

Geo-informatics in the electrical energy sustainable development

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1 ACKNOWLEDGING THE ENERGY PERSPECTIVE

Almost all the aspects we plan/develop for the modern future Europe – from infrastructures to culture, from urban to rural communities – require a lot of energy, and mainly electrical energy. Buildings we erect, residences we spread, streets and highways, water-ducts, telecommunication ways – anthropogenic facts covering almost all the planet; beyond their effects over the natural environment (which we have to mind, too), they all need a lot of 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 resources (natural or cultural).

1.1 Why we need durable energy approaches

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 fragile and threatened by mankind's activities, thus understanding that we all have the obligation to develop and promote high quality, clean, renewable energy sources, in an acknowledged effort to preserve our shared environment. Why must we keep “lobbying”? Because it seems more education is needed, to make people aware of the sustainability and concern for the future. The world requires a development that complies with the needs of present generations without compromising the future. Why? Because many of the energy sources are limited and not renewable (or renewable in a too long time), so we need energy policies to ensure not only the energy cover for our next demands, but also for the necessities of the future people generations. And again, why? We have to be aware that most of the existing electrical energy producing facilities stimulate the climate changes. 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. We need to create an ethical dimension of energy production and consumption.

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. And the efficiency and the care of energy exploitation have an impact on the world we live in.

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.

1.2 The electrical energy situation

Electricity was introduced at the end of the 19th century in the United States and Europe, and until nowadays it has become essential to the operation of most modern technological systems –industrial, commercial, cultural or domestic/residential. For this reason electricity has attained the status of a ‘meta-technology’, and it is often viewed as an essential public good in contemporary society. [John Byrne, Yu-Mi Mun, 2003]

The electricity systems developed over the last century are mainly based on large-scale power plants and on extensive networks for delivering electricity at affordable prices. (In many countries most citizens are connected to the electricity grid.) On the other hand, such power plants are estimated to account for almost two-thirds of carbon and sulphur dioxides emissions in Europe and North America.

We can find that the accounts of the sources of nowadays' world primary energy are [WEC, 2001]:

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 a priori as being the worst:

- large-scale biomass crops rise worries about the loss of bio-diversity, and adverse impacts on agriculture and hydrology [WEC, 2000];

- 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 (whose composition is usually methane (~83%) and ethane (~16%)) do not emit carbon monoxide (due to the good aeration and to the lower carbon content). Therefore the natural gas is a relatively clean fossil fuel by comparison to coal and oil [WEC, 2001];
- tidal/wave power developments cause adverse affections of migratory bird populations.
- despite the fact that nuclear power raises severe questions concerning waste disposal and operational safety, it has zero greenhouse gas emissions; the nuclear option is not only little disruptive from this point of view, but it is also a very efficient alternative (the cost of the typical nuclear power plant investment is 2-3 billion Euro, but the cost per unit proves that it is a cheap energy);
- conversion of ocean energy disturbs the salt gradients.

Because all energy forms have some negative effects, we have to choose carefully. Thus 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 APPLICABILITY OF GIS IN DESIGNING AND 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 informatics – and of the GIS technologies in particular – to help in sustainable development of electrical energy is clear.

The dedicated information systems must be able to deal (through its storage/capturing, re-aggregating and analysing functions, but also through its human coordinates) with information from a variety of domains, including engineering, geography, environmental science, 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) – or even to become part of them – for a proper collaboration between governmental institutions and non-governmental organizations, as well as for leveraging public participation.

It is already a common fact that IT&C technologies help manage the electric energy supplying services: Enterprise Resource Planning, Document Management, Electric Operations Switching, Electric Network Connectivity, Outage Management System; Electric System Design; Meter Reading; Enterprise GIS; Location Based Services (Mobile Applications); Intranet; Database Management; etc.

Most of the integrated IT&C solutions are (to be) engaged for gaining a plus in efficiency and comprehensiveness. As an example, a well-known fact: GIS supplies a framework for better decisions, because problems can be considered in a geo-spatial context rather than in isolation.

Geo-information for the management of electricity production/distribution:

_ AM/FM – technical and economical administration (managing facilities and equipment for a better exploitation)

_ SCADA – real-time parameters monitoring (assuring normal functioning; remote controlling; load adjusting)

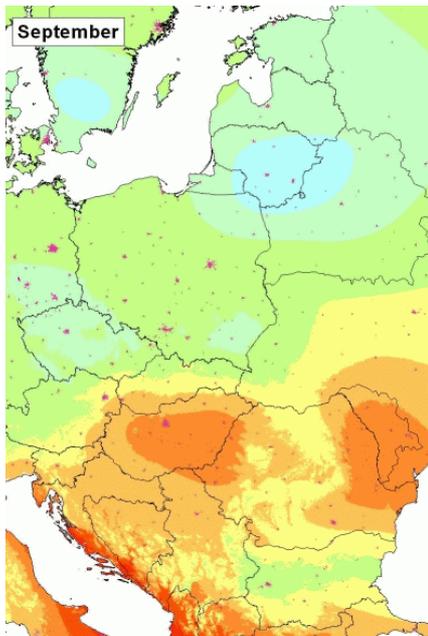
_ OMS/MMS – outage/maintenance management (assisting revisions and restorations of the equipments)

_ DSS – executive management (supporting strategical and tactical decisions)

_ ERP, CRM – interoperation with other enterprise information applications/systems (we mind that a modern practical goal is the GIS-ERP integration for energy enterprises).

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

Beyond the electricity production, GIS can significantly contribute to electricity distribution: networks/grids development and administrations, and even in power station engineering and management.



<fig. – A grid map showing average solar radiation>

From a somehow transcendental point-of-view, the previous experience has shown that a pathway to sustainable development must be directed through processes of learning and adaptation, and this requires new types of analysis and communications tools. [TERI & IISD, 2003]

GIS applicableness at low-impact and renewable electricity

We can use GIS for creating average solar radiation 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/advanced GIS solutions can provide instantaneous values of such parameters, computed on the basis of geographic location on the globe, of the terrain 3D particularities, and of the date/time of determination, but the virtual analysis should be confronted and completed with on-the-field measurements.

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: *gases (air molecules, ozone, CO_2 and O_2); solid and 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 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 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 parametrized, mean wind-farm installable density (in MW/km^2) – can disclose optimums.

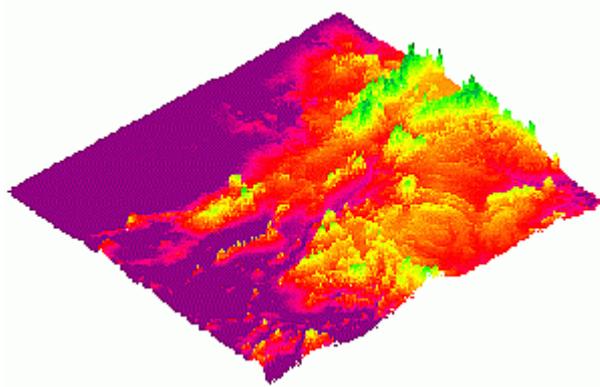
In the offshore wind-farms construction and maintenance a key issue is sediment transport monitoring (bottom-sea sand) – thus a geo-information application showing the sedimentological and hydrographic distributions and dynamics could be welcomed. Maps of individual bedforms (megaripples, sandwaves etc) 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. – A wind map>

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 (such as average wind directions and speeds) – can help to search locations suitable for wind farms (aeolian generators).

<fig. – Wind farm>



In the same approach of considering the weather as being 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, expanding).

Also, the strategic comparison of electricity production from several spatially-related resources can reveal choices and approaches 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 assuring).

Many of the critical problems that our world faces – about 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, such as pollution, waste contamination, biomass large crops, etc; therefore this is considered as an appropriate indicator for environmental monitoring).

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). Do not forget that many planners see today the “GIS” as being the central nervous system of 21st century urbanization.

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, controlling/managing) can benefit from geo-information techniques.

Some special 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 / heating, census, population densities, economical power, etc).

In order to support a durable development of electricity – and consequently 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 GIS technologies 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 EFFICIENCY AND CAREFULNESS IN ENERGY EXPLOITATION

For electricity companies it is often difficult to bring into agreement the necessity of making a profit with the social and environmental responsibilities. But a prime and affordable solution to find that approach between pragmatism and idealism is to improve efficiency.

Promoting energy efficiency more actively is firstly an economical/financial issue (and the competition pressure will improve the efficiency in electrical energy production), but also a main lever to satisfy the Kyoto agreement concerning CO₂ emissions reduction. An improved energy efficiency will lead the European countries to a more sustainable energy policy [EC, 1998].

The administrative organizations can follow several key criteria concerning electricity saving by using a geo-spatial information approach, at European, regional, national and community levels: for representing and monitoring the economic potential for energy efficiency (including marketing and demographic analysis); to reveal the successes and failures of the policies followed so far; to evaluate of the results; to publicly promote the energy efficiency and stimulate open discussions on a demographic base; to coordinate policies and subscribed actions.

The European Union has previously adopted a strategy which aims to reduce by 30% the average CO₂ emissions of new cars to 120g/km in 2005-2010 against the 1990 baseline, and a main measure – related to the electrical power – consists in leveraging the rail transport, which may benefit of GIS help in planning, developing and exploitation. Naturally, most of the measures from that strategy need IT applications/systems for traffic modeling/simulation and optimisation.

The European Commission consider that one of the most difficult institutional barriers in the electricity market is the practice of selling energy in the form of kWh instead of energy services such as heating and cooling, lighting and power [EC, 1998].

One of the easiest ways to save the planet is to become really cheap; practising energy conservation with every opportunity. And this concerns anyone of us, whether considered as an employee at work or as residing at home. A main energy conservation way consists in a continuous process of monitoring and evaluating the building and utilities use and the building construction (including educating home-owners on the importance of assessing the entire building envelope). New building construction (and renovations where applicable) will be designed to provide at least a 20 percent energy improvement where technically feasible and where payback is reasonable.

Raising awareness about the electricity consumed in “stand-by” regime by many household systems, which – accounted for a large community – can rise to a significant amount, is advisable.

In the purpose of leveraging efficiency at energy producing stage several particular measures can be engaged:

- _ designing the turbine to be flexible enough to handle varying steam loads with a wide range of controlled and uncontrolled extraction pressures while maximizing electrical output;
- _ using residual heat from the turbo-generator to heat a nearby industrial development;
- _ facility which converts garbage into steam, during the incineration process, in order to provide this steam to a nearby small enterprise, or for a turbo-generator to create electricity (addressing nearby community needs).

Micro-turbines and small-scaled power plants may have higher unit costs, but they have the significant advantage of being more easily sited near loads/consumers than large power plants – thereby saving transmission and distribution losses (thus reducing dependence on energy capital).

4 ELECTRICAL ENERGY CHOICES FOR THE FUTURE

The use of energy has been and will be 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 [WEC, 2001]

On a hand, the world population growth (foreseeing a number of 10 billion people until 2050) will impose increasing nourishment and accommodation costs. In the following 20-50 years, the world must triple the energy efficiency, so it will be necessary to pass (or to avoid) technological barriers.

The reliable future, from this energy perspective, counts significantly on renewable energy, in spite of its actual lower “energy density”. Conventional machinery used in electricity production (from thermo-electrical and nuclear plants) operates at extremely

high pressure, temperature and velocity: the “energy density”, taken into account as expenses per unit of output, is cheap in comparison with that of the renewable energy.

It is known that the exploitation of the renewable energies – solar, wind, wave/tidal, water's thermal power – require large and expensive machinery. But, in a strategic approach (long-term planned and very well environmentally tuned), this obstacle can be, if not directly overpassed (by technological breakthroughs/advances), then at least positively assumed. It is about projects which will be conceived in tens of years, with a chance to be deployed and exploited when many key conditions and constrains will be others than now.

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 energy sources (to get the best and environmental-friendly solutions in capturing the power of wind, water and sun).

For instance, one of the oldest quasi-renewable power sources is the hydroelectric power, and in the future its ponder will probably rise, the only concern is that the new projects have to be conceived and deployed in more harmony with the natural environment. It is about many good sites for hydro-electrical power plants on large rivers in the developing countries, but also about the stress people must lay on micro-power-plants on small rivers (creeks or even brooks). If for those large hydroelectric plants, the IT&C materialised in GIS have great importance mainly at national/regional level (because the local management activities rather use the maintenance and telecommunication support and the real-time monitoring/controlling of the energy supplying parameters; SCADA), for the networks of micro-plants a surprising use of geo-spatial data applications (modeling hydrological networks, planning the water flow, charge balancing, assets management, disaster management) it might be possible. [Bădut, 2003]

It can be noticed that there is an inherent contradiction between the large-scale and high-intensive electricity sources (such as nuclear power) and the soft options of low-impact or renewable energy, because the former sustain a centralized electricity supplying and are based on increasing demands from consumers, while the latter promote a decentralized and moderate-scale model, based on lowering the consumption. [John Byrne, Tze-Luen Lin, 2000]

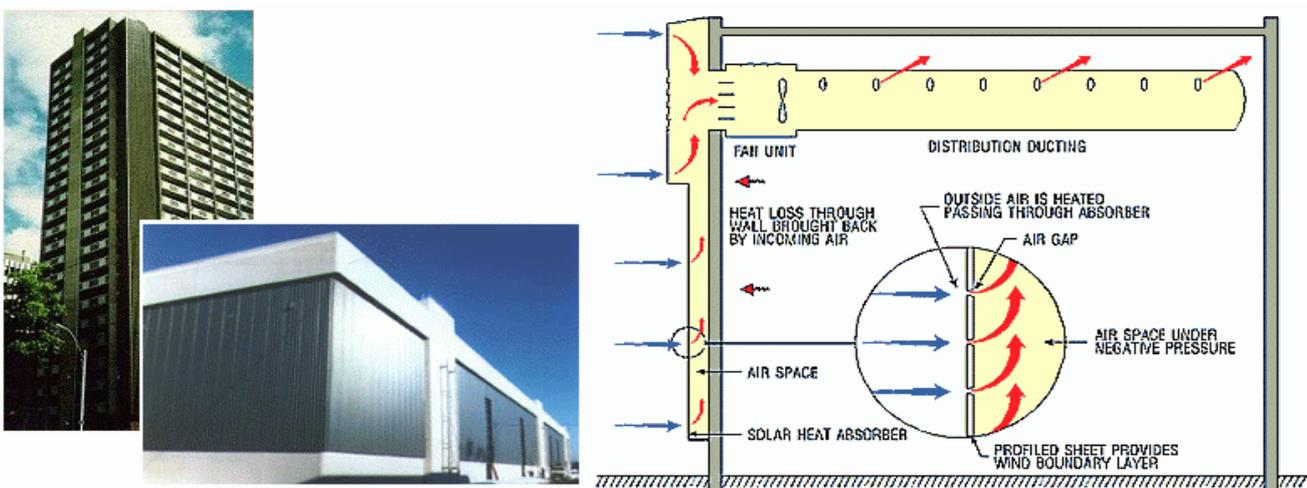
4.1 Enhancements in producing and consuming conventional electricity

Obviously, one of the key factors of sustainability consists in improving the efficiency of energy use and in saving it. It is known that nearly 35% of the energy we use is wasted by default in our cumulative uses (heating, cooking, cooling), and a similar percent is applicable to most of the electricity-based industrial processes. There is high potential for improving the ways in which we use the energy, and we have to acknowledge this and to find ways for it.

Also, the production of the electrical power must be subject to searching more efficient approaches: from the already-classical co-generation, the simultaneous production of electrical power and thermal energy, which lowers the cost of electricity and steam and reduce air pollutants, to non-traditional solutions such as small geo-thermal power plants producing power by conversing exhausted industrial heat, to micro-plants which recover the clinker cooler heat or the gas-turbines exhausted heat.

Several methods for measuring the energy efficiency can be conceived and applied, such as the “Best Practice Benchmarks” established by “World Energy Council” for electricity production and distribution [WEC, 2001]

For residential, commercial and industrial buildings we can apply a series of building improvements and upgrades that will reduce energy consumption (wall and roof envelopes; natural light traps). The governments/parliaments can release building regulations in order to largely adopt approaches of rational use of energy (for the building envelope as well as for heating, lighting, ventilation and



cooling) and for heat loss control (by designing solutions regarding house conception, walls, windows, etc).

<fig. – Two famous solar buildings: Bombardier and Windsor Housing>



<fig. – Light traps>

Subscribed under sustainable design strategies, a major issue is made by the reduction in energy costs/consumption, assumed at individual, local, municipal, regional, national levels (the latter proving geo-information modeling/analysing valences).

As it is the case for solar-thermal applications, the PhotoVoltaic systems are always associated with European Union's "Rational Use of Energy" measures in buildings and can be evaluated as part of the significant effort of reducing energy consumption.

We note that for an efficient electric lighting (private/public) the LED illumination is already a proved solution for low consumption. Also, photocell controls and occupancy sensors can be used in conjunction with electronic fluorescent dimming ballasts to save energy in the areas receiving daylight. Related to this, the RoHS directive recently legislated by the EU ("Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment") has mandated that, by July 1, 2006, the manufacturers must restrict the use of several classical electric materials (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, polybrominated diphenyl ethers) for environmental protection reasons. And such legislation will cause fundamental changes in electric industry. For instance, the high-brightness LED technologies (seen as a future alternative for public illumination) can benefit from this RoHS directive.

An advanced ventilation solution (especially HVAC for large building-sites/facilities), includes variable speed air-handling and pumping systems. This solution, which has been utilized extensively in Europe, features low-velocity air introduced at the floor level to efficiently condition the space and remove indoor air pollutants. Displacement ventilation uses the principles of buoyancy and thermal stratification to effectively condition and clean the air in a space.

But we will observe that there are situations when we can not reduce the electricity demands: for example, we all hopefully expect electrical vehicles, as an healthier alternative to fossil-fuel-based cars.

4.2 Renewable and low-impact energies

Mankind is already searching for environmentally-sustainable technologies, and we hope that in the future enough of the low-impact electricity solutions – harnessing solar power, wind power, biomass/biogas energy, hydropower, geothermal power, wave power, and converting them into electrical power (or also into other energy forms) – will be found viable for mass exploitation. Let us review these physical possibilities:

Solar energy - can be captured by several (almost-stated) technologies:

PhotoVoltaics (PV): directly convert the sun's energy into electricity using electronic devices. Having an annual global growth rate in sales over 25%, the PV technology provides operational cost savings in many on- and off-grid applications. Often, such local installations require backup power systems.

Solar thermal: converts solar energy into thermal energy for water/air heating. Applications include solar water heating systems as well as solar walls for large-scale space heating.

Passive solar: uses building design techniques to capture and store the sun's energy for temperature regulation and for illumination into residential and commercial buildings.

Wind energy - is captured by wind-turbines and converted into electricity. It is the fastest growing form of energy in the world and has achieved by now compelling cost reductions. The most versatile aeoliane generators are "wind-seeker turbines" (automatically catching the best orientation by the wind blowing). The wind turbines come in all sizes and many European manufacturers are now building individual wind turbines big enough to provide the electricity for more than 500 residencies.

Earth energy - stored below the earth surface (few meters, or into deep), this free energy can be retrieved using a ground-source heat pump, and then can be delivered as hot air/water for houses or stores. The process can also be reversed for air-conditioning.

No-dam hydro – the natural flowing of river/creek spins a generator which will convert the water movement into electricity, without building a dam to store water specifically for this purpose. Micro- and mini-hydro technologies are often suitable for smaller-scale generation in rural or remote locations (off-grid).

Tidal energy – it is about using special offshore developments or estuarine barrages to convert the wave/tide movement/power into electricity. A close-related application is trapping the energy of the ocean currents.

Biomass fuels - are produced from a variety of agricultural crops as well as from wood and agricultural wastes. Ethanol is one example of a biomass fuel that is already commonly used as a gasoline additive. Also the “bio-diesel” (oil-seed rape) is used as automotive fuel (and the miscanthus is becoming strategic crops in developed countries). Fuel cells, although they are not a renewable resource in themselves, have the potential to deliver versatile low-impact electricity in combination with renewable resources.

Ocean thermal – capturing the heat of the ocean water.

These resources can replace fossil fuels in a variety of areas, including electricity and building climatization and water heating.

In the last years several researches were deployed and even implementations based on alternative **fuels** (hydrogen, methanol, ethanol, bio-gas, vegetable-oil) were achieved, and this will be a hopeful direction for future. Until now, the energy supplied by some of these (such electrolysis hydrogen, ethanol) is less than the effort required to produce them. But even so there still remains the potential advantage of low pollution. Perhaps in future it will be easier to reduce the producing costs of such fuels than to reduce the pollution of the fossil fuels. Also, in a (closer or further) future the “energy density” criterion could fall from its top position in developing strategies.

Because the national/local governments and many international agencies have to formulate and implement economical, legislative and administrative frameworks concerning durable energy [WEC, 2001], 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 graphical-user interface, and also as implementation architecture – which are obvious trends) already helps organizations to largely assimilate GIS technologies.

Decisions regarding electrical energy:

- _ strategic (*developing energy production enterprises; researching new electricity production technologies; planning long-term consumption*);
- _ tactical (*day-by-day behaviour – small ordinary decisions – concerning energy consumption and/or energy savings/economy*).

The GIS facilities involvable in the research over sustainable electrical energy can help us in creating low-energy architectures for appliances and especially for industrial/manufacturing enterprises, and in increasing efficiency and reducing waste too.

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

- _ representing and monitoring the main environmental impacts (related to each location and energy type);
- _ 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 (mainly caused by population pressures and energy demands);
- _ supporting calamity crisis management.

The greenhouse effect and atmospheric pollution are caused by carbon oxides, sulphur dioxide and nitrogen emissions released into the atmosphere.

Greenhouse gas (GHG) emissions cause the global climate warming and the sea levels rising.

The principal greenhouse gases (GHGs) are: carbon dioxide (CO₂ - 60%), methane (CH₄ - 22%), ozone (O₃), nitrous oxide (N₂O - 5%), sulphur dioxide (SO₂) and chlorofluorocarbons (CFCs). Among these, CO₂ (emitted by fossil fuels burning) is the most significant by volume.

The biggest solar power plant: Goettelborn, Germany; estimated costs: 50 million Euro; City Solar AG; 50000 solar panels; production: 7 MWh per year.

For people familiarized with geo-information it is easy to imagine how a GIS application – which naturally handles key information about the studied areas and their water, wind, solar and tidal resources, aggregating them in specific and focused analysis – can be useful in establishing the most suitable locations for electricity project development. 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.

A broader approach is necessary for the success of an electricity development, because for most renewable energy technologies a sufficient resource theoretically exists in many locations, but there other issues will be the determining factor in identifying projects with development potential. Furthermore, these other issues (e.g., public acceptance, land availability/ownership, utility grid size) are subject to change over time, so the geo-spatial model should include a time coordinate, enabling a long-term deployment. For example, future developments in the studied area may either enhance or decrease the opportunities for renewable energy projects (power grid expansion/diminishing; network load re-balancing; changes in land uses due to urban expansion or to conversion for tourism or agriculture).

For large energy sites (such as wind-turbine farms), the GIS application can be used to capture, monitor, collect, and analyze long-term data about the power resource, even after the beginning of exploitation. The data-mining and analysis results can help the managers to operate changes in the electricity producing/providing way, and even to make strategic decisions regarding the expansion of the business model (DSS).

The potential development can also become affected by factors such as changes in the operating characteristics of the grid utilities, incorporation of energy storage, widespread use of electric vehicles, or districts interconnection.

The land-intensive energy projects are difficult to site in other areas than those used for agricultural purposes. Most of the biomass energy crop projects assume replacement of existing crops with an energy crop. A number of the wind and solar project sites also displace existing agricultural land uses.

The public acceptance of energy projects is difficult to quantify and it is subject to change. As these technologies become more common, public perception of their use, particularly in terms of visual impact, is likely to change. [RLA Consulting, 1995]

From a geographical point of view, we can observe that the renewable energy sources are indigenous (often having rural roots), and, as a result, they can contribute to reducing dependence on electricity transports (or even imports), and therefore increasing security of supply.

Preparing for the “Third Conference of the Parties to the United Nations Framework Convention on Climate Change”, Kyoto, December 1997 (five years after the Rio Conference), the European Union adopted a negotiating position of a 15% greenhouse gas emissions reduction target for industrialised countries by the year 2010 from the 1990 level. Then the European Parliament proposed a goal of a 15% share of renewables for the European Union by the year 2010, and it calls on the European Commission to submit 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 photo-voltaic roofs, 15,000 MW of wind and 1,000 MW of biomass energy. [EC, 1997]

A strategy for promoting the renewables requires many initiatives circumscribing a wide range of policies: energy, environment, employment, taxation, competition, research, technological development, agriculture, regional and external relations policies. The European Council resolution stated that such a comprehensive strategy should be based on certain key priorities: harmonisation of standards concerning renewables; appropriate regulatory measures to stimulate the market; investment aid in appropriate cases; dissemination of information to increase market confidence with specific actions to increase customer choice. [EC, 1997] The Committee on Agriculture and Rural Development of the European Parliament has also issued an opinion in which it considers that the contribution of biomass-derived energy to the primary energy mix could reach 10% by 2010. But this objective – which was a pre-Kyoto scenario – will be perhaps re-estimated, as a result of the 2004 massive enlargement of the Union.

In spite of the fact that some technologies – in particular biomass, small hydro and wind – are currently economically viable, and even competitive in comparison with other decentralised applications, a serious obstacle to greater use of certain renewables still exists: a higher initial investment cost as compared with conventional energy cycles.

The main contribution of RES (Renewable Energy Source) growth in the European Union (90 Mtoe) could come from biomass, tripling the current level of this source. Wind energy, with a contribution of 40 GW is likely to have the second most important increase. Significant increases in the solar thermal collectors (with a contribution of 100 million m² installed by 2010) are also foreseen. Smaller contributions are expected from photo-voltaics (3 GWp), geothermal energy (1 GWe and 2.5 GWth) and heat pumps (2.5 GWth). Hydro-power will probably remain the second most important renewable source, but with a relatively small future increase (13 GW), keeping its overall contribution at today's level. (The current share of renewables in the energy mix of approximately 6% including large-scale hydro, for which the potential for further exploitation, for environmental reasons, is very limited.) Finally, passive solar could have a major contribution in reducing the climatization energy demand in buildings. [EC, 1997]

The 96/92/EC Directive of the European Parliament and of the Council of 19 December 1996 (concerning common rules for the internal market in electricity), in Article 8(3), permits electricity from renewable sources to be given preference in dispatching. In that order, the transmission system operators should accept renewable electricity when offered to them, and the regulatory institution will issue guidances concerning the price to be paid to a generator from renewable sources, which should at least be equal to the avoided cost of electricity on a low voltage grid of a distributor plus a premium reflecting the renewables' social and environmental benefits and the manner in which it is financed. [EC, 1997] This kind of strategy stresses that the environmental benefits of renewable energies justify favourable financing conditions. There is a variety of actions – whether of a fiscal, financial, legal or other nature – addressed to facilitate the penetration of the technologies into the market, and most of them have a geo-spatial nature, thus being able to benefit from GIS support in conceiving, deploying and monitoring.

TYPE OF ENERGY	EU SHARE IN 1995	EU SHARE BY 2010
1. Wind	2.5 GW	40 GW
2. Hydro	92 GW	105 GW
2.a. Large	(82.5 GW)	(91 GW)
2.b. Small	(9.5 GW)	(14 GW)
3. Photovoltaics	0.03 GWp	3 GWp
4. Biomass	44.8 Mtoe*	135 Mtoe
5. Geothermal		
5.a. Electric	0.5 GW	1 GW
5.b. Heat (incl. heat pumps)	1.3 GWth	5 GWth
6. Solar Thermal Collectors	6,5 Million m ²	100 Million m ²
7. Passive Solar		35 Mtoe
8. Others		1 GW

(* Mtoe - Million Tons of Oil Equivalent)

In Europe, where the electricity grid is omnipresent, a large part of the future PhotoVoltaics market will be associated with building applications. The “500,000 PV roof and façade” campaign of the European Union will represent, on the basis of 1kW generators, a total capacity of 500 MWp. The EU campaign should incorporate specific actions such as: promotion of photo-voltaics in schools and other public buildings; incentives for photo-voltaics applications in tourism, in sports and recreational facilities; etc. [EC, 1997] The above assumptions of contributing with 3 GWp installed capacity from photo-voltaics by 2010 would be mainly accounted for by grid-connected installations incorporated into the structure of buildings as well as a certain number of large-scale power plants (0.5-5.0 MWp).

The estimated contribution of 40 GW wind power in the RES (Renewable Energy Source) development by 2010 for the EU is realistic given the strength of the trends. An enormous potential is found in offshore wind farms, which have the advantage of higher wind speeds, although access is clearly more difficult.



<fig. – An offshore wind farm>

The electricity providers have to prepare themselves (by investing in research and development) for a market in which perhaps the renewable energy will provide 5%-10% of the world’s energy supply by 2020 and 50% by 2050.

Quasi-totality of the renewable and low-impact electricity sources are somehow related to terrain or to other geography, thus the geo-spatial feature of their implementation and exploitation is obvious.

Projected electricity production by RES (Renewable Energy Source) (in tWh) for 2010 [EC, 1997]:

TYPE OF ENERGY	PROJECTED FOR 2010	
	TWh	% of total
Total	2,870 (Pre-Kyoto)	
1. Wind	80	2.8 %
2. Total Hydro	355	12.4 %
2.a. Large	(300)	
2.b. Small	(55)	
3. Photo-voltaics	3	0.1 %
4. Biomass	230	8.0 %
5. Geothermal	7	0.2 %
	675	23.5 %
2 TOTAL RENEWABLE ENERGIES		

During the implementation of this strategy there is a need for a constant monitoring – emphasizing geo-spatial criteria at continental, zonal, national, regional, local levels – in order to follow closely the progress achieved in terms of penetration of RES (12-15% by 2010), and to ensure and improve co-ordination of programs and policies under the responsibilities of the Community and the Member States. [EC, 1997]

4.3 Energy future in the socio-political space

The main goals of sustainable design are mitigation of the natural areas destruction, of air and water pollution and solid waste, reducing the depletion of finite resources. Thus, a healthier and safer environment.

In several European developed countries the government legislation requires that in a relatively short time (i.e. 2010) a significant percent (5-15%) of the whole electrical energy supply come from renewable sources. (In Europe, where wind resources are not rich, wind energy already serves the domestic electricity needs of more than 5 million people.)

Also, for developing- or poor-countries a reliable and affordable access to modern energy services can play the role of an indicator of sustainable development. [WEC, 2001]

It is worth mentioning the “Energy Sustainability Gauge” project of the “International Institute for Sustainable Development” [TERI & IISD, 2003], which is an Internet-based analysis and communications tool designed to help governments and the public study the community’s progress towards economic, social and environmental sustainable development, and it was successfully used for Canada and India (1998-2002) along with other effective measures (see also <http://www.iisd.org>). The “Energy Sustainability Gauge” tool assists in answering the following questions:

1. Which are the pertinent indicators of sustainable energy development for a country?
2. How is society progressing towards sustainability in a specific area as defined by an indicator?
3. Is the national government implementing a mix of policy instruments to address the issue? (taxes, laws, incentives, etc).



<fig. - “Energy Sustainability Gauge”
[<http://www.iisd.org/energy/gauge.asp>]>

The monitoring of progress toward sustainability is indispensable for making the concept of sustainable development operational. It helps decision makers and the public define development objectives and targets, and assess progress made in meeting those targets. [TERI & IISD, 2003]

Let us review now several environmental policies and regulatory measures to encourage the development of renewable and low-impact electrical energy:

- market-wide incentives for stimulating low-impact and renewable electricity generation (measures to provide consumers with information in order to understand the impact of electricity generation, and to empower them to make smarter choices about how much and what type of electricity to consume; commitment of the administration institutions to acquire a portion of their electricity from renewable energy sources);
- removal of those taxes which can obstruct the renewable energy generation;
- leveraging the financing for low-impact and renewable technologies (encouraging the market by consumer/producer beneficial rebate and/or credit for “green power”);
- government guarantee preferred mortgage rates for citizens who choose to build “green standards” homes;
- low interest loans (or tax incentives) for residential energy efficient retrofits;
- access to financing and tax breaks for home-owners who invest in energy-efficient retrofits;
- “bi-directional net metering”: creating the technical, economical and juridical possibilities for giving credit to electricity consumers whenever their on-site generation from solar, micro-hydro or wind exceeds their electricity use, so in such cases the excess power they generate can be fed back to the electricity grid/network; etc.

Such measures – which can be seen as investment in future, or as prices paid for the future – have begun or are in process of implementing in countries like the U.S., the U.K., Japan, Germany, France and Canada. This kind of policies will have several great effects: significantly reduce greenhouse gas emissions; create thousands of new jobs; reduce health-care costs. But there is significant market/behaviour inertia favouring traditional electricity sources (like investor comfort, utility expertise, market structures, energy delivery infrastructure, house habitudes, etc). Thus, a lot of education and information about energy and our choices must be broadly supplied to the people. Also, the decision makers, potentially responsible with such policies/measures, can benefit from geo-information in conceiving and deploying such electricity incentives, to study many aspects of the geo-spatial situation.

We have to understand that pollution is often a result of inefficiency in energy production, and also to see the low-impact electricity enhancement as economic opportunities.

Another priority of the new sustainable energy paradigm must be removing the global inequalities associated with current energy arrangements.

Competition on electricity market, started mainly in the late 1980s, have changed the character of the gas and electricity business, and influenced the relationships between companies and customers. A notable effect was favouring the smaller-scale generation.

If the first energy policies, starting from the 1970s, responded mainly to concerns about security of supply and about satisfying the community demands (also arising the affordability issues), later governmental policies encouraged energy conservation and efficiency. Now, they have new responsibilities: climate changes, and fostering a sustainable development.

A quarter century ago, a set of institutional reforms – privatisation of ownership, separating charges for energy services, introduction of competition into the generation sector – was seen as a global solution to the existing and potential problems of the electricity industry. People believed that this reform will more efficiently leverage this sector than regulated monopoly arrangements, and what also appeared was the presumption that “power liberalisation” will enhance environmental quality by driving out old technologies. Also, governing the electricity industry by market dynamics, rather than by socio-political considerations, promises to result in its more efficient operation. [John Byrne, Yu-Mi Mun, 2003]

But the energy reform raise several contradictions, too:

- economical contradictions – one spread result of power liberalisation consists in the concentration in ownership of electricity systems on a regional and global scale (creation of electricity oligarchies by mergers and acquisitions across national borders);
- environmental contradictions – because power liberalisation promotes an electricity system that is geared by short-term profits, a long-term public interest in sustainable alternatives can be neglected;

- political contradictions – the neo-liberal ideology, which places the individual above the socio-political choice, reduces the space for collective, deliberative decision-making;
- social contradictions – the population could experience price or quality discrimination (e.g., because the large energy consumers may negotiate low prices with competitive providers, domestic consumers can pay higher unit prices). [John Byrne, Yu-Mi Mun, 2003]

Another important issue is due to the fact that older, highly polluting power plants can have competitive advantages compared to newer modes of power generation because prices do not include environmental costs. This issue must be addressed by stronger environmental regulations, otherwise the liberalised electricity markets appear likely to add to environmental harm in the search for a cheaply priced electricity commodity. Also we can observe that regulatory measures needed for adequate supervision of market activities are more complex than those required under regulated monopoly regimes [John Byrne, Yu-Mi Mun, 2003].

When participation of all stakeholders – from government, business sectors, and from civil society – is institutionally supported and encouraged, then diverse concerns are discussed in an open and transparent manner, the needs and aims of society regarding electricity service can be better clarified, and the possibility of reaching social consensus can be advanced.

One of the side-effects of new energy approaches is that the energy services tend to become – from commodity services, sold/measured by the unit – services where the quality (including security and environmental-friendliness) is essential.

Modern information&communication technologies can empower the public and administrative willingness into revealing and choosing the renewable energy options available (in particular, identifying and managing geo-spatial conditionings may benefit from GIS technologies).

5 A SORT OF CONCLUSION

Mankind has to consider beyond people's short-term interest, anticipating environment facts, foreseeing durable paths.

From my point of view, 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 determined / 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.

And we have to continuously keep in mind the same two ways for preserving some future:

- _ carefully promoting electricity usage and increasing the consumption efficiency (by consumer education and awareness);
- _ developing durable energy sources (by developing new/only viable solutions for power production, and even by shutting-down old/disrupting plants).

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 forgetting about the planet's future.

Because there are already partisans of governmental/political regulation, and opposite are people who believe that the energy future will be assured only by the technological solutions, perhaps we have to find a right balance, between legislative constraints and technological innovation, a vivid combination of them.

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