The EnerGEO Platform of Integrated Assessment (PIA): environmental assessment of scenarios as a web service

To cite this version:
The EnerGEO Platform of Integrated Assessment (PIA): environmental assessment of scenarios as a web service

Isabelle Blanc¹, Benoit Gschwind¹, Mireille Lefevre¹, Didier Beloin-Saint-Pierre¹, Thierry Ranchin¹, Lionel Ménard¹, Janusz Cofala², Sabine Fuss², Artur Wyrwa¹, Kamila Drebszok³, Daniel Stetter⁴, Martijn Schaap⁵

Abstract

With the International Energy Agency estimating that global energy demand will increase between 40 and 50 percent by 2030 (compared to 2003), scientists and policymakers are concerned about the sustainability of the current energy system and what environmental pressures might result from the development of future energy systems. EnerGEO is an ongoing FP7 Project (2009-2013) which assesses the current and future impact of energy use on the environment by linking environmental observation systems with the processes involved in exploiting energy resources. The idea of this European project is to determine how low carbon scenarios, and in particular scenarios with a high share of renewable electricity, affect emissions of air pollutants and greenhouse gases (GHG) and contribute to mitigation of negative energy system impacts on human health and ecosystems. A Platform of Integrated Assessment (PIA) has been elaborated to provide impact results for a selection of scenarios via a set of models (large-scale energy models, Life Cycle Assessment models, ...). This PIA is currently available through a web service. The concept of the PIA is detailed and to illustrate its interest, a set of results is given with the use of the simulation mode of the European version of GAINS for a selection of scenarios.

1. Introduction

With the International Energy Agency estimating that global energy demand will increase between 40 and 50 percent by 2030 (compared to 2003), scientists and policymakers are concerned about the sustainability of the current energy system and what environmental pressures might result from the development of future energy systems. Recognizing this strong need for the assessment of current and future impacts of energy use on the environment, the EnerGEO project has been designed to enable the linkage of large-scale energy models projecting medium-run to long-run developments with more detailed models focusing on renewable energies to contribute to the improvement of projections, policy recommendations, and environmental assessments. A Platform of Integrated Assessment (PIA) has been elaborated to host the outcomes of the linkage of this set of models which in turns provide impact results for a set of scenarios. Several steps have been required to design and to run the PIA for assessing environmental impacts of scenarios:

1. Linking energy use and environmental impact by making use of state-of-the-art environmental, and energy models under different socio-economic scenarios as the underlying concept of the PIA,

¹ Observation, Impacts, Energy Center, MINES ParisTech, Sophia Antipolis, France, isabelle.blanc@mines-paristech.fr
² IIASA, Laxenburg, Austria
³ Faculty of Energy and Fuels, AGH University of Science and Technology, Krakow, Poland
⁴ DLR, Germany
⁵ TNO, The Netherlands
2. Collecting the necessary datasets and deriving indicators from them by exploring the current contributions to GEOSS and global in-situ networks,
4. Facilitating the access to EnerGEO data by building a portal within the context of GEO and based on GEO-ADC-recommendations (http://geoportal.energeo-project.eu)
5. Enabling to run global scenarios on energy use and environmental impacts by giving access to the PIA through a webservice http://viewer.webservice-energy.org/energeo_pia/index.htm

This article describes the architecture of the PIA, its content and how to use it through its related web services.

2. Architecture of the PIA

Figure 1 summarizes the concept of the Platform for Integrated Assessment (PIA). The DPSIR framework (EEA, 1999) is the underlying concept of the PIA as it is a relevant concept to structure thinking about the relation between the environment and socio-economic activities.
DPSIR stands for: Driving forces - Pressures - State - Impact – Responses. The DPSIR framework is a supportive framework assuming a chain of causal links between Driving forces and the resulting environmental Pressures, on the State of the environment, on the Impacts resulting from changes in environmental quality and on the societal Responses to these changes in the environment.

Examples of the most relevant indicators for the EnerGEO project are the followings according to the DPSIR typology:

- **Drivers**
  - Energy production and consumption by country/fuel/sector
  - Contribution of biomass to energy supply
  - Electricity demand
  - Electricity generation by fuel
  - Renewable electricity generation

- **Pressures**
  - GHG emissions (CO$_2$, CH$_4$, N$_2$O, F-gases)
  - Emissions of air pollutants (SO$_2$, NO$_x$, PM2.5, PM10, BC, OC, NH$_3$, NMVOC, Hg)

- **State**
  - Concentrations and depositions of air pollutants
  - Global warming potential from GHG emissions and air pollutants

- **Impacts**
  - Global temperature change
  - Premature mortality from fine particles (years of life lost – YOLLs)
  - Health impacts attributable to ground-level ozone

- **Responses**
  - Increased investments in renewable energy, i.e. renewable power generation
  - Fuel switching and energy efficiency improvement
  - Stricter emission limit values for air pollutants and taxes (or caps) on GHG
  - Investments in air pollution controls

Environmental impacts depending on the structure of energy production and consumption are analyzed within the EnerGEO Project. The PIA is positioned within the DPSIR structure at the Impact level. Several inputs feed the PIA: (1) Pilots environmental indicators through a depositary action, (2) Life Cycle Assessment (LCA) outcomes applied to scenarios through a depositary action and (3) Energy models State indicators. These latter state indicators are converted into impact indicators through the PIA webservice application. These three types of impact indicators are the ones used to assess the environmental performances of each scenario under study within EnerGEO. Currently four scenarios have been developed and are now described.

### 3. Elaboration of the scenarios

Scenarios were developed by linking the IIASA GAINS model (Amann *et al.*, 2011) with the DLR scenario generation tool (ReMiX) as used in the TRANS-CSP study (Trieb *et al.*, 2012), (Trieb *et al.*, 2006). First, IIASA compiled national energy scenarios using available long-term projections and studies to forecast countries future activities and related electricity demand. Next, DLR used this electricity demand forecast and their ReMiX model to determine the structure of power generation by country following assumptions of the different scenarios. Finally, the GAINS model has been applied to the resulting demand for primary
energy of each scenario to generate what we call the State indicators (Cofala/Bertok/Heyes/Rafaj/Sander/Schöpp 2012) (Figure 1).

We defined the 4 following scenarios:

1. The “Baseline” scenario, which assumes that policy will not change by 2050,
2. The “Open Europe” scenario, which assumes import of solar power from North Africa, high renewable energy share in electricity generation, and a phase-out of nuclear energy.
3. The “Island Europe” scenario, which allows a high share of power generation from renewable sources but no imports from outside Europe; missing electricity can be generated by nuclear plants.
4. The “Maximum Renewable Power” scenario, which assumes the highest possible electricity generation from renewable sources.

These scenarios assume for each country a successful enforcement of current air pollution control legislation (international and national emission limit values as well as fuel quality and product standards). The Baseline scenario is the EnerGEO reference scenario which enables analyses of other scenarios. This scenario includes current policies with regard to mitigation of climate change, as taken into account in various studies available for Europe.

4. An example of PIA use: human health indicators

To illustrate how the PIA is supporting impacts analysis of different scenarios, we will focus on human health indicators. Human health indicators are computed from time series of concentration of air pollutants. In this example of the PIA use, we calculate Loss of Life Expectancy (LLE) from PM$_{2.5}$ concentration (Particulate Matter with a 2.5 micrometer in diameter) (Gschwind/Lefevre/Blanc 2012), (Lefevre/Gschwind/Blanc/Ranchin/Wyrwa/Drebszok/Cofala/Fuss. 2013) and (Drebszok/Wyrwa/Blanc 2012). PM$_{2.5}$ concentration time series are obtained from GAINS for each country and for each scenario based on information collected by available international emission inventories and on national information supplied by individual countries (Cofala/Bertok/Heyes/Rafaj/Sander/Schöpp 2012). Table 1 reports Loss of Life Expectancy expressed in Years of Life Lost (YOLL, in thousands) due to PM$_{2.5}$ for people above 30 years in 2005 for different countries in Europe.

<table>
<thead>
<tr>
<th></th>
<th>Baseline scenario</th>
<th>Island Europe scenario</th>
<th>Max. Ren. power scenario</th>
<th>Open Europe scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>1384</td>
<td>1334</td>
<td>1327</td>
<td>1336</td>
</tr>
<tr>
<td>Belgium</td>
<td>3497</td>
<td>3401</td>
<td>3389</td>
<td>3405</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>1737</td>
<td>1673</td>
<td>1667</td>
<td>1676</td>
</tr>
<tr>
<td>Cyprus</td>
<td>127</td>
<td>94</td>
<td>94</td>
<td>95</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>2549</td>
<td>2471</td>
<td>2458</td>
<td>2476</td>
</tr>
<tr>
<td>Denmark</td>
<td>1068</td>
<td>1043</td>
<td>1040</td>
<td>1044</td>
</tr>
<tr>
<td>Estonia</td>
<td>194</td>
<td>187</td>
<td>187</td>
<td>187</td>
</tr>
<tr>
<td>Finland</td>
<td>475</td>
<td>455</td>
<td>456</td>
<td>458</td>
</tr>
<tr>
<td>France</td>
<td>10980</td>
<td>10763</td>
<td>10729</td>
<td>10775</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>2010</td>
<td>2020</td>
<td>2030</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Germany</td>
<td>21378</td>
<td>20695</td>
<td>20636</td>
<td>20732</td>
</tr>
<tr>
<td>Greece</td>
<td>1788</td>
<td>1698</td>
<td>1682</td>
<td>1705</td>
</tr>
<tr>
<td>Hungary</td>
<td>2981</td>
<td>2891</td>
<td>2884</td>
<td>2909</td>
</tr>
<tr>
<td>Ireland</td>
<td>329</td>
<td>321</td>
<td>319</td>
<td>321</td>
</tr>
<tr>
<td>Italy</td>
<td>10375</td>
<td>10113</td>
<td>10025</td>
<td>10078</td>
</tr>
<tr>
<td>Latvia</td>
<td>383</td>
<td>373</td>
<td>372</td>
<td>373</td>
</tr>
<tr>
<td>Lithuania</td>
<td>673</td>
<td>656</td>
<td>654</td>
<td>656</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>122</td>
<td>118</td>
<td>118</td>
<td>119</td>
</tr>
<tr>
<td>Netherlands</td>
<td>5232</td>
<td>5061</td>
<td>5042</td>
<td>5070</td>
</tr>
<tr>
<td>Poland</td>
<td>10620</td>
<td>10338</td>
<td>10269</td>
<td>10332</td>
</tr>
<tr>
<td>Portugal</td>
<td>1428</td>
<td>1413</td>
<td>1412</td>
<td>1414</td>
</tr>
<tr>
<td>Romania</td>
<td>5437</td>
<td>5234</td>
<td>5221</td>
<td>5243</td>
</tr>
<tr>
<td>Slovakia</td>
<td>1332</td>
<td>1290</td>
<td>1284</td>
<td>1295</td>
</tr>
<tr>
<td>Slovenia</td>
<td>426</td>
<td>411</td>
<td>409</td>
<td>412</td>
</tr>
<tr>
<td>Spain</td>
<td>4382</td>
<td>4295</td>
<td>4293</td>
<td>4302</td>
</tr>
<tr>
<td>Sweden</td>
<td>778</td>
<td>754</td>
<td>753</td>
<td>756</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>10384</td>
<td>10188</td>
<td>10133</td>
<td>10196</td>
</tr>
<tr>
<td>EU-27</td>
<td>100059</td>
<td>97270</td>
<td>96853</td>
<td>97365</td>
</tr>
</tbody>
</table>

Another human health indicator delivered in the PIA is the premature deaths per year due to ozone. As for the PM$_{2.5}$ concentration, time series are obtained from GAINS for each country and for each scenario. Figure 2 presents the number of cases in 2005 for the baseline scenario in the form of map for each country. Table 2 reports the same results along with cases in 2050 (maximum renewable scenario compared to baseline) for different countries in Europe.

![Figure 2: Number of premature deaths per country due to Ozone in 2005](image)
In both cases (PM$_{2.5}$ and O$_3$) results are available in the PIA in the form of tables, maps with national values per country, or gridded maps with a resolution of 20 x 20 km$^2$.

Table 2: Cases of premature death due to Ozone in 2005 and 2050

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>119</td>
<td>153</td>
<td>131</td>
<td>-14</td>
</tr>
<tr>
<td>Austria</td>
<td>427</td>
<td>341</td>
<td>297</td>
<td>-13</td>
</tr>
<tr>
<td>Belarus</td>
<td>324</td>
<td>186</td>
<td>153</td>
<td>-18</td>
</tr>
<tr>
<td>Belgium</td>
<td>458</td>
<td>422</td>
<td>396</td>
<td>-6</td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
<td>220</td>
<td>159</td>
<td>121</td>
<td>-24</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>603</td>
<td>264</td>
<td>219</td>
<td>-17</td>
</tr>
<tr>
<td>Croatia</td>
<td>342</td>
<td>198</td>
<td>164</td>
<td>-18</td>
</tr>
<tr>
<td>Cyprus</td>
<td>33</td>
<td>70</td>
<td>62</td>
<td>-12</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>568</td>
<td>337</td>
<td>273</td>
<td>-19</td>
</tr>
<tr>
<td>Denmark</td>
<td>194</td>
<td>163</td>
<td>149</td>
<td>-8</td>
</tr>
<tr>
<td>Estonia</td>
<td>22</td>
<td>15</td>
<td>13</td>
<td>-9</td>
</tr>
<tr>
<td>Finland</td>
<td>58</td>
<td>57</td>
<td>53</td>
<td>-7</td>
</tr>
<tr>
<td>France</td>
<td>2768</td>
<td>2510</td>
<td>2306</td>
<td>-8</td>
</tr>
<tr>
<td>Germany</td>
<td>4065</td>
<td>3313</td>
<td>3025</td>
<td>-9</td>
</tr>
<tr>
<td>Greece</td>
<td>735</td>
<td>719</td>
<td>643</td>
<td>-11</td>
</tr>
<tr>
<td>Hungary</td>
<td>754</td>
<td>370</td>
<td>300</td>
<td>-19</td>
</tr>
<tr>
<td>Ireland</td>
<td>83</td>
<td>143</td>
<td>138</td>
<td>-3</td>
</tr>
<tr>
<td>Italy</td>
<td>4861</td>
<td>4353</td>
<td>3957</td>
<td>-9</td>
</tr>
<tr>
<td>Latvia</td>
<td>60</td>
<td>34</td>
<td>31</td>
<td>-11</td>
</tr>
<tr>
<td>Lithuania</td>
<td>101</td>
<td>58</td>
<td>50</td>
<td>-14</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>20</td>
<td>20</td>
<td>17</td>
<td>-14</td>
</tr>
<tr>
<td>Malta</td>
<td>26</td>
<td>28</td>
<td>26</td>
<td>-9</td>
</tr>
<tr>
<td>Netherlands</td>
<td>459</td>
<td>500</td>
<td>471</td>
<td>-6</td>
</tr>
<tr>
<td>Norway</td>
<td>91</td>
<td>115</td>
<td>110</td>
<td>-4</td>
</tr>
<tr>
<td>Poland</td>
<td>1539</td>
<td>1022</td>
<td>851</td>
<td>-17</td>
</tr>
<tr>
<td>Portugal</td>
<td>601</td>
<td>582</td>
<td>558</td>
<td>-4</td>
</tr>
<tr>
<td>Republic of Moldova</td>
<td>192</td>
<td>100</td>
<td>82</td>
<td>-18</td>
</tr>
<tr>
<td>Romania</td>
<td>1177</td>
<td>713</td>
<td>585</td>
<td>-18</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>4185</td>
<td>3063</td>
<td>2819</td>
<td>-8</td>
</tr>
<tr>
<td>Serbia</td>
<td>612</td>
<td>412</td>
<td>347</td>
<td>-16</td>
</tr>
<tr>
<td>Slovakia</td>
<td>290</td>
<td>178</td>
<td>136</td>
<td>-24</td>
</tr>
<tr>
<td>Slovenia</td>
<td>124</td>
<td>85</td>
<td>70</td>
<td>-17</td>
</tr>
<tr>
<td>Spain</td>
<td>2478</td>
<td>2723</td>
<td>2563</td>
<td>-6</td>
</tr>
<tr>
<td>Sweden</td>
<td>206</td>
<td>185</td>
<td>172</td>
<td>-7</td>
</tr>
<tr>
<td>Switzerland</td>
<td>346</td>
<td>345</td>
<td>311</td>
<td>-10</td>
</tr>
<tr>
<td>FYR Macedonia</td>
<td>96</td>
<td>102</td>
<td>92</td>
<td>-9</td>
</tr>
<tr>
<td>Turkey</td>
<td>1894</td>
<td>4585</td>
<td>3147</td>
<td>-31</td>
</tr>
<tr>
<td>Ukraine</td>
<td>2620</td>
<td>1309</td>
<td>1135</td>
<td>-13</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1785</td>
<td>1996</td>
<td>1935</td>
<td>-3</td>
</tr>
<tr>
<td>EUROPE</td>
<td>35536</td>
<td>31928</td>
<td>27908</td>
<td>-13</td>
</tr>
</tbody>
</table>
5. Access to impact indicators through Web services within the PIA

These results are available through a set of standard OGC (Open Geospatial Consortium) Web Map Services (WMS) which provide maps of computed indicators available in the geocatalog\(^1\). We also provide a WPS (Web Processing Service) another OGC standard which gathers all PIA results to enable a one point access to data available. This WPS is currently used by our Web Client\(^2\). This Web Client provides an easy human interface which enables the download of results and the view of maps.

Figure 3: Example of the PIA Web Client

Bibliography


\(^1\) [http://geocatalog.webservice-energy.org/geonetwork/srv/eng/main.home](http://geocatalog.webservice-energy.org/geonetwork/srv/eng/main.home)

\(^2\) [http://viewer.webservice-energy.org/energeo_pia/index.htm](http://viewer.webservice-energy.org/energeo_pia/index.htm)


GAINS Model : http://www.iiasa.ac.at/web/home/research/researchPrograms/GAINS.en.html


