MYANMAR WOODFUELS SECTOR ASSESSMENT

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WOODFUELS SECTOR ASSESSMENT

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Environment, Natural Resources and The Blue Economy Global Practice

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Acknowledgments

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Acronyms

AGB	Above-ground biomass
CF	community forestry
CSO	Central Statistical Organization
DZGD	Dry Zone Greening Department
FD	Forest Department
fNRB	fraction of non-renewable biomass
FRI	Forest Research Institute
GDP	Gross Domestic Product
ha	hectare
ICS	Improved cookstove
LHV	Lower Heating Value
LPG	Liquified Petroleum Gas
MONREC	Ministry of Natural Resources and Environmental Conservation
MRRP	Myanmar Reforestation and Rehabilitation Program
RECOFTC	Center for People and Forests
t	metric ton
UN	United Nations

Executive Summary

Context

There is renewed interest in woodfuels as locally produced, low-carbon energy sources, integrated in resilient landscapes and forest restoration strategies, provided that negative impacts related to forest degradation and emissions can be addressed. Woodfuels represent 75% of energy consumption in Myanmar. As well as dominating household cooking, they are a significant energy source for industries and commercial catering. This study, commissioned by the World Bank in collaboration with the Forest Department and Geres, quantifies woodfuel demand in Myanmar, characterizes commercial value chains, identifies hotspots of pressure on forests, and proposes options for the development of a sustainable woodfuels sector.

Woodfuel consumption

Total annual **household demand** for woodfuels is estimated at **23.8 million metric tons (t) in wood-equivalent** (34 million m^3), comprising 10.8 million t of firewood collected for own use, 4.4 million t of purchased firewood, and 1.4 million t of charcoal (8.6 million t wood-equivalent). 60% of Myamnar's population rely on firewood as their primary cooking fuel. Electricity is the second most common cooking energy, used by 28% of households, with charcoal accounting for 9.4% and liquified petroleum gas (LPG) for 1.4%. There has been a decline in woodfuels as the primary cooking fuel in favor of electricity, but firewood and charcoal continue to be used as supplementary fuels. In fact, households using woodfuel in combination with electricity may reduce their woodfuel consumption by less than 50% compared with households using firewood or charcoal alone. These dynamics are important for understanding the impacts of electricity and LPG adoption on woodfuel demand.

Commercial catering consumes 460,000 t of firewood and 105,000 t of charcoal per year, for a total of **1,090,000 t in firewood-equivalent**. Four **main industries** (brickmaking, garment manufacture, fish paste and dry shrimp, and noodle production) consume an estimated **648,000 t/year of firewood**. Demand would be higher with the inclusion of smaller industries and non-registered businesses, for which further research is required.

Total national woodfuel consumption is **25.4 million t of wood-equivalent per year** (36.3 million m^3). Household consumption significantly outweighs the combined demands of commercial catering and industry. The estimated annual value of the charcoal market is around US$ 300 million at retail, while firewood purchased and collected by households could be worth up to US$ 1 billion.

Woodfuel value chains

Charcoal supply is well-structured from kiln sites to middlemen's depots, where quality grading may take place, and onwards to urban centers in covered trucks, where small-scale transporters distribute to wholesalers, retailers and end-users. Charcoal for Yangon comes mainly from hardwood trees, potentially contributing to forest degradation, while charcoal in the Dry Zone comes mainly from village land and farmland. There is significant diversity in kiln design and producer skill, resulting in wide variation in efficiency. At least 108,000 t of unlicensed charcoal is exported each year to China (worth at least US$ 21.4 million), and a further 77,000 t to Thailand (worth US$ 8.72 million).

Price is a more important factor in firewood supply than quality, and a higher percentage of lower grade species and residues are therefore used. Rubberwood could supply 3.78 million t of firewood per year from residues, so has important potential - and already supplies industrial consumers in the lower-central region.

A computer model was developed to project demand for commercial woodfuels to likely harvesting locations, overlay this with biomass stocks, and thus identify potential hotspots of woodfuel-induced forest degradation. The model highlights three areas at risk due mainly to charcoal production: the supply chain of Yangon affecting Pathein and Bago; the Tanintharyi area, mostly due to export to Thailand; and the intersection of Mandalay, Sagaing, Shan, and Kachin States.

Intervention Options

Woodfuels meet the energy needs of a majority of households in Myanmar, as well as important commercial and industrial sectors. In a situation of diminishing forest resources, it is essential for both livelihood resilience and economic stability that forest resources are more sustainably managed for woodfuels, that woodfuel processing and utilization becomes as clean and efficient as possible, and that fuel switching strategies are well-informed and approached strategically. Intervention options are proposed accordingly.

a) Promote appropriate alternative fuels

LPG and electricity for household cooking

LPG has the potential to displace woodfuel, although it is perceived as dangerous by some consumers. Subsidy will also be needed if uptake is to be significantly accelerated. Based on experiences from Indonesia and India, this will require significant public investment and tradeoffs with other spending priorities. There is a need to **establish and enforce standards and regulations** for LPG cylinders, stoves and regulators; to **organize information campaigns and demonstrations** on the benefits and safety of LPG; and to **pilot financing solutions to reduce LPG entry and refill costs** in areas of woodfuel scarcity, including subsidized starter kits for poorer households, loans, and pay-as-you go technologies. Even with accelerated LPG adoption, however, there will be still be significant rates of woodfuel use as supplementary fuels in many households.

The adoption of **electricity** for cooking is also likely result in a switch in the main cooking fuel. Similar 'energy stacking' effects are likely to be observed, however, leading to continued use of woodfuels. Given Myanmar's ambitious electrification goals, there is a need for further **research on the impact of electrification on woodfuel consumption** in order to formulate an appropriate policy position.

Rice husk pellets and briquettes for industry

Biomass fuels such as pellets provide a low-carbon alternative to coal and oil for direct heat applications and steam production for industry. Myanmar has an annual output potential of more than 6 million t of wood-equivalent in rice husks. Interventions should focus on offering **financing products to co-fund boiler modifications to burn rice husk pellets or briquettes**, and **linking rice husk suppliers and industrial consumers**.

There is significant potential for offshore fishing rafts to switch from firewood to rice husk pellets for boiling fish and shrimp. The **adoption of rice husk pellets in the fisheries sector should be investigated**, together with the potential for high efficiency pellet stoves. A **subsidy or tax break for rice husk pellets** should be considered.

Charcoal briquettes for commercial catering

Charcoal briquettes can partially substitute for wood charcoal for commercial catering, and there is scope to grow this market. **Technical assistance and hands-on training** should be provided to briquetting firms to re-design production processes, raise quality and improve efficiency, drawing on expertise from the Mekong region. **Co-financing should be offered for upgrades** in capacity, drying facilities, and briquette quality. There is a need for **minimum quality labelling for briquettes**, and a **communication campaign** on such labeling.

b) Support sustainable woodfuels production

Large-scale plantations residues

Fuelwood plantations offer virtually no return on investment, so will remain driven by public sector. Alternative plantation models focusing on higher value products (such as timber or veneer) are more likely to provide an economically viable supply of woodfuel from harvesting and processing residues. An assessment is proposed of the **economics of woodfuel production from plantation residues**, and the necessary **regulatory environment to support such investment**. This should include **simplified procedures for charcoal production and transport**.

Tree plantations at village and household level

Decentralized, mixed-use tree growing for multiple purposes is a viable option for supplying woodfuels in areas of high deficit, in multi-strata home gardens and woodlots, and along field boundaries. Selected tree species should provide fruit, fodder, wood products, wind break, shade, and nitrogen-fixing services, with woodfuels as a byproduct. This requires a shift away from current interventions that are centralized and government-led, to **focus on mixed-used forestry models that respond to farmers' needs** and build on their existing practices.

Community forestry and forest restoration

The development of sustainably managed Community Forests could allow a consistent level of wood supply to be maintained and for degraded areas to be restored to a level where they can also contribute to energy supply. These activities should be directed towards woodfuel deficit areas - but keeping in mind that community-based resources management will not work in every situation. The development of Community Forest Enterprises has the potential to generate significant quantities of whole trees and residues for local charcoal producers. To realize its full potential, however, such charcoal needs to be differentiated from illegally produced woodfuels with **lighter-touch regulation and tax incentives** to ensure competitive market access.

c) Reduce energy loss across the value-chain.

Modernization of charcoal production

The enforcement of onerous rules concerning charcoal is virtually impossible, because trucks carrying charcoal cannot be identified and there is no system for monitoring adherence to allowed quotas. Most charcoal production is therefore illegal, which provides no incentives for investing in greater sustainability. There is a need to **ease the regulatory conditions applicable to sustainable charcoal,** to encourage compliance and bring the industry fully into the formal economy. To **improve the tracking of charcoal flows**, distributors could be obliged to declare their trips and the quantity of the charcoal they intend to deliver. Roadside checks and automatic number recognition could assist in reconciling output with licenses. With good law enforcement, **fees and fines can be reinvested in sustainable forestry**. The **inclusion of the charcoal sector in emissions reduction programs** could lead to a virtuous cycle.

Charcoal production is relatively inefficient, with high variability in operator skill. While a technology switch may be feasible in some cases, for most producers, significant gains are best achieved by **promoting incremental changes in charcoal-making operations**, including improved techniques for wood drying, kiln design, and operations. The organization of **local and regional exchange visits** could build a regional network of trainers. Technical materials and a **program of training for producers and Forest Department staff** should be introduced.

Cleaner and more efficient woodfuel use

Several organizations are promoting improved household cookstoves. All are subsidized to some extent, but the nature and size of the subsidy varies. This distorts the market and undermines in-country manufacture. The same resources should be **directed away from blanket stove subsidy** to give partial subsidy, to cover poor or remote locations, or to fund marketing and promotion. The study also recommends **developing a national cookstove strategy** with harmonized guidelines on subsidies; organizing marketing campaigns on improved cookstoves; supporting local producers to boost quality and marketing capacities; and developing fiscal incentives for local firms to invest in the manufacture of high-grade stoves within Myanmar.

There is potential for **improving the efficiency of steam production in industry** using condensate recovery systems, pipe insulation, solar thermal pre-heating, fuel pre-drying and better in-house energy management. Additional efficiency gains can be achieved by switching to boilers optimized for rice husk pellets. Priority should be given to areas of woodfuel shortage in the central Dry Zone. In the brickmaking industry, energy savings of 65% can be achieved by providing financial support for a **switch to more efficient brick kilns**.

d) Build an enabling framework for sustainable woodfuels

Given, the wide range of sectors with an interest in woodfuels, an **inter-ministerial coordination mechanism** is essential to answer to woodfuel challenges and opportunities. A **Decision Support System is recommended**, using an improved version of the model developed for this study to **calculate the fraction of non-renewable biomass (fNRB) at township level for different woodfuel value chains**. Such a system would allow interventions to be prioritized based on their impact on forest resources as well as CO_2 emission reduction.

Carbon finance is widely applied to woodfuel projects, and there is growing interest from multinational companies in tree planting and other carbon offsets. This represents an opportunity to support tree planting and reforestation, integrated in a coherent strategy to contribute to long-term supply of woodfuels. By attributing a reduction in forest degradation to a woodfuels-related activity, this approach could also attract REDD+ financing.

1. INTRODUCTION

1.1. Context of the study

Trees have been a source of energy since the beginning of human civilization. With the development of fossil fuels in the 19th and 20th centuries, this role decreased in many parts of the world. By the 1980s, using wood as a source of energy had become seen as non-desirable due to adverse environmental and health impacts. More recently, however, the need to reduce dependence on fossil fuels and to mitigate climate change through the development of carbon sinks has reactivated interest in wood-based energy as a locally produced, low-carbon fuel, integrated in resilient landscapes and forest restoration strategies.

Generally gathered under the term “woodfuels”, firewood, charcoal, and wood pellets cover many different realities in terms of actors, value chains, and end-uses. A tendency to overgeneralize can mean that complex issues are often misunderstood, leading to ineffective policies that inadequately address the challenges of the sector or capitalize on its opportunities.

The degree to which woodfuel use impacts forest ecosystems is one topic that generates conflicting views. Depending on the value chain in question, woodfuels may be portrayed as a significant driver of deforestation or a minor contributor to forest degradation. These contrasting perspectives reflect the fact that the environmental impact of woodfuels depends on the quantity extracted, the harvesting practices employed, the species concerned and their regeneration potential, and the local landscape dynamics over the long term.

To address woodfuel issues and develop policies that incorporate woodfuels in a modern, sustainable energy mix, policy-makers therefore need nuanced, landscape-specific assessments of the contribution of woodfuels to deforestation and forest degradation, the structure and dynamics of commercial woodfuel value chains, and a better understanding of the current and future role of woodfuels in energy supplies.

This study provides an overview of the commercial woodfuels sector in Myanmar for policymakers and stakeholders to address these issues. It consists of three parts:

a) An assessment of woodfuel demand in Myanmar, estimating consumption by households, commercial catering and industries. This was based on primary data collected through field visits and phone survey, as well as compilation and re-analysis of previous work.

b) In-depth investigation of selected woodfuel value chains representing the diversity of the sector, to assess supply-demand dynamics and identify hotspots of pressure on forest resources. This was based on field assessment of prominent value chains and computer modeling of supply and demand.

c) Drawing on these analyses, the study offers strategies and policy options to support the development of a sustainable woodfuels sector in Myanmar.

1.2. Background to the woodfuels sector

a) Historical perspectives

❖ *The 1970s woodfuels crisis*

In the mid-1970s, following the first global oil price shock, interest in the sustainability of energy supply started to grow. First estimations of woodfuel consumption suggested that demand was going to exceed the sustainable supply from forest growth in many developing countries. This supposed “fuelwood gap” would affect the livelihoods of rural people and could be “the most profound ecological challenge of the late 20th century”.[1] Widespread deforestation, erosion, and soil fertility loss due to firewood and charcoal consumption were identified, threatening food production in a context of growing population. To tackle the expected woodfuel shortages and associated threats, development actors adopted four main strategies: fuel switching; promoting fuel-efficient cooking stoves; improving supply chain efficiency; and developing woodfuel plantations.

[1] Erik P. Eckholm, *The Other Energy Crisis: Firewood* (Washington: Worldwatch Institute, 1975).

❖ *The 1980s and 1990s switch in policy*

A decade later, the expected switch to 'modern' fuels had not materialized, given the many factors at play in cooking fuel choices (investment cost of a new cookstove, cost of fuel, safety concerns, cultural practices, etc.). At the same time, migration to urban areas continued to drive a global increase in charcoal consumption.

As these dynamics led to increasing demand for wood-based energy, it also became clear that the extraction of wood for fuel was not in fact the main force driving deforestation in many regions. This is because firewood for domestic cooking is generally collected close to the point of consumption, and a significant portion comes from trees, shrubs and bushes that can regenerate.[2] Further significant quantities of woodfuel come from residues from land cleared during agricultural expansion,[3] which generates woodfuel as a byproduct. Open access to forests, together with government subsidies for LPG, meanwhile suppressed the price of woodfuels in many countries, making commercial energy plantations economically unviable. Ambitious woodfuel plantation schemes did not reduce fuel scarcity for households as intended, due to these unfavorable economics and lack of access for the populations intended to benefit from them.

This led in the 1990s to the development of participatory forest management and community forestry concepts, in which woodfuel was one component (but rarely the primary focus) of integrated forestry interventions.[4] Programs supporting woodfuel plantations came to an end and the discourse around sustainability shifted from woodfuel supply to switching to 'modern' sources of energy like liquified petroleum gas (LPG) or electricity.[5]

❖ *Today's perspectives*

More recently, woodfuel debates have focused on the need to reduce household air pollution (HAP). Burning solid biomass in simple, small-scale devices can release significant amounts of particulate matter and carbon monoxide, among other pollutants, affecting women and children in particular. Recent findings rank HAP as the fourth largest global disease burden, behind high blood pressure and tobacco.[6] In Myanmar, poor households are likely to be the most affected by HAP, as less than 10% were cooking with clean energy in 2017.[7]

According to the United Nations (UN) Sustainable Development Goals, the share of households cooking with clean cooking fuels and technologies increased from 57% in 2010 to 61% in 2017. Despite this modest progress and the attention this issue has been receiving, close to 3 billion people worldwide still rely on wood, coal, charcoal or animal waste for cooking and heating,[8] the majority of it used in traditional ways that are inefficient and polluting (Figure 1).

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[2] Wouter H. Maes and Bruno Verbist, "Increasing the Sustainability of Household Cooking in Developing Countries: Policy Implications," *Renewable and Sustainable Energy Reviews* 16, no. 6 (August 1, 2012): 4204–21, https://doi.org/10.1016/j.rser.2012.03.031.
[3] J.E. Michael Arnold, Gunnar Köhlin, and Reidar Persson, "Woodfuels, Livelihoods, and Policy Interventions: Changing Perspectives," *World Development* 34, no. 3 (March 2006): 596–611, https://doi.org/10.1016/j.worlddev.2005.08.008.
[4] Michael Arnold et al., "Fuelwood Revisited: What Has Changed in the Last Decade?" (Center for International Forestry Research, 2003), JSTOR, www.jstor.org/stable/resrep02182.
[5] Arnold, Köhlin, and Persson, "Woodfuels, Livelihoods, and Policy Interventions: Changing Perspectives."
[6] Stephen S Lim et al., "A Comparative Risk Assessment of Burden of Disease and Injury Attributable to 67 Risk Factors and Risk Factor Clusters in 21 Regions, 1990–2010: A Systematic Analysis for the Global Burden of Disease Study 2010," *The Lancet* 380, no. 9859 (December 15, 2012): 2224–60, https://doi.org/10.1016/S0140-6736(12)61766-8.
[7] Central Statistical Organization (CSO), UNDP, and World Bank, "Myanmar Living Conditions Survey 2017: Socio-Economic Report" (Nay Pyi Taw and Yangon, Myanmar: Ministry of Planning, Finance and Industry, UNDP and WB, January 2020).
[8] United Nations, "Sustainable Development Goal 7: Ensure Access to Affordable, Reliable, Sustainable and Modern Energy for All," accessed January 14, 2020, https://sustainabledevelopment.un.org/sdg7.

Figure 1 - Smoky kitchen in Pathein, Ayeyarwaddy Region

The debate between the need to accelerate the switch to modern fuels and the need to burn biomass in cleaner appliances remains.[9] Those who frame woodfuels as a cooking and health issue tend to promote a switch to LPG, while energy/environment stakeholders are more likely to promote improved stoves and sustainable woodfuel sourcing.[10] The high-profile Global Alliance for Clean Cookstoves is at the center of these debates and supports a switch to LPG *and* improved biomass cooking, depending on the context. The HAP debate tends to group woodfuels as a homogeneous group, but while firewood is a significant indoor pollutant, especially in rural areas, a transition to charcoal comes with significantly lower emissions and can help achieve important HAP reductions.[11]

Renewed interest in woodfuel and cooking stoves has also been prompted by the development of carbon finance, which has become an important source of funding for clean energy projects. The calculation of the contribution of cooking stoves to CO_2 emissions is complex, but the development of methodologies based on simplified calculations of the fraction of non-renewable biomass (fNRB) generally leads to high estimates of emissions reduction potential, often significantly higher than more rigorous approaches.[12] Carbon finance has therefore been used to catalyze many projects in the field of biomass cooking, including some where the objective of generating carbon credits arguably over-rides the quality of the cookstoves being disseminated and the sustainability of the business model.

b) Woodfuels in Myanmar

Woodfuels - and biomass more generally - are a major source of energy Myanmar. In fact, woodfuels represent 75% of the country's total final energy consumption, with 21,772,000 metric tons (t) of oil-equivalent per year, according to the International Energy Agency (Figure 2).[13]

As well as dominating household cooking, woodfuels are also a significant energy source for certain industries and commercial sectors, such as garment manufacture, commercial catering, food and beverage production, and brickmaking. These sectors are all explored in this report.

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[9] Gregory L. Simon et al., "Current Debates and Future Research Needs in the Clean Cookstove Sector," *Energy for Sustainable Development* 20 (June 1, 2014): 49–57, https://doi.org/10.1016/j.esd.2014.02.006.
[10] Kirk R. Smith, "Changing Paradigms in Clean Cooking," *EcoHealth* 12, no. 1 (March 1, 2015): 196–99, https://doi.org/10.1007/s10393-015-1020-9.
[11] Robert Bailis, Majid Ezzati, and Daniel M. Kammen, "Mortality and Greenhouse Gas Impacts of Biomass and Petroleum Energy Futures in Africa," *Science* 308, no. 5718 (2005): 98–103.
[12] Robert Bailis et al., "The Carbon Footprint of Traditional Woodfuels," *Nature Climate Change* 5, no. 3 (March 2015): 266–72, https://doi.org/10.1038/nclimate2491.
[13] International Energy Agency (IEA), "Data & Statistics," accessed February 5, 2020, https://www.iea.org/data-and-statistics/data-tables.

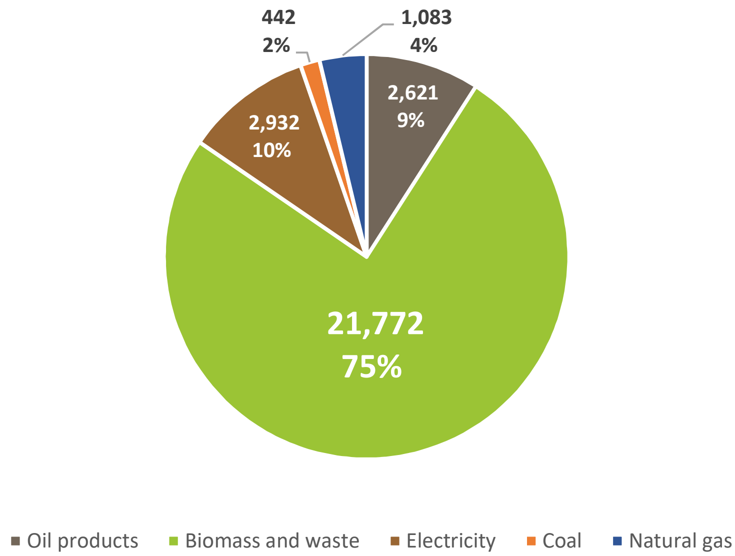

Figure 2 - Final energy consumption in Myanmar ('000 t of oil-equivalent, 2017)

Adequate energy supply is essential for economic development, which in turn is a significant driver of poverty reduction. In the economies of Southeast Asian countries, gross domestic product (GDP) is closely correlated with final energy consumption, and is usually accompanied by a rising contribution from fossil fuels relative to biomass (including woodfuels) (Figure 3).

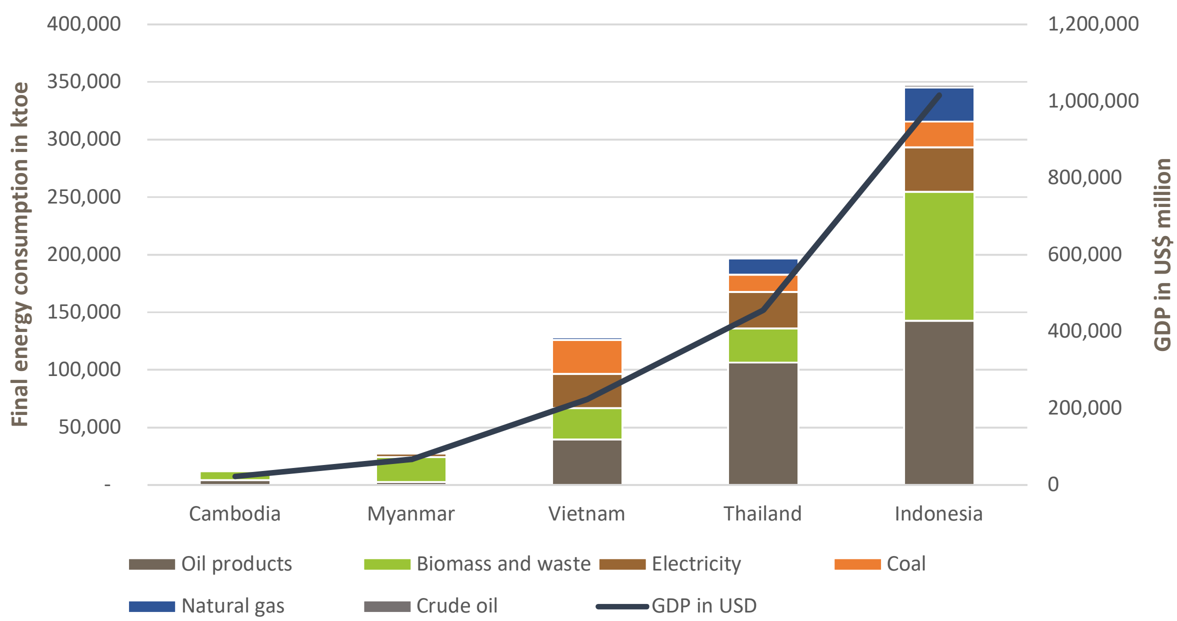

Figure 3 - Final energy consumption and GDP for Southeast Asian countries (Source: IEA and World Bank)

Given that GDP growth and energy consumption are strongly correlated, a rise in energy demand can be expected as Myanmar's economy grows. Achieving the same rate of growth with reduced uptake of fossil fuels, in line with Myanmar's commitments under the Paris Agreement on climate change, will require a higher contribution from renewable energy sources such as woodfuels. The development of a modern woodfuels sector to deliver clean energy for cooking, commercial applications and industrial use therefore has the potential to play a significant role in a more sustainable future energy mix for Myanmar. Woodfuel can support a growing economy with lower net emissions than the traditional pathway for newly industrializing countries.

In Myanmar, however, many actors interviewed during this study identified a close relationship between woodfuel use and a decrease in forest and tree cover. Commercial woodfuels have been described as the fatal blow to many forests, following behind timber-led degradation with massive "unplanned and apparently uncontrollable commercial firewood production", amplifying the degradation to a point where the forest would be converted to plantation or agricultural production.[14] Yet the woodfuels sector has received little rigorous investigation compared to the timber sector, which has itself been described as the major threat to forests, especially due to decades of over-harvesting for teak.[15]

Concern around the scale of woodfuel extraction is supported by FAO data on annual production volumes of woodfuels versus industrial roundwood (Figure 4).[16] While these estimates suffer from important uncertainties, the quantity of woodfuels is significant and consistently represents nearly 10 times the amount of industrial roundwood produced over the last 10 years.

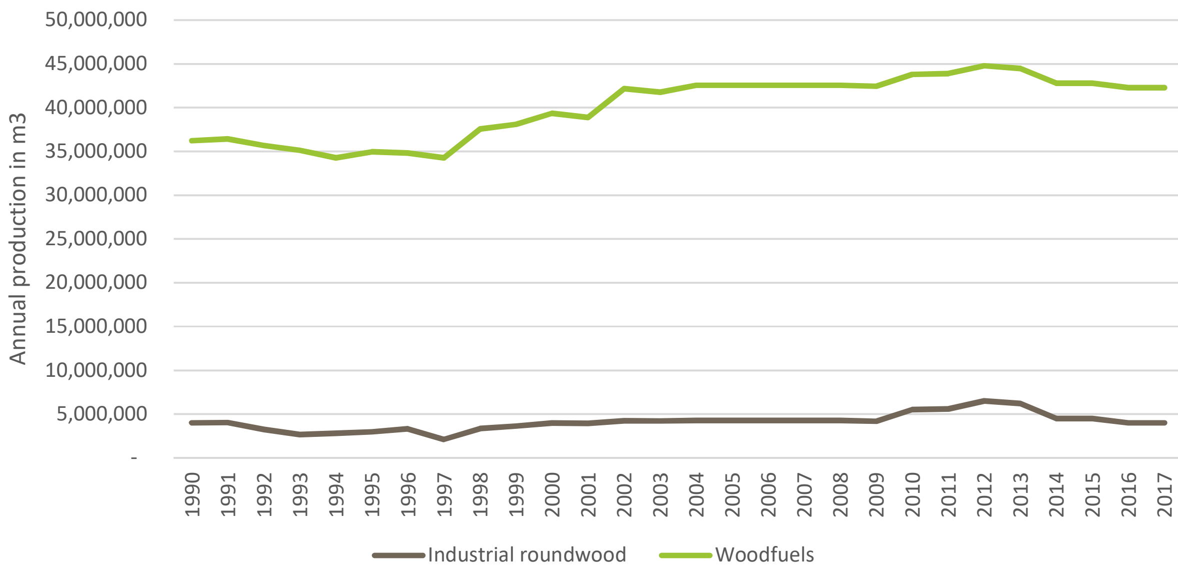

Figure 4 - Annual production of industrial roundwood and woodfuels in Myanmar (source: FAOStat)

The central Dry Zone and mangrove ecosystems reportedly face particular pressures from woodfuel extraction. To mitigate these effects to and prevent the degradation of forests to a point where they would be at risk of conversion to other land uses such as agriculture, the Government of Myanmar has implemented a series of measures under the National Forest Master Plan (2001/02 – 2030/31). The Dry Zone Greening Department (DZGD), under the Integrated Plan for the Greening of the Central Dry Zone (2001/02 - 2030/31), has a strong focus on fuelwood (Figure 5) and especially the development of fuelwood plantations. These account for 50% of the plantations it has helped establish.[17]

1. Establishment of forest plantations:
   - To fulfill people's basic needs for forest products: Firewood, poles and posts. Especially through One Village, One Acre Plantation.
2. Protection of remaining natural forests:
   - To provide local people with firewood, including by-products of conservation of natural forests in the short term.
3. Promotion of fuelwood substitutes:
   - To reduce dependence of local people on natural forests for firewood.
   - To promote utilization of renewable energy from agricultural residues.

Figure 5 - Main activities of the Dry Zone Greening Department related to woodfuels

In 2016, the Ministry of Natural Resources and Environmental Conservation (MONREC) launched the 10-year Myanmar Reforestation and Rehabilitation Program (MRRP), which targets the establishment of 311,875

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[14] Thorsten Treue, Oliver Springate-Baginski, and Kyaw Htun, "Legally and Illegally Logged out: Extent and Drivers of Deforestation & Forest Degradation in Myanmar" (University of Copenhagen, University of East Anglia, EcoDev/ALARM, March 2016).

[15] Thomas Enters, "Drivers of Deforestation and Forest Degradation in Myanmar" (Yangon: UN-REDD/Myanmar Technical Support Programme, December 2017).

[16] As defined by FAO Stat, industrial roundwood includes logs used for manufacture of sawnwood, railway sleepers, and veneer, as well as poles and posts.

[17] Justin Whittle, "Evaluation of the Dry Zone Greening Department (DZGD) between 1997-2017," March 2017.

hectares (ha) of community-owned forests and 42,333 ha of village plantations to increase the supply of sustainable woodfuels. The importance of woodfuels for the wellbeing of Myanmar's population and the sustainability of its energy supplies for a growing economy is well understood by the government. It is hoped that this assessment can contribute to a better understanding of the opportunities for developing woodfuels as a clean, modern component of the national energy mix.

1.3. Study objectives and methodology

The objective of the assessment was to analyze commercial woodfuel value chains in Myanmar and identify policy and investment options, as well as legal, institutional or administrative interventions, to move towards a more sustainable and productive woodfuel economy.

This was to be achieved through:

a) Assessment of charcoal and firewood consumption, identification of depletion hotspots, and characterization of value chains in the national charcoal and firewood trade; and

b) Identification of interventions to address issues of concern related to woodfuel trade and consumption.

The assessment included desk review of available literature, field data collection and phone survey, data analysis and modeling, as well as interviews with representatives of government agencies, private sector actors and associations, and NGOs. The main steps are outlined below, with more details provided in Annex 6.1.

- ***Desk review and assessment of knowledge gaps***

A desk review of available literature and datasets allowed us to identify knowledge gaps. This review was complemented by interviews with key stakeholders from government, the private sector, and development organizations, to ensure comprehensive access to relevant published literature. This led to the selection of priority sectors for field data collection, to fill gaps in knowledge and understanding.

- ***Qualitative and quantitative field data collection***

A team of three surveyors surveyed charcoal value-chains, firewood suppliers, industries, restaurants, and street food vendors using firewood, charcoal, rice husks or briquettes as an energy source. A total of 19 charcoal producers, 17 middlemen, 33 retailers and 30 woodfuel-using industries were visited. An additional 51 industries and restaurants, as well as 100 rice millers and sawmills, were interviewed by phone. Data from these visits and surveys allowed woodfuel consumption to be estimated for representative industrial and commercial operations, and extrapolated to national scale using census data and the Statistical Business Register from the Central Statistical Organization (CSO).

- ***Data analysis and modeling for nation-wide extrapolation***

Using a modeling approach, the most likely sources of wood extraction were identified to locate hotspots of woodfuel-induced degradation, and to compute the contribution of the woodfuels sector to climate change. This methodology is described in more detail below.

- ***Stakeholders consultation and peer-review***

Two round-table consultations were organized to launch the draft report and share the findings with sector stakeholders. The first took place at the World Bank in Yangon on January 28th, 2020, and was attended by representatives of donor organizations, NGOs, and the private sector. The second took place at the Forest Department headquarters in Naypyitaw on January 29th, attended mainly by government staff. At both gatherings, the findings and recommendations of the draft report were presented by the study team. Verbal and written feedback was invited and led to revisions for this final version.

1.4. Study limitations and recommendations for future work

This study sought to provide a comprehensive assessment of the woodfuels sector in Myanmar, its risks and opportunities, and potential interventions to address these. Given the scale and diversity of the sector, and the relatively short timeframe available (November 2019 to January 2020), certain limitations should be mentioned:

❖ *Household woodfuel consumption*

This assessment combines data from several previous surveys, including field consumption tests from Geres[18,19] and ADB,[20] and the 2014 Population and Housing Census from the CSO. As most of these data were collected between 2014 and 2015, the assessment offers a picture of the woodfuel demand at that time. The rate of household electrification has since increased, and a growing percentage of households have acquired electric rice cookers or electric pans. While an increase in grid connectivity is generally assumed to reduce woodfuel consumption, the precise nature of the dynamics of electrification and woodfuel demand is poorly researched. Research referenced in this study suggests that a switch from firewood to electricity-plus-charcoal for cooking may actually *increase* woodfuel consumption in terms of wood-equivalent. Further work is needed to quantify the evolution of woodfuel consumption after electrification, and its sensitivity to variation in electricity costs, and such research is proposed in the recommendations.

❖ *Catering and industrial woodfuel consumption*

Accurately assessing woodfuel consumption in the commercial catering and industrial sectors is a challenging task. Firstly, a wide range of industries, restaurants, street food vendors, and cottage industries use firewood and charcoal, with great diversity within and between categories. The fuel mix used within each sector varies based on location, with industries close to rice mills or tree plantations being more likely to use rice husk or plantation residues than the others, for example. A very large sample size is therefore required to achieve high statistical confidence, capturing each sub-sector and physiographic zone. Extrapolation for this study was mostly based on data from the CSO's Statistical Business Register.[21] While this compilation of business listings from City Development Committees and Development Affairs Organizations provides useful data, it also has limitations. A cursory analysis of the number of businesses per capita compared to other Mekong countries reveals much lower ratios, suggesting that many businesses may be unregistered.[22]

The study concentrated on the four main industrial and commercial consumers of woodfuel in Myanmar. It was not possible to capture a number of additional industries known to use woodfuel in some of their processes. These include producers of animal feed, soap, boxes and cartons, sugar, jaggery, alcohol, lime, and pickle tea. Additional research on woodfuel consumption is these industries is required. Having said this, even if commercial and industrial demand was under-estimated by 100% in the study, it would still amount to less than 10% of the woodfuel demand for domestic use (see findings below).

❖ *Modeling of the impact on forest resources*

Like any simulation of reality, the woodfuel supply-demand model developed for this study suffers from certain limitations in its ability to represent the real impact of consumption on forests. Modeling impacts was not the core focus of this research, and future work could no doubt improve the model's accuracy.

Such future work should ideally focus on improving the estimation of the biomass stocks and annual increments for different types of forests. The new space-based LIDAR system[23] and upcoming SAR satellite[24] will soon allow much better estimations of biomass stock in the world's forests. Combined with future results from the forest inventory system, this has the potential to significantly improve the modeling of both aboveground biomass and sustainable increment.

Some of the principles of the model could also be improved. For example, the current model assumes that the demand for woodfuels is distributed evenly across all potential production areas. This might lead to an underestimation of the real pressure as harvesting intensity might, in reality, be more concentrated. On the

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[18] Emerging Markets Consulting, "Myanmar Cookstoves Market Assessment" (Yangon: Geres, June 2015).
[19] Upadhyay Basudev, "Implementation of Kitchen Performance Test in Myanmar" (Geres, 2017).
[20] Asian Development Bank, "Myanmar Energy Consumption Surveys," September 2017.
[21] Central Statistical Organization, "Statistical Business Register," 2019.
[22] Khin Ohnmar Myint Thien et al., "Developing a Statistical Business Register (SBR) in Myanmar" (Central Statistical Organization and UN ESCAP, 2019).
[23] Global Ecosystem Dynamics Investigation LIDAR (GEDI): https://gedi.umd.edu/
[24] ESA BIOMASS: https://www.esa.int/Applications/Observing_the_Earth/The_Living_Planet_Programme/Earth_Explorers/Biomass

other hand, those involved in harvesting might adjust their practices according to the quantity of biomass available, reducing the amount by which their actions exceed the sustainable increment.

The model also takes no account of other pressures on forest resources, so may create that impression that woodfuel is the primary driver of degradation and deforestation in locations where extraction is predicted to have a major impact on above-ground biomass. In practice, woodfuels may be a byproduct or residue of a process of clearing for some other purpose, such as timber extraction or agricultural expansion. Care should be taken in interpreting 'over-harvesting' predicted by the model as a phenomenon driven purely by woodfuel demand. The real-world dynamics are far more complex, and while incremental adjustments to the model could improve prediction accuracy, there is no perfect way to quantify the impact of woodfuels on forests at the scale of a country. Despite its limitations, this approach can support decisionmakers in identifying priority areas for supply-side interventions.

2. WOODFUEL CONSUMPTION

2.1. Household consumption

Household consumption of woodfuel is heavily dominated by cooking. Any additional consumption for heating in mountainous areas was not assessed in this study.

a) Main energy sources for cooking

❖ ***Firewood***

According to data from the 2014 Population and Housing Census, firewood is by far the largest source of energy for cooking in Myanmar. At national level, 70% of the population rely on firewood as their primary cooking fuel. More recent data from the 2017 Myanmar Living Conditions Survey[25] indicate that the share of households using firewood as their main fuel dropped to 60%, driven mainly by changes in urban areas (where firewood use declined from 44% to 17%). There was more limited change in rural households (with a reduction from 81% to 76%). The use of firewood is widespread in rural areas, except in the far southeast (Figure 6).

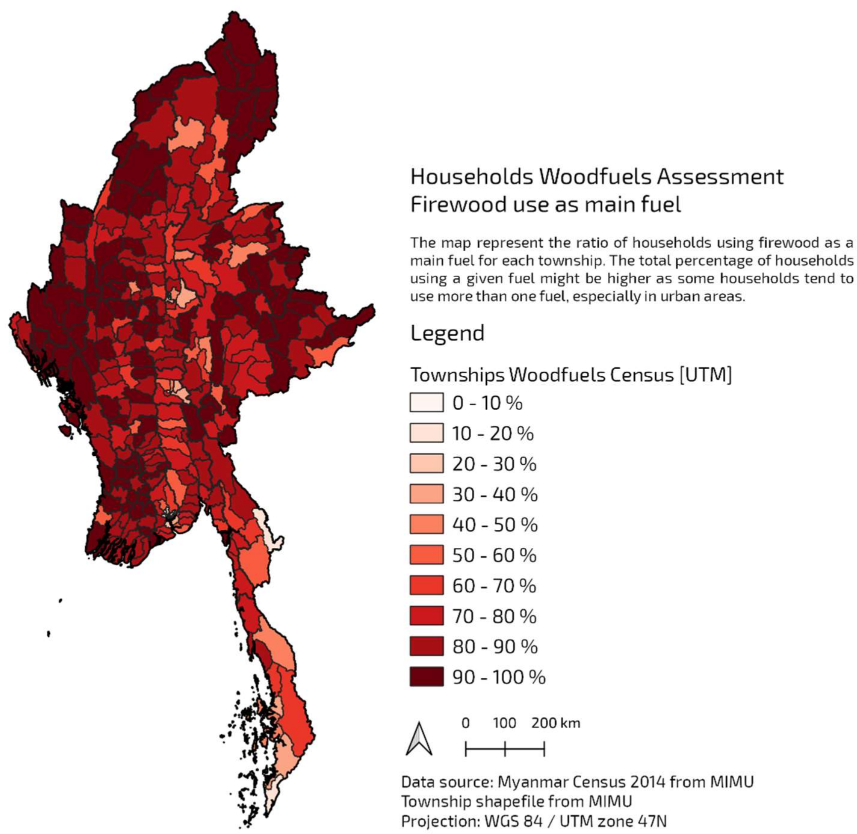

Figure 6 - Percentage of households using firewood as their main cooking fuel

❖ ***Electricity***

Electricity was the second most common energy source for cooking in 2014, used by 17% of all households. Its use had increased nationally to 28% by 2017, due mainly to an upsurge in adoption rates in urban areas (rising from 35% to 61% of urban households) (Figure 7). As with firewood, change was more limited in rural areas, with an increase from 10% to 15% of households using electricity as their main source of cooking energy. While these changes may be partly explained by growing rates of grid connectivity, other factors such as household purchasing power play a significant role in energy switching. The usage of electricity for cooking is 3.7 times greater for non-poor households than it is among poor households.[26]

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[25] Central Statistical Organization (CSO), UNDP, and World Bank, "Myanmar Living Conditions Survey 2017: Socio-Economic Report."

[26] The national poverty line in 2017 is 1,590 kyat per adult equivalent as per the Myanmar Living Conditions Suvey 2017.

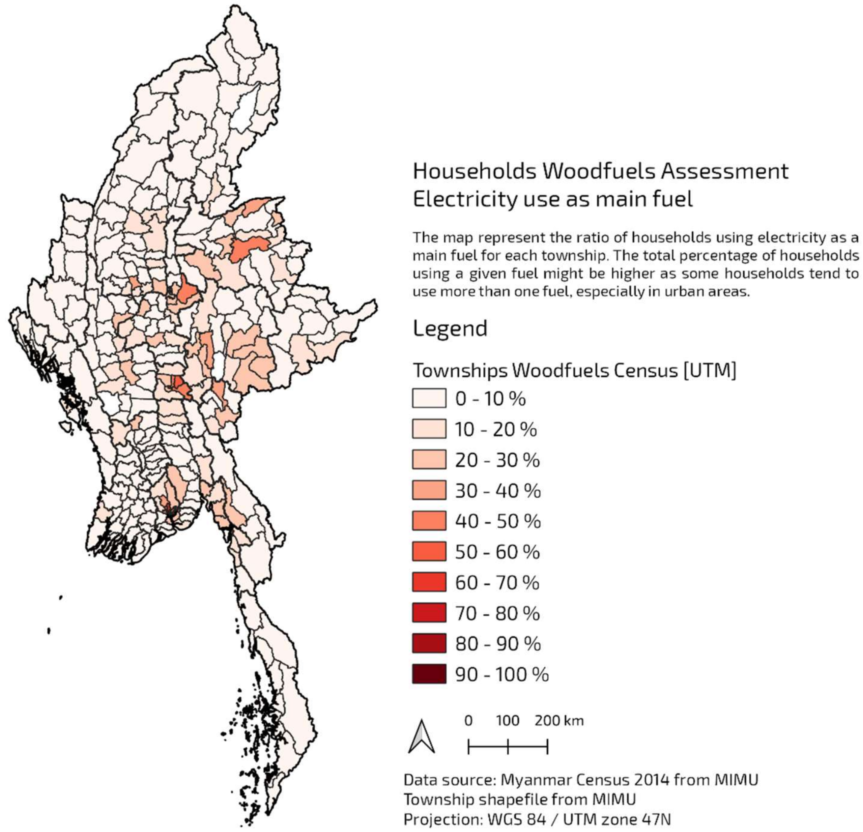

Figure 7 - Percentage of households using electricity as their main cooking fuel

- ***Charcoal***

After firewood and electricity, charcoal is the country's third most common source of cooking energy, used by 9.4% of the population as their main cooking fuel in 2017, compared with 13% in 2014. In 2014, 20% of urban households and 9% of rural households used charcoal as their main cooking fuel.

By 2017, the percentage of households using charcoal as their main cooking fuel had decreased slightly to 17% and 6% in urban and rural areas, respectively. Charcoal is therefore more commonly used in urban areas, but also in rural parts of the southeast coastal zone - up to 49% of households use charcoal as their main cooking fuel in Tanintharyi (Figure 8).These areas have also been reported to be hotspots of charcoal production for export to Thailand, Malaysia and China.[27,28]

The national decline in charcoal usage rates is surprising, given that this fuel is generally associated with urbanization. It is possible that rapid expansion of the electricity grid has led to a significant increase in its adoption for cooking, in place of charcoal. Electricity is particularly well suited to rice cooking. It is also probable that charcoal use as a secondary fuel has remained high, which may be disguised by data on primary cooking fuels (see discussion on fuel stacking in next section).

- ***Liquified Petroleum Gas***

At the time of the census in 2014, the use of LPG for cooking was negligible (0.5% of households). By 2017, national usage rates had increased significantly to 1.4%, although LPG use remained marginal in rural areas (0.4%) and was still the primary cooking fuel for only 3.9% of urban households. Spatial analysis shows the importance of LPG imports from Thailand, with the highest LPG usage rates found in the far southeast, close to the Thai border (Figure 9).

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[27] Emmanuel Freudenthal, "Burning down the House: Myanmar's Destructive Charcoal Trade," Mongabay Environmental News, October 26, 2017, https://news.mongabay.com/2017/10/burning-down-the-house-myanmars-destructive-charcoal-trade/.
[28] Wudan Yan, "Illegal Charcoal Trade Threatens Myanmar's Remaining Mangroves," Mongabay Environmental News, April 18, 2019, https://news.mongabay.com/2019/04/illegal-charcoal-trade-threatens-myanmars-remaining-mangroves/.

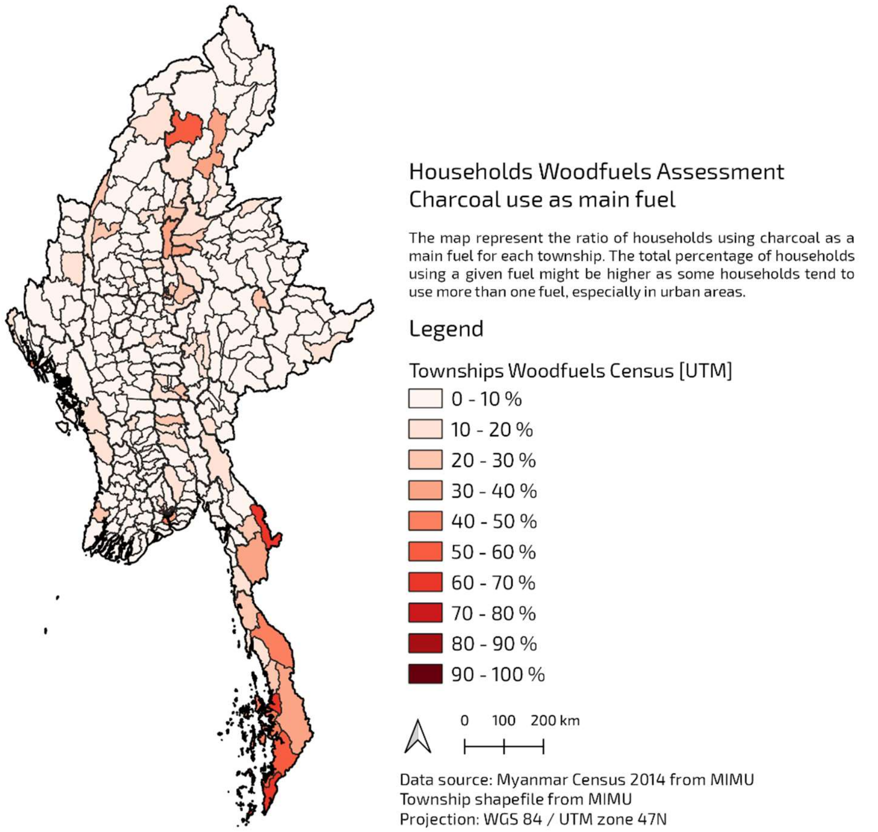

Figure 8 - Percentage of households using charcoal as their main cooking fuel

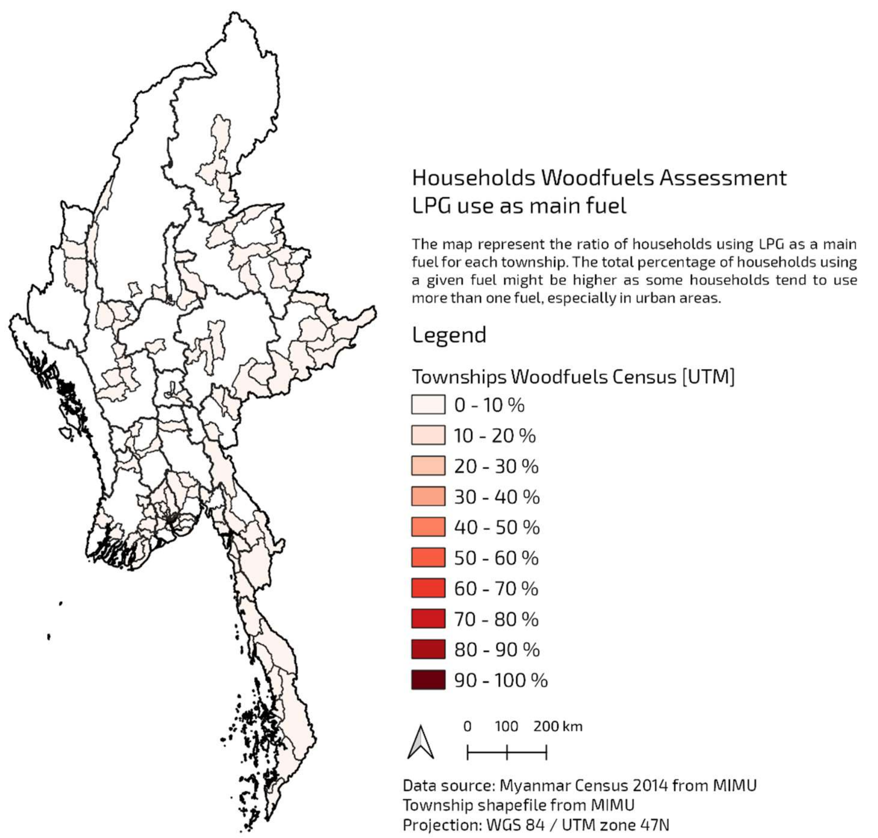

Figure 9 - Percentage of households using LPG as their main cooking fuel

b) The energy ladder and fuel stacking

A comparison of fuel use between the 2014 Census and the 2017 Living Conditions Survey reveals a significant increase in the adoption of clean cooking fuels over this period, especially in urban areas. There is a trend for households to climb the so-called 'energy ladder',[29] which describes the theoretical evolution in household cooking fuel choices linked to socio-economic development. Two forces driving a switch to modern energy can be identified: an increase in household income, allowing people to buy more sophisticated (and more expensive) cooking appliances; and an increase in reliable access to modern fuels.

The first barrier to fuel switching is appliance cost. The cost of more advanced appliances tends to increase with the modernity of the fuel. From 3-stone open fires, which have no cost, to standard charcoal stoves costing a couple of US$, to more advanced charcoal stoves costing around US$ 5 to LPG and electric stoves reaching US$ 50 to 60, the barrier for households with lower incomes to switch to cleaner fuels is clear.

The second barrier to fuel switching is poor access, especially in the case of those fuels that require major infrastructure improvements (such as electrification) or the development of complex supply chains (such as LPG). The more remote households are from major trading centers or national grid infrastructure, the more likely they are to rely on biomass fuels, whatever their income. Like the previous stove cost barrier, this is supported by empirical evidence from many countries that show an increase in modern fuel use as city sizes increase, suggesting both a rise in purchasing power and improved access to these fuels.

The energy ladder principle can be seen in the data from the 2017 Living Conditions Survey, which shows a clear increase in clean cooking fuel use with household consumption (a proxy for wealth) (Figure 10). It notes that "most of the population in Yangon Region has clearly moved up the energy ladder, while the population in Ayeyarwaddy Region, Chin State, and Rakhine State remains in the first level of the energy ladder".[30]

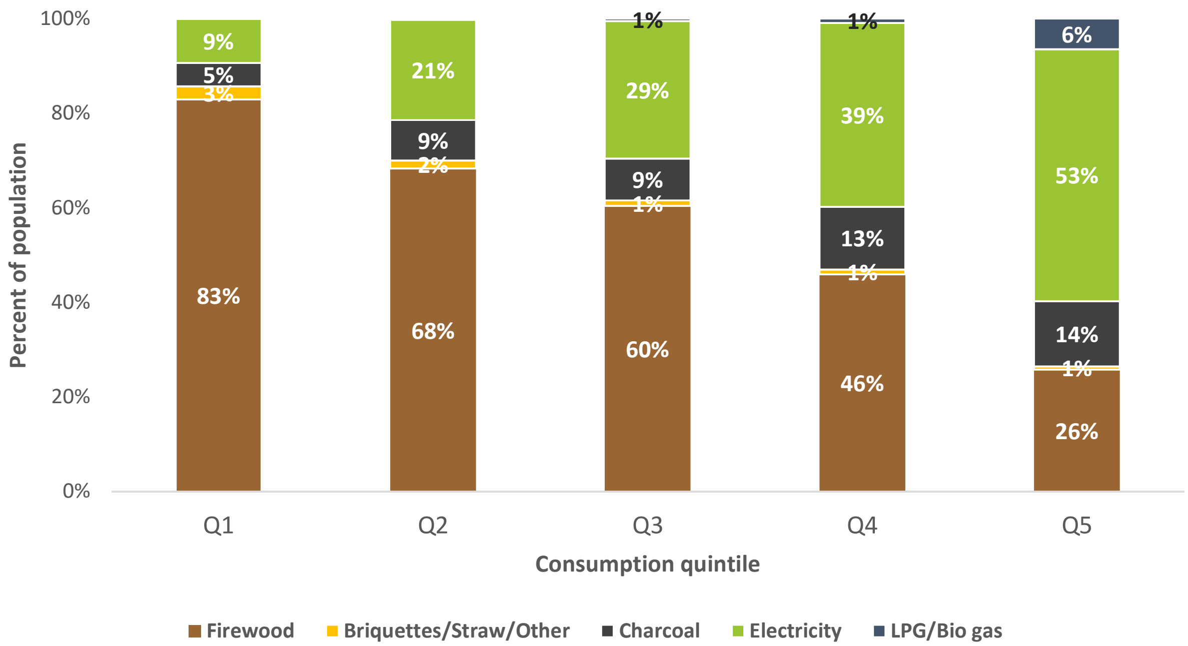

Figure 10 - Representation of the energy ladder in Myanmar according to consumption level[31]

Source: Myanmar Living Conditions Survey 2017 (CSO, UNDP and WB, 2020)

The energy ladder is based on the idea that households use only one fuel and that there is a 'universal hierarchy' of fuels that starts from firewood and ends with electricity. In fact, households tend to use multiple fuels; a

[29] Gerald Leach, "The Energy Transition," *Energy and the Third World* 20, no. 2 (February 1, 1992): 116–23, https://doi.org/10.1016/0301-4215(92)90105-B.
[30] Central Statistical Organization (CSO), UNDP, and World Bank, "Myanmar Living Conditions Survey 2017: Socio-Economic Report."
[31] Q1 to Q5 represent per-adult-equivalent consumption quintiles, with Q1 being the poorest and Q5 the wealthiest.

phenomenon known as 'fuel stacking'. This may lead to under-estimation of woodfuel consumption by excluding households who do not cite firewood or charcoal as their primary cooking fuel.

As shown in Figure 11 and Figure 12, socio-economic development not only leads to increased adoption of cleaner fuels, but it also leads to an increase in the number of fuels used. In the energy stacking model, charcoal tends to remain widely used as a secondary fuel for grilling, in combination with an electric rice cooker or wok. Such use of woodfuels alongside 'modern' energy sources buffers the impact of households going up the energy ladder on reducing woodfuel demand. This is especially the case if those households retain charcoal (as opposed to firewood) as a secondary fuel, given that charcoal requires twice as much wood to provide the same amount of energy as firewood in unprocessed form.

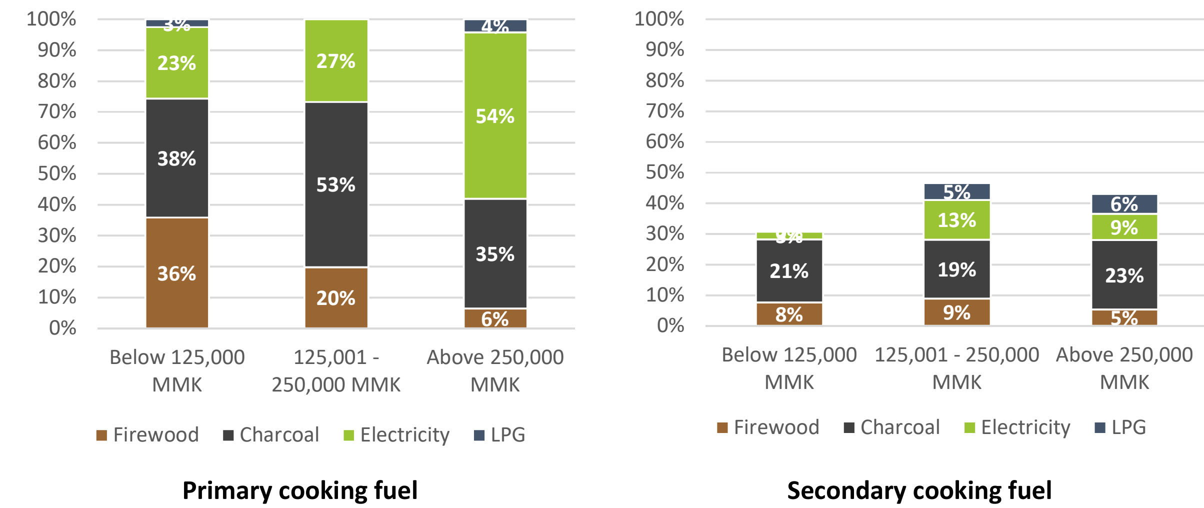

Figure 11 - Energy stacking in urban areas by monthly income band

Source: Myanmar Cookstoves Market Assessment

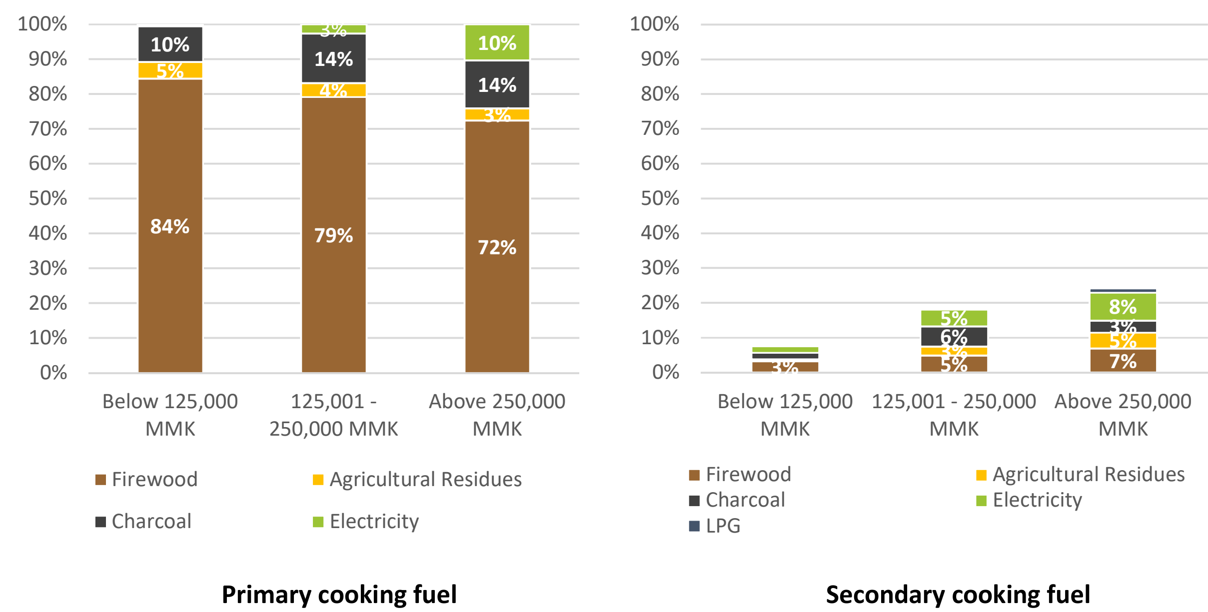

Figure 12 - Energy stacking in rural areas by monthly income band

Source: Myanmar Cookstoves Market Assessment

More precise data on primary and secondary fuel combinations are provided below for urban areas (Table 1) and rural areas (Table 2).

Table 1 - Cooking fuel stacking in urban areas of Myanmar

		Main fuel					
		Electricity	LPG	Charcoal	Firewood	Agri. residue	**Total**
Secondary fuel	Electricity	0%	1%	9%	0%	0%	**10%**
	LPG	3%	0%	3%	0%	0%	**5%**
	Charcoal	16%	1%	0%	4%	0%	**21%**
	Firewood	1%	0%	6%	0%	0%	**8%**
	Agri. residue	0%	0%	0%	0%	0%	**0%**
	None	15%	0%	27%	13%	0%	**56%**
	Total	**35%**	**2%**	**45%**	**18%**	**0%**	

Source: Geres/Emerging Markets Consulting (EMC) Myanmar Cookstoves Market Assessment, 2015

Table 2 - Cooking fuel stacking in rural areas of Myanmar

		Main fuel					
		Electricity	LPG	Charcoal	Firewood	Agri. residue	**Total**
Secondary fuel	Electricity	0%	0%	2%	2%	0%	**4%**
	LPG	0%	0%	0%	0%	0%	**0%**
	Charcoal	1%	0%	0%	3%	0%	**4%**
	Firewood	1%	0%	2%	0%	2%	**5%**
	Agri. residue	0%	0%	0%	2%	0%	**2%**
	None	1%	0%	8%	74%	2%	**85%**
	Total	**3%**	**0%**	**13%**	**80%**	**4%**	

Source: Geres/Emerging Markets Consulting (EMC) Myanmar Cookstoves Market Assessment, 2015

Despite the significance of fuel stacking, few studies have assessed its impact on woodfuel consumption. A 2016 study in Yedashe township in Bago Division[32] found that the largest proportion of households (accounting for 42% of the population) were using a combination of electricity and charcoal for cooking. These households using saw a reduction of only 44% in their charcoal consumption compared to households using charcoal alone, while households using electricity plus firewood used only 48% less firewood than households using firewood alone (Table 3). Other households (not shown in the table) were either using electricity alone, or a combination of firewood, charcoal, and electricity.

Table 3 - Fuel stacking in urban areas of Yedashe township

Cooking fuel(s)	**Share of the population**	**Firewood + charcoal consumption (kg/person/yr)**	**Consumption in wood-equivalent (kg/person/yr)**	**Fuelwood savings from electrification**
Firewood only	9.1%	362.3	362.3	
Electricity + firewood	25.8%	189.0	189.0	**48%**
Charcoal only	10.6%	109.8	658.8	
Electricity + charcoal	42.4%	62.0	372.0	**44%**

Based on data from Zar Chi Win et al., 2018 (Table 2 - Types of cooking energy consumed in urban area of Yedashe Township)

This research shows that the dynamics of fuel stacking are significant for understanding the impact of electrification on woodfuel consumption, and that research focused only on primary fuels will underestimate total demand.

[32] Zar Chi Win et al., "Consumption Rates and Use Patterns of Firewood and Charcoal in Urban and Rural Communities in Yedashe Township, Myanmar," *Forests* 9, no. 7 (July 2018): 429, https://doi.org/10.3390/f9070429.

c) Household woodfuel demand

Based on population and cooking fuel data from the 2014 Census, information on cookstove use from the Asian Development Bank[33] and Geres,[34] and Kitchen Performance Test results from Geres,[35] the total consumption of woodfuel (firewood or charcoal) as a main fuel was calculated. In order to account for fuel stacking, the woodfuel consumption of households using electricity as a main fuel was also included, assuming that this would be 48% and 44% less, respectively, if charcoal or firewood was the secondary fuel rather than the primary fuel.

The following section presents the results of the household woodfuel demand analysis in terms of 'demand density' for both self-collected and purchased woodfuels, measured in metric tons (t) per km^2. Separate maps are provided for self-collected firewood (Figure 13), purchased firewood (Figure 14), and charcoal (Figure 15). The data in the maps account for both primary and second woodfuel use, based on the effects of stacking as previously described.

❖ *Household firewood consumption – self-collected*

Firewood collected for own use represents the largest share of household woodfuel demand, at 10,780,000 t per year, and accounts for 45% of total household demand for cooking. It accounts for more than 50% of total woodfuel demand in Ayeyarwaddy, Bago, Chin, Kayah, Mon, Rakhine, and Shan States, and is the primary source of woodfuel in Kachin, Kayin, Magway, and Sagaing.

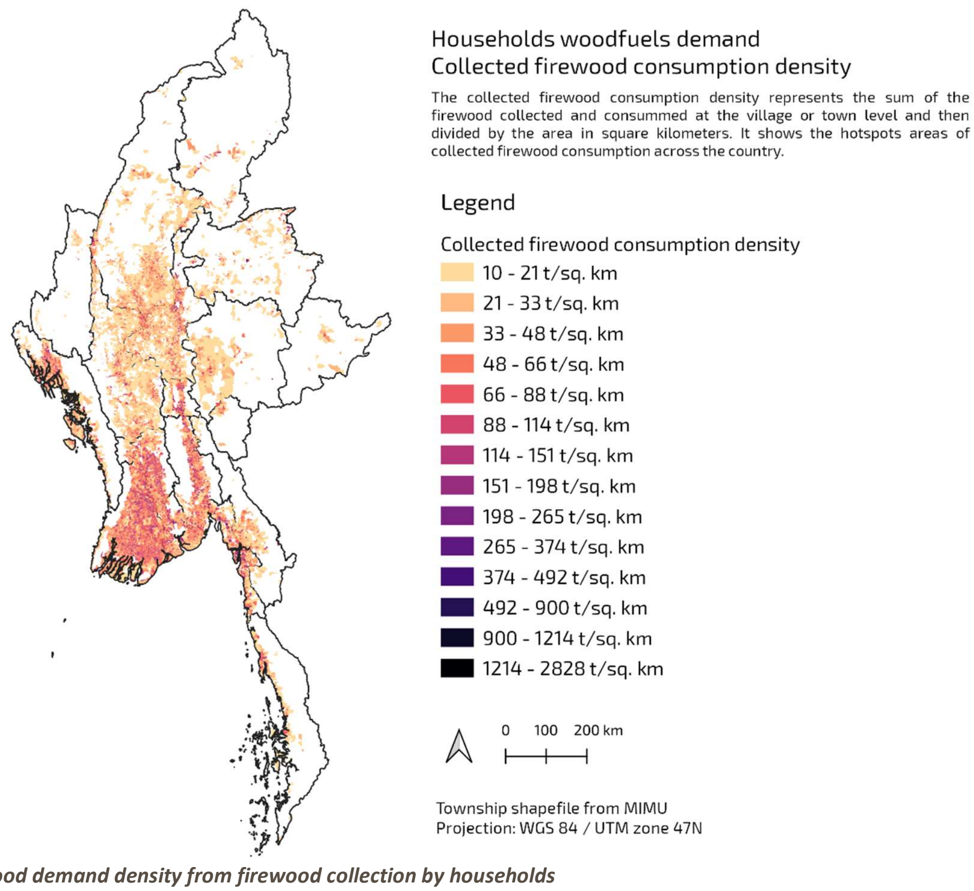

Figure 13 - Wood demand density from firewood collection by households

The central Dry Zone shows a different pattern, with high rates of purchase. In Mandalay Division, for example, purchased firewood represents the main source of household woodfuel. Purchased firewood is also important in Magway and Sagaing. This presumably reflects higher rates of fuel scarcity in the Dry Zone than in other areas of the country.

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[33] Asian Development Bank, "Myanmar Energy Consumption Surveys."
[34] Emerging Markets Consulting, "Myanmar Cookstoves Market Assessment."
[35] Basudev, "Implementation of Kitchen Performance Test in Myanmar."

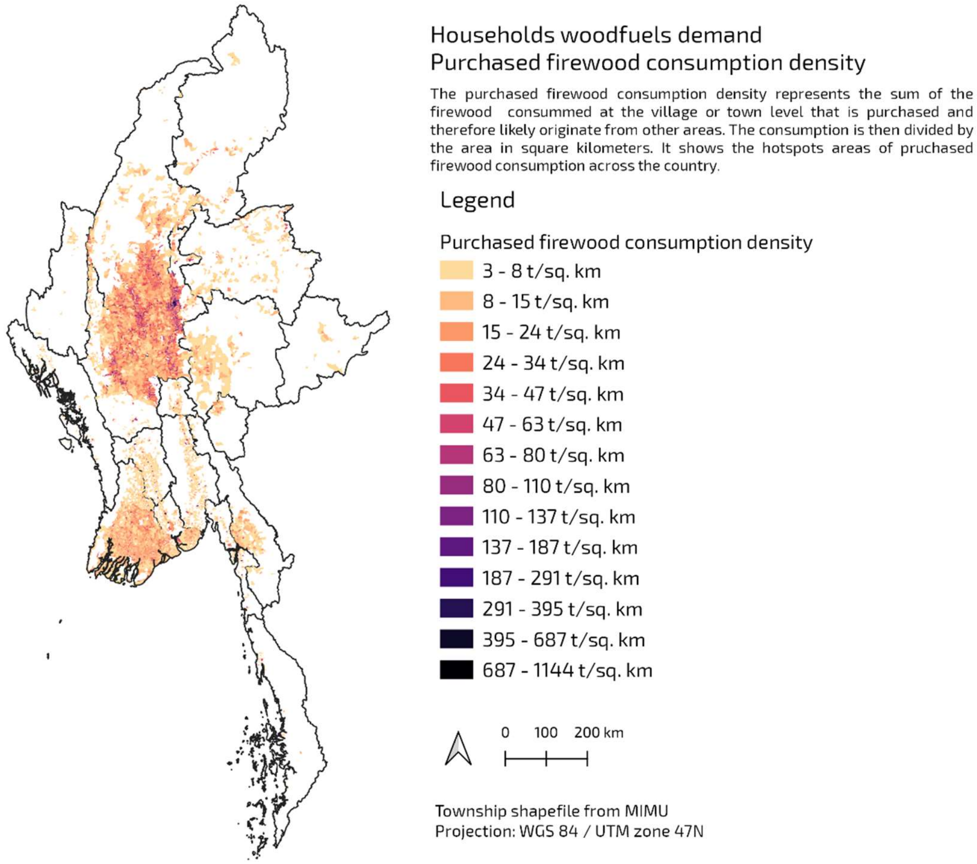

Figure 14 - Wood demand density from firewood purchase by households

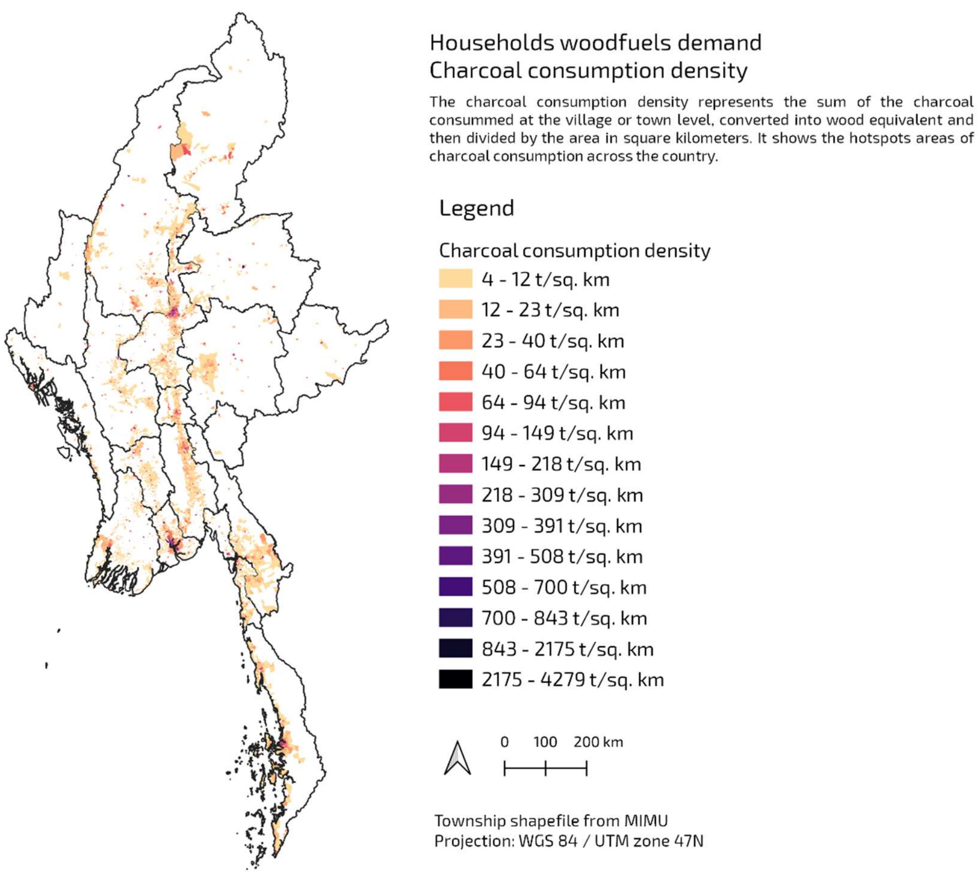

Figure 15 - Wood demand density from charcoal purchase by households

❖ *Household firewood consumption - purchased*

Purchased firewood is the third largest source of woodfuel supply nationally (4,415,000 t/yr), after self-collected firewood and charcoal, representing 19% of total household demand for cooking. The secondary use of firewood for households using electricity as their main cooking energy represents 312,000 t/yr of this total (7%) so is a significant consideration when calculating total demand.

❖ *Household charcoal consumption*

Charcoal represents the second largest source of woodfuel for household cooking energy, at 1,434,000 t per year (or 8,605,000 t/yr of wood-equivalent[36]), representing 36% of national demand in wood-equivalent. It is the main source of cooking energy in Yangon and Naypyidaw, as well as in Tanintharyi, which shows unique consumption patterns. Beyond this exception, charcoal demand follows the usual pattern of urban and peri-urban concentration that is observed in other parts of the world.

Energy stacking (where charcoal is used to supplement electricity) accounts for 12% of the national charcoal consumption figure (almost 1 million t of wood-equivalent). Charcoal demand is expected to increase significantly if it continues to be used as a second fuel in combination with electricity in urban and peri-urban areas.

❖ *Total household woodfuel demand*

Combining the above figures for self-collected firewood, purchased firewood and charcoal, **total annual demand for woodfuels in Myanmar is 23,801,000 t** (34,002,000 m^3) in wood-equivalent.[37] This is consistent with an FAO estimate of 38,286,041 m^3.[38] This estimate is likely to be conservative, as the decrease in the proportion of households using woodfuels as their main source of cooking fuel will have been partly offset by a population increase of 2.73% between 2014 and 2018.

The breakdown of woodfuel demand by Region/State is shown in Table 4.

Table 4 - Woodfuel demand for household cooking by Region or State (t/yr wood-equivalent)

Region/State	Charcoal	Firewood purchased	Firewood self-collected	*Total demand*
Yangon	2,835,541	320,349	604,708	***3,760,598***
Mandalay	983,023	1,219,151	856,505	***3,058,678***
Ayeyarwaddy	495,611	451,751	1,820,829	***2,768,191***
Shan	803,428	321,881	1,418,667	***2,543,976***
Sagaing	591,956	677,887	1,124,434	***2,394,277***
Bago	663,651	368,310	1,309,450	***2,341,411***
Magway	359,973	530,442	856,476	***1,746,890***
Mon	333,983	93,442	601,940	***1,029,364***
Rakhine	207,014	66,690	715,910	***989,613***
Kachin	381,789	70,672	396,137	***848,598***
Tanintharyi	342,091	48,161	324,190	***714,442***
Kayin	264,684	71,652	320,482	***656,818***
Nay Pyi Taw	254,167	128,471	231,026	***613,663***
Chin	49,040	30,908	130,378	***210,327***
Kayah	39,662	15,816	69,297	***124,775***
Total	**8,605,613**	**4,415,583**	**10,780,427**	***23,801,622***

[36] Assuming a mass conversion efficiency of 16.7%.
[37] Conversion using Forest Research Institute values of 1 t = 0.02 cubic feet; or 1 m^3 = 0.7 t
[38] FAO Stat

2.2. Commercial catering

The commercial catering sector includes restaurants, tea shops and street food vendors selling products such as mohinga,[39] deep fried snacks, street pancakes, mont-lin-mayar,[40] mung bean cakes, and tofu (Figure 16).

Figure 16 - Fried tofu seller in Mandalay division

❖ *Fuel use*

Woodfuel demand for commercial catering was derived from Forest Research Institute (FRI) data[41] and phone surveys of 50 businesses in Ayeyarwaddy, Bago, Mandalay, Sagaing, and Yangon. Their contacts were extracted from the Statistical Business Register (SBR).[42]

The findings suggest that restaurants and fried food sellers consume the largest quantity of woodfuel per outlet, followed by mohinga vendors and tea shops (Figure 17).

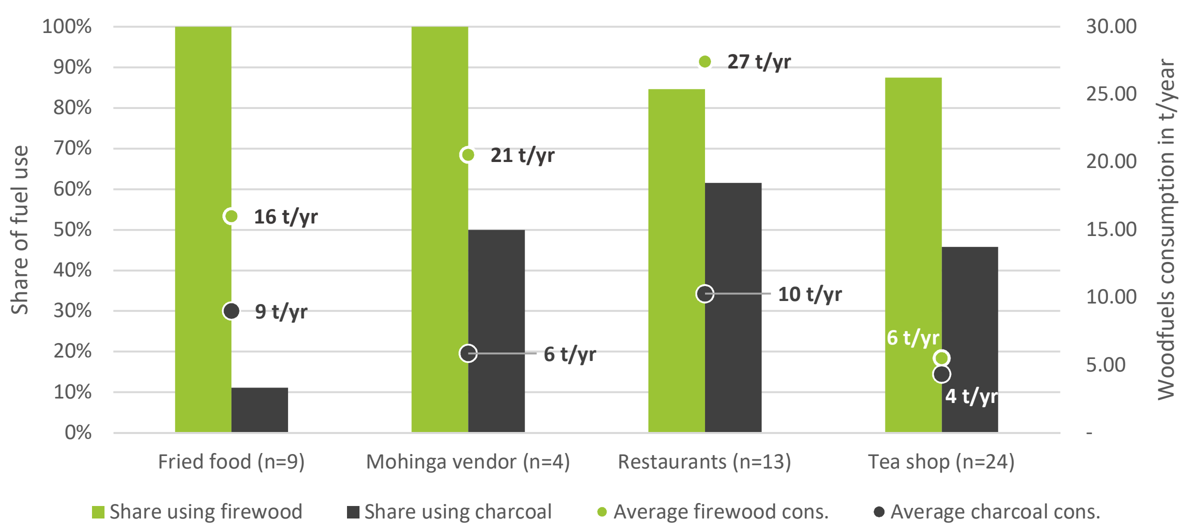

Figure 17 - Woodfuel consumption in the commercial catering sector

[39] Rice noodle and fish soup.
[40] Small savoury pancakes made with a batter consisting of rice flour, quail eggs, chickpea and spring onion.
[41] Forest Research Institute, "Study of Biomass Fuel Consumption," 2014.
[42] Central Statistical Organization, "Statistical Business Register."

In 2017, there were 34,843 restaurants and mobile food services listed in the SBR. Averaging the consumption data across the sample of catering businesses, this means that commercial catering consumes 460,000 t of firewood and 105,000 t of charcoal per year (representing 630,000 t in firewood-equivalent) (Figure 18). Combining the two fuels, commercial catering may account for annual woodfuel demand of 1,090,000 t in firewood-equivalent, making it one of the country's largest woodfuel-consuming sectors - but still only 5% of the woodfuel consumption by households for cooking.

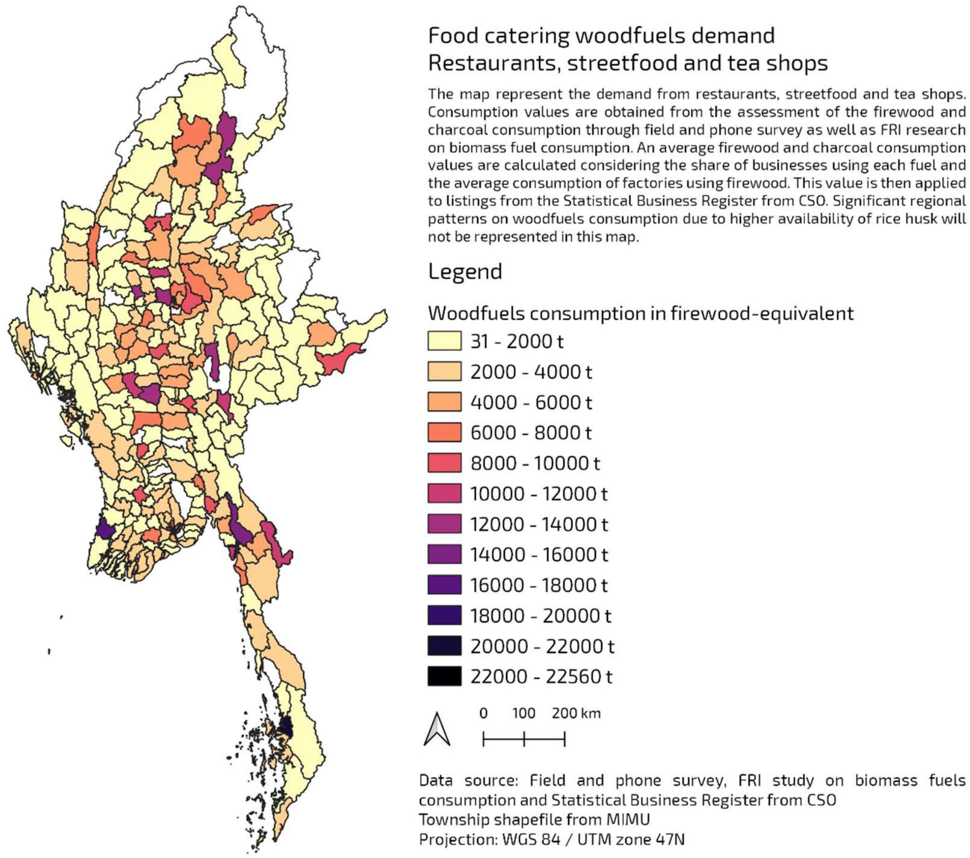

Figure 18 - Woodfuel demand in the commercial catering sector (t of firewood-equivalent/yr)

2.3. Industrial sectors

This assessment investigated the primary industrial consumers of firewood in Myanmar, covering garment manufacturing, food and beverage production (with a focus on noodles and vermicelli), brickmaking, and the boiling and drying of fish and shrimp.

a) Garment manufacturing

❖ ***Fuel use***

Garment manufacture has become one of Myanmar's main drivers of economic growth, with an estimated export value of US$ 2.7 billion in 2017 (EuroCham Myanmar, 2018). The garment industry is a significant user of thermal energy for bleaching, dyeing, drying, washing, and pressing. Most of the heat is provided by steam boilers, either supplying whole factories or individual production lines. Energy sources used for steam generation include diesel, firewood, coal, and loose biomass such as rice husk, sawdust, wood chip, cashew nut shells, and rice husk pellets. Research by Geres for H&M,[43] integrating data from SMART Myanmar,[44] confirms that firewood is still the main source of fuel for steam boilers in around half of all garment factories (Figure 19). Electricity is meanwhile used for non-thermal purpose such as lighting, air conditioning, dehumidification, and pumping, and for powering machinery for cutting, sewing, and knitting.

[43] Aude Petelot, "Sustainable Alternatives for Steam Production in Garment Factories Supplying H&M in Myanmar" (Geres, October 2019).

[44] SMART: SMEs for Environmental Accountability, Responsibility and Transparency.

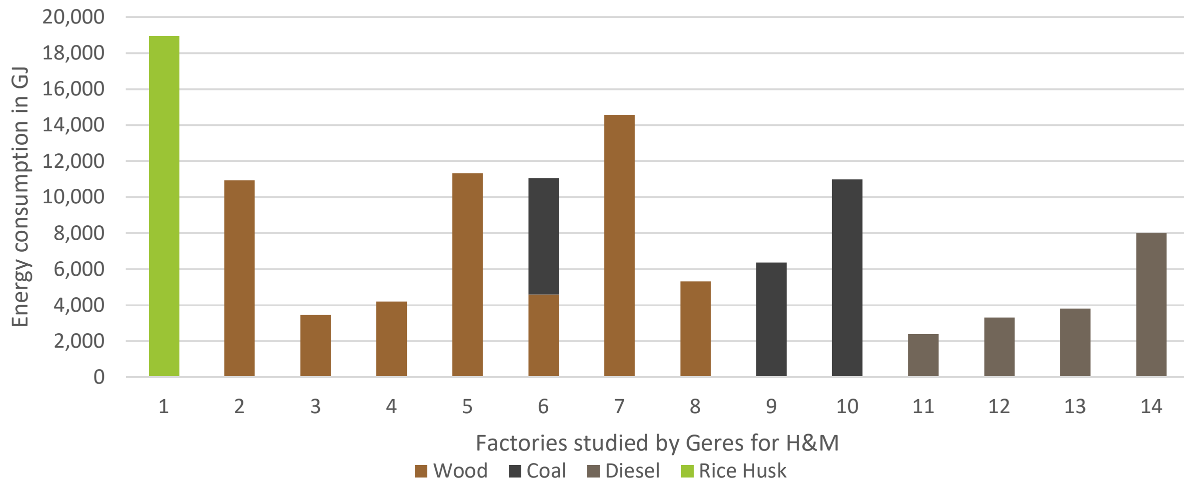

Figure 19 - Energy consumption for steam generation in the garment sector

Source: Geres for H&M

❖ *Firewood consumption*

According to the SBR[45] there were 669 apparel factories in Myanmar in 2017, which is higher than the number of factories registered with the Myanmar Garment Manufacturers Association (533 factories in 2019), so it is likely that the SBR sample includes smaller units.

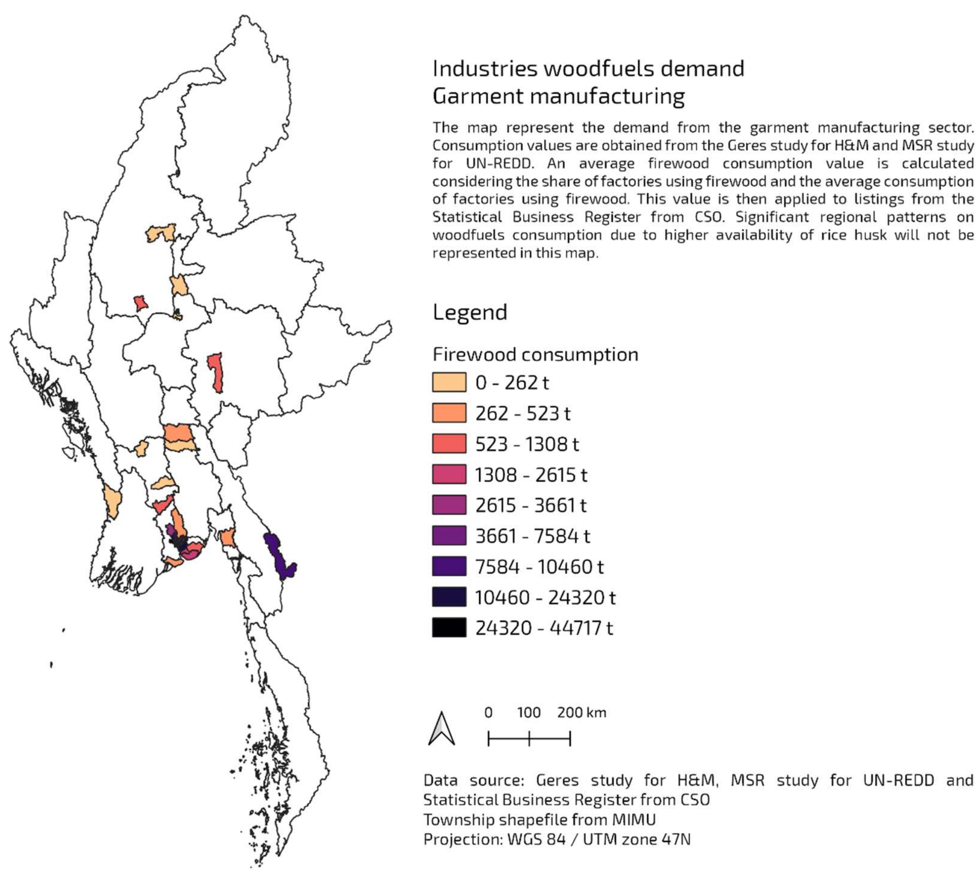

Figure 20 - Firewood demand in the garment sector

Based on data from Geres and UN-REDD[31], the annual consumption of factories relying on firewood averages 523 t. Total woodfuel consumption in the garment sector is therefore around 175,000 t/yr, using the SBR data on factory numbers (Figure 20).

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[45] Central Statistical Organization, "Statistical Business Register."

b) Industrial food and beverage production

❖ *Overview*

Myanmar has an agriculture-based economy and 18% of the country's registered businesses are in the food and beverage (F&B) industry. The sector is the second largest formal employer (12.3%), after the textile industry.[46] According to the SBR, 1,463 noodle and vermicelli factories are operating in the country, which makes this the largest industry in the F&B sector. There are also 137 registered alcohol distilleries and 13 breweries.

Steam energy is used for a number of processes in the F&B industry (Figure 21 and Figure 22), with specific needs varying according to the exact nature of the products concerned, as summarized in Table 5.

Table 5 - Food and beverage industry process and temperature requirements

Industrial sector	Operation	Temperature range (°C)
Food	Drying	30-90
	Washing	60-90
	Pasteurizing	60-80
	Boiling	95-105
	Sterilizing	110-120
	Heat Treatment	40-60
Beverages	Washing	60-80
	Sterilizing	60-90
	Pasteurizing	60-70

Source: IRENA and ETSAP[47]

Figure 21 – Manual feeding, solid fuel boiler at Hong Kong vermicelli factory, Yangon

Figure 22 – Wood-fired vertical boiler at Eagle Brand Chilli Sauce factory, Yangon

❖ *Fuel use*

As shown in Figure 23, the F&B companies that were sampled rely heavily on rice husk and other biomass residues for generating heat and producing steam.

[46] UNIDO and Ministry of Industry, "Strategic Directions for Industrial Development," 2017.
[47] IRENA and ETSAP, "Solar Heat for Industrial Processes," Technology Brief, January 2015.

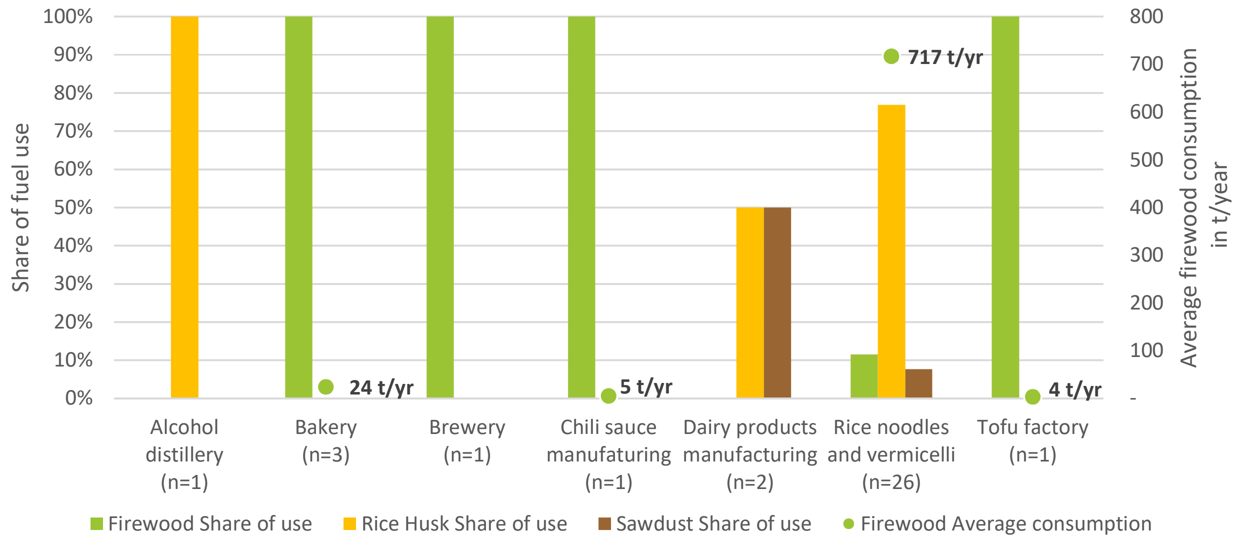

Figure 23 - Energy consumption in sampled industries in the food and beverage sector

Given the small sample size, only estimates for rice noodle and vermicelli production have been calculated. Assuming that 12% of these factories use firewood, with average consumption per unit of 727 t/year (as per original survey for this study), national firewood consumption for noodle production is estimated at 121,000 t/yr, distributed as shown in Figure 24.

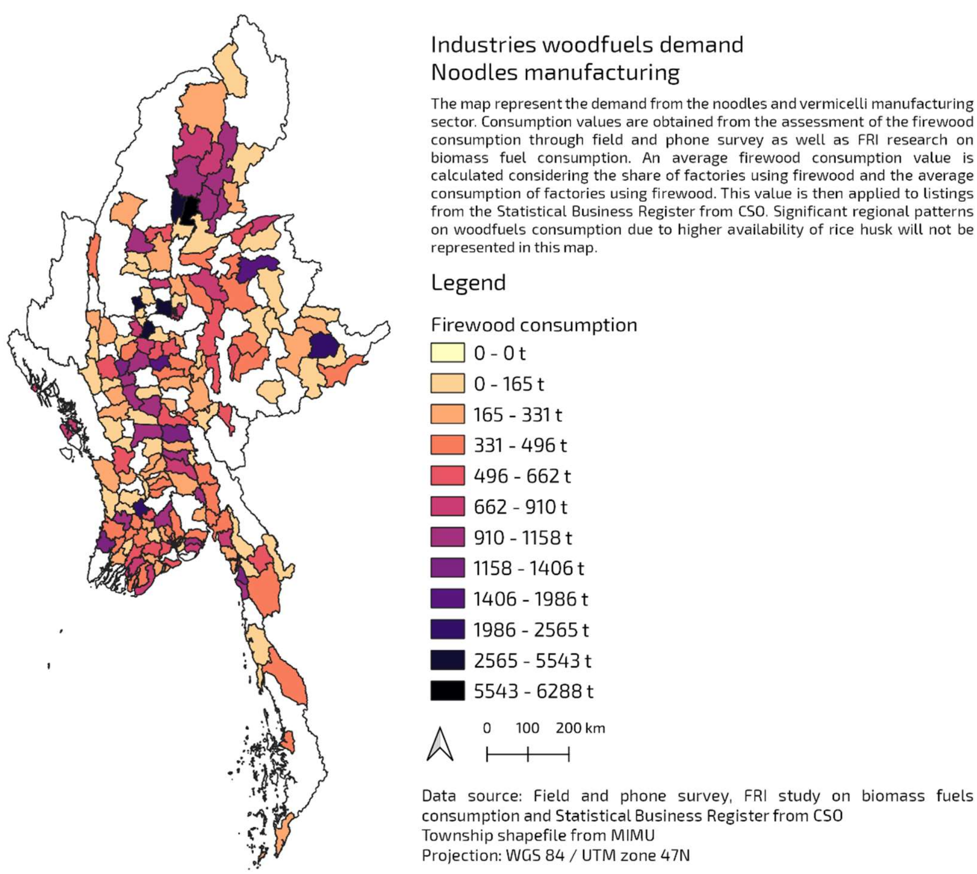

Figure 24 - Firewood demand for noodle production

c) Fish paste and dry shrimp production

❖ ***Overview***

With four main river basins, the Ayeyarwaddy delta area, and a long coastline, the fisheries sector is a significant part of Myanmar's economy. In 2013, 4.7 million t of fish and shellfish (47% freshwater and 53% offshore) were landed.[34] The Department of Fisheries reports that the output of the fishery sector increased from 4.7 million t to 5.0 million t between 2012 and 2014,[48] making it the fourth largest contributor to GDP.

The area of Pyapon in the Delta Region is the main area for production of fish paste (*ngapi)* and also an important area for dried shrimp. Both *ngapi* and dried shrimp production operate using large bamboo rafts that are used as offshore platforms to capture, boil, and dry both fish and shrimp. These rafts usually stay at sea for eight months of the year, right through the dry season (September to May).

❖ ***Fuel use***

According to Myanmar Biomass Power,[49] together with information obtained during a field visit to Pyapon, most fishing rafts are fitted with a large clay, cement or metal wood-stove, which is used to boil the fish or shrimp before it is processed back onshore into paste (Figure 25). According to MSR, 80% of these rafts use firewood as their main source of energy.[50] The rest rely on charcoal and rice husk pellets. Each raft using firewood consumes an average of 209 t/yr. No accurate consumption data for charcoal or pellets was available.

Figure 25 - Fish/shrimp boiling with metal cookstove on a raft at Pyapon

Source: bbc.com/burmese

❖ ***Woodfuel consumption***

According to the chairman of the Kyar Phaung Fishery Enterprises Association, there are around 1,000 bamboo rafts producing *ngapi* and dried shrimp in Pyapon.[51] According to Frontier Myanmar, quoting the Myanmar Fisheries Federation, Pyapon township produces 80% of the *ngapi* and dried shrimp consumed in the country. Based on this estimate, annual firewood demand for fish paste and dry shrimp is 167,200 t/yr for the Pyapon area only. The inclusion of the other coastal areas would increase this estimate.

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48 https://opendevelopmentmyanmar.net/topics/fishing-fisheries-and-aquaculture/

49 Meeting with Dr. Hla Soe, Founder and Managing Director of Myanmar Biomass Power, November 28, 2019.

50 Myanmar Survey Research, "Analysis of Household Fuelwood and Charcoal Consumption" (UN-REDD, 2019).

51 Hein Thar, "The Abuse behind Myanmar's Fish Paste Industry," Frontier Myanmar, accessed January 24, 2020, https://frontiermyanmar.net/en/the-abuse-behind-myanmars-fish-paste-industry.

d) Brickmaking

❖ *Overview*

Since Myanmar's population is increasing rapidly, especially in urban areas, the construction sector has seen an annual growth rate of up to 10%. It is one of the major drivers of the economy, contributing 16.5% of GDP, and the industry was worth more than US$ 9.5 billion in 2018.[52]

Figure 26 - Firewood being prepared at a brick factory in Mandalay

❖ *Fuel use*

Brickmaking is one of the country's most energy-intensive industries. Field visits, phone surveys, and data from FRI confirm that firewood is the dominant fuel used (Figure 26). Manufacturers surveyed for this study estimate that energy represents 30 to 50% of their production costs. It is therefore essential for them to secure the cheapest possible sources. As shown in Figure 27, brick producers therefore tend to use a wider variety of fuels than other industries as they are less sensitive to quality, making use of residues such as rice husk, sawdust or coal where available. Electricity is used to power blowers.

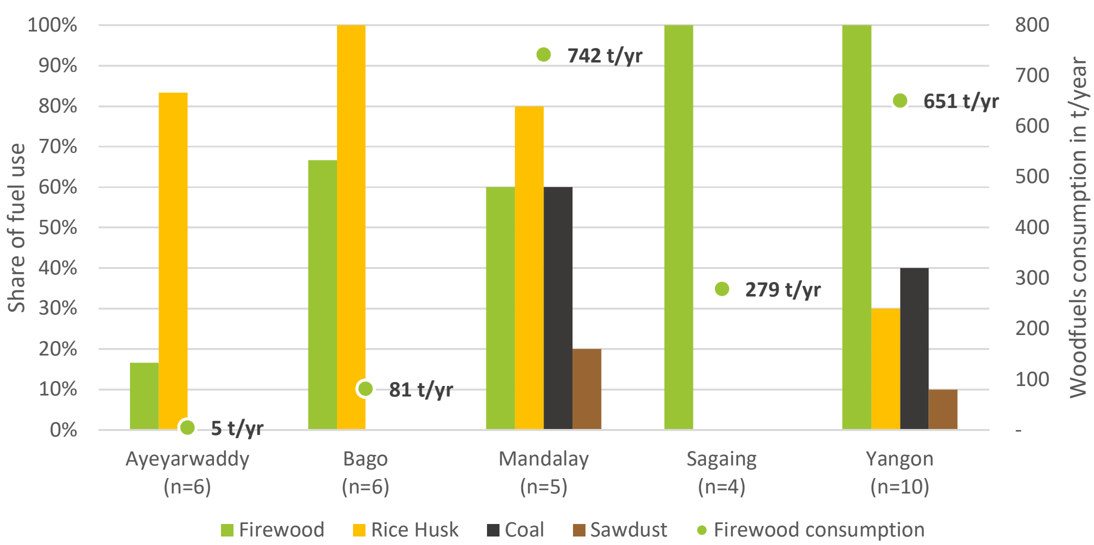

Figure 27 - Energy consumption in the brickmaking sector

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[52] Piet Flintrop, "Emerging Opportunities in Myanmar's Construction Sector," *ASEAN Briefing*, April 2019.

❖ ***Woodfuel consumption***

With 587 registered factories, brickmaking is an important national industry. 71% of these factories use firewood, with average annual consumption of 444 t (Figure 28). This makes brick production the main consumer of firewood in the industrial sector, accounting for an estimated 185,000 t/year.

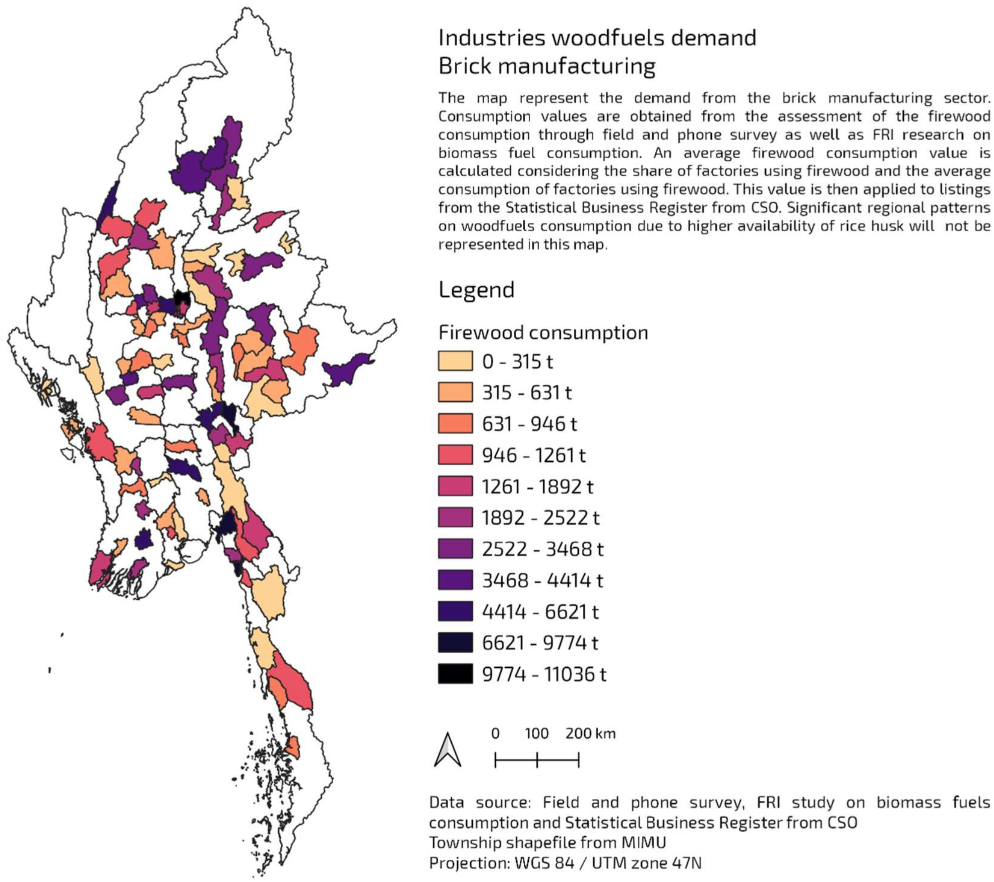

Figure 28 - Distribution of brickmaking by firewood demand

e) Other industries

While the industries described above are believed to be the major consumers of woodfuel in Myanmar, additional industries are known to use firewood in some of their processes. Further research is necessary to assess their usage rates. For example:

- **Animal feed production**: Steam boilers are used in animal feed production. Most use firewood and other biomass, according to data from the Boiler Inspection Department. This is confirmed by interviews with UNIDO and the Myanmar Food Processors and Exporters Association.
- **Soap production**: According to rice husk briquette and pellet manufacturers, some soap manufacturers are large users of biomass. One producer in Mandalay has been using pellets as a replacement for firewood.
- **Box and carton production**: According to an ADB survey,[53] box and carton factories use various fuels including natural gas, diesel, wood chip, and electricity. The study confirmed that one such factory uses 1,100 t of woodchip per year.

[53] Asian Development Bank, "Myanmar Energy Consumption Surveys."

- **Sugar production**: The same ADB survey indicates that a sugar production factory included in their sample was consuming 237 t of woodchip annually. In addition, electricity, diesel and coal are consumed in sugar production processes.
- **Jaggery production**: Since palm trees are abundant in the central Dry Zone and jaggery is a traditional snack, small-scale jaggery production is common in this area. Traditional jaggery producers use firewood or rice to apply thermal energy through a furnace or stove. An FRI study found that one jaggery producer consumed around 5 t of firewood per year.
- **Alcohol distillation**: Small-scale local distilleries also tend to rely on firewood and other biomass for fuel. These are mostly found in the Dry Zone and mountain regions.
- **Lime burning:** A 1996 report by FAO[54] reported lime production to be a major firewood consumer among Myanmar's cottage industries. Limestone burning demands high energy inputs, with a reported requirement of 1.5 t of firewood per metric ton of lime. An FRI survey documents one lime factory in Mandalay with an annual consumption of 150 t/year.
- **Pickled tea production:** In Myanmar, tea is common drink but also a traditional side dish in the form of pickled tea leaf. According to the Myanmar Tea Association, there are 800,000 acres (323,748 ha) of tea plantation in Myanmar, with 85% located in Shan State.[55] Tea factories mainly use firewood to produce pickled tea. The bigger factories tend to use steam, while smaller ones boil the leaves using traditional firewood stoves. According to the Taung Tan Ni factory, around 1 viss[56] of firewood is required to produce 10 viss of pickled tea.

f) Total industrial woodfuel demand

Total estimated firewood demand from the four highest-consuming industries in Myanmar is around 648,260 t/year. Actual demand is likely to be higher with the inclusion of other sectors such as those listed above. Even if total demand was twice the level estimated, it would still be several orders of magnitude lower than woodfuel demand for domestic and commercial cooking combined. Industrial firewood demand is concentrated in Ayeyarwaddy (due to high consumption from the fisheries sector) and Yangon (due to the larger number of garment factories). Demand from other sectors is more balanced across the country (Figure 29).

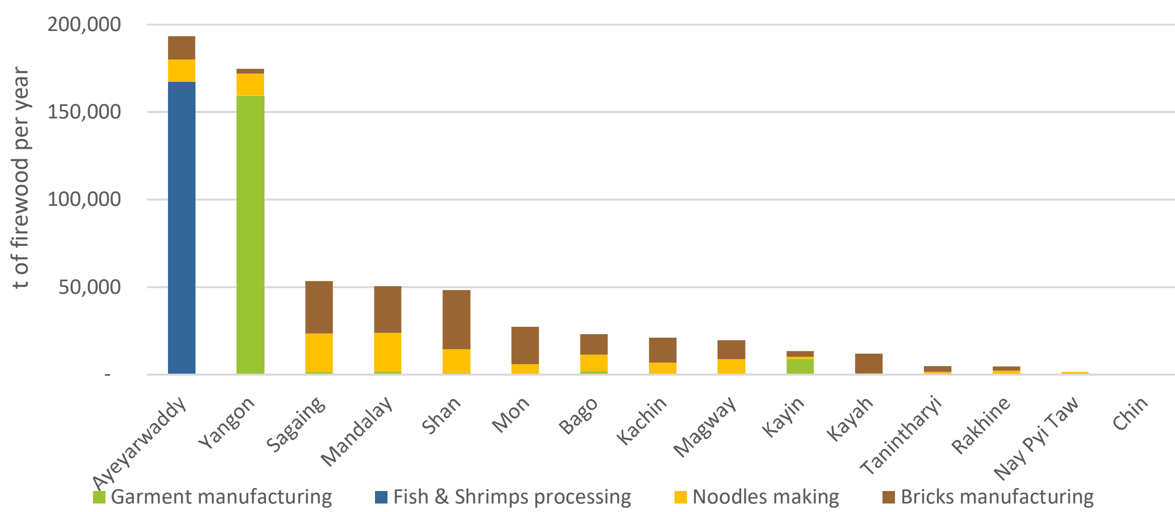

Figure 29 - Firewood demand for industrial use by Division/State

[54] FAO, "The National Training Workshop on Woodfuel Trade in Myanmar" (Yezin, 1996).
[55] Aatif Somji and Dr Than Than Sein, "Brewing Opportunity: A Market System Analysis of The Tea Sector in Southern Shan State, Myanmar" (ILO, 2019).
[56] The viss is a traditional Myanmar unit of weight unit equivalent to 1.633 kg

2.4. Woodfuel demand summary

Estimated total national woodfuel consumption combining the household, catering and industrial sectors is around 25,539,000 t of wood-equivalent per year, or a volume of 36,484,000 m^3. While some industries have not been studied, the summary (Figure 30) shows that household consumption significantly outweighs consumption for industrial uses and commercial catering. Even if total commercial and industrial demand was twice the level estimated, it would still be only a fraction of woodfuel demand for domestic and commercial cooking combined.

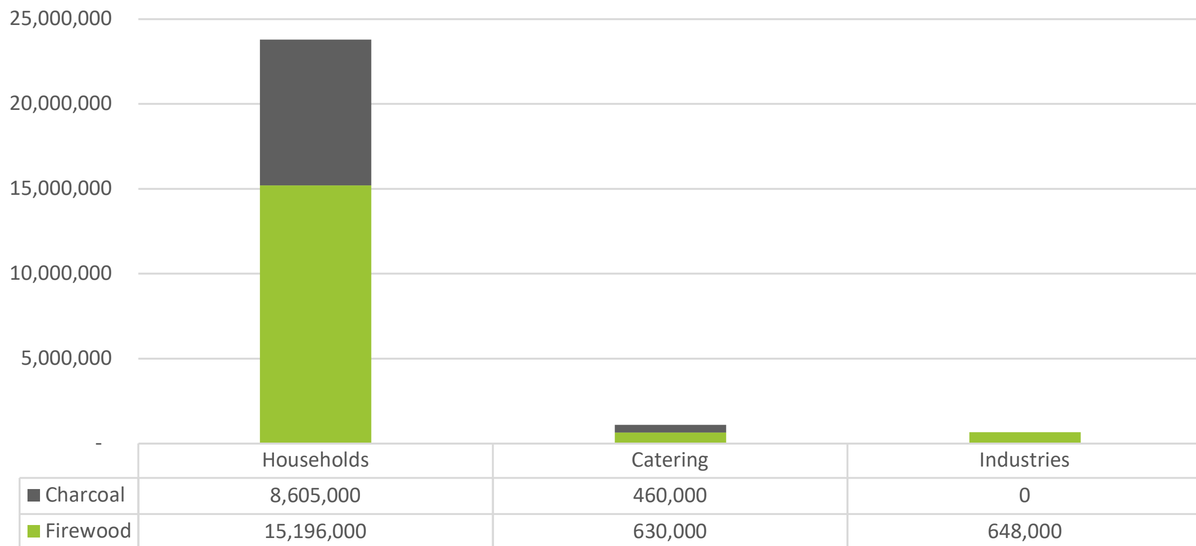

Figure 30 - Distribution of woodfuel demand in Myanmar by sector (t/yr wood-equivalent)

The results by State/Division are presented in below in Table 6

Table 6 – Total woodfuel consumption by State/Division (t/yr wood-equivalent)

State/Division	Households	Catering	Industries	*Total*
Yangon	3,760,598	259,088	174,832	**4,194,517**
Mandalay	3,058,678	175,770	50,555	**3,285,003**
Ayeyarwaddy	2,768,191	78,374	193,349	**3,039,914**
Shan	2,543,976	99,493	48,338	**2,691,806**
Sagaing	2,394,277	107,283	53,433	**2,554,993**
Bago	2,341,411	48,902	23,107	**2,413,419**
Magway	1,746,890	69,457	19,655	**1,836,003**
Mon	1,029,364	59,101	27,341	**1,115,806**
Rakhine	989,613	25,937	4,537	**1,020,087**
Kachin	848,598	40,579	21,055	**910,232**
Tanintharyi	714,442	37,044	4,957	**756,443**
Kayin	656,818	38,139	13,600	**708,557**
Nay Pyi Taw	613,663	25,061	1,572	**640,296**
Chin	210,327	11,013	-	**221,340**
Kayah	124,775	14,893	11,930	**151,597**
Total:	**23,801,622**	**1,090,133**	**648,260**	**25,540,015**

3. WOODFUEL VALUE CHAINS

3.1. Charcoal value chains

a) Supply to Yangon and Mandalay

❖ ***Structure of the value chain***

The assessment investigated the charcoal value chains supplying key markets, both for households and for commercial uses, by sampling the main markets and going back down the value chains to the producers. As indicated in Figure 31, the charcoal sold in the Yangon market is mostly sourced from locations in Pathein, east Bago, and west Bago. Mangrove charcoal from Myeik was also reported by some retailers as being of particularly high quality, but it represented only a small share of the charcoal being sold.

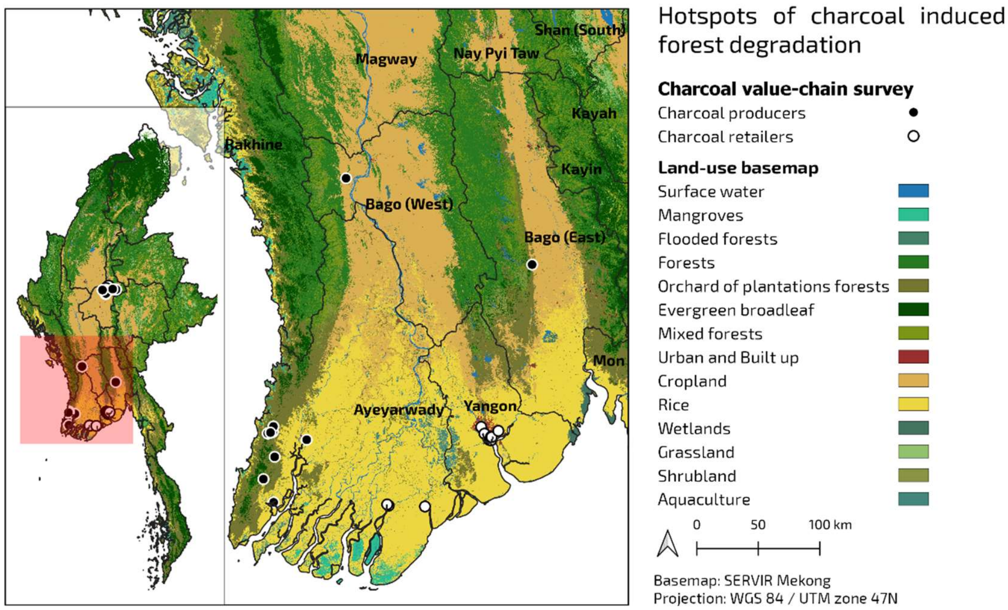

Figure 31 - Location of charcoal retailers, distributors, and producers surveyed during Yangon value chain assessment

Meanwhile in Mandalay, Forest Department staff reported that Sagaing was a major source of charcoal. But all the producers identified during this study were located inside Mandalay Division and much closer to the market, as illustrated in Figure 32.

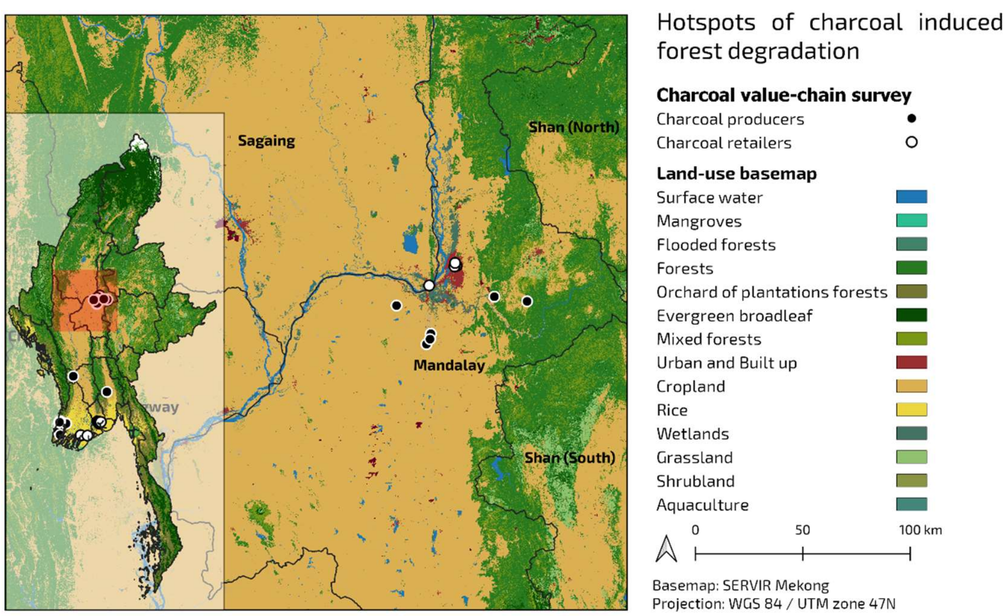

Figure 32 - Location of charcoal retailers, distributors, and producers surveyed during Mandalay value chain assessment

It was ascertained that some supply channels are structured around dominant actors who control significant parts of the value chain. In Bago, for example, some producers reported owning 30 kilns and employing more than 100 workers.

The retail price of charcoal in Yangon is around 600 Kyat (MMK) per viss (US$0.25 per kg), around 50% higher than the equivalent price in Mandalay. Despite this difference in retail price, the revenue accruing to producers was similar in the two areas (Figure 33). Distributors and retailers absorb much of the margin in the Yangon value chain due to the significant distances from source areas to the market. In Mandalay, haulage distances are shorter, and some producers sell directly to households and restaurants to increase their margins. Bago producers also engage in direct sales to households and restaurants, as well as to distributors and middlemen. The producers surveyed at Pathein were all dependent on distributors to access the markets.

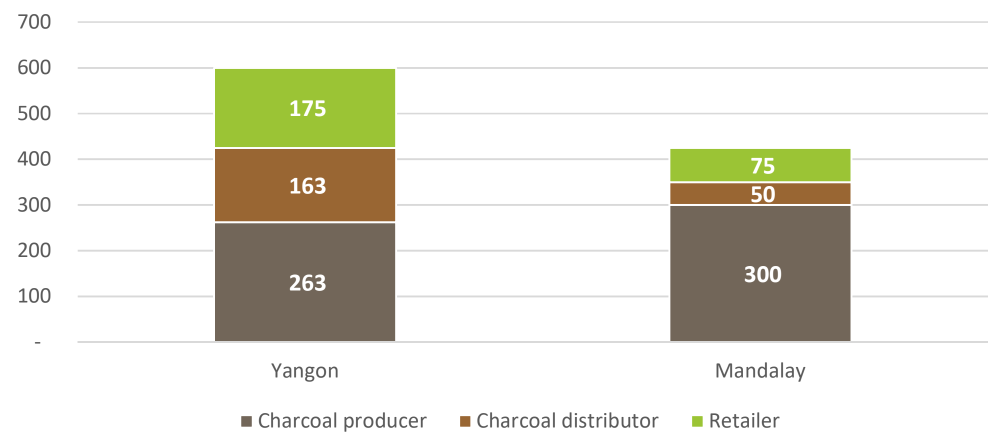

Figure 33 - Price build-up in the Yangon and Mandalay charcoal value chains

Charcoal production in the Pathein area seems to be the longest established, with some producers having started in 1989. Production in Bago is a more recent phenomenon; producers surveyed there have been in business for an average of 10 years.

Even though Ayeyarwaddy is the State/ Region with the highest licensed charcoal output (Figure 34), none of the eight producers interviewed there had a license. In Bago, two out of the three visited had a license. Consistent with the very low level of authorized production in Mandalay (55 cubic t/yr), no charcoal producers surveyed there had a license. Fewer than 20% of producers surveyed had a license from the Forest Department, which means that most operate illegally. It was reported that even licensed producers frequently exceed their authorized limits, reportedly with the knowledge of Forest Department agents.

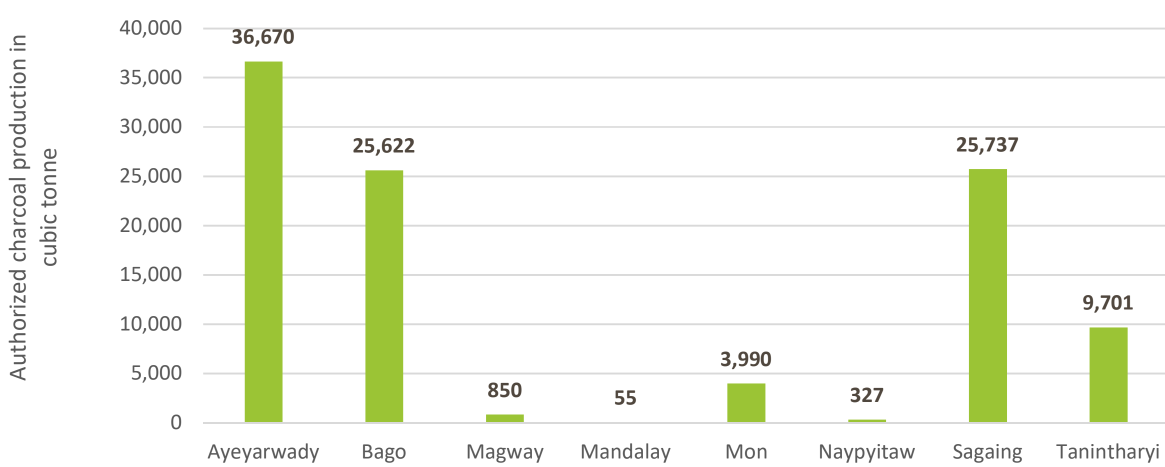

Figure 34 - Charcoal production authorized by the Forest Department in 2018/2019

Source: Forest Department.
'Cubic ton' is a unit used by the Forest Department to represent a weight of 1 metric ton, but variable volume depending whether firewood or charcoal is being referred to.

❖ *Wood origin and collection patterns*

Figure 36 summarizes the origin of wood for charcoal-making in the three areas studied, based on field survey. The charcoal produced in Bago and Ayeyarwaddy to supply Yangon is made from wood almost entirely harvested from Forest Reserves in Bago, the Pathein area, and South Rakhine (Figure 35). This usually comes from hardwood species (Table 7) (some of which are on the IUCN Red List), which makes these value chains potential drivers of forest degradation.

Figure 35 - Forest Reserve in Pathein District (at rear) where trees are harvested for charcoal production

The situation in Mandalay is quite different, with a high proportion of trees for charcoal-making sourced from village land and farmland. Myanmar Social Research (MSR) for UN-REDD,[57] observed a similar pattern in the Magway market, which confirms the importance of trees on farmland for charcoal production in the Dry Zone.

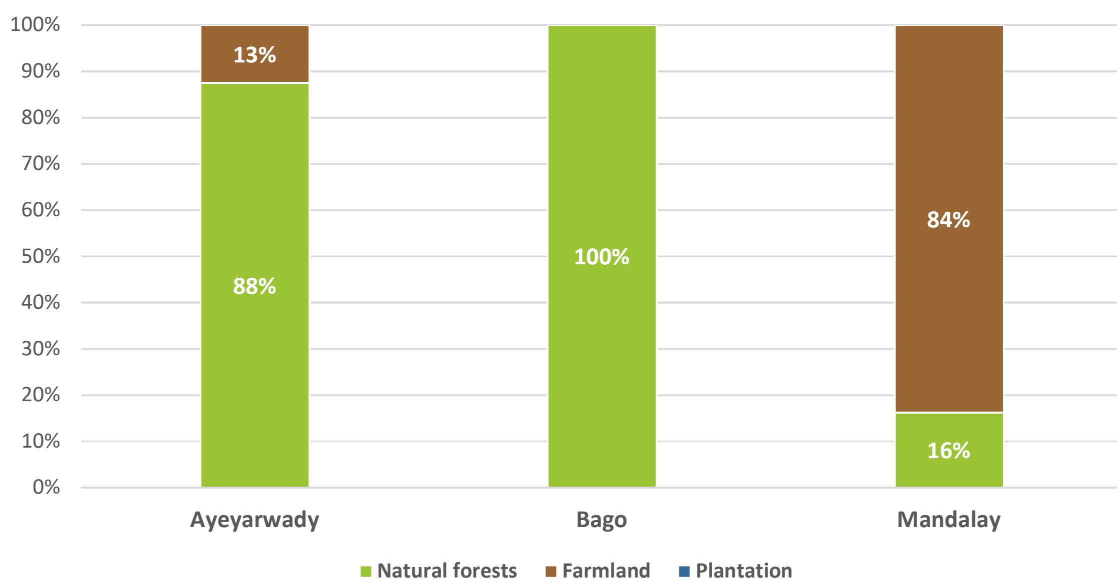

Figure 36 - Origin of wood used for charcoal production by Division and land cover

[57] Myanmar Survey Research, "Analysis of Household Fuelwood and Charcoal Consumption."

The most commonly used species for charcoal-making in three sampled regions are summarized in Table 7.

Table 7 – Tree species harvested for charcoal production in the value chains studied

Ayeyarwaddy	Bago	Mandalay
Thitpoke (*Tetrameles nudiflora*) Thit-pyauk (*Sapium insigne*) Ma-U (*Nauclea orientalis*) Phatwine (*Macaranga denticulate*) Rambutan (*Nephelium lappaceum)* Tamarind (*Tamarindus indica*) Baepyar (*Cratoxylon neriifolium*) Kanyin (*Dipterocarpus dyeri*)	Pyinkado (*Xylia xylocarpa*) Teak (*Tectona grandis)* Rosewood (*Pterocarpus indicus*), Sitsee (*Gluta usitata*) Unspecified "low quality" species	Thitya (*Shorea obtusa*) Thanat (*Cordia myxa*) Yingu-akyi (*Quercus helferiana*)

Source: field survey

In areas with higher hardwood availability, these species are preferred by producers and buyers. This potentially makes charcoal production a greater threat to natural forests than firewood, where quality is of less importance.

It has been reported that woodfuel extraction amplifies a process of forest degradation initiated by timber production, which can result in the eventual conversion of the land to an alternative use.[58] While the current assessment does not provide definitive evidence of this, it is interesting to note that the three producers sampled in Bago reported a need to keep moving to new locations for charcoal-making, while some producers in Ayeyarwaddy and Mandalay were able to come back to previous harvesting locations after 3 to 7 years (Figure 37), suggesting a greater degree of sustainability. No scarcity of wood was reported, except in Bago and Mandalay source areas, where (respectively) one-third and one-fifth of producers reported some supply scarcity. When asked for their views on the impact of charcoal production on the forest, two out of three producers in Bago believed that it had a negative impact, compared to only one out of seven in Ayeyarwaddy, and none in Mandalay. The small sample size means that these findings should be interpreted with care.

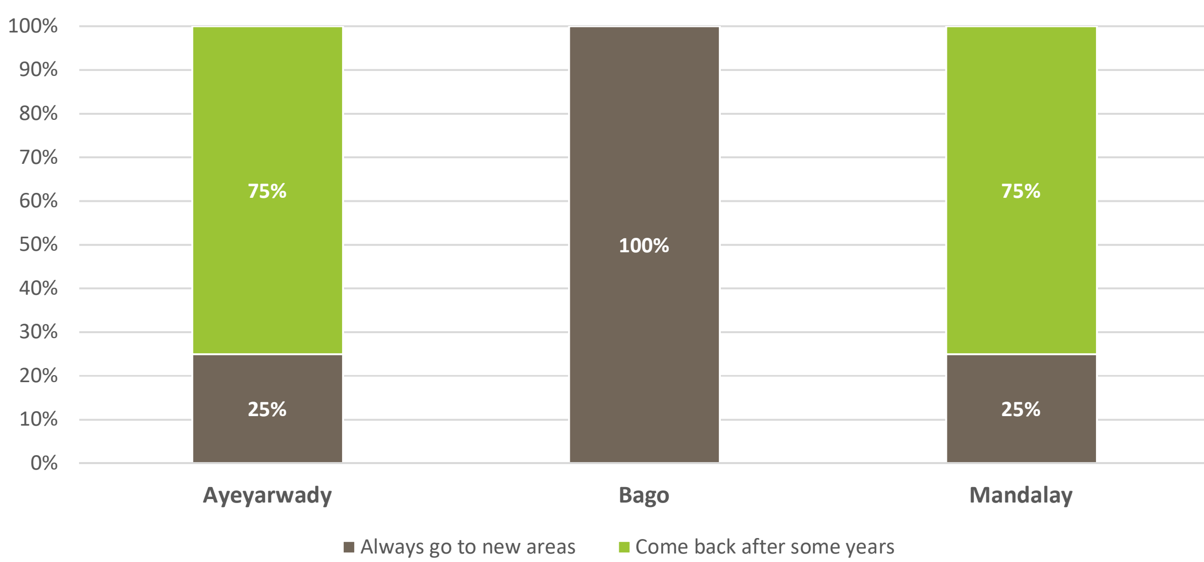

Figure 37 - Rotational harvesting patterns for charcoal, by production area

❖ *Charcoal transformation*

In Ayeyarwaddy and Bago, charcoal producers tend to operate kilns close to the forest. This allows them to minimize the laborious haulage of the wood to the kiln, and to conceal their operations from law enforcement

58 Treue, Springate-Baginski, and Htun, "Legally and Illegally Logged out: Extent and Drivers of Deforestation & Forest Degradation in Myanmar."

agents. In Mandalay, where wood is mostly sourced from village and farmland (so is not subject to government scrutiny), kilns are generally located on the owner's land or close to roads (Figure 38).

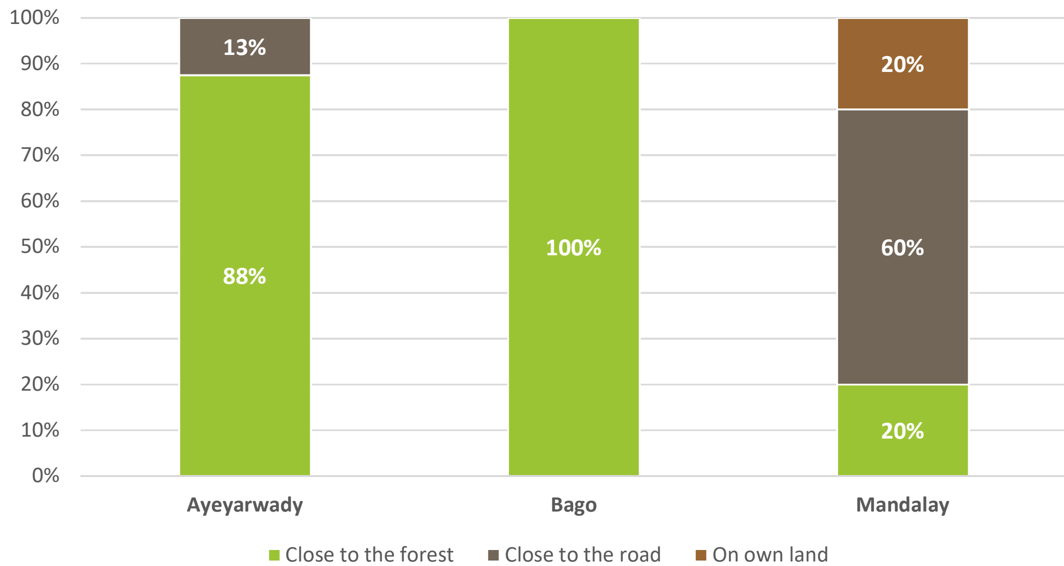

Figure 38 - Location of charcoal kilns by region

There is high diversity in kiln technology. In Mandalay, basic earth mound kilns are common (Figure 39). These have the lowest efficiency due to poor insulation, poor air circulation, and limited control over oxygen inflow.

Figure 39 - Earth mound charcoal kiln in Mandalay Division

In Ayeyarwaddy, the majority of producers surveyed were using a pit kiln (dug into the ground) (Figure 40). These were also common in parts of Mandalay. This method has the advantage of providing insulation and can also be easily concealed. It offers poor heat circulation and limited airflow control, however, which are essential for improving efficiency.


Figure 40 - Charcoal pit kiln in Mandalay Division

Few advanced practices were observed, with the exception of a producer in Pathein District whose technology dated back to the time of mangrove charcoal production in Bogale, and was reportedly transferred to Pathein after the decline of production there (Figure 41).


Figure 41 - A Pathein charcoal producer explains his technology imported from Bogale in the 1980s

While this technology provides good airflow, oxygen control, and insulation, it has the significant drawback of being fixed in its location, further away from the wood resources, and is also difficult to conceal from law enforcement agents.

❖ *Charcoal distribution*

Charcoal is usually moved by motorbike from the kiln location to a middleman or distributor's warehouse (Figure 42). Middlemen usually undertake quality sorting to separate dust, rock or small pieces of charcoal. Some may also grade the charcoal according to quality.

Figure 42 - Charcoal producers ferry their product from the kiln in the forest to the middleman.

From there, the charcoal is transported by truck to the main markets. During transit the charcoal trade becomes invisible, as the vehicles are usually covered with tarpaulin or may even be fully enclosed (Figure 43). This makes monitoring and enforcement of regulations very difficult.

Figure 43 - Charcoal truck at a middleman's warehouse, Pathein

b) Charcoal exports

❖ *Exports to Thailand*

In the 1980s, the area of Bogale was reportedly a hotspot for mangrove-based charcoal production. With the depletion of those resources, mangrove charcoal production moved to Tanintharyi, most of it to be exported to Thailand (Figure 44).

This value chain has been documented by Mongabay,[42] which reports that charcoal exports started following a ban on charcoal production in Thailand, prompting 'charcoal tycoons' to cross the border into Myanmar to train villagers there in production techniques. The combination of the decline in fisheries, along with debt bondage schemes, resulted in massive charcoal production in southeastern Myanmar as an alternative livelihood, linked with corruption of the local authorities.

Figure 44 - Boats offloading mangrove charcoal from Tanintharyi at the Port of Ranong, in Thailand.

Photo by Victoria Milko for Mongabay[59]

According to the UN International Trade Statistics Database (UN Comtrade),[60] the annual trade in wood charcoal from Myanmar to Thailand was 77,081 t in 2018 (similar to the demand from the whole of Ayeyarwaddy Division), with a value US$ 8.72 million (Figure 45). This is likely to be a significant under-estimate, given that most of the charcoal is smuggled.

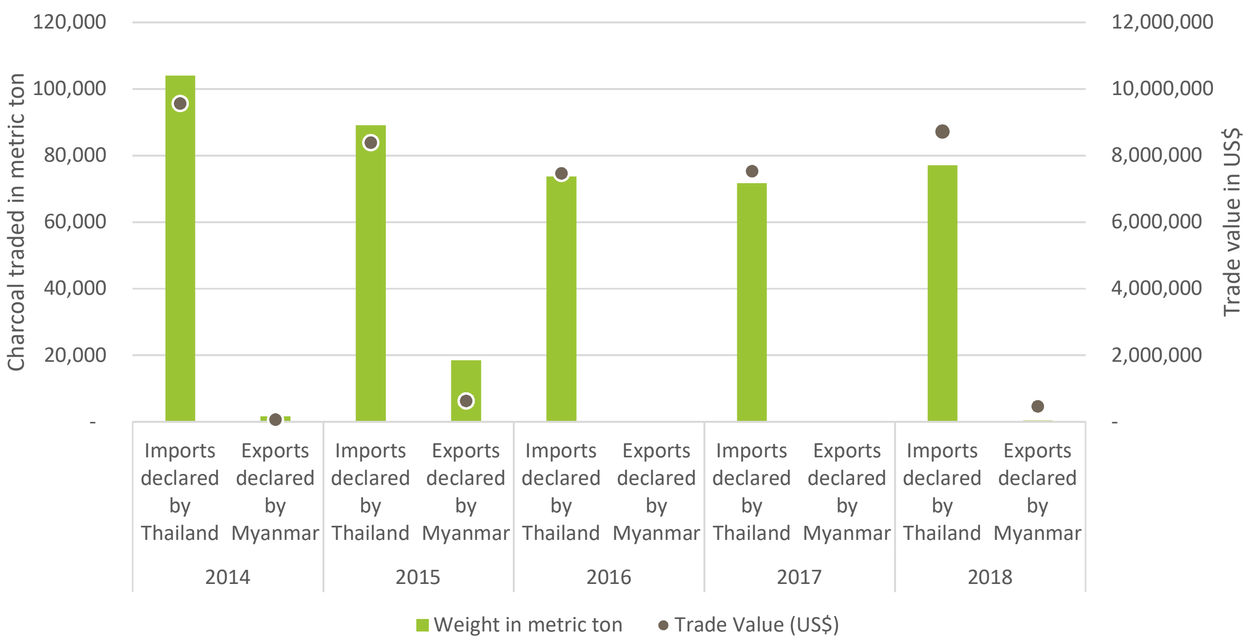

Figure 45 - Charcoal trade from Myanmar to Thailand, according to UN Comtrade data

While some of the charcoal from Tanintharyi is sold in the Yangon market, 75% would be heading to Thailand according to some Forest Department staff, confirming comments from a member of parliament in Tanintharyi (reported by Mongabay) that *"a small portion of charcoal […] gets sold domestically to Myeik or Yangon"*. The MSR survey seems to indicate that mangrove charcoal is sold on the Myeik market, along with rubber and other plantation wood charcoal, even though the report did not separate the wood species by production area.

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59 Yan, "Illegal Charcoal Trade Threatens Myanmar's Remaining Mangroves."
60 Request to UN Comtrade (comtrade.un.org/data/) with commodity code 4402: Charcoal of wood other than bamboo.

❖ *Exports to China*

In a separate investigation, Mongabay found that illegal charcoal export to China is supplying the ferrosilicon and silicon metal industries of Dehong in western Yunnan Province.[61] The charcoal is used as a reducing agent to produce metals for a range of applications from stainless steel to semiconductors for electronics. The charcoal is produced in the northern part of the country along the Ayeyarwaddy River in Sagaing Division and Kachin State, and shipped north by boat before being transferred to trucks bound for China (Figure 46).

Figure 46 - Charcoal repacking at Bahmo, close to border with China

Photo by Nathan Siegel for Mongabay[45]

Figures from UN Comtrade[62] suggest that the wood charcoal trade from Myanmar to China totaled 108,204 t in 2018, based on China's reporting (Figure 47). While this includes legal charcoal briquettes made from rice husk and other biomass, Myanmar only declared 387 t of exports for this period, suggesting that the difference between the figures is mostly wood charcoal.

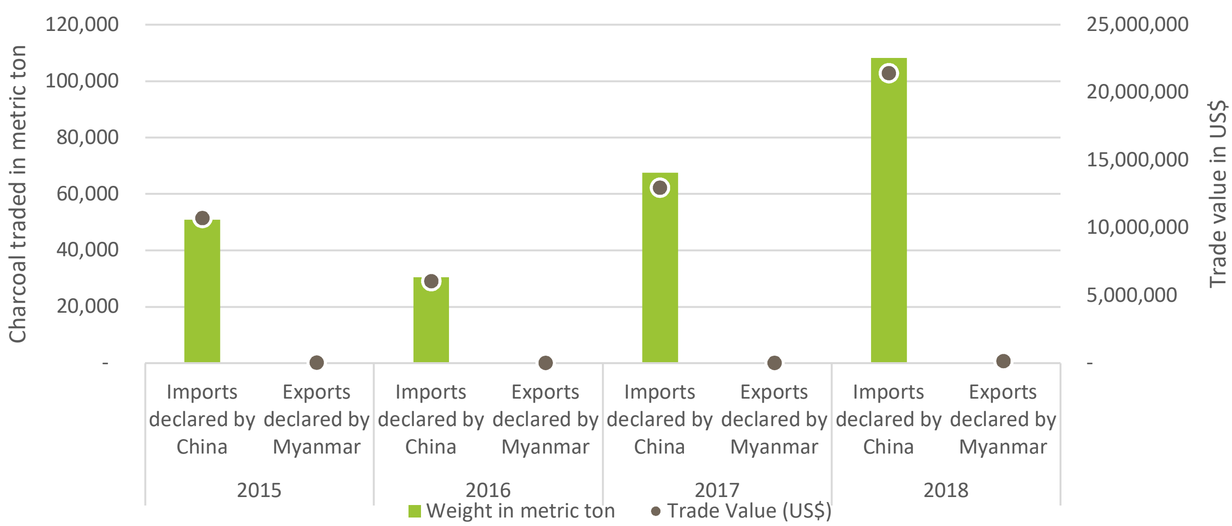

Figure 47 - Charcoal trade from Myanmar to China

Source: UN Comtrade

As with exports to Thailand, official figures are likely to underestimate the actual scale of the trade. Using data from the Dehong Commission of Industry and Information Technology, Mongabay estimated the demand from

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[61] Freudenthal, "Burning down the House."

[62] comtrade.un.org/data commodity code 4402: "Wood charcoal (including shell or nut charcoal), whether or not agglomerated".

China to be around 216,273 t/yr, seven times the UN Comtrade figure. It is probable that the volumes traded are significantly higher than the reported figures.

3.2. Firewood value chains

The nature of the firewood supply chains for industrial use is highly uncertain due to the fact that authorization is usually required before visiting industries, especially the garment and F&B factories located in industrial zones. It is also difficult to visually verify whether the trees species declared by factory owners are the actual species being used. An in-depth assessment with law enforcement authorities and experts in wood species identification is necessary to validate this information.

In contrast with charcoal value chains, price is a more important factor in firewood supply than wood density or calorific value. A higher percentage of residues is also found in firewood value chains. While firewood from natural forests may be relatively expensive, plantation residues can be often be sourced much more cheaply.

In seems that rubberwood satisfies much of the industrial demand for firewood in the Yangon area and the Delta and, very likely, Mon and Tanintharyi (Table 8). Rubberwood from Mon State is even used on fish and shrimp rafts, in addition to firewood from natural forests (from Pathein and Bogale) and (formerly) mangrove wood. According to MSR, the firewood is transported to the rafts at sea by motorboat. Rubberwood is often combined with hardwood residues from Bago, which may only be available in small pieces but are sought-after due to their high energy density.

Table 8 – Main tree species used in the industrial sectors per division/state

State/Division	Main firewood species used by industry
Ayeyarwaddy	Rubber (Hevea brasiliensis) Thit Mhae (*Sonneratia alba*) Inn Kanyin (*Dipterocarpus dyeri*) Pyinkado (*Xylia xylocarpa*)
Mandalay	Sitsee (*Gluta usitata*) Inn (*Dipterocarpus tuberculatus*) Letpan (*Salmalia malabarica*) Kokko (*Albizzia lebbek*) Palm (Borassus flabellifer) Banyan (Ficus kurzii)
Sagaing	Kokko (*Albizzia lebbek*) Shar (*Acacia catechu*) Tamarind (*Tamarindus indica*) Mango (*Mangifera indica*)
Yangon	Rubber (*Hevea Brasiliensis)* Pyinkado (*Xylia xylocarpa*) Kokko (*Albizzia lebbek*) Mango (*Mangifera indica*) Tamarind (*Tamarindus indica*) Thit Mhae (*Sonneratia alba*)[63] Kanyin (*Dipterocarpus dyeri*) [56]

Source: Field and phone survey, as well as MSR for UN-REDD[64]

Given its high prevalence for the industrial firewood supply of Yangon and Ayeyarwaddy, the sustainability of the current supply of rubberwood is of crucial importance. This wood comes from routine removal of trees that

[63] From MSR for UN-REDD. The report does not differentiate between species used in the garment factories in Yangon and fisheries rafts in Pyapon, therefore this species might be used in Pyapon only.
[64] Myanmar Survey Research, “Analysis of Household Fuelwood and Charcoal Consumption.”

have reached then end of their productive life, usually after 25 to 30 years. Replacement can happen earlier, if the plantation owner decides to switch to other trees or alternative land uses that become more profitable.

Research in Thailand[65] suggests that only 46% of the rubber tree biomass is usable as roundwood (diameter at breast height greater than 15 cm). Only 30% of this roundwood is, in turn, suitable as sawnwood, meaning that 86% of the standing tree is not used. Rubberwood residues therefore represent a major potential source of firewood from branches, stumps, small diameter trees, and sawmilling and processing residues. With an average biomass stock of 183 t/ha at the time of replacement in Thailand, the replacement of one hectare of rubberwood after 25-30 years could generate 158 t of firewood under a scenario of local sawnwood production.

Considering that Myanmar has approximately 657,000 ha under rubber plantations,[66] and assuming evenly distributed age classes, the country's rubber sector could supply 3,775,000 t of firewood per year. This exceeds total firewood demand in the industries surveyed, plus the combined demand for firewood and charcoal from the entire regions of Tanintharyi, Mon, and Kayin.

Several informants mentioned that current levels of rubberwood supply might be traced back to a massive expansion of plantations 25-30 years ago in Mon State, and that such high levels might not be sustainable. Others mentioned a shift away from rubber production that could reduce the amount available in the long-term. This nevertheless appears to be a very significant source of supply with important potential for further development.

[65] S Prasertsan and P Krukanont, "Implications of Fuel Moisture Content and Distribution on the Fuel Purchasing Strategy of Biomass Cogeneration Power Plants," *Biomass and Bioenergy* 24, no. 1 (January 1, 2003): 13–25, https://doi.org/10.1016/S0961-9534(02)00088-0.

[66] Pramod, "Myanmar Huge Potential for NR Production," Rubber Asia, March 19, 2019, https://rubberasia.com/2019/03/19/myanmar-huge-potential-for-nr-production/.

4. IMPACTS OF WOODFUELS ON FORESTS AND CLIMATE

4.1. Overview of the modeling approach

To aggregate woodfuel supply and demand data to national level, a modeling approach was applied that projected demand for charcoal and commercial firewood to the most likely harvesting locations, overlaid this with known biomass stocks, and thus identified potential hotspots of woodfuel-induced forest degradation.

The approach was based on a cost-distance model to identify areas with suitable biomass stocks accessible within a commercially viable transportation distance of the main demand centers. After deducting potential supply from plantation residues, in this case rubberwood, the remaining firewood and charcoal demand was projected to suitable areas and compared to Above Ground Biomass (AGB) stocking to identify potential hotspots.

The modeling process is illustrated in Figure 48 and additional methodological notes are in Annex 6.1. Assumptions were made about the time needed to cross 21 different types of land cover, and this allowed the model to identify those areas accessible within eight hours of the major town in each district of Myanmar, as well as the two best-known charcoal export locations. Commercially viable woodfuel sources within this time radius were identified, based on a minimum AGB threshold of 50 t/ha for charcoal production and 5 t/ha for commercial firewood supply. Demand was then compared with supply, to quantify commercial woodfuel demand as a percentage of AGB. The higher the percentage, the greater the pressure. A similar approach has been used to assess woodfuel impacts on forest resources across various areas in the tropics[67] and to develop woodfuel management scenarios at country scale.[68]

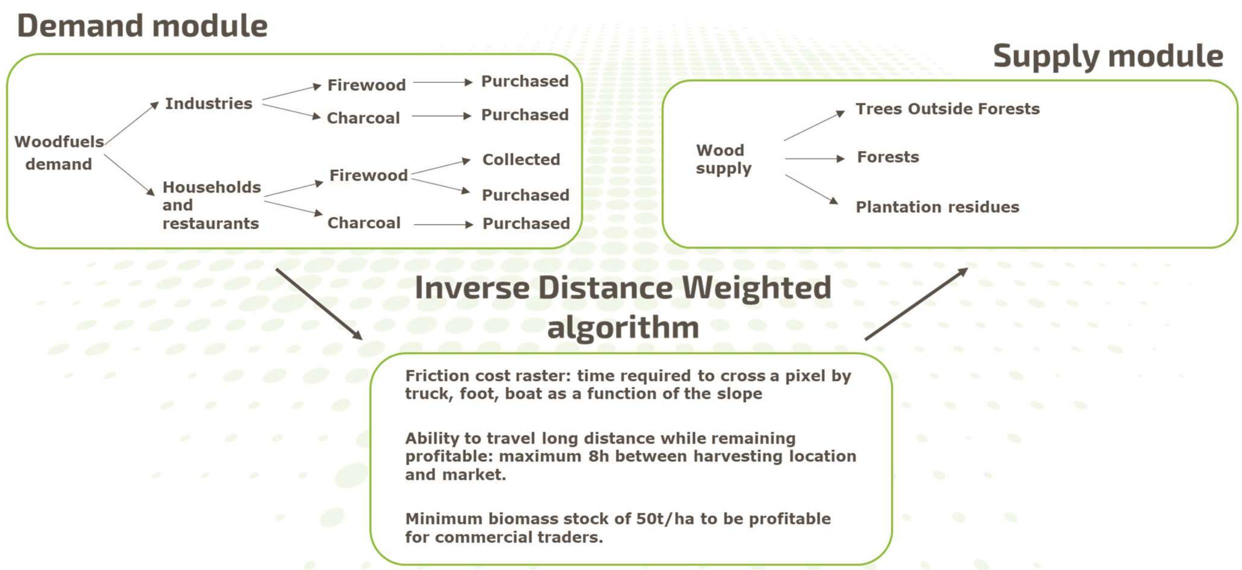

Figure 48 - Schematic of the cost-distance modeling approach for identifying hotspots of woodfuel-induced forest degradation

4.2. Results

The cost-distance modeling shows that the charcoal producers surveyed during the study are located in the predicted location of charcoal production areas for Yangon (Figure 49), which provides useful validation of the methodology. This does not mean that all the predicted source areas are supplying charcoal, as many factors

[67] Bailis et al., "The Carbon Footprint of Traditional Woodfuels."
[68] Adrian Ghilardi, Andrew Tarter, and Robert Bailis, "Potential Environmental Benefits from Woodfuel Transitions in Haiti: Geospatial Scenarios to 2027," *Environmental Research Letters* 13, no. 3 (March 2018): 035007, https://doi.org/10.1088/1748-9326/aaa846.

not included in the model may make the actual area accessible for producers much smaller. The following results should therefore be considered conservative, as actual pressure is likely to be more concentrated than shown on the maps.

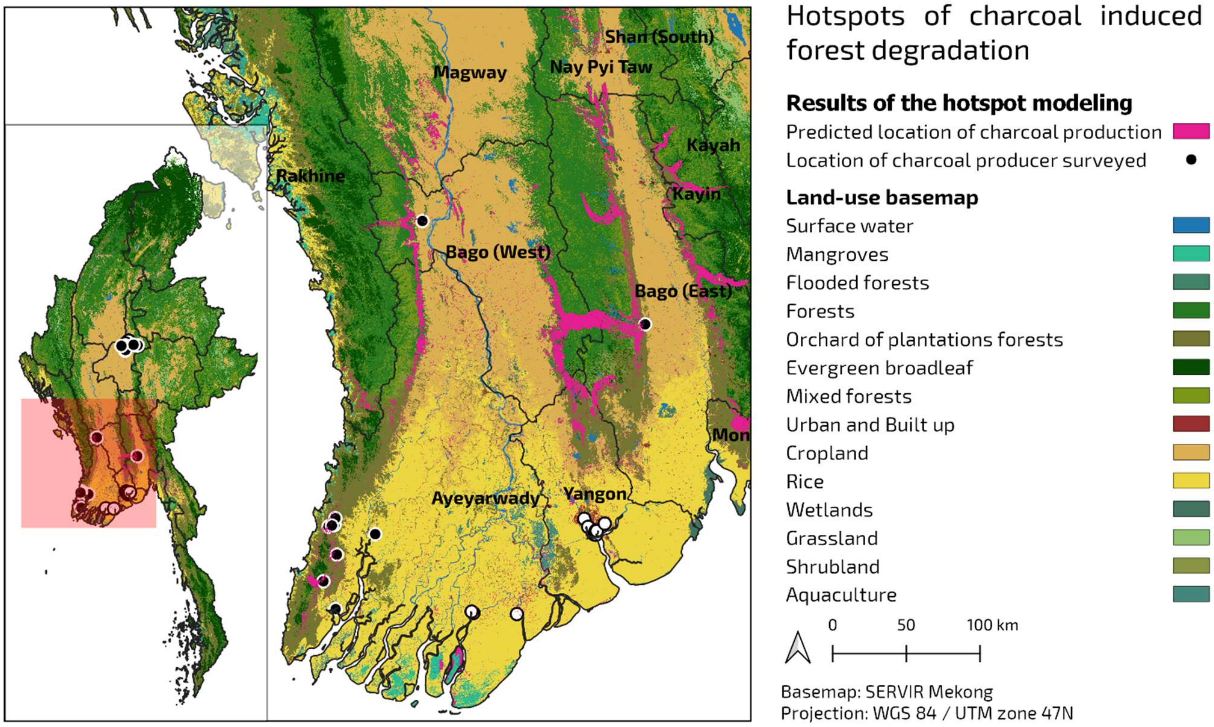

Figure 49 – Modeling prediction of charcoal production areas for Yangon, compared to known locations of sampled producers

The results highlight three hotspot areas at risk due to charcoal production. The first is in the supply chain of the Lower Central Myanmar dominated by Yangon, with harvesting levels likely to exceed the mean annual increment in Bago, Ayeyarwaddy, and south Rakhine (Figure 50).

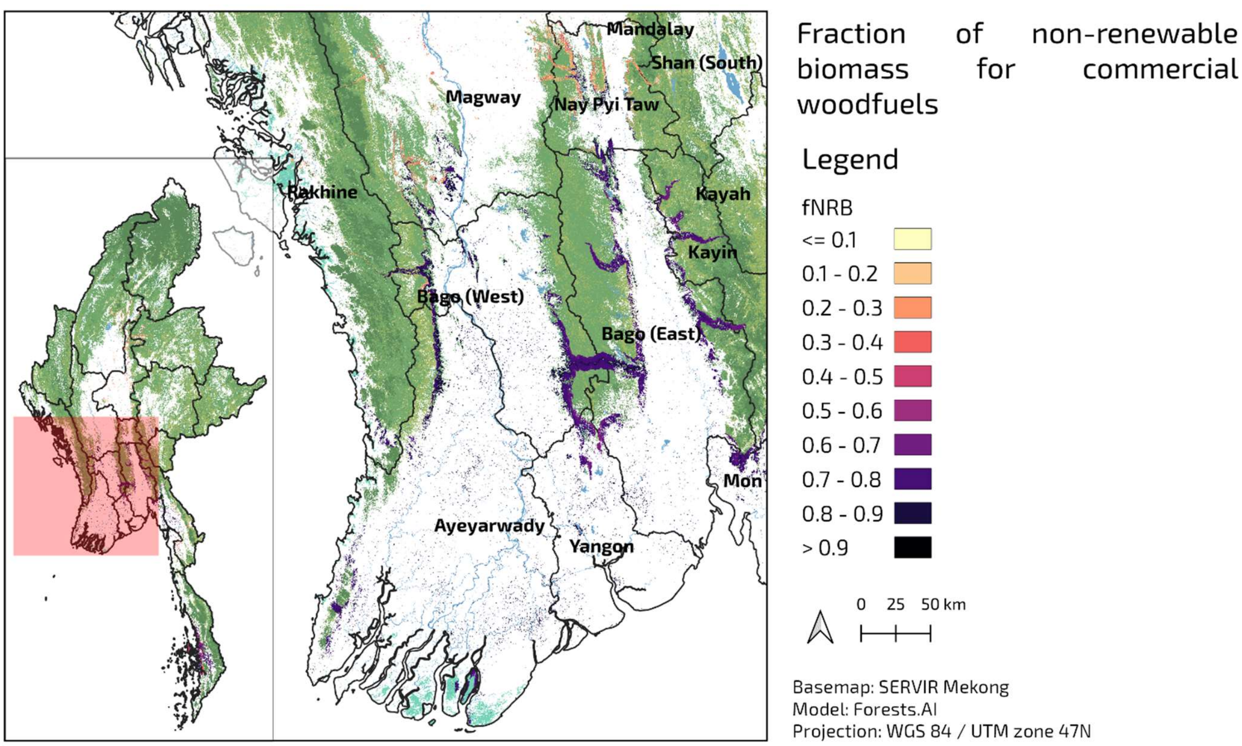

Figure 50 – Predicted hotspots of charcoal-induced forest degradation: lower central Myanmar

The second hotspot area is in Tanintharyi, where projections of demand for mangrove charcoal for export to Thailand represent a very high percentage of AGB (Table 9). It is important to note that this value chain was not studied directly, and that the potential impact is based partly on an assumption of export volume.

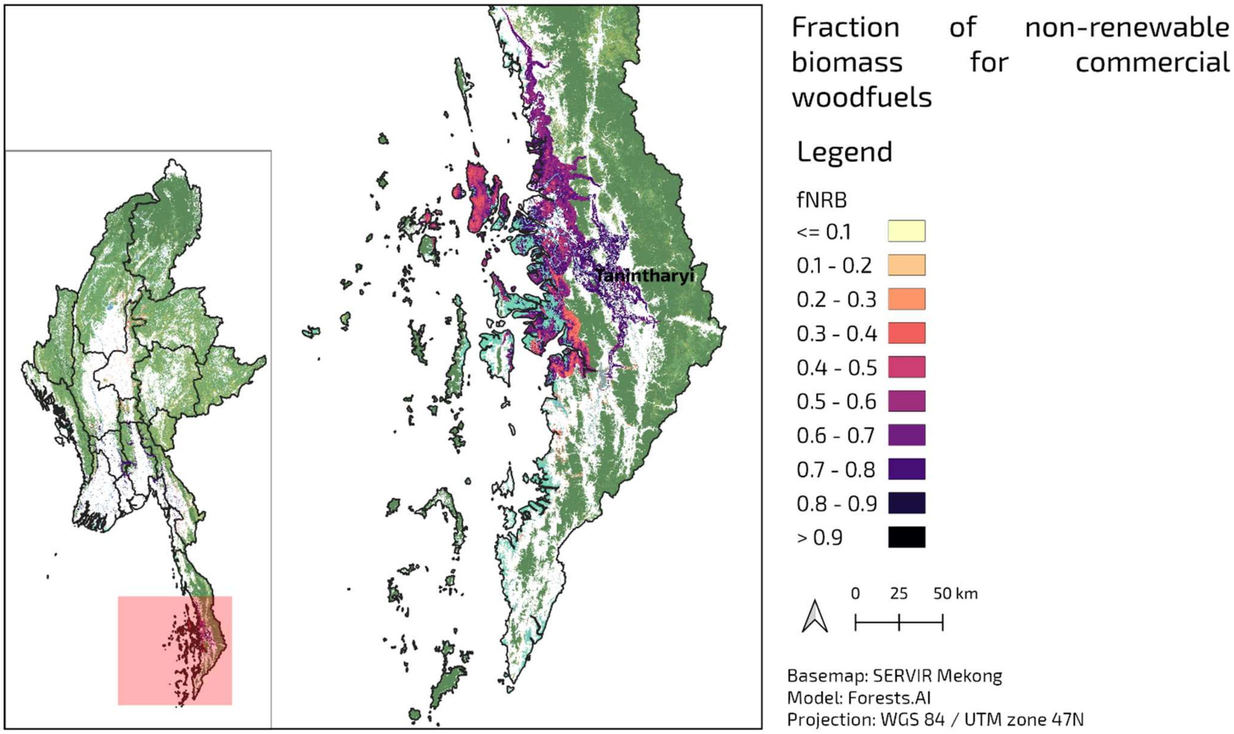

Table 9 – Predicted hotspots of charcoal-induced forest degradation: Tanintharyi

A third area of concern is at the intersection of the regions of Mandalay, Sagaing, Shan, and Kachin (Figure 51). Even if pressure appears to be less intense here as a percentage of AGB, the area could still suffer from degradation from charcoal production due to the additional demands for firewood, as well as harvesting practices that are likely to be more concentrated than presented on the map.

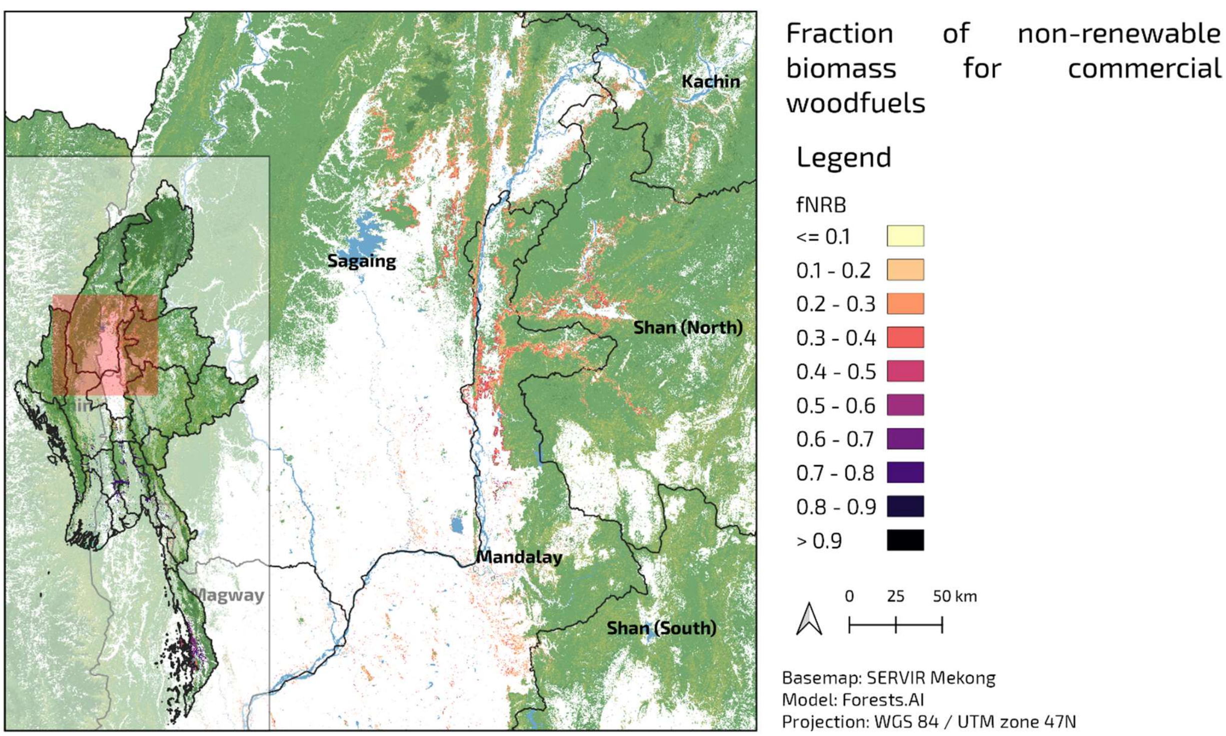

Figure 51 – Predicted hotspots of charcoal-induced forest degradation: Northern Myanmar

It important to bear in mind that the pressure from commercial woodfuels will add to the pressure from timber and pole extraction, firewood collection from populations leaving close to forest areas, and from other significant threats to forests such as agricultural expansion and growth of settlements. Hotspots of potential over-harvesting would likely show higher levels of pressure if these additional removals were considered. In addition, AGB estimates are likely to be inaccurate in areas of low biomass density, due to technical challenges in determining stocking levels in such areas.

4.3. Carbon footprint of woodfuels in Myanmar

Despite the fact that carbon finance is widely applied to woodfuel projects, the science of attributing plausible emission reductions to woodfuel savings is still evolving.[69] Current approaches used in carbon finance methodology tend to assume very high fNRB levels (95% for Myanmar[70]), significantly over-estimating the actual impact of woodfuels on forests and thus the climate. The modeling approach presented in this study can be used to develop more credible fNRB values at township-level for specific value chains. This would allow policymakers to prioritize interventions and better manage the sector. At the time of the writing, however, such detailed fNRB values have not been calculated.

The methodology used to calculate the carbon footprint of woodfuels follows the approach developed by Bailis *et al.* and is presented in Annex 6.1. As presented in Table 10, the carbon footprint of commercial woodfuels is estimated at 15 million tCO_2/yr with an average non-renewable fraction of 52%.

This value is much lower than the UNFCCC fNRB of 95% used in carbon finance projects, but also higher than the value of 5.3% calculated by Bailis *et al*. The UNFCCC fNRB suffers from major methodological limitations. The figure from Bailis *et al.* is based on a significant under-estimate of charcoal consumption (94,000 t/yr for the whole country) compared with firewood consumption (22,136,000 t).[71] In the model used for the current study, charcoal demand is based on more reliable primary research, and proves to be a major contributor to the higher fNRB figure.

In addition to the modelling limitations already discussed in the methodology section, it is important to note that this fNRB applies only to *commercial* woodfuels. The inclusion of collected woodfuels, if considered as fully renewable, brings the national fNRB figure down to 32%.

Table 10 – CO2 emissions from "non-renewable" commercial woodfuel harvesting per State/Region

State/Region	Total woodfuels harvesting (t/yr)	Non-renewable biomass (t/yr)	fNRB	CO2 emissions (tCO_2/yr)
Bago	2,302,547	1,867,534	81%	3,262,955
Tanintharyi	1,740,424	1,501,373	86%	2,623,199
Kayin	980,204	839,688	86%	1,467,103
Ayeyarwady	1,155,010	778,556	67%	1,360,293
Shan	2,730,592	623,006	23%	1,088,517
Magway	1,534,882	586,106	38%	1,024,044
Sagaing	1,925,675	585,859	30%	1,023,612
Mandalay	1,220,556	548,857	45%	958,964
Kachin	1,435,164	449,326	31%	785,062
Mon	440,962	386,184	88%	674,741
Yangon	402,391	304,212	76%	531,519
Nay Pyi Taw	409,348	264,104	65%	461,442
Rakhine	397,909	126,845	32%	221,624
Chin	151,326	2,972	2%	5,193
Kayah	90,421	487	1%	851
National	**16,917,410**	**8,865,108**	**52%**	**15,489,117**

[69] Bailis et al., "The Carbon Footprint of Traditional Woodfuels."
[70] https://cdm.unfccc.int/Panels/ssc_wg/meetings/035/ssc_035_an20.pdf
[71]

5. Intervention Options

Woodfuel accounts for more energy use in Myanmar than all other sources combined. The estimated value of the charcoal market (1.5 million t of charcoal or 9 million t of wood-equivalent) is around US$ 300 million at retail,[72] while the value of the firewood purchased and collected by households (around 15 million t) could be worth up to US$ 1 billion per year.[73]

Woodfuels are crucial for supporting the livelihoods of a majority of the country's citizens for household use, and play a leading role in sustaining important commercial and industrial sectors. In a situation of diminishing forest resources that threaten the viability of Myanmar's dominant source of energy, it is essential for the sustainability of livelihoods and the economy as a whole that forest resources are more sustainably managed for woodfuels, that woodfuel processing and utilization becomes as clean and efficient as possible, and that fuel switching strategies are well-informed and approached strategically. Intervention options are proposed accordingly.

A number of intervention options are proposed accordingly to 1) Promote alternative fuels, 2) Support sustainable woodfuels production, and 3) Reduce energy loss across the value-chain. While the scale and timeframe of these interventions vary, they have a complementary role to play in the development of a sustainable woodfuels sector, supporting sustainable socio-economic development, and contributing to climate change mitigation and adaptation (Figure 52).

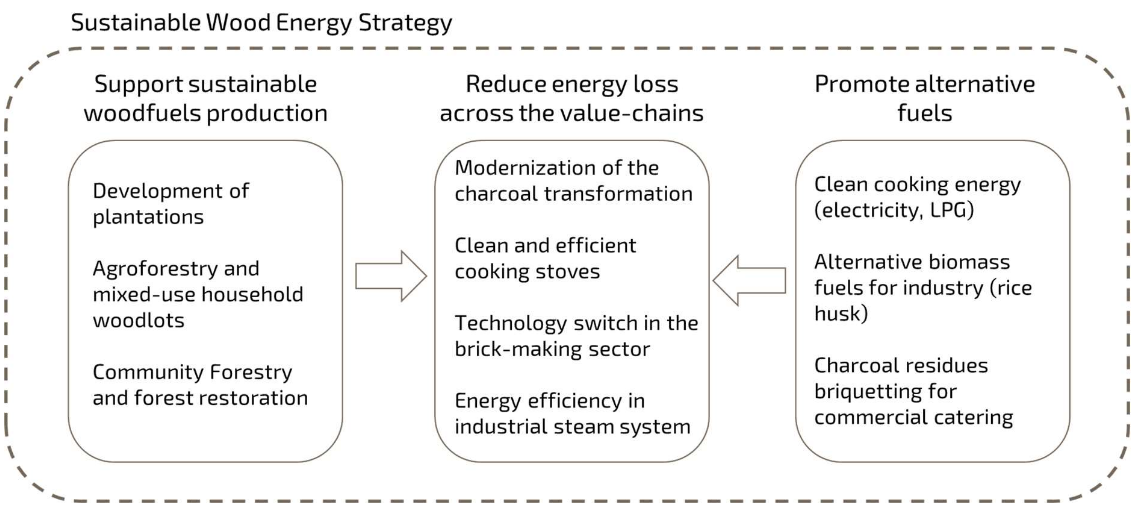

Figure 52 – Framework for a modern, sustainable woodfuels sector

5.1. Promote appropriate alternative energy sources

a) Support switching to clean cooking fuel

Based on data from Sustainable Energy for All, Myanmar has one of the lowest levels of access to clean cooking fuels and technologies in Southeast Asia, and close to the average of all Least Developed Countries (Figure 53). Indonesia and Vietnam have made significant progress in the promotion of clean energy since 2000 and can represent a source of inspiration for Myanmar.

Many stakeholders emphasize fuel switching as a desirable strategy to transition away from woodfuels, especially for household cooking. Significant barriers exist, however, in terms of cost, access, familiarity, and cultural preference. There is nevertheless potential for some households, businesses and industries in Myanmar to be encouraged to switch to alternative (non-woodfuel) energy sources.

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[72] Considering an average price of 500 MMK/Viss (US$ 210 /t).

[73] Considering the retail price of firewood in the Meiktila area, around 110 MMK/kg ($US 75/t).

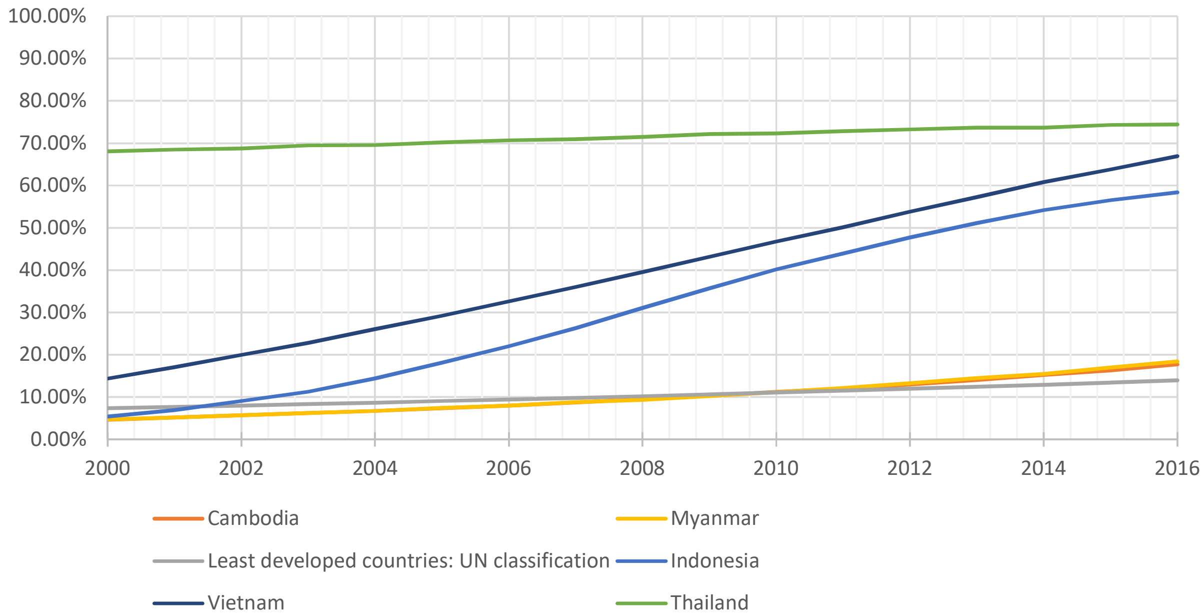

Figure 53 - Access to clean fuels and technologies for cooking in Southeast Asian countries

Source: World Bank, Sustainable Energy for All, from WHO Global Household Energy database

❖ *LPG*

Despite being a key fuel in many ASEAN countries' strategies for cooking energy, LPG use in Myanmar is still very low. Demand is growing, however, and LPG has significant potential to displace woodfuel (especially charcoal), particularly in areas that lack reliable and affordable electricity access.

There are only three state-owned LPG factories in Myanmar, with a combined production capacity of 900 t/month. An additional 4,000 to 7,000 t/month is imported from Thailand. The border regions of Mon and Tanintharyi show significantly higher LPG adoption rates than the rest of the country (Figure 54). According to EMC for Geres, Myeik is also the place where LPG is the cheapest.[74] This suggests that better availability and lower prices could stimulate households in other parts of the country to switch to LPG. The government has sought to develop public-private partnerships to develop LPG import capacity, with a target of one million households using LPG in 2020.[75] A meeting with the Myanmar Petrochemical Enterprise in Naypyidaw confirms, however, that this target will not be met.

Based on survey and interviews during this study, LPG is perceived as dangerous by a range of consumers and there is limited trust in the products found in the market. Expanding LPG use more rapidly will require pro-active awareness-raising interventions on the benefits of LPG and safety aspects, in addition to some form of subsidy. Mass conversion programs from other countries can provide useful lessons.

In 2007, the Government of Indonesia launched in a massive LPG promotion program intended to phase out the use of kerosene. The program focused on areas where consumption of kerosene was high and where LPG infrastructure was already in place. In these areas, a free LPG 'starter pack' was distributed to households and small businesses, comprising a 3 kg cylinder, single-burner stove, rubber hose and regulator, worth around US$ 33.[76] Demonstrations were organized to explain how the starter kits worked.

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[74] Emerging Markets Consulting, "Myanmar Cookstoves Market Assessment."

[75] https://www.mmtimes.com/news/government-strengthens-aim-distributing-lpg-million-households-2020.html

[76] Katharine Thoday et al., "The Mega Conversion Program from Kerosene to LPG in Indonesia: Lessons Learned and Recommendations for Future Clean Cooking Energy Expansion," *Energy for Sustainable Development*, Scaling Up Clean Fuel Cooking Programs, 46 (October 1, 2018): 71–81, https://doi.org/10.1016/j.esd.2018.05.011.

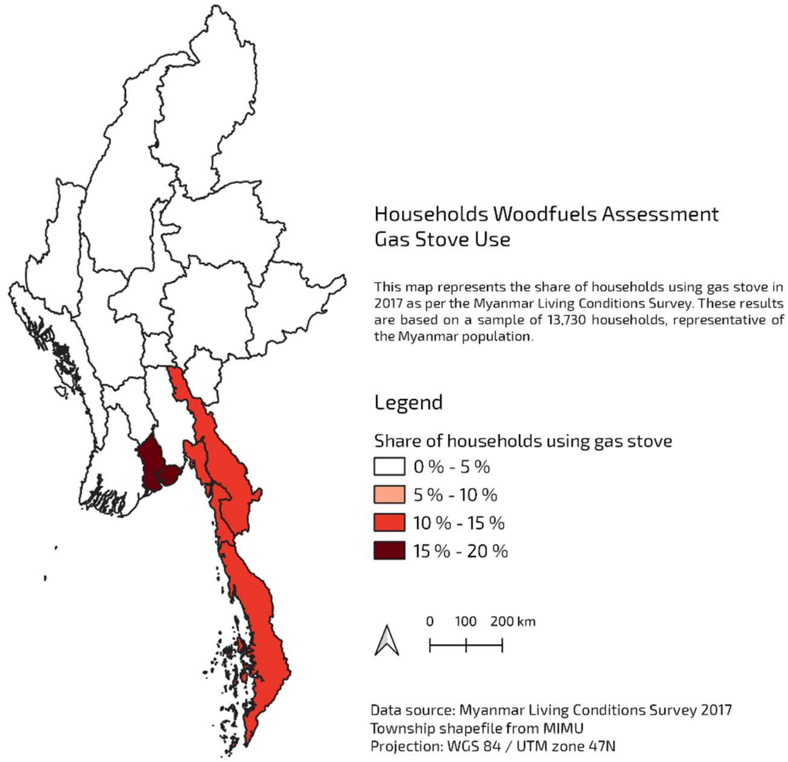

Figure 54 - Percentage of households with an LPG stove (2017)

The Indonesian LPG model is based on cylinder recirculation, which requires households to exchange their empty cylinders for full ones at a government-subsidized rate. This has allowed safety to be addressed within the supply-chain, as LPG distributors are responsible for refilling only their own branded cylinders.

The government subsidizes only the smallest 3 kg cylinders (Figure 55), to make them more affordable to poor people. Richer households generally use larger cylinders and higher quality burners. In December 2019, the subsidized price of a 3 kg LPG cylinder was between 17,500 IDR (US$ 1.28) in urban areas and 30,000 IDR (US$ 2.20) in rural areas.

Figure 55 - Subsidized 3 kg LPG cylinders for sale in Aceh province, Indonesia

The subsidy program, combined with the development of distribution infrastructure, has made cooking with LPG very cheap in Indonesia. This means that a household in rural Indonesia cooking with LPG will pay only around 27% of the amount paid by a household cooking with firewood in the central Dry Zone of Myanmar, per unit of useful energy (Table 11). Considering the ability of an LPG stove to deliver the exact amount of energy needed for the task in hand, the actual savings may be even higher. This does not take into account additional advantages of LPG, such as faster cooking and lower HAP exposure.

Table 11 – Cost of cooking with subsidized LPG in rural Indonesia compared with firewood in the central Dry Zone of Myanmar

	Stove efficiency	Fuel cost (US$/kg)	Fuel LHV_{wet} (MJ/kg)[77]	Cost of useful energy (US$/GJ)
LPG in rural Indonesia	60%[78]	0.73[79]	46.10	26.51
Firewood in the Dry Zone of Myanmar	15%[80]	0.08[81]	13.83[82]	36.15

Even if initially focused on phasing out kerosene, Indonesia's proactive LPG program resulted in a 67% reduction in the proportion of households using firewood as their main fuel over 12 years (Figure 56).[83] Although the program has been very successful, fuel stacking is common and there are still relatively high rates of firewood use as a supplementary fuel - in the same way that charcoal and firewood remain widely used among electricity users in Myanmar.

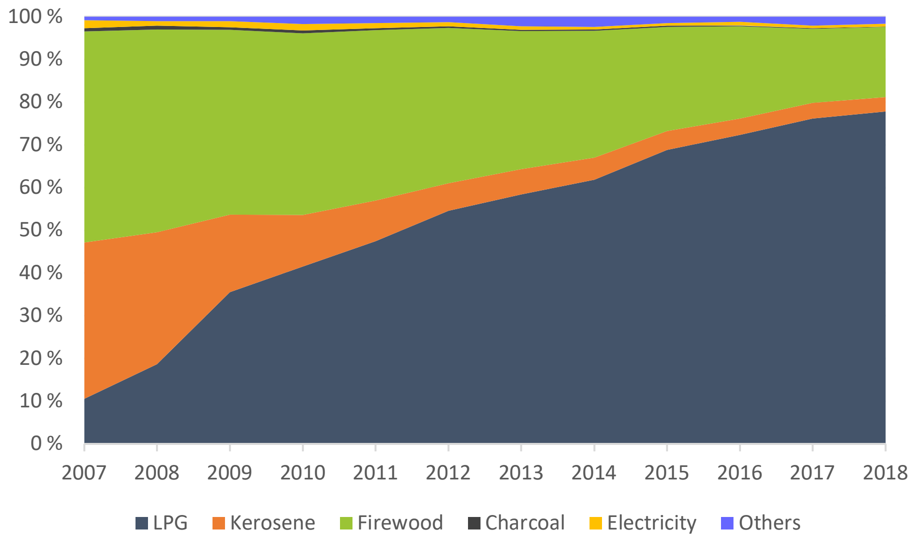

Figure 56 - Evolution of cooking energy sources for households in Indonesia

Source: Statistics Indonesia (BPS)[84]

The program has also been costly. It is estimated that the dissemination of 57.2 million starter packs between 2007 and 2016 cost US$ 1.02 billion, in addition to LPG subsidy costs of US$ 3.5 billion in 2018 alone. In Indonesia's case this was in place of subsidies for kerosene. Subsidies tend to benefit richer households, as they are the largest energy consumers. Such programs are arguably an ineffective use of public funds at the cost of investment in public infrastructure and social programs. In order to address this, the Indonesian government decided to reallocate the LPG subsidies to the poorest 40% of its population, and to prioritize LPG distribution in more remote areas.[85] Adopting the Indonesian subsidy concept in Myanmar, it can be estimated that LPG would be competitive at a cost of US$ 1 per kg in the Dry Zone, if starter kits could be fully subsidized.

[77] Lower Heating Value, wet basis, which is the energy available in the fuel after evaporating the water it contains.
[78] Estimation of the efficiency of a traditional one burner LPG stove
[79] US$ equivalent cost of 3kg LPG cylinder sold in rural Aceh, Indonesia for 30,000 IDR. Data collected December 2019.
[80] Estimated efficiency of improved 3-stone fire
[81] US$ equivalent cost of firewood bundle in the Meiktila area in the Dry Zone. Data collected January 2020 by Geres.
[82] Calculated from an LHV_{dry} of 19.23 MJ/kg and a moisture content of 25%
[83] BPS - Statistics Indonesia, "Statistical Yearbook of Indonesia 2019," 2019.
[84] BPS - Statistics Indonesia, "Statistical Yearbook of Indonesia 2019."
[85] Thoday et al., "The Mega Conversion Program from Kerosene to LPG in Indonesia."

In addition to the government-subsidized model of LPG dissemination found in Indonesia (and also in India[86] and in other parts of the world), there are private sector initiatives promoting LPG in rural areas of developing countries using innovative technologies and business models. The company Fenix, for example, a subsidiary of the French firm ENGIE, is promoting LPG in Uganda using a pay-as-you go model. Users pre-pay for small quantities of gas via mobile phone and the gas is released by entering a code on a control device connected to the regulator.[87] This model could be introduced to Myanmar to bring clean energy to areas currently non-electrified.

Recommendations:

- Establish and enforce standards and regulations for LPG cylinders, stoves and regulators.
- Organize cooking demonstrations and information campaigns on the benefits and safety of LPG, to raise awareness among consumers.
- Pilot financing solutions to reduce LPG entry costs and spread the cost of refills in areas with high rates of firewood purchase, especially the central Dry Zone, including subsidized starter kits, loans and pay-as-you go models.

❖ *Electricity*

A switch to electricity for cooking has been an important factor in the transition of households up the energy ladder. It was mentioned by many of those interviewed as the main driver of a switch away from woodfuels, and it can have climate benefits as a significant proportion of electricity produced in Myanmar is from low carbon energy sources, especially hydropower.[88]

As presented earlier, however, most households continue to use firewood or charcoal even if they switch to electricity as their main cooking fuel. They typically experience a reduction in woodfuel consumption of less than 50% if switching to electricity as their main source of cooking energy. This level of fuel saving could also be achieved by investing in a high-efficiency biomass cookstove.

A recent increase in the electricity tariff (Table 12)[89] may further reduce the expected effect of fuel switching on woodfuel demand. The price rise and the unreliability of supply means that the observed trend of switching to electricity is likely to slow down or may even reverse.

Table 12 - Myanmar electricity tariff

Electricity consumption (kWh/month)	Unit cost pre-July 1, 2019 (MMK/kWh)	Unit cost from July 1, 2019 (MMK/kWh)
1-30	35	35
31-50		50
51-75		70
76-100		90
101-150	40	110
151-200		120
>200	50	125

[86] https://economictimes.indiatimes.com/news/economy/policy/government-achieves-87-per-cent-of-8-crore-free-lpg-connections-target/articleshow/68322381.cms

[87] https://innovation.engie.com/en/news/news/energy-communities/fenix-fumba-cookstove-making-cooking-in-africa-clean-and-affordable/12983

[88] https://www.iea.org/countries/Myanmar

[89] "Myanmar's Tariff Hikes: Daring but Worth the Risk," The Myanmar Times, July 5, 2019, https://www.mmtimes.com/news/myanmars-tariff-hikes-daring-worth-risk.html.

While electricity will likely represent a significant and growing part of the cooking energy mix, it is important not to underestimate the barriers that remain for large-scale adoption as a substitute for woodfuels. Given the importance of electrification in the energy policy of Myanmar, it is essential to better understand the dynamics and drivers of household woodfuel use in a context of electrification. With a transition period that could last more than a generation, the promotion of cooking with electricity should be paired with other interventions that specifically address the woodfuels sector.

Recommendations:

- Conduct further research on fuel stacking, including the impact of electrification on woodfuel consumption and its sensitivity to price.
- Review electrification expansion plans and determine how these could affect household consumption of woodfuels.

b) Potential of rice husk for industrial use

❖ *Rice husk potential for industrial use*

With annual production of around 7.3 million t of risk husk, Myanmar has an output potential of more than 6 million t of wood-equivalent if these husks were used as fuel (Table 13). The Ayeyarwaddy region, "the rice pot of Myanmar", accounts for more than half of this theorical potential. Ayeyarwaddy also hosts large rice processing facilities, where husks are centralized and thus readily available for nearby industries.

Table 13 – Estimation of rice husk production potential by physiographic zone

Zone	Paddy production in milled rice equivalent ('000 t/yr)[90]	Rice husk production ('000 t/yr)[91]	LHV_{wet} (TJ/yr)[92]	Wood-equivalent (t/yr)[93]
Delta	9,403	3,834	43,399	3,138,000
Dry Zone	3,964	1,616	18,295	1,323,000
Coastal	1,901	775	8,774	634,000
Highlands	2,729	1,113	12,595	911,000
Total	**17,997**	**7,337**	**83,063**	**6,006,000**

Actual potential will be lower than indicated, as some rice husk is used for paddy drying, on-site energy generation or other purposes. In addition, an important share of rice husk is already used to supply the F&B and brick-making industries (Figure 57). Interviews with experts in the energy sector suggest a high degree of uncertainty in the amount of rice husk currently discarded. Some actors report significant volumes dumped in the rivers of the Ayeyarwaddy delta, while others report that this is no longer the case and that all rice millers in the delta are selling their husk.

A good indicator of the balance between demand and supply is the price of rice husk in the local market. Rice husk is generally either free or very cheap. Rice husk pellets producers in the Pyapon area pay 12,000 MMK/t (around US$ 8.15/t) for their raw material, which includes delivery to the pellet plant. One pellet producer even reported that millers deliver husk to his factory for nothing, and others reported only a minimal transport charge. These low valuations indicate that the supply potential exceeds current demand, at least in some rice growing areas of the country.

[90] Data from DAO, MOALI, 2016.

[91] Calculated using a milled rice ratio of 0.65 and residue to product ratio of 0.265.

[92] Lower Heating Value, wet basis. Assumes LHV_{dry} 12.85 MJ/kg and moisture content 10%.

[93] Assumes LHV_{dry} 19.23 MJ/kg and moisture content 25%.

Figure 57 – Rice husk at a brick factory in Mandalay

To better assess potential rice husk availability, a phone survey was conducted with a sample of 43 rice millers randomly selected from the SBR. From the results (Figure 58), it is estimated that 23% of rice millers nationally are dumping husks. Rice husk seems to have most value in areas where there is little cheap firewood available from plantation residues (Mandalay, Sagaing). Such areas may have the greatest potential for processing husks into pellets or briquettes. In contrast, there appears to be an excess of rice husk in Tanintharyi, where a lot of rubberwood residue is available as a higher quality fuel alternative, and in Ayeyarwaddy, where there is a concentration of rice milling operations.

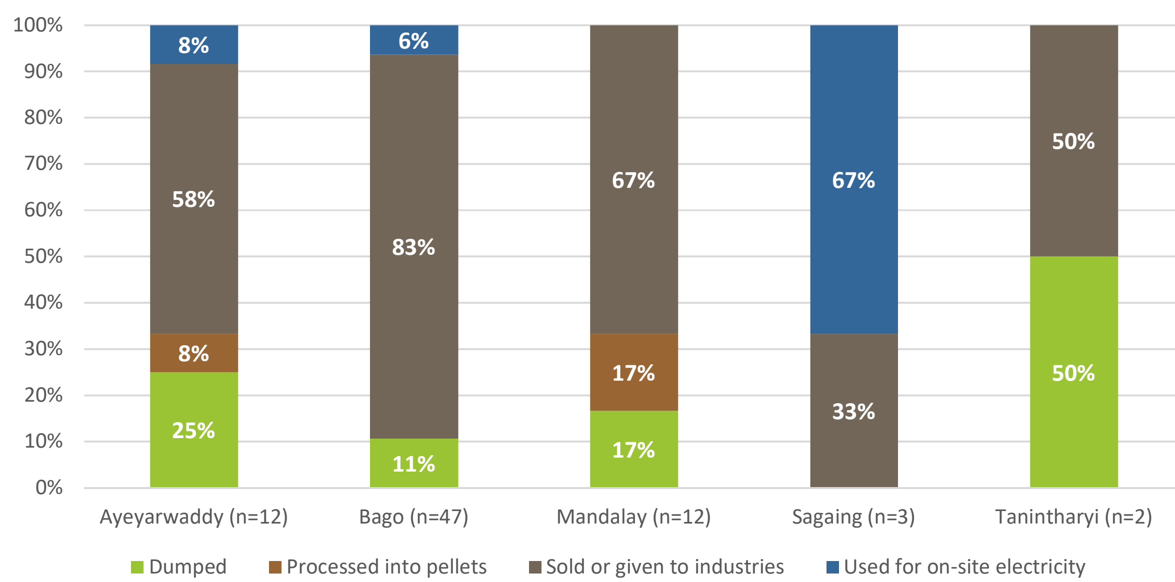

Figure 58 - Use of rice husk by surveyed millers

Loose rice husk is expensive to transport due to low density, so it is usually densified for transport by pelletizing or briquetting (Figure 59). Rice husk briquettes or pellets can replace firewood in many applications, without modification of the combustion technology. Due to their lower specific surface area, however, they deliver lower combustion efficiency and are more difficult to use with more advanced, automated feeding technologies.

Figure 59 - Worker in a rice husk briquette and pellet factory in Sagaing division

There may be a cost barrier to large scale adoption of rice husk pellets and briquettes, especially for boiler users. For example, Geres (for H&M)[94] found that firewood is currently the cheapest source of energy for steam generation in Yangon garment factories, along with coal (Figure 60). Producing steam using diesel-fired boilers costs between two and four times as much as firewood, though diesel offers more operational flexibility.

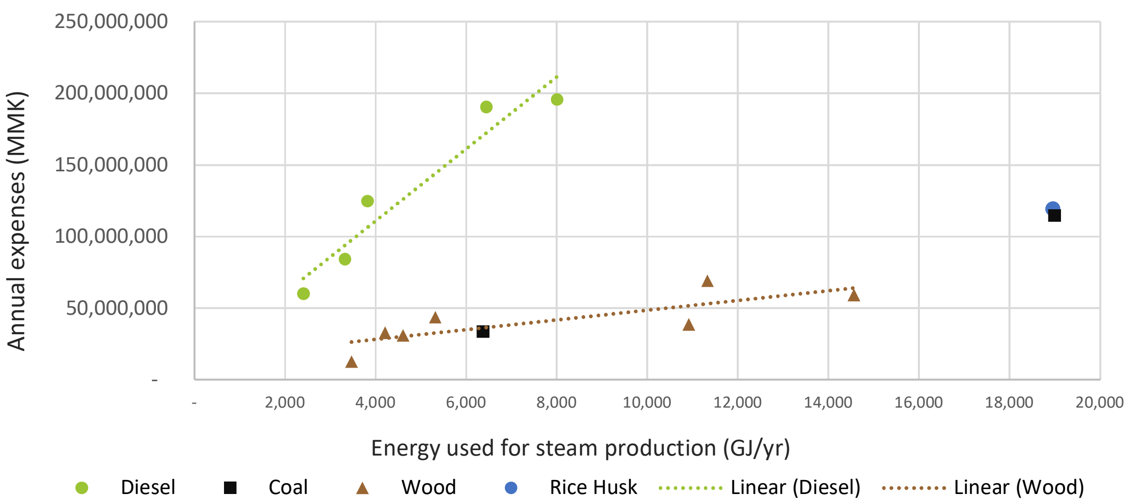

Figure 60 - Annual energy consumption and costs for steam production in 14 garment factories

Source: Geres for H&M[57]

If rice husk briquettes can be cost-competitive with firewood and coal, there may be displacement potential. But a growth in rice husk processing has been observed, especially in the Ayeyarwaddy region, which will likely lead to an increase in the cost of the husk. Between 2008 and 2018 in Vietnam, the share of rice husk use in boilers went from virtually zero to more than 2.5 million t/year, causing the price of rice husks to rise from US$10/t to US$45/t.[95] It is therefore essential that any measures intended to increase the use of rice husk as industrial fuel are carefully balanced with available supply, to avoid unforeseen price rises that might later render the fuel switch uneconomic.

According to an interview with the Duwum Rice Vermicelli Factory, a high volume of ash remains after burning rice husk pellets. This requires removal and increases workers' exposure to potentially hazardous particles. If

[94] Petelot, "Sustainable Alternatives for Steam Production in Garment Factories Supplying H&M in Myanmar."
[95] Phan Hiếu Hiền presentation during "Alternative Biomass Fuels for Sustainable Thermal Energy in the Garment Sector" meeting. March 19, 2019, Phnom Penh, Cambodia.

not managed carefully, the ash can also block the fire tube in horizontal fixed-grate boilers. Incomplete combustion can also occur due to inappropriate feeding or air control, leading to a loss of efficiency.

Taking everything into consideration, some of the identified barriers are easy to solve. For example, some pellet/briquettes suppliers (such as Myanmar Biomass Power) offer an ash recovery service, so that the user does not need to worry about ash management. Reports from Vietnam suggest that a market can even develop for rice husk ash in agriculture. While there may be ways to cope with the ash limitation in industrial situations, high ash renders rice husk briquettes and pellets unsuitable as cooking fuel for household use.

Interventions should focus on linking rice husk suppliers and industrial consumers. The organization of district-level networking events gathering biomass suppliers on the topic of biomass densification technologies can support the emergence of clusters of rice millers investing in briquetting/pelleting technologies, especially if linked with financing support. Similarly, support should be given to adjustment of current technologies to rice husk, especially on ash management issues, to promote the use of rice husk in boilers.

Recommendations:

- Support rice husk valorization into pellets and briquettes through organization of networking and capacity building events targeting rice millers, including exchange visits to millers already producing pellets and briquettes.
- Assess best practices from Vietnam on rice husk ash valorization and rice husk ash market development.
- Offer financing products to assist biomass consumers with any equipment modifications required to convert to using rice husk.
- Condition financial support on energy efficiency investment to the adoption of rice husk pellets or briquettes as a woodfuel replacement.

❖ *Rice husk potential for fish and shrimp boiling*

Given the high woodfuel consumption of the fisheries sector, there may be significant potential for a switch to risk husk pellets. Myanmar Biomass Power and other local rice millers have already been supplying rice husk pellets to the fisheries sector of Pyapon (Figure 61). Given the high energy density of pellets and their competitive price, this may be a promising option for the whole sector.

Figure 61 - Workers loading rice husk pellets for fishery sector (foreground) and unloading rice husk (background) at Myanmar Biomass Power factory, Ayeyarwaddy.

All the stoves on fishing rafts should be compatible with rice husk pellets and briquettes. In addition, Myanmar Biomass Power have been developing an adapted version of the A1 household stove to equip it with a feeding attachment, making it easier to operate with pellets (Figure 62). While it does not seem that this stove is widely used, this is an interesting intervention and further work on identifying energy efficient pellet stoves matching the specific needs of the fish and shrimp boiling rafts should be supported.

Figure 62 - A1 stove modified by Myanmar Biomass Power to be used with pellets

Myanmar Biomass Power claim that a switch to rice husk pellets by fishing raft operators could be evidenced by the fact that firewood storage sites in some of their target villages were unused in the subsequent season (Figure 63 and Figure 64). While this could not be definitely linked to a fuel switch, a move to rice husk briquettes could certainly bring positive benefits.

Figure 63 - Firewood storage in Kya Pyat village during 2018 fishing season, before intervention of Myanmar Biomass Power

Photo: Myanmar Biomass Power

Figure 64 - Empty firewood storage locations at Kya Pyat village in 2019 fishing season, after intervention of Myanmar Biomass Power

Photo: Myanmar Biomass Power

Recommendations:

- Further investigate the barriers for mass adoption of rice husk pellets in the fisheries sector, and the potential for high efficiency pellet stoves.
- Based on results and the environmental impact of the sector, consider a subsidy for rice husk pellets for use in fisheries processing.

c) Perspectives on wood pellets

The wood pellet sector was not studied in detailed for this assessment as it appeared that the potential for pellets to supply the domestic market centered on rice husks. However, wood pellets have additional potential that is worth exploring further.

A phone survey of 20 sawmills revealed that sawdust is generally sold loose, mostly to households, tea shops, brick factories and other industries, and could be replaced by cleaner, more efficient fuels such as LPG and electricity. For industrial heat and steam applications, sawdust has significant potential if densified to pellets, which are more consistent in quality and easier to handle with automated feed systems than loose sawdust. Wood pellets could therefore play a useful role in the decarbonization of industry. Coal is currently a major source of energy for many industries in the garment, brickmaking and F&B sectors. Most of these factories use low-efficiency boilers and coal with high sulfur and ash content, leading to significant pollution and high carbon emissions. If the Paris Climate Agreement objectives are to be met, a global phasing out of coal will need to happen. A progressive replacement of coal should therefore be envisioned in Myanmar's industries, at least for smaller steam needs. Under such a scenario, biomass pellets, including both rice husk and wood pellets, provide a viable alternative based on renewable resources.

China is often mentioned by pellet manufacturers as an example of how to progressively develop pellet manufacturing capacity as a replacement for coal. In areas like Beijing, small-scale coal-fired boilers were shut down to reduce the notorious level of air pollution. In addition, China's Intended National Determined Contribution has defined specific goals such as lowering carbon dioxide emissions per unit of GDP by 60% from 2005 levels, and to increase the share of non-fossil fuels in the primary energy mix to approximately 20%.[96]

In the context of the Paris Climate Agreement, the development of a sustainable woodfuels sector can be a 'no-regrets' solution if planned properly. The progressive development of a market for pellets for industry, through regulation of some types of carbon pricing, will allow price stability as it will give clear direction for private sector investments in tree plantation and pellet manufacturing capacities.

d) Charcoal briquettes for commercial catering

Made from discarded charcoal dust and fines, or carbonized biomass residues such as coconut shell or rice husk, charcoal briquettes can provide a partial substitute for wood charcoal and hence reduce total demand. Several commercial charcoal briquette producers are already established in Yangon (Figure 65 and Figure 66) and Mandalay (Figure 66), and some of them export to Thailand and China.

Figure 65 - Briquette extrusion using charcoal residues, Yangon

Figure 66 - Rice husk charcoal briquettes sun-drying, Mandalay

High quality charcoal briquettes have successfully displaced traditional charcoal for street food and BBQ restaurants markets in countries like Cambodia, which shares similarities with the woodfuels sector in

[96] China's INDC, https://www4.unfccc.int/sites/submissions/INDC/Submission%20Pages/submissions.aspx

Myanmar. Even lower grade briquettes with high ash content can be successfully marketed if they have attributes that users desire, such as a long steady burn.

Looking at the production process of these factories, it appears that significant progress could be made in increasing quality and efficiency, right from the mix preparation through to the extrusion and drying stages. Improvements in production processes could make charcoal briquettes more competitive with wood charcoal and become a significant supply for street food vendors and tea shops. Several companies in Cambodia have been successful in producing high quality char-briquettes for the street food sector, and would be a relevant source of technical support for Myanmar entrepreneurs.

Table 14 – Khmer Green Charcoal factory, Cambodia

Source: OTAGO marketing materials

Recommendations:

- Provide technical assistance and hands-on training to Myanmar charcoal briquette entrepreneurs to re-design their production processes, raise product quality and improve efficiency.
- Subsidize investments in production capacity, drying facilities and quality improvement through a call for proposals targeting existing producers.
- Establish minimum quality labelling for charcoal briquettes on calorific value, ash content and mechanical strength, and support producers through a communication campaign on the label.

5.2. Support sustainable woodfuels production

a) Large-scale plantations residues

The massive supply of firewood coming from rubber plantations in Mon State and from hardwood residues in Bago show that, in the long-term, models of plantation focusing on higher-added value products able to leverage private sector investment are more likely to provide an economically viable and sustainable supply of firewood than dedicated fuel plantations (which are discussed below).

Table 15 - Acacia mangium plantation in Pathein area

Different value-chains provide different quantities of residues that can be used as firewood. Veneer or timber production generate significant residues to supply households and industries from both harvesting and processing. At the other extreme, where residues are processed for woodchip for pulp and paper production, there is unlikely to be any surplus at all.

In the Pathein area, 16,000 acres (6,475 ha) of private plantations have been established, of which 80% is under *Acacia mangium* mono-cropping. An additional 2,000 acres (809 ha) were to be planted in 2019. The markets that will be developed for these plantations will have important implications for woodfuel supply. The production of veneer or sawnwood would generate significant quantities of residues that could be used by local charcoal producers who currently supply Yangon to the east. And contribute to address one of the main hotspots of woodfuels-induced degradation.

An in-depth assessment of the economics of private plantation development, the opportunities they present for woodfuel production from residues, and the regulatory environment that might support such investment, could inform future government policy and potentially make a significant contribution to meeting woodfuel demand. With the proper incentives, a transition of charcoal production from forest wood to plantation residues could lead to major transition in the sector. This requires enabling framework and much simplified administrative procedures for charcoal producers to transition from an informal to a formal activity.

Recommendations:

- Conduct an economic assessment of plantation configurations that can generate significant quantities of woodfuel residues, while providing higher added-value outputs.
- Informed by the findings, develop incentive mechanisms to encourage investment in plantations on both private and public land and use of the plantation residues as firewood and charcoal for the domestic market.

b) Tree plantations at village and household level

- ***The case of fuelwood plantations***

To address the environmental challenges of land degradation in the central Dry Zone linked to firewood consumption, the DZGD has been supporting the establishment of fuelwood plantations since 1997, intended to reduce pressure on natural forests and contribute to meeting the energy needs of the population (Figure 67).

Figure 67 - Firewood plantation managed by the Forest Department in the Meiktila area of the central Dry Zone

Given the harsh climatic conditions and low soil fertility, exotic fast-growing tree species with high coppicing capacity (such as *Eucalyptus camaldulensis)* have been preferred. In regions with higher precipitation, other species have been planted, e.g. *Acacia mangium*, *Dipterocarpus tuberculatus*. These plantations represent a significant part of the MRRP target and have been a core component of DZGD's interventions. The DZGD has an annual target of 2,000 acres (809 ha) of such plantations, which are established with government funds then 'handed over' to communities after five years.

The process of plantation establishment begins with mechanical hole digging. Firebreaks 12 feet wide and 1 m weeding zones around each seedling are maintained for the first three years (Figure 68).

Figure 68 – Site preparation for eucalyptus woodfuel plantation

Photo: Justin Whittle

Establishing such plantations is an expensive process and requires significant effort to identify viable sites, as local communities have often established their farms within the Forest Reserves in which the Forest Department would otherwise aim to set up these plantations.

The annual growth rate of eucalyptus in the Dry Zone is 1.53t/ha/year (ranging from 0.54 to 2.97 t/ha/year[97]). Data from the Forest Department staff suggests that the failure rate could be between 73% and 85%,[98] which will significantly decrease biomass production.

As presented in Figure 69, even without accounting for plantation failure, maintenance and management costs, firewood plantations offer virtually no return on investment.[99] This means that they will remain driven by public sector funding to meet local firewood deficit, and will not be an attractive proposition for farmers or private investors. This is evidenced by the absence of such plantations outside government-funded schemes.

The cost of this intervention, which is designed to increase firewood sustainably to areas in serious deficit, can be compared with the cost of an improved cookstove that has the potential to save an equivalent amount of firewood. The Table 16 compare the cost-benefit of a firewood plantation in the Dry Zone against the dissemination of an improved stove (in this case the 'A1') in a context where households are cooking using 3-stone fires.

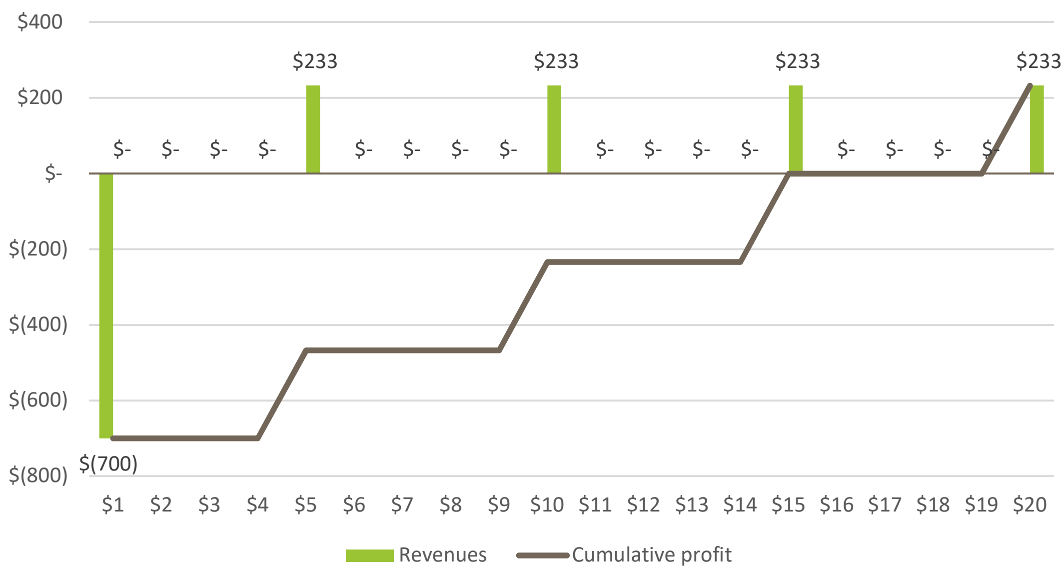

Figure 69 - Profitability of a eucalyptus plantation in the central Dry Zone

The data suggest that it costs more than 11 times as much to grow 1 t of firewood as it does to save 1 t of firewood using an improved stove in the Dry Zone. The difference in effective cost could in fact be even larger, if part of the stove cost was recovered from a user contribution. In addition, the plantation costs do not include firebreak maintenance after the first rotation, nor do they include failure ratio.

Table 16 – Effective cost of firewood grown in plantations compared to saving from improved cookstove in the central Dry Zone

	Initial cost (US$/ha or US$/stove)	Lifetime (years)	Cost annualized (US$/year)	Firewood impact (t/yr)	**Effective cost (US$/t/yr)**
A1 stove dissemination	2.73[100]	2	1.36	0.70	**1.95**
Eucalyptus plantation	700[101]	20	35	1.53	**22.88**

[97] Min Zaw Oo et al., "Biomass of Planted Forests and Biotic Climax of Shrub and Grass Communities in the Central Dry Zone of Myanmar," *Bulletin - Forestry and Forest Products Research Institute Ibaraki* 5, no. 4 (2006): 271.
[98] Establishment of village firewood plantation by Forest Department, presentation of the Natural Forest and Plantation Division during roundtable workshop in Naypyidaw, January 29, 2020.
[99] Potential revenues based on 50% of firewood retail price per bundle at the market in Meiktila. Growth rates from Min Zaw Oo *et al.*
[100] Price in remote locations of 4,000 MMK/stove.
[101] Authors' conservative estimate.

There is also scope for improvement in the plantation approach. The current eucalyptus plantations use relatively poor quality planting material from seeds germinated in central nurseries (of which there is at least one for each of the 53 townships in the Dry Zone). Given the ambition of such a program, the use of high-quality clones from tissue culture would ensure better productivity, while potentially generating higher added value for the plantations through better ability to produce poles or sawnwood.

While eucalyptus plantations are a useful contribution to wood supply in some areas of the Dry Zone, the unfavorable economics of monoculture for energy mean that other interventions are needed for commercial-scale production to meet the challenge of growing demand for charcoal. The need to increase biomass production in the Dry Zone is evident, but given the low survival rates of plantation and the poor economic potential, priority should be given to household planting and private investment in plantations with other primary outputs (as proposed above) - in addition to fuel-saving stoves (discussed below).

Figure 70 - Research plot in Meiktila area using clones from tissue culture

This illustrates the need for a comprehensive approach to the woodfuels sector. In order to satisfy commercial demand, it is necessary to promote models of tree growing and management that can generate significant firewood residues, while providing other services that are more economically attractive. In areas where few species other than eucalyptus can grow, significant productivity gains could be achieved by using better genetic stock.

❖ *Towards agroforestry systems for firewood supply*

The high rate of failure of the fuelwood plantations illustrates that other models are necessary to increase the supply of woodfuels from sustainable sources. While tree plantation for the main purpose of firewood production might not be commercially viable, analysis of current woodfuels supply trends suggests that household agroforestry and small private woodlots are more likely to succeed in the long-term.

Indeed, home gardens are already a major supply of firewood for many families, and a significant proportion of the trees used to produce charcoal in the central Dry Zone were orginally planted for reasons other than growing fuel, but have later been sold for this purpose: Mango (*Mangifera indica*), Kokko/rain tree (*Albizia lebbeck*), Tamarind (*Tamarindus indica*), and Sitsee (*Gluta usitata*), for example. This suggests that decentralized, mixed-use tree growing for multiple purposes – including fuel – is a viable option for supplying firewood and even charcoal in areas of high deficit, particularly as natural forest resources are depleted.

More could be done to support farmers to plant trees around their fields, develop multi-strata home gardens and woodlots, as well as to encourage tree planting in public parts of villages, building on models that are already popular with farmers. These trees should be selected to provide added-value in terms of improved soil fertility using nitrogen-fixing trees (such as *Gliricidia sepium*), income generation (fruits, poles, timber), and other services such as wind break and shade.

These models will also provide firewood as a residue. While the potential supply per hectare might be lower than a dedicated fuelwood plantation, and the first harvest is likely to come later, the rate of success is likely to be much higher than fuelwood plantations if closely integrated into farmers' practices. In the longer-term this could represent a significant source of woodfuels. But it requires a significant shift in interventions that are currently highly centralized and led by government authorities, to focus instead on mixed-used forestry models that integrate with farmers' needs and builds on their existing practices.

Recommendations:

- Research the coverage and nature of mixed-used tree configurations on farms, to establish their prevalence and determine their woodfuel production potential, with a view to potentially supporting an expanded approach.
- Re-orient farmer support from the Forest Department and Dry Zone Greening Department towards demand-responsive supply of high-quality planting material suitable for mixed-use household configurations.

❖ *Community forestry and forest restoration*

Community forestry (CF) was introduced in Myanmar in 1995, with the issuance of Community Forestry Instructions by the Forest Department. The model of CF was inspired by successful experiences in Nepal, with an initial goal of addressing a perceived deficit of firewood.

According to the Center for People and Forests (RECOFTC), there are around 255,000 ha of community forests and 4,800 user groups in Myanmar, mostly located in Sagaing, Magway, Ayeyarwady, Rakhine, and Tanintharyi.[102] Despite this, CF has not spread widely beyond areas where it was supported by development projects. While CF initially focused on forest preservation and subsistence use, the government updated the Community Forestry Instructions in 2016 to allow Community Forest Enterprises to be set up for productive commercial purposes.

As such, CF establishment is not expected to increase significantly the amount of firewood available in the short-term without significant investment in restoration, sustainable forest management or plantations. Indeed, many community forests are established on forest lands where firewood collection is already happening. While the implementation of sustainable forest management practices will allow a sustainable level of supply to be maintained, and hopefully increase the amount of wood that can be sustainably sourced, it will not add significant supply volumes in the short-term.

The real potential of CF in relation to woodfuels lies in avoiding non-sustainable harvesting and restoring degraded areas to a level where they can contribute to national sustainable energy supply. The MRRP aims to restore 331,392 ha of natural forests and implement enrichment planting in an additional 59,623 ha. These activities, along with the expansion of CF, should be directed towards the identified hotspot areas as much as possible, to maximize the potential impact on the woodfuels sector.

In addition to restoration initiatives, the development of Community Forest Enterprises, in partnership with the private sector, has the potential to generate significant quantities of residues. More specifically, it might allow better valorization of the residues for local charcoal producers, as most of the target areas for community forests are already used for charcoal production.

[102] Dr. Maung Maung Than, personal communication.

Figure 71 - Community forest in Ayeyarwaddy

To realize its full potential, however, local communities will need to access markets and differentiate their products from illegally produced woodfuels. In addition, the contribution of CF to firewood supply goes beyond the by-products of timber production, as many models aiming at livelihoods or landscape restoration might also generate residues that will contribute to reducing firewood-related pressure.

It is important to have realistic expectations that reflect local realities. Some communities might have difficulty accepting common ownership in particular areas, that is especially the case in areas highly affected by charcoal production. In these areas, transition from an un-controlled harvesting to community-based natural resources management might be difficult to achieved.

In some areas close to commercial plantation producing charcoal-grade residues, linkage with private sector could be an interesting way to engage in a change of practices. This will however, require an enabling policy framework to provide incentives for charcoal producers to switch their practices.

Recommendations:

- Identify and promote community forestry models that can generate significant quantities of residues with woodfuel potential, particularly oriented to timber production.
- Explore opportunities for including charcoal production from whole trees in community forest management plans, where not commercially suitable for timber or pole markets.
- Introduce tax incentives for community forestry products, along with a simplified Chain of Custody system.
- Be realistic in expectations of local community capacities, and provide long-term support in following up the management plan.
- Ensure that legal, sustainable woodfuels sourced from community forests face less bureaucracy and offer buyers a lower cost than charcoal from unlicensed sources.

❖ ***Lead voluntary carbon investments in tree planting***

There is significant and growing interest in tree planting by major multinational companies from the technology, oil, and airline sectors. As recent examples, Microsoft have recently announced ambitious climate plans involving carbon offset in the forestry sector;[103] oil companies such as Shell[104] and BP[105] are committed to offsetting part of their emissions; and Total has created a dedicated business unit to invest in tree plantation projects, with a budget of US$1 billion.[106]

The market for afforestation and reforestation carbon credits increased by 342% between 2016 and 2018, to reach 8.4 million tCO_2e.[107] It is expected that this market will continue to grow, although the price of these credits is likely to remain low, which will favor monocropping projects with potential negative impacts on local environments. Carbon finance could nevertheless represent a good opportunity to support tree planting and reforestation, if proper government leadership is assured. To maximize their impact, these projects should be integrated into a coherent strategy in order to contribute to long-term supply in the woodfuels sector.

c) Modernization of charcoal production

❖ *Governance and traceability of the charcoal sector*

The charcoal sector has been identified as the most significant woodfuel in terms of forest degradation risks. One metric ton of charcoal would, on average, lead to the emission of 5.5 tCO_2 (fNRB of 52% as calculated in previous section). With carbon pricing of US$ 20/tCO_2, this would represent US$ 110, around half of the current retail price. This illustrates how the charcoal price fails to include any environmental externalities, and shows a significant gap in today's regulation.

Most of this production is currently illegal, given that the amount of charcoal production authorized is one order of magnitude lower than the current level of demand. This is counterproductive as it does not provide incentives for improving the sustainability of the system. In addition, the regulations on charcoal (presented in Annex 6.2) require all the actors to register and obtain permits from the Forest Department. The monitoring of these regulations is made virtually impossible, however, because it is impossible to identify trucks carrying charcoal or to keep track of the flows of charcoal and adherence to allowable quotas (Figure 72).

Figure 72 - Charcoal middlemen transferring charcoal from a modern truck to distribution vehicles in Yangon

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[103] https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/

[104] https://www.ft.com/content/bae6481a-59da-11e9-939a-341f5ada9d40

[105] https://www.bp.com/en/global/corporate/sustainability/climate-change/case-studies/selecting-carbon-offsetting-projects.html

[106] https://www.total.com/en/commitment/environmental-issues-challenges/climate-change/carbon-sink-businesses

[107] Stephen Donofrio et al., "State of the Voluntary Carbon Markets Report 2019" (Washington: Forest Trends' Ecosystem Marketplace, 2019).

The inclusion of the charcoal sector in emission reduction programs could lead to a virtuous cycle. As a starting point, it requires acknowledgment of the failings of the current situation and the development of a transition plan to switch production away from natural forests.

In each region, based on the current demand and supply balance, a strategy should be elaborated to increase supply. This could come by providing incentives to private plantations to sell their residues to local charcoal producers, using tax breaks or results-based financing based on the greenhouse gas emissions avoided.

Given the current gap between the reality of trade volumes and the level of authorized production, there is also a need to ease the conditions of authorization to encourage compliance and bring the industry fully into the formal, mainstream economy. There could be a progressive increase in the official fees and the fines imposed on unregistered production and transport of charcoal, for re-investment in forest restoration activities.

To improve the tracking of charcoal flows, distributors could be obliged to declare their trips and the quantity of the charcoal they intend to deliver. Random checks along major roads could incentivize distributors to declare their production. For trucks with license plates, automatic number recognition could also be achieved using artificial intelligence that is already widely used in other parts of the world.

Initial investments would be needed to finance the first restoration activities, but in the longer-term, if law enforcement is strong enough, this investment can be partially paid back by fee collection, fines and results-based financing.

- ***Improvements in charcoal production efficiency***

Charcoal production in Myanmar is relatively inefficient, partly due to the inherent nature of the conversion process which delivers a product primarily composed of carbon and emits significant energy (heat) in doing so, but also due to the fact that producers often use inefficient technologies and processes, probably achieving conversion efficiencies of no more than 15% by weight. Producers are not a homogenous category, however, and a wide range of technologies and practices are observed, demonstrating high variability in knowledge and skills (Figure 73).

Figure 73 - Charcoal kilns of increasing technical sophistication

Conversion efficiencies of 30-40% can be achieved using the most advanced carbonization technologies. Improved charcoal kilns have therefore been promoted around the world as a way to increase the sustainability and profitability of the sector. There are, however, few successful examples of their long-term adoption.

This is because existing technologies are often well-adapted to the local context. Charcoal producers in Pathein, for example, locate their kilns close to the wood source to minimize haulage distances and to stay hidden from the authorities. This makes the introduction of more efficient fixed kilns unfeasible. Meanwhile producers in the central Dry Zone may not be able to access clay with which to build more advanced kilns in which airflow can be properly controlled. Brick or metal technologies meanwhile require significant investment. A small-scale retort, for example, costs around US$ 1,500. This is beyond the investment capacity of many actors in the sector, and in addition requires materials that may be difficult to find in remote areas.

While a technology switch may be feasible in some case, for the vast majority of charcoal producers, significant energy efficiency is better achieved using low-cost techniques and incremental change in technology and operations, as presented below:

1. **Wood drying:** During the first phase of the charcoal production process, the energy released by the burning wood will be re-absorbed to evaporate the water it contains. During this phase the temperature in the kiln will remain around 100^{o}C until the wood is completely dry. This is a wasteful use of the wood energy, yet none of the charcoal producers surveyed were drying their wood, resulting in high energy losses through evaporation. Even if proper drying of the wood load may not be feasible for producers operating in the forests, this practice should at least be promoted for producers in the Dry Zone.

2. **Switch to locally adapted kilns:** All the charcoal producers surveyed learned their skills from colleagues or family members. There is little evidence of innovation, and unimproved practices are recirculated. Significant improvements can be made to local methods, especially in the case of the earth kiln, which is the least efficient technology observed due to improper air circulation and air flow control. A switch to technologies that allow better control of carbonization and air flow would allow producers to achieve significant energy savings and yield improvements, while not incurring additional costs and retaining most elements of the kiln with which they are already familiar.

3. **Improving kiln operations:** Charcoal yield is directly correlated with operational factors such as heating rate, peak temperature, and residence time. Not only can the type of technology strongly influence the ability to control these parameters, but the skill of the operators and their willingness to improve quality and yield can also make a significant difference. In Cambodia, minor adaptation to existing kilns and training in better operations resulted in a reduction in the carbonization cycle from 21 days to 10 days, increased yields by 50%, increased fixed carbon content by 40%, and raised calorific value by 10%.[108] Given the low baseline efficiency of charcoal kilns in Myanmar, similar gains could be achieved with such adjustments. If skilled trainers are initially required to train charcoal producers, they can in return become trainers of new charcoal producers and contribute to the dissemination of best practice.

The organization of field exchange visits inside Myanmar and to other Mekong countries would be beneficial for building a regional network of trainers. This field learning could be run alongside theorical training applied to the process of charcoal making, to allow Forest Department staff and charcoal producers to better comprehend the science of carbonization, and to be able to disseminate this knowledge during large-scale training programs including regional exchange.

Recommendations:

- Develop technical training materials for Training of Trainers on energy efficiency and quality improvement for charcoal production.
- Train Forest Department field staff on basics of charcoal production and key principles to improve operation efficiency.
- As part of the licensing process, provide quick training to charcoal producers and distribute a guide on how to operate charcoal kilns efficiently.
- Consider larger-scale training of non-registered charcoal producers.
- Develop a Mekong-wide regional training program, with interaction and exchange between charcoal producers to improve artisanal skills for better quality and efficiency.

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[108] Mission report from Dr. Patrick Rousset, researcher on biomass energy conversion processes.

5.3. Support cleaner and more efficient woodfuel use

a) Clean and efficient household cookstoves

❖ ***Market-based and fully subsidies approach***

At the time of the Myanmar Cookstoves Market Assessment in 2015, household cooking was dominated by the 3-stone open fire in rural areas and multi-purpose charcoal stoves in urban areas (Figure 74). At that time, 65% of households in rural areas of the Delta, Dry Zone and Plains were relying on 3-stone fires, leading to significant energy losses during cooking and a risk of HAP if kitchens are not well ventilated.

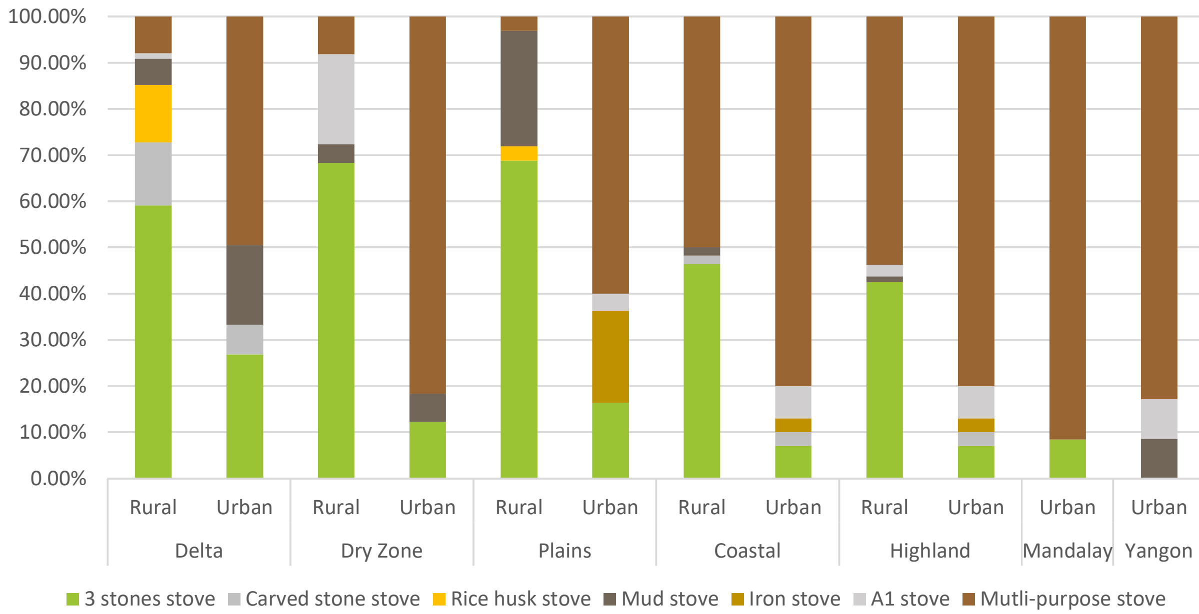

Figure 74 - Share of cookstove use in Myanmar

Source: Emerging Market Consulting for Geres

A modified version of the 3-stone fire made of cement blocks or cut stones can now be found across the Delta and the Dry Zone (Figure 75). It is often classified as an 'improved' stove, though remains relatively inefficient.

Figure 75 - The most common types of cookstoves for firewood in Myanmar

Several actors have been involved in improved cookstove dissemination, following different models and strategies.

Geres (with funding from EU SWITCH) has been running the 'SCALE' program[109] to support the dissemination of the 'A1' stove in the central Dry Zone and an improved version of the Pathein stove (Figure 76), both locally manufactured. Based on the Kitchen Performance Test, these cookstoves deliver savings of 0.7 t and 0.12 of firewood per stove per year, respectively, representing 35% and 7% fuel savings. While the SCALE program has

[109] 'Strengthening improved Cookstove Access towards a better quality of Life and Environment'.

supported stove promotion and given technical assistance to producers, there has been no subsidy at the point of sale.

Figure 76 - Worker in a Pathein stove workshop in Ayeyarwaddy

Mercy Corps has meanwhile been working with MONREC to disseminate the high efficiency Chinese-made Envirofit 'Super Saver' stove, which reportedly delivers a 50% fuel saving compared to the 3-stone fire. Dissemination is subsidized by carbon finance under the Gold Standard.[110]

Figure 77 - Cooking with a high-efficiency cooking stove as part of the Myanmar Stove Campaign

Photo: Mercy Corps

More recently, the South Korean NGO Climate Change Center (CCC) has established a partnership with the DZGD for a fully subsidized campaign to disseminate the 'E-FREE Cook Stove', which is locally manufactured by the Myanmar Ceramic Society. Dissemination is funded through a carbon credit program under the UNFCCC Clean Development Mechanism and aims to reach 224,000 households in the Dry Zone. On average, 24% of households in each township are targeted.

Another fully subsidized stove intervention is under development, led by the Global Green Growth Institute, to support dissemination in hard to reach villages of the Delta. Once again, the model is expected to be funded by

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[110] Carbon credits can be purchased online on the Gold Standard website: https://www.goldstandard.org/projects/myanmar-stoves-campaign

the sales of carbon credits under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA),[111] which may generate between 1.6 and 3.7 billion t of demand for offsets between 2021 and 2035.[112]

These initiatives illustrate different models of improved cookstove distribution using both locally manufactured and more efficient imported stoves, with different levels of subsidy.

Given the ability of the Geres / Mercy Corps project to sell improved cookstoves in the Dry Zone and Delta (Figure 78), the resources invested in heavily subsidized stove programs could be usefully redirected away from blanket hardware subsidy, for example to give partial subsidy, or to cover the poorest or most remote villages, or to fund marketing campaigns and promotional work.

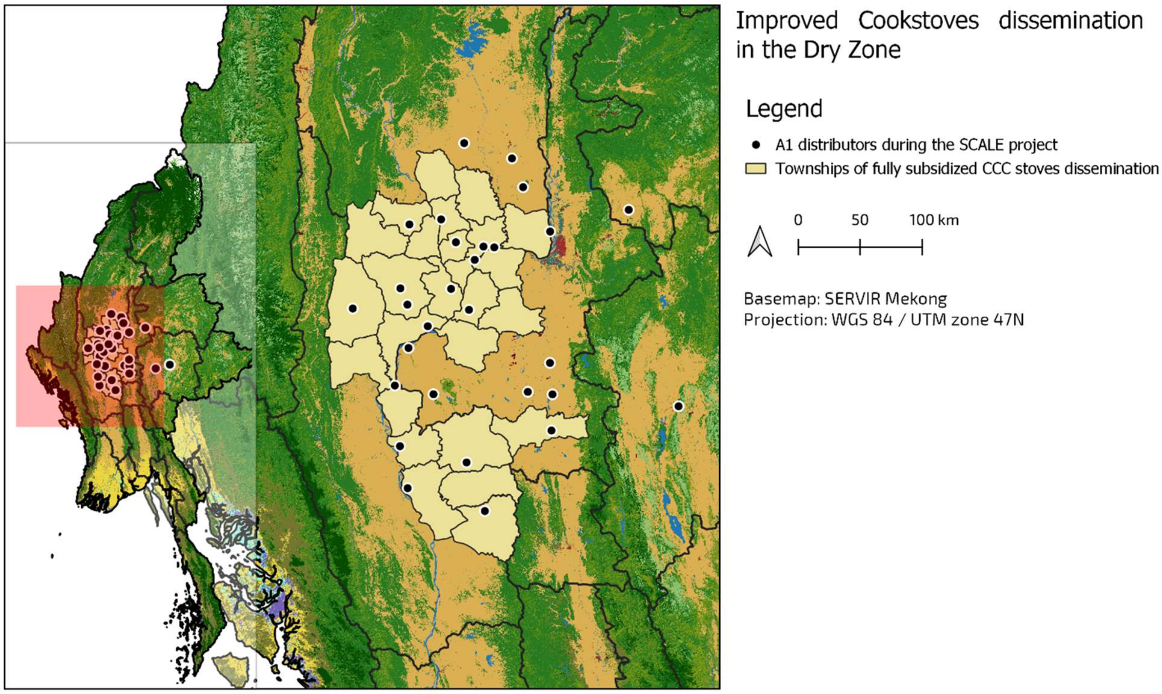

Figure 78 - Townships targeted by CCC and distributors supported by Geres for improved stove dissemination in the Dry Zone

With the exception of the stove disseminated by Mercy Corps, the cookstoves described have a relatively short lifetime, sometimes less than two years. While replacement is planned for in most fully subsidized schemes, this depends on the capacity of the project developers to sell the carbon credits in a market that is already saturated.

Most of these initiatives target firewood stoves, while charcoal consumption is likely to be more impactful on the forest resources. Further support should therefore be directed towards improved charcoal stove design, production and promotion. Charcoal users are wealthier than firewood users and are likely to be more interested in investing in a device that saves them fuel – and hence money. Charcoal stoves producers in Pathein, previously supported by Geres, noted that demand for their products was going down, mostly due to households shifting to lower performance cement stoves in the absence of awareness-raining activities and promotional campaign on the benefits of higher quality appliances.

With the exception of the Envirofit stoves imported by Mercy Corps, the cookstoves being promoted are artisanal and made locally at small scale. Given the size of the woodfuels sector in Myanmar and the on-going industrialization of the country, greater emphasis should be given to building industrial scale cookstove manufacturing within the country, targeting both firewood and charcoal consumers. That would require phasing away from fully subsidized and government-led distribution of cookstoves, to models that support the private sector to establish local fabrication and distribution networks countrywide. Improving the efficiency of

[111] CORSIA is a program run by the International Civil Aviation Organization to reduce and offset carbon emissions from international aviation and meet the industry goal to achieve carbon-neutral growth from 2020.
[112] Donofrio et al., "State of the Voluntary Carbon Markets Report 2019."

household energy use, while developing the capacity to produce high-quality, high efficiency cookstoves within Myanmar, should be seen as a priority for the sector.

- ***Trends in carbon finance for improved cookstoves***

Carbon finance has been playing a key role in many improved cookstove (ICS) programs that were either directly funded through carbon finance or had carbon finance as part of their long-term strategy. While some improvement in the consistency of the use of carbon funds to support ICS has been noted, they remain a crucial source of funding for such programs.

Globally, the market for clean cookstoves increased by 113% between 2016 and 2018, from 2.3 to 4.9 million tCO_2e, with a relatively steady (but low) price of US$ 5/tCO_2e in 2018.[113] After many years of decline, there is renewed in interest in offsetting from major companies.

The development of the CORSIA carbon market is expected to increase the regional demand for carbon credits. The involvement of major Southeast Asian airlines from the beginning of the program will likely lead to an demand for credits from countries in the region, as these companies will be looking for positive impact stories beyond the carbon offset.

It is important to note that current carbon methodologies for carbon calculations significantly overestimate the amount of credits generated by ICS, as they do for other interventions intended to woodfuel consumption. However, given the current low price of carbon credits, this overestimate means that the funding received comes closer to the level required to achieve a transformational impact.

Recommendations:

- Develop a national cookstove strategy for Myanmar, including harmonized guidelines on the use of subsidies to ensure a level playing field and maximize sustainability.
- Organize advertising and marketing campaigns on improved cookstoves adapted to the cooking practices of each region.
- Support local stove producers to ensure a minimum level of quality and build their technical and marketing capacities.
- Develop tax and other incentives for local manufacturing firms, to encourage private investment in the mass production of high-performance stoves within Myanmar.

b) Energy efficiency in industries

- ***Energy efficiency in industrial steam production***

There is significant potential for improving the efficiency of steam production in industrial installations, and thereby reduce energy costs, making these industries more competitive and in some cases leading to greenhouse gas emission reductions.

Before embarking on a fuel switch or boiler retrofits, several lower-cost interventions can first be considered to reduce energy consumption by upgrading existing machinery:

- **Install steam condensate recovery system**: A steam condensate recovery system using steam traps is one of the best solutions for improving boiler efficiency. Reusing condensate water reduces the need for blowdown (adding new water to the system) and reduces the energy consumption of the boiler by pre-warming the water in the system.
- **Improve steam pipe insulation**: Leakage of steam and poor insultation of steam pipe is another common source of energy loss. Energy audits shows that insulation along the steam pipe is not very

[113] Donofrio et al.

common, especially in small-scale industries with a steam production capacity of less than 1 t/hr. Installing foam pipe insulation block can improve the steam system in both SMEs and large industries.

- **Install solar thermal assistance**: Direct solar heating systems can be used to produce hot water for low temperature processes, such as textile dyeing, where a temperature of 70-90 °C is required. However, solar heating has low potential to pre-heat boiler water for factories with steam condensate recovery systems.
- **Biomass fuel pre-drying**: Depending on the solar radiation availability in the industry location, fuel with high moisture content can be pre-dried using solar dryers. The use of wet fuel is commonly seen in the garment and F&B industries.
- **Increase capacity for energy management**: Energy Management Systems are new in the Myanmar energy sector and there is frequently not accurate monitoring of energy consumption or personnel with the necessary skills for effective industrial energy management. The lack of reliable data on historical energy consumption also makes it difficult for Energy Service Companies to engage with factories through an 'energy-as-a-service' model.

In addition to the potential savings that can be achieved at low cost, significant gains in energy efficiency can be achieved by retrofitting or switching boiler technologies. According to the Boiler Inspection Department, around 1,179 boilers are registered using "unwaste biomass" (mainly firewood or rice husk) as their main fuel. 65% have a steam production capacity below 2 t/hour (Figure 79). These boilers generally have low efficiency, sometimes below 40%, with high-energy savings achievable by switching to advanced horizontal fixed or moving grate solid fuel boilers optimized for rice husk pellets.[114] For factories equipped with low efficiency boilers, the payback time could be less than two years, with energy savings higher than 50%.[115]

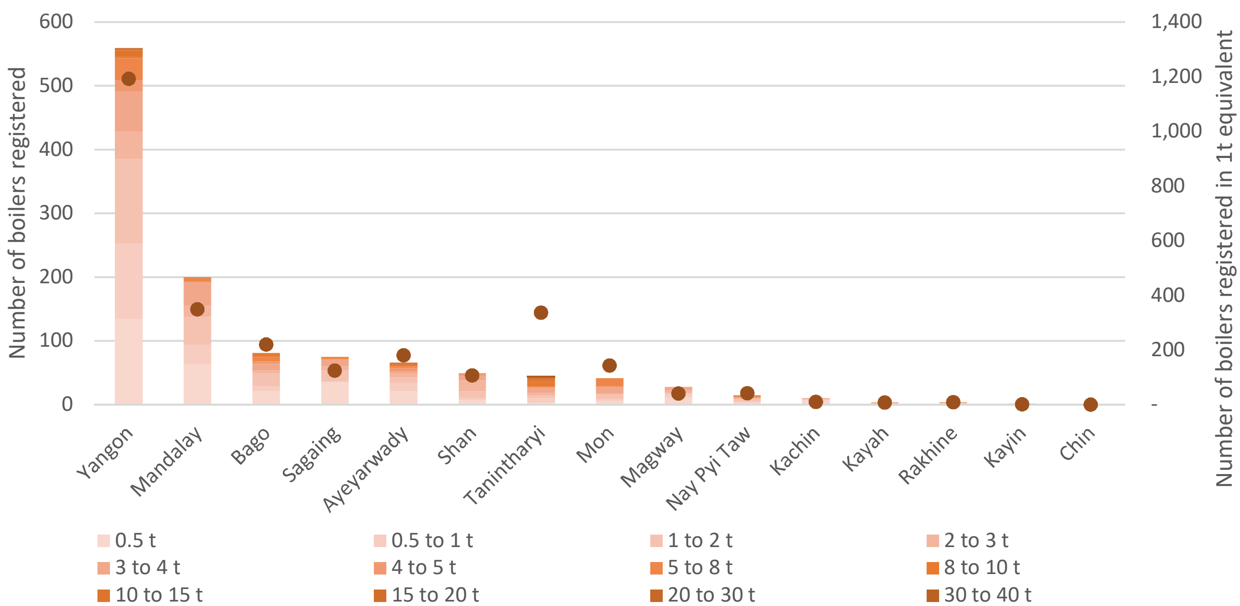

Figure 79 - Number of "unwaste biomass" boilers registered with the Boiler Inspection Department per division/state

Based on data from Geres (for H&M), the relationship between boiler steam production capacity and firewood consumption can be established (Figure 80). Based on this regression and the energy saving potential, it can be estimated that a switch in boiler technology can lead to average fuel saving of around 135 t of firewood per metric ton of steam production capacity.

[114] Petelot, "Sustainable Alternatives for Steam Production in Garment Factories Supplying H&M in Myanmar."
[115] Eric Buysman, "Feasibility Study of a Credit-Line Program for Energy Efficiency Projects in Cambodia" (Geres for AFD, 2018).

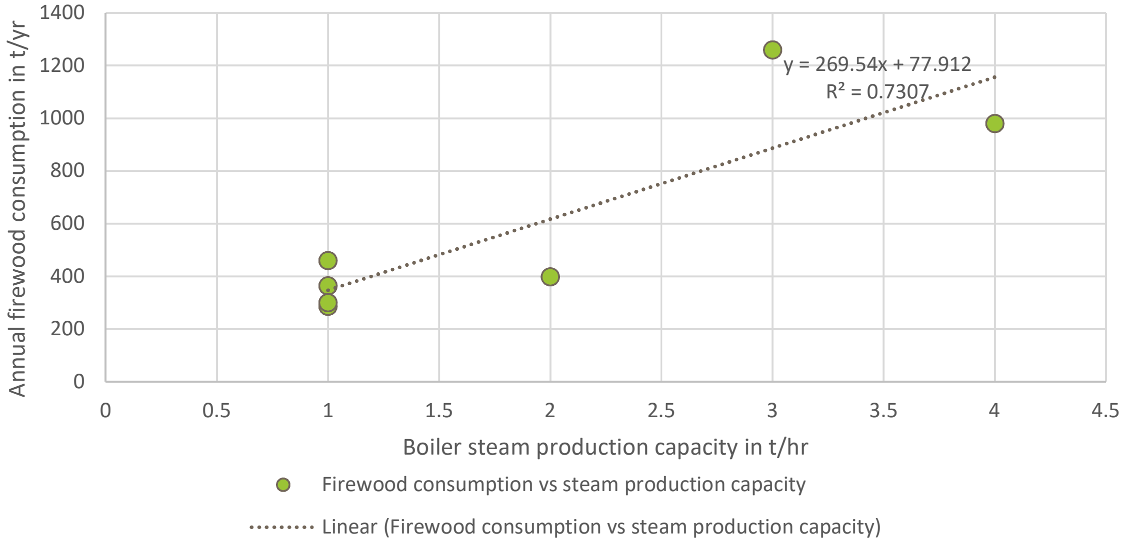

Figure 80 - Relationship between boiler steam production capacity and firewood consumption

While improving efficiency is relevant to reduce cost in many locations, priority for improving boiler technology should be given to those areas most at risk from non-sustainable biomass use. Based on data from the Boiler Inspection Department, 303 boilers are registered in the states of Magway, Mandalay, and Sagaing, where availability of rice husk and wood from plantations residues is the lowest. In these areas, 211 boilers have an evaporation capacity of less than 2t/ha and should be targeted first for a boiler switch intervention.

Recommendations:

- Promote synergies with energy efficiency programs such as the Responsible Business Fund to support factories to invest in energy-efficient boilers and retrofit steam systems in priority areas for the firewood sector.

❖ ***More efficient brick-burning systems***

The main brick kiln technologies found in Myanmar are highly inefficient. Field survey reveals that clamp kilns and skove kilns are the dominant methods used (Figure 81 and Figure 82).

Figure 81 - Clamp kiln in Kakapyan village, Hmawbi Township, Yangon

Figure 82 - Skove kiln in Sartalin village, Hlegu Township, Yangon

These two kiln types, mostly used by small-scale producers, consist of a temporary structure made by stacking raw bricks, which are then fired in a batch. Some basic improvements involve daubing the outside layer with clay or mud insulation, which turns a standard clamp kiln into a skove kiln. Using these technologies, energy consumption is as high as 8 MJ per kg of finished brick.

Significant energy savings can be achieved by switching to a Chimney Bull Trench Kiln (Figure 83). This is an improved technology found in larger-scale factories. In this case the process is continuous with a moving fire that is always lit and moves forward in the direction of the air flow, thanks to a draught provided by a chimney. This results in better combustion efficiency due to the draught and the continuous nature of the process. Energy consumption is 1.5-2.8 MJ/kg of brick, with potential savings of up to 65% compared with clamp kilns.

Figure 83 - Chimney Bull Trench Kiln using firewood, Mandalay Division

The most advanced technology found is the Hoffman kiln (Figure 84). This is also a continuous production system, but in this case a mechanical air extractor provides stronger forced air draught to the chimney. While the investment requirement is higher than for the other technologies, the draught created by the air extractor leads to high combustion quality and circulation of the heat where it is needed, yielding the highest efficiency of all.

Figure 84 - Workers laying raw bricks in a Hoffman kiln as fire is progressing towards them

As well as being relatively efficient, Hoffman kilns accept a variety of fuels thanks to the good air circulation. A factory visited in Mandalay Division uses rice husk as its base fuel and adds sawdust and coal depending on availability and price. This multi-fuel strategy gives resilience to cost and availability fluctuations. For these reasons, this technology is the most commonly used option in Vietnam and Cambodia.

Figure 85 - Worker adding a mix of rice husk, sawdust, and coal to a Hoffman brick kiln in Mandalay

Recommendations:

- Provide technical training on Chimney Bull Trench Kilns and Hoffman kiln construction and operation.
- Subsidize investments for brick manufacturers located in priority areas (see below) for installation of chimneys and blowers.

❖ *Policy framework for energy efficiency in industry*

Energy efficiency programs like the Responsible Business Fund have been very successful in leveraging private sector investment. Their third phase aims to develop a guarantee scheme to reduce risks for banks investing in energy efficiency programs, as well as reducing interest rates.

Such programs generally have carbon emission reduction objectives or are even directly funded by climate change mitigation programs. Today, however, due to the methodological bias of the use of an unrealistically high fNRB figure, a factory in Yangon reducing its rubberwood consumption would be attributed the same emission reduction as a factory in Sagaing relying on non-sustainable firewood. The development of a Decision System Support with location-specific and value chain-specific fNRB values would allow such programs to prioritize their interventions more appropriately so that resources are allocated where they can achieve the highest impact.

5.4. Building an enabling framework for sustainable woodfuels

The wide range of sectors with an interest in woodfuels and the of variety of interventions required, mean that ministries other than MONREC (and its Forest Department and Dry Zone Greening Department) need to be involved in the design and implementation of an integrated approach to the development of a sustainable woodfuels sector. As an example, one of the key sources of firewood for industry is rubberwood, the production of which falls within the mandate of the Department of Agriculture in the Ministry of Agriculture, Livestock and Irrigation. The Ministry of Energy (and its Myanmar Petrochemical Enterprise in the context of LPG) has a lead role to play in promoting any fuel switch. The Ministry of Planning, Finance and Industry is meanwhile instrumental in programs to improve energy efficiency in industry or promoting the use of rice husk and sawdust to support sustainable industrial development that reduces reliance on fossil fuels. An inter-ministerial coordination mechanism is therefore essential to answer to woodfuel challenges and opportunities.

One of the objectives of this study was to assess policy options for developing a more sustainable woodfuels sector in Myanmar and, more specifically, the potential for carbon pricing to support this process. Although applying a carbon pricing mechanism in the context of a developing country like Myanmar is very challenging, there is great potential to implement a science-based carbon approach to prioritize interventions in the woodfuels sector, within the framework of a coordinated inter-ministerial approach, and prepare the sector for potential inclusion in REDD+ activities or other results-based financing mechanisms.

As presented in the previous sections, the impact of woodfuel value chains on Myanmar's forests varies significantly according to location and the specifics of the value chain in question. If firewood supply for industries in Yangon or the Delta area might not be of significant concern due to the (suspected) high availability of rubberwood and rice husk, this is not the case for the charcoal sector which, for the same areas, is responsible for a level of wood extraction that is not sustainable. In the central Dry Zone, the low potential for rice husk supply and the long distances from plantations also means that the woodfuel supply is at risk of exceeding the mean annual increment and being non-sustainable.

Most carbon finance initiatives related to woodfuels rely on an assumed fNRB to calculate the impact of proposed interventions on the climate. These methodologies tend to significantly over-estimate the impact of woodfuels on carbon emissions.[116] More importantly, when calculated at the national level they are not able to inform policymakers on which value chains they should focus their limited resources. The modeling approach developed for this study has been able to identify and quantify priority hotspots of charcoal- and firewood-induced forest degradation. It has allowed a first estimate to be made of a more reliable fNRB for Myanmar, which could be improved with future work.

Better fNRB figures allow the carbon emissions linked with various value chains to be compared, and therefore for interventions to be prioritized based on their carbon pricing potential. Forest and energy programs could be compared against the supply-demand model to assess their impact on the sustainability of the value chain in question.

In addition, by being able to attribute a reduction in forest degradation to a woodfuels-related activity, this approach could allow the sector to benefit from future REDD+ financing. The inability to measure forest degradation means that woodfuel activities might not be directly included in current carbon calculations for REDD+, but this may change in the near future with the development of a National Forest Inventory along with a new space-based LIDAR system[117] and upcoming SAR satellite.[118]

In the meantime, further work is necessary to reliably quantify carbon emissions from the woodfuel pressure areas. Firstly, the contribution from plantations to the supply of firewood needs to be better estimated. That requires accurate mapping of the plantations using remote sensing and machine learning techniques. Current assumptions on mean annual increment then need to be established with much higher accuracy than at present, to determine if the level of sustainable harvesting is being exceeded.

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[116] Bailis et al., "The Carbon Footprint of Traditional Woodfuels."

[117] Global Ecosystem Dynamics Investigation LIDAR (GEDI): https://gedi.umd.edu/

[118] ESA BIOMASS : https://www.esa.int/Applications/Observing_the_Earth/The_Living_Planet_Programme/Earth_Explorers/Biomass

6. Annexes

6.1. Study Methodology

a) Woodfuel consumption for household cooking

The assessment of woodfuel demand for household cooking was made by clustering household cooking patterns into physiographic zones, to establish average woodfuel demand per adult-equivalent for households using either firewood, charcoal or electricity as their main fuel. A variety of data sources were used, as illustrated in Figure 86.

National level

- Woodfuels use per type of technology per adult-equivalent
  Data: Kitchen Performance Tests from Geres (2017)

Physiographic level

- Households main cooking stove use
  Data: Myanmar Cookstove Market Assessment from EMC/Geres (data collection in early 2015)
- Firewood collection / purchase patterns
  Data: National survey from ADB (data collection in 2014) and Geres (data collection in early 2015)

Township level

- Main cooking fuel used by households
  Data: Population and Housing Census (2014)

Village/Town level

- Population in adult-equivalent
  Data: Population and Housing Census (2014)

Figure 86 - Data sources used for estimation of woodfuel demand for household cooking

For consistency and accuracy, it was decided to use data on primary cooking fuels from the 2014 Population and Housing Census. As well was offering detailed information down to township level, the census was implemented at the same time as the Myanmar Cookstove Market Assessment (by EMC for Geres)[119] and the ADB Myanmar Energy Consumption Surveys,[120] which provide compatibility between the datasets.

These surveys were used to provide information on cooking stove use (both ADB and Geres) and firewood collection patterns (Geres only). These data were combined with results from Kitchen Performance Tests,[121] which measure household fuel consumption in adult-equivalent, to establish averages of fuel consumption and fuel collection patterns based on the primary cooking energy sources for the main physiographic regions of Myanmar: Delta, Plains, Dry Zone, Highland, and Coastal, as well as for Yangon and Mandalay (Figure 87).

Data on the percentage of households cooking with firewood or charcoal as their main energy source was extrapolated to township level, based on the population in adult-equivalent of each village and town from the 2014 Census.

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[119] Emerging Markets Consulting, "Myanmar Cookstoves Market Assessment."
[120] Asian Development Bank, "Myanmar Energy Consumption Surveys."
[121] Kitchen Performance Tests give an estimation of household fuel consumption based on actual cooking stoves and practices. For more information: https://www.cleancookingalliance.org/technology-and-fuels/testing/protocols.html

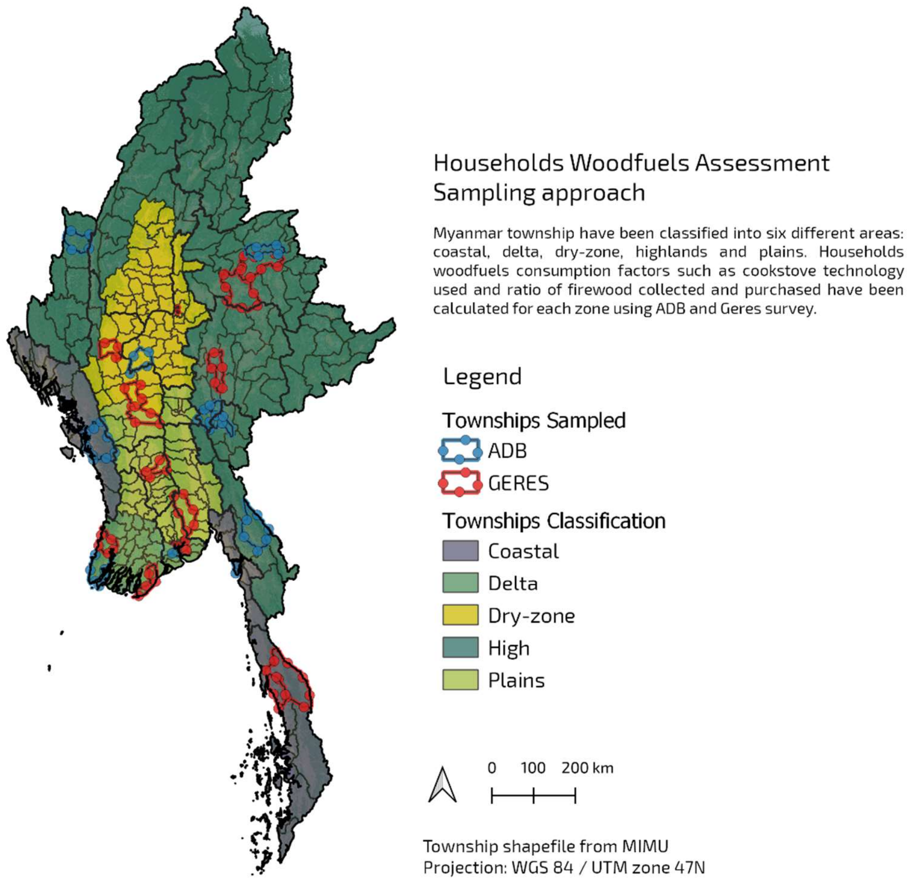

Figure 87 - Townships sampled by ADB and Geres to estimate household woodfuel demand

b) Woodfuel consumption in commercial and industrial sectors

Woodfuel consumption in the industrial sector was assessed based on field survey, phone survey, and compilation of previous research.

In 2014, the FRI carried out a study[122] on fuel consumption in cottage industries in townships in Ayeyarwaddy, Mandalay, Sagaing, Bago, and Shan States. This study investigated woodfuel consumption by cottage industries in four of these five states (excluding Shan). In 2019, MSR undertook an assessment of the fish and shrimp drying and garment sector for UN-REDD, providing some consumption data for the firewood users in these sectors. In 2019, Geres carried out research for H&M to assess the situation of boilers and opportunities for alternative biomass use in the garment sector. This provided consumption data and analysis of boiler technologies and improvement opportunities. These data were combined with 30 field visits across Myanmar targeting unexplored sectors. These visits were supplemented with phone survey to collect quantitative information on fuel use, as well as current use of rice husk in the rice milling sector. The distribution of the samples used in the assessment of the industrial sector is presented in Table 17.

Table 17 – Sample sizes for industry and commercial catering surveys

	Ayeyarwaddy	Bago	Magway	Mandalay	Sagaing	Tanintharyi	Yangon	Total
FRI	4	20		15	8			**47**
Field survey	5			8			17	**30**
Geres for H&M							14	**14**
MSR for UN-REDD	8						10	**18**
Phone survey	23	78	1	21	20	3		**151**
Total	**40**	**98**	**1**	**44**	**28**	**3**	**41**	**260**

[122] Forest Research Institute, "Study of Biomass Fuel Consumption."

Using these data, firewood use ratio and average firewood consumption for firewood users were estimated and extrapolated using data from the CSO Statistical Business Register.

c) Woodfuel value chains

To characterize the charcoal value chains of Myanmar's main urban centers (Yangon and Mandalay), three surveyors hired by Geres conducted surveys to trace supply 'backwards' from city retailers to the charcoal kilns, and sometime right back to the forests where the wood was harvested.

Over a period of three weeks in November and December 2019, 33 charcoal retailers, 17 intermediaries, and 16 producers were interviewed. This revealed three different types of charcoal value chains with their origins in Pathein, Bago, and Mandalay Divisions. This work complements a previous assessment by MSR for UN-REDD, which surveyed the local markets of Magway, Myeik, and Pathein.

While the small sample size and potential biases inherent in 'snowball' research mean that these results may not be a comprehensive representation of the national charcoal sector, the findings do illustrate the diversity of the industry in terms of products, structure, and potential impact on forest resources.

d) Hotspot modeling

As the modeling approach was relatively computationally intensive, instead of running the model for all the village and towns of Myanmar, the demand from households and industries was applied only to the main town in each district. To account for smuggling to China and Thailand, two additional demand points were added close to the export locations, with an assumed demand equal to three times the official export values for each country reported to UN Comtrade. To account for the supply of rubber for household and industrial use, no commercial firewood demand was considered for the regions of Tanintharyi, Mon, Kayin, Yangon, and East Bago. A cost-distance model was then run outwards from the demand centers using a friction raster with the parameters listed in Table 18.

Table 18 – Parameters used for the development of the cost-distance friction model

Land cover/land use		Crossing time (min/km)
River		12
Road	Main	1
	Secondary	1.5
	Tertiary	2
Land-use	Surface water	12
	Snow and ice	30
	Mangroves	48
	Flooded forests	30
	Forests	30
	Orchard or plantations	30
	Evergreen broadleaf	30
	Mixed forests	30
	Residential	2
	Cropland	6
	Rice	6
	Mining	30
	Bare areas	6
	Wetlands	30
	Grassland	6
	Shrubland	30
	Aquaculture	30

A discount factor was applied to each crossing time based on slope, using the following equation:

$$Crossing\ time_{new} = \frac{Crossing\ time_{old}}{e^{(-3*slope\ percentage)}}$$

Once the locations reachable within 8 hours from each district center were identified, the areas below a defined commercially viable biomass stocking level were excluded. Using a global map of AGB from the European Space Agency,[123] a minimum AGB stock of 50 t/ha was assumed as the commercially viable threshold for charcoal, while a minimum AGB stock of 5 t/ha was applied to traded firewood. To represent the impact of demand from Thailand on the mangroves of Tanintharyi, a minimum of 5 t was applied to correct uncertainties related to mangrove biomass estimation in the European Space Agency data.

The demand from each district center was then applied to these areas and another iteration was run for the next district, before summing the pressures from all districts and producing a national pressure map.

e) Carbon footprint

The carbon footprint was calculated using the approach developed by Bailis *et al.*[124] All the following formula are taken from this source, unless stated otherwise.

First, AGB was converted to dendro-energy biomass (which excludes twigs, leaves, and stumps) using Equation 1.

Equation 1 – Formula for the calculation of dendro-energy biomass (DEB)

$$DEB = \begin{cases} 0.80 \times AGB, if\ AGB < 46\ t/ha \\ 0.85 \times AGB, if\ AGB \geq 46\ t/ha \end{cases}$$

Based on the DEB, a sustainable increment was then computed using the relationship shown in Figure 88.

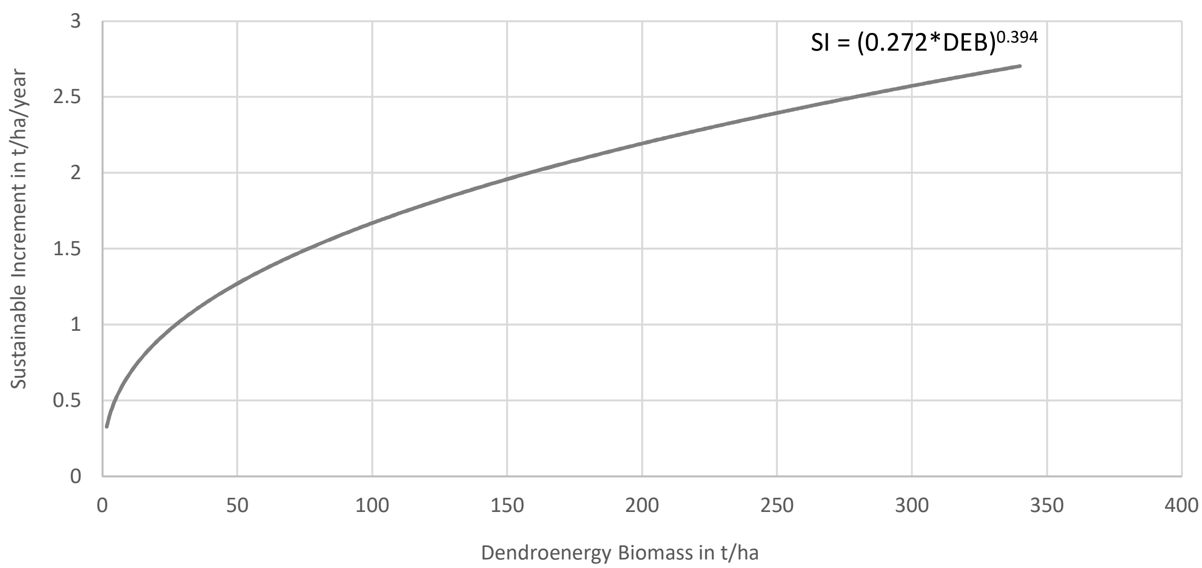

Figure 88 – Calculation of Mean Annual Increment of the dendro-energy biomass

Using the previously calculated values, the fraction of non-renewable biomass was calculated using Equation 2.

Equation 2 – Formula for the calculation of the fraction of non-renewable biomass

$$fNRB_i = \frac{\sum_j (H_j - S_j)}{\sum_j H_j}$$

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123 European Space Agency (ESA), "New Biomass Map to Take Stock of the World's Carbon," accessed January 17, 2020, https://www.esa.int/Applications/Observing_the_Earth/Space_for_our_climate/New_biomass_map_to_take_stock_of_the_world_s_carbon.

124 Bailis et al., "The Carbon Footprint of Traditional Woodfuels."

(where S_j and H_j are the sustainable increment and woodfuels harvest in the cells j contained in township *i*).

Finally, the emissions in tCO_2 were calculated using Equation 3.

Equation 3 – Formula for the calculation of CO2 emissions

$$E\_CO2_i = H_i \times fNRB_i \times NCV \times EF$$

where:

NCV	=	*Net Calorific Value*	=	*0.0156 TJ/t (IPCC, 2003)*
EF	=	*Emission Factor*	=	*112 TJ/t (IPCC, 2003)*

and SI_i , $SEIF_i$ and H_i are as defined previously.

6.2. Regulatory requirements for charcoal production and trade

According to notification number 9/85, the felling of indigenous trees to produce charcoal and to trade without legal permission from State/Division authority is permissible under the Forest Law Section 33 Sub-section 2.c. Legal charcoal production and trade procedures were released by the (former) Ministry of Agriculture and Forest in 1986.

There are seven stages in the charcoal-making process that require official licensing:

1. **Kiln construction:** To construct a kiln, permission is required from the township officer of the Forest Department. Applications must be accompanied by the location of kiln, type of kiln, output per batch, and output per year. The township officer is expected to ascertain the condition of the forest, estimate the sustainable wood supply, and secure approval from his/her superiors, including the State/Division level officer and Township People's Council Executive Committee.
2. **Tree felling for charcoal production:** In Delta Region, fuelwood plantation areas are open for cutting under a coppicing system, based on guidelines from the State/Division Forest Department Officer. The areas for coppicing must be visually demarcated to differentiate them from areas being reserved for subsequent years. The township officer is responsible for estimating the available supply from these plantations, specifying where cutting is allowed and the amount of firewood that can be produced. Charcoal production from mangrove wood is not officially permitted.
3. **Record keeping at kiln sites:** The following records must be kept:
    I. Kiln construction permit and firewood cutting permit;
    II. Quantity of inbound wood for charcoaling, with date and weight (cubic ton);
    III. Charcoal production (in bags);
    IV. Charcoal transport, with date and number of bags, on Form Ka Ka Wa (4) and Message Form L41; and
    V. List of laborers authorized for tree felling and charcoal making.
4. **Charcoal transport permit:** Within reserved forests, Form Ka Ka Wa (4) is needed for transporting the charcoal in Delta Area, while Message Form L41 is needed for transporting outside the reserved forest area.
5. **Charcoal trading permit:** Any person who trades in charcoal is required to register with the Township People's Council Executive Committee. The trader is expected to keep records of prices and sales.
6. **List of bad reputation:** The township officer needs to inform the Township People's Council Executive Committee of any permit holders who violate the terms of their permits or relevant laws. Their names are recorded in a 'list of bad reputation', and they should not be issued with another permit for kiln construction, tree cutting or charcoal trading for at least 5 years.
7. **Supervision of charcoal production:** The Township Forest Department should closely supervise all stages (kiln construction, tree felling, charcoal burning, transport, and trading) to ensure regulatory compliance.