SUSTAINABLE
ENERGY FOR ALL

REPUBLIC OF RWANDA

MINISTRY OF INFRASTRUCTURE

Sustainable Energy for All

Action Agenda

2016 Update – Draft

3 November 2016

Supported by AfDB

Executive Summary

The Sustainable Energy for All (SE4All) Initiative was launched in 2011 by the UN Secretary General Ban Ki-moon, with three 2030 objectives of 1) achieving universal energy access, 2) doubling the global rate of improvement in energy efficiency and 3) doubling the share of renewable energy in the global energy mix. On 1 January 2016, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development — adopted by world leaders in September 2015 — officially came into force. Over the next fifteen years, with these new Goals that universally apply to all, countries will mobilize efforts to end all forms of poverty, fight inequalities and tackle climate change, while ensuring that no one is left behind. For SDG 7 covering access to clean and affordable energy, it has been agreed that the country-level engagement should build on appropriate current efforts, in particular the SE4All Action Agendas developed as the umbrella energy sector document, and national implementation framework for SDG 7.

The purpose of this SE4All Action Agenda for Rwanda is therefore to provide a strategic roadmap for the country's energy sector. It identifies country-specific goals that are aligned with global objectives, taking into account Rwanda's energy and economic resources as well as its development and poverty-reduction priorities. The Action Agenda estimates the levels of required investment and identifies the barriers and actions that need be taken to achieve these goals.

Rwanda's SE4All Action Agenda has been integrated into the workplan of the country's Sector Working Group, the main coordination and advisory body bringing together stakeholders in the sector including the key ministries, government agencies, development partners, private sector representatives, civil society and NGOs. The Action Agenda reflects inputs from all these groups.

In the biomass sector, major transformations are required to bring production and consumption of woodfuel into balance. Charcoal production wastes 70% of the input energy. Continuing to rely on current charcoal technologies for cooking in urban areas by 2030 would threaten to seriously deplete Rwanda's forestry plantations as population and urbanisation continues to grow. To address this, much more efficient technologies will be required: i) advanced cookstoves rated tier 3 or 4 by ISO standards can save more than 60% wood compared to current methods, ii) charcoal production needs to improve yield from 11% to 18% through more appropriate regulatory regimes and improved technology iii) switching from charcoal to alternatives like biomass pellets and LPG in urban areas and biogas in rural areas will reduce woodfuel consumption, iv) productivity of forestry and agro-forestry can be significantly improved through regulatory reform, better management, and introducing better quality stock.

In the electricity sector, Rwanda has the opportunity to achieve 100% access by 2030, with urban areas achieving this level well before that date. Targets are based on the SE4All Mult-tier Framework definitions of different levels of access. The rural electrification strategy aims for at least 70% access at Tier 1 or higher by 2018, split approximately equally between on-grid and off-grid access. This Action Agenda targets Tier 1 access or above for 100% of household by 2020, in line with Rwanda's Vision 2020 goals. Quality of access would continue to increase after this time, and by 2030 100% of households are expected to reach at least Tier 2 access. There are various ways this can be achieved. This Action Agenda estimates that grid connection rates would be 100% for urban areas, and 48% for rural areas, making the average for the country as a whole 63%, the remainder with off-grid and mini-grid solutions. This would be achieved against a backdrop of increasing population. It requires the number of new household grid connections to be increased up to 120,000 per year from the current level of 70,000-90,000 per year.

Based on the pipeline of projects with signed power purchase agreements, the share of renewables for on-grid electricity generation is set to decrease from 62% currently to 38% by 2021 as new peat and methane generation is added to the system. The share of renewables then rises to around 44% by 2025 as further regional hydro plant are completed. These agreed projects more than satisfy expected demand over this period – in fact there may be a period of substantial over-capacity in electricity supply. Beyond 2025, there is again flexibility over what type of generation is built. Realistic scenarios range from a base case[1] of 44% renewables to the Government of Rwanda's target of 60% renewables by 2030. Cost-effective renewable energy sources are available to meet this target, and could help reduce the average cost of electricity generation. Meeting the 60% renewables target would require additional capital of around $290m, but would save around $40m per year in operating costs, making it a cost-effective investment. The Government will further assess pathways to meet this target in its revised generation masterplan to be carried out in 2017.

Energy efficiency is also essential to meeting Rwanda's energy goals, and will contribute to reducing the cost of energy provision. There is already significant capacity to improve energy efficiency, principally In the lighting sector by supporting a transition to LED lighting, and reducing the losses in the electricity transmission and distribution system. As the economy grows, there will be increasing opportunities and needs to promote energy efficiency in the industrial and commercial sectors.

Rwanda's SE4All high-level targets for 2030 are:

Sector	Target
Access to clean and sustainable cooking	1. To close the gap (currently about 20%) between production and consumption of biomass to make it a sustainable source of energy 2. To supply a growing and urbanising population with clean secure supplies of biomass for cooking, requiring: a. 100% access to much more efficient cookstoves b. Reduction in losses from charcoal by improving charcoal production and promoting alternatives such as biomass pellets, biogas and LPG c. Increasing production by improving forestry management and improved incentives for small producers 3. To ensure that the efficient cookstove solutions noted above address health issues by significantly reducing indoor air pollution
Access to electricity	1. To achieve 100% electricity access: By 2020, all households will have at least basic levels of access (Tier 1 and above), and by 2030, all households will have at least moderate access to electricity services (Tier 2 and above). 2. Progress to higher quality and quantity of electricity over time, with >70% of the population having Tier 3-5 access by 2030.
Renewables	1. Exceed the global SE4All target (26%) of renewable energy as a percentage of the primary energy supply 2. Achieve 60% of on-grid electricity generation from renewable sources
Energy efficiency	1. At least double the efficiency of biomass energy use 2. Extend current rates of electrical efficiency improvement to 2030

[1] The base case assumes the share of renewables in the generation mix remains unchanged between 2025-2030. The share of renewables includes Rwanda's share of regional hydro projects, but excludes imports from neighbouring countries. It is based on the share of installed capacity. The share of power generated depends on the order of dispatch of plant and will vary from year to year, depending on the level of excess capacity on the system, as well as seasonal and yearly variation in rainfall affecting hydro power dispatch. In general, dispatch rates from renewable energy sources tend to be higher in Rwanda since they have low marginal running cost.

In addition, targets are identified in the report relating to nexus issues covering the interactions between energy, health, water, food and gender equality.

Costs estimates are shown in the table below. This shows that the annual capital investment required to meet the SE4All targets is $249m per year higher than under the base-case scenario. Overall however, the SE4All scenario would lead to cost reductions of $81m per year due to reduced fuel consumption associated with meeting the energy efficiency and renewable energy targets.

SE4All Goal	Investment	Annual cost in 2030 ($m)					
		SE4All Scenario		Base-case Scenario		SE4All cost relative to Base case	
		Capital cost	Total cost	Capital cost	Total cost	Capital cost	Total cost
Access to clean and sustainable cooking	Total	175	297	21	442	154	-144
Access to electricity for households	Grid - transmission & distribution	118	129	67	74	51	56
	Mini-grid & off-grid	79	85	75	76	4	10
On-grid electricity	Total generation costs	267	415	242	433	25	-17
	(of which, to service additional HH connections)	*(171)*	*(265)*				
Energy efficiency[2]	Total	15	15	-	-	15	15
Total		653	942	405	1024	**249**	**-81**

The projected cost for the energy system in 2030 (excluding transport sector) is $942m per year, including household expenditure items such as cookstoves and off-grid lighting, as well as large-scale investments such as on-grid generation, transmission and distribution. This represents around 5% of GDP in 2030[3], comparable to international standards – European non-transport energy expenditure is around 4.5% of GDP. Nevertheless, achievement of the SE4All targets will require significant additional capital expenditure. The on-going running costs of the energy system should be affordable (at $300m per year, representing 1.7% of GDP in 2030). In the longer-term, the energy system can become fully self-financing (including capital replacement costs) by Rwandan consumers, as long as energy consumption grows less strongly than GDP. This puts emphasis on the need for continued focus on energy efficiency and targeting productive (wealth-creating) uses of energy.

The enabling actions to achieve these goals are outlined below. The total cost of these enabling actions is estimated to be around $12.4m over 5 years ($2.5m/yr) across all sectors.

<u>Access to clean and sustainable cooking</u>

The whole biomass supply chain needs to be reformed, with a focus on providing a medium to long-term reduction in reliance on charcoal, whilst retaining the rural economic value of biomass by promoting cost-effective alternatives. This can be done by redirecting jobs to other parts of the alternative biomass value chain, radically improving cookstove emissions and efficiency performance to reduce energy costs, and improving the productivity and sustainability of wood production. Key actions that have been identified during the SE4All consultation:

[2] Only includes costed energy efficiency actions up to 2020.

[3] Assuming average GDP growth of 6% over the period 2012-2030

- Develop and implement a more detailed Biomass energy strategy, building on the findings of the Action Agenda.
- Reform and simplify the regulatory regime particularly for small landholders to ensure they are not disincentivised by burdensome rules from investing in increased productivity and efficiency.
- Introduce a harmonised tax regime for charcoal which rises over time, and reduce taxes on alternatives (e.g. biomass pellets) at least to the level of taxes on charcoal or lower
- Support alternative livelihoods for charcoalers, including re-training and diversion into other aspects of the alternative biomass supply chain (e.g. biomass pellet production & distribution)
- Support transition to much more efficient charcoal production methods, including investment in necessary equipment
- Create cross-ministerial taskforce (national and district) to effectively coordinate biomass-related activities; in particular national awareness-raising strategies to increase demand for higher tier stoves and fuels, and avoid subsidies that lock-in low Tier performance
- Support local manufacturers and suppliers with development, production, marketing and retailing of higher performing cookstoves. Remove import tariffs on materials required[4]
- Phase-in minimum standards on cookstoves that rise over time, providing testing and certification services, and implementing quality control and enforcement, and combine with public awareness campaigns
- Support to financial service providers (FSPs) to work with modern cooking market actors to increase access to financing for entrepreneurs and end users of cooking solutions.
- Support improved forest management techniques, to be defined in an updated Forest Management Plan

Access to electricity

The roll-out of the grid has been successful to date in terms of the rapid increase in numbers of households connected. Extending the grid more widely into rural areas where consumption levels of individual households are low will eventually create economic pressures for the utility. A key challenge in this environment is to plan how quickly the grid can be extended whilst maintaining financial viability, and to coordinate with off-grid solutions. Key actions:

- Adopt a rural electrification strategy that clearly identifies plans for roll-out of the grid with a focus on targeting productive uses of electricity (e.g. promoting small businesses & rural load centres), taking account of availability of finances.
- Target areas away from the planned grid extensions to promote off-grid and mini-grid solutions, but recognise that uncertainties will remain over actual achieved grid extensions.
- Provide risk mitigation measures to compensate for these uncertainties, including developing regulatory framework and standard contracts to allow rural mini-grid sites to sell own-generation power to grid and allow for net metering.
- Develop legal and regulatory environment for off-grid & mini-grids, with simplified licensing framework
- Support private investment in off-grid and mini-grid by setting up a Fund to facilitate access to capital for households, equipment retailers and project developers
- Adopt international quality standards and certification for stand-alone solar products and invest in consumer awareness
- Consider costs and benefits of potential fiscal policy support measures such as reducing VAT & import taxes on renewable energy equipment.

[4] Tariff reform will need further analysis to assess how to define such products.

Renewable Electricity

Rwanda has a range of options for on-grid renewable energy generation, including regional and local micro-hydro projects, solar, and potentially in the longer term geothermal. It also has the potential to import energy from large international renewable energy sources such as geothermal from Kenya and hydro from Ethiopia. Key actions:

- Take strategic decision on long-term energy mix, assessing the viability of developing a greater share of renewable energy to 2030 taking account of any constraints on capital expenditure, and identify potential financing sources
- Improve planning capability in relevant institutions to inform strategic long-term decisions on issues such as economic impacts of different generation sources on tariffs, planning under technology and financial uncertainties, balancing risks and benefits of import dependence etc.
- Assess the role of flexible renewable energy options including reservoirs with pump-storage to replace current thermal peaking plant
- Review contract design to allow appropriate risk-sharing
- Address barriers to imports of critical energy sector equipment
- Incorporate environmental assessments more fully into energy sector planning, and develop an energy-sector land-use plan to reduce competition

Energy Efficiency

In addition to the major energy efficiency improvements outlined above in the biomass sector, the following actions are needed:

- Develop detailed energy sector strategy, assessing technical potential in all sectors and identifying policy and financing instruments required to overcome market barriers.
- Develop implementation options including dedicated technical unit within the utility, as well as options for setting up a financial facility within the proposed Energy Development Fund.,
- Implement enabling actions to stimulate the market for more energy efficient products such as: behavioural change campaigns; addressing affordability issues for households; incentives to increase private sector investment in commercial and industrial applications
- Assess role of performance standards, including EAC-wide standards and labelling
- Develop industrial energy efficiency strategy, and implement programme of audits and benchmarking
- Revise building codes to incorporate energy efficiency for commercial buildings, and consider other legal measures required to enforce EE strategy.
- Develop a long-term plan for the investments required to minimize grid-loss as the grid expands.
- Develop and implement a programme for energy efficient lighting, to enable a transition towards LED lighting

General (All Sectors)

- Continue to improve monitoring and evaluation frameworks in the energy sector

- Invest in data gathering in the energy sector, and maximise the potential of the Multi-Tier Framework survey process to be undertaken in Rwanda. Integrate data collection processes into national statistical data systems to the extent possible.

Acknowledgement

This work was supported by the African Development Bank, and was implemented through the GEF-financed Africa Climate Technology and Finance Center project.

Preamble

The SE4All Action Agenda for Rwanda has been developed in line with the guiding principles contained in the Guidelines for Developing National Sustainable Energy for All Action Agendas in Africa that were developed by African stakeholders, notably: (i) Building on existing plans/programmes/strategies; (ii) Political commitment and leadership; (iii) A balanced and integrated approach; (iv) An inter-ministerial and cross-sectoral approach; (v) Adherence to sustainable development principles; (vi) Participation and meaningful involvement of all stakeholders; (vii) Gender equality and inclusiveness; and (viii) Transparency and accountability.

The Government has shown strong commitment in accelerating Rwanda's SE4All plans, and integrating these within the broader policy framework, notably the Economic Development and Poverty Reduction Strategy and Vision 2020, which provides the main framework for national development. SE4All builds on these foundations to look at additional strategic issues that will need to be addressed to meet the longer-term challenges in the energy sector.

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SUSTAINABLE ENERGY FOR ALL

ACRONYMS AND ABBREVIATIONS

ACRONYM	DESCRIPTION
AfDB	African Development Bank
BEST	Biomass Energy Strategy
BTC	Belgian Technical Corporation
CFL	Compact Fluorescent Lamp
CVC	Charcoal value chain
DFMP	District Forestry MasterPlan
DFNC	Department of Forestry and Nature Conservation
EAC	East African Community
EDCL	Energy Development Corporation Limited
EDPRS	Economic Development and Poverty Reduction Strategy
EE	Energy Efficiency
EICV	Enquête Intégrale sur les Conditions de Vie
ESSP	Energy Sector Strategic Plan
EU	European Union
EUCL	Energy Utility Corporation Limited
FSC	Forest Stewardship Council
GDP	Gross Domestic Product
GIZ	Gesellschaft für Internationale Zusammenarbeit: German International Cooperation Agency)
GTF	Global Tracking Framework
M/GWh	Mega/Giga-Watt hour
HFO	Heavy Fuel Oil
ICS	Improved Cook Stoves
IPP	Independent Power Producer
ISO	International Standards Organisation
JICA	Japan International Corporation Agency
kWh	Kilowatt-hour (Unit of electricity)
MDGs	Millennium Development Goals
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government
MINECOFIN	Ministry of Finance and Economic Planning
MINICOM	Ministry of Trade and Industry
MININFRA	Ministry of Infrastructure
MINIRENA	Ministry of Natural Resources
mt	Million tonnes
mtoe	Million tonnes oil equivalent (energy units)
mtode	Million tonnes oven dry weight equivalent (wood energy unit)
NAFA	National Forestry Authority
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PSF	Private Sector Federation
PV	Photovoltaic
RBS	Rwanda Bureau of Standards
REG	Rwanda Energy Group
REMA	Rwanda Environment Management Authority
RNRA	Rwanda Natural Resources Authority
RWF	Rwandan Franc
SDG	Sustainable Development Goal
SSA	Sub-Saharan Africa
SWAp	Sector Wide Approach
SWG	Sector Working Group
SWH	Solar Water Heater
VAT	Value Added Tax

1. Introduction: Issues & Challenges in the Energy Sector

The energy sector is key to Rwanda's economic development and poverty reduction goals. Rwanda has an ambitious strategic framework for developing the energy sector in pursuit of these goals. Successive documents set out this strategy in increasing levels of detail, running from Vision 2020, the second Economic Development and Poverty Reduction Strategy, the Energy Sector Strategic Plan, and the Rural Electrification Strategy. These documents set out targets for the immediate planning period to 2017/18, and up to 2020. The principal aim of this SE4All Action Agenda is to act as the umbrella energy sector document that can be used to support country-level engagement under Sustainable Development Goal 7 covering access to clean and sustainable energy. It does so by; i) facilitating longer-term strategic planning by extending the goals for the energy sector to 2030, in line with the global SE4All goals on energy access, renewable energy and energy efficiency; and ii) identifying investment requirements, key gaps and actions that are needed to enable Rwanda to achieve these goals. The Action Agenda mainly covers biomass energy and electricity energy sources.

In Rwanda, biomass consumption, mainly wood and charcoal for cooking, currently dominates primary energy supply. Although its share of primary energy will decline over time as other energy sectors grow, biomass will remain a key pillar of Rwanda's energy system. Ensuring the sustainability of biomass supply and use is one of the key challenges of this SE4All action agenda. Current cooking methods lead to pollution-related illnesses and deaths that feature amongst Rwanda's top health problems. Continued reliance on current technologies is not an option; increasing urbanisation and population growth threatens Rwanda with a severe security of supply crisis if the efficiency of the biomass supply chain from production through to consumption is not radically improved by 2030. However, with suitable reforms, the biomass sector can become a secure and sustainable local energy supply for Rwanda, contributing an important source of income to support rural livelihoods for small landholders. Market barriers need to be removed to ensure landholders receive appropriate economic incentives to increase productivity, investment and efficiency throughout the biomass supply chain.

Electricity currently represents a small share of Rwanda's overall energy consumption, but is set to expand rapidly over the next few years. Businesses have identified access to affordable energy the number one challenge they face when considering their expansion plans in the country. The country is planning special economic zones to encourage growth in business, and the supply of electricity will have to expand significantly to service their demand. Meeting Rwanda's goals of rapidly increasing access to electricity for households will require further expansion of the electricity system. Rwanda has ambitious targets to rapidly scale up its energy infrastructure starting from a low base. But with high levels of poverty in the general population, doing this in an affordable way presents a formidable challenge. Firstly, the scale of the investment is high. Even if the upfront capital for such investments can be raised, building assets at this scale also creates large liabilities in terms of operation and maintenance, as well the need to service the financial costs and depreciation. Even excluding the upfront capital costs, the affordability and financial sustainability of the energy system therefore needs careful consideration. Implementing such major expansion of infrastructure presents another formidable challenge in terms of the capacity of supply chains to deliver. In terms of human capacity, skills, equipment and know-how Rwanda may face challenges in terms of absorptive capacity for managing such large investment sums over a relatively short period of time.

The electricity generation mix currently includes around 62% renewable energy, but this is set to change in the next few years as a series of new generation plant are added to the system. Power purchase agreements (PPAs) have been signed for approximately 300 MW of new capacity, of which around 36% is renewable (hydro), and the remainder is split between methane from lake Kivu (34%), peat (23%) and imports from Kenya (6%). This will bring the share of renewables down to 44% of installed capacity by around 2021, after which supply is likely to exceed demand until the mid 2020s.

Additional renewables, notably from the Nyabarongo II hydro, as well as new regional hydro and solar projects can be brought on stream in the mid-2020s to help meet the 60% renewables target by 2030. There are various choices the country can make that could increase the level of renewable energy in the mix, and reduce the costs of the electricity system.

Expansion of the electricity system also raises issues of foreign policy and trade. Many of the energy resources at Rwanda's disposal such as hydro and methane are shared with its neighbours, requiring international agreements to be forged on how these resources should be exploited. Developing regional trade in electricity is another major opportunity for Rwanda to gain access to lower-cost electricity for example from Kenya and Ethiopia. Whilst the issues raised by international trade are different from those of the shared energy resources for hydro and methane, important questions remain about the ability to establish the long-term trade relationships and contractual terms needed to ensure security of supply. The role of imports in Rwanda's electricity supply is therefore a major strategic decision, affecting the balance between large-scale investments in interconnectors vs. development of domestic supply.

Rwanda has already taken major steps towards addressing these challenges. There is a strong commitment at the highest levels of Government towards energy goals which are very well aligned with the overall global goals of SE4All. These include goals for increasing energy access, development of clean low-carbon energy sources and improving energy efficiency, set out in the Energy Sector Strategic Plan (ESSP) and the Rural Electrification Strategy. These set out a framework and specific actions for achieving policy goals to 2018 in all areas of the energy sector which provide an essential starting point for the roadmap towards longer-term SE4All goals. Some of these goals (such as development of regional hydro projects) have to be undertaken jointly with Rwanda's neighbours, limiting Rwanda's control over the speed with which projects can proceed.

At an implementation level, the country has seen some remarkable successes, notably in electricity access roll-out programme (EARP), which has seen the number of households connected to the grid grow from around 11% of the population in 2010 to 22% of the population in December 2014. The level of planning for the expansion in distribution of electricity to households and small and medium enterprises is sophisticated, taking account of detailed spatial information and comparative costs of supplying different areas depending on distance from grid, terrain etc. There is currently less detail in the planning of electricity generation, which tends to be based on an assessment of the current pipeline of potential projects. Steps are being taken to strengthen the ability to assess future power supply options on a more strategic basis. Energy efficiency also needs to be strongly embedded and will require the ability to appropriately assess and target energy intensity taking into account changes in the structure of the economy (e.g. the share of energy-intensive industry vs commerce and service sector).

The private sector is expected to be instrumental in delivering SE4All goals. Whether it is supplying components and materials that are then installed by the state-owned utility company, or more direct investment in energy projects as independent power producers or suppliers of household equipment (improved cook stoves, biogas digesters, solar home systems etc.), the private sector will need to take an increasing role. There are many challenges to overcome in order to realise this however, including the capacity of Rwanda's energy sector supply chains, access to finance, human resources in terms of skills and knowledge, enforcement of quality standards, market building and consumer awareness.

2. Vision and Targets until 2030

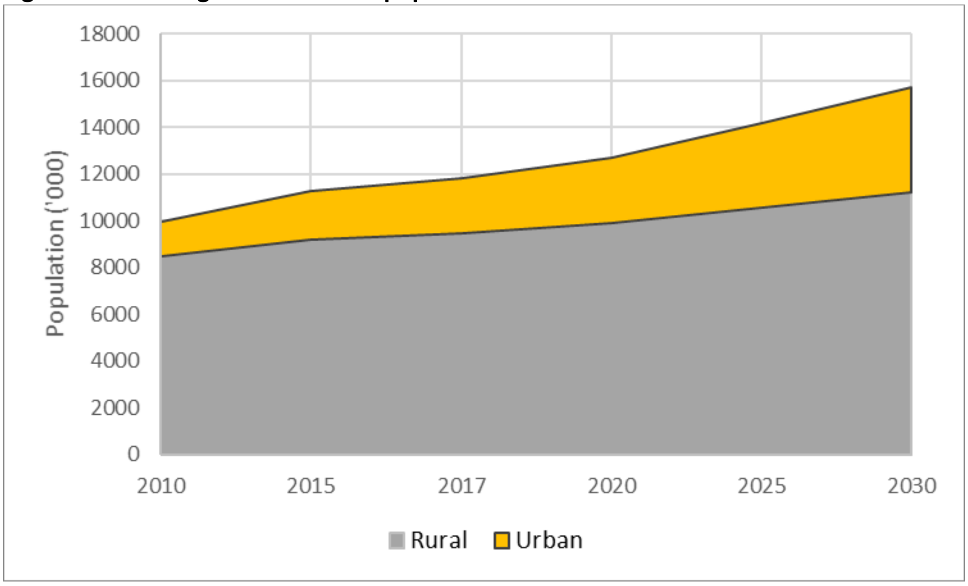
In this report, targets and trajectories up to 2018 are in line with those set out in the Government of Rwanda's Energy Sector Strategic Plan, and the subsequent Rural Electrification Strategy. This is to ensure consistency between the SE4All Action Agenda and the government's current policy and planning framework which is already ambitious in the fields of energy access, renewables and energy efficiency. New targets and costings are then set for the period beyond 2018 up to 2030, and actions required to achieve these are identified.

2.1. Energy Sector trajectory

In 2009, Rwanda's total primary energy supply was 2 million tonnes oil equivent mtoe, mostly in the form of traditional biomass. Household cooking is the dominant consumtion of energy (83%), followed by the transport sector (9%), electricity consumption (4%) and industry (3%). Households are also the dominant consumers of electricity (51%), which is primarily used for lighting. The second largest consumer of electricity is the industrial sector (42%), which mainly comes from motor-drivers and lighting. Public sector consumption (6%) is mostly used for public buildings, street lighting and water pumping[5].

In terms of household cooking energy, 97% of all consumption comes from biomass energy resources, comprising firewood 86%; charcoal 11%; crop waste 2%; and other fuels 1% (2009 data from ESSP). In urban areas, electric stoves and microwaves are used to a limited extent. Commercial establishments and wealthier households are increasingly using Liquefied Petroleum Gas (LPG). The balance of energy will shift over coming years due to a projected increase in demand for electricity – the scenarios explored in this work lead to a 4-fold increase in electricity generation capacity from 2015 to 2030. Nevertheless, under the scenarios developed in this Action Agenda, the main primary energy source in Rwanda will continue to be biomass over this period, principally used in cooking. Total thermal energy under these scenarios increases by 15% even with significant improvements to cooking technologies. Including projected increases in transport fuel, overall primary energy supply is expected to increase by 90% by 2030 relative to 2009.

Figure 1 Increasing share of urban population[6]

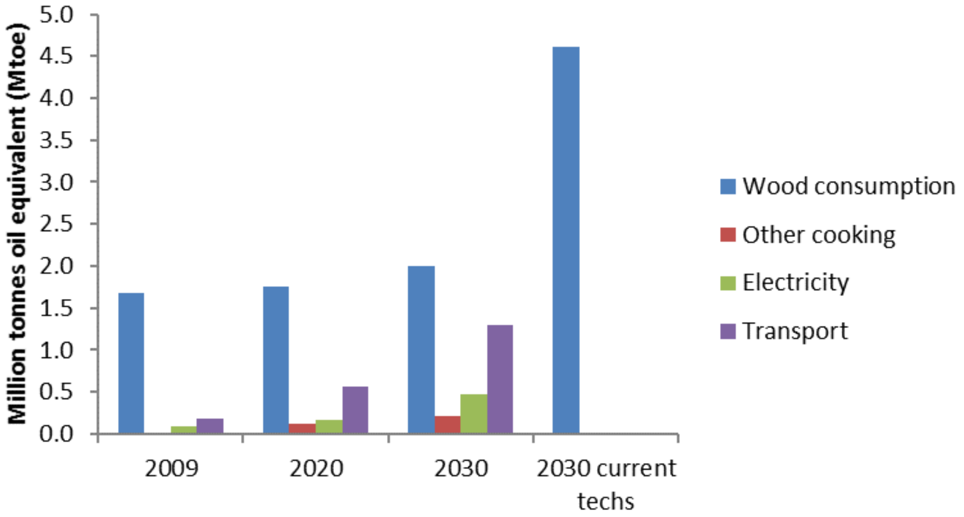


[5] Draft National Energy Efficiency Strategy, January 2014
[6] Source, Rwanda National Statistics: http://www.statistics.gov.rw/publication/rphc4-population-projections

One of the key demographic trends affecting the energy sector is the rate of urbanisation (Figure 1) rising from 15% in 2015 to 29% in 2030. Urban populations are due to double over this period. This is particularly important in the biomass sector, because the energy source most used in urban areas is charcoal which currently wastes 70% or more of the input energy of the wood during the manufacturing process, so an increase in urban population puts a particularly heavy burden on wood supplies.

As a result of these pressures, alternatives to charcoal and much more efficient charcoal conversion technologies need to be found. In this report, an illustrative pathway towards meeting the biomass target is that charcoal will be reduced to only 37.5% of the share of urban cooking, with LPG also accounting for 25%, and the remainder 37.5% being supplied by alternative biomass sources (e.g. pelletized biomass). A reference 2030 scenario ("current techs") is also calculated for wood consumption based on a continuation of current technologies in the biomass sector. This is shown for comparative purposes, although as shown in Figure 2, such a scenario would require more than 2.5 mtoe additional energy from wood fuel. This means that in reality the current technologies scenario would not be practicable because of a lack of wood supply. Under the efficient scenario, renewable energy as a share of primary energy (including transport) would be 54%.

Figure 2 Projected Primary Energy Supply



2.1.1. Biomass Sector

Biomass is an important resource for Rwanda, and contributes significantly to rural livelihoods. It has the potential to be a sustainable, locally-sourced and therefore secure energy source, since the great majority of Rwanda's woody biomass comes from plantations or agro-forestry sources, not from protected forests. In this analysis, biomass resources are in general considered renewable, but only to the extent that consumption of biomass stays within the limits of annual sustainable production levels of the country. However, currently, production (i.e. the amount of new wood grown each year) falls short of consumption (i.e. the amount of wood cut from trees).

Biomass is almost wholly relied on for cooking and related uses by both urban and rural households. The sustainability of biomass in Rwanda is potentially better than in many other SSA countries as data indicates that it comes predominantly from either planted trees (mostly eucalyptus) or agricultural residues. Nevertheless, demand is already higher than supply and is growing as the population grows, as household incomes rise, and as urbanisation increases (leading to greater share of charcoal use).

This Action Agenda focuses on this gap between supply on the one hand, and the usage (or demand) on the other as a key indicator of sustainability. Demand currently exceeds sustainable supply because more wood is cut from plantations than grows each year. This leads to depletion of tree stocks over time. If this growing gap between supply and demand is not addressed, it will lead to a crisis both in terms of the security of this vital energy supply, as well as in environmental terms as people may be forced to migrate to less sustainable sources of energy.

There is some uncertainty over the size of the gap between supply and demand for firewood in Rwanda, partly due the difficulty of assessing tree cover from satellite data on large numbers of small plantations (trees typically cover 0.1 hectare or less for 74% of the households with a farm[7]). The 2009 biomass energy strategy (BEST) estimates that demand is about double the sustainable rate of production from eucalyptus plantations (the main source of wood fuels). Despite this gap, in BEST, biomass is regarded as a potentially sustainable fuel source so long as this gap can be closed, and recommends taking this route rather than shifting to fossil-based fuels such as LPG or kerosene. BEST recommends a mix of supply side measures to increase productivity and demand-side measures to improve efficiency of usage to close the supply gap.

In the report "Supply Master Plan for fuelwood and charcoal" (SMP / WISDOM[8] study) based on an update of the WISDOM model in 2012, the supply-demand gap was estimated to be considerably smaller due to improved information on coverage of small plantations using new forest map produced by CGIS-NUR released in October 2012. This revealed a plantation area far greater than that previously estimated. In this report, total demand for conventional woody biomass in 2009 was estimated to be approximately 4.2 mt, and sustainable supply potential in 2009 was estimated at 3.2 mt. Whilst this gap is smaller than estimated in BEST, the study projects that due to urbanisation, population and income growth, by 2020 under a business-as-usual (BAU) scenario, demand will grow to 5.7 Mt. Under an 'ameliorated' (AME) scenario, demand would grow to 4.4 million tons. Business-as-usual (BAU) supply is expected to increase by 10% to 3.6 mt due to current trends and programmes. This leaves a supply gap of 0.8-2.1 mt depending on the demand scenario considered. The study noted that this gap is sensitive to assumptions about productivity, which could vary the sustainable supply potential anywhere from 2.6-4.3 Mt. It points to measures that could be taken to improve productivity to further close the supply-demand gap, suggesting that woodfuel production could go up to around 5.6 mtode per year by 2030 with some expansion of land dedicated to forestry or agro-forestry, extracting only from managed plantations or agro-forestry sites. These figures are due to be updated in the revised BEST strategy during 2016, but still provide a sound basis for identifying key actions in the sector.

Under UN projections of population growth and urbanisation rates, the demand for wood would exceed 11mt/year by 2030 under current demand technologies, more than double the sustainable rate of production[9]. As shown in

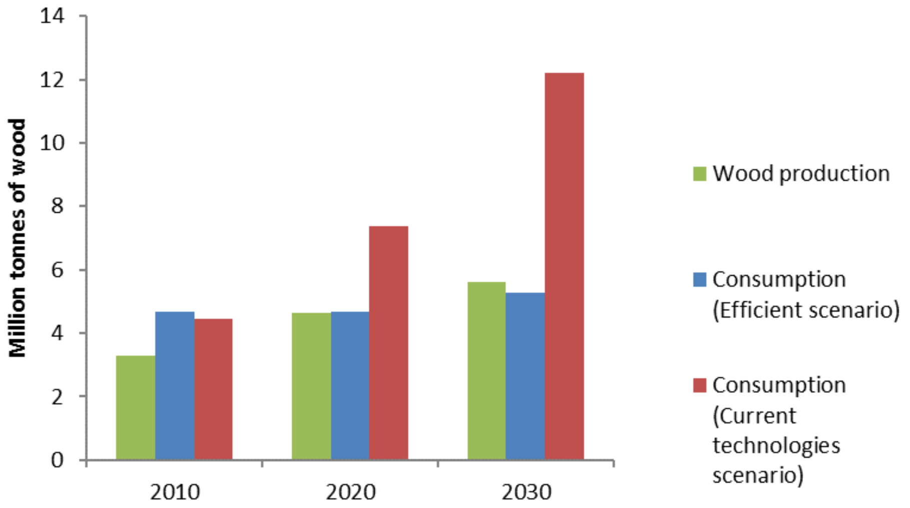
Figur**e 3**, under the 2030 current technologies scenario, over 50% of biomass would be considered non-renewable by 2030. Under the efficient scenario by contrast, consumption is brought down to within annual production levels, so that biomass can be considered a fully renewable energy source. These scenarios are discussed in more detail in Section 2.2.1.

[7] BEST – Volume3 Rural Supply & Demand

[8] Update and upgrade of WISDOM Rwanda and Woodfuels value chain analysis as a basis for the Rwanda Supply Master Plan for fuelwood and charcoal. July 2013. Ministry of Natural Resources

[9] These scenarios are based on projections for the household sector which account for 94% of fuelwood consumption by value . Non-household uses (e.g. secondary schools, prisons, brick makers and tea factories) assumed to remain unchanged at about 6% of total demand.

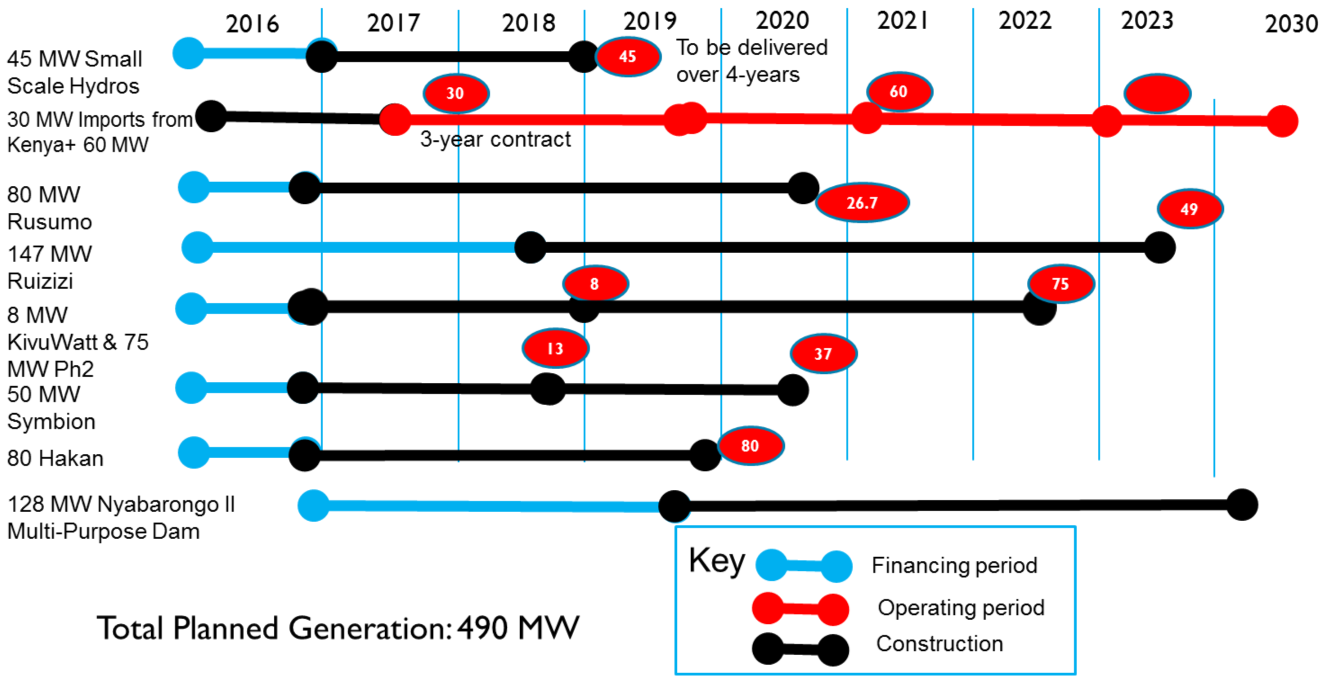
Figure 3 Supply and demand balance for biomass to 2030



2.1.2. Trends in the Electricity Generation Sector

Supply of electricity is due to expand significantly in the next few years, with over 300 MW of PPAs signed for new plant to be commissioned by around 2021. The overall supply-demand balance situation is for tight supply up to around 2018, with a potential over-supply from 2019 until mid-2020s when demand catches up with supply. Based on planned new-build, the level of renewable energy on the system is expected to drop to 44% in 2025. This expected mix in 2025 is taken as a base-case planning scenario for 2030, based on an assumption that the share of renewables would stay unchanged between 2025-2030. However, there is potential for additional renewable investments beyond this base-case scenario, including up to 128MW of hydropower from the Nyabarongo dam, to meet the target of 60% in 2030.

Figure 4 Supply and demand balance in the on-grid electricity sector to 2030



2.2. Energy access target until 2030

2.2.1. Clean and sustainable cooking

Headline Targets:

1. To close the gap (currently about 20%) between production and consumption of biomass to make it a sustainable source of energy
2. To supply a growing and urbanising population with clean secure supplies of biomass for cooking, 3 main pillars of the sector will need to be addressed:
    a. 100% access to much more efficient cookstoves than currently used
    b. Reduction in losses from charcoal by improving charcoal production and promoting alternative fuels such as biomass pellets and biogas
    c. Increasing production by improving forestry management
3. To ensure that the efficient cookstove solutions noted above address health issues by significantly reducing indoor air pollution

In these discussions, ***production*** of woody biomass is the annual amount of wood grown each year, whilst ***consumption*** is the amount cut each year. If consumption exceeds production, then the stock of trees will be reduced over time. Nearly all the woody biomass used in Rwanda comes either from dedicated plantations or agro-forestry sources. Therefore, if production and consumption can be balanced, biomass represents a secure and sustainable source of energy for the country.

The following scenarios provide illustrative pathways to achieve the above headline targets. These pathways address the three pillars of the biomass sector as noted in the headline targets. For the second pillar relating to the share of charcoal in the cooking mix, two different scenarios are provided to illustrate alternative pathways:

- **Scenario 1** looks at a direct substitution from charcoal to biomass pellets, which reduce thermal losses at the production stage, and allow for use of very efficient stoves. In Scenario 1, use of pellets reaches 38-40% of the mix for both urban and rural areas, with charcoal in urban areas down to 38%. Biogas use in this scenario reaches 10% of rural population, based on an assumption that all households with 2 cows would use this source of energy.
- **Scenario 2** looks at a significant expansion in the use biogas. This scenario requires the proportion of households with 2 or more cows to double compared to current levels. Supply from biogas reaches 23% share, reducing the pressure on use of firewood in rural areas. This allows charcoal consumption in urban areas to remain higher at 55%, and less emphasis on use of pellets. The knock-on environmental and food-security issues of substantial increase in the number of cows has not been investigated as part of this study, and would need further attention to assess the viability of this scenario.

Table 1 Biomass sector: Illustrative SE4All pathways to achieving the targets

Sector	Issue	SE4All goal 2020	SE4All goal 2030
Use efficient cook-stoves	Progressively move towards higher performance biomass cookstoves. [currently 40% Tier 0, 60% Tier 1]	**Tier 0: 0%** **Tier 1: 40%** **Tier 2: 30%** **Tier 3 - 4: 30%** Phase out use of unimproved cooking techniques. Establish supply chains and measurable growth in markets for Tier 2-4 stoves. This leads to around 40% wood savings relative to current technology.	**Tier 0: 0%** **Tier 1: 10%** **Tier 2: 20%** **Tier 3 - 4: 70%** Eliminate use of unimproved cooking, recognising that poorest households may still use Tier 1-2. Establish Tier 3-4 as the main cooking technology saving more than 60% of wood compared to current technology.

<table>
<tr><td rowspan="9">Reduce charcoal losses</td><td>Alternatives to charcoal for urban areas</td><td colspan="8">All households have access to choice of fuels to enable clean cooking
Eliminate barriers and level the playing field between different fuel types to allow private sector to develop supply chains based on consumer choice. This may include initial support for alternatives such as biomass pellets and/or biogas</td></tr>
<tr><td rowspan="7">Substantially reduce share of charcoal in cooking mix
[over 90% currently]</td><td colspan="3">Share of households:</td><td></td><td colspan="2">Scenario 1</td><td colspan="2">Scenario 2</td></tr>
<tr><td></td><td>Urban</td><td>Rural</td><td></td><td>Urban</td><td>Rural</td><td>Urban</td><td>Rural</td></tr>
<tr><td>Charcoal</td><td>73%</td><td></td><td>Charcoal</td><td>38%</td><td></td><td>55%</td><td></td></tr>
<tr><td>Firewood</td><td></td><td>90%</td><td>Firewood</td><td></td><td>50%</td><td></td><td>57%</td></tr>
<tr><td>Pellets</td><td>15%</td><td></td><td>Pellets</td><td>38%</td><td>40%</td><td>20%</td><td>20%</td></tr>
<tr><td>Biogas</td><td></td><td>10%</td><td>Biogas</td><td></td><td>10%</td><td></td><td>23%</td></tr>
<tr><td>LPG</td><td>13%</td><td></td><td>LPG</td><td>25%</td><td></td><td>25%</td><td></td></tr>
<tr><td>Improve yields and sustainability of remaining charcoal production
[current yield 11% by weight]</td><td colspan="3">15% yield by weight
25% certified ‘green’

Requires elimination of sub-optimal production, plus 25% production from improved techniques, 5% state-of-the-art techniques</td><td colspan="5">18% yield by weight [10]
90% certified ‘green’

Elimination of sub-optimal production, plus 30% production from improved techniques, 25% state-of-the-art techniques</td></tr>
<tr><td>Increase wood supply</td><td>Increase productivity of wood production

[9.5 t/ha/yr in 2009]</td><td colspan="3">12.4 t/ha/yr
Increase from 2009 base of 9.5t/ha/yr. Based on SMP/WISDOM AME scenario. Including 10% increase in forest cover, this leads to national production of 4.65 million tonnes dry wood equiv.</td><td colspan="5">15 t/ha/yr
Based on experiences in other SSA countries and lower end of the technical potential 15-30 t/ha/yr identified in National Forest Policy. Without any further increase in forest cover after 2020, this would lead to production of 5.6 mt dry wood equiv.</td></tr>
</table>

Two alternative efficient scenarios are explored here. Both result in a reversal of the supply-demand gap by 2020, and maintaining consumption below production levels through to 2030 (**Error! Reference source not found.**). Both efficient scenarios rely on much improved cookstove efficiencies, a reduction in the share of charcoal in the fuel mix, and much improved efficiencies for charcoal production. The two scenarios show alternative pathways to how the woodfuel energy supply could be balanced.

- **Scenario 1** requires a huge scale-up in the use of biomass pellets. These avoid the heavy energy losses inherent in charcoal production, and enable the use of much more efficient stoves than is possible with raw firewood. Key challenges in this scenario will be to establish the infrastructure and supply-chains necessary for replacing charcoal use in urban areas at such high volumes. Biogas is assumed to be fully rolled out to all rural households with at least 2 cows assuming the proportion of households with 2 or more cows remains the same in 2030 as it is now (estimated in this analysis at around 22%[11]).
- **Scenario 2** assumes less reliance on biomass pellets, but instead greatly increases the role of biogas. A key challenge of this scenario is the implied level of ownership of cows in the country. Scenario 2 assumes the proportion of households owning at least 2 cows will more than double to 50% of rural households. Given expected rural population growth, cattle numbers would need to grow from the current number of 1.5 million to 4.4 million by 2030

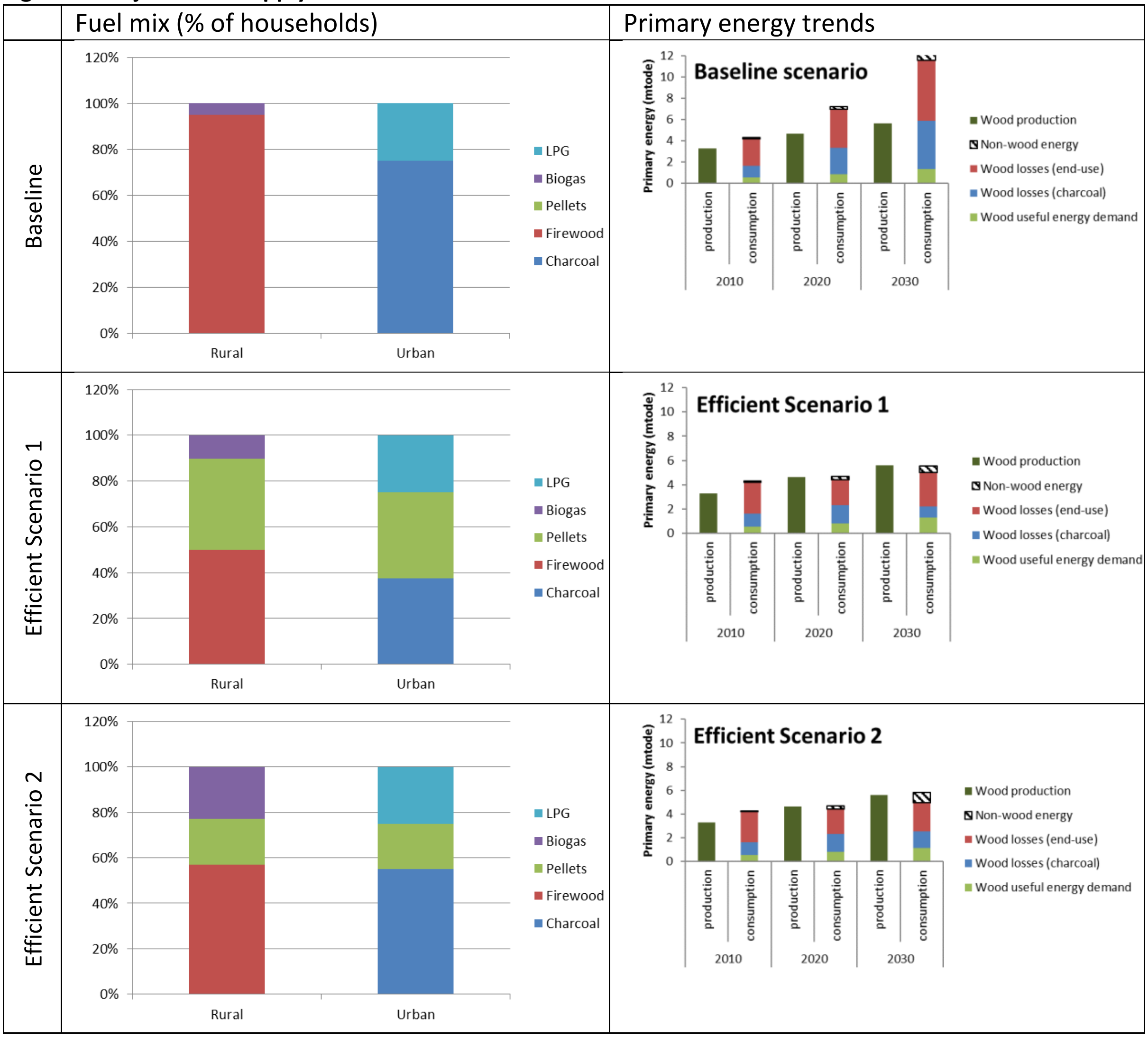
[10] Figure from CAMCO report Nov 2014 “Development Of A Sustainable Charcoal Production CDM Programme of Activities/NAMA In Rwanda” Report for DG Environment, Climate Change Section, Brussels - Belgium

[11] Direct figures on households with 2 or more cows were not available. The estimate of 22% is based on data showing total cattle ownership rates in Rwanda at 32% (from NISR 2012 housing census thematic report "Characteristics of households and housing"). Since average ownership is 2 cows, it was estimated that around 30% of households may only have 1 cow in order to balance those households that have more than 2 cows. However, this may be a considerable over-estimate of the potential for biogas. The Strategic Environmental Assessment of the ESSP carried out in 2014 estimated that the total number of households with dairy cows kept in zero-grazing conditions was only 120,000, or 5% of the population.

to achieve this. The knock-on pressures on land-use, water and other environmental impacts of this scenario have not been investigated here, and would need further study to assess the viability of this scenario.

Scenario 2 reduces total woodfuel demand by providing energy from a different source. This allows a greater share of charcoal to be used in the mix, so that total firewood consumption is the same in both scenarios, although total primary energy is higher in Scenario 2 taking into account the biogas use. Biogas and LPG primary energy is shaded differently in Figure 5 to highlight that these non-wood sources do not feature in the balance of production and consumption of woodfuel.

Figure 5 Projection of supply and demand of woodfuel for households to 2030



Annual fuel costs in the biomass sector are currently in the region of $100m per year, if wood fuel is valued at market prices. In practice, this economic value is not always realised since many rural households collect biomass without payment, and their time is not valued in monetary terms. Nevertheless, this time does represent an opportunity cost for those collecting the wood, and should be valued accordingly. In this analysis, biomass is therefore valued at prevailing prices for wood in Rwanda where it is sold commercially. Under these assumptions, the cost implications of these scenarios are shown in Table 2**Error! Reference source not found.**.

Under the current technology scenario, an assumption is made that the increased pressure on wood supply would lead to an increase in wood fuel prices of 2% real per year (leading to fuel prices 50%

greater in 2030 than current prices). This scenario results in almost 11mt/ year of wood consumption, over three times current production, and far exceeding Rwanda's capacity for sustainable production. This huge increase in demand, coupled with higher wood prices leads to total annual costs of $371m in 2030, 75% more than the efficient scenario.

Under the efficient scenarios, consumption of firewood does not increase above sustainable levels of production, so firewood prices are assumed to stay at current levels in real terms. The four main elements of capital expenditure in these efficient scenarios are for efficient stoves, improved charcoal production facilities, biomass pelletizers and biogas systems. In both scenarios, the energy cost savings compared to the baseline significantly outweigh these additional capital expenditure requirements, so that total costs of the efficient scenarios are lower than the baseline scenario. Expenditure on increased productivity of forestry is not included in these estimates.

Table 2 Capital and operating costs of investment required for access to clean cooking ($m/yr)

$m/yr		2012	2030 Baseline (Current technologies)	2030 Efficient Scenario 1 (pellet focus)	2030 Efficient Scenario 2 (biogas focus)
Annual capital costs	**Stoves**	5	3	65	65
	Improved charcoal prod'n	0	0	41	60
	Pelletizers			33	17
	Biogas systems		18	36	81
Biomass energy costs		103	421	122	122
Total costs		108	442	297	345

2.2.2. Electricity Access

<u>Headline Targets:</u>

1. To achieve 100% electricity access. By 2025, all households will have at least basic levels of access (Tier 1 and above), and by 2030, all households will have at least moderate access to electricity services (Tier 2 and above).
2. Access will progress to higher quality and quantity of electricity over time, with >70% of the population having tier 3-5 access by 2030.

Electricity access is more complex than whether or not there is a connection to the grid. Quality, quantity and reliability of supply also play a part. The World Bank defines access according to a multi-tier framework where access is measured as a function of peak capacity, daily demand, duration of supply, as well as reliability and safety indicators. A selection of these indicators are shown in Table 3.

Table 3 World Bank Multi-tier Framework for defining electricity access[12]

ATTRIBUTES	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Quantity (peak available capacity)	—	>1W	>50W	>200W	>2,000 W	>2,000 W
Duration of supply (hours)	—	>4	>4	>8	>16	>22
Evening supply	—	>2	>2	>2	4	4
Affordability (of a standard consumption package)	—	—	Affordable	Affordable	Affordable	Affordable
Legality	—	—	—	Legal	Legal	Legal
Quality (voltage)	—	—	—	Adequate	Adequate	Adequate

Tier 1 represents very low power applications such as task lighting and mobile-phone charging. These can be provided by solar lanterns (usually Tier 1 would require more than one per household), or basic solar home systems which can provide multiple room lighting. These basic energy services are often the initial requirements of households, particularly in rural areas, and Tier 1 represents an important step on the access ladder. In the context of setting goals for 2030 under the SE4All framework, a further goal is to reach Tier 2 levels of access or above for 2030. Tier 2 access can be provided by larger SHS, whilst Tier 3 and above would typically be provided by mini-grids or mains grid connection, though larger SHS are technically able to meet these power needs as well.

It is important to note that the Tier system represents marker points in what is in reality a continuous spectrum of improving access. Households may approach Tier 1 by acquiring a number of good quality solar lanterns which can provide the basic lighting and mobile charging they need. SHS systems vary in size, across the relatively wide range spanned by Tier 1 and Tier 2. The targets set out below therefore differentiates between basic Tier 1 from more substantial Tier 1 SHS, denoted Tier 1+.

The projected total annual expenditure required to meet the electricity access goals are presented in **Error! Reference source not found.Error! Reference source not found.**, and amount to $380m per year by 2030. This includes the cost of capital as well as operating costs. For on-grid and mini-grid access, this includes the cost of the generation plant required to supply households with electricity. Capital costs are annualised at an assumed discount rate of 8%. These costs are estimated using the Global Tracking Framework Access Investment Model (AIM).

Table 4 Capital and operating costs of investments required for household electricity access[13]

$m/yr	2015	2018	2020	2025	2030
Basic Tier 1	0	8	22	9	0
Tier 1+	3	35	31	17	0
Tier 2	0	7	12	26	37
Tier 3-5	88	121	214	345	362
Total	91	170	279	396	400

[12] From Appendix 3 of the SE4All Global Tracking Framework document, available at: http://documents.worldbank.org/curated/en/2013/05/17765643/global-tracking-framework-vol-3-3-main-report

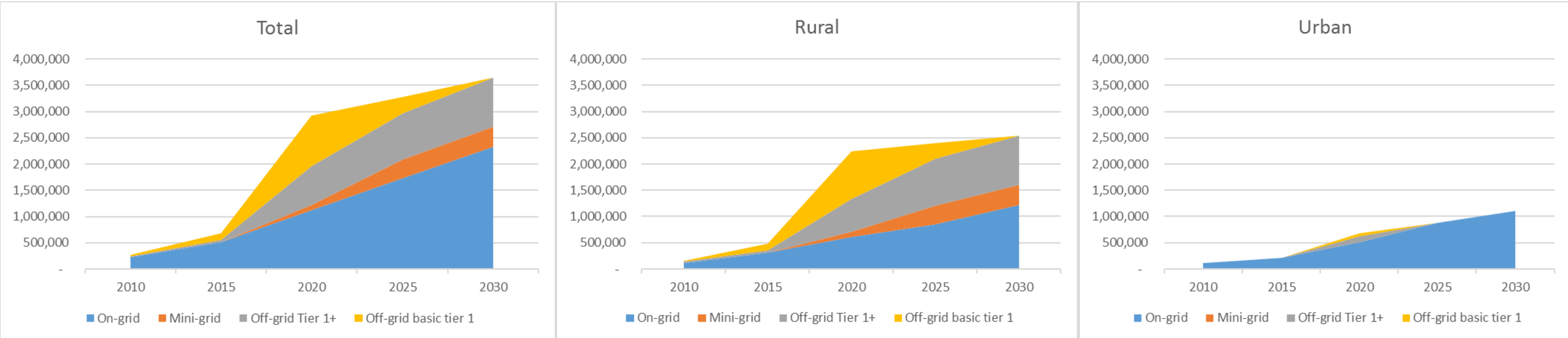
[13] For on-grid and mini-grid access (included under Tier 3-5), these costs include the capital and operating costs of power generation plant required to supply the electricity to the connected households.

Table 5 and Figure 6 provides an illustrative pathway to reach the electricity access target of tier 2 and above by 2030. Urban grid access is assumed to reach 100% by 2025. Total access rates are a weighted average of rural and urban access levels.

Table 5 Targets for electricity access by Tier type

		Rwanda Average				Rural				Urban			
		2015	2018	2020	2030	2015	2018	2020	2030	2015	2018	2020	2030
# Households	Basic Tier 1	126,826	370,000	979,289	-	125,130	292,213	908,940	-	-	77,787	58,921	-
	Tier 1+	42,275	521,086	492,378	-	41,710	424,000	421,585	-	-	96,174	67,640	-
	Tier 2	-	130,271	246,189	957,653	-	106,000	210,793	937,936	-	24,043	33,820	-
	Tier 3-5	511,367	873,217	1,206,242	2,688,075	312,824	513,970	706,385	1,606,875	205,731	372,101	516,016	1,100,917
	Total	**680,468**	**1,894,574**	**2,924,099**	**3,645,728**	**479,664**	**1,336,182**	**2,247,703**	**2,544,811**	**205,731**	**570,105**	**676,396**	**1,100,917**
Percentage	Basic Tier 1	5%	14%	33%	0%	6%	14%	40%	0%	0%	14%	9%	0%
	Tier 1+	2%	19%	17%	0%	2%	20%	19%	0%	0%	17%	10%	0%
	Tier 2	0%	5%	8%	26%	0%	5%	9%	37%	0%	4%	5%	0%
	Tier 3-5	20%	32%	41%	74%	15%	24%	31%	63%	40%	65%	76%	100%
	Total	**26%**	**70%**	**100%**	**100%**	**23%**	**62%**	**100%**	**100%**	**40%**	**100%**	**100%**	**100%**

Figure 6: Access targets by type of connection (no. of Households)



2.3. Renewable Energy target until 2030

Headline Targets:

1. Exceed the global SE4All target (26%) of renewable energy as a percentage of the primary energy supply
2. Achieve 60% of on-grid electricity generation from renewable sources

Global energy production from renewables as a share of total primary energy supply is currently 13% (2010 data, OECD statistics database). Doubling this share by 2030 would bring the global mix to 26%. By contrast, the total share of renewable energy in Rwanda's total primary energy mix is currently high, but is expected to drop as transport fuels and non-renewable sources of electricity increase. Nevertheless, Rwanda is projected to have more than double the global target level of renewables as a share of total primary energy supply. This is mainly as a result of the potential for sustainable biomass, as discussed under the energy access Section 2.2.2 and Section 3.1. If the identified actions are taken to ensure that biomass becomes a sustainable and renewable energy source for Rwanda, then renewable energy would be expected to provide 54% of Rwanda's primary energy needs. Since the trends for thermal renewables are dominated by these biomass issues already discussed, this section focuses mainly on renewable electricity.

The global share of electricity generated from renewable sources is currently around 22%. Doubling this by 2030 would take the global total to 44%. This is in line with Rwanda's base case scenario. However, there is technical potential to significantly increase renewable energy in Rwanda beyond these levels if sufficient international finance were available to compensate for the additional costs. The Government of Rwanda therefore intends to expand renewable energy generation above the base-case to meet a target of 60% by 2030.

The percentage of electricity generated from renewables is expected to drop in the short-term due to a diversification of the energy mix to exploit domestic resources such as methane[14] and peat. Further renewable sources can be developed after the mid-2020s to increase the share of renewable energy by 2030. Three scenarios are identified in the chart below:

1. Continuation of current trends. This assumes that the plant added to the system after 2025 will follow the same mix of plant currently existing and contracted to be in place by 2025. This leads to renewable generation making up **44%** of capacity.
2. Maximum renewable energy. This assumes that all plant built between 2025 and 2030 will be renewable. This leads to renewable generation making up between 52-66% of capacity depending on the level of demand growth. A mid-point in this range of **60%** has been adopted as the government's target.
3. Minimum renewable energy. This assumes that none of the plant built between 2025 and 2030 will be from renewable sources. This leads to renewable generation making up **33%** of capacity, based on medium demand growth assumptions.

The evolution of the share of renewable capacity in the generation mix to 2030 is shown in Figure 7 and Table 6

[14] Methane although a cleaner energy source than diesel or peat, is not considered as renewable in the Action Agenda. See page 44 for a detailed explanation.

Figure 7 Renewable Energy as a share of total generation capacity (medium demand growth assumptions)

Table 6 Scenarios for on-grid renewable electricity to 2030

MW	Existing + Committed due to be installed by 2025	Scenario 1: Base case (current trend) 44% RE	Scenario 2: SE4All target 60% RE	Scenario 3: Minimum renewables 33% RE
Year:	**2025**	**2030**	**2030**	**2030**
Hydro	109	147	176	109
Regional Hydro	80	108	161	80
Solar	9	11	17	9
Imports	22	29	22	35
Methane	132	178	132	214
Peat	72	97	72	117
Thermal	24	33	24	40

These illustrative scenarios are technically achievable based on projects that have already been identified, but are uncommitted. For example, in addition to the new capacity already committed by 2025, Scenario 2 requires 68 MW of local hydro, 81 MW of regional hydro, and 9 MW of solar PV. This compares to an identified but uncommitted project pipeline of at least 90 MW of local hydro (of which 48 MW from Nyabarongo 2[15] plus 45 MW of identified micro-hydro projects), 95 MW of regional hydro (Ruzizi 4), and 10 MW from a single proposed solar project. Technical potentials are considerably higher still.

Cost estimates have been carried out to determine the relative costs of the three identified scenarios. Renewable energy sources tend to be capital intensive, but cheap to operate once they are built. These costs are based on estimated costs of the various energy generation sources such as methane, peat and hydro that are in the current project pipeline. They take account of the additional plant that would need to be built between around 2025 and 2030 to meet growing demand over that time period. They do not include the investment costs for the plant that have already been committed to prior to 2025. Capital costs are annualised at an assumed discount rate of 8%. The results of the cost estimates show that scenario 3 (minimum renewable energy scenario) would require the least upfront capital expenditure, but that savings in capital would be more than outweighed by the increase in

[15] Excluding pump-storage elements of the project

operating and fuel costs, making it the most expensive option overall, at $97 m/yr. Scenario 2 with the maximum renewables by contrast is indicated to be the lowest overall cost at $49 m/yr. Scenario 1 (continuation of the current and committed generation mix) is between the two, with intermediate capital and total costs.

Table 7 Cost estimates of the renewable electricity scenarios

		Scenario 1: current trend 44% RE	Scenario 2: Maximum renewables 60% RE	Scenario 3: Minimum renewables 33% RE
Total additional capital	$m	676	966	423
Annual capital cost	$m/yr	63	88	40
Total annual cost	$m/yr	125	108	136

Based on these estimates, scenario 3 is less credible because it leads to the highest overall system cost. Scenario 1 and Scenario 2 should therefore be used as guidelines for long-term planning.

Moving from the current trend (Scenario 1) to the maximum level of renewables (Scenario 2) would require additional capital of around $290m, and would save around $40m per year in operating costs, making it a cost-effective investment. However, the Government will need to take into account the availability of capital when assessing the most appropriate generation mix. The Government will therefore take a flexible approach to its planning, using Scenario 2 as guidelines towards a likely pathway. Project planning will need to start now in order to plan the appropriate financing sources, and to carry out detailed technical assessments, including assessment of demand growth.

2.4. Energy Efficiency target until 2030

Headline Targets:

1. At least double the efficiency of biomass energy use for cooking
2. Extend current rates of electrical efficiency improvement to 2030

At an economy-wide level, it is not possible define an energy intensity target (i.e. the relationship between energy and GDP) without much more detailed sectoral growth projections (for example the growth rates of energy intensive industries vs. service sector growth).

Within the cooking sector, it is possible to identify a more specific energy efficiency target. In these scenarios, based on a population growth rate of 2.5% per year, and assuming that each household on average will experience a 2.5% per year growth in cooking demand, the total useful energy demand[16] for cooking heat grows by over 250%. However, under the projected energy savings in scenarios developed for the Action Agenda, the actual energy consumed for cooking grows by only 15%. This means that the efficiency of cooking is more than doubled by 2030 relative to 2009. Based on these scenarios, it is recommended that the GoR adopts a target of doubling the rate of energy efficiency in the cookstove sector by 2030.

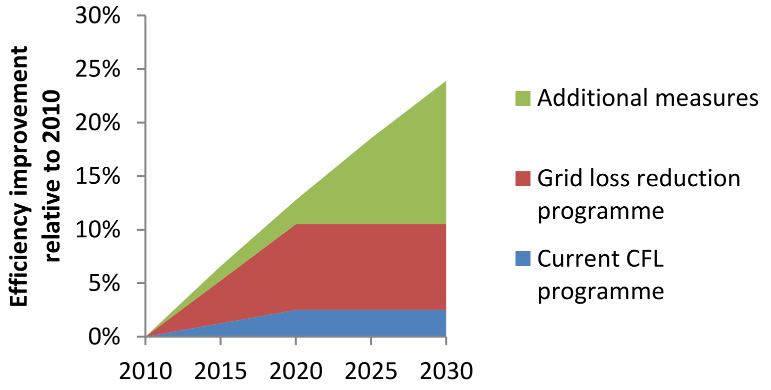
In terms of the efficiency of electricity use, there are ambitious programmes underway, including substantial investment of over $60m planned for grid-loss reduction, as well as an additional programme on efficient lighting. These programmes are expected to achieve savings in the region of 11% by 2018. The potential for energy efficiency beyond this timeframe has been estimated at 24% compared to business-as-usual. This represents an approximately equal rate of efficiency improvement per year compared to current programmes. This implies that to achieve the 2030 energy

[16] Useful energy demand measures the level of energy service received, not the energy inputs, and so excludes any energy efficiency effects.

efficiency target would require new programmes after 2018 that are at least as ambitious as current programmes. Further work is required to assess what such programmes would entail, taking into account further projections on sectoral growth projections for the country.

Additional economy-wide efficiency improvements beyond these specific programmes will also be important especially as the industrial and commercial sectors start to grow, and more households are connected to the grid over time. There also needs to be an incentive for the utility to promote EE and DSM. Estimates by the McKinsey Global Institute[17] estimates that across Africa as a whole, efficiency improvements could reduce energy consumption by almost around 6.5% every 5 years over the period to 2020. Assuming these rates of improvement can be continued, the total efficiency improvement by 2030 relative to 2010 would be almost 25% in total. Under the ESSP, actions have been identified which achieve approximately this same level of efficiency improvement over the period to 2018. These actions are assumed to continue at a constant pace after 2018 i.e. the same grid loss programme is applied to new grid infrastructure as it is rolled out. Based on the McKinsey estimates, additional savings of around 13% of total energy consumption would be available through additional measures (**Error! Reference source not found.**). One example currently under consideration by MININFRA to undertake a programme to implement LED in place of CFLs in the existing lighting stock. It is estimated that this could save around 30-40 MW of peak load. As demand grows over time, the savings would be correspondingly larger. These opportunities are being developed under an energy efficiency implementation plan by the Ministry.

Figure 8 Potential energy efficiency improvements to 2030. Area in green is additional to efficiency improvements assumed in the generation scenarios



An important impact of such efficiency savings would be to reduce costs in the electricity sector, in particular reducing the amount of generation capacity which needs to be built (reducing capital costs), with consequently smaller O&M costs of operating a smaller generation fleet and meeting a lower level of demand. The unit costs of generation do not change significantly, since the whole generation system is assumed to scale down accordingly to meet the lower demand[18]. These additional energy efficiency savings have been put into the electricity sector costing model, which shows that by 2030 the annual cost of electricity sector provision (including capital plus O&M) could be reduced by around $110m depending on the exact generation scenario. Aggregated over the period 2020 -2030, these efficiency improvements would result in savings worth around $500m.

[17] McKinsey Sustainability & Resource Productivity 2012. "Energy Efficiency, a compelling global resource" available at http://www.mckinsey.com/search.aspx?q=energy+efficiency accessed Jan 2015

[18] In fact there is a small increase in unit costs under the energy efficiency scenario since transmission & distribution costs remain roughly the same, so these same fixed costs are spread over a smaller number of units consumed.

The cost of achieving these savings is uncertain. The estimated cost of the current energy efficiency programme under ESSP is estimated at around $10/year. It is likely that given the law of diminishing returns, expenditure would need to increase to sustain the same rate of efficiency improvement. Assuming an expenditure of approximately $15m/year, the cumulative expenditure between 2020-2030 required to achieve the additional savings identified by the green section of Figure 8 would be in the region of $150m.

2.5. Relevant nexus targets until 2030

Energy intersects with several other socially important development themes to create the so-called 'nexus' issues. Some attempt is made here to make specific quantitative targets, but this is not always easy, especially given the lack of baseline data. In some cases therefore, the targets are qualitative. Nevertheless, specifying these targets should help in terms of streamlining nexus issues into the SE4All Action Agenda and government's further implementation of energy policy.

Table 8 Indicative goals for nexus issues

Nexus Issue	Issue	Target
Health	Indoor air quality from cooking (predominantly affects women and children, overlapping with other nexus issues)	All households to be at Tier 3 or above air quality standards by 2030 defined by ISO standards in line with WHO guidelines. For those using cookstoves that do not meet this standard, implement other methods such as ventilation for improving air quality.
Water	Coordination of water planning	Hydro plant fully integrated into IWRM plans by 2020 for domestic use, energy, agriculture, and industry. Multi-use schemes routinely considered in project planning.
	Vulnerability of hydro supplies to climate change impacts	By 2020 at the latest, all hydropower and multi-use schemes fully assessed for climate vulnerabilities and adaptation measures identified and costed. By 2030 at the latest, majority of schemes have risk-mitigation strategies implemented.
Food	Land-use competition	Beyond 2020, net expansion of land use for forestry or other energy production will only be considered if there is no conflict with food security objectives.
	Energy consumption for irrigation	Water irrigation is planned to increase significantly, and solar PV powered pumps should be routinely considered as the way to provide energy for such systems. Such technologies can help improve resilience to climate change.
Gender	Time spent on biomass collection	Halve the amount of time women in rural areas spend collecting firewood by 2030.
	Quality of cooking options	Involve women in the selection of technologies (e.g., cook stoves) and in the selection of relevant research topics in support of the SE4All targets.
	Training	Provide relevant training to women (e.g., on better water management or water storage for energy purposes, including for biogas installations, improved cookstoves etc.
	Employment	Involve women as actors in the value chain for marketing the stoves as energy entrepreneurs

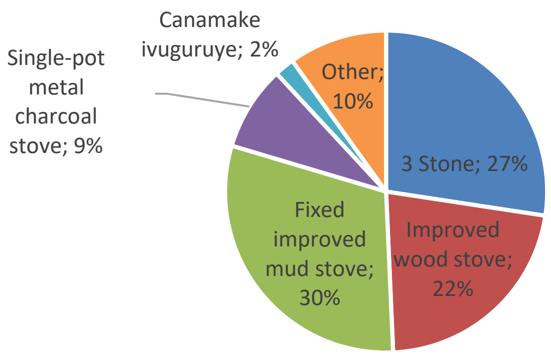
3. Priority Action Areas

3.1. Energy Access: Clean Cooking

3.1.1. Current status

According to a recent study, traditional wood fuel is the energy used by the vast majority of rural households (i.e. over 90%) for cooking[19]. The average household uses around 1.8 tonnes of firewood each year to satisfy its cooking needs with a traditional stove. The average monthly consumption per household on fuel wood is RWF 1,930. There has been a long-running government program since the 1980s which has achieved 60-70% household penetration. A survey[20] of stove types in use in Rwanda carried out in 2012 found the following breakdown (Figure 9).

Figure 9 Estimated breakdown of stove types in use in Rwanda



Data from the survey is limited regarding the quality of performance of different cookstove types, but it is estimated that most of the improved cookstoves identified in the survey operate at around Tier 1 efficiency levels. Private sector led efforts are also promoting cook stoves that are up to three times more efficient than the traditional 3-stone stove, operating at Tier 3 or Tier 4 levels of performance.

However, the quality of the baseline data in this sector is still lacking. Further data collection is due to be carried out during 2016 as part of the SE4All Multi-tier Framework assessment, for which Rwanda is one of the first pilot countries to carry out detailed surveys on energy access (including cookstoves and lighting solutions). As a result, a more accurate baseline assessment will soon be available.

A recent market analysis by Accenture for the Global Alliance on Clean Cookstoves[21] identified the market potential for cookstove interventions in Rwanda as being 2.4 million households. Important differentiation exists in this market between urban and rural households, between those who collect fuel for free vs. purchasing fuel, and between those living in areas of high wood fuel deficit and/or poverty, vs. those in less vulnerable areas. It will be important to address the different nature of these markets (e.g. willingness to pay, affordability of solutions etc.) when designing programmes targeting different parts of the population. The survey also identifies the key market players and stakeholders in the improved cookstove sector, including:

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[19] EWSA. Baseline Impact Evaluation Survey for the EARP Sub-Components in Rwanda August 2014

[20] "BIOMASS USE SURVEY IN URBAN AND RURAL AREAS IN RWANDA" AESG contracting to EWSA, May 2012

[21] Global Alliance for Clean Cookstoves. "Rwanda Market Assessment Sector Mapping". Accenture Development Partnerships, April 2012

- Government departments and implementing agencies, including Ministry of Infrastructure, Rwanda Energy Group, Rwanda Environment Managament Authority and the Ministry of Health
- Private sector actors, including local and international companies involved in manufacturing and retailing various types and standards of improved cookstove
- NGOs, including SNV, Practical Action and others involved in promoting clean cooking solutions at a local level

The potential biogas market in Rwanda is estimated at 150,000 households, among predominantly rural customers. Government has put in place an elaborate program for disseminating bio digesters in households, schools and prisons to reduce demand for wood and charcoal and improve people's health since 2007—the National Domestic Biogas Programme (NDBP). The NDBP's initial focus was on capacity development, training technicians and entrepreneurs, and social marketing. The institutional Biogas Program began at KIST as a pilot in 1999. In 2008, Government announced a policy to introduce biogas digesters in all schools (estimated at around 600), large health centers and institutions with canteens. Through this Institutional biogas program, 11 out of the 14 prisons in Rwanda are currently using biogas for cooking. Since the beginning of the program, 3,687 domestic biogas digesters have been installed in households and 68 institutional digesters have been installed mainly in schools and prisons. Government continues to subsidize biogas technologies, with a 50% government subsidy and the use of local microfinance institutions, even after the termination of financial support by DPs to the program. The biogas systems installed in the schools and prisons have reduced firewood consumption by close to 60% and 40% respectively, along with significantly improved hygienic conditions and cost savings.

3.1.2. Existing plans/strategies

Responsibility for the biomass sector straddles multiple Ministries in Rwanda. MININFRA has responsibility for energy usage, so have the mandate to promote efficient cookstoves, and have instigated various initiatives and programmes over the years, together with its main implementing agencies (previously EWSA, now the Rwanda Energy Group). From an energy perspective, the strategy framework for the biomass sector is set out in the Biomass Energy Strategy (BEST) of 2009. However, this document is now due to be reviewed and replaced during 2016. The Ministry of Health also plays a role in the cookstove sector. Because of the significant health impacts of indoor air pollution, the Ministry has supported various clean cookstove initiatives in the past.

From the upstream wood supply perspective, the lead institution is the Ministry of Natural resources and its implementing agency, the Rwanda Natural Resources Authority. The important strategy document is the "Supply Master Plan for fuelwood and charcoal". Again, the data in this document is due to be updated with new information arising from the ongoing Forestry Inventory review and revisions to the Forest Management Plan and Forestry Policy. Due to the ongoing nature of these strategy reviews, the analysis in this Action Agenda is based on the earlier strategies, but it is expected that the conclusions regarding key required actions are nevertheless robust.

3.1.3. Gaps

The key issues facing the biomass sector generally fall into two separate categories; demand-side issues, relating to the use of energy (mainly in cookstoves) and supply-side issues relating to the energy supply value chain. These are discussed separately in the following sub-sections.

Demand-side issues – clean cookstoves

The single most important appliance in the biomass sector is the cookstove. This determines the efficiency with which biomass is used, and therefore has a strong impact on overall demand. In addition, cookstoves can have a very large health impact: household air pollution causes over 5000 deaths per year in Rwanda, more than HIV/AIDS, and rates as having one of the highest burdens of disease in the country[22]. The following gaps and barriers have been identified as factors that limit the uptake of clean cookstoves[23].

Table 9 Gaps & barriers for clean cookstoves

Issue	Comments
Affordability and Willingness to Pay	In the case of intermediate and advanced biomass cookstoves and modern fuels, affordability to the end-consumer is a major barrier to adoption. Cost is likewise a critical obstacle for the bottom 15-30% of sub-Saharan Africa consumers even where low cost artisanal ICS solutions are concerned. Willingness to pay is an even more important cross-cutting issue. Even when the affordability challenge can be removed via subsidies, there is abundant evidence that Africans are unwilling to pay for the health benefits of clean cooking and have substantial behavioral barriers to replacing their existing stoves with clean cooking technologies.
Consumer awareness	Consumer awareness of the harmful effects of traditional solid fuels and knowledge of the availability and benefits of improved affordable alternatives is low. It is a market failure that cannot be addressed by the private sector alone; it will require significant government and donor support to drive consumer demand and change the surmountable behaviors holding back the adoption and use of improved and clean cookstoves.
Last-mile distribution	Distribution of clean cooking products is costly, with no easy answers to the challenge of reaching rural consumers; progress will require both experimentation with new institutional and retail approaches and significant investment into channel development. In the immediate term commercially oriented ventures likely need to focus on more profitable urban and charcoal user consumer segments; reaching the rural consumer requires cross-subsidization from more profitable urban market segments or less commercially driven business models.
Producer capacity	The technical capacity of domestic clean fuel and improved stove producers is low, there are major business management and technical skill gaps for producers in the market seeking to move up the product quality and performance ladder. For international industrial manufacturers, technical capacity challenges are less of an issues. Overall, producer capacity is a less significant challenge in the cooking market than in other donor supported off-grid product markets like solar home systems and solar lanterns.
Producer finance	Building successful last mile clean cooking businesses in Africa is a costly endeavor, due to product importation hurdles, logistic and transport challenges, the need for intensive consumer marketing, and the importance of extending credit to both last mile retailers and end-users (i.e., via pay as you go schemes). While working capital financing is generally a challenge for African SMEs, the issue is compounded for cooking solution enterprises because they are often promoting new technologies in markets with uncertain or still limited consumer demand and limited understanding by financial institutions of their products and economics.
Cookstove quality and performance	The number of improved cookstove models and fuel production solutions customized for local environments is still low, there is evidence that many basic ICS perform poorly in the field at least in part due to the difficulty of accessing high quality materials, and systemic support for innovation and R&D on breakthrough solutions that can offer higher performance (e.g., fan gasifiers) and, even more important, more attractive and functional end-user focused designs, is still limited. For clean cooking and improved solutions that do reach the market, access to standardized testing is limited or unaffordable for many, and does not increase end user understanding of their likely performance so they're able to make informed purchasing decisions.
Policy environment	Ineffective or perverse incentives are common in regulations governing solid-fuel production and improved biomass cookstoves; incentives for scaling up clean fuels are often absent or, in the case of large, direct modern fuel subsidies, unsustainable; and high, poorly targeted import duties currently hold back the development of more-effective domestic clean cooking sectors. Donors programs can crowd out private sector investment and compound policy challenges.

The Woodfuel Supply MasterPlan (SMP/WISDOM) study points to improved cookstoves (ICS) as being an essential element of the strategy to address the supply-demand gap. However, it is rather cautious in its assumptions. Both SMP / WISDOM and AESG studies estimates that ICS would lead savings of 23% for fuelwood stoves and 23-26% for charcoal stoves compared to traditional cooking techniques

[22] http://www.healthdata.org/sites/default/files/files/country_profiles/GBD/ihme_gbd_country_report_rwanda.pdf

[23] World Bank "State of the Clean and Improved Cooking Energy Sector in Sub-Saharan Africa" December 2014

such as 3-stone fires. Since it is estimated that 70% of the population already use ICS[24], there is only an additional 30% of the population could take up ICS in the SMP / WISDOM more efficient AME scenario.

Technically however, ICS and advanced cookstoves (ACS)[25] are capable of significantly greater wood savings of 60% or more compared to 3-stone fires, and over the longer-term timescales relevant to SE4All, it will be important to aim for more ambitious targets. This is especially important given the additional health benefits that more advanced cookstoves can offer compared to the more basic ICS in use today. An International Standards Organisation workshop agreement (IWA)[26] identified four performance tiers for cookstoves depending on their efficiency, environmental and health impacts: Tier 0 includes to unimproved traditional cooking methods; Tier 1 relates to measurable improvements; Tier 2 substantial improvements; Tier 3 currently achievable technology for biomass stoves; Tier 4 stretch goals for targeting ambitious health and environmental outcomes.

An on-going review by the World Bank ACCES project[27] (WB/ACCES) of the status of clean cookstoves in sub-saharan Africa (SSA) shows how different types of available stove perform compared to these Tier levels. The majority of ICS used in Rwanda today operate at Tier 1 level. However, the report shows that more advanced versions such as natural draft gasifier and fan or forced-draft gasifiers have substantially better performances, and can potentially perform close to those of kerosene or LPG stoves. These tier level classifications include not just energy criteria, but also criteria relating to emissions of indoor air pollutants such as particulates which create significant health impacts, particularly on women and children who tend to be most exposed. In terms of potential wood savings, the performance of the Tiers is estimated by WB/ACCES as shown in Table 10.

Table 10 Cookstove efficiency ratings for proposed ISO Tiers

Proposed ISO Tier	Illustrative stove type	Efficiency[28]	Energy savings[29] relative to Tier 0
Tier 0	3-stone fire	<15%	0%
Tier 1	ICS	>15%	23%[30]
Tier 2	Rocket stove	>25%	>40%
Tier 3	Forced draft	>35%	>57%
Tier 4	LPG / advanced biomass	>45%	>67%

Changing cooking practices will ultimately require that clean cooking solutions are cheaper for the end user than current practices, as willingness to pay, particularly regarding health benefits, appears to be low for most households. However, the cost of fuel, particularly in urban areas is relatively high, creating the potential for cleaner and more efficient stoves to have a positive economic benefit. From a survey carried out for MININFRA[31] of households in Kigali City it was found that the average charcoal

[24] "BIOMASS USE SURVEY IN URBAN AND RURAL AREAS IN RWANDA" AESG contracting to EWSA May 2012
[25] Advanced cookstoves include gasification technologies, see GIZ " Micro-gasification: cooking with gas from dry biomass" http://www.giz.de/fachexpertise/downloads/giz2014-en-micro-gasification-manual-hera.pdf
[26] ISO International Workshop Agreement Guidance for Clean Cookstoves 2012. A collaborative effort of The Partnership for Clean Indoor Air, The Global Alliance for Clean Cookstoves, and The Cookstove Community
[27] World Bank "Clean and Improved Cooking in Sub-Saharan Africa: A Landscape Report" ACCES: Africa Clean Cooking Energy Solutions Initiative. July 2014 (Draft for Review)
[28] From WB / ACCES report Table 1.1 referenced to Global Alliance for Clean Cookstoves
[29] Own calculations
[30] 23% saving typical for Rwanda, figure taken from SMP/ WISDOM report
[31] "Baseline Assessment on Improved Cook Stoves (ICSs) in Urban Area" – report by Practical Action for MININFRA 2011

consumption of a household is 2.1 bags per month (the average weight of a bag of charcoal is 35kg). In other urban areas, the average consumption per household is 1.6 bags. Households using wood consume 1.2 and 1.6 stere[32] per month in Kigali city and other urban areas respectively. The average cost of a bag of charcoal in Kigali City is RWF 6,047 and 6,314 in other urban areas. Firewood users in Kigali pay RWF 6,000 for a stere of wood whereas in other urban areas the average amount paid per stere was estimated as RWF 5,200. This means that charcoal users are paying around US$180-225 per year, and wood users are paying US$130-150 per year. With fuel savings potentials of up to 50% or more for the most efficient fuel stoves available, annual savings of $70-100 are possible.

The economics in rural areas may be harder to address, since fuels are cheaper (often free), and household incomes and ability to pay for more expensive stoves will be lower. Greater levels of intervention may be required. The World Bank / ACCES report states that widespread dissemination of Tier2-Tier4 stoves would require carefully designed subsidies or credits to be put in place.

Gaps: Supply-side issues

Effectiveness gaps exist in many parts of the supply-side of biomass in Rwanda. A more detailed analysis of some of the key areas that need improvement is provided in Appendix 1. The following table summarises some of the key issues, drawing from the SNV report on the charcoal value chain (CVC), and from interviews with stakeholders.

Table 11 Gaps & barriers in biomass supply

Issue	Comments
Lack of management of plantations	For managed plantations and agro-forestry, the largest effectiveness gap for wood producers is the lack of management. Wood producers often have very little knowledge about proper forestry management. Furthermore, there is very little investment put into forests. This may be due to lack of: capital, being able to receive a loan, knowledge about the benefits of investment and/or certainty of future forest policies and legislation. Agro-forestry sources are an important source of wood, but smaller landholders are often disincentivised to engage in or increase wood production because burdensome regulation leads to a 'grey' market, and lack of proper market signals to allow them to invest.
Lack of skills & institutional capacity	**Charcoal**: the biomass supply masterplan sets out the actions, but there is not sufficient skills amongst the charcoal manufacturers nor capacity within the relevant local government institutions for these to be carried out. For example, more technicians are needed on the ground who can monitor any standards that are set. **Wood supply**: there is a need for more technicians to be able to focus on improving standards in the agro-forestry sector. Wood growers should be encouraged to combine crop growing, planting trees on the edges of their land. Increasing productivity will require increasing the number of people who have sivicultural management skills & knowledge.
Problems with Permitting	One of the major bottlenecks in the CVC comes from the cutting permit process. Due to lack of capacity, it may take the District Officer weeks or months to visit the site and grant the permit which hinders the entire CVC. Furthermore, it is not always known by producers upon what basis the permit will be granted or rejected. In addition, District NAFA Officers may not necessarily be foresters but may be trained in other relevant fields which results in capacity issues. This uncertainty can also act as a barrier to entry for farmers considering growing trees. Addressing this issue could improve economic attractiveness of the sector and increase production There appears to be a lack of clarity about whether the permit, and its time restriction, applies to only cutting or to cutting and carbonization. This issue should be clarified and applied uniformly across all districts. The 2010 regulations were changed to allow tree cutting if it is for home use (up to some level) without permit, and in 2013 the limit was increased. It will be important to assess the effectiveness of raising these levels on the wood-cutting practices associated with the charcoal industry.

[32] A stere is a measure of volume. 1 stere of wood typically weighs 350kg.

Charcoal producers	One of the most significant effectiveness gaps is the use of traditional carbonization techniques by the vast majority of charcoal producers; there is a very low penetration level of improved techniques. There is also a large variety in quality of charcoal sold on the market; the quality depends on the type of raw material used, how dry the raw material is, the carbonization process, etc. No standards are applied to the charcoal supply industry, so poor quality fuels from cheaper and less efficient processes compete equally with higher-quality more efficient processes. This creates disadvantages for users, because the lower quality charcoal is also less efficient in the cooking stage.
Transportation	Around 10% of charcoal is wasted as dust, which could in principle be collected and used as a low-quality briquette suitable for use in institutions.

3.1.4. Actions needed to achieve clean cooking access

The following table contains the actions set out in the ESSP, with minor alterations reflecting comments arising from the stakeholder engagement process.

Table 12 Biomass actions

Sector / Issue	Action	Details / Commentary
Sector strategy	Update 2009 BEST strategy	Whole sector needs strategic review, with new data for cookstoves and updated forestry supply and demand balance information.
	Review biogas sector	Carry out biogas sector needs assessment, market study and technology feasibility studies, and develop guidelines on technology standards
	Review charcoal sector	Review regulatory framework for small-scale charcoal producers, design and implement local-level training programs
		Consider a planned and phased approach to reducing dependence over time on charcoal in urban areas
Financing	Incorporation of biomass and cookstove sectors into national financing mechanisms such as Energy Development Fund	Enable provision of credit lines to financial service providers targeted at small businesses involved in the biomass sector. There is an acute need for more access to small-scale loans to enable greater levels of investment in equipment and materials to increase productivity. This applies to the whole supply chain, from plantation owners, charcoal producers, and stove manufacturers and distributors.
	Fiscal measures	Consider tax measures that incentivise more efficient stoves (Tier 3-4), and discourage the less efficient stoves (Tier 1-2). Consider role of carbon financing
		Replace patchwork local tax system for charcoal with single national rate (10%), collected locally, with funds put towards verification & enforcement mechanisms
		Harmonise taxes (VAT) on alternatives to charcoal. Consider favourable tax regime for alternative biomass fuels to promote transition away from charcoal
Stoves	Review of subsidy design	Subsidies and/or financing schemes (access to credit) likely to be required, but need to avoid lock-in to Tier 1 technologies that are not sufficient to solve Rwanda's biomass supply and related health problems. Government support mechanisms need to recognise the vital role of the private sector, and ensure that business models and competition are enhanced not undermined by subsidy programmes. Support should focus on providing critical public goods with emphasis on consumer education, access to finance, funding for R&D, expansion of testing & standards, and enabling fiscal and trade reforms. Also consider results-based financing approaches and carbon markets.
	Phase in standards and certification for cookstoves to gradually shift the market from towards Tier 2-4 models	Phasing in standards over a realistic timescale will send a signal to manufacturers that they need to improve their products and introduce new designs. Processes for certification and expansion of testing facilities will need to be implemented. Standards need to be well

		designed in order avoid being too cumbersome which could hinder market entry for high-quality producers.
	Public awareness campaigns to promote of improved cooking options	Awareness campaigns and market-building activities by government may be necessary to support private-sector growth and uptake of improved cookstoves by households. Other cooking options such as pressure cookers or pots skirts may also be appropriate to include.
	Support manufacturing of higher quality stoves (Tier 2-3)	Review import duties on materials (e.g. steel plate) required to manufacture more efficient designs, and review R&D needs and access to financing through the EDF.
	Develop alternatives such as biomass pellets	Support experimental development of biomass pellets as an alternative to charcoal, pilot in 1 or 2 districts to identify the feasibility of pellets / gasifier stoves, and identify barriers that need to be addressed and further develop the action plan required for the country as a whole.
	Develop M&E framework to support the strategy	Build on the planned Multi-tier Framework (MTF) assessment in Rwanda to embed data collection into the national statistical processes to help inform future strategy development and implementation.
Wood production	Review regulatory approach to ensure it is effective at providing incentives for small landholders to invest, increase planting, productivity	Need to remove impression that wood production and charcoal sector in particular is illegal and avoid covert manufacturing. In 2013, the limit on how much wood could be cut for private consumption was raised. It will be important to assess whether this has had a positive impact on wood cutting practices in the charcoal industry. Following this assessment an awareness campaign should be carried out to ensure clarity among permit recipients.
	Develop a national inventory of current and potential plantation productivity	Forest productivity data is scarce in Rwanda and a nation-wide inventory of biomass sources specifically focused on their sustainable growth potential is urgent.
	Improve management of larger private plantations	Develop and promote silvicultural practices among private plantation owners in order to preserve and improve their standing stock, increase the forestry productivity and favour rational and sustainable tree-cutting.
	Improve management of government plantations (~20% of total)	Stop illegal cutting of trees in public plantations, set up management plans for restoring public national and district plantations, develop and promote adapted tree management and rational cutting methods, train local bodies and professionals, in order to have 50% of public plantations under management and rational cutting by 2015 (75% by 2020), with considerably better forestry productivity (x 2 in managed areas); reinforce private sustainable management of public plantations.

More work is required to assess the costs of carrying out these actions. However, initial estimates suggest that cost of these enabling actions is approximately $4.5m over 5 years[33], excluding capital expenditure and expenditure on forest management actions.

3.1.5. High-Impact Opportunities

This sector not only provides major opportunities for Rwanda, but many of the issues addressed here have been formally identified as 'high-impact opportunity areas' for SE4All at the global level (see http://www.se4all.org/actions-commitments/high-impact-opportunities for more details on the high-impact opportunities). In particular, these include:

Energy and Women's Health. It is mostly women (and children) who suffer the worst health impacts from cooking-related air pollution. These groups stand to benefit hugely from a determined and ambitious plan to move towards much more highly performing cookstoves.

Sustainable bioenergy. The actions outlined in this Action Agenda relating to both reductions in demand through massive efficiency savings associated with moving away from charcoal, combined

[33] Internal costs of the relevant institutions are not included in this estimate - in some cases there may be a need for additional capacity-building or expert input to support these activities which could have a direct cost implication. Improved forest management activities are not costed.

with measures to improve production levels would put Rwanda's biomass sector onto a sustainable track. The goals and actions outlined here would allow consumption to be well within the ability of the country's managed forests and agroforestry sectors to meet demand.

Universal Adoption of Clean Cooking Solutions. The goals outlined in this action agenda set out how Rwanda can provide universal adoption of clean cooking based on biomass solutions. This has the advantage of avoiding a major increases in use of LPG/kerosene (which in many developing countries has had to be subsidised). Biomass also retains a considerable share of the supply value chain within rural communities, and represents a major source of rural employment.

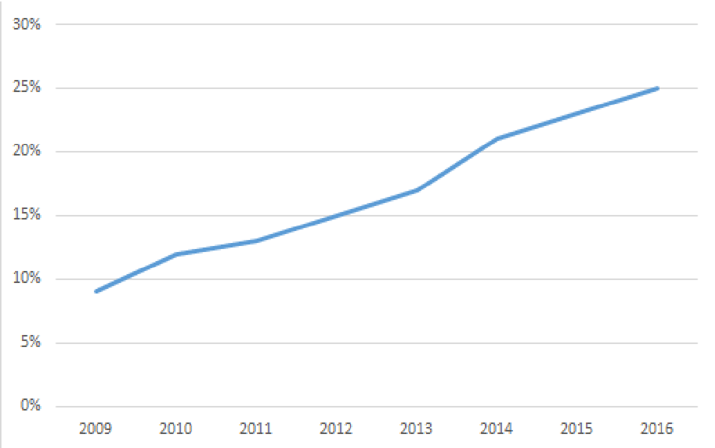
3.1. Energy Access: Electricity

3.1.1. Current status

Roll-out of the electricity grid to households

The access priority over the last 7 years has been on extending the national distribution system across the country and providing consumers with access to the grid electricity as indicated in Figure 10 below. These efforts have been led by the ***Electricity Access Roll-out Programme (EARP)***, under which access has increased from 364,000 households in June 2012 to an estimated 590,000 households (24% of the total) by June 2016.

Figure 10 Percentage of the population with grid access (Source: EARP)



On average, 75,000 new households have been added to the grid each year for the past five years, and the trend is set to continue. As outlined below, the continued rollout of the EARP presents a number of economic challenges. In the light of these challenges along with emerging technologies which can deliver access more cost effectively a more holistic approach to energy access is required. This more holistic approach is the focus of this Rural Electrification Strategy

Access rates in urban areas are higher at 45%/60% for periurban / Kigali city because of the greater density of population and significantly lower cost of connection compared to rural areas which have around 15% access. Urban households also tend to have higher Tier access levels because they generally have higher levels of income and therefore higher consumption levels. Connection costs in rural areas depend on the distance of a household from the existing grid infrastructure, but typically average around $1000 per connection including connection fees and meters. Barriers include remote areas of population & poor access roads in rural areas. The cost of connecting so-called 'in-fill' households, where a new house is built close to an area that already has electricity provision can be much lower, around $350 per connection. This figure is typical of connection costs in urban areas. On average, the connection cost in Rwanda to date has been $650 per household.

The majority of the connection fee is currently subsidised by government and development partners (DPs). Although such subsidies can make initial roll-out affordable, it is important to take into account recurring costs including O&M and depreciation costs. Estimates for these costs have not been provided by EUCL. Calculations using the SE4All costing tool suggest these amount to $200m per year by 2030 depending on the access rates achieved. Any new grid infrastructure installed now will need to be replaced over about a 25 year time frame[34], and the replacement costs need to be built into the cost structure and economics of the sector.

The household tariff for electricity is around US¢20/kWh. This is lower than the cost of provision, but a high proportion of total costs for households are fixed (associated with the costs of connection of up to US$1000) rather than varying with the level of consumption. This means that the lower the level of electricity consumption, the higher the unit costs of providing that electricity, since the fixed costs are divided over a small number of units.

Total costs of providing electricity access therefore depend on the roll-out of other policies and social trends relating to urbanisation and the policy of *Imidugudu* (development of village-level population clusters). Urban population are expected to grow significantly faster than the average, rising from 24% of the total population in 2010 to 42% in 2030. These trends also affect the cost-effectiveness of provision of many other services such as health and education, as well as increasing opportunities for a wider range of economic activity and employment. The trend towards more concentrated settlements and greater urbanisation helps reduce connection costs over time. On the other hand this benefit will be counterbalanced to some extent by the fact that the later stages of rural electrification will tend to be connecting to harder-to-reach households and because distribution lines will have to be upgraded to deal with higher power requirements across the country as demand grows.

Provision of off-grid access

Off-grid electricity covers a wide range of different technological solutions depending on the application. They can include small off-the-shelf products for individual households such as solar lamps and solar home systems. Larger stand-alone systems are also available for commercial applications, schools, clinics and other public administration buildings in remote areas. Off-grid solutions can also include mini-grids which would service a local area such as a village, perhaps including productive loads such as localised businesses and industries. The policy support mechanisms vary considerably for these different approaches. The relative advantage of off-grid, mini-grids, and on-grid supply are outlined in the table below.

Table 13 Pros and cons of different types of electricity access

	Pros	Cons
Off-grid	Small modular units suitable for low-power usage makes initial capital outlay affordable. This can include over-the-counter products like solar lamps and solar systems with minimal infrastructure requirements and relatively lower levels of technical skills for buyers and sellers.	Need for storage. Cannot easily share power between multiple households. Unit cost of electricity can be high. Power levels generally not suited to higher demand productive loads such as industrial uses.
Mini-grid	Moderate economies of scale can reduce generation costs relative to off-grid. Lower cost of connection compared to on-grid. Can share power between households, reducing total power requirement.	Economies of scale not as great as on-grid. Moderate unit costs. Needs greater levels of infrastructure and technical expertise than stand-alone off-grid systems.

[34] 25 years is the lifetime ascribed to T&D infrastructure in the World Bank META model https://www.esmap.org/node/3051

On-grid	Greater economies of scale lead to lower generation costs. Mixed portfolio of plant means that storage generally not required. Unit costs can be low for households with moderate-higher usage.	High fixed costs of transmission & distribution lead to high unit costs for households with low consumption levels. System relies on centralised utility model, with less control for consumers.

There has been an acceleration of interest and activity in the off-grid sector over recent years, driven by cost reductions in solar technology as well as innovations in business models which are making solar power a cost-effective option compared to kerosene. Recent programmes to promote household access to solar power are summarised in the table below[35].

Table 14. Recent programmes for promoting off-grid solar in Rwanda

Project name	Funding amount €m	Funded by	Estimated Target of project
Energy Small and Medium Enterprises Project (ESME)	3.1	Russian Federation through World Bank	46,773 solar lamps, eq. of 10,000 HH
Mobisol	6.0	EU grant	49,000 HH
Azuri / GVEP	0.9	USAID	10,000 Azuri Indigo solar systems, eq. of 8,000 HH
Ignite Power		Liquidnet and the Agahozo-Shalom Youth Village	Pilot project: 1,000 solar home systems eq. to 1,000 HH.
		MoU with MININFRA	250,000 units
SNV IRES		Netherlands	20,000 households
Energising Development (Solar lighting)	3.4	Energising Development (Germany, Netherlands, Norway, Australia, UK, Switzerland)	328,000 solar lamps, eq. of 176,000 HH
Energy and Environment Partnership		Finland, Austria, UK	1,840 HH
One Acre Fund			100,000 lamps distributed over past 3 yr

Companies planning to enter the market in Rwanda still need to overcome several important barriers (notably access to working capital and roll-out of distribution and servicing channels) before they could deliver at these scales. The private market for solar home systems in sub-Saharan Africa in general has been growing rapidly, with a number of companies entering the market and raising substantial funds for expansion. In most of these countries, the market is still at a relatively immature stage, with companies needing to further demonstrate track-record before being able to raise fully commercial sources of financing. Nevertheless, the increasing interest from investors in the sector reflects improved business models that address affordability for customers by spreading out payment over months or years, combined with remote sensing and mobile banking options that improve the ease and reliability of payments. Rwanda is becoming a focus for several of these companies as a proving-ground for their business models because of its relatively compact nature and ease of doing business.

3.1.2. Existing plans/strategies

The strategic framework for Rwanda's energy sector is established in the Energy Sector Strategic Plan (ESSP) and the National Energy Policy which set targets up to 2017/18. These documents recognize the essential role of electricity access in accelerating economic development, as well as improving

[35] From Table 1, SREP Investment Plan.

health outcomes and standards of living for people in Rwanda. The target for electricity access is for 70% of households to have access by 2017/18, to be met through a combination of on-grid and off-grid supply. Further to this, 100% access to electricity is targeted by 2020.

An additional strategy specifically relating to rural electrification is now under preparation by the GoR. This strategy has been developed recognising that advancing technology means that there is an ever expanding range ways through which households can access electricity: from a solar light that would charge a phone or radio, through to a larger solar home system capable of lighting an entire house and powering appliances such as a television right up to a to Grid connection, required for large scale commercial and industrial power use. In recognition of this range of technologies and range of consumption requirements from different households and businesses, a key principle of the new strategy is to provide the most appropriate form of electricity access to households based on their consumption. A pathway will be established such that as households energy requirements increase in line with the country's economic growth they can graduate to more costly, higher powered forms of electricity. The access target proposed in the strategy is shown in Table 15

Table 15 Tier breakdown of access target in Rural Electrification Strategy

	Target 2017/18
Tier 0 (no access)`	30%
Tier 1	22%
Tier 2	48% (of which approx. 31-35% grid)
Tier 3	
Tier 4-5	
Total Access	**70%**

The financing and implementation of this strategy will be undertaken in partnership with the private sector, where competition will be leveraged to help drive down costs and improve customer choice. This builds upon the significant private sector interest that exists in both solar home systems and mini-grids in Rwanda and more widely across Africa. The strategy contains four distinct programmes:

1. Government funds to be targeted towards facilitating access to modern energy services for those with the lowest income;
2. Establish a risk mitigation facility to the private sector such that solar products will be made available on financial terms the population can afford;
3. Mini-grids will be developed by the private sector with the Government playing a key role in identifying sites and establishing a framework through which these become financially viable investments;
4. The government will continue to roll-out the electricity network through the EARP programme, focusing on connecting high consumption users and driving economic growth.

The programme is expected to channel around $120m of investment by the end of 2017/18 and provide access to 880,000 households.

These developments in off-grid and mini-grid solutions are due to be supported by a major programme under the Scaling up Renewable Energy Program (SREP). This is one of the channels of the Climate Investment Fund (CIF), for which Rwanda successfully applied for $50m funding to support off-grid renewable energy developments in the country. This programme is currently under development, and is expected to start dispersing funds to projects in 2017.

3.1.3. Gaps

A number of barriers have been identified affecting electricity access:

Affordability of electricity: Both on-grid and off-grid solutions face the challenge that especially in rural areas, households have very little capacity to pay for significant amounts of energy. Off-grid solutions have some advantage in this respect, as they can be scaled to very low levels, but affordability remains a barrier to achieving more ambitious levels of access.

Ensuring financial sustainability of network investments: The average annual cost of each connected consumer is around $50 (around $45 in financing the loan required for the connection and a provision of $5 to contribiute towards operations and maintenance, for which full cost estimates are not well-established). Consumers need to use 130kWh per month in order to fund the cost of their own connection. Currently around half of consumers are using less than 20KWh per month.

Uncertainty over budget for grid roll-out: Budgets are often set by the timescales of development partners, but a longer time frame is required in order to initiate an efficient procurement process. Long-term planning is also required in order to coordinate with planning of off-grid solutions.

Coordination between the distribution plans and the generation plans: Though difficult due to the different determining factors of the two plans, there is urgent need to harmonize the distribution planning and coordination with the changing generation plans to ensure that they go hand-in-hand to meet the set targets.

Coordination between distribution plans and the provision of off-grid solutions: Given the uncertainty over the rate of roll-out of the grid to rural areas, it is hard for private companies to plan off-grid investments. The sector currently has too many different players and no clear strategy. MININFRA / REG involvement is in danger of crowding out private investment. Other Ministries (e.g. Health) need to coordinate with MININFRA / REG, especially in relation to coordination with roll-out of the grid. One way forward should be the donor/government-led identification of business cases in the off-grid area (e.g. updating the hydro power atlas) to reduce the burden on investors.

Need better technical specifications in competitive tenders: Currently, the tendering process is targeted at achieving lowest cost projects, but the quality of projects needs to be maintained by carefully specifying the quality of materials to be used in the tender specification. Whilst this may lead to slightly higher prices, the durability and sustainability of the project will ultimately be better.

Capacity: There is urgent need to build both institutional and individual capacities in ministries and their implementing agencies (including local governments) so as to be able to effectively deliver on the set targets[36].

Access to off-grid finance and commercial sustainability: The private sector is small in this area, and due to low purchasing power of the rural population, the return on capital may not be an attractive option. Specific support measures to be identified during the implementation phase of the rural electrification strategy and aligned with the SE4All action agenda. Careful attention is needed to ensure viable commercial structures are in place for off-grid providers to ensure financial sustainability of business models.

Data and analytics: baseline and market information on-grid and off-grid solutions is essential to managing the sector effectively. M&E frameworks can be linked to global efforts, and should maximise the use of Rwanda's engagement as the first pilot country to carry out surveys under the World Bank's Multi-tier Framework (MTF) assessment of energy access.

[36] SOFRECO, March 2013

3.1.4. Actions needed to achieve electricity access

The following table sets out the actions identified to meet the targets in the field of electricity access.

Table 16 Electricity Access Actions

Sector / Issue	Action	Details / Commentary
Financing	Establishment of a Energy Development Fund (EDF)	Provide access to early-stage project finance for project developers. Concept to be elaborated and established as the primary means to co-finance strategic domestic energy projects. Its main purpose would be to provide finance and risk-mitigation, leveraging more private capital into the sector.
		Collaboration with local financial institutions to develop mechanisms to scale up access to finance
Grid	Develop long-term financial planning for grid	Currently no strategy exists for O&M and replacement. Costing estimates need to be developed. As network gets bigger, will need workforce for maintenance and repairs – in rural areas needs to be decentralisation so technicians available in local areas. Could have private companies providing the maintenance – crews based locally for call-out repairs etc.
	Cost-reflective tariff calculations to include demand projections	Demand projections including urbanisation rates need to be incorporated into the analysis, as well as projections of the changes in generation mix. A realistic time-frame for when full capital costs need to be re-couped needs to be factored in to the calculations.
Harmonise grid & off-grid planning	Improve visibility of forward planning of grid extensions	Update and publish 3-year plans to help improve coordination for short-term planning, and work with development partners to increase the time over which there is forward visibility over funding pipeline for grid extension
	Identify long-term saturation levels of grid access	In order to allow efficient planning of off-grid and possible mini-grid solutions, greater foresight of which areas of the country should be targeted for off-grid and mini-grid generation will be an essential element underpinning off-grid electrification strategy.
	Target productive users and public service connections	Ensure provision of electricity to industrial other productive users, as well as public services such as schools, health clinics etc. Ensure coordination between grid connections, mini-grids and off-grid provision
Mini-grids	Develop regulatory frameworks and enabling environment	Revision of simplified licensing framework Analyse eventual inclusion under REFIT with grid expansion -Hybrid system comparative analysis Develop innovative private sector support concept for off-grid development and pilot
Off-grid	Development and approval of off-grid strategy	To include assessment of programs, instruments and institutions required to grow and support off-grid sector Develop legal and regulatory environment alongside and informed by the off-grid strategy
	Support new business models	New business models are emerging such as pay-as-you go. Subsidies may be required for the poorest households, but the design of any incentives, subsidies or other types of support needs further analysis, it will be important that these not distort private sector activities and competition in the sector.
	Financial support	Develop financial products such as loans and guarantees, working through national and local financial institutions that can support both local and international companies.
	Develop and implement quality standards	Avoid lock-in to poor quality technical solutions by for example requiring certification for any solar lanterns distributed (e.g. to Lighting Africa standards). Any support mechanisms should take into account the need to promote the long-term sustainability and reliability of equipment installed.
	Consumer awareness	Customer education to make informed decisions on electricity access plans, financing, and efficient use, and actions to build and grow the market.
	Fiscal policy options	Consider costs and benefits of fiscal policies such as reducing VAT & import taxes on renewable energy equipment, and materials to encourage local production.
	Data & analytics	Maximise the use of Rwanda's engagement as the first pilot country to carry out surveys under the World Bank's Multi-tier Framework (MTF) assessment of energy access. Data collection needs to be incorporated into the country's ongoing statistics and data collection processes..

Excluding capital investments, the total estimated expenditure associated with these actions amounts to around $2.8m over 5 years (not including the costs of setting up the Rwandan Energy Development Fund for which funding is available under the SREP preparation grant). These cost estimates do not include the cost of actions which are assumed to be within existing budget of the responsible institutions, although additional funds over and above those identified here may be necessary to support these actions (e.g. regarding capacity building and other technical support).

3.1.5. High-Impact Opportunities

The most relevant global high-impact opportunities in this sector are:

Off-Grid Lighting & Charging. A major emphasis on this SE4All action agenda is to help accelerate the government's plans to stimulate private sector-led off-grid solutions. These actions are particularly focussed on rural populations, for whom the primary need for electricity is for lighting mobile phone charging and access to electronic media.

Clean Energy Mini-Grids. More work is required to fully assess the economic potential for mini-grids in Rwanda, and compare their cost-effectiveness with stand-alone systems or on-grid access options. They have been identified as an area to be further explored in the energy strategy, and in the actions identified in this Action Agenda.

Energy for Health. Off-grid electricity access is an essential element to upgrading and modernising provision of healthcare in rural areas. Where such provision is currently made through diesel generators, replacement with solar PV units can considerably reduce cost, allowing money to be prioritised for provision of health services. An assessment needs to be made of the energy needs of remove health centres and clinics, and to draw up appropriate investment prospectuses. These projects need to ensure that operation and maintenance costs are fully reflected, and that maintenance schedules are adhered to in order to create reliable and sustainable energy systems.

3.2. Renewable Energy

Issues relating to renewable heat have been covered under the discussion of biomass in the energy access sections of the report (Section 3.1). This section therefore deals with renewable electricity.

3.2.1. Current status

The electricity generation sector faces a wide set of challenges. In the short term, the challenge is to deliver the pipeline of current projects to time and budget given their relatively high technical complexity compared to existing plant on the system. This requires significantly greater institutional capacity and a step-up in the ability for commercial deal-making with IPPs. In the medium term, the challenge will be for the government to take a lead in executing a more strategic vision for the sector to bring down electricity costs through improved planning methods, taking a flexible and adaptive approach to dealing with technical risks. In the long-term, a key challenge will be limitations to Rwanda's indigenous energy resources. New sources (e.g. biomass) may need to be considered, and / or more aggressive strategy on imports.

Renewables have important advantages for Rwanda. As for any country, renewable energy reduces emissions of greenhouse gases and other pollutants, and can reduce reliance on imports of costly fossil fuels, improving energy security. For Rwanda, there is a further benefit in terms of being able to reduce or remove the need to exploit peat resources. Peat energy is being developed in Rwanda, and in the baseline scenario represents a significant share of Rwanda's energy mix. However, extraction of peat can be environmentally damaging for reasons as set out in Appendix 2. The renewable scenarios are therefore important for Rwanda to consider.

Each source of generation has its own issues and barriers, discussed in more detail in Appendix 2.

3.2.2. Existing plans/strategies

The strategic framework for the electricity generation sector is set out in Rwanda's ESSP, which aims to resolve many of the issues raised in the technology-specific analysis above. In addition, cross-cutting issues and gaps can be identified.

As noted above, Rwanda's energy utility has contracted for sufficient power to be delivered to meet demand growth up to the mid-2020s, after which time there will again be scope to influence the generation mix.

Planning is currently carried out primarily by EUCL and EDCL, the two constituent / subsidiary companies of the Rwanda Energy Group. Planning for generation tends to be based on an assessment of the technical and commercial viability of projects in the pipeline. In the longer-term, it will be important to take a more strategic view of future electricity generation developments.

Rwanda has a policy of minimising adverse environmental impacts of the energy sector. This is contained in the Green Growth and Climate Resilience Strategy 2011 (GGCRS)[37]. In May 2014, The GoR under REMA initiated a costing of the GGCRS. This resulted in a report on the investment needs to meet the GGCRS objectives in the energy sector[38]. A key finding was that the total cost of the electricity system could be reduced by moving towards a greater share of renewable energy in the mix, and this could result in significant lower emissions of CO_2 in the period following the current planning period (i.e. after 2020). Whilst the overall system costs including fuel and other operational costs could be reduced in this way, the initial capital investment costs would rise as a result due to the higher capital intensity of renewable plant.

Environmental impacts of the ESSP are also assessed in the recent draft Strategic Environmental Impact Assessment (SEA)[39]. This identifies impacts in areas such as local pollutants, greenhouse gas emissions, watersheds and wetland ecosystems, forests and protected areas, and biodiversity. Human activities are assessed in agriculture and farming systems, land management practices, exploitation of energy resources, as well as taking account of trends in urbanisation, demography and water and sanitation usage. The report proposes actions to minimise these impacts which have been incorporated into this SE4All Action Agenda.

3.2.3. Gaps

In the short-term, there is a need to move towards a cost-reflective tariff, so that the finances of the energy utility are put onto a sound footing to enable the necessary investment to be carried out. Currently, although tariffs for households are high by regional standards (at around ¢20/kWh), they are not high enough to cover the entire cost of providing on-grid electricity including the connection costs which are currently subsidised.

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[37] Green growth and climate resilience strategy Green growth and climate resilience strategy http://minirena.gov.rw/index.php?id=168&L=1&tx_ttnews%5Btt_news%5D=164&cHash=d5de05551d34bb363bbd716b892cfc14

[38] AfDB Technical Paper "Towards Inclusive Green Growth in Rwanda: Costing of Investment Needs, Focal Area: ENERGY" May 2014

[39] Strategic Environmental Assessment Of The Energy Sector Policy In Rwanda October 2014. Prepared for: Delegation of the EU to Rwanda. Prepared by: ETI Consulting, Pem Consult A/S And Particip Gmbh

Rwanda Utilities Regulatory Authority (RURA) performs two tasks in relation to these issues. Firstly it is responsible for approving the rates negotiated under PPAs which have a direct impact on the overall cost of generation. Secondly, they are responsible for setting tariffs for consumers which provide the income to the utility. RURA therefore plays a key role in ensuring the balance between costs and revenues in the sector. This balance not only underpins the financial viability of the energy utility, it also determines the attractiveness of the Rwandan energy sector for private sector investment. This is important as the energy policy identifies private sector engagement as being key to the development of the energy sector due to the need for external sources of financing. The policy includes not only a preference for use of independent power producers for new projects, but also the leasing of existing government-owned plant to be privately operated and managed. This creates a tension between on the one hand the need to offer attractive tariffs to companies in order to get the necessary investment, and on the other hand the need to keep tariffs low to make electricity affordable to households and to make energy available at reasonable cost to industrial and commercial users to attract investment and growth in the wider economy.

Planning needs to become more strategic, and to avoid the potential for problems such as over-supply due to mismatch between forecasts of supply and demand. This will involve other institutions in addition to the utility, and will ideally lead to a greater level of capacity for strategic planning within MININFRA. RURA also runs its own model of the electricity sector to inform its tariff-setting decisions. Whilst there is value in having different models for different purposes, and these institutions need to retain their independence from each other, there would also be value in coordinating these planning activities at least to the extent that each institution is clear about the various assumptions being made, so that differences between model outputs can be explained.

It will be essential to ensure that planning in the energy sector takes sufficient account of the security of supply, not only of individual sources, but also taking account of the interactions between sources. Different energy sources are generally subject to different types of risk, and often a portfolio of generation plant will overall be more secure than relying heavily on only a few sources. In addition to environmental impacts of energy generation, it will be important to assess the vulnerability of different sources to changes in the environment – for example, changes in rainfall patterns that could alter availability and average load factors for hydro plant.

Issues associated grid integration of renewables arise mainly in the context of solar power. Hydro and geothermal are mostly baseload and provide predictable levels of generation. Currently, the electricity system has around 155 MW generation capacity. There is one large utility-scale solar plant of 8.5 MWp. Another 10MWp solar plant is being negotiated, but this is seen as getting close to the technical limit of what the electricity grid could reasonably integrate with the grid at its current size.

As the electricity sector grows, its capacity to absorb more solar power will also grow. In the longer term, if grid roll-out starts to overlap significantly with areas which have installed stand-alone solar system, then planners will need to assess how they can integrate these into the grid, and what the cost implications will be in terms of grid reinforcements. Currently, it is too early to assess the needs regarding this issue, but it will certainly need to be addressed in the longer term.

Another grid integration issue facing Rwanda is the need to provide a flexible portfolio of generation plant that can balance supply and demand during varying load patterns that occur during the day. Currently there is pronounced peak during the evening. This profile may change in the future depending on the mix of households, industrial and commercial enterprises connected to the grid, as well as the possible rise of demand management options. However, it will always be important for Rwanda to have some capacity on the system that can respond rapidly to daily demand fluctuations. This is an issue in the context of Rwanda's renewables portfolio, since most of the renewables are not dispatchable – i.e. the operators cannot cost-effectively control the rate of production. Some level of fossil fuel plant is therefore likely to remain essential, albeit prioritised to run for short durations during peak hours.

3.2.4. Actions needed to achieve renewable energy targets

Actions required to achieve the renewable energy targets are set out in the table below.

Table 17 Renewable Electricity Generation Actions

Sector / Issue	Action	Details / Commentary
Planning tools and action plans	Take strategic decisions on long-term energy mix	Assess candidate projects to come on-stream mid-2020s, and assess the viability of moving towards greater share of renewable energy, subject to capital cost constraints. Consider the role of renewable peaking capacity (such as hydro plant with reservoirs and/or pump-storage) to replace thermal peaking plant.
	Boost MININFRA capacity for strategic planning decisions	MININFRA needs to be able to drive planning at a strategic level, rather than being reactive. This will require in-house human and technical resources need to be expanded, including acquiring suitable high-level planning tools/models (including load forecasting) and the resources to run these. This will allow the Ministry to set appropriate policy-level targets.
	Supply and demand planning needs to be strengthened	To ensure a balance between supply and demand, clear tools for demand planning are required. Ensure demand projections are used to inform all levels of supply planning from feasibility studies through to contract negotiation. Least-cost plans / integrated resource assessments should be undertaken and published to increase transparency for all stakeholders.
	Extend time-frame of planning	Timeframes for electricity sector planning need to be extended to at least 2030. Long-term plans are needed for new sectors such as geothermal. A mechanism for reaching political resolution may be needed in areas where there are potential resource-use conflicts such as peat and hydro.
	Flexible and adaptive planning and policy framework	Future costs and availability of Rwanda's energy sources are currently uncertain. Feasibility studies planned under ESSP (including for imports, solar PV, hydropower, and thermal energy sources) can be further developed into roadmaps, with scenarios developed to feed into the planning process. The uncertainty needs to be managed by taking a flexible approach which can adapt to new information that arises as new projects come on stream.
Financing & contracting	Review contract design to assess suitable risk-sharing agreements	Risk sharing / de-risking needs to be carefully designed so that contracts ensure appropriate build-quality, and incentivise timely completion of construction and commissioning. Contracts also need to be able to adapt to plant running in a flexible way, since not all plants can run at baseload. This is particularly the case for new thermal plant coming onto the system.
	Enable local enterprises	Empower local enterprises to engage in energy sector deals and introduce more competitive, transparent approaches to service provision. Wherever feasible, standardized legal documentation will also be used to reduce delays in negotiations.
	Work with local financial institutions to unlock finance	Collaboration with local financial institutions to develop mechanisms to scale up access to finance. Consider use of PPP, carbon finance and other financial mechanisms necessary to support investment. These may also require awareness campaigns to be undertaken.
	Move towards cost-reflective tariff	Undertake 'ability to pay' assessment, and develop a realistic roadmap for moving towards a financially sustainable model for the provision of on-grid electricity based on cost-reflective tariffs.
Human skills & Institutional capacity	Increase technical capacity of key institutions	Thermal generation technology requires a higher level of operation & maintenance and skillsets which are currently not available in the Utility. Although new plant are to be run by IPPs who manage the technical risk, GoR institutions need to be able to manage the contracts, and set up suitable PPAs at the start of the contract. This

		will require considerable technical, legal and financial expertise to achieve good deals and enforce contracts that represent Rwanda's interests and that adequately reflect the risks.
Operation & maintenance	Improve planning and budgeting of O&M	Maintenance cost requirements should be included in infrastructure planning from the concept phase to ensure availability of budget, spare parts, tooling, equipment and adequately trained personnel.
Address import barriers	Reduce barriers to importing critical items of equipment for energy sector including for the private sector	Import barriers (tariffs and administrative barriers) can be a major reason for cost overruns on new build, and for poor performance of plant requiring maintenance and repair. A review of these bottlenecks is required to find options for how these can be addressed

The total estimated cost of these actions is around $4.1m over 5 years. Internal costs of the relevant institutions are not included in these estimates, although it should be noted that in some cases there may be a need for additional capacity-building or expert input to support these activities which could have a direct cost implication. These estimates may therefore underestimate the overall budget support requirement of these activities.

3.3. Energy Efficiency

3.3.1. Current status and trajectory

Due to lack of historical time series data for energy consumption, it is not possible to accurately track the trajectory of energy efficiency over historical time period. According to Global Tracking Framework data, the level of primary energy intensity expressed as MJ per unit of GDP ($2005 in PPP terms) improved from 10.3 in 1990 to 8.6 in 2010. This is an improvement rate of 0.9% per year, which is close to the average for Sub-Saharan Africa of 1.1% improvement per year. The future trajectory is very dependent on GDP growth rates and the sectoral breakdown of the economy (e.g. levels of industry vs service sector).

Nevertheless, at a sectoral level, there have been a number of important interventions in energy efficiency. The promotion of efficient cookstoves has already been discussed in Section 3.1. In addition, efficiency in the electricity supply system has received considerable attention. A grid system loss reduction plan was developed in 2013, encompassing priority proposals and measures identified through an earlier study.[40] An investment of $60m over 3 years will result in over $180m of potential energy savings. This will reduce losses from 23% to 15%, capacity savings equivalent to constructing a 15MW power plant. The proposed measures will need to be carefully analysed and prioritized in order to generate the greatest savings in operational cost for a given level of capital expenditure. The plan will be implemented as soon as feasibly possible to reduce forecasted generation capacity requirements.

3.3.2. What are the existing plans/strategies and what are the gaps?

It is essential that demand planning is fully integrated into the electricity system planning process, incorporating the opportunities for maximising end-use efficiency. These include lighting and appliances in households and commercial users, and efficient processes and equipment in the industrial sectors. The ESSP identifies energy efficiency as a separate strategic objective of energy policy, in order to give it the priority it needs. REG has also recently drafted a strategy on promoting energy efficiency. The ESSP actions include the following.

[40] Manitoba (2013)

New Laws, Regulations and Codes

MININFRA will develop an Energy Efficiency Strategy[41] and Law to serve as underlying implementation framework to support a series of new regulations by RURA, RHA, and other agencies that can mandate energy efficiency measures in public institutions, households, and commercial businesses. MININFRA will be responsible for integrating the promotion of energy smart building technologies into monitoring and implementation of new government asset management policy. Together with RHA, it is also responsible for introducing energy-smart and energy-efficient technologies and practices into Rwandan building codes. RURA is already developing a solar water heater regulation. Considering building codes specifically: EE measures will be implemented in the form of improved building design and use of building materials that increase EE over the entire lifetime of facilities help to reduce lighting, mechanical ventilation and air conditioning energy consumption. Mandatory installation of solar water heaters for all large water consumers (e.g., hotels, integrated developments) will take effect, in parallel to extending subsidy to end-users to incentivize switching. In addition, a training program on how to comply with the new EE building code should be established for architects, engineers and builders. Fostering green building through climate oriented urban planning principles and green architecture will have a strong long-term impact on reducing the need for electricity, and to reach this orientation of house and settlement should follow urban planning. Pilot efforts to promote energy smart building codes, particularly for green field construction projects, are being promoted in the six secondary cities of Huye, Nyagatare, Rusizi, Musanze, Rubavu and Muhanga, in conjunction with the National Urbanization and Rural Settlement Sector Strategy.

Dedicated Demand-Side Management Unit in the Utility

REG will establish a dedicated EE/DSM unit to oversee the design and implementation of relevant efficiency programs to clip electrical peak demand. REG shall develop a staffing and business plan as soon as possible as part of its restructuring/institutional reforms. The unit shall collaborate with MININFRA on improving electricity end-use data collection, so as to better understand trends and patterns and to design appropriate strategies for structuring and target energy efficiency programs. Key metrics include: per capita and total consumption by service and consumer group; breakdown of daily peak demand; and electricity end-use by region. Regular surveys shall be taken to obtain this information, targeting households, industries (e.g., motor drives, boilers, and furnaces), and public utilities (e.g., water and wastewater pumping).

Energy Audits

Major users of energy, such as industrial and commercial consumers, shall be encouraged and incentivized to carry out regular energy audits. MININFRA will develop a strategy and business model for an energy efficiency finance facility to bankroll audits (50/50 cost split) and retrofits for industry, which would be initially capitalized by MINECOFIN through a reallocation of the subsidy of the power tariff,DP contributions and possible carbon financing. The facility would be replenished on the basis of savings achieved. It would also undertake establishing energy performance benchmarks whereby Industries shall be encouraged and required to meet or exceed these benchmarks. This will provide a financial incentive to implement EE/DSM programs. RSB and MININFRA are responsible for developing and adopting minimum energy performance standards (MEPS) for motors and promoting the use of high efficiency motor-drives such as variable speed drives (VSDs) in the industries.

EAC-Wide Energy Standards and Labelling Scheme

[41] A draft Energy Efficiency strategy (Econoler 2014) already exists and will be revised accordingly.

RSB is responsible for the development and adoption of an EAC-wide energy standards and labelling scheme for common household appliances and to establish a working group to align regional standards with EAC under existing regional integration processes. A baseline for Rwanda will be established through a market assessment of current conditions.

Efficient Lighting

For household lighting, EE/DSM Unit will investigate expanding and managing bulk procurement and distribution of CFLs for residential customers (based on current consumption and end-user affordability) with targeted subsidies for retrofits. The existing CFL program has already distributed 800,000 heavily subsidised units, resulting in an estimated annual saving of 36GWh. Therefore the CFL program will continue under the EP. As well as this an EE code for street lighting shall be developed. Payments and maintenance for street lighting shall be shifted to local authorities to incentivise them to use them efficiently. An assessment study is also underway to replace the sodium HPS street lamps with LEDs. The EE/DSM unit will provide technical support to conduct economically viable energy-efficient street lighting retrofits and in public institutions.

Under SE4All, additional consideration should be given to replacing CFLs in these lighting programmes with LEDs which provide stronger energy savings, and perform better in terms of durability, and avoid the problem of mercury contamination on disposal compared with CFLs.

Green Procurement Guidelines (Public Sector)

MININFRA is responsible for promoting efficient use of energy in the public sector. The main electricity consuming facilities in the public sector are government buildings, water and waste water pumping stations and street lighting. RPPA and REMA shall be responsible to institutionalize “green” public procurement guidelines and strategies focused on equipment with a high energy footprint and to develop clear criteria, guidelines for integrating energy and resource efficiency into existing procurement policy and processes.

3.3.3. Actions needed to achieve Energy Efficiency target

The costs of providing electricity can be reduced significantly by increasing the efficiency of electricity consumption, which reduces the need to build additional generation plant. Rwanda is already embarking on a number of important energy efficiency initiatives, notably promotion and provision of compact fluorescent lightbulbs in the household and commercial sector, and reducing losses in the electricity transmission and distribution system. Additional actions are identified in the table below.

Table 18 Energy efficiency actions

Sector / Issue	Action	Details / Commentary
Develop EE strategy and implementation plan	Develop strategy including EE institutional arrangements	Assess technical potential in all sectors, and identify policy and financing instruments required to overcome barriers
		Develop implementation options including dedicated technical unit within the utility, as well as options for setting up a financial facility within the proposed Energy Development Fund.
		Develop and implement a grid-loss reduction plan. Initial implementation phase up to 2018 for existing system. Further planning to be carried out to take into account longer-term grid-extension plans.
		Assess potential for industry energy audits, develop benchmarks
		Assess role of performance standards, including EAC-wide standards and labelling
		Consider role of green procurement, including necessary legal requirements
	Enabling actions	Implement necessary enabling actions to stimulate the market for more energy efficient products such as behavioural change campaigns and addressing affordability issues for households, and stimulating private sector investment in commercial and industrial applications.
Technical assessments	Buildings	Revise building codes for commercial buildings, and assess potential for net-zero energy consumption in the longer-term. Assess how EE unit can promote improved energy efficiency in existing buildings including building components and systems
	Appliances and equipment	Assess additional market transformation policies that may be needed to complement planned EAC standards & labelling .
	Efficient lighting	Phase-out of inefficient lighting products, particularly incandescent lightbulbs. Consider promotion of LEDs instead of CFLs
	Transport	Introduce mandatory vehicle fuel-efficiency standards. Consider overall transport system efficiency, including the long-run impact of urban planning decisions on future transport demand.
	Industry	Develop & promote energy management systems and high-efficiency industrial equipment and systems. Consider how energy efficiency services for small- and medium-sized enterprises could be provided as part of the EE DSM unit role. Consider complementary policies to support industrial energy efficiency, including possibility of additional incentive mechanisms such as carbon financing.

Beyond 2020, additional programmes will be needed to sustain this rate of improvement (see Box 1). In conjunction with the ESSP, the energy efficiency strategy needs to be further developed to adapt these recommendations to Rwanda's circumstances, taking account of which specific sectors are expected to develop most as the economy grows. Promotion of efficiency lighting should move beyond CFLs to include promotion of LED lighting, and a programme on LED lighting should be undertaken as soon as is practicable.

The costs of energy efficiency actions over the next 5 years include a number of significant**Error! Reference source not found.** capital expenditure items, including $85m in grid loss reduction programme, and $8.5m for investment in smart meters on distribution transformers. The annualised capital cost of this expenditure would be around $10m per year based on 7% discount rate and amortisation over 15 years. Additional large expenditure items include $11m on setting up a revolving fund for industrial energy efficiency, and around $4m for behavioural change campaigns including bulk procurement and distribution of efficient lighting. Spread over 5 years, together these programmes amount to an annual expenditure of $3m per year.

Together, capital expenditure of approximately $15m/year is therefore required for the current programme. It is expected that at least the same level of expenditure will be needed to achieve the SE4All Action Agenda goals by 2030, such that cumulative expenditure between 2020-2030 would be in the region of $150m.

An additional estimated $1m would be required over the 5 year period for various studies and institutional set-up costs.

3.3.4. High-Impact Opportunities

The following global high impact opportunities are relevant to Rwanda:

- Advanced Lighting & Appliance Efficiency,
- Energy Efficiency in Buildings

Energy efficiency has been identified as one of the five strategic pillars of the energy sector strategic plan, and the government intends to set up a dedicated energy efficiency team to carry out this strategy. This raises the profile of energy efficiency very strongly, and a key focus will be on lighting, appliance and building efficiency objectives, as described in the sections above.

3.4. Additional nexus actions

The key nexus issues arising in the energy sector are environmental, health, food security, gender impacts and impacts on water. The following actions have been identified to manage these interactions, and to work towards meeting the nexus targets.

Table 19 Nexus actions

Issue	Action
Water / Climate	Hydro plant fully integrated into Integrated Water Resource Management plans by 2020 for domestic use, energy, agriculture, and industry.
	Multi-use schemes routinely considered in project planning.
	By 2020, all hydropower and multi-use schemes fully assessed for climate vulnerabilities and adaptation measures identified and costed. By 2030, majority of schemes have risk-mitigation strategies implemented.
	Integrate robustness into the design of infrastructure to cope with climate change & variability
Gender	Incorporate gender impact assessments into existing planning tools
	Incorporate full economic opportunity costs associated with time spent by women using unimproved cooking methods. Value all biomass at market prices.
Environment	Integrate environmental criteria into route-selection process
	Implementation of school and hospital electricity access projects
	Make transparent how trade-offs between cost, carbon intensity, diversification etc. will be decided
	Incorporate SEA on Rwanda's wetland habitats into Peat Strategy
	Complete a stand-alone ESIA for all projects, incorporating mitigation measures and cumulative impacts where necessary
	Highlight environmental management requirements included in tender evaluation criteria, and ensure financial bids reflect these in budget.
	Integrate environmental criteria into the licensing process
Land-use / Food	Develop an energy sector land-use plan to reduce competition and clarify where to locate infrastructure
	Avoid environmentally sensitive areas when siting energy installations
	Integrate environmental and agricultural criteria into site selection process
Health	Fully integrate health benefits into all areas of energy policy, particularly in biomass for cooking which creates one of Rwanda's largest health problems
	Implementation of hospital and clinics electricity access projects in order to help modernise and improve health care provision

3.5. Enabling Action Areas

Enabling actions have been incorporated into the various sector actions identified in the previous sections of the report. The following issues are key themes cutting across all sectors:

Energy planning and policies. In some areas, energy policies are quite well developed in Rwanda, but still need more development particularly in the areas of off-grid electricity and in the biomass sector. Energy planning needs to be improved across the board in order to improve implementation and coordination between different Ministries, Agencies and other stakeholders.

In addition, data collection and tracking of progress made against targets will be essential to be able to monitor the effectiveness of policy actions and make any corrective changes. The following actions should therefore also be taken:

- Annual assessment of energy targets in 3 main areas of access, RE and efficiency.
- Regular detailed mapping to assess status of all energy markets including market actors, supporting inputs, services and finance, and enabling environment factors.

Business model and technology innovation. Engagement of the private sector is central to Rwanda's development model, as set out in EDPRS-II, and elaborated in the ESSP. In some sectors, the private sector is already actively engaged, for example with an active policy of transferring existing government-owned micro-hydro plants to private ownership, and new plants generally being tendered to IPPs. In the off-grid and improved cookstove markets, private sector providers are already actively engaged. In the ESSP, the following actions have been highlighted:

In order to create a more favourable environment for private investors in the sector, Government will develop a coordinated plan to streamline investment procedures, guarantee stable and positive returns, and reduce perceived and real risks to energy infrastructure investment. Among these measures include updating the investment code, developing a dedicated energy fund, and clarifying the rules and modalities of engagement for PPPs.

Finance and risk management. Addressing financing risks is key to enabling private sector growth in the markets addressed in this Action Agenda. The government is committed to developing a range of measures, including setting up an Energy Development Fund (EDF) to provide access to capital and risk-mitigation instruments to help support companies to grow and invest. Further detailed work on financial instrument design is due to be undertaken as part of Rwanda's implementation of its SREP program, which focuses in particular on supporting investment in off-grid electricity. These could include for example access to capital (loans), risk-mitigation instruments (e.g. risk-sharing arrangements with banks), and potential subsidy mechanisms to address affordability. This work on instrument design is likely to be also very relevant to other sectors such as biomass, and could be replicated under the broader EDF proposed to be set up.

Consumer awareness and market building. The market transformation actions identified in the Action Agenda will need consumers to be aware of the new products and services that are to be provided. They will need to be aware of the benefits that can come from adopting higher levels of energy access based on cleaner and more efficient. Such awareness can spread quickly once the market has begun to be established, but may need some public input at the start of new programs when uptake is starting from low levels. It will be essential that such promotional campaigns go hand-in-hand with implementation of strict quality standards, to ensure that households get a good experience when they transition to improved technologies.

Human skills, capacity building and knowledge sharing.The energy sector is large, complex and rapidly changing. This creates many challenges in terms of the institutional capacity to manage the sector. Key ongoing activities include the re-structuring of the utility to split energy and water into two separate companies, and further divide energy into a development arm, which manages project development of new plant, and a utilities arm which either runs the plant or manages the contracts with IPPs once projects have been built. In addition, there are institutional capacity reviews of MININFRA due to be undertaken in 2015 which will help to identify more broadly what the capacity building requirements are at the level of policy-making and oversight. Capacity building also goes more widely out into the need for training and awareness raising in the private sector, and in the financial sector.

The main action required is to develop a capacity-building needs assessment of key institutions with regard to the ability to implement the energy sector strategy plan. Specifically, it is already clear that there is a need to boost MININFRA strategic long-term planning capacity by developing in-house models & analytical capacity, and to increase technical capacity of key institutions (MININFRA, RURA, REG) to deal with the more complex generation plant, and complex regulatory environment these create.

4. Coordination and follow-up

4.1. National SE4ALL coordination structure

The management of Rwanda's SE4All Action Agenda has been fully integrated into the energy Sector Working Group (SWG), operating under the energy Sector Wide Approach Programme (eSWAP) established in 2008. The rationale for eSWAP is to provide a mechanism for coordination and prioritisation of activities in the energy sector involving all stakeholders including other government ministries and agencies, development partners, private sector representatives and civil society.

To execute a comprehensive, inclusive strategy, the Ministers of Finance and Energy and senior development partners launched the energy SWAp in 2008 with the main objectives of meeting basic energy needs, providing electricity for accelerated growth, and powering the social sectors. A Memorandum of Understanding between the GoR, represented by the MININFRA and the DPs have been signed the 3rd of July, 2008.

A Sector Wide Approach secretariat was then established in the Ministry of Infrastructure early in 2010 as a central advisory unit that acts as an interface between government and the development partners to support better aid coordination and harmonization of sector priorities with the government development agenda through the Sector Working Group. Specific objectives of the Energy SWG are to:

a. Develop and update the energy sector strategic plan (ESSP);
b. Develop and update the energy sector logical framework;
c. Develop, update and validate energy sector M&E frameworks;
d. Conduct joint energy sector reviews, at least twice a year as per planning calendar
e. Review and validate public expenditure review reports in the energy sector;
f. Develop energy sector wide approaches; and
g. Determine analytical work to be undertaken in the energy sector in any particular year

To this list has now been added responsibility for following up and updating the SE4All Action Agenda, recognising that it effectively complements the ESSP with a longer-term perspective. A key element in this process will be the involvement of the SE4All Focal Point who is the individual within MININFA responsible for coordination of the national SE4All process, and can help to integrate SE4All into the work of the eSWAP and SWAP.

In order to allow more detailed technical discussions, a series of technical working groups (TWGs) have been established, following the main themes of the ESSP, namely: biomass, electricity access, electricity generation and energy efficiency. A fifth group, the Civil Society Organisation (CSO) Liaison Group has also been established to allow consultation with CSOs. These inputs are coordinated by the eSWAP secretariat, which provides the link between the TWGs, the SWG, the Donor Coordination Group, and is responsible for ensuring follow up of the actions arising from these groups within the Ministry of Infrastructure (Figure 11).

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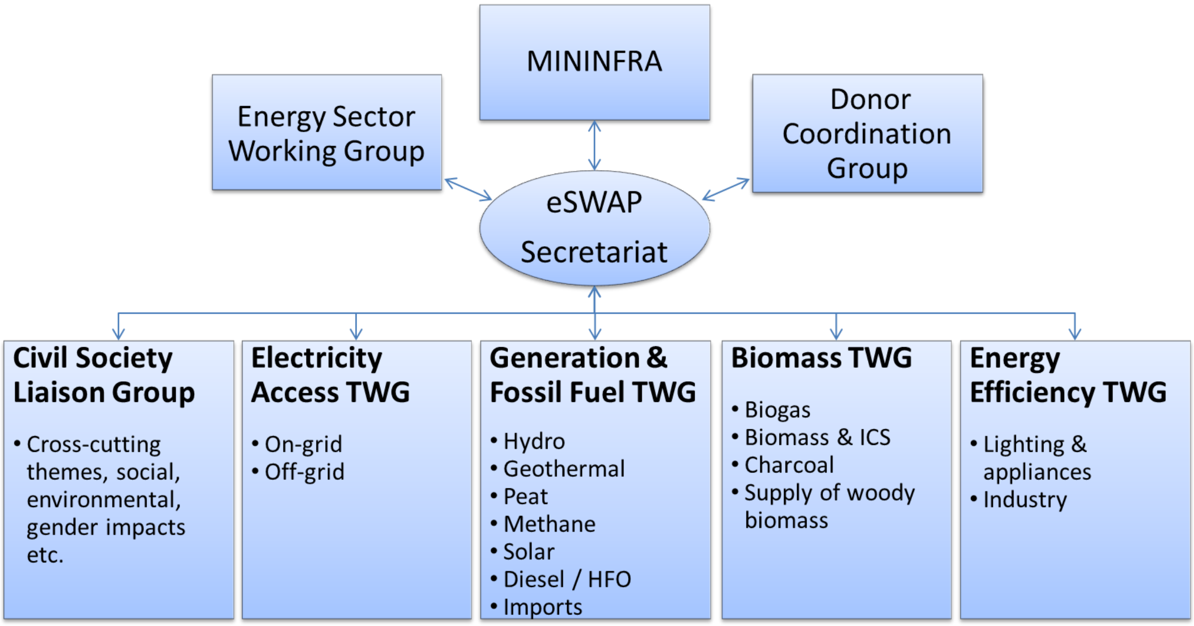
Figure 11 National SE4All coordination aligned to Sector Working Group structure



Additional consultative groups can also be incorporated into this structure as and when they arise. For instance, there is soon planned to be a private sector-led platform created to represent the views of cookstove manufacturers and distributors. This group will be invited to have representation on the Biomass TWG, thus allowing liaison between policy implementation and the private sector.

The terms of reference of the SWG have been amended to include the following items relating specifically to the SE4All:

- Endorse and contribute to the development of the ESSP and the SE4All, as owned by MININFRA and its agents.
- Lead the preparation of the SE4All Action Agenda. Regularly present progress reviews including the identification and prioritization of Actions to the ESWG for validation.
- Coordinate inputs from TWGs regarding actions required to implement the ESSP & SE4All Action Agenda.
- Coordinate common donor responses and activities in line with sector priorities and plans as set out and agreed in the ESSP and SE4All Action Agenda.

SE4All is also embedded into the terms of reference of the TWGs as follows:

- The Technical Working Group's overarching aim is to coordinate and structure action plans including identifying and removing barriers to meeting the Energy Policy, ESSP and SE4All targets related to the relevant sub-sectors.
- Support medium-term operational planning and the development of Action Plans by MININFRA for the relevant sub-sectors, including relevant SE4All Action Agenda components and resource development Action Plans to accompany the ESSP.
- TWGs provide input on prioritizing actions that need to be carried out, for example, in line with the SE4All Action Agenda, but Actions will ultimately need to be agreed upon with the Chairs of ESWG for validation in that main forum.

- Assessing gaps and barriers to achieving goals set out in the EP, ESSP and SE4All global framework, including examining challenges and opportunities along cross-cutting thematic issues, (e.g., finance, capacity building, policy/regulatory development, and building effective markets).
- Lead the preparation of the SE4All Action Agenda components relevant to the subsector concerned. Regularly present progress reviews, including the identification and prioritization of Actions to the ESWG for validation.
- Ensure good communication among all DPs active in the sub-sector, including developing common responses in line with sector priorities and plans as set out in the ESSP and SE4All AA.

It is also intended to provide an open-access database for all policies and studies relevant to the energy sector that can allow all stakeholders to have access to latest information available. The database should also provide visibility of studies that are in progress, showing when results are expected to become available. This should help coordinate activities in the sector and help to avoid duplication of efforts. The beginnings of this database are presented in Appendix 1.

4.2. Follow-up analysis

There is a need for additional follow-up analysis in two main areas. Firstly, there is a need to develop more detailed action plans with priorities, timelines and budgets in each of the main themes covered by the different TWGs. These plans can then be used to manage and track implementation of the actions. These plans will integrate actions arising from the SE4All Action Agenda with those in the ESSP, and additional actions identified in other strategies such as the recent Strategic Environmental Assessment. Initial work has been carried out to provide a structure for these action plans, organised according to the themes covered by the TWGs and is presented in Appendix 3.

Secondly, additional scenario analysis is required to assess the costs of different pathways to the SE4All goals, and to explore sensitivity of the goals themselves to various sources of uncertainty. These include technical uncertainties (e.g. availability of different sources of generation), as well as economic and social uncertainties such as the affordability of different solutions, and the degree of regional integration of energy systems. In practice, the goals outlined in this Action Agenda are illustrative, and the government will need to keep these goals under review and revise as necessary in response to new emerging information and as progress is made between now and 2030. Some initial scenario and sensitivity analysis is presented in Appendix 4.

4.3. Monitoring, evaluation and reporting

Monitoring, evaluating and reporting of actions will be the responsibility of MININFRA. As discussed above, the action plans for SE4All are embedded into the work of the TWGs and SWG, and coordinated by the eSWAP secretariat. The M&E and reporting framework will therefore be the same as for the ESSP. Some further work is required to develop these mechanisms, including standardised minutes and reporting protocols. These reporting mechanisms will be the responsibility of the Ministry to take forward in time for the next round of TWG and SWG meetings. At minimum, these activities should include:

- Annual assessment of energy targets in 3 main areas of access, RE and efficiency.
- Regular detailed mapping to assess status of all energy markets including market actors, supporting inputs, services and finance, and enabling environment factors.

There will also be an external dimension to monitoring and evaluation in terms of the links with bodies such as the SE4All Global Facilitation Team, the Africa Hub and the Thematic Hubs. These bodies will enable the Rwanda SE4All Focal Point to tap into additional technical expertise and advice. Reporting can also make use of the Global Tracking Framework, with links to external data sources for tracking progress against the SE4All targets. Under the Multi-Tier Framework (MTF), Rwanda has been selected as the first of a multi-country pilot for an extensive survey of household energy access, including an assessment of lighting and cooking technologies. This is expected to produce a much more accurate baseline on which to build policy interventions. A simplified form of the survey then needs to be incorporated into ongoing data collection processes by the statistical agencies in Rwanda so that it can provide the basis for ongoing M&E on the sector.

4.4. Link to Investment Prospectuses

Detailed investment prospectuses will need to be developed following on from this Action Agenda. In order to provide some guidance to these, estimates are provided here of the costs of following these SE4All 2030 scenarios and the associated actions in the Action Agenda. Work is already underway to develop off-grid and mini-grid renewable energy under the Scaling-up Renewable Energy Programme (SREP). This effectively covers the role of an investment prospectus for this subsector. Other actions identified here will require separate investment prospectuses to be developed, in particular to cover investment opportunities in biomass, energy efficiency and renewable heat.

To facilitate the development of these Investment Prospectuses, the costs of actions identified in this Action Agenda have been estimated. These are divided into capital expenditure, total operating costs (including fuel and maintenance costs). These are summarised in Table 20.

Table 20 Summary of annual capital and overall energy costs (excluding transport fuels)

SE4All Goal	Investment	Annual cost in 2030 ($m)					
		SE4All Scenario		Base-case Scenario		SE4All cost relative to Base case	
		Capital cost	Total cost	Capital cost	Total cost	Capital cost	Total cost
Access to clean and sustainable cooking	Total	175	297	21	442	154	-144
Access to electricity for households	Grid - transmission & distribution	118	129	67	74	51	56
	Mini-grid & off-grid	79	85	75	76	4	10
On-grid electricity	Total generation costs	267	415	242	433	25	-17
	(of which, to service additional HH connections)	*(171)*	*(265)*				
Energy efficiency[42]	Total	15	15	-	-	15	15
Total		653	942	405	1024	**249**	**-81**

In addition, a range of non-capital expenditure will be required to support the actions such as studies, data gathering, development of regulatory regimes, market building activities etc. identified in Section 3 aimed at improving the enabling environment to support the capital investments. These identified actions would require a total expenditure of around $12.4m over the next 5 year period ($2.5m per year), covering the following parts of the Action Agenda:

- Access to clean cooking: $4.5m
- Access to electricity: $2.8m
- Renewable electricity: $4.1m

[42] Only includes costed energy efficiency actions up to 2020.

- Energy efficiency: $1m

To assess the affordability of this level of expenditure, we can compare with projections of national wealth. If GDP is assumed to grow on average by 6% per year (around 3.5% per capita growth), then GDP in 2030 would be $18bn. This means that non-transport related energy expenditure of $945bn per year as indicated in the above table would represent 5.1% of GDP (3.4% of which would be capital costs, 1.7% operation, maintenance and fuel costs). This suggests that once the infrastructure is in place, the running costs of the energy system should be affordable without further subsidy. The overall level of expenditure is roughly consistent with international standards: expenditure on non-transport energy in Europe 2010[43] was 4.5% of GDP.

Nevertheless, capital expenditures of $660m/year are substantial, particularly by the standards and size of today's economy in Rwanda. In order for Rwandan consumers to be able in the long-term to afford both on-going running costs as well as the capital replacement costs, energy consumption will have to grow considerably slower than GDP as a whole. Such a capital expenditure programme would require considerable scaling up from current levels, and increased access to capital. Once installed, assuming steady economic growth and continued focus on energy efficiency, the sector should be able to be self-supporting.

[43] PRIMES energy model EU27 baseline study

Appendix 1. Key Issues in the Biomass Supply Sector

Fuel wood production

Fuel wood production is a significant source of income in rural areas, employing up to 300,000 people to some extent according to SNV, making it a hugely important sector benefiting rural people. This employment is almost exclusively individuals or small informal enterprises, with small farmers producing wood from their own plantations. According to SNV, The largest effectiveness gap in the wood supply chain is the lack of appropriate skills and knowledge of these small producers regarding proper forest management. This means that productivity is relatively low in Rwanda (estimated at 9.5t/ha/yr in SMP/WISDOM report). By comparison, productivity in South Africa, Lesotho and Swaziland is 15t/ha/yr[44], and the National Forest Policy envisions even greater increases into the range 15-30t/ha/yr. Whilst these higher increases may be challenging to achieve and maintain over time, it seems clear that productivity improvements are technically achievable. The SMP/WISDOM report targets an improvement from 9.5 to 12.4t/ha/yr by 2020 (relative to 2009) in their AME scenario. This is based on improving management of 50% of existing plantations, targeting in particular charcoal producing areas, combined with creation of new forests and promoting increasing plantations by farmers (agro-forestry). Increasing productivity will require investment as well as improved skills and knowledge. Currently, there is a lack of provision of loans from financial service providers at a reasonable rate for small businesses, and this sector needs to become more engaged.

29 District Forest Management Plan (DFMP) were established between 2009 to 2011, but were not based on accurate forest cover maps and adequate forests inventory. To solve this problem, the RNRA is currently engaged in conducting a complete national forest inventory, covering all districts. More accurate data on available stock (m3/ha) and on productivity (m3/ha/year) will be available, providing a base for a national policy. This work also includes updating the National Forestry Policy and a revision of DFMP for over 20 districts.

According to SNV[45], the regulatory process represents a major barrier to rationalising and improving forest management. Wood producers are required to request a permit to cut wood. If the forest is less than 1 ha, the sector official can grant the permit. For cutting of a forest of greater than 1 ha, it is necessary for the District Official from the National Forest Authority (NAFA) to grant a permit. This acts as a significant bottleneck in the supply chain. These permits have a limited time duration of between 1 week and 1 month. Due to lack of capacity in NAFA there can be significant delays to obtaining such permits, and the basis for granting or rejecting permits is not always clear to producers. The short duration and uncertainty of when permits will be granted leads to difficulties with planning and managing production of woodfuel. It can lead producers towards operating without a permit, which has adverse impacts on charcoal production due to the need to operate clandestinely, which reduces production efficiency as discussed below.

A key issue for GoR to address is the tension between the desire to control and regulate the supply of woodfuel, and the fact that the regulatory process is seen both as an impediment to rational management of existing plantations (for example, encouraging unofficial production of charcoal), and a barrier to entry for farmers who could provide the source of new increased production. GoR should consider the pros and cons of de-regulating the market, particularly for smaller producers to avoid these pitfalls.

[44] Interview with RNRA

[45] SNV Rwanda 2011 "Charcoal Value Chain and Improved Cookstove Sector Analyses" p13

Charcoal production / value chain

Charcoal is the dominant fuel in urban areas because it is lighter than wood and more transportable, and is considered by users to be much superior to wood because of its greater heating potential and reduced smoke. The charcoal industry is an important source of revenue in many rural areas, and is a significant employer, with charcoal production providing 24 man-days employment per ton charcoal, around 60% of the total employment in the charcoal value chain.

However, according to the 2007 energy balance, wood for charcoal accounts for about 33% of total wood demand, but only produces 11% of net energy supplied from wood sources. Approximately 70% of the gross energy content of wood used for charcoal is lost in the conversion process. This is a significant issue, not just because of the current level of losses incurred, but because there is likely to be a trend towards a greater share of charcoal use in the future as household incomes and urbanisation levels increase.

The key energy-related issue to address in Rwanda's charcoal industry is the low efficiency of production. Current manufacturing in Rwanda has an efficiency of around 11-12% (measured in terms of kgs of charcoal per kg of wood)[46]. Charcoalers now use earth kilns capable of transformation efficiencies of 14-15%. However, many producers do not even achieve 11% efficiency because of a significant proportion of charcoal is produced outside of the times specified by permits. The perception of illegality pushes many producers to operate sub-optimally, for example speeding up the process to avoid detection, so that wood may not be properly dry before producing the charcoal. This can push efficiencies as low as 8% or less. Producing charcoal under more optimal conditions, even with traditional techniques should allow efficiencies of 14%. As noted in BEST[47]:

> *"…the general perception that charcoal is illegal is forcing farmers and charcoalers to operate accordingly and incur high technical losses. Avoiding illegal charcoal operations could reduce the total annual harvesting of wood for commercial fuels by an estimated 15-20%"*

Modernising the production process could lead to further significant savings. Commercial operations in Rwanda are already producing high-quality charcoal for industrial applications with efficiencies of around 20%[48], representing a wood savings potential of 45% compared to traditional techniques. Using simple techniques such as adding chimneys to better control the carbonization process this can be improved to about 20-22%, as was demonstrated in the late '80s. Wood savings of 30% are possible if the average efficiency increases from 14% to 20%. Using modern kilns, efficiencies can reach about 25%; however, such kilns easily cost Euro 250,000 for a kiln with a production capacity of 1000 t of charcoal per year[49]. Some recent developments based on Adam retorts claim efficiencies of up to 35%[50], although their efficacy in the field is not yet proven.

In the 'efficient' biomass scenarios, a mixture of these improved production techniques is assumed to be adopted, so that the average yield of charcoal production rises from 11% to 18% by 2030. Also by 2030, the goal is for all charcoal production in the country to be certified as 'green'. In order to ensure the green charcoal production, a licence must be provided to charcoal maker based on prove that

[46] SNV Rwanda 2011 "Charcoal Value Chain and Improved Cookstove Sector Analyses"
[47] BEST – Vol 3 Rural Supply & Demand p24
[48] Data provided in interview with RNRA
[49] BEST – Vol 2 Background Analysis p61
[50] Maes, W.H. and Verbist, B., 2012. Increasing the sustainability of household cooking in developing countries: Policy implications. Renewable and Sustainable Energy Reviews, 16(6): 4204-4221.

wood used for charcoal production come from FMU using well managed and sustainable techniques. Importantly, charcoal producers must have a long-term contract with FMU used for providing wood. These approaches should take into account the findings of the recommended review into regulatory practices required to avoid the perception of illegality and consequences for sub-optimal practices in the forestry management and charcoal production.

Alternative fuels

There are alternative fuels sources which are currently used at relatively low levels in Rwanda, but have the technical potential to significantly reduce dependence on wood and charcoal. As noted above, two of these, pelletized biomass and biogas, are assumed to expand considerably in the illustrative 'efficient' scenarios. Both fuel sources can have considerable advantages, but also will need to overcome significant hurdles and supply-chain gaps if they are to become reliable energy sources for Rwanda. These gaps are outlined below.

Biomass Pellets. Pelletizing woody fuels helps to increase the energy density and reduce the cost of transportation, and enables the use of high-efficiency ICS and ACS because of the more regular form in which the energy is contained in a pellet compared with the raw biomass materials. Biomass has to be shredded and then compressed in special pelletising machines. This process can itself be relatively energy intensive and requires a source of electricity[51]. Typically, biomass pellets made from woody feedstocks will have an energy content of 4100 kCal/kg. This is somewhat higher than raw wood because of the additional drying, but the process requires 1000 kCal/kg, so that the net energy balance for pellets is 3100 kCal/kg, representing a net energy loss of 23% compared to raw wood. However, the gains from increased densification, reduced transport costs and improved stove performance capability more than outweigh these losses. This makes biomass pellets in principle a viable alternative to charcoal, which could offset much of the heavy energy losses associated with charcoal production.

A shift from charcoal to biomass pellets (using the same primary source of biomass) will depend on the economics at the individual household level, as well as consumer choice regarding fitness for purpose of the fuel and associated cook stove, whilst supply chains for the fuel would also have to adapt. Given the potentially large energy savings that are technically possible, these factors require further investigation. In the meantime, tax rates need to be reviewed to ensure a level playing field and avoid unfair competition between charcoal and pellets. For example, VAT is charged on pellets at 15%, whilst no VAT is charged on charcoal and other taxes on charcoal are set at a lower level.

Probably the largest hurdle to the mass scale-up of biomass pellet usage is the need to build new infrastructure and supply-chains. Supply-chains exist currently for charcoal, so in principle the problems are not insurmountable. New biomass collection and processing points would need to be set up around the country with sufficient electricity supply at each to power the chipping and pelletizing operations, with transport arranged to get the biomass from remote rural areas to these collection points. The bulk transport of biomass pellets into the urban areas is likely to be less of a problem, and could make use of existing roads and vehicles used by the charcoal industry. The two industries are likely to have quite strong synergies that could be encouraged.

Biomass pellets are less energy dense than charcoal (4100 kCal/kg compared to 7500 kCal/kg), so transport costs for pellets are likely to be higher than for charcoal. However, this does not significantly

[51] Further details can be found in GIZ "Micro-gasification: cooking with gas from dry biomass" http://www.giz.de/fachexpertise/downloads/giz2014-en-micro-gasification-manual-hera.pdf

affect the overall energy balance benefits of pellets compared to charcoal since transport fuel is a small share of the overall energy balance of the sector[52].

Biogas. Since 2007 the National Domestic Biogas Programme has been targeting households with at least 2 cows to use cow dung. Digesters have been based on a standard construction design using local materials. Since initiation roughly 5,000 digesters have been disseminated as of February 2015, with 50% government subsidy and the remaining through local credit institutions. If the program is to reach 100,000 digesters (close to the current population of households with cows[53]) by 2018 the total cost, which includes the training of masons, subsidy etc., is estimated at $37.3M. Although performance is satisfactory once installed, people are currently not accessing biogas in large numbers because of the cost, and uptake is low. More research is needed on how to improve the design, ideally to reduce costs whilst improving reliability and durability. It will also be important to better understand the market barriers and how to address these. The institutional biogas program has so far resulted in 68 installations, with 11 out of 14 prisons reached and the remaining 3 under development.
Recent research on the impacts of Rwanda's biogas programme on firewood expenditure[54] shows that fuelwood savings of 46% are achieved on average for those households that have a functioning biogas system. These households typically supplement their biogas with other forms of cooking, running additional firewood stoves etc. This figure of 46% saving is assumed to be the same in the projections to 2030. The average fuelwood savings for the programme as a whole was lower at only 28%, because a number of the biogas systems installed were found not to be functional.

Significantly scaling up biogas will require significant challenges to be overcome. Firstly, the technology need to develop in order to improve reliability. Secondly, affordability of systems needs to be addressed. At around $400 per system, the installation of biogas systems requires considerable financial outlay which is generally beyond the means of households. Thirdly, and perhaps most significantly, the potential of biogas depends on the number of households with at least 2 cows. The biogas figures in this analysis assume that all households with at least 2 cows will run biogas systems. In Scenario 1, the share of the rural population with at least 2 cows (estimated at 22% for 2012) is assumed to be maintained in the face of growing population through to 2030. In Scenario 2, the share is assumed to grow to 50% (equating to almost threefold increase in the population of cows in the country). The environmental, food security and land-use implications of such a scenario need careful further consideration to assess the viability of such a scenario.

Agricultural wastes / other sources of biomass. There are various other sources of biomass potentially available as energy resources, which include papyrus, typha, coffee husks, rice husks and other biomass residues. If fully developed, these resources could amount to over 300,000 tons of dry biomass per annum[55], although environmental impact assessments are required to assess the degree to which papyrus and typha could be grown without disrupting wetland environments. High ash content also makes it challenging to market fuels based on these plants for cooking applications. Currently, rice and coffee husks are already used for energy purposes, particularly for brick and tile making where the use of firewood is prohibited. Potential competition for such biomass sources (e.g. use as organic fertiliser / soil improvers vs. energy usage) needs to be addressed[56]. Given the scale of the biomass sector challenge (i.e. the need to reduce baseline woodfuel consumption from over

[52] The entire transport sector for Rwanda as a whole currently consumes less than 10% of the energy used in biomass
[53] Strategic Environmental Impact Assessment of the ESSP estimates that 120,000 households currently have cows under zero-grazing conditions.
[54] Arjun S. Bedi, Lorenzo Pellegrini and Luca Tasciotti (2014) "The Effects of Rwanda's Biogas Program on Energy Expenditure and Fuel Use" Forthcoming in World Development, accepted Nov. 6 2014
[55] BEST – Volume 3 p26-27
[56] Interview with MINAGRI officials

11 mtode to less than 5 mtode), together with the apparent limitations on supply of these alternatives, the scenarios developed in this work did not consider any major additional contribution from these other agricultural sources of biomass.

Appendix 2. Overview of On-grid Electricity Sources

Hydropower

Hydropower has been a mainstay of electricity supply in Rwanda, with an installed capacity of 57MW representing 51% of total power generation capacity in 2013. In 2014, an additional 28MW was installed at Nyaborongo, currently operating at 50% capacity during the commissioning period.

Category	Name	Installed Capacity (MW)	Available Capacity (MW)
On-grid Hydro Power	Nyaborongo	28.0	28.0
	Ntaruka	11.3	10.0
	Mukungwa	12.0	11.0
	Gihira	1.8	1.8
	Gisenyi	1.2	0.6
	Rukarara	9.0	9.0
	Rugezi	2.2	2.0
	Nkora, Keya, Cymbili	3.2	2.0
	Murunda (REPRO)	0.1	0.1
Imported/Shared Hydro Power	Rusizi I (SNEL)	3.5	3.5
	Rusizi II (SINELAC)	12.0	11.0
Off-grid Micro Hydro Power	Nyamyotsi	0.1	0.1
	Mutobo	0.2	0.2
	Agatobwe	0.2	0.2
	Nyamyotsi	0.1	0.1
	Rushaki	0.04	0.04
TOTAL		**84.9**	**79.6**

In terms of new projects, studies suggest that Rwanda's topography is most suitable for medium to high head pico and micro-hydro run-of-river schemes. Rwanda's overall technical hydropower potential has been estimated at 400 MW, but the most significant resource assessment conducted to date—the Rwandan Hydropower Atlas—which was conducted roughly five years ago found that the majority of sites identified would be rated between 50 kW and 1 MW in capacity. This study estimated a potential of 96 MW for the category of micro-hydro projects. Although fairly comprehensive, with some 333 potential sites identified across a large number of locations, additional viable sites have already been, and are likely to continue to be identified.[57] An assessment of the energy sector undertaken by the African Development Bank in 2012 estimated the domestic hydropower potential at 313 MW, broken down into 130 MW of domestic hydro and 183 MW of regional hydro resources. Feasibility studies have been completed or are under way for a number of sites representing at least 32 MW of technically viable new capacity. In addition, over 192 sites have been identified for pico-hydro with a capacity below 50 kW.

[57] Roughly 20% of proposed sites to be developed to date were not already included in the Hydropower Atlas. Informal communication with Rwanda Development Board, 30 May 2014

The potential for private sector involvement is relatively strong. There is a policy to transfer responsibility for operation and maintenance of all existing micro-hydro plant to the private sector, and all new micro-hydro plant are intended to be tendered to IPPs. There is a system of approval for self-initiated projects as follows: i) Get local district approval; ii) Get MoU with MININFRA to authorise investor to exploit the site, developers then get 6 months to do feasibility study; iii) REG assesses project; iv) Negotiate tariff / power purchase agreement (PPA) with REG, RDB; v) Developers arrange financing; vi) Get generation licence from RURA, who then police the terms of the PPA. For example, there is Russian financing for 3 micro-hydro projects using this approach, but currently this is a minority route.

Most projects are initiated by the government, who decide whether projects should be carried out by REG (usually the larger projects) or tendered for private investment. Tendering for these smaller private investments is usually preceded by feasibility studies carried out by government to try to provide some assurance to potential investors. 52 such feasibility studies for micro-hydro have carried out to date. These are to be tendered for competitive bids. The typical approach is to tender a concession for 25 yrs. PPA would then be signed with REG, agreeing on the tariff to be received per unit of electricity generated. These tariffs are within the range set by RURA for micro-hydro. Projects less than 5MW are led by REG, whilst larger >5MW projects are led by RDB.

Financing costs from local banks are relatively high, with cost of debt typically around 16-18%, and equity around 20% per year. Local banks are still very new and lack experience of lending to energy sector projects. Rwanda Development Bank (BRD) has more experience and is somewhat more well-disposed to provide financing. Nevertheless financing barriers remain high. A public-private partnership draft law led by RDB and due for approval by Parliament could help provide a way forward on financing. GIZ/ GVEP also offer technical assistance for business planning help to get financing. GIZ/Energising Development has implemented a private sector support programme under the "PSP Hydro" programme since 2006, using a mix of grant financing, technical and business advice to support Rwandese hydro entrepreneurs. So far three projects have been completed, 8 more are under development.

Rwanda's share of regional hydropower is estimated at about 183 MW of which Rusumo Falls on the border with Tanzania and Rusizi III and Rusizi IV on the border with the DRC are scheduled for joint development with Tanzania/Burundi and Burundi/DRC respectively. There are presently two operational plants on Rusizi with Rwanda's share amounting to a capacity of 15.5 MW. Two additional phases of Rusizi III (48 MW) and Rusizi IV (98 MW) are under active consideration. A preliminary estimate of the capital costs for Rusizi III and Rusizi IV are $150 million and $240 million, respectively. Also at the feasibility stage is the project at Rusumo Falls with 20.5 MW of capacity and an estimated capital cost of $53 million. The development of the regional power projects would require interconnection between Ruzizi sites and Kibuye (the connecting point to the grid) with an estimated cost of $28 million[58].

Solar

Relative to other technologies, solar projects face less technical problems regarding individual projects, and can be installed relatively quickly. An 8.5 MW plant was recently installed and has been contributing to grid electricity during the course of 2014. There is currently no fixed tariff for solar plant, PPAs are negotiated separately for each project with RDB, with input from REG and MININFRA, whilst RURA provides the generation licences. Projects are typically initiated by government. Following a REG pre-feasibility study to collect technical information on site / plant, an EoI was recently put out for a 10 MW plant, asking companies to provide bids including estimated tariffs. 45 bids were received,

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[58] AfDB 2013 "Rwanda Energy Sector Review and Action Plan"

GoldSol proposed a tariff at c21/kWh. IPP then carries out a feasibility study, and REG will assess this feasibility study again.

Whilst individual projects are relatively straightforward from a technical point of view, one of the key technical issues with solar is the integration with the rest of the grid, in particular:

i. Solar plant is intermittent, and daily generation is very variable. Cloud cover can reduce output from a single plant from near maximum to near minimum very rapidly, over a period of say 10-15 minutes. This means that the rest of the generation plant needs to have the capacity to continue providing enough power to keep the system stable.
ii. Solar PV power only produces during daylight hours. In Rwanda, peak loads occur during the evening due to demand for lighting. Without storage (such as batteries which are an expensive addition), solar does not therefore contribute to supplying this peak demand.

The first of these issues has led to expectations that solar power should not exceed 20MW (for now), representing roughly 15-20% of total generation capacity. This limit is sensible in relation to the current small size of the electricity generation fleet, but underestimates the need and potential for solar power in the longer term, given that ambitions of the energy policy are to achieve over 500 MW by 2018. A collection of multiple solar projects located around the country would exhibit less variability during the day than the single plant currently installed because their output would not be fully correlated. Whilst weather conditions will exhibit national patterns, individual levels of cloud cover can vary significantly in different parts of the country. Further work is needed to investigate these likely correlation factors and the impact on collective load factors for multiple solar plant.

The second of these issues means that solar plant cannot be used to displace peak generation plant from the system. However, solar power can be used to displace electricity generated during the day from more expensive diesel and HFO-fired plant. Fossil-fuel plant are economically better suited to providing peak-hours electricity, and should not be used as baseload generation because of the high cost of the input fuels. Solar plant can help towards phasing out the use of fossil-fired plant for baseload generation. They can also contribute towards conserving water in hydropower schemes which have reservoirs, allowing hydro to be used more extensively during peak hours.

Geothermal

Geothermal exploration is a capital intensive and technically complex process. The first step is analysing topography, looking for fault lines, identifying the potential for underground streams and rivers etc. Magnetometry, gravitometry are used to measure types and density of rocks, with seismic data used as a next stage to gain more detail. Drilling is the last and most expensive stage. The first well is usually drilled in the most promising area, second well try to use to estimate area of reserve if the first well is successful. Typical costs are $6-10m per well. Ethiopia drilled 7 test wells, and in Kenya drilled 9 before resource was proven, and there is a risk of false negatives from such test wells. Slim drilling (17” wells instead of 26”) are cheaper at $2-3m per well. At up to 2.5km deep these can produce steam if they successfully tap into a suitable resource. Shallow wells are cheaper still at $0.5-1m. These go to a depth of 500m and are for data collection purposes only, not for production.

Despite the cost of exploration, such information is essential in order to attract investors. Exploration to date has been done by private companies with a range of different sources of funding including from development partners and from government. The viability and technical approach used for exploitation of geothermal resources depends on the temperature of the water, the ideal situation being reserves of steam trapped in the rocks which can be used directly for electricity production. Lower temperature (hot water) reserves are not as valuable, but in principle may be used in a co-firing steam cycle to improve efficiency of fossil fuel plant.

There are currently 4 main prospects in Rwanda which have surface manifestations such as hot springs etc. At one of these, Karisimbi, 2 test wells (26” wells) were drilled, but they did not prove a viable reserve. Work is ongoing to try to correlate data obtained from the wells with surface observations. Other prospects have not been drilled. As a result of the negative results of the Karisimbi test wells, other studies have slowed down.

Recent analysis of these test results for a study funded by JICA indicates that total resource potential is now estimated at 47MWe at 80% confidence, with a lower 50% confidence that potential could be as high as 90MWe as shown below.

Field Name	Resource Potential at 80% Condidence Level (Mwe)	Resource Potential at 50% Condidence Level (Mwe)
Kinigi	32.6	58.6
Bugarama	6.6	15.1
Gisenyi	1.9	3.7
Karago	2.5	4.9
Iriba	3.7	7.2
Total	47.3	89.5

Peat

Peat is not considered a renewable fuel. Electricity generation plant burning peat are currently being built, and the ESSP plans considerable scale-up of this technology. Peat is also used in smaller volumes as an input in cottage industries, cement production, and as a cooking fuel in a small number of decentralized institutions. Rwanda has estimated reserves of 155 million tons of dry peat spread over about 50,000 hectares in Akanyaru, Nyabarongo, Rwabusoro and other areas. Approximately one-third of this resource is currently commercially extractable for industrial heat or electric power production. These resource estimates are largely based upon a ‘high level’ master plan undertaken in 1993, with only a small number of samples being taken and the majority of work carried out as desk-based research. In late 2013 and early 2014, more detailed resource assessments are being undertaken by Rwanda Energy Group (REG) in order to complement and refine the existing peat master plan. Parallel to this, several projects have independently developed feasibility studies based on peat resource potentials identified in specific locations. It is important that at the national level Rwanda has an accurate assessment of its resources in order to determine how to use them most efficiently and sustainably. In addition, some peat resources are located in environmentally sensitive habitats. Peat bogs can play an important role in regulating water flow rates. It is therefore important that any peat extraction programmes assess the potential impacts on these environmental services, and any knock-on impacts on the ability to regulate flooding or drought conditions. The potential environmental damage that can be caused by exploiting peat resources is explored in more detail in the Green Growth & Climate Resilience Strategy costing for the energy sector. This recommends minimising reliance on peat, and is a key rationale for moving towards greater use of renewable energy sources.

There is one significant power sector development which is a government-owned 15 MW peat-to-power plant at Gishoma[59]. Currently the role of the private sector is confined to fuel supply to this plant is provided by a private company who is responsible for the investments required for peat harvesting and preparation. Further prospects for private sector investment in the whole chain from peat mining through to power generation is developing. There is considerable international expertise in the necessary technologies from countries such as Ireland, Finland and Sweden. The first private sector investor has come to an initial agreement on land requirement as the first stage of an investment deal. However lack of data regarding the depth of peat resources is an issue in these negotiations, since without this data it is difficult to know what area of land is required. Current estimates are based on spot checks. More comprehensive data and resource mapping is therefore required, at an estimated cost of around $1.5m.

Institutional responsibility for peat is split between MINIRENA (responsible for overall peat resource management), and MININFRA responsible for energy usage. This can create coordination problems, and potentially conflicts between environmental conservation priorites vs. energy production. It is important therefore to find a way to efficiently coordinate actions between the two Ministries in order to serve the overall best interests of Rwanda.

Methane

Lake Kivu is estimated to contain 55 billion cubic metres of methane gas, with a further 150 to 250 million cubic metres of methane being generated annually in the lake. According to feasibility studies undertaken by the energy utility, the gas potential of Lake Kivu is sufficient to extract around 700MW of power generation over a period of 50 years. This would put the national resource potential at 350MW, as the resources are shared equally by both Rwanda and DRC through an international agreement. The commercial viability of power generation from gas extracted from Lake Kivu has already been demonstrated at a pilot plant operated and owned by Kibuye Power I (KP I) with an installed capacity of 3.6MW. This plant is contributing to the R&D required to develop the methane resource.

Technical risk remains a significant issue. Whilst in principle the technology required to exploit the methane resource is not especially complex, there are almost no international precedents for this kind of extraction. This means that there is no supply-chain established, and parts are bespoke and tend to be expensive to import.

The private sector has been strongly involved, and has led to the expected commissioning of the 25MW KivuWatt power plant in mid-2015 will be an important next step in assessing the feasibility of Lake Kivu methane gas. As part of IPPs government provides basic infrastructure such as road, water, power lines etc. There has also been an exemption on royalties for gas extraction.

In terms of data requirements, given the number of previous studies, there is no need for any further resource assessments, but more R&D is required to optimise the gas extraction technology given Rwanda's unique setting. The cost-effectiveness & also environmental impacts are therefore not fully established, which is holding back the development of the sector. Part of the argument for exploiting the resource relates to the potential safety benefits of extraction to manage concentrations significantly over the next 50 years. This probably requires further analysis in order to weigh up the pros and cons against the potentially negative environmental impacts of exploiting the resource. Likewise, the definition of whether or not methane counts as a renewable resource is not currently clear. In principle, if methane is extracted from the lake at the same rate at which it is generated from

[59]http://www.theeastafrican.co.ke/Rwanda/Business/Rwanda--peat-firm-finally-seal-Rwf1bn-energy-agreement-/-/1433224/2339986/-/wv1wjg/-/index.html

decomposing organic matter, then the supply of gas could last indefinitely and would be renewed annually. However, this annual production level is not known with any degree of confidence, and even the source of the methane (i.e. organic vs. fossil) is not entirely certain. Whilst methane can be considered as a cleaner greener source of energy than diesel and peat, for the sake of this study, the contribution of methane to the energy mix is not included in the proportion of renewables. If information arises that shows that methane is in fact renewable, then the proportion of renewables in Rwanda's energy mix could be higher than indicated here.

In terms of policies, there is a need to assess the value of different uses of methane (e.g. electricity generation, LPG, fertiliser production, inputs to industrial uses etc.), as currently there is no strategy on how to share the resource between different uses.

Whilst there is currently an MoU with DRC noting that the two countries have an equal share of the methane, it will be important to negotiate a more comprehensive treaty with DRC regarding the exploitation of Kivu methane. This will need to cover how the resource is to be shared over time, what monitoring mechanisms will be put in place, potential for joint projects, and revenue-sharing arrangements in the case where one party extracts gas more quickly than another. A methane gas law has been developed and is in the review process. Once adopted, this should provide more clarity to investors.

Diesel and Heavy Fuel-Oil (HFO)

Diesel and HFO are expected to comprise 52MW in 2015, accounting for over 30% of installed capacity in Rwanda. 24MW of diesel plant are privately operated, under contract to REG, with energy inputs are provided by REG, and the company charges a fee for operating the plant.

This heavy reliance came about in the past 10 years when water resources for existing hydro plant came under pressure. The advantages of diesel and HFO plant is that they are relatively cheap and quick to build, being much less capital intensive than most renewable technologies. However, they are very expensive to run. With the high cost of input fuels at around $1/litre, the fuel cost of generation is in the region of ¢37/kWh (¢34/kWh plus ¢2-3/kWh taxes). Added to this is the fee paid to the company for operating the plant of around ¢3/kWh. With these characteristics, such plant are ideally suited to provide generation during peak hours, since this minimises the use of fuel. The low load factors associated with only running at peak times do present a much smaller economic cost than for other types of plant because of the low capital costs of the plant.

However, currently, these plant are not operating in this way, but are utilised for baseload operation (i.e. 24 hours per day). This makes them a particularly uneconomic way of generating electricity, and is the major cause for the high average cost of generation in Rwanda. A key priority of the government is to phase out use of these plant, and replace them with lower-cost and less polluting forms of generation.

It should be noted that the key priority ought to be to migrate these plant from baseload to peak hours operation, which would cut down fuel expenditure and environmental impacts by around a factor of 5-10. Phasing out the plant themselves should be less of a priority, since it is the fuel savings rather than removal of the plant which will create the greatest overall cost saving to the system. In fact, retaining these plant for peak hours production may be essential to maintaining a suitably flexible supply system. Such considerations will be developed further as part of the least-cost development planning project currently being undertaken in the sector.

Such a shift from baseload to peak operating would require a change to the terms of the contract with the private sector operators, perhaps charged on the basis of availability rather than per unit generated.

International Imports & Exports

Rwanda is actively participating in a range of regional energy development initiatives, where it has a share of resources which lie on or across national boundaries. The Eastern Africa Power Pool (EAPP) was formally established in February 2005. There are currently 10 members including Egypt, Libya, Rwanda, Ethiopia, Sudan, Kenya, Uganda, Tanzania, Burundi and the DRC. The key power line projects which will help enable imports into Rwanda are:

- Gilgel Gibe III (Ethiopia) - Suswa (Kenya), High Voltage Direct Current: financing completed, expected completion date in December 2018.
- Lessos (Kenya) – Tororo (Uganda), 400 kV: under construction, expected completion date in June 2017
- Masaka – Mbarara (Uganda) designed for 400 kV but to be initially operated at 220 kV: currently under discussion, preliminary expected completion date in December 2019
- Mbarara – Mirama, 220 kV double circuit: under construction, expected completion date in June 2017
- Mirama – Shango, 220 kV double circuits and substation: under construction, expected completion date in June 2017

Rwanda is also a member of the Nile Basin Initiative (NBI). Apart from using its share of regional hydro plants - SINELAC and Rusizi I (SNEL), Rwanda is not connected to any regional transmission network; however, it's pursuing cross-border interconnections with Uganda and Kenya.

The governments of Rwanda and Uganda recently reached an agreement with AfDB and Japan (JICA), as part of the Nile Equatorial Lakes Subsidiary Action Plan (NELSAP), to develop a 220 kV transmission line, which is under implementation and is expected to be completed by 2016.

The long-term vision is that Rwanda will become an active electricity trading partner to the regional grids; exporting electricity to the network while also importing power when cheaper supplies can be secured from sources like hydro plants in the Lower Kafue Gorge of Zambia (to be imported via Tanzania), and hydro plants in Ethiopia (to be imported via Kenya and Uganda). Other major power generation investments in Kenya, Uganda and Tanzania should also boost availability of supply. International experience has shown that the establishment of wholesale trading arrangements to facilitate full cross border trade can take a considerable amount of time and in the short to medium term trade is likely to take place utility to utility. There are ongoing projects within the EAC that are building cross border interconnectivities to facilitate energy trade.