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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,

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2. Collecting the necessary datasets and deriving indicators from them by exploring the current contributions to GEOSS and global in-situ networks,
3. Running dedicated pilots to assess environmental impacts: Biomass, Solar Energy, Wind and Fossil Fuels.
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

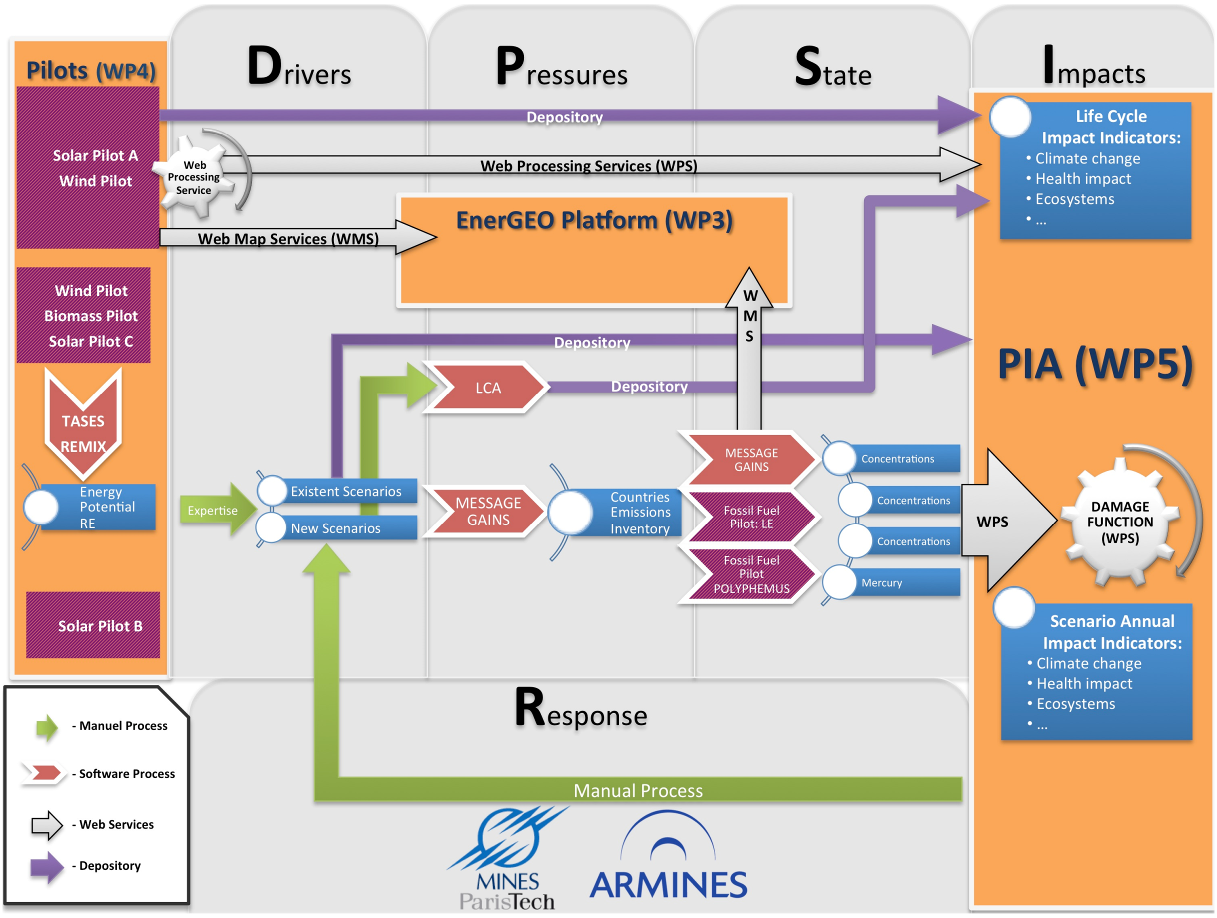

Figure 1: Architecture of the EnerGEO Platform of Integrated Assessment (PIA)

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_2O, 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 1 : Years Of Life Lost (thousands) due to $PM_{2.5}$ for people above 30 years in 2005

	Baseline scenario	Island Europe scenario	Max. Ren. power scenario	Open Europe scenario
Austria	1384	1334	1327	1336
Belgium	3497	3401	3389	3405
Bulgaria	1737	1673	1667	1676
Cyprus	127	94	94	95
Czech Republic	2549	2471	2458	2476
Denmark	1068	1043	1040	1044
Estonia	194	187	187	187
Finland	475	455	456	458
France	10980	10763	10729	10775

Germany	21378	20695	20636	20732
Greece	1788	1698	1682	1705
Hungary	2981	2891	2884	2909
Ireland	329	321	319	321
Italy	10375	10113	10025	10078
Latvia	383	373	372	373
Lithuania	673	656	654	656
Luxembourg	122	118	118	119
Netherlands	5232	5061	5042	5070
Poland	10620	10338	10269	10332
Portugal	1428	1413	1412	1414
Romania	5437	5234	5221	5243
Slovakia	1332	1290	1284	1295
Slovenia	426	411	409	412
Spain	4382	4295	4293	4302
Sweden	778	754	753	756
United Kingdom	10384	10188	10133	10196
EU-27	100059	97270	96853	97365

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.

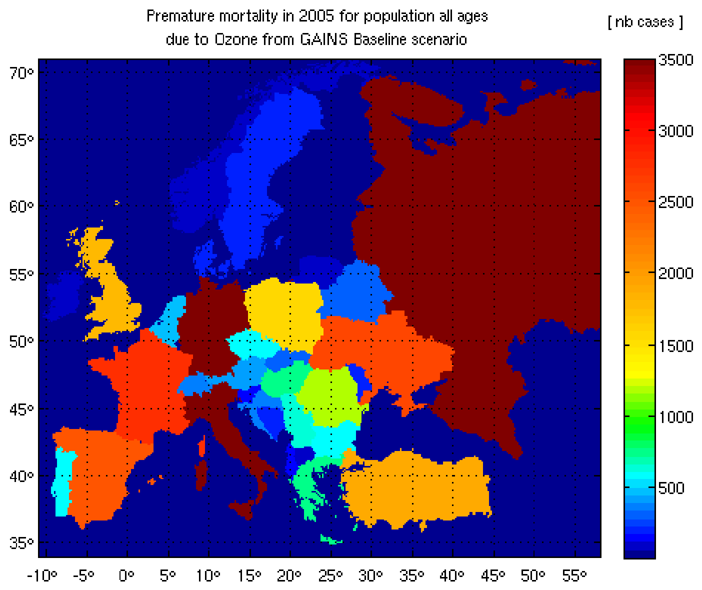

Figure 2: Number of premature deaths per country due to Ozone in 2005

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

	Baseline 2005	Baseline 2050	Max. Ren. Power 2050	Diff. Baseline / Max.ren. power (%)
Albania	119	153	131	-14
Austria	427	341	297	-13
Belarus	324	186	153	-18
Belgium	458	422	396	-6
Bosnia and Herzegovina	220	159	121	-24
Bulgaria	603	264	219	-17
Croatia	342	198	164	-18
Cyprus	33	70	62	-12
Czech Republic	568	337	273	-19
Denmark	194	163	149	-8
Estonia	22	15	13	-9
Finland	58	57	53	-7
France	2768	2510	2306	-8
Germany	4065	3313	3025	-9
Greece	735	719	643	-11
Hungary	754	370	300	-19
Ireland	83	143	138	-3
Italy	4861	4353	3957	-9
Latvia	60	34	31	-11
Lithuania	101	58	50	-14
Luxembourg	20	20	17	-14
Malta	26	28	26	-9
Netherlands	459	500	471	-6
Norway	91	115	110	-4
Poland	1539	1022	851	-17
Portugal	601	582	558	-4
Republic of Moldova	192	100	82	-18
Romania	1177	713	585	-18
Russian Federation	4185	3063	2819	-8
Serbia	612	412	347	-16
Slovakia	290	178	136	-24
Slovenia	124	85	70	-17
Spain	2478	2723	2563	-6
Sweden	206	185	172	-7
Switzerland	346	345	311	-10
TFYR Macedonia	96	102	92	-9
Turkey	1894	4585	3147	-31
Ukraine	2620	1309	1135	-13
United Kingdom	1785	1996	1935	-3
EUROPE	35536	31928	27908	-13

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.

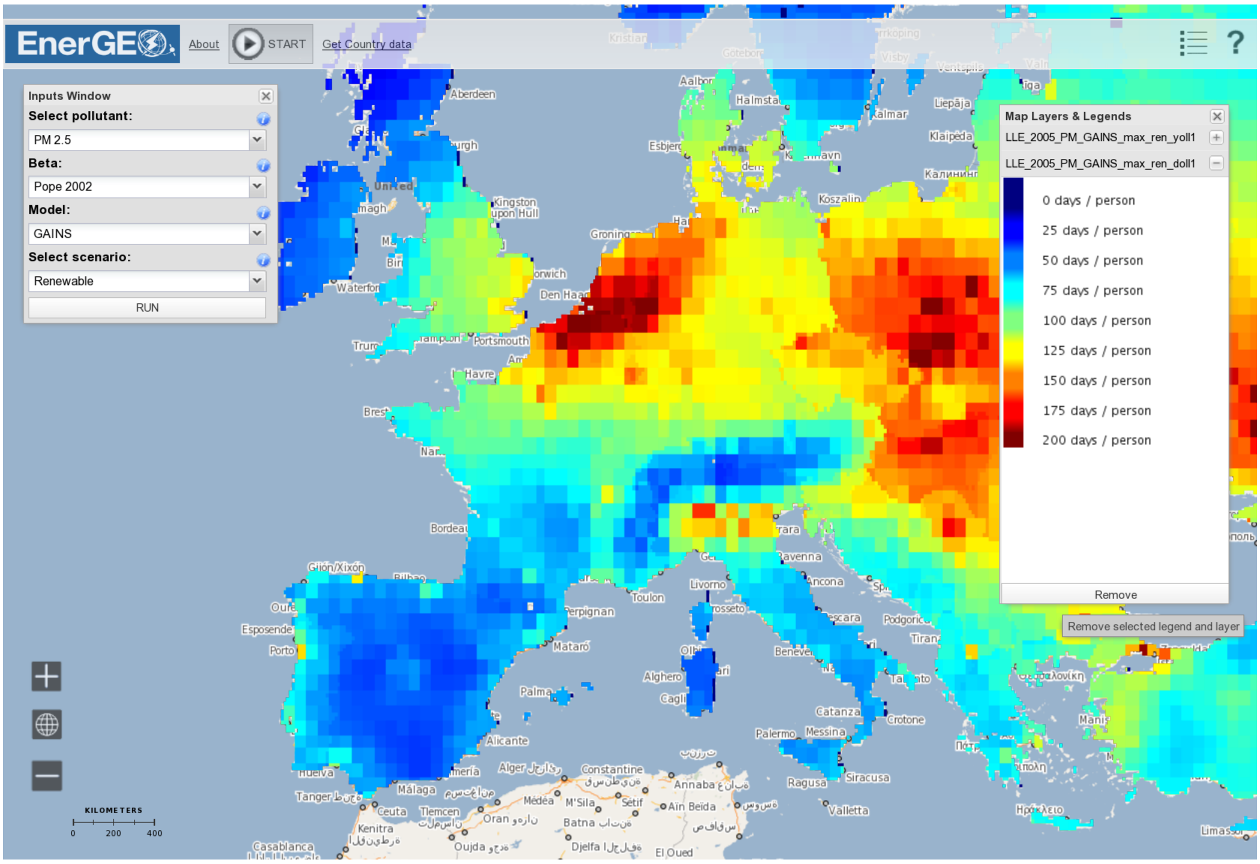

Figure 3: Example of the PIA Web Client

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