

Technologies that contribute to reducing environmental impacts of electrical production

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Abstract

The World Summit on Sustainable Development (WSSD) was attended by approximately 21 000 international delegates in Johannesburg, South Africa in 2002. The aim was to institute ecologically sound environmental management. Research has shown that fossil fuel or coal fired power plants are the major cause of air pollution in electricity generation. This paper seeks to show technologies that can contribute to reducing the environmental impacts of electricity production, via emission control systems, industry energy policy, renewable energy technologies etc. and the promotion of active research and development in alternative energy applications in Africa. Innovative energy technology research and development and applications such as smaller scale distributed generation and solid state lighting (SSL) are seen as capable of adding a positive contribution in this area.

Keywords: energy technology, environmental impacts, electrical production, energy consumption, research and development

The need for energy technology R&D

Throughout the world, access to energy services and the development of modern energy forms have been major driving forces for economic growth, social security and technological progress. The estimated electric power generation is estimated, worldwide, to be more than 3 million installed megawatts (Peng 2004). In fact, efficient energy use plays an important role in the social and economic development. It contributes, for example, to slowing

down population growth, and reducing pollution and environmental pressures. Electric power has largely supplanted oil as the most controversial energy issue of the 1980's and 90's and is growing by more than 80 000 MW per year. Souring costs, high interest rates and environmental damage caused by large power plants have wreaked havoc on the once booming industry.

In most countries, electric prices have risen faster than the general rate of inflation since the mid 1970's. In this regard electricity generation has been mostly that of coal fired power plants. These are a major cause of air pollution, and are implicated in the predominant environmental issue of the time, namely acid rain and global warming. Although there is still considerable uncertainty about the exact degree of global warming expected over the next few decades, the greenhouse warming is real. Water vapour, carbon dioxide and other naturally occurring gasses trap heat in the earth's atmosphere. This energy drives atmospheric and oceanic circulation, redistributes energy more evenly across the planet, raises the average surface temperature to about 33°C, and makes the earth a pleasant place to live. Most climate scientists now agree that doubling the concentration of CO₂ from pre-industrial levels to the present level will increase the surface temperature by about 1 to 3.5°C by 2100.

About 70% of the increase in CO₂ concentrations, however, have occurred in the last 50 years, and have been attributed to coal and other fossil fuel burning for energy generation (IPCC 1996; Morgan & Keith 1995). Even with the introduction of stringent policies, the world's energy systems will continue to add CO₂ to the atmosphere. Once released the CO₂ remains in the atmosphere for

about a century. Given the dependency of the world's economies on energy and the growing aspirations of the people of Africa, China and India, the introduction of draconian 60% less CO₂ emissions is simply not going to happen. More and more people are going to want large homes with good heating and air conditioning, a wide range of electrical consumer products, and a varied diet that includes some meat. All these things require energy.

The only plausible technique by which we can reduce CO₂ emission is new energy technology. New energy should be able to provide people with the goods and services they demand as well as using far less energy i.e. it must be efficient, and it should be able to produce that energy with fewer environmental consequences. Figure I shows the carbon dioxide levels in countries that are industrialized (David & Herzog 2000).

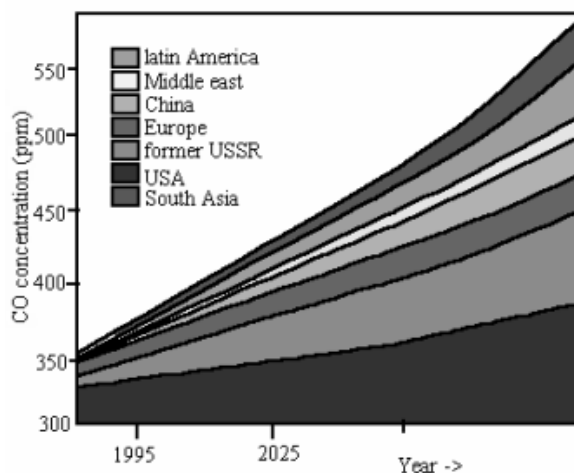


Figure I: Carbon dioxide levels in industrialized countries

Where will new technology come from?

Despite popular perceptions, the market place does not magically create new technology whenever it is needed. Although markets forces can drive the development of technologies whose fundamentals have been established, markets typically underinvest in what Branscomb calls basic technology research (Branscomb 1997). Electricity remains to be a vital component of national development. It accounts for about 40% of total global energy consumption (Davis 1991) and is considered to be a good indicator of economic progress. The most important development of the early 80's is that large scale power plants no longer entirely dominate the electricity planning.

In this regard various sectors of industry have an important role to play in the realization of a sustainable future. Also industries that operate in the fossil sector have a considerable contribution to make. The growth of developing countries of Asia,

Latin America and Africa, as well as the transition economies of Central and Eastern Europe and the former Soviet Union, and the expected population increase in the coming decades present a huge environmental challenge to humanity. This challenge is very acute in the power generation, transmission and distribution sector. As it seems today, a large part of the energy of the developing countries will come from fossil fuels. In China, for example, about 70 percent of the rising demand is still expected to be met by burning coal (Morgan & Keith 1995).

The comments and findings in the paragraph above may make the future look bleak and, truly, there are several problems that have to be addressed in this context. There are, however, also some important bright spots. One of these is the fact that the mature industrial countries have learnt from their own mistakes and now have both technologies and know-how that can contribute to reducing the environmental impacts of electricity production.

Eco-friendly electric power

Electrical utilities and their suppliers have been working hard to reduce the emissions from their power plants and to improve the efficiency of power generation and delivery. The latter is not least important when it comes to the use of limited natural resources, the higher the efficiency, the lower the fuel consumption will be.

Natural gas is the least polluting fossil fuel available for electricity generation. Modern technology can further improve the environmental performance of gas fired power plants. NO_x emissions can be reduced significantly and fuel efficiency can be boosted if waste heat from the gas turbine is used to produce steam to drive a second turbine in the same plant, the so called combined cycle technology.

Since 1980, the gross efficiency of a typical power plant has risen from 46 to close to 60 percent. Over the same period, N-O_x emissions have been reduced by more than 90 percent (Kane, Fernau & South: 1991).

Coal emissions

As mentioned above, it seems that coal will continue to be an important source of energy for many years to come. Since economic growth and development require energy technologies that safeguard environmental quality, the need for clean coal technology will thus be immense in the developing countries. Modern environmental technology can remove harmful pollutants from the smokestack emissions, making coal much less harmful and with an environmental performance almost equivalent to that of natural gas. For example, the pressurized fluidised bed combined cycle is a clean coal combustion process suitable for all types of coal which,

besides increasing efficiency, emits 90 percent less SO₂ and 50 to 70 percent less NO₂ than conventional coal combustion technologies.

Another way to provide a better environment is to install emission control systems that can remove more than 99 percent of particulate matter. This should also remove at least 90 percent of SO₂ from flue gases at coal fired power plants. The by-products yielded from these systems can often be used elsewhere (Fernau & South 1991; Stallard & Ferguson 1991).

Transmission of power

As economic growth continues in Central and Eastern Europe and the former Soviet Union, the existing extensive power and industrial infrastructure in the region will require upgrading. New technology is already helping to improve environmental quality while supporting this region's infrastructure changes. This is most important when it comes to the distribution of electricity.

In the world's most efficient transmission and distribution systems, between 5 and 10 percent of generated electricity is lost during transmission. In countries with poor or little infrastructure to support electrical distribution, these losses can add up to as much as 30 percent.

With regard to alternating systems (AC), advanced compensation technology can boost the capacity of long distance power lines by 30 per cent as well as significantly improve their stability. Efficiency gains can also be achieved through high voltage direct current transmission systems. This technology can reduce power losses by up to 50 percent compared to AC systems. Obviously, these technologies should be kept in mind when distribution systems of developing countries are improved or expanded (Holdren 1991).

Technology transfer

There are several technologies that contribute to economic growth while safeguarding environmental quality. An important part of the challenge is to transfer these technologies and the necessary know how to developing countries and the transition economies. This responsibility must be shared between politicians and business leaders. According to the author an important task for political leaders is to provide an efficient industrial policy with free trade and clear rules.

The patterns of world trade have shifted dramatically in the past 10 to 15 years and developing countries have more than doubled their share of global manufacturing exports. There remain, however, pressures to protect uncompetitive sectors in some western countries through trade barriers and subsidies. This protective policy closes the door to exports from developing countries and the transition economies. It also slows economic growth,

channels consumers' money into uncompetitive business in the western world, and prevents needed global structural changes (Holdren 1991).

It is imperative that business should play a more important role in many of the big energy and environmental issues facing the world today. When it comes to promoting eco-efficiency, business should use a decentralized approach to business development, transferring environment friendly technologies and know-how to build up the global competitiveness of our local companies. This generates clear benefits not only for business but also for the environment and the communities where we do business.

The philosophy of business development in the new markets is to invest locally and become a long term partner. This means that most decisions are delegated to a local level, by training people in multicultural environments and providing access to international markets (Wayachut 1993). This is a win-win situation: business wins with access to local markets, while the communities that big business invests in benefit from eco-efficiency, i.e. economic growth and improved environment.

Perspective on industry energy policy

'Developing countries' is a generic expression still widely applied in international contexts and plays an important role in shaping development assistance policies. However, identifying the emerging growth clusters in the developing world is essential to better define their needs and design policies for each of them.

As far as the African continent is concerned, the continued dependence on fuel wood as the final end use energy form for the vast majority of the population has significant negative impacts on economic performance. The widespread deficit of energy services in most communities of Africa may not be simply the consequence of poverty as many analysts argue, but its primary cause.

Basic needs, poverty alleviation and development

Most energy specialists would agree with the basis and objectives of a government policy framework for support of a sustainable energy sector in developing countries. Such policy should aim at satisfying basic needs to alleviate poverty and improve living standards through efficient utilization of local energy sources. However, the implementation of these macro-policies will have to be closely connected to the relationship between energy and economics in a transition process to be defined at the regional level.

Many projections of comparative energy scenarios indicate the persistence of Africa's low ranking in terms of GDP and energy consumption in the coming decades. The energy transition in Africa is

necessary and unavoidable if we are serious about tackling this inequitable situation. Consequently, planning for the delivery of adequate, appropriate and affordable modern energy services is integral to the overall socio-economic development planning of the continent. Plans should be designed and studies carried out to find out how the situation can be improved with the least possible contribution of fossil fuels (Fuggle 1989; World Bank 1997).

Distributed generation and renewable energy

There is no doubt that the use of new and renewable energy sources should be supported in building a sustainable energy sector world-wide. However, some technical assistance agencies' and developing countries government's strict policies of dealing exclusively with renewable energy technologies have resulted in renewables being chosen for projects in which they were clearly inappropriate and considerably more expensive than conventional options. The incremental costs born by the continent due to these experiments have been very high in the 70s and 80s.

This is not to say that new renewable energy technologies should not be applied. On the contrary, more knowledge of the conditions under which these technologies are the most suitable is needed. Renewables should be subject to the same technical, financial and social analyses as the commercial options are being subjected to. Only in this way can a commercial market and trust in the new technologies be attained (Levine 1993).

When introducing modern energy services one has to look further than the energy source and the technology used. The whole fuel chain from source and generation to distribution should be seen as a package with technical regulatory mechanisms and institutional frameworks as integral components. The success stories of rural electrification co-operatives is an example of innovative approaches when addressing small and fragmented markets, while also recognizing the need to mobilize citizens to fully participate in the implementation of programs.

Distributed generation (DG) systems differ from the usual regulated electric power plant deployment. With the standard electric power utility, the deployment consisted of large generation capacity (fossil fuel driven or nuclear) and an extensive transmission grid, connecting finally to the consumers several hundred kilometres away. With DG systems, the generation and end user are fairly close together, reducing the risks and increasing the predictability of the overall system (Peng 2004). Power electronics is the enabling technology in distributed generation systems. Initially distributed generators could supply end users in isolation, off grid, or could also be connected to a smaller grid and what is often discussed in the literature today, the IEEE

1547 standard for interconnecting distributed resources with electric power systems (Peng 2004).

Energy consumption reduction: the case for solid state lighting

Up to now, the most common electrical lighting technology used was conventional incandescence and fluorescence [Steigerwald et al: 2002]. Improvements in lighting efficiency will have a major impact on worldwide energy consumption reduction. The most recent technology in lighting is Solid State Lighting (SSL). Electrons and holes are injected into a solid-state semiconductor. These electron-hole re-combinations emit a narrow spectrum of light in the visible spectrum. Its wavelength can be adjusted to increase the efficiency, to convert the narrow spectrum to semi-broadband emissions, which covers the entire visible light spectrum. This cannot be achieved by incandescence and fluorescence technology. A semiconductor High Bright light emitting diode (HB-LED) is pyramid shaped and emits light in a wide angle. Built-in reflectors enhance maximum light emission. This cannot be achieved by the normal monochromatic LED.

HB-LEDs have become as bright as, and more efficient than incandescent and fluorescent lamps. HB-LEDs have already begun to replace incandescent bulbs in many applications requiring durability, compactness, cool operation and directionality. It is aimed to improve the efficiencies of visible white light HB-LEDs by ten times that of incandescent lamps and twice that of fluorescent lamps in 2012, as shown in Table I (Drennen, Haitz & Tsao 2000).

According to Drennen, Haitz & Tsao (2000) SSL should be more competitive than conventional lamps regarding their:

- Constant white colour at a specified low temperature.
- Reliability of 100 000 hours lifetime, but with a drop in light emissivity.
- Environmentally friendliness – the material is disposable, non-toxic and mercury free.
- Low cost per 'light hours'
 - due to small chip area per packaged lamp
 - If compared to the price of equipment for renewables (solar panels etc).

Up to now the fluorescent technology has provided remarkable energy savings. SSL will significantly, further improve this energy saving in general lighting. As this technology advances, light quality and market penetration will increase and prices will fall. SSL market penetration and its energy saving potential in general lighting will be driven by economics. This will depend on how quickly SSL developments will occur.

If prices drop to that of incandescent lamps, SSL will achieve full market penetration in all lighting applications by 2020 as shown in Figure 2 (Kendall

Table I: SSL-LED lamp targets

Technology	SSL-LED 2002	SSL-LED 2007	SSL-LED 2012	Incandescent	Fluorescent
Efficiency (lm/W)	>25	>75	>150	16	85
Lifetime (khr)	20	>20	>100	1	10
Input power (W/lamp)	1	27	6,7	75	40
Colour rendering index (CRI)	75	80	>80	95	75
Market penetration	Low flux	Incandescent	Fluorescent		

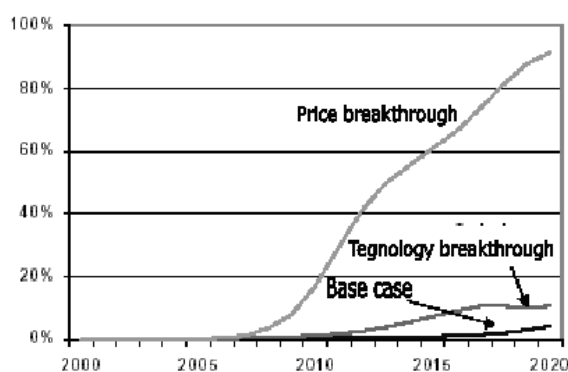


Figure 2: The percentage of annual available lumen market captured by SSL

& Scholand 2001). This will result in enormous energy savings per annum. In Japan an SSL market penetration of 13%, with efficiency of 120 lm/W by 2010 is targeted (Tagutchi 2001). In the USA it is 50% by 2012 and 90% by 2020 (Kendall & Scholand 2001). If the technology performance targets listed in Table I are met, it will enable penetration of incandescent lighting by 2007 and of fluorescent lighting by 2020.

Since semiconductor technologies are low DC voltage technologies, four different approaches can be adopted to supply the SSL LEDs, namely additional low-voltage building reticulation, built-in luminaire voltage regulation, built-in lamp voltage regulation and low-voltage output from renewables like solar panels. The high cost and storage of solar panels are enough reason why white LED's are more cost effective.

Environmental impact assessments

A broader use of environmental impact assessments is certainly welcome in African countries. However, the boundaries of responsibilities in a less organized context require a continuous research effort which is not usually built into environmental impact assessments being carried out today. Supporting joint research between academics, policy makers, industries and the public is another area to be considered in the energy sector support. In the early 1970's there were several attempts to formulate a series of

steps that should be followed in technology assessment but no formal procedure has received universal acceptance. A study of 24 technology assessments [mainly done by teams at universities or consulting firms under the sponsorship of the national science foundation in the US] (Hopper 1988) finds considerable diversity among the methodologies actually employed but the study indicates that the assessment process in all cases could be described functionally under two headings. Below is a summary of these findings:

1) Technology description

Each technology assessment team first assembled data on the current state of technology and the patterns that its future development might take. Typically this was done by interviews with a series of technological experts and an extrapolation of current trends; with some allowance for forces that might alter these trends. Since both the technological development and its impacts would be affected by the future social context; some social forecasting had to be included; implicitly if not explicitly.

Usually a basic continuity was assumed and past social trends were projected; for example; it was assumed that lifestyles and social institutions would not change significantly. In some cases; more varied alternative futures were visualized by the presentation of scenarios imagined and plausible sequences of events reflecting a wider range of assumptions.

2) Environmental impact

Environmental, economic, political and social impacts on critically affected population segments were listed. Secondary and higher order impacts then were traced from each of these primary impacts. Typically this was done by a series of checklists and by reliance on experts in several disciplinary fields (though social scientists were not strongly represented; except for economists). A preference for the use of mathematical models to predict quantifiable impacts was evident in these technology assessments.

There were difficult judgments in bounding each study, establishing its temporal horizon, geographical scope, and the impacts selected for detailed analysis. Uncertainties in estimating impacts created

problems. Sometimes upper and lower limits could be given, or a range of estimates or probabilities could be agreed on.

Conclusion

In general we would have to look at regional and sub-regional approaches to tackle the problem. Africa has more than 50 countries that need integrated policies, particularly in the energy sector. The development support should take both the regional and sub-regional reality into account. Unfortunately, even climate change mitigation policies in which trans-boundary aspects are evident are mainly treated within the narrow national context (EIA 1993). Sub-regional support should be designed to promote more cooperation among countries, regional technology transfer and the formation of regional markets for alternative energy utilization (IEA, 2002). Most northern continents have already moved far in this direction or are in the process of doing so.

The development of a modernized power system, including renewable and clean technologies as a matter of planning is required now more than ever. Distributed generation technology, with detailed standards are needed in planning the next stages in electric energy deployment.

Conventional lighting technology (candles and paraffin lamps) is the main rural domestic lighting source in South Africa. Unfortunately, this state of affairs will be prolonged, as it will take decades before an electrification network will be established in all rural areas. The low-voltage output of solar panels can be utilized to drive HB-LEDs, which could solve the lighting dilemma in rural areas, with domestic, traffic and railway signalling applications etc. It may become a reality that a 15W solar panel supplying four SSLs would provide sufficient light in a (rural) home. This is remarkable compared to one incandescent lamp dissipating 60W. It would be affordable enough to ensure full ownership to the homeowner.

We need to promote the development of African dynamic regions to promote active research and development in reduced energy consumption and alternative energy applications.

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