

Earth observation for monitoring and assessment of the environmental impact of energy use

Version 03

Project overview



Seventh Framework Programme

Theme 6 - Environment

FP7-ENV-2008-1


GA No. 216364













- 12 partners from 6 countries
- Project duration: 11/2009 – 10/2013
- EC contribution: € 6 010 930
- Coordinator: Dr. Menno Dillen, TNO
- Website: <http://www.energeo-project.eu>

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No	Beneficiary name	Beneficiary Short name	Country	Logo and website
1	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, Coordinator	TNO	Netherlands	 TNO innovation for life
2	Association pour la Recherche et le Développement des Méthodes et Processus Industriels	ARMINES	France	 ARMINES
3	Deutsches Zentrum für Luft- und Raumfahrt	DLR	Germany	 DLR
4	ARGOSS	ARGOSS	Netherlands	 BMT ARGOSS
5	Research Studios Austria Forschungsgesellschaft mbH	RSA	Austria	 rsa Research Studios Austria Forschungsgesellschaft mbH
6	International Institute for Applied Systems Analysis	IIASA	Austria	 IIASA
7	Uniresearch B.V.	UNR	Netherlands	 UNIRESEARCH
8	Paris-Lodron-Universität Salzburg Centre for Geoinformatics Z_GIS	PLUS	Austria	 UNIVERSITÄT SALZBURG Z_GIS
9	AGH University of Science and Technology / Krakow	AGH-UST	Poland	 AGH
10	Pakistan Space and Upper Atmosphere Research Commission	SUPARCO	Pakistan	 SUPARCO
11	Institut für Energie- und Umwelttechnik IUTA e.V.	IUTA	Germany	 iuta
12	Stichting Ruimte Onderzoek Nederland	SRON	Netherlands	 SRON

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- Worldwide demand of energy is growing and will continue to do so for the next decades to come.
 - The *International Energy Agency IEA* has estimated that **global primary energy demand will increase by 40 – 50 %** from 2003 to 2030 (2005 estimates) depending on the fact whether energy policies are directed towards energy-saving and fuel-diversification will be effectuated.
 - Since energy production, transportation and consumption place considerable **pressures on the environment**, there is serious concern regarding the **sustainability** of the current and future pattern of **energy consumption**.
- EnerGEO develops products and methodologies that provide energy companies, consultants and policy makers (local, regional, global) with the tools to **evaluate the environmental impact of changes in energy use** in terms of the **complete life cycle** including exploration, development, exploitation, maintenance and decommissioning.

Project objectives

EnerGEO develops a strategy for a **global assessment** of current and future **impacts of the exploitation of energy resources on the environment and ecosystems** based on the use of the *Global Earth Observation System of Systems (GEOSS)* capacities. This strategy is demonstrated for a variety of energy resources worldwide (fossil fuels, biomass, solar and wind energy).

EnerGEO combines:

1. **Existing energy system models** and models capable of assessing and forecasting environmental impacts and costs of energy exploitation
2. **Existing global earth observation datasets** from which environmental indicators are derived in order to quantify changes to freshwater systems, biosphere, ecosystems, atmosphere and oceans

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Project objectives

4 Pilots were selected for testing and demonstrating the observation system and developed scenarios:

Fossil fuels: impact on atmospheric composition and land degradation

Biomass: impact on ecosystems, biodiversity and food security

Solar energy: select optimum power plant locations and support electricity grid integration

Wind: assess the potential (net) energy, assess environmental impacts of the substitution of fossil energy by wind power

→ all pilot outputs will be converted into **Environmental Impact Assessments** and tentatively **integrated through the Platform Integrated Assessment (PIA)**

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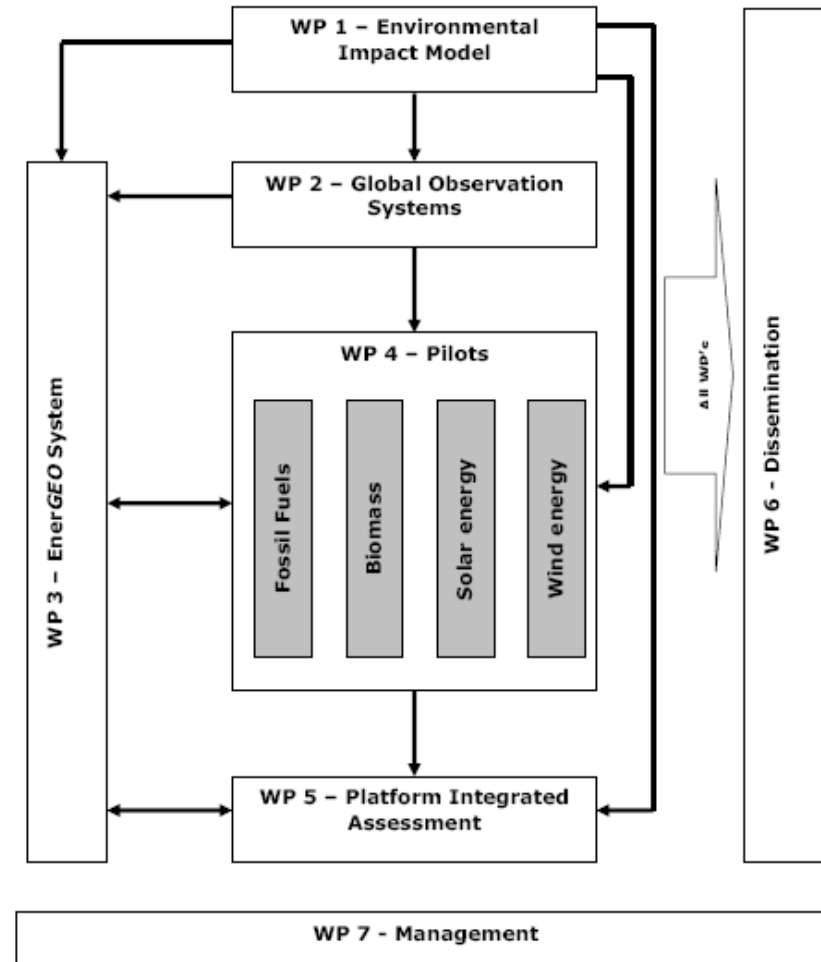
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Project logic

The project logic aims at **connecting environmental impact assessment** for the various energy resources **with existing observation systems**, developing an integrated, distributed observation capacity and demonstrating its applicability in a number of **pilot-projects**.

Based on the experience of the pilot-projects, first steps towards a **global assessment** of environmental impact for the extraction, transportation and use of energy resources are being made.



Overview of workpackages

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GEO Context

EnerGEO represents a major contribution of the European Commission to **GEOSS**, in particular to the Societal Benefit Area (SBA) **Energy** and the **GEO-tasks**

- **EN-07-02** (Energy Environmental Impact Monitoring) and
 - **EN-07-03** (Energy Policy Planning)
- (or any GEO Workpackage derived from these).

By developing a distributed system based on the recommendations of the **GEO-Architecture and Data Committee (ADC)**, global collection and dissemination of data relating to the impact of energy use on the environment will be supported.

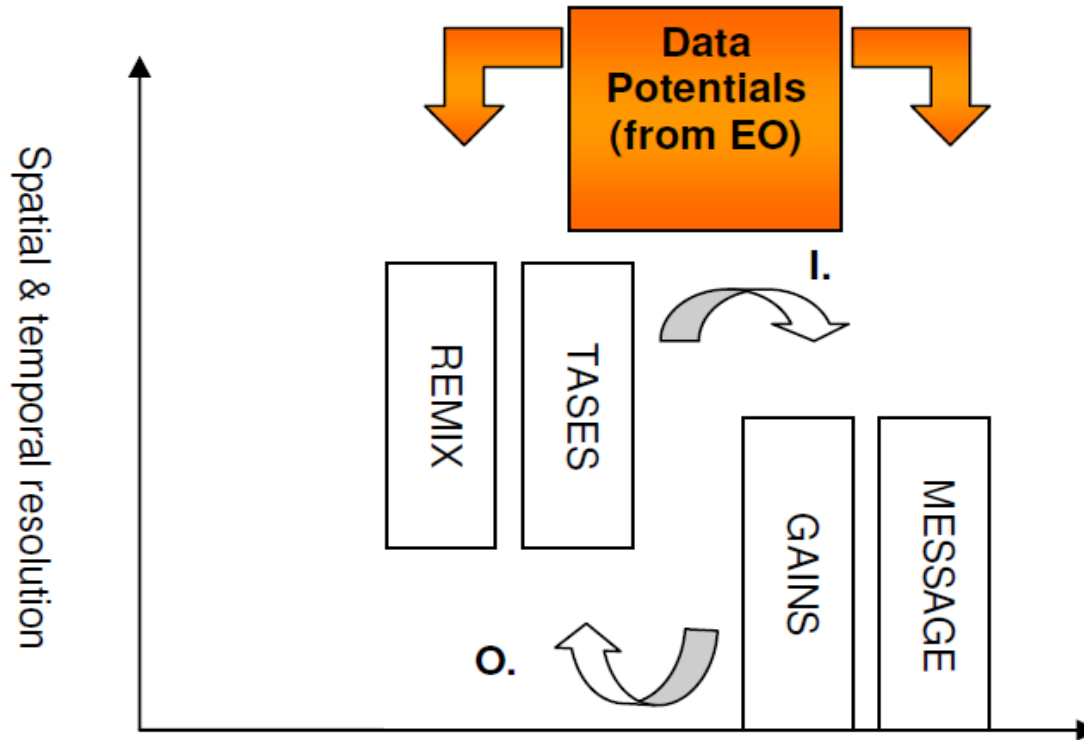



The SBAs of GEOSS

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EnerGEO Integrated Assessment Framework


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- I.
 1. **Technology characteristics and costs comparison and harmonization**
 2. **Systems integration:** Conditional operating reserves (grid, energy generation mix, demand, storage, ... etc)
- O. **Downscaling**

EnerGEO Indicator Overview following DPSIR Approach

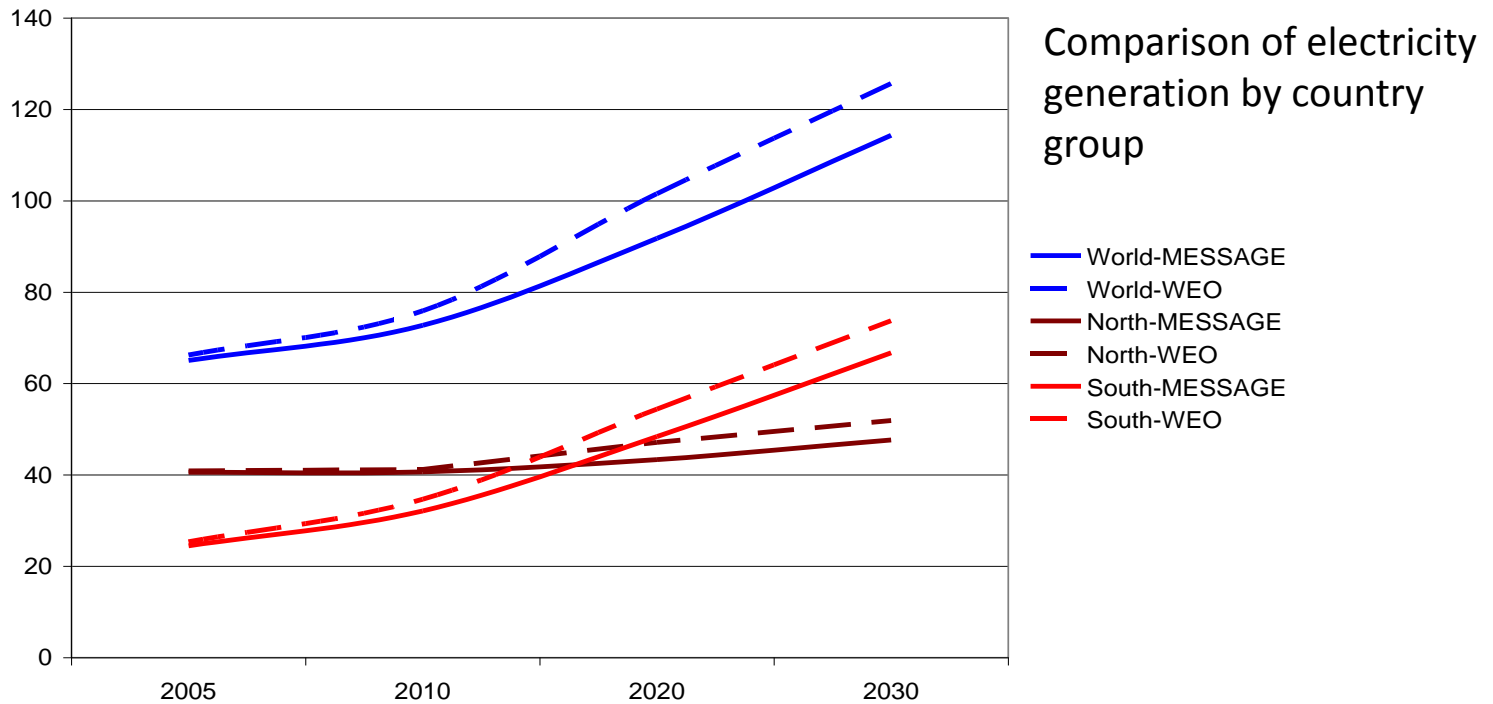
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Drivers	Pressures	State	Impact	Responses
Energy production and consumption by country/fuel/sector	Emissions of GHG (CO ₂ , CH ₄ , N ₂ O, F-gases)	Radiative forcing from emissions of greenhouse gases	Global temperature change	Increased use of renewable energy (focus of EnerGEO)
Contribution of biomass to energy supply	Emissions of air pollutants (SO ₂ , -NO _x , PM _{2.5} , PM ₁₀ , BC, OC, NH ₃ , NMVOC, Hg)	Concentrations and depositions of air pollutants	Premature mortality from fine particles (indoor and outdoor – YOLLs)	Fuel switching and energy efficiency improvement
Electricity demand	Land-use change (due to biomass production)		Health impacts attributable to ground-level ozone (SOMO35 - deaths/year)	Stricter limit values for air pollutants (primary PM, SO ₂ , NH ₃ ...)
Electricity generation by fuel	Waste and oil spills		Impacts of ozone on forests and crops (AOT40 – productivity losses)	...

EnerGEO Scenario Database – Drivers/Pressures

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- 2 baselines: **long run** (MESSAGE-GEA-Mix) & **medium term** (GAINS, WEO)
- **Drivers & pressures:** projections for population & economic growth, comparison of primary energy demand & electricity generation
- Comparable paths for both scenarios, but differences in fuel consumption composition & absolute demand at the regional level. Electricity generation 9% higher in the MESSAGE scenario in 2030.

Fossil Fuels

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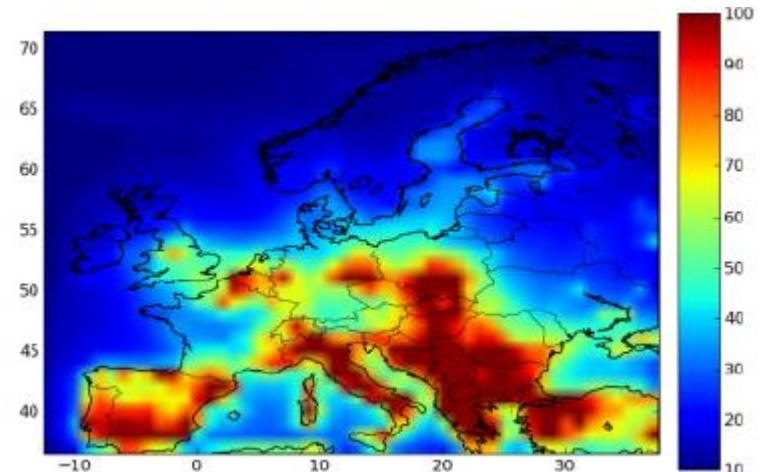
The pilot study focuses on the combined impact of the **production, transportation and use** of fossil fuels (oil, gas and coal) on **air quality** and **atmospheric composition** as well as on **land degradation** through the objectives of:

- assessing energy transition scenarios in terms of **air quality**
- assessing the contribution of fossil fuels to global **CO₂ concentration**
- modeling the concentration and deposition of **mercury** across Europe as indicator for coal combustion
- assessing land degradation due to coal mining

Models used: air quality models LOTOS-EUROS, POLYPHEMUS, TM5 [...]

Study areas:

- Europe (air quality)
- Globe (changes in atmospheric composition)
- Germany, Central and Eastern Europe (land degradation by coal mining)



Hg^{II} distribution over Europe

Fossil Fuels – Energy Transition

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Large scale energy transitions have a significant impact on air quality.

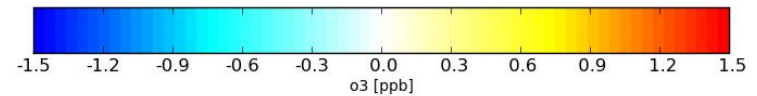
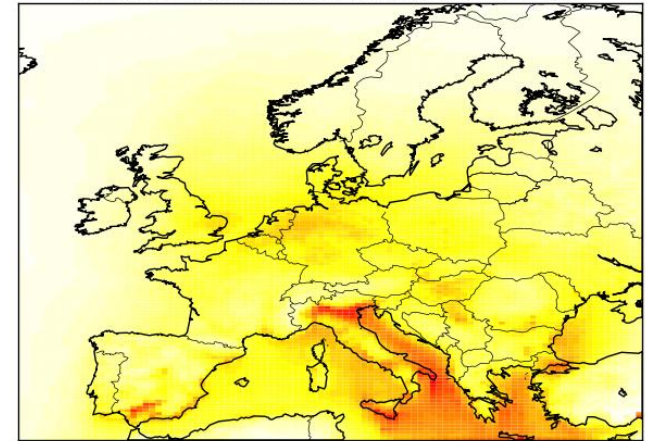
Generally air quality will benefit from less emissions, but there are some issues:

- Large-scale reductions of emissions will change the chemical regime in the atmosphere
- Large-scale use of biomass will be accompanied by large scale biomass production and potentially additional air pollutant emissions
- Because solar and wind energy revenue is dependent on meteorology, the timing of emissions from the back-up fossil fuel combustion will change as well. This may significantly alter the regional distribution of the impact of fossil fuel use.

Model used: air quality model LOTOS-EUROS

Study areas: Europe

new landuse-current landuse [2006-04-01 00:00,2006-10-01 00:00]



Example: increase in summer surface ozone when 5% of the European agricultural land is converted into poplar for biomass production

Fossil Fuels – Air Quality Trends

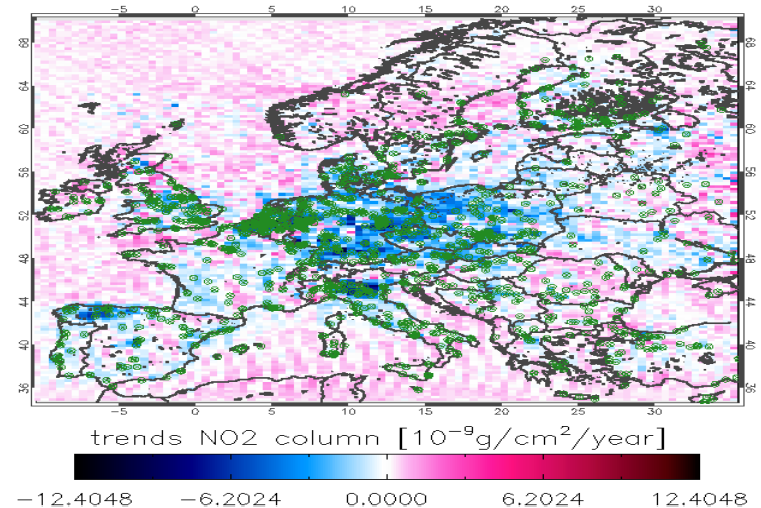
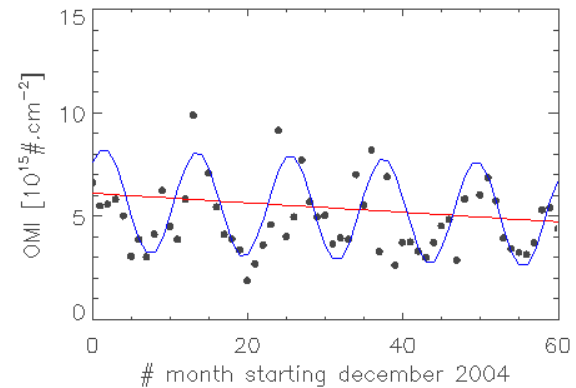
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Objective: quantify the trend in NO_x emissions over Europe based on satellite observations of NO_2 from the OMI instrument.

The observed vertical column concentrations are fitted using a linear annual decrease (red line) and a seasonal pattern (blue line). The trend is corrected for meteorological variability using a model.

Preliminary results show a **decrease in NO_x emissions over Europe**, especially for electricity generation and road transportation.

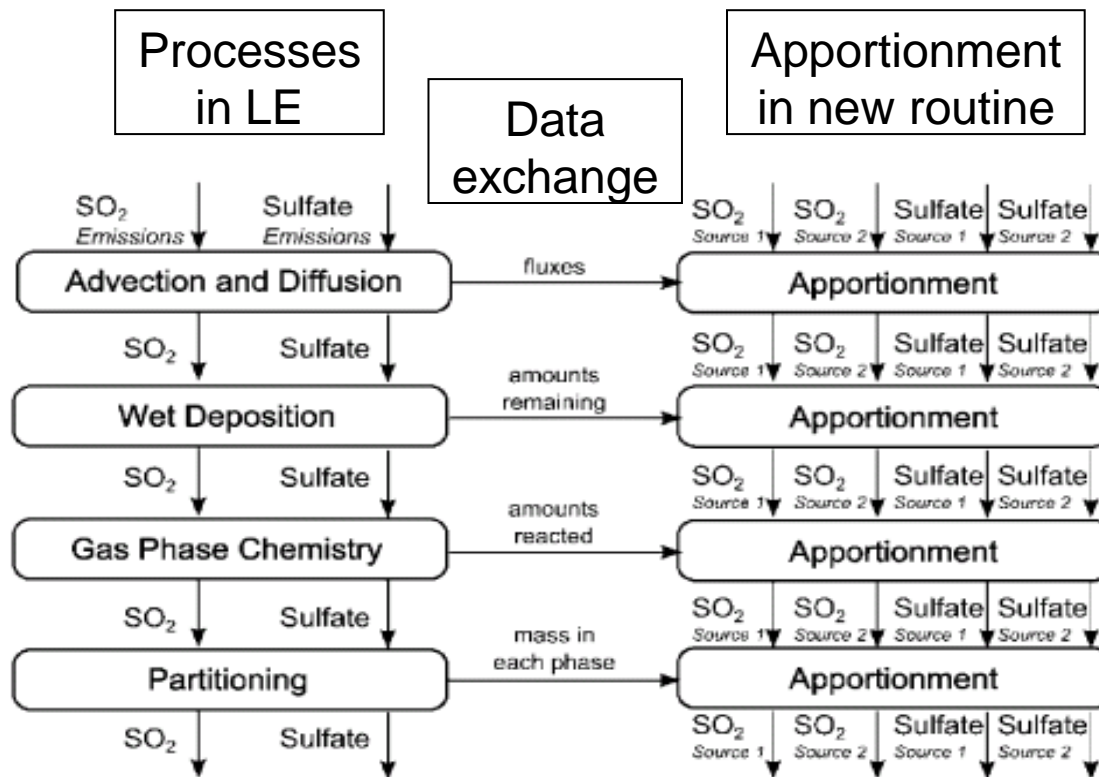
A similar study is being conducted for CO on a global scale.



*Preliminary results (blue represents a decrease in emissions)
Green dots are power plant locations.*

Fossil Fuels – Source Apportionment

Particulate matter (PM) has a negative impact on human health. We improve the modeling of PM concentrations over Europe including the development of a source apportionment tool to assess the contribution of fossil fuel combustion. These developments are complemented with dedicated analyses of observed PM composition.



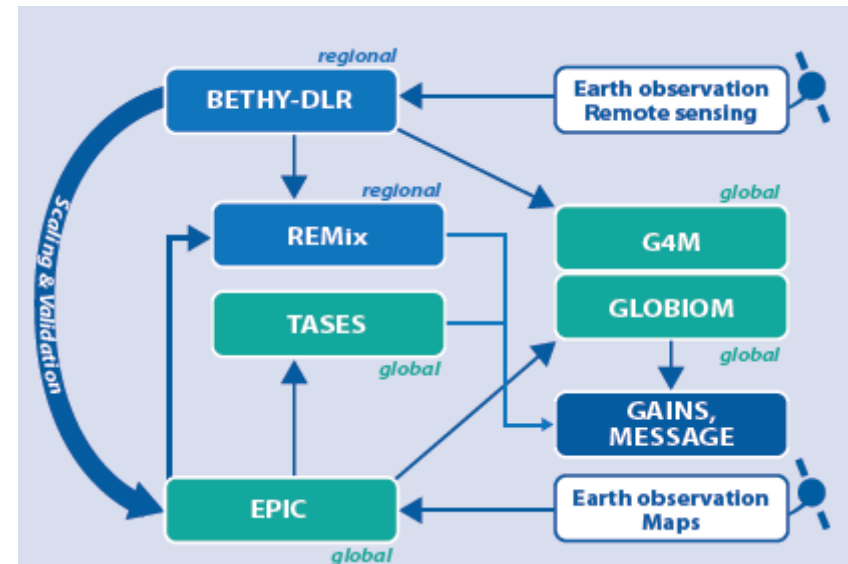
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Biomass

Evaluate the environmental impacts in bioenergy use which are related mainly to emissions of **burning biomass**, use of cooling water, solid waste generation, **land use changes**, changes in **trace gas emissions** like CH₄, NO₂, and CO₂, changes in albedo due to land use changes, **deforestation**, agricultural changes in fertilization, humus reduction, increased **erosion** and **desertification**.

Models used for providing energy crop specific and dynamic vegetation modeling: **EPIC** (IIASA), **BETHY** (DLR)

Study areas: Austria (Sauwald), Pakistan



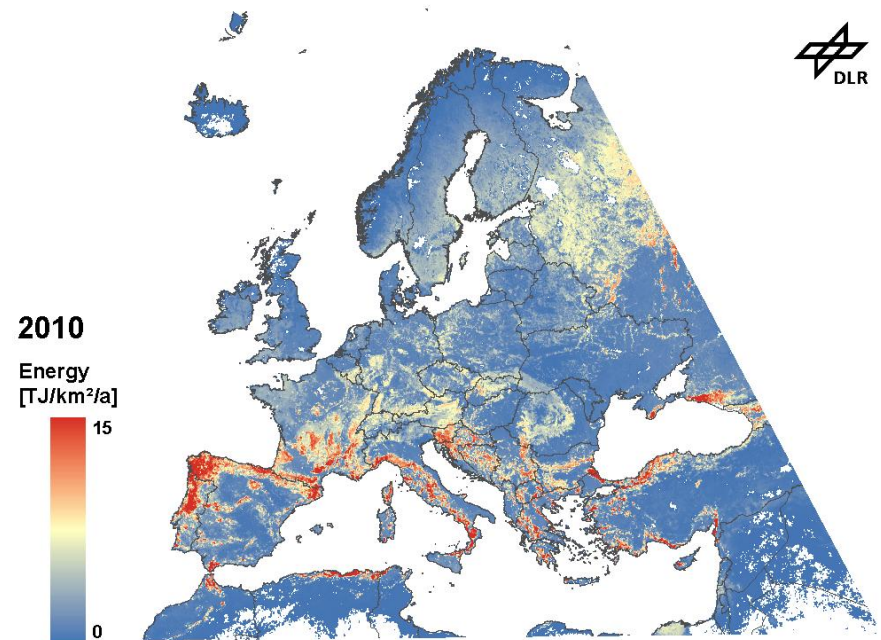
Model schema for biomass pilot (DLR-DFD)

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Biomass - Energy potentials

The BETHY/DLR model is driven by **remote sensing data** (time series of Leaf Area Index and land cover classification) and **meteorological data**. The output is annual **Net Primary Productivity (NPP)** which is transferred to theoretical **energy potentials** using conversion factors.

Sustainable management and **food security** are prerequisites for deriving theoretical energy potentials from NPP



Theoretical energy potential for 2010 as computed with BETHY/DLR, including forest, agriculture and grassland.

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Solar energy

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Environmental impacts of solar energy are related to:

- reduction of fossil fuels
- visual impacts of large photovoltaic systems in a landscape and land use effects

The aim of this pilot to support decision making by:

- defining **the best site for solar energy production** and options for **grid integration** and fossil fuel replacement
- assessing the use of existing **solar power prediction schemes**
- modeling time-dependent averaging effects and cross-border energy flows over larger time periods and regional areas

→ **Solar Pilot A ‘Siting Support’, Solar Pilot B ‘Grid planning support’, Solar pilot C ‘Large scale generation’**

Models used: ECMWF, DLR/AFSOL, NCEP, REMIX, TASES [...]

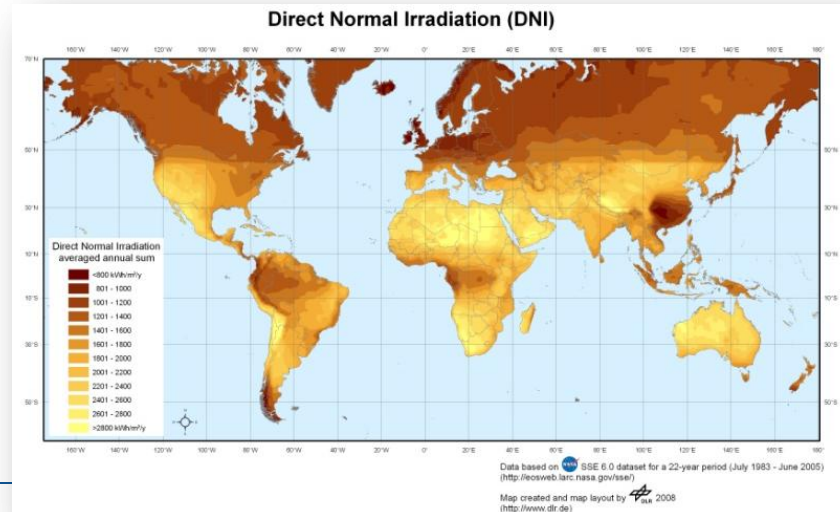
Study areas: Spain, France, Germany, Italy and Northern Africa



*Solar plant near Seville, Spain
(<http://earthobservatory.nasa.gov/>)*

Solar energy

- **TASES (Time And Space resolved Energy Simulation)**
 - performs geographic explicit energy scenario analysis on a global scale for discrete points in time
 - modelling and optimisation tool for future energy systems
 - estimates potentials, costs and environmental impacts
 - models base-and peak load of solar power on different spatial scales
- **REMix (Renewable Energy Mix for Sustainable Electricity Supply in Europe)**
 - uses a geographic information system for analyzing the highly dynamic renewable electricity generation potentials in Europe
 - electric power generation potentials are linked to an optimization model which balances renewable electricity generation with demand
 - calculates the least cost electric power supply option at given constraints such as renewable energy share and import restrictions



*Solar Energy Resource
Assessment*

Wind Turbines Energy & Environmental Impacts

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The aims of this pilot are:

- To assess the **potential (net) energy** produced by wind offshore farms in a given area
- To assess environmental impacts of substitution of fossil energy by wind power related to the complete **energy balance** of wind power over the **total life cycle** of a project (construction, operation, maintenance and decommissioning)

The pilot is based on a Life Cycle Assessment (LCA) study where Impacts (Global warming, human health, ...) are investigated for several turbines and foundation types.

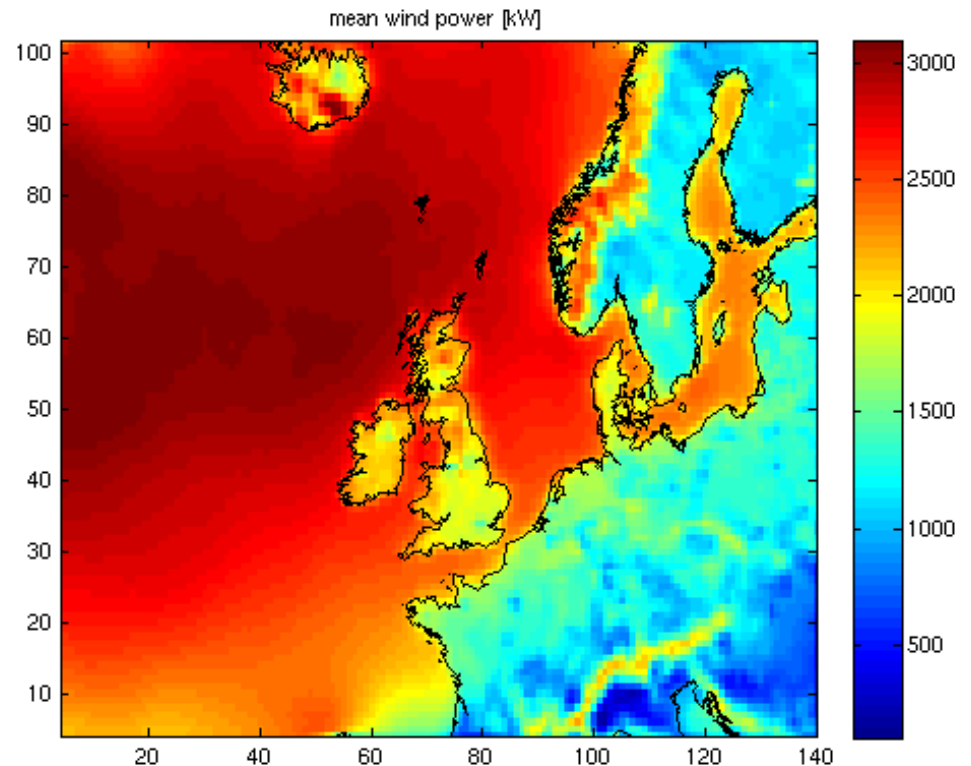
Outputs: Maps of wind potential, energy potentials and environmental impacts



Wind - Potential wind energy

High-resolution meteorological models are used to analyse potential energy yields. These models are calibrated and validated using in-situ and satellite measurements. Studied aspects are:

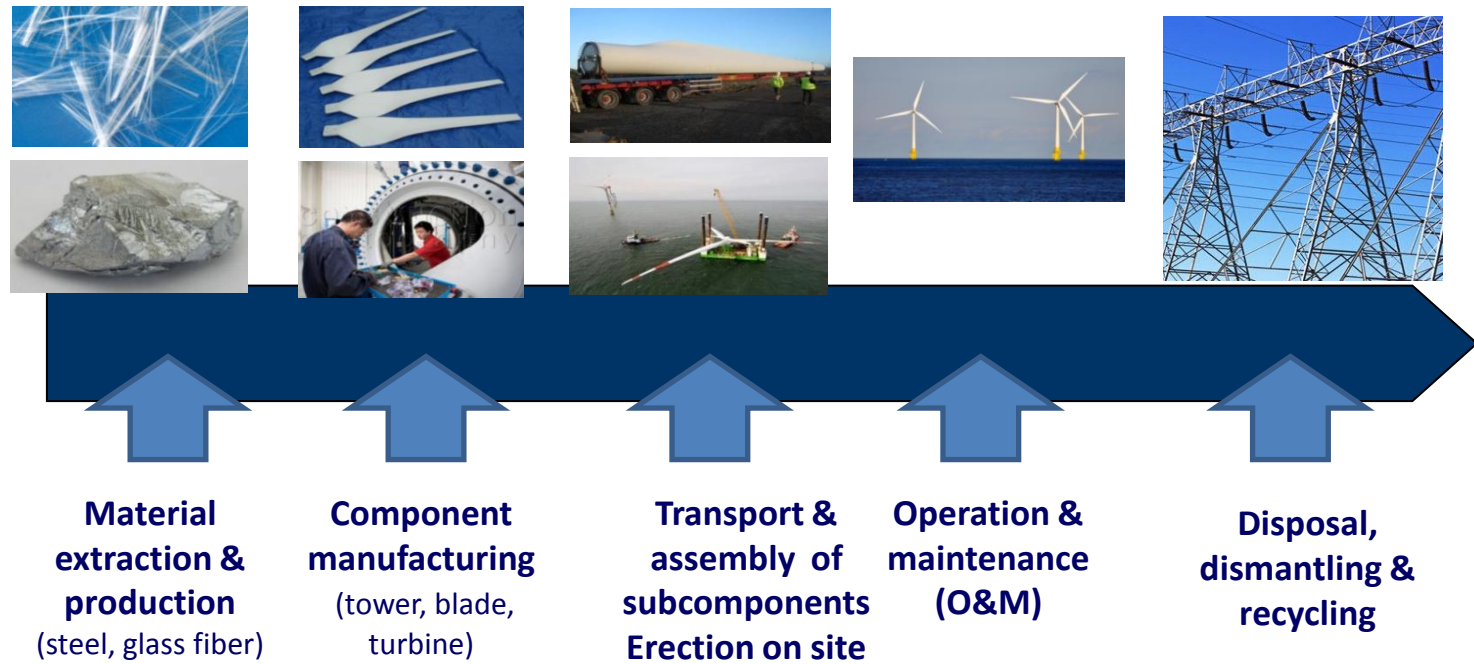
- Wind energy potential in Europe;
- Model accuracy;
- Energy production predictability;
- Energy production intermittency
- MetOcean statistics for turbine maintenance



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Wind - Life Cycle of a wind turbine

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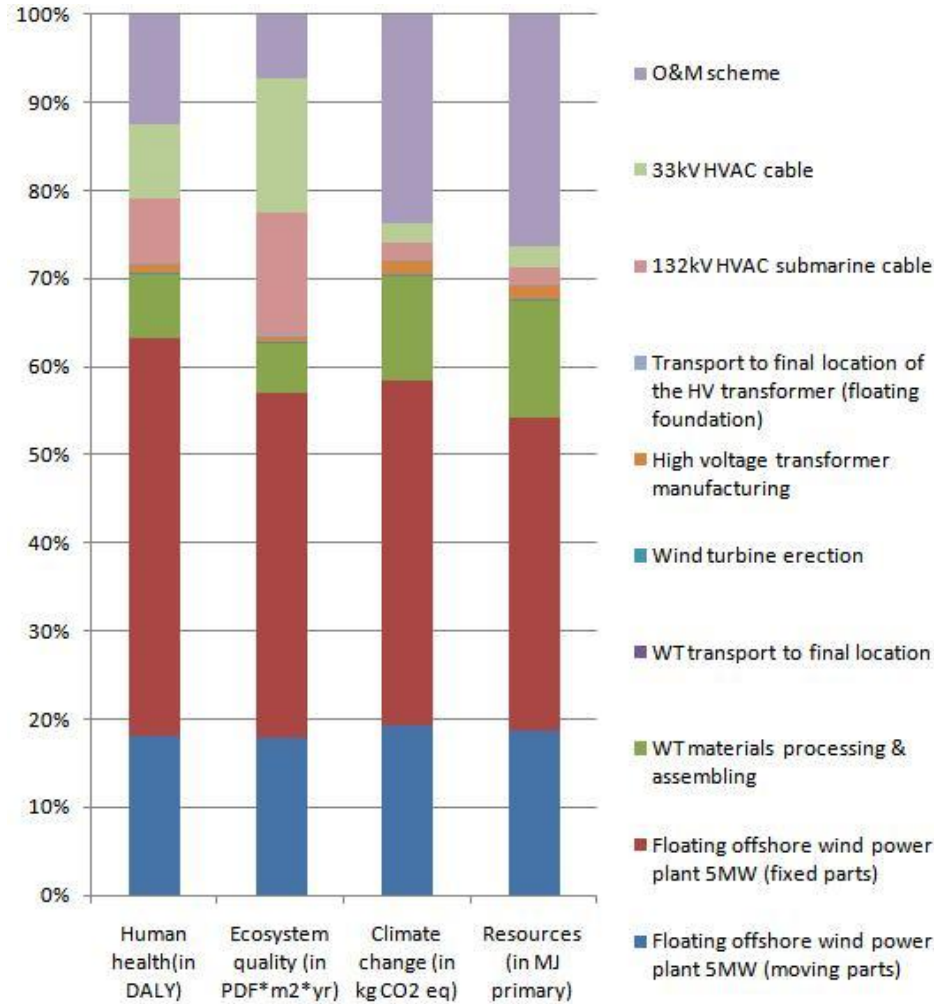


Goal : assess the environmental impacts related to the production of 1 kWh of electricity from offshore wind farms located in northern Europe over their life cycle

Wind - Preliminary LCA Results:

Environmental impacts / kWh produced at the high-voltage onshore grid

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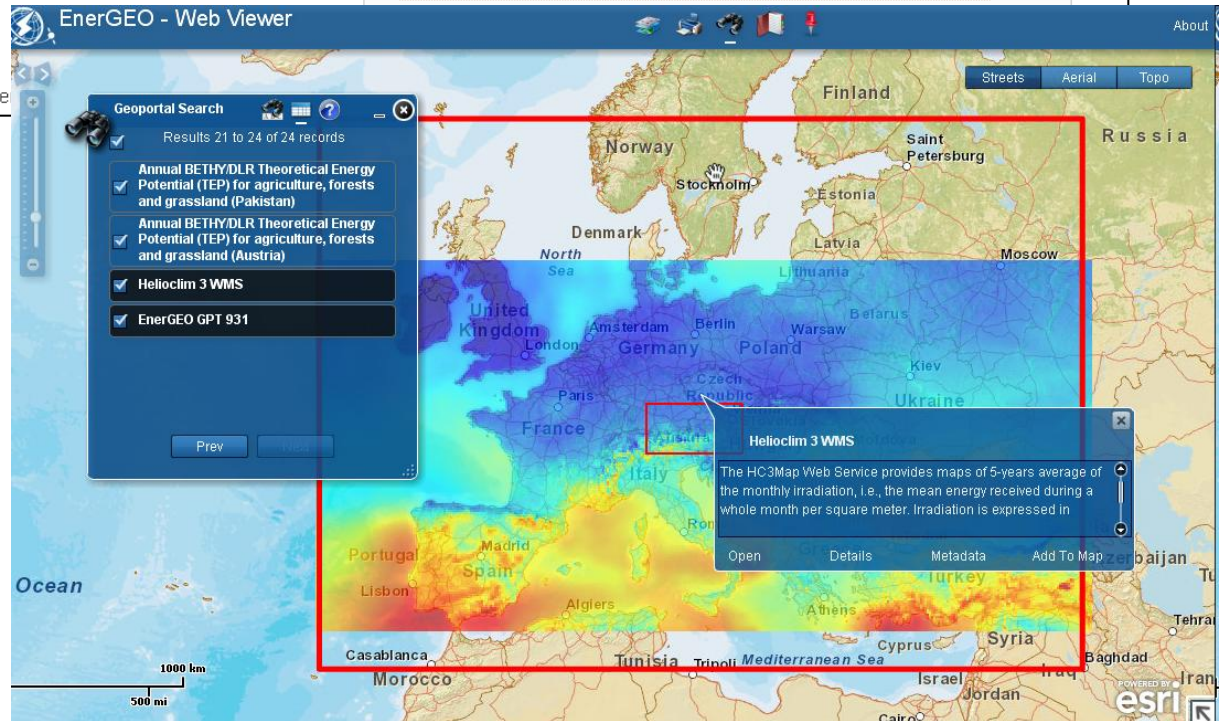
Main assumptions:

- 50 Wind Turbines per farm and per HV transformer
- Load factor: 53%
- WT lifetime : 20 years
- HV transformer lifetime: 35 years
- Submarine cables lifetime: 40 years
- Distance to shore: 50km
- O&M scheme: inspection 4 times per year by helicopter + 1 return transport farm/harbor by transoceanic tanker during the life time of the farm
- No additional recycling scheme considered (Ecoinvent already include recycled materials in its inventories)

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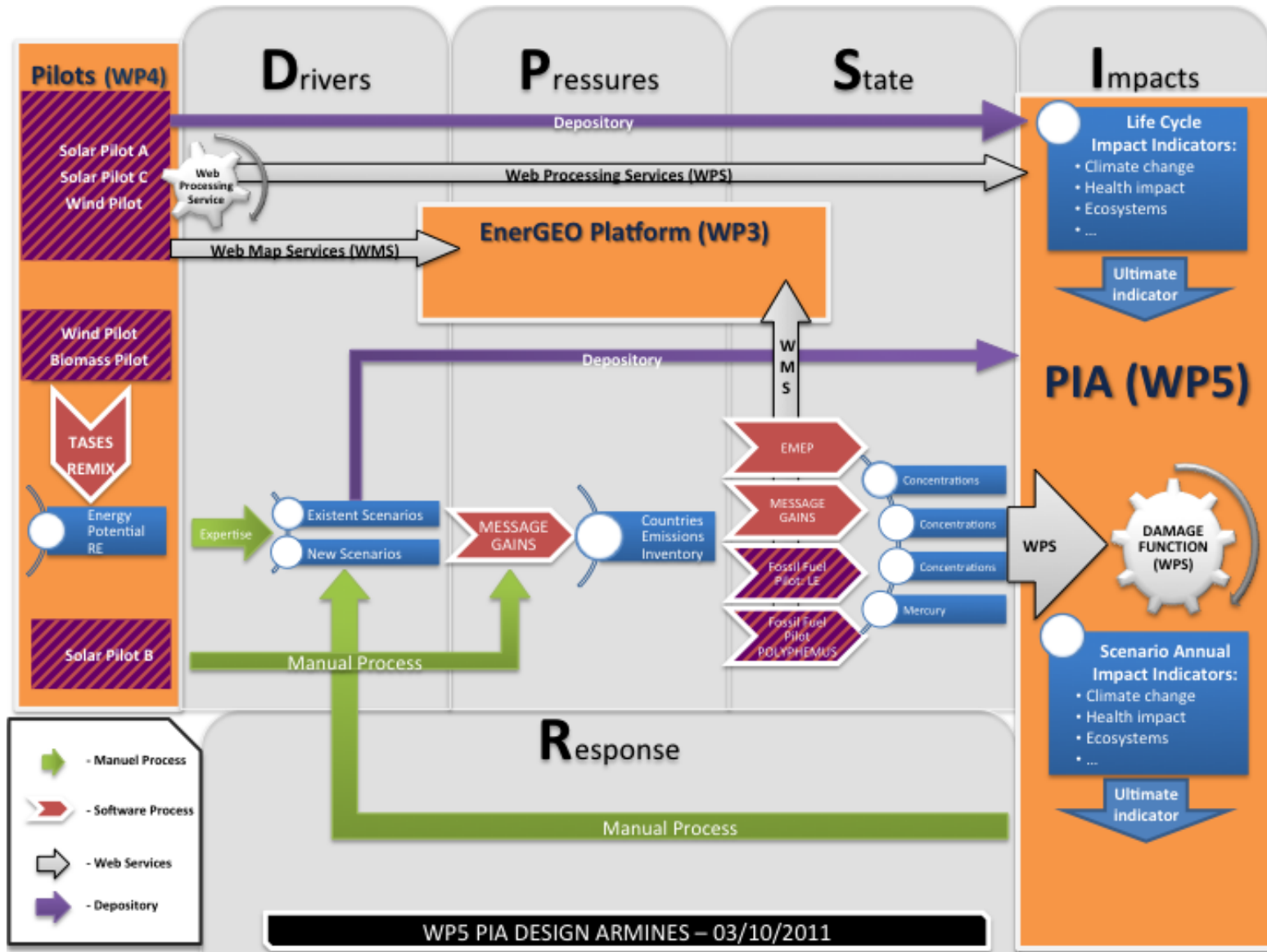
The screenshot shows the EnerGEO Geoportal search interface. At the top, there is a navigation bar with 'HOME', 'SEARCH', 'BROWSE', 'PILOTS', 'HELP', and 'MAP VIEWER'. A search bar contains the text 'irradiance' and a 'Search' button. Below the search bar, it indicates 'Results 1-6 of 6 record(s)'. There are options to 'Expand results', 'Zoom To Results', and 'Zoom To Searched Area'. A list of search results is shown, including 'Relief shadow effect on Solar Resource' and 'PACA Region (FRANCE) 250 m. resolution Irradiation Map (WMS)'. There are also 'Additional Options' like 'Clear' and 'WHERE' with radio buttons for 'Anywhere' and 'Inter'.



<http://energeo.researchstudio.at/>

Platform Integrated Assessment: PIA

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Features of the PIA

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- A translation of the design of the integrated assessment defined in WP1 into a consistent framework following the **DPSIR (Drivers, Pressure, State, Impact, Response)** concept
- A Focus on the conversion from **STATE** indicators into **IMPACT** indicators through damage functions
- Different types of **links between each model**: manual process, software process, Web services or a depository process
- Manual feedback from the PIA outputs to the definition of new energy scenarios (**RESPONSE**)
- A display of pilot results through graphical **Web clients** and **depository process**

Results and Outputs

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- **Linking Energy Use and Environmental Impact** by making use of state of the art environmental, energy and scenario models
- **Collecting the necessary datasets** and deriving **indicators** from them by connecting to current GEO-contributions and state-of-the-art in-situ global networks
- Enabling the collection of and access to EnerGEO-data by building a **portal** within the context of GEO and based on GEO-ADC-recommendations
- Testing the EnerGEO approach through dedicated **pilots** making our approach viable and supportive
- **Proposing perspectives from Pilot-scale to Global Scale** enabling to run global scenarios on energy use and environmental impact

Thank you

<http://www.energeo-project.eu/>