UN-ENERGY/Africa

A UN collaboration mechanism and UN sub-cluster on energy in support of NEPAD

Energy for Sustainable Development: Policy Options for Africa

UN-ENERGY/Africa publication to CSD15

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Preface

The supply and use of energy have never been static subjects. Scientifically, technologies change; some are entirely new and others result in improved function and efficiency. Economically, the primary resource base changes, with some resources being indigenous and therefore relatively secure, while other resources are imported with significantly less security. Structurally, supply organizations vary, ranging from nationalized utilities to privately owned companies. Environmentally, all energy processes have impacts; some are heavily polluting, some cause effectively no pollution, and most have less polluting alternatives. The United Nations is concerned with all these aspects of energy supply and use, as its agencies seek to encourage responsible sustainable development and the reduction of poverty. These aims are not new, but circumstances change; for instance, we now have to consider urgently the challenges and opportunities presented by climate change.

This book reviews the activities of several UN and other agencies in the area of energy and sustainable development in Africa. We are aware of the changing global scene and are concerned that our actions free of historic impediments and conscious of new concepts. Thus, we are aware of the global trend towards liberalized utility suppliers working within *regulated frameworks*. We appreciate the rapid improvements in *electronic communication*, which are transforming the news media, education, business etc, and enabling the emergence of new industrial processes, dependent on automated machinery and data acquisition. We are waiting for increased development opportunities related to *international carbon abatement and climate change mitigation*. The aim is to strengthen opportunities for reliable and affordable energy supply, both to urban and rural populations. This is most likely to occur with clear strategies and regulated policy, which will allow enterprising industrial and commercial firms to plan for innovation and sustainable development.

The various chapters of this book relate to the views and activities of different UN agencies and development banks co-operating within UNEA (UN-Energy/Africa). Each chapter therefore focuses on different, but related, themes. In total, a broad spectrum of issues is addressed, including the need for an effective commercial and industrial development policy, a favourable environment for energy end-users and an appropriate regulatory framework, successful approaches to enhance energy access for economic and human development, and structural changes in the context of sustainable development and economic planning, as well as specific challenges for energy investment in the present global situation and the potential contribution of nuclear power in the energy sector.

Whatever its focus, each agency understands that energy is important, not as an end in itself, but rather as a means to tackle the major developmental challenges that exist in Africa today. Our task is to be positive and support development, with the expectation that employment and wealth income will increase and that the resulting economic structures and products will be beneficial, both locally and nationally. Having an international perspective, the UN sees the advantages of *harmonized policies and methods*, which we hope will be accepted by individual countries. There are obvious advantages in such harmonization, which facilitates increased trade between countries, e.g. in electricity and gas, and in commonly labelled and standardized goods and professional employment.

Regarding the scale and operation of technical development worldwide, there are two complementary trends. The first is towards *diversified and less-intensive industry*, and the second is towards greatly enhanced national and international *communication*. The former appears as a coalescing of what has been called 'appropriate technology', with centralized large-scale production (as, for instance, with micro-generated and embedded electricity supply), while IT and networks, electronic control systems and remote monitoring demonstrate the second trend. These technology trends are certainly transferable, for they are already universal, although dissemination and scaling up need a coherent approach supported by harmonized policies and strategies to address the challenges in strategic partnership. By recognizing these trends, energy policy in Africa can avoid the mistakes made elsewhere and launch itself into a sustainable future.

This book is intended to explain the energy-related work of UN and other world agencies, with particular reference to Africa. We hope that you will enjoy it and be stimulated by it.

Mr. Kandeh K. Yumkella,
Director General of UNIDO,
Chair of UN-Energy/Africa

Foreword

In Africa, as around the world, energy issues have moved higher in the development agenda of policy-makers. This was mostly prompted by the recognition that without energy most development objectives, including the Millennium Development Goals, cannot be met. The current volatility of oil prices is also a factor in the increasing attention paid to energy issues. In order to sustain the encouraging overall growth of African economies of the recent past and also to make substantial progress in overcoming the poverty challenge on the continent, African nations would need to address various challenges in the energy sector. This would require increasing access of the majority of Africa's population to electricity. The continent would also need to deal with the high usage of traditional biomass fuels to meet the energy needs for cooking and heating of most Africans.

The improving economic trend in Africa also brings its own challenges. Indeed, experts estimate that, unless stronger commitments are made by all concerned and effective policy measures are taken to reverse the current trends, half of the population in sub-Saharan Africa will still be without electricity by year 2030, and the proportion of the population relying on traditional fuels for household energy needs will remain highest compared to all world regions.

It is against this background that the World Summit on Sustainable Development (WSSD) adopted a Plan that calls upon the international community, including the United Nations system, "to take joint action and improve efforts to work together at all levels to improve access to reliable and affordable energy services for sustainable development sufficient to facilitate the achievement of the millennium development goals (MDGs), including the goal of halving the proportion of people in poverty by 2015, and as a means to generate other important services that mitigate poverty, bearing in mind that access to energy facilitates the eradication of poverty". The Plan also calls for "dealing effectively with energy problems in Africa through establishing and promoting programmes, partnerships and initiatives to support Africa's efforts to implement NEPAD objectives on energy".

As there is no entity specifically established within the United Nations system to deal with energy issues at the global level, and given that the New Partnership for Africa's Development (NEPAD) has been recognized as the appropriate framework for implementing WSSD outcomes, the UN agencies working in Africa have agreed to set up an inter-agency coordination and collaborative mechanism, called UN-Energy/Africa, that would allow them coherence and synergy in their support to African Union's (AU) priority programme on energy, in particular the AU/NEPAD energy initiatives.

This publication on "Energy for Sustainable Development: Policy Options for Africa", which builds on experiences and lessons learned in implementing energy projects by some of the United Nations agencies working within the framework of UN-Energy/Africa, is a commendable example of what the United Nations system can achieve when it decides to pool resources and work together to deliver as one. In this undertaking, entities of the UN system have benefited from the contribution of non-UN members of UN-Energy/Africa, such as the NEPAD Secretariat and the African Union Commission.

The publication, which is to be launched at the fifteenth session of the Commission on Sustainable Development (CSD-15), will be made available to African policy-makers and the donor community. It highlights policy options that could help address some of the energy challenges in Africa, some of which are promoting renewable energy and energy efficiency development, addressing energy problems in urban settlements, mitigating negative impacts of power sector reforms, linking energy planning and expanded energy services, scaling-up access to energy services through a regional approach, and accelerating investment in the electricity sector in Africa.

I commend the participating institutions for taking the initiative to produce this book, which is recommended to all energy stakeholders, especially African policy-makers who have a primary responsibility for improving the well-being of the African people.

Abdoulie Janneh
Executive Secretary
United Nations Economic Commission for Africa (ECA)

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This milestone flagship publication of UN-Energy/Africa was made possible by the collective and concerted efforts of all UN agencies, programmes and non-UN organizations such as the AU and the AU/NEPAD, members of UN-Energy/Africa.
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Deepest appreciations to higher management of all agencies, programmes and organizations, in particular to Mr. Abdoulie Janneh, UNECA Executive Secretary, and Mr. Kandeh K. Yumkella Director General of UNIDO for overall support and the drafting of the preface and foreword.

ACRONYMS

ADB	African Development Bank
AFREC	African Energy Commission
AU	African Union
CEB	Chief Executives Board for Coordination
COMESA	Common Market for Eastern and Southern Africa
CSD	Committee on Sustainable Development
EAPP	Eastern Africa Power Pool
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States
EE	Energy Efficiency
EU	European Union
FAO	Food and Agriculture Organization
GVEP	Global Village Energy Partnership
GWh	Gigawatt hour
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IPP	Independent Power Producer
JPOI	Johannesburg Plan of Implementation
LPG	Liquefied Petroleum Gas
MDG	Millennium Development Goals
MTOE	Million Ton Oil Equivalent
NEPAD	New Partnership for Africa's Development
NGO	Non Governmental Organization
ODA	Official Development Assistance
OECD	Organization for Economic Cooperation and Development
PEAC	Pool Energétique d'Afrique Centrale
PRSP	Poverty Reduction Strategy Paper
R&D	Research and Development
RE	Renewable Energy
REC	Regional Economic Communities
REEEP	Renewable Energy and Energy Efficiency Partnership
SADC	Southern African Development Community
SAPP	Southern Africa Power Pool
SSA	South Saharan Africa
SWER	Single Wire Earth Return
UN	United Nations
UNEP	United Nations Environment Programme
UNDESA/DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNECA (or ECA)	United nations Economic Commission of Africa
UN-Habitat	United Nations Programme for Habitat
UNIDO	United Nations Industrial Development Organization
WAPP	West African Power Pool
WB	World Bank
WEC	World Energy Council
WSSD	World Summit on Sustainable Development

UN-Energy/Africa:
A Brief Presentation

Mandate of UN-Energy/Africa

In its resolution 57/2 of 16 September 2002, entitled "United Nations Declaration on the New Partnership for Africa's Development" (NEPAD), the General Assembly of the United Nations has welcomed NEPAD as an African Union led, owned and managed initiative and has affirmed that international support for its implementation was essential.

Further, the UN General Assembly of 4 November 2002, brought to a close the United Nations New Agenda for the Development of Africa in the 1990s (UN-NADAF) and urged the international community and the United Nations system to organize support for African countries in accordance with the principles, objectives and priorities of NEPAD (resolution 57/7).

An important component of the UN Secretary-General's reform agenda is the need to achieve improved coherence in the activities of the various UN agencies at the regional level. Building on the reform agenda launched by the Secretary-General in 1999, the ECOSOC in resolution 1998/46 urged the establishment of regional consultative meetings among UN agencies working in each region. The overall purpose of these regional consultative meetings is to promote synergy and coordination among the agencies and organizations of the UN system, so as to improve the collective response by the UN system in addressing priority needs of each of the five regions.

In Africa, the coordinated support of UN agencies to the AU and AU/NEPAD is organized in a thematic cluster arrangement. The Regional Consultation Meeting approves currently nine clusters, convened by various UN agencies, bodies or programmes. The infrastructure cluster, composed of the 4 sub-clusters deals with the issues of water (UN-Water/Africa), energy (UN-Energy/Africa), transport, and ICT. UN-Energy/Africa therefore serves as the sub-cluster on Energy.

The Creation of UN-Energy/Africa

Following the creation on 14-15 April 2004 in Rome of UN-Energy, African Energy Ministers gathered in a meeting co-organized by UNEP, ECA and the African Union on 8 May 2004 in Nairobi, adopted a recommendation for the creation of UN-Energy/Africa. UN-Energy/Africa should along the line of UN-Water/Africa be a regional collaborative framework with the objective to promote more efficient, coherent and coordinated actions of UN and non-UN organizations working in Africa on the issues of energy for development.

On 27 May 2004, responding to the recommendation of the African energy Ministers, five UN agencies (UNECA, UNIDO, UNEP, UNDP, and UN-Habitat) gathered in the context of the operationalization of the sub-cluster on energy in support of NEPAD, agreed to the creation of UN-Energy/Africa (UNEA). It was suggested, following the model of UN Water/Africa, that UNEA would be a subsidiary of UN-Energy in order to insure a linkage between global and regional energy issues and will serve as the UN-Agencies sub-cluster on energy in support of NEPAD. UN agencies requested UNIDO, UNEP and ECA to assume the function of chair, vice-chair and secretary respectively for a period of two years.

The TOR of UN-Energy/Africa were drafted with due consideration to the one adopted by UN-Energy and based on the considerations guiding the elaboration of inter-agency coordination/collaborative arrangements approved by the High Level Committee on Programme (HLCP).

Activities of UN-Energy/Africa are based on an approved Programme of Work, which emanates from priority areas identified by Agencies and Programmes and requests or needs transpiring from the programmes of the AU Commission and the NEPAD energy initiatives.

Highlights on Some Activities Implemented and in the Process of Implementation

The work programme of UN-Energy/Africa includes the following specific activities that were implemented or are in the process of being implemented:

- **Improving rural energy access and consumption**

Unleashing Energy Access in Africa: Rural Energy Access Scale-Up Mechanism. The study seeks to promote the mainstreaming of best practices in rural energy development in Africa, and the design and development of the Rural Energy Access Scale-Up Mechanism (REASUMA) with the ultimate objective to design and assess the feasibility of a Rural Energy Development Facility.

- **Policy and institutional reform**

Study on Power Sector Reform in Africa: The Sustainable Development Division of ECA, in partnership with UNEP, in the framework of UN Energy/Africa carried out an in-depth analysis of the economic, social and environmental impacts of power sector reforms in Africa. The study titled "Making Africa's Power Sector Sustainable" also maps the way forward for making Africa's power sector more sustainable with regards to social and environmental objectives. It covered 14 countries in various depths, and was completed in December 2005.

Policy Dialogue Stakeholders' Forum: The findings of the above-mentioned study were presented during a high-level multi-stakeholders policy dialogue forum, co-organized by ECA, UNEP and UNDESA. High-level decision makers and senior officials from power sector ministry/departments, regulatory bodies and utilities from 19 countries (Burundi, Cameroon, Côte d'Ivoire, Ethiopia, Ghana, Kenya, Lesotho, Malawi, Mali, Mozambique, Namibia, Nigeria, Senegal, the Sudan, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe), and representatives from 9 regional and international organizations (African Union Commission, ECOWAS, SADC, COMESA, IEPF, AFREPREN, UNDESA, UNEP, and ECA) participated in the forum. The Forum adopted a policy summary on "Making the Africa's Power Sector Reform Sustainable", and a "Policy statement on power sector reform in Africa" presented at CSD-14.

- **Capacity development and investment**

Micro/Mini-Hydropower development: The project aims at developing capacity in designing and managing micro/mini hydropower plants and promoting investment in these systems in order to increase electricity access for rural people in sub-Saharan Africa. Twenty countries are to benefit directly from this initiative.

Capacity-building in Integrated Resource Planning (IRP): This activity was jointly implemented by the IAEA and ECA, in December 2006. It aimed at training African energy planners from Regional Economic Communities (RECs), Power Pool and river basin organizations on integrated resource and energy planning in the energy sector. This training was based on the IAEA model MEAD. Fifteen people participated in this training.

- **Energy information dissemination and coordination**

Development of a UN-Energy/Africa website linked to ECA UN Regional Consultation Clusters to enhance e-discussions amongst UN agencies and pertinent non-UN organizations on energy issues.

- **Advocacy actions**

UN-Energy/Africa is to publish "*Energy for Sustainable Development: Policy options for Africa*" to serve as a UNEA flagship input to CSD-15. The publication will comprise chapters written by various institutions members of UN-Energy/Africa, and should contain key policy guidelines.

- **Support to AU-NEPAD and the African Union**

UN-Energy/Africa finally plays an important advocacy role in support of NEPAD energy initiatives, and aims at supporting the African Union in operationalizing the African Energy Ministerial Forum, an important institutional tool for the mainstreaming of successful practices in energy sectors' development. Also, UN-Energy/Africa provides various technical supports to the African Union, and participates in the *development of the Africa's Energy Vision 2030*.

Overview

Over the last four decades, the gap between energy supply and demand in Africa has been growing. Projections by experts in the field forecast that this gap will continue to grow, and the livelihood of more Africans will continue to be critically impaired by energy poverty, that will seriously slow down the socio-economic development of the continent. Energy has been supplied in insufficient quantity, at a cost, form and quality that has limited its consumption by the majority of Africa's population, making the continent the lowest per capita consumer of modern energy of all regions of the world. The challenges are indeed daunting, and more than ever, a concerted effort by all actors is required to achieve any significant progress.

Most UN agencies and programmes have endeavoured to address some aspects of the African Energy challenge in their work programmes. In this UN-Energy/Africa flagship book, key issues related to policy, regulation, renewable energy development, energy access in urban, peri-urban and rural areas, regional strategies for addressing energy poverty, power sector reforms, energy planning, and energy finance are addressed by various UN agencies and programmes, with the objectives to highlight the main challenges and provide some policy guidelines to accelerate energy supply and access in Africa.

In chapter one, UNIDO focuses on Commercial and Industrial policies and regulations that would significantly increase the share of renewables and decentralize energy services in the supply of energy. It is argued that market opportunities occur when governments devolve services and when modern technology is introduced. Such regulated policy allows enterprising industry and commerce to plan for innovation and avoid mistakes made elsewhere. Within the broad compass of international policy for Sustainable Development, the desire for economic growth and for widespread energy services has been joined by the need to mitigate Climate Change; these three factors are driving the twin objectives of Renewable Energy generation and Efficient Use of Energy. This process finds itself intertwined with the Liberalization and the Privatization of energy supply, whereby governments use law for the Regulation of such services to the public. This chapter reviews this situation, especially for industrial participation in electricity supply and use in sub-Saharan Africa. It is concluded that present trends strengthen the opportunity for reliable and affordable energy supply to both urban and rural populations, whilst providing market opportunities for national industry and commerce.

In chapter two, UN-Habitat addresses the linkages between environment, energy and cities. It is argued that most of the commercial and non-commercial energy produced today is used in and for cities, and a substantial percentage of it is used by the household sector. In the chapter, it is pointed out that increasing the efficiency of energy use to reduce its polluting effects and to promote the use of renewable energies must be a priority in any action taken to protect the urban environment. This will require major policy changes to re-orient the current focus on energy supply to an end-use oriented approach, and thus contribute to the sustainable human settlements development goals. The chapter contends that for most developing country cities, capacity-building for appropriate urban energy management will be a long-term and dynamic process, refining and strengthening existing strategies, skills and capabilities. External assistance will be crucial in building the necessary capacity to plan and implement environmental strategies at local level. Principal areas where such support should be considered are: (a) environmental research and policy analysis needed to formulate urban environmental strategies and action plans at local level; (b) policy reform, institutional development and resource mobilization; and (c) financial support for improving efficiency of urban energy services, and for the promotion of renewable energy technologies.

In Chapter three, the UNECA, based on a study jointly commissioned with UNEP, revisits the achievements of power sector reforms initiatives in Africa. The chapter recalls that since more than a decade and half, a number of African countries have embarked on implementing Power Sector Reform (PSR) programmes in a bid to address the deficiencies in the management and operations of their power utilities so as to improve technical and financial performance and extend electricity services. The chapter highlights that preliminary results of these reforms indicate that, while they helped achieve some institutional efficiency, the overall impact on the sector leaves a lot to be desired. These are due to, inter alia, the low interest in the private sector to improve electricity access levels as well as their unwillingness to commit the levels of investment needed to increase generation capacity and improve transmission. Furthermore, reforms often entailed negative social and environment implications, such as reduced access to electricity for low-income households due to tariff increases, limited electricity coverage due to slowdown of rural electrification programmes, reduced employment due to labour shedding, and negative environmental impacts. The chapter suggests policy guidelines to increase supply, improve the overall performance of the sector, address the specific needs of the poor, and maintain sound environmental standards.

In Chapter four, UNDP provides a unique assessment of the Role of Regional Economic Communities in Scaling-up Access to Modern Energy Services to meet the Millennium Development Goals (MDGs), and reviews recent development to mainstream energy issues in regional development priorities. The chapter examines the experience of the Regional Economic Communities (RECs), especially the ECOWAS and the EAC, as the coordinating regional institutional framework through which countries develop and adopt policies and strategies to scale-up access to modern energy services to meet the MDGs. Building on countries' national commitments to meeting the MDGs, several RECs have recently widened their strategies and action plans to include these targets and set up new objectives to significantly increase access to modern energy services, as reflected in recently adopted regional energy access policies and strategies by EAC, ECOWAS, and CEMAC. These documents and the framework investment plans have been adopted by the heads of state and government of the regional communities and are being implemented by member countries.

In Chapter five, the World Bank discusses the challenges and key requirements for accelerating investments in the grid and off-grid electricity sector in Africa. The chapter highlights the investment requirements and shortfall, provides rough estimates of the investment levels involved, and summarizes the main existing sources of investment in the sector. The chapter then provides some policy guidelines that could assist government create environments conducive for accelerating investments, and discusses the role of bilateral and multilateral agencies in this regard. In each section, challenges and opportunities are discussed.

In Chapter six, the IAEA discusses the needs for efficient energy system analysis conducive for good energy planning in Africa. It is contended that expanding access to clean and affordable energy services requires careful planning. The role of the Agency in developing and transferring planning models and data, training local experts, analyzing national options, and assisting to establish continuing local planning expertise is highlighted. The chapter summarizes, first, the IAEA's energy system analysis and planning tools that are available to member States. Second, it highlights current energy system analysis and planning activities involving member States in Africa. Third, it reviews prospects for nuclear power in Africa and additional IAEA assistance of interest to those member States that choose to explore the possibility of beginning a nuclear power programme.

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Chapter 1

Regulation and Policy initiatives for Sustainable Energy in sub-Saharan Africa

By
United Nations Industrial Development Organization[1]

1. Introduction

Environmental change and sustainable development present a challenge for all nations. Developed countries have to dismantle and change historic practice before progressing, whereas developing countries can move directly to new technology and new institutional frameworks. This chapter seeks to identify trends in energy supply and use that both improve sustainability and provide opportunities for commerce and industry. Worldwide experience is studied for application in sub-Saharan Africa (abbreviated as 'Africa' henceforward). Such application is central to UNIDO's programmes in energy and environment. These programmes consider both the supply and the demand sides, by the provision of energy for industry, use of renewable energy resources and improved industrial energy end-use efficiency. Key factors are de-linking intensity of energy use from economic growth and reducing environmental damage from energy supply and use

The background for this chapter is "Sustainable Energy Regulation and Policy-making for Africa" **(UNIDO, 2007a)**, a set of 20 training-modules produced for UNIDO and REEEP (the Renewable Energy and Energy Efficiency Partnership[2]). The modules will be used by governments, regulatory offices and industry in Africa for stimulating policy and commercial development in renewable energy and energy efficiency. Of particular relevance is the general trend to more liberalized electricity supplies, as regulated within new legislation. Within each country, institutional frameworks can be changed and improved for the benefit of both citizens and commerce alike. There is a common trend worldwide to include institutional mechanisms for the increase of renewable energy generation and the efficient use of energy within regulatory legislation, e.g. **(Harrington et al., 2007)**.

Government involvement and ministerial regulation is most common for electricity. In all countries, the introductory stages of electricity supply have been strongly influenced by national and local government action and ownership. However, once initiated, an established market economy, involving many competitive private companies, should produce electricity at less cost to the consumer and the nation, than if wholly owned and operated by government. Such improvement requires a carefully constructed legal framework, especially because there are many monopoly aspects of electricity supply. The administration and control of the legal objectives requires jurisdiction, usually by the appointment of a Regulator with a specialist and independent staff. Thus, hand-in-hand with the liberalization of energy supplies is the requirement for regulation.

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1 Written by the Programme Development and Technical Cooperation Division, Energy and Cleaner Production Branch, Energy Efficiency and Climate Change Unit.

2 See www.reeep.org

Since 1990, *liberalization of energy supply*, especially of electricity, has been introduced throughout Europe. The main actions have been at national level; consequently, individual national policies and methods dominate. Nevertheless, having an integrated European electricity grid encourages commonality throughout Europe. Associated with liberalization is the growth of private company participation and hence the need for legally enforceable regulation by a *Regulator*. The pattern of development in Europe is similar to many other world regions including North America. However, European electricity supply is older and the population more concentrated than in most other regions, therefore the opportunity for structured liberalization came first in Europe. Consequently, the European experience is important for formulating policy elsewhere, including Africa. However, without competition from several private companies for each contract, liberalization may well fail to deliver the improved services and reduced energy tariffs expected; chapter three considers such experience.

Coincidentally with the trend to energy supply liberalization, has come the need for *renewable energy supplies* and *increased energy efficiency*. This change is promoted by several factors, including: *sustainable development, new technology, reduced emissions and climate change*. New technology enables improvements in the efficient generation and use of energy, thus bringing financial savings and reduced environmental impact. Renewable energy, e.g. sunshine (solar), wind or biomass, utilizes local resources with no fossil-fuel costs, with acceptable emissions and with enhanced security of supply. The turnover for European business in energy efficiency and renewable energy is now of the order of 25 billion euro per year[3], associated with about 150,000[4] full-time-equivalent jobs. Such economic activity provides stimulation for similar industrial and commercial development in Africa. The need to improve energy-supply security and the necessity to reduce carbon dioxide emissions, have led to legislation and targets to increase the efficient use of energy both by good management practice (which is cheap) and by targeted capital expenditure (which usually has rapid payback time, perhaps less than a year and usually within three years). Using energy more efficiently is highly profitable for business.

2. Electricity supply: Development and change

2.1 Networks

The first public electricity supplies were from European and American municipal networks around 1890 [e.g. 3]. The number and international extent of these local schemes grew rapidly, so by 1930, separate networks were becoming integrated into national grids with generation mostly from coal-fired and hydro-electric power stations. The initial aim of such an electrical network was for the wires to pass power back and forth, strengthening supply throughout and with moderate scale generation *embedded* within it. Such a structure looked like a 'grid-iron', i.e. a metal net-like structure used for cooking over a fire; hence, the abbreviation to '*grid' or 'net'*.

In 1950, emphasis was given to *large thermal stations* (electricity generating capacity ~ 1000 MW) exporting power into a radial arrangement of high-voltage transmission lines. Along this star-like arrangement, connection points to the transmission lines took power to low-voltage networks that distributed electric-

[3] Author's informed estimate from Eurfores and EREC basic data
[4] Author's informed estimate from Eurfores and EREC basic data

ity to consumers. No longer was dispersed and embedded generation expected. Such large-scale generation, either coal or nuclear suited nationalized government and large company ownership especially when linked to similar ownership of coal mining. In the 1960s, oil-burning thermal stations formed similar centralized power sources. The waste heat from such centralized thermal stations was seldom used for heat supplies[5], so usually only about 33 per cent of the energy in the fuel became electrical energy, with the remaining 67 per cent discharged as waste heat.

In the 1980s, fossil-gas (mostly methane, misguidedly called 'natural gas') was used increasingly for power generation. The gas combusts at high-temperature, allowing more efficient and smaller power plant to be used, e.g. combined cycle of gas turbine followed by steam turbine. Such plant could be installed throughout the network; usually financed and operated privately and often linked with use of the otherwise waste heat. Therefore, conversion to electricity was possible at about 50 per cent efficiency, and to combined heat and electrical power at perhaps 85 per cent overall efficiency. Such dispersed and embedded fossil-fuelled generation is 2 to 3 times more efficient than the large centralized coal and nuclear plant.

The 1980s also saw the introduction of *new and different forms of renewable energy*, especially electrical power from *wind, small hydro, solar photovoltaic and non-fossil landfill-gas and biomass sources*. Such plant was usually connected as dispersed *embedded generation* within the local distribution networks, emulating the original 'grid-iron' concept. Europe now has around 12,000 MW[6] of such new distributed capacity with thousands of new companies and about 100,000[7] employees involved directly in renewables and associated new technology.

Thus, the structure of modern electrical supplies has some common features with the original concepts of linked dispersed generation. However, this analogy is only superficial since the technology for controlling the grid voltage, frequency, stability and power flows is completely new relying much on modern *solid-state electronics and SCADA* (supervisory control and data acquisition). Cost accounting is also much developed since different cost-centres or companies are integrated for generation, transmission, distribution, supply and metering, yet each has to be paid separately. The operation of both the equipment and the accounting is very dependent on *computer-based technology and communication.* It is obvious that the total change in electricity systems since 1980 has given opportunities for new industries and new enterprise.

2.2 Isolated and stand-alone electrical power

Stand-alone electricity systems, although not connected to a grid network, are extremely common in all countries. Where there is a comprehensive grid, the majority are for emergency standby power, especially in hospitals and factories. The UK for instance, has about 100,000[8] such systems, not including portable generators. If the grid is distant, the stand-alone systems are for regular power in rural homes and schools. It is a mistake to think that stand-alone power systems are only for less developed regions; however, in such situations stand-alone power can transform living conditions and increase economic benefit. The most common generation for stand-alone power is from motor-generators and/or photo-

5 There were definite exceptions, especially in Scandinavia and Eastern Europe, where local-scale distribution of heat from a 'heat grid' allowed combined generation of heat and electrical power.
6 Author's summation from several technology-specific studies.
7 Author's summation from several technology-specific studies.
8 Author's estimate.

voltaic solar modules[9], although wind and small-hydro generation is also used where appropriate. The motor-generators may be fuelled by fossil fuels or by biofuels. Small systems usually require electricity storage in batteries to smooth the supply.

Mini-grids not connected to a main 'utility' grid, may be installed to serve a group of consumers. Indeed, the original municipal grids of around 1900 were of this type. The power generation for mini-grids is usually similar to that for stand-alone power but at a larger scale and usually with professional management. In developed economies, mini-grids supply permanent power for small islands and remote locations.

2.3 Microgeneration

Grid connected, small-scale electricity generation can be installed at a building for both on-site and exported power. Power used on-site displaces otherwise imported power and power exported becomes income. The local grid may therefore receive power from many such microgeneration stations as dispersed input and usually controlled by modern solid-state electronics. Common examples worldwide are photovoltaic solar arrays on buildings. Such microgeneration may be significant for sustainability since the owners show responsibility for their own needs whilst interacting with others via the grid. A major challenge for microgeneration is obtaining the institutional permissions for such connection and financial dealings.

Note that the power generators for stand-alone installations and isolated mini-grids are of the same kind as for grid-connected microgeneration. Therefore, if a new utility grid reaches an originally isolated system, a connection can be made so the original stand-alone generation becomes grid-connected micro-generation. Such a transition requires the original stand-alone system to have been designed for such a possibility which, although not common, is not an expensive condition.

3. Government policy and regulation of energy services

3.1 Worldwide experience

Energy supply is essential for all aspects of life, industry and commerce. A successful economy depends on both supply and use being secure, safe and efficient. Therefore, it is a *duty of governments* to have clear policies for national energy supply as administered and checked by regulatory mechanisms[10]. Most governments link such actions with policies for industry, commerce and environmental care. Within energy supply and use, electricity is always of major interest especially since grid supply has monopolistic characteristics and there are always concerns for safety and security. Although government policies and regulation apply also to fuels and heat, it is electricity that attracts most attention.

Public electricity supply systems began about 110 years ago with municipal authorities and governments much involved. Today, electricity supply is considered an *essential service* to be provided by a government

9 Worldwide, there is about 1 million 'solar homes' using stand-alone photovoltaic power. This number is increasing annually.

10 See (1) www.utilityregulation.com for US information. (2) www.globalregulatorynetwork.org for developing country regulatory activity generally and links to global regulatory activity. (3) www.raponline.org international and US developments in regulation, especially energy. (4) www.afurnet.org for African Forum of Utility Regulators.

or private utilities. Whenever and wherever public electricity supply has been initiated, the same pattern of events has occurred. Cables have to be installed along public highways and safety has to be assured; therefore, government planning policies and standards has to be developed and legalized. The monopoly nature of the distribution cables requires structured government supervision and common technical standards for voltage, frequency and stability. In addition, initial capital costs are large but the initial consumer base is small, so government and municipal finance is needed. In general, government or municipal ownership of generating plant and distribution lines has been the development norm worldwide, as in much of Africa today.

However, continued public ownership of established electricity supply systems has a downside. The State Utilities become huge organizations, which governments find expensive and hard to control. Indeed, these organizations tend to become feudalistic oligarchies, answerable to neither the public nor shareholders. Often, further public finance is restricted as other government expenditures take priority. Consequently, the introduction of new technology, capital and market enterprise is handicapped and may be barred. In general, consumers may not receive the service they expect. At such a stage, governments may involve private companies, either to manage government owned installations or to purchase and operate plant and lines. Consequently, there is worldwide trend to privatization and liberalization of state-owned utilities and services for competition and consumer choice **(Hunt et al., 1996)**.

3.2 Regulation of services and trade

Whether in private or public ownership, the energy industry remains a 'utility' for public service and so government regulation is still essential. This regulation may remain internal within government, e.g. within a government ministry, or may be established as an independent body without immediate government control. If the latter, then government legislates accordingly, usually within wider legislation for the reform of energy supply, to establish a *Regulator* for the public service, in the manner of a judge or sheriff who interprets, adjudicates and takes action to uphold law. The Regulator is usually empowered to prevent market abuse, ensure good service and transparency of essential information, limit unjustified company profit and reduce environmental harm. The method of operation is usually to issue licenses related to the following functions **(Berg et al., 2000)**:

- setting performance standards;
- monitoring the performance of regulated firms;
- establishing the level and structure of tariffs;
- establishing a uniform accounting system;
- arbitrating disputes among stakeholders;
- performing management audits on regulated firms;
- developing human resources; and
- reporting sector and regulatory activities to government.

The overriding purpose of liberalization is to have efficient, secure and cost-effective services within a framework of market opportunity for competitive business. Therefore, it is essential that the Regulator understands and supports opportunities for developing industry and trade, whilst at the same time protecting consumers. In practice, responsibilities are often shared by several regulatory and ministerial bodies, e.g. Energy, Competitive Trade, Environment, Health and Safety.

For liberalized[11] energy services, especially for electricity, clarification is needed between energy generation, delivery (e.g. electricity transmission and distribution), supply (e.g. purchase and sale) and measurement (e.g. metering). These functions have to be operated by separately accounted entities (if there is some Government ownership) or companies (if privatized); this '*unbundling*' discourages monopolies and encourages competition. Unbundling may be 'vertical' (e.g. for electricity supply, separating generation, transmission, distribution, metering and supply) and/or 'horizontal' (separating companies of the same type so there is market competition wherever possible). Such liberalization provides stimulating opportunities for business.

In a fully liberalized electricity system with significant unbundling, the competitive market mechanism for electricity supply also operates under regulation. The technical requirement is that the total supply has to equal the total demand continuously, with a short-term accuracy of less than about 1 per cent. The balance is maintained within a hierarchy of competitively tendered contracts for future generation at least 24 hours ahead. Fine-tuning depends on special contracts for rapid generation when needed. This highly sophisticated market works within clearly defined rules and, perhaps surprisingly, is able to sustain a reliable and low-cost electricity supply.

Capital investment is always a difficulty for government, so privatization thrusts the problem onto business to raise finance. Indeed, government may mandate (obligate) the private utilities to invest, say in renewable energy and energy efficiency. It is common then for the Government, as administered by the Regulator, to allow a *levy* to be charged to consumers to help meet the obligated expenditure.

3.3 Sub-Saharan Africa

Information on energy supply and use in Africa may be obtained from key international organizations, such as the International Energy Agency[12] and UN Energy Statistics[13]. The EIA of the United States Department of Energy is a comprehensive source of information[14]. Although up-to-date detailed information may be difficult to obtain and characteristics vary by country, the general trends are clear. In Africa, per capita energy use and per capita emissions from fossil-fuel are very small and renewable energy use is proportionally (but not absolutely) significant.

Carbon emissions

In a world seeking to reduce the emissions of fossil-carbon into the Atmosphere, sub-Saharan Africa should be awarded credit for having the least per-capita emissions of any strongly populated region worldwide. The average per capita carbon emission[15] is 0.1 tonne Carbon/y, which contrasts with the world average of 1 tC/y, the European average of about 2.5 tC/y and the United States of 5.5 tC/y **(EIA, 2000)**. We may note the ethical target for all countries to converge to equal low values of per capita climate-change gaseous emissions.

There is a marked variation of fossil-carbon emissions by country in Africa and elsewhere, Fig 1, mostly because some countries (e.g. Botswana) use their own coal deposits and because oil-producing countries

11 Alternatively named 'privatised' or 'deregulated' (despite being regulated!)

12 See http://www.iea.org/index.asp

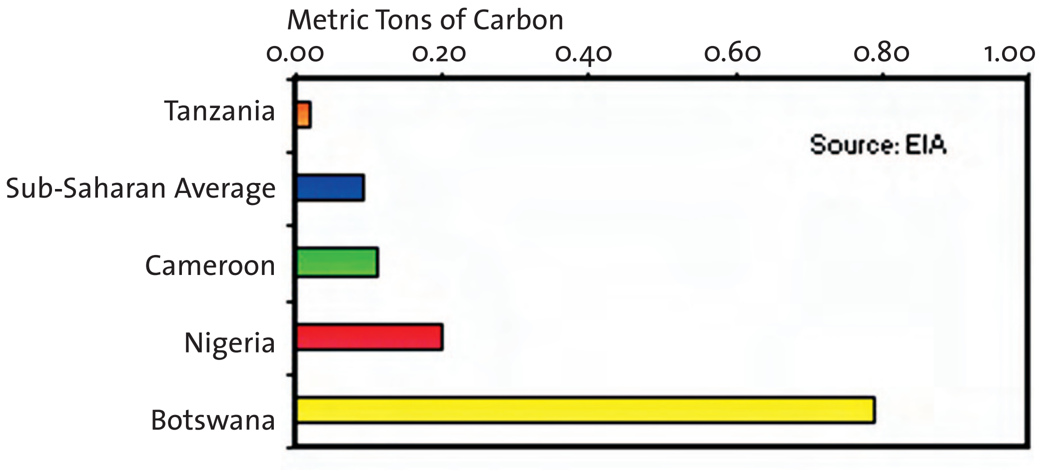
13 See http://unstats.un.org/unsd/energy/default.htm

14 See http://www.eia.doe.gov/emeu/cabs/subafricaenv.html

15 i.e. the carbon mass in CO_2, = 12/44 of the CO_2 mass

(e.g. Nigeria) export significantly. It is also possible that fuelwood carbon (which does not add to the climate burden) is incorrectly included in African statistics for climate-change emissions, so the actual climate-change impact from Africa is even less.

Figure 1: Energy related carbon emissions from Sub-Saharan Africa. Year 2001. Taken from [6]. (Note, if the data includes traditional fuelwood, then the climate-change impact is even less than implied).



The EIA **(EIA, 2000)** quotes the World Bank's estimate that African oil and gas extraction plant continuously flares gas as waste; this wasted energy is equivalent to twelve times the energy that the continent is using. This flaring releases carbon dioxide directly into the atmosphere without any benefit. Utilizing the otherwise waste gas seems an obvious development, but this may not be beneficial in the long-term if distracting from truly sustainable and renewable resources.

Energy Intensity

A crude measurement of energy efficiency at national scale is *Energy Intensity*. Energy Intensity (E) is the ratio of national energy supply (energy units) to national GNP (money units). As an indicator of economic success and sustainability, *E should decrease with time, whilst GNP increases.* If energy supply is expensive and use of energy is inefficient, then E is likely to increase with time, even if GNP increases. Since initial improvements in energy efficiency are relatively cheap, E is more likely to decrease by improved efficiency of end-use than by strategies to increase supply. Obviously improving the efficiencies of both supply and end-use is the best strategy; however, the methods required for each are considerably different.

The greatest benefit of measuring national Energy Intensity (E) comes from the changes with time of E for each country. Comparisons between countries are not easy to interpret, since lifestyles, economic structures, energy resources and industries vary considerably. However, over the last 25 years, it is evident that only the industrialized countries have consistently reduced national energy intensity whilst increasing GNP. This indicates that only these countries that have addressed energy efficiency as a long-term national issue; see Box 1.

Box 1: Energy Intensity: E

Considerable information is available from the Energy Information Administration of the Department of Energy, USA (see http://www.eia.doe.ov/pub/international/iealf). Information below is from this source. The unit used is Btu (=1056 Joule) per $US (year 2000) of purchasing power.

1. *Industrialized and OECD countries* now have E in the range of 14,000 (Canada), 9,300(USA) to 7,000 (European). For most of these countries, E has reduced steadily during the last 20 years by about 20 per cent, i.e. at about 1 per cent per year.

2. The *oil producing countries* have E in the range of about 30,000 to 50,000. For some of these countries, values tended to peak around 1990 and then decrease. However, the overall impression is that E remains large without steady reduction.

3. *Sub-Saharan African countries without fossil-fuel resources* have E about 2,000 (e.g. the Gambia) to 4,000 (e.g. Kenya). Some countries have increased E with time, others have decreased, and for most there is no consistent pattern.

4. *Sub-Saharan African countries with fossil-fuel resources* have E in the range of 12,000 (South Africa) to 2,500 (e.g. the Sudan). Some countries have increased E with time, others have decreased, and for most there is no consistent pattern.

source: (EIA, 2000)

Carbon intensity

Carbon intensity (strictly fossil-carbon intensity) is defined in a similar manner to Energy Intensity, as the national carbon (or carbon dioxide) emissions per unit of GNP. The EIA **(EIA, 2000)** is a comprehensive source of such information. Note that the ratio of the mass of carbon per mass of carbon dioxide is 12/22. Table 1 gives data in units of metric tones per million US$ (dollar value normalized to year 2000); unfortunately 'fossil-carbon' from coal is not distinguished from 'biotic-carbon' from fuelwood; this distinction is important for statistics for Africa. If carbon intensity is a measure of responsibility for abating climate change, then having large values is irresponsible and having small values is responsible. By this criteria Africa does well. However, values that are decreasing with time may also indicate climate-change responsibility, in which case Africa is not doing so well. The implication is that development in Africa is not introducing clean technology and improved energy efficiency.

Table 1: Carbon (dioxide) intensity **(EIA, 2000)**

Region	**CO_2 intensity 1990** tonne per million US $ (value, year 2000)	**CO_2 intensity 2003** tonne per million US $ (value, year 2000)
Africa	444	441
Europe	510	396
USA	701	562

The crux of the matter for Africa is that energy supplies are in practice limited and very expensive in proportion to available income. It makes sense to improve the energy efficiency, so costs reduce and productivity increases.

As with all regions, Africa has both good and bad energy management. An outstandingly good example in principle is the *sugar cane industry*, which is capable of being self-heated and self-electrified by waste bagasse combustion. Important by-products can be produced, including bio-ethanol for transport fuel. Another example is *traditional housing*, which is usually passively insulated and ventilated in contrast with much modern construction that requires substantial electricity for cooling and ventilation. Throughout Africa, *vehicle transportation* is often inefficient per vehicle because of poor roads, poor maintenance and lack of railways, but may be considered efficient per passenger because of crowded use.

Most African electricity supply utilities have been government owned and operated. Cities and towns have been the priority for grid supplies and the allocation of generating capacity. As in all countries, providing grid electricity to dispersed rural population is expensive, technically inefficient and with little return on expenditure. To date, no sub-Saharan African country has managed to provide a grid to reach a significant majority of the rural population. In cities, increasing demand for air conditioning (usually for uninsulated and unshaded buildings) is sapping generating capacity, often with the threat of black-outs. Facing all these challenges, improvement strategies could include initiating one or more of:

- unbundling;
- management contracts to private companies;
- corporations (government owned companies);
- accepting power from Independent Power Producers (IPPs);
- sale of infrastructure to independent private companies; and
- major amendment to energy law, e.g. Electricity Acts.

Several African countries have legislated for such change towards greater liberalization of energy supply, especially of electricity, and usually within a continuing structure of government ownership[16]. However, the experience to-date has not always been straightforward, see Chapter three. In general there is a lack of comprehensive and integrated legislation for infrastructure development of energy supply and use, and lack of total jurisdiction by an independent national Regulator. There is pressure from the World Bank and other international agencies to progress to liberalization of public services, as for instance the Bank's support of the African Forum of Utility Regulators (AFUR)[17].

There is of course a fundamental difficulty in pushing for private business, yet expecting social service to continue to the poor. Business expects profit, which is least likely from poor customers. Therefore, the very people most in need of support may be of little interest to private companies. Such unfortunate experiences have been known for water supply in Tanzania, Brazil, and the USA, and for electricity supply in the UK. Thus, the terms of liberalization of utility services must be carefully drafted to protect supply at affordable tariffs to the very poor; for instance, initial supplies can cheap, with the unit price increasing in proportion to the quantity consumed. Prepayment metering is also a common stratagem.

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16 Module 4 of ref 1 gives an excellent summary of mid - 2006.

17 See www1.worldbank.org/afur/

Particular examples of progress to the liberalization of energy supply and the establishment of regulation in Africa can be given. Further details are in **(UNIDO, 2007a)** and in the information given below.

4. Renewable energy

4.1 Policies

Renewable energy supplies are obtained from natural, repetitive and persistent flows of energy occurring in the immediate environment **(Twidell et al., 2006)**. Obvious examples are solar (sunshine), hydro and biomass energy. Two general benefits are immediately apparent; the energy is intrinsically sustainable[18] and without fossil-carbon emissions. Such sustainable development is an obvious need for all countries **(Dirk et al., 2006)**. Throughout Africa there is considerable experience of fuelwood as renewable energy, there is large and well-established hydropower capacity across the continent and geothermal power generation is established in the Rift Valley of Kenya. To such 'established' energy supplies, many 'new' technologies have been commercialized worldwide in the last 30 years; examples include wind turbine electricity, solar photovoltaic electricity, small hydro plant, and a wide range of secondary biofuels. Especially in North Africa, there is considerable expectation of relatively large scale generation of electricity from solar photovoltaic.. Nevertheless, to date in Africa, most experience of the new renewables relates to small-scale installations, especially for stand-alone rural electricity. The potential is very large, but there are few African countries with comprehensive legislation to link liberalization of national utilities with increase of renewable energy from local and national resources. In many countries, there are no national targets specifically to increase renewable energy.

The somewhat tentative steps towards modern renewable energy in Africa contrast with policy change in OECD and EU countries, where renewables are of mainstream interest and often included within strategies to regulate liberalized energy supplies. It seems clear that the Kyoto Protocol commitments and pressures on the industrial countries have spurred these countries to increase renewable energy supplies to mitigate climate change emissions, especially from fossil-carbon. The inference is that in the OECD and EU, the opportunity has been taken to link the liberalization energy supply with policies for sustainable development[19]. Such policies combine the aims of greater energy security, protection from fossil-fuel price increase and reductions in fossil-carbon emissions. For instance, in the UK, the electricity and gas Regulatory office (Ofgem) manages the Renewable Energy Certificate mechanism for a steady increase in electricity supply from renewables. Such policy overlap is yet uncommon in Africa, although there are clear examples of such preliminary actions in some counties, as outlined in Table 2.

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[18] i.e. if human action allows the 'natural' processes to continue.

[19] Despite the failure of the Federal Government of the USA to ratify commitments under the Kyoto Protocol, there has been significant positive action within States of the USA.

Table 2: Case Study examples of integrated liberalization and sustainability initiatives in Africa, taken from **(UNIDO, 2007a)**.

Country	Regulatory Board/Act	Renewables policy	Mechanism Class
Ghana	Energy Foundation (from 1997)	Information and promotion.	-
Ghana	Electricity Commission Act 1997	Grants for renewables, especially rural electrification	4
Kenya	Electricity Act (1997)	Geothermal power	
Mauritius	Sugar Industry Efficiency Act (1991)	Exported electricity from sugar mills	1
Uganda	Republic of Uganda Act 1999, sect 66	Grants and subsidies for renewables from a 'rural electrification fund'	4
Zambia	Energy Regulation Board (from 1997)	Zero-rated license fees	4

There is now significant experience worldwide, especially in the EU, of various policy mechanisms to increase renewable energy supplies. **(Mallon, 2006)**. Thus, private industry benefits from installing and managing new technology, governments benefit from not having to fund new investment and the public benefits from the environmental and sustainability improvements. The cost to consumers needs to be regulated either directly within government or via an empowered Regulator.

The four main classes of mechanism to increase renewable energy generating capacity and supplies as enforced (obligated) by state or federal governments are:

1. *'Feed laws'*, i.e. favourable obligated fixed-rate tariffs for generators to sell renewable energy (usually as electricity) to networks. The purchasing 'suppliers' are therefore obligated to buy at the special tariff rate and are allowed to fund the extra cost from a relatively small levy on all their consumers;

2. *'Quotas'* of renewable energy, by amount or proportion, e.g. as obligated for electricity suppliers and perhaps assisted by a market in 'green certificates'. In the USA, this class is named the 'Renewables Portfolio Standard' – RPS;

3. '*Competitive Tendering*' for government contracts for generation; usually linked with obligations on suppliers to purchase the renewables electricity at a premium price and pass the cost to consumers as a levy; and

4. '*Financial incentives*' e.g. tax and fee exemptions and/or grants.

Specific 'Power Purchase Agreements (PPA)' may be contracted between utilities and private generators for usually long-term (10 to 15 year) periods with set tariffs; such agreements are a form of feed-law, but, without general application, they do not encourage widespread business. Successful examples relate to small-scale hydropower in Sri Lanka and Nepal **(UNIDO, 2007a)**.

A major task in Africa is the provision of electricity to *rural communities* distant from a utility network grid. Traditionally, this was considered a task for either the nationalized utility (with an 'in house' subsidy from government finance) or a private enterprise, working separately from the nationalized utility and probably with a different ministry and a N.G.O., often with financial subsidy from international aid. The technology required is an appropriate form of stand-alone power, often with renewable energy generation. Having a national policy for energy liberalization requires distinct legislation, in which case the opportunity can be taken to include innovative policy for rural electricity as an aspect of liberalization. For instance, there may be special benefits and tariffs to encourage community-owned stand-alone mini-grids. Another opportunity is to include both generation and energy-efficiency as activities for Energy Service Companies, e.g. for individual solar-homes[20], where best use of home generation requires efficient consumption.

An excellent example of integrating renewable energy generation into a national utility service is available from Mauritius **(UNIDO, 2007a)**. This demonstrates several mechanisms: (1) liberalization of a nationalized utility, (2) purchase of power from an Independent Power Producer, (3) tariffs set to motivate private power exports, (4) more secure national sustainability and (5) support for local employment with internal national cash flow.

4.2 Renewable Energy Technologies

Energy supply is best understood as being needed for heating, transportation fuel and electricity. Within each category, a range of renewable energy technologies has become reliable and cost effective; these 'new' technologies are now accepted for successful business and industry. Examples are:

- ***Heating*:** solar water heaters, passive solar building design (also incorporating cooling), biomass crops and waste, biogas, geothermal sources, heat pumps;
- ***Transportation fuel:*** ethanol (e.g. from sugar cane processing) for spark ignition engines, biodiesel (e.g. for diesel compression engines from sunflower, canola, coconut);
- ***Electricity:*** solar photovoltaic, wind, hydro (including run-of-the-river), geothermal, biomass thermal generation, biofuel engine generators.

The growth of renewable energy business is now substantial worldwide. Such growth is predominantly in those countries having governmental market support mechanisms and accreditation procedures and standards. It is particularly noticeable how small companies, often founded by committed entrepreneurs, have become major players, e.g. the Danish wind energy companies such as Vestas. As the market opportunities have increased, so has the interest of major companies, e.g. General Electric, which often enter the market by buying successful smaller companies. The market is strong, not only for companies providing technology for 'prime sources', but also in companies providing infrastructure, e.g. 'Sunny Boy' (electricity inverters from Germany) and 'Renewable Energy Supplies – RES' (windfarm developers from the UK).

With institutional support for market incentives, there are major opportunities in Africa for new companies and agencies dealing in renewable energy. For instance, there is now a worldwide trend for govern-

20 Buildings with electricity generated from photovoltaic modules with battery storage.

ments to have mandatory proportions of biofuels as a component of all transportation fuels. An example is given in Box 2. There is an established history of some African countries, e.g. Malawi, including ~ 10 per cent bioethanol with fossil-petroleum, so the technology and practice is certainly not new. However, it is only recently that governments have included environmental reasons for adopting the policy and have included natural plant oils as components of diesel fuel.

Box 2: **South African biofuel programme**

In February 2007[21], the South African Cabinet adopted a strategy for mandatory biofuel components of both petroleum (for spark ignition engines) and diesel (for diesel cycle engines). The strategy, to become law in 2007, is for:

- Mandatory proportions of 8 per cent bioethanol (E8) in petroleum and 2% biodiesel (B2) in diesel;
- 100 per cent fuel-levy exemption on initial biodiesel production;
- 100 per cent fuel-levy exemption for small producers of bioethanol;
- reduced fuel-levy on other biofuel production;
- use of a central hedging fund to maintain steady prices for biofuel crops;
- encouragement for government agencies to support biofuel initiatives.

The bioethanol is expected to be from fermentation of molasses as a by-product of the sugar cane industry and from fermentation of yellow maize. Biodiesel will be from oil producing plants, such as palm oil and jatropha. The production will create new agribusiness.

South African synthetic fuels company, Sasol, which pioneered the use of petrol and diesel from coal and natural gas in a joint effort with the government's Central Energy Fund, will build a biodiesel production plant based on soya beans.

The benefits of the government's plans are:

- diversification in agriculture;
- utilizing and transforming the countries expertise in producing oil from coal;
- 55,000 new jobs, mostly rural;
- reduction in national unemployment by 1.3 per cent;
- increase in GNP by 0.12 per cent (6 per cent of the rural fraction of GNP);
- reduction of imported oil, improving balance of payments by nearly 4 billion Rand per year;
- meeting 75 per cent of the national renewable energy target of 10,000 GWh/year by 2013; and
- reducing fossil-carbon emissions to support the South African Kyoto target.

(**Source:** South African agency 'Engineering News, 02/2007)

4.3 Know-how and standards

Renewable energy policies and markets are only successful if underpinned by substantial effort in *training personnel and setting technical standards*. The present success of renewable energy in Europe has occurred after 25 years of sustained support in research, development, demonstration and education by

[21] Information from the South African agency 'Engineering News', http://www.engineeringnews.co.za (accessed 27/2/07)

the European Commission. Without such background support, countless renewable energy projects have foundered due to public misunderstanding, poor design, unsatisfactory installation, lack of maintenance, lack of spare parts and consumer misunderstanding. Only governments, working with interest groups and trade associations, can give the comprehensive support needed to initiate and maintain such new technologies. Nevertheless, without an ongoing market, such efforts will be in vain. A successful market depends on well-defined Government incentives for renewable energy and energy efficiency, so that business and investment banks are confident of sustained market conditions and income for many years ahead.

4.4 Implementation

The positive implementation of new renewable energy technologies within liberalized markets in the national grids of OECD countries contrasts with Africa. Many African countries have involved private companies in management and ownership of plant, e.g. as Independent Power Producers (IPP), but almost exclusively such plant is powered by fossil fuel and not renewable energy. An exception is geothermal plant in Kenya. The reason is that both the governments and the private companies have short-term aims, for example to meet a power crisis and to repay invested capital rapidly. There may be no immediate financial benefit in reducing emissions or favoring sustainability. An IPP will initiate improved energy efficient generation, but only if this is cost effect for the company. Without some other financial mechanism, the relatively large initial capital cost of renewables generation excludes such technology.

The use of renewable energy in Africa is usually supported by governments for rural development, especially for electricity **(Ranganathan, 1992)**. There are many thousands of successful installations, mostly solar homes but also including local networks. Such applications often feature in energy legislation. The motivation is mostly for immediate benefit, despite the implications for long-term sustainability.

Reduction in carbon emissions has not been a primary reason for introducing renewables in Africa. However, such environmental reasons are seen as increasingly important **(Foster-Pedley et al., 2006)**, often associated with the conditions for funding. For instance, major multilateral funds and mechanisms exist for offsetting carbon emissions in industrial countries, such as the Global Environmental Facility (GEF)[22].

Similarly the Clean Development Mechanism (CDM) allows the developed signatory countries of the Kyoto Protocol to offset excessive climate change emissions by financing clean technology in developing countries through a credit mechanism.

In practice, predominantly large-scale developments are supported, often involving efficiency improvements with fossil fuels, rather than installing renewables. Such 'carbon-dioxide equivalent verified emission' (CER) offset schemes also exist between entities in industrial countries and renewable energy programs in developing countries. Some small-scale renewables developments are being funded from money given by individuals and companies offsetting their carbon emissions by voluntary donations through dedicated offset agencies, e.g. the company 'Climate Care' in the UK[23].

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22 The GEF finances support from the World Bank, UNDP and UNEP for the aims of the UN Framework Conventions on Climate Change and Biological Diversity, and the Stockholm Convention on Persistent Organic Pollutants.

23 See http://www.climatecare.org/

5. Energy efficiency

There are many opportunities for improving the efficiency of the supply and use of energy. The interest of utilities tends to emphasize supply-side equipment and plant, so leaving demand-side efficiency improvement to other agencies. For instance, a recent study under UNIDO auspices **(Williams et al. 2005)** considers industrial electric motor systems, which consume a significant fraction of every nation's electricity supply for services (e.g. water supply, air conditioning, refrigeration), and for manufacturing processes. The study shows that technological improvements in motor drives and training in their use could reduce national electricity consumption in China by 20 per cent.

There are many other opportunities regarding heating, transport and other applications of energy supply. Not only can there be improvements in the *efficiency of supplying energy*, but there are many opportunities for improving the efficiency of the use of the energy (*end-use efficiency*). These subjects are of major importance for systems optimization and for consumer interests; yet the efficient use of energy receives far less attention than efficient supply. Nevertheless, the efficiency of supply is affected by the demand, so it may be more cost-effective for a supplier to reduce the demand by improvement of demand efficiency, than to install extra supply plant or to increase fuel consumption; this is called '*demand-side management*'. Consumers benefit most when the emphasis is placed on *energy service*; not only is cost reduced for the consumer, but the same generation benefits more people.

There are several factors affecting the efficiency of supply and use of energy. These include:

- technical improvements;
- technical standards;
- operation and maintenance;
- information exchange and communication, e.g. electronic communication and accounting;
- economic and financial improvements;
- public understanding and knowledge, e.g. through *energy labeling*, by *transparent disclosure of information;* and
- obligated Regulatory Conditions.

In general, increased efficiency improves the service from a resource without increasing the primary supply. It also makes the same supply available to more consumers, which is particularly important in many supply-limited regions of Africa. Energy efficiency maximizes the benefits of energy use whilst minimizing the impacts of generation.

The Stern Review 'The Economics of Climate Change' **(Stern, 2007)** includes an analysis of how technological transfer and emission-abatement credit funding can simultaneously improve wealth production in developing counties and give carbon-emission reductions in both the 'donor' and 'receiver' counties. The example of a Technical Needs Assessment (TNA) and its subsequent support is given for Ghana[24]. In 2003, the TNA was submitted by Ghana to the UN Framework Convention on Climate Change (UNFCCC) with a range of projects that could reduce Ghana's climate change gaseous emissions and increase sustainable development; these included:

- demand-side energy efficiency improvements, including increased boiler efficiency;
- methane gas capture and use from landfill;
- growth and use of jatropha oil as biofuel; and
- extensive deployment of compact fluorescent lamps (CFL) to replace incandescent lamps.

24 Box 23.2, page 565 of [12]

The programme in Ghana was funded by UNDP via the Global Environmental Facility (GEF), and from the United States via the Climate Technology Initiative and the Dept. of Energy, with technical support from the Renewable Energy Laboratory of the US. This donor funding promotes emission reductions in donor countries. The CFL deployment seeded an extended programme that gave a 6 per cent reduction in Ghana's national electricity demand (lighting consumed 50 per cent of electricity).

5.1 End-use efficiency improvement

Reducing resource consumption, e.g. electricity, is well understood, with much information available. However, few consumers take the task seriously. A major mistake is not to evaluate lifetime costs (purchase plus lifetime operation), but only consider purchase costs. Thus increased capital expenditure may be financially sensible if operating costs are reduced. An example regarding lighting is given in Box 3, and an analysis related to conditions in South Africa is in **(Fritz, 2006)**. This example is typical, in that simple changes in consumer purchases can make significant changes in energy efficiency and in long-term total expenditure. Other common examples of at least 50 per cent reduction in energy consumption, without reduction in service occur with building construction, refrigeration, heating, electronic equipment and vehicles. In many case, but not all, such energy saving requires increased capital expenditure, which is recouped within a few years by reduced operational cost. Many consumers tend to purchase at least cost, so, often unwittingly, committing themselves to increased operational cost and long-term expense.

Box 3. Lighting

The easiest example for average consumers to appreciate is the benefit of compact fluorescent lights compared with 'ordinary' incandescent electric lights. The simplest measure of efficiency is the ratio of the energy delivered in visible light to the electrical energy consumed. In general, the energy efficiency of an incandescent light bulb is about 4 per cent (lifetime ~1000 h), and a compact fluorescent light with an electronic starter 22 per cent (lifetime ~10,000h). The lifetime cost of a compact fluorescent (purchase plus electricity used for 10,000h) is about 80 euro <u>less</u> than the lifetime cost of 10 incandescent lights (1,000 h each) giving the same light. This is a most significant saving. This example shows how basic information should be made available to consumers, e.g. by compulsory labeling and how technical back-up is needed for optimum practice.

End-use energy efficiency is helped by:

- standards*;
- appliance labeling*;
- easily understood and widely available information*;
- government advice centers and agencies1*;
- media attention;
- inclusion in school education*;
- monitoring and feedback of results;
- professional energy management and auditing;
- annual accounting; and
- preferential taxation relief and grants*.

Source: International Association of Energy Efficient Lighting,www.iaeel.org

All these factors should induce *behavioral change*, which is essential for improving end-use efficiency. Note how aspects of government policy (marked * on the list above) can be used to support and encourage consumer response.
For commerce, there are very considerable benefits if a nation stresses the efficient use of energy. Not only can companies save on their own energy expenditures, but there is an increased market in good quality and more expensive products, which may have an increased profit margin. With a correct policy for the efficient use of energy, everyone wins – consumer, manufacturer, shopkeeper and the nation.

For improvements in energy efficiency, a major difference between energy supply and end-use is the numbers of people involved. For instance, considering just paid employees, on the supply side, we can expect about 1 employee per megawatt of supply capacity, whereas, at end-use in industry and business, employees will number 100's to 1000's per megawatt capacity. If the domestic and general public is included, then there are tens of thousands of consumers per megawatt capacity. Passing information to end-use consumers and training them in good practice is therefore a major task of national proportions. Success can only come by constant and targeted interaction with the energy users, providing them with information in attractive formats and stimulating training. An example of such a program is the UNIDO series of 'handy manuals for energy conservation', produced for employees on major energy-consuming industries, such as food processing, paper and pulp, cement and textiles **(UNIDO, 2007b)**.

5.2 Supply-side energy efficiency

The supply of commercial energy is a highly professional and technical task, which can be mirrored in the approach to improve efficiency and reduce environmental harm. Since many standards and regulations already exist, governments can amend and add to these. With a government mandate, Regulators can include energy efficiency and environmental improvement within licensing requirements.

Section 2.1 mentions technology available and experienced for improved efficiency from electricity generation. There are many other possibilities at all stages of the energy generation and supply chain. In practice, innovation and change in nationalized industries is restricted by lack of capital, lack of motivation and acceptance of the status quo 'for an easy life'. With liberalization and regulation, energy and business efficiency may be greatly improved, especially where there is competition for licensing and trading. Global trade in carbon-abatement credits should provide incentives for improved efficiency. Some examples of improved energy supply efficiency in the electricity sector are:

- combined heat and power;
- combined-cycle electricity generation;
- co-firing of coal with biomass;
- improved turbine runners in hydro plant;
- incorporating embedded generation;
- incorporating new renewables, e.g. wind and solar power;
- demand-side management (for the benefit of supply);
- astute tariff rates to balance supply and demand;
- improved distribution lines and transformers;
- balancing real and reactive power; and
- preventing theft.

In principle, any of these factors can be set as requirements for obtaining licenses in a regulated industry. Such regulatory requirements are easier to apply in industries with horizontal unbundling and hence opportunities for competition. In general, liberalization gives opportunities to readdress the balance of priorities though:

- unbundling;
- management contracts;
- corporization within public ownership;
- independent power producers; and
- full privatization of all sectors.

Most of these factors require new or revised governmental Energy Acts, into which many aspects of sustainability and improvement can be included. Almost all of these developments can be structured for industrial and commercial participation.

5.3 Matching supply to demand

To understand the role of energy in an economy, it is important to match supply to demand. There are two scientific parameters used for such matching; one relates to how much energy passes (the *extensive amount*, in units such as megajoule and kilowatt hour) and the other relates to what that energy can do (the *intensive amount*, related to the mechanical work that could theoretically be obtained from that heat source). This second parameter can be called the *quality* of the energy and relates to the service that it can provide.

For example, energy can be available in a volume of warm water, but this is a very inefficient source to power a machine[25]. Therefore, the energy in warm water may be large, but this energy is low-quality. However, the same amount of energy may be obtained from electricity, which can be almost entirely transformed into mechanical work by an electric motor. Therefore, electricity is high-quality energy. It follows that we should always consider why energy is demanded and so match the supply to the demand by quality as well as extent. In practice high-quality energy supply, such as electricity and petroleum, is expensive per unit of amount, and low-quality energy, such as fuelwood, is cheaper, so we have a financial motive for correct matching.

If these principles are brought into energy planning and policy, then a better matched and improved efficiency systems results. Examples are:

- avoid using electrical heating for domestic hot water supplies; provide such hot water from solar water heaters with back-up from boilers. (See Box 4);
- reduce electrically powered air-conditioning by having shaded and passively ventilated buildings. In dry climates, use evaporative coolers whenever possible, and not compressed fluid air-conditioners which use about 20 times more electricity per unit of cooling;
- lighting is a high-quality service, so make sure the electricity intended for lighting does not dissipate as heat, e.g. use fluorescent and not incandescent lamps, or better still, light-emitting–diodes (LED);
- encourage safe bicycling for personal transport, rather than a fuel-powered vehicle;
- avoid unnecessary standby power, i.e. continuously powered remote switching devices, by having easily operated mechanical on/off switches. In many countries, e.g. the UK, 10% of consumers' electricity is used uselessly for such standby and other needlessly connected loads.

25 For instance, as found in the trial development of Ocean Thermal Energy Conversion **(Gratwick, 2006)**

Box 4. Solar Water Heating in Addis Ababa[26]

It is common for hotels and the wealthier residents of Addis Ababa to heat their domestic hot water by electricity, which is an expensive and limited resource. (Most of the remaining population does not have hot water supply). However, a majority of the premises can be fitted with solar water heaters, costing, for a house, between about US$500 (locally made) and US$800 (imported, usually from China). Larger systems are available for hotels, hospitals etc. These solar heaters provide acceptable service throughout the year, with payback against electricity of about 6 years.

Initial local manufacture was by two charity organizations, but by 2006 there were more than 5 local manufacturing companies, with several others engaged with imports. About 10 companies supply and fit the installations. Skilled employment is provided by both manufacture and installation, and the companies are profitable.

The removal of government subsidies from electricity supplies and increased price of generating fuel, has led to an increase in the price of electricity. This in turn has increased the demand for solar water heaters. Note that the removal of a subsidy has led to greater local economic activity and greater sustainability.

It was a scientific mistake to use electricity for heating domestic water, and it was economically mistaken to subsidize that electricity. The use of solar water heaters allows: (i) electricity to be freed for high-quality services in the economy, (ii) opportunities for manufacturing and business, (iii) more local skilled employment, (iv) increased local cash flow from employment and profit, and, (v) less carbon and other emissions from marginal electricity generation. Nevertheless, only about 10 per cent of the population of this capital city can afford the initial capital cost of a solar water heater, therefore institutional support by way of grants and small loans would benefit others. In addition, it is essential that government agencies and trade associations produce technical standards for the manufacture and installation of the solar devices, as indeed for electricity supplies.

26 [1. Module 16, Case Study]

5.4 Further initiatives

Governments alone cannot produce sustainable development; they must be supported by the public sector. Success is most likely when corporate bodies begin to change their own perception of environmental responsibility, whilst at the same time improving their business. Some outstanding examples of good practice are being claimed in Africa, with many related to agricultural industries. Box 5 gives an example.

Box 5: Corporate sustainable development

Unilever has major interests in sustainable tea growth and production **(Unilever, 2003)**. Energy use relates to electricity for machines and heat for drying. The company and its subsidiaries are prominent in explaining the need to generate their own electricity on tea estates, e.g. hydropower as in Kenya, and their own heat from local sustainable tree plantations, e.g. with a balance of maintaining natural forest and sustaining plantations of Eucalyptus. Many improvements can be made in the drying processes, which results in less wood burnt. The public declaration of such aims to its shareholders is seen as giving authority and responsibility to the company.

Development funding and government regulation can play a significant role for improving energy efficiency in an economy. Such initiatives are beginning to be taken in Europe, especially when directed by the European Commission and other European-wide initiatives. The EBRD funds development programs in the recently independent countries of Eastern Europe (the transition countries)[27]. The Bank has a successful method to increase energy efficiency as it finances industrial, small and medium scale enterprises (SME), municipal infrastructure and power sector projects. Central to the policy is a core team that vets and assesses energy efficiency in all applications. Typical projects have been in district heating (not an African problem), public transport and traffic management. The Bank has special energy funds within the Sustainable Energy Initiative and the Multilateral Carbon Credit Fund. Development funding for and within Africa has always had poverty alleviation and economic growth as the main objectives; energy efficiency has not been specified explicitly as an overriding objective. However, if the example of the ERBD is followed, then this general policy will change. If capital costs are alleviated, then the efficient supply and use of energy reduces energy payments, therefore generally reducing poverty, and frees money for other initiatives, therefore generally contributing to economic growth. The introduction of policies to reduce pollutant emissions from fossil fuels adds to the importance of energy efficiency.

[27] See Box 23.4 of [12]

6. Policy implications

Policy for innovation in energy supply and use is now affected by 3 main drivers:

1. Liberalization
2. Regulation
3. Sustainability

This chapter has considered how two key factors in energy supply, Renewable Energy and Energy Efficiency, relate to these drivers and how progressive industry and business can participate. It is noticeable that all 3 drivers gelled into discernable policy objectives for many governments from about 1985, being made statutory objectives from about 1990. The desire for liberalized, and therefore identifiable and often competitive, services led naturally to more sophisticated and independent regulation; therefore, these two drivers are closely linked. However, including sustainability objectives with liberalization and regulation is not an obvious development.

On the supply side, fossil-fuels are not ultimately sustainable, their sources are not secure for importing nations, often they are expensive and their emissions, especially carbon dioxide, need to be limited to mitigate climate change. Consequently, there is now a bias for improved efficiency and for renewable energy resources, which are infinite, derive from national and local resources, have technologies that are becoming mainstream with a trend to reducing cost, and do not cause climate change. *On the demand side*, greater efficiency in the use of energy reduces the pressure for supply and is financially beneficial for consumers.

For a government moving to liberalization of utility services and conscious of sustainability objectives, it makes sense to use the regulatory authorities to promote renewable energy and energy efficiency, alongside their responsibilities for regulation generally. Thus, there are good reasons why liberalization, regulation and sustainability are closely linked.

National energy supplies can be classified as for fuels, heat and electricity. In all countries, electricity supply is closely related to the provision of essential services and has the characteristics of a natural monopoly, including supply from a grid. Therefore, governments have been closely involved in the development and ownership of the electricity utility service. Such strong government presence is not so apparent in the provision of fuels and heat, yet nevertheless governments are closely involved. As the utility services have matured, governments have seen the advantage in disassociating themselves from hands-on operation; for instance raising capital can be moved from taxation to private investment and pressures to subsidize services are reduced. In addition, the electorate does not immediately blame governments for failures of supply!

Most developing countries do not have the business and investment infrastructure to move immediately to fully privatized utilities, despite pressure from international agencies, such as the World Bank, for this. Nor are they directly part of international policies and treaties for the mitigation of climate change. Therefore, the movement to liberalization, regulation and sustainability may appear somewhat tentative. However, such judgment is hasty, since there are fewer opportunities than in the 'intensive' countries for unbundling of services and the provision of services, e.g. electricity, to the whole population is far from complete. Such developments in Africa must not be driven by dogma, but by careful preparation and experience; thorough legislation, to both support and regulate competitive industry, is essential.

It is into this situation that opportunities appear for increased use of new renewable energy resources and for much improved energy efficiency. The technologies of renewable energy and energy efficiency are now well established. The scale and diverse use of the equipment are appropriate for installation and management by individual companies and cooperatives; hence, the field is open for national industrial and business growth. Regulatory administrations exist for transparency and fair market competition, so there is a sympathetic ear to the needs of commerce.

It is misleading to see the liberalization and regulation of utility services as the cold hand of legalistic dogma. Beneath the surface, radical change can occur to benefit both consumers and business alike. With the inclusion of renewable energy and energy efficiency, there are open opportunities for national and local scale enterprise.

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the original version of this publication had graphics on the front page, and at the beginning of each chapter. That version was 10.6 mb. The graphics have been removed for this online version to bring down the size to 1.3mb.

Chapter 2

Environment, Energy and Cities: Issues, Problems and Strategic Options for Urban Settlements of the Developing World

By
UN-Habitat

1. Introduction

As the world has moved into the 21st century, energy-related challenges have already grown quite severe in cities throughout the world and in countries at all levels of development. From all corners of the globe, city residents are exposed to unhealthy levels of energy-generated pollution. Urban emissions are also having negative regional development impacts, reducing crop yields and forest integrity in wide areas across North America, Europe and Eastern Asia. Furthermore, the greenhouse gas emissions generated in the course of providing power to the world's cities are contributing significantly to the problem of global climate change.

At the same time that the negative environmental impacts of urban energy consumption are manifesting themselves on local, regional and global levels, the demand for energy continues to grow. This relentless growth in demand for modern energy resources is understandable in cities throughout the developing world, where per capita consumption rates still remain comparatively low. Unfortunately, the environmental externalities generated by conventional energy systems are eroding the health and productivity of citizens in many developing country cities, and so new paths towards more efficient and sustainable patterns of energy consumption must be pursued in these areas.

It has been estimated that about three-quarters of the world's commercial energy is consumed in cities. More specifically, over 75 per cent of carbon emissions from fossil fuel burning and cement manufacturing, and 76 per cent of industrial wood consumption, occur in urban areas. A primary function of the world energy system is to provide urban settlements with massive quantities of electricity, petrol and heat for use in commercial, transport and residential sectors (World Energy Assessment, UNDP, 2000).

Urban societies in developing countries are dual in nature: in some segments of the society, incomes are quite high, and their energy-consumption patterns are similar to those of industrialized countries, with increasing demand for high-intensity energy-consuming services, such as refrigeration, air-conditioning and personal transport. For the remaining segments of society, which constitute the overwhelming majority of the population, consumption patterns are similar to those in rural areas. Indeed, almost a billion urban residents live in informal settlements in developing country cities in conditions identical to or is some cases worse than their rural poor counterparts.

Energy is a key input for meeting basic needs and for achieving socio-economic development goals that include, inter-alia, fuel for cooking, heating and lighting in households, power for industry, and petroleum products for transportation. The supply of and the demand for virtually every type of energy generates varying degrees of environmental externalities that affect human health, ecological stability and economic development. These effects can occur at the household, local, regional, national or transnational level.

There are approximately two billion people, who lack access to electricity, and a further two billion depend on traditional fuels, such as wood and animal and crop waste, for cooking and heating. In Africa, two thirds of the population does not have access to electricity. Over a billion of these reside in informal settlements within developing country cities. For one-third of the world's population, dependence on traditional fuels results in a significant number of hours being spent each day gathering wood, primarily by girl children and women, even in urban areas**.** In part due to poor infrastructure and prohibitively high up-front costs, the poor often face much higher energy costs than the non-poor. This is compounded by the limited access to appropriate financing schemes that can allow the poor to overcome the high-up front costs of cleaner energy devices and appliances. Other important energy challenges facing the poor, include low incomes that are not sufficient for the procurement of energy services to meet basic needs such as sufficient energy to cook food, provide affordable transport, power pumps for potable water; sterilize medical equipment; and, provide space heating.

Cities, with their high population densities, tend to concentrate environmental problems that elsewhere, are otherwise geographically dispersed. A classic example of this is air pollution in cities where both point (e.g. industrial emissions from smokestacks) and nonpoint (e.g., vehicle exhaust) sources are concentrated in a limited, densely populated geographic area. The degree of the problem varies with prevailing winds and thermal stratification patterns, urban geography, levels of industrialization and motorization, and the incidence of indoor as well as outdoor human exposure. It is important to note that the cause of many of these problems may be urban but the impact can be felt both inside and outside the city. In addition, ambient air pollution may affect the health of urban residents and damage the crops of farmers in rural areas.

2. United Nations mandates for work in energy

Access to affordable, modern energy services is a pre-requisite for sustainable development and poverty alleviation, and, more specifically, for achieving each of the Millennium Development Goals (MDGs). Lack of access to reliable, safe and mostly environmentally –friendly energy is a strong constraint on human development. Energy services can play a variety of direct and indirect roles to help achieve MDGs: Access to energy facilitates economic development- *access to energy means that value-adding income generating activities are enhanced. Micro-enterprise/livelihood activities can be extended beyond daylight hours, creating additional employment opportunities. Access to energy assists in bridging the digital divide.*

- Access to energy reduces hunger and improves access to safe drinking water – *energy services can improve access to safe drinking water through pumping facilities.*
- Access to energy reduces disease and reduces child mortality – *energy is a key component of a functioning health system, through refrigerating medicines, sterilizing equipment and providing transport to clinics*
- To achieve universal primary education and the empowerment of women – *energy reduces the time spent by women and children on basic survival activities (fetching water, firewood, cooking etc); lighting permits improved levels of home study for children.*
- More efficient use of energy promotes environmental sustainability – *improved energy efficiency and use of cleaner alternative forms of energy helps to achieve a more sustainable use of natural resources and reduces harmful emissions.*

- Access to energy for affordable transport enhances urban mobility – *improved urban mobility allows better access to wider employment and other economic opportunities within the city.*

The World Summit on Sustainable Development (WSSD**),** building on the outcome of the Ninth Session of the Commission on Sustainable Development (CSD9), identified the following five key areas as critical to achieving the goal of energy for sustainable development:

- Increasing access to energy services, particularly for the poor;
- Improving energy efficiency;
- Increasing the proportion of energy obtained from renewable energy sources;
- Advanced energy technologies; and
- Reducing the environmental impact of transport.

Paragraph 145 of the Habitat Agenda states: The use of energy is essential in urban centers for transportation, industrial production, and household and office activities. Current dependence in most urban centres on non-renewable energy sources can lead to climate change, air pollution and consequent environmental and human health problems, and may represent a serious threat to sustainable development. Sustainable energy production and use can be enhanced by encouraging energy efficiency, by such means as pricing policies, fuel switching, alternative energy, mass transit and public awareness. Human settlements and energy policies should be actively coordinated.

The United Nations (UN) General Assembly reiterated in its 56th session (2001) that mutually supportive efforts at the national and international levels are imperative in the pursuit of sustainable development, which includes the provision of financial resources and the transfer of technology for the application of cost-effective energy and the wider use of environment-friendly, renewable energy technologies.

Under the UN Framework Convention on Climate Change, parties have agreed to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. As the global energy system is the major source of greenhouse gases, this commitment will have to be considered in the design of the future world energy system. The Kyoto Protocol provides a first specific step in addressing the issue, building on the principle of common but differentiated responsibilities.

Progress is being made in forging the necessary will to tackle the energy problem at the appropriate levels. In April 2006, for example, the Fourteenth Session of the UN Commission on Sustainable Development (CSD-14) highlighted the value of networking amongst centers of excellence in the area of access to energy services so that these could support and promote efforts at capacity-building and technology transfer activities, as well as serve as information clearing houses. The Commission agreed that lack of local capacity is a major obstacle to expanding energy services in the developing world, stating 'it is important that institutions, infrastructures, and human resources in developing countries be strengthened … through international public and private cooperation that supports sustainable development objectives.' CSD-14 also remarked that 'information and knowledge sharing on technologies and policies facilitate efforts to achieve energy for sustainable development', and that 'relevant information could direct decision makers to suitable policy and energy supply options'. The lack of such information and knowledge sharing was recognized as a barrier preventing countries from adopting new approaches in energy planning and technology applications.

The Fifteenth Session of the Commission for Sustainable Development (CSD-15) which will take place 30 April to 12 May, 2007, is a unique opportunity to focus the world's attention on the energy needs of the worlds urban poor, particularly those residing in informal settlements. UN-Habitat must build on the momentum created for enhancing access to clean, modern energy services by the urban poor residing in informal settlements – momentum which has been created from our participation at CSD-14. No other UN organization dealing in the area of energy for sustainable development has the particular mandate to specifically deal with the energy needs of the urban poor.

3. Historical patterns of energy production and consumption in cities

Historically, cities throughout the world have been arenas of tremendous economic and social development. The higher densities of people and material resources found in urban areas allow significant gains in productivity to be achieved, while reducing human impacts on natural ecosystems. These higher densities also make it easier to provide basic services to citizens, and as a result urban areas also have the potential to offer better health, education, sanitation and electrical services than are found in most rural areas. From both a human development and environmental point of view, therefore, it makes eminent sense to encourage the continued growth of high-density population centres — provided underlying developmental problems can be addressed.

However, urban structures affect energy requirements and consumption patterns in many distinct ways. Low-income rural-migrant populations, generally used to relatively easy access to non-commercial fuels in their villages, find it hard to secure such fuels when they migrate to cities and are often forced to buy commercial fuels for the very first time and at great expense.

Traditional food processing and cooking are too time-consuming for most women who have to seek paid work to earn the money necessary to purchase essentials: thus, an increasingly important activity in burgeoning urban agglomerations is the street sale of foods – often utilizing highly energy inefficient cooking appliances.

As a whole, global reliance on hydrocarbon resources has increased exponentially throughout the modern era. Today, coal, oil and natural gas resources combined provide approximately 90 per cent of all world commercial energy requirements. The non-hydrocarbon industries of nuclear energy and large-scale hydroelectric power together provide most of the remaining 10 per cent. All alternative energy technologies combined (small hydro, geothermal, wind, solar, tidal) currently provide less than 1 per cent of the world's commercial energy; a sobering statistic for those concerned about the environmental sustainability of modern urban society.

4. The structure of urban energy use

Household energy

Energy is used in buildings for cooking, space heating/cooling and lighting, and also for productive activities. The patterns of energy use within buildings vary a great deal according to use and location. In residential buildings, household income and climate have major influences both on energy sources and end-use patterns. In most low-income countries, a high proportion (up to 90 per cent) of the energy used in residential building is for cooking. In poor urban communities, firewood alone often meets nearly all the energy needs of households. In areas where there is a substantial annual heating requirement, coal is often used, the combustion of which adds considerably to urban air pollution. Available information on how households use energy is scarce and as a result, it is difficult to assess scientifically efficiency progress in the past and to understand how efficiency increases could affect future demand. Even where data is available on the energy use of the sector, the economic impact of household energy conservation cannot be assessed, except in very general terms. Without such information, it is difficult for governments to prioritize conservation programmes or allocate programme funds to those areas that promise the greatest return.

Embodied energy in buildings

The construction industry in the developing economies is facing an immense and apparently worsening problem of required materials shortage aggravated by rising prices. In most countries, frequent shortages have often led to further increases in prices and profiteering, thus marginalizing more and more people beyond the affordability level. The consequent impacts are severe: skyrocketing housing costs and expanding unplanned settlements in urban areas, and an ever-deteriorating housing quality in both urban and rural settlements. Public policy and private investment should, together, facilitate an adequate supply of cost-effective building materials, construction technology and bridging finance to avoid the bottlenecks and distortions that inhibit the development of local and national economies. By improving the quality and reducing the cost of production, housing and other structures will last longer, be better protected against disasters, and be affordable to low-income populations and accessible to persons with disabilities, which will provide a better living environment.

Businesses promote more and more the use of innovative composite materials based on local resources from forestry, agriculture, natural fibres, plant materials, and other local resources like agricultural and industrial wastes available within small geographical regions. Besides meeting the needs of housing sector, the industrial production of the composite materials would greatly help in environmental protection, energy efficiency and employment generation in the manufacturing sector.
While the largest component part of energy consumption in the household and building sectors are consumption from within buildings-in-use, the energy used in the production of buildings themselves is a significant and a growing element of this total energy use. There are proven reasons for seeking to reduce the energy "embodied" in buildings, which are mainly because of environmental considerations. In general, the energy consumption in the production of buildings is a relatively small part of the total lifetime energy use, perhaps 10 to 15 per cent, if a lifetime of about 25 years is assumed. But much of this lifetime energy use, particularly in developing countries, is in the form of cooking energy, over which the initial design of buildings has little effect. The high proportion of the embodied energy in buildings (80-90 per cent) is related to the production and transportation of energy-intensive building materials such as cement, steel, bricks, concrete-elements, aluminium etc. Increasing the efficiency, of energy use in building-materials production is, therefore, an essential prerequisite to reduce the cost of materials and to arrest environmental impacts caused by excessive use of energy in the production process. Some strategies to optimize the use of energy in the building materials production process include: careful study and auditing of all kiln processes; use of low-grade fuels where possible, use of recycled materials; reduction of transportation costs by expanding the small-scale sector; use of locally available and indigenous building materials; use of solar energy or waste kiln heat in low-temperature operation, etc. (See Box 1).

Box 1: ADAPT, Egypt

Between 1966 and 1986, 80 percent of the housing built in Egypt was shanty housing built by local masons or the residents themselves. The "slum upgrading" market is thus a significant center of demand for quality construction materials and techniques. ADAPT is working with low income communities to meet this demand in a sustainable way. The organization uses local ingredients common to the ancient Egyptians, along with treated waste products like rice straw, cement dust, and iron-fabric leftovers to produce environmentally-friendly building materials that are high quality (certified by the Egyptian government) and low cost (30 percent below standard alternatives). ADAPT involves local youth in the material innovation and production processes and trains them in design and construction—for example, using the traditional Kasbah layout with small alleys for women, central courtyards, and double walls and ceilings to make indoor spaces cooler. These youth then act as catalysts, spreading their skills in their communities. Two of ADAPT's early settlements in Algeria, totaling 220 units in 1985, have expanded to more than 20,000 units through this mechanism.

Source: UN-Habitat, Global Report on Human Settlements, 2003

Renewable energy technologies for human settlements development

The field of Renewable Energy Technology (RET), involving the use of sun, wind, hydro and biomass is broad, complex, multidisciplinary and impossible to generalize. At the present state of development, renewable sources of energy play a limited role globally but could play an important role locally, particularly within informal settlements in developing country cities. A general elaboration of the "state-of-the-art" of renewable energy provision is also complicated by the fact that some technologies are mass-produced and widely used on a small-scale but remain at an early and experimental stage for large scale applications. This is primarily because the cost-effectiveness and hence the commercial viability of different energy conversion technologies is strongly influenced by the scale of operation. It is well known that economies of scale apply to larger systems, but the variation of economy of scale with size differs considerably for different technologies. Hence, some technologies become much more economical when scaled up but others (like solar photo-voltaic) do not offer similar variations with size and, therefore, tend to be most economically competitive initially for the smallest applications.

Currently, the most viable option for meeting the energy needs of the majority of urban poor in developing country cities is the rational use of modern biomass. To this end, conversion of biomass into gas, through the use of digesters, and use of improved and more energy-efficient cookstoves are the most effective ways of using this resource. The technologies of photovoltaic systems offer prospects for meeting the lighting, telecommunications, refrigeration and other power needs of the rural poor in a cost-effective and efficient manner in areas that are remote from national electricity grids. For households in urban areas, the use of low-power energy-efficient appliances and the judicious substitution of cost-effective new technologies for fossil fuels such as solar water-heaters and other space-heating and cooling devices, offer opportunities to reduce the cost of energy services, whilst, at the same time, conserving resources.

An important constraint faced by most developing countries is that renewable-energy technologies designed and developed in industrialized countries are often not compatible with the levels of managerial and manufacturing skills available in developing countries. Another constraint is lack of information about developments in renewable-energy technologies: this has greatly impeded investment in these technologies in developing countries. Public awareness about the use of renewable-energy sources, their costs, benefits and reliability is very limited. Consequently, entrepreneurs are not motivated to venture into investment in unknown technologies with uncertain market potential. The lack of financial resources, at both the individual level and the governmental level, is another constraint to the propagation of technologies. The transition from a "non-cost" traditional fuel such as fuelwood or cow-dung to a modernized renewable fuel, such as biogas, or to an energy-efficient wood stove requires an initial capital investment on the part of the individual user which is beyond the capability of the urban poor. The attitude of key policymakers towards renewable-energy technologies that ranges from caution to skepticism is another hampering trend, which assigns a low-priority to renewables in national energy planning. Each of these problems is of considerable economic and political complexity and unless initiatives are taken at the national and international levels the inadequacy of existing technology-transfer mechanisms will remain a barrier to the introduction of renewable-energy technologies.

Biomass already supplies 14 per cent of the world's energy and the many future projects being assessed, if implemented, could increase the role of biomass in the overall energy system. In Africa, biomass energy accounts for 47 per cent of the total primary energy supply where it is the largest single energy source. Biomass energy is likely to remain an important global energy source in developing countries well into the next century. A number of developed countries also use biomass quite substantially, e.g., the United States of America which derives 4 per cent of its total energy from biomass (nearly as much as it derives from nuclear power), Sweden 14 per cent and Austria 10 per cent. Biomass is generally and wrongly regarded as a low-status fuel, and rarely finds its way into energy statistics. Nevertheless, biomass can lay claim to being considered as a renewable equivalent to fossil fuels. It offers considerable flexibility of fuel supply due to the range and diversity of fuels that can be produced. It can be converted into liquid and gaseous fuels and to electricity via gas turbines; it can also serve as a feedstock for direct combustion in modern devices, ranging from very-small-scale domestic boilers to multi-megawatt size power plants.

Biomass-energy systems can increase the energy available for economic development without contributing to the greenhouse effect since biomass is not a net emitter of CO_2 to the atmosphere when it is produced and used sustainably. It also has other benign environmental attributes such as lower sulphur and NO emissions and can help rehabilitate degraded lands. There is a growing recognition that the use of biomass energy in larger commercial systems based on sustainable, already accumulated resources and residues, can help improve natural resource management. Integrating biomass energy in national energy planning and policy-making on an equal footing with other energy sources will not be easy and will require concerted action at national and sub-national levels. This will also require adopting measures to modernize the traditional biomass sector, so as to make it sustainable. A reliable information base will have to be developed on the supply and utilization of biomass energy in the country; the policy environment must be made responsive to the needs of the biomass-energy sector; research, development and engineering efforts will have to be stepped up in required areas; and the commercialization of biomass technologies will have to be promoted through selective and well-targeted subsidies and fiscal and other forms of incentives.

5. Linking energy with water and sanitation service provision

There are many linkages between energy, water and sanitation services. From the supply side, energy has been more market responsive resulting in frequent tariff increases, whereas water tariffs have not kept pace with increasing demand. Unreliable power supply results in increased energy costs due to the need for back-up power, and installation of protection systems to prevent damage to electrical systems. Inefficiency in the operations of water utilities results in high levels of Non Revenue Water (NRW) and Unaccounted for Water (UAW). The use of old equipment that is past its economic lifespan results in higher energy costs and inefficiency in system operations. Lack of energy efficient system designs increases the Operations and Maintenance costs for the utilities, while unreliable power supply may damage the electrical installations in water supply and sanitation systems, thereby increasing their operational costs. Low levels of awareness about energy costs within the utilities results in unaccountable cost items, as does lack of awareness in utilities about the high energy costs for pumping and distribution of water. Inadequate technical expertise for Maintenance and Operations within the water and sanitation utilities results in sub-optimal operations, with higher energy consumption and higher costs.

On the demand side, unreliable service delivery by water, sanitation and electricity utilities results in higher operational costs, including pumping costs, costs of installing alternative power supply systems (back-up supply), higher costs of vendor services, and higher costs of energy for fetching water. Moreover, unreliable service delivery by water, sanitation and electricity utilities has undesirable hygiene and health implications. Often, there is also a lack of awareness among consumers about energy and water efficient products (electrical appliances and sanitary fittings).

The linkages on the household and commercial user side are as follows: (i) Energy efficient electrical and sanitary fixtures. (ii) Lack of awareness among users about water conservation. (iii) Lack of awareness about the cost of water and sanitation services. (iv) Need for guidelines for energy efficient water supply and sanitation practices.

Quite often, upwards of 50 per cent of total operating costs associated with small-scale water utility operations are the running costs of providing electricity to power water pumps. Reducing this burden either through supplementing power provision through appropriate renewable energy technologies such as wind and solar or by implementing cross-subsidy arrangements through municipally owned and operated water, sewerage and power companies through cost-sharing mechanisms, is recommended. At the same time, energy generation (and often electricity) can be realized through the utilization of "energy to waste" schemes. Indeed, often-poor urban waste management is primarily due to the lack of sufficient resources to collect and properly dispose of municipal waste. Generation of energy from this waste has the potential of greatly altering the situation. The income generated from the sale of energy produced from municipal waste would lead to a reduction in the net financial costs of waste disposal in most developing country cities. It may actually make the whole venture economically self-sustaining. Thus, municipal wastes which are always a function of the size of the urban population will increase proportionally, thereby providing more raw material for the energy production processes. On the other hand, the exploitation of energy from wastes will greatly reduce (by over 60 per cent) the amounts of urban wastes, which will need to be disposed of.

6. Development constraints created by urban energy consumption patterns

Overall, cities throughout the world are growing increasingly dependent on petroleum resources imported from a small number of regions. A number of oil-exporting countries have achieved impressive levels of economic growth on the basis of this trade. However, cities are exposing themselves to substantial economic vulnerability by turning towards heavier reliance on imported oil supplies. Urban planners need to recognize that the world's production of oil is likely to reach its apex sometime in the next decade or two, and once this occurs petroleum prices will become increasingly volatile. It would be shortsighted to construct urban infrastructure that is predicated on false assumptions about the availability of cheap and secure oil imports, given these widely acknowledged resource constraints.

While many people in the developing world struggle to gain access to modern energy and technologies, urban residents in the global north are generally consuming energy resources at an unsustainable rate. The high levels of energy use found in wealthy countries are the source of most greenhouse gases emitted into the atmosphere today. In contrast, most developing country city residents produce relatively little GHG emissions. Since these gases remain in the atmosphere for long periods of time, it should also be noted that nations of the developed north have emitted most of the total greenhouse gases accumulated in the atmosphere over the last two centuries.

At the same time as the environmental problems of conventional patterns of energy consumption are becoming manifest, there is growing need for modern forms of energy in the developing world. To put the challenge in perspective, consider that during the period 1970—1990 approximately 40 million people per year gained access to modern energy services. Given the number of people currently in need of service, combined with expected population growth, almost 100 million people would have to be connected to modern energy systems each year in order to achieve universal access by around 2020. This is certainly a daunting task, especially given tightening resource and environmental constraints.

Many of the people in direst need of access to modern energy systems are located in rapidly growing urban settlements throughout the developing world. With diminishing traditional sources of fuel, the citizens of medium and large cities often face escalating energy prices while they are forced to contend with the pollution generated by conventional energy industries.

Many of the most severe challenges confronting cities originate from the manner in which energy resources are produced and consumed. While energy is a key input for urban development, virtually every type of power generates varying levels of environmental problems. Some of these impacts are experienced outside city limits. The harvesting of wood for use by impoverished city residents in Asia and Africa, for instance, has led to extensive deforestation around numerous urban areas. Within cities meanwhile, intensive levels of energy consumption are leading to unprecedented spatially concentrated forms of pollution, particularly along major transportation corridors.

7. Sustainable urban transport/Air quality/Land use

It has been estimated that more than 1 billion people throughout the world live in urban settlements where air pollution levels exceed health standards. The human consequences of this energy-generated pollution can be quite significant. In the United States, for instance, it is thought that at least 28 per cent of the urban population is exposed to harmful levels of particulates; a level of exposure that causes the premature death of an estimated 40,000 United States residents each year. Meanwhile, 46 per cent of the United States urban population is exposed to unhealthy levels of ozone, which exacerbates respiratory and cardiovascular diseases in a growing portion of the population. In European cities, conditions are equally bad with high levels of energy-related pollution causing elevated cases of chronic pulmonary disease and mortality.

Meanwhile, in the developing world, conditions are even more extreme. In Mexico City, high levels of pollution are estimated to cause over 6,500 deaths each year. Meanwhile, over 52,000 people in 36 Indian cities are thought to have been killed by air pollution in 1995 alone. And in China, air pollution is estimated to cause from 170,000 to 280,000 deaths each year. In addition to the human toll registered in these figures, there are growing financial costs as well. In developed countries, air pollution is estimated

to cost around 2 per cent of GDP; in developing nations such pollution can cost from 5 to 20 per cent of GDP. On a global scale, the health costs of urban air pollution are thought to approach US$100,000 million annually (World Energy Assessment, UNDP, 2000).
Though the problems inherent in low-density, automobile-reliant cities are increasingly in evidence in more developed countries and cities, this model of urbanization is being replicated in many other developed countries. One of the most salient features of life in the 20th century has been the rise of the private automobile, which has completely reshaped urban life. While exclusively the domain of developed countries for decades, less developed countries have joined the same bandwagon and are suffering from the same grave social and environmental consequences. Annual increases in rates of motorization in many developing countries has approached 10 per cent — rates substantially higher than have ever been found in countries like the United States, considered the bastion of private automobile ownership and use.

Changes in urban land use patterns can have important effects on the viability and attractiveness of the modes of transport that are most important to the urban poor - non-motorized transport (walking, cycling, animal traction etc) and public transport. These modes are vital to allowing low-cost mobility and hence access to a range of urban opportunities for the poor, including a wider choice of housing. Certain common trends in land use as cities motorize have a tendency to undermine these low-cost modes to the detriment of the mobility of poor.

The result has been that energy efficiency gains have slowed or even been reversed in some transport and residential sectors in numerous developed nations in recent years. As a result of these dynamics, the largest per capita contributors to energy-related environmental problems continue to be affluent citizens living in cities throughout the developed world. The primary responsibility for reducing such impacts therefore should rest on those living in the wealthiest regions of the world economy. Still, there are also serious energy-related problems emerging in cities in the developing world. The World Health Organization estimates that 1.6 millions deaths per year, of which 60 per cent are women and children, are associated with indoor air pollution from the use of biomass. UN-HABITAT recent studies show that the urban poor and especially slum-dwellers are particularly hard hit by lack of access to modern energy. They pay more for their cooking, water and electricity than wealthier people connected to the service networks. They pay this penalty because they are poor.

While cities in the developed world confront problems originating primarily from over-consumption, metropolitan areas in the developing world face a much more complex set of energy dilemmas. On the one hand, the vast majority of urban residents in cities throughout the Southern hemisphere suffer from inadequate access to modern energy systems. On the other hand, even at low per capita levels of consumption many of these cities are generating very intense forms of pollution. There are a number of factors that are producing this unfortunate combination of low per capita consumption rates and high aggregate urban emissions throughout the developing world.

Box 2: ACCESS AFRICA – Ghana, Senegal, South Africa and Tanzania

The Institute for Transportation and Development Policy (ITDP) is carrying out a programme called *Access Africa* that aims at promoting liveable, healthy cities by making sure transportation systems are designed for all the people who use them. In Ghana, Senegal, South Africa and Tanzania, ITDP is working in the following programme areas:

- International Bus Rapid Transit Programme, which aims at promoting BRT as a way to provide a sophisticated, high-quality transit system at a fraction of the cost of other options. ITDP is working with leaders in each country to support the development of formalized public transit, provide technical assistance for the development of new systems, and secure funding for their design and implementation.
- The California Bike Coalition, which aims at improving the quality of bicycles available in sub-Saharan Africa through a unique partnership with the international bicycle industry. By shouldering the risk of importing the bicycle into Africa, ITDP has created a proven social enterprise that provides the local bicycle industry with economies of scale, business development and product diversification. Member retailers are given skills training and then accredited through a programme that includes quality standards for bicycle assembly, repair and customer service.
- Improving Safety for Bicyclists and Pedestrians. It aims at promoting safe space for all modes of transportation. ITDP is working with officials in each country to provide: safer and more attractive routes for bicyclists and pedestrians; and bicycle master plans.

Source: (ITDP, Sustainable Transport, March 2007.)

8. Issues and options to meet the urban environmental challenge

Household level

At the household level, urban dwellers in many cities are exposed to excess levels of indoor air pollution, which results from lack of proper ventilation and incomplete combustion of biomass, coal, and other fuels used to meet residential cooking and/or heating needs. Health effects include acute respiratory infection, low birthweight, and eye problems. Impacts vary greatly according to cooking practices, fuel use, type of dwelling and duration of exposure. The groups that are most at risk are women and children because they are indoors and responsible for cooking in most cultures. Short-term options to address this environmental health risk include: (a) production and dissemination of more efficient cookstoves that are more clean-burning, (b) installation of chimneys to vent smoke from dwellings, and (c) consumer education about the adverse health effects of indoor smoke inhalation. Longer-term approaches include the upgrading of kitchens and heating systems; formulating pricing policies that result in energy conservation and substitution of cleaner fuels for cooking and heating; and tackling other sources of indoor pollution such as cigarette smoke, hazardous chemicals, and radon.

Urban poverty strongly reinforces the social and environmental impact of energy use at the household level. A study of low-income groups in Rio de Janeiro suggests that the poor do not have adequate information about, or access to, more efficient (less-polluting) equipment and fuels. Furthermore, because the distribution network is less well-functioning or absent in the poorer sections of the city, those in poverty are served by a parallel market in which they pay more than the well-to do, making it more difficult to afford other available options. In addition, low-income families often settle in undesirable (but affordable) sections of the city that may suffer from energy-generated pollution, e.g., near major roadways or factories. This increases their exposure to daily doses of pollutants as well as the risk of accidents.

Local level

There are two important issues that need to be addressed at the local level. First, those concerned with energy and environmental matters in the urban context need to focus on problems where an identifiable population is exposed to a significant threat. For example, when comparing emissions rates from a large coal power station with those of smaller, decentralized woodburning plants, one needs to account for total output of pollutants and impact on affected population. The large central facility may be located in a remote, underpopulated, and well-vented- airshed while decentralized sources may be both more numerous and much closer to population centres, thus exposing a large number of persons to emissions. A recent study carried out in Bombay shows a clear spatial/population nexus for energy-based environmental problems. This issue can best be resolved through an improved understanding of the Importance not only of volumetric measurements of pollutants but also their spatial locations, human health effects, and economic/environmental costs.

The rapid growth of cities in Latin America, Africa and Asia has generated such high densities of people that even modest levels of energy consumption at the individual level can translate into severe environmental problems. Unlike in large cities in the Northern hemisphere, local municipal agencies in the Southern hemisphere are rarely able to mobilize sufficient resources to cope with these growth-related challenges. In fact, budgetary pressures have forced many cities throughout the developing world to reduce environmental expenditures in general, and energy management in particular, even as the scale of the problems continues to expand.

The fact that certain large cities in the Northern hemisphere have had some success in confronting energy-related challenges indicates that population pressures can be managed. High population densities in the Southern hemisphere, while certainly posing a significant challenge, are clearly not the sole factor leading to problematic outcomes.

Of at least equal importance as population pressures, are the severe social inequalities found in cities throughout the developing world. While privileged classes in the Southern hemisphere often replicate the modern, energy-intensive lifestyles found in the developed world, substantial numbers of impoverished urban inhabitants are forced to subsist on heavily polluting resources such as wood and coal. Public policy often exacerbates these inequalities. For instance, the limited subsidies for energy products provided in many developing countries have been shown to benefit, wealthier residential or industrial groups, while the truly impoverished typically pay high unit costs for resources purchased in informal markets. In short, affluent urban consumers generally contribute disproportionately to pollution problems while poorer residents are again subjected to higher levels of exposure to energy-generated pollution throughout the developing world.

A final factor that contributes to energy-related difficulties in less affluent cities has to do with technological inadequacies found in the power sector. Electrical power plants currently in operation in the developing world, for instance, are estimated to be between 20 and 40 per cent less efficient than plants typically found in industrial countries. Transmission losses, meanwhile, are thought to lead to losses of another 20 per cent. This means that more than half the energy that is normally put to use in developed countries is often lost in the developing world, though the environmental externalities are still being generated. In the case of transport sectors, huge efficiency losses are again incurred because of old vehicles and congested roads. More seriously, the continuing use of leaded petrol in many developing country cities is causing neurological, cardiac and other health problems in urban residents.

Technological upgrading is sorely needed in energy sectors throughout the Southern hemisphere. The dilemma is how this can be achieved. Some analysts believe that the development process itself will inherently address these issues. For instance, it has recently been suggested that a bell-shaped, Kuznets-type curve describes the relationship between local pollution and levels of economic development. At very low levels of development, poverty appears to limit the ability to pollute and so emissions rates tend to be low. As industrialization and urbanization begin to accelerate, however, larger quantities of resources are often consumed in relatively archaic, unregulated conditions and air quality tends to worsen. It is generally thought that only once a city or country has reached higher levels of affluence, and social demands for better qualities of life have been articulated, that resources will be mobilized to improve technological systems and counteract the impact of pollution (World Energy Assessment, UNDP, 2000).

While the potential existence of this Kuznets curve has led some to assume that development automatically cures underlying environmental problems, the fact that the majority of the world's urban residents are located at the beginning of the curve has troubling implications. Unless concerted efforts are made to bypass the curve, through proactive policies of technology transfer and careful regulation, the human and environmental damage generated by urban energy consumption will escalate dramatically.

9. Cities and climate change

The combined effects of energy over-consumption in affluent cities and inadequate energy sectors in developing cities are clearly producing serious pollution problems on local and regional levels. Though the casual connections are less obvious, it is also known that urban settlements are contributing significantly to the problem of global warming.

Cities themselves are thought to be particularly vulnerable to the consequences of climate change. It is expected that infectious diseases will proliferate in a warmer world, especially in dense urban settlements. Regional temperature rises will foster more urban smog. Changes in precipitation will adversely affect urban water supplies. An increase in extreme weather events will cause damage to urban infrastructure, and a rise in sea levels will begin to threaten coastal cities throughout the world.

Given the likely consequences of climate change, urban managers throughout the world are facing a closing window of opportunity in which to undertake proactive strategies of damage control. As the financial costs of global warming begin to mount, fewer and fewer cities will have the resources to foster the diffusion of new energy technologies that could reduce environmental impacts. The time for concerted action is clearly upon us. But are there alternative energy technologies that could provide solutions to the energy-related developmental constraints that are emerging in both affluent and impoverished cities? A growing body of evidence suggests that the answer to this question is a tentative yes.

A variety of options exist to reduce municipal outputs of greenhouse gases in the developing world: (a) Pricing energy products to cover their economic costs, thus encouraging conservation; (b) Removing market imperfections that impede efficient energy use in households, industries, enterprises, transport, and the public sector; (c) Reducing losses in the supply of energy, e.g., generation, transmission, and distribution losses to urban electricity consumers; (d) Promoting the substitution of cleaner alternative fuels and technologies, e.g. crop residues for agro-industries and households, and natural gas in industry and transport;(e) Improving transportation systems through pricing, investment, technological options, and regulatory measures to reduce urban traffic congestion; and (f) Managing peri-urban lands to maintain green zones and increase forested areas that, through photosynthesis, are important sinks for CO_2. However, even if they were successfully implemented now, these measures would not preclude the unavoidable need to develop urgent pro-poor adaptation measures in cities.

10. Sustainable energy technologies appropriate for urban applications

Advances in a variety of new energy technologies offer considerable promise for reducing pollution, increasing efficiencies and broadening the resource base of urban energy sectors in countries at all levels of development. The new energy systems that hold the most promise for enhancing sustainability include small-scale hydroelectric, wind, solar modern biomass and fuel cell technologies. While the literature on these new energy systems has generally highlighted the potential for their utilization in rural areas, it is becoming clear that they can make a significant contribution in urban energy sectors as well.
A few of these new energy technologies are locationally restricted, but they could provide power to urban areas when only short distance transmission lines are required. Small-scale hydroelectric stations, for instance, offer one of the most benign forms of energy production available to the world. In contrast to disruptive large-scale hydroelectric projects, small-scale systems allow electrical power to be generated without significantly altering the flow of rivers. Wind systems offer similarly benign options for electrical generation in areas surrounding cities. And large-scale solar arrays have been shown to be capable of generating electricity that can then be fed into utility grids. If development agencies, governments and corporations begin supporting such alternative energy systems, a more environmentally sustainable network of facilities can begin to bring electricity to urban communities throughout the world in the coming decades.

Urban areas have long benefited from preferential treatment in terms of energy provision. Indeed, inadequate access to modern energy services in rural areas is one factor prompting migration to cities in many regions of the world. It is therefore important for policy makers to ensure that the benefits of new energy technologies are equitably shared by rural and urban settlements alike. Moreover, it is crucial that cities begin reducing their burdens on rural areas by generating their own power. Urban-based solar, biomass and fuel cell technologies offer opportunities to improve the self-reliance of urban energy sectors.

Solar thermal and photovoltaic systems designed for use in metropolitan areas have received increasing attention in the last decade. In part, this continued growth is the result of public support. In the United States, for instance, the Million Solar Roofs Programme has helped to foster the diffusion of solar thermal and photovoltaic systems in numerous cities. In Japan, the New Earth 21 programme has aggressively promoted solar system construction in urban areas. In Western Europe, publicly funded programmes have supported the proliferation of photovoltaic roofs and building facades. Smaller government programmes in Brazil, China India, Mexico, and South Korea have fostered solar systems for domestic use and export as well.

Of crucial importance, meanwhile, has been recent growth in private investments in solar systems. Indeed, major multinational energy corporations are increasing their participation in solar power sectors. While there are still many small manufacturing companies in solar sectors, the trend is towards greater involvement by sophisticated, high technology companies with access to the capital required to fully commercialize solar technologies. All of these initiatives are increasing the usable electricity and heat generated by built structures in cities throughout the world.

Another strategy for expanding city-based energy production involves the utilization of modern biomass technologies to turn waste materials into sources of useful power. The huge volumes of solid and liquid waste generated by metropolitan areas throughout the world are replete with combustible resources.

Urban waste contains large amounts of organic material, while landfills and sewage tailings spontaneously generate methane gas: a powerful greenhouse gas. These solid and gaseous materials can be fed into a variety of incineration systems, thereby simultaneously reducing the volume of wastes while generating heat and electricity from inexpensive, plentiful urban resources. Given this combination of advantages, waste-to-energy projects have proliferated throughout North America, Western Europe and Japan. Similar projects are underway in developing countries such as Brazil, China, Chile, Hong Kong, Indonesia, and South Africa.

Greater use of urban-based solar and biomass technologies provides options to increase the efficiency and reliability of local electrical grids that supply power to residential and commercial locations. Also, liquid biofuel technologies are increasingly serving the energy-intensive transport sector, which generates a great deal of pollution. The fuel cell and liquid biomass (ethanol or biodiesel), however, can be used to power automobiles.. Given its remarkable flexibility, the fuel cell is emerging as a new energy technology with tremendous potential applications in urban settings. More and more countries in Africa are investigating the production and use of liquid biofuel to mix the fuel used in automobiles.

Comparative cost information gathered on different kinds of electrical generation systems reveal a closing price gap between conventional and new energy systems. It should be noted that, for a variety of reasons, these data on electrical generation costs must be treated with caution. To begin with, these cost estimates are averages from many regions of the world and they are based on facilities with widely varying technologies and operating histories. Second, it is difficult to account for the effects of subsidies on generation costs. Since it has been well documented that conventional power sectors receive extensive subsidies throughout the world, it is likely that the generation costs shown for these sectors underestimate true costs. Similarly, it is hard to factor in externality costs for conventional energy systems, again resulting in an underestimation of true conventional energy costs. Even given these price distortions, however, it is clear that wind, biomass, solar and fuel cell systems are approaching commercial viability in many markets throughout the developed and developing worlds.

The world commercial environment appears set at last to foster the expansion of new energy systems. Although it is impossible to predict how quickly new energy technologies can spread, it nevertheless appears that they are in a strong position to begin processes of rapid diffusion in the coming decades. A variety of new energy technologies have clearly attained the engineering maturity required for use in many different urban settings. Researchers at the World Bank, the World Energy Council, the International Energy Agency and the United States Department of Energy have also gathered evidence indicating that numerous alternative energy systems are approaching the price competitiveness required for large-scale commercialization Indeed, in a recent analysis published by the World Bank it was argued that, given relatively moderate levels of public support, alternative energy systems could be providing 20 per cent of the world's energy by the year 2100.

Box 3: Wind generators for domestic use, Kenya

Craftskills Enterprises, a small engineering company based in Nairobi's Kibera slums manufactures and installs small-scale wind generators for domestic use to produce electricity for household needs. The *wind-cruiser* generators can provide enough electricity to run domestic lighting, television and radio, the fridge, computers and other home appliances. It has installed over 50 wind generators so far in both urban and rural areas. According to the manager, Simon Mwacharo Guyo, the price could come down dramatically if the demand increases.

Source: UN-Habitat, Energy Advisor, 2007

11. Strategies for achieving reform in urban energy sectors: some best practices

As the world enters the 21st century, the long-term viability of urban energy sectors throughout the world is increasingly being called into question. If new generations of city residents are to be provided with access to vital energy systems, and urban environments are to be simultaneously improved, at least three underlying developmental challenges must be addressed. First, existing urban energy systems must be reorganized in order to enhance efficiencies. Second, new energy technologies which minimize urban pollution, must be made widely available to cities throughout the world. And third, the inequalities embedded in the world energy system must be reduced.

It is only when local civic organizations and business interests participate in designing and implementing reform agendas that efforts to achieve sustainability have a reasonable chance of success. Fortunately, it would appear that policy reformers are taking these lessons to heart. Indeed, in the field of urban management there has been a proliferation of programmes intended to foster public-private coalitions and enhance cooperation between local, national and international organizations. Given innovative efforts such as the International Council on Local Environmental Initiatives (ICLEI), Cities for Climate Protection Campaign, the Clean Cities Programme and the Local Agenda 21, among others, it appears that the institutional environment is at last favouring participatory approaches to reform. The achievements of some of these coalitions will be highlighted as we turn to a review of contemporary initiatives that are underway to improve urban energy sectors.

Although new energy technologies can play a role in improving urban sustainability, energy efficiencies can also be enhanced at the city level by reorganizing urban services and directing growth in specific directions. Perhaps the best example of this strategy can be found in the city of Curitiba, Brazil. Urban planners working in close consultation with local residents and businesses, began by designating a number of transport corridors that ran along the axes of the city as open only to authorized buses. These corridors substantially improved the efficiency and reliability of public transport, resulting in a very high level of usage. Furthermore, this coordinated planning allowed real estate developers to build new properties in specified locations, with the confidence that the public would have easy access to their commercial and residential areas on the transit lines. These low-cost strategies have resulted in improved transport efficiencies and lower rates of urban pollution in Curitiba. Many other cities, including Copenhagen, Portland, Singapore, Surabaya, Toronto and Zurich, have pursued similar strategies of reorganizing existing urban areas in order to improve transport efficiencies.

It is also possible to upgrade energy systems, thereby achieving higher efficiencies and lower environmental impacts. For instance, emissions from urban transport sectors can often be reduced by shifting to alternative fuels such as compressed natural gas, liquefied petroleum gas, **ethanol and biodiesel.** This is precisely the strategy that will be pursued in Hong Kong, where extremely high levels of ground-level pollution prompted taxi and truck drivers to organize a protest in which they demanded that city officials accelerate conversion to liquefied petroleum gas. In another example of system upgrading, existing electrical power plants can often be transformed into cogeneration systems that make more effective use of the large amounts of heat generated in the process of producing electricity.

Many cars already on the road in the world's cities can burn advanced biofuels. Brazil has already vastly reduced its oil imported and three-fourths of Brazil's new cars can burn either pure ethanol or pure gasoline. Other countries are following their lead. For example, Sweden plans to be oil-independent by 2020, chiefly **via ethanol** made from forest wastes.

UN-Habitat remains committed to exploring the economic, social and environmental impacts behind the use of **more sustainable biomass use**, including ethanol and other bio-fuels. We look forward to working with the Brazil, one of the world's leading proponents and users of the various related ethanol technologies to ensure wider adoption, particularly in more developing countries and cities. Bio-diesel systems using vegetable oils such as jatropha oil cause less pollution. Mali, a country without oil reserves, has started production to reduce its dependence on imported fossil fuel. With a grant of 4 million US dollars, Mali plans to have a number of cars running on bio-diesel by 2009. The president of Mali recently inaugurated the first village electrified with jatropha oil in Keleya (3,000 inhabitants). The project uses a modified diesel engine to drive a generator that provides 10 hours electricity daily.

The virtue of these strategies of system upgrading is that they can often be carried out by local municipalities, at quite moderate cost. Consider for instance, the achievements of the ICLEI. The ICLEI consists of over 300 cities in all regions of the world that are committed to reducing their carbon dioxide emissions. At the 1997 Kyoto Climate Change Summit, the ICLEI reported that these cities had together succeeded in reducing carbon emissions by more than 41 million tons. Moreover, it was shown that in nearly every case these reductions were associated with an improvement in the local economy. Many other urban coalitions, including the United States Clean Cities Programme and the European Energie-Cités project, are having similar success in improving efficiencies and reducing energy-related pollution at little or no cost.

In addition to upgrading existing energy systems, it will also be necessary to accelerate the diffusion of new energy technologies to urban areas throughout the world. As discussed in the previous section, a variety of innovative energy systems have reached the engineering maturity required for successful utilization in metropolitan regions. The challenge now is to foster commercial expansion in new energy sectors.

To accomplish this, fair market conditions must first be introduced into energy industries. Currently, decentralized energy providers are generally prevented from connecting to power grids. Opening utility grids to small-scale electricity producers would reduce one institutional barrier that has inhibited the expansion of alternative energy sectors in many countries. In Africa, no countries have adopted an aggressive policy to even encourage self-producers of energy.

More importantly, the massive subsidies provided to conventional fossil fuel and nuclear power sectors must be substantially reduced. While removing subsidies is often politically difficult, it is important to note that these subsidies tend to benefit large industrial producers and consumers rather than the truly impoverished. It will then be equitable to provide the same level of subsidies to RET developers and users. Once the commercial playing field is leveled in these ways, private sector dynamics can begin to foster the expansion of new energy systems in cities throughout the world.

There are other market-based mechanisms that are likely to provide additional support to environmentally friendly energy systems. For instance, emissions trading schemes are already encouraging private companies to invest in domestic acid rain-reduction technologies in North America. Similar agreements show promise on the international level. The Prototype Carbon Fund, an emissions trading system administered by the World Bank that focuses on renewable energy systems, attracted more private investments in its first six months of operation than had been expected for its entire first year of operations. The Joint

Implementation and Clean Development Mechanisms, meanwhile, should facilitate the international transfer of new energy systems; under the provisions of these agreements companies headquartered in developed countries will be able to get credit for emissions reductions they achieve by investing in new energy ventures in developing countries.

While these market-based strategies are certain to be important components of any global effort to accelerate the diffusion of new energy technologies, by themselves they are not likely to represent a sufficiently robust policy response. In part, this is because emissions trading mechanisms may allow cities that are currently over consuming resources to purchase relatively inexpensive permits and thereby continue such behavior. What is needed as well is an influx of public and private investments that can finance the construction of new energy infrastructures. Unfortunately, at present, the level of funding for new energy projects does not appear to be adequate to the task.

Since the economic crisis of 1997-1999, governments throughout the world have sharply scaled back public funding for energy infrastructure development. In place of public financing, it has been hoped that energy sector restructuring would prompt private companies to increase their investments in energy projects. While a few countries in Latin America have seen modest growth in private investments, the vast majority of cities throughout the world have been forced to contend with declining public and private energy sector investments.

While a contraction in energy-related investments by national governments, private companies and multilateral development agencies has been occurring in recent years, it is expected that this trend will eventually reverse itself and a new round of financing will become available for energy development projects. Once this occurs, it is likely that a substantial portion of these new resources will be utilized to expand sustainable energy systems. A variety of international mechanisms, such as the Global Environment Facility and the Clean Development Mechanism, are now available to utilize capital resources more effectively. National governments, under moderate pressure from the Kyoto Accords, are also committing themselves to pursuing emissions-reduction strategies that favour new energy technologies.

And city-level coalitions such as the ICLEI and Local Agenda 21 have proved to be capable of spearheading innovative energy reforms in many metropolitan regions. In short, the policy environment appears to be at last to favour true changes in urban energy industries in urban centers throughout the world.

There still remains, of course, uncertainty regarding how to reform the severe inequalities in energy consumption that are embedded in the contemporary world energy system. As shown, high-income nations consume a disproportionate share of the energy resources available for human use. These consumption practices cannot be universalized without causing rapid environmental crises at regional and global levels.

12. Conclusions and policy guidelines

Most of the commercial and non-commercial energy produced today in developing countries, is used in and for human settlements, and a substantial percentage of it is used by the household sector. Developing country cities are at present faced with the need to increase their energy production to accelerate development and raise the living standards of their populations, while at the same time reducing energy production costs and energy-related pollution. Increasing the efficiency of energy use to reduce its polluting effects and to promote the use of renewable energies must be a priority in any action taken to protect the urban environment. The urban sector, being the dominant sector of commercial energy use and a major sector in the use of biomass fuels, will have to take a leading role towards increasing energy efficiency. This will require major policy changes from "business as usual" to imaginative innovations in lifestyle, energy use and energy policy planning to re-orient the current focus on energy supply to an end-use oriented approach, thus contributing to sustainable human settlements development goals.

Recognizing that a comprehensive approach for the promotion of sustainable energy development and use and to extend the provision of more energy-efficient technology and alternative/renewable energy for human settlements and to reduce negative impacts of energy production and use on human health and on the environment (including promoting efficient and environmentally sound transport systems), UN-Habitat has identified three key prerequisites which are crucial to the successful implementation of energy-related action plans.

These are:

- **Understanding the problem**, with a view to improving policy-making and for building capacity to plan and implement responses to the urban environmental challenge;
- **Establishing an enabling policy environment**, that takes into account the full range of issues and options, the special needs and abilities of those affected and the key actors, and provides an optimal mix of regulatory and incentive-based actions in the appropriate urban context;
- **Capacity-building**, based on an institutional strategy that mobilizes public support and broadens decision-making processes, and develops the managerial, technical and financial capacities of those responsible for the planning and implementation of actions.

To improve policy-making so as to better manage urban energy-use related environmental problems, planners and policy-makers need informed analysis based on adequate data. For example, it is not enough to know qualitatively the energy-related environmental impacts in the urban sector. The magnitude and the significance of these impacts must be assessed and physical impacts will have to be converted into economic costs to assess which ones require priority attention.

Urban energy policy-making will require a multidisciplinary perspective, incorporating urban, transportation, and health planning. Urban planning needs to incorporate the environmental dimensions of energy use in its analyses. How this is done in practice will vary depending on the municipal, regional, and national configuration of actors and institutional responsibilities. Regardless of where planning is sectorally located, decision makers should be clear about the environmental tradeoffs that are involved in policies and programmes that involve urban energy use.

Policies and programmes that permit improved energy efficiency will be an important first step in dealing with environmental problems stemming from urban energy use. By investing in efficiency, developing countries can stretch the energy services from existing supply capacities free up capital for needed investment in the sector, and reduce CO_2 emissions.

A serious obstacle to improving energy efficiency in the urban sector lies in the institutional structure of energy decision-making. Access to information and access to capital are not concentrated in the hands of energy users, but in the supply-side of the energy equation. Utilities make supply-side investment decisions, builders determine the appropriate level of building insulation, appliance manufacturers determine the energy efficiency of their products, and none of them pay the energy bill. Energy and product markets also fail to capture externalities that are borne by others. This is a challenge that must be met by new and innovative policy initiatives.

Tariffs, as a policy instrument have been used successfully in some developing countries to promote environmentally cleaner fuels like LPG in household-use and unleaded gasoline in automobiles. At the same time, such subsidies have often been criticized for breeding inefficiency. Nevertheless, there is a growing recognition of the efficacy of incentive-based economic instruments for policy implementation. They can reduce excessive reliance on regulation and investment programmes to control pollution and stimulate innovation.

Concerted action will be required at all levels to put renewables in the national energy mix, but success will primarily depend on the abilities of developing countries to support private renewable-energy investors through selective and well-targeted subsidies, fiscal and other forms of incentives and innovative venture capital schemes to speed up commercialization of renewable energy technologies. The **private sector** has been and will remain a key driver behind the successful diffusion of clean energy-related technologies. UN-Habitat must work with private sector companies and government regulators to ensure an open and level playing field in terms of market-entry into the sustainable energy field.

Implementing urban environmental strategies to tackle energy-use related problems will require integrating environmental considerations into existing responsibilities, initiating new environmental actions or programmes that address critical problem areas and mobilizing financial resources to perform the related tasks. UN-Habitat will be working with a variety of UN partners including but not limited to UNDP, WHO, UNIDO and UNEP in the development and implementation of plans, programmes and projects in the area of improving access to clean modern energy for the urban poor.

It will be expedient for most cities to build on existing structures and capacities to meet new environmental responsibilities rather than developing new institutions or authorities. The principal capacity-building tools include training, technical assistance, private sector participation, public information and outreach programmes. A participatory approach with end-user involvement will be crucial to successful formulation, implementation and follow-up of projects and programmes.

For most developing country cities, capacity-building will be a long-term and dynamic process, refining and strengthening existing strategies, skills and capabilities. External assistance will be crucial in building the necessary capacity to plan and implement environmental strategies at local level. Principal areas where such support should be considered are: (a) environmental research and policy analysis needed to formulate urban environmental strategies and action plans at local level; (b) policy reform, institutional development and resource mobilization; and (c) financial support for improving efficiency of urban energy services, and for the promotion of renewable energy technologies.

the original version of this publication had graphics on the front page, and at the beginning of each chapter. That version was 10.6 mb. The graphics have been removed for this online version to bring down the size to 1.3mb.

Chapter 3

Power Sector Reform in Africa: Policy Guidelines for the Sustainability of the Sector

UNECA

By
United Nations Economic Commission for Africa

1. Introduction

Since more than a decade and half, a number of African countries have embarked on implementing power sector reform programmes in a bid to address the deficiencies in the management and operations of their power utilities. The rationale for power sector reforms was to: (i) improve the technical, commercial and financial performance of utilities; (ii) boost sector cash flow and enhance utilities' creditworthiness; (iii) facilitate mobilization of resources for capital investment on a commercial basis, thereby releasing public funds for other investments; and (iv) extend access to electricity to poor and rural communities.

However, one of the most critical drivers for power sector reform, which is linked to lack of capital to expand and rehabilitate existing systems, is probably pressure from the development finance institutions including the World Bank. Most African countries have thus decided to embark on reforming their power sectors following the announcement of the 1993 World Bank's Electric Power Lending Policy calling developing countries to demonstrate a clear indication to implement comprehensive power sector reform programmes as a precondition of the Bank's continued assistance in the sector.

Under this Bank's new policy, developing countries were invited to:

- Establish transparent regulatory processes;
- Commercialize and corporatize the power enterprises;
- Allow for importation of power services in some cases; and
- Encourage private investment in the power sector.

As a follow-up to its new electric power lending policy, the World Bank Energy Sector Management Assistance Programme (ESMAP) organized a symposium on "Power Sector Reform and Efficiency Improvement in sub-Saharan Africa" in Johannesburg, South Africa, in December 1995 with a view to addressing the problem of inefficiencies in operations and management of the power utilities. The purpose of the symposium was to provide an open forum in which high-level decision-makers in the Ministries of Finance and Energy of sub-Saharan African countries, along with the utility managers, could critically and cooperatively examine the issues and challenges facing their power sector. Senior officials were able to conduct extensive discussions on planning and implementing the best sector reforms and efficiency improvements.

In a report published in 2004 (Reyes et al, 2004), the World Bank recognizes that it "underestimated the complexity of the reforms needed and the time required for those reforms to mature and achieve lasting and equitable country-sector outcomes". The report also stated that the Bank "mostly advocated privatization and private sector participation" rather than the staged approach called for in its 1993 Electric Power Lending Policy. It was also recognized that much work remained to be done to integrate poverty reduction and environmental mainstreaming into the design of power sector reform and PSDE strategies, which to date have focused mostly on sector efficiency and macro-fiscal objectives.

It is therefore not surprising that a number of recent global studies, which also considered the socio-economic impacts of power sector reforms in some sub-Saharan African countries, revealed that few of these reform initiatives have not resulted in significant improvement in the provision of electricity services to the poor, especially with regard to rural electrification. In addition, some analysts contend that, although power sector reforms have produced positive outcomes in a few sub-Saharan African countries, there is some evidence that in many countries, far from reducing energy poverty, market-oriented reforms in particular may have increased energy poverty.

Yet, some proponents of the market-oriented power sector reforms have argued that by making utilities technically and financially efficient, power utilities would be then able to afford provision of electricity to the poor. However, when one compares the current pace of electrification with population growth rates in sub-Saharan Africa, it appears that the region will be the only region in the world whose population without electricity will increase by 2030[28].

It is against this background that ECA decided, in partnership with the United Nations Environment Programme (UNEP), to carry out within UN-Energy/Africa framework the study on "Making Africa's Power Sector Sustainable". While there is a growing number of studies of power sector reforms in Africa, most publications focus on the economic impacts of reforms, few assess the social impacts, and almost none analyzes in a comprehensive manner the full impact of reforms on the sustainable development objectives of African countries. Therefore, the study referred to in this paper, assesses the socio-economic and environmental impacts of power sector reforms especially on the poor in fourteen selected countries and uses the results of the assessment to analyze the extent to which reforms have contributed the sustainability of the power sector in sub-Saharan Africa. The findings and recommendations of the study served as a basis to propose policy guidelines for ensuring the sustainability of the reforming power sectors in Africa.

2. Overview of power sector reform in Africa

2.1 Overview of the African power sector

The African power sector is characterized by small systems, with over three quarters of the continent's installed capacity coming from South Africa and North Africa. The installed capacity of most sub-Saharan African countries ranges from some 10 MW to 2,000 MW with the exception of South Africa with more than 40,000 MW, Nigeria with more than 5,000 MW and DR Congo and Mozambique with more than 2,000 MW. In addition, only 14 out of the 53 African countries (the five North African countries and eight sub-Saharan African countries) have an installed capacity of 1000 MW and above. These include the five North African countries of Algeria, Egypt, Libya, Morocco and Tunisia; and nine sub-Saharan African countries (Côte d'Ivoire, DR Congo, Ghana, Kenya, Mozambique, Nigeria, South Africa, Zambia and Zimbabwe). This means that over 80 per cent of sub-Saharan African countries have small systems with less than 1000 MW of installed capacity. It should be mentioned that, in all countries, the effective power capacity are only fraction of the installed values due to diverse causes, including mostly maintenance, faulty design factors, and poor operation conditions.

The African power sector is also overwhelmingly dominated by conventional thermal power generation due to large coal-fired power plants in Southern Africa and large oil- and gas-fired power plants in North Africa and Nigeria. Thermal power generation accounted for 80.4 per cent of Africa's total electricity production in 2004, while hydropower generation contributed 16.5 per cent, nuclear power 2.5 per cent and renewable energy sources 0.6 per cent (IEA, 2006).

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28 The International Energy Agency (IEA) estimates that close to half of the population living in sub-Saharan Africa (about 650 million people) will have no access to electricity by 2030.

Total Africa's electricity production amounted to 539.4 TWh in 2004. South Africa and the five North African countries of Algeria, Egypt, Libya, Morocco and Tunisia accounted for close to 80per cent of this total. On the other hand, Nigeria accounted for 3.75 per cent of the total. This means that the remaining 46 sub-Saharan African countries (excluding South Africa and Nigeria) totaled 89.4 TWh or only 16.5 per cent of Africa's total electricity production (IEA, 2006).

Total Africa's electricity consumption was also overwhelmingly dominated by South Africa and the five North African countries which accounted for 80 per cent of the 477 TWh of Africa's total electricity consumption in 2004. Nigeria accounted for 3 per cent of this total. This means that the 46 sub-Saharan Africa (excluding South Africa and Nigeria) accounted for only 17 per cent of the total.

2.2 Barriers to the performance of the power sector in Africa

The performance of any power sector can be broadly categorized into: (i) technical performance; and (ii) financial performance.

Technical performance

(i) Electrification access levels

National electrification access levels in many sub-Saharan African countries are very low and are estimated at less than 30per cent. Rural electrification access levels are even much lower with the majority of the countries recording levels of less than 10 per cent in the rural areas. In some least-developed countries, rural electrification access levels can be as low as 1 per cent or less (e.g. Chad).

(ii) Electricity consumption

The average electricity consumption per capita in sub-Saharan Africa (excluding South Africa) is estimated to be about 135 kWh. This level is well below the figure of 4976 kWh per capita for South Africa or even 1058 kWh per capita on average for North African countries. Compared to northern African countries and South Africa, many sub-Saharan African countries register electricity consumption levels well below 100 kWh per capita, particularly in West Africa and the Great Lakes regions. In some countries, it is reported that the per capita consumption of electricity has been declining since population growth rates have been higher than electricity production increase rates (IAE, 2006).

(iii) System losses

Partly due to poor maintenance on the transmission and distribution system, many countries in sub-Saharan Africa are characterized by high system losses that can be as high as 41 per cent when compared with the international target of about 10 per cent to 12 per cent. High levels of system losses not only further constrain the amount of electricity delivered but also affect the financial performance of the power utilities.

Financial performance

One of the major drivers for power sector reforms in almost all reforming countries in sub-Saharan Africa has been the poor financial performance of their power utilities. Prior to reforming their respective power sectors, a sizeable number of utilities recorded a string of loss-making experiences. By reducing the high system losses and improving electrification access levels as well as applying higher tariff levels, electricity utilities should be able to realize higher revenue levels. Tariff reforms will particularly continue to play a significant role in the profitability of electricity utilities in sub-Saharan Africa.

2.3 Overview of the status of reforms in Africa's region

Reform options

The major reforms that have been taking place in Africa have involved structural changes and ownership/management changes, including privatization. Structural changes refer to the process of unpackaging vertically integrated utilities into separate generation, transmission and distribution entities (vertical unbundling) and conversely unpackaging national utilities into smaller utilities (horizontal unbundling).

On the other hand, management/ownership changes involves the following options:

- Commercialization/corporatization of the power utility while leaving its ownership in the public sector and its management with managers under performance contracts;
- Giving responsibility to the private sector to run the public utility under management contracts, including operations and maintenance expenditure;
- Allowing the private sector to own and operate specific new generation facilities using independent power producers (IPPs) under long-term concessions; and
- Allowing the private sector to take full responsibility for operation of existing assets and for investment, whether through a long-term concession or through full change in ownership.

In terms of structural changes, some countries such as Kenya have opted to only unbundle the generation segment, while others such as Uganda and Zimbabwe, have taken the extreme option of completely unbundling the entire formerly integrated utility into generation, transmission and distribution. However, horizontal unbundling has been effective in the distribution segment of the electricity supply industry of South Africa and Namibia with the creation of regional electricity distributors (RECs).

The most common privatization path undertaken by most African countries in power sector reforms has been the commercialization/ corporatization, management contract and stop at allowing the entry of independent power producers (IPPs). However, with the private sector participation in the electricity supply industry, there has been need to establish a legal and regulatory framework to safeguard the interests of all stakeholders (i.e. the government, the private investors, the power utility and consumers) by enacting new electricity acts/laws and establishing independent electricity regulatory authorities.

Status of reform implementation

(i) Commercialization/corporatization

Commercialization and corporatization of power utilities in many African countries have often involved awarding management contracts to private managers as a means to improve efficiency and profitability of the utilities. The foreign firms involved in management contract in Africa have mainly been dominated by French entities. However, South African firms (Net Group Solutions and Eskom Enterprises – a subsidiary of the South African utility, Eskom) have recently begun showing interest in the African power utility management contract market. South African-led management contract initiatives are now underway in Malawi, Uganda and Tanzania.

Commercialization/corporatization has also involved reforms in the tariff setting process. The resulting increase in tariff levels was expected to help achieve the following objectives: (i) to recover the cost of electricity generation, transmission and distribution; (ii) to fairly and equitably spread the above costs to consumers based on the true cost of service delivery, consumption levels & patterns, and affordability to pay; and (iii) to promote the efficient use of electricity.

To mitigate the negative impact of tariff increase on the poor, some countries have adopted a tariff structure that provides for a lifeline tariff for the first 50 kWh aimed at the poor. South Africa has made a step further by introducing a new tariff structure that provides for basic free electricity services amounting to 50 kWh of electricity per household per month.

(ii) New/Amended electricity act/law

In the countries covered in the ECA/UNEP study, the Electricity Act often provides the legal and regulatory framework. In these countries, the legal and regulatory framework was originally designed for state-owned power utilities, with little or no provision for private sector participation. Recently, with the exception of Tanzania, all other countries have amended their Electricity Acts leading to a number of important regulatory changes.

The key changes that have taken place include:

- redefinition of the state-owned power utility from a welfare-driven government agency to a limited liability commercial entity and providing for its unbundling and privatization;
- dismantling the monopoly of the state-owned power utility to encourage private participation, specifically in electricity generation and distribution; and
- minimizing direct intervention of the Government by shifting its role of policing the electricity sector from the Ministry to an independent Electricity Regulatory Body/Agency.

(iii) Establishment of electricity regulatory agencies

The establishment of independent regulatory bodies for the power sector alongside the amendment/enactment of new Electricity Acts is the second most desirable reform options implemented in most countries. However, although the regulatory bodies are expected to be independent, past developments in some countries cast doubt over the autonomy of these bodies, notably in Kenya, Malawi and Uganda. But it is to be noted that delays in putting in place electricity regulatory agencies may result in preventing the governments to be provided with advice needed to take informed decisions in such matters as awarding concessions/licenses for private participation into the development, management and operation of the power sector.

(iv) Independent Power Producers (IPPs)

Independent Power Producers (IPPs) constitute an important form of private sector participation in Africa's power sector. With demand outstripping supply in many African countries, independent power projects are expected to become a major source of new power generation capacity in these countries. In this regard, it can be noted that less than half of the countries covered in the study succeeded to attract private investors in the development of IPPs. Côte d'Ivoire succeeded to attract IPPs totaling more than 500 MW (210MW for CIPREL and 300MW for Azito) during a 5-year period between 1994 and 1999. Other countries that succeeded to attract IPPs include Ghana, Kenya, Senegal and Tanzania. However, it is worth noting that some countries have been facing problems with regard to win-win power purchase agreements (PPAs) and to easily comply with the fuel supply agreements for fossil fuel based power plants. Inefficient or inexistent electricity regulatory authorities have also contributed to the mixed results of IPPs' experience in these countries.

(v) Independent Power distributors (IPD)

In the countries covered in the study and indeed in the sub-Saharan African region, very few independent power distributors (IPDs) have been established. The only countries where IPDs have been established are Namibia, South Africa, Zimbabwe, Uganda, and Ghana. In other countries, privatization of power utilities through long-term concessions for the operation and management of power system assets and for the supply of electricity is facing the risk of being renegotiated or terminated, as this has been the case in Senegal and Mali in 2000 and 2005 respectively. It is expected that the developments in Senegal and Mali might deter other countries in the region from privatizing their utilities. On the positive side, Côte d'Ivoire appears to be a success story of power sector reform in Africa since it was able to attract IPPs for 510 MW and to renew the concession awarded to the Compagnie Ivoirienne d'Electricité (CIE) for another 15-year term.

3. Key findings and lessons learnt

Power Sector Reforms in Africa are at various stages in different countries, and drawing general conclusions is not an easy endeavour. However, the findings of this study converge with other previous works on some key findings and lessons that constitutes overall trends of the various country experiences.

3.1. Key findings

The first key finding is that power sector reforms were not explicitly designed to ensure socio-economic and environmental sustainability of the power sector. They were primarily designed to bridge short-term generation shortfalls and enhance the financial health of state-owned power utilities. It is, therefore, not surprising that they have marginally contributed to socio-economic and environment improvements in the power sector.

This study regarded socio-economic impacts of reforms (especially electrification of the poor) as an important indicator of the power sector's sustainability. In overall terms, socio-economic impacts of reforms on the poor appear to be negative or neutral. This is because, first and foremost, electrification of the poor was not significantly addressed in the reform process and was, in several cases, almost an afterthought with the exception of Cote d'Ivoire, Cameroon, Malawi, Burkina Faso, Senegal, Zimbabwe, South Africa and Mauritius. As a result, electrification access or levels of the poor (especially in rural areas) in many reforming sub-Saharan countries, except in the aforementioned countries, have either stagnated or declined altogether.

While increased access to electricity especially in rural areas is important, its affordability is widely recognized as a vital impetus to economic development. A key finding with regard to the impact of reforms on the poor is the increase in the cost of electricity and the associated reduction or removal of subsidies for the poor. Tariff increases were motivated by the desire to improve the financial health of the state-owned utilities as well as to attract private investors. While these are desirable attributes as far as the sustainability of the power sector is concerned, placing a heavy financial burden on the poor to the extent of leading to disconnections (e.g. in Ghana) is neither desirable nor does it contribute to a sustainable power sector. It is for this reason that the World Bank has in its recent study on subsidies for the poor, advocated for continued subsidization of the poor, however, more targeted ((Komives, et al, 2005).

In a limited number of countries, measures were taken in the reforms to improve the affordability of the electricity services. In South Africa for example, the government introduced a new policy for supplying free basic electricity services up to 50kWh per household per month to the poor in selected areas, and for poor consumers not connected to the electricity grid, such as those using solar systems, it is allocated up to R48 per month to offset the operational and maintenance costs of the systems. In Zimbabwe, South Africa, Malawi, Kenya, and Uganda, the electricity utilities have reduced the upfront costs to enable the poor afford connection especially for productive uses. These were often financed partly by levies raised on the urban consumers to the benefit of rural electrification programmes.

However, an important positive outcome of power sector reforms is the establishment, in many countries, of Rural Electrification Agencies and associated Rural Electrification Funds. These have begun delivering benefits to the rural areas in some countries where adequate means were bestowed to the Agency. For example, in Zimbabwe, the Rural Electrification Agency (REA) established in 2002 has designed a programme to expand rural electrification dubbed the Accelerated Rural Electrification Programme with End Use Infrastructure Development. The Zimbabwe programme covers the eight regions in Zimbabwe, and in only 3 years, rural electrification levels rose from 20 per cent to 25 per cent, while in Uganda no significant progress in terms of electrification of the poor has been reported 6 years after the advent of the Rural Electrification Authority.

The limited or no results obtained by REA are in part, due to the fact that the rural electrification funds and boards have not provided effective and innovative mechanisms that would ensure they achieve their objectives. Their design appears to have largely replicated that of past (and failed) mechanisms.
Another key finding is that overall, reforms have failed to boost investments in the sector and attract the private sector as initially expected. In countries such as Malawi and Cameroon, in spite of reforms, not a single Independent Power Producer (IPP) has invested in the country. In other countries, despite the presence of some IPPs, investments in new generation capacity were insufficient to meet demand, and load shedding has ensued (e.g. Tanzania and Uganda).

It is also important to note that, in part, the involvement of IPPs has led to aforementioned increase in tariffs. Based on the experiences of Kenya and Ghana, this is mainly due to three key reasons: Firstly, most of the IPPs use fossil fuel based electricity generation plants[29]. Therefore, the high and rising cost of fuel has been transferred to the consumers. Secondly, a significant number of IPPs have been invited in on an emergency basis thereby escalating the cost. Thirdly, the licenses and Power Purchase Agreements (PPAs) issued to the IPPs appear to have a short time span leaving IPPs with no choice but to ensure that they recover their investment costs and make attractive returns within the limited time. In Kenya, for instance, the selling price of electricity from one IPP fell by about a half when the license and PPA was renewed but for a much longer period.

Another key finding is that, in many countries in the region, power sector reforms appear to have marginalized local private investment in the power sector. Current trends seem to indicate that, in the medium term, the state will be effectively handing over a significant share of electricity industry to non-national operators. In the long-term, this may be an unsustainable arrangement. In part, local private participation, especially in IPPs, has mainly been hampered by the emphasis on large-scale investment. However, there are examples in Zimbabwe and Mauritius that indicate that potential exists for local private investment in the power sector especially using decentralized energy systems based on small-hydro, wind, solar, and bagasse-based cogeneration and as long as the entry requirements are designed to accommodate local investors.

With regard to the financial sustainability of the electricity utilities, reforms appear to have largely met the objective of turning electricity utilities into profitable entities. Good examples include Ghana, Zimbabwe, Kenya and Uganda. This is important as it ensures that the resources that previously went into salvaging the utilities are utilized to meet other social and economic needs such as health, education and infrastructure. Furthermore, reforms also provided for a more sustainable financing mechanism for rural electrification through the introduction of a levy mainly imposed on urban electricity consumers.
On the environmental impacts of power sector reforms, one of the key findings is that the amendments of the Electricity Acts have partially contributed to the sustainability of the power sector by ensuring that Environmental Impact Assessments are carried out prior to major electricity generation, transmission and distribution installations. However, the amended Acts are silent on environmentally unfriendly installations that were established prior to the new Electricity Acts.

Another key finding is the worrisome trend in many countries, except for Zimbabwe, Kenya and Mauritius, whereby the share of IPPs generating electricity from sustainable energy sources such as hydro, solar, wind, geothermal and bagasse-based cogeneration, is declining. Prior to reforms, in the countries covered in this study, most of the electricity generation came from non-fossil fuel-based sources, mainly hydro. However, this proportion is rapidly decreasing because recent estimates by AFREPREN show that only 37 per cent of the total installed capacity of all the implemented and planned IPP investments are using environmentally friendly electricity generation options such as hydro, wind, bagasse-based cogen-

29 It could be that most IPPs favour fossil fuel based electricity generation due to the fact that fuel supply is borne by the host government (i.e. through a Fuel Supply Agreement) and the lead-time for developing thermal power stations, including return on investment, is shorter than for a hydropower plant for example.

eration and geothermal. If this trend continues unabated, it will not only imply an increase in the level of greenhouse gases emissions from the energy sector in sub-Saharan Africa, it may also lead to an increase in the cost of electricity thus affecting the poor negatively as discussed earlier.

One should note that major concern has been raised over the development of large-scale hydropower plants, especially the proposed Bujagali Dam in Uganda. Environmental lobby groups in the region have put up a substantial amount of resistance citing potential environmental destruction associated with the proposed dams. However, although environmental lobby groups appear to gradually accept well-designed hydropower dams, continued resistance and stringent disbursement conditionalities might affect the development of hydropower.

Analysis of the performance of Electricity Regulatory Agencies indicates that they have done little to ensure the sector's sustainability. In part this is attributed to the weakness of the regulatory agencies to enforce the Electricity Act as a result of two key factors: Firstly, the electricity regulatory agencies are relatively new entities and have, therefore, not built significant capacity (e.g. Cameroon). Secondly, in some instances, even where capacity exists, the ability of the regulatory agency to perform its duties has been compromised by its lack of the requisite independence as a result of politically motivated appointments of the members of the respective agencies' boards (e.g. Kenya and Malawi). The fact that limited intervention has been made by the regulatory agencies to protect the poor from negative impacts of the high cost of electricity and ensuring their electrification is a clear indication of the regulatory agencies' disinterest among the poor.

Furthermore, the regulatory agencies have done little to promote an environmentally sustainable power sector by reviewing electricity generation options. For example, there is no indication of regulatory agencies setting specific targets for the share of electricity generated from renewables energy technologies. In addition, with the exception of Mauritius, the regulatory framework in most of sub-Saharan African countries does not provide for attractive tariffs to sustainable energy generation options such as small-hydro, wind, bagasse-based cogeneration and geothermal.

3.2 Lessons learnt

Perhaps the most important lesson learnt is that reforms do not appear to have solved the power sector's problems. With the exception of increased profitability of the utilities, key issues that provided the impetus for reforms continue to prevail long after reform have been implemented. For example, generation capacity shortfalls still persist in most sub-Saharan African countries. Furthermore, several countries have put in place the requisite reform measures but that has not guaranteed the desired results.

Another important lesson learnt is that private sector involvement in the power sector is not the ultimate solution. Developments in the management contracts in Mali, Senegal, Cameroon and to a lesser extent Cote d'Ivoire indicate a significant degree of dissatisfaction in the private sector involvement. In Mali and Senegal, for example, the involvement of the private sector in the power sector has been reversed.

Sub-Saharan African countries that have implemented power sector reforms, especially privatization, at a slower pace appear to have produced better results than those that have carried out reforms in a rush. Botswana Ghana, Mauritius, South Africa, and Zimbabwe are good examples of countries that have not rushed into privatization of their power sector. In these countries, the power sector has performed relatively well particularly in terms of increased access to electricity among the population, including the poor. Other countries such as Kenya, Malawi and Uganda where reforms appear to have implemented in a hurried fashion, the outcomes have not been satisfactory. In Kenya and Uganda, reforms have, for instance, led to a significant increase in tariff levels as well as stagnation and indeed reduction (e.g. Uganda) in the electrification levels.

Another important lesson learnt is that Government involvement and commitment in the reform process is critical, especially with regard to providing long-term strategies for the power sector. Invariably, countries that have implemented reforms at a slower pace appear to be those with long-term strategies and the commitment to realize the set objectives. In South Africa, Zimbabwe and Ghana for example, their long-term strategy includes significant rural electrification. In these countries, Government involvement and commitment has been significant and it is only after achieving relatively high rural electrification levels have they begun privatizing their power sector.

An important lesson learnt is that it is possible to separate rural electrification and electrification of the poor from utility reform. However, rural electrification and the electrification of the poor cannot be alienated from power sector reform. It is only in countries where power sector reforms have been designed to carry out privatization in parallel or after undertaking massive electrification of the population that have produced desirable outcomes. Examples include Ghana, Mauritius, South Africa and Zimbabwe.

Finally, heavy reliance on large hydropower in Africa may pose a threat to the sustainability of the power sector, as hydropower has proven unreliable in the past. This is because it is dependent on rainfall, and is therefore vulnerable to drought and other climatic variations. Many sub-Saharan African countries have experienced serious droughts in the past, which have affected hydropower generation. Therefore regulations that favour solar, wind, geothermal and bagasse-based cogeneration energy source, which are not reliant on rainfall, can reduce the weather related risks. For instance, during the drought period of 1998–2000 in Kenya, geothermal plants offered almost 100 per cent availability to cover base load deficits regardless of prevailing weather conditions, and bagasse-based cogeneration was used to meet the power deficits caused by drought in Mauritius in 1999. Energy security of supply can further be improved substantially by setting up regulations that foster regional energy integration allowing for cross-border power trade among countries.

4. Policy guidelines for sustainability of the power sector

This section proposes possible policy strategies by highlighting opportunities and options for making the power sector sustainable by focusing on four key issues: (i) Enhancing access to electricity among the poor; (ii) Technical Options for Improving Access to the Poor; (iii) Ensuring the use of environmentally-sound electricity generation options; and, (iv) Addressing gaps and barriers in the legal and regulatory framework.

- *Enhancing Access to Electricity among the Poor*

The need for enhancing access to electricity among the poor cannot be overemphasized. In sub-Saharan Africa, the poor - especially in rural areas, form the majority of the population. Therefore, access to electricity is likely to widen their scope of income generating opportunities. There are several options for enhancing the poor's access to electricity and these are discussed below.
Sequencing reforms: sub-Saharan African countries whose reforms are not at advanced stages should ensure that they establish structures and mechanisms for increased rural electrification before embarking on large-scale privatization reforms. Evidence from Ghana, Zimbabwe, South Africa, Mauritius and other developing countries indicates that higher levels of access to electricity among the poor, especially in rural areas, have been achieved when rural electrification initiatives precede major market oriented reforms such as privatization.

Linking electrification targets to contract renewals REAs Board Members: The newly formed rural electrification agencies should have specific targets for electrifying the poor. This should be enforced through making the targets as part of the agencies' annual reporting as well as renewal of the contracts of the board members as well as the executive employees of the agencies. A similar system is already in place in Kenya through the newly instituted performance contracts for public institutions including key officials in Ministry of Energy and the Heads of the electricity utilities.

Linking electrification targets to licenses renewals and tariff increments: The electricity regulatory agencies could also enforce the electrification of the poor through linking set targets to issuance of licenses and concessions to electricity distribution utilities. Linking the number of connections to licenses and concessions is critical to ensuring the electrification of the poor. This approach has successfully been implemented in the licensing of mobile telephone operators in Kenya. The licensing of the operators is based on, among other prerequisites, a demonstration of the firm's ability to significantly increase the number of mobile telephone connections and areas of geographical coverage. The license awarded to successful operators includes a target number of new connections and geographical coverage over a specified period. Subsequent renewal of the operator's license largely depends on the extent to which it meets the target indicated on its license (CCK, Personal Communication, 2003). As a result of stringent regulatory enforcement, mobile telephony in has dramatically increased and has also lead to enhanced access and affordability of communication services among the poor. Kenya now registers one of the highest penetration rates in Africa in mobile telephony (ECA/UNEP, 2005).

In addition, to ensure that the poor's access to electricity is sustainable, the regulatory agencies should ensure that tariff increments do not adversely affect the poor by providing for subsidies as well as encouraging utilities to utilize low cost electrification options.

- *Technical Options for Improving Access to the Poor*

To ensure increased access to the poor at an affordable cost, low-cost electrification technical options are an ideal solution. Some African countries have already adopted low-cost electrification options. Botswana, Cote d'Ivoire, Eritrea, Gabon, Malawi, Morocco, South Africa, Tunisia, Uganda, and Zimbabwe are case examples of countries that have successfully adopted low cost electrification options. These options include: Longer distances between distribution transformer; Single pole transformer mounting; Shorter, smaller and fewer poles; Pre-fabricated wiring systems; Load limiters; Single Wire Earth Return (SWER); Reduced conductor sizes: High-mast community floodlights; and Equipment standardization that lowers costs as it allows for bulk procurement of parts and components for rural electrification.

- *Ensuring the Use of Environmentally-Sound Electricity Generation Options*

With regard to ensuring the sustainability of the power sector from an environmental perspective, the following are possible options:

Review of Electricity Acts: Electricity Acts should be amended to ensure environmentally harmful electricity generation, transmission and distribution entities that were installed prior to EIAs becoming mandatory are assessed and mitigating measures carried out. The electricity regulatory agencies could enforce this requirement by linking it to renewal of licenses and the review of tariffs.

Explicit targets for the share of renewables in the electricity generation mix: To mitigate the negative trend of having an excessively large share of IPPs generating electricity from fossil fuel-based power plants, it is proposed that the regulatory agencies in collaboration with the Ministries of Energy should set explicit targets for the share of electricity generation from proven renewable energy technologies such as hydro, wind, solar PV, bagasse-based cogeneration and geothermal. Kenya provides a model example where such targets have been set. In Kenya, the Government has set a target of 25 per cent of electricity generation to come from geothermal by the year 2020. There is already an IPP actively exploiting this option as part of the process aiming at meeting the year 2020 target.

Modular development of electricity generation facilities: In order to minimize the potential negative environmental effects of large scale electricity generation installations, power development planners in the region should consider small- to medium-scale but reliable power plant that are also environmentally friendly. Small hydro, wind, solar, bagasse-based cogeneration and geothermal energy sources appear to fit into these criteria. In addition, modular development of electricity generation facilities can ensure an incremental growth in generation capacity to meet the increase in demand in an economically and cost-effective fashion.

Promotion of energy efficiency: Energy efficiency is one area that power sector reforms have not addressed. In most sub-Saharan African countries, demand for power invariably significantly exceeds supply. With the exception of Ghana, the only solution applied so far in most countries has been increasing generation capacity through the introduction of IPPs. However, implementation of energy efficiency measures could reduce power demand thereby reducing the deficiency gap between power supply and demand. In addition, it could defer investments in new large electricity generation installations thereby providing opportunities smaller generation installations that could be met through small hydro, wind, solar, bagasse-based cogeneration and geothermal energy sources.

- *Addressing Gaps and Barriers in the Legal and Regulatory Framework*

The following measures could help ensure the power sector's sustainability:
Strengthening the regulatory agencies: Probably the most effective measure in addressing the gaps in the legal and regulatory framework is ensuring the independence of the regulatory agencies. This can be achieved by enhancing the representation among the board members. For example, having representatives of various segments of consumers, including rural on the board of the regulatory agency could ensure that the plight of the disadvantaged is heard especially with respect to electrification and review of electricity tariffs.

Mobilizing local capital investment: The examples of Zimbabwe and Mauritius demonstrate the potential financial and technical capability and viability of local private investors in the power sector. This is corroborated by findings from recent AFREPREN studies which seem to indicate that local private investors can own and operate small to medium scale entities in the power sector, either on their own or with foreign partners (see Marandu and Kayo, 2004). Appropriate policy and financial incentives such as lowering entry requirements and tax holidays should be enacted to encourage local private investment in a privatized electricity industry. The ideal entry point, as in the case of Zimbabwe and Mauritius, is likely to be in small hydro and wind energy sources as well as through local cogeneration in the agro-based industries.

Issuing licenses and Power Purchase Agreements (PPAs) covering a longer period: Issuing longer-term licenses and PPAs can ensure that the selling price of electricity by IPPs is moderated. This is essentially because, longer-term agreements allow for sufficient time for the investor to pay off project financing debts as well as provides adequate amortization period for the equipment.

Overcoming challenges of rural electrification: Perhaps the most common barrier of rural electrification identified is the high cost of grid extension. An immediate option to lower the cost of rural electrification is the use of proven low cost electrification options such as those identified in this study. Another option is the promotion of decentralized electricity generation in rural areas using hydro, wind, bagasse-based cogeneration and where applicable geothermal. This would greatly reduce the need for transmission lines to transverse long distances and sometimes-difficult terrain. The other option for consideration is the cross border connections between towns/villages in neighboring countries, which reduces costs of supply by avoiding long transmission lines within individual countries. However, while these technical options are attractive, the policy framework has to provide adequate incentives to realize the benefits of these options.
Leveling the 'playing field': As mentioned earlier, electricity regulatory agencies could play a significant role in promoting proven environmentally friendly electricity generation options such as hydro, wind

solar PV, bagasse-based cogeneration and geothermal. The regulatory agencies could promote these technologies through setting of specific targets as well as providing for preferential tariffs for their electricity sales. In addition, regulatory agencies could provide attractive incentives to investors willing to install electricity generation plants based on these energy sources.

5. Conclusion

Based on preliminary assessments of the socio-economic and environmental impacts of power sector reforms, this study concludes that reforms have not done enough to ensure the sustainability of power sector. To ensure the sector's sustainability, reforms have to be redesigned to ensure that access to the majority of the population - the poor - is enhanced. In addition, the sustainability of the power sector can also be enhanced by ensuring a favourable share of renewables in electricity generation mix. Above all, the electricity regulatory agencies must carry out their mandate of protecting the poor by ensuring increased access to electricity and provision of subsidies as well as promoting proven renewable energy options for electricity generation. There is also need to address the identified gaps and barriers in the legal and regulatory framework as proposed in this study to ensure that the power sector is sustainable.

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the original version of this publication had graphics on the front page, and at the beginning of each chapter. That version was 10.6 mb. The graphics have been removed for this online version to bring down the size to 1.3mb.

Chapter 4

Regional Initiatives to Scale-up Energy Access for Economic and Human Development: Lessons learned from the East African Community and the Economic Community of West African States

By
United Nations Development Programme

1. Introduction

This chapter presents the experience of two African Regional Economic Commissions (RECs) - East African Community (EAC), Economic Community of West African States (ECOWAS) - who, with assistance from the UNDP, have moved towards developing and implementing regional strategies to increase access to modern energy services (UNDP, 2006a).

The Johannesburg consensus: access to energy underpins development and poverty reduction

The Johannesburg Plan of Implementation (JPOI) includes an emerging international consensus on the role of energy in sustainable development:

1) **Energy services are an essential input to economic development and social progress, notably to achieving the Millennium Development Goals[30].** Energy services are necessary for successful implementation of almost all sectoral development programmes, notably revenue generating activities, health, education, water, food security, agricultural development, etc. Increased access to energy fuels economic growth and poverty reduction. "The lack of modern fuels and electricity in most developing countries entrenches poverty, constrains the delivery of social services, limits opportunities for women, and erodes environmental sustainability" (UN-Energy, 2005).

2) **Under current economic conditions, provision of energy services to poor populations in many developing countries is not attractive to market actors.** Experience in the decades before and after Johannesburg had amply demonstrated the positive and negative aspects of a purely market based approach to the provision of energy services. On the positive side, in the power sector for instance, privatization and deregulation had in many cases reduced expenditure of public funds in support of money losing public utilities. However, on the negative side, these attempts only rarely achieved improvement in the quality or reliability of service in urban areas (see Chapter 3). In almost no cases had they achieved improvement in the rates of access to electricity in rural and peri-urban areas. Similarly, access to, and sustainability of, provision of domestic fuels and of fuels for transport had not improved under the pure market approach.

30 The DFID document "Energy for the Poor" clearly exposed the many linkages between energy and the multiple aspects of development.

3) **As a consequence, public authorities must act vigorously to create the conditions that will allow greatly expanded access to energy services.**

The role of the Regional Economic Commissions (RECs)

In the African context, whereas the new consensus had concluded that public intervention in appropriate forms was essential, an inventory of public action showed that energy was rarely mentioned in African national and regional development strategies. As a result, public action, in all forms – investment, regulatory action, ODA – was almost absent in the energy sectors in Africa.

Consequently, after Johannesburg, a broad movement began, led in part by the RECs to integrate energy considerations into national and regional development strategies in support of economic development, poverty reduction and achievement of the Millennium Development Goals. This is the main goal of the EAC and ECOWAS Regional Energy Strategies presented in this chapter. UNDP, through the "Energy Poverty Regional Programme (REPP)" supported this process.

The two regions covered in this document represent a broad range of situations in sub-Saharan Africa (SSA) countries. The 20 countries of the 2 regions (out of almost 50 in SSA) include a major oil exporter, many oil importers, electricity exporters and importers, as well as several LDCs and LLDCs. Despites these disparities, what these countries have in common is a low level of access to modern energy services, particularly in rural areas. Nevertheless, it must be kept in mind that other situations exist in Africa, for instance in Northern Africa and within the country members of the Southern Africa Power Pool (SAPP), the most advanced in sub-Saharan Africa.

2. Overview of access to energy in EAC and ECOWAS regions

African energy poverty, a barrier to development

Inadequate and unreliable access to modern energy is a significant constraint to the development of industrial activities, to increased agriculture productivity, and to the provision of basic services such as health, education and water.

Currently, the rate of access to modern energy sources remains very low: electricity or LPG is available only for a few urban centres and economic structures, with the majority of the poor excluded. As a whole, Africa accounts for 13 per cent of world population, produces 7 per cent of world's commercial energy but only contributes 2 per cent of the world's GDP and accounts for 3 per cent of global commercial energy consumption. In East African, less than 3 per cent of the rural population and 32 per cent of its urban population is connected to the national (electricity) grids. In West Africa, traditional energy sources (biomass) represent on average 90 per cent of total energy consumption, and only 12 per cent of the 260 million inhabitants of the region have access to electricity (ECOWAS, 2006a). In both regions, under 10 per cent of the rural population has access to electricity.

Furthermore, in terms of access to modern energy, women in particular are disadvantaged within the household, bearing the bulk of energy related tasks such as cooking, carrying water and collecting firewood: "Energy has an explicit gender dimension when considered from the poverty point of view" (EAC, 2006a).

Insufficient investment, weak policy framework

While lack of energy services constitutes a barrier to development in Africa, "business as usual" will not improve the situation. In fact, under current trends, in absolute terms, the number of people without access to electricity would even increase in the coming decades.

On one hand, private investments in energy have been declining, and is limited to urban areas; on the other, public intervention in energy remained very limited, in great part because of lack of public finance, and as a result of structural adjustment programmes of the last two decades, that called for the privatization of large government owned enterprises, such as power utilities.

Furthermore, as shown by a recent UNDP study, the public policy framework for intervention in the energy sector is weak or non-existent (UNDP, 2007). While energy services are essential inputs for achieving most of the MDGs, energy is not directly mentioned in these goals. It might be expected that energy inputs would appear as components of sectoral development strategies, but, as shown in the UNDP study, the linkages between energy and sectoral goals in PRSPs is weak: "Only 57 per cent of the African PRSP reports made explicit links between energy and income poverty. The connection between energy and other economic issues - such as debt sustainability and international trade - was not prominently reflected in other PRSPs". Furthermore, according to this report, the linkages between energy and social development factors, like education, gender equality and health are also notably marginalized in many PRSPs.

Lack of access to energy, insufficient private and public investment, and weak policy framework: the combination of these three elements makes progress difficult. In order to reverse the current trends, public action will be necessary, to:

- attract private investments through the creation of conducive investment environments;
- mobilize the capacity to pay off energy users;
- allocate national and international public resources to investment in energy infrastructure.

Thus, creating an adequate policy framework to sustain public action is a priority.

The national and regional levels

The principle of subsidiarity requires that for optimal efficiency and responsiveness to local needs, specific energy measures should be carried out by the smallest geographical/administrative/social entity possible. This might be a communal structure, a sub-national entity (department, canton, county, etc.) or a national organization.

If the subsidiarity principle suggests that work should be done at local or national level, why work at the supra-national regional level? What is the relationship between national and regional efforts? Actions at the supra-national level should be limited to cases where pursuing implementation within a smaller geographical area is clearly sub-optimal, or cannot succeed, as under the following conditions:

- **Need for scale economies.** Combining efforts at the regional level can lead to economies of scale. Rather than building several small national structures, one larger regional structure may provide better quality and lower cost and at the same time ensure profitability. Nevertheless, it must be kept in mind that proper governance of an multi-national publicly supported facilities is a challenge: many past efforts have failed, in part due to poor management, and insufficient support from the local administrations.
- **Need for a critical mass for institutions and markets.** Most national energy markets in Africa are quite small. Combining small national markets into a regional market may create the "critical mass" capable of attracting international investors. Similarly, national administrative structures may be too small and weak to carry out essential tasks.
- **Need for increasing reliability, and maximising the benefit of local energy resources.** Physical inter-connection of national infrastructure can increase the overall performance of energy systems. Cross border infrastructure can sometimes prove to be the most cost effective way to provide energy services. This is particularly pertinent for harnessing Africa's vast potential for natural gas and renewable energy sources, that are often low cost, but regionally unevenly distributed.
- **Need for harmonization of markets and frameworks.** Harmonization, standardization and increased uniformity of economic, regulatory and legislative frameworks within a region can make

markets more attractive to potential investors, by lowering the cost of doing business in the countries of the region.

In Africa, adopting a regional approach appears optimal or even essential, since the continent is divided into a large number of small countries, including almost 30 of the Least Developed Countries with populations of under 20 million. The national energy markets are small and fragmented. Furthermore, in these small mostly poor countries, it is a challenge for governments to design and implement policies to address the complex issues related to energy access. Thus, support from the RECs has proved essential.

3. Integrating access to energy into development strategies

The Johannesburg consensus concludes on the necessity for action to be taken by public authorities to create conditions to increase access to modern energy. This includes regulatory and legislative measures at national and/or regional levels, the allocation of public funds from national budgets, and the increase of Official Development Assistance.

Since priority actions undertaken by public authorities are implemented in the context of existing development strategies and policies, a first and essential step is to ensure that energy issues are duly integrated into national policies and strategies, and reflected in documents such as Poverty Reduction Strategy Documents.

EAC Development and Energy Access Strategies

The regional energy policy of the East African Community (EAC) aims to enhance economic and social development by sharply increasing access to modern energy sources.

EAC Development Strategy

The 3rd EAC Development Strategy (2006-2010) focuses on the challenges that the Community is facing, in order to identify the areas for priority interventions. Among these challenges, the most significant are: globalization; high poverty levels; low access to energy; and the rising price of oil. This latter challenge "is likely to have considerable implications on the oil importing East African economies considering that the current level of oil dependence is high (at 3.5 per cent of the GDP) and is likely to rise further as these countries industrialize".

The objective of the 3rd strategy is to highlight its potential capability to reduce extreme poverty and to boost economic growth in the region. Taking into account that increasing access to energy services should help implement the Strategy, the document spells out the key pillars of East African integration: cross-cutting priority intervention and sectoral priority intervention.

- **Cross cutting priority intervention.** There are two different ways to link the interventions concerning access to energy (EAC, 2006b): having the capacity to boost access to energy or conversely; being positively influenced by an increased access to energy. This latter link is clearly demonstrated in the two following examples: Combating HIV and AIDS, one of the most sensitive priority interventions in EAC, requires increased access to modern energy services. According to a UN-Energy policy paper: "electricity for communication such as radio and television can spread important public health information to combat deadly diseases. Health care facilities, doctors and nurses, all require electricity and the services that it provides (…) to deliver effective health services" (UN-Energy, 2005).
- **Sectoral priority interventions.** The Development Strategy views energy as one of the sectoral priority interventions together with agriculture and food security, environment and natural resources, health and education, etc. For the Energy Sectoral Intervention: "the emphasis (…) will be to ensure

availability of sufficient, reliable, and cost effective energy services which will assist in addressing the broader EAC objectives of attracting investments, and promoting competitiveness and trade (…). Some of the proposed strategic interventions" are as follows (ECA, 2006c): implement the East African Power Supply Master Plan; promote the energy mix system involving non-and renewable energies; extend gas pipelines. These supply sided strategic interventions are considered the first steps in increasing access to energy.

Beyond the Energy sectoral intervention, increased access to energy can have a significant impact on the achievement of other priority interventions. In the case of Agriculture and Food security "the regional Strategy of enhancing supply capacities in agriculture will entail identifying high value agricultural sub-sectors (…) and capitalise on investments that can facilitate the shift from comparative to competitive advantages by facilitating movement up the value chain" thus requiring additional, reliable and cost-effective energy.

As shown above, energy, either as a sectoral intervention or as a means to achieving other interventions, already benefits from an increased attention within the EAC Development Strategy. Overall, the Key Pillars of East African Integration, Crosscutting Priority Intervention and Sectoral Priority Intervention as set out in the Development Strategy, are an opportunity for the EAC to go beyond a "business as usual" supply-side approach. The EAC general objective is therefore to launch policies and programmes aimed at boosting economic growth and reducing poverty by increasing access to energy services. Also, it is currently developing a two-sided policy with on the one hand, the East African Energy Master Plan to increase supply capacities; and on the other hand, the strategy on scaling up access to modern energy services – demand driven guiding principle, which makes it unreservedly innovative.

EAC Regional Strategy on Scaling up Access to Modern Energy Services

The objective of the EAC Regional Strategy on "Scaling-up Access to Modern Energy Services Regional Strategy" is to support the achievements of the MDGs by enabling "at least half the population to have access to modern energy services by the year 2015. This means enabling 9.6 million more households and 23,000 extra localities to access modern energy services" with an additional US$3.4 billion in resources. Payments for services by end users are expected to play an important role in the financial and economic equilibrium of energy investments. The inclusion of Rwanda and Burundi into the EAC will increase impact: for instance, resources will increase by over US$1.2 billion. It is expected that user payment for services will cover almost half of the budget.

The strategy uses two significant concepts when addressing the topic of access to energy services to achieve the MDGs.
"Energy poverty" can be defined as the lack of sufficient choice that would give access to adequate, affordable, effective and environmentally sustainable energy services that could support economic and human development.
"Energy services" refers to the end use applications of an energy delivery system that meet tangible and/or intangible life and livelihoods needs and social services (e.g., recreation, lighting, cooking, communications, transportation, heating).

The four strategic targets for scaling-up access to modern energy services

In the process of endorsing the scaling up strategy, the EAC adopted four targets to address the energy access challenges posing the largest risk to meeting the MDGs in the EAC. The following targets are based on a set of progressive and demand oriented guiding principles (which is already a major breakthrough):

- Usage of modern cooking practices by 50 per cent of those who at present use traditional biomass for cooking, including reducing indoor air pollution to safe levels, and increasing the sustainability of biomass-derived fuel production;

- Access to reliable electricity for all urban and peri-urban poor;
- Access to modern energy services such as lighting, refrigeration, information and communication technology, and water treatment and supply for all schools, clinics, hospitals and community centres;
- Access to mechanical power for all communities for productive uses.

Prerequisites to achieve the strategic targets at national/policy level

In addition to the socio-economic factors hindering the smooth functioning of the community, member States are aware that three prerequisites have to be addressed before reaching the adopted targets. EAC countries themselves must:

- mainstream energy into MDG-based National Development Strategies (NDS)/ Poverty Reduction Strategies (PRSs);
- develop pro-poor energy policies and regulatory frameworks to attract required investments from all sources such as Official Development Assistance, the private sector and national revenue; and
- build national capacity to deliver modern energy services for the poor and unserved".

Focus to achieve the targets at local level: meeting the market demand

One of the main conclusions of the strategy is that there is a significant market for increased access to modern energy services. The strategy points out that households (excluding the top 20 per cent income household) spend up to US$1.2 billion a year on inferior energy services. This shows that part of the required resources are available through end user payments and that private sector and international donors' assistance will be needed to unlock the capacity of households to invest. Public action will be required to create the enabling environment for profitable business models to provide energy services. Furthermore, public subsidies will be required in certain cases in view of reducing extreme poverty.

The three areas where there is need for public targeted interventions are: the market for improved cooking stoves in rural areas; the market for urban and peri-urban connection to the electricity network; and the market for community services and access to modern energy services.

The ECOWAS Regional Energy Access Policy

Sectoral policies have failed in the last twenty years to reduce poverty and to increase access to modern energy services in rural and peri-urban areas. ECOWAS considers that large-scale access to energy services is crucial to achieve the MDGs and boost GDP growth. However, current trends of access to energy services in rural and peri-urban areas are not sufficient to ensure the attainment of these goals. Consequently, there is urgent need for decisive actions to expand energy access. In response to this challenge, ECOWAS countries and regional institutions have launched the Regional Energy Access Policy, embodied by the White Paper endorsed by ECOWAS Heads of State and Government in January 2006 in Niamey.

Objectives of the White Paper

The Regional Energy Access Policy aims to ensure access to modern energy services to at least half the population living in rural and peri-urban areas by 2015, in line with the MDGs. The challenge is immense. For instance, it will entail "supplying 36 million more households and 49,000 more localities with access to energy services". Other objectives of the policy are to:

- strengthen regional integration with a view to fostering development and building capacities;
- help harmonise political and institutional frameworks (i.e. PRSPs, MDG monitoring framework, etc.); and
- develop, on the basis of national political frameworks, coherent energy policies based on reducing poverty in rural and peri-urban areas and achieving the MDGs.

The ECOWAS White Paper fixes three targets to be achieved by 2015:

- 100 per cent of the total population should have access to improved domestic services;
- 66 per cent of the population in rural and urban areas should have access to individual electricity supply; and
- 60 per cent of the population living in rural areas should have access to motive power for productive uses[31].

Added value of the region

The value added of the ECOWAS collective regional response lies in its proven ability to "establish a knowledge management system that will directly support capacity-building strategy by fostering expertise based on shared practices" (ECOWAS, 2006b). In addition, the Community can be a catalyst, notably concerning the mobilization of investment funds, like the first achievements of WAPP and WAGP grids". Overall, ECOWAS, as an organization, brings significant benefit at an upstream level, i.e. institutional reforms, technical standards, financial mechanisms, and cross-border tariff issues.

Required investment

ECOWAS estimates that for achieving the three targets by 2015, three types of investments are necessary: investments in access (the equipment required for access to modern energy services); investments in operating costs (including cost of generation and transmission) and; investments in technical studies and accompanying measures. The cost of implementing the three policies can be broken down into:
17.5 billion dollars (over ten years) for investment in equipment needed for access to modern energy services and for studies and accompanying measures;
34.6 billion dollars (over ten years) for energy related costs: international donors should support a significant part but end users would also be able to finance a portion.

Institutional framework to implement a multisectoral energy policy

The main guiding principle of the approved policy is to follow a participatory and multi-sectoral approach when developing MDG based policies and programmes for energy access. This is done through the development of a national vision for energy access for 2015, based on a need assessment that involves all key players in the identification of the energy services needed to implement other sectoral policies and programmes in the field of education, health, water, agriculture, etc. Other guiding principles include technological neutrality and the promotion of public-private partnership.

Countries are building the required institutional framework in order to apply the regional policy. This includes the creation of National Multisectoral Committees (NMC) in the participating countries, whose mandate is to coordinate national stakeholder efforts in developing Energy for Poverty Reduction Action Plans and National Investment programmes. At the regional level, a Regional Multisectoral Committee, with representatives from all national committees, provides oversight and guidance for the implementation of the White Paper and helps harmonize the work of the NMCs. In parallel, an energy service needs assessment is being launched in each country to help create a vision at the national level, while a regional capacity-building action plan is being built to support countries.

The White Paper also proposes "the establishment of a Regional Agency for Energy Access (RAEA) to mobilize the necessary resources for tackling the enormous challenge to provide modern energy services

31 The regional strategy documents use three categories for energy services: domestic fuels; electricity; motive power. The documents have been strongly influenced by the work of the Millenium Project that put forward this categorisation. From an energy analysis standpoint, this categorisation is incomplete, leaving aside important services such as process heat or transport fuels. Nevertheless, the categorisation, by stressing what is important for achieving the MDGs, has proved useful in creating a political consensus on the necessity for public action to provide energy services.

to more than half the region's population by 2015" (Abeeku et al., 2006). The mission of the RAEA, which is expected to become an ECOWAS specialized body, would be to lead and coordinate the implementation of the regional plan of action for increasing access to energy services.

Implementation status

ECOWAS has already launched the first phase of preparatory activities (2006 and 2008) that aim to create both an enabling environment and sufficient capacity within the region, to build market visibility and confidence. The preparatory activities will prepare the ground for the next phase (2008-2015) of the White Paper, i.e. implementation of the regional action plan and investment programmes needed to reach the objectives set by the White Paper.

At this moment in time, ECOWAS countries need reliable and long-term support from the international community, in order to meet the challenge of the low access level to modern energy services through a multisectoral approach. This will positively influence development policies in Health, Education or Agriculture and Food processing, etc. According to the White Paper, the overall cost of implementing this access to modern energy services is around 16 dollars per inhabitant per year, around 4.3 per cent of regional GDP.

4. Building large scale regional energy infrastructure

Both EAC and ECOWAS have initiated ambitious programmes to build large-scale regional energy infrastructure.

Box 1: Regional electric power pools

The South African Power Pool (SAPP), and the developing West African Power Pool both allow optimal use of complementary power generation facilities using cheap hydropower when it is available, and sharing thermal generation when necessary. Furthermore, regional power pools increase the reliability of service, allowing neighbouring systems to provide backup facilities in case of outage of one power plant.

Lessons: Regional infrastructure can optimise energy systems, improving reliability and use of renewable resources.

The East Africa Power Master Plan (EAPMP)

East Africa is endowed with abundant and cost effective resources to produce electricity, i.e. gas, geothermal, hydro and promising coal resources. These resources can meet future energy demands and, if well managed, form the economic foundation of future economic growth of EAC countries.
The East Africa Power Master Plan (EAPMP) shows that there are economies of scale associated with electricity interconnection and trade within EAC countries. In addition, the Plan demonstrates that the development of hydro projects in Uganda and Tanzania would increase EAC capacity to produce cost-effective electricity and reduce its level of imported oil dependency. The EAPMP also provides the basis for coordinated action among the three countries, under the leadership of the East African Community. The Plan lays out a 20-year programme (beyond 2015) of investment in the energy sector, with clear objectives and investment targets to meet the expected growth in demand for power. According to the Plan, the economic rational is clear and substantive, i.e. a coordinated, integrated approach can achieve economic benefits of some US$456 million net present value (NPV) over the next 20 years.

However, the Plan calls for high-level political commitment in order to attract major private investment to the sector. The Plan states that this commitment should be translated into measures that will reduce investor uncertainty, as this type of project requires significant financial investment.

The Plan calls for fast tracking the implementation of three key projects in order to demonstrate EAC's capacity to lead this type of complex process. These projects are the hydropower dam of Bujagali in Uganda; a 360 MW of additional gas fired power plant in Dar-es-Salaam (Tanzania) aimed at supplying Kenya demand; and the Arusha-Nairobi power interconnection. These three projects, if underway within 18 months, will demonstrate that East Africa is acting together to meet its power needs in a Kyoto-friendly, low cost manner. The Plan also calls for targeted activity aimed at assessing potential Emission Reduction Credits (ERC) under the Kyoto Protocol that would arise from implementation of the EAPMP and at using these credits as a source of co-finance for implementation.

The Plan goes much further in terms of technical proposals and specific actions to develop. Among these, the most important proposals are: to set up an integrated electricity system for the three or five countries, based on the East African Power Pool.

With the Plan, EAC priority is to ensure reliable, adequate and cost effective access to modern energy sources. This access is required to unlock the development of industrial and agricultural activities and to increase household connection rate to national electricity grids in the three countries. However, the EAC crucially needs international financial and technical resources to achieve this supply sided policy.

The West African Power Pool

As demand for energy services in West Africa is expected to grow by 5 per cent annually over the next 20 years, the region needs to increase its generating capacity by about 17,000 MW to keep up[32] the pace. Pooling power at the regional level is economically rational, permitting savings estimated at US$ 3 to5 billion over 20 years.

Objectives of the WAPP

In response to the long-acknowledged lack of reliable access to energy, the vision of the West African Power Pool (WAPP) is to integrate the national power system operations into a unified regional electricity market. The main priorities[33] are to quadruple interconnection capacities within the next 20 years and to generate additional electricity capacities. Furthermore, the project aims to increase trade in energy amongst ECOWAS countries and promote Foreign Direct Investment (FDI) in the sector. With an estimated investment of US$16 billion over the period, ECOWAS expects the WAPP mechanism to help ensure reliable, affordable and cost-effective electricity supply for the inhabitants of the region.

Power trading within West African countries is still in the early stages of development. However, there is already a network of bilateral cross-border interconnections supporting energy trading between the countries[34] and by 2011, most countries in the region are expected to be interconnected. In addition, ECOWAS has made substantial progress in building the regional institutional and regulatory framework for the implementation of regional power trade.

32 For further information see http://www.usaid.gov/missions/warp/ecintegration/wapp/

33 The following objectives are assigned to the WAPP General Secretariat: Increase collaboration in the region; Improve reliability and efficiency of power supplies; Minimise network operating costs; Encourage investment in energy; Introduce and enforce operating standards; and Increase the overall level of power supply in the region.

Key achievements

Four key achievements are:

- **Creation of the WAPP Secretariat.** The WAPP was created in 1999 by ECOWAS member States (A/DEC.5/12/99) and granted the status of ECOWAS Specialized Institution in 2006 (A/DEC.20/01/06) to address the issue of inadequate power supply within West Africa.
- **Adoption of the ECOWAS Energy Protocol.** The 2003 Protocol calls for the elimination of cross-border barriers to trade in energy. It encourages investment by providing for investor-friendly terms such as: international arbitration for dispute resolution; the repatriation of profits; and protection against expropriation of assets. With respect to the electric power sector, the Protocol provides open and non-discriminatory access to power generation sources and transmission facilities, and envisions an enforcement mechanism supported by the ECOWAS Secretariat.
- **Creation of the WAPP Information and Coordination Centre.** The WAPP Information and Coordination Centre was established to: collect energy supply and demand balances; provide forecasts of potential energy surpluses available for trading; coordinate maintenance schedules; and engage in long-term generation and transmission capacity expansion planning. It has now been integrated into the new WAPP General Secretariat in Cotonou, Benin.
- **Establishment of a Regional Regulatory Body.** As cross-border trade in electricity grows, the task of the RRA is mainly to supervise an effective system for dispute resolution; establish and provide the enforcement of uniform technical rules for the management of trade; and review bulk power transactions between systems of member State entities.

The WAPP mechanism has already succeeded in persuading the international community of its potential: "Under its new approach for lending on regional integration projects, the World Bank has made the WAPP its number one priority for West Africa. (…) World Bank loans can now be made to national governments for the segment of an international transmission line lying within its territory"[35]. However, the current priority for the Community is to ensure that international donors assist with the financial constraints in implementing this mechanism. Opening up the path, by providing substantial financial support will help launch priority projects and endow the WAPP with its own resources.

The West African Gas Pipeline (WAGP)

Another major success of ECOWAS in the energy sector is the establishment of the WAGP. The pipeline owned and operated by a private-public consortium, is currently under construction and should be fully operational in September 2007.

The purpose of this project is to construct a 600 km pipeline at a total cost of about US$ 615 million to transport natural gas from Nigeria to Benin, Togo and Ghana. Through this initiative, cheaper and cleaner energy sources will reach member States for electricity generation and industrial purposes. One of the benefits of the pipeline will be a reduction of the overall industrial production costs resulting in greater industrial growth and economic integration. Moreover, environmental pollution caused by electricity generation will be greatly reduced.

The economic effects of the WAGP are manifold: 10,000 to 20,000 primary sector jobs will be created; new power supplies will stimulate the growth of new industry potentially creating 30,000 to 60,000 secondary jobs; and an additional US$800 million in new industrial investment should occur in the region. The World Bank estimates that Benin, Togo and Ghana can save nearly US$500 million with the newly built WAGP over a 20-year period.

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34 The following objectives are assigned to the WAPP General Secretariat: Increase collaboration in the region; Improve reliability and efficiency of power supplies; Minimise network operating costs; Encourage investment in energy; Introduce and enforce operating standards; and Increase the overall level of power supply in the region.

35 West African Electricity Sector Integration, p. 11.

5. UNDP: Capacity development for expanding energy access in Africa

Energy has a profound bearing on the lives of the poor. It is central to every aspect of human endeavours, making its availability, reliability and affordability a critical element to the achievement of the MDGs. UNDP works on energy for sustainable development as part of its commitment to "Energizing the MDGs".

UNDP provides an integrated approach to addressing the multidimensional problems of sustainable energy development, and capacity development lies at the heart of this approach. Whether at the global, regional or local level, UNDP aims to strengthen the capacity of its partners to address the energy challenges of the poor. As the UN Resident Coordinator, UNDP can draw on the UN system's knowledge and network of experts, including the experience of 136 Country Offices working on environment and energy issues to help governments formulate locally-appropriate, integrated, sustainable energy solutions.

To "energize" the MDGs, UNDP assists governments in mainstreaming energy considerations into MDG-based national development plans and poverty reduction strategies as well as developing local capacity to expand access to energy services for the poor.

Since the adoption of the MDGs, over half of UNDP's recent energy-related projects and financing have dealt with expanding access to modern energy services. Over the past decade, UNDP has commanded a portfolio of US$2.5 billion in total energy-related projects, for which the Global Environment Facility (GEF) has been a major source of funding; and the list of partners and co-funding sources is growing, allowing the energy access portfolio to expand. In fact, between 2001 and 2005 the energy access portion of UNDP's portfolio has included over US$700 million in financing.

The largest growth in the energy access portfolio has unquestionably been in Africa. UNDP support for energy-related projects in Africa rose to over US$120 million in the past 5 years—a three-fold increase over previous 5-year periods—with almost all of that funding related to increasing access to energy. UNDP has been able to mobilize a significant degree of regional and national support for this work with substantial cost-sharing supplied by other organizations.

In addition to its global- and country-based programmes, UNDP also maintains three regional energy programmes, including one in Africa. The Dakar-based Africa programme is the main driver of UNDP's increasing involvement in energy in the region. It is designed to help share lessons learned from national experiences and upscale country level actions while encouraging cooperative action through the consolidation of political commitments at the regional level. Through this regional Energy For Poverty Reduction programme, UNDP offers capacity development support and technical and financial assistance for the implementation of the EAC and ECOWAS Policies on energy access in addition to its capacity development work at the country-level.

6. Conclusion: investing in energy for development

The work accomplished by EAC and ECOWAS in developing a political consensus on access to energy has laid the foundations for national and regional energy infrastructure investments. Many projects and programmes are already underway, often predating the regional energy access strategies. These include:

- regional power pools with projects on cross-border power transmission lines and on regulation of power pools (WAPP, EAPMP);
- national rural electrification programmes; and
- national and regional programmes on sustainable production and use of domestic fuels.

The challenge these regions now face is to translate national and regional political consensus into investment programmes that will increase availability and use of affordable energy services for productive use and wealth creation. It will be particularly important to provide the services that will favour the development of rural industries, adding value to local resources. The following guidelines should map the way toward maximizing the chances for success.

Address specific regional issues such as trade barriers, regional integration, and the transnational nature of many energy resources. In addition to local and national needs, if energy services are to be viable over the long-term and scalable in a manner that will serve the millions in need, they will have to address larger regional and international issues such as trade barriers, regional integration, and the transnational nature of many energy resources such as river basins. The example of Manatalli is illustrative of a good approach to solve this type of challenges.

Integrate Energy Planning and Implementation into National and Regional Strategies.

- Ensuring that access to rural energy services is placed at the forefront of the national or rural development framework, sustained by a common vision for a rural energy demand approach and corresponding strategies and sectoral action plans to implement the vision.
- Using advocacy and lobbying to create a space for negotiations and debates and to illustrate the role of improved access to energy in promoting growth and social development.
- Coordinating existing strategies and policies (e.g. for EAC, setting along the same lines the objectives of the Master Plan and Scale up strategy) and building on lessons learned from existing energy access projects and programmes, and potential synergies. The combination of local productive enterprises, local energy resources, technical improvements in production, efficiency improvements in use, emissions control, and sustainable land-use practices can all add up, leading to productivity enhancement and simultaneous reduction in unit costs while allowing beneficial use of an otherwise potentially harmful energy source.
- Formulating policies that recognize and support the successful existing energy delivery systems in poor communities, in the absence of more organized efforts.
- Creating a political space for discussing energy access for poverty reduction at the regional and national levels.
- Providing an opportunity and motivation at the national level to examine how energy needs to be approached to help achieve the MDGs.

MDG-based PRS works to align partners to national priorities. As ECOWAS White Paper processes show:

- Once national and regional governments integrate energy in their macro planning, that has worked to align all partners behind the set national priorities;
- This also greatly helps prioritize external assistance in support of national priorities.

Creating a multisectoral process or political fora to discuss and develop a national consensus on energy is key to expanding access to modern energy for the poor.

- Rural development activities - agriculture, transport, water supply, education, income generation, health care - all have energy requirements. Yet the ministries and departments responsible for these activities rarely coordinate or cooperate with the ministry of energy or with one another to arrive at the most rational integrated solution to their energy needs.
- An institutionalized forum for coordinating and cooperating on energy strategies and action plans across government ministries and departments' supports mainstreaming energy into the development process. It is the reason why ECOWAS has been promoting a cross-sectoral approach based on a

regional committee of cross-sectoral experts (mainly energy and finance) and national cross-sectoral groups involving key sectors and actors as health, education, agriculture, private sector, etc.

- Both providers of energy services (public sector, private sector) and the beneficiaries (agriculture, small business, industry, health, education, etc.) must be involved at all levels (local, national).

Design Effective Regulatory Framework. 'Pro-poor' energy policies will need to be implemented within a regulatory framework that prioritizes the provision of energy services to poor communities and rural areas. Regulatory frameworks should be designed to use energy as an instrument to effectively deliver social needs, stimulate productive activities, enable work that adds value in agriculture and services, and spur economic growth. Sustained political commitment is required to create a framework of market conditions amenable to energy-based approaches to poverty reduction. Macroeconomic policies and fiscal management should encourage economic diversification, the diversification of energy resource portfolios, the participation of communities and a larger number of private entrepreneurs in delivery systems, and the most efficient use of these resources through market incentives.

Reduce Costs through Financing Mechanisms and Subsidies.

- Economic barriers limiting access to energy services by the poor can come in a range of patterns. The poor also often pay a much higher share of their disposable income (20 to 30 per cent) for energy services than the higher income groups (5 to10 per cent). In other cases, high capital expenditures or recurring costs, irregular incomes, lack of access to credit, lack of legal residential status, and lack of formal legal assets for collateral can prevent the poor from obtaining energy services. Innovative financing and microfinance institutions also represent a very important development tool.
- Therefore, it is recommended to:
  - improve the affordability, availability and safety of energy services for increasing access; and
  - create incentives to increase generation capacity and invest in distribution infrastructure to serve a larger population.

Enhance Human Capacity through Education, Training, and Research. Action at regional level can go a long way towards overcoming the shortage of skilled human resources in rural and urban areas. To support national and regional infrastructure development, as well as consumer-responsive service delivery systems, education and training programmes are needed for skilled technicians, planners, entrepreneurs, financial services and community workers.

Action must be taken to build the capacities required to devise harmonized political and institutional frameworks that rank energy as a national priority, and to develop coherent energy policies and programmes geared towards reducing poverty. Information and awareness raising is necessary for a broad range of actors:

- Staff in public institutions in member States, local authorities and attached services and agencies;
- Public or private operators working at local level (producers, energy system users and equipment manufacturers and fitters);
- Civil society organizations and consumer representatives (cooperatives, NGOs, consumer associations, trade organizations, etc.).

Highlighting successful local experiences can help to draw attention to existing energy poverty issues and cost-effective solutions.

- Regional bodies can help create work methods that avoid the failure of policies attempting to reproduce schemes and models conceived elsewhere.
- There is a strong need within the member States to develop national strategies of energy access based

on their own experiences. Small/medium-scale interesting experiences have been developed in the Region, especially through initiatives as MEPRED, EUEI, GVEP, etc. Those experiences need to be shared and scaled-up to allow a large access to energy.

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the original version of this publication had graphics on the front page, and at the beginning of each chapter. That version was 10.6 mb. The graphics have been removed for this online version to bring down the size to 1.3mb.

Chapter 5

Investment in Electricity for Development

By
The World Bank[36]

1. Introduction

In this short chapter, we discuss first the role of reliable and affordable electricity in underpinning economic development and in enabling the achievement of the MDGs in health and education. We then review some estimates of investment requirements for energy needs in sub Saharan Africa. In the next section we discuss briefly how financing sources for investment in the sector in sub-Saharan Africa are constrained. In the main and final section we list priority policies, which, if implemented, can help overcome these constraints so that increased amounts of investment begin to flow into the sector, resulting in the desired improvement in electricity services.

2. Why investment in the electricity sector is a priority

The economic transformation of Africa is one of the great challenges of our time. Africa's slow and erratic growth performance has been identified as the single most important reason behind its lagging position in eradicating poverty (Estache, 2006).

African policy-makers recognize that boosting economic growth in sub-Saharan Africa is dependent to a large extent, on expanding energy infrastructure along with transport and other infrastructure. Adequate, reliable and affordable energy services are not of course the only condition for growth. Fair business regulations and their enforcement; stability of the macroeconomy; protection of property rights; the proper functioning of the financial system, human capital and technological progress are also important conditions. However, it is a fact that most African countries urgently need greatly increased levels of electricity services and modern liquid fuels in order to raise the productivity and competitiveness of business to enable the delivery of education and health services and to provide households with lighting and cooking energy.

At the firm level, costly and unreliable electricity services directly influences costs of production; at the industry level it often relates to market structure and competition. The effects are felt more heavily in traded sectors than in primary production and extractive resource sectors because the former tend to more intensively require "inputs" of logistics, infrastructure and regulation. They are ruinous for small-scale and medium-scale manufacturing that are less able to cope (by having their own stand-by

[36] Written by the Energy Unit for sub-Saharan Africa

generation) with poor electricity service than large-scale manufacturing. Whenever firms, (whether big or small) are forced to allocate investment funds in generators, their productive investment will be reduced and their operating costs will increase (Ndulu et al., 2005).

MDGs in education and health will be difficult to achieve in countries where the majority of schools and health clinics lack electricity and fuel. Sterilization of equipment, clean water supply and refrigeration of essential medicines are impaired in health facilities without adequate electricity. For example, in Kenya only 50 per cent of the health centers are connected to electrical supply and 20 per cent must rely on stand-by generators. Unavailable electricity service is a disincentive for teachers, doctors, and nurses to reside in rural areas, further undermining the delivery of these services. Many poor households in Africa do not have modern lighting that would facilitate reading, studying and safety after dark. Education of children is impaired for lack of adequate illumination in poor households that rely on candles or simple kerosene lamps that are unsafe in the confined interiors of African homes.

The crisis has many causes, including inadequate tariff levels, the drought that has reduced available hydropower capacity for long periods in east and west Africa, destruction of systems in countries during conflicts, poor utility management resulting in inappropriate investment choices and excessive technical and commercial losses. Serious under-investment in electricity infrastructure in the 1990s and early 2000s is mainly responsible for just 32 GW of generation capacity being installed in SSA (not including South Africa) for a population of 680 million whereas Latin America with a population of 541 million has installed capacity of nearly six times larger (200 GW).

3. Investment costs

The Commission for Africa estimated that Africa need to spend an additional US$20 billion a year on infrastructure investments and maintenance until 2015 to sustain a growth rate of 7 per cent (CFA, 2005). The electricity sector would account for about a quarter of this. Other sources have estimated the investment needs to be much greater. The IEA for example estimates that US$344 billion is required in new electricity infrastructure that translates into more than US$13 billion per annum (WEA, 2006). Investment costs are made of costs for generation rehabilitation and additional capacity, for upgrading and extending transmission and distribution networks, for mini-grid and off-grid supply and for household connections (the "drop" from the low voltage network to the customer's meter.) Customers' own costs are additional to these and include the cost of in-house wiring. For households that will not be provided with electricity service either by means of grid or off-grid supply, we may consider the cost of modern lighting technologies.

To say that the electricity sector is capital intensive is to state the obvious. Household connection costs can range from US$200 per connection in peri-urban areas where a grid has already been constructed but more often reaches to US$1,500 per connection in Africa, when the grid must be extended to villages that are remote from the existing grid (World Bank, 2006). Unit costs for new generation capacity vary with technology and range from roughly US$700 million per MW in the case of gas to US$1,500 per MW in the case of coal. In the case of hydro, costs are site specific, but can range from US$1,000 per MW to as much as US$5,000. Rehabilitation of existing thermal and hydro capacity costs upwards of US$300 per MW. The unit cost of mini-grid and off-grid options is usually in the range of US$800 to US$1,200 per household connection. Construction of a 200kV transmission line may cost US$300 thousand per kilometer.

Approximately US$4 billion per annum is needed to increase household electricity access to 35 per cent[37] by 2015 in sub-Saharan Africa. In order to achieve this electrification rate, almost 26 million new household connections would need to be made by means off-grid, mini-grid and off-grid extensions. This scale-up implies roughly US$4 billion per annum for access in generation capacity, transmission and distribution networks and in off-grid electricity supply. If this level of investment was maintained through 2030, an overall household electrification rate of 47 per cent by 2030, implying 76 million new connections is achievable. This estimate uses common approximate values for unit costs for all countries and makes conservative assumptions of demand for newly connected urban and rural households (0.58 kW and 0.25 kW at system peak, respectively) reflecting conditions commonly encountered in Africa. In the case of rural households, this level of demand is typically associated with electricity consumption for basic lighting needs and for a few small appliances. The estimate includes investment to provide a modern lighting package based on renewable energy technology for about 50 per cent of the population that will not be provided with electricity service.

4. Financing electricity access

The public sector will remain an important – and often the main – source of financing for investment over the medium-term for the energy sector in sub-Saharan Africa where the country or regulatory risk deters private investors (UN-Energy, 2005). However, in the case of large generation projects especially those that serve regional needs, private investment will be essential. In most countries in sub-Saharan Africa power sector investments are funded much differently from middle-income countries in other regions, due to country risk factors, and financial constraints and credit-worthiness issues. In middle-income countries in Asia and Latin America, source of sector investments include public sector financing (equity, debt, or subsidies), private sector financing (equity, debt, self-financing from revenues), and community and users' contribution. In many low-income countries in sub-Saharan Africa by contrast, internal cash generation as a source of investment funds is very limited because of low tariff levels and poor collection that result in utilities not covering even their O&M costs, much less generating profits that would allow them to invest in expansion of their networks. IFIs, ECAs and bilateral donors play an important role in financing new investments in these countries. Government support in the form of grants, equity contributions and debt also play an important role in some of these countries depending on the Government's fiscal circumstances.

In Africa, private participation and private sources of funds (both debt and equity) have been extremely limited but are reviving. Private sector participation—(investment, management, etc.) will be necessary to complement public electrification programmes. In most countries private sector debt and equity investment leveraged by guarantee instruments of IFIs will be critical to developing large generation projects needed. In the case of electricity distribution entities that are loss making the scope for outright sale to a private sector investor is extremely limited. However, management contracts and distribution business outsourcing under which a selected part of the distribution network or a customer cluster would be ring-fenced and outsourced to a private party for a 3 to 5 year period can support increased efficiency and be a first step in bringing private sector investment in the distribution business. Finally, the delivery of lighting systems to households and small businesses that do not have electricity service should be based on programmes that rely on private sector led market development as well as on consumer credit mechanisms that are geared to low income households.

[37] This is a national rate that does not reflect official national targets. Recently, targets for access to modern energy services (as distinct from access to electricity service) have been developed by the Regional Economic Communities (c.f. UNDP chapter in this publication).

5. Policies to support investment in the electricity sector

The role of government in undertaking broad-based reforms is key to closing, if not eliminating the financing gap. All countries that have been successful in bridging the electricity sector financing gap have done so through: good governance, both at the policy and utility level; maintaining a financially healthy power sector characterized by a self-financing capacity for new investments within the sector of at least 30 per cent[38]; a combined focus on both supply and demand-side opportunities; and facilitating trade to keep the cost of supply low. Good governance and transparency at the state and corporate level are the keys to attracting foreign and domestic investors in the sector. The combination of good billing and collections practices with reasonable pricing policies provides the financial liquidity within the sector and enables both public and privately-owned power companies to gain access to capital to meet investment needs. The combination of an enabling environment that allows non-payers to be disconnected and good governance to implement this policy has consistently been the hallmark of successful power companies and financially healthy power sectors. Utilities that achieve a self-financing capability of at least 30 per cent generally manage to meet the remaining investment needs through debt, or through the purchase of services from private suppliers and keep demand and supply in balance. Public sector resources will remain crucial for investing in energy service delivery for the poorest groups and marginal areas due to private sector perception of risk, even within reformed markets. Governments should create fiscal space for these investments, so that other publicly financed programmes that benefit the poor are not displaced by them under the general scarcity of public financial resources.

Improved regulatory systems can support electrification. Four general principles are recommended to create regulatory systems that will "help" rather than "hurt" electrification: adopt light-handed and simplified regulation; enable the national or regional regulator to "contract out" or delegate, either temporarily or permanently, regulatory tasks to other
government or non-government entities; allow the regulator to vary the nature of its regulation depending on the entity that is being regulated and the technology that is used by that entity; and promote realistic, affordable, monitorable and enforceable quality of service standards (Reiche et al., 2006). The latter also provide governments a way to balance tariffs with services and provide stronger rationale for consumer satisfaction when inevitable tariff increases have to be made.

In undertaking large programmes of electrification institutional arrangements are less important than adherence to sound commercial principles. Experience from countries that have successfully and rapidly scaled up electricity access, point to the need for an inter-ministerial and/or interdisciplinary mechanism supported by a dedicated agency that can tackle the local nature of many challenges for delivering electricity services. A review of ten successful rural electrification programmes in diverse countries showed that success does not necessarily depend on the nature and form of the dedicated institutional arrangement. In successful countries, these arrangements have varied from rural electric cooperatives (Bangladesh, Costa Rica, Philippines), public companies (Mexico, Thailand, Tunisia), private distributors (Chile), and decentralized power companies (China). The cases reveal that success relies more on adhering to strict business principles in distribution company operations than on the specific institutional mechanisms used (Barnes, 2007).

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[38] For example Vietnam managed to be successful at meeting annual electricity demand growth of 16 per cent per annum over 10 years and now has achieved 92 per cent household electricity access rate. The power company EVN maintained a sound billings and collection systems, while the Government maintained price levels sufficient to enable the power company to maintain its ability to self-finance 30-50 per cent of investments from internally generated cash. The financial health of the sector also enabled private sector financing in generation (IPPs).

Energy issues and electricity development should be mainstreamed into PRSPs and other country development strategies. Many PRSPs development strategies treat energy only within the context of large-scale infrastructure projects. They also tend to focus only on electricity while ignoring issues such as fuel availability and energy access which are of greatest importance to the poor. Less than half of all PRSPs in sub-Saharan Africa, for example, include explicit targets and timelines to meet the energy priorities of the poor. Only one third of the PRSPs actually allocate budgetary resources to national energy priorities in their Mid-Term Expenditure Framework (MTEF). The country energy plans, either at the sector or subsector level, rarely have a special focus on poverty reduction, even when they are well integrated with national development objectives. Enhanced coordination of energy development programmes with social and economic development programmes is needed to ensure that the poor benefit fully from greater access to energy services.

Low cost technologies can reduce the costs of electrification. Many African countries have inherited European standards for their distribution networks, standards that were adopted for high density, high demand centers in continental Europe. This has often resulted in oversized networks with unnecessarily high costs for connecting rural loads. In spite of these problems, some countries in Africa, especially Tunisia and South Africa, have been addressing these issues through an active pursuit of measures to decrease the costs per connection and in the process developing their own locally adapted low-cost standards. In Tunisia, the utility STEG concluded that the 4-wire system was less expensive by 18 to 24 per cent than a 3-wire MV system and adopted *Mise-A-La-Terre* (MALT referring to the grounded neutral) as their network of choice. In Ghana, shield wire system that uses the existing shield wires on the top of the transmission lines as power conductors costs about 15 per cent of a conventional power line. Single wire earth return systems (used in Australia for example) can save 30 per cent - 50per cent of the network cost compared to conventional systems and are particularly applicable to lightly loaded rural networks over long distances. Appropriate engineering that takes a no-frills approach can reduce construction costs by 30 per cent to 50 per cent and is based on accurate estimates of electrical loads, upgradeable networks, making all assets, especially transformers work at optimal capacity and ensuring that every single component that is installed on a network is really required. The use of "ready-boards" (in Swaziland for example) that comes complete with circuit breakers, socket outlets and a light can mean a huge cost saving for the householder who does not have to install fixed wiring in their home.

Demand management, optimal generation planning, electricity trade across countries and joint investments in regional projects can significantly reduce the volume of incremental investment needs. Increased support for energy efficiency is essential to meet growing demands in a sustainable manner. Efficiency improvements, demand management, improved planning and operation and increased electricity trade could be used to moderate the volume of investments needed and thus help bridge the supply-demand gap. This includes energy efficiency actions at the household level; in the building, industrial and agricultural sectors; in power generation and transmission; and in transportation.

There is need for greater alignment and harmonization of IFI and bilateral support for electricity sector development. Most donor financing for electricity access is channeled to governments on a project by project basis. Multiple projects do not favour the development of a coherent national energy sector policy and lead to fragmentation, duplication of efforts, unbalanced sectoral development (at geographical and subsectoral level), and high transactions costs. There is a clear imperative that donor support for energy access programmes move to a more coordinated country led approach that would be funded through sector-wide financing syndications of investment programmes. This approach would entail the use of pooled funding that would be pledged to a long-term (15 year) expenditure programme and would embrace multiple activities in electrification (grid, off-grid, stand-alone lighting). Large regional generation and transmission projects that are more suitable to a project approach would be harmonized with such a sector wide approach for energy access. Regional projects require innovative and coordinated support among IFIs, bilaterals and the private sector, given the very large capital needs.

Electrification programmes need to be well integrated into programmes of national and rural development so that investments are prioritized to areas where electrification will bring about the greatest returns (e.g., improved farm productivity in areas where there is potential for electricity to replace diesel driven motors in irrigation).

Sector subsidies should be redirected to promoting access for poor households. Subsidies in the electricity sector come in various sizes and shapes and are financed in different ways. They include cross-subsidies between categories of customers, low interest rates on loans to state owned utility companies, and government budgetary support for rural electrification funds. There is no justification for subsidies to utility companies which should in any case operate according to commercial principles. Neither is there any justification for low tariffs that usually benefit richer households although there may be some justification for a "lifeline" tariff for the 1st block of monthly consumption. Subsidies should be easy to administer (efficient), have an impact on the desired population (effective), and reach the poorest of society (equitable). Worldwide, all rural electrification programmes have involved some form of subsidy. Subsidy schemes for electrification are more sustainable when applied to the capital investment rather than to the ongoing operating and maintenance costs. Financing and credit mechanisms that allow the initial costs (meter deposit and other costs) for new utility customers to be spread over time can promote electrification by making it more affordable for poor households. Helping and protecting poor households requires governments to balance short-term support in terms of subsidies with the longer-term need to let market forces influence the choice of fuels and energy practices, and also to let sound fiscal policies influence government funding of subsidies.

Large regional hydro and thermal generation plants offer economies of scale that can reduce the current high cost of power supply to distribution utilities in many SSA countries. These generation projects will require associated investments in regional transmission interconnections. Regional projects require innovative and coordinated support among IFIs, bilaterals and the private sector given very large capital needs. Expanded donor support is needed for project preparation and for the critical need of strengthened capacity-building to design and implement such coordinated investment programmes.

Electrification programmes should support grid, mini-grid and off-grid supply options. Country factors such as population density, spatial distribution, topographical characteristics and rural-urban drift will determine the relative proportions of grid and off-grid solutions that are least cost. In SSA and in the countries of Asia where there are large populations of urban dwellers without access, grid extension will be the least cost option for a large share of the households that will be provided with access in the medium-term. In countries where rural access rates are already high, mini-grid and off-grid supply will be the least cost option to reach the remaining isolated communities that do not have access.

Use of geo-reference information can facilitate analysis of the least cost option of supplying the electricity needs in rural areas. High capital costs are the chief disincentive to supplying grid electricity to rural areas. Use of geo-reference information of settlements can help determine whether grid extension or a decentralized supply such as by solar PV is least cost, depending upon the size of the requirements and costs of a grid connection**.** It is often the case that rural populations are much more nucleated than commonly assumed. In some countries, spatial analysis reveals that rural households have a nucleated settlement pattern and that the spatial distribution of villages is such that extension of the national grid would be the least-cost option of providing electricity access to the majority of the unelectrified population. In the case of Senegal, such analysis has shown that grid electrification is the least-cost option for close to 80 per cent of the non-electrified rural population.

Electricity access strategies should target public facilities, such as schools, health clinics, and communications that benefit the whole population in a rural area. The reason why these facilities are not properly equipped with energy services is usually because of poor planning and because investment programmes in the health and education sectors are often not aligned with those for provision of electricity. Electrification of public facilities such as schools and clinics through grid and off-grid solutions with donor support could be implemented through a focused campaign approach that would see the retrofitting of the majority of facilities in 5 to 7 year programmes. Participation of all key stakeholders, including the private sector, would be needed for these programmes to succeed.

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the original version of this publication had graphics on the front page, and at the beginning of each chapter. That version was 10.6 mb. The graphics have been removed for this online version to bring down the size to 1.3mb.

Chapter 6

Fostering Medium- and Long-term Energy Planning and Prospects for Nuclear Energy in Africa

By
International Atomic Energy Agency[39]

1. Energy and sustainable development

Energy is and will continue to be a primary engine for economic development. The opening paragraph of the Commission on Sustainable Development's (CSD) 2001 decision on energy says simply that, "Energy is central to achieving the goals of sustainable development" (UN 2001). The linkage is echoed in the Secretary-General's report to the fourteenth session of the CSD five years later.

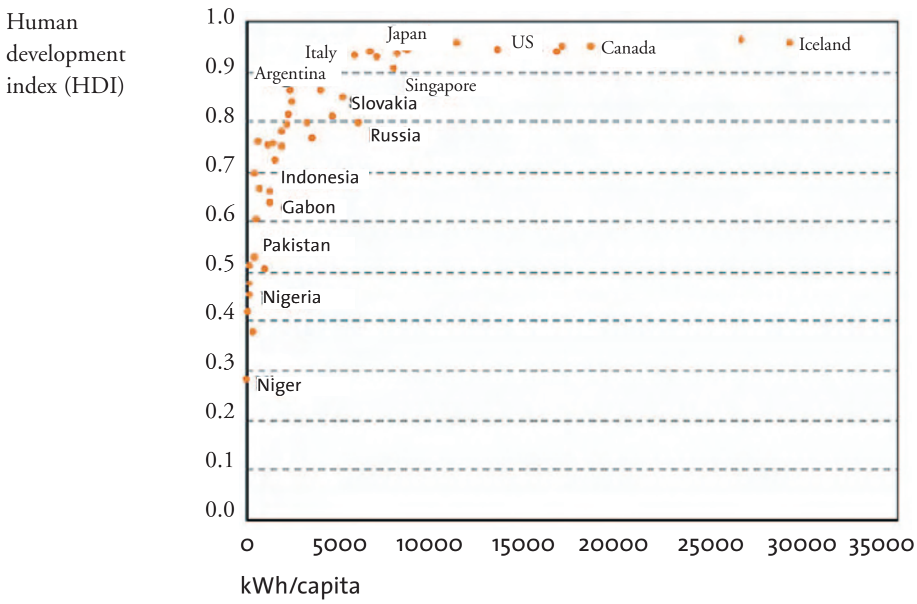
> "Socio-economic development requires energy for improved living standards, enhanced productivity, the transport of goods to markets and as input to a wide range of other economic activities. The transition from traditional energy sources – notably traditional biomass – to modern energy sources is associated with a variety of social benefits, including improving the health, well-being and income generating opportunities of women and facilitating access to employment, education and social services in both urban and rural areas. Extending access to affordable, cleaner energy is thus integral to the process of social and economic development. It contributes to addressing the cross-cutting issues of poverty eradication, improved health and gender equity." (UN 2006a)

Both the quality and quantity of energy are important. Reliance on human power, draft animals and traditional fuels cannot sustain the same level of economic activity as ready access to refined petroleum products and electricity.

Moreover, energy systems have grown more complex over time, particularly with urbanization and industrialization. Modern manufacturing and service industries, and today's urban environments, rely especially on electricity — a computer cannot run on coal. All demographic projections anticipate continued urbanization, which together with economic development will cause electricity needs to grow even faster than energy needs in general.

39 Written by Planning and Economic Studies Section

Figure 1. Human development index and per capita electricity consumption (UNDP (2005).



The per capita consumption of electricity correlates well with a country's social well-being as measured by the UN Human Development Index (HDI), a composite index based on measures of health, longevity, education, and economic standards of living (UNDP 2005).

Figure 1 plots the HDIs of 43 countries against their per capita electricity use. An HDI of 0.8 or higher corresponds to almost 3000 kWh per capita and an HDI greater than 0.9 to more than 6,000 kWh per capita.

However, Figure 1 shows only national averages, which hide the reality that an estimated one quarter of the world's population today — 1.6 billion people — have no access to electricity (IEA 2004). Ensuring such access — 'connecting the unconnected' — has been highlighted by the CSD as an essential task for advancing sustainable development. This access has been further emphasized by UN-Energy as a requirement for meeting the Millennium Development Goals (MDGs) (see Box 1). The MDGs were established at the 2000 Millennium Summit to "form a blueprint [for development] agreed to by all the world's countries and all the world's leading development institutions" (UN 2006b). UN-Energy was created after WSSD to coordinate energy related activities throughout the UN system.

Box 1. "Main Messages "

- Energy services such as lighting, heating, cooking, motive power, mechanical power, transport and telecommunications are essential for socioeconomic development, since they yield social benefits and support the generation of income and employment.
- The poor obtain energy services by gaining access to modern fuels, electricity and mechanical power. This access is particularly important for women and girls since they are often the most affected by inadequate energy services.
- Reforms to the energy sector should protect the poor, especially the 1.1 billion people who live on less than US$1 per day, and should take gender inequalities into account in recognizing that the majority of the poor are women.
- The environmental sustainability of energy supply and consumption should be enhanced to reduce environmental and health hazards. This requires measures that increase energy efficiency, introduce modern technologies for energy production and use, substitute cleaner fuels for polluting fuels, and introduce renewable energy.
- Large amounts of financial resources need to be mobilized for expanding energy investments and services in developing countries. They account for a much larger share of gross domestic product compared with OECD countries. Public sector resources will remain crucial for investing in energy service delivery for the poor due to the private sector's limited appetite for risk in emerging markets.
- The role of energy and the costs of energy services should be factored into overall national economic and social development strategies, including poverty reduction strategies and MDG campaigns, as well as to donor programmes in order to reach development goals. Energy planning must be linked to goals and priorities in other sectors.

Source: The Energy Challenge for Achieving the Millennium Development Goals (UN-Energy 2005)

2. IAEA capacity-building for energy system analysis

Analytical approaches and specific tools

The previous section argued that access to clean and affordable energy services is essential for sustainable development. Expanding access to such services requires careful planning. Poor planning in the past has led to adverse environmental impacts ranging from local deforestation driven partly by firewood consumption, to global warming driven largely by CO_2 emissions from energy use. All countries do not have equal access to energy planning expertise and tools. OECD countries and some others have plenty of university departments, government departments, think tanks, and consulting firms to analyze policy options and future alternative strategies. Other countries do not have those resources but are interested in analyzing and planning with the same sophistication, modern tools and know-how. This section describes a set of analytical tools (models) developed or adapted by the IAEA, principally for such member States. The IAEA develops and transfers these models on request. It transfers the latest data on technologies, resources and economics. It trains local experts. It jointly analyzes national options and interprets results. The objective is capacity-building, i.e. to establish the continuing local planning expertise necessary to chart national paths to sustainable development.

Table 1, contains aggregated numbers of total releases to Agency Member States for each corresponding model. The models are periodically peer reviewed, and model enhancements are implemented based on priorities agreed with the user community.

Table 1: Numbers of IAEA Energy Model Releases to member States

	Releases to member States
ENPEP – Energy and Power Evaluation Programme	69
FINPLAN – Model for Financial Analysis of Electric Sector Expansion Plans	19
MAED – Model for Analysis of Energy Demand	71
MESSAGE – Model of Energy Supply Strategies and their General Environmental Impacts	60
SIMPACTS – Simplified Approach for Estimating Impacts of Electricity Generation	32
WASP – Wien Automatic System Planning Package	85
112 Member States are using the IAEA's Energy Models	

Model for Assessment of Energy Demand (MAED)

The starting point for using MAED is the reconstruction of base year energy use patterns (IAEA 2006a). This requires the establishment of an energy balance by fuels and sectors, reconciling data from different sources and adjusting various input parameters to be consistent with the base year energy balance. This helps calibrate the model to the specific situation of the country.

MAED then calculates future energy demand based on medium- to long-term scenarios of socio-economic, technological and demographic developments. Energy demand is disaggregated into a large number of end-use categories, each one corresponding to a given service or to the production of a certain good. The demands for goods and services are dependent on population growth, household size, transportation preferences, efficiency improvements, the spread of new technologies or fuels, etc. Future trends for these determining factors are exogenously specified and introduced into the model. The key to plausible and useful scenarios is internal consistency of assumptions, especially for social, economic development and technological change. The model then provides a systematic accounting framework for evaluating the effect on energy demand of all these driving factors.
Special attention is given to the calculation of electricity demand, which is performed not only annually as for all other fuels, but also on an hourly basis. These calculations in turn, can serve as input to the WASP, ENPEP or MESSAGE models described below. These calculations determine the electric load, which will then permit WASP to select suitable generation technologies that match the variation in demand within a year or season.

Wien Automatic System Planning Package (WASP)

WASP is the IAEA's long-standing model for analyzing electricity generation system expansion plans. Initially developed in the 1970s, it has been enhanced and upgraded over time to match emerging needs.

WASP finds the least-cost expansion plan for a power generating system over a long period and within specified constraints defined by the analyst (e.g. system reliability, fuel availability and emission limits). The user first inputs the technical, economic and environmental characteristics of all power plants within the existing system. Then for any projected annual demand for electricity, WASP explores all possible sequences of capacity additions that satisfy demand while meeting the constraints. To identify the least-cost strategy, each sequence is evaluated according to a cost function composed of capital investment costs, fuel costs, operation and maintenance costs, fuel inventory costs, the salvage value of investments and the cost of energy demand not served.

Energy and Power Evaluation Programme (ENPEP)

The ENPEP model is designed to simulate energy markets by determining the long-term energy supply and demand balance for a given country. The model takes into account all energy production, conversion, transport, distribution, and utilization activities in the country as well as the flows of energy and fuels among those activities. The model uses a non-linear, equilibrium approach to balance energy supply and demand. This equilibrium modeling approach is based on the concept that the energy sector consists of autonomous energy producers and consumers seeking to maximize their benefits. However, their decisions are made within system boundaries determined by government policies, regulations, existing capital stock, new technological opportunities, personal preferences, etc.

For its simulation, the model uses an energy network designed to trace the flow of energy from primary resource (e.g. crude oil, coal) through to final energy demand (e.g. diesel, fuel oil) and/or useful energy demand (e.g. residential hot water, industrial process steam). The model solves simultaneously for the demand-supply intersections of all forms of energy in the energy system. The equilibrium is reached when the model finds a set of prices and quantities that satisfies all relevant equations and inequalities. Since energy purchase decisions are not always solely based on price, premium multipliers are used in the model to simulate the preference that consumers may have for some commodities over others. In addition, the model uses a lag parameter to simulate the time that is required for prices and demands to reach an equilibrium or balance. In general, capital-intensive industries have longer lag times than those that require relatively smaller capital investments.

Environmental considerations are also taken into account by calculating the emissions of various pollutants arising from a given fuel mix at each stage. The model then calculates the environmental costs associated with these emissions and adds these to the energy costs.

Model for Energy Supply Systems and their General Environmental Impacts (MESSAGE)

MESSAGE is designed to evaluate alternative energy supply strategies and to find the least-cost strategy given available technologies, resources, policy goals and policy constraints. Technologies are defined by their inputs and outputs, their efficiency, and the degree of variability if more than one input or output exists, e.g. the possible production patterns of a refinery or cogeneration plant. Technologies and associated fuels are combined to construct 'energy chains' along which the energy flows from resource extraction to demand for energy services.

The model takes into account existing installations, their vintage structure and their retirement. Investment requirements can be distributed over a plant's construction period and subdivided to reflect more accurately requirements from significant industrial and commercial sectors. Requirements for basic materials and non-energy inputs can also be accounted for by tracing their flow from the relevant originating industries. Environmental aspects can be analyzed by keeping track of, and if necessary limiting, the amounts of pollutants emitted by various technologies at each step of the energy chains. This helps to evaluate the impact of environmental regulations on energy system development.

The most powerful feature of MESSAGE is that constraints and links can be defined among all types of technology-related variables. One technology can be limited in relation to other technologies (e.g. a maximum share of wind energy that can be handled in an electricity network); limits can be set on a group of technologies (e.g. a common limit on SO_2 and thus on technologies emitting SO_2); and constraints can be defined between production and installed capacity (e.g. take-or-pay clauses in international gas contracts). The model is extremely flexible and can also be used to analyze energy/electricity markets, climate change issues including greenhouse gas mitigation, local air quality or regional acidification.

Model for Financial Analysis of Electric Sector Expansion Plans (FINPLAN)

FINPLAN is designed to evaluate the financial implications of an expansion plan for a power generating system. The model evaluates the consequences of adding a set of power plants, over a given time period, on the overall financial performance of the company. The model can also be used to analyze the financial viability of a single plant in specified market conditions.
Inputs to the model are: (1) data specific to the expansion plan, such as the types, sizes and timing of power plant additions and investment, fuel and operating costs; (2) economic and fiscal parameters, such as inflation, exchange rates, prices and taxes; and (3) financial parameters defining financing possibilities such as fixed-rate credits/loans, variable-rate loans, bonds and equity.

For developing countries, arranging funds in foreign exchange is an added difficulty. The model treats all expenditures in two currencies, one foreign and the other local, and the impact of future exchange rate changes is analyzed accordingly.

In addition to calculating discounted cash flows, the model generates various standard financial statements such as sources and allocation of funds, current accounts of revenues and expenditures, income statements and balance sheets. It also computes financial ratios that can be used as indicators for the financial status and creditworthiness of a company, i.e. working capital, equipment renewal, leverage, gross-profit rate, debt repayment time, exchange rate risk, break-even point, and interest charge weight.

The model does not optimize the financing package. The user identifies financial equilibrium through an iterative process. While this is more time consuming, it also permits flexibility for creative financial proposals.

Simplified Approach for Estimating Impacts of Electricity Generation (SIMPACTS)

SIMPACTS consists of separate modules for estimating the impact of energy facilities on human health, agricultural crops and buildings resulting from routine atmospheric emissions of pollutants. It covers fossil fuelled electricity generation, nuclear energy and hydropower installations. It first estimates physical damages and health impacts, then provides a monetary valuation of these damages and calculates external costs associated with different energy supply strategies. A decision-aiding module permits comparisons of the relative merits of different technologies based on a set of criteria. The key advantage of SIMPACTS is its simplicity. It is designed for use with a minimum of data input as compared to other external cost models that are complex and require large amounts of data.

For airborne pollution, whether from fossil fuelled or nuclear energy plants, the model uses the impact-pathway approach. In this approach, the emission source is characterized and an inventory of airborne releases is prepared. The changes in ambient concentrations of various pollutants are estimated using atmospheric dispersion models, and in the case of radioactive emissions or deposits, exposure response functions are used to relate the change in pollutant concentration to a physical impact on the relevant receptors. In the case of hydropower, the model offers a simplified approach to estimate the loss of land, population displacement, and emissions during construction from hydro dams as well as the impacts from dam failures. Finally, all the impacts and burdens are monetized and aggregated.

The model also allows a user to make a range of external cost estimates ranging from rough to quite accurate, depending on the availability of data. Given the high uncertainties involved in any estimation of external costs, SIMPACTS produces results well within the range of more complex models.

Indicators for Sustainable Energy Development (ISED)

Because the objectives of sustainable development are very broad, governments and policy makers need a set of quantifiable parameters (indicators) to measure and monitor important changes and significant progress towards the achievement of these objectives. This was recognized in Agenda 21, which specifically (Chapter 40) requires that countries and international governmental and non-governmental organizations develop the concept of Indicators of Sustainable Development (ISD).

In 1995, the CSD initiated a worldwide programme on ISD. The CSD's expert group on ISD uses a conceptual framework that emphasizes policy issues and themes related to sustainable development. The current version of the ISD package has 57 indicators, which are classified into four dimensions, 15 themes and 38 subthemes. Energy is a subtheme with three indicators.

The IAEA-led project on Indicators for Sustainable Energy Development (ISED) represents an independent energy module that fits into the ISD system (see Table 2). The ISED use as inputs or components a number of indicators from the CSD umbrella scheme already included in other areas that are also relevant to the energy sector. In addition, data parameters and indicators that are not part of the ISD package but that are necessary to build the ISED are also used as inputs. Countries have the option of selecting the energy indicators in the specific areas or themes (e.g. energy security, intensity, affordability) that better reflect their policy priorities (i.e. countries do not need to implement all the indicators).

The ISED scheme has a variety of practical applications. First, the indicators present statistical information on energy system changes (environmental, economic and energy efficiency performance) over time, provide a snapshot of the current situation of a country, highlight important relationships among different development and policy parameters, and provide statistically consistent tracking of such changes and relationships as part of general energy statistical analysis. Second, they can gauge the success, or lack thereof, of different practices or policies of the past as well as help users to understand the desirability of certain trends over time and how to adjust them. Here the output of the planning tools presented above may provide input to ISED, and policy makers can assess the effectiveness and efficiency of their national energy policy framework in meeting their sustainable development objectives.

Table 2: List of Energy Indicators for Sustainable Development (EISD)

Theme	Sub-theme	Energy indicator	
Social Dimension			
Equity	Accessibility	SOC1	Share of households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy
	Affordability	SOC2	Share of household income spent on fuel and electricity
	Disparities	SOC3	Household energy use for each income group and corresponding fuel mix
Health	Safety	SOC4	Accident fatalities per energy produced by fuel chain
Economic Dimension			
Use and Production Patterns	Overall Use	ECO1	Energy use per capita
	Overall Productivity	ECO2	Energy use per unit of GDP
	Supply Efficiency	ECO3	Efficiency of energy conversion and distribution
	Production	ECO4	Reserves-to-production ratio
		ECO5	Resources-to-production ratio
	End Use	ECO6	Industrial energy intensities
		ECO7	Agricultural energy intensities
		ECO8	Service/ commercial energy intensities
		ECO9	Household energy intensities
		ECO10	Transport energy intensities
	Diversification (Fuel Mix)	ECO11	Fuel shares in energy and electricity
		ECO12	Non-carbon energy share in energy and electricity
		ECO13	Renewable energy share in energy and electricity
	Prices	ECO14	End-use energy prices by fuel and by sector
Security	Imports	ECO15	Net energy import dependency
	Strategic Fuel Stocks	ECO16	Stocks of critical fuels per corresponding fuel consumption
Environmental Dimension			
Atmosphere	Climate Change	ENV1	GHG emissions from energy production and use per capita and per unit of GDP
	Air Quality	ENV2	Ambient concentrations of air pollutants in urban areas
		ENV3	Air pollutant emissions from energy systems
Water	Water Quality	ENV4	Contaminant discharges in liquid effluents from energy systems including oil discharges
Land	Soil Quality	ENV5	Soil area where acidification exceeds critical load
	Forest	ENV6	Rate of deforestation attributed to energy use
	Solid Waste Generation and Management	ENV7	Ratio of solid waste generation to units of energy produced
		ENV8	Ratio of solid waste properly disposed of to total generated solid waste
		ENV9	Ratio of solid radioactive waste to units of energy produced
		ENV10	Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste

Source: IAEA et al. (2005).

3. National and regional aspects of energy planning

In the past, energy system planning was largely restricted to national boundaries. Energy trade with neighbouring countries was often regarded as a last resort. Focusing planning exclusively within national boundaries, however, ignores many synergies that can be exploited if countries were to adopt a regional approach to energy planning. Constraining factors, such as sub-critical grid and market capacities, large unit plant sizes, large distances between demand and supply centers, limited institutional infrastructure and technical know-how, and workforce requirements, could be alleviated by joint infrastructure and resource development and sharing. Furthermore, many issues of sustainable energy development such as energy security and reliability, environmental protection and economic viability may be better advanced in a regional context. A good example of a regional approach is the West African Gas Pipeline Project, which in its first stage will make Nigerian gas resources accessible to Benin, Togo and Ghana. Another example is the Southern African Power Pool — an association of 14 national utilities in the southern African region. Information and best practice sharing in the field of biofuel production or utilizing economies of scale or create better negotiating possibilities with suppliers are further benefits of regionalization that may help bring down costs and thus improve the accessibility and affordability of energy services. In short, infrastructure sharing by two or more countries could reduce economic and financial constraints and associated financial risks, improve load factors for capital intensive infrastructures, and make it easier to meet national or international environmental targets.

Regional energy planning does not obviate national energy planning — the latter is an inevitable first step — it just takes it one step further. For example, in the three Baltic countries of Estonia, Latvia and Lithuania, the IAEA analysis tools were first applied to each country individually. The main objective was to test the cost-effectiveness of various measures to improve national energy supply security by increasing each country's energy self-sufficiency to some specified level. A list of cost-effective measures for each country was established. In a second round, the three national models were linked with each other (plus additional energy trade connections to Poland, Finland and Sweden were introduced). With an integrated approach, the same national energy security objectives were achieved at considerably lower costs. Sharing of Latvia's large underground gas storage facilities, utilization of Estonia's shale oil resources or the joint construction of a nuclear power plant were some of the outcomes resulting from this regional approach.

Regional energy planning is not a panacea but it can identify potential low-cost energy supply opportunities that would otherwise not be straightforwardly visible in a national context only. While in any particular situation, there may well be numerous other non-energy considerations that hamper the actual implementation of regional energy infrastructure projects, it is still important to highlight and quantify such opportunities so that decision makers can make informed decisions.

4. Current IAEA support for energy system analysis in Africa

The IAEA's Technical Cooperation Programme operates on two-year cycle. It is currently in the first year of the 2007-2008 cycle, which includes 10 national projects and one regional project assisting African member States in capacity-building in the area of sustainable energy development planning.

National projects

The project with Algeria on Sustainable Energy Development and Preparation for Nuclear Power aims to enhance national capabilities in the area of energy planning and electricity system expansion analysis and to support national efforts aimed at establishing the country's first nuclear power plant for electricity generation. IAEA assistance will help national counterparts at the Ministry of Energy and Mines to develop appropriate methods using IAEA tools such as MAED, ENPEP, and MESSAGE to evaluate the country's future energy requirements and to establish a long-term balance between energy supply and demand, along with the formulation of an optimal power system expansion programme up to 2025.

The objective of the project with Botswana on Energy Economics and Electricity Expansion Planning is to assist the country in developing a medium- to long-term national energy plan by projecting future energy and electricity demand and analyzing the optimal energy supply mix and optimal expansion plan for the electric power sector. The national team will be provided training in MAED and MESSAGE, with subsequent follow-up missions to help conduct a detailed country study.

The objective of the project with Burkina Faso on Energy Demand Planning is to apply IAEA tools to assess future energy demand and analyze supply options for meeting this demand in a sustainable manner. There is an emphasis on analyzing options for providing clean energy to replace the use of biomass in households. The role of the IAEA is to provide technical support in terms of analytical tools and training to national energy professionals who will be responsible for the planning activities.

The project with Chad on Sustainable Energy Development aims to establish national capabilities for sustainable energy development planning and to diversify energy production sources. The national team will be provided IAEA's analytical tools (MAED and MESSAGE) and training in the use of these tools to carry out national energy planning studies.

The objective of the project with Ghana on Planning for Sustainable Energy Development is to assist Ghana in developing a long-term energy plan by determining future energy and electricity demand, the future optimal energy supply mix and an optimal expansion plan for the electric power sector. The project will incorporate detailed analysis of the role of renewable energy in sustainable energy development in Ghana. UNIDO will assist in identifying potential sources of renewable energy at the project level. The national team is responsible for carrying out studies to help formulate the long-term energy plan. A one-week general training course on MAED was conducted in 2006. In March 2007 a two-week course was conducted on MAED-El for electricity load projection and on application of WASP for power system expansion planning.

The goal of the project with Côte d'Ivoire on Energy Planning is to analyze how to change energy consumption patterns to improve health and economic conditions in the country. Currently, fuel use in Côte d'Ivoire is depleting natural resources, and the lack of energy supplies is hindering socio-economic development. The role of the IAEA is to provide technical support in designing a country case study and to provide appropriate analytical tools and training to carry out the case study.

The objectives of the project with Libya on Sustainable Energy and Power Planning Study are to build up local capabilities in the area of energy planning and to conduct comprehensive studies for designing a national energy strategy that is compatible with sustainable development goals. The studies will cover: (a) an assessment of future energy and electricity needs for all sectors of the economy; (b) an assessment of the availability of conventional energy resources and their future potential for expansion; (c) an assessment of the potential role of renewable energy sources and advanced energy technologies, including wind, solar, nuclear and hydrogen, in meeting future energy needs; (d) the development of alternative energy scenarios and optimal development paths for the energy supply system and the electric system; and (e) an assessment of the social, economic and environmental impacts of alternative energy scenarios.

The Mauritanian government (Ministère de l'Energie et du Pétrole) and IAEA are implementing a project on Sustainable Energy Development — Strengthening Capacity in Energy Planning to train energy planners and professionals in the area of sustainable energy development particularly in the analysis of techno-economic and environmental issues of power system expansion. The planning tools for projecting energy/electricity demand (MAED) and for analyzing energy systems (MESSAGE) will be used to assess energy demand through 2025 and establish a long-term supply/demand balance. The expertise will also help national bodies to develop scenarios appropriate to the country and to evaluate social, economic and environmental factors related to power generation chains.

The project with Niger on Sustainable Energy Development is being implemented in collaboration with the Ministry of Mines and Energy. A country study will be carried out to analyze options to reduce fuelwood consumption and to ensure the better use of local resources, thereby helping to reduce the share of imported energy in the country's total energy supply. The role of the IAEA is to provide technical support in designing the case study and to train energy professionals in the use of the IAEA's analytical tools for energy planning for sustainable development.

The Sudan began a country study under an IAEA regional project, Sustainable Energy Development in sub-Saharan Africa during the IAEA's 2005-2006 project cycle. The Sudan will now carry out an energy planning study using IAEA planning tools but with the inclusion of nuclear power as an option for electricity expansion plan in the medium- to long-term. Based on this report, the Sudan plans to establish an Inter-Ministerial Committee for Nuclear Power Planning, supported by a Nuclear Power Implementation Team (NPIT) with a chairman who will act as the interface with the IAEA for the Nuclear Infrastructure Development Project. The identified coordinator of the NPIT will be responsible for planning and implementing project activities and coordinating with other ministries and departments and with the IAEA.

Regional project: strengthening planning capabilities for sustainable energy development

This regional project includes Algeria, Angola, Benin, Botswana, Burkina Faso, Cameroon, Central African Republic, Côte d'Ivoire, Democratic Republic of the Congo, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Libya, Madagascar, Mali, Mauritius, Morocco, Namibia, Niger, Nigeria, Senegal, Sierra Leone, South Africa, the Sudan, Tunisia, Uganda, Tanzania, Zambia and Zimbabwe. The overall objective is to enhance the capabilities of the participating States to elaborate national energy strategies for sustainable development. To that end, the project will:

- assist countries in strengthening institutional capabilities for energy planning;
- assist countries in establishing human resources development programmes in the field of energy planning;
- assist countries in conducting national studies on sustainable energy development;
- facilitate comparative assessment studies of electricity supply options using interconnected grids and related sustainable energy strategies;
- assist countries in strengthening integration at the national level among energy agencies and national development organs; and
- enhance regional cooperation and networking for energy planning.

Additional IAEA support for energy system analysis in Africa

A study presented at CSD-14 in May 2006, entitled Assessing Policy Options for Increasing the Use of Renewable Energy for Sustainable Development: Modeling Energy Scenarios for Ghana, looked at generic policies to increase the share of renewable energy in a country's generation mix, one of the policy goals called for in the Johannesburg Plan of Implementation (UN-Energy 2006). The study was a joint effort of the UN Department of Economic and Social Affairs, the IAEA, the UN Food and Agriculture Organization, the UN Environment Programme, the UN Industrial Development Organization, and the Energy Commission of Ghana. It analyzed four scenarios using Ghanaian data: a baseline least-cost scenario through 2030, a 'Portfolio Standard / Renewable Energy Quota' scenario that required utilities to generate a certain percentage of their electricity from renewables, a 'Public Benefit Fund' scenario that created a fund through a levy on electricity transmission that was then used to partly finance renewable energy projects, and a Clean Development Mechanism scenario that sold on the international market the certified emission reductions generated by renewables. The policy scenarios were assessed in terms of effectiveness, total costs, operating and maintenance costs, and the source of the funds (utilities, consumers or foreign funders).

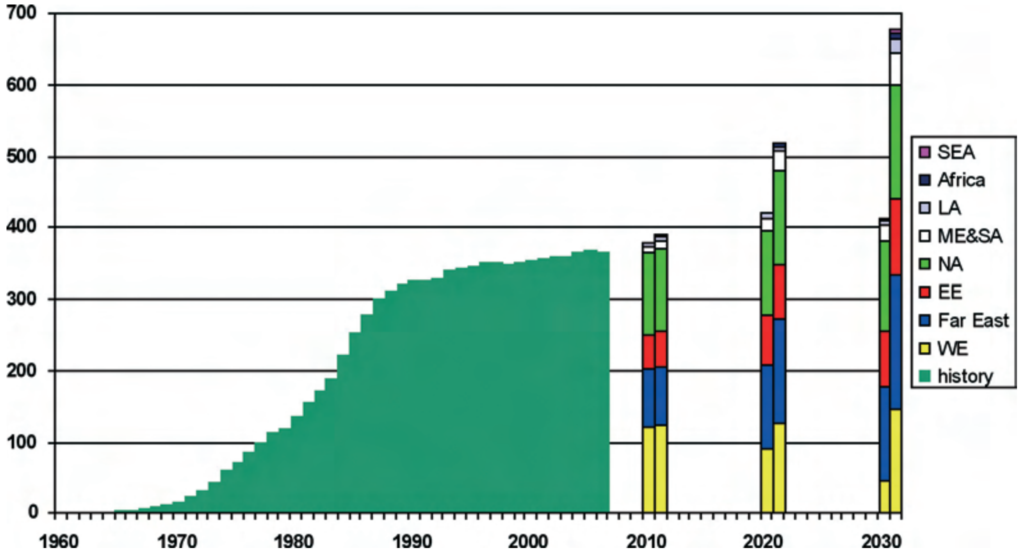
Also, within the framework of UN-Energy/Africa, the Economic Commission for Africa (ECA) and the IAEA recently conducted a regional workshop in Addis-Ababa, Ethiopia on Integrated Resource Planning (IRP) for Energy/Electricity in Africa. The objective was to raise awareness about the benefits of IRP and build the participants' capacity to use IRP to mainstream sustainable development considerations in planning investments in the electricity supply industry at the regional and national levels. The workshop was attended by energy planners from the West Africa Power Pool; the Southern Africa Power Pool, the 'Communauté des Etats Sahélo-Sahariens', the East African Community, Energie des Grands Lacs, the Inter-Governmental Authority on Development and the Eastern Africa Power Pool. This event represents a first step in future collaboration between the IAEA and ECA in the field of energy planning and strategies.

5. Prospects for nuclear energy in Africa

Of the 435 nuclear power reactors operating around the world today, just two are in Africa – Koeberg1 and Koeberg-2 in South Africa. Of the 30 nuclear power plants currently under construction none is in Africa although South Africa announced in February 2007 plans to build an additional conventional nuclear power plant in the near term, with the decision on the preferred supplier to be made very soon.

Nor is significant nuclear power expansion expected in Africa in the near future. The IAEA publishes two updated medium-term projections each year — a low projection, which assumes that no new nuclear power plants are built beyond what is under construction or firmly planned today, and a high projection, which incorporates additional reasonable planned and proposed nuclear power projects beyond those already firmly in the pipeline. Figure 2 shows historical worldwide nuclear power capacity in dark green on the left, plus the latest projections for 2010, 2020 and 2030. The projections are subdivided by region. The high projection is on the right of each pair and the low projection is on the left. Africa, in black, is essentially invisible in the low projection (2.1 GW(e) in 2030) and still quite modest even in the high projection (10.3 GW(e) in 2030) (IAEA 2006b).

Figure 2. Installed nuclear power generating capacity worldwide, actual through 2006 and low (left) and high (right) IAEA projections for 2010, 2020 and 2030. (SEA: South-East Asia; LA: Latin America; ME&SA: Middle East and South Asia; NA: North America; EE: Eastern Europe; WE: Western Europe.)



In the longer-term, however, nuclear power may provide a significant share of Africa's electricity. South Africa has immediate plans for expansion. In 2006 Egypt and Nigeria announced steps they are taking toward their first nuclear power plants. In 2007, Namibia announced interest in looking into the option of nuclear power for the longer-term. Egypt, Libya, Morocco and Tunisia are at different stages of exploring or developing seawater desalination using nuclear energy. And some of the capacity-building projects described in Section 0 made lead in the long-term to the introduction of nuclear power in additional African countries.

An important challenge for many African countries in the near to medium-term would be that of bridging the gap between the economies of scale that favour large nuclear plants and their present smaller electrical grids and capital capabilities. Possibilities are, first, new small and medium-size reactor designs and, second, integration of electricity grids among neighbouring countries.

Indeed, of the handful of promising new small- and medium-size reactor designs now reaching the prototype stage, an important one is African — South Africa's 165 MW(e) Pebble Bed Modular Reactor (PBMR). The PBMR is expected to be commissioned around 2010. The South African Government has allocated initial funding for the project and orders for some lead components have already been made. In the Russian Federation, a barge mounted floating 35 MW(e)/200 MW(th) KLT-40S cogeneration plant (to produce both electricity and district heat) has been licensed for construction in Severodvinsk in 2007. A number of small- and medium-size reactor designs are in the category of 'reactors without on-site refuelling'. These are reactors designed for infrequent replacement (every 5 to 25 years) of well-contained fuel cassettes in a manner that impedes the clandestine diversion of nuclear fuel material. This category includes factory fabricated and fuelled reactors, and the general expectation is that the supplier country would retain all back-end responsibilities for spent fuel and waste. The potential benefits include: possibly lower construction costs in a dedicated facility in the supplier country; lower investment costs and risks for the purchaser, especially if the reactor is leased rather than bought; reduced obligations for spent fuel and waste management; and possibly a higher level of assurance of non-proliferation to the international community.

Section 0 mentioned briefly regional analysis to identify opportunities for cost sharing and cost savings through regional integration of electricity systems. In the next step in introducing nuclear power, infrastructure development, there are also opportunities for cost sharing and cost savings through regional cooperation and integration.

The infrastructure to support the implementation of a new nuclear power project has many components, ranging from the physical facilities and equipment associated with the delivery of the electricity, the transport of the material and supplies to the site, the site itself, and the facilities for handling radioactive waste; to the legal and regulatory framework within which all of the necessary activities are carried out; and the human and financial resources necessary to implement the required activities. The IAEA has recently completed a brochure providing integrated initial advice covering the full range, Considerations to Launch a Nuclear Power Programme (IAEA 2007).

With the exception of issues relating to commercial decisions, the IAEA can assist by providing technical support for the owner operator for the assessment of potential technology, the potential managerial approaches that can be used in the implementation of a project and issues related to ensuring the safe and economic operation of a nuclear power plant. Assistance is also available through the IAEA's legislative assistance programme for developing comprehensive national legal frameworks. Specific IAEA support can also be sought in assisting the development of regulatory bodies to ensure that they are effective and fully competent to oversee the licensing of facilities, and in providing review services covering all aspects of a nuclear power programme.

6. Additional IAEA publications on infrastructure

Basic infrastructure for a nuclear power project

Basic infrastructure for a nuclear power project (IAEA 2006c) provides initial guidance on the infrastructure that a country needs to develop in order to ensure that it is prepared for the introduction of a nuclear power plant. This infrastructure is relevant whether the nuclear power plant is planned for the production of electricity or for seawater desalination. The guidance is not meant to prescribe an all-inclusive list and should be utilized with due consideration of the existing legal, institutional, industrial and financial conditions of the country. The development stages and extent of the infrastructure institutions and facilities depend on the long-term plans for nuclear power and the role envisaged for the government and the private sector in its development. This includes sources of funding for the construction of the plants, the timing and capacity of nuclear generation, technology alignments and agreements, commercial conditions and the types of contracts envisaged for the planned projects.

Potential for sharing nuclear power infrastructure between countries

The burden of infrastructure can be reduced significantly if a country forms a sharing partnership with other countries. The sharing could be organized regionally or internationally. It can include physical facilities, common programmes and knowledge, all of which might yield economic benefits. Potential for sharing nuclear power infrastructure between countries (IAEA 2006d) describes areas where countries may be able to achieve the required level of infrastructure by sharing resources and facilities. This publication provides guidance for analyzing and identifying the potential benefits of sharing nuclear power infrastructure during various stages of a nuclear power project's life cycle.

Infrastructure milestones

A guidance document currently in preparation will present milestones that can be used in developing the necessary infrastructure to plan, operate, and maintain safe and reliable nuclear power plants. This document will supplement basic infrastructure for a nuclear power project and is intended to provide useful assistance for both planning and assessing progress related to infrastructure development.

Managing a first nuclear power plant

Historically, the time between a country's initial policy decision to consider nuclear power and the initial operation of its first nuclear power plant is about 10-15 years. The proper management of the wide scope of project activities during this period represents a major challenge for all governmental, utility, regulatory, supplier and other support organizations that are involved. The main focus is to ensure that the project is implemented successfully from a commercial point of view while remaining in accordance with appropriate engineering and quality requirements, safety standards and security guides. The IAEA will shortly publish a guidance document on managing a country's first nuclear power plant, which will provide an introductory overall description of the main project management activities and give references to related detailed guidance.

Updating Existing Guidance

Past IAEA guidance publications on planning and managing nuclear power projects contain much valuable information but also, in many cases, need to be updated. In light of rising expectations for nuclear power around the world, and increasing requests for assistance from member States, the IAEA has embarked on an effort to restructure, update and further develop relevant guidance and support documents to better address current needs of member States and reflect the changing social and commercial environment in which the application of nuclear energy must now considered.

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