Energy and sustainable development

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Chapter 1
Energy and Sustainable Development

The world is facing a strong evolution due to the advancement of information and communication technologies that set the knowledge technologies at the base of productivity, competition and power. The world is more and more interconnected than ever before, i.e. people, ideas, images, goods and money are being distributed more frequent and faster than ever before. We live in a network society, which is not divided into independent and isolated nations or communities, and at the same time enterprises are organised in network, i.e. there has been an increase of teamwork, networking, outsourcing, subcontracting and delocalisation. All these features may represent the advancement of our civilization, but at what price are we paying for the environmental and socioethical impacts?

Historically, we have discovered that the production and consumption system did not only produce advantages, but also disadvantages. This happened in the economic boom of the 1960s when industrialised countries faced a strong acceleration of consumption and production system development.

Since that moment, we became aware that human activities may determine harmful and irreversible environmental impacts, and it carries the notion of environmental limits.

It was in 1972 when the book *Limits to Growth* [12] was published based on a first computerised simulation of the effects on the nature of the ongoing system of production and consumption. It was the first scientific forecast of a possible global eco-system collapse. Fifteen years later, in 1987, the United Nations World Commission for Environment and Development (WCED) provided the first definition of Sustainable Development:

> A social and productive development that takes place within the limits set by the "nature" and meets the needs of the present without compromising those of the future generation within a worldwide equitable redistribution of resources.

In fact, this incorporates even the fundamental challenge of social equity and cohesion (i.e. the socioethical dimension of sustainability).

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In the recent period, the concept of sustainable development has been linked to the one of accesses to sustainable energy. Indeed, it has become a shared understanding that sustainable development is not possible without sustainable energy access to all. Energy is the world's largest industrial sector ($\sim$70% of world GDP) whose output is an essential input to almost every good and service provided in the current economy. Energy services have a profound effect on productivity, health, education, food and water security, and communication services. Therefore, that access to energy can contribute to reduce inequality and poverty.

Very often, problems of the production system are only related to materials impacts, i.e. residues, pollution caused by cars, planned obsolescence: which we can see and experiment the effects of it. However, energy represents the hidden side of others. First, energy enables us to produce things by the way we do, and environmental impacts start with the transformation of a given resource.

On the other hand, there are implications connected to energy. Transforming resources into energy requires the capability (in terms of technologies) and the financial resources to face it. At the same time, our current energy system, based on a fossil fuel model, implies a kind of resource that is not available in all the countries. Both features—localization and budget—mean that there is interest around energy, which include politics and economics issues. What is clear for now is that only those who have the control of the energy system have the possibility to increase their development. Access or no access to energy determines our quality of life and its limited access represent one of the key barriers to achieve sustainable development.

1.1 United Nations Sustainability Energy for All (SE4A) Agenda

Sustainable development emerged as a major global issue back in the 1970 with the publication of the report 'Limits to Growth' [12]. In the 1980 and 1990 milestones such as the Brundtland Report (Our Common Future) by the United Nations World Commission for Environment and Development [22] and the Earth Summit held in Rio de Janeiro in 1992 paved the way to worldwide acknowledgement for the necessity of major changes related to environmental and social pressures now felt as a global problem. Not only it gained public recognition but achieved a stage of maturation, with new policies being created and implemented at various scales.

More recently, the United Nations General Assembly designated the year 2012 as the International Year of Sustainable Energy for All and unanimously declared 2014–2024 as the Decade of Sustainable Energy for All. *United Nations Secretary-General* Ban Ki Moon has appointed a High-Level Group on the same topic, which delivered a Global Action Agenda prior to the UN Conference on Sustainable Development (Rio + 20). As Ban Ki Moon stated launching the Sustainable Energy for All Initiative [21], '*Energy poverty is a threat to the achievement of the Millennium Development Goals. At the same time, we must move very rapidly toward a clean energy economy to prevent the dangerous warming of our planet*'.

The Sustainable Energy for All Initiative, identified three inter-linked objectives to be achieved by 2030 and pursued during the SE4All decade, necessary for long-term sustainable development in relation to access to energy:

– ensure universal access to modern energy services;
– double the rate of improvement in energy efficiency;
– double the share of renewable energy in the global energy mix.

To continue pursuing the above efforts, expressed by the Sustainable Energy for All Initiative, the Sustainable Development Goal number 7 of the Global Action Agenda [20] advocates for the need to ensure access to affordable, reliable, sustainable and modern energy for all.

The SDG number 7 targets that by 2030 the following should have been achieved:

- Ensure universal access to affordable, reliable and modern energy services;
- Increase substantially the share of renewable energy in the global energy mix;
- Double the global rate of improvement in energy efficiency;
- Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil fuel technology, and promote investment in energy infrastructure and clean energy technology;
- Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, least developed countries, small island developing states and land-locked developing countries, in accordance with their respective programmes of support.

A study conducted by Rogelj et al. [16] on the compatibility of the 'Sustainable Energy for All' initiative with a warming limit of 2 °C shows that achieving the three energy objectives could provide an important entry point to climate protection, and that sustainability and poverty eradication can go hand in hand with mitigating climate risks. However, the researchers warn that the likelihood of reaching climate targets within the scenarios depends as well on a variety of other factors, including future energy demand growth, economic growth and technological innovation. Therefore, securing energy for all within the existing environmental boundaries requires further political measures and financial resources. According to Nilsson [14] '*Investment costs for these pathways are large but often profitable for society and most of them have already been set in motion. Still, progress is slow and must be accelerated at national and regional levels. Carbon pricing is necessary but not sufficient: beyond this, governance responses need to be put in place to induce transitions through scaling up a diversity of supply and demand options. White and green certificates, feed-in tariffs, technology standards and removal of fossil subsidies are important first steps already under way. These contribute to nurturing and scaling up new technological regimes, as well as destabilizing old and unsustainable ones*'.

The Sustainable Energy for All Global Action Agenda defines specific requirements for different contexts. Low- and middle-income country governments must create conditions that enable growth by establishing a clear vision, national targets, policies, regulations and incentives that link energy to overall development, while strengthening national utilities. More than 80 governments from low- and middle-income countries have joined the SE4A initiative. Industrialised country governments must focus internally on efficiency and renewable energies while externally supporting all three objectives through international action. They elaborate on current plans to increase the deployment of domestic renewable energy and improve energy efficiency through the entire value chain, from production of primary energy-using energy services. The Global Action Agenda highlights also sectoral action areas addressing both power generation and the principal sectors of energy consumption. These include

- Modern cooking appliances and fuels;
- Distributed electricity solutions;
- Grid infrastructure and supply efficiency;
- Large-scale renewable power;
- Industrial and agricultural processes;
- Transportation;
- Buildings and appliances.

It is important to underline that the sectoral actions have to be combined in order to assure immediate basic energy access to improved quality of life and well-being, but also to build energy services for long-term autonomous sustainable development.

According to the Agenda, those solutions include all distributed options for electrification, which range from island-scale grid infrastructure to mini-grids to much smaller off-grid decentralised individual household systems and targeted applications for productive uses. Experience has demonstrated that the best progress has come in low- and middle-income contexts that pursued strategies and policies to expand access to all (i.e. both urban and rural communities) by including the full range of electrification options in a balanced way. The *World Energy Outlook* 2011 [8] concludes that grid extension is the best option for achieving universal access in all urban areas but in only 30% of rural areas. The IEA projects [8] that around 45% of the additional connections needed for universal access will come from grid expansion, while the remaining 55% will depend on micro-grids and off-grid solutions.

In distributed electricity solutions, opportunities can be perceived for the involvement of different stakeholders, i.e. governments, donors, businesses and civil society.

Examples of already active initiatives that fall into this area are Lighting Africa and Lighting Asia, driven by the World Bank and International Finance Corporation (IFC); Lighting a Billion Lives under The Energy and Resources Institute (TERI); regional development banks' distributed energy projects such as those promoted under 'Energy for All' by Asian Development Bank (ADB) and by African Development Bank (AfDB) under the Scaling-Up Renewable Energy Programme in Low-Income Countries; African Caribbean Pacific, Europe (ACP-EU) Energy

Facility-Energy Project of United Nations Development Programme and Global Environment Facility (UNDP/GEF); and Global Lighting and Energy Access Partnership (LEAP) led by U.S. Department of Energy.

1.2 Sustainable Energy for All in Africa

Africa is the second largest continent, with over 2000 languages spoken in the 54 nations. The burgeoning youthful population and abundance of human and natural resources inspire optimism for unprecedented growth as we advance into the twentieth century. Additionally, 2008 marked the first time in human history when more people lived in urban areas than rural one—a phenomenon that has a far more dramatic impact on developing regions of the world such as those found in Africa. Instructively, since 2011, six of the twelve fastest growing economies are from the African continent. This increased socioeconomic development has led to greater demand for food, shelter and energy (among other key resources).

In Africa, the speed at which distributed and networked technologies are proliferating is quite interesting. Examples abound from mobile telephony and ICT of cost-effective and accessible product-service-system offerings that make the continent an ideal context for the deployment of distributed solutions. Whereas the continent abounds with minerals and myriad natural resources, the majority of its denizens still do not have access to adequate housing, water, electricity and related basic needs to help propel its communities into a truly sustainable future. To this end, sustainable energy systems are crucial and indispensable to desired socioeconomic development. Further, the massive size of the continent demands creative distributed systems that take cognisance of the sociotechnical and geopolitical aspirations of myriad societies.

There is a school of thought that Africa will be unable to alleviate poverty and improve the well-being of its people, reduce inequalities, if it cannot sustainably produce its own energy. Africa has abundant sunshine and vast water resources which can be used to generate cleaner, cheaper and accessible sustainable energy. On the contrary, over 600 million people in Africa still live in darkness without electricity. This lack of access to electricity has reduced the continent's economic growth, quality of education especially in rural areas and greatly affected health facilities and agricultural activities. It is not yet late to reverse this challenging scenario. This challenge provides an opportunity to critically think about clean, efficient, resilient and low-carbon technologies and sustainable development to reduce overdependence on fossil fuels. Access to sustainable energy will cut household costs, releasing resources to productive health and education investment as well as boosting the renewable energy businesses. This has the potential to drive economic growth and create jobs. In 2011, the United Nations launched the Sustainable Energy for All (SE4All) initiative to ensure universal access to modern energy services, doubling the global rate of improvement in energy efficiency, and doubling the share of renewable energy in the global mix. The aim is to achieve these three goals by 2030.

Such an initiative provides Higher Education Institutions (HEIs) in the continent with a unique opportunity to contribute to efforts at capacitation, research and pedagogy in redressing the pressing challenges associated with the quest for sustainable energy security. Notwithstanding, dedicated research, design and development initiatives focusing on sustainable energy systems are few and far between.

1.2.1 Sustainable Energy for All in Kenya

Kenya opted to be part of the SE4All UN Initiative because the Government had achieved significant strides in developing the framework for energy development, thanks to the Energy Policy, 2004, and Energy Act, 2006. Review of these two documents is expected to further improve the enabling environment for the engagement of a wide range of stakeholders, and particularly private sector, in the delivery of clean and modern energy services. It also happens at a time when petroleum resources have been discovered in the country and will therefore be instrumental in diversifying the energy mix and addressing energy poverty.

The SE4All Action Agenda (AA) for Kenya[1] presents an energy sector-wide long-term vision spanning the period 2015–2030. It outlines how Kenya will achieve her SE4All goals of 100% universal access to modern energy services, increase the rate of energy efficiency and increase to 80% the share of renewable energy in her energy mix, by 2030 (Table 1.1).

Biomass

In the context of the SE4All, access to modern energy involves electricity and energy for cooking. Kenya has chosen the baseline year for electricity access as 2012. For the purpose of the AA, the definition of electricity access is connections to the national grid system or distributed (off-grid) electricity solutions which include Solar Home Systems (SHS) and mini-grids. In the baseline year, only 23% of the population, which represents 1.97 million households, had grid electricity supply. Access to modern cooking services refers to access to improved cookstoves and non-solid fuels. The baseline year for access to improved cookstoves was 2013, being at the level of 3.2 million households, according to market assessment of Clean Cookstoves Association of Kenya (CCAK) under the Kenya Country Action Plan 2013 (KCAP). Over 80% of Kenyans rely on the traditional use of biomass as the primary source of energy for cooking and heating, with firewood contributing 68.7% and charcoal 13.3%. The Kenyan government is putting in place measures to regulate the fuelwood sector with a draft Forest Act[2] envisaging a six-point system of control from producer to consumer.

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[1]SE4All > Action Agenda for Kenya: www.se4all.org/sites/default/files/Kenya_AA_EN_Released.pdf.

[2]The 2009 charcoal production regulations developed by the Kenya Forest Service are yet to be adopted.

Table 1.1 SE4All initiative Kenya targets

Universal access to modern energy services	Doubling global rate of improvement of energy efficiency	Doubling share of renewable energy in global energy mix	Universal access to modern energy services	
Percentage of population with electricity access	Percentage of population with access to modern cooking solutions	Rate of improvement in energy intensity	Renewable energy share in Total Final Energy Consumption	
			Power	Heat
100%[a]	100%	−2785%/year[b]	80%	80%

Legend [a]Projected to be reached by 2022
[b]The energy intensity is expressed in negative as its improvement is a reduction on the energy intensity
Source Beyond Connections: Energy Access Redefined, Technical Report, Energy Sector Management Assistance Program, World Bank Group and SEforALL

Biomass contribution to Kenya's final energy demand is 69% and provides for more than 90% of rural household energy needs. The main sources of biomass for Kenya include charcoal, wood fuel and agricultural waste.[3] Fuelwood demand is at 35 million tonne per year, while the supply is at 15 million tonne per year representing a deficit of 20 million tonne. The deficit is largely the cause of high rate of deforestation, resulting in adverse environmental effects such as desertification, land degradation, drought and famine. One of the ways of arresting this is through the promotion of improved cooking stoves.

Because rural energy suffers low priority and status in both planning and development resource allocation, the Energy Bill 2015 proposes the establishment of the Rural Electrification and Renewable Energy Corporation. Amongst other functions, the Corporation will develop and update the renewable energy master plan taking into account County-specific needs and the principle of equity in the development of renewable energy resources. The Bill also proposes the establishment of energy centres in the Counties and a framework for collaboration with the County Governments in the discharge of its mandate. This framework includes undertaking on-farm and on-station demonstration of wood fuel species, seedling production and management in order to address the deficit in the national fuelwood demand.

Electricity

According to the March 2011 Least Cost Power Development Plan (2011–2031),[4] the required installed capacity for the reference scenario in 2030 will be 15,065 MW. The present value for this installed capacity amounts to €34.8 billion, (committed projects excluded) expressed in constant prices as of the beginning of 2010.

[3]Source www.erc.go.ke, 2016.

[4]Complete information about Least Cost Power Development Plan (2011–2031), available at http://www.renewableenergy.go.ke/index.php/content/44.

The transmission development plan indicates the need to develop approximately 10,345 km of new lines at an estimated present cost of €3.8 billion. Transmission development during the planning horizon will be based on 132,220 and 400 kV. According to the 5-year (2013–2017) corporate strategic plan for the electricity sub-sector, Kenya targets installed capacity of 6762 MW consisting of 49.9% Renewable Energy, 15.5% Natural Gas, 28.4% Coal and 6.2% diesel by 2018. The total generation capital expansion cost up to 2018 cost is estimated at €6.5 billion under the moderate estimations.

There are 41 transmission investment programmes associated with implementation of the additional 5000+MW investment by 2018 at an estimated cost of €3.1 billion. The corporate strategy plan targets 3325 km of new transmission lines and 3178 MVA of new transmission substation capacity for transmission systems and 3768 km of new MV lines.

The distribution system targets 69 new substations of capacity 6225 MVA; 20 new bulk supply points of capacity 1237.5 MVA for distribution systems and 70% household connectivity to electricity. The estimated cost of implementing the distribution system is €1.1 billion.

Implementers of transmission and distribution projects are Kenya Electricity Transmission Company (KETRACO) and Kenya Power and Lighting Company (KPLC), respectively.

1.2.2 Sustainable Energy for All in Uganda

Electrification access in Uganda stands at approximately 26.1% nationally (14.88% centralised grid and 11.22% decentralised) and 7% in rural areas. Since 2001, the government of Uganda has stepped up its efforts to extend energy access to the rural communities. Several statutory agencies (Central Government, Local Governments, civil society, the private sector and international agencies) are key contributors to the institutional framework for energy access. The Ministry of Energy and Mineral Development is the lead Government body responsible for policy development, guidance and implementation in the energy sector. Its activities are grounded in the national development plan.

The National Development Plan foresees investment in the energy infrastructure to raise electricity consumption from 75 to 674 kWh/capita, a rate comparable to that of Malaysia and Korea. Hence, generation capacity will be increased to meet the needed 3500 MW. Work has started for the construction of several hydropower production plants, namely, Bujagali HPP 250 MW, Karuma HPP 700 MW, Ayago HPP 700 MW, Isimba HPP 130 MW and Arianga HPP 400 MW. It is also envisaged that additional energy shall be generated from renewable sources as follows: Thermal plants 700 MW, Mini HPP 150 MW, Solar thermal 150 MW, Geothermal 150 MW and cogeneration from biomass 150 MW. Consequently, rural electrification, which currently stands at 4%, is expected to increase by 20% and reduction of power losses by 16%.

The Rural Electrification Agency (REA) was established as a semi-autonomous agency by the Minister of Energy and Mineral Development through Statutory Instrument 2001 No. 75, to operationalise Government's rural electrification programme. During the same year, having observed that the forest cover in Uganda is fast diminishing, the shrinking rate being estimated at 55,000 ha per year or 2%, a Forestry Policy was passed. The Forestry Policy assigns the responsibility of developing and implementing strategies for biomass energy conservation, focusing on households, charcoal producers and industrial consumers to the MEMD.

Subsequently, in 2002, the government passed the Uganda Energy Policy, and in 2007 the Renewable Energy Policy was enacted. The overall objective of the Renewable Energy Policy is to diversify the energy supply sources and technologies in the country. In particular, the Policy goal strives to increase the use of modern renewable energy from the current 4–61% of the total energy consumption by the year 2017. The operationalization of the Renewable Energy Policy culminated in the establishment of a Renewable Energy Department and an Energy Efficiency and Conservation Department in the Ministry of Energy and Mineral Development, establishing a National Energy Committee at the National Level and District Energy Committees and District Energy Offices at the Local Governments.

With the above policies in place, and with support from the development partners, the promotion of sustainable energy resources has received significant attention. Currently, three factories in Uganda, namely, Kakira Sugar Works Ltd., Kinyara Sugar Works Ltd. and Sugar Corporation of Uganda Ltd.—run cogeneration plants based on bagasse. The total capacity is 22 MW. Out of this, 12 MW from Kakira Sugar Works is supplied to the grid. Several industries have also embraced the use of wood chips from the carpentry and coffee husks as alternative sources of energy. The use of improved stoves is currently promoted by the Ministry of Energy and Mineral Development with support of the Uganda German Development Corporation through the Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP).

In addition, the government of Uganda through its rural electrification programme is promoting the use of solar energy in the areas that have no access to the grid. This programme also involves extension of low and medium voltage lines in the rural areas. So far, over 3000 km of Medium Voltage lines (33 and 11 kV) and 2500 km of Low Voltage lines have been constructed and commissioned and an additional 2100 km of MV and 1000 km of LV are currently under construction. A total of 1280 rural communities (villages, trading centres, social centres and public institutions) with a potential of 120,000 connections have access to electricity and at least 38,530 connections have been achieved outside the main grid (Development of Indicative Rural Electrification Master Plan—2009). Two private companies and two cooperatives were awarded operation and maintenance concessions in seven areas of the country for large regional lines outside UMEME areas of operation. Ready boards have been introduced to ease connection of poorer households to electricity. Besides, in order to streamline consumption and payment of bills, the use of prepaid metering has been introduced and the Rural Electrification Agency (REA) has awarded concessions to users in rural areas.

1.2.3 Sustainable Energy for All in South Africa

National Energy Efficiency Strategy
The draft National Energy Efficiency Strategy under the auspices of the Department of Energy is currently undergoing revision.

Sustainable Energy Strategy for the Western Cape
A recent energy crisis in the Western Cape has highlighted the need to develop a plan for sustainable, secure energy provision in the Western Cape. Although various national efforts are underway to increase energy provision to the Western Cape, the Provincial Government believes that additional efforts need to be made to address the other energy challenges facing the Province, including the challenges of

- Reducing the Province's carbon footprint;
- Providing access to energy to all citizens in the province, and
- Addressing the numerous health, social and environmental problems associated with our current energy use patterns.

These challenges need to be addressed in the context of supporting the Province's economic development and job creation. The development of this discussion document was preceded by a Status Quo and Gap Analysis which highlighted the need for an effective energy policy to ensure the availability of background information and data for policy-makers, provide an effective institutional structure for sustainable energy management, develop a regulatory and policy framework, develop a training, communications and awareness raising programme and establish partnerships with public and private sector bodies.

Based on the gaps identified, certain actions have already been taken (Western Cape Government 2007), including

- The formation of an Intergovernmental Energy Task Team (IETT);
- Ongoing engagement with stakeholders at provincial and national level;
- Completion of a provincial energy inventory, which has been used to inform the adoption of a resolution at the Sustainable Development Conference requiring the Province to develop a strategy to address energy and climate change.

Skills Development for the Green Economy
The vision of the Western Cape Government (WCG) *Skills Development for the Green Economy* (2013) is a knowledge-driven project being championed by the CHEC-WCG Coordinating Group on Climate Change:

> The future of the South African economy is threatened by poverty and unemployment, the impact of climate change, declining and degraded natural resources. Solving these problems lies in a transition to a green economy, one characterised by low carbon emissions, the efficient use of resources and social inclusion (2013:3).

The vision of the Western Cape Government is to be the centre of this transition in South Africa, to make the Province a 'Green Economic Hub' for green investment and business opportunities that alleviate poverty, restore degraded eco-systems that provide essential services to society, and achieve energy, water and food security. To realise this vision, the Provincial Government has produced a Green Economy Strategy to outline a framework for public, private and community sectors to co-operatively pursue this green economic growth. The Green Economy Strategy itself is informed by and arose from the requirements of the Western Cape Climate Change Response Strategy, which highlights the need for planning, preparation and innovation to maximise the province's capacity to adapt to the impacts of climate change. However, there is currently a lack of suitably qualified professionals and technicians to successfully implement the Climate Change Response Strategy and Green Economy Strategy. The Province has thus identified an urgent need for skills development in the areas of climate change mitigation and adaptation, the green economy and infrastructure development. To this end, representatives of the Western Cape Government (WCG) met with the Cape Higher Education Consortium's (CHEC) Coordinating Group on Climate Change, and communicated the need to match university education with the knowledge and core competencies that will be required by the Climate Change Response Strategy and Green Economy Strategy. Subsequently, the task team was requested to extend the scope of the project to cover Further Education and Training Colleges if support from the CEOs of the colleges was provided and suitable researchers could be found.

The vision of the CHEC representatives is for the four universities to collaborate with one another and with the Province to provide up-to-date, relevant education in the areas of the green economy and climate change, and equip professionals with the skills and core competencies necessary to bring the 'Green Economic Hub' to life.

1.2.4 Sustainable Energy for All in Botswana

As of 2013, the total population in Botswana which had access to electricity was 66% and of these, 75% were in urban areas and 54% in rural areas (Statistics Botswana 2017). About 700,000 people do not have access to electricity, mainly those who are far away from the main grid. In Botswana, 98.5% of the electricity is generated from fossil fuels and only 1.5% is generated from renewable sources (Statistics Botswana 2017). These statistics show that Botswana is still far from achieving sustainable energy for all due to over-reliance of generating electricity from fossil fuels.

Botswana Power Corporation is the sole parastatal utility which was formed in 1970 by an Act of Parliament and its mandate is to generate, transmit and distribute electricity within Botswana. According to the Corporation's mandate, throughout the years, efforts were focused on reducing the Corporation's activities' impact on wildlife, Greenhouse Gas (GHG's) emissions and the landscape and thus striking a balance between the interests of industry and the effective use and conservation of resources.

The Corporation has initiated the replacement of insulated low voltage overhead line conductor with insulated Ariel Bundled Conductor (ABC) in the distribution network and this blends in well with the above environmental concerns, in that little if any tree clearing is done to facilitate low voltage line construction.

Generation waste management by the Corporation has focused on the following activities:

- Ash disposal;
- Waste water treatment;
- Groundwater pollution monitoring;
- Greenhouse gas emission monitoring.

As a mitigation measure, the Corporation supports research projects for provision of electricity using other efficient alternatives to thermally generated electricity and is working with some international entities that are currently involved in a pilot project for the supply of electricity using alternative sources of energy such as solar energy. As a project to encourage efficient use of energy, Botswana Power Corporation has installed 1 million Compact Fluorescent Lamps (CFLs) in households across the country and this will greatly save energy. To address some of the challenges, an environmental or a sustainable development policy is being formulated that will serve the Corporation and the nation well into the future.

Botswana Power Corporation has a 1.3 MW Photovoltaic solar power plant at Phakalane, a suburb of Gaborone. The solar power project was implemented through a Japanese grant as part of a strategy called '*Cool Earth Partnership*' which Japan announced in 2008 to address environmental issues. Under the *Cool Earth Partnership*, Japan has provided funds through the Japanese International Corporation Agency amounting to €8 billion to 52 partner countries including Botswana for their efforts in the environmental issues and this project was funded as part of the strategy. Furthermore, in October 2017, the Botswana Power Corporation signed a power purchase agreement with private entities to electrify 20 villages in rural areas which are mainly far from the grid using distributed network solar plants in the next 12 months. This is a positive step towards a greener environment by increasing Botswana's green energy—up to 25% by the year 2025.

Department of Energy Affairs, Ministry of Minerals, Energy and Water Affairs

The Department of Energy is responsible for the formulation, regulation, technical implementation of projects, direction and coordination of the national energy policy. The main focus of the Energy Policy is to increase the contribution of renewable energy to the country's energy needs. The policy also seeks to provide affordable, environmentally friendly and sustainable energy services in order to promote social, economic and sustainable development.

The Government is committed to exploring renewable energy, especially solar energy which provides clean energy to compliment the coal-based energy sources which are currently being used to provide electricity. For example, the use of solar energy will reduce Botswana's energy-related carbon dioxide emissions by promoting renewable and low greenhouse gases technologies. It is reported that Botswana has abundant solar energy, receiving over 3200 h of sunshine per year, with an average insolation on a flat surface of 21 MJ/m^2 per day. This rate of irradiation is one of the highest in the world. Solar energy is recognised as a promising renewable energy source in Botswana and it is currently used for water heating, refrigeration and lighting. However, its current contribution to the national energy consumption is insignificant. In order to achieve sustainable energy for all, the government has set up two organisations which are dealing with issues of renewable and clean energy.

Botswana Innovation Hub
Botswana Innovation Hub has a centre called Clean Technology, whose mandate is focussed on catalysing activities related to clean technologies, energy and environmental research and development and commercial activities within these areas. The Centre's emphasis is on sustainability and environmental protection in renewable energy, cleaner coal, water conservation and waste management.

Botswana Institute for Technology Research and Innovation
The Botswana Institute for Technology Research and Innovation, Energy Division focuses on needs based research, development and adoption of Clean Energy Technologies for Botswana, as well as optimisation of existing ones. The key areas under consideration are

- Solar powered solutions;
- Biomass technologies, and
- Optimisation of energy systems.

1.2.5 Sustainable Energy for All in Europe

European Union's policy regarding efficiency and renewable' is already running since several decades, it is nowadays regulated by the Directive 2009/29/EC of the European Parliament and of the Council, which builds on the commitment the European Council made in March 2007 to reduce the overall greenhouse gas emissions of the Community by at least 20% below 1990 levels by 2020 and by at least 50% below their 1990 levels by 2050.

The Directive 2009/29/EC prescribes

- To develop renewable energies to meet the commitment of the Community to using 20% renewable energies by 2020;
- As well as to develop other technologies contributing to the transition to a safe and sustainable low-carbon economy and to help meet the commitment of the Community to increase energy efficiency by 20% by 2020.

These goals are not directly comparable to those of the Sustainable Energy for All Global Action Agenda since they have different references, for example, regarding target years. Nevertheless, they show a common effort towards energy efficiency and renewable energies deployment.

As part of the commitment to achieving the objectives of the Sustainable Energy for All Initiative the European Commission announced on 16 April 2012 the Energizing Development Initiative,[5] which will provide developing countries with the support they need to assist them in providing access to sustainable energy. With the help of the EC, developing countries that sign on to the initiative will have the opportunity to adopt cleaner, more efficient technology from the start, leapfrogging technologies and infrastructure that developed countries established in the past.

The goal of the initiative is to provide energy services to 500 million people by 2030, by empowering developing countries through programme elements such as

- The creation of a world-class Technical Assistance Facility, drawing upon EU experts to develop technical expertise in developing countries;
- A focus on refining, expanding and improving energy-related innovative financial instruments and risk guarantee schemes in developing countries in order to unlock greater private investment;
- An effort to mobilise an additional several hundred million Euros to support concrete new investments in sustainable energy in developing countries, with the goal of leveraging even greater flows of additional investment from the private sector.

Attention should be given to the implementation of the initiative to avoid dependence phenomena regarding technologies, know-how or suppliers and to avoid the risk to exploit local renewable energies only to feed the European market.

1.3 Defining Access to Energy

A key issue in the transition towards a sustainable society is the access to modern fuels/energy for cooking [6, 7]. We know that worldwide 2.7 billion people access energy through traditional biomass, i.e. traditional three-stone wood fires for cooking. This habit carries problems around healthy and involves a gender issue. The fumes of burning fuels are a death killer for low-income people that do not have other modern fuels or energy sources for cooking. In poor context, 4000 premature deaths everyday are due to biomass fumes that is 1.5 million a year, they kill more than malaria. Furthermore, women and children make several kilometres a day to collect wood.

[5]Energizing Development Initiatives is promoted by the United Nations, aiming to provide 500 million people in the developing world with the support they need to gain access to sustainable energy. More at https://sustainabledevelopment.un.org/partnership/?p=601.

This is one of the main astonishing problems, but more in general, lack of access to energy hampers the provision of basic services such as health care, security and education [7].

Some numbers related to Energy Access [6, 7]:

- 1.2 billion people worldwide lack access to electricity;
- Furthermore, 1 billion do not have reliable access to electricity.

Who are those living without electricity?

- More than 95% are in the sub-Saharan Africa and low-income Asia countries;
- 80% of the world total are in rural areas.

Therefore, access to energy may strongly contribute to reducing inequality and poverty. Energy is an essential input to almost every good and service provided in the current economies. Energy services have a profound effect on productivity, health, education, food and water security, and communication services.

Modern fuels for cooking and heating relieve women from the time-consuming drudgery and danger of travelling long distances to gather wood. Electricity enables children to study after dark. It enables water to be pumped for crops, and foods and medicines to be refrigerated.

The World Energy Outlook 2015 highlights that access to energy also involves consumption of a specified minimum level of electricity, and the amount varies based on whether the household is in a rural or an urban area. The initial threshold level of electricity consumption for rural households is assumed to be 250 kilowatt-hours (kWh) per year and for urban households it is 500 kWh per year [7]. The higher consumption assumed in urban areas reflects specific urban consumption patterns. Both are calculated based on an assumption of five people per household. In rural areas, this level of consumption could, for example, provide for the use of a floor fan, a mobile telephone and two compact fluorescent light bulbs for about five hours per day. In urban areas, consumption might also include an efficient refrigerator, a second mobile telephone per household and another appliance, such as a small television or a computer.

Another important issue that defines access to energy is linked to the affordability of supply and legality of connection, which represent several problems, especially in low-income countries. Illegal connections are mostly in precarious housing, which increases the insecurity of families that live inside them.

Given the complexity and multiple variables which have an impact on defining energy access, SE4All's Global Tracking Framework (GTF) 2013 report introduced multi-tier frameworks for measuring it. It is divided into three areas of energy use: (i) households, (ii) productive engagements and (iii) community facilities, that together are termed as the *locales of energy access* (World Bank, 2015). Further, the model proposes indexes, organised hierarchically, that include, under the umbrella of the *overall energy access index,* the following indexes:

- Index of household access to energy, which includes energy for electricity, cooking and heating;
- Index of access to energy for productive engagements;
- Index of access to energy for community facilities, such as street lighting, health facilities, community buildings and public offices (World Bank 2015).

Considering the index of household access to energy, we can go in depth in the provision of cooking facilities. They can be used without harm to the health of those in the household and which are more environmentally sustainable and energy efficient than the average biomass cookstove currently used in low-income countries.

What we know is that the energy system we have now, mostly based on fossil fuels and centralised generation system, is whatever but not sustainable, neither in economic terms nor environmental, nor in social terms. Therefore, it is clear that we need to undergo a paradigm shift in the way we produce, supply, use and dispose of the energy.

Indeed, Distributed Renewable Energy (DRE) generation is understood by many authors [10, 15], UN [21], [1, 4, 11, 25], IRENA [9] as the paradigm shift needed in the energy sector for a Sustainable Energy for All.

The transition towards DRE is introduced in the next section.

1.4 Distributed Renewable Energy: A Key Leverage Towards Sustainable Energy for All (SE4A)

The **Distributed Renewable Energy (DRE) generation** could be defined as '*a small-scale generation units harnessing renewable energy resources (such as sun, wind, water, biomass and geothermal energy), at or near the point of use, where the users are the producers—whether individuals, small businesses and/or a local community. If the small-scale generation plants are also connected with each other (to share the energy surplus), they become a Renewable Local Energy Network, which may in turn be connected with nearby similar networks*'.

The main environmental benefits of a DRE are, since they use non-exhaustible resources, they have low greenhouse gas emissions, they produce low environmental impact for extraction, transformation and distribution (low-energy transmission losses) compared to non-renewable centralised energy generation units.

The main socioethical and economic benefits are due to the small scale of generation units that require small economic investment, are easy to instal, maintain, manage and allow individuals and local communities to instal/manage them, thus leading to democratisation of access to resources, which improves quality of life and enhances local employment and dissemination of competences.

One of the most committed and known researchers on the sustainable energy topic is Jeremy Rifkin, who is speaking about the *third industrial revolution* [15] and his core idea claims 'the creation of a renewable energy regime, loaded by buildings, partially stored in the form of hydrogen, distributed via an energy internet—a smart intergrid—and connected to plug in zero emission transport'.

In accordance with his thinking, it is possible to set up some useful features or needed pillars for the third industrial revolution [15]:

- Shift to renewable energy (solar, wind, hydro, geothermal, ocean waves and biomass);
- Transform buildings as power plants;
- Deploy hydrogen and other storage technologies in every building and throughout the infrastructure to store intermittent energies;
- Use internet technology to transform the power grid of every continent into an energy-sharing inter-grid that acts just like the internet;
- Transition the transport fleet to electric, plug-in and fuel cell vehicles that can buy and sell electricity on a smart continental interactive power grid.

These pillars, using Distributed Renewable Energy (DRE) systems, represent promising steps towards Sustainable Energy for All.

Both the DRE and their sustainability benefits are fully described in Chap. 2.

1.5 Sustainable Product-Service Systems Applied to Distributed Renewable Energy: An Introduction

Since the end of 90s, Sustainable Product-Service System (S.PSS) has been studied as a promising opportunity for sustainability [2, 3, 5, 13, 17–19, 23, 24, 27–28]. S. PSS are defined [26] as 'offer models providing an integrated mix of products and services that are together able to fulfil a particular customer demand (to deliver a 'unit of satisfaction'), based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the providers continuously seeks environmentally and socioethically beneficial new solution'.

Sustainable Product-Service System has been considered within the LeNSes project as a promising model for the diffusion of Distributed Renewable Energies in low- and middle-income contexts.

In fact, the following is the outcome of the multiregional research carried out during the LeNSes project: '*A S.PSS applied to DRE is a promising approach to diffuse sustainable energy in low/middle-income contexts (for All), because it reduces/cuts both the initial (capital) cost of DRE system purchasing (that may be unaffordable) and the running costs for maintenance, repair, upgrade,* etc. *(that may cause interruption of use), while increasing local employment, related skills and entrepreneurship, as well as fostering for economic interest the design of low environmentally impacting DRE products, resulting in a key leverage for a sustainable development process aiming at democratizing the access to resources, goods and services*'.

The articulation and characteristics of such promising outcome are presented in this book, together with the role the designer should play to develop them, i.e. the new discipline of System Design for Sustainable Energy for All (SD4SEA), namely the design of S.PSS applied to DRE.

The following section examines one case study to further introduce S.PSS applied to DRE.

Solarkiosk, Africa

The Solarkiosk AG (German company) targets local intermediaries to manage and guarantee the provision of energy services in rural areas of Kenya, Rwanda and Tanzania. Solarkiosk designs, instals and owns the E-Hubb, a charging station provided with solar panels and various equipment and products depending on the location, such as computer, printer, solar lanterns and fans. A local intermediary is responsible (with a maximum of 5 collaborators) of the local E-Hubb, where (s)he provides a wide range of energy services such as Internet connectivity, copying, printing and scanning, etc. *Customers pay per use, e.g. pay to print, or they can buy some offered products or food products. Local intermediary receives training for management, selling and accountability of the E-Hubb, as well as to solve basic maintenance and repair. Currently, as new market segment for the E-Hubb, Solarkiosk is offering energy connection to local shops, thus entailing more favourable conditions for the local economy, e.g. in food shop, the access to reliable energy can power refrigerators to keep goods.*

For the customer, the opportunity to obtain her/his result is given from the small payment (s)he can give for each use. For example, to send out an email, the customer pays a fixed amount, without making any initial investment to buy a computer to send it, neither paying unexpected costs in case an upgrade or repair of the computer if needed. In the case of products which are sold to the customer, e.g. solar lantern, the local intermediary is in charge to solve technological problems related to the product as additional service, without extra costs for the customer. The products, both used in the E-Hubb and sold, are certified, so that quality and efficiency are ensured, both for the local intermediary to work on them and for the clients. For the local intermediary, the training courses can increase their competencies and future opportunities for job career. On the side of the Solarkiosk AG Company, they had the opportunity to enter the untapped market of rural areas. In fact, even though all customers have limited power purchase, the possibility to cover high numbers still gives them margins of return. Finally, on the environment, the use of Renewable Energy solutions, both the E-Hubb as well as the products such as lanterns and efficient cookstoves, can increase the quality of the given results, while reducing their environmental impact.

The Distributed Renewable Energy (DRE) systems and the Sustainable Product-Service System (S.PSS) win-win models are, respectively, introduced in Chaps. 2 and 3 of this book. The S.PSS applied to DRE approach is presented in Chaps. 4 and 5. Consequently, the new key role for designers defined as System Design for Sustainable Energy for All (SD4SEA) is presented in Chap. 6, as the way for the designers to contribute to the transition towards a sustainable society.

Chapters 7 and 8 are dedicated to the method and the tools to support the designers in their practice (developed by the LeNSes project partners), together with on-field experiences conducted during the same project.

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