GEO-INFORMATICS IN SUSTAINABLE ELECTRICAL ENERGY DEVELOPING

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The paper emphasizes the suitability of geo-informatics (GIS) for planning, designing and managing renewable and low-impact energy applications, such as: terrain modeling of large areas, providing useful wind aspects (blowing directions and speeds, time quantification); searching locations suitable for aeolian generators; meaningful studies over the sunlight; offshore waves statistical mapping. Such geo-spatial studies not only help to find suitable location for energy capturing sites, but they can assist the specialists to make strategic and tactic decisions concerning the electrical power facility. Also the applicableness of GIS in governmental energy-related decisions and in monitoring gas emissions and the nuclear wastes is stressed.

Te original aspect of the paper consist mainly in the novelty of the subject and its original approach.

Keywords: GIS; environment; low-impact; renewables; sustainable energy.

1. Need for durable energy approaches

Almost all human activities require a lot of energy, and mainly electrical energy. The anthropogenic facts, covering almost all the planet – beyond their effects over the natural environment (which we have to mind, too) – need electricity. Therefore we have to find reliable ways to support a sustainable development of electricity production, ways for ensuring our increasing energy demands without forgetting about the next generations.

This paper is firstly an attempt to reveal applicability directions and practical issues about using GIS in planning, developing and managing the electrical energy. It presents various aspects of the geo-spatially approach in planning durable electricity, disclosing and even assessing the potential natural or cultural resources. But, at the same time, this workpaper is also a call for a more balanced development of the electrical energy sources: remembering that the Earth is threatened by mankind's activities, thus understanding that we all have the obligation to promote high quality, clean, renewable energy sources, in an acknowledged effort to preserve our shared environment. Because many of the energy sources are limited and not renewable (or renewable in a too long time) we need energy policies to ensure not only the energy cover for our next demands,

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but also for the necessities of the future people generations. Power stations are actually a lead contributor in the whole anthropogenic emissions, and many of the electricity consumption forms stress vital elements of the life. Like many of the human activities, energy production always has an impact on the environment: on the soil, land, water, air. On the other hand, we all use electrical energy for heating, cooking, lighting, manufacturing, transportation, travelling, cooling, communication, entertainment.

Because there are strong (although sometimes not very obvious) links between the choices people make concerning electrical energy and both the natural environment and the society's life, the future decisions must be more and more carefully made, and the GIS technologies can help to reveal, to represent, and to control many of the durable development related issues.

Table 1

The accounts of the sources of nowaday's world primary energy are [3]

Energy primary source	Percent	Observations
Oil	34,00%	
Natural gas	21,00%	
Coal	22,00%	
Nuclear power	6,50%	About 16% of the world's electricity
Hydroelectric power	2,20%	
Traditional fuel wood, crop wastes, animal dung	12,00%	
Modern renewable energy sources (biomass/biogas, wind, solar, geothermal, tidal/wave, small hydropower)	2,30%	The solar energy produces now 750 MWh per year

Some energy sources are more efficiently converted into electricity than others (and this is a prime issue, because the productivity plays a leading role on the energy market), and some have a smaller environmental impact. Others are cheaper to produce, but carry 'hidden' costs, such as acid rain, air pollution, adverse water quality impacts, long-lived radioactive wastes, enduring energy-based economic inequalities, and widening security threats.

Sometimes even the best renewable energy has unwanted side-effects, and sometimes the traditional energy sources can not be judged apriori as the worst:

• large-scale biomass crops rise worries about the loss of bio-diversity, and adverse impacts on agriculture and hydrology [3];

• in spite of the fact that the use of fossil fuels is implicated in emissions of "greenhouse gases" (sulphur, nitrogen, carbon oxides, etc), the natural gas (methane 83%; ethane 16%) do no emit carbon monoxide (due to a good aeration and a lower carbon content), thus being a relatively clean fossil fuel [3];

• tidal power developments affect the migratory bird populations;

• despite the fact that nuclear power rises severe questions concerning waste disposal and operational safety, it has zero greenhouse gas emissions, and it is also a very efficient alternative (having a very good cost per unit);

• capturing the ocean energy disturbs the salt gradients and the marine life.

Because all energy forms have some negative effects, we need to understand these impacts, and we have to encourage the future development of technologies involvable in the mitigation of the environmental impact. Consequently – also due to the fact that the environment health has to become a constant theme among public discussions, researches and designs related to electrical power – geo-information must be involved in such activities.

2. GIS applicability in designing/managing durable energy solutions

The accomplishment of a long-term balanced relation between nature (and its regeneration capacity) and the demands place on it by man inherently calls for new methods and instruments. And because on the one hand the environmental issues have a geo-spatial spread, and on the other hand the mankind activities are usually deployed in communities covering large spaces too, ***the geographical attributes are obvious***. Therefore, the potential of the geo-informatics (GIS) to help in sustainable development of electrical energy is clear.

The dedicated information systems must be able to deal (through their storage/capturing, re-aggregating and analysing functions, but also through their human coordinates) with information from a variety of domains, including engineering, geography, environmental science, administration and politics.

Such GIS solutions involved in durable development of the electrical energy must become related to the European, national or regional Spatial Data Infrastructures (SDI) for a proper collaboration between governmental institutions and non-gov. organizations, as well as for leveraging public participation.

For electrical power enterprises, the GIS solutions already assist the assets management, the network/grid exploitation, the maintenance activities, the customer connectivity and consumption, but also the electrical network strategic development. In addition, geo-informatics can contribute to managing the enterprise's relation with the surrounding environments: markets, economical, people, social, cultural, natural. [1]

We can use GIS for creating average <u>solar radiation</u> maps, showing the *irradiance* (solar energy falling on a unit area per unit time – W/m^2), the *irradiation* (the amount of solar energy falling on a unit area over a stated time interval – Wh/m^2), the *insolation* values (the resource available to a flat plate collector facing south, at a vertical angle equal to the latitude of the collector location), and also for revealing the local/particular attenuation factors and the latitude lean condition.

Certain specialized GIS solution can provide instant values of such parameters – computed considering the geographical position on the globe, the terrain's altimetrical particularities, and the date/hour of determination – but the virtual analysis should be compared or eventually fulfilled with on-the-field concrete measurements.

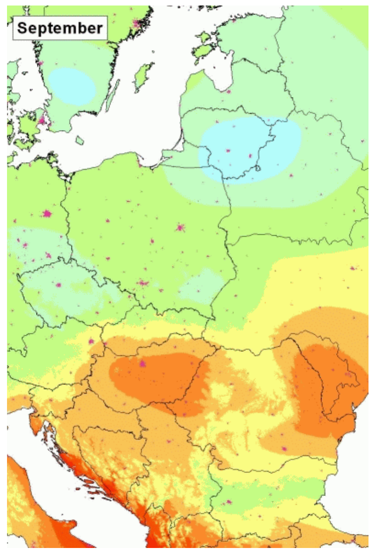

Fig. 1. A grid map showing average solar radiation.

The interaction of solar radiation with the earth's surface is determined by:
1. the Earth's geometry, revolution and rotation (declination, latitude, solar angle);
2. terrain (elevation, surface inclination and orientation, shadows);
3. atmospheric attenuation (scattering, absorption) by: gases (air molecules, ozone, CO_2, O_2); solid/liquid particles (aerosols, including non-condensed water); clouds (condensed water).

The global radiation consists in:
1) the radiation, selectively attenuated by the atmosphere, which is not reflected or scattered, and reaches the surface directly is named *direct radiation* (beam radiation).
2) the scattered radiation that reaches the ground is *diffuse radiation*.
3) the small part of radiation that is reflected from the ground onto the inclined receiver is *reflected radiation* (related to "albedo").

A wind resource assessment program starts with a survey of the entire focus region's potential, and this step may involve several wind resource digital maps, and information about meteorological characteristics and wind speeds. The same GIS can assist to develop and disseminate detailed maps of the region, including land use restrictions, obstacles and other limitations. The GIS analysing features will help us to develop criteria for identifying promising sites by assessing all factors influencing the wind development. A gridded map with classification of wind speeds – assuming a given, or rather a parametrized, mean wind-farm installable density (in MW/km^2) – could disclose optimums.

In the offshore wind-farms construction and maintenance a key issue is sediment transport monitoring (bottom-sea sand) – thus a geo-information application showing the sedimentological and hydrographic distributions and dynamics could be welcomed. Maps of individual bedforms (megaripples, sandwaves etc) can be created from the interpreted side-scan sonar records, and when any gross changes of sediment transport regime are detected, then the GIS analysis features can make a comparison with natural seasonal and interannual bedforms variations.

Like in the solar energy GIS support, we can benefit from numerical modelling techniques (3-D digital terrain modelling) coupled with meteorological expertise & field measurements (data capturing from anemometers – remote sensing data for wind resource monitoring).

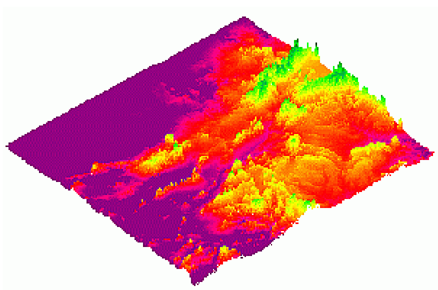

Fig. 2. A wind map.

Fig. 3. An offshore wind farm.

A three-dimensional terrain model of a large area – associated with a special-focused statistical analysis regarding several key parameters of wind blowing (supplied by a long time monitoring from some meteorological/specific measuring points), providing basic winding aspects (wind directions and speeds) – can help to search locations suitable for wind farms (aeolian generators).

In the same approach of considering the weather as a resource, meaningful studies can be done – with certain GIS technologies – on the sunlight (flux, brightness, mean daylight duration, typicalness of the clouds-shading, etc), very useful for planning, designing and exploiting/managing solar energy applications (solar thermal collectors; photo-voltaics; sunlight traps for building illumination; etc). Such geo-spatial studies not only help to find suitable locations for wind/solar capturing sites, but furthermore they can assist the specialists (engineers, responsible people, managers) to choose the most efficient solutions (what type of generation principle or equipment is more suitable – e.g. high or low speed turbines; if a PV is more applicable than a solar heat transfer; path changes), to make strategic and tactic decisions concerning electrical power facility (distributing, grid-connection, exploitation, maintenance, optimizing).

Also, the strategic comparison of electricity production from several spatially-related resources can reveal choices for finding lasting solutions.

In addition, weather monitoring through GIS can be involved in decisions for operating and monitoring such energy facilities (load balancing, QoS).

Many of the critical problems that our world faces – air quality/pollution, water stresses, land uses, climate changes, deforestation, soil erosion, urban sanitation, etc – are specific energy related challenges. Geomatics can be used for monitoring relevant indicators regarding the environment (not necessarily directly linked to the energy sources, e.g. the bird population are very sensitive to changes affecting the environment, therefore it is considered as an appropriate indicator).

By using GIS in planning and deploying energy development projects, many and valuable key issues and indicators can be revealed, especially if the responsible people involve some expert features and continuously keep in "mind" a general sustainable development framework (economic, social and environmental) without forgetting the energy specific keys (efficiency, security, accessibility/acceptableness and cleanness).

Many research efforts and investments have been allocated for wave and tidal energy development, which – along with solar and biomass energy – will play an important role in the future energy. Almost all these sources (along with the associated facilities for production, storing, distribution, managing) can benefit from geo-information techniques.

GIS applications can assist the surveillance of the nuclear wastes stores, because such residues must be kept in specific locations, packaged and sealed.

Geo-informatics can also be engaged in demographically and geo-spatially monitoring of many aspects related to electrical energy consumption/usage (human activities, travelling, environmental risks, weather, utilities distribution, HVAC, census, population densities, economical power, wealthiness/poverty).

In order to support a durable development of electricity – and thus to help the integration of the geo-informatics – some governmental/parliamentary support for geography education will be needed (a broad/high use of geo-informatics require efforts/skills). Also many national and international organizations have to deploy significant standardization efforts, concerning systems interoperability, data/information exchanging (ISO/TC211), Internet mapping (GML, XLM), data translators, metadata publishing, etc.

We have to accept, by synthetization, that GIS can really help us seek to ensure that economic and social developments are fully integrated with the protection of the natural environment and consequently with our health. The future decision must be more carefully made, and the geo-informatics can help us to disclose, to represent, and to control many of the durable development related issues. This technology can play a key role in worrying about the environment and respecting the society, in raising awareness, shifting attitudes and behaviours.

3. Electrical energy choices for the future

The use of energy is a key contributor to our comfort, safety, eating, health, travelling and education. It is foreseen that the world energy needs are going to double by the year 2050 (when the world will have 10 billion people). [3]

The reliable future, from this energy perspective, counts significantly on renewable energy, in spite of its actual lower “energy density”. It is known that the exploitation of the renewable energies – solar, wind, wave/tidal, water's thermal power, bio-mass – require large and expensive machinery. But, in a strategic approach (long-term planned and very well environmentally tuned), this obstacle can be overpassed by technological advances, or positively assumed.

The regular course of increasing electrical energy demands, conditioned by the finiteness of fossil energy sources (coal, oil, natural gas, wood), will force us to find and deploy world-wide, regional and national energy policies and strategies, for many years to come. And the geo-informatics will play a key-role in conceiving, defining, monitoring and disseminating such strategies. There will be a world-wide planning, so all the involved people must know and assume the same information standards (concerning geo-data representation, world-scale resource monitoring, rules and policies, etc). The GIS will assist our future challenge to expand existing energy infrastructure (representing, searching, re-aggregating, revealing, monitoring, leveraging), but also for finding new solutions, mainly in the direction of renewable and low-impact energy sources.

Until now, the supplying efficiency of these “green” energies is sometimes little, but even so there still remains the advantage of low pollution. Perhaps will be easier to reduce the producing costs of such energies than to fight the pollution.

Because the national/local governments and many international agencies have to formulate and implement economical, legislative and administrative frameworks concerning durable energy, these organizations have consequently to control various geo-spatial aspects, therefore they must learn to use GIS for supporting such tasks. The increasing accessibility (as GUI; as implementation architecture) already helps organizations to largely assimilate GIS.

But the geo-informatics can also help us to manage negative side-effects of energy exploitation (as a first step into negative-effect mitigation):

_ monitoring the main environmental impacts;

_ assisting in moving the pollution from a populated to an unpopulated area;

_ revealing and monitoring other side-effects: chemical waste, electromagnetic perturbations, sonic disturbance, landscape and soil degradation;
_ observing the climate changes;
_ supporting calamity crisis management.

Beside the initial identification of possible renewable energy project sites with significant development potential, such applications can consider, reveal, or monitor other issues too. Therefore, a strategic model/concept, assisted by GIS, can engage (and crossbreed) secondary or even adverse aspects: environmental constraints, economical or demographical requirements. Identifying the most promising project locations can consequently rely on factors such as resource intensity, land availability, environmental constraints, utility interconnection, zoning, public acceptance.

There already are a lot of environmental policies and regulatory measures meant to encourage the development of renewable and low-impact electrical energy. The decision makers, potentially responsible with such policies/measures, can benefit from geo-information in conceiving and deploying such strategies, to study many aspects of the geo-spatial situation. Moreover, modern IT&C can empower the public and administrative willingness into revealing and choosing the renewable energy options available.

4. Conclusions

Mankind has to consider beyond people's short-term interest, anticipating environment facts, foreseeing durable paths. I believe we firstly need a great amount of information about the energy future and about the approaches we can choose. Also maybe we need more firm policies from the European institutions regarding both energy utilisation and future energy developments. Surely we need international debates about energy, first for formulating sustainable policies, and second to reconcile the economic, social and environmental hopes of the modern society. Governmental and non-governmental organizations have to focus on the global-to-local long-term electricity demands and to implement coherent strategies to fulfil them, without forgeting about the planet's future.

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