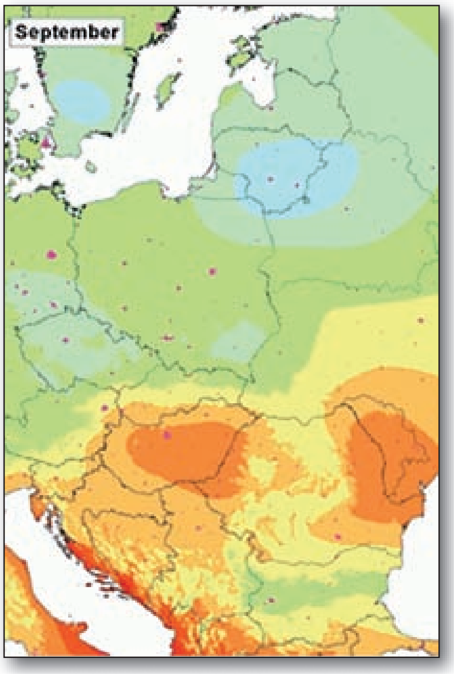
Geoinformatics for Renewable and Non-impact Energies

The Energy Perspective

In Europe today we are faced with many choices concerning the use of energy. GIS technologies can help us make the right choices as we look at our natural environment for the facts and the arguments

By Mircea Bădut



Grid map showing average solar radiation

Almost all aspects of our plans for future development in Europe, from infrastructure to culture, from urban to rural communities, require a lot of energy. Buildings, streets and highways, water and telecommunications systems, industries, commerce, job activities, household life, and entertainment, as anthropogenic entities, cover almost all the land. In addition to their effects on the natural environment, which we have to keep in mind, they all need a lot of energy. Therefore we have to find reliable ways to meet our increasing energy demands without forgetting the wellbeing of future generations.

Because there are strong links between the choices people make concerning energy and both the natural environment and society, these decisions must be made carefully. GIS technologies can help to reveal, to represent, and to control many of the issues related to durable development.

The Energy Situation

Current world sources of primary energy are [WEC, 2001]: See table below.

Some energy sources are converted into electricity more efficiently than others. This is a prime issue, because productivity plays a leading role in the energy market. 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 waste, economic inequality, and security threats.

Sometimes even the best renewable energy has unwanted side-effects, and sometimes traditional energy sources cannot be judged a priori as being the worst: Large-scale biomass crops, for instance, raise concerns about the loss of biodiversity and adverse impacts on agriculture and hydrology [WEC, 2000]. Although the use of fossil fuels is implicated in emissions of 'greenhouse gasses' (sulphur, nitrogen, carbon oxides, etc.), natural gas, whose composition is usually methane (~83%) and ethane (~16%), does not emit carbon monoxide due to good aeration and lower carbon content. [WEC, 2001]. Tidal and wave power developments have adverse effects on migratory bird populations. Conversion of ocean energy disturbs salt gradients. Nuclear power, which imposes crucial questions concerning waste disposal and operational safety, has zero greenhouse gas emissions and is also very efficient, with low costs per power unit.

Because all energy forms have some negative effects, we have to choose carefully. Thus we need to understand these impacts and encourage development of the technologies involved.

Applicability of GIS

Achieving a long-term balanced relation between nature, its regeneration capacity, and the demands placed upon it by man inherent-

Energy primary source	Percent
Oil	34,0
Natural gas	21,0
Coal	22,0
Nuclear power	6,5
Hydroelectric power	2,2
Traditional fuel: wood, crop wastes, animal dung	12,0
Modern renewable energy sources (biomass/biogas, wind, solar, geothermal, tidal/wave, small hydropower)	2,3

World source of primary energy.

ly calls for new methods and technlogies. Because environmental issues have a geospatial spread, and human activities are usually deployed in communities covering large spaces, the geographical attributes are obvious. Geoinformatics clearly has the potential to help in sustainable energy development.
Dedicated geoinformation systems must be able to deal, through capture, storage, re-aggregating and analysing functions, and also through its human coordinates, with information from a variety of domains including engineering, geography, environmental science, and politics. For proper collaboration between governmental and non-governmental organizations, and for leveraging public participation, such GIS solutions must be related to European, national or regional SDI's (Spatial Data Infrastructures), or even become part of them.
For electrical power enterprises, GIS solutions already assist asset management, network and grid exploitation, operational maintenance activities, customer connectivity and consumption, plus the strategic development of the electrical network. Geoinformatics contributes to the management of relations with the surrounding environment, whether commercial, economic, human, social, cultural or natural.

The interaction of solar radiation with the earth's surface is determined by three groups of factors:

1. The Earth's geometry, revolution and rotation (declination, latitude, solar hour angle)
2. Terrain (elevation, surface inclination and orientation, shadows)
3. Atmospheric attenuation (scattering, absorption) by gasses (air molecules, ozone, CO_2 and O_2); solid and liquid particles (aerosols, including non-condensed water); clouds (condensed water)

Global radiation consists of:

1. the radiation, selectively attenuated by the atmosphere, which is not reflected or scattered and reaches the surface directly, is direct radiation (beam radiation);
2. the surface 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").

We can use GIS to create average solar radiation maps, showing irradiance (solar energy falling on a unit area per unit time – W/m^2). Maps can also show irradiation, the amount of solar energy falling on a unit area over a stated time interval – Wh/m^2. Other measures include insolation values, the resource available to a flat plate collector facing south at a vertical angle equal to the latitude of the collector location, local and particular attenuation factors, and the latitude lean condition.
Certain specialized GIS solutions can provide instantaneous values of such parameters computed on the basis of geographic location on the globe, 3D terrain specifics, and the date and time of determination. However, this virtual analysis should be confirmed and completed with in-the-field measurements.

Wind Speed Map

A wind resource assessment program starts with a survey to determine the potential of the focus region. This step may involve several wind resource digital maps, and information about meteorological characteristics and wind speeds. The same GIS can help develop and disseminate detailed maps of the region, including land use restrictions, obstacles and other limitations. GIS analysing features will help us develop criteria for identifying promising sites by assessing and quantifying all factors influencing large and small scale wind development. For instance, a gridded map with classification of wind speeds, assuming a given, or rather a parameterized, mean wind-farm-installable density (in MW/km^2), can disclose optimums.
In the construction and maintenance of off-shore wind farms a key issue is sediment transport monitoring. A geoinformation application, showing sedimentological and hydrographic distributions and dynamics, would therefore be welcome. Maps of individual bed-

Type of Energy	EU share by 2010
1. Wind	40 GW
2. Hydro	105 GW
2a. Large	(91 GW)
2b. Small	(14 GW)
3. Photovoltaics	3 GWp
4. Biomass	135 Mtoe*
5. Geothermal	
5a. Electric	1 GW
5b. Heat (incl. Heat pumps)	5 GWth
6. Solar Thermal Collectors	100 Milion m2
7. Passive Solar	35 Mtoe*
8. Others	1 GW

(* Mtoe - Million Tons of Oil Equivalent)

forms, like megaripples and sandwaves, can be created from interpreted side-scan sonar records. When any gross changes in the sediment transport regime are detected, GIS analysis features can make a comparison with natural seasonal and inter-annual bedform variations.

As with solar energy GIS support, for wind resource monitoring we can benefit from 3D digital terrain and numerical modelling techniques, coupled with meteorological expertise and field measurements, utilizing data capture from anemometers and remote sensing technology.

A 3D terrain model of a large area, associated with a special-focus statistical analysis of key wind-related parameters, can help identify suitable locations for wind farms. The data are supplied by long-term monitoring from specific meteorological measuring points, providing basic wind aspects such as average wind direction and speed.

Solar Heat

In considering the weather as a resource, meaningful studies can also be done on sunlight, flux, brightness, mean daylight duration, typical cloud shading etc. This is very useful for planning, designing and implementing solar energy technologies, such as solar thermal collectors, photovoltaics, sunlight traps for building illumination, etc. Such geospatial studies not only help to find suitable locations for wind and solar capturing sites, but they can help specialists like engineers and managers make strategic and tactical decisions when choosing the most efficient solutions. For example, what type of generation is more suitable, high or low speed turbines? is photovoltaic more applicable than solar heat transfer? In addition, weather monitoring through GIS can be involved in decision-making when operating and monitoring energy facilities, load balancing and Quality of Service assuring.

Strategic Outlook

Many of the critical problems that our world faces about air quality and pollution, water stresses, land uses, climate changes, deforestation, soil erosion, urban sanitation, etc., are challenges related to specific forms of energy. Geomatics can be used for monitoring relevant indicators regarding the environment that are not necessarily linked directly to the energy sources. Bird populations, for example, are very sensitive to changes affecting the environment: pollution, waste contamination, large biomass crops etc.

By using GIS in planning and implementing energy development projects, many key issues and indicators can be revealed, especially if the people responsible keep in mind a sustainable development framework -- economic, social and environmental -- without forgetting key energy-specific issues like efficiency, security, accessibility, acceptability and cleanness. We know that many planners see GIS as the central nervous system of 21st century urbanization.

Many research efforts and investments have been allocated to wave and tidal energy development, which along with solar and biomass energy will play an important role in supplying future energy. Almost all these sources, along with the associated facilities for production, storage, distribution, control and management, can benefit from geoinformation techniques.

Special GIS applications can assist in the surveillance of nuclear wastes stores, because such residues must be kept in very specific conditions. Geoinformatics can also be engaged in demographic and geospatial monitoring of many aspects related to energy usage, human activities, travel, environmental risks, weather, utilities distribution, HVAC, census, population densities, economic power, etc.

In order to support the durable development of electricity, governmental support for geography and geomatics education will be needed. As well, many national and international organizations have to undertake significant standardization efforts concerning systems interoperability, information exchange (ISO/TC211), Internet mapping (GML, XLM), data translators, metadata publishing, etc.

In formulating and implementing economic, legislative and administrative frameworks concerning durable energy, national and local governments and international agencies have to control various geospatial aspects. They must learn to use GIS for supporting such tasks. The trend toward increased accessibility involving graphical-user interfaces and implementation architecture is already helping organizations to assimilate geoinformatics technologies.

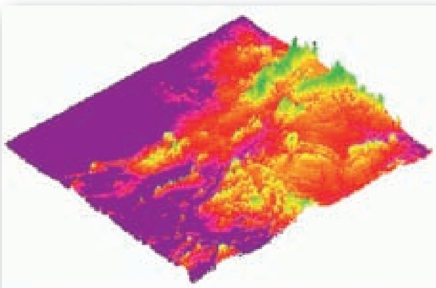
Key Role for GIS

Future decisions must be made more carefully. GIS technologies can help us to disclose, to represent, and to control many of the issues related to durable development. This technology can play a key role in caring for the environment, respecting society, raising awareness, and shifting attitudes and behaviours.

Geomatics can also help us manage negative side-effects of energy exploitation by:

- representing and monitoring the main environmental impacts related to each location and energy type;
- assisting in moving pollution from populated to unpopulated areas;
- revealing and monitoring other side-effects such as chemical waste, electromagnetic perturbations, sonic disturbance, landscape and soil degradation;
- observing climate changes; supporting crisis management.

People familiar with geoinformation can easily imagine how a GIS application can be useful in establishing the most suitable locations for electricity project development, by handling key information about the studied areas and their water, wind, solar and tidal resources, and aggregating it in specific focused analysis. Besides the initial identification of possible renewable energy project sites, such applications can consider, reveal, or monitor other issues too. A strategic model can incorporate secondary and even adverse aspects such as



Wind 3D map.

environmental constraints and economic and demographic requirements. Identifying the most promising project locations can consequently take into account such factors as resource intensity, land availability, environmental constraints, utility interconnection, zoning and public acceptance.

A broad approach is necessary for the successful development of electrical generation because, for most renewable energies, a sufficient resource exists theoretically in many locations. Other issues, however, will be the determining factor in identifying projects with real potential. Furthermore, these other issues, like public acceptance, land availability and ownership, land use, grid and network size, and load balancing, are subject to change over time, so the geospatial model should include a time coordinate. Land-intensive energy projects are difficult to site in areas other than those used for agricultural purposes. Most biomass energy crop projects, for example, assume replacement of existing crops with an energy crop, and part of wind and solar project sites displace existing agricultural land uses.

For large energy sites, GIS applications can be used to capture, monitor, collect, and analyze long-term data about the power resource. Data-mining and analysis can help managers make changes in production and distribution, and even make strategic decisions regarding the expansion of the business model (Decision Support System).

Kyoto

For the "Third Conference of the Parties to the United Nations Framework Convention on Climate Change", Kyoto, 1997, the European Union adopted a 15% greenhouse gas emissions reduction target by the year 2010 from the 1990 level. The European Commission then submitted specific measures to facilitate the large-scale use of renewable energy sources. A significant part of this common program consists in including a further 1,000,000 photovoltaic roofs, 15,000 MW of wind and 1,000 MW of biomass energy. [EC]

Measures Are in Place

A variety of fiscal, financial, legal and other actions will facilitate the penetration of new energy technologies. With most of them geospatial in nature, they will be able to benefit from GIS support.

During the implementation of this strategy, there is a need for constant monitoring to follow closely the penetration of renewable energy sources (12%-15% by 2010), and to enhance coordination of programs and policies. [EC]

Decision-makers can benefit from geoinformation throughout this process.

Many environmental policies and regulatory measures are in place to encourage the development of renewable and low-impact energies, with many more to come. These kinds of policies will have several major effects: reduced greenhouse gas emissions, thousands of new jobs, and reduced health-care costs. Traditional energy sources, however, are favoured through the weight of a number of significant factors: investor comfort, utility expertise, market structures, power delivery infrastructure, domestic habits, etc. People need to learn more about energy and new energy choices through education and accessible information.

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