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sustainable economy meets sustainable technology

Sustainable Energy Systems

Definition

As an essential element in eliminating poverty, the recent World Summit on Sustainable Development in Johannesburg placed heavy emphasis on the need for developing countries, with the support of developed countries, to create energy systems that are:

- Reliable,
- Affordable,
- Economically viable,
- Socially acceptable and
- Environmentally sound.

These five requirements essentially define the basis for the sustainable energy systems that will be put in place to serve the majority of humanity for the next 40-50 years. While emphasising a strong role for energy efficiency, conservation and renewables, the WSSD recognised the continuing dominant role that fossil fuels will play (Wilson, O. 2005).

The social and economic development of human societies is inextricably linked to energy use. However, in developed countries today the linkage between growth in energy consumption and economic growth shows signs of de-coupling.

Nonetheless it is doing so at a level (4.7 toe/capita in the OECD) that is significantly above the current energy consumption levels of the least developed countries (0.6 toe/capita in Africa). The continued growth in global population and the justifiable demand for all humans to have access to energy will ensure that total annual global energy consumption will continue to increase well into the future (from approximately 10 Gtoe p.a. in 2000 to 25 Gtoe p.a. in 2050) under business-as-usual conditions.

Potential Applications

Cost-effective Supply of Renewable Energies

Future research should focus on bringing the next generation of more cost-effective renewable energy technologies to the market, with particular emphasis on markets in Europe. The results should enable these technologies to compete in the liberalised energy markets of the future with substantially reduced levels of subsidy, and help to bring them within reach of developing countries. The main tasks to be carried out will explore ways to reduce the costs of the energy delivered by specific renewable energy technologies, in the form of green electricity, heating/cooling, and liquid/gaseous biofuels.

Priority Areas

- Innovative combinations of biomass with fossil
- Innovative demonstrations of improvements to energy recovery and renewable electricity production using waste materials and other commonly available biomass feedstocks
- Innovative approaches to improving the yield of medium to large scale biogas
- Innovative combinations of biomass and wastes with fossil fuels
- Innovative wind farms, components and design tools
- Innovations in PV manufacturing plant at an industrial scale
- Geothermal energy
- Ocean / marine energy technologies

Biomass

Biofuel is any fuel that derives from biomass — recently living organisms or their metabolic by-products, such as manure from cows. It is a renewable energy source, unlike other natural resources such as petroleum, coal and nuclear fuels. The carbon in biofuels was recently extracted from atmospheric carbon dioxide by growing plants, so burning it does not result in a net increase of carbon dioxide in the Earth's atmosphere. As a result, biofuels are seen by many as a way to reduce the amount of carbon dioxide released into the atmosphere by using them to replace non-renewable sources of energy.

Agricultural products specifically grown for use as biofuels and waste from industry, agriculture, forestry, and households — including straw, lumber, manure, sewage, garbage and food leftovers — can be used for the production of bioenergy.

Current Biomass Applications

In 2001, Stadtwärme Lienz started operations at a biomass-fired cogeneration plant, launching district heat supply after a construction phase of only 7 months. The 18 km supply piping of the first network phase connects 280 transfer stations for households and municipal buildings such as the hospital and the home for the elderly.

The biomass cogeneration plant saves 29,700 t CO_2 emissions annually, which is more than half of total emissions (118%); electric heating systems are also substituted by the district heat. Similarly, SO_2 emissions are cut by 114%, or 29.9 t. NOx emissions are reduced by 53% or 17.4 t, and dust emissions by 37% or 1 t.

Potential Biomass Applications

By the year 2010, 12% of the gross inland energy consumption of the European Union is to be covered by renewable sources of energy. To meet this goal, intensified use needs to be made of biomass, both for heating purposes and for power generation. Timber and forestry residues are available in ample quantities, but the required investment costs are a barrier to the broad-based use of this energy source. In most countries of the European Union, wood plays only a minor role beyond its traditional use in rural areas. Scandinavia and Austria are the exception to this rule. Thus, for instance, the town of Lienz started up the largest biomass facility of Austria in October 2001, thus making a sustainable contribution to improving local air quality[1]. Further examples are planned for the future.

Current Barriers to Biomass

Currently, most biofuel is burned to release its stored chemical energy. Research into more efficient methods of converting biofuels and other fuels into electricity utilising fuel cells is an area of very active work. Bioenergy covers about 15% of the world's energy consumption. Most bioenergy is consumed in developing countries and is used for direct heating, as opposed to electricity production. However, Sweden and Finland supply 17% and 19% respectively, of their energy needs with bioenergy, quite high for industrialised countries. Biomass can be used both for centralised production of electricity and district heat, and for local heating[2].

Polygeneration

Cogeneration (or, in the broader sense, polygeneration) refers to the generation of combined heat and power (CHP). It usually involves combined electricity and steam generation, which is more efficient than a central power plant generating only electricity that requires large coolers to condense steam.

Current Polygeneration Applications

China's desire to seek alternative liquid fuels is so great that estimates indicate that liquefaction technologies could be providing it with more than 50 million tonnes of fuel per year by 2020. "This is a personal estimate," he stresses — but one that will be music to the ears of China's leaders. If these estimates are correct, coal liquefaction could reduce China's demand for crude by 100 million tonnes per year, or about one-third of its anticipated imports by 2020.

Coal is also central to the thinking of researchers at the Tsinghua-BP centre, which is focusing on a strategy called polygeneration in which a single plant would convert coal into syngas, then use it in gas turbines to generate electricity and also convert it into liquid fuels[3]. Sulphur is removed as an integral part of gasification, cutting pollution. To demonstrate the technology's potential, Zheng and his colleagues at the centre have conducted a 'syngas city' simulation for Zaozhuang in the eastern Shandong Province. Like many industrial centres in China, Zaozhuang faces a major problem: how to continue growing when the only readily available fuel is high-sulphur coal.

In the 'syngas city' model, the Zaozhuang authorities would provide incentives to promote polygeneration, which not only generates electricity but also produces methanol for vehicle fuel and dimethyl ether for domestic cooking and heating. The simulation suggests that polygeneration could meet more than a quarter of Zaozhuang's electricity needs by 2020. It would also achieve drastic cuts in sulphur dioxide emissions while reducing the need to invest in expensive flue-gas

[1] A case study entitled *Biomass-Wood* was prepared in 2001 by Energie-Cités in cooperation with the town of Lienz, Austria, and with the financial support of the European Commission DG TREN within the scope of the ALTENER Programme
[2] http://en.wikipedia.org/wiki/Biomass_fuel
3 Zheng, L. et al. Energy Sustain. Dev. 7, 57−62 (2003).

desulphurization technology at conventional power plants[4]. Further reductions in air pollutants, such as ozone-forming compounds, would come from the wider use of methanol and dimethyl ether.

Potential Applications for Polygeneration

Future research in this field should be aimed at improving the efficiency of an overall system covering supply and demand; therefore, they should cover the complete spectrum from primary energy sources to energy services for private or industrial consumers. Future research should set out to demonstrate the supply of primary energy sources to polygeneration sites, their conversion to energy, the supply and distribution of the energy produced, the provision of energy services to consumers and the eventual production of energy carriers or other useful products.

Research projects should concentrate on the demonstration of innovative pre-commercial technologies in market-oriented actions, and with short to medium term exploitation prospects, addressing one of the following applications:

1) Polygeneration for residential and commercial buildings, district networks and the tertiary sector. Emphasis should be placed on measures to improve operating efficiency, security, reliability of performance at reduced costs and a large reduction of green house gas emissions and
2) Polygeneration for industrial applications with significant improvements on energy efficiency.

Priority areas:

- Improvement of the competitiveness of Polygeneration
- Innovative integration of polygeneration

Current Barriers to Polygeneration

The demand for electricity is expected to grow significantly over the next decade, but the liberalisation of the energy market has lead to a significant reduction in the installed over-capacity of base load power plants. In some EU countries the demand for electricity peaks more often in summer than in winter, due to a very significant increase in the demand for cooling. In a growing number of regions the low voltage distribution network to the end users shows weaknesses. Some of these problems can be addressed by installing medium and small scale power generation units, including renewable electricity generating plants, in strategic locations to stabilise the grid instead of installing new power lines[5].

Priority areas:

- Distributed generation
- Management of electricity grids linked to large-scale decentralised wind power generation

Cogeneration has been limited, however, due to various reasons, including regulated electric utilities resistance, inadequate cogen "heat hosts," and the use of cogeneration technology that results in a low power-to-cogen heat ratio.

Hydroelectricity

4 Hongtao, Z. et al. Energy Sustain. Dev. 7, 63−78 (2003).

5 http://www.managenergy.net/conference/infoday0604.html

Hydroelectricity is a form of hydropower used to produce electricity. Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator. Less common variations make use of water's kinetic energy or undammed sources such as tidal power. Hydroelectricity is a renewable energy source.

The energy extracted from water depends not only on the volume but on the difference in height between the source and the water's outflow. This height difference is called the head. The amount of potential energy in water is directly proportional to the head. For this reason, it is advantageous to build dams as high as possible to produce the maximum electrical energy.

Current Hydroelectric Generation Applications

While many hydroelectric schemes supply public electricity networks, some projects were created for private commercial purposes. For example, aluminium processing requires substantial amounts of electricity, and in Britain's Scottish Highlands there are examples at Kinlochleven and Lochaber, designed and constructed during the early years of the 20th century. Similarly, the 'van Blommestein' lake, dam and power station were constructed in Suriname to provide electricity for the Alcoa aluminium industry.

In most parts of Canada (the provinces of British Columbia, Manitoba, Ontario, Quebec and Newfoundland and Labrador) hydroelectricity is used so extensively that the word "hydro" is used to refer to any electricity delivered by a power utility. The government-run power utilities in these provinces are called BC Hydro, Manitoba Hydro, Hydro One (formerly "Ontario Hydro"), Hydro-Québec and Newfoundland and Labrador Hydro respectively. Hydro-Québec is the world's largest hydroelectric generating company, with a total installed capacity (2005) of 31,512 MW

The La Grande Complex in Quebec, Canada, is the world's largest hydroelectric generating system. The eight generating stations of the complex have a total generating capacity of 16,021 MW. The Robert-Bourassa station alone has a capacity of 5,616 MW. A nineth station (Eastmain-1) is currently under construction and will add 480 MW to the total. An additional project on the Rupert River, currently undergoing environmental assessments, would add two stations with a combined capacity of 888 MW.

Countries with the most hydro-electric capacity include:

- Canada, 341,312 GWh (66,954 MW installed)
- USA, 319,484 GWh (79,511 MW installed)
- Brazil, 285,603 GWh (57,517 MW installed)
- China, 204,300 GWh (65,000 MW installed)
- Russia, 173,500 GWh (44,700 MW installed)
- Norway, 121,824 GWh (27,528 MW installed)
- Japan, 84,500 GWh (27,229 MW installed)
- India, 82,237 GWh (22,083 MW installed)
- France, 77,500 GWh (25,335 MW installed)

These are 1999 figures and include pumped-storage hydroelectricity schemes.

Potential Applications for Hydroelectric Generation

The Three Gorges Dam in China is currently under construction. The first power was generated by the dam in July 2003, but the structure is not scheduled for completion until 2009. This dam will have a capacity of 18,200 MW.

Current Barriers to Hydroelectric Generation

In practice, the utilization of stored water is sometimes complicated by demand for irrigation which may occur out of phase with peak electricity demand. Times of drought can cause severe problems, since water replenishment rates may not keep up with desired usage rates. Minimum discharge requirements represent an efficiency loss for the station if it is uneconomic to install a small turbine unit for that flow.

Concerns have been raised by environmentalists that large hydroelectric projects might be disruptive to surrounding aquatic ecosystems. For instance, studies have shown that dams along the Atlantic and Pacific coasts of North America have reduced salmon populations by preventing access to spawning grounds upstream, even though most dams in salmon habitat have fish ladders installed. Salmon smolt are also harmed on their migration to sea when they must pass through turbines. This has led to some areas barging smolt downstream during parts of the year. Turbine and power-plant designs that are easier on aquatic life are an active area of research.

Generation of hydroelectric power can also have an impact on the downstream river environment. First, water exiting a turbine usually contains very little suspended sediment, which can lead to scouring of river beds and loss of riverbanks. Second, since turbines are often opened intermittently, rapid or even daily fluctuations in river flow are observed. In the Grand Canyon, the daily cyclic flow variation caused by Glen Canyon Dam was found to be contributing to erosion of sand bars. Dissolved oxygen content of the water may change from preceding conditions. Finally, water exiting from turbines is typically much colder than the pre-dam water, which can change aquatic faunal populations, including endangered species.

The reservoirs of hydroelectric power plants in tropical regions may produce substantial amounts of methane and carbon dioxide. This is due to plant material in newly flooded and re-flooded areas being inundated with water, decaying in an anaerobic environment, and forming methane, a very potent greenhouse gas. The methane is released into the atmosphere once the water is discharged from the dam and turns the turbines. According to the World Commission on Dams report, where the reservoir is large compared to the generating capacity (less than 100 watts per square metre of surface area) and no clearing of the forests in the area was undertaken prior to impoundment of the reservoir, greenhouse gas emissions from the reservoir may be higher than those of a conventional oil-fired thermal generation plant. In boreal reservoirs of Canada and Northern Europe, however, greenhouse gas emissions are typically only 2 to 8 percent of any kind of conventional thermal generation.

Another disadvantage of hydroelectric dams is the need to relocate the people living where the reservoirs are planned. In many cases, no amount of compensation can replace ancestral and cultural attachments to places that have spiritual value to the displaced population. Additionally, historically and culturally important sites can be lost, such as the Three Gorges Dam project in China, the Clyde Dam in New Zealand and the Ilisu Dam in Southeastern Turkey.

Some hydroelectric projects also utilize canals, typically to divert a river at a shallower gradient to increase the head of the scheme. In some cases, the entire river may be diverted leaving a dry riverbed. Examples include the Tekapo and Pukaki Rivers[6].

Wind Energy

Air moves around the earth because of the differences in temperature and atmospheric pressure that exist. Wind turbines harness the movement of air to produce energy. The wind turns the

[6] Graham-Rowe, D.G. (2005). Hydroelectric power's dirty secret revealed New Scientist Print Edition. http://www.newscientist.com/article.ns?id=dn7046

blades, which turn a rotor shaft. This produces mechanical power used to drive an electric generator[7].

Current Applications for Wind Energy Generation

Plans for a massive offshore wind farm in the Moray Firth have gained £6m of funding from the U.K. government. The project will see two of the largest turbines in the world installed to test the feasibility of a 200-turbine wind farm.

A spokeswoman from the Scottish Green Party is quoted in the article saying:
"The two governments can muster only £6m for offshore wind - a pitiful amount compared to the billions spent on nuclear power over the years."

If the £24m pilot proves successful, a full 200-turbine wind farm will be built 12 miles offshore and would have a one gigawatt of electricity generation capacity.

This compares to the recent announcement of Scotland's largest wind farm, which recently opened which produces only 50 megawatts of electricity. This is a mere 5% of the potential capacity of the offshore project. If we are serious about replacing fossil fuels we need to think big[8].

Solar Energy

Solar Energy is derived directly from the sun. Passive solar heating involves the design of homes and other buildings to make full use of direct sunlight for heating purposes. Houses can be designed with large windows in the south facing walls and small windows in the north facing walls, reducing the need for other heating sources such as electricity or fossil fuels. Active solar heating includes the use of solar panels to heat large tanks of water mainly for domestic hot water systems and swimming pools. Active solar radiation also includes the use of photovoltaic cells, where the solar energy is converted to electricity[9].

Current Applications for Solar Energy

The world's largest solar power station was officially put on-line in September 2004 in the eastern German town of Espenhain in a project hailed by Environment Minister Juergen Trittin as advancing the timetable to make the sun's power cheaper.

The five-megawatt facility, located on a former lignite mine ash deposit, consists of some 33,500 solar modules.

The output equates to the electricity needs of some 1,800 households while sparing the atmosphere of some 3,700 metric tons of carbon dioxide emissions annually, officials said. "We need this development in the megawatts capacity so that solar power can become cheaper more quickly through the mass production of solar cells," Trittin, of Germany's environmentalist Greens party, said about the EUR 22 million project.

[7] http://www.climatechangenorth.ca/H1_Glossary.html
[8] http://news.bbc.co.uk/1/hi/scotland/3602026.stm
[9] http://www.climatechangenorth.ca/H1_Glossary.html

He said that Germany's solar technology industry was seeking to be a world leader in the sector. "In around 20 years the global annual turnover is going to be over EUR 100 billion," Trittin predicted about the solar energy sector[10].

Tidal Energy

Tidal changes in sea level can be used to generate electricity by constructing dams across coastal bays or estuaries which have large differences between low and high tides. The difference in water levels creates water pressure that can drive turbines, generating electricity[11].

Current Applications for Tidal Energy Generation

The river Mersey in the North of England is to be subjected to tests, which environmentalists hope, will make it the first river in Britain to generate electricity from its tides.

A renewable energy conference attended by Sir Jonathon Porritt was held on the 22nd of November to discuss plans to draw on the Mersey's vast renewable energy potential by constructing a tidal power fence which, according to initial estimates, could generate up to 2,000 megawatts of electricity, enough to power 15% of the North-West of England's electricity requirements[12].

Geothermal Energy

Power generated by the harnessing of heat from the interior of the earth when it comes to -or close to – the earth's surface. The regions with highest underground temperatures are in areas with active or geologically young volcanoes. The term geothermal energy is also sometimes used to describe ground-source heating[13].

Current Applications for Geothermal Energy Generation

Japan's Mitsubishi Heavy Industries (MHI) has won an order from Reykjavik Energy, a city-owned utility in Iceland, to build two 40 MW (megawatt) geothermal power plants at Hellisheidi, approximately 20 kilometres east of Reykjavik. The order marks the eighth geothermal power plant assigned to MHI by the utility provider.

Iceland, known as the "Land of Fire and Ice," is located where the Eurasian and North American plates meet. A country of numerous volcanoes, Iceland is well suited to use of geothermal energy. Because of abundant water supply, however, the country relies on hydroelectric generation to meet approximately 90% of its power demand, but the remainder depends chiefly on geothermal power. Very few plants use fossil fuels such as coal or oil as their energy source. In this way, Iceland obtains almost its entire power supply from clean energy resources[14].

Current Barriers to Sustainable Energy Systems

10 http://www.expatica.com/source/site_article.asp?subchannel_id=26&story_id=11598&name=World+largest%27s+solar+powerplant+opens+in+Germany

11 http://www.climatechangenorth.ca/H1_Glossary.html

12 Herbert, I (22 November 2005). River 'fence' to harness tidal power of Mersey. www.news.independent.co.uk

13 http://www.climatechangenorth.ca/H1_Glossary.html

14 Ikuno, H (2004). Mitsubishi Press Release on Geothermal Power Plant Order. Mitsubishi Heavy Industries, Ltd. Japan Corporate News Network

The distribution of electricity to customers via a distribution network or 'grid' has helped electricity become one of the commonest energy sources for domestic use in the West. Electricity is extremely versatile, clean, easy to use, and can be turned on or off at the flick of a switch. Electricity has brought enormous social benefits in all areas of life. It is the preferred method of supplying power for many household applications, especially lighting, but connection to the national electrical grid is a rare occurrence in rural areas of the developing and under developed world.

Bulk electricity is generated and transmitted in 3 phase, alternating current (a.c. - 50 or 60 cycles per second) form and distributed to the consumer as three phase or single phase depending on the end use requirements. Transmission by direct current (d.c.) is also used, losses associated with d.c. electricity being lower than a.c., but other costs are incurred as heavy duty rectification equipment is then needed to supply a.c. electricity to the consumer.

After generation, the voltage has to be stepped up (to a high voltage) for transmission and distribution using a transformer and then stepped down (to a lower voltage) for end use, again requiring a transformer. The step down process is usually done in several stages as the network is reduced in capacity. Typical consumer voltage is210V or 415V for three-phase and 120V or 230V for single phase depending on national standards (EC standard from the 1st of January 2004 governs mains supply between 218.5V and 243.8V at 50Hz). Three-phase electricity is used for higher power equipment such as factory or workshop machinery whereas all domestic electricity supply is single phase.

The grid can be owned privately or by the state and is not necessarily owned by the electricity producer. The type of fuel source, which will be used to provide electricity, is dependent upon several factors:

- A country's fossil fuel resources
- Cost of importing fossil fuels
- Government energy policy
- Availability of sites for
- Exploitation of renewable
- Energy sources e.g. large rivers, dams or lakes for hydro power technical expertise available in country

There are many constraints to rural grid based electrification. Firstly, there is the question of cost. The cost of grid connection is influenced by the voltage and proximity of the grid and whether there is a step down transformer already serving the area in question. Capital cost of the distribution system is very high and demand in rural areas is very low. Households can be widely dispersed and often rural consumers will want to use only a few light bulbs and a radio in the evening. The cost-benefit relationship shows that there is little incentive for an electricity producing utility to extend the grid into remote rural areas. Often rural regional centres will be electrified but the network will usually stop there or bypass the remoter villagers as high voltage cables passing overhead.

This is a detailed overview of one of the many taxation, market trade, policy and technical issues, which complicate the generation and distribution of sustainable energy systems throughout Europe. Other factors currently under debate in the industry relate to the sporadic nature of some renewable energy sources, energy storage and the complex nature of `ownership` with regards to outputs from polygeneration.

Regulations

Regulations Summaries

- **Panorama**
- Security of energy supply
- Internal market in energy
- Energy and sustainable development
- Energy efficiency
- Renewable energy sources
- Taxation of energy products
- Trans-European networks
- Relations with third countries
- Applicant countries and Community *Acquis*

Legal Texts

- Treaties
    - Treaty establishing the European Atomic Energy Community (EURATOM)
    - Treaty establishing the European Coal and Steel Community
    - Treaty establishing the European Community (Articles 49 to 55, Title XV , Title XIX)
- Legislation in force
- Legislation in preparation and monitoring of the decision-making process between institutions
    - Search in the Legislative Observatory of the European Parliament
    - Search in the Public Register of the Council of the European Union
    - Search in PreLex
    - Opinions of the European Economic and Social Committee
    - Opinions of the Committee of the Regions

- Recent case-law of the Court of Justice and the Court of First Instance

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Resources

Society takes energy for granted. Fuel shortages and power cuts are rare, but timely, reminders that we rely on energy for transport, for heating our homes in winter, cooling them in summer and running our factories, farms and offices. However, many energy resources are finite. In addition, energy use is often a source of pollution. Sustainable development means using less fossil fuel more intelligently. Find out more...

Commission

Report on progress in creating the internal gas and electricity market.
Energy
Grants
Let us overcome our dependence.

European Parliament

Committee on Industry, Research and Energy

Council of the European Union

Transport, Telecommunications and Energy
The European Ombudsman
EURATOM Supply Agency
European Investment Bank
AGORES

Documentation

Press releases
Bulletin of the European Union
General Report on the Activities of the European Union
Publications
Statistics
Expiry of the European Coal and Steel Community