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

**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

Decrease of demand and simultaneous growth of renewables reduce the production by thermoelectric plants.

Natural gas replaces other fossil sources.

"Gray period"

"Green period"
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.
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
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 for new renewables
Panel: Stepping up the penetration of renewables against infrastructural and financial barriers

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?**
“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
Source: Robert Sansom (Imperial College), Winter Peak Heat Demand
Central Italy Region MARCHE
HV/MV TRANSFORMED POWER [MW]
(source Terna)

550 GW
PV power installed in this region in 1 year
(source GSE)

Figure 1: Net load on the CAISO system

Note: All data taken from CAISO website. Graph summarizes hourly data, March 28–April 2, 2013–2016.
Flexibility California

Source: U.S. Energy Information Administration, based on ABB Energy Velocity
Market response to solarization

California Independent System Operator average hourly day-ahead energy market prices
January through June average dollars per megawatthour

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

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

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
### BNEF EV lithium-ion battery pack price survey results

<table>
<thead>
<tr>
<th>Battery pack price ($/kWh)</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/kWh</td>
<td>1,000</td>
<td>800</td>
<td>642</td>
<td>599</td>
<td>540</td>
<td>350</td>
<td>273</td>
<td>209</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Year</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/kWh</td>
<td>167</td>
<td>134</td>
<td>107</td>
<td>86</td>
<td>68</td>
<td>55</td>
<td>44</td>
<td>35</td>
</tr>
</tbody>
</table>

- **LCOE**: $0.06 to $0.01

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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 separate 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

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 nondiscriminatory 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

>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

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

Power Market Study 2025, © 2015 Deloitte Consulting GmbH
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