SEI Stockholm Environment Institute

Envisaging alternative bioeconomy pathways: a case study from Rwanda

SEI report
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1. Introduction

In 2018, SEI embarked on a new initiative on Governing Bioeconomy Pathways. The aim is to devise a strategic framework for analysis to guide decision makers towards more cohesive and constructive governance of bioresource pathways. Among other things, this has involved using SEI's Long-range Energy Alternatives Planning (LEAP) tool to model the intersection between energy- and non-energy-related products and the resulting land-use implications, and explore "the cross-sector (energy, agriculture, forestry) effects of different pathways". (SEI, 2020).

Neither the country nor the context for this exploration was specified when the initiative was originally proposed. After reviewing possible candidates, Rwanda was selected in order to build on ties established with Rwandan stakeholders during past projects. SEI had previously co-created a LEAP model in partnership with the government ministries overseeing energy planning and forest management, as well as Belgium's development agency, Enabel, which has been working with both sectors to develop a national Biomass Energy Strategy.

On 18 September 2019, a small and informal one-day workshop was held in Kigali, Rwanda to enable a free-flowing discussion of the background to and context of Rwanda's Biomass Energy Strategy and the Government of Rwanda's plans to update the LEAP model and implement the Biomass Energy Strategy. It reviewed the inputs into and results from the original model, as well as the directions that alternative pathways might take based on emerging policies and knowledge gained since the original strategies were developed. Specific attention was also paid to broader bioeconomy issues.

This discussion brief summarizes the updating of the LEAP model for Rwanda and the proceedings of the workshop, and reviews the future plans for collaboration with Rwandan partners. A list of attendees is included in the appendix to this report.

2. Conceptualizing resource flows in the bioeconomy

As a conceptual approach, the bioeconomy provides a cross-cutting lens on interconnected societal challenges at the environment-development interface, such as food security, sustainable land use, resource scarcity and climate change (Dubois and San Juan 2016). The bioeconomy spans many different sectors of economic activity and its make-up varies widely across regions. This means that enabling policies and institutions can be quite diverse, depending on the availability and distribution of land, water and other resources, as well as other political and economic factors (GBC 2015; Virgin and Morris 2016; Wesseler and Aerni 2011; El-Chichakli et al. 2016).

In one common formulation, the bioeconomy is contrasted with "natural" and "fossil fuel-based" economies (Ministry of Employment and the Economy 2014; F. X. Johnson 2017). The natural economy is heavily reliant on unprocessed biomass. Bioresources are produced mainly through extensive agriculture and traded in informal markets. Many, if not all, inputs are renewable, but supply chains involve little value-added and economic output is relatively low. In contrast, fossil fuel-based economies are heavily reliant on non-renewable resources and there is intensive crop production using fossil fuel-based inputs such as plastics, mineral fertilizers and agrochemicals. Markets are formal and many supply chains add extensive value through downstream processing. Many states in sub-Saharan Africa straddle the natural and fossil fuel-based economies.

The bioeconomy has elements in common with both natural and fossil fuel-based economies. Like the natural economy, it relies on renewable, bio-based resources. On the other hand, production is more intensive, as in the fossil fuel-based economy, but inputs are sustainably produced and either efficiently repurposed, reused or recycled (Potting et al. 2017). Markets are formal and value is added in downstream processing along the supply chain.

Many developing countries have abundant bioresources, limited access to fossil fuel resources and minimal levels of industrial development. A shift from natural economies to bioeconomies could avoid the pitfalls associated with heavy dependence on fossil fuels, while increasing productivity and value addition in their bio-based supply chains. For example, shifting from traditional bioenergy such as fuelwood or charcoal to processed biofuels such as biomass pellets or ethanol could reduce pressure on forests and woodlands while also adding value to local supply chains (Johnson et al. 2019). Increased agricultural productivity and higher value added in agro-processing could lead to greater economic output while also increasing the availability of agricultural waste and residues for animal feed, composting or energy feedstocks. Increased recycling would also increase the availability of biomass for both energy and non-energy uses. Some newly available or "saved" biomass in future pathways could facilitate strategies for forest conservation or land restoration, which would contribute to ecological health and greenhouse gas mitigation.

The physical extent of the bioeconomy can be measured by biomass flows, which are determined by the fundamental economic concepts of supply and demand. Biomass supply comes from many types of land: (a) grassland provides grazing for livestock; (b) agricultural land supplies grains as well as crop residues; (c) forests, woodland, plantations and many smallholdings provide woody biomass for energy and for use as construction materials; and (d) lakes and rivers supply aquatic biomass (Lewandowski 2015). Demand is determined by societal need for food, animal feed, bioenergy and biomaterials such as natural fibres, biochemicals and pharmaceuticals (Kitchen and Marsden 2011). Flows may be localized, as with rural subsistence-based economies, or they may cross intra- and international boundaries in the form long-range trade in foods, fuels and fibres.

SEI's LEAP tool, with its new ability to account for land-based resources and land-use change, provides an opportunity to monitor biomass flows and account for land conversion driven by resource extraction under different land management scenarios. Accounting for and the management of biomass resources also depend on national regulation and policy. LEAP can be used to estimate the impacts of implementing various policies on energy access, biomass stocks, pollution emissions and other outcomes.

3. Biomass Resource Planning in Rwanda

Modelling bioenergy strategies in Rwanda has provided an opportunity to examine the relationship between the energy use of woody biomass and resource planning related to non-energy products and conservation over time. The Rwanda team also added both supply- and demand-side data, and refined the model to enable it to inform its evolving strategy.

SEI's use of LEAP in the Bioeconomy Initiative to examine synergies between the energy-related and non-energy uses of bioresources linked well with Rwanda's use of the model. It presented an opportunity for stakeholders in Rwanda to improve their modelling capabilities and for SEI to use a real-world case study to refine LEAP's new module on land use and land cover. In the first phase of the initiative (2018–19), SEI developed the LEAP model using inputs from previous baseline scenarios and initiated a consultative dialogue with the Rwandan LEAP team. In the second phase (2020–21), SEI is working more closely with Rwandan stakeholders to harmonize the model, update critical inputs on both supply and demand, and increase LEAP functionality based on feedback from stakeholders.

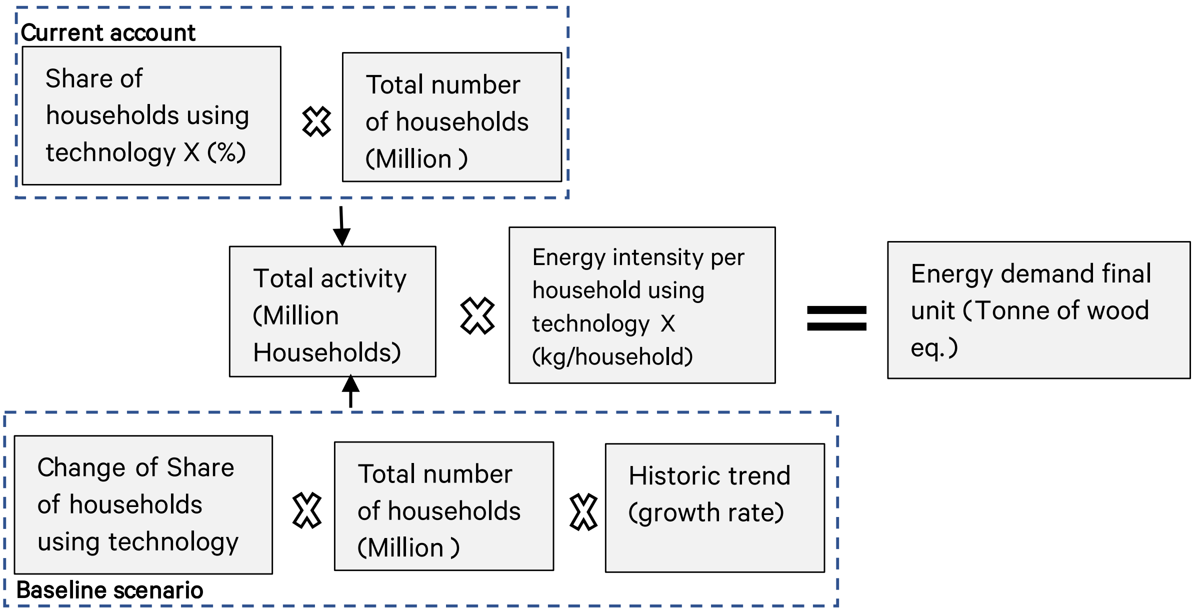
4. Approach: applying LEAP in Rwanda

Estimating bioresource demand

Biomass demand for LEAP's current accounts was estimated based on a combination of bottom-up and top-down approaches. Residential consumption, which is the largest source of demand, can be calculated using a bottom-up approach because sufficiently detailed data is available. Total wood consumed by the residential sector each year is estimated by calculating the product of three values: the total number of households, the fractional share of each household cooking technology used in that year and the energy intensity of each cooking technology. By contrast, very little data is available for the commercial and service sectors so a top-down approach was used.

For all components, the model starts from the base year of 2015 and runs through to 2050. The baseline scenario factors in changes in the level of technology adoption, applies Rwanda's historic rate of population growth of 2.0% in rural areas and 6.4% in urban populations, and assumes a modest change in household cooking technologies (see Table 1). Urban growth is a key driver because when people move to the towns and cities, they typically shift away from collecting fuelwood to use of charcoal, kerosene or other commercial fuels (Bailis et al. 2005). In addition, the model assumes average gross domestic product (GDP) growth of 7.9% (NISR 2012). Data for the demand analysis was based on national statistical abstracts, Rwanda's population and housing census, biomass use surveys in urban and rural households, and a recent wood fuel supply and demand analysis (NISR 2012; Drigo et al. 2013; NISR 2014).

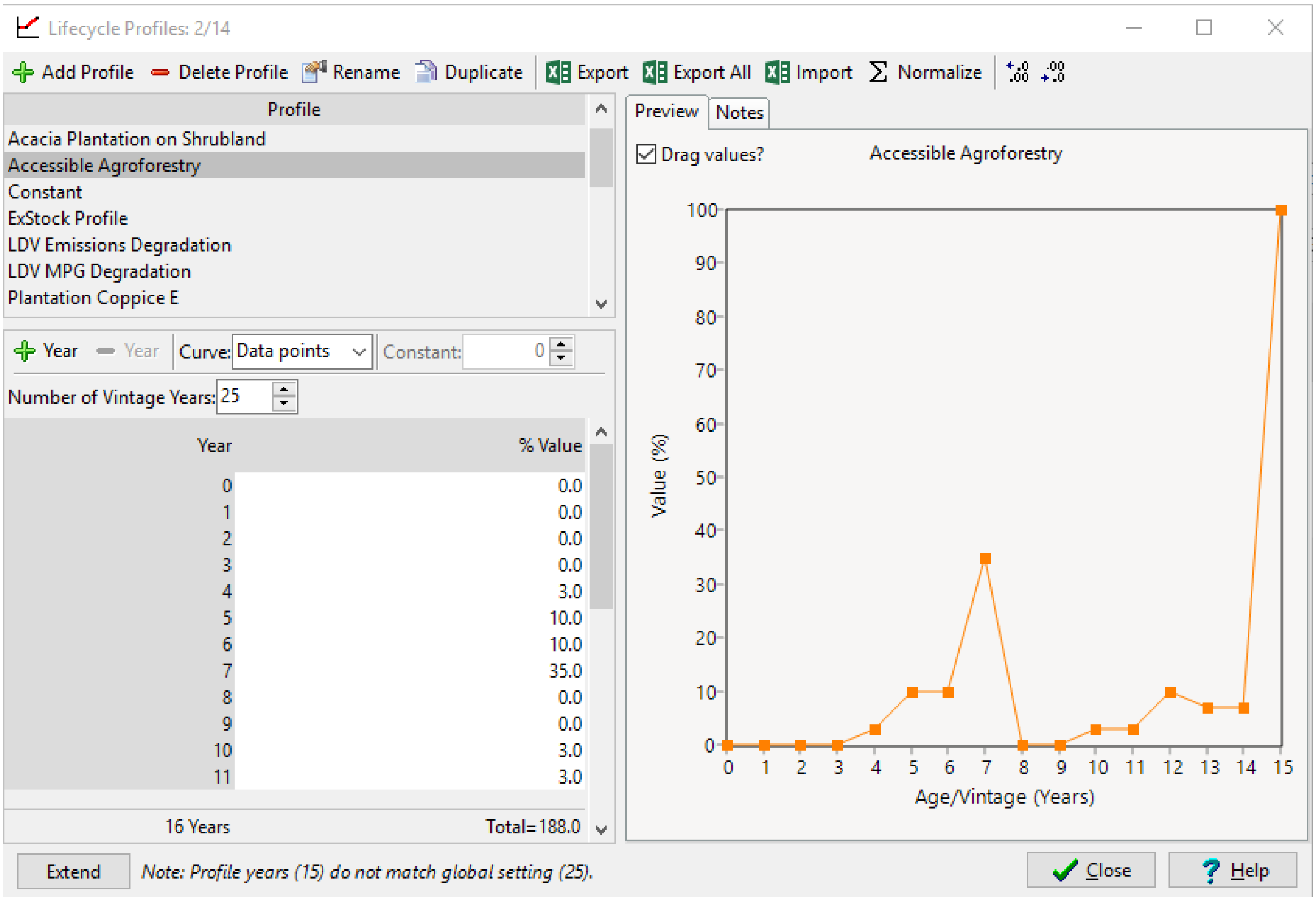
Figure 1. LEAP estimate of the demand for wood in the current account and baseline scenarios



Land-use change and land-based resource accounting

LEAP's land-use change and land-based resource accounting module was parameterized in three steps. First, we entered Rwanda's specific land cover categories based on its recent national forest inventory. Second, forest resources in each land type were allocated a region-specific stock (tonne/ha), growth rate (tonne/ha/year), accessibility percentage and management practice. For example, all land designated as woodlots was assigned a management profile that defined the way in which the wood is harvested (Figure 2). Finally, land conversions were modelled by defining how each land area was expected to change over time, based on expected wood harvesting patterns and national objectives for forest management and agroforestry.

Figure 2. Example of life cycle regime for the accessible agroforestry land type



Sustainable resource use scenario

The sustainable resource use scenario targets were based on the Rwanda supply masterplan for fuelwood and charcoal, which was designed to enhance energy efficiency and fuel transitions in 2020 and 2030 respectively (Drigo et al. 2013). However, these targets were enhanced to long-term (2050) projections using the country's Energy Sector Strategic Plan (MININFRA 2018). Fuel-switching to clean fuels such as biogas offers multiple benefits, notably improved health, reduced climate impact and better energy access (Van de Ven et al. 2019). Three measures were analysed in LEAP:

- Access to improved cooking solutions: the scenario projects that 86% of urban and 63% of rural households will have access to some clean cooking solutions by 2030. Access reaches 100% of both populations by 2050 (MININFRA 2014).
- Whereas in the baseline scenario, natural economic growth was assumed to increase LPG adoption to 4% of urban households by 2020 and 10% by 2050, the Sustainable Resource scenario projects a more rapid transition, with LPG adopted by 10% of urban households by 2020 and 40% by 2050. Rural areas progress more slowly, but still achieve 20% LPG adoption by 2050 (Drigo et al. 2013).
- The government target in Rwanda's Economic Development and Poverty Reduction Strategy (EDPRS) was that 3,500 households would adopt biogas each year from 2009, resulting in linear growth to 35,000 households having adopted biogas by 2020. However, exponential growth increases the adoption rate to a conservative 10% adoption share by 2050, representing around 450,000 households using biogas in rural areas (MININFRA 2014).

5. Results

The analysis shows that in the baseline scenario, total biomass energy demand increases by 48% to 4.8 million tonnes of wood equivalent in all sectors (see Table 1) in 2030 and 10.2 million tonnes in 2050. This growth is mainly attributed to population increase and urbanization. In addition, although biomass-dependent industries such as tea processing, brickmaking, construction and timber represented just 5% of biomass consumption in 2015, demand is projected to increase rapidly, contributing 9% of total consumption by 2030 and 14% in 2050. The sustainable resource scenario, however, was only implemented in the residential sector.

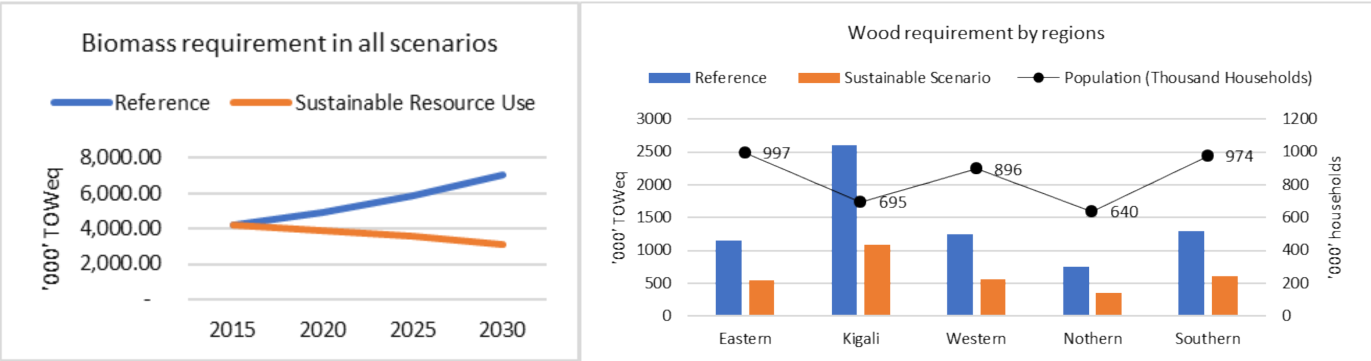
Table 1. Biomass demand

	BAU '000' tonnes wood equivalent			SRU '000' tonnes wood equivalent		
	2015	2030	2050	2015	2030	2050
Household	**2,935**	**4,158**	**7,884**	**2,935**	**2,270**	**2,886**
Urban	437	1,029	3,386	437	608	1,499
Rural	2,498	3,129	4,498	2,498	1,662	1,387
Commercial	**88**	**207**	**783**	**88**	**207**	**783**
Manufacturing	**181**	**407**	**1,461**	**181**	**407**	**1,461**
Public Facilities	**54**	**62**	**73**	**54**	**62**	**73**
Total	**3,258**	**4,834**	**10,200**	**3,526**	**3,560**	**7,445**

Demand in the baseline model was calibrated to closely reflect the updated 2013 WISDOM report, with slight differences linked to conversion factors and computation methods (Drigo et al. 2013). This would be a suitable reference on which to build different bioeconomy pathways. However, the workshop participants expressed concerns about the methodology and approach used in the WISDOM report to estimate biomass demand. These are examined in the discussion below.

The sustainable resource scenario introduces targets for household firewood requirements. Implementing the scenario would reduce the amount of wood required to meet demand by about 2 million tonnes by 2030 and about 5 million tonnes by 2050 (see Table 1). Nearly 40% of this reduction is attributable to decreased demand in Kigali, because of the high dependence of residents on charcoal in the baseline scenario (Figure 3). The population of eastern, western and southern Rwanda is about 40% higher than the population in Kigali, but the wood requirement to meet charcoal demand in Kigali is nearly double that of other regions. The transition to charcoal at the current level of technological development (inefficient conversion and cooking technologies) is unsustainable. Thus, direct firewood use in rural areas demands less biomass compared to heavy charcoal reliance in urban areas.

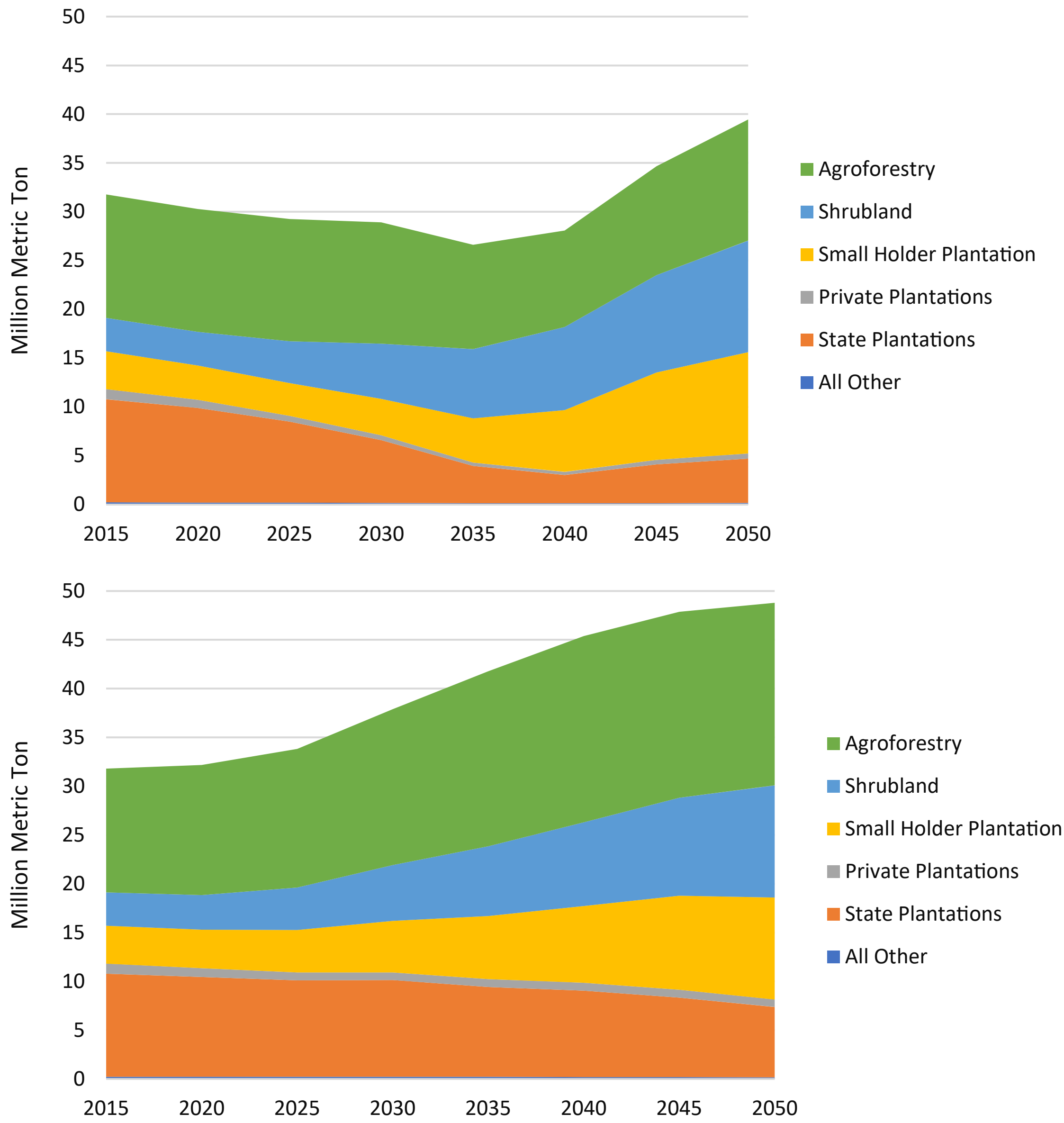
Figure 3. Biomass requirement in all scenarios and by regions in 2030



The land-use module in LEAP can translate these trends into changes in forest stocks based on varying land management practices. In the baseline scenario, biomass stocks in state plantations are rapidly harvested so that very little biomass remains by 2040. Agroforestry remains unharvested until 2030, after which it is exploited. Nonetheless, the area gradually increases due to evolving land management practices that are "baked into" current Rwandan government policies. Protected shrubland, forest and smallholder plantation also increase in area because they are largely inaccessible to wood fuel harvesters (Figure 4a) and due to stringent government policies.

In the sustainable resource scenario, practices are altered so that wood fuel is derived mainly from smallholder and agroforestry plantations and there is rapid regrowth in almost all plantation types. Overall, the stocks of woody biomass controlled by smallholders increase because agroforestry stocks are growing. In addition, the state plantations, which suffered under the baseline scenario, are preserved (Figure 4b).

Figure 4. Biomass changes by land types in the baseline (top) and sustainable resource use (bottom) scenarios



6. Discussion

Several themes emerged during the development of Rwanda's LEAP model and the stakeholder workshops. These will guide future efforts.

Harmonization of models

The LEAP model described in this report differs from the model developed by Rwandan stakeholders. The SEI team primarily relied on demand inputs from the 2013 WISDOM study but the Rwandan team has questioned the reliability of this data. During the September 2019 stakeholder workshop, the Rwandan partners announced that a nationally representative survey was planned for early 2020. This will generate new data that supersedes previous estimates of residential and commercial wood energy demand.

Input into a planned national - survey of energy use

The stakeholders also revealed that Rwandan partners would like to adopt some of the variations introduced in SEI's version of the model. However, the changes implemented in the SEI model are likely to require updated data. The group agreed that the SEI team will coordinate with the Rwanda team on the design of the survey and harmonizing the demand inputs once the survey data is available.

Technical issues with the LEAP model

Stakeholders also raised a number of issues concerning the capabilities of the LEAP model itself, particularly the land use module. The Rwanda team asked specifically about:

- Biomass exchange between subnational units in order to capture exchanges from surplus to deficit regions has not yet been incorporated into LEAP but is necessary in order to model interregional resource flows accurately. The bioeconomy team will coordinate with SEI's LEAP developers to support this.

- Stakeholders mentioned difficulties with the way LEAP calculates biomass stock and growth under varying management regimes. Specifically, they mentioned that they would like the ability to define a minimum ceiling stock and to improve on the "dispatch" functions between different sources of biomass supply; that is, the order in which harvesters move from one source to another based on accessibility or other factors.

- The consultation also discussed the need to include more accurate carbon accounting in LEAP. For example, when alternative scenarios result in increased biomass stocks, the resulting carbon sequestration should be reflected in the model's overall carbon accounts. Currently, LEAP shows whether biomass stocks increase under certain scenarios but does not reflect this growth in overall carbon accounting

- Finally, the users expressed a desire to learn whether it is possible to include cost-benefit accounting, specifically on the supply side of LEAP's land-use module.

7. Next steps

The stakeholder workshop was held in the closing weeks of Phase I of SEI's Initiative on Governing Bioeconomy Pathways. This put the team in a good position to contribute suggestions for a component of the second phase that could build directly on these activities and allow continued engagement with Rwandan stakeholders. Phase II funding will enable the team to re-engage with Rwandan partners in order to build consensus on the data that stakeholders feel is weakest, implement the functionality in LEAP that stakeholders are currently seeking, and further define bioeconomic pathways that best reflect scenarios of interest to Rwandan stakeholders.

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Appendix Tables

Table 2: Attendees of the 18 September Workshop in Kigali

Name	Organization
Stephen Bihinda	MININFRA
Jacques Peeters	Enabel
Vincent Nsabuera	Enabel
Therance Ndisanga	European Union
Manas Puri	FAO. Rome
Sylvain Hakizimana	FAO, Kigali
Steve Niyonzima	Rwanda Resource Efficient and Cleaner Production Centre
Dismas Bakundukiize	RWFA

Table 3: Summary of Rwanda's estimation of the volumes and aboveground, belowground and total living biomass (AGB, BGB and LB) of trees in productive forest areas, trees in shrublands (including wooded savannah) and trees in agroforestry areas (including agriculture)

Stratum	Total merchantable volume	Total merchantable stem volume	Above- Ground Biomass	Below- Ground Biomass	Living Biomass
Units	[m^3]	[m^3]	[tonnes @ 0% moisture]	[tonnes @ 0% moisture]	[tonnes @ 0% moisture]
Derivation	A	B = A x 0.85	C = B x 1.94	D = C x 0.26	E = C + D
Productive forests	12,889,478	10,956,056	21,254,749	5,526,235	26,780,984
Shrubland (incl. wooded savannah)	1,407,155	1,196,082	2,320,399	603,304	2,923,703
Agroforestry (incl. agriculture)	10,602,432	9,012,067	17,483,410	4,545,687	22,029,097
TOTAL	**24,899,065**	**21,164,205**	**41,058,558**	**10,675,226**	**51,733,784**

Source: (RNRA 2016)

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