AGING OF EUROPEAN POWER PLANT INFRASTRUCTURE AS AN OPPORTUNITY TO EVOLVE TOWARDS SUSTAINABILITY

Javier Farfan and Christian Breyer
LUT School of Energy Systems
Lappeenranta University of Technology, Finland

7th Neo-Carbon Energy Researchers’ Seminar
Lappeenranta, January 24–25, 2017
Content

- Introduction
- Methodology
  - Dataset
  - Lifetime Analysis
- Data Analysis and Results
- Conclusions
Introduction

- Energy systems are experiencing constant evolution.
- There are more than enough energy resources.
- Projections of future scenarios differ between organizations.
- There is a common denominator: change.

The following results are published in:
## Methodology: Dataset

### Table 1: Compiled databases, characteristics and type of aggregation.

<table>
<thead>
<tr>
<th>Database name</th>
<th>Characteristics and advantages</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>GlobalData</td>
<td>Detailed dataset for all available technologies, has the potential to provide the maximum amount of information about each included power plant.</td>
<td>Power plant aggregation. Used as base for collected dataset.</td>
</tr>
<tr>
<td>GlobalData - Generation capacity</td>
<td>Accurate total yearly cumulated capacity deployed by technology by country for the period 2000-2014.</td>
<td>Capacity aggregation.</td>
</tr>
<tr>
<td>GRanD</td>
<td>Detailed dataset on hydro reservoirs, accurate information on reservoir location and dimensions. Useful only for complementing hydropower plant's information.</td>
<td>Complementing information</td>
</tr>
<tr>
<td>IRENA</td>
<td>Cumulated yearly capacity information by country and by technology in the period of 2000-2014.</td>
<td>Capacity aggregation</td>
</tr>
<tr>
<td>Platts</td>
<td>Power plant information limited to name, capacity, year, fuel, technology and location.</td>
<td>Power plant aggregation and complementing information.</td>
</tr>
<tr>
<td>Werner C. et al.</td>
<td>Accurate cumulated solar PV capacities by country, for the period 2009-2014.</td>
<td>Capacity aggregation</td>
</tr>
<tr>
<td>BMWi</td>
<td>Accurate yearly cumulated wind capacity deployed in Germany in the period 1990-2013.</td>
<td>Capacity aggregation</td>
</tr>
</tbody>
</table>
Methodology: Lifetime Analysis

- Present in the database and taken into account for the analysis:
  - 104800 active power plants
  - 4400 deactivated power plants
- Most registered decommissioned power plants are fossil fuel-based or nuclear.
- Lifetime analysis of new renewables is still not possible:
  - Not enough power plants of new renewables have been decommissioned to make a significant sample for analysis.
  - The few plants registered as decommissioned are based in a state of the technology that is no longer representative to the power plants being installed now (especially talking about wind and solar).
- Average age of the deactivated nuclear reactors is 20 years while active reactors average 29 years.
Analysis and Results: Cumulated end of 2014

EUROPE
Total Capacity by end of 2014
1486 GW
Sustainability Indicator
14 %

50.7% Fossil
17.9% Non-Hydro RE
20.6% Hydro
11% Nuclear

- Hydro/Run-of-River 81.6 GW 5 %
- Hydro/Reservoir 171 GW 12 %
- Hydro/Pumped-Storage 53.2 GW 4 %
- Biogas 3.5 GW 0 %
- Ocean 251 MW 0 %
- Solar CSP 2.37 GW 0 %
- Wind 134.8 GW 9 %
- Solar PV 89.3 GW 6 %
- Gas 407 GW 27 %
- Biomass 28.5 GW 2 %
- Geothermal 2.20 GW 0 %
- Nuclear 160 GW 11 %
- Coal 285 GW 19 %
- Oil 62 GW 4 %
The summit of nuclear installations happened during the 1980s.
Wind power started having significant presence from the early 1990s.
Solar PV has shown an exponential growth since the early 2000s.
Bioenergy has increased presence since the late 1990s.
Hydropower is active from the beginning of records because it does not decommission.
Analysis and Results: Added 2000 to 2014

EUROPE
Total Capacity from 2000 to 2014
572 GW
Sustainability Indicator
54%

38.5% of Europe’s Total Active Capacity

43.7% Fossil

9.8% Hydro

43.7% Non-Hydro RE
Aging of European Power Plant Infrastructure as an Opportunity to Evolve Towards Sustainability

Javier Farfan
Javier.Farfan.Orozco@lut.Fi

Analysis and Results: Global

- Peak value
- 90% of power plants operate below this limit
- Weighted average age

10% of coal and oil power plants show lifetimes of over 45 years.
10% of gas power plants show lifetime of over 43 years.
10% of nuclear power plants show lifetime of over 39 years.

Weighted average age
Active/Deactivated:
Coal 21/40 years
Oil 28/34 years
Gas 18/34 years
Nuclear 29/20 years
Analysis and Results: Europe

The average age of European power plants is:
- Gas 21 years
- Oil 34 years
- Coal 35 years
- Nuclear 29 years

Percentage of European power plants exceeding decommissioning age:
- 26% Gas
- 55% Oil
- 40% Coal
- 6% Nuclear
Aging of European Power Plant Infrastructure as an Opportunity to Evolve Towards Sustainability

Javier Farfan
Javier.Farfan.Orozco@lut.Fi

Following the global tendency, Europe would have to decommission:

- 2024
  - 36% Gas*
  - 64% Coal
  - 34% Nuclear
  - 75% Oil

- 2030
  - 49% Gas*
  - 79% Coal
  - 82% Nuclear
  - 78% Oil

- 2050
  - 100% Gas*
  - 94% Coal
  - 99% Nuclear
  - 100% Oil

* fossil gas fuel needs to be phased out, however biomethane, renewable electricity and sustainable CO₂ based power-to-gas is fine
The top 5 countries + Nordics host 72.3% of the installed fossil capacities of EU28.

Most of the active coal capacity is in Germany.

Most of the active nuclear capacity is in France.

Italy, UK & Spain fossil capacities are mostly Gas.

Nordic fossil capacities are slightly dominated by nuclear, though including similar shares of coal, gas and oil.
Analysis and Results

• The individual decommissioning curve of every country can be very different.
• Steep early decommissioning slopes indicate very old operating capacities.
• Flatter decommissioning curves indicate recently commissioned fossil capacities.
• Constant decommissioning curve indicate a constantly renovating energy system.
Analysis and Results

- The slope of the decommissioning curve was fitted to a linear approximation.
- EU28 was divided into 3 groups depending on their decommissioning slope:
  - Slope < -2.75 (Group A)
  - -2.75 < Slope < -2.25 (Group B)
  - Slope > -2.25 (Group C)
- The slope can be used to determine the evolution behavior of the energy sector of the country.
Analysis and Results

- Countries from Group A tend to have steep decommissioning rates in the later years (recently installed fossil capacities).
- Countries of Group B have rather constant decommissioning (constantly evolving energy system).
- Countries of Group C have an early steep decommissioning curve (old active fossil capacities).
### Analysis and Results

#### Clustering by fossil and nuclear capacity

<table>
<thead>
<tr>
<th>Large players &gt; 32 GW</th>
<th>32 GW &gt; Medium players &gt; 10 GW</th>
<th>Small players &lt; 10 GW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany&lt;br&gt;France&lt;br&gt;Italy&lt;br&gt;United Kingdom&lt;br&gt;Spain&lt;br&gt;Nordics&lt;br&gt;Belgium&lt;br&gt;Czech Republic&lt;br&gt;Greece&lt;br&gt;Netherlands&lt;br&gt;Poland&lt;br&gt;Romania&lt;br&gt;Bulgaria&lt;br&gt;Austria&lt;br&gt;Portugal&lt;br&gt;Hungary&lt;br&gt;Ireland&lt;br&gt;Slovakia&lt;br&gt;Estonia&lt;br&gt;Lithuania&lt;br&gt;Slovenia&lt;br&gt;Croatia&lt;br&gt;Cyprus&lt;br&gt;Latvia&lt;br&gt;Malta&lt;br&gt;Luxembourg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- All large players place within the medium to high RE share.
- All large players place below -2.25% (recently installed capacities, constantly evolving).
- All medium players place within medium to low RE share.
- All medium players place above -2.75% (old fossil capacities, slow evolution).
- All small players distribute rather evenly among the different clusters and RE share.
- Most small players stand either over -2.25% or below -2.75% (either early or late steep decommissioning rates).

#### Clustering by RE share

<table>
<thead>
<tr>
<th>High RE (&gt; 50%)</th>
<th>Medium RE (50% &gt; share &gt; 25%)</th>
<th>Low RE (&lt; 25%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luxembourg&lt;br&gt;Austria&lt;br&gt;Nordics&lt;br&gt;Portugal&lt;br&gt;Latvia&lt;br&gt;Croatia</td>
<td>Romania&lt;br&gt;Germany&lt;br&gt;Spain&lt;br&gt;Slovakia&lt;br&gt;Slovenia&lt;br&gt;Italy&lt;br&gt;Greece</td>
<td>Belgium&lt;br&gt;Bulgaria&lt;br&gt;France&lt;br&gt;Ireland&lt;br&gt;Lithuania&lt;br&gt;United Kingdom&lt;br&gt;Czech Republic</td>
</tr>
</tbody>
</table>

- All large players place below -2.25% (recently installed capacities, constantly evolving).
- All medium players place above -2.75% (old fossil capacities, slow evolution).
- All small players distribute rather evenly among the different clusters and RE share.
- Most small players stand either over -2.25% or below -2.75% (either early or late steep decommissioning rates).

#### Clustering by fitted relative decommissioning rate

<table>
<thead>
<tr>
<th>Rate &lt; -2.75%</th>
<th>-2.75% &lt; Rate &lt; -2.25%</th>
<th>Rate &gt; -2.25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luxembourg&lt;br&gt;Portugal&lt;br&gt;Malta&lt;br&gt;Spain&lt;br&gt;Italy&lt;br&gt;Hungary&lt;br&gt;Ireland</td>
<td>Austria&lt;br&gt;France&lt;br&gt;Belgium&lt;br&gt;Cyprus&lt;br&gt;Greece&lt;br&gt;United Kingdom</td>
<td>Netherlands&lt;br&gt;Slovakia&lt;br&gt;Nordics&lt;br&gt;Germany&lt;br&gt;Czech Republic&lt;br&gt;Romania&lt;br&gt;Slovenia&lt;br&gt;Bulgaria&lt;br&gt;Latvia&lt;br&gt;Poland&lt;br&gt;Croatia&lt;br&gt;Lithuania&lt;br&gt;Estonia</td>
</tr>
</tbody>
</table>
Conclusions

- In Europe before the year 2000, most active installed capacities are of gas, coal and nuclear power plants.
- This trend has been stopped by the commercial entrance of new alternative renewable energy sources, which have dominated since the turn of the millennium.
- Nuclear power installations have been reduced close to zero since the year 2000.
- Power plants are aging, and the current installations are increasingly shifting to renewables.
- Despite resistance and lobbying from certain groups, the transition towards sustainability is steady.
- 66.8% of EU28 fossil capacities are in 5 countries (Germany, UK, France, Italy, and Spain), and 72.3% when the Nordics are included.
- The slope of the linear fit to the decommissioning curve can be used as indicator of the type of energy sector evolution of a country.
- A close to full transition to zero emissions in Europe’s power sector can be achieved by 2050 just by switching investments TODAY to renewables.
- Taking into account the COP21 targets of total emission reduction and climate change mitigation, the aging of the current power plant fleet presents a great opportunity to transition into a sustainable future.
Thank you for attention

- Any Questions?
NEO-CARBON Energy project is one of the Tekes strategy research openings and the project is carried out in cooperation with Technical Research Centre of Finland VTT Ltd, Lappeenranta University of Technology (LUT) and University of Turku, Finland Futures Research Centre.