WWF

REPORT

UG

2015

THIS REPORT HAS BEEN PRODUCED IN COLLABORATION WITH:

ivl

ASD

KTH

ENERGY REPORT FOR UGANDA

A 100% RENEWABLE ENERGY FUTURE BY 2050

ACKNOWLEDGMENT

The Energy Report for Uganda is a scenario study that presents options and opportunities for developing the energy system for Uganda in a renewable and sustainable manner. This study was carried out by a team comprising of Mathias Gustavsson from IVL Swedish Environment Research Institute (Sweden), Mark Hankins and Karin Sosis from African Solar Design (Kenya) and Oliver Broad from KTH Royal Institute of Technology (Sweden). We would like to acknowledge the input from Air Water Earth Consultants that provided data on a number of key items linked to power supply and demand as well as the support from Mark Howells and Manuel Welsch at KTH (Sweden) in the design of the energy model used to form the scenarios.

Appreciation is extended to the following WWF staff for their role in reviewing, providing contributions and technical guidance to the report: Dr. Isaiah Owiunji, Ibrahim Mutebi, Jacqueline Mbabazi and Jacob Etunganan (WWF Uganda Country Office), Marte Ness, Stefan Norris and Anders Blom (WWF Norway), Mattias de Woul (WWF Sweden), Agnete Schønau Winther (WWF Denmark), Adam White (WWF European Policy Office), Robert Ddamulira and Ivan AmanigaRuhanga (WWF Regional Office for Africa) and Jean-Philippe Denruyter (WWF Greater Mekong)

We also recognize the input from energy and environment experts and other stakeholders in Uganda that shared experiences and provided view points on the energy situation in the country.

CONTRIBUTORS

Mathias Gustavsson
IVL Swedish Environmental Research Institute (Sweden)

Oliver Broad
KTH Royal Institute of Technology (Sweden)

Mark Hankins
African Solar Design (Kenya)

Karin Sosis
African Solar Design (Kenya)

Published in October 2015 by
WWF-World Wide Fund For Nature - Uganda Country Office
(Formerly World Wildlife Fund), Kampala, Uganda.

ENERGY REPORT FOR UGANDA
A 100% RENEWABLE ENERGY FUTURE BY 2050

CONTENTS

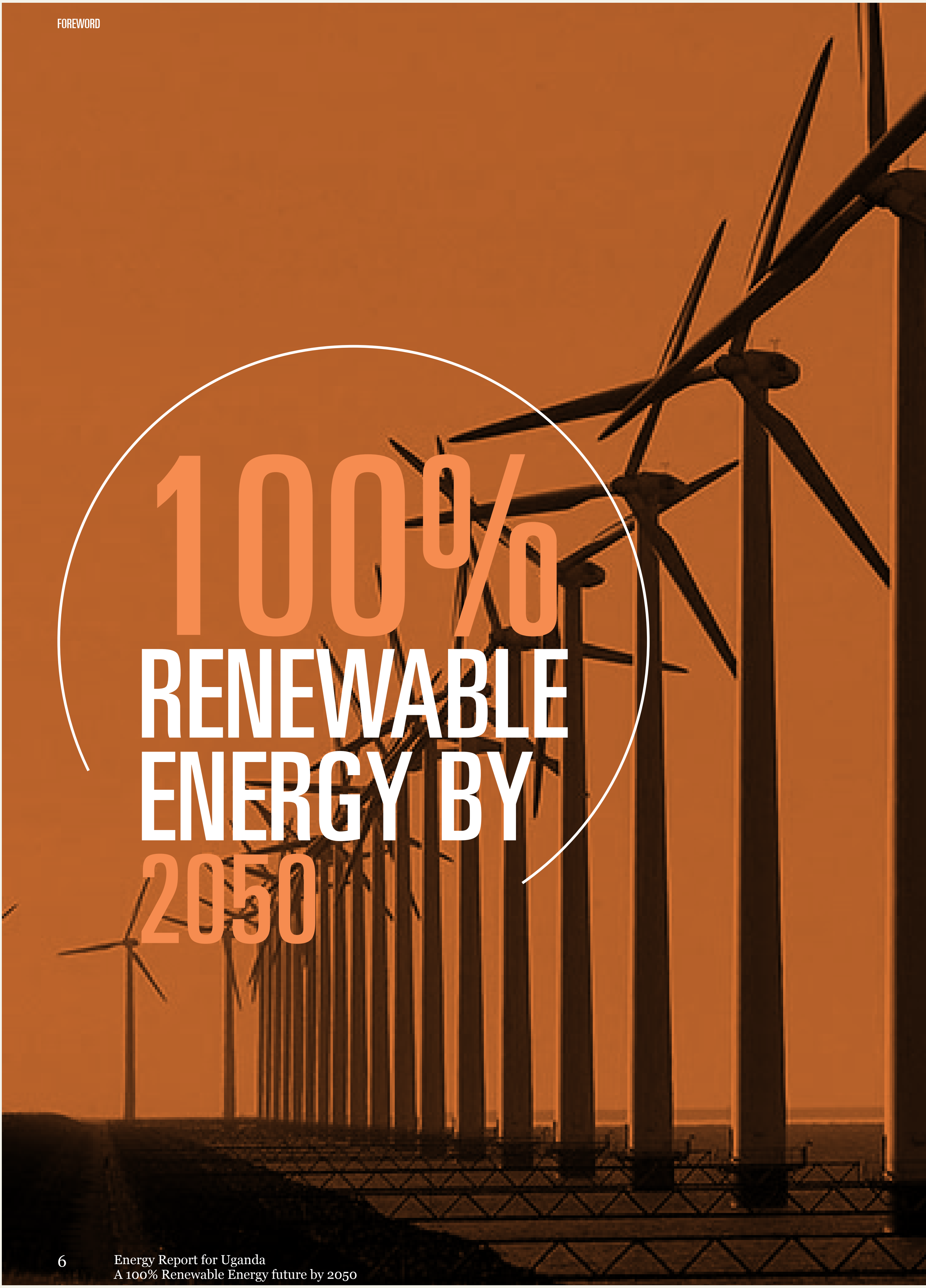
LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

$CO_{2\,EQ}$	Carbon dioxide equivalents
CSP	Concentrated Solar Power
ERA	Electricity Regulatory Agency
ERT	Energy for Rural Transformation
GDP	Gross domestic production
GETFIT	Global Energy Transfer Feed-in Tariffs - Uganda project
GHG	Greenhouse gas
GWP	Global warming potential
HVAC	Heating, ventilation, and air conditioning
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
LEAP	Long-range Energy Alternatives Planning System
LPG	Liquefied Petroleum Gas
LV	Low voltage
MV	Medium voltage
NGO	Non-governmental Organisation
NPV	Net Present Value
PKM	Person kilometre
PSH	Peak sun hours
PV	Photovoltaic
REA	Rural Electrification Agency
REFIT	Renewable Energy Feed-in Tariff
RET	Renewable energy Technologies
SE4ALL	Sustainable Energy for All
SME	Small and Medium Enterprises
SSA	Sub-Saharan Africa
TED	Technology and Environmental Database
TKM	Tonne kilometre
UEDCL	Uganda Electricity Distribution Company Limited
UEGCL	Uganda Electricity Generation Company Limited
UETCL	Uganda Electricity Transmission Company Limited
USD	United States dollar
VOC	Volatile Organic Compounds
WWF UCO	WWF Uganda Country Office

From \To	**MJ**	**toe**	**kWh**
Mega joule (MJ)	1	2.39 x 10-5	0.278
Tonne oil equivalent (toe)	41.9 x 103	1	11.6 x 103
Kilo watthour (kWh)	3.6	8.60 x 10-5	1



100% RENEWABLE ENERGY BY 2050

FOREWORD

Uganda is endowed with abundant renewable energy potential from sources such as biomass, water, wind and the sun. However, this potential has not been fully utilized resulting in a situation where 15% of the population has access to electricity, while the majority (over 90%) depend on unsustainably used biomass and use rudimentary technologies to meet their energy needs.

It is clear, that the provision of sustainable energy solutions in Uganda is crucial for alleviating poverty, strengthening the country's economy and protecting the environment. Indeed, the Government of Uganda is committed to securing a stable energy supply for long-term social and economic development of the country. This is emphasised in the Constitution of Uganda (1995) and the Energy Policy (2002), whose goal is "To meet the energy needs of Uganda's population for social and economic development in an environmentally sustainable manner."

While this is an on-going process (provision of sustainable energy solutions), a study commissioned by WWF Uganda Country Office (WWF UCO) has shown that it is possible to meet 100% of Uganda's energy needs from renewable energy sources by 2050. The Energy Report for Uganda is a scenario study that presents options and opportunities for developing the energy system for the country in a renewable and sustainable manner. The suggested scenario is developed considering the need for all Ugandans to access modern energy services, but also the need to ensure that energy demand is met by sustainable and renewable energy resources as opposed to non-renewable energy sources. The scenario is also based on a realistic but optimistic approach to delivering modern energy services in the country.

Therefore, the purpose of this report is to highlight to all Ugandans, that a renewable energy future is not only possible, but perhaps the most appropriate path to take towards the transformation of Uganda's energy sector. The report also shows that the transition to 100% renewable is cost effective, affordable and sustainable.

It is also important to note that, though this transition towards renewable energy may come with some challenges, it is my hope that this report offers inspiration to government, businesses, and other stakeholders to look towards overcoming these challenges and move boldly towards a renewable energy future.

David Duli
Country Director

EXECUTIVE SUMMARY

THIS IS THE FIRST WWF ENERGY REPORT PRODUCED FOR A SUB-SAHARAN AFRICAN (SSA) COUNTRY. THE REPORT HAS THREE PARTS.

1. *An analysis of the current total energy demand and supply patterns for Uganda,*
2. *The featured 'renewable energy scenario' presents a path that enables the Ugandan energy sector to transition to a modern, environmentally sustainable system. (60% renewable by 2030, and (near) 100% renewable by 2050), and*
3. *A "course of action" that outlines how Uganda can attain the renewable energy targets presented in the 'renewable energy scenario'.*

The Uganda renewable energy scenario presents a viable model in which modern energy services, based on currently available technology, are accessible to all. It explores how Uganda can stimulate a growing economy based on renewable energy instead of venturing down a business-as-usual path with increased dependency on fossil fuels. The model recognizes that, for Uganda, achieving universal energy access is as important as achieving a 100% renewable energy production target. It also recognizes that to be sustainable, the renewable energy solutions presented must have limited negative impact on biodiversity, ecosystems and climate.

The renewable energy model presented here incorporates a) desk studies of baseline information, b) quantitative scenario models and c) supporting course of action storylines that include policy and business changes that are needed to drive change. The quantitative representation of the scenarios has been developed using the Long-range Energy Alternatives Planning System (LEAP) software, a modelling tool commonly used in energy projections. All energy consumption is defined at the base year (2010) and based on this demand energy carriers are assigned and linked to different supply sources. The household demand has been operationalised applying a multi-tiered approach based on SE4All frameworks where consumers gradually move up the energy access ladder.

Total Ugandan energy demand in 2013 was 136 TWh (MEMD 2014). It can be divided into household, commercial, industrial and transport sectors – with household energy makes up the bulk of primary demand (a majority from inefficient use of traditional biomass). In the 2010 baseline, industry used a main share of the electricity supply.

Uganda has ample renewable energy potential. Given even conservative estimates of commercially-viable biomass, hydro, solar and geothermal resources, it can, with determined effort, position itself as a regional leader with an energy system based on renewable sources by 2050. The figures below show a scenario where 92% of the primary demand is provided by renewable energy in 2050.

High, inefficient and unregulated use of solid biomass energy is a key limitation to attaining sustainability in the sector. Even if existing biomass sources and end-use technologies are nominally renewable, they are not sustainable. Without a massive push for reforestation and sustainable biomass production, Uganda will not be able to provide its citizens with sufficient biomass to meet their energy needs.

Implementation of energy efficiency measures will play a major role in the transition to a 100% renewable energy future. Measures can be done in all sectors and along the whole value chain. These efforts need to be coupled with effective long-term programs that provide the required levels of support. Efficient conversion and end-use of biomass and increased production of biofuels will decrease the overall pressure on bioenergy resources.

With large-scale adoption of on- and off-grid solar energy, continued use of hydropower and new use of geothermal, Uganda can leapfrog old energy-intensive, fossil-fuel based development models. However, for a transition to 100% access to be possible for a growing population, the country must greatly expand its current energy resource base and prioritise improvements in energy supply diversification, transformation, and end-use efficiency.

A transition to universal access powered by 100% renewable energy will require a **course of action** that achieves changes in four critical areas:

- **Modernizing the biomass sector** so that use of firewood, charcoal and agricultural by-products is done efficiently, and biomass is managed holistically and produced sustainably. Biomass will remain a cornerstone of the Ugandan energy supply for some time. Key to modernization is the transition by both industry and households to use of efficiently produced biomass fuels and efficient cooking and conversion devices.
- **Expanding the clean grid-based electricity sector** through investment in hydro, solar and other renewable sources. New capacity should be developed while ensuring that environmental values are preserved. A modern electric grid infrastructure will incorporate both centralized and distributed grid-tied production, encouraging investment by power companies, institutions and households in their own power systems. As can be seen in Figure 1, on-grid electricity supply increase 25 times by 2050, with the largest growth seen in solar photovoltaic and hydropower.
- **Encouraging the development of off-grid electricity infrastructure** that can supply remote off-grid areas, as well as grid-proximate consumers who currently cannot afford grid costs, with affordable electricity. Stand-alone renewables, pico-solar and mini-grids should continue to receive support. Increasingly, the distinction between “on-grid” and “off-grid” will disappear as consumers find that off-grid solar systems can become competitive with the national grid.
- **Building an efficient people- and climate-friendly transport sector** that is based on a transition to modern electric and biofuel-powered vehicles and intelligent road, rail and waterway infrastructure.

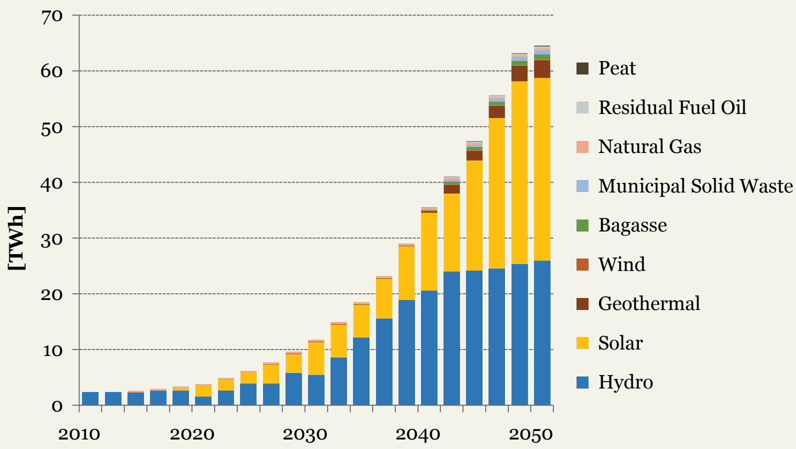


Figure 1: Electricity supply and specification of electricity mix – renewable energy scenario

The renewable energy scenario envisions that even with Uganda’s expected population growth, total energy demand will stabilize by 2025 before starting to grow again around 2040. This stabilization will largely result from replacing inefficient biomass conversion technologies with efficient solutions delivering the same energy services – including efficient stoves, alternative fuels such as briquettes and pellets, and efficiently produced charcoal (see Figure 2). Biogas and other fuels based on animal, agricultural and other wastes are introduced and diversify the energy mix.

Liquefied petroleum gas (LPG) will play an important transitional role for cooking and heating services. It is expected that this will help reduce pressure on forests as modern efficient fuels and practices are introduced and as other renewable fuels are developed. In the long term, we expect that cooking will transition to biofuels and electricity, but it is important to note that wood and charcoal will remain in use modern in stoves even in 2050, especially for rural communities.

The scenario foresees national energy use growing rapidly through the modernization of biomass fuels and an increasing share of new renewable electricity supplies. At the same time, traditional wood fuel use decreases and fossil fuel use is constrained. The share of renewable sources is very high in Uganda today – almost 90%. This level is in a sense artificial as it is the result of high shares of cooking energy demand being served by woody biomass using highly inefficient systems in combination with an economy marked by low use of other energy sources. On-grid electricity will become an increasingly important supplier of energy, though will still account for less than 25% of the overall energy supply by 2050. Liquid biofuels will be introduced and scaled to combine with electric power as the prime drivers of the transport sector.

The renewable share is expected to decrease in the beginning of the period as a logic consequence of making the transition towards modern bioenergy carriers and improve efficiency in end-use technologies (Figure 3). The motivation is to get demand for wood fuel in par with sustainable levels of production as well as reduce the health risks people are exposed to using traditional stoves and wood. The share of renewables is then expected to increase again and reach 92% in the end of the period.

The renewable energy scenario can be contrasted with a reference energy scenario. The reference energy scenario illustrates what would happen if no actions are taken to change the path into which it is heading at present. The reference energy scenario does not include any changes induced by regulations or changes in behaviour after those that are already in the pipeline. In the reference case, total energy supply will be more than twice as high as

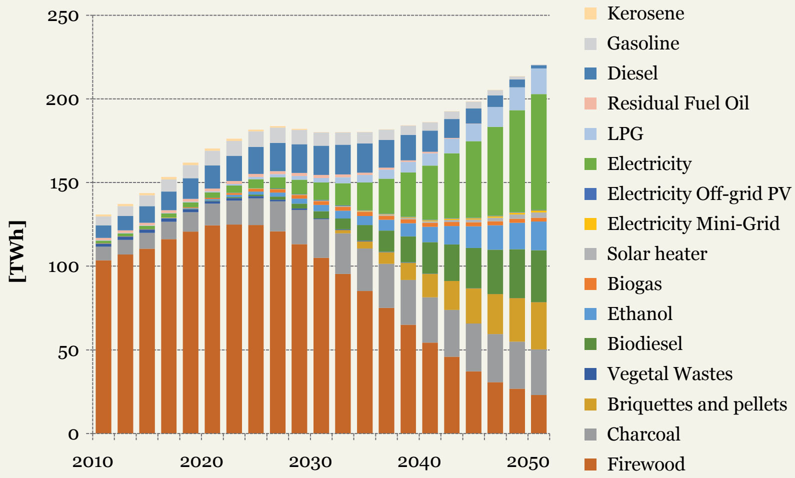


Figure 2: Energy demand in Uganda and the energy carriers to supply the energy service - renewable energy scenario

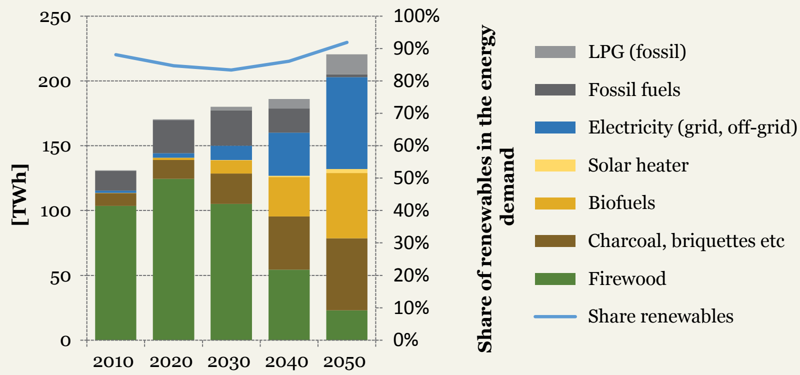


Figure 3: Energy demand in Uganda (bars) and the share of renewables in the energy system (line) -– renewable energy scenario

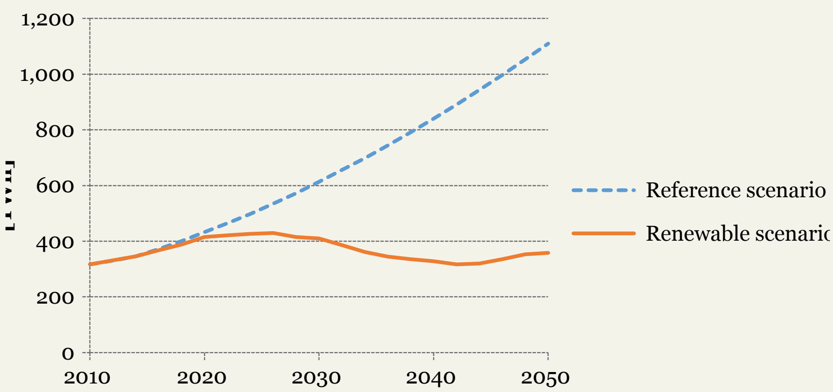


Figure 4: Primary energy supply - renewable energy scenario and reference energy scenario.

in the renewable energy scenario, primarily because the scenario does not aggressively push for efficient use and conversion of biomass (Figure 4).

The renewable energy scenario does not exclude the oil extraction currently getting underway in Uganda. The renewable energy scenario does however keep full focus on building a resilient and renewable energy system and to do that low-cost petroleum products should not venture onto the domestic market. Any revenues from oil extraction and oil exports should be used to invest in building and investing in infra-structure, new supply as well as supporting the required exchange of end-use equipment in households and other sectors.

Emissions of greenhouse gases in the 100% renewable energy scenario will be drastically reduced as compared to the reference energy scenario (Figure 5). Reduced deforestation and less dependency on fossil based energy will result in these reduced emission levels.

Two levels of cost data are accounted for in the report (Figure 6). On the one hand, there are system costs relating to primary and secondary fuel production activities. On the other hand, the analysis has included externality costs to represent the negative impact that these fuel production activities may be having on the country, but that currently go unnoticed from an economic point of view. Although no system is currently in place in Uganda to monitor these externalities, the implied cost of burning fossil fuel and using unsustainable wood harvesting and burning practices, while keeping current practices for demand provision, must be considered. Avoided costs are in relation to the reference case and illustrate the added financial benefits that can be received through the renewable energy scenario.

The scenario shows that it is possible to have a sustainable and near 100% renewable energy system in Uganda where energy is equitably available to all. This would drastically reduce greenhouse gas emissions and provide added financial benefits as compared to the reference energy scenario. The country now has a window of opportunity to make the changes needed to start on the path towards a truly sustainable energy sector, and to lead East Africa towards a green future.

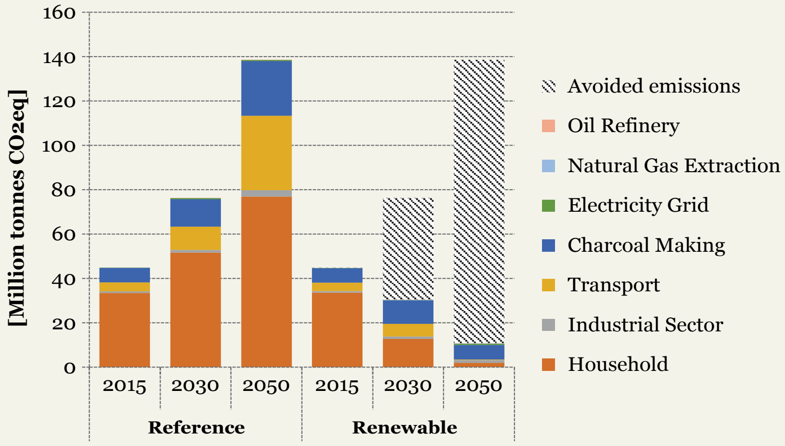
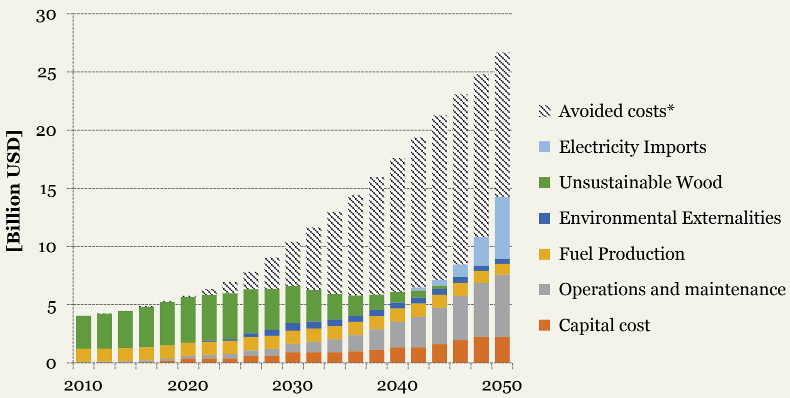
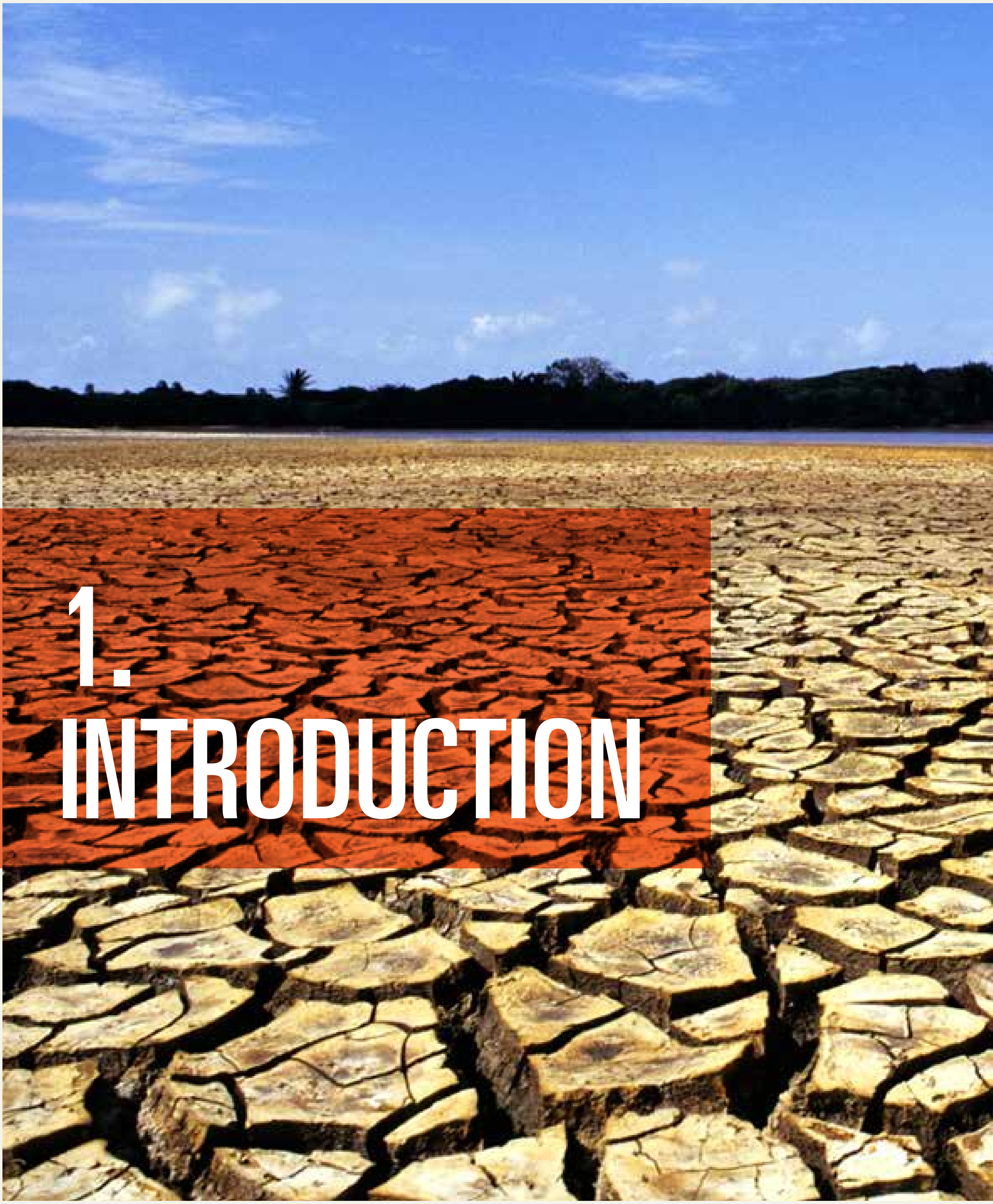


Figure 5: Greenhouse gas emissions from the Uganda energy system – reference and renewable energy scenario



**difference between the sum of all costs in the Reference energy scenario and the Renewable energy scenario*

Figure 6: Costs associated with the renewable energy scenario Uganda including avoided costs as compared to the reference energy scenario



1. INTRODUCTION

©Adriano Gambarini/WWF

This report presents a Ugandan energy system which is based on a very high share of renewable energy and which provides energy access to the entire population. It is one of a series of WWF-supported documents that highlight the choices facing decision makers in world where emissions-induced climate change requires immediate action.

In 2011, WWF International launched "Energy Report - 100% Renewable Energy by 2050" (WWF 2011f) which showed how, in one generation, the global community can source close to 100% of its energy from renewable sources. It explained why a transition to renewables is necessary to curtail climate change, avoid dependency on fossil energy which is a finite resource and avoiding expensive nuclear power. It also pointed out that to achieve a 100% renewable world, massive commitments and investments from a wide range of stakeholders across the globe will be required. Governments must, it said, take leadership roles in this endeavour.

The Global "100% Renewable Energy" report was followed by a number of national reports which broke down the global "100% renewable" vision on a country-by-country basis (Sweden: Gustavsson et al. 2011; WWF 2011c; general African approach: Khennas et al. 2013; India: WWF and Teri 2013; Kerala state in India: WWF and WISE 2013; China: Chandler et al. 2014). The Energy Report - Uganda is the first report that envisions a 100% renewable energy scenario for a Sub-Saharan Africa (SSA) country.

The region of SSA presents enormous opportunities, and challenges, for the development of renewable energy infrastructure. First, whereas most developed countries already have 100% electricity access, only 15% of the Ugandan population currently has access to electricity and only about 10% of the households have a modern stove (Fische 2014). Secondly, as per capita electricity consumption in Uganda is extremely low compared to the rest of the world, massive increases in energy and electricity supplies are needed. Thirdly, the discovery of, and investment in, fossil fuel resources in the country has the potential to defer investment in renewable energy infrastructure and put the country on an unsustainable and carbon-intensive path.

This report is about important choices that need to be made today to assure Uganda's clean energy future. We propose a "double helix" approach that simultaneously builds access to modern energy services while investing in on and off-grid renewable energy supplies. It shows that a national focus on increasing energy access in the country can and must go hand-in-hand with development of a 100% renewable energy supply. Indeed, Uganda and sub Saharan Africa have the opportunity to take advantage of the global renewable technology revolution to leap-frog past dirty energy development.

In this report a renewable energy scenario is presented where national goals for both 2030 and 2050 are set for energy access and renewable energy development. The scenario target achieving universal access to modern energy services in Uganda by 2030 and ensure at least 60% share of renewables in the energy balance. The goal for 2050 is to greatly develop supplies of energy in Uganda based on renewable sources. We propose a modern renewable energy system that is resilient and that has low impacts on environment and climate.

In the report that follows, three tasks have been completed. First, a basic analysis of the current total energy demand and supply patterns for Uganda is completed. Secondly a renewable energy scenario (60% renewable share in the energy balance and universal access to modern energy services by 2030 and by 2050 close to 100% renewable energy system) was developed. Thirdly, a course of action is proposed which outlines how Uganda can attain the 2030 and 2050 renewable energy targets above envisioned by WWF.

This report is expected to be a crucial planning tool for Uganda to pursue in a low carbon energy development pathway. In the medium term perspective (up to 2030) it outlines energy demand and supply issues linked to the realisation of Sustainable Energy for All (SE4All) ambitions. The SE4All goals for Uganda 2030 are more than 98% of population with electricity access, more than 99% of population with access to modern cooking solutions, a yearly improvement in energy intensity by 3.5% and renewable share in final energy consumption for power at least 90% and for thermal 36% (Fische 2014).In the long-term perspective (up to 2050) the renewable energy scenario aligns with ambitions set in "Uganda Vision 2040" (NPA 2007). These include increase in access to electricity services, improve natural resource management (e.g. forests, biodiversity, water resources), development of road and transport infra-structure.

THE RENEWABLE ENERGY SCENARIO SHOWS A COURSE OF ACTION TO TACKLE DEFORESTATION, ENERGY ACCESS AS WELL AS MODERN TRANSPORT. WE ARGUE THAT:

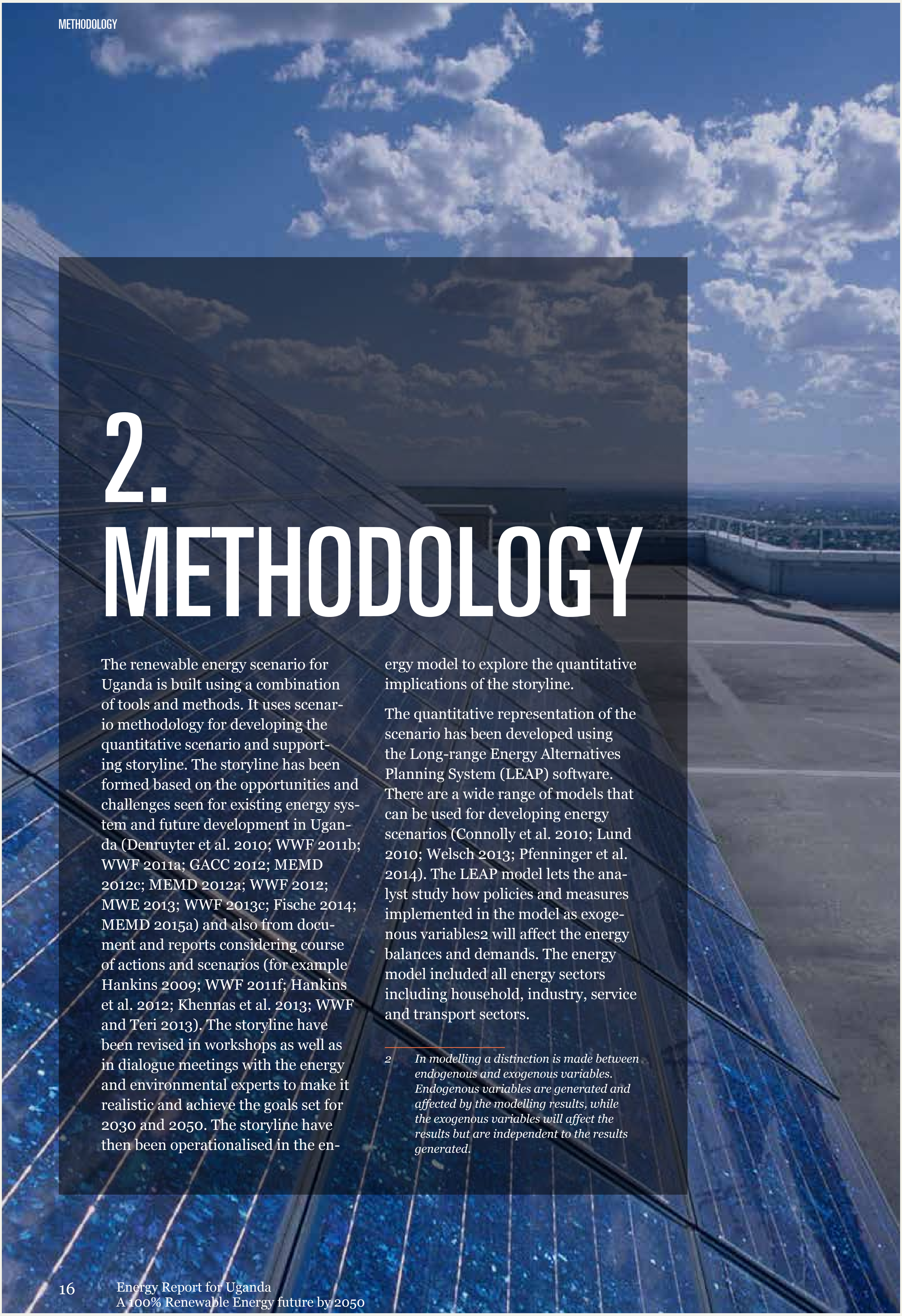
- HYDRO POWER AND SOLAR POWER CAN DOUBLE THE GRID CAPACITY IN THE NEXT TEN YEARS.
- SMALL SOLAR PHOTOVOLTAIC (PV) SYSTEMS CAN TRANSFORM THE LIVES OF MILLIONS OF RURAL UGANDANS HOUSEHOLDS.
- MODERN BIOMASS FUELS AND IMPROVED END USE TECHNOLOGIES CAN BECOME AVAILABLE AND GREATLY REDUCE THE PRESSURE ON WOOD AND REDUCE THE DRUDGERY AND ADVERSE HEALTH IMPACTS OF OLD END-USE TECHNOLOGIES (E.G. STOVES)[1].
- UGANDA CAN PRODUCE BIOFUELS BASED ON BIOMASS SOURCED WITHIN THE COUNTRY AND REPLACE DEMAND FOR PETROLEUM PRODUCTS WITHIN 50 YEARS.

1 *Modern biomass fuels refer to fuels that are based on biomass and produced in efficient and well-managed production processes and value-chains. This includes the forestry management as well as cutting, transportation and upgrading. The end-use technology could also be considered in this respect and then providing a modern energy services. Here safety and health aspects are key items.*

In moving quickly beyond the petroleum age, Uganda has the opportunity to bypass the technologies that have caused the current climate change crisis. It can also embrace a cleaner era which uses local energy resources and which employs local people to build, manage and maintain them. Clean renewable energy technologies are here today and they are affordable (see for example Edenhofer et al. 2011).

This is only the beginning and we must be optimistically ambitious. Still, long-term scenario building is not the same thing as forecasting the future. Our scenario tells the story of a possible route. In the end, these scenarios must be driven by intelligent national choices that include ambitious plans, dedicated investment and committed execution. Government, business, consumers and other stakeholders must work together to make the change happen.

A local resident of Kasese District in Western Uganda holding out a liner meant for an improved charcoal stove



2. METHODOLOGY

The renewable energy scenario for Uganda is built using a combination of tools and methods. It uses scenario methodology for developing the quantitative scenario and supporting storyline. The storyline has been formed based on the opportunities and challenges seen for existing energy system and future development in Uganda (Denruyter et al. 2010; WWF 2011b; WWF 2011a; GACC 2012; MEMD 2012c; MEMD 2012a; WWF 2012; MWE 2013; WWF 2013c; Fische 2014; MEMD 2015a) and also from document and reports considering course of actions and scenarios (for example Hankins 2009; WWF 2011f; Hankins et al. 2012; Khennas et al. 2013; WWF and Teri 2013). The storyline have been revised in workshops as well as in dialogue meetings with the energy and environmental experts to make it realistic and achieve the goals set for 2030 and 2050. The storyline have then been operationalised in the energy model to explore the quantitative implications of the storyline.

The quantitative representation of the scenario has been developed using the Long-range Energy Alternatives Planning System (LEAP) software. There are a wide range of models that can be used for developing energy scenarios (Connolly et al. 2010; Lund 2010; Welsch 2013; Pfenninger et al. 2014). The LEAP model lets the analyst study how policies and measures implemented in the model as exogenous variables2 will affect the energy balances and demands. The energy model included all energy sectors including household, industry, service and transport sectors.

2 *In modelling a distinction is made between endogenous and exogenous variables. Endogenous variables are generated and affected by the modelling results, while the exogenous variables will affect the results but are independent to the results generated.*

There are two scenarios referred to in this report. The main scenario is the *Renewable energy scenario* which represents the scenario aiming for showing how Uganda energy sector can make a transition towards a modern and more sustainable energy system. This is the main focus of the report.

The second scenario that is referred to in the report is a *Reference energy scenario* which represents a business as usual scenario. The reference energy scenario is used for comparison between the main scenario (the renewable energy scenario) and a reference. The reference energy scenario illustrates what the energy balance would be if no actions are taken to change the path into which it is heading at present. The reference case does not include any changes induced by regulations or changes in behaviour after those that are already in the pipeline. Plans for activities, such as those expressed in *Uganda 2040 Vision* (NPA 2007), would not be part of a reference energy scenario as these activities are not yet in the implementation phase. Hence, the reference energy scenario should not be understood as the Government scenario. Existing Government plans and ambitions (e.g. Vision 2040 and SE4All action plan) are to some extent found as part of the main renewable energy scenario.

A set of key assumptions are set to form the basis for the model. These include demography, economic growth and activities as well income. The key-assumptions are exogenous and are not changed as compared between the renewable energy scenario and the reference case. These inputs are presented in more details in chapter 6.

The model is demand driven, which means that demands are defined at the base year of 2010 and based on the demand energy carriers are assigned and linked to different supply sources. Different sources of energy supply are defined in the model and if the demand is exceeding the specific supply level this will be noted as import to the energy system. The household sector has a bottom-up approach in defining the demand side. This means that demands are defined in the model and with time these demands change giving the new demand structure that will be serviced through primary energy transformed in the different transformation technologies.

Available statistics to form the baseline in the model have been taken from different official sources. The baseline year is set to 2010. In cases where data is known data for years up to 2014 the projections for the first years generated in the model have been cross checked towards those found in official statistics in order to adjust assumptions to be aligned with actual trends.

The household demand has been operationalised applying the multi-tiers approach as presented in the SE4All framework (SE4All 2013; Fische 2014; IEA and World Bank 2015). The framework categorise households depending on their energy service demand and energy use. One of the goals in the renewable energy scenario is to have all households in Uganda have modern cooking options as well as access to basic electric services by 2030. By categorising the households in different tiers at the starting point and letting them progress up-wards in the tiers, the energy demand per households can be assessed[3]. Details are given in Appendices I. The strength of this approach is that energy demands become more dynamic than if applying a growth factor to each household category.

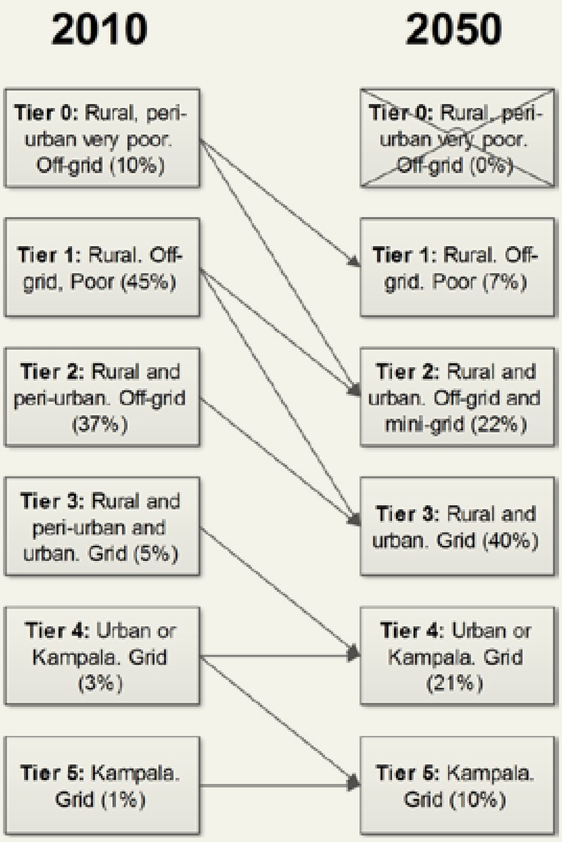


Figure 7: The tiers approach illustrating the progress of households from one tier to another. Percentages in brackets are share of Uganda household belonging to this tier4.

The energy demand in the tiers will shift between 2010 and 2050. One example is for households in Tier 1 off-grid electricity services are at the starting point 2010 served through dry-cell batteries, while

3 *This approach have been used in other scenario making, see for example Nerini et al. (2015)*
4 *In 2010 there are almost 6.7 million households and in 2050 the number of households is projected to 21.6 million.*

in 2050 more powerful off-grid solutions are universally found providing light and other electricity based energy services. In 2050 no tier 0 households will be found. The categorisation of households in the different tiers are based on census data (for example UBOS 2010; UBOS 2014a), assessments on SE4All data (MEMD 2012a; SE4All 2013; Fische 2014) and triangulation with other studies of energy demands in SSA Africa and results generated in the LEAP model.

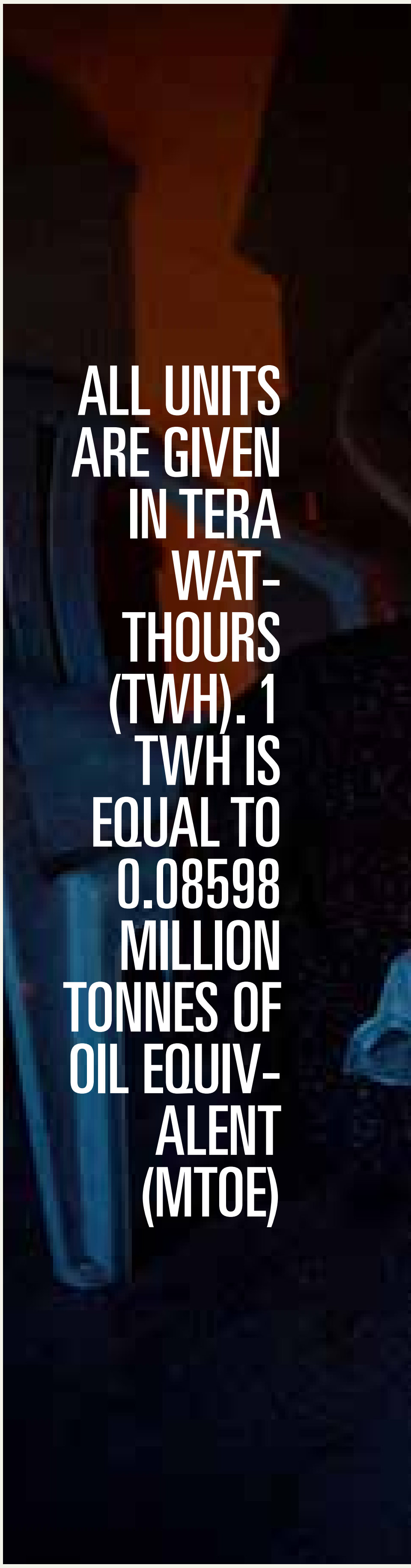
Growth and changes in the industrial and commercial and institutional sectors have been operationalised in a top-down approach. The demand of different energy services has been defined at a starting point and based on this there is a yearly growth as represented in the reference energy scenario. Technologies applied in the sector will alter the final demand set.

The transportation sector is based on growth of transportation work demand for personal transport and for goods. The transport work is defined in terms of person kilometre and tonne kilometre. This transportation work is then met by applying various transportation means. A bus with a full load of people, for example 40, will be more efficient in terms of supplying a transportation work than a car with only one person, in this case 40 times as efficient. The Uganda transportation data is old and can be traced back to transportation work studies in 2003. The 2003 data is the basis for the transportation master plan (UNRA 2008). The transportation sector has undergone major changes in recent years with rapid growth of number of vehicles etc. A number of studies have looked at especially the situation in Metropolitan Kampala which is suffering from increasing traffic congestions (see for example ITP and IBIS 2010) The baseline and assumptions used to calculate the transportation work is found in Appendices B.

Sustainable levels of hydropower has been assessed using a number of reports assessing potentials of hydropower in Uganda (NPA 2007; JICA 2010; MEMD 2012c; MEMD 2012b; WWF 2013b; WWF 2013a; NPA 2015). Full technical potential is not applied as this does not give room for taking high level of environmental consideration in design of hydropower stations. To define the sustainable level of biomass from forests the assessment found in MEMD (2015a) is used. The charcoal sector in Uganda has been studied in Basu et al. (2013). Biofuels potentials are closed in on using a number of sources (NEMA 2010; Hermann et al. 2014). Solar power is applied on large scale and the potential is based on (Hermann et al. 2014). Geothermal potential is based on WWF (2011b) and Bahati (2012).

As far as possible the source for the data that forms the basis in the model. In those cases where input data to the model have been calculated and assumptions have been made, these are presented in the report. Bioenergy is the main source of energy and large parts of this is produced and traded in the informal sector. There are a number of recent studies that investigate the bioenergy sector (MEMD 2015a) and the charcoal sector (Basu et al. 2013). The national plan for the forestry sector is relatively updated (MWE 2013). In the transportation sector the background data is less up-to-date. In 2003 a transportation survey was made and based on calculating progress the existing transportation is projected and found to form the basis in the transportation master plan (UNRA 2008).

There is a long-term development plan in Uganda called the “Vision 2040” (NPA 2007). This document gives indications of what long term development ambitions are. The plan have two follow-ups, one in 2010 (NPA 2010) and one in 2015 (NPA 2015). The renewable energy scenario aligns with ambitions set in “Uganda Vision 2040” (NPA 2007) but there are some exceptions. The national long-term vision (NPA 2007) includes establishing nuclear power in Uganda on a big scale. Nuclear is not a renewable energy source, and is thereby disqualified from the Scenario – but equally importantly, the energy system envisioned in this Scenario would not benefit from nuclear power (indeed nuclear would face, and itself create, a number of challenges for Uganda (see for example Jewell 2011)).



©WWF-Norway/Will Boase

LIMITATIONS

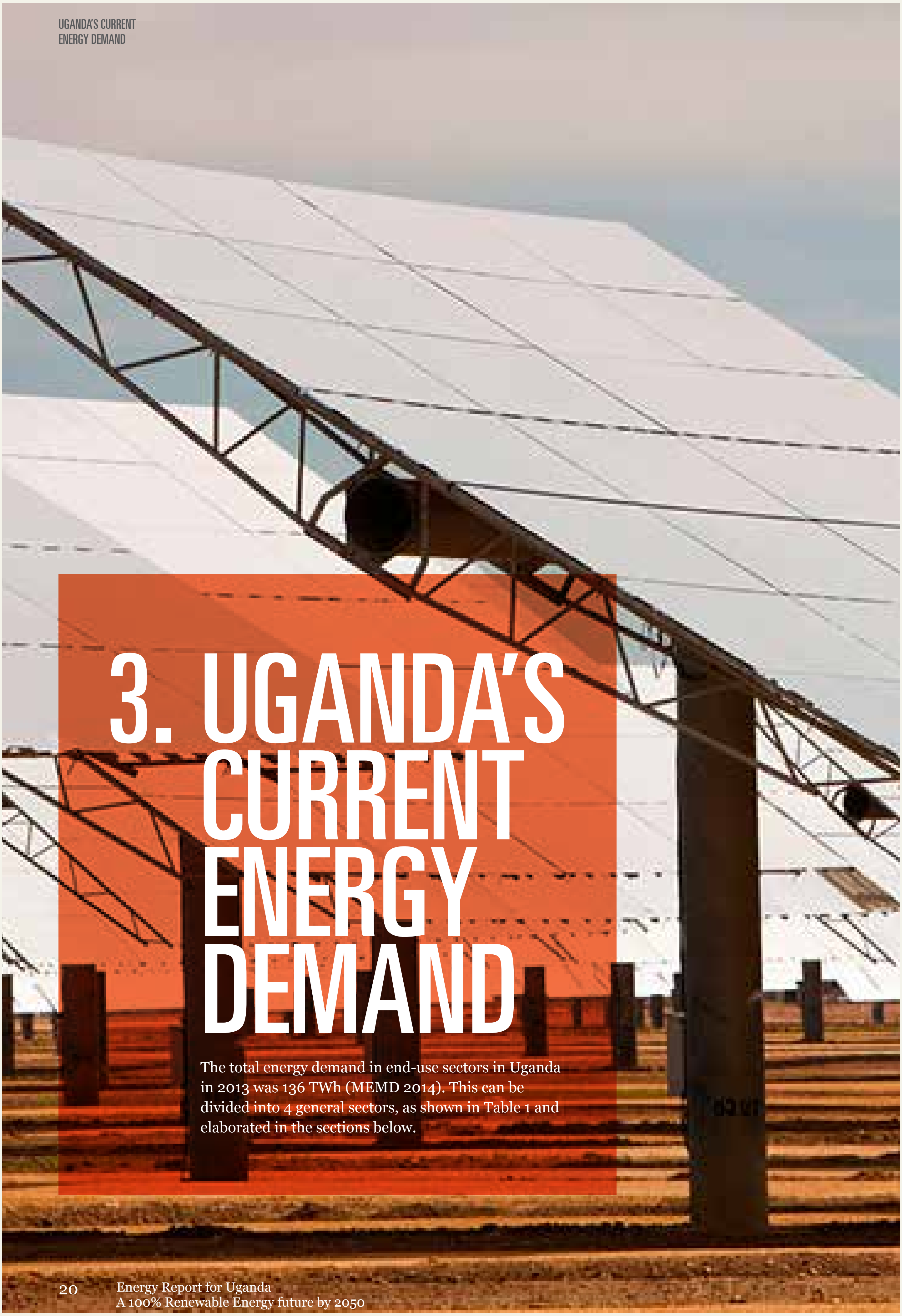
Energy demands linked to international transport to and from Uganda was not included in the model as the scenario does not account for the energy demands associated with imports and exports of goods and service.

The input to the energy models designed is publically available data. The quality and level of detail of these sources varies. In those cases it has been possible the data have been triangulated using a number of different sources. A validation workshop was held in august 2015 in order to get feedback from stakeholders on the scenario and the input data and methodology applied.

The scenario includes large investments in energy supply technology such as hydropower and solar power as well as energy transmission and distribution infrastructure, as well as indirectly transportation systems such as roads and railway. These are long-lived installations and thus will be exposed to the effects from climate change which is an aspect that needs to be carefully considered in further discussions on the future energy system of Uganda (see for example Jeuland and Whittington 2013; Lumbroso et al. 2015; Mercer 2015). The report does not include any sensitivity analysis towards climate change impacts on hydrology, weather patterns or seasonal changes and what it would mean for the energy production.

The level of available biomass is considered stable even though there is evidence that deforestation has been going on for a long period of time. The reason for this is lack of data on how available biomass would change over time. The results from the energy model suggest that further attention should be given to options to increase and ensure safe and sustainable supply of woody biomass and other biomass.

The model and energy scenario is based on existing technologies today. Technological innovation will take place, but is realised as increased efficiency and competitiveness of the technological options.



©Adriano Gambarini/WWF

3. UGANDA'S CURRENT ENERGY DEMAND

The total energy demand in end-use sectors in Uganda in 2013 was 136 TWh (MEMD 2014). This can be divided into 4 general sectors, as shown in Table 1 and elaborated in the sections below.

The household sector takes up the bulk of primary energy demand (the majority of this demand is in the form of traditional biomass). The industrial sector uses a lion's share of the electricity supply but note that, overall, electricity makes up less than 2% of Uganda's primary energy supply.

ELECTRICITY DEMAND IN THE ENERGY BALANCE 2013 WAS 2.9 TWH INCLUDING 0.86 TWH LOSSES IN TRANSMISSION AND DISTRIBUTION (MEMD 2014).

TABLE 1: ENERGY CONSUMPTION AND DEMAND BY SECTOR (MEMD 2014)

DEMAND:	PORTION OF OVERALL ENERGY SUPPLY	PORTION OF ELECTRICITY SUPPLY
Household	66.2%	25.7%
Commercial	14.3%	14.9%
Industrial	12.8%	59.4%
Transport	6.2%	0.0%

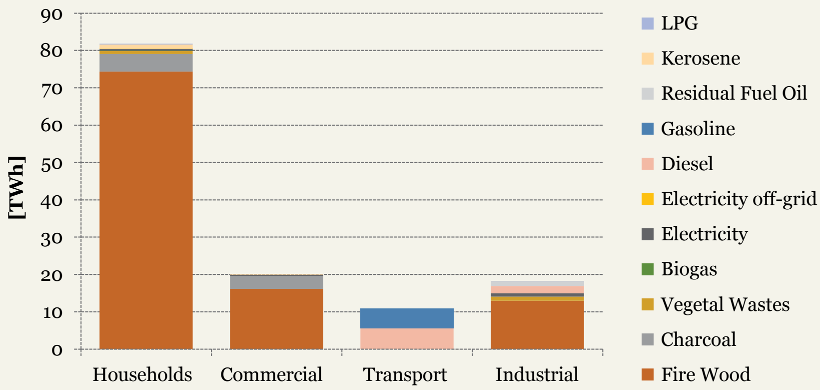


Figure 8: Uganda Annual Energy Demand (TWh) in 2010 and energy carriers to meet the demands

Per capita energy demand in 2013 was 4,050 kWh/person/year. The major part of this energy use is supplied from woody biomass and only a small portion is in the form of electricity (Figure 8). The government plans to increase per capita consumption of electricity from the current 80 kWh per capita to 588 kWh by 2020 and 3,668 kWh by 2040 (NPA 2015).

3.1 HOUSEHOLD SECTOR

The total energy consumption in households was about 82 TWh in 2010 (MEMD 2012d). Firewood, charcoal and agricultural residues used for cooking (respectively, 86%, 5.8% and 7.0%) constitute the bulk of household energy use. Because of the low access to modern energy sources Liquefied Petroleum Gas (LPG) (0.06%) and electricity (0.45%) make up a relatively small portion of overall household energy demand.

The per capita consumption of firewood in rural and urban areas is 680 kg/year and 240 kg/year respectively. Per capita charcoal consumption is 4 kg and 120 kg in rural and urban areas respectively (MEMD 2012b). Use of biomass is highest in rural areas where, in addition to wood, "lower" forms of energy such as agricultural wastes and dung are commonly used as cooking fuel when wood is not available.

Wood-burning "three stone stoves" found in rural Ugandan households have a low efficiency. Efficiency rates for such stoves vary widely; in lab tests thermal efficiency ranges between 20 to 30%, while in actual practice efficiency of as low as 5% can be experienced (ARC 2011). The stoves also expose family members to numerous pollutants causing health problems such as acute respiratory infections (WHO 2007; Jagger and Shively 2014).

HOUSEHOLDS IN URBAN AREAS MAINLY COOK WITH CHARCOAL. CONTRIBUTING ABOUT 6% OF THE OVERALL HOUSEHOLD ENERGY DEMAND, CHARCOAL IS A PREFERRED URBAN FUEL BECAUSE IT HAS A HIGH ENERGY DENSITY AND IT CAN BE CONVENIENTLY TRANSPORTED AND STORED (MEMD 2015A).

The charcoal is typically produced in low-efficiency earth kilns in rural areas and high losses are experienced throughout the value-chain. LPG and electricity are used almost exclusively in high income groups. This illustrates that energy use varies considerably depending on income and geographical location of the household. Rapid positive changes in energy access development make "average" energy use data less informative and also underline the need to focus on efficiency and modern devices.

In the SE4All framework a multi-tiered approach illustrates how household energy demand will shift (SE4All 2013). Applying this framework to Ugandan households shows current end-use differences as well as possible options for improvement. It is common practice in many households to rely on multiple fuels for attaining the necessary energy services for cooking and lighting (Heltberg 2003; Lee 2013). As shown in the table below, tier demand is defined by device ownership in households and whether or not the household has a grid connection (Table 2).

©Adam Oswell/WWF

Rice husks are a common raw material used in production of briquettes

TABLE 2: MULTI-TIER REPRESENTATION OF THE HOUSEHOLDS IN UGANDA (2010)

APPLIANCE CATEGORY	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
	Rural, Peri-urban. Very poor	**Rural**	**Rural or peri-urban settlements**	**Rural, urban, peri-urban and Kampala**	**Urban or Kampala**	**Kampala**
	Off-grid	Off-grid	Off-grid	Grid	Grid	Grid
% of households	10%	45%	37%	5%	3%	1%
Off-grid electric appliances	Torch (dry-cell)	Torch (dry-cell) PV-lantern Radio	Torch (dry-cell) Radio/music system Solar powered lantern Cell phone	Torch (dry-cell) Radio Back-up lantern	Torch (dry-cell) Radio Back-up lantern	Torch (dry-cell) Radio Back-up lantern
On-grid electric appliances	None	None	May have appliances in anticipation of connection or from earlier house	Lighting Cell phone Music system Television	Lighting Cell phone Music system Television Refrigerator Iron Kettle Fan	Lighting Cell phone Music system Television Refrigerator Iron, kettle Fan, air-condition Pump Water heating Washing machine
On-grid electricity demand (kWh/hh/yr)				2.2	1331	1862
Fuel based appliance	Traditional grass Kerosene, with tadooba	Tadooba Hurricane lantern	Hurricane lantern	Hurricane lantern	Hurricane lantern	
Primary cooking device	Three stone fire using gathered wood or waste	Three stone fire with gathered wood	Three stone fire, or traditional charcoal stove	Traditional charcoal stove or improved charcoal stove. Kerosene stove.	Traditional charcoal stove or improved charcoal stove. Kerosene stove and LPG	Traditional charcoal stove or improved charcoal stove. Kerosene stove LPG Electricity

3.2 INDUSTRY SECTOR

Industry is largely made up of Small and Medium Enterprises (SMEs), agro-processing factories (i.e. coffee, sugar, tea) and other businesses associated with the agricultural sector. Industry is heavily reliant on firewood, which contributes about 60% of the sector's total energy need (Figure 8). At 9% and 7% respectively, diesel and electricity are second and third largest energy contributors in the sector. Combined, diesel and LPG contribute 3.2% of the sector's energy consumption.

Uganda has a relatively low level of industrialisation. Wood fuel is used extensively for process heat and to fuel brick-burning, tea drying and lime production. Brick making is wide spread, but lime production mostly occurs in Kasese, Tororo, Kisoro and Moyo. Use of firewood in lime burning industries has contributed to extensive deforestation in Tororo and Kasese. Efficiency rates in the tea, tobacco, lime, brick-making industry can be greatly improved (MEMD 2015a). Energy audits to identify potential measures to improve energy efficiency are a key tool to make this happen.

Left over cane stalks (bagasse) contribute significantly to sugar production process heat and electricity generation. In recent years a number of sugar mills have installed co-generation capacity improving the overall efficiency in their processes. There is general trend in industry to use biomass residues and wastes to meet energy demands (MEMD 2015a).

3.3 COMMERCIAL AND INSTITUTIONAL SECTOR

The commercial sector is an active part of the informal urban and rural economy, made up of restaurants, bakeries, service enterprises, shops and institutions. Institutions includes schools, prisons etc. In terms of overall energy use, it takes up a larger portion of demand than industry because of the large number of small players.

- Wood and charcoal, which make up 98% of energy use in the sector (Figure 8), are used mainly for food preparation and heating water.
- Cooking appliances tend to be inefficient and unsophisticated (MEMD 2015a). There is a large potential for energy saving stoves as well as introduction of water heaters in the sector. Inefficient stoves in commercial and institutional applications can be greatly improved.
- Electricity and kerosene is used for lighting and powering appliances. Expansion of the grid will increase enterprise productivity considerably.

3.4 TRANSPORT SECTOR

In recent years the number of cars and vehicles on the roads of Uganda has increased dramatically (Figure 9). As a result the traffic situation in and around Kampala and other urban centres has deteriorated, resulting in increased congestion and reduced productivity of people forced to sit in traffic jams. Initiatives to improve the situation are under way; efficient public transport is one of the key approaches under consideration (see for example UNRA 2008; World Bank 2015).

As can be seen from Figure 2 and Table 3, there are several major forms of transport in use:

- Walking and cycling are still dominant, and critical, transportation modes for people throughout the country which statistics tend to ignore.
- "Boda-bodas" (motorcycles used for hired carriage of one or more passengers) use is increasing rapidly in urban and peri-urban areas. They have associated negative safety, congestion and pollution side-effects. For example, boda-boda's account for over 42% of the traffic on the road but less than 9% of the total passengers.
- Urbanization has also greatly increased the number of mini-buses on the roads.
- Use of private vehicles in urban areas is increasing – and is a major contributor to increased congestion. Private vehicles are a primary cause of morning and evening peak period traffic jams.

Though the number of vehicles in Uganda can be tracked from registration of vehicles a full understanding of the transportation sector is yet to be developed (i.e. how far vehicles travel, how many passengers travel in each vehicle, specific vehicle loads). This report uses data from a national transportation survey made valid in 2003 as a basis for its transportation sector modelling.

Transportation sector demand indicators (person kilometres (pkm) for person transports and tonne kilometres (tkm) for goods) are found in Table 3 and Table 4 below.

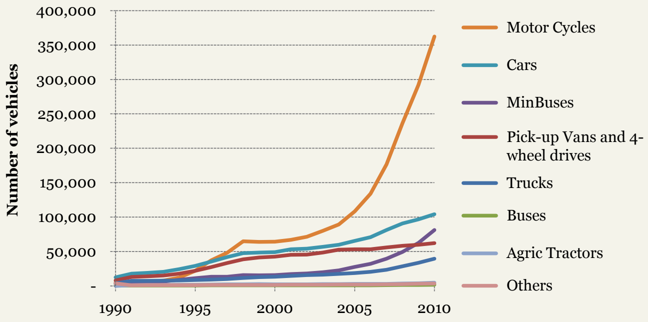


Figure 9: Number of vehicles registered in Uganda, different categories (UBOS 2003; UBOS 2007; UBOS 2013)

TABLE 3: PASSENGER TRANSPORT DEMAND 2003 (UNRA 2008)

TYPE	MILLION PERSON KM	DESCRIPTION OF TRANSPORTATION
Private cars	515	Private cars
Taxis	1,594	Smaller cars used for taxi service
Minibuses ('Matatus')	9,026	Minibus used for public transport
Buses (large)	2,664	Large busses
Motorcycle (private)	265	Private motorcycles
Boda-boda	1,126	Motorcycles used for taxi service
Railway	0	Train
Boat traffic	6	Ferry services
Total transportation demand (pkm)	***15,197***	

TABLE 4: FREIGHT TRANSPORT DEMAND - GOODS 2003 (UNRA 2008)

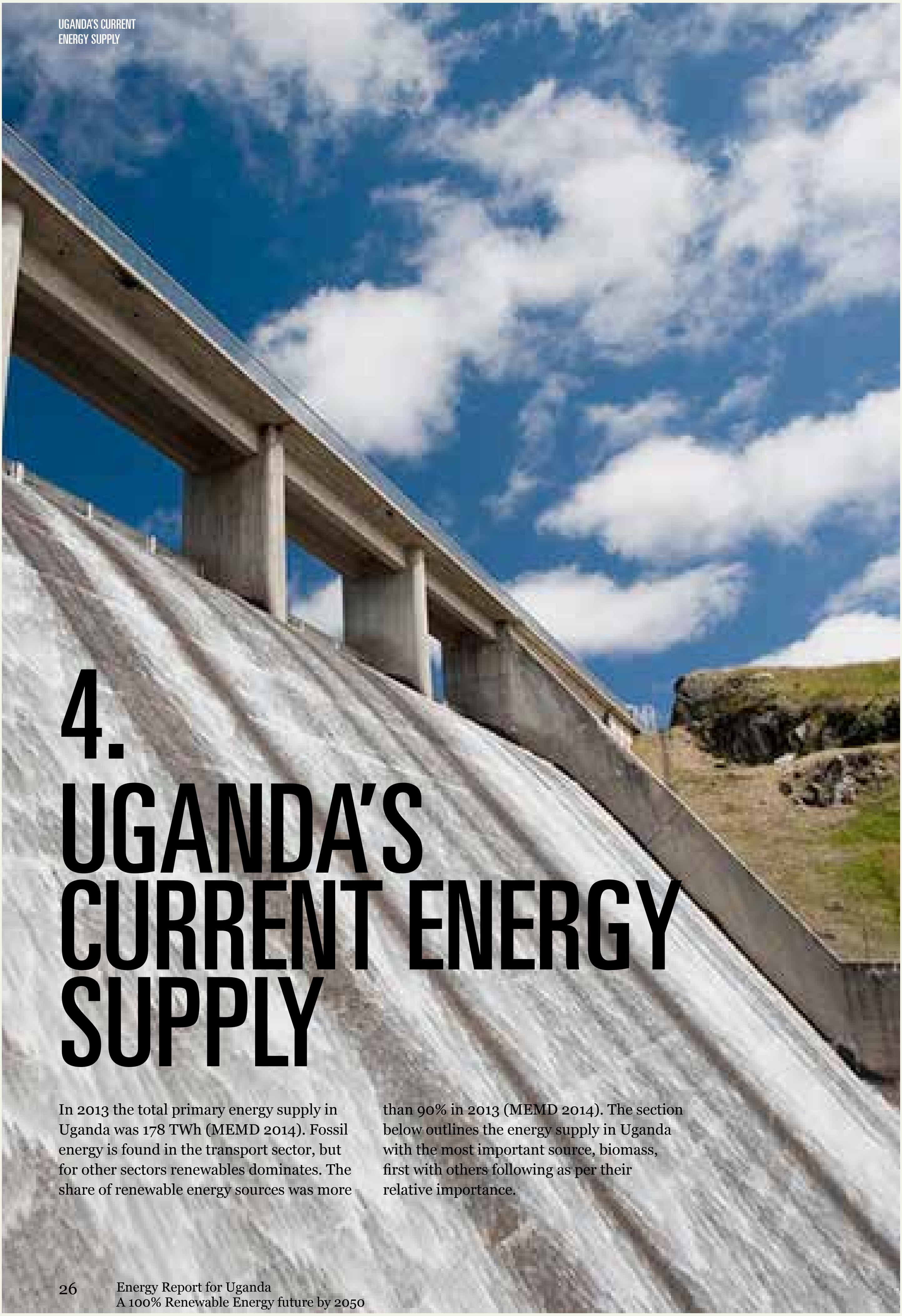
TYPE	MILLION TONNE KM	DESCRIPTION OF TRANSPORTATION
Light goods vehicles	765	Light transportation vehicles including 4 wheel drive pick-ups.
Single unit trucks	2,381	Single unit trucks
Trailers and articulated	678	Trucks with trailers or articulated
Railway	0	Train
Boat traffic	0	Ferry services
Total transportation demand (tkm)	***3,824***	

The national transport master plan (UNRA 2008) assessed the annual growth rate of transportation at 8% between 2003 and 2013. From this, Ugandan transportation demands in 2010 are estimated to be:

- Passenger movement demand (person-km): 26,045 pkm
- Goods transport demand (tonne-km): 6,554 tkm

There are on-going work to improve the transportation system in Uganda including the National Transport Master Plan (UNRA 2008), studies for improved bus systems for Kampala metropolitan area (ITP and IBIS 2010) and as part of the national plans (NPA 2007; NPA 2010; NPA 2015).

Recent positive developments on the railway system, which has not carried passenger traffic since 1998, may have important implications for the transport sector. In April 2015, the Ugandan government signed an agreement with the Chinese government to construct a new railway line linking Kampala and Mombasa. The construction of the Standard Gauge Railway is expected to significantly reduce on the number of days it takes to transport goods from the Mombasa port as well as increase the capacity of the railway (CPCS 2009).



©Global Warming images/WWF Canon

4. UGANDA'S CURRENT ENERGY SUPPLY

In 2013 the total primary energy supply in Uganda was 178 TWh (MEMD 2014). Fossil energy is found in the transport sector, but for other sectors renewables dominates. The share of renewable energy sources was more than 90% in 2013 (MEMD 2014). The section below outlines the energy supply in Uganda with the most important source, biomass, first with others following as per their relative importance.

IN THE CURRENT SUPPLY SITUATION, SEVERAL GENERAL OBSERVATIONS CAN BE MADE:

- Biomass overwhelmingly serves basic demand for cooking and heating in household, institutional and the private sector (Figure 8). The level of demand exceeds the sustainable biomass production levels and is adding to the deforestation taking place in the country.
- Petroleum fuels are used in the transport sector and, to a lesser extent, for electricity generation. Though insignificant in overall quantity, kerosene meets a significant share of household lighting demand (MEMD 2012a).
- Electricity is primarily generated in hydropower plants. It accounts for a small portion of overall energy supply mix (<2%) but is extremely important to the industry and commercial sectors and thereby to the national economy.
- Solar and battery-based electricity in off-grid sites is quite small in absolute energy terms but is important because it provides hundreds of thousands of remote consumers with affordable entry-level electricity services. Though actual numbers of operational off-grid solar PV systems in Uganda is not known, there is an active over-the-counter and private company-driven market in place is[5].

4.1 BIOMASS AND OTHER BIOMASS DERIVED SOURCES

Uganda's primary energy supply is dominated by biomass (wood, charcoal and agricultural residues). It accounts for over 89% of energy demand and contributes as much as 6% to the country's overall Gross domestic production (GDP) (MWE 2013). It is especially important in rural areas where it provides both energy and income. The bulk of biomass is locally-sourced.

Though biomass is considered a renewable resource, present management of forest resource is unsustainable and there is considerable deforestation occurring in the country. Commercial use of wood and production of charcoal both contribute to this deforestation. Other driver for the deforestation is expansion of agricultural land. As of 2013, the country was losing 1.8% of its forest per year (MWE 2013; MEMD 2014). Between 1990 and 2010, an estimated 47% of forest cover was lost. It is, therefore imperative that steps are taken to protect the 2.6 million ha of forest remaining (11% of total land) (MEMD 2014).

Current demand for woody biomass is estimated at 44 million tons/year. However, the same study suggests that current forests can sustainably supply only 26 million tons/year (MEMD 2015a), resulting in a supply shortfall of 18 million tons/year. Uganda's particular challenge is thus to balance woody biomass production and consumption in a sustainable manner.

Note that demand for fuel is not the only driver for deforestation. Other major drivers include expansion of agricultural land and timber harvesting. Although woody biomass supplies over 90% of household primary energy demand (UBOS 2010), rural household fuel gathering activities are not a major cause of deforestation. Commercial harvesting (informal and formal) of wood fuel and charcoal production often have a much higher impact on forests than rural household use.

Forest management is guided by the 2001 Forestry Policy (MWLE 2001) and 2010 National Forest Plan (MWE 2013). National efforts to manage and improve wood supplies are underway including activities on forest law enforcement, governance and trade strengthening of institutions responsible for forest management, planting trees and forests (i.e. supply of quality seed and planting material for commercial plantations, urban plantations and on-farm tree planting), restoration of degraded natural forests and promotion of forest-based industries and trade (MWE 2013; WWF 2013c).

Charcoal is an appealing urban fuel because it has a high-energy value and because it is easier to transport and sell than wood. However, Uganda's charcoal consumption, estimated at 1.8 million tonnes per annum, is derived inefficiently from about 16 million tonnes of wood (MEMD 2015a). Moreover, charcoal use growing at 6%/year (Basu et al. 2013). High losses, inefficient processes along the value chain and unregulated markets results in an energy carrier that might be attractive due to its price, but far from a modern energy source. Replacement of charcoal in urban areas will be challenging because of a lack of attractive alternatives as well as structures to change the current trade.

Nationally, charcoal production earns rural households more than any other cash crop (MEMD

5 For example M-KOPA Solar reports that they have made 20,000 households able to receive mobile charging and light services (M-KOPA 2015). Also see the review by Hansen et al. (2014).

2012a). Its production is typically not regulated and its manufacture from wood is carried out in low-efficiency traditional kilns. Efficiency in traditional charcoal kilns are typically low and with an energy transformation efficiency of about 15-25% (van der Plas et al. 2012; Basu et al. 2013; Chidumayo and Gumbo 2013; Neufeldt et al. 2015). There are improved kilns, such as the Adam retort kiln (Domac and Trossero 2008; Adam 2009; Basu et al. 2013), the Euro Kiln (Basu et al. 2013) and different industrial scale systems (Domac and Trossero 2008; Meyer et al. 2011), which all greatly increase the yields. As well, greenhouse gas emissions from traditional kilns are substantial and these emissions contribute significantly to total Uganda greenhouse gas (GHG) emissions. As compared to earth kilns these improved systems will require investments. But in order to bring charcoal to become a modern biomass fuel this shift is necessary, along with improving the sourcing of wood feedstock, transportation and sales. This would mean bringing charcoal to the formal sector which is a necessary step.

Today, bagasse from sugar plantations supplies 17 MW onto the national grid[6]. Other agricultural wastes (i.e. coffee and rice husks, maize cobs, groundnut shells, etc) are already in use for industrial power and interest is on increase. True North Power, for example, is planning a pilot 1 MW biogas gasification power plant in Northern Uganda using maize waste.

Agricultural bio-residues, forest residues and bio-wastes can likely supply another 10 million tonnes to the biomass supply (MEMD 2015a). They can be a major contributor to energy supply, especially for industry.

Biogas is used at a small scale for domestic heat and cooking in Uganda. The National Domestic Biogas Programme has completed more than 5,000 installations of family sized biogas units (SNV 2014). Biogas has a large potential with commercial and industry (dairy, etc) sector (REA 2007) as well as for household applications (Pandey et al. 2007; KRC 2013). Investment costs, need for zero-grazed cattle and access to water supply are challenges to scaling up of the technology, especially at household level.

There is no large scale bio-ethanol or biodiesel production in Uganda today. Although a biofuel program was launched in 2011 (which also includes biogas, methanol as well as components of proposing blending), results are yet to bear fruit (Tumwesigye et al. 2011). Large sugar plantations have a potential resource base that has not yet been seriously explored even though there is interest in the sugar sector. Other feedstocks such as cassava is considered for biofuel production (Asimwe 2015). Cultivation of crops such as jatropha for biodiesel has not yet produced commercial quantities of fuel.

6 *Kakira sugar factory generates 22 MW and will expand this to over 50 MW*

Uganda faces a number of challenges in making overall use of woody biomass more sustainable and in developing its biomass fuel potential. Difficulty of implemenw ting and enforcing biomass policy is the major challenge for the sector. Lack of regulation has profound implications for its modernization / professionalization, potential to generate income for suppliers and government alike, and resource management. The awareness of the options available are low and high up-front cost of efficient conversion/ use technologies represents barriers. The above barriers result in a lack of interest from investors.

4.2 PETROLEUM PRODUCTS

Uganda's highest single commodity import expenditure is on petroleum (this is followed by motor vehicles, (MEMD 2014). Petroleum represents 9.2% of the primary energy supply (MEMD 2012a) and its use is increasing with the number of vehicles in use in the country. Costs for fossil-fuels in Uganda have gone up by more than 50% between 2009 and 2013 (UBOS 2014b). As well, political disturbances in Kenya have impacted significantly on local supply of fuels.

Petroleum fuels have four major end uses in Uganda:

- Diesel and petrol for transportation. Vehicles, air and shipping transport are the largest users of petroleum in Uganda. Use of petroleum has increased with economic growth.
- Diesel for on- and off-grid power generation. Uganda Electricity Generation Company Limited (UEGCL) uses generators for peak generation and for remote rural mini-grids. Industry and commercial groups use generators for back-up power and off-grid base load.
- Kerosene for household lighting. Wick lamps (locally known as tadooba) and hurricane lanterns are primary lighting devices in Uganda. Use of kerosene dropped by 13% between 2012 and 2013 (UBOS 2014b).
- LPG for cooking. LPG is only been affordable by top-tier households and is only used by a small number of institutions and industries.

End-use of different petroleum products is presented below (Figure 10). As can be seen, there has been a drastic increase in sales of diesel and petrol since 2004.

An estimated 6.5 million barrels of oil reserves have been discovered in the Albertine Graben, of which

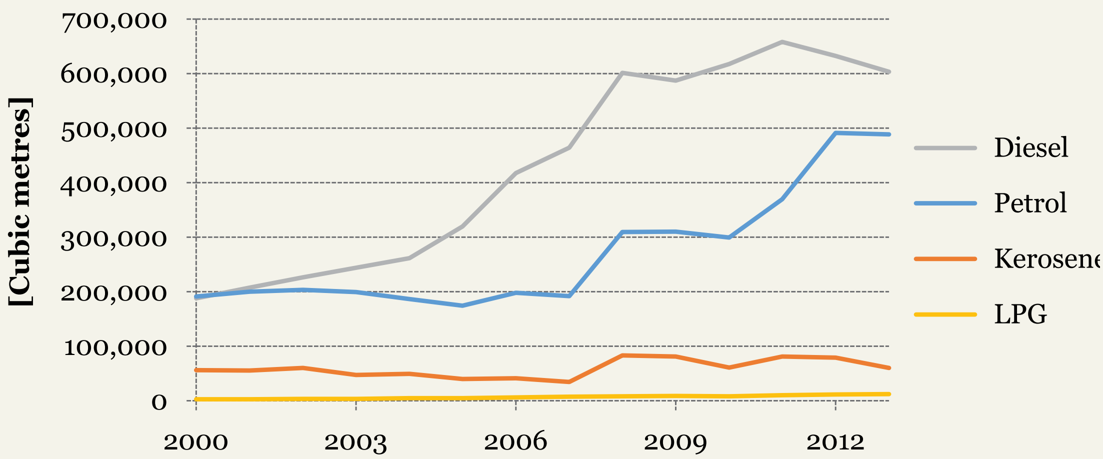


Figure 10: Sales of selected petroleum products in Uganda 2000-2013 (UBOS 20 2; UBOS 2007; UBOS 2014b)

about 20% are currently retrievable (PwC 2013; NPA 2015). The Government of Uganda is supporting establishment of both production wells as well as construction of oil refinery (MEMD 2012e; MEMD 2015b). Predicted exploitation rates mean that Uganda is likely to be an oil producer and net exporter for about 30 years. A refinery planned for Hoima District will produce 30,000 barrels/day initially and up to 60,000 barrels/day by 2020 (MFPED 2014; MEMD 2015b). Some of the identified oil reserves are found in protected areas and there are environmental concerns in extraction of these resources that must be assessed and acknowledged.

4.3 ELECTRICITY – ON-GRID

4.3.1 Hydro-based electricity generation

Uganda's power grid is predominately reliant on hydro resources. Currently hydropower supplies 85% of grid electricity in the country, though variations in water flow cause significant variations between installed capacity (683 MW) and actual generation (300-350 MW). Hydropower stations on River Nile include Bujagali (250 MW), Nalubaale (180 MW) and Kiira (200 MW).

Two power stations are under construction on the Nile: Isimba (183 MW) and Karuma (600 MW) (MEMD 2014). Detailed planning for construction of Ayago (600 MW) hydropower station has also been completed (NPA 2015). Small hydropower, with installed capacity below 10MW, is also supported by Uganda government. In 2013 the installed capacity was documented to 22.4 MW (Liu et al. 2013).

Rainfall and river volume changes brought about by climate change, variation in weather patterns and siltation have led to significant output reductions of hydropower stations. Such changes in hydrology have also called into question investment in smaller scale hydro sites.

4.3.2 Transmission and distribution

The Uganda power system is split up into transmission (33 kV and above) and distribution (below 33 kV) with an estimated 14,312 km of cables. Estimated losses in the year 2011 were 4% in transmission and 26% losses for distribution (MEMD 2012e). With relatively limited transmission and distribution coverage (Figure 11) only about 14% of the population in Uganda has access to grid electricity. Rural electrification access rate is about 7% of households (NPA 2015).

The state-owned Uganda Electricity Distribution Company Limited (UEDCL) builds and owns distribution network at 33kV and below. Umeme Uganda's primary power company, operates, maintains and expands UEDCL's distribution network under a 20 year concession agreement. Umeme is fully-privatized and publically traded on Uganda's stock exchange.

Umeme supplies power to approximately 450,000 consumers (MEMD 2012b; MEMD 2012a). It has reduced energy losses from 38% to 27.7%; replaced over 120,000 poles, 2,000 transformers and 40 sub-stations; refurbished over 1,500kms of medium voltage (MV) and low voltage (LV) lines. It has introduced a prepayment system and automated meter reading (MEMD 2012b). Challenges include bill payment and collection and illegal connections (the latter accounts for 50% of grid losses) and cost of last-mile connections

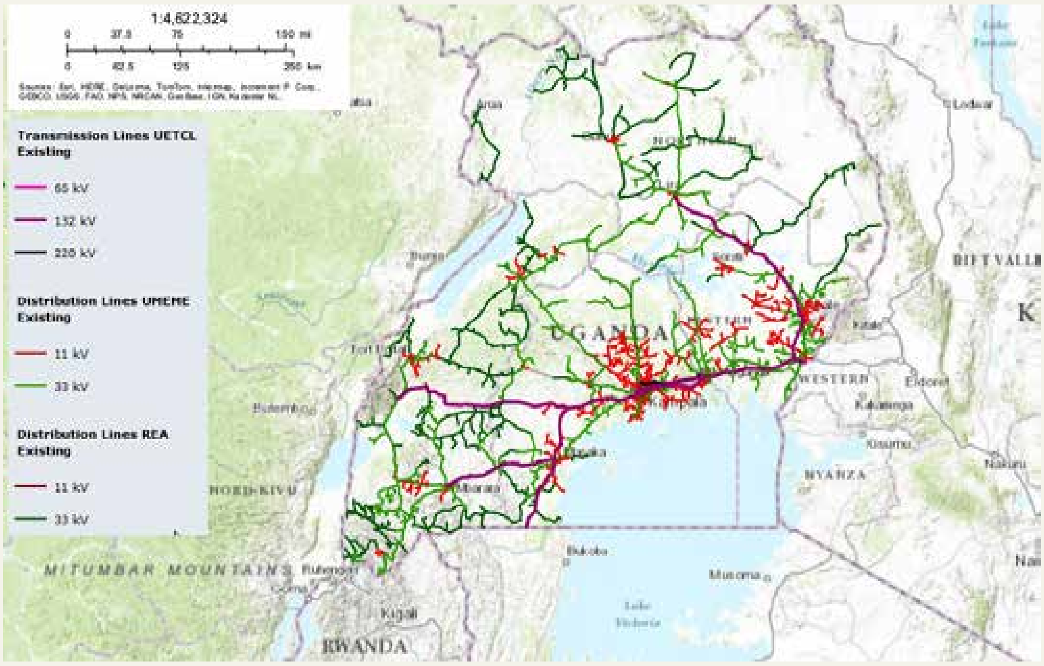


Figure 11: Existing grid and transmission lines in Uganda (Energy Sector GIS working group 2014)

Six smaller private distributors are licensed to distribute electricity and also run mini-grids[7], Mini-grids are being implemented in 11 newly granted off-grid concession sites. The Government sees considerable potential to reduce pressure on main grid and cater for communities with mini-grid approaches.

Uganda Electricity Transmission Company Limited (UETCL), the state owned transmission company, builds, owns and operates the high voltage network above 33 kV. UETCL manages the transmission grid, acts as system operator and is the single bulk supplier and buyer of power for the national grid in Uganda. UETCL publishes standardized tariffs for renewable energy generation systems on an avoided cost principle.

UETCL is implementing a 10-year USD 1.2 billion grid investment plan to better evacuate power from new plants, improve the grid network, extending the current system, upgrade substations and facilitate regional power trading. 220 kV interconnection projects with Kenya and Rwanda are under development while interconnection with Tanzania and the Democratic Republic of Congo are still at feasibility stage.

4.3.3 Feed in Tariffs for renewable electricity

The Uganda Global Energy Transfer for Feed–in–Tariffs (GETFiT) programme, under the Electricity Regulatory Agency (ERA), is at an operational stage and currently includes both hydro and PV projects (GET FiT Uganda 2013; GET FiT Uganda 2015).

The program aims at supporting 20-25 projects representing about 170 MW of additional generation capacity in renewable electricity. Some examples of approved projects are Kikagati 16 MW hydro project and a number of multi-megawatt PV projects. Three small hydro power projects (Nyamwamba, Rwimi and Nengo) with a total capacity of 22 MW are at negotiation stage. GETFiT targets rolling out 20 MW of grid connected PV.

Additionally, a Renewable Energy Feed-in Tariff (REFIT) program supports green electricity. The program includes hydro power up to 20 MW, as well as electricity generated from biomass (ERA 2012).

7 *Ferdsult Engineering Services Ltd (Masaka-Rakai-Isingiro, Rukungiri-Kanungu and Kyenjojo-Kagadi-Kibaale), Bundibugyo Energy Cooperative Society (Kabarole – Bundibugyo), Pader-Abim Community Multi-purpose Electric Cooperative Society (Pader-Abim), Kilembe Investments Limited (Kasese-Mpondwe-Bwera-Ibanda), Kyegegwa Rural Electricity Co-operative Society (Mubende, Kyegegwa and Kyenjojo) and West Nile Rural Electrification Company Ltd.*


© Shutterstock Tuomix studio/WWF

4.4 ELECTRICITY – OFF-GRID

Off-grid electricity systems deliver important energy services to the population. Though relatively small in terms of overall quantity and though not easily included in national statistics, off-grid power systems are significant. They include stand-alone PV systems in isolated sites and back-up systems that provide power when the grid is on "brown-out" (voltage-drop in the grid). They also include dry cell batteries and battery based systems that provide critical power to many off-grid households.

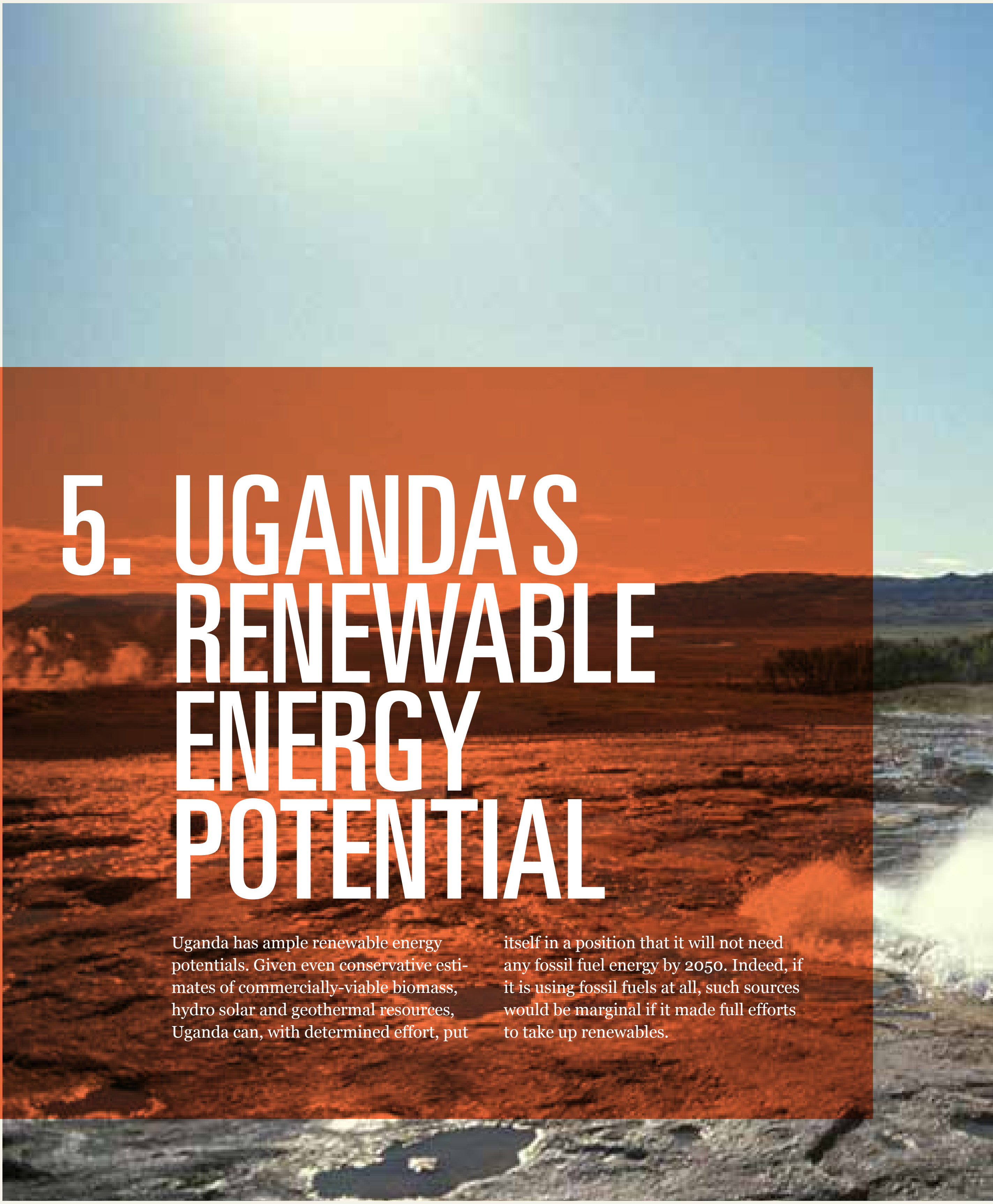
4.4.1 Off-grid solar PV

The market for solar electricity has been growing steadily in the last 15 years, with increasing number of private businesses and a high pico- and solar home system demand (Hansen et al. 2014; Alstone et al. 2015). Over 1.1 MW in off-grid systems was installed as of 2012 and, at the time, the industry was growing at over 20% per year (MEMD 2012b).

The World Bank-financed Energy for Rural Transformation (ERT) Programme helped to stimulate the solar PV market through a variety of incentives and capacity building measures for the private sector. Hundreds of thousands of small off-grid installations are in place. These include the following:

- PICO SOLAR SYSTEMS are widely available over the counter. Large numbers of households make use of solar lanterns. Some dealers have been approved by the Lighting Africa program, but much of the available equipment is low quality and short-lived. New players (including M-Kopa) have introduced Pay As You Go systems that greatly reduce up-front costs for consumers (Alstone et al. 2015; M-KOPA 2015).
- SOLAR HOME SYSTEMS provide significantly more power than pico-solar (typically solar modules of 20-100 W). By 2012 solar PV systems had been installed in 5,600 households, 420 small commercial and 1,700 institutions through schemes initiated by Rural Electrification Agency (REA) and other donor agencies (MEMD 2012b). This can be contrasted with active over-the-counter sales, an estimated 12,000 solar home systems are sold per year (Hansen et al. 2015).
- INSTITUTIONAL PV SYSTEMS provide power in schools, health centres, police posts and other institutions. Government has supported their implementation and they supply a key intermediate step in areas where grid power is not available.

Primary challenges for the off-grid PV sector are low rural consumer ability to pay, lack of financing schemes, widely varying equipment quality and a lack of capacity to install systems to minimum standards.



5. UGANDA'S RENEWABLE ENERGY POTENTIAL

Uganda has ample renewable energy potentials. Given even conservative estimates of commercially-viable biomass, hydro solar and geothermal resources, Uganda can, with determined effort, put itself in a position that it will not need any fossil fuel energy by 2050. Indeed, if it is using fossil fuels at all, such sources would be marginal if it made full efforts to take up renewables.

©Peter Prokosch/WWF

5.1 RENEWABLE ENERGY: FROM THEORETICAL POTENTIAL TO COMMERCIALLY VIABLE

Historically renewable resources have often been seen as "cornucopias" which can be used independent on scale of the use. Today we know that renewable resources must be managed and used wisely in order for them to not deteriorate. There are technical, social, environmental, economic, financial, political and commercial barriers to the immediate implementation of renewable energy. Figure 12 provides an illustration of how "theoretical estimates" of available renewable energy resources can be compared to actual delivered and commercially viable renewable energy.

The **theoretical renewable energy resource potential**, as seen on the bottom of the pyramid, is the net energy contained in the wind, solar, hydro, biomass or geothermal resource. This is the total amount of energy in the resource.

The **technically viable energy potential** is that energy that could be harvested with existing equipment on all currently available land. When assessing this, there is need to consider existing technology limitations (storage, conversion, etc) and how much area can be set aside for the technology.

The **economically and ecologically viable renewable** resource potential is that energy that could be viably harvested and which is a better solution to other alternatives for the economy and environment as a whole. When assessing this, there is need to consider technology costs vis-a-vis costs and impacts of the alternatives and also to scrutinize protected areas where environmental considerations prevent exploitation (regardless of whether the site is viable).

The **commercially viable renewable potential** is the energy that is cost effective for investors, end-users and other market players. Important considerations include existing enabling policies and incentives, investor appetite and willingness and ability to pay for the delivered products.

All exploitation of energy sources will cause environmental impacts. Energy sources are rarely 100% environmentally friendly. The renewable energy scenario in this report presents "ecologically viable" hydro, solar and biomass projections.

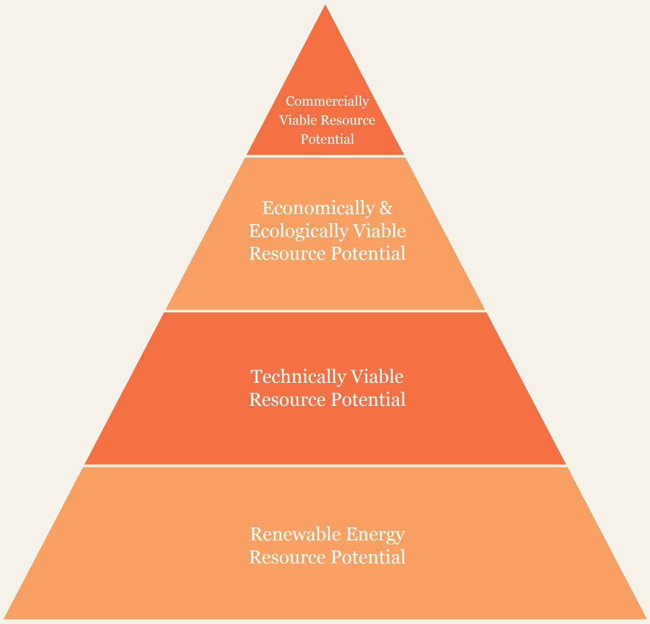


Figure 12: Pyramid representing how potential of a certain resource will be defined

Though final sustainable levels for the exploitation of natural resources in Uganda have yet to be fully defined the Biomass Energy Strategy study (MEMD 2015a) does recommend a "sustainable" level for biomass extraction. In other cases (i.e. hydro, solar) a reasonable estimate has been made by the project team based on available data.

Such ecologically viable values are defined by considering the design, positioning and operational parameters of the power station. Power systems must be built so that impacts on the natural and built environment are as small as possible. Negative impacts on the environment are normally seen in relation to the benefits arising from the energy production. Environmental Non-governmental organisations (NGO) work to support good practise in this field and bring forward good examples. WWF have developed a range of guides to help making renewable energy more sustainable; e.g. hydropower (USAID et al. 2010; WWF 2011a; WWF 2014), certification schemes (Schlamann et al. 2013), palm oil (WWF 2011d) and forestry (WWF 2011e).

The table below summarizes the starting point for the potential of each of the six sources of renewable energy in Uganda.

TABLE 5: OVERVIEW OF POTENTIALS OF DIFFERENT RESOURCES (NPA 2007; HERMANN ET AL. 2014; MEMD 2015A)

	ESTIMATED TOTAL ENERGY AVAILABILITY (TWH/YEAR)	ESTIMATED MAXIMUM TECHNICAL POTENTIAL
Solar PV	9,470	±5,189 GWp capacity at 5 Peak sun hours (Psh)
Concentrated Solar Power	8,582	
Wind	815*	
Hydro power		39,420 GWh/year
Forestry biomass	90	
Non-woody biomass	71	

** All areas with wind capacity factor greater than 20%*

5.2 BIOMASS POTENTIAL

Woody biomass: Current woody biomass exploitation is unsustainable. About 44 million tonnes/year of woody biomass is harvested while local forests produce only 26 million tonnes of biomass/year sustainably (MEMD 2015a). Thus, using 19 GJ/tonne of woody biomass and 30% moisture content, the estimated total sustainable energy content available from woody biomass per year is about 90 TWh[8].

The sustainable production potential could be significantly increased if better forestry management practices were introduced. The suggested scenario would, as a consequence of formalising the charcoal and wood trading, give ample options to the government and forestry sector to improve management and increase levels of sustainable output from forests as well as collecting revenues from the sales.

Non-Woody biomass: The theoretical energy potential of biomass residues generated in Uganda has been assessed at 71 TWh as shown below in Table 6.

Actual use of biowaste and bioresidues on a sustainable level would obviously be much less than the potentials presented above. The renewable energy scenario presented herein suggests a sustainable level to 20 TWh non-woody biomass per year.

8 *To calculate energy content in wood, this formulae is used: NCV= 19.0 GJ - (0.2164 * Moisture Content Value) = x GJ/tonne.*

TABLE 6: ENERGY POTENTIAL IN BIORESIDUES FOUND IN UGANDA ON AN ANNUAL BASIS (OKELLO ET AL. 2013)

SOURCE OF ENERGY	ENERGY POTENTIAL [TWH/YEAR]
Crop residues	41
Animal residues	18
Forest residues	12
Total	**71**

It is worth noting that biogas production from animal wastes would allow nutrients in the effluent to be re-circulated to the fields as valuable fertilizers.

Bio-residues have enormous potential as modern solid fuels. "Upgrading" and transforming such resources into marketable higher energy forms such as torrefied pellets or briquettes is one option. Pellets would require new end-use technologies (possibly targeted towards large institutional and industrial users). Torrefied pellet is an existing technology providing opportunities for a high-value biomass fuel based on a range of biomass combinations (Sultana et al. 2010; Nilsson et al. 2011; Chen et al. 2012; Agar et al. 2015; Chen et al. 2015), but the concept is yet to be scaled up in Africa.

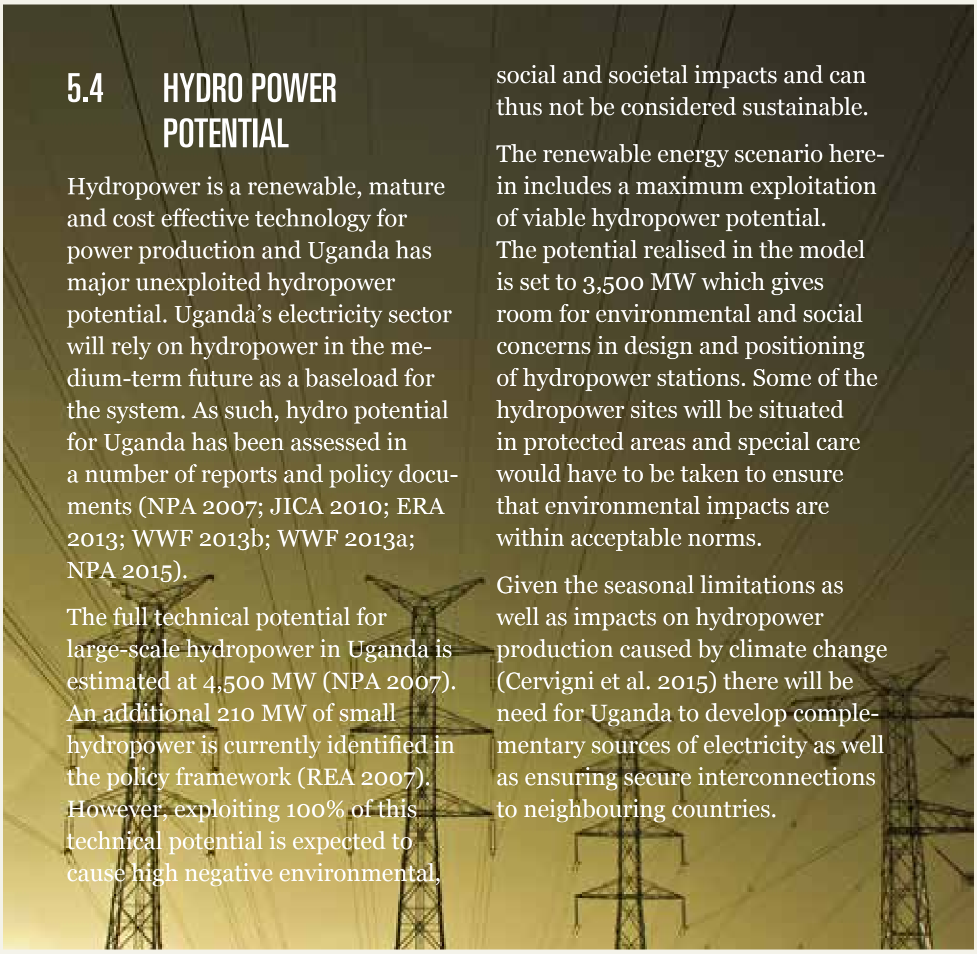
5.3 BIOFUEL POTENTIAL

While demand for liquid fossil fuels is increasing rapidly, currently the use and production of biofuels in Uganda is at a very early stage. In order to get to a renewable energy system would require replacement of fossil fuels with renewable liquid fuels, gas or electricity.

Ethanol from sugar cane is a proven replacement for petroleum. Potential bioethanol production from sugar based bio-ethanol is about 3.7 million m^3/year for Uganda. This potential is based on first generation transformation technology using rain-fed sugarcane feedstock with restriction in terms of land area (indicated by Hermann et al. (2014). This equals about 20 TWh/year[9].

Biodiesel can be produced from a range of different feedstock including oil palm fruits, soy bean and jatropha. Meeting current demands would require about 30 TWh of biodiesel production (about 2.8 million tonnes) per year. This production level can be met with first generation technologies. One way of reducing the risk of unacceptable negative environmental and socio-economic impacts is to have sustainability certification schemes linked to the production and processing of the feedstock (Scarlat and Dallemand 2011).

Obviously, feed stocks for biofuel production will compete with land used for other purposes. A number of studies have been done where the competition for land has been taken into consideration and based on that an estimate of the production is found. The NEMA (2010) report presents data for sugarcane, maize, jatropha and oil palm based on land availability in Uganda.



©National Geographic Stock/ Jason Edwards / WWF

5.4 HYDRO POWER POTENTIAL

Hydropower is a renewable, mature and cost effective technology for power production and Uganda has major unexploited hydropower potential. Uganda's electricity sector will rely on hydropower in the medium-term future as a baseload for the system. As such, hydro potential for Uganda has been assessed in a number of reports and policy documents (NPA 2007; JICA 2010; ERA 2013; WWF 2013b; WWF 2013a; NPA 2015).

The full technical potential for large-scale hydropower in Uganda is estimated at 4,500 MW (NPA 2007). An additional 210 MW of small hydropower is currently identified in the policy framework (REA 2007). However, exploiting 100% of this technical potential is expected to cause high negative environmental, social and societal impacts and can thus not be considered sustainable.

The renewable energy scenario herein includes a maximum exploitation of viable hydropower potential. The potential realised in the model is set to 3,500 MW which gives room for environmental and social concerns in design and positioning of hydropower stations. Some of the hydropower sites will be situated in protected areas and special care would have to be taken to ensure that environmental impacts are within acceptable norms.

Given the seasonal limitations as well as impacts on hydropower production caused by climate change (Cervigni et al. 2015) there will be need for Uganda to develop complementary sources of electricity as well as ensuring secure interconnections to neighbouring countries.

5.5 SOLAR PV AND SOLAR HEATING POTENTIALS

Uganda's location astride the equator makes solar power an increasingly viable potential power supply over much of the country, especially the drier northern parts of the country. Given Uganda's area (236,040 km^2), and over 5 kWh/m^2/day, Uganda has more than 400,000 TWh of solar energy arriving each year on its surface area10. Of course, this energy must be collected and stored so that it can be used.

Solar electricity. Solar energy can be converted to electricity on and off-grid through photovoltaic or concentrated solar power (CSP) technology. Over 200,000 km2 of Uganda's land area has solar radiation exceeding 2,000 kWh/m^2/year (i.e. 5.48 kWh/m2/day) and would be considered high potential for solar power investment (Hermann et al. 2014).

TABLE 7: SOLAR PV DATA (HERMANN ET AL. 2014)

	KM² FOR CSP	PV*
Total area	241,278	241,278
Exclusion area	30,828	30,828
1,800-2,000 kWh/m²/year	1,742	-
2,000-2,500 kWh/m²/year	203,108	210,450
2,500-3,000 kWh/m²/year	5,600	0

9 *3.7x109 l/year * 20 MJ/l * 1/3.6x109 TWh/MJ = 20.5 TWh*

10 *236,000 km² * 5x10-9 TWh/m²/day * 365 days =430,700 TWh/year*

**Urban areas, bodies of water, protected areas, sloped areas and forests are not included. Does not include rooftop solar!*

A relatively small area with installed solar PV or CSP, thus, could theoretically power all of Uganda! A solar PV array of four square kilometres could produce over 1,000 MW which is more than the current output of the Uganda grid[11].

Given the above resource data, it should be clear that in Uganda virtually any available land, or any rooftop space, is a possible generation site for solar PV. As well, any amount of space, from a square meter to hundreds of hectares, can be considered as for potential electricity generation.

Solar thermal potentials. The same solar energy is also available to be used directly to heat water, dry crops, sterilize, and cook using technologies such as solar water heaters, solar driers, solar stills and solar cookers.

- **Solar water heating** presents a low-hanging fruit for domestic and commercial end-users who require hot water. Solar water heating typically have payback periods of 3 years or less depending on hot water demand and other operational parameters (see for example Da Silva et al. 2010).
- **Solar drying** has been proven as a viable method of preserving fruits in Uganda. It can also be used to process and dry a number of commercial and agro-industry products.
- **Solar cooking** has a potential, especially where biomass resources are unavailable and where users are willing to change their habits. Solar cooking is yet to be scaled-up in Africa because of technical limitations, social preferences and the cost of equipment.

5.6 GEOTHERMAL POTENTIAL

The western part of Uganda is situated in the Rift Valley which is an area where potential sites for geothermal power production has been identified (Bahati 2012). The theoretical potential geothermal energy in Uganda has not been fully explored but assessment indicates geothermal potential for electricity generation at 450 MW (Bahati 2012).

Three potential areas have been identified in Kabale, Hoima and Kasese districts of Western Uganda. Though it poses a lesser opportunity here than for its East African neighbour Kenya, geothermal may will be a promising resource for Uganda as well (WWF 2011b).

Geothermal should receive strong research and development support in Uganda given the proven resources in the region.

5.6 WIND POWER POTENTIAL

As can be seen in the table below drawn from an Africa-wide study (Hermann et al. 2014), Uganda has only limited areas with demonstrated high wind potential.

TABLE 8: WIND DATA FOR UGANDA (HERMANN ET AL. 2014)

	AREAS AVAILABLE [KM2]
Total area	241,278
Exclusion area	30,828
Wind speed <4m/s	142,469
Wind speed <5m/s	50,650
Wind speed 5-6 m/s	10,549
Wind speed 6-7 m/s	5,468
Wind speed 7-8 m/s	1,312

Though more study of the sector is necessary, informal studies and wind speed measurements show relatively low speeds of (i.e. 2-4 m/s). Uganda wind speeds have not thus far been shown to be attractive for commercially large-scale investments.

With advancement in technology, there could be a variety of low speed wind turbines which can be used to harness wind power in areas such as Tororo, Nebbi, Gulu, Apac, Moyo, Moroto, and Kotido.

11 *With irradiance of 1,000 W/m2 and solar panels of 10% overall efficiency covering 4km², a PV array could easily supply 1,000 MW*

©Martin Harvey/WWF Canon

6. POPULATION AND SECTOR GROWTH PROJECTIONS USED IN THE SCENARIOS

This chapter introduce the input parameters of population growth and growth estimates in the household, transport, commercial and institutional and lastly industrial sectors used to form the energy demand in the renewable energy scenario as well as the reference energy scenario.

6.1 POPULATION GROWTH

In the 2014 census the Uganda population had reached almost 35 million people (UBOS 2014a). Uganda's population is predicted to grow to about 90 million by 2050 (Figure 13).

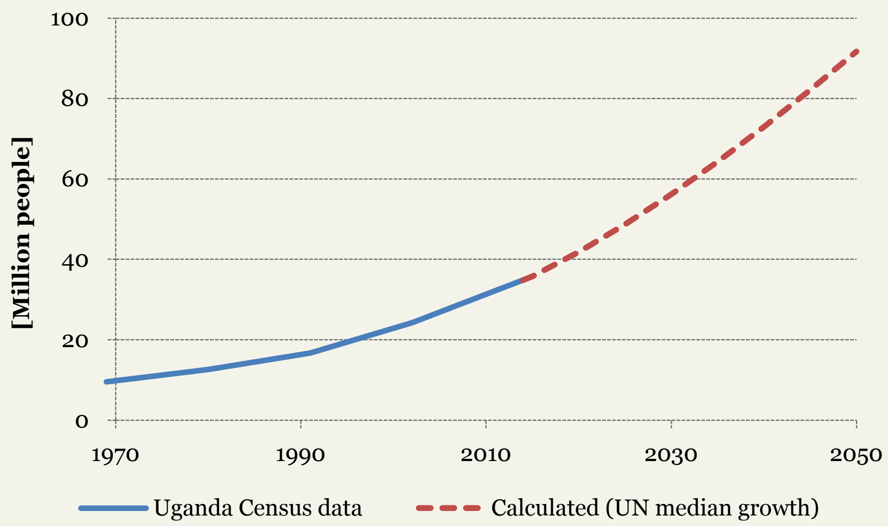


Figure 13: Population growth in Uganda as predicted in the scenario[12]

12 The population growth trajectory has been projected using 2014 census data (UBOS 2014) and growth trends used in UN (2015). POPSEC (2014) reports a similar trajectory but projects a higher growth of population between 2002 and 2014 which results in a projected population in 2050 of more than 100 million people.

As of 2014, a majority (82%) of Ugandans live in rural areas and 18% live in urban areas (UBOS 2014a). With the high rate of urbanisation this rural-urban balance will shift over the next few decades. These shifts are represented as changes in the share of households found in different energy use tiers. At 1.5 million inhabitants, Kampala is Uganda's largest city and it is projected to remain so. Building up the country's other cities will be important for distributed economic growth. Such growth will require functional infrastructure for energy efficient transport of people and goods in all urban centres (World Bank 2015).

Uganda's anticipated population growth for the period up to 2050 is, by global standards, relatively high (UN 2015). It will result in increased energy demands in the household sector as well as in the transportation and social services sectors.

6.2 ENERGY SERVICE GROWTH IN THE SOCIETY

The scenario projects steady 8% per annum economic growth during the years up to 2025 and then a slow decline to 7.5% in 2050 (these levels are similar to those in NPA 2007). This means a steady increase in the GDP both in absolute terms as well as on a per capita basis.

The different sectors provide different growth patterns in the energy demand which is the variable studied in this report. Growth seen in the reference case best illustrates the inhibited growth seen without changing the end-use technologies and energy mixes (Table 9).

TABLE 9: GROWTH IN ENERGY DEMAND IN THE REFERENCE CASE

BRANCHES	2015	2020	2025	2030	2035	2040	2045	2050
Household	2.9%	3.2%	2.8%	2.6%	2.5%	2.2%	2.0%	1.7%
Commercial	3.3%	3.4%	3.5%	3.4%	3.5%	3.3%	3.3%	2.9%
Industrial Sector	4.8%	4.8%	4.4%	4.6%	4.4%	4.4%	3.9%	3.5%

The transport demand is expected to increase in Uganda, which is a consequence of the increase of population, but also as a consequence of higher mobility and economic growth in the country. The growth is divided into transportation demand of people and transportation demand of goods. The growth rate of transportation has been assessed in the National transport master plan (UNRA 2008) to annual increase by 8% between 2003-2013, 7% 2013-2025. In the period 2026-2050 we have anticipated a growth by 6% (Figure 14).

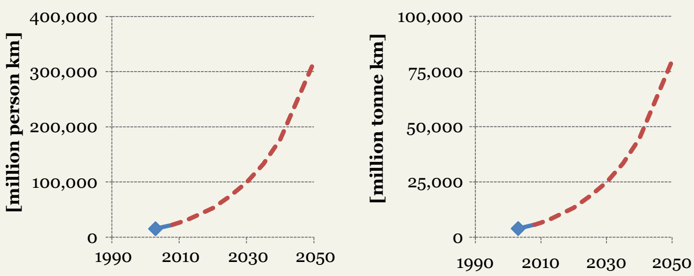
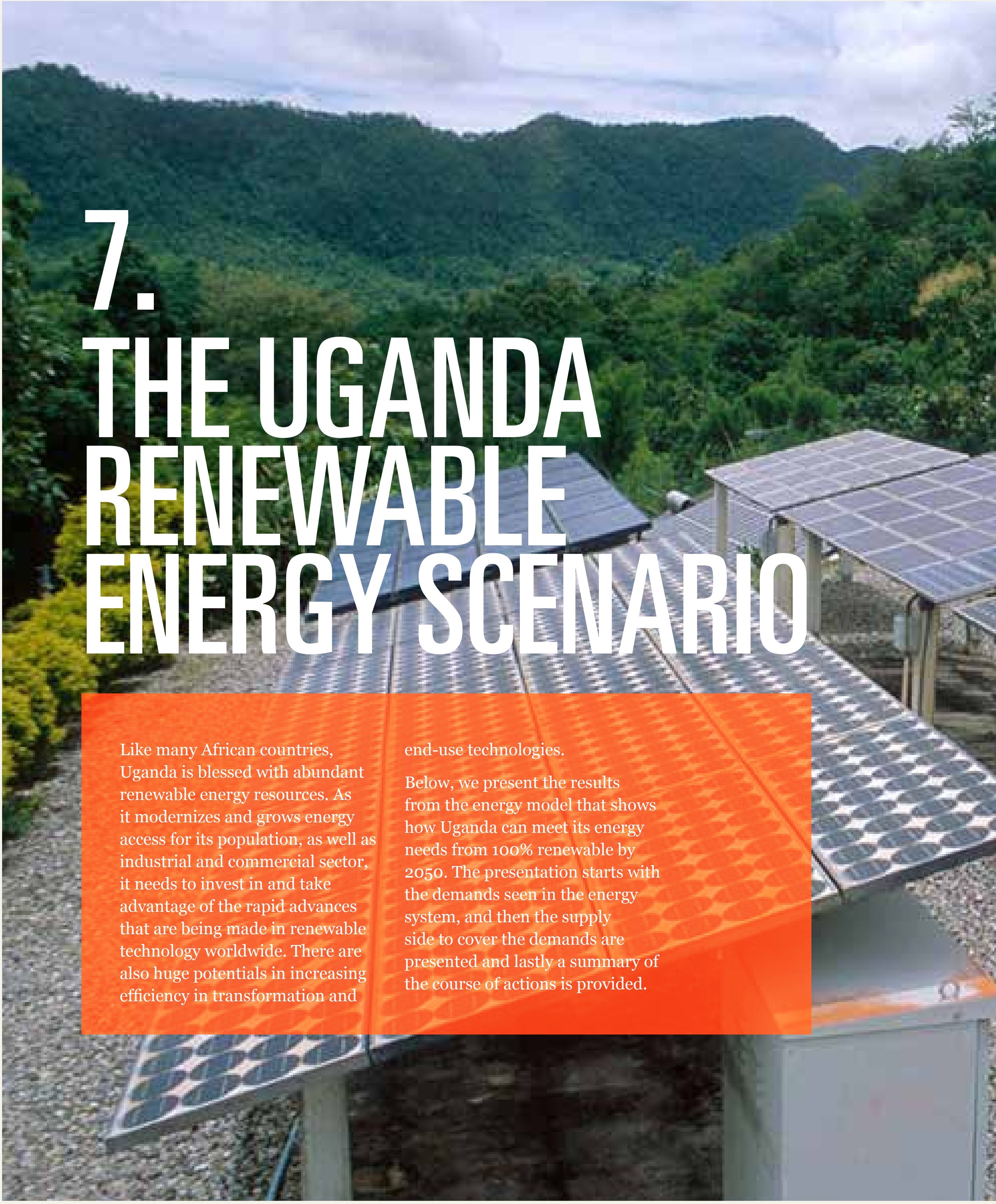


Figure 14: Projected increase of transportation demand, people (right) and goods (left), 2002-2050

As a result of the steady economic growth, the industrial sector energy demand will also grow. This growth has been operationalised as growing demand for heat and electricity. Reference energy scenario shows a growth from 18.3 to 99.5 TWh over the study period – 5.4 fold increase. The growth is different for different industrial sectors but is between 5-10% growth of energy demand per year. Main consumer is industrial heat – based on unsustainable wood burning for the reference energy scenario using basic wood boilers (67%) of final demand in 2050. The reference energy scenario will give a good indication of the growth if no changes are made. In renewable energy scenario basic wood boilers are replaced by improved efficiency wood boilers and a combination of LPG, Electricity and Ethanol based systems so that the final demand serviced by wood is only 26% of the final demand. In general other industrial sectors are also assumed to switch to efficient options in order to reduce pressure on the national energy system and improve the overall system efficiency.

Commercial sector is divided into hotels & restaurants and institutional buildings. Each sector is modelled based on its demand for final services within lighting, cooking, heating, ventilation, and air conditioning (HVAC) and general appliances. Following the reference energy scenario, the commercial sector's energy consumption is expected to grow significantly reaching 17 to 18% increase in energy demand per year. The largest consumption areas in both subsectors are related to energy requirements for cooking representing over 90% of the final energy demand.

Changes related to the renewable energy scenario focus specifically on fuel switching and energy efficiency measures: the large consumption areas of the business as usual baseline relies strongly on the unsustainable use of firewood. With this in mind, the renewable energy scenario phases out the use of traditional open stove systems and focuses on the use of institutional size technologies. It also assumes a fuel diversification, replacing part of the firewood with sustainable charcoal and a 25% proportion of LPG based systems. Newly installed systems are further assumed to have higher efficiencies than existing traditional systems. This combination of fuel switching and energy efficiency measures offers the dual benefit of reducing the sectors' reliance on already stressed wooded biomass reserves while reducing the overall sectorial demand of energy.



7. THE UGANDA RENEWABLE ENERGY SCENARIO

Like many African countries, Uganda is blessed with abundant renewable energy resources. As it modernizes and grows energy access for its population, as well as industrial and commercial sector, it needs to invest in and take advantage of the rapid advances that are being made in renewable technology worldwide. There are also huge potentials in increasing efficiency in transformation and end-use technologies.

Below, we present the results from the energy model that shows how Uganda can meet its energy needs from 100% renewable by 2050. The presentation starts with the demands seen in the energy system, and then the supply side to cover the demands are presented and lastly a summary of the course of actions is provided.

©Adam Oswell/WWF Canon

7.1 THE FINAL ENERGY DEMAND

In this section the composition of final energy demand based on identified key sectors, is presented and discussed. In Figure 15 the energy demand in the renewable energy scenario is compared to the demand in the reference energy scenario.

In the renewable energy scenario the total energy demand will already by 2025 be flattened as a results of replacing inefficient end-use technologies and transformation technologies with more efficient solutions delivering the service or product to meet demands from the different sectors.

The energy demand is served through different energy carriers. The energy carriers are electricity, heat, and different gaseous-, liquid- and solid fuels. The demand for the renewable energy scenario with the different energy carriers is found in Figure 16

The starting point shows a use of biomass use exceeding the sustainability levels set and in the renewable energy scenario priority is given to change the trend of increased use of woody biomass in the energy sector. The increased trend will stop around 2020 and will require major efforts from all stakeholders in society. Already plans are implemented to secure sustainable use of charcoal and biomass in Uganda (WWF 2012; Basu et al. 2013; MWE 2013; MEMD 2015a) but the trend of growing demand will not change overnight.

Strategic work looking to halt deforestation in the long run and tackle structures that hinders successful implementation of plans is needed. The renewable energy scenario envisions that the companies, institutions and individuals that ensure the energy supply must become part of the formal sector. In addition to this, regulations forming and regulating the whole value chain from land area where the biomass originates, transportation transformation/up-grade up to the end-user must be implemented and enforced. Added benefits from this would be increased tax revenues as much of the energy supply today is outside the formal sector, improved forestry and land use management can be supported and implemented and income opportunities will be created for the local communities.

The energy demands will evolve in the renewable energy scenario differently over time in the different sectors' of the society (Figure 17).

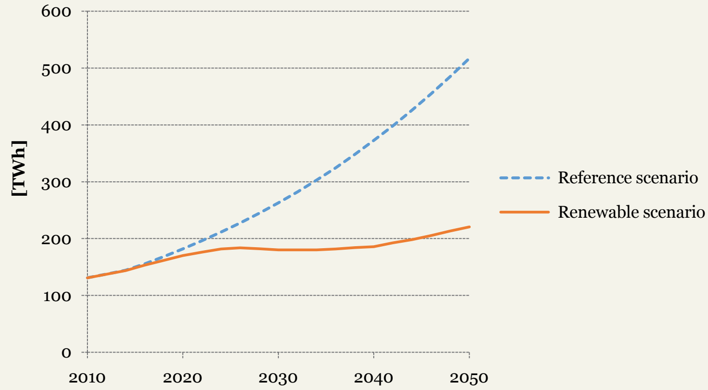


Figure 15: Cumulative energy demand in Uganda - renewable energy scenario and references scenario

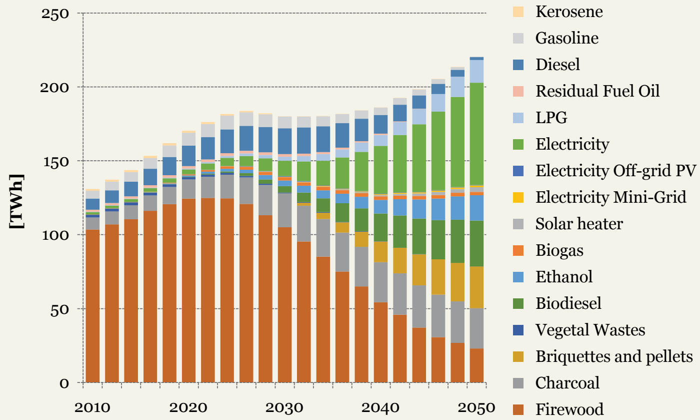


Figure 16: Energy demands and the energy carrier to supply the energy service - renewable energy scenario

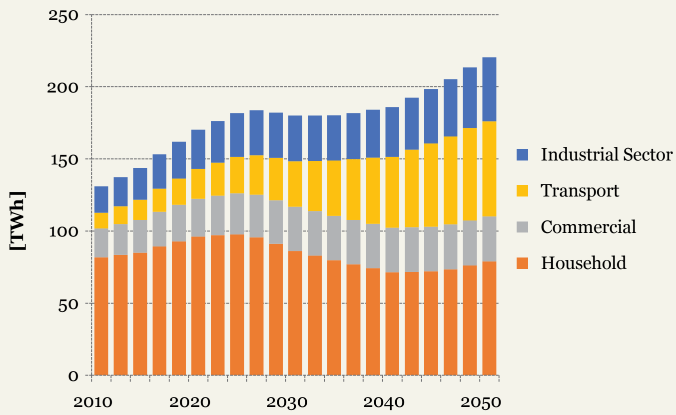


Figure 17: Sector-wise energy demand - renewable energy scenario

Population growth, a growing economy as well as the very low access to modern energy services today drives the increase of energy in all sectors. Energy demand for each sector is discussed in the following sections.

7.1.1 Household sector – energy demand

Clean and reliable energy is a fundamental need of rural and urban populations. Improved energy access will rely on moving households up the energy ladder in methods that are cost-effective and realistic. This is operationalised in households climbing the tiers as presented earlier. While all groups (tiers) will have better energy supplies and access, there will be different approaches meeting these for rural and urban populations.

As a consequence of targeted actions to improve efficiency in stoves and transformation of cooking fuels the energy demand in the household sector will not drastically increase relatively current levels. The quality and quantity of energy services enjoyed by households will increase. The reference energy scenario describes a steady increase as a consequence of population growth.

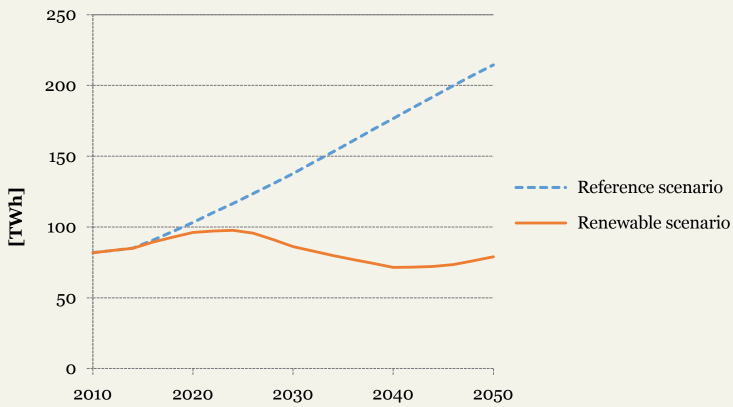


Figure 18: Energy demand in the household sector - renewable energy scenario and reference energy scenario

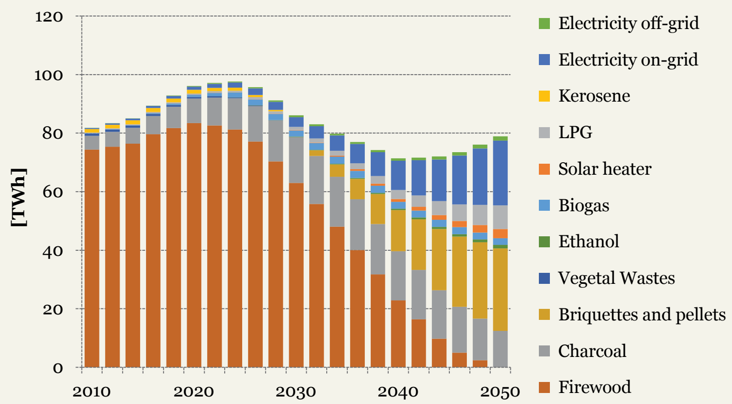


Figure 19: Households energy demand - renewable energy scenario

The energy demand is mainly served with woody biomass and charcoal in 2010. The renewable energy scenario describes an increasing number of energy carriers used by the households (Figure 19).

The renewable energy scenario recognises the challenges in shifting cooking technology in households. The vast improvements to be made in terms of efficiency, as well as reduction of exposure to harmful pollutants for those doing the cooking or being close are strong incentives to continue prioritise efforts.

In order to make electricity services universally available for lighting and appliances a combination of on- and off-grid electricity will be applied.

ON-GRID ELECTRICITY. Investment in the national electric supply will enable major rollout in connections. Connection costs will be affordable. Mobile metering and billing will improve the roll-out of grid based connections. Efficient lighting and appliances will be used by a majority of customers. The power supply will have enhanced stability which will partially be supported by household customers who produce distributed solar/wind/biogas electricity on a net-metered basis.

OFF-GRID. Having recognized that off-grid solutions will speed up and enhance the goal of achieving 100% electricity access, Uganda will continue to open up the space for off-grid power suppliers.

- Mini-grid concessions will operate where Umeme is not represented. They will offer customers competitively-priced electricity generated by hydro, solar and hybrid sources.
- Stand-alone PV (and other renewable systems) will be available in a variety of sizes and with various financing plans so that a wide range of rural off-grid income groups can use them.
- Off-grid solutions will enable consumers to start small and to gradually build up their energy usage before connecting to the grid.

Biomass will remain a critical cooking fuel for much of the population but management of the resource, and upgrade will be introduced. For a large portion of the population, particularly for rural people, biomass will remain a key cooking fuel.

- Modernized biomass cooking devices will provide better cooking services, high efficiency and lower smoke/particulate emissions
- New devices will utilize convenient pellets and briquettes that ease cooking tasks
- Biogas systems and biofuels will be available for a significant portion of the population.

FIREWOOD. Address large scale users first (education, kilning, commercial) by introducing attractive improved stove products and services. This will have a rapid impact. Second is to have three stone stoves replaced by improved and more efficient stoves that also ensures that exposure to harmful pollutants from the smoke is avoided

CHARCOAL. An overhauled sector will produce and deliver charcoal sustainably and more efficiently. Investments in efficient production of charcoal will grow the supply and professionalize the industry. Charcoal makers, tree owners, re-sellers and transporters will participate in a regulated and fair market that generates revenue for local Governments as well as supports creation of local job opportunities.

LPG (and to a lesser extent kerosene) will be used to expand modern cooking access, particularly in urban areas. LPG is a transitory fuel source that is gradually phased out in long run in favour of modern biobased fuels and electricity. In Kampala the LPG for cooking will reduce the pressure for biomass fuels such as charcoal.

BIOGAS, BIO-FUELS AND INDUCTIVE ELECTRIC COOKING SYSTEMS will be strategically introduced as increasing numbers of households have the incomes (and desire) to switch away from wood and charcoal. Solar heated water will be used by urban families.

The renewable energy scenario realise the Uganda goals formulated as part of the SE4All activities. Modern cooking devices and access to electricity services on a universal level has been operationalised which means that by 2030 all households are found on Tier 1 or higher.

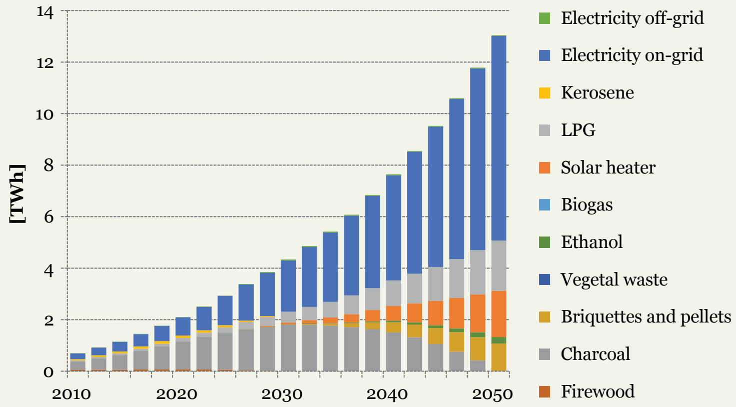


Figure 20: Energy demand in the household sector for households in Kampala – renewable energy scenario

As discussed above the strategies to serve the household energy demands will differ between urban and rural areas. The energy demand for the household sector in Kampala is shown in Figure 20.

Kampala households will rely on upgraded energy carriers to a large extent. Electricity will of course be used to a relatively high level as access to the grid services is the highest in the country already today and will be further improved. Solar water heaters are introduced. Advanced biofuels in the form of briquettes and pellets are introduced on the market to replace charcoal. Efficient cooking stoves need to be introduced along with these new fuels.

The energy demand in the household sector in rural areas illustrates major demand

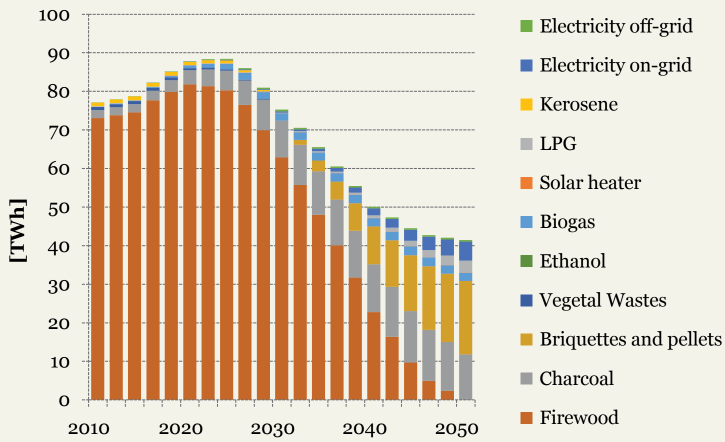


Figure 21: Energy demand for households in rural area – renewable energy scenario

reductions which are mainly the results from shifting away from inefficient stoves (Figure 21).

Introduction of advanced biobased fuels in form of charcoal produced in modern charcoal production processes and briquettes and pellets will create income opportunities, improve the control of cutting and acquisition of the biomass and make use of biowastes/ bioresidues.

7.1.2 Industry sector - energy demand

In 2050, Uganda industry will have improved energy use and will often generate their own renewable electricity and manage production of biomass and biofuels. To support economic development this sector will require safe supply of energy (Figure 22).

During transition to renewable alternatives, process heat and cooking will rely on biomass,

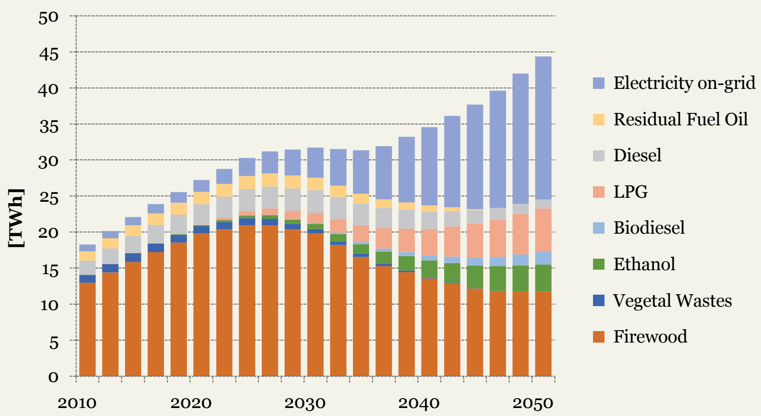


Figure 22: Total energy demand in the industry sector – renewable energy scenario

but in more efficient and modern forms. Industry, commercial and institutional will, in the immediate future, continue using wood fuels. There will be a gradual shift away from biomass as biofuels and super-efficient electric processes are developed to replace them.

- In the long term, there will be a transition to biofuels that will be aided by industry itself. These will include carbonized biomass residue, biogas made from wastes and biofuels (ethanol, biodiesel). Industry will be encouraged to develop these processes.
- LPG is used as a bridging fuel in industry and commercial thermal needs..
- Where wood fuels continue to be the most viable energy source (tea, tobacco industry), industry will be required to ensure that its fuel source is sustainably produced.
- The energy demands in the agricultural sector are growing. The main energy carrier is for operating machinery. The diesel is substituted with biodiesel.

Greater electrical connectivity combined with electricity from renewable sources will improve productivity. Heightened electricity access for these sectors will stimulate greater productivity because of better lighting, communication, and computer and information technology availability and system controls. Industry will monitor and manage electricity use and, in many cases, self-generate power on-site as this becomes economically viable.

- Greatly expanded national electricity supplies will provide lower cost stable and continuous electricity supplies for industry
- Large electricity users will replace expensive back-up diesel generators with self-generated green electricity from co-generation, hydro, solar and other sources.
- Industries will collaborate with Independent Power Producers (IPP) to invest in power projects that utilise local renewable resources for themselves and surrounding communities.
- Efficient use of electricity will be a focus of private sector and Government. Good practice will be rewarded.

7.1.3 Commercial and institutional sector – energy demand

The commercial and institutional sector in Uganda is today fully dependant on charcoal and firewood. It is foreseen that this dependency on solid biomass will continue, but there is a shift towards modern biomass energy as well as introduction of more efficient end-use technologies (Figure 23).

The commercial and institutional sector includes

- More efficient use of wood fuels will be crucial to modernization of this sector. Efficient stoves, a switch to pelletized systems that use wood, charcoal and agricultural residues and better management of industrial and commercial energy will be key.
- Targeting schools and institutions where cooking is taking place to ensure that

efficient stoves are used and to gradually ensure that fuel are sourced from sustainable sources is a strategy to get this transition moving.

Improved access to electricity will enable access to information technology, entertainment (through radio, tv and entertainment systems) and other energy services provided from electricity.

7.1.4 Transport sector – energy demand

Uganda in 2050 will have a much larger population than today. The renewable energy scenario envisions that people and goods transports will increase. The need for better life and productivity for rapidly growing cities will stimulate investment in transport systems that rely more on public transports, planned neighbourhoods that enable people to live near their work places, and an intelligent mix of road, rail, waterway, air and walking transportation.

The increased transportation work will result in higher energy demands in the transport sector. The renewable energy scenario will take advantage of more efficient transportation technologies and options (Figure 24).

Transport and the transition from petroleum to renewable power

The oil extraction and processing in Uganda should not result in low cost fossil fuels available on the domestic market. This is a key item in the renewable energy scenario. Taxes on petroleum and diesel fuels will support infrastructure developments in green transport.

- By 2050, more than 63% of its transport fuel budget will be met by biofuels (Figure 25).
- About 30% of its transport energy budget will be powered by electricity.
- Public transport will be widely available. Light rail systems will be in place in the 3 largest cities in the country.
- Rail transport will enable convenient travel and transports of goods within Uganda and to and from Kenya, Tanzania, Rwanda and Burundi.

By 2050, there will be significant shift to biofuels and electric vehicle (Figure 26). Much of this will be will be subsidized by petroleum revenues.

- A strong push for better, affordable,

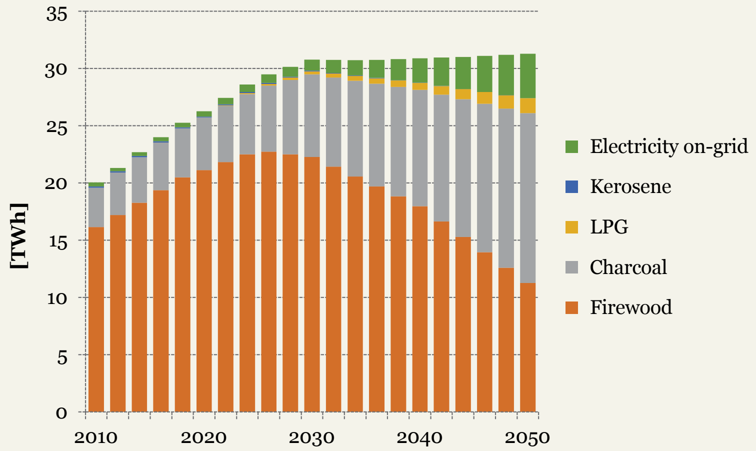


Figure 23: Total energy demand in the commercial and institutional sector – renewable energy scenario

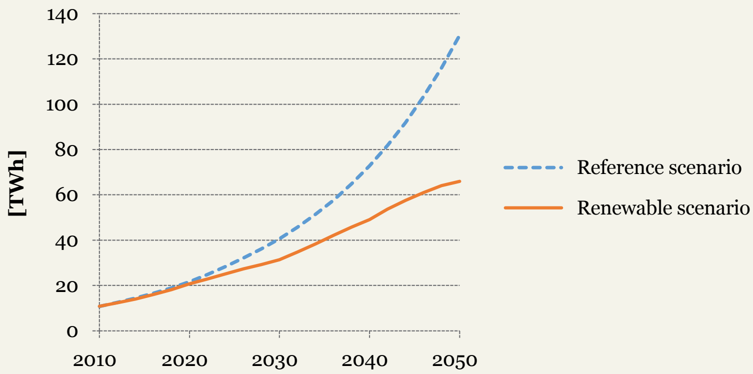


Figure 24: Energy demand in the transportation sector – renewable energy scenario and reference energy scenario

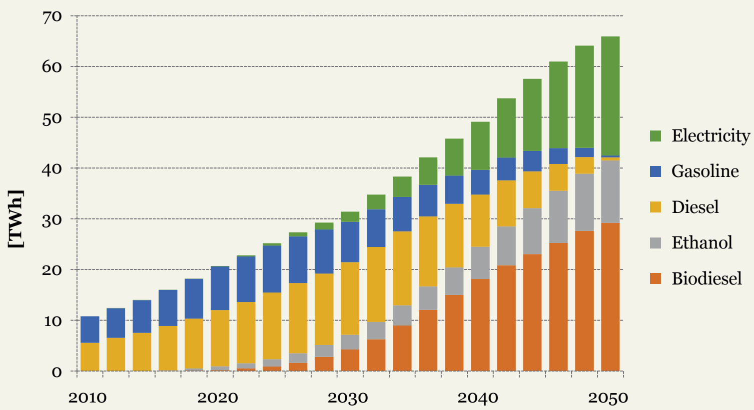


Figure 25: Total energy demand by type of fuel in the transport sector (person and goods) – renewable energy scenario

©Kate Holt/WWF UK

Women play a critical role in energy access issues at all levels

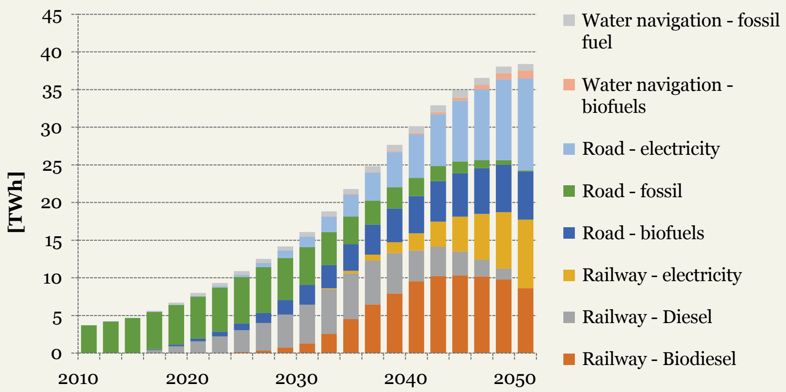


Figure 26: Energy demand for transportation of people illustrating the shifts foreseen – renewable energy scenario

comfortable and convenient public transportation will enable citizens to move about urban areas and in the country more easily.

- A focus on an interconnected road, rail and waterway transport pathways planning will produce an integrated system which is usable by all parts of the population
- A move towards renewably-powered electric and biofuel-powered (e.g. biodiesel, ethanol, human) vehicles will enable the transport sector to power itself with local energy sources. Standards for private, commercial and public vehicles will ensure that emissions are limited.
- Innovation in transport will be encouraged. Much of the industry change will be driven by the private sector and by carefully designed incentives. As is the case in other parts of the world, a close watch on state-of-the-art developments will enable Uganda to pick and choose the best transport solutions for its needs.

Population growth along with an improved infrastructure and public transportation services will support transportation options that have higher capacity and are more energy efficient per transport work (person km and tonne km). In Figure 26 an example is given to illustrate how certain technologies are faced out and new options are given more room.

7.2 THE PRIMARY ENERGY SUPPLY

The section below presents the primary energy supply in Uganda required to meet the energy demands between 2010 and 2050. The primary energy supply in the renewable energy scenario will be substantially lower than for the reference energy scenario (Figure 27).

The primary energy supply is however provided through a mix of different sources. The present energy supply is totally dominated by woody biomass. The primary energy mix will however be diversified in the medium and long time scale. Introduction of solar, biofuels and bio-based fuels reduce dependency on wood and are forming the basis for providing modern energy services. The supply to the renewable energy scenario is shown in Figure 28.

Uganda will commence fossil extraction and refining of petroleum products and this is visible in the energy supply (Figure 28). The renewable energy scenario suggest that most of this is not used inside the country as the more strategic route is to venture on a renewable route preparing and plan for basing energy demands on only renewable energy resources. The substantial revenues from exporting the oil should be invested in developing renewable energy in the country.

7.2.1 Supply of biomass and biofuels

Biomass is a cornerstone of the energy supply in Uganda today and increasing access to energy services and envisioning the further economic development in the country will not change this. But, in the renewable energy scenario Uganda will have to utilize the biomass resources in the country in a way that is more efficient, more sustainable and introduce modern technology for transformation and end-use. Many players will derive benefits from this development process. Linkages between forestry and agricultural sectors and the energy and environment sectors management must ensure sustainable use is and management of biomass.

- A sustainable forest management system should be in place that meets international standards as well as local community and biodiversity needs.
- Local charcoal conversion and supply should be sustainable and well-managed. Its production will use modern equipment and methods, meet international efficiency standards and the industry will generate income for all stakeholders, including local Government.
- Agricultural residues and the residues of forestry and charcoal production should be utilized as biomass fuels. Modern "pellet" stoves and briquettes will be used by industry, commercial, institutional and household customers.

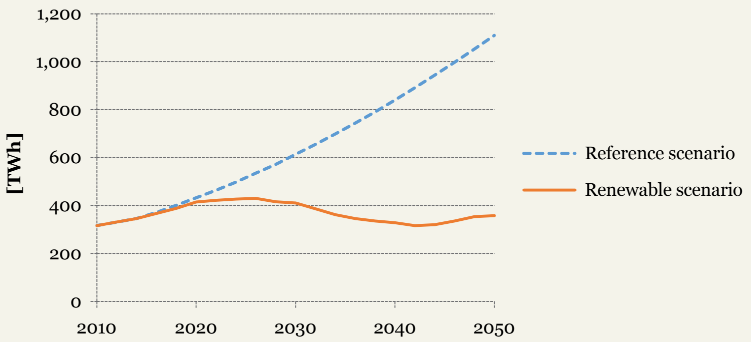


Figure 27: Primary energy supply - renewable energy scenario and reference energy scenario

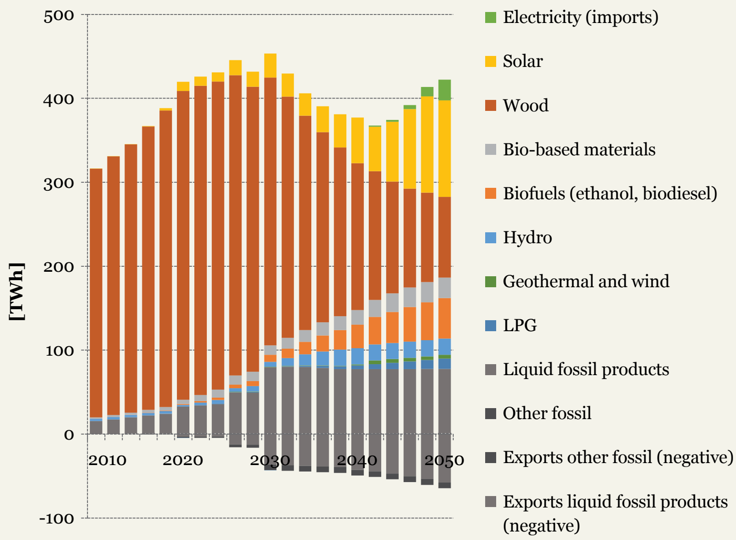


Figure 28: Primary energy supply to the energy system including imports and exports (exports are indicated as negative values) – renewable energy scenario[13]

13 Negative values indicate exports of fossil products produced in Uganda. Positive values indicate the full supply to the energy sector. To get the final energy supply used in the country (renewable energy scenario Figure 27), exports are subtracted from the positive value.

- A shift to modern fuels will have occurred among large portions of the private, institutional and household sectors. These will include biogas, biodiesel, bioethanol and other biofuels currently being developed. LPG will form an important part of the transition and will be retained for those who are unable to use biofuels.
- Modern efficient cooking stoves and practices will be taken up on a national basis. For industry, institutional and commercial uses, the focus will be on efficient energy use with state-of-the-art equipment. For household, improved stoves will programs will stress health, safety, convenience as well as energy use improvements.

7.2.2 Grid electricity

The national electric grid, which currently supplies less than 3% of Uganda's energy supply, will have to be greatly expanded and strengthened. Reducing losses in especially the distribution system and preparing the system to include distributed power generation and higher flexibility will be required.

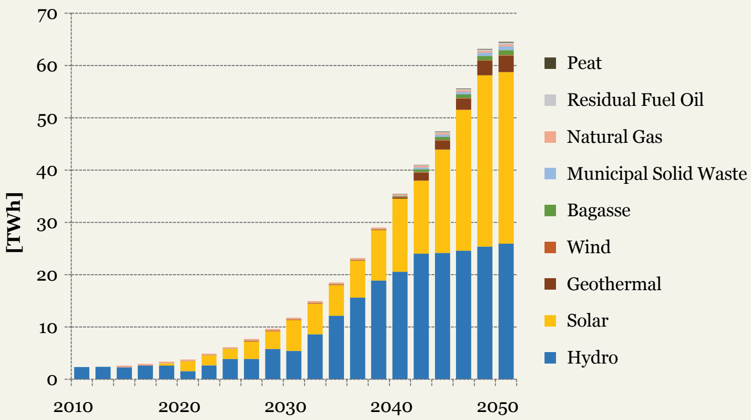


Figure 29: Electricity supply and specification of electricity mix – renewable energy scenario

The electricity demand per person in 2050 will be 755 kWh/year. This level is based on the growth levels and Tiers progression depicted in this scenario. Already the expansion seen is 25
The electricity supply in the renewable energy scenario will have the following features in 2050.

- Hydro power will still be a major base load electric supply source with an installed capacity in the end of the period of about 3,500 MW in mainly large hydropower installations but also some small hydropower installations will be operational. The supply from hydropower is essential to facilitate the renewable energy scenario but careful planning and design of the power plants is required in order to safeguard environment and ecosystem services. No-go areas in combination with environmental legislation safeguarding environment and people's rights will have to be established and respected by stakeholders.
- Important electricity contributions will come from solar PV, cogeneration using bagasse. Biogas, geothermal and wind will contribute to electricity production as well. These sources will be largely developed by IPPs as part of feed in tariff contracts.
- Uganda must strengthen transmission and distribution network that is able to transport electricity from major suppliers to consumers. The distribution and transmission also needs to accommodate for distributed power generation to feed back to the main grid. The government are pursuing these items already (REA 2007; MEMD 2012c).
- Modern billing and metering that encourage better management of power and will enable consumers to take advantage of lower electricity costs when sources such as solar are plentiful.
- Distributed supplies from customer-financed PV, biogas, hydro, and cogeneration will be encouraged and will be part of a well-managed "smart grid".

7.2.3 Off-grid and distributed power

It is estimated that in 2050 about 5.9 million households in rural areas will be off-grid and depend on distributed generation, as compared to 6.8 million on-grid. Off-grid electricity sources will supply as much as 4% of the overall electricity supply. Even though a rather small percentage it will serve to provide a high number of households and institutions in areas where the national grid is not available with electricity energy services. This enables rural areas to access information and communication technologies and other services requiring electricity. The consumers, the private sector and Government will have recognized the role that off-grid electricity sources can play in development of remote areas (and for customers that cannot connect to the grid).

- Franchised mini-grids will supply remote communities with affordable electricity. Powered by solar, hydro, co-generation and hybrid generators, these mini-grids will cooperate with (and be supported by) private industry and communities in key off-grid areas. As the national grid expands, it will easily incorporate pre-developed mini-grids into its expansion.
- Stand-alone off-grid renewable energy sources will power businesses, tourist sites, institutions and households in many parts of the country. These systems (most of which will be solar PV) will be supplied by local installers and financiers that can upgrade the systems as consumer loads increase and that can connect the systems to the national grid when it becomes available.
- Millions of low income households will use privately financed pico solar systems that enable them to have lighting, mobile money, cell phone and internet services and that also enable them to upgrade to larger systems as they climb the "energy ladder".
- Increasingly, the distinction between "on-grid" and "off-grid" will disappear as consumers find that off-grid solar systems can become competitive with the national grid. The grid will be used by many customers as a "back-up" source to their installed rooftop PV systems.

7.3 THE RENEWABLE ENERGY SCENARIO – FRAMEWORK FOR ACTION

Achievement of 100% renewable energy by 2050 will require significant efforts in short term (2015-2030), medium term (2030-2040) and long term (2040-2050) time perspective. The table below presents summarise the key changes that would be needed to realise the Renewable energy scenario. By 2050 the energy system in Uganda would then be ready for a post-2050 development based on sustainable and renewable sources of energy. The access to modern energy services and transports will be good in the country. Afforestation is taking place and natural resources are used extensively but also managed in a good way.

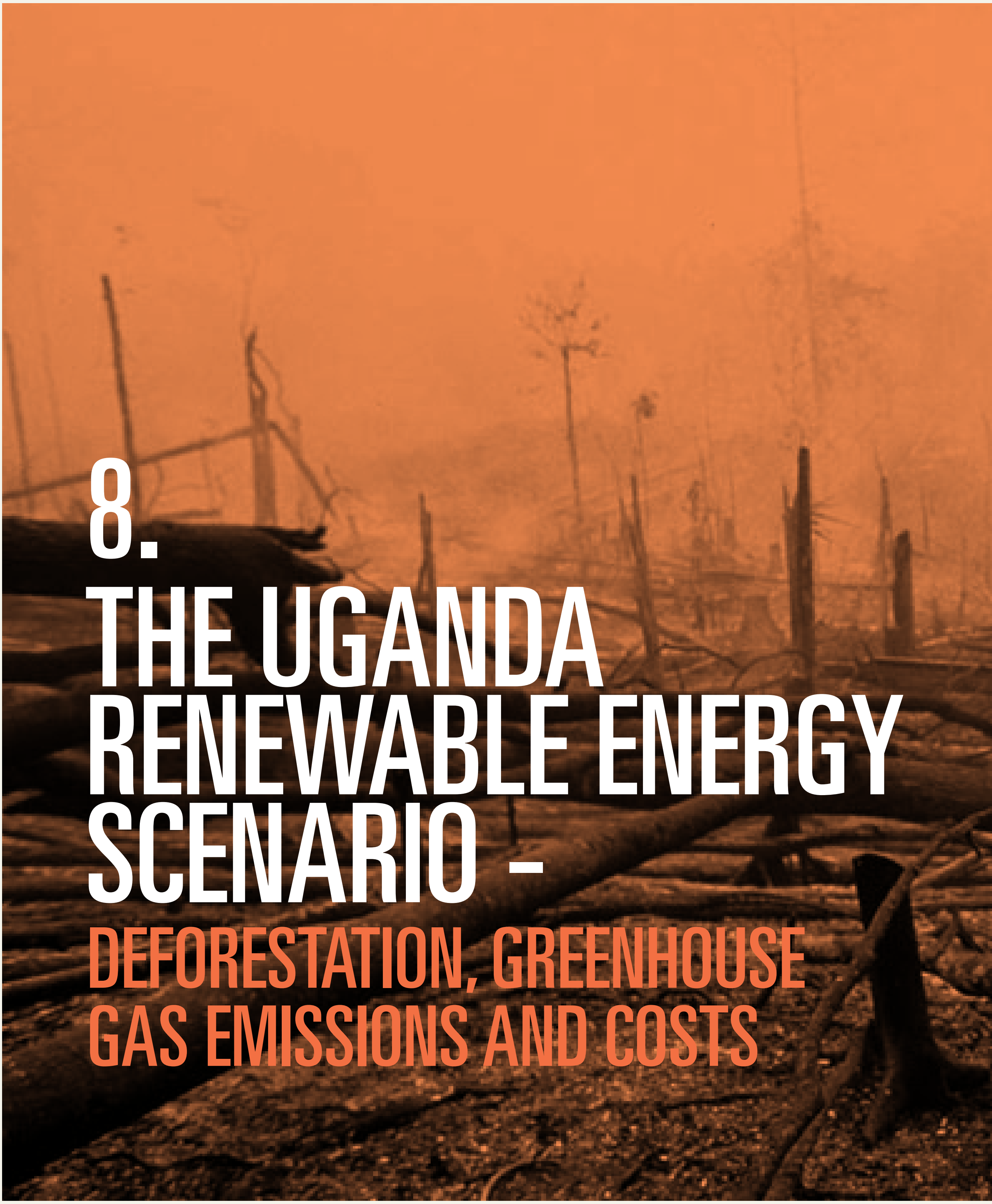
©Kate Holt/WWF UK

AFFORESTATION IS TAKING PLACE AND NATURAL RESOURCES ARE USED EXTENSIVELY BUT ALSO MANAGED IN A GOOD WAY

TABLE 10: SUMMARY OF STARTING POINTS IN SCENARIO (2010), NEED FOR CHANGE AND END-POINTS (2050)

PRIORITY	STARTING POINT (2010)	NEED FOR CHANGE (TO GET TO BY 2050)	END POINT OUTCOMES
Cooking, heating & industrial process. Reduction of solid biomass fuel dependency. Increase of overall solid fuel efficiency. Improved technology.	Biomass is in wide use: but not sustainable. Deforestation partially driven by regional commercial and charcoal fuel demands.	High priority on short-term actions to halt deforestation and ensure sustainable biomass supply. Strong policy will promote modernization of biomass sector, more energy efficiency and shifting to other energy sources (including electricity, solar heat, energy efficiency, etc). Program to modernize biomass sector so that use of firewood, charcoal and agricultural by-products is done efficiently and sustainably. Efficient modern wood and charcoal stoves are introduced in households and institutional sectors on a large scale.	Uganda will be less dependent on use of solid biomass fuels. Modern stoves will be used all over in Uganda by 2030 in line with the SE4All initiatives. Overall solid fuel efficiency will be increased Overall use of biomass will be reduced Biomass use will rely on more modern fuels and appliances Negative health impacts caused by traditional stoves greatly reduced
Switch to liquid/gas biofuels and electricity.		Support for substitutions away from solid fuels. LPG (which will be phased out in long term), Biogas & bio-fuels for cooking and heating Green electricity.	Liquid bio-fuels will substitute for solid biomass on a significant scale Plentiful electricity will be used in some sectors for cooking and process heat.
Major expansion of on-grid electricity through added hydro, solar, biomass and other Renewable Energy Technologies (RET).	Current grid electricity base is mostly renewable (hydropower and bagasse contribute over 85% of national grid). However, extremely low per capital demand and low number of connections require huge investments.	Expansion of grid electricity services is a priority. Short-term & medium scale focus on identified hydropower & biomass Transition in medium and long term to new sources including solar, geothermal, new biomass and, where viable wind. National grid will encourage investment in both centralized and decentralized production. Power companies, institutions and households encouraged to invest in their own renewable power systems to supplement their own use and the grid. Expansion of power supply will require strong operational directives to ensure acceptable environmental and social impacts from new energy generation. Binding laws safeguarding environmental and socio-economic values are put in place No-go areas are set aside as areas for protection of undisturbed ecosystems	All consumers in Uganda to have access to electricity services by 2030 (through grid and off-grid strategies). Expansion of grid-based electricity sector through investment in hydro, biomass, solar, and other renewable sources to continue up to 2050. Growth will result in major new capacity towards the end 2050. Power pooling in East Africa greatly strengthened (though overall ambition is for domestic resources to cover energy demand).

PRIORITY	STARTING POINT (2010)	NEED FOR CHANGE (TO GET TO BY 2050)	END POINT OUTCOMES
Major expansion of off-grid electricity sector for rural access	Strong PV and hydro off-grid industry but finance, quality and regulatory environment in early stages of development. There is an off-grid momentum in development which is supported by government.	Investment is required to stimulate and modernize off-grid sectors. New renewable business models promoted for stand-alone and mini-grid technology. Mobile based financing and metering modernise off-grid energy services in rural settings and deliver high quality power attractive independent energy services encouraged by strong national policy.	Off-grid electricity technologies will supply many areas remote from the grid. Some customer that cannot afford grid connection costs will use small-scale pico-solutions in short term. By 2050, many off-grid renewable technologies will be well enough developed that there is no need to connect to the grid at all.
Transport and movement of goods shifts to biofuels	Currently largely petroleum powered --- though human-powered walking and cycling are important for transport sector	Need for strong investment, planning and policy for development of biofuel and electric vehicle sector. Coordinated physical planning and infrastructure development in Kampala and other towns will evolve to deliver better transport (and living) services that attract people and industries to areas in balanced ways. Policy focus on efficient lorry, train and bus transport services Fossil fuels are phased out in favour of electricity and biofuels. This will commence on a larger scale in the medium time scale. Domestic production of biofuels put in place through planned policy. Transportation technology that can use these biofuels introduced already in a short time scale. Industrial sector encouraged to become biofuel suppliers (i.e. sugar industry, other biofuel sectors) NB: This RE scenario accounts for oil extraction in Western Uganda. However, local fuels are not considered a domestic energy asset. The scenario expects Uganda to use revenues from the oil industry for activities that support transition to 100% renewable vision.	The transport sector is developed in favour of efficient transportation modes. Efficient desirable train and bus-services available to all consumers. People friendly transport services connect urban centres with housing areas. Train and more efficient lorry traffic for goods transport. Cars, smaller busses, cycles and motorcycles are also in use. The country is fully reliant on a combination of biofuels, electric powered and efficient vehicle that are part of a well-developed transport sector.



8. THE UGANDA RENEWABLE ENERGY SCENARIO - DEFORESTATION, GREENHOUSE GAS EMISSIONS AND COSTS

©Mark Edwards/WWF Canon

This chapter presents results linked to demand of woody biomass and leveling with sustainable biomass levels, cost analysis of the scenarios and lastly associated greenhouse gas emissions from the energy scenarios.

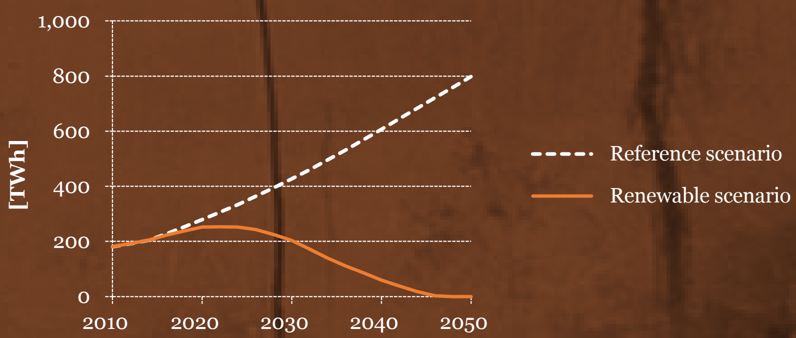


Figure 30: Energy sector demand for wood that exceeds the sustainable level set in the model – renewable energy scenario and reference energy scenario

8.1 THE DEMAND FOR WOODY BIOMASS - LEVELING WITH SUSTAINABLE LEVELS

The present demand for wood from the energy sector in Uganda is in the level of about 320 TWh/year and is growing. Most of this wood is originating from the forests and lands in Uganda and there is a well-documented and highly worrying deforestation taking place in the country (Struhsaker 1987; NEMA 2009; MWE 2013). The demand from the energy sector is one of the contributing factors that pushes this negative trend. The renewable energy scenario is built on the realisation that Uganda will have to rely on solid biomass fuels also in the future. The scenario introduces measures in the short term to reduce the pressure for wood. Still the trend of increased demand of wood will result in increased pressure for wood. In Figure 30 the wood demand that exceeds the set sustainable level of 90 TWh in the model is plotted against the reference energy scenario.

The renewable energy scenario shows a shift in the trend of increased wood demand already in the short time perspective. By 2050 there is no longer any demand of wooded biomass that exceeds the set sustainable levels. In the last three years, from 2047 onwards, the demand is than the current sustainable yield for the country. By 2050 only 83% of the sustainable yield is used. Considering the higher demand that precedes this situation there is concerns of the status of Uganda forests in the mid-term period and how these land areas can get afforested again.

One energy carrier that is used to reduce the pressure for wood is LPG. LPG will have to be imported in the renewable energy scenario. The level of required imports of LPG is given in Figure 31.

Electricity demands will be met with renewable capacity inside Uganda up to about 2045 after which the model results in need for some imports of electricity. The interconnectors with neighbouring countries give opportunities for power pooling. The renewable energy scenario stress that new power generation should be developed considering high level of environmental and socio-economic concern. Power pooling could mean sourcing electricity from non-renewable power sources as well as from power plants that are built and/or operated in an unsustainable manner.

The increase in electricity generation in Uganda will increase from present level of about 3 TWh/year to more than 60 TWh in 2050.

There is a major expansion in the electricity generation as compared to the historical trend. This expansion will have impacts on environment. Not only from the power plants, but also from installation of infrastructure to support the power plants as well as transmission and distribution lines and road constructions to get access to the power plants as well as roads for constructions. New roads can also mean that new settlements are built and land use changes taking place. The renewable energy scenario narrative calls fort proper regulations and laws must be in place to ensure that the environmental and social impacts are acceptable. The challenge is not only to have laws and regulations in place, but ensure that the existing systems are followed and enforced.

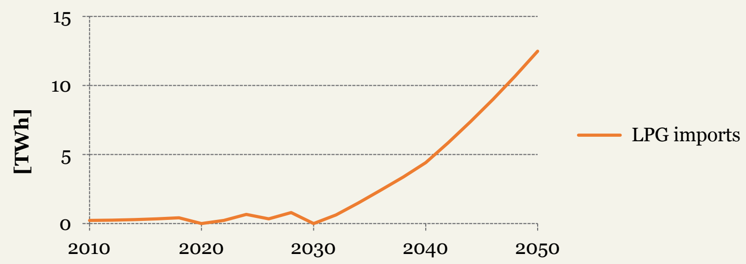


Figure 31: Imports of LPG - renewable energy scenario

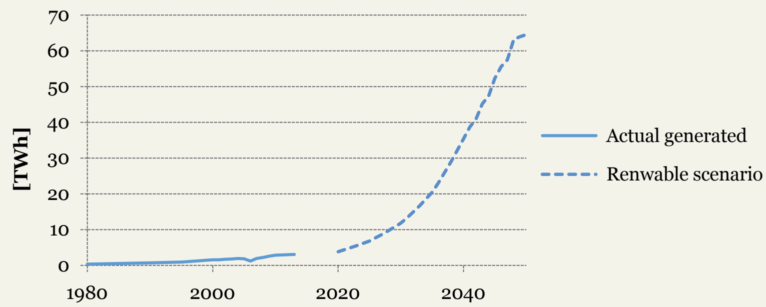


Figure 32: Electricity generation in Uganda 1980-2013(UBOS 2002; UBOS 2003; UBOS 2007; UBOS 2012; UBOS 2014b; ODfA 2015), and renewable energy scenario results

8.2 RENEWABLE ENERGY SCENARIO AND ASSOCIATED COSTS

Within this modelling effort, social costs represent the overall system costs accounted for within each section of the energy system as well as for the entire system. These include demand costs, fuel transformation costs[14], domestic resource costs, export benefits as well as environmental externality[15] costs. This analysis does not include investment costs for new technologies outside of the electricity generation sector since specific data for these elements should be the focus of separate and focused analyses for Uganda.

Figure 33 and Figure 34 show the yearly costs for the entire system for the reference and the renewable energy scenario respectively. These are divided into their most representative components including the cost of importing electricity, of using unsustainable wood, of generating GHG emissions, of producing all other fuels, of operating and maintaining the generation system as well as the cost of capital.

14 *Including capital costs, fixed and variable maintenance costs.*

15 *Uncompensated impacts on the system related to generation and consumption patterns and that will affect consumer utility while remaining outside existing market mechanisms (OECD 2007).*

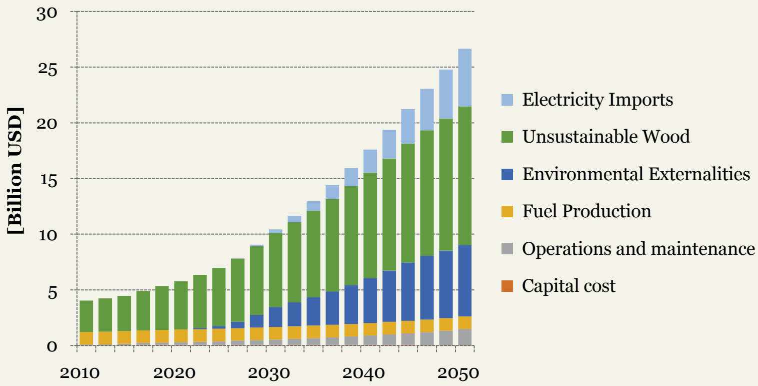
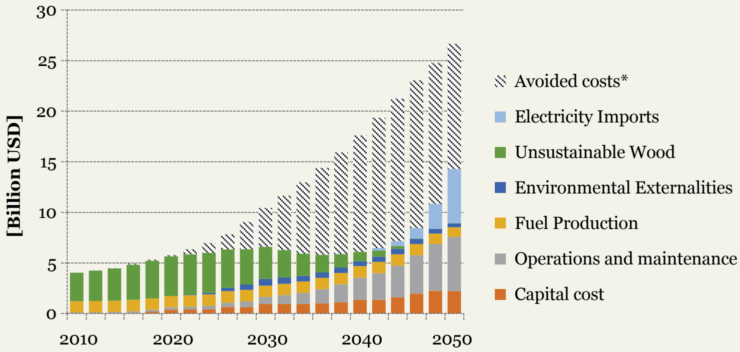


Figure 33: Yearly costs entire system - reference energy scenario



* *difference between the sum of all costs in the Reference energy scenario and the Renewable energy scenario*

Figure 34: Yearly costs entire system - renewable energy scenario

When considering the results from the present modelling exercise, two levels of cost data are accounted for. On the one hand, there are system costs relating to the production of primary and secondary fuels. On the other, the analysis has included externality costs to represent the negative impact that certain activities may be having on the country but that currently go unnoticed from an economic point of view. No system is currently in place in Uganda to monitor these externalities. Nevertheless, the hidden cost of following current practices of burning fossil fuels and using domestic wood reserves unsustainably to provide the demand should be taken into account. As such, these indicative results show the size of this impact and help to support the case of a renewable energy scenario.

With this in mind, the comparison between the reference and the renewable energy scenario also offers two levels of understanding. On the one hand, the more efficient and more centralised systems involved in providing the energy demand in the renewable energy scenario generate much higher capital and operation costs than in the reference case. On the other, the large amounts of unsustainable wood fuel[16], electricity imports and high emission levels reached by the reference energy scenario stand to cost much more than the excess investment required for the renewable case to see the light of day. Specifically, Figure 34 shows that by reducing the use of unsustainable wood and moving towards a more efficient system relying on higher value fuels the renewable energy scenario is avoiding costs of up to 12.4 Billion USD in 2050. Note however that higher investments and annual expenditures in operation and maintenance are needed to support the development such a system where higher value energy (e.g. electricity) is produced in larger quantities by a more centralised system to provide higher levels of service to final users.

From a Net Present Value (NPV)[17] perspective, the reference case would represent total expenditures 1.5 times higher than when considering the renewable energy scenario with NPVs of 127 Billion USD and 86 Billion USD respectively. This remains valid even when removing the cost of GHG emissions – which could be considered unnecessary (see appendix G).

In order to support this vision for the transformation of the energy system in Uganda it will however be necessary to invest large amounts of funds both into developing the centralised electricity generation system and into enforcing the fuel switch and efficiency measures required to improve each individual demand sector. From an NPV perspective, this represents an extra expenditure in excess of 11 billion USD as compared to the reference case.

8.3 GREENHOUSE GAS EMISSIONS ASSOCIATED WITH THE SCENARIO AND SHARE OF RENEWABLES

Greenhouse gas emissions from the Ugandan energy sector are increasing as a consequence of increased use of fossil energy

16 *The amount of wood used within the system that exceeds the current sustainable yield of 26.8 million tonnes of wooded biomass.*

17 *Sum of all costs for each year of the modelling period discounted back to the first year.)*

resources, but also as a consequence of the use of inefficient and unsustainable woody biomass. The two scenarios result in different amounts of GHG emissions as calculated in the model. From a modelling perspective, emissions are included by including so called "emission factors" to activities that produce the GHG. These ratios represent the quantity of each emission type that are produced for one unit of activity (i.e. per unit of output) of the technology considered. In this work, all technologies that burn fuel, either fossil or renewable, include standard Intergovernmental Panel on Climate Change (IPCC) emission factors (see for example IPCC 1996; IPCC 2006). This applies to e.g. transportation, cooking systems, electricity generation, industrial heat and power production etc.
Emissions included in the analysis are: Carbon Dioxide (Biogenic and non-Biogenic), Carbon Monoxide, Methane, Nitrous Oxide, Nitrogen Oxides (NO_x), Sulphur Dioxides, Volatile Organic Compounds (VOC - including PM10). Non biogenic carbon dioxide refers to CO2 that is generated outside of closed and sustainable natural cycles. These include emissions related to for example deforestation activities that release carbon normally re-captured in a sustainable forestry enterprise.

Emissions are included from the base year in both scenarios and results show reduced emissions in the Renewable case from 2015 onwards suggesting that even the small changes achieved within a single year can make an impact on overall GHG levels for Uganda. By 2025 results indicate that 35% of Reference case emissions can be avoided. By reducing the use of unsustainable firewood, shifting the technology for charcoal production from earth kilns to modern high-efficient processes and phasing out the consumption of diesel oil and gasoline, this avoidance can reach up to 94% by 2050.

Non- biogenic carbon dioxide is the main gas emitted in both the reference and the renewable energy scenario representing respectively 92.5% and 73.4% of the 100 year Global Warming Potential in 2050[18].

18 *By default the LEAP modelling software uses the most up-to-date global warming potential (GWP) factors recommended by the IPCC. The GWP value of a given greenhouse gas is a measure of the amount of heat a certain mass gas traps in the atmosphere over a specific time horizon relative to the amount that would be trapped by a corresponding mass of carbon dioxide. It is thus a unit free factor. For example, the GWP 100 of Methane is 25 (IPCC 2007).*

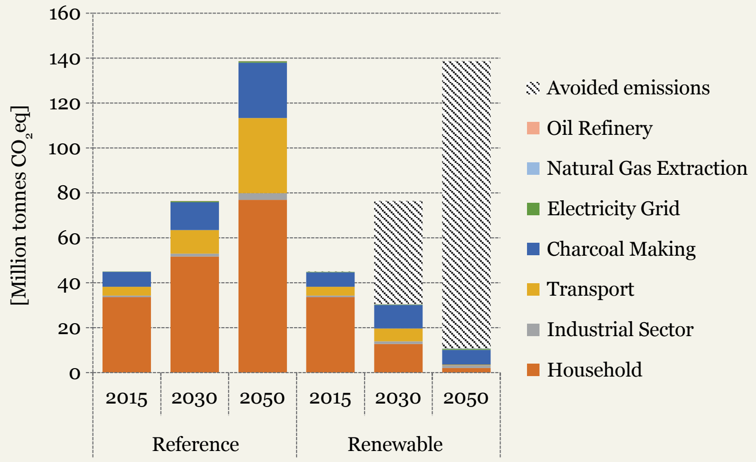


Figure 35: Emissions of greenhouse gases – renewable energy scenario and reference energy scenario

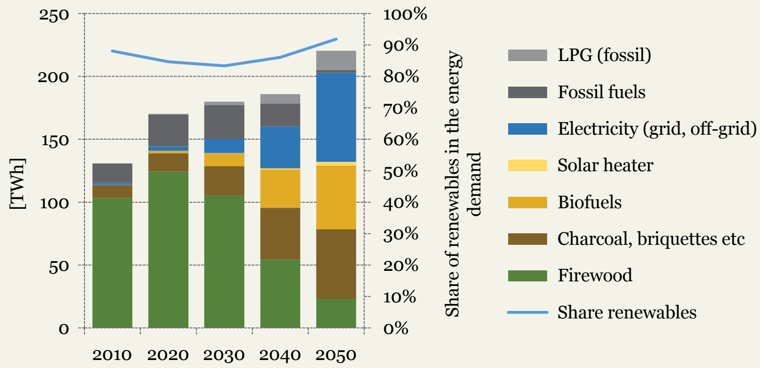


Figure 36: Energy demand in Uganda (bars) and the share of renewables in the energy system (line) – renewable energy scenario

The main emission sectors vary from one scenario to the next. In the Reference case, high amounts of firewood used in low-efficiency traditional cooking systems makes the household sector the highest emitting part of the Ugandan energy system with respectively 74.6% and 55.5% of emissions in 2010 and 2050. Over time, increased demand for charcoal products and the development of a traditional transportation sector will add to increasing GHG emissions and will come to represent respectively 17.8% and 24.2% of total emissions. Conversely, the renewable energy scenario allows for the introduction of both fuel switching and general improvements in technology efficiencies across all sectors thereby drastically reducing overall emission levels. By preferring a centralised, monitored, high efficiency charcoal production industry this scenario provides higher amounts of charcoal for a net reduction in emissions of

STILL SOLID BIOMASS WILL CONTRIBUTE SIGNIFICANTLY TO THE ENERGY BALANCE OF UGANDA IN 2050

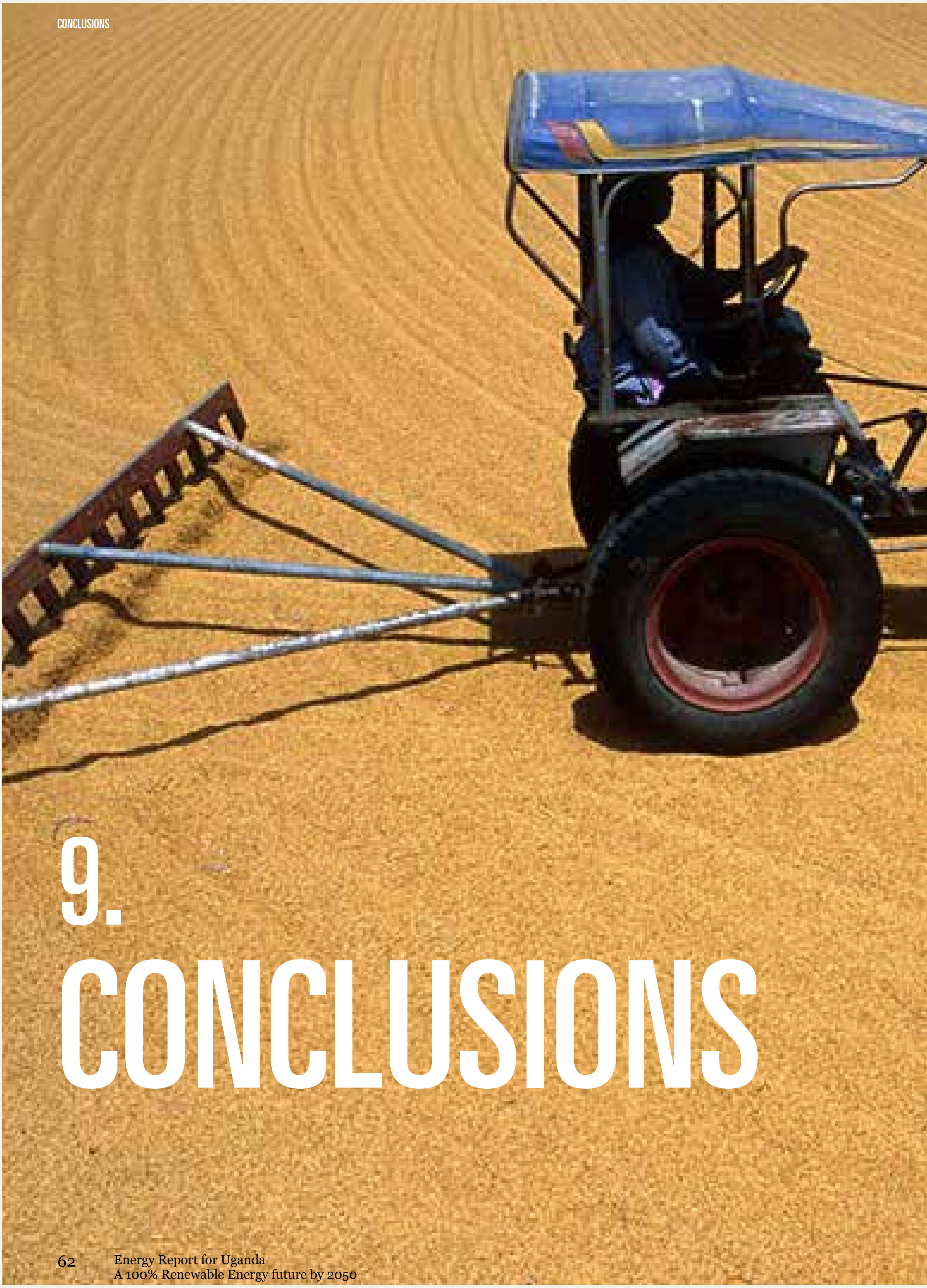
18 Million Tonnes of CO_2 eq in 2050 alone. Correspondingly, emissions from the household sector are all but removed reaching just 3% of 2015 levels.

The share of renewable resources in the scenario will reach 92% by 2050. As a consequence of the need to reduce pressure on forests for biomass there is a reduced share of renewables in the Uganda energy system up to 2040. From 2040 the share of renewables in the Uganda energy system will increase.

The high share of renewables in the energy mix in 2010 is artificial: it is linked to very high shares of cooking energy demand being served by woody biomass using highly inefficient systems. Switching to more diversified cooking systems, some of which use LPG, and using higher efficiency options means that the total energy demand stagnates and that the share of firewood decreases: thus the decrease in renewables. This decrease is also caused by a growing transportation sector initially based on higher shares of fossil based technologies. Over time, the energy system becomes more balanced and renewables are introduced into the centralised electricity generation while sustainable forms of renewables are confirmed in the transportation and household demand sectors.

The 2050 energy system will be based on a larger variety energy sources and also characterized by high level of energy efficient end-use technologies.

Still solid biomass will contribute significantly to the energy balance of Uganda in 2050 but with sources of biomass coming from sustainable sources and many times upgraded to modern bioenergy fuels. The system thus creates a framework that can be maintained and further developed further after 2050.



©Adam Oswell / WWF

9. CONCLUSIONS

OFF-GRID SOLUTIONS WILL BE THE OPTION FOR MANY RURAL AND REMOTE AREAS IN ORDER TO MEET THE 2030 TARGETS

Uganda is in a situation where low access to modern energy services and safe supply of power is affecting the entire society. Further, the dependency on woody biomass to cover cooking demand is a strong driver for deforestation and the current transport system is a growing concern and nuisance to the people due to inefficiency, high accident rates and congestions in cities. The Government of Uganda and other stakeholders in Uganda are working hard to tackle these challenges.

The renewable energy scenario presented in this report depicts a way forward that would help provide modern energy services to people. Not only does this scenario increase supply by expanding the existing system, it also implies a deeper transformation that would bring each piece of the Ugandan energy system to rely on renewable sources while including higher amounts of centralised and efficient technologies thereby making it more resilient.

High efficiency energy transformation, distribution and end-use technologies will have to be phased in and eventually replace much of the existing system. In addition the whole energy sector, including biomass, needs to be brought into the formal sector to reduce environmental degradation and deforestation. This change would also represent new sources of revenue for the government.

Obviously this is no simple task – it will take time, money and a strong commitment. The report provides strong evidence that a ‘wait and see’ policy would result in lost opportunities and a further reduction and destruction of valuable environmental and natural resources.
Based on the results from this study there are four priorities that should be given special attention in the short and medium term:

- Modernisation of the solid biomass sector to ensure that biomass becomes a truly renewable and sustainable source. The modelling results show that demand of firewood will continue to increase and plateau around 2025 despite the actions envisioned in the renewable energy scenario. Sourcing of firewood needs to comply with laws and forestry plans. Large users (private and public sector) should be committed to ensuring that the firewood they use is sourced from legal logging. Support to get households to adopt efficient and safe stoves is needed but is expected to take time. Targeting large

consumers such as schools and industries, to make full use of efficient stoves and boilers is a priority. Charcoal is, and is expected to continue being, an attractive fuel to consumers in urban areas. The charcoal sector thus needs to develop from its present state to become an industrial activity where efficient transformation technologies and distribution is used. This would also include becoming a part of the formal sector and complying with environmental legislation and regulations. For charcoal producers, vendors and transportation businesses this will mean large changes as compared to the current situation. It is only by reaching this more industrial stage that charcoal can become a modern energy carrier.
- Expanding the grid-based electricity sector including supply, transformation and distribution systems. There are large potentials in solar PV, hydropower, geothermal and co-generation in the country. In the next 35 years it is expected that total installed generation capacity needs to increase by a factor of 25. The expansion should include high levels of consideration of environmental and social impacts. In addition coordination is needed in order to avoid conflicts of interest (e.g. tourism, water rights, and land rights). Proper frameworks to minimize and mitigate negative impacts need to be put in place and enforced; also support for ensuring effective use of on-grid electricity should be considered. This, for example, may mean supporting the use of efficient end-use technologies and alternative solutions such as solar water heaters to ensure that electricity demand not exceed generation capacity.
- Encouraging the development of off-grid electricity infrastructure. On- and off-grid solutions need to go hand in hand. Off-grid solutions will be the option for many rural and remote areas in order to meet the 2030 targets. Support will have to continue for pico- and distributed generation systems, including mini-grids. Off-grid needs to be part of the mainstream options for rural electrification. At present the off-grid expansion currently taking place, especially the market driven expansion, is not covered in national statistics even though bringing electricity services to a large number of people.
- The transport sector is growing and action is needed to further stimulate public transport and efficient goods transportation. High numbers of private vehicles and boda-bodas should be avoided as they will congest traffic in urban areas affect both private and public transport. Planning of road system, new building areas and transport system needs to go hand in hand. Fossil fuels should be phased out in favour of biofuels and this new sector needs to be established in the medium time scale.

The good news is that promising actions are being made by the government, as well as by private actors and other stakeholders, in order to support these priorities. Plans are in place that outline action in the directions indicated above. Support is given to relevant programs and projects. The results from the modelling show however that much more has to be done. Actions need to be implemented on a broad scale to have any major impact on the national energy system.

The suggested scenario would require substantial capital investments, as well as political will and commitment from large stakeholders, in order to be realised. Positive impacts would include the creation of new income opportunities and livelihoods, as well as avoiding environmental degradation and stopping deforestation. Added benefits such as reduced risks of exposure to harmful pollutants from cooking, as well as reduced risk of accident in transportation sector are also foreseen.

For policy makers one of the challenges is that many needed changes in the energy system will affect peoples' livelihoods (e.g. boda-boda drivers, charcoal makers, fuel vendors and transporters) and could become a source of potential opposition. Still - any changes need to be carefully planned and in order for it to happen, policy makers need to seek and get acceptance for the proposed action among the public. But moving towards a renewable and more sustainable energy system is a road to prepare, and ensure that Uganda will have a safe and reliable energy supply also in the future. The Energy report Uganda has taken its point of departure in existing technologies. The challenges to popularise and make people adopt these new technologies should not be underestimated. At the same time – if new solutions are experienced as more attractive and better options than the previous ones, things can, and will, change.

10. REFERENCES

Adam, J. C. (2009). "Improved and more environmentally friendly charcoal production system using a low-cost retort–kiln (Eco-charcoal)." Renewable Energy 34(8): 1923-1925.

Agar, D., J. Gil, D. Sanchez, I. Echeverria and M. Wihersaari (2015). "Torrefied versus conventional pellet production – A comparative study on energy and emission balance based on pilot-plant data and EU sustainability criteria." Applied Energy 138: 621-630.

Alstone, P., D. Gershenson, N. Turman-Bryant, D. M. Kammen and A. Jacobson (2015). Off-grid Power and Connectivity. Pay-as-you-go Financing and Digital Supply Chain for Pico-Solar, Lighting Global Market Research Report, Lighting Global, the World Bank Group, Washington, USA, May 18, 2015, pp 41.

ARC (2011). Test Results of Cook Stove Performance, Aprovecho Research Center (ARC), Partnership for Clean Indoor Air (PCIA), Shell Foundation, and US Environmental Protection Agency (EPA), Cottage Grove, USA, pp 128. http://www.aprovecho.org.

Asimwe, D. (2015). Cassava growers in Uganda find market at ethanol plant. East African. Nairobi, Kenya, Nation Media Group Limited, Saturday, March 14.

Bahati, G. (2012). Geothermal Energy Development in Uganda: A Country Update 2012. African Rift Geothermal Conference, Nairobi, Kenya.

Basu, A., C. Blodgett, N. Müller and A. Soezer (2013). Nationally Appropriate Mitigation Action Study on Sustainable Charcoal in Uganda, United Nations Development Programme (UNDP), New York, USA, pp 88.

Cervigni, R., R. Liden, J. E. Neumann and K. M. Strzepek, Eds. (2015). Enhancing the Climate Resilience of Africa's Infrastructure. The Power and Water Sectors. Africa Development Forum Series. Washington, USA, The World Bank.

Chandler, W., C. Shiping, H. Gwin, L. Ruosida and W. Yanjia (2014). China's Future Generation. Assessing the Maximum Potential for Renewable Power Sources in China to 2050, WWF, Gland, Switzerland, February, pp 70.

Chen, W.-H., K.-M. Lu and C.-M. Tsai (2012). "An experimental analysis on property and structure variations of agricultural wastes undergoing torrefaction." Applied Energy 100: 318-325.

Chen, W.-H., J. Peng and X. T. Bi (2015). "A state-of-the-art review of biomass torrefaction, densification and applications." Renewable and Sustainable Energy Reviews 44: 847-866.

Chidumayo, E. N. and D. J. Gumbo (2013). "The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis." Energy for Sustainable Development 17(2): 86-94.

Connolly, D., H. Lund, B. V. Mathiesen and M. Leahy (2010). "A review of computer tools for analysing the integration of renewable energy into various energy systems." Applied Energy 87(4): 1059-1082.

CPCS (2009). East African Railways Master Plan Study, Final Report, CPCS Transcom International for the East African Community, Bridgetown, Barbados, January, pp 68.

Da Silva, I. P., K. Bechtfl and P. Mugisha (2010). Prospects and Promotional Initiatives for Renewable Energy Technolgies in Uganda, Unpublished paper, Faculty of Technology, Makerere University, Kampala, Uganda, pp 12.

Denruyter, J.-P., P. Roberntz, H. Sosovele, I. Randriantiana, L. Máthé and K. Ogorzalek (2010). Bioenergy in Africa – Time for a Shift? Sud Sciences & Technologies. Ouagadougou, Burkina Faso, Institut International d'Ingéniereie de l'Eau at de l'Environnement: 145-158.

van der Plas, R. J., S. Sepp, M. Pigaht, A. Malalane, S. Mann and G. Madon (2012). Mozambique Biomass Energy Strategy, Republic of Mozambique, December, pp 171. http://www.euei-pdf.org/country-studies/biomass-energy-strategy-best-mozambique.

Domac, J. and M. Trossero (2008). Industrial Charcoal Production, TCP/CRO/3101 (A) Development of a sustainable charcoal industry, North-West Croatia Regional Energy Agency, Zagreb, Croatia, June, pp 33.

Edenhofer, O., R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer and C. von Stechow, Eds. (2011). IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge, United Kingdom and New York, NY, USA., Cambridge University Press.

Energy Sector GIS workinggroup. (2014). "Energy Utilities of Uganda." Last Updated: 11/06/2014. from http://www.gis-uganda.de/Energy-GIS/.

ERA (2012). Guidelines - Uganda Renewable Energy Feed-in Tariff (REFIT). Phase 2, Annual report, Energy Regularatory Authority (ERA), Kampala, Uganda, Revised 15th November, pp 21. http://www.getfit-uganda.org.

ERA (2013). Developments and Investment Opportunities in Renewable Energy Resources in Uganda, Energy Regularatory Authority (ERA), Kampala, Uganda, June, pp 62. www.era.or.ug/.

Fische, F. (2014). Kick-start of the Implementation Phase of the Sustainable Energy for All (SE4All) Initiative in Uganda. Uganda's Action Agenda (AA), European Union Delegation to Uganda, Draft, September, pp 59.

GACC (2012). Uganda Market Assessment. Sector Mapping, Global Alliance for Clean Cookstoves (GACC) and Global Village Energy Partnership (GVEP) International, London, UK, March, pp 70.

GET FiT Uganda (2013). Overview Brief - GET FiT Program Uganda, GET FiT Uganda, Kampala, Uganda, pp 5. http://www.getfit-uganda.org.

GET FiT Uganda (2015). Annual report 2014, Annual report, GET FiT Uganda, Kampala, Uganda, pp 56. http://www.annualreport.getfit-uganda.org/2014/.

Gustavsson, M., E. Särnholm, P. Stigsson and L. Zetterberg (2011). Energy Scenario for Sweden 2050 Based on Renewable Energy Technologies and Sources, Report B2008, IVL Swedish Environment Institute and WWF Sweden, Göteborg and Stockholm, September, pp 100.

Hankins, M. (2009). A Renewable Energy Plan for Mozambique, Justiça Ambiental, Maputo, Mozambique, September, pp 64.

Hankins, M., M. Gustavsson and F. Hinrichs (2012). "Changing Africa's Energy Picture. Keys to Renewable Energy Potential." Renewable Energy World 15(5): 28-32.

Hansen, U. E., M. B. Pedersen and I. Nygaard (2014). Review of Solar PV market development in East Africa, UNEP Risø Centre Working Paper 12, United Nations Environment Programme (UNEP) Risø Centre, Roskilde, Denmark, March, pp 22.

Hansen, U. E., M. B. Pedersen and I. Nygaard (2015). "Review of solar PV policies, interventions and diffusion in East Africa." Renewable and Sustainable Energy Reviews 46: 236-248.

Heltberg, R. (2003). Household Energy Use in Developing Countries. A Multicountry Study 27588, United Nations Development Program (UNDP) and World Bank Energy Sector Management Assistance Programme (ESMAP), New York, USA, October, pp 115.

Hermann, S., A. Miketa and N. Fichaux (2014). Estimating the Renewable Energy Potential in Africa. A GIS-based approach, IRENA-KTH working paper, International Renewable Energy Agency (IRENA), Abu Dahbi, UAE, June, pp 73.

IEA and World Bank (2015). Progress Towards Sustainable Energy 2015, Global Tracking Framework Report, International Energy Agency (IEA) and World Bank - Sustainable Energy for All (SE4All), Washington, USA, pp 332. www.worldbank.org/se4all.

IPCC (1996). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, *The Intergovernmental Panel on Climate Change (IPCC), Hayama, Japan http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html.*

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. H. S. Eggleston, L. Buendia, K. Miwa, T. Ngara and K. Tanabe, Institute for Global Environmental Strategies (IGES), on behalf of the The Intergovernmental Panel on Climate Change (IPCC), Hayama, Japan http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.

IPCC (2007). Climate Change 2007: The Physical Science Basis. Contribution of WG I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller Cambridge University Press, Cambridge, UK.

ITP and IBIS (2010). Pre-Feasibility study for the Development of a long term intergrated Bus rapid transit system for greater Kampala Metropolitan Area, Final Report, ITP and IBIS for the The World Bank, Kampala City Council, Government of Uganda, Kampala, Uganda, May, pp 210.

Jagger, P. and G. Shively (2014). "Land Use Change, Fuel Use and Respiratory Health in Uganda." Energy Policy 67: 713-726.

Jeuland, M. and D. Whittington (2013). Water Resources Planning under Climate Change. A "Real Options" Application to Investment Planning in the Blue Nile, Discussion Paper Series 13-05, Environment for Development (EfD), March, pp 58. http://www.efdinitiative.org.

Jewell, J. (2011). "Ready for nuclear energy?: An assessment of capacities and motivations for launching new national nuclear power programs." Energy Policy 39(3): 1041-1055.

JICA (2010). Project for Master Plan Study on Hydropower Development in the Republic of Uganda, Draft Final Report, Japan International Cooperation Agency (JICA) and Ministry of Energy and Mineral Development (MEMD), Uganda, Kampala, Uganda, December, pp 534.

Khennas, S., S. Coupe and J.-P. Denruyter (2013). Boa Nguvu: An African Sustainable Energy Country, WWF (World Wide Fund for Nature), Brussels, Belgium, May, pp 70.

KRC (2013). A Case Study - Gender and Workload in Biogas Adoption, Uganda, Kabarole Research and Resource Centre (KRC) for Hivos, SNV and HEIFER, Fort Portal, Uganda, June, pp 65.

Lee, L. Y.-T. (2013). "Household energy mix in Uganda." Energy Economics 39: 252-261.

Liu, H., D. Masera and L. Esser, Eds. (2013). World Small Hydropower Development Report 2013. Hangzhou, China International Center on Small Hydro Power, United Nations Industrial Development Organization (UNIDO).

Lumbroso, D. M., G. Woolhouse and L. Jones (2015). "A review of the consideration of climate change in the planning of hydropower schemes in sub-Saharan Africa." Climatic Change.

Lund, H. (2010). Renewable Energy Systems, The Choice and Modeling of 100% Renewable Solutions. London, UK, Elsevier.

M-KOPA (2015). M-KOPA Solar Lights up over 20,000 homes in Uganda, Press release, M-KOPA Solar, Kampala, Uganda, 24 March 2015, pp 2.

MEMD (2012a). Energy Rapid Assessment and Gap Analysis. Uganda, Ministry of Energy and Mineral Development (MEMD), Kampala, Uganda, Final draft, June, pp 63.

MEMD (2012b). Renewable Energy Investment Guide, Ministry of Energy and Mineral Development (MEMD), Kampala, Uganda, May, pp 57.

MEMD (2012c). Rural Electrification Strategy and Plan Covering the Period 2013-2022, Ministry of Energy and Mineral Development (MEMD), The Government of the Republic of Uganda, Kampala, uganda, September, pp 33.

MEMD (2012d). Energy and Minerals Sector Review, Ministry of Energy and Mineral Development, Kampala.

MEMD (2012e). Energy and Mineral Sector Performance Report 2011-2012, Ministry of Energy and Mineral Development (MEMD), Kampala, Uganda, pp 203.

MEMD (2014). 2013 Statistical Abstract, Ministry of Energy and Mineral Development (MEMD), Kampala, Uganda, November, pp 140.

MEMD (2015a). Biomass Energy Strategy (BEST) Uganda, Ministry of Energy and Mineral Development (MEMD), Kampala, Uganda, pp 114.

MEMD (2015b). Uganda's Oil Refinary - an Opportunity for Transformation, PM, Ministry of Energy and Mineral Development (MEMD), Kampala, Uganda, pp 3.

Mercer (2015). Investing in a Time of Climate Change, Mercer with support from UKAid, International Finance Corporation, London, UK, pp 108.

Meyer, S., B. Glaser and P. Quicker (2011). "Technical, economical, and climate-related aspects of biochar production technologies: a literature review." Environ Sci Technol 45(22): 9473-9483.

MFPED (2014). Energy Sector - Annual Budget Monitoring Report Financial Year 2+13/2014, Ministry of Finance, Planning and Economic Development (MFPED), Republic of Uganda, Kampala, Uganda, October, pp 110.

MWE (2013). The National Forest Plan 2011/12 - 2021/22, Ministry of Water and Environment (MWE), Kampala, Uganda, pp 118.

MWLE (2001). The Uganda Forestry Policy, Ministry of Water, Lands and Environment (MWLE), Kampala, Uganda, pp 36.

NEMA (2009). Uganda. Atlas of Our Changing Environment, National Environment Management Authority (NEMA), Republic of Uganda, Kampala, Uganda, pp 220.

NEMA (2010). The Potential of Bio-fuel in Uganda. An Assesment of Land Resources for Bio-fuel Feedstock Suitability, National Environment Management Authority (NEMA), Kampala, Uganda, January, pp 52. www.nemaug.org.

Nerini, F. F., R. Dargaville, M. Howells and M. Bazilian (2015). "Estimating the cost of energy access: The case of the village of Suro Craic in Timor Leste." Energy 79: 385-397.

Neufeldt, H., K. Langford, J. Fuller, I. Miyuki and P. Dobie (2015). From transition fuel to viable energy source: improving sustainability in the sub-Saharan charcoal sector, ICRAF Working Paper No. 196, World Agroforestry Centre., Nairobi, Kenya. www.worldagroforestry.org.

Nilsson, D., S. Bernesson and P.-A. Hansson (2011). "Pellet production from agricultural raw materials – A systems study." Biomass and Bioenergy 35(1): 679-689.

NPA (2007). Uganda Vision 2040, National Planning Authority (NPA), Kampala, Uganda, pp 136. http://npa.ug/wp-content/themes/npatheme/documents/vision2040.pdf.

NPA (2010). National Development Plan (2010/11 - 2014/15), National Planning Authority (NPA), Kampala, Uganda, pp 441. http://www.npa.ug.

NPA (2015). Second National Development Plan (NDPII) 2015/16 - 2019/20, National Planning Authority (NPA), Kampala, Uganda, June, pp 344. http://www.npa.ug.

ODfA. (2015, 19 July, 2015). "Electricity Consumption, Export & Import 1980-2013." from http://uganda.opendataforafrica.org.

OECD (2007). Glossary of Statistical terms, Organisation for Economic Co-operation and Development (OECD), Paris, France, pp 863.

Okello, C., S. Pindozzi, S. Faugno and L. Boccia (2013). "Bioenergy potential of agricultural and forest residues in Uganda." Biomass and Bioenergy 56: 515-525.

Pandey, B., P. S. Subedi, M. Sengendo and I. Monroe (2007). Biogas for a Better Life: An African Initiative. Report on the Feasibility for a National Household Biogas Commercialization Program in Uganda, Final draft report, Winrock International, prepared for the Dutch Ministry of Foreign Affaires, Little Rock, USA, May 29, 2007, pp 122.

Pfenninger, S., A. Hawkes and J. Keirstead (2014). "Energy systems modeling for twenty-first century energy challenges." Renewable and Sustainable Energy Reviews 33: 74-86.

POPSEC (2014). The State of Uganda Population Report 2014, Harnessing Uganda's Demographic Divedend for Socio-Economic Transformation, Population Secretariat (POPSEC), Ministry of Finance, Planning and Economic Development, Kampala, Uganda, pp 75.

PwC (2013). From promise to performance. Africa oil & gas review, Pricewaterhouse Coopers (PwC), Johannesburg, South Africa, June, pp 44. www.pwc.co.za.

REA (2007). The Renewable Energy Policy for Uganda, Rural Electrification Agency

(REA), Republic of Uganda, Kampala, Uganda, pp 128.

Scarlat, N. and J.-F. Dallemand (2011). "Recent developments of biofuels/bioenergy sustainability certification: A global overview." Energy Policy 39: 1630-1645.

Schlamann, I., B. Wieler, M. Fleckenstein, J. Walther-Thoß, N. Haase and L. Mathe (2013). Searching for Sustainability - Comparative Analysis of Certification Schemes for Biomass used for the Production of Biofuels, Final report, WWF Deutschland, Berlin, Germany, 28.11.2013, pp 86.

SE4All (2013). Global tracking framework, ESMAP, World Bank and IEA - Sustainable Energy for All (SE4All), Washington, USA, pp 289. www.worldbank.org/se4all.

SNV (2014). Uganda Country Programme, Country information fact sheet, SNV, Kampala, Uganda, pp 2.

Struhsaker, T. T. (1987). "Forestry issues and conservation in Uganda." Biological Conservation 39(3): 209-234.

Sultana, A., A. Kumar and D. Harfield (2010). "Development of agri-pellet production cost and optimum size." Bioresources technology 101(14): 5609-5621.

Tumwesigye, R., P. Twebaze, N. Makuregye and E. Muyambi (2011). Key issues in Uganda's energy sector. Pro-Biodiversity Conservationists in Uganda (PROBICOU), International Institute for Environment and Development (IIED), London, UK, pp 58.

UBOS (2002). Statistical Abstract 2002, Uganda Bureau of Statistics (UBOS), Kampala, Uganda, pp 237. www.ubos.org.

UBOS (2003). Statistical Abstract 2003, Uganda Bureau of Statistics (UBOS), Kampala, Uganda, September, pp 239. www.ubos.org.

UBOS (2007). Statistical Abstract 2007, Uganda Bureau of Statistics (UBOS), Kampala, Uganda, pp 244. www.ubos.org.

UBOS (2010). Uganda National Household Survey 2009/2010 - socio-economic module, Uganda Bureau of Statistics (UBOS), Kampala, Uganda, Abridged report, November, pp 222. www.ubos.org.

UBOS (2012). Statistical Abstract 2012, Uganda Bureau of Statistics (UBOS), Kampala, Uganda, June, pp 288. www.ubos.org.

UBOS (2013). Statistical Abstract 2013, Uganda Bureau of Statistics (UBOS), Kampala, Uganda, August, pp 264. www.ubos.org.

UBOS (2014a). National Population and Housing Census 2014, Uganda Bureau of Statistics (UBOS), Kampala, Uganda, Revised edition, November, pp 73. www.ubos.org.

UBOS (2014b). Statistical Abstract 2014, Uganda Bureau of Statistics (UBOS), Kampala, Uganda, November, pp 306. www.ubos.org.

UN. (2015). "World Population prospects." Retrieved 16 April, 2015, from http://esa.un.org/unpd/wpp/.

UNRA (2008). National transport master plan, including a transport master plan for Greater Kampala metropolitan area, Uganda National Roads Authority (UNRA), Kampala, Uganda, pp 197.

http://ric-uganda.com/rc/files/1.1-A-master-plan-for-transport-in-Uganda.html.

USAID, ADB, MRC and WWF (2010). Rapid Basin-wide Hydropower Sustainability Assessment Tool (RSAT), United States Agency for International Development (USAID), Asian Development Bank, Mekong River Commission and WWF, USA, September, pp 104.

Welsch, M. (2013). Enhancing the Treatment of Systems Integration in Long-term Energy Models. Department of Energy Technology. Stockholm, Sweden, KTH Royal Institute of Technology. PhD: 329.

WHO (2007). Indoor Air Pollution: National Burden of Disease Estimates WHO/SDE/PHE/07.01 rev, Whold Health Organization (WHO), Geneva, Revised, pp 8.

World Bank (2015). The Growth Challenge: Can Ugandan Cities get to Work? Uganda Economic Update 5th Edition, Report No 94622, The World Bank, Washington, USA, Feb, pp 90.

WWF (2011a). Rivers for Life. The Case for Conservation Priorities in the Face of Water Infrastructure Development, Guide, WWF Deutschland, Berlin, Germany, October, pp 64.

WWF (2011b). Opportunities and Barriers to the Use of Renewable Energy Technologies in Uganda, Report, WWF Uganda Country Office, Kampala, Uganda, pp 64.

WWF (2011c). Hållbar Energi. 100% förnybart på naturens villkor, Rapport, Stiftelsen Världsnaturfonden (WWF), Stockholm, September, pp 20.

WWF (2011d). Palm Oil Buyers' Scorecard 2011: Measuring the Progress of Palm Oil Buyers, Palm Oil Buyers' Scorecard, World Wide Fund for Nature (WWF), Gland, Switzerland, November, pp 45.

WWF (2011e). Forest and Energy, Chapter 2. WWF Living Forest Report. WWF International. Gland, Switzerland: 38.

WWF (2011f). The Energy Report 100% Renewable Energy by 2050. S. Singer, WWF International, EcoFys and Office for Metropolitan Architecture (OMA), Gland, Switzerland, February. http://wwf.panda.org/what_we_do/footprint/climate_carbon_energy/energy_solutions/renewable_energy/sustainable_energy_report/.

WWF (2012). Opportunities and Barriers to the Use of Renewable Energy Technologies in Uganda - fact sheet, Fact sheet, WWF Uganda Country Office, Kampala, Uganda, November, pp 4.

WWF (2013a). Uganda - Electricity Infrastructure Network. Kampala, Uganda, WWF Uganda Country Office in partnership with Republic of Uganda, GRID Arendal and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

WWF (2013b). Electricity overview maps contributing to electricity sustainable electricity development, WWF Uganda Country Office, Kampala, Uganda, pp 6.

WWF (2013c). Forestry Programme 2013-2015, WWF Uganda Country Office, Kampala, Uganda, September, pp 51.

WWF (2014). Global Network Position: Dams, WWF Global Network Position Dams, WWF, November, pp 6. http://d2ouvy59p0dg6k.cloudfront.net/downloads/141205_wwf_dams_position.pdf.

WWF and Teri (2013). The Energy Report - India. 100% Renewable Energy by 2050, WWF - India and Teri, New Delihi, India, pp 109.

WWF and WISE (2013). The Renewable Energy Report - Kerala. 100% Renewable Energy by 2050, WWF India and World INstitute of Sustainable Energy (WISE), New Delhi, India, pp 272.

APPENDICES

DATA TABLES OF INPUTS TO THE MODEL AND TABLE OF THE RESULTS

The appendices are supportive and informative additions to the results presented in the report. The tables give the precise numbers backing the diagram displayed in the scenario section.

A. SHORT INTRODUCTION TO THE LONG-RANGE ENERGY ALTERNATIVES PLANNING SYSTEM (LEAP) MODEL - INFORMATIVE

LEAP, the Long-range Energy Alternatives Planning System, is a widely used medium - to long - term modelling tool for integrated resource planning. It is applied to assess climate change mitigation strategies and analyse energy policies by investigating yearly capacity expansions. The underlying dispatch of technologies is calculated for each user - defined time slice within a year. LEAP is mostly used for comparing various future pathways to reference energy scenarios, from which other diverging scenarios inherit their main assumptions. Geographically, applications span across a wide range, from cities to national, regional and global models. The model enables a consideration of various economic sectors, technologies, costs and emission profiles and comprises the entire energy supply chain, from resource extraction to processing, conversion, delivery and consumption. LEAP includes a Technology and Environmental Database (TED) which lists technology specific cost s and performance data including emission factors. As in other modelling platforms, technology outages are usually considered by de-rating capacities.

While LEAP may calculate energy demands based on top - down macroeconomic assumptions, it is much applied to facilitate technologically detailed representations of energy systems. It may therefore rather be categorised as bottom - up energy model. Previously, it has been described as an accounting framework with elements of a simulation model. In this respect, the order and scale of individual future capacity expansions has to be predefined by the analyst. In this case, all factors determining future development pathways are exogenously specified by the user. As such, the results obtained for different scenarios are not considered optimal, they are the reflection of the pathways defined by the analyst. In this respect, the LEAP model is used to help the user to understand the implications of the pathways he/she designs and to follow its implications for the different parts of the energy system.

LEAP dates back to 1980 and is currently developed by Stockholm Environment Institute. It is applied by over 5,000 users in more than 190 countries. LEAP licences for non-commercial use are freely available for modellers from developing countries. Over 200 publications are listed at its website which refer to LEAP or build on it for their analysis.

This text is adapted from Welsch (2013)

B. TRANSPORT BACKGROUND DATA AND ASSUMPTIONS - INPUT

The transport data used as the starting point in the model is based on data from 2003 which are the most recent and also those that forms the basis in the Transportation master plan (UNRA 2008).

TABLE 11: CALCULATION OF TRANSPORT WORK GOODS WHICH ARE USED AS BASIS IN THE MODEL

ID	VEHICLE TYPE	MILLION VEHICLE KMS*	AVERAGE LOAD (TONNES/VEHICLE KM)*	MILLION TKM
2	Light goods vehicles (inc 4WD)	785.8	0.97	765
5	Trucks (single-unit)	417.8	5.7	2,381
6	Trucks (trailers and articulated)	118.9	5.7	678
	Total transport work - freight			3,824

** Based on information from UNRA (2008)*

TABLE 12: CALCULATION OF TRANSPORT WORK PEOPLE WHICH ARE USED AS BASIS IN THE MODEL

ID		SHARE OF USE*	MILLION VEHICLE KM**	AVERAGE NO OF PEOPLE IN VEHICLE*	PKM
1	Cars and taxis (special hire)		817.4		
	Private cars	35%	286.09	1.8	515
	Taxis	65%	531.31	3.0	1,594
3	Minibuses and taxis ('Kamunye')		752.2	12.0	9,026
4	Buses		59.2	45.0	2,664
7	Motor cycles		804.4		
	Private	30%	241.32	1.1	265
	Boda-boda	70%	563.08	2.0	1,126
	Walking	Unknown - substantial			
	Cycling	Unknown			
	Railway (master plan section 4-21)				0
	Boat traffic (master plan section 4-41)				6
	Total transport work - people				15,197

** The assessment of share of use and average people in vehicle are based on own assessments.*
*** Based on information from UNRA (2008)*

TABLE 13: GROWTH OF TRANSPORT WORK IN UGANDA 2008-2050

PERIOD	PERSON TRANSPORT	GOODS TRANSPORT	SOURCE
2002-2007	8.0%	8.0%	(UNRA 2008)
2008-2013	8.0%	8.0%	(UNRA 2008)
2013-2025	7.0%	7.0%	(UNRA 2008)
2026-2035	6.0%	6.0%	Own assessment
2036-2050	6.0%	6.0%	Own assessment

TABLE 14: TRANSPORT WORK DEMAND IN UGANDA 2003-2050 AND USED IN MODEL

YEAR	TOTAL PERSON TRANSPORT (MILLION PKM)	TOTAL GOODS (MILLION TONNE KM)
2003	15,197	3,824
2008	22,329	5,619
2010	26,045	6,554
2013	32,809	8,256
2020	52,684	13,257
2025	73,892	18,593
2030	98,884	24,882
2035	132,329	33,298
2040	177,087	44,560
2050	317,135	79,801

C. ENERGY SUPPLY IN RENEWABLE ENERGY SCENARIO - RESULTS

TABLE 15: RENEWABLE ENERGY SCENARIO - RESOURCES: PRIMARY REQUIREMENTS RESOURCES (TWH)

FUELS	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	-	-	-	-	-	-	-	1.20	24.42
Natural Gas	-	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Gasoline	5.24	6.77	1.10	-6.15	-23.1	-24.6	-26.2	-27.3	-30.7
Jet Kerosene	-	-	-2.84	-5.88	-11.7	-11.7	-11.7	-11.7	-11.7
Kerosene	1.32	1.53	1.34	1.00	0.07	0.05	0.02	0.00	-
Diesel	7.53	10.69	10.23	9.19	2.36	1.99	-2.36	-7.31	-13.2
Residual Fuel Oil	1.31	1.54	0.97	0.30	-1.37	-1.85	-2.28	-2.71	-2.01
LPG	0.22	0.31	-0.20	0.12	-0.22	1.96	4.41	8.19	12.48
Crude Oil	-	-	18.50	38.28	76.56	76.56	76.56	76.56	76.56
Peat	-	-	-	-	-	-	0.07	0.13	0.26
Wood	296.2	329.5	367.7	366.0	319.1	239.3	174.7	123.4	96.04
Biogas	0.11	-	-	-	-	-	-	-	-
Ethanol	-	0.02	0.92	2.10	3.76	5.97	9.19	13.95	17.20
Animal Wastes	-	0.85	3.56	9.38	10.79	11.97	11.73	12.04	11.15
Vegetal Wastes	1.89	2.08	1.55	1.32	0.56	2.90	5.49	9.30	11.00
Bagasse	-	-	0.03	0.03	0.05	0.12	0.36	1.12	2.37
Wind	-	-	-	0.50	0.50	0.50	0.50	0.50	0.50
Solar	-	0.31	11.05	17.90	28.58	31.12	54.59	94.80	115.1
Hydro	2.48	2.59	1.77	3.34	5.95	13.81	19.27	19.27	19.27
Geothermal	-	-	-	-	-	-	0.63	3.38	3.94
Municipal Solid Waste	-	-	-	-	-	-	0.03	0.03	0.04
Bitumen	-	-	-0.25	-0.51	-1.03	-1.03	-1.03	-1.03	-1.03
Petroleum Coke	-	-	-1.12	-2.32	-4.65	-4.65	-4.65	-4.65	-4.65
Lubricants	-	-	-0.27	-0.55	-1.10	-1.10	-1.10	-1.10	-1.10
Biodiesel	-	-	0.22	1.17	4.40	11.06	18.86	25.03	31.00
Electricity Off-Grid	0.04	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.01
Total	**316.4**	**357.0**	**415.0**	**436.0**	**410.2**	**353.0**	**327.8**	**333.7**	**357.6**

TABLE 16: RENEWABLE ENERGY SCENARIO - ON-GRID ELECTRICITY ORIGIN BY GENERATION SOURCE (TWH)

FUELS	2010	2015	2020	2025	2030	2035	2040	2045	2050
Natural Gas	-	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Diesel	-	-	-	-	-	-	-	-	-
Residual Fuel Oil	-	-	-	-	-	-	-	0.15	0.39
Peat	-	-	-	-	-	-	0.03	0.05	0.11
Bagasse	-	-	0.01	0.01	0.02	0.05	0.15	0.45	0.95
Wind	-	-	-	0.13	0.13	0.13	0.13	0.13	0.13
Solar	-	-	1.91	3.36	5.88	7.03	13.97	26.98	32.76
Hydro	2.34	2.44	1.55	2.98	5.44	12.93	20.56	22.52	25.95
Geothermal	-	-	-	-	-	-	0.25	1.35	3.15
Municipal Solid Waste	-	-	-	-	-	-	0.06	0.32	0.74
Total	**2.34**	**2.76**	**3.80**	**6.80**	**11.79**	**20.47**	**35.47**	**52.28**	**64.50**

D. DEMANDS IN THE RENEWABLE ENERGY SCENARIO BY SECTORS – RESULTS

TABLE 17: RENEWABLE ENERGY SCENARIO – TOTAL ENERGY DEMAND BY SECTOR (TWH)

BRANCHES	2010	2015	2020	2025	2030	2035	2040	2045	2050
Household	81.82	87.50	96.08	97.69	86.07	78.26	71.41	72.33	78.91
Commercial	20.06	23.37	26.26	29.16	30.77	30.72	30.88	31.04	31.28
Transport	10.81	15.04	20.70	26.44	31.42	40.19	49.11	59.09	65.91
Industrial Sector	18.26	23.03	27.23	31.06	31.71	31.25	34.56	38.46	44.35
Total	**130.95**	**148.94**	**170.26**	**184.36**	**179.98**	**180.42**	**185.96**	**200.92**	**220.46**

TABLE 18: RENEWABLE ENERGY SCENARIO – DEMAND BY HOUSEHOLD CATEGORY (TWH)

BRANCHES	2010	2015	2020	2025	2030	2035	2040	2045	2050
Kampala	0.69	1.29	2.11	3.16	4.33	6.33	8.88	12.17	15.76
Other urban	2.11	3.71	4.45	4.78	5.28	8.13	11.82	16.74	21.72
Informal Settlements	1.90	1.76	1.67	1.48	1.17	0.88	0.61	0.33	0.00
Rural	77.11	80.74	87.85	88.27	75.29	62.92	50.09	43.09	41.44
Total	**81.82**	**87.50**	**96.08**	**97.69**	**86.07**	**78.26**	**71.41**	**72.33**	**78.91**

** Informal settlements is a sub-category to the Kampala and Other Urban categories. Informal settlements are no longer found in 2050.*

TABLE 19: RENEWABLE ENERGY SCENARIO – DEMAND BY COMMERCIAL SECTOR AND DEMAND SPECIFICATION (TWH)

BRANCHES	2010	2020	2030	2040	2050
Hotels_Restaurant\Appliance	0.01	0.02	0.04	0.06	0.10
Hotels_Restaurant\Cooking	4.09	5.77	7.45	8.34	8.19
Hotels_Restaurant\HVAC	0.00	0.01	0.01	0.01	0.01
Hotels_Restaurant\Lighting_	0.15	0.17	0.24	0.53	1.16
Institution Buildings\Appliance	0.03	0.06	0.12	0.23	0.40
Institution Buildings\Cooking	15.56	19.99	22.52	20.83	19.97
Institution Buildings\HVAC	0.00	0.01	0.01	0.01	0.01
Institution Buildings\Lighting	0.20	0.23	0.39	0.86	1.44
Total	**20.06**	**26.26**	**30.77**	**30.88**	**31.28**

TABLE 20: RENEWABLE ENERGY SCENARIO – DEMAND BY INDUSTRY SECTOR AND TYPE OF DEMAND (TWH)

BRANCHES	2010	2020	2030	2040	2050
Agricultural\Biodiesel	0.00	0.00	0.13	0.71	1.79
Agricultural\Tractors Diesel	0.62	0.79	1.01	0.83	0.00
Appliances\Efficient Appliances	0.00	0.02	0.13	0.48	1.01
Appliances\Standard Appliances	0.10	0.15	0.20	0.11	0.00
Electricity Generation\Diesel Generators	1.35	1.81	1.21	0.52	0.00
Electricity Generation\Efficient Diesel Generators	0.00	0.23	0.91	1.07	1.24
Electricity Generation\Ethanol Generator	0.00	0.18	0.74	2.36	3.74
Heating\Agric Waste Biolers	1.08	0.98	0.54	0.11	0.00
Heating\Electric Bioler	0.05	0.09	0.96	1.76	0.00
Heating\Fuel Oil Boilers	1.31	1.54	0.78	0.00	0.00
Heating\Furnace_LPG	0.01	0.06	1.10	1.28	0.00
Heating\Improved Agric Waste	0.00	0.00	0.02	0.03	0.03
Heating\Improved Residual Fuel Oil	0.00	0.18	0.98	0.86	0.00
Heating\Improved furnance LPG	0.00	0.00	0.29	2.38	6.00
Heating\Improved wood boilers	0.00	1.24	10.81	13.57	11.73
Heating\Wood Boilers	12.98	18.59	9.04	0.00	0.00
Heating\improved electric biolers	0.00	0.00	0.26	3.28	8.84
Lighting\Fluoroscent lamp	0.02	0.03	0.06	0.10	0.16
Lighting\Halogen Lamp	0.00	0.00	0.01	0.00	0.00
Lighting\High Pressure Discharge Lamp	0.00	0.00	0.00	0.00	0.00
Lighting\Incadecent bulb	0.01	0.02	0.00	0.00	0.00
Lighting\LED	0.00	0.00	0.01	0.03	0.07
Lighting\Low Pressure Sodium Lamp	0.00	0.00	0.00	0.00	0.00
Lighting\Mercury Vapour Lamps	0.00	0.00	0.00	0.00	0.00
Machines\Efficient motors	0.00	0.11	0.88	3.88	9.75
Machines\Standard Motors	0.73	1.20	1.65	1.21	0.00
Total	**18.26**	**27.23**	**31.71**	**34.56**	**44.35**

E. DEMANDS IN THE RENEWABLE ENERGY SCENARIO BY FUEL – RESULTS

TABLE 21: RENEWABLE ENERGY SCENARIO – TOTAL ENERGY DEMAND BY FUEL (TWH)

FUELS	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	1.63	2.18	3.23	5.99	10.49	18.42	32.46	49.47	69.25
Gasoline	5.24	6.77	8.61	9.41	7.95	6.48	4.89	3.74	0.39
Kerosene	1.32	1.53	1.34	1.00	0.07	0.05	0.02	0.00	-
Diesel	7.53	10.69	13.87	16.72	17.41	17.03	12.68	7.74	1.84
Residual Fuel Oil	1.31	1.54	1.72	1.86	1.76	1.29	0.86	-	-
LPG	0.22	0.31	0.51	1.59	2.72	4.90	7.34	11.12	15.42
Carbonised Pellets	-	-	-	-	-	4.47	9.63	16.67	19.74
Charcoal	8.15	9.78	12.97	16.65	22.90	25.97	27.00	28.78	27.22
Charcoal Briquettes	-	-	-	-	-	1.02	4.37	6.27	8.51
Biogas	0.11	0.17	0.71	1.88	2.16	2.39	2.35	2.41	2.23
Ethanol	-	0.02	0.92	2.10	3.76	5.97	9.19	13.95	17.20
Vegetal Wastes	1.89	2.08	1.55	1.32	0.56	0.42	0.14	0.04	0.03
Solar	-	0.00	0.00	0.01	0.12	0.46	0.99	1.84	3.16
Biodiesel	-	-	0.22	1.17	4.40	11.06	18.86	25.03	31.00
Electricity Off-Grid	0.04	0.04	0.10	0.20	0.36	0.27	0.26	0.23	0.21
Electricity Mini-grid	0.01	0.01	0.11	0.18	0.25	0.36	0.57	0.89	1.28
Firewood	103.5	113.8	124.4	124.3	105.1	79.86	54.36	32.72	22.98
Total	**130.9**	**148.9**	**170.3**	**184.4**	**180.0**	**180.4**	**186.0**	**200.9**	**220.5**

TABLE 22: RENEWABLE ENERGY SCENARIO – DEMAND IN HOUSEHOLD SECTORS BY FUEL (TWH)

FUELS	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	0.37	0.63	1.05	1.96	3.34	5.85	10.00	15.43	22.11
Kerosene	1.21	1.39	1.25	0.91	-	-	-	-	-
LPG	0.21	0.30	0.44	0.70	1.05	1.83	3.07	5.19	8.12
Carbonised Pellets	-	-	-	-	-	4.47	9.63	16.67	19.74
Charcoal	4.70	5.69	8.39	11.25	15.70	17.30	16.86	16.29	12.38
Charcoal Briquettes	-	-	-	-	-	1.02	4.37	6.27	8.51
Biogas	0.11	0.17	0.71	1.88	2.16	2.39	2.35	2.41	2.23
Ethanol	-	-	-	0.05	0.14	0.29	0.50	0.79	1.18
Vegetal Wastes	0.80	0.82	0.58	0.28	-	-	-	-	-
Solar	-	0.00	0.00	0.01	0.12	0.46	0.99	1.84	3.16
Electricity Off-Grid*	0.04	0.04	0.10	0.20	0.36	0.27	0.26	0.23	0.21
Electricity Mini-Grid**	0.01	0.01	0.11	0.18	0.25	0.36	0.57	0.89	1.28
Firewood	74.36	78.44	83.45	80.27	62.96	44.02	22.81	6.31	-
Total	**81.82**	**87.50**	**96.08**	**97.69**	**86.07**	**78.26**	**71.41**	**72.33**	**78.91**

** Electricity off-grid is solar PV systems*
*** Electricity mini-grids can be mini-hydro, PV or combinations*

TABLE 23: RENEWABLE ENERGY SCENARIO – DEMAND IN RURAL HOUSEHOLD SECTORS BY FUEL (TWH)

FUELS	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	-	-	0.04	0.13	0.31	0.78	1.81	3.15	4.89
Kerosene	0.92	0.98	0.85	0.67	-	-	-	-	-
LPG	0.10	0.11	0.13	0.15	0.18	0.32	0.71	1.65	3.12
Carbonised Pellets	-	-	-	-	-	2.83	6.46	11.27	13.09
Charcoal	2.06	2.16	3.64	5.52	9.57	11.73	12.41	13.46	11.86
Charcoal Briquettes	-	-	-	-	-	0.76	3.36	4.56	5.87
Biogas	0.11	0.15	0.61	1.69	1.91	2.14	2.13	2.25	2.15
Vegetal Wastes	0.80	0.82	0.58	0.28	-	-	-	-	-
Solar	-	-	0.00	0.00	0.01	0.01	0.03	0.04	0.06
Electricity Off-Grid*	0.03	0.03	0.08	0.16	0.32	0.23	0.22	0.20	0.18
Electricity Mini-Grid**	0.01	0.01	0.08	0.13	0.15	0.14	0.18	0.21	0.23
Firewood	73.06	76.47	81.84	79.53	62.85	43.97	22.79	6.30	-
Total	**77.11**	**80.74**	**87.85**	**88.27**	**75.29**	**62.92**	**50.09**	**43.09**	**41.44**

** Electricity off-grid is solar PV systems*

*** Electricity mini-grids can be mini-hydro, PV or combinations*

TABLE 24: RENEWABLE ENERGY SCENARIO – DEMAND IN KAMPALA HOUSEHOLDS BY FUEL (TWH)

FUELS	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	0.23	0.42	0.71	1.26	1.99	2.87	4.09	5.82	7.95
Kerosene	0.04	0.09	0.10	0.07	-	-	-	-	-
LPG	0.04	0.07	0.13	0.25	0.43	0.67	0.99	1.41	1.95
Carbonised Pellets	-	-	-	-	-	0.62	1.24	2.14	2.71
Charcoal	0.34	0.64	1.09	1.52	1.81	1.74	1.51	0.91	-
Charcoal Bri-quettes	-	-	-	-	-	0.10	0.39	0.68	1.08
Biogas	-	-	-	-	-	-	-	-	-
Ethanol	-	-	-	-	0.01	0.02	0.06	0.13	0.25
Solar heater	-	-	-	-	0.07	0.28	0.58	1.06	1.80
Electricity Off-Grid*	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.03	0.02
Firewood	0.05	0.07	0.07	0.05	-	-	-	-	-
Total	**0.69**	**1.29**	**2.11**	**3.16**	**4.33**	**6.33**	**8.88**	**12.17**	**15.76**

** Electricity off-grid is solar PV systems*

TABLE 25: RENEWABLE ENERGY SCENARIO – DEMAND IN INDUSTRY SECTOR BY FUEL (TWH)

FUELS	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	0.91	1.20	1.63	2.75	4.15	6.48	10.85	15.43	19.82
Diesel	1.97	2.45	2.82	3.02	3.14	2.89	2.42	1.68	1.24
Residual Fuel Oil	1.31	1.54	1.72	1.86	1.76	1.29	0.86	-	-
LPG	0.01	0.02	0.06	0.77	1.39	2.62	3.66	4.98	6.00
Ethanol	-	-	0.18	0.42	0.74	1.46	2.36	3.39	3.74
Vegetal Wastes	1.08	1.26	0.98	1.04	0.56	0.42	0.14	0.04	0.03
Biodiesel	-	-	-	0.02	0.13	0.37	0.71	1.16	1.79
Firewood	12.98	16.57	19.83	21.17	19.85	15.71	13.57	11.80	11.73
Total	**18.26**	**23.03**	**27.23**	**31.06**	**31.71**	**31.25**	**34.56**	**38.46**	**44.35**

TABLE 26: RENEWABLE ENERGY SCENARIO – DEMAND IN COMMERCIAL AND INSTITUTIONAL SECTOR BY FUEL (TWH)

FUELS	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	0.36	0.34	0.46	0.70	0.96	1.43	2.13	2.97	3.89
Kerosene	0.12	0.14	0.09	0.09	0.07	0.05	0.02	0.00	-
LPG	0.00	0.00	0.00	0.12	0.27	0.44	0.61	0.96	1.30
Charcoal	3.45	4.08	4.58	5.41	7.20	8.67	10.14	12.49	14.84
Firewood	16.13	18.81	21.12	22.85	22.27	20.12	17.98	14.62	11.26
Total	**20.06**	**23.37**	**26.26**	**29.16**	**30.77**	**30.72**	**30.88**	**31.04**	**31.28**

TABLE 27: RENEWABLE ENERGY SCENARIO – DEMAND IN TRANSPORT SECTOR BY FUEL (TWH)

FUELS	2010	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	-	0.01	0.08	0.57	2.04	4.66	9.48	15.63	23.43
Gasoline	5.24	6.77	8.61	9.41	7.95	6.48	4.89	3.74	0.39
Diesel	5.56	8.24	11.05	13.69	14.27	14.14	10.26	6.06	0.60
Ethanol	-	0.02	0.74	1.62	2.89	4.22	6.33	9.77	12.28
Biodiesel	-	-	0.22	1.15	4.28	10.68	18.15	23.88	29.22
Total	**10.81**	**15.04**	**20.70**	**26.44**	**31.42**	**40.19**	**49.11**	**59.09**	**65.91**

F. ONE HUNDRED YEAR GLOBAL WARMING POTENTIAL – RESULTS

Note: The table below shows the CO_2eq measurement of all emissions in the model - per fuel consumed. Emission factors associated with the different sources and technologies are those included in the Technology and Environmental Database (TED) linked and maintained as part of the LEAP software. The emissions factors referenced in the TED database are from IPCC and other renowned institutions.

TABLE 28: RENEWABLE ENERGY SCENARIO – ONE HUNDRED YEAR GLOBAL WARMING POTENTIAL (MILLION TONNES OF CO_2EQ)

FUELS	2010	2015	2020	2025	2030	2035	2040	2045	2050
Natural Gas	-	0.15	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Gasoline	1.31	1.69	2.15	2.34	1.97	1.61	1.21	0.93	0.10
Kerosene	0.32	0.37	0.33	0.24	-	-	-	-	-
Diesel	1.64	2.36	3.13	3.86	4.03	3.99	2.93	1.74	0.16
Residual Fuel Oil	0.34	0.40	0.45	0.47	0.44	0.30	0.20	0.11	0.30
LPG	0.04	0.06	0.10	0.30	0.49	0.90	1.36	2.05	2.84
Crude Oil	-	-	0.02	0.05	0.09	0.09	0.09	0.09	0.09
Peat	-	-	-	-	-	-	0.02	0.04	0.09
Wood	5.44	6.52	8.20	9.54	10.52	9.11	8.53	8.09	6.51
Charcoal	0.08	0.10	0.15	0.20	0.28	0.31	0.30	0.29	0.22
Charcoal Briquettes	-	-	-	-	-	0.02	0.08	0.11	0.15
Vegetal Wastes	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Bagasse	-	-	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Firewood	31.38	33.15	32.69	25.88	12.39	3.36	0.81	0.07	0.07
Total	**40.55**	**44.81**	**47.53**	**43.19**	**30.53**	**20.00**	**15.83**	**13.85**	**10.85**

TABLE 29: EMISSIONS OF NON-BIOGENIC CARBON DEMAND SECTOR, AND TRANSFORMATION SECTOR (MILLION TONNE OF CO_2)

BRANCHES	2010	2020	2030	2040	2050
Demand\Household	31.73	33.12	12.75	1.72	2.00
Demand\Industrial Sector	0.60	0.81	1.11	1.24	1.28
Demand\Transport	2.78	5.07	5.74	3.92	0.26
Transformation\Charcoal Making	5.44	8.20	10.52	8.53	6.51
Transformation\Electricity Grid	-	0.15	0.15	0.17	0.55
Transformation\Natural Gas Extraction	-	0.17	0.17	0.17	0.17
Transformation\Oil Refinery	-	0.02	0.09	0.09	0.09
Total	**40.55**	**47.53**	**30.53**	**15.83**	**10.85**

G. COSTS ASSOCIATED WITH THE RENEWABLE ENERGY SCENARIO AND REFERENCE ENERGY SCENARIO – PER COST CATEGORY

TABLE 30: ASSOCIATED SOCIAL COSTS – REFERENCE ENERGY SCENARIO (BILLION USD)

COST CATEGORIES	2010	2020	2030	2040	2050
Capital cost		0.08	0.08	0.08	0.05
Operations and maintenance	0.10	0.23	0.47	0.82	1.44
Fuel Production	1.13	1.13	1.13	1.13	1.13
Environmental Externalities			1.78	4.03	6.42
Unsustainable Wood	2.82	4.35	6.67	9.47	12.46
Electricity Imports	0.00	0.00	0.31	2.07	5.17
Total	**4.0**	**5.8**	**10.4**	**17.6**	**26.7**

TABLE 31: ASSOCIATED SOCIAL COSTS, INCLUDING AVOIDED COSTS - RENEWABLE ENERGY SCENARIO (BILLION USD)

COST CATEGORIES	2010	2020	2030	2040	2050
Capital cost		0.39	0.93	1.36	2.22
Operations and maintenance	0.10	0.22	0.71	2.19	5.36
Fuel Production	1.13	1.13	1.13	1.13	0.94
Environmental Externalities			0.65	0.51	0.40
Unsustainable Wood	2.82	3.94	3.18	0.93	
Electricity Imports	0.00	0.00	0.00	0.00	5.37
Total	4.0	5.7	6.6	6.1	14.3
Avoided costs*	0.0	0.1	3.8	11.5	12.4

** difference between the sum of all costs in the Reference energy scenario and the Renewable energy scenario*

H. NET PRESENT VALUE – COMPARISON OF REFERENCE AND RENEWABLE ENERGY SCENARIO – RESULTS

TABLE 32: NET PRESENT VALUE - COMPARISON REFERENCE AND RENEWABLE ENERGY SCENARIO

	REFERENCE	RENEWABLE	COMMENTS
Demand	-	-	There are no system costs (i.e. use costs or technology costs) defined in the demand sector. Therefore there are no costs in the NPV calculation for this section. This part is paid more by the consumer than by the system operator.
Household	-	-	
Commercial	-	-	
Transport	-	-	
Industrial Sector	-	-	
Transformation	6.12	17.32	The transformation sector contains mainly costs related to the electricity generation sector. There are no extra investment costs taken into account in the charcoal making for example as data was difficult to come by. Was subject to some assessment in the charcoal NAMA study.
Pelletisation	-	-	
Briquetting	-	-	
Charcoal Making	-	-	
Wood Harvesting	-	-	
Transmission and Distribution	4.29	7.74	This section is more expensive in the Renewable energy scenario because of the development of a stronger centralised electricity generation system.
Electricity Grid	1.74	9.32	
Electricity Mini Grid	0.10	0.25	
Electricity Off Grid			
Oil Refinery	-	-	
Natural Gas Extraction	-	-	
Biogas Digester	-	-	
Resources	105.40	65.69	This takes into account all extraction costs for fuel resources as well as import and export costs and benefits.
Production	17.55	17.51	Improvements could include adding the sales price for commodities produced by the refineries that are not used in the country.
Imports	87.85	48.18	This shows however that high levels of wood imports in the reference energy scenario are slashed in the renewable case.
Exports	-	-	
Unmet Requirements	-	12.29	
Environmental Externalities	15.29	3.01	This represents the total cost of all emissions in the model over the entire period between the two scenarios.
Net Present Value	**126.82**	**86.01**	Overall, the NPV of the renewable energy scenario is markedly lower: i.e. if you had to pay upfront today to make one scenario happen, the renewable energy scenario would be your best bet. This remains true even if you remove the CO_2 financing.
GHG Emissions (Mill Tonnes CO2e)	3,301	1,233	

I. HOUSEHOLD DEMANDS AND CATEGORISATION – INPUT

Note: the following tables gives the assumptions and starting points in the assessment and operationalisation of the household energy demand. It also gives the end-point in 2050 and the distribution of households in the different Tiers.

Note: the technologies in the tier will change over time. For example in tier 1 in 2010 three stone stoves are commonly found, but these have been phased out in the renewable energy scenario by 2030 and are thus not found in tier 1 in 2050. Another example is that Tier 1 households have off-grid electricity generation in 2050, while this is not the case in 2010.

TABLE 33: DIVISION OF HOUSEHOLDS ON DIFFERENT TIER 2010 (CHECKED AGAINST CENSUS 2010)

CURRENT (2010)		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5	
	Class	**Rural, Peri-Urban very poor**	**Rural, Peri Urban, Poor**	**Rural, Peri-Urban**	**Urban, Peri-urban, Kampala**	**Urban, Kampala**	**Kampala**	**Total**
Current share (2010)	**Est. % of pop.**	**10%**	**45%**	**37%**	**5%**	**3%**	**1%**	**100%**
	Peri Urban - Kampala	4%	4%	2%	1%			3.0%
	Peri Urban - Other	4%	4%	4%	1%			3.7%
	Rural	92%	92%	94%				85.4%
	Urban				87%	65%		5.9%
	Kampala				11%	35%	100%	2.0%
No of hh [x1000]	Peri Urban - Kampala	23	102	42	3			169
	Peri Urban - Other	23	102	84	3			211
	Rural	601	2,706	2,273				5,580
	Urban				325	162		486
	Kampala				43	92	44	178
Total no household		**647**	**2,910**	**2,399**	**374**	**254**	**44**	**6,628**

TABLE 34: DIVISION OF HOUSEHOLDS ON DIFFERENT TIER 2050

FUTURE (2050)		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5	
	Class		**Rural, P-Urban, lw income**	**Rural, , middle income**	**Urban, Rural**	**Urban, Kpala, high income**	**Kampala**	
Future share (2050)	**Est. % of pop.**	**0%**	**7%**	**22%**	**40%**	**21%**	**10%**	**100%**
	Peri Urban - Kampala							0.0%
	Peri Urban - Other							0.0%
	Rural		100%	100%	94%			66.6%
	Urban				6%	73%	15%	19.2%
	Kampala					27%	85%	14.2%
No of hh [x1000]	Peri Urban - Kampala							0
	Peri Urban - Other							0
	Rural		1,518	4,770	8,153			14,441
	Urban				657	4,199	411	5,267
	Kampala					1,686	2,528	4,214
Total no household		**0**	**1,518**	**4,770**	**8,810**	**5,885**	**2.939**	**23,922**

TABLE 35: DEMANDS AT HOUSEHOLD LEVELS DEPENDING ON THE ASSOCIATED TIER - CURRENT SITUATION 2010

CURRENT (2010)		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Area		**Rural, Peri-Urban very poor**	**Rural, Peri Urban, Poor**	**Rural, Peri-Urban**	**Urban, Peri-urban, Kampala**	**Urban, Kampala**	**Kampala**
Proportion of households		**10%**	**45%**	**37%**	**5%**	**3%**	**1%**
Type of access to electricity		**OFF-GRID**	**OFF-GRID**	**OFF-GRID**	**GRID**	**GRID**	**GRID**
Appliance	**Fuel Source**	**'X' – indicates that the technology typically is found in the household**					
Off Grid Electric							
Torch	Dry Cell	X	X	X	X	X	X
Radio	Dry Cell/ PV/BBS		X	X	X	X	X
Light	PV/BBS			X	X	X	X
Cell Phone	Solar			X			
Fuel Based							

CURRENT (2010)		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Area		**Rural, Peri-Urban very poor**	**Rural, Peri Urban, Poor**	**Rural, Peri-Urban**	**Urban, Peri-urban, Kampala**	**Urban, Kampala**	**Kampala**
Proportion of households		**10%**	**45%**	**37%**	**5%**	**3%**	**1%**
Type of access to electricity		**OFF-GRID**	**OFF-GRID**	**OFF-GRID**	**GRID**	**GRID**	**GRID**
Appliance	**Fuel Source**	**'X' – indicates that the technology typically is found in the household**					
Obsolete lighting	Wood/grass	X					
Tadooba	Kerosene		X				
Hurricane Lantern	Kerosene			X	X		
Gas Lantern	biogas						
Gas Lantern	LPG						
On Grid Electric Appliances							
Lighting (Incandescent)	Grid/other				X	X	X
Lighting (CFL)							
Lighting (LED)							
Cell phone					X	X	X
Television						X	X
Music						X	X
Computer/ laptop						X	X
Fan						X	X
Refrigeration						X	X
Washing machine							X
Kettle						X	X
Iron						X	X
Pump							X
Water heating							X
Cooking							
3 stone fire	Waste	X					
3 stone fire	Wood	X	X				
Improved stove	Wood			X			
Trad charcoal stove	Charcoal			X	X		
Improved charcoal stove	Charcoal				X	X	X
Kerosene stove	Kerosene				X	X	X

CURRENT (2010)		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Area		**Rural, Peri-Urban very poor**	**Rural, Peri Urban, Poor**	**Rural, Peri-Urban**	**Urban, Peri-urban, Kampala**	**Urban, Kampala**	**Kampala**
Proportion of households		**10%**	**45%**	**37%**	**5%**	**3%**	**1%**
Type of access to electricity		**OFF-GRID**	**OFF-GRID**	**OFF-GRID**	**GRID**	**GRID**	**GRID**
Appliance	**Fuel Source**	**'X' – indicates that the technology typically is found in the household**					
Gas stove	LPG, biogas					X	X
Electric stove (hot plate)	Electricity						X
Electric stove (induction)	Electricity						X
Microwave	Electricity						X
Electricity demand							
Electricity Consumption / hh (kWh/yr)					2.19	1331.5	1862.0
Other Consumption /hh		1.8	4				

TABLE 36: DEMANDS AT HOUSEHOLD LEVELS DEPENDING ON THE ASSOCIATED TIER – FUTURE SITUATION 2050

FUTURE (2050)		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Area		**Rural, very poor**	**Rural, Poor**	**Rural, urban**	**Rural, Urban, Kampala**	**Urban, Kampala**	**Kampala**
Proportion of households		**0%**	**7%**	**22%**	**40%**	**21%**	**10%**
Type of access to electricity		**OFF-GRID**	**OFF-GRID**	**OFF-GRID, GRID**	**GRID**	**GRID**	**GRID**
Appliance	**Fuel Source**	**'X' – indicates that the technology typically is found in the household**					
Off Grid Electric							
Torch	Dry Cell		X	X	X	X	X
Radio	Dry Cell/ PV/BBS		X	X	X	X	X
Light	PV/BBS		X	X	X	X	X
Cell Phone	Solar		X	X			
Fuel Based							

FUTURE (2050)		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Area		**Rural, very poor**	**Rural, Poor**	**Rural, urban**	**Rural, Urban, Kampala**	**Urban, Kampa-la**	**Kampa-la**
Proportion of households		**0%**	**7%**	**22%**	**40%**	**21%**	**10%**
Type of access to electricity		**OFF-GRID**	**OFF-GRID**	**OFF-GRID, GRID**	**GRID**	**GRID**	**GRID**
Appliance	**Fuel Source**	**'X' – indicates that the technology typically is found in the household**					
Obsolete lighting	Wood/grass						
Tadooba	Kerosene		X				
Hurricane Lantern	Kerosene			X	X		
Gas Lantern	biogas						
Gas Lantern	LPG						
On Grid Electric Appliances							
Lighting (Incandescent)	Grid/other			Mini Grid	X	X	X
Lighting (CFL)				Mini Grid	X	X	X
Lighting (LED)				Mini Grid	X	X	X
Cell phone				X	X	X	X
Television						X	X
Music						X	X
Computer/ laptop						X	X
Fan						X	X
Refrigeration						X	X
Washing machine						X	X
Kettle						X	X
Iron						X	X
Pump							X
Water heating							X
Cooking							
3 stone fire	Waste						
3 stone fire	Wood						
Improved stove	Solid mod-ern biomass		X	X			
Trade charcoal stove	Charcoal			X	X		
Improved charcoal stove	Charcoal			X	X	X	X
Kerosene stove	Kerosene				X	X	X
Gas stove	LPG, biogas			X	X	X	X

FUTURE (2050)		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Area		**Rural, very poor**	**Rural, Poor**	**Rural, urban**	**Rural, Urban, Kampala**	**Urban, Kampa-la**	**Kampa-la**
Proportion of households		**0%**	**7%**	**22%**	**40%**	**21%**	**10%**
Type of access to electricity		**OFF-GRID**	**OFF-GRID**	**OFF-GRID, GRID**	**GRID**	**GRID**	**GRID**
Appliance	**Fuel Source**	**'X' – indicates that the technology typically is found in the household**					
Electric stove (hot plate)	Electricity			X	X	X	X
Electric stove (induction)	Electricity			X	X	X	X
Microwave	Electricity						X
Electricity demand							
Typical elec-tricity Con-sumption /hh kWh/year				297.84	918.34	2524.965	3055.465

REPORT

WWF

ENERGY REPORT FOR UGANDA - A 100% RENEWABLE ENERGY FUTURE BY 2050

MANAGING RESOURCES

Renewable resources must be managed and used wisely in order for them to not deteriorate

RENEWABLE ENERGY SHARE

The share of renewable sources is very high in Uganda today-Almost 90%

RENEWABLE ENERGY POTENTIAL

Uganda has ample renewable energy potential with commercially viable biomass, hydro, solar and geo-thermal resources

SUSTAINABLE USE

Without a massive push for re-forestation & sustainable biomass production, Uganda will not be able to provide its citizens with sufficient biomass to meet their energy needs

For more information:

WWF Uganda Country Office, Plot No. 2, Sturrock Road, Kololo
P.O. Box 8758, Kampala, Uganda
Tel: +256 414 540064/5, **Fax:** +256 414 531166
Email: kampala@wwfuganda.org

WWF-Uganda / @WWFUganda

WWW.PANDA.ORG/UGANDA