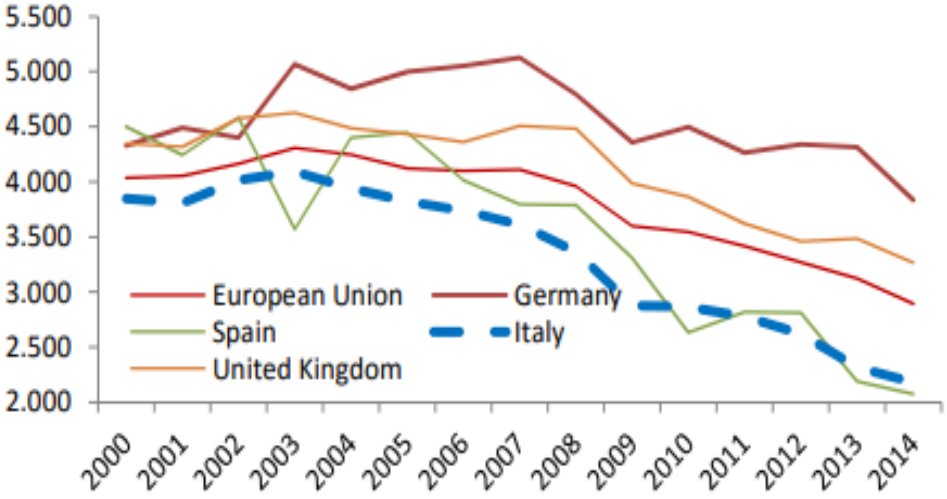


Panel: Stepping up the penetration of renewables against infrastructural and financial barriers

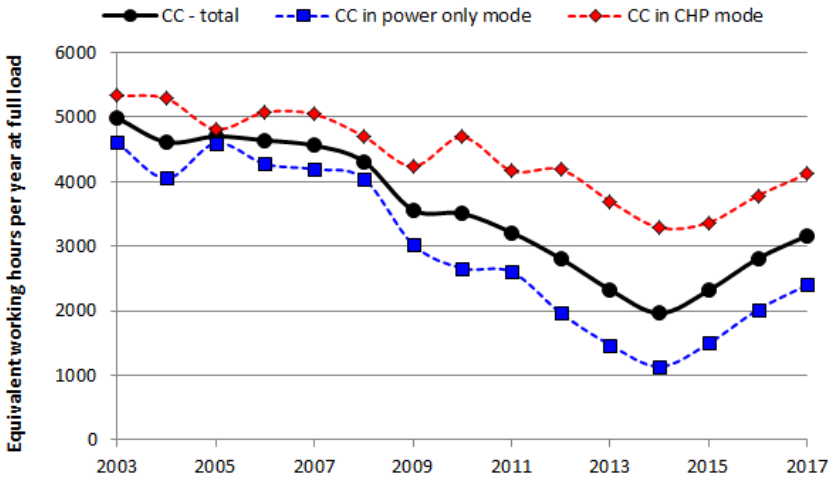


Panel: Stepping up the penetration of renewables against infrastructural and financial barriers

Working hours of fossil-fuel based power plants

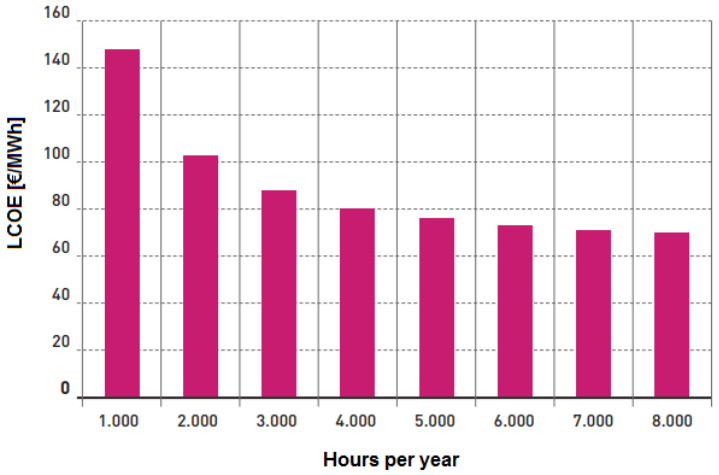


Source: Agora Energiewende (2016): *Energy Transition in the Power Sector in Europe: State of Affairs in 2015. Review of the Developments and Outlook for 2016.* Data processed by Entso-E

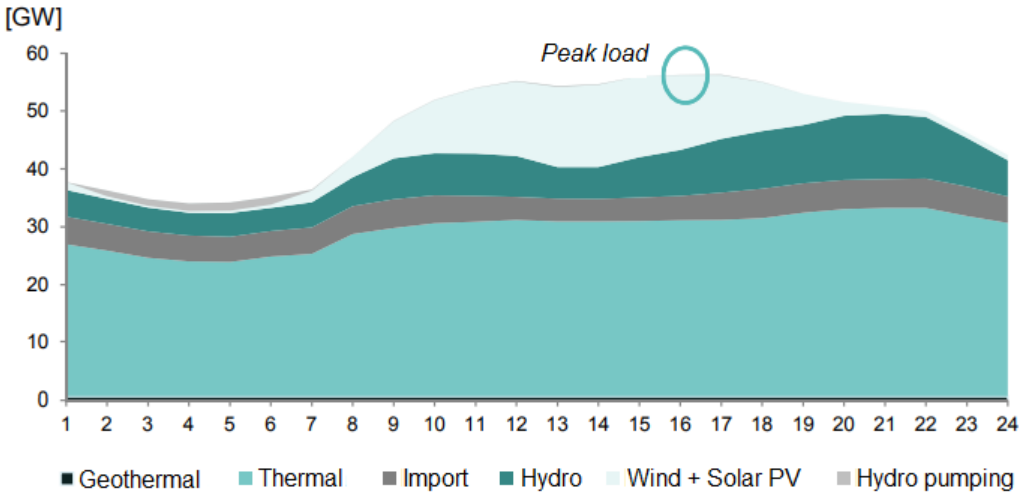


Source: Elaboration of statistical data provided by TERNA

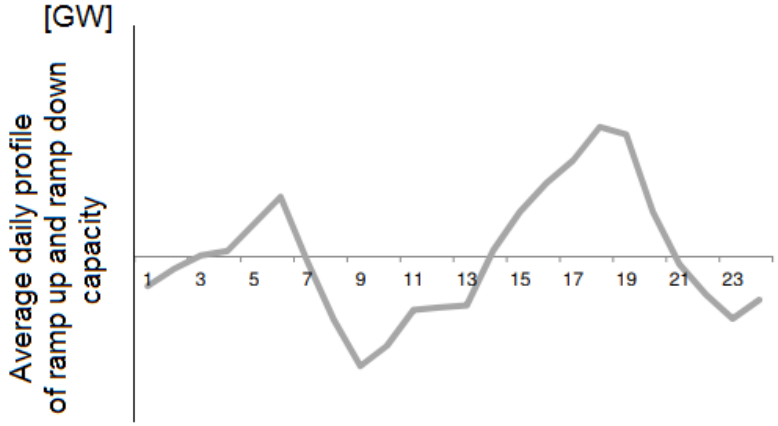
Based on historical market prices and in the hypothesis of ideal control, marginal costs of CC are covered for 3800-4000 hours per year, while from an LCOE perspective (i.e. including fixed costs) maximum profitable operation would be 2000-2200 hours per year.



Panel: Stepping up the penetration of renewables against infrastructural and financial barriers



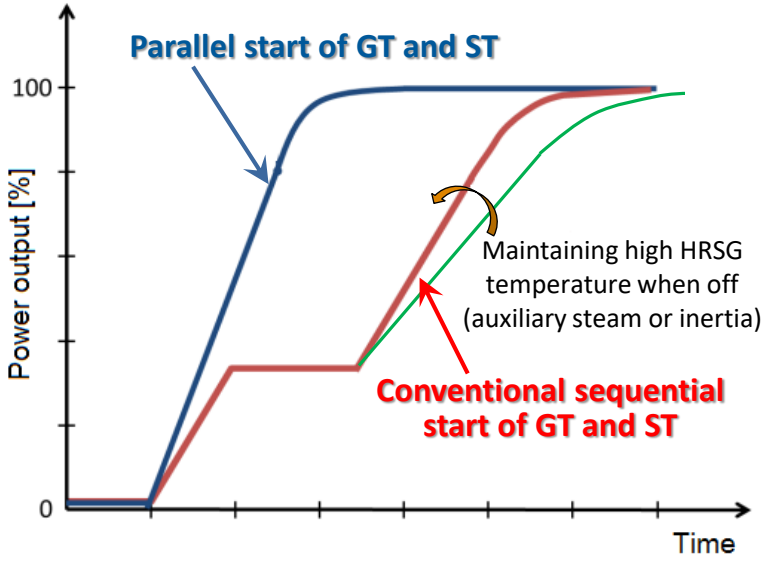
Source: TERNA monthly report on the Electric System (July 2018)



Source: Assoelettrica audition to the Senate of Italian Republic, 2016

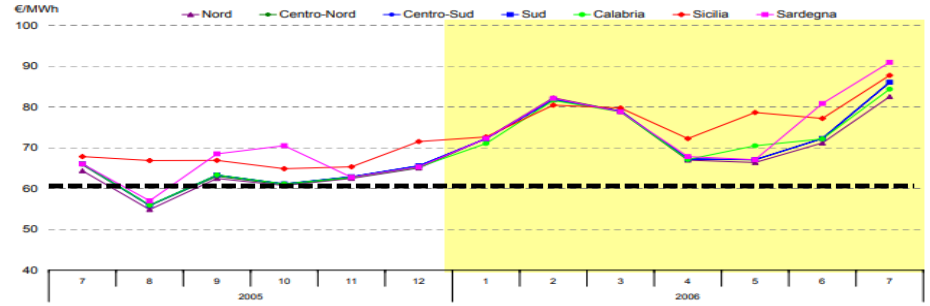
In order to play a more relevant role on the reserve market, increasing nominal efficiency is going to become a secondary goal compared to rapid load transient …

… and for existing plants, retrofit actions are being implemented to enable the plant to modulate its capacity more quickly …



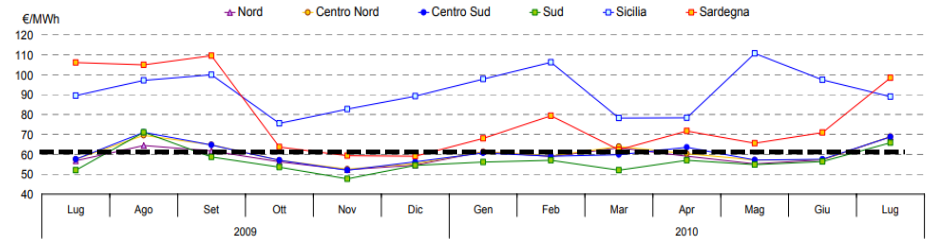
Panel: Stepping up the penetration of renewables against infrastructural and financial barriers

Transmission system



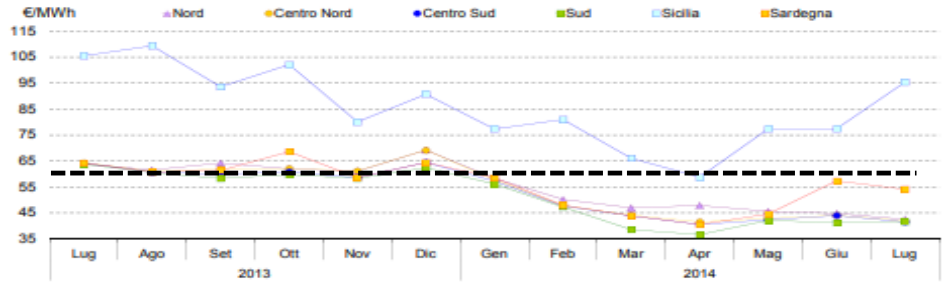
2006 – Very similar local Day Ahead prices in all the electric macrozones ..

Highest prices in summer



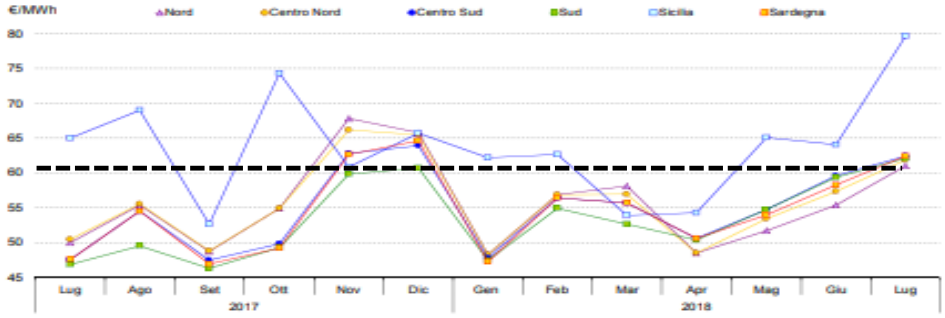
2010 – Sardinia and Sicily, the two large islands, experience much higher DA prices ..

Yearly price profile gets smoother



2014 – Sardinia connected to rest of Italy, Sicily remains the only critical area ..

Lowest prices move to summer

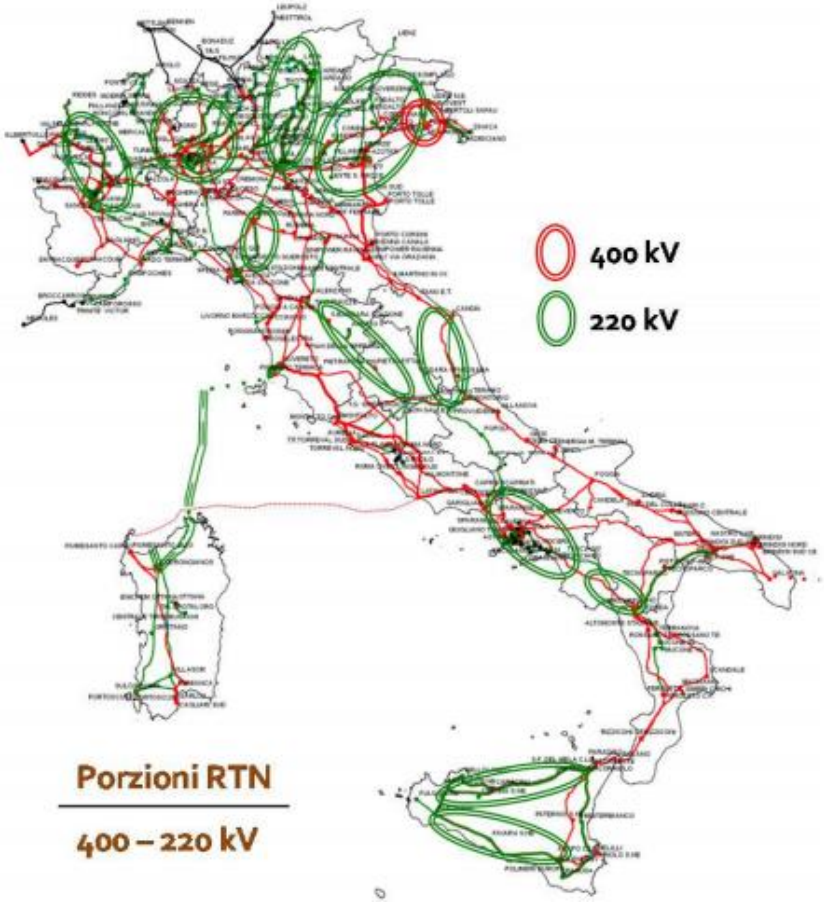


2018 – Situation of Sicily slightly improves …

Prices experience a reduction

Panel: Stepping up the penetration of renewables against infrastructural and financial barriers

Transmission system

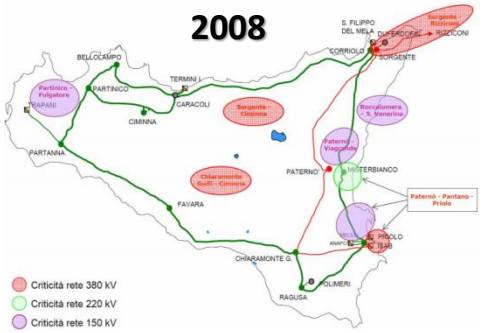


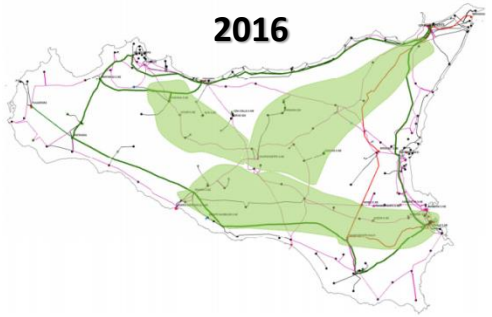
Based on detailed analysis of critical power fluxes, large investments have been made in High Voltage transmission system …

Assuming the congestion rent (CR) as an indirect measure of infrastructural performance, improvement are testified by its gradual decrease from over 700 M€ down to approximately 300 M€ in the last years …

In Sicily …

- … Criticisms related to a very limited 380 kV grid and a 220 kV ring …
- … Only partly solved by improving 150 kV connections with internal areas





Areas with 150 kV grid being improved to allow for connection fo new renewables

Other countries are experiencing more or less similar trends …

… like if grid stability issues, uncertainty on future demand levels and pressure exerted by conventional power suppliers tighed the potential for new renewables in as a sort of vise …

How to debottleneck local systems when, after reaching 30-35% penetration, renewable capacity tends to stagnation?

UNIVERSITY OF ZAGREB
FACULTY OF MECHANICAL ENGINEERING AND NAVAL ARCHITECTURE
DEPARTMENT OF ENERGY, POWER AND ENVIRONMENTAL ENGINEERING

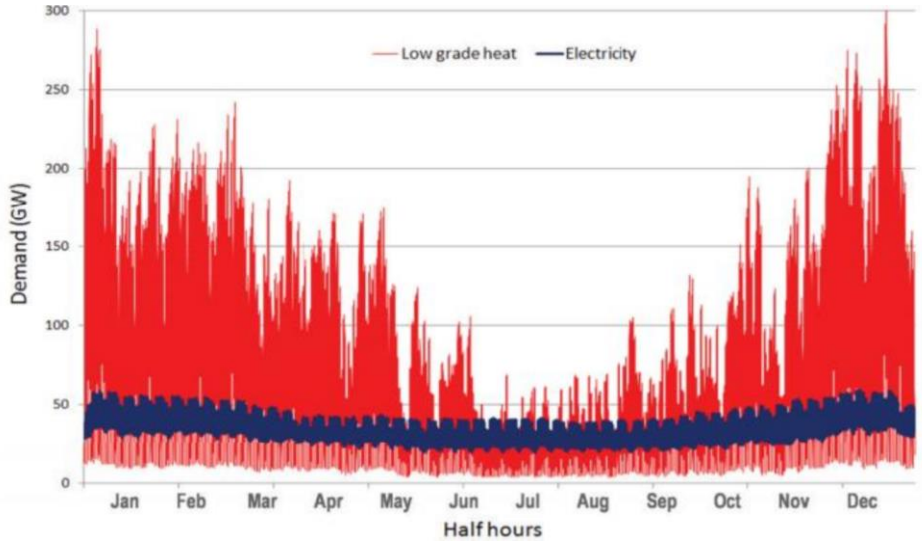
"Unlocking flexibility potential"

Panel: Stepping up the penetration of renewables against infrastructural and financial barriers

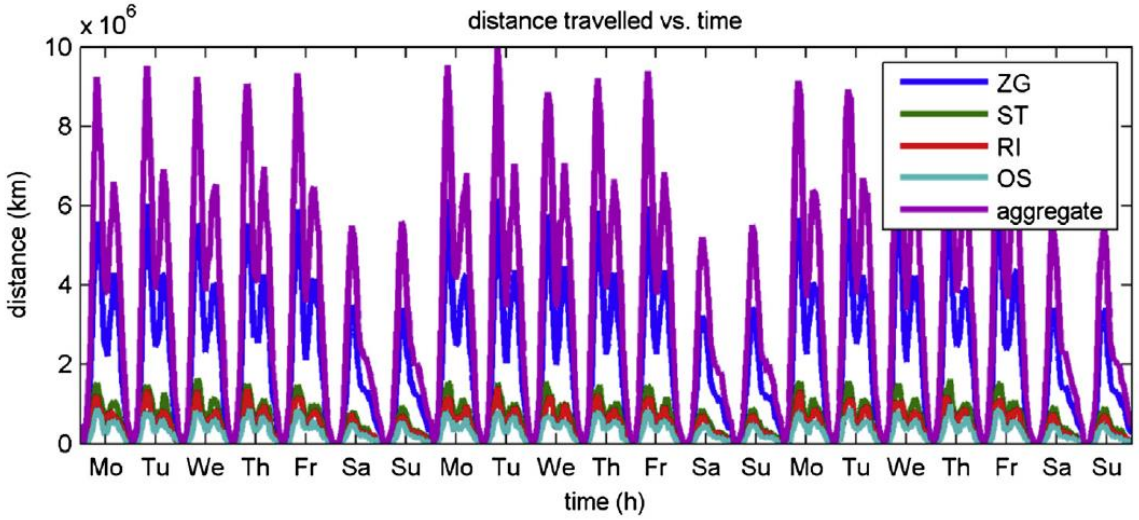
Asst. prof. Goran Krajačić, dipl. ing.

Palermo 03/10/2018

sdewes
13th CONFERENCE ON SUSTAINABLE DEVELOPMENT OF ENERGY, WATER AND ENVIRONMENT SYSTEMS



Source: Robert Sansom (Imperial College), Winter Peak Heat Demand



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Agent based modelling and energy planning – Utilization of MATSim for transport energy demand modelling

T. Novosel [a, *], L. Perković [a], M. Ban [a], H. Keko [b], T. Pukšec [a], G. Krajačić [a], N. Duić [a]

[a] University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Department of Energy, Power Engineering and Environment, Ivana Lučića 5, 10002 Zagreb, Croatia
[b] Energy Institute Hrvoje Požar, Department for Energy Generation and Transformation, Savska 163, 10001 Zagreb, Croatia

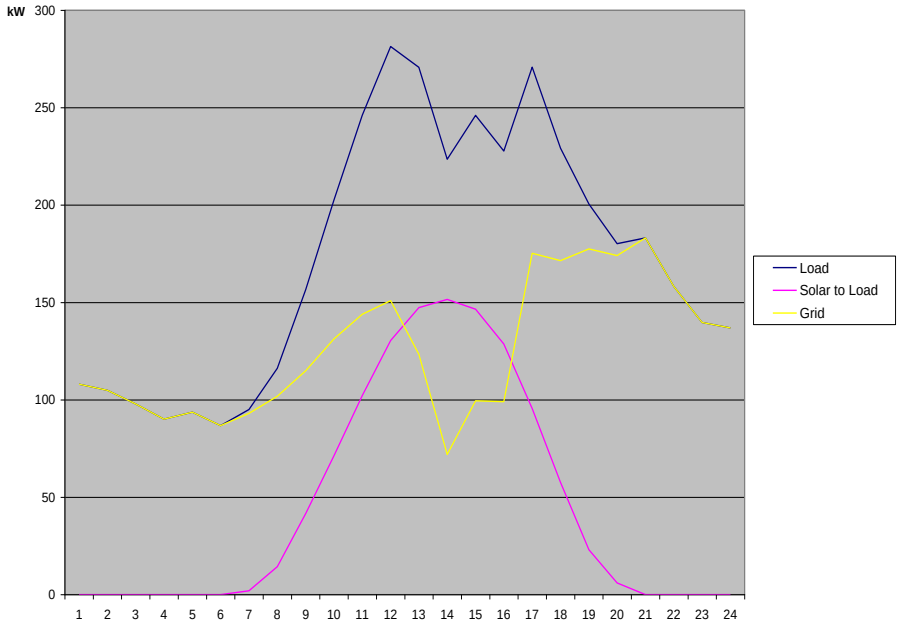
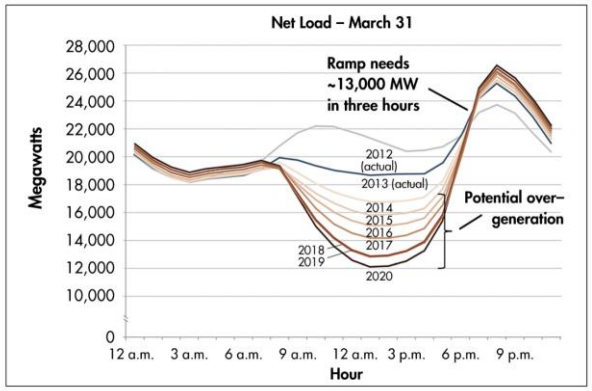
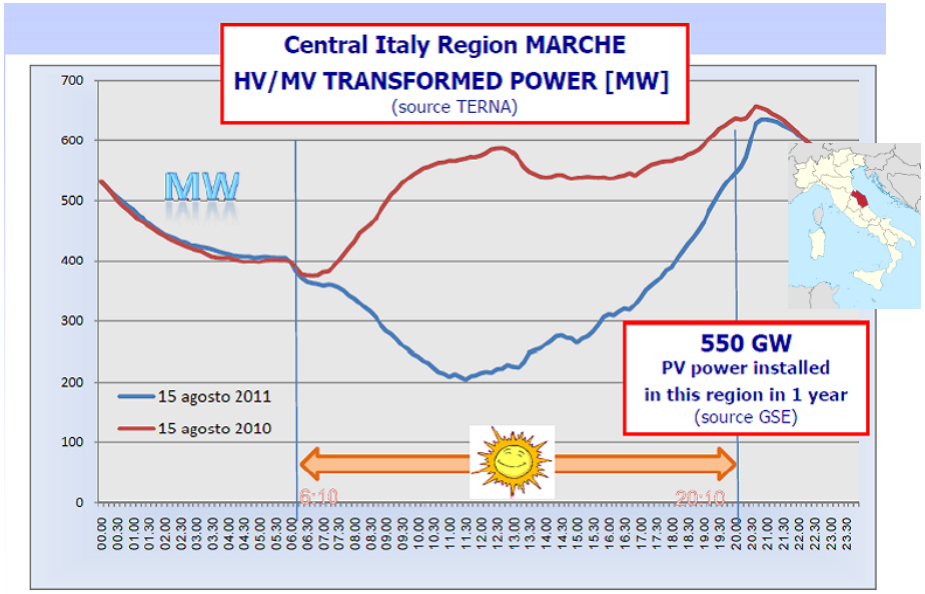
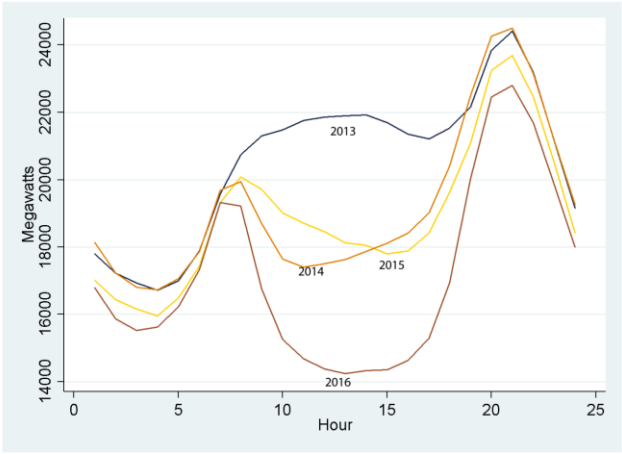


Figure 1: Net load on the CAISO system



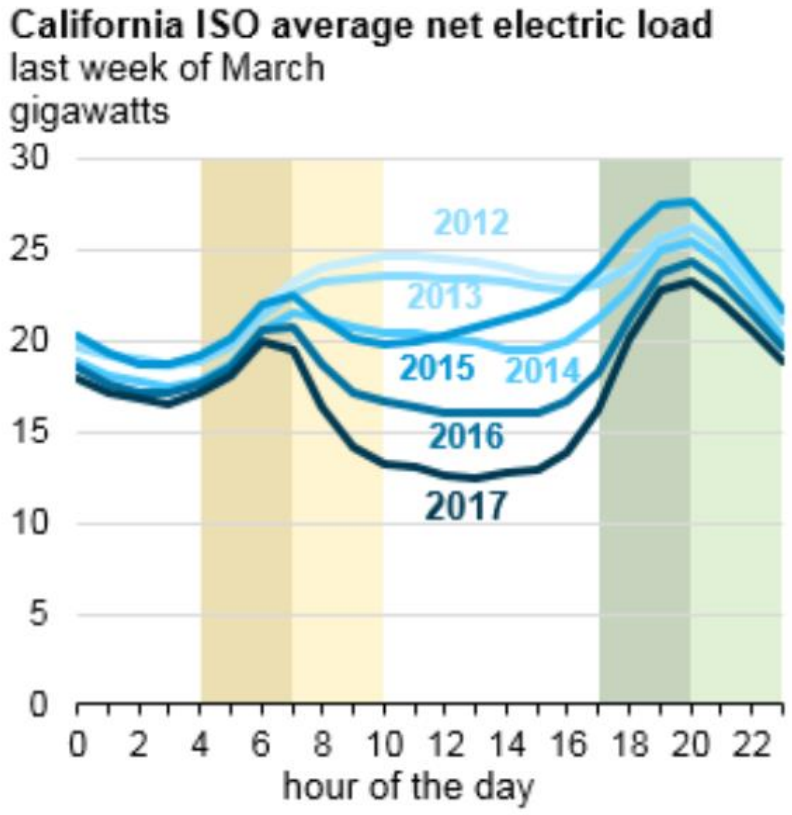
Source: CAISO

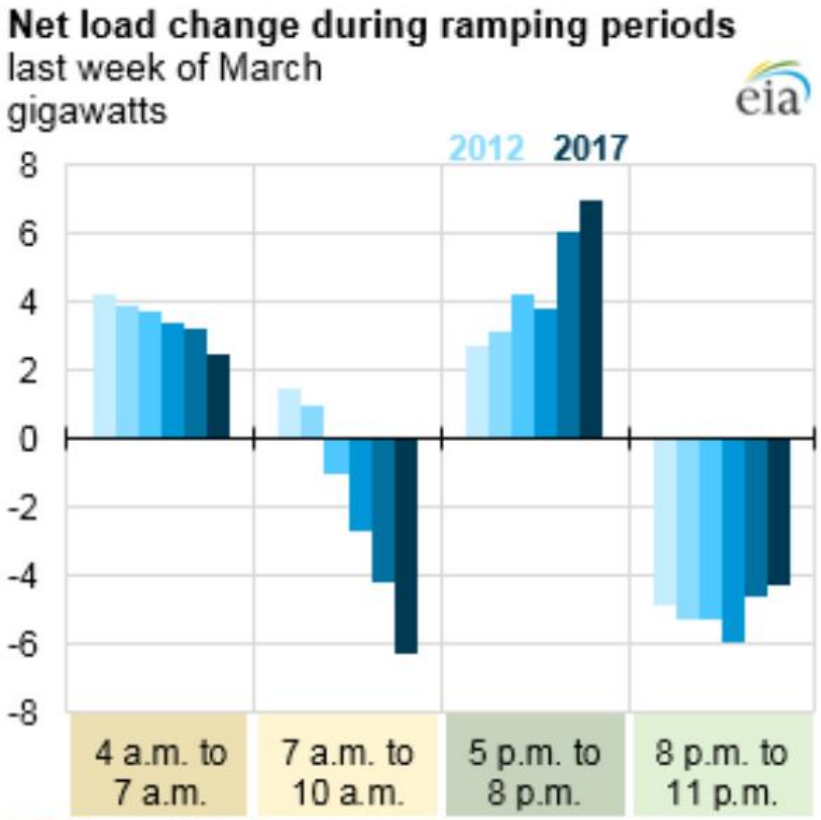




Note: All data taken from CAISO website. Graph summarizes hourly data, March28-April 3, 2013-2016.

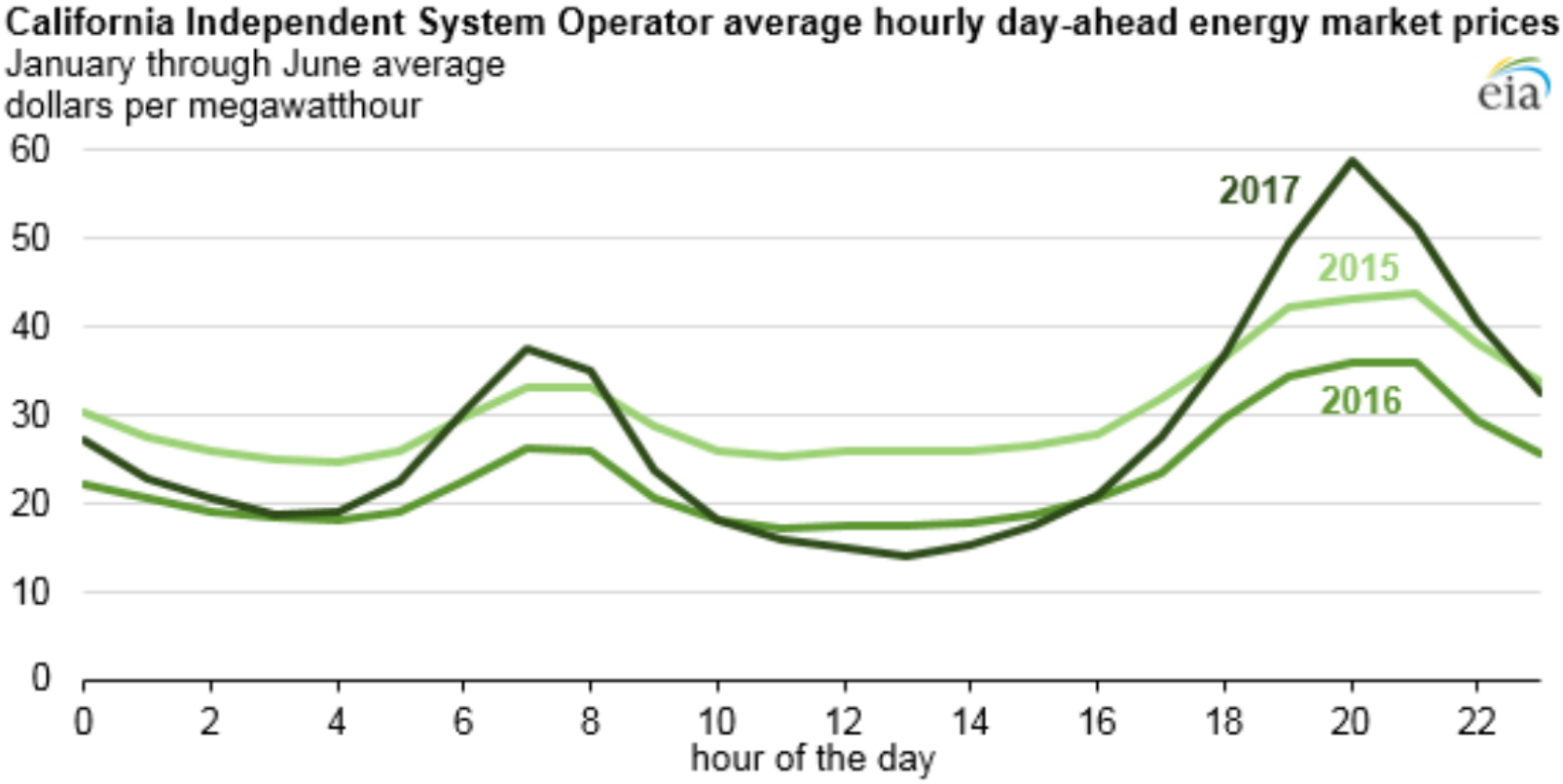
Flexibility California



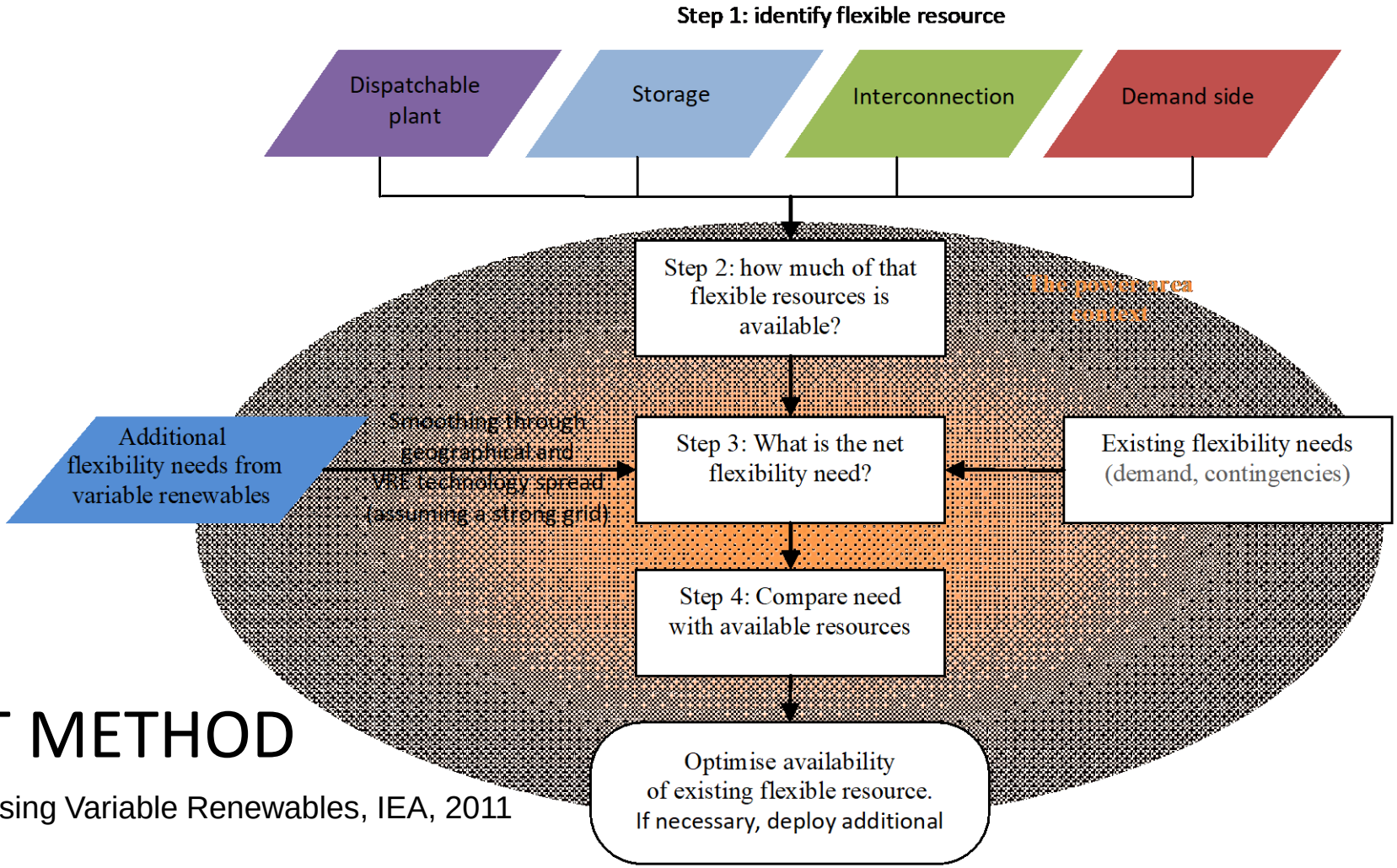


Source: U.S. Energy Information Administration, based on ABB Energy Velocity

Market response to solarization



Source: U.S. Energy Information Administration, based on ABB Energy Velocity
Note: Prices are simple averages of CAISO trading hubs ZP26, NP15, and SP15 from January 1 through June 30 of each year.



FAST METHOD

•Harnessing Variable Renewables, IEA, 2011

Flexible resources in the Iberian Peninsula

Time scale	*Dispatchable plant – up (MW)*	*Dispatchable plant – down (MW)*	*Demand side (MW)*	*Storage (MW)*	*Interconnection (MW)*	*TR – up (MW)*	*TR – down (MW)*
15 mins	5 000	7 000	2 360	5 805	2 100	15 268	15 168
1 hr	6 250	12 110	2 360	5 805	2 100	16 518	22 368
6 hrs	43 811	23 118	2 360	5 805	2 100	54 079	33 386
36 hrs	49 314	25 417	2 360	5 805	2 100	59 662	35 685

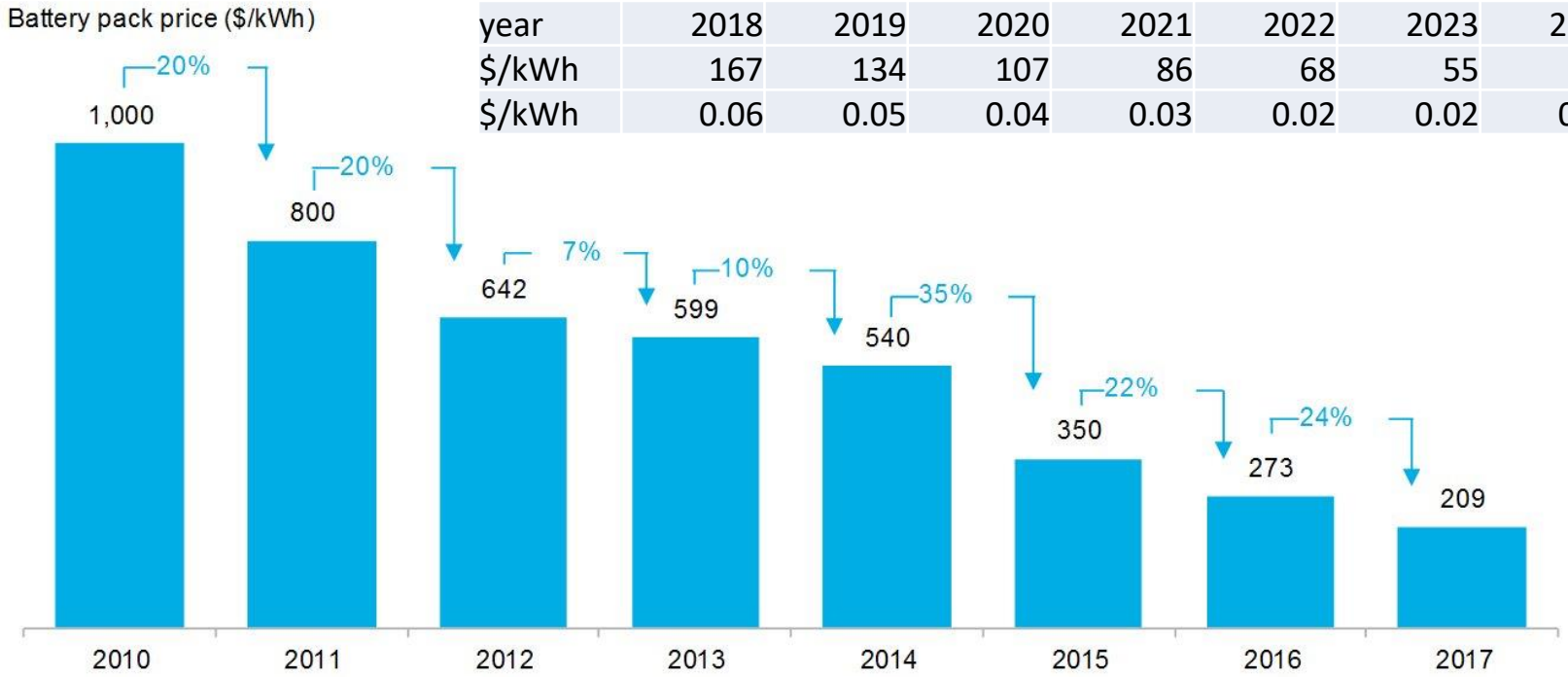
Note: With regards to dispatchable power plant, the table represents more than just the simple technical resource presented in the text so far. Directly extracted from the Iberian case study in Part 2, the figures also reflect the *likely operation* of dispatchable plants, which is discussed in Step 2 of the FAST Method, when the availability of flexible resources is the focus.

- Harnessing Variable Renewables, IEA, 2011

Capacity	1	kWh
Cost	209	$/kW
Lifetime	10	year
Capital cost	5%	
Yearly cost	27.07	$
Daily 1 kWh	365	kWh
LCOE for 1 kWh	0.07	$/kWh

BNEF EV lithium-ion battery pack price survey results

year	2018	2019	2020	2021	2022	2023	2024	2025
$/kWh	167	134	107	86	68	55	44	35
$/kWh	0.06	0.05	0.04	0.03	0.02	0.02	0.02	0.01



Source: Bloomberg New Energy Finance. Pack level pricing. Weighted average of BEV and PHEV packs

Bloomberg New Energy Finance

Market Phases

Within the last 10 years, regulation has changed the German Utilities market for good

2005-2009

Market Liberalization
- *National Energy Act*, 2005
- Transformation of negotiated into regulated third party access

Unbundling
- Regulation-induced separation of utilities' generation and sale operations from transmission networks as of 2007
- Creation of separated legal and informational entities

Upcoming Competition
- End of price authorization in 2007
- Increasing competition through new market players without own power plans or supplier networks
- Steady decline in number of customers served by four largest German energy companies

KEY DRIVER:
Release of Market Forces

2009-2014

Nuclear Phase-Out
- Start of nuclear plant decommissioning in reaction to the Fukushima accident in 2011

Renewables Push
- *Renewable Energy Act* empowered installation of 80 GW renewable capacity (as of 2014) with power production of 157.3 TWh (ca. 25%)

Ownership Unbundling ITOs
- Regulation-induced application of non-discriminatory measures by ITOs (legally independent transmission subsidiaries)

First Smart Initiatives
- Evolving linkage of generation, grids, storage and consumption to adjust towards the variable nature of renewable energies

KEY DRIVER:
Release of Decentralized Power Market

>2014

Flexible Energy System
- Introduction of decentralized storage capacity
- Increasing usage of micro-generation
- Real-time demand & supply management

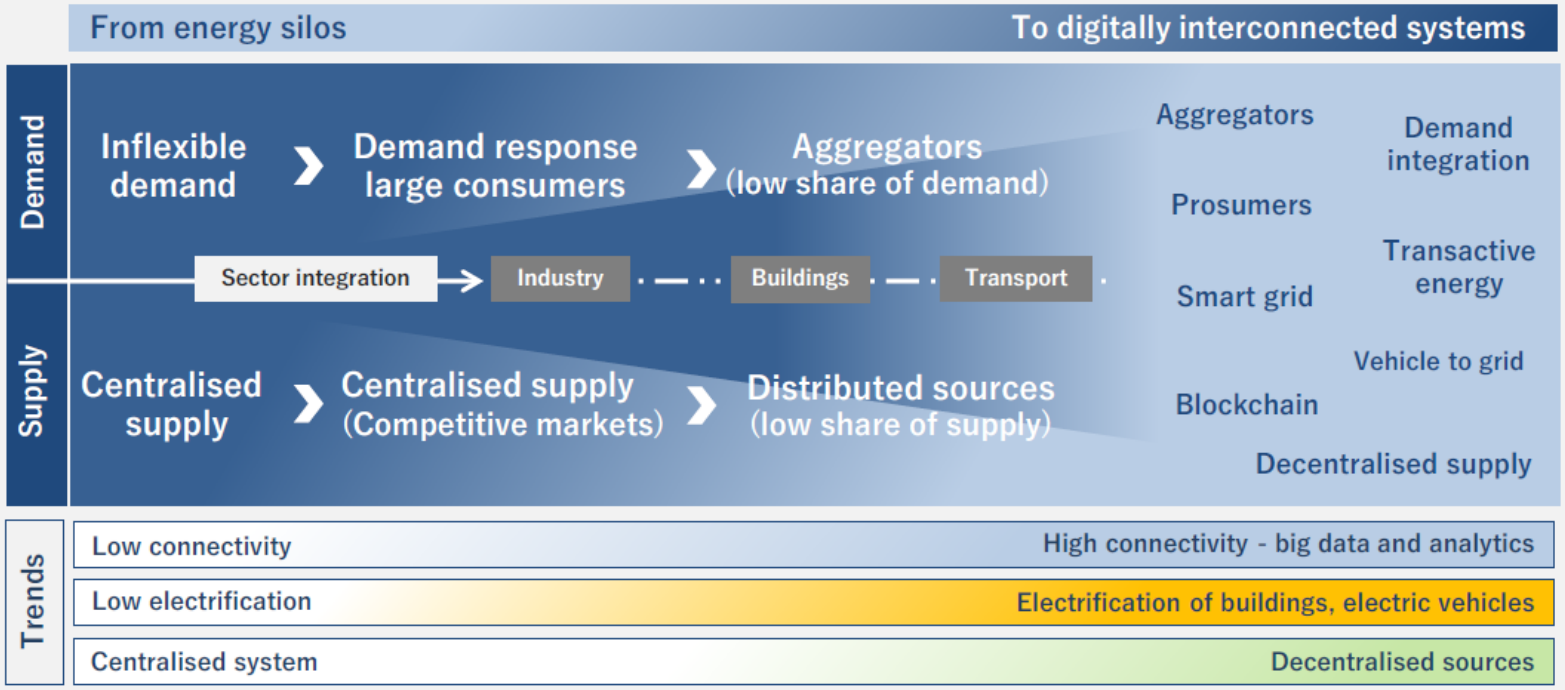
Smart Network Technology
- Introduction of smart metering
- Big data analytics
- Smart consumer devices
- Machine to machine communication

Digital Customer Engagement
- Gamification, proliferation of social media
- Voice analytics
- Proliferation of digital channels

KEY DRIVER:
Technology & Business Model Innovation

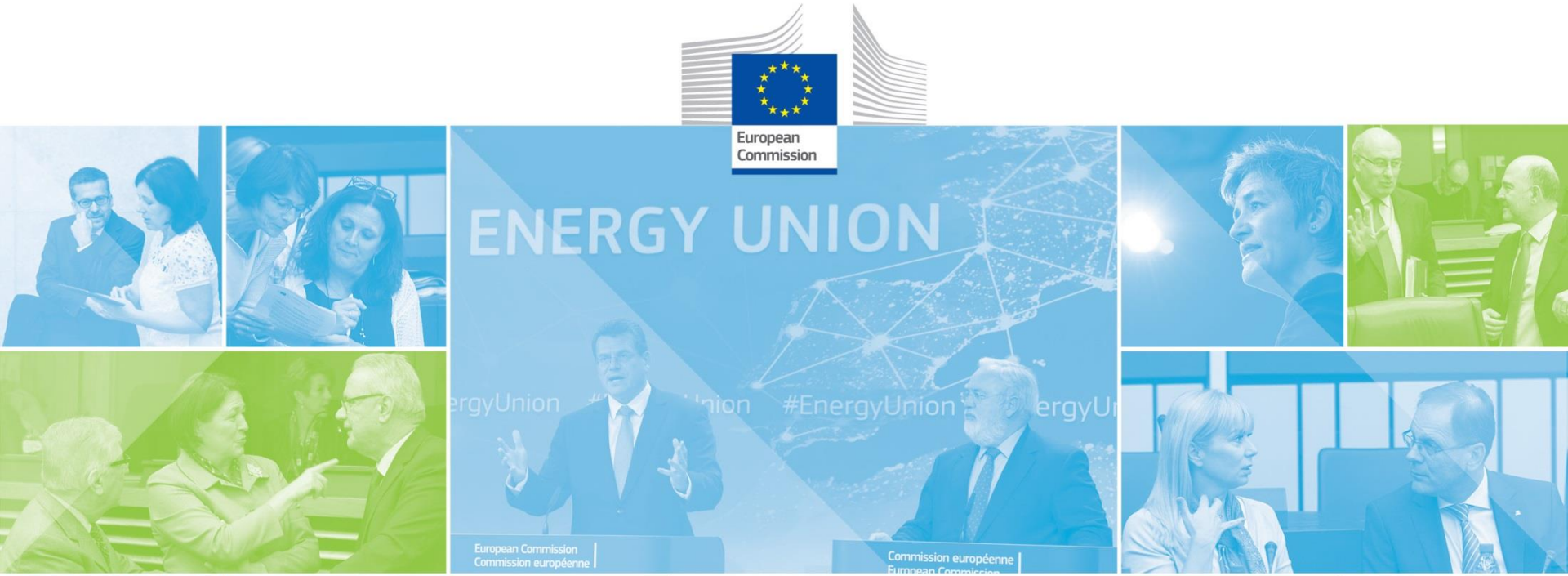
Source: Federal Ministry of Economics and Technology (BMWi), BDEW, Deloitte Analysis

Digital energy transition



Key message: The deployment of digital technologies is creating a more interconnected and responsive electricity system, with the potential to help increase flexibility, efficiency and reliability.

Digitalization & Energy, IEA, 2017



CLEAN ENERGY FOR ALL EUROPEANS