Life Cycle Assessment of Electricity in Portugal

Workshop on Life Cycle Assessment and GIS Tools for Energy planning (TW3-TW4)

Flávio Martins
fmartins@ualg.pt

António Mortal
amortal@ualg.pt

Marisa Madeira
mimadeira@ualg.pt

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This presentation is based on the following paper:

Life-cycle assessment of electricity in Portugal
Rita Garcia, Pedro Marques, Fausto Freire

ADAI-LAETA, Department of Mechanical Engineering, University of Coimbra, Polo II Campus, R. Luís Reis Santos, 3030-788 Coimbra, Portugal

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CrossMark
Materials and Methods of LCA

• Functional unit: 1 kWh
• Boundary: Portuguese electricity generation included transmission and distribution:
  – Comprise extraction;
  – Processing and transport fuels;
  – Operation of power plants;
  – Construction and decommissioning of power plants;
  – Waste management
Impact categories

- nREn – cumulative non-renewable fossil energy demand;
- GW – global warming;
- AD – abiotic depletion;
- AC – acidification;
- ET – eutrophication;
- PO – photochemical oxidation;
- OD – ozone layer depletion.
## Environmental Life cycle Impacts per kWh Generated by Technology

| Technologies                  | CED  | CML  |  |  |  |
|-------------------------------|------|------|  |  |  |
|                              | nREN (Mj\textsubscript{prim} fossil) | AD (g Sb eq) | GW (g CO\textsubscript{2} eq) | AC (g SO\textsubscript{2} eq) | PO (mg C\textsubscript{2}H\textsubscript{4} eq) | EUT (g PO\textsubscript{4}\textsuperscript{3-} eq) | OD (μg CFC-11 eq) |
| **Non-renewables**            |      |      |  |  |  |
| Coal w/ out DeSOx & DeNOx    | 11.04| 7.55 | 988 | 8.72 | 291 | 2.48 | 6.52 |
| Coal w/ DeSOx & DeNOx\textsuperscript{a} | 11.48| 7.81 | 1021 | 2.84 | 75 | 2.42 | 8.05 |
| Fuel oil                     | 13.16| 5.86 | 912 | 19.00 | 748 | 0.57 | 113.04 |
| Natural gas CC               | 7.38 | 3.61 | 423 | 0.35 | 31 | 0.06 | 51.81 |
| Natural gas CHP gas engine   | 9.40 | 4.59 | 588 | 0.74 | 61 | 0.15 | 65.92 |
| Natural gas CHPCC            | 6.47 | 3.16 | 370 | 0.29 | 27 | 0.04 | 45.39 |
| **Renewables**               |      |      |  |  |  |
| Hydro reservoir\textsuperscript{b} | 0.04 | 0.02 | 17 | 0.02 | 1 | 0.06 | 0.00 |
| Hydro run-of-river\textsuperscript{b} | 0.04 | 0.02 | 4 | 0.02 | 1 | 0.01 | 0.00 |
| Hydro small-hydro\textsuperscript{b} | 0.05 | 0.03 | 5 | 0.03 | 1 | 0.01 | 0.00 |
| Wind                         | 0.04 | 0.17 | 23 | 0.11 | 8 | 0.06 | 1.24 |
| Biomass CHP                  | 0.37 | 0.19 | 33 | 0.65 | 17 | 0.23 | 2.81 |
| Biomass                      | 0.60 | 0.29 | 56 | 1.40 | 31 | 0.44 | 4.55 |
| Biogas                       | 1.31 | 0.65 | 239 | 0.72 | 68 | 0.13 | 9.73 |
| Photovoltaic                 | 0.65 | 0.36 | 51 | 0.25 | 15 | 0.16 | 9.60 |
| Waste incineration           | 1.71 | 0.83 | 147 | 1.28 | 44 | 1.19 | 14.85 |

\textsuperscript{a} DeSOx: Desulfurization, DeNOx: Denitrification

\textsuperscript{b} Hydro reservoirs and hydro run-of-river can be located offshore or onshore.
Life cycle impacts of the electricity generation mix: non renewable fossil (nREn) and global warming (GW)
Life cycle impacts of the electricity generation mix: abiotic depletion (AD) and acidification (AC)
Life cycle impacts of the electricity generation mix: eutrophication (EUT) photochemical reduction (PO)
Life cycle impacts of the electricity generation mix: ozone depletion (OD)

Ozone depletion ($\mu g$ CFC-11 eq/kWh)
Life cycle impacts of the electricity generation mix: resume

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<tr>
<td>nREn (MJ prim fossa)</td>
<td>6.67</td>
<td>7.46</td>
<td>8.47</td>
<td>6.72</td>
<td>6.30</td>
<td>6.44</td>
<td>6.09</td>
<td>4.35</td>
<td>5.08</td>
<td>5.72</td>
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<tr>
<td>AD (g Sb eq)</td>
<td>4.04</td>
<td>4.47</td>
<td>4.91</td>
<td>4.01</td>
<td>3.72</td>
<td>3.73</td>
<td>3.59</td>
<td>2.46</td>
<td>2.98</td>
<td>3.53</td>
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<tr>
<td>GW (g CO₂ eq)</td>
<td>533</td>
<td>585</td>
<td>646</td>
<td>523</td>
<td>480</td>
<td>477</td>
<td>459</td>
<td>312</td>
<td>380</td>
<td>456</td>
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<tr>
<td>AC (g SO₂ eq)</td>
<td>4.76</td>
<td>4.67</td>
<td>5.74</td>
<td>3.91</td>
<td>3.43</td>
<td>1.37</td>
<td>1.17</td>
<td>0.69</td>
<td>0.88</td>
<td>1.22</td>
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<tr>
<td>PO (g C₂H₄ eq)</td>
<td>0.17</td>
<td>0.17</td>
<td>0.21</td>
<td>0.14</td>
<td>0.13</td>
<td>0.05</td>
<td>0.04</td>
<td>0.03</td>
<td>0.03</td>
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<tr>
<td>EUT (g PO₄²⁻ eq)</td>
<td>1.01</td>
<td>1.04</td>
<td>1.06</td>
<td>0.92</td>
<td>0.80</td>
<td>0.72</td>
<td>0.74</td>
<td>0.43</td>
<td>0.60</td>
<td>0.86</td>
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<td>OD (µg CFC-11 eq)</td>
<td>22</td>
<td>26</td>
<td>36</td>
<td>24</td>
<td>24</td>
<td>27</td>
<td>24</td>
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Conclusions

• An overall reduction in the environmental impacts was achieved between 2003 and 2012.
• The higher reductions were realized in acidification (AC) (-299%) and photochemical oxidation (PO) (-326%), due to:
  – Decommissioning of large fuel oil power plants (2008);
  – Installation of denitrification and desulfurization systems in coal power plant
• The impacts are strongly influenced by the share production of the renewables and these are influenced by meteorological factors like hydro variability.
THANK YOU

Flávio Martins
fmartins@ualg.pt

António Mortal
amortal@ualg.pt

Marisa Madeira
mimadeira@ualg.pt
Electricity generated by technology ($E_j$), total electricity generation ($E_{gen}$) and supply ($E_{sup}$) (GWh) [30,41].

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<td>Non-renewables</td>
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<tr>
<td>Coal</td>
<td>13,641</td>
<td>13,952</td>
<td>14,291</td>
<td>14,070</td>
<td>11,663</td>
<td>10,423</td>
<td>11,942</td>
<td>6553</td>
<td>9128</td>
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<td>Fuel oil</td>
<td>6.6%</td>
<td>5.1%</td>
<td>11.8%</td>
<td>3.4%</td>
<td>3.0%</td>
<td>1.9%</td>
<td>0.7%</td>
<td>0.1%</td>
<td>0.0%</td>
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<td>Natural gas</td>
<td>51.5%</td>
<td>25.1%</td>
<td>27.9%</td>
<td>22.7%</td>
<td>24.6%</td>
<td>30.6%</td>
<td>25.4%</td>
<td>21.6%</td>
<td>20.4%</td>
<td>13.2%</td>
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<tr>
<td>Non-renewable CHP&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1550</td>
<td>2052</td>
<td>2540</td>
<td>2806</td>
<td>3252</td>
<td>3011</td>
<td>3590</td>
<td>4480</td>
<td>4767</td>
<td>4406</td>
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<td>Hydropower</td>
<td>15,709</td>
<td>9911</td>
<td>4916</td>
<td>11,196</td>
<td>10,220</td>
<td>7095</td>
<td>8710</td>
<td>16,243</td>
<td>11,820</td>
<td>6423</td>
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<td>Wind</td>
<td>2.5%</td>
<td>2.0%</td>
<td>4.2%</td>
<td>6.6%</td>
<td>9.4%</td>
<td>13.8%</td>
<td>16.6%</td>
<td>18.2%</td>
<td>19.3%</td>
<td>24.4%</td>
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<td>Biomass CHP</td>
<td>0.3%</td>
<td>1.2%</td>
<td>3.2%</td>
<td>3.4%</td>
<td>3.7%</td>
<td>3.7%</td>
<td>3.4%</td>
<td>3.5%</td>
<td>3.8%</td>
<td>5.7%</td>
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<tr>
<td>Biomass</td>
<td>43</td>
<td>54</td>
<td>60</td>
<td>71</td>
<td>149</td>
<td>146</td>
<td>305</td>
<td>612</td>
<td>688</td>
<td>676</td>
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<td>Waste incineration&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.2%</td>
<td>0.3%</td>
<td>0.4%</td>
<td>0.7%</td>
<td>1.2%</td>
<td>1.5%</td>
<td>1.6%</td>
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<tr>
<td>Biogas</td>
<td>0</td>
<td>9</td>
<td>25</td>
<td>24</td>
<td>47</td>
<td>59</td>
<td>71</td>
<td>92</td>
<td>149</td>
<td>182</td>
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<td>Photovoltaic</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>33</td>
<td>140</td>
<td>167</td>
<td>187</td>
<td>227</td>
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<tr>
<td>Pumping&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-485</td>
<td>-408</td>
<td>-568</td>
<td>-703</td>
<td>-541</td>
<td>-639</td>
<td>-929</td>
<td>-512</td>
<td>-587</td>
<td>-1379</td>
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<td>Total generation ($E_{gen}$)</td>
<td>40,261</td>
<td>39,025</td>
<td>41,125</td>
<td>43,733</td>
<td>42,581</td>
<td>41,153</td>
<td>45,075</td>
<td>49,602</td>
<td>47,152</td>
<td>40,971</td>
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<td>Imports ($E_{imp}$)</td>
<td>4433</td>
<td>7460</td>
<td>7528</td>
<td>7649</td>
<td>9088</td>
<td>9478</td>
<td>5616</td>
<td>4350</td>
<td>4446</td>
<td>8297</td>
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<tr>
<td>Exports ($E_{exp}$)</td>
<td>1633</td>
<td>976</td>
<td>702</td>
<td>2267</td>
<td>1591</td>
<td>40</td>
<td>827</td>
<td>1718</td>
<td>1635</td>
<td>403</td>
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<tr>
<td>$T$ losses ($E_{loss \ T}$)</td>
<td>738</td>
<td>677</td>
<td>648</td>
<td>562</td>
<td>577</td>
<td>585</td>
<td>523</td>
<td>961</td>
<td>788</td>
<td>770</td>
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<tr>
<td>$D$ losses ($E_{loss \ D}$)</td>
<td>3258</td>
<td>3451</td>
<td>3439</td>
<td>3168</td>
<td>2591</td>
<td>3633</td>
<td>3277</td>
<td>3778</td>
<td>3464</td>
<td>3904</td>
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<tr>
<td>Total supply ($E_{sup}$)</td>
<td>39,059</td>
<td>41,377</td>
<td>43,858</td>
<td>45,444</td>
<td>46,901</td>
<td>46,366</td>
<td>46,052</td>
<td>47,486</td>
<td>45,713</td>
<td>44,190</td>
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