ENERGY TECHNOLOGIES FOR AFRICA'S SUSTAINABLE DEVELOPMENT[1]

Background

Energy is an expression of mechanical motion, thermal heat, or electrical *power* consumed, radiated, dissipated, or stored over a period. Conventional energy sources include wood, water, oil, gas, coal, and nuclear fuels. The growing world population requires all these, as well as new sources such as solar energy, biomass, and wind energy. All must be made clean, safe, less expensive, and in the aggregate, abundant. Energy may be sourced centrally, locally, or portably. It must be generated, transformed, distributed, and properly utilized from all these sources. Future sources may include, for example, hydrogen, which is abundant in water, gas, and biomass; albeit a challenge to "extract" and store

Today there is wide agreement that access to affordable and readily available energy services is a necessary but insufficient condition for sustained socio-economic development. On a continent where the majority of the population does not have access to electricity, and where most depend on access to biomass for daily survival, availability of energy can and must be used as catalyst for development.

Within the context of the priorities identified during August 2002 at the World Summit on Sustainable Development (WSSD) in Johannesburg, by Secretary-General Kofi Annan, there are direct links among the five key areas where concrete results can and must be obtained: water and sanitation, energy, health and the environment, agriculture and biodiversity and ecosystem management (WEHAB). As pointed out in the WEHAB Working Group report (WEHAB, 2002), for development to be sustainable, it is preferable to concentrate on delivering energy services that can meet the needs of people, using a variety of technologies and fuels tailored to local conditions, rather than simply working towards increasing fuel and electricity supplies.

Energy is linked with practically all aspects of development and, in particular, with the other four issues in the WEHAB cluster of critical concern. Energy is an engine for growth and poverty reduction, and therefore it should be accorded high priority and reflected in policies, programmes and partnerships at national and international levels. Current energy systems are not consistent with the goals of sustainable development, however, and a fundamental reorientation is required in order to make the transition to more sustainable energy systems so that energy can become an effective tool for sustainable development.

Importantly, the Working Group points out that making the global energy system compatible with the tenets of sustainable development will require a large and sustained effort that includes awareness raising, capacity building, policy changes, technology innovation and investment. The shift towards a sustainable energy economy involves sound analysis of the

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options by policymakers, good decisions and the sharing of experience and knowledge of individuals and organizations wrestling with the many practical challenges that such a transition presents. These activities, and the changes they foster, are needed in industrial as well as developing countries.

Accessibility

The relative position of African countries in comparison to some developed economies in Europe is shown in Table 1 below. Even South Africa, as dominant economy on the continent compares unfavourably to these European countries on a GDP basis as well as energy supply as vector of development.

Wider access to affordable energy services is a necessary condition for meeting the challenge of the Millennium Development Goal of halving the proportion of people living on less than US$1 a day by 2015. Indeed, greatly expanded access to reliable, affordable and socially acceptable energy services is a prerequisite to meeting most of the targets outlined in the Millennium Declaration. Energy consumption is highly uneven between North and South and, within countries, between rich and poor people.

As can be expected, WEHAB stresses that the greatest access challenges are currently found in rural areas, though with the current trend towards urbanization in developing countries, this problem is increasingly present in large poor communities within and at the margins of cities. WEHAB thus concludes that rural development should be the overall priority in meeting the

TABLE 1: KEY ENERGY INDICATORS FOR SOME COUNTRIES: 1999 (1990 US$)

SOURCE International Energy Agency, Paris

Country	Popula-tion (M)	GDP (US$B)	TPES (Mtoe)	Electr Cons (TWh)	TPES per Capita	TPES / GDP (000$)	Electr (KWh per Capita)	Electr Cons (KWh per US$)
Morocco	28.2	38.4	9.9	15.2	0.35	0.26	538	0.40
Senegal	9.3	5.5	3.0	1.1	0.32	0.54	122	0.21
Algeria	30.0	47.0	28.3	19.8	0.94	0.60	661	0.42
Libya	5.4	32.1	12.3	20.0	2.26	0.38	3699	0.62
Egypt	62.7	74.6	44.5	60.2	0.71	0.60	960	0.81
Ethiopia	62.8	7.1	18.2	1.5	0.29	2.59	24	0.21
Sudan	29.0	8.7	15.4	1.4	0.53	1.76	50	0.16
Nigeria	123.9	31.0	87.3	11.0	0.70	2.82	89	0.36
Kenya	29.4	9.9	14.7	3.8	0.50	1.48	127	0.38
Angola	12.4	6.4	7.6	1.1	0.61	1.18	92	0.18
Tanzania	32.9	6.2	15.0	1.8	0.46	2.43	55	0.29
Zambia	9.9	3.8	6.2	5.6	0.63	1.61	568	1.46
Zimbabwe	11.9	8.4	10.2	11.2	0.85	1.22	940	1.34
Mozambique	17.3	3.4	7.0	0.8	0.40	2.04	48	0.24
South Africa	42.1	164.4	109.3	188.6	2.60	0.67	4479	1.15
NOTE: No recent info available for Botswana, Lesotho, Swaziland								
United Kingdom	59.5	1256.0	230.0	351.2	3.87	0.18	5901	0.28
Sweden	8.9	267.3	51.1	138.9	5.77	0.19	15450	0.51
Germany	82.1	2603.0	337.2	532.0	4.11	0.13	6480	0.20
France	60.3	1698.0	255.0	430.0	4.23	0.15	7142	0.25

TPES: Total Primary Energy Supply
toe: tonnes of oil equivalent

access challenge, with a focus on increasing investments,

People focus

The United Nations Millennium Development Goals (MDGs) comprise a range of key objectives in the pursuit of sustainable development:

- Eradicate extreme poverty and hunger;
- Achieve universal primary education;
- Promote gender equality and empower women;
- Reduce child mortality;
- Improve maternal health;
- Combat HIV/AIDS, malaria and other diseases;
- Ensure environmental sustainability; and
- Develop a global partnership for development

These goals had a strong influence on the agenda and outcome of the WSSD. The Summit, building on Agenda 21 of the UN Conference on Environment and Development in 1992 and the MDGs, clearly creates a human-centred framework for sustainable development. The WSSD Plan of Implementation quotes the Rio Declaration as stating "human beings are at the centre of concerns for sustainable development, and … are entitled to a healthy and productive life, in harmony with nature." In the human-centred framework, sustainable development, supported by good governance at all levels, and leading to sustained economic growth, is a means to an end. The end goal is human development.

Energy has a pervasive role in meeting the requirements for human development. The WEHAB initiative, in preparation for WSSD, created a framework for action on energy, based on a set of key issues and challenges:

- **Access to energy and modern energy services**, a necessary condition for meeting the MDG of halving the proportion of people living on less than US$1 per day by 2015;
- **Energy efficiency**, especially with a view to extending the impact of limited existing installed capacity;
- **Renewable energy**, with opportunities to extend energy services beyond existing grids based on proven renewable technologies;
- **Advanced fossil fuel technologies**, with emphasis on improved efficiency and lower environmental impacts at local and global levels; and
- **Energy and transport,** providing transport services in support of development while reducing the environmental impacts associated with this energy-intensive sector.

The analysis of key issues also illustrates the inextricable interrelationships between energy and the other WEHAB dimensions of Water, Health and Environment, Agriculture, and Biodiversity and Ecosystem Management.

The WSSD Plan of Implementation addresses MDGs and the WEHAB framework. Poverty eradication is to be addressed through, *inter alia*, "the access of the poor to reliable, affordable, economically viable, socially acceptable and environmentally sound energy services". Suggested actions include the integration of energy considerations with affordability and accessibility into socio-economic programmes. At the same time, the plan recognises that energy is a key component of globally unsustainable patterns of consumption and production, and calls for actions to address energy efficiency, cleaner technologies, and

increasing the contribution of renewable energy resources and technologies. Institutional and economic means are also addressed in the action plan.

The NEPAD link

The New Partnership for Africa's Development (NEPAD) provides the programmatic framework for the attainment of UN MDGs and the WSSD Plan of Implementation.

NEPAD "…. is a pledge by African leaders, based on a common vision and a firm and shared conviction, that they have a pressing duty to eradicate poverty and to place their countries, both individually and collectively, on a path of sustainable growth and development…." (www.NEPAD.org). The extent of the challenge is dramatically illustrated by the fact that about 500 million people in sub-Saharan Africa do not have ready access to electricity, and almost 600 million are dependent on traditional biomass sources for daily survival (IEA, 2002)**.**

Africa is in the early stages of its development journey, and has a wide range of options regarding development pathways and resource utilization. Energy is an essential consideration in this development, and choices taken in the near future will have far-reaching consequences on development, impacts on global change and the sustainable use of ecosystems and non-renewable resources on a continental scale.

Energy-specific objectives within the infrastructure initiative of NEPAD include:

- "To increase from 10 per cent to 35 per cent access to reliable and affordable commercial energy supply by Africa's population in 20 years;
- To improve the reliability as well as lower the cost of energy supply to productive activities in order to enable economic growth of 6 per cent per annum;
- To reverse environmental degradation associated with the use of traditional fuel in rural areas;
- To exploit and develop the hydropower potential of river basins of Africa;
- To integrate transmission grids and gas pipelines so as to facilitate cross-border energy flows; and
- To reform and harmonize petroleum regulations and legislations in the continent. "

These objectives clearly identify the lack of reliable and affordable energy as a barrier to development. But Africa faces critical issues in overcoming this barrier:

a) Africa, especially in the southern states, has a high dependence on coal. While this provides a source of energy in countries often too arid to depend on hydropower, the environmental and sustainability issues are significant. At the same time, Africa has to weigh alternative energy technologies on the basis of affordability and the implications for future development.
b) The spatial distribution of renewable (principally hydro) energy sources does not correspond with areas of highest demand. Regional coordination and integration is essential to establish equitable access to regional resources.
c) The mix of renewable and non-renewable energy sources in the evolving African energy picture will have a very large influence on resource use patterns, ecosystems and global change. Care will be needed to ensure that choices are not unduly influenced by considerations of local optima and short-term affordability.
d) Africa lacks the research and development (R&D) capacity to support decision-making on energy. This is recognized in the WSSD Plan of Implementation, which advocates the

promotion of technology development, transfer and diffusion to Africa, and to further develop technology and knowledge available in African centres of excellence. Even in South Africa, relatively little work has been done to project future energy use and greenhouse gas (GHG) emissions, and resources have not been available to conduct detailed studies of GHG mitigation measures (Chandler *et al.*, 2002)

It is clear that the **key challenge in terms of energy for sustainable development is to meet developmental goals while mitigating the environmental costs**.

The role of energy in supporting the attainment of development goals, and need for science and technology to support this role, have been recognised by the NEPAD Secretariat, who, with the South African Department of Science and Technology, held a workshop in February 2003 on the development of a Science and Technology Strategic Framework (NEPAD Secretariat, 2003). The workshop noted that "NEPAD cannot realize the goals of economic transformation, improvement of the quality of life and sustainable development without making deliberate investments in science and technology"(S&T). Critical factors constraining or limiting improved scientific and technological development in Africa include:

- Weak links between scientific and political institutions;
- Historic lack of attention to long-term aspects of S&T development;
- Low, and often declining, funding of research and development (R&D);
- Declining quality of science and engineering education at all levels;
- Loss of leading S&T expertise to other regions of the world;
- Lack of focus on innovation for poverty reduction and sustainable development; and
- Weak links between public R&D institutions and industry and general society.

The workshop recommended a series of actions to address these issues, and recommended that a NEPAD High Level Forum be established as a platform to develop NEPAD's S&T strategic framework and action plans. The Forum would comprise African ministers of science and technology, science advisors and senior policy makers, and would be advised by a panel of eminent African experts.

Energy research and development

Recent scenario work demonstrates the impending inability of oil and coal reserves to meet energy demand, and the uncertain role of gas in bridging the gap to be filled in moving to alternative energy sources. These resource constraints, together with emerging and future technologies and social and personal priorities, will determine future energy realities (Shell International, 2001).

The simple scientific definition of energy is *the ability to accomplish work*.

There is no universally accepted definition of *Energy R & D*. A useful definition is given by the Global Climate Change Group at the Pacific Northwest National Laboratory, USA (1999) as:

"the linked process by which an energy supply, energy end use, or carbon management technology moves from its conception in theory (including necessary enabling basic research) to its feasibility testing and small scale deployment."

"Carbon management technologies" include but are not limited to advanced agro-forestry practices intended to enhance the absorptive capacity of soils to hold atmospheric carbon dioxide and engineered carbon capture (pre- and post-combustion) and engineered carbon storage (e.g., in depleted gas and oil wells, coal-bed methane seams, deep saline reservoirs, and in the ocean).

Energy R&D traditionally includes basic and applied research, and technology development and demonstration, in all aspects of:

- Resource extraction and production;
- Power generation (e.g., nuclear, fossil, and renewable energy);
- Transmission, distribution and energy storage;
- Energy efficiency; and
- Carbon management technologies.

Importantly in African context however, this definition excludes the socio-economic elements necessary for a human-centred sustainable development approach. The key issue to be addressed globally is how to address the growing energy needs of the one third of the population without electricity, without depleting the natural resource base and compromising the environment in terms of local (air pollution), regional (acid deposition) and global (climate change) scales (Watson *et al.*, 2003).

Developed country public research interests are predominated by the United Nations Framework Convention on Climate Change objective of stabilising greenhouse gas concentrations in the atmosphere at a level (below 550 ppm) that would prevent dangerous anthropogenic interference with the climate system.

Energy R&D initiatives in Africa

The implementation mechanisms identified in the WSSD Plan of Implementation give prominence to the development and transfer of technologies and corresponding know-how to developing countries, and to strengthen S&T networks and institutions. Access to multilateral and global research programmes, including those supported by Type 2 Partnerships, is instrumental in this regard. Specific actions are called for to support energy for sustainable development: “Promote increased research and development in the field of various energy technologies, including renewable energy, energy efficiency and advanced energy technologies, including advanced and cleaner fossil fuel technologies, both nationally and through international collaboration; strengthen national and regional research and development institutions/centres on reliable, affordable, economically viable, socially acceptable and environmentally sound energy for sustainable development”.

The African Energy Commission (AFREC) was established in 2001 under the auspices of the then OAU. While not having a direct R&D focus, AFREC is planning to establish a continental energy information system and data base, promote training and education in the sector, and establish a network of technical assistance between member states. A workshop was held in Algiers during April 2003 to review progress in the development of an African Energy Information System (AEIS). Progress has been hampered through lack of political and technical development and shortage of skills and manpower. The initiative is receiving support from a joint initiative of the International Energy Agency and the World Energy Council.

Probably the single largest R & D organisation on the African continent – the CSIR in South Africa – is preparing itself to properly address the energy challenges of the continent with the assistance of Shell International through an evaluation of the options that could emerge as reflected through Shell's scenario development expertise. Although still in progress, the work already points to the need for imaginative thinking to embrace not only a step change but also paradigm-breaking approach in supplying the energy needs of particularly the rural poor and in exploiting Africa's mineral wealth through value addition and beneficiation for Africa's benefit.

Priority areas of R&D

The WSSD Plan of Implementation calls on individual governments and the international community to work towards improving access to reliable, affordable, economically viable, socially acceptable and environmentally sound energy services and resources, taking into account national specificities and circumstances, through various means, such as enhanced rural electrification and decentralized energy systems, increased use of renewables, cleaner liquid and gaseous fuels and enhanced energy efficiency, by intensifying regional and international cooperation in support of national efforts, including through capacity-building, financial and technological assistance and innovative financing mechanisms, including at the micro and meso levels, recognizing the specific factors for providing access to the poor.

To achieve these objectives, it is imperative that the right suite of problems and projects be identified. Without too much effort, areas deserving of attention can be lifted out. However, a critical question will remain on those that were left out, and more pointedly on what basis these areas were identified. Another question that has to be addressed is how the suite of actions would slot into the wider infrastructure development picture, given that the key challenge in terms of energy for sustainable development is to meet developmental goals while mitigating the environmental costs. The real challenge therefore lies in ensuring that the current state of energy in Africa is factually correct and that through an ordered process agreement is reached on where individual countries and the continent as a whole wish to be, going forward.

NEPAD actions to meet energy-related objectives include:

- Establishing a forum and associations for regulations,
- Prioritisation and implementation of regional projects,
- Accelerating the supply of energy to low-income housing, and
- Biomass energy conservation.

In the spirit of the NEPAD vision of using Africa's resources for the benefit of Africans, the immediate challenge facing energy decision makers is to base these actions on policies, projects and technologies that meet Africa's development needs, as well as those of investors and marketers. There is, however, very limited R&D capacity in Africa to support such decisions. As in the rest of the world, there is a particular need to develop socio-economic and environmental capacity to address energy aspects of a human-centred framework of sustainable development.

An African energy research strategy should be informed by:

- Regional and national energy policy and strategic priorities;
- Knowledge of where the energy sector currently is;
- A vision of where we wish the energy sector to be in 10, 20 or 30 years;

- Scenario analyses that provide an enhanced understanding of the African and Global context, and change drivers;
- An understanding of international energy research frontiers;
- An audit of current research capacity and research activity in Africa; and
- A thorough historical understanding of research lines, research capacity and institutional development in Africa.

This information would provide the platform on which to develop a strategy, which should:

- Identify priority energy research challenges and issues;
- Propose institutional arrangements and mechanisms for updating and refining research priorities and for ensuring that the research has an output focus;
- Analyse gaps in research activities with regard to these priorities;
- Propose mechanisms for establishing regional and national research programmes;
- Propose an indicative multi-year budget framework for R&D programmes, coordination and technology sharing;
- Propose funding mechanisms and channels;
- Identify institutions that could serve as centres of excellence in key strategic research areas;
- Create new institutions or centres to fill strategic gaps; and
- Propose a regional strategy for training energy researchers and building adequate capacity.

A number of actions are foreseen in the process to develop an African energy R&D strategy:

- Commission a continent-wide audit of current energy research capacity and activity (probably based on the collation of national audits);
- Integrate, build and expand on current work on energy scenarios,
- Assemble a team comprising local and international experts to develop a draft energy research strategy, informed also by the analytical process above; and
- Embark on a consultative process to refine the strategy.

A possible institutional model for a national energy research strategy could fall within that proposed in the synthesis report on the February 2003 workshop on developing a Science and Technology Strategic Framework (NEPAD Secretariat, 2003):

- An African Energy Research Advisory Committee is established under the auspices of the NEPAD High Level Forum comprising African ministers of science and technology, science advisors and senior policy makers;
- The Research Advisory Committee is given a clear mandate to support AFREC in its objectives as well as addressing the broader requirements of NEPAD;
- The Research Advisory Committee is responsible for:
  - Commissioning the activities suggested in this document, and developing an African Energy R&D strategy in support of NEPAD objectives; and
  - A co-ordinated programme of energy research distributed between a range of regional institutions.

The content of the African energy R&D strategy should be developed in parallel to the strategic and institutional processes, and provide input into the emerging strategy in an iterative fashion to allow for learning and skills development. Again, there should be emphasis on ensuring an appropriate direction that supports NEPAD objectives and focuses limited resources on the key leverage points. The approach should include:

- An analysis of resources available to provide energy in Africa, their extent and existing levels of utilization;
- An analysis of existing access to energy, energy use patterns and use of technologies in the generation and utilization of energy;
- An assessment of the gaps in energy provision that will need to be closed to ensure the attainment of NEPAD goals;
- Analysis of the needs and challenges in the evolution of an African energy infrastructure in support of NEPAD;
- Techno-economic feasibility and full life-cycle assessments of available energy resources and technologies in terms of their abilities to contribute to development objectives while maintaining ecosystem integrity; and
- A preliminary assessment of the existing energy information collection, management and dissemination systems and processes in Africa, based on experience in the project and an assessment of the validity of current information.

Approach

There is no existing framework within which to develop energy R&D capacity***. Given also the current lack of coordination of energy R&D activities and institutions in Africa, this paper advocates an initial focus on strategy and institutional arrangements, rather than listing R&D priorities***. This will ensure that the limited R&D resources will be focussed activities that will achieve greatest leverage in attaining development goals. In addition, a focus on research projects, without regional direction and collaboration would likely result in such priorities being addressed by international R&D organisations, without the wherewithal to transfer and develop the necessary skills and capacity into Africa.

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