Smart Power Myanmar

Energising Agriculture in Myanmar

A Guide To Prioritising Energy Access Investments into Agricultural Value Chains

–

SEPTEMBER 2021

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SmartPower Myanmar

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List of abbreviations

ADS	Agricultural Development Strategy
API	Application programming interface
ASEAN	Association of Southeast Asian Nations
BOO	Build-own-operate
BPO	Bean, pulses and oilseeds
CAPEX	Capital expenditure
CDZ	Central dry zone
DRD	Department of Rural Development
DRE	Distributed renewable energy
EAC	Electricity Authority of Cambodia
EPC	Engineering, procurement and construction
GDP	Gross domestic product
GIS	Geographic Information System
IEC	International Electrotechnical Commission
IFPRI	International Food Policy Research Institute
ha	Hectare
kg	Kilogram
kWh	Kilowatt hour
LCOE	Levelised cost of energy
MADB	Myanmar Agricultural Development Bank
MIMU	Myanmar Information Management Unit
MJ	Megajoule
MFI(s)	Microfinance institution(s)
MMK	Myanmar kyat
MOEE	Ministry of Electricity and Energy
MSME(s)	Micro, small and medium enterprise(s)
NEP	National Electrification Project
O&M	Operations and maintenance
OPEX	Operational expenditure
oz	Ounce
PAYG	Pay-as-you-go
PV	Photovoltaic
QAF	Quality Assurance Framework
RBF	Results-based financing
SPAM	Spatial Production Allocation Model
t	Tonne
V	Volt
VAT	Value added tax
VEC	Village Electrification Committee
VIDA	Village Data Analytics

Glossary

Agri-processor	An entity specialised in the processing of agricultural produce.
Captive power	An off-grid or behind-the-meter grid-connected energy system designed for a single offtaker.
Carding	A cotton processing step whereby fibres are disentangled to produce continuous strips called slivers.
Colour sorting	A processing step in the rice and bean value chains. Similar to grading, colour sorting involves the separation of low-quality produce from high quality produce.
Combine harvester	A mobile machine used to harvest a variety of crops. Most combine harvesters perform a variety of steps at once, including cutting crops, threshing and winnowing.
Crop production	For the purposes of this report, crop production is a geospatial data layer that signifies total annual crop production in tonnes.
Crop yield	For the purposes of this report, crop yield refers to production per area, measured in tonnes per hectare.
Downstream processing	In the chronology of agricultural processing activities, downstream processing takes place after upstream processing. These are typically more sophisticated processes and are geared towards quality-conscious markets.
Dehulling	A processing step in the beans, pulses and oilseeds value chain whereby the skin of the kernel is removed.
De-husking	A processing step in the rice value chain whereby the rice kernel is separated from its husk.
Deshelling	A processing step in the beans, pulses and oilseeds value chain whereby the kernel is removed from its casing.
Destoning	A processing step in the rice and beans, pulses and oilseeds value chains whereby unwanted materials such as stones are removed from the harvest. This forms part of the cleaning process.
LCOE	The cost of generating energy, calculated by dividing CAPEX and discounted annual expenses by discounted energy generation. Expenses and generation are discounted using a discount rate.
Loom	A device used to perform weaving of cotton.
Micro-utility	A grid-connected captive power system owned by the developer which sells electricity units to one or more customers through a behind-the-meter network.
Milling	Milling is a loosely defined term that can be used in a variety of ways in different contexts. In this report, it refers to a series of rice processing steps to make rice suitable for human consumption. This includes threshing, de-husking, destoning, grading, sorting, polishing and parboiling.
Mini-grid	A distributed renewable energy system that supplies electricity generated by one or more energy sources to a variety of off-takers through a low voltage network. Mini-grids can be connected to the main grid, but are typically isolated.
Productive use of energy	Energy used for the purpose of performing agricultural, commercial or industrial activities. Energy demand from productive uses typically exceeds that of household use.
Upstream processing	In the chronology of agricultural processing activities, upstream agricultural processing follows harvest. Except in cases of vertically integrated processing, upstream processing typically takes place on farms and in villages in rural areas.
Paddy	Rice before harvest
Parboiling	An optional rice processing step whereby rice is partially boiled in the husk. This is done to increase the nutritional value of rice and to reduce breakages during polishing.

Polishing Polishing either refers to the conversion of brown rice to white rice by removing the bran and the germ, or to advanced polishing, whereby the texture of white rice is smoothened.

Roving A processing step in the cotton value chain whereby the slivers (generated through carding) is thinned out in preparation for spinning. The output of roving is yarn.

Spinning A processing step in the cotton value chain whereby yarn is winded onto a spool.

Threshing A processing step in the rice and beans, pulses and oilseeds value chains whereby kernels are removed from the ear (the grain-bearing tip of the stem).

Throughput The amount of output that a processing machine can deliver within a given timeframe. Throughput is typically measured in kg/hour.

Value chain continuum A continuum illustrating the chronology of value chain activities, from production to wholesale and retail. Upstream activities are typically performed on farms and in villages in rural areas while downstream activities typically take place in grid-connected towns and cities.

Viss A Myanmar unit of weight measurement equaling 1.63 kg.

Weaving A processing step in the cotton value chain whereby yarn is interlaced to produce fabric.

Winnowing A processing step in the rice and beans, pulses and oilseeds value chain where airflow (wind or fan) is used to separate lighter kernels from heavier kernels and to separate leftover husks and shells from the kernels.

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About Smart Power Myanmar

As part of The Rockefeller Foundation's global initiative to end energy poverty, Smart Power Myanmar works at the intersection of the public and private sectors to achieve one goal: accelerate electrification through catalysing new sources of investment, knowledge and know-how, to end energy poverty and promote economic opportunity in Myanmar. Smart Power Myanmar is a part of Pact, a global non-profit development organisation, and is managed by The Rockefeller Foundation.

Smart Power Myanmar focuses on three key areas which can accelerate Myanmar's rate of rural electrification:

1. Supporting the development of a sustainable mini-grid sector;
2. Mobilising finance for household connections at village level;
3. Supporting integrated electrification planning through data analytics and research.

In partnership with multilateral and bilateral donors (including The World Bank, JICA and The Rockefeller Foundation), private banks, off-grid developers, non-profit development organisations and communities across Myanmar, since launching in 2018 Smart Power Myanmar has:

- Directly financed nearly 2,000 connections and enabled another 40,000, impacting 224,000 people with connections to both on-grid and off-grid electricity;
- Facilitated 31,000 micro-finance loans for last-mile grid connections nationwide with our sister organisation, Pact Global Microfinance, totaling $13M in approximately 2,200 villages;
- Advised on more than $150M of other development finance initiatives, including:
  - Agence Française de Développement (AFD) Sovereign Loan Facility to support mini-grid investments in Myanmar ($61M)
  - Japan International Cooperation Agency (JICA) Two Step Loan Phase 3 for both mini-grid investments and community connections ($50M)
  - KfW innovative finance for leveraging mini-grid investment ($20M)
  - Italian Agency for Development Cooperation (AICS) funds for mini-grid project development and productive use support ($30M)
  - Designed local bank facilities mobilising more than $18M in support of mini-grids;
  - Created the $575,000 Energy Impact Fund, a revolving fund to help support community connections and productive uses in rural communities; and
  - Provided groundbreaking research, insights and business intelligence to assist government, developers and other investors in making informed decisions.

About TFE Energy

TFE understands that access to affordable, clean energy will unlock the great potential of frontier markets. Working in collaboration with our partners, we continuously test and validate new data technologies in the field because we believe that they enable the high resolution insights needed to scale up decentralised energy in under-electrified places. This first-hand experience is brought into our advisory work with donor organisations, governments and private companies on decentralised energy policy, technology and delivery models. Our team consists of data technologists, community electrification experts and energy market, finance and policy analysts.

Sustainable Development Goal 7 enshrines the universal right to affordable, modern energy. We understand that this is only a first step; using this to catalyse local sustainable development requires consideration of what can most productively be done with this energy. Given the reliance of rural areas and developing economies on agriculture, energising agricultural value chains presents a clear opportunity. Leveraging our data technology and on-ground market expertise, we specifically examine the nexus between energy and agriculture in great detail, teasing out the crucial, crop, country and context specific characteristics of key value chains. Analysis of these allows us to define the practicalities, social impact, regulatory considerations and commercial viability of energy access interventions along value chains from off-grid community producers to on-grid urban exporters. This provides an invaluable guide to any organisation looking to prioritise their own investment into modernising agriculture and impactful energy access.

Foreword

This publication is targeted to everyone interested in evidence-based investment and planning related to rural electrification and the agri-food value chain in Myanmar. Beyond Myanmar, we believe that it also contains insights that add to the growing global body of knowledge around the critical link between rural energy and agricultural value chains, and the potential for improving the way electrification can power businesses at scale.

Few people would disagree that energy plays a critical role in increasing productivity of enterprises and in improving livelihoods. For a country that once boasted one of the largest agricultural markets in the world, rural agriculture in Myanmar has tremendous potential to raise rural welfare through agricultural transformation. Productivity growth in agriculture – which predominates the livelihoods of the Myanmar's rural poor – could be several times more effective than growth in other sectors in reducing rural poverty. Developing energy intensive agricultural processes, such as large-scale irrigation or milling activities can help to significantly increase the commercial viability of electricity provision.

This publication, the latest from Smart Power Myanmar, was born from our conviction that as myriad players work towards connecting the remaining two-thirds of the country to reliable electricity, we all need to better understand how to bridge the gap between supplying electricity, and linking that power to existing and future value chains to maximise rural incomes and economic growth.

Thanks to the outstanding work of TFE's research team along with their partners at AFSIM, this study explores the opportunities for synergy between the goals of rural electrification and agricultural transformation in Myanmar, based on our hypothesis that leveraging complementary investments in agriculture and electricity can yield huge dividends in terms of poverty alleviation. Our approach for this study was to assess the energy requirements of the most important agricultural value chains and to develop/propose energy solutions and business models that can help deliver access and reliable supply of electricity to these value chains in a timely and cost-effective manner.

The greatest challenge to increasing electricity access in Myanmar is how to make electricity provision financially viable in low-demand rural households and micro-enterprises. Commercially attractive rural customers – in Myanmar this means current and potential rural agricultural processing enterprises – are key to reducing the barriers to accelerating grid and off-grid approaches to rural electrification.

Despite the billions being invested in electricity infrastructure in Myanmar through private capital, government financing, concessional loans and subsidies, few resources are being channeled towards the critical and complex nexus between sources of supply of electricity, and how that power is used productively in rural value chains and businesses. Donor funded programmes focusing on agriculture in Myanmar almost universally do not include energy as a component in programme design. Off-grid and grid extension programmes generally have not had access to quality on-the-ground research, data and analytical information to be able to make informed site selection and realistic demand prediction. Mini-grid developers often lack the resources and expertise to invest in rural development to grow demand, leading sometimes to underutilised plants that have greater potential. We believe that this study will go some way to help address this gap in knowledge and data, and that it will help provide a foundation for how electrification planning and financing should be best directed for maximum benefit for both on-grid and off-grid customers.

An understanding of how value chains can be strengthened is essential for investors, customers, government and long-term sustainability and revenue flows. Prior to the political upheaval of 1st February 2021 Myanmar was beginning to successfully attract investment interest and had secured multilateral financing for critical electrification infrastructure; on the other, national agriculture programmes, bilateral funding and development organisations were supporting a variety of agriculture programmes. However, there was little to no evidence that any programme or initiative was focusing strategically on how electrification and the productive use of electrification – incorporating the critical link with value chains – were related.

A brighter future for Myanmar's rural poor will require not only access to power, but access to power ***within the context of complex rural value chains***. For Myanmar's rural poor to be able to step up and out of well-trodden cycles of poverty, electricity needs to be configured to power productivity, and for this to happen, tens of thousands of villages across the country will need the access and means to convert their micro-enterprises to improve the way produce is irrigated, processed, milled, stored and transported.

We hope that the findings from this report will encourage policy makers, financing institutions, private companies and technical support agencies from both the energy and the agricultural sectors to support a more informed and strategic approach towards the vital connection between electrification planning and the agri-food value chain. Ultimately, this can help Myanmar to move closer to meeting ambitious sustainable development goals.

Richard Harrison
CEO, Smart Power Myanmar

June 2021

Executive summary

As an agrarian society, Myanmar's economy is tied to its currently underperforming agricultural productivity. Mechanisation and improved farming practices will boost the sector, but both rely on affordable and reliable access to energy.

Energy access challenges are not confined to rural off-grid regions, they extend down agricultural value chains to on-grid urban markets where larger processors prepare output that is ready for wholesale or export markets.

As one of the first of its kind to explore the agriculture/energy nexus beyond village scale productive uses, this study:

- Describes tools that can be used to evaluate agricultural processes along the entire value chain continuum from small off-grid processors in the village to large on-grid urban factories.
- Combines existing best practice,[1] geospatial data, on-ground surveys and market information[2] to evaluate the energy needs, value addition and practical characteristics of processing steps along three economically significant value chains in Myanmar; rice, cotton and BPO (beans, pulses and oilseeds).
- Outlines opportunities to strategically invest in improving energy access along value chains to increase the value captured by rural farmers, boost processor productivity and strengthen this nationally vital sector.

1 Access to Energy Institute, Productive Use Report, 2019 (*link*)
Springer-Heinze, Andreas & GIZ, ValueLinks 2.0. Manual on Sustainable Value Chain Development, 2018 (*link*)

2 Smart Power Myanmar, Decentralised Energy Market Assessment in Myanmar, 2019 (*link*)
The World Bank, Myanmar Rice and Pulses: Farm Production Economics and Value Chain Dynamics, 2019 (*link*)
The World Bank, Myanmar Food and Agriculture System Project PID/ISDS, 2020 (*link*)
IFC, Myanmar Distributed Generation Scoping Study, 2019 (offline)

Key findings

Energy, agriculture and their contextual dynamics can be visualised as a continuum ranging from upstream, off-grid regions on one end, to downstream on-grid areas on the other. This provides a useful framework for evaluating the challenges, opportunities and likely impacts of an intervention focused on energy and agriculture at different points along the value chain.

Along the agricultural value chains analysed, **processing provides the most promising opportunity for electrification investment.** This is true for the electrification of typically manual upstream processes like rice threshing in the village as well as providing back-up power to large downstream processors like cotton spinning factories in areas where the grid is unreliable.

- Decentralised energy technologies have a higher LCOE than the subsidised grid tariff. They also deliver more reliable energy supply, meaning machines can keep running. The resulting **increased income can justify the LCOE from decentralised renewable energy systems.**

  Recommendation: *Focus electrification efforts on agricultural processing activities with high utility (those that add significant value to the product).*

- Interventions at different points of the value chain require different investments and deliver different types of outcomes. Focusing an energy intervention on small-scale **upstream agricultural processing** (e.g. threshing rice and pressing oilseeds) is well suited to mini-grids in off-grid areas where the addition of agricultural processing can stimulate energy demand directly and indirectly strengthen the local economy. This in turn enhances mini-grid commercial viability.

  Recommendation: *Facilitate dialogue and better linkages between the agriculture and energy sectors. Leverage existing and emerging businesses (e.g. fintech providers) and distribution channels (e.g. mini-grid operators, agricultural extension workers) to extend the reach of financial services into rural areas so that farmers and processors can access processing equipment.*

- Although upstream, off-grid projects will generally be more resource intensive (e.g. technical assistance and training) and require more grant and other development finance, they will also tend to yield greater **social impact (**e.g. improving rural livelihoods).

  Recommendation: *Support local project developers with standardised designs, bulk procurement, data and GIS tools to identify high-value sites. Develop, establish and maintain an effective enabling environment for off-grid project developers and operators. This includes tailored finance, technical assistance and better clarity on tariffs, licensing and grid encroachment.*

- Energy interventions focused on **downstream** medium- and large-scale processing (e.g. bean colour sorting and cotton spinning) will be well suited to captive power systems like rooftop solar and/or battery storage to supplement grid supply during blackouts.

  Recommendation: *Improve access to data on grid location and quality at agriculturally significant weak-grid locations. On-ground surveys and sensor networks could help fill these gaps.*

- Downstream projects will have higher value addition, better economies of scale and lower LCOE than upstream off-grid interventions meaning that they can better compete with grid tariffs and fuel generators. The increase in processor uptime and hence revenue facilitated by reliable energy supply yields greater **economic return per dollar invested.**

  Recommendation: *Enhance coordination between the public and private sectors to establish, develop and maintain an effective business enabling environment for DRE project developers. This might include developing support programmes, updating regulation and tailoring finance for captive power solutions.*

- The economic profile of downstream interventions means that they suit **scaled investment that is able to leverage commercial finance.**

  Recommendation: *Build the capacity of local lenders to develop financial products tailored to captive power solutions specifically. Develop national support mechanisms to de-risk investment into the sector (e.g. first loss pools).*

1.0 Introduction

As the world globalises and once disparate markets continue to merge, the complex web of our food systems spreads ever wider. This brings down costs for consumers and widens the selection and availability of produce. However, it also introduces new pressures of competition between producers; those with mechanised, efficient operations are favoured. Underpinning almost all of these operations is access to affordable and reliable energy. This dependency or nexus between agriculture and energy becomes increasingly relevant as developing economies begin to engage in international markets and their local, often rural producers shift from subsistence to facing more intense competition as they attempt to sell their products into global markets. As a predominantly agrarian nation, Myanmar is one such emerging player:

- With agriculture contributing 30% to gross domestic product (GDP)[3] and providing livelihoods for nearly 70% of the population, Myanmar's economy is tied to agricultural productivity.
- With vast tracts of fertile soil, abundant labour and the expansive waterways of the lower Mekong basin, Myanmar is endowed with significant agricultural resources. It is also strategically located between the two major export markets of India and China.
- However, many years of insufficient investment in critical infrastructure has meant that Myanmar is not converting its competitive advantages into realised value.[4]
- The country consistently ranks poorly among its regional peers in terms of productivity and profitability of cultivated land.
- A key constraint is the low level of access to the energy required to produce more, and better quality, agricultural produce and value by processing what is grown.
- At approximately 50%, Myanmar has the lowest electrification rate in South East Asia,[5] with farming areas having even lower rates of electrification. Even on-grid areas suffer from regular outages.

Figure 1: Rice productivity across seasons for regional peers[6]

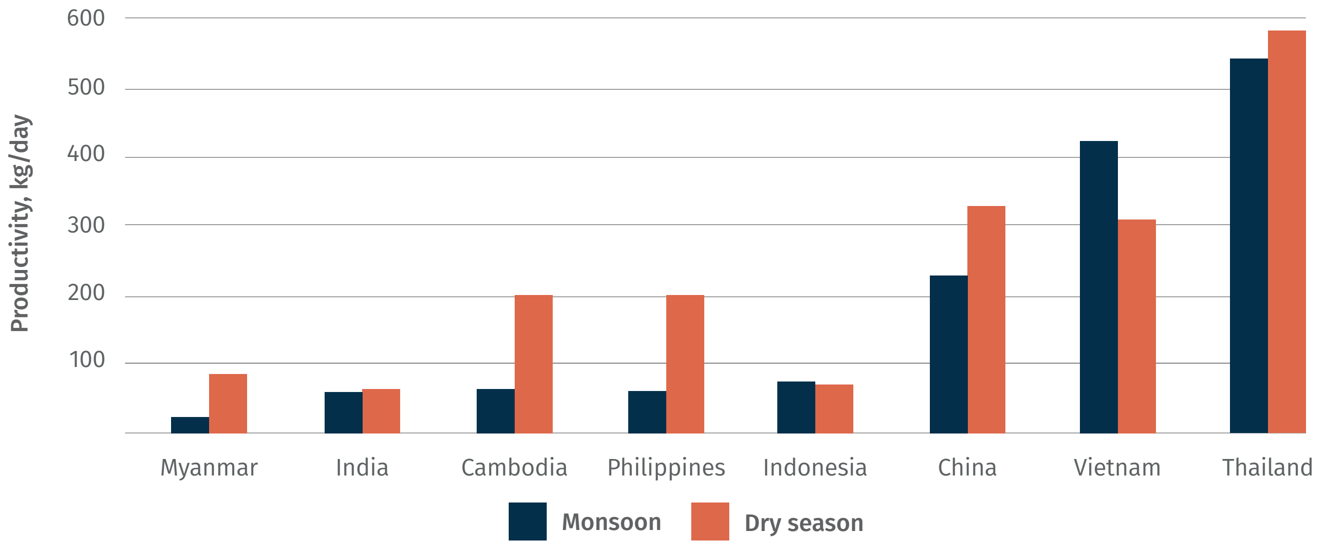
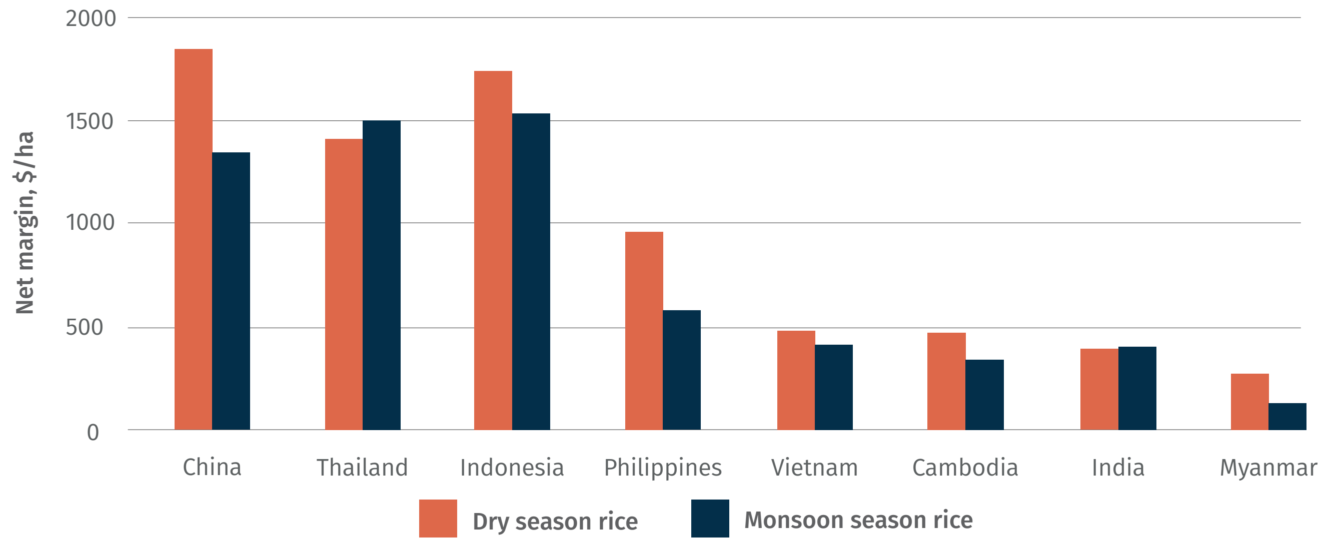


Figure 2: Profits from rice production compared to regional peers



3 The World Bank, Myanmar Food and Agriculture System Project, 2020 (*link*)
4 The World Bank, Myanmar Farm Production Economics, 2016 (*link*)
5 The World Bank, Press Release (*link*)
6 Data for Myanmar are for Ayeyarwady. Data for other countries refer only to one key rice-growing area. Day refers to one workday. The World Bank, Myanmar Farm Production Economics, 2016 (*link*)

1.1 Deriving value from energy access

Between 1990 and 2015, the per capita energy consumption in Myanmar increased five-fold to around 250 kWh annually.[7] Over the same period, the country's energy intensity, a measure of how efficiently energy is converted to economic value (as measured by GDP), declined from more than 15MJ/$ to around 3MJ/$, indicating a five-fold improvement.[8] Geographically inconsistent access to energy infrastructure however means that these gains are not realised equitably across the country. The pattern is a common one; in most developing economies, energy gets more expensive and less available the further one travels from central, urban areas. The effects of this are particularly evident when looking at the value chains of sectors that span rural and urban economies.

Agriculture in Myanmar is one such sector; low levels of energy access in rural areas limit the ability of rural producers to process their crops. This drives energy-enabled value addition further down the value chain and further away from agriculturally productive rural communities. Despite their critical role at the source of these key value chains, rural communities receive a fraction of the total value created between field and consumer. Instead, value capture is concentrated in large commercial downstream processing or lost to market inefficiencies. This, in turn, exacerbates the rural/urban divide and keeps rural communities in Myanmar locked in a cycle of poverty.

Improving energy access at the local level can help shift agricultural value addition upstream to both strengthen value chains and drive rural socio-economic development.

7 International Energy Agency, Myanmar Country Profile, 2021 (*link*)
8 World Development Indicators (WDI) access through Knoema (*link*)

1.0 Introduction

1.2 Productive uses of energy and the complexity of value chains

Access to better quality energy is not the only factor driving the value addition further down the value chain and out of the reach of rural communities. There is a plethora of publications[9,10] and projects promoting productive uses of power as a panacea to rural poverty. However, these do not always recognise that unlocking the full value of increased production or improved output quality is a function of factors wider than those at the village level.

1. Firstly, once local demand for produce is met, the value of increased supply can only be realised via access to external markets where surplus can be sold.
2. Secondly, the dynamics that make an agricultural processing activity commercially viable are complex, crop specific and highly dependent on local and national enabling environments. For example, **the economic profile of an agricultural processor is highly sensitive to throughput,** in other words, the quantity and regularity of product being processed. To achieve viability, minimum thresholds of throughput are required to compensate for the upfront capital expenditure of processing equipment. This will tend to favour processors at points of aggregation rather than at the source point of production in the villages, and low-cost equipment that can be used to process multiple types of crops with different seasonal profiles.

9 IIED, Remote but productive: Practical lessons from productive uses of energy in Tanzania, 2019 (*link*)
10 Cabraal, R.A., Barnes, D.F. & Agarwal, S.G., Productive Uses of Energy for Rural Development, 2005 (*link*)

Stand-alone solar irrigation

An effective energy-based agricultural intervention is the provision of stand-alone solar irrigation systems such as those offered by Proximity Designs and AgroSolar, both based in Yangon. These can significantly boost smallholder yields, provide additional cropping seasons and reduce costs[11] as well as help to insulate farmers from climate shocks and unpredictable rains. The challenges associated with solar-powered pumps and their widespread adoption centre around accessing credit to purchase the pumps and maintaining pumps of rural customers. Because they are a productised, self-contained mobile farm 'input' they differ from larger, more infrastructure-like energy interventions which provide a kWh-based energy service. Therefore along with standalone solar systems that can usefully provide light and service small loads like phone charging, these systems have not been included in this analysis.

Improved access to energy can improve agricultural value chains in three important ways:

1. **Improving farm level productivity:**[12] Improved energy access can enhance both land and labour productivity by saving on human labour and increasing efficiency.
2. **Improving off-farm processing:** Reliable and affordable energy access increases processing efficiency and quality while improving the investment case for better quality equipment.
3. **Improving market linkages and competitiveness:**[13] Increasing energy access can help reduce input costs and minimise process and transport losses. This increases competitiveness thereby unlocking access to high value markets.

Achieving the Myanmar government's Agricultural Development Strategy goals of improving national competitiveness, increasing food security and accelerating rural development, requires development in all three areas.

11 Agrosolar Myanmar claim that a farmer replacing a diesel pump with one of their solar powered systems can save $45 per month (30% of their operational costs) (*link*)

12 Shamsul, A.M. & Miah, D.M., The nexus between access to electricity and labour productivity in developing countries, 2018 (*link*)

13 USAID, Rice Productivity Improvement in Myanmar, 2013 (*link*)

1.0 Introduction

1.3 Key questions

This study provides an exploratory assessment of selected agricultural value chains in Myanmar, including their dynamics, energy-related challenges, and opportunities for electrification to reinforce or improve the functioning of those value chains. It seeks to test whether electrification and agricultural value chains can be symbiotically developed, where agricultural productive uses of energy make rural and peri-urban electrification commercially viable, and whether electrification improves the quality, volume and sale price of agricultural outputs. To maintain coherence at the intersection of two complex sectors, the study is structured around three key questions:

1. **What makes a value chain attractive for targeted energy investment?**
   - Which agricultural value chains are economically significant, suitable for decentralised energy applications and extend into rural unelectrified areas?
   - How does energy use add value to agricultural output as it flows from field to the wholesale market and what are the main energy access challenges?
2. **What methodologies can be used to prioritise intervention points along a value chain?**
   - How do structural (e.g. costs of energy, reliability of supply) and localised factors (e.g. access to markets, transport costs, aggregation potential) vary upstream and downstream?
   - What are the techno-economic considerations of a specific processing activity and how does this affect commercial viability?
   - How is data useful to guide the geographic prioritisation of investments and interventions?
3. **How to design delivery models and technologies to best convert opportunity into impact?**
   - Which energy technologies best meet local requirements?
   - Which delivery models are more suitable upstream and downstream and what type of enabling finance is most appropriate?

2.0
Key agricultural value chains in Myanmar

Agricultural value chains in Myanmar comprise a diverse mix of structures and farming systems across various regions, seasons and markets. The historic prevalence of subsistence farming and policies centred around self-sufficiency, primarily for rice paddy, have focused government support on a select few value chains at the expense of others. As a result, the agricultural sector as a whole has had limited diversification and asymmetrical private sector involvement. This has negatively affected competitiveness and the sector's potential as a driver of rural development. Recent initiatives by the World Bank and others have prioritised increasing diversification of agricultural practices, both to improve nutrition and boost agricultural livelihoods. Increasing production of livestock products, fisheries, fruit, and various industrial crops including tea, cotton, and sugarcane are promising early indicators of continued diversification and emerging investment opportunities in the country.

Yet despite the sector's shift toward greater diversification, **rice, beans and pulses continue to dominate agricultural production, collectively constituting 67% of crop output in 2016 and 75% of cultivated land in Myanmar.** Rice accounts for more than a third of agricultural output and occupies 60% of cultivated land. Beans and pulses account for another 17% of agricultural output, and together with oilseeds like sesame, are key crops for export.[14] These sectors are core to economic activity in Myanmar and also to national food security.

This suggests two important drivers of agricultural activity in Myanmar. The first is that **activities are highly concentrated in a few large and well-established sectors** with significant institutional support and economic momentum. The other is that **increasing diversification and modernisation continues to affect** the sectoral status quo, and will likely continue to do so as their benefits build momentum and early stage investment begins to bear fruit.

Considering the balance of agriculturally focused electrification priorities in light of these opposing market forces, evaluating which value chains are 'key' requires a robust assessment of several characteristics. **Characteristics and specific criteria for identifying key value chains are structured along three central themes:**

Figure 3: Dimensions for evaluating and prioritising electrification of agricultural value chains

Economic significance	• Market size: annual crop value and production volumes • Sector structure: number and size of producers and processors
Degree of convergence	• Intersection with other value chains • Geographic proximity (to other value chains, markets, infrastructure) • Similar or complementary seasonality
Energy-driven value addition	• Current and potential energy use • Potential increases in productivity and/or value addition

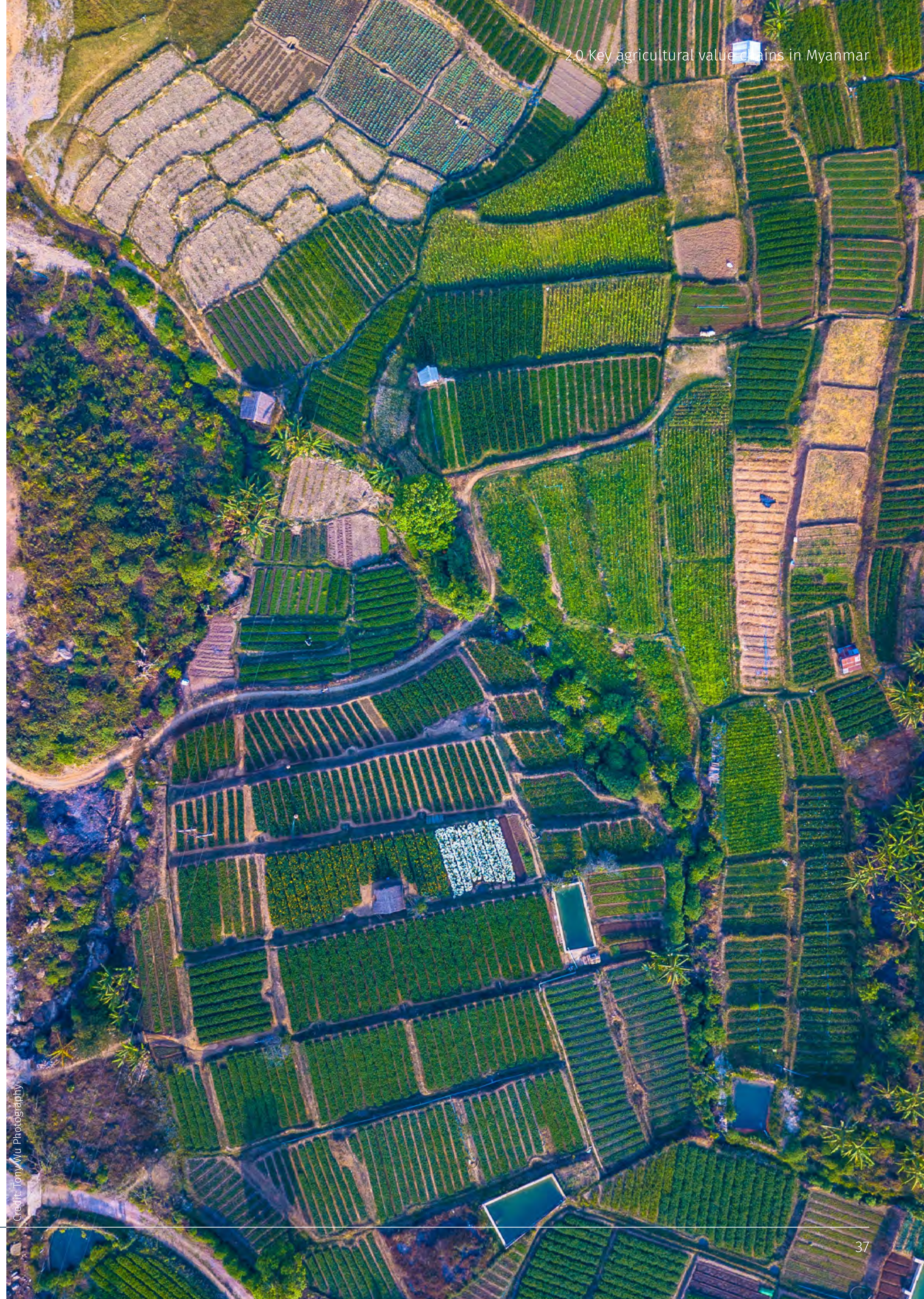
14 The World Bank, Myanmar Food and Agriculture System Project, 2020 (*link*)

Data streams used in this study

An initial longlist of key agricultural value chains was compiled using a variety of sources of secondary data such as the Ministries of Agriculture and Commerce and the Myanmar Information Management Unit (MIMU). A shortlist of value chains for deep dive analysis was generated based on selection criteria outlined in Appendix A. The final shortlist consisted of three value chains, namely rice, cotton and a grouping of beans, pulses and oilseeds. Surveys consisting of structured interviews were conducted with input suppliers, farmers, processors, traders and industry associations in each value chain. A detailed discussion of the survey process is outlined in Appendix A. Survey data was a key input for a number of analyses including energy use assessments, value addition analyses of each activity in the value chain and techno-economic modelling of agricultural machinery and energy systems.

Alongside surveying, the team performed geospatial assessments of each value chain. A variety of geospatial tools and data sources were used towards this end. These included the International Food Policy Research Institute's (IFPRI) Spatial Production Allocation Model (SPAM) database and TFE Energy's Village Data Analytics (VIDA).[15] SPAM uses a cross-entropy approach[16] to make plausible estimates of crop distribution within $10km^2$ 'pixels'. This mapping process reveals spatial patterns of crop performance. VIDA used daylight and night light satellite imagery of the whole of Myanmar, population datasets, road data, administrative boundary data, agriculture data, land cover data, township data and other relevant datasets to identify geographic determinants that would affect project location. Comprehensive details of how geospatial data was used to prioritise on-grid and off-grid interventions are presented in Appendix D.

15 TFE Energy, Village Data Analytics, 2021 (*link*)
16 A statistical approach based on the Monte Carlo method to improve and optimise sampling.


Credit: Tony Wu Photography

2.0 Key agricultural value chains in Myanmar

2.1 Rice

2.1.1 Key takeaways

- Of the value chains investigated, rice is the most relevant for scaled rural energy interventions. With the largest total crops sown area (nearly three times more than the next largest) any successful intervention on the rice value chain would have wide applicability across the country.
- However, the scale of the sector also means that there is significant competition, and the margins are thin.
- The lack of upstream processing means that rural communities in Myanmar capture a significantly smaller proportion of rice value than those in neighbouring countries.
- High value addition, reasonable capital costs and the possibility of being powered by standalone, mini-grid or captive power systems make threshing a high value, early-stage opportunity for electrification.
- Irrigation increases yields and the potential number of crop cycles. Pumping is primarily done in-field, and so best suited to standalone energy systems like solar pumping.
- De-husking provides relatively high value addition and good potential for electrification at various scales, however because rice husk protects grain during handling, transport and storage, it is important to consider the positioning of the de-husking process along the value chain.
- Farmers typically do not use electricity on-farm, even if they have access. Fuel powered machinery is used for soil preparation, water pumping and threshing purposes.
- Small-scale processors resort to fuel generators and rice husk gasification to power processing machinery in the absence of a grid connection. Medium-scale processors, benefitting from better grid access, also resort to generators during grid downtime.

Rice accounts for more than a third of Myanmar's agricultural output and is widely grown in Ayeyarwady, Bago, Sagaing and Shan states. Large and medium farms (larger than 4 ha) dominate rice production in Bago and Ayeyarwady where national production is the highest, with 75% of farms larger than 2 ha (~5 acres). Conversely, Sagaing and Shan each have higher proportions of small farms (smaller than 4 ha).[17]

17 A farm is considered small-scale if the cultivated area is less than 4 hectares (~10 acres), and farms with larger area under cultivation are collectively classified as medium or large scale.

Figure 4: Location, energy source and value addition of priority activities on the rice value chain

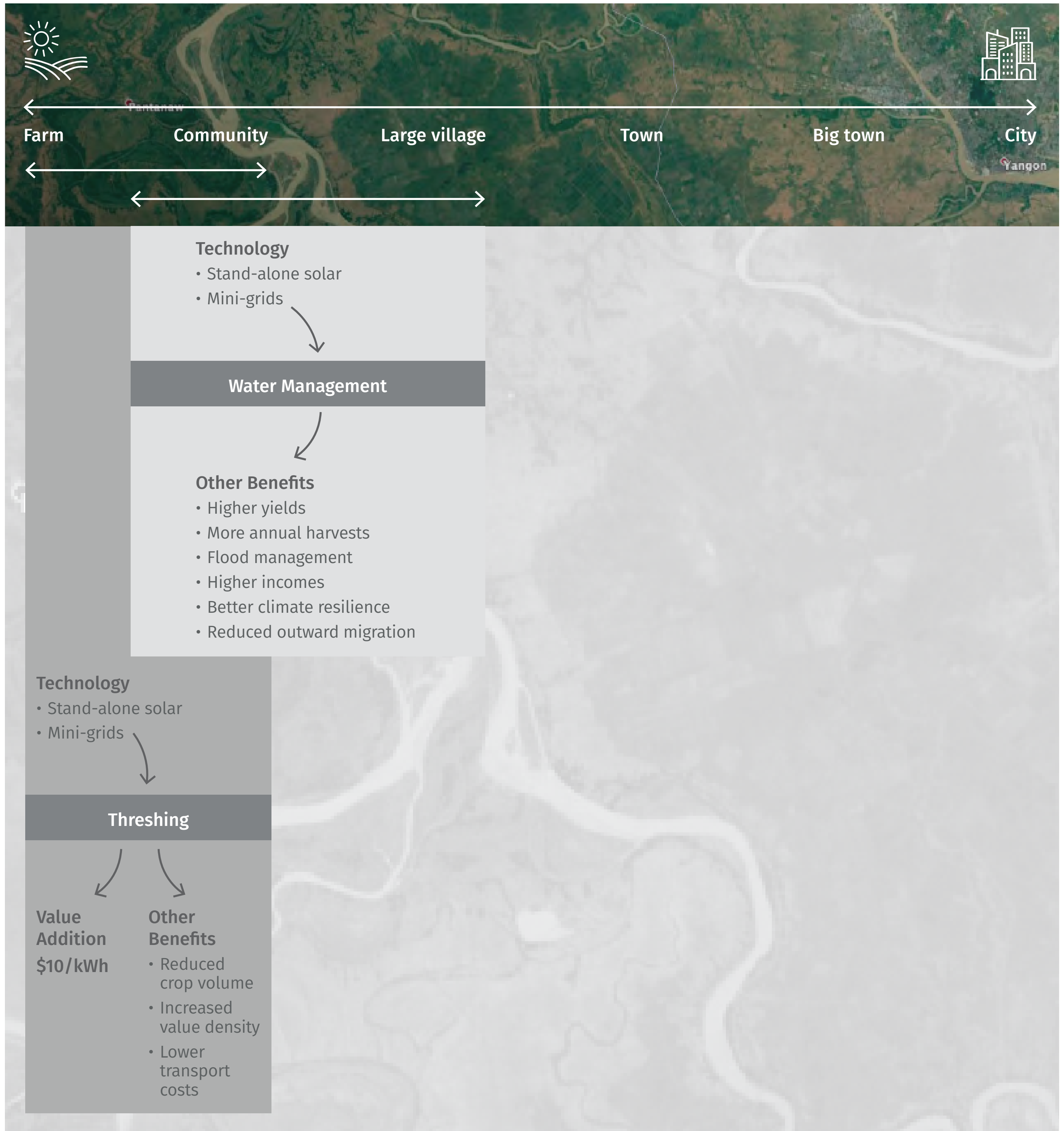
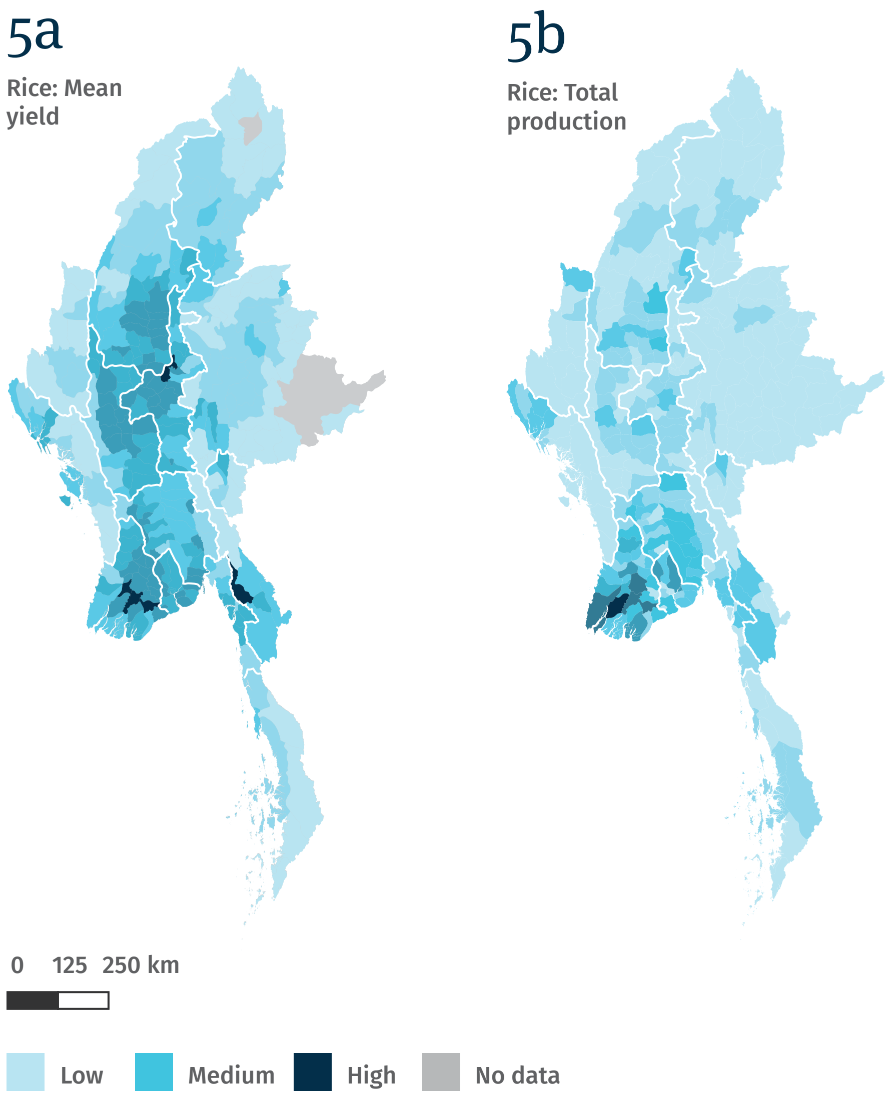


Figure 5: Rice production and yield in Myanmar[18]



Rice in Myanmar is cultivated year-round and growing seasons are generally categorised either as monsoon or dry season, owing to differences in methods, application of inputs, varieties, yields and prices across different areas. Yields (production weight/area) in the dry season exceed those in the monsoon season by around 25%. However, absolute production volumes in the monsoon season far outweigh those of the dry season due to many more farmers growing rice during the monsoon season.[19]

18 Production refers to the total production quantity of the relevant township (measured in tonnes). Yield is calculated as total production divided by the total area of the township, which makes it a measure of agricultural productivity.

19 The World Bank, Myanmar Farm Production Economics, 2016 (*link*)

Farmers cultivating dry season rice are concentrated in one of four regions: saltwater zone in Ayeyarwady, dryland and irrigated tract in Sagaing and the border area in Shan state. During the dry season, paddy is sown or transplanted between December and April, and harvest lasts from March to mid-June depending on the region. Direct seeding is the preferred method for crop establishment during the dry season, because it is less costly and labour- and water intensive than transplanting, although also less profitable.

The main months of sowing and/or transplanting in the monsoon season spread from May to August while harvest months typically fall in September and October with slight variation across regions. The most common crop establishment method in the monsoon season is transplanting, rather than direct seeding. This is generally considered to be a preferable method due to more uniform plant spacing, better control of weeds through mechanised equipment and better development of the rice plants themselves.

2.1.2 Value chain structure and energy needs

The rice value chain offers significant opportunities for electrification to improve value chain functioning at various scales and contexts. Operators across the scale spectrum are adversely affected by limited capacity and poor reliability of energy supply, affecting their ability to deliver high quality output and achieve attractive prices. For example, as a percentage of wholesale rice price, the farm-gate price of rice in Myanmar is only 47%, compared to Cambodia (53%), Vietnam (64%) and Thailand (77%).[20] There is potential for improved energy access to increase the value capture of rice higher up the value chain. Our surveys identified water management, drying, threshing, polishing, length grading and colour sorting as some of the key energy challenges.

None of the surveyed small-scale farmers and processors had grid access, resorting to standalone solar for household loads and generators for processing machinery. In a small number of cases, small-scale processors power their processing machinery with electricity from rice husk gasification. In the case of medium-scale operations, energy is primarily sourced from the national grid, with some instances of diesel backup where grid supply quality is poor.

20 The World Bank, Myanmar Farm Production Economics, 2016 (*link*)

2.0 Key agricultural value chains in Myanmar

a. Production

The small-scale farmers surveyed rely on oxen and diesel-powered machinery. Tractors for soil preparation and combine harvesters tend to be rented, while water pumps, threshing machines and grass cutting machines for animal feed are usually owned. Medium scale farmers reported better electricity access, yet on-farm use is not practiced. These farmers mainly use fuel-powered pumps to pump water, while land preparation and harvesting is done by means of fuel-powered motors of varying sizes, ranging from single cylinder walking tractors to combine harvesters. Machines are often rented or contracted as a service (on a per-day or per-hectare basis) from equipment suppliers as many farmers lack the scale, capital and capacity utilisation potential to justify acquisition.

Proper water level management is essential for wet paddy cultivation[21] and hence pumping increases farmers' yields and resilience to drought and flooding. Yet low access to irrigation and water management equipment remains a key driver in Myanmar's low paddy yield compared to other countries growing similar varieties.[22]

Table 1: Weighted average rice production per hectare by season

Season	Irrigated paddy (tonne/ha)	Rainfed paddy (tonne/ha)	Difference (%)
Monsoon Season	3.15	2.56	23%
Dry Season	4.15	3.41	22%

Farmers often rotate rice crops with beans and oilseeds intended for larger local markets and export. While this enhances utilisation of land and the capacity factor of transferable equipment like pumps, it means that crop- or season specific machinery may go underutilised for large parts of the year. Farmers are well aware of the impact of seasonality on pricing as a function of supply and therefore machine utilisation, yet most small-scale farmers and processors lack adequate storage facilities and so are unable to trade produce outside of harvest season.[23]

21 Wet paddy cultivation is defined as using more than 800 mm water over the growing season. This form of cultivation produces more than 20% higher yields than dry paddies.

22 The World Bank, Myanmar Rice and Pulses: Farm Production Economics and Value Chain Dynamics, 2019 (*Link*)

23 While it is understood that most agricultural techniques are taught across generations, the study found no evidence of culturally linked harvesting processes or a possible aversion to increasing process efficiency due to cultural beliefs. It should be noted that Myanmar has more than 100 recognised ethnicities and as a result, culturally specific agricultural practices may be common in some belief systems. However, these fall outside the scope of this study.

b. Drying

Post-harvest drying is done to remove excess moisture from the paddy before threshing can happen, while downstream drying is required to allow bulk storage and milling[24] operations. Many farmers and processors rely on sun-drying or dryers powered by burning rice husk, yet both medium-scale and small-scale farmers and processors indicated a need for better drying facilities. Mechanical drying offers the advantage of timeliness in drying, maintaining grain quality and better control over the drying process. Quality is an important factor, as current in-field and sun drying cracks kernels, resulting in Myanmar's output remaining in the lower quality tiers of export, with low selling prices and shrinking markets.

Excessively high post-harvest moisture content can severely impact the quality of rice, which in turn adversely affects prices. Dried paddy with a moisture content of around 14% sells at a premium of between 8% – 20% compared to newly harvested paddy with a moisture content of around 25%.[25] Excessive moisture content also hampers the ability of farmers and processors to store rice, which is essential for smoothing the supply curve. Smoothing supply helps prolong the processing period which reduces high demands on limited processing capacity during harvest season and allows value chain actors to sell rice when the price is higher outside of harvest season.

c. Post-harvest processing

Upstream, post-harvest processing activities are critical to increasing productivity and ensuring quality, forming a foundation for downstream processing. For example, threshing and destoning increase the density of desirable rice and in turn reduce transport requirements and cost. Weak post-harvest processing negatively affects profits, as the quality of the product remains low and farmers need to sell at times of peak supply (immediately post-harvest).

Small-scale farmers and processors of all sizes indicated a specific need for better access to threshing equipment. Threshing is the process of separating rice kernels from the ear and can be done by hand or mechanically. Threshing machines are mainly used during monsoon season, while combine harvesters can only be used when soil is dry enough for machines to drive on; in dry

24 Milling is a loose umbrella term that describes a series of rice processing steps to make rice suitable for human consumption. The term is used generally to include a range of different processes which can include threshing, dehusking, destoning, grading, sorting, polishing and parboiling. This is not to be confused with rice flour milling.

25 The World Bank, Myanmar Farm Production Economics, 2016 (*link*)

seasons. In-field threshing lends itself more to fuel-based equipment (because of the mobility requirement), while threshing at centralised locations on-farm or in villages are better suited for electrification.

Small-scale processing is largely done using traditional or outdated and inefficient machinery. Mid-chain processors, typically operating in regional hubs, indicate a need for upgrading current machinery, and for acquiring additional machinery like drying, polishing and colour-sorting to improve the quality and sale price of rice produced. There is clear demand for reliable electricity to power processing machines, especially those resulting in higher value addition and hence higher achievable sales prices. **All processors interviewed indicated a firm willingness to pay more for electricity if it would be more reliable.**

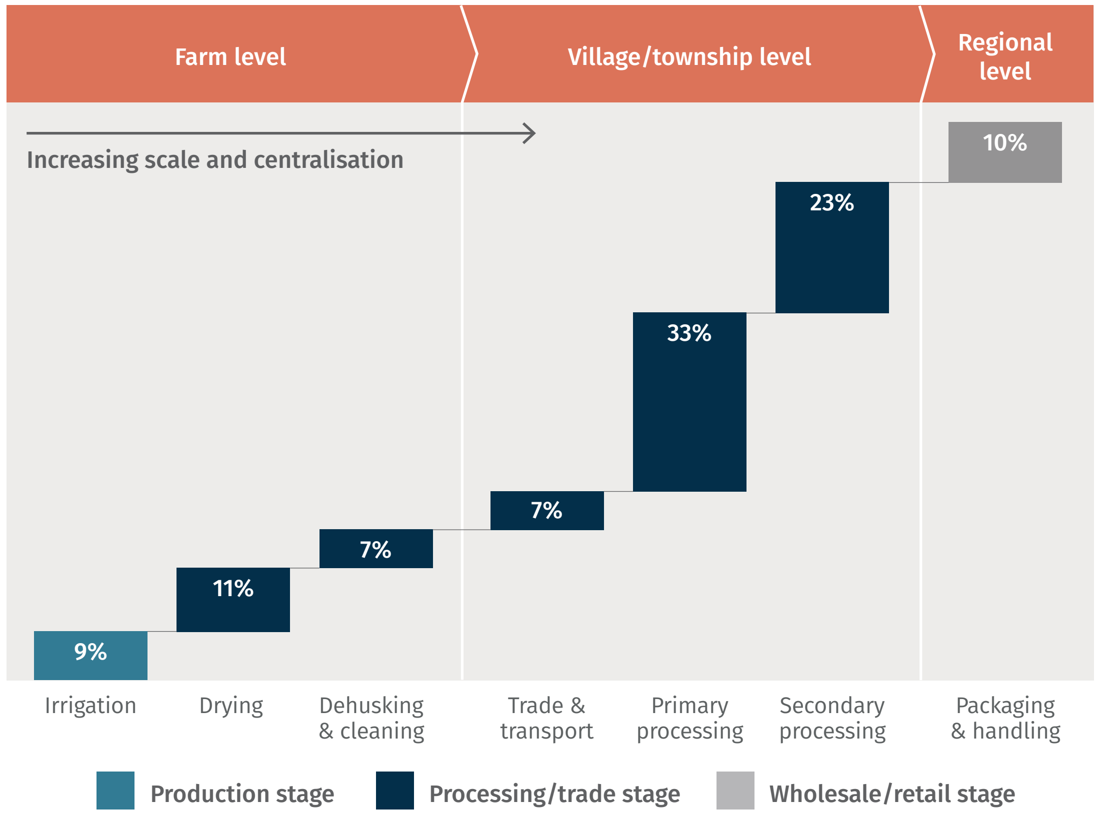
d. Secondary processing

After harvesting and threshing, farmers sell their paddy to traders, brokers or processors who move it down the chain. The roles of traders and processors are often integrated, especially in more rural areas where local small-scale processors provide critical market linkages between farmers and distributors in addition to transport, aggregation and processing services. They also provide important storage capability to help balance the large supply influx during harvest season with processing capacity, often cooperating with nearby peers. Most processors rely on small, existing networks and specific markets to buy and sell their products. Processors sell their products to local wholesalers and retailers or to wholesalers, retailers and exporters in big cities (Yangon, Mandalay, NayPyiDaw).

Downstream processing typically occurs at the medium and large scale and constitutes the final preparation of rice before being sold to market. These activities remain more relevant to addressing the demands of quality-conscious consumers, mostly in export markets. The processors and traders surveyed indicated that they experience particular energy challenges related to polishing, length grading and colour sorting. Downstream operations require significant capital investment and are thus likely to be more centralised. As Figure 6 shows, centralised downstream activities capture a larger share of the total value due to several factors including scale, networks, logistics and competition.

2.0 Key agricultural value chains in Myanmar

Figure 6: Proportional value addition of specific activities in the rice value chain[26]

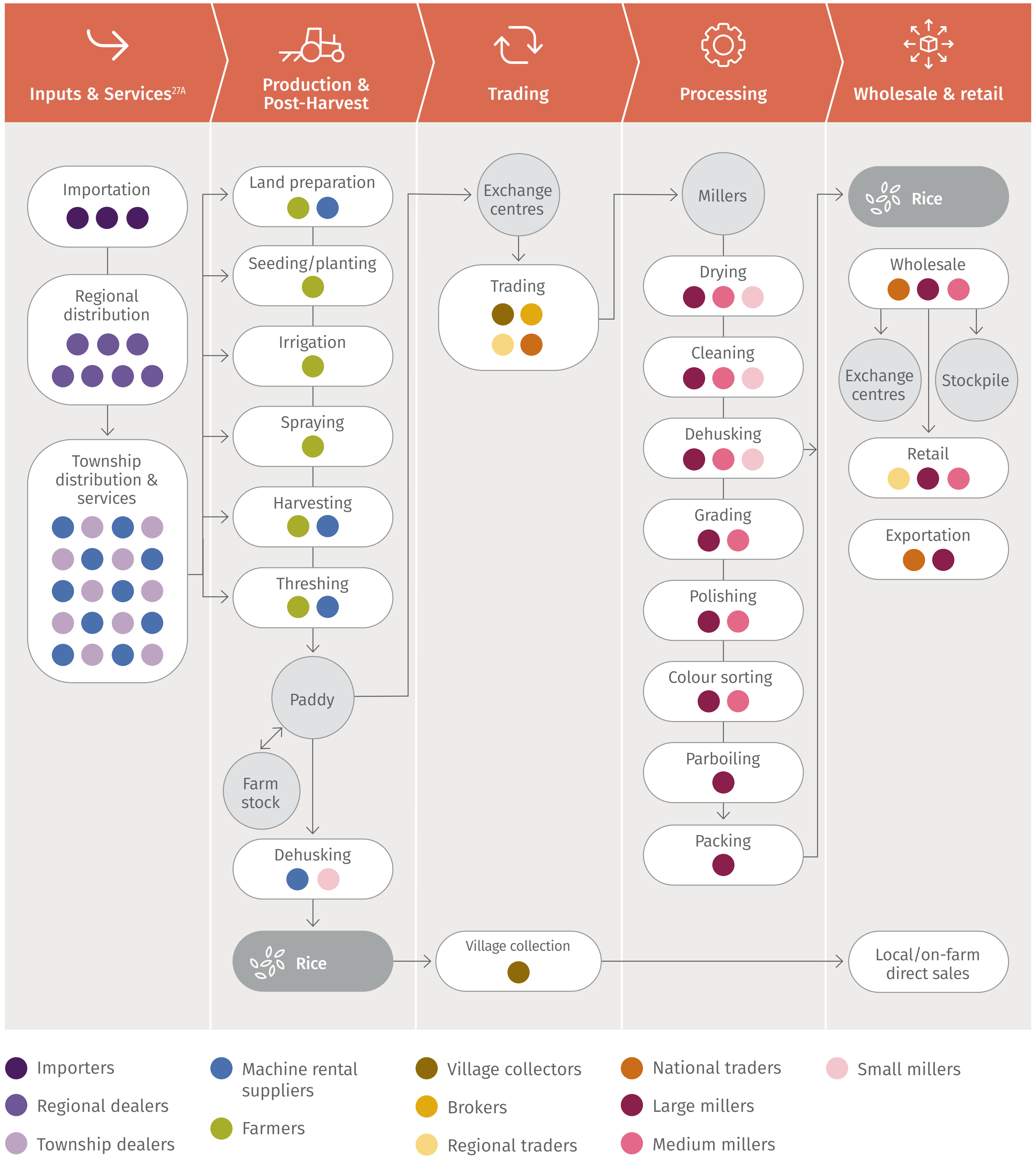


e. Wholesale and retail

Many traders position themselves across multiple successive steps in the value chain to maximise value capture and increase profits. For example, traders often purchase paddy from farmers, paying processors a fee for processing paddy into rice (and occasionally rice products like flour), and ultimately selling to exporters, wholesalers or retailers. Full details of the market conditions of the value chain are presented in Appendix B. Detailed maps of energy use in the rice value chain are presented in Appendix C.

26 Primary processing here refers to de-husking, sorting and basic polishing (transforming brown rice to white rice). Secondary processing refers to advanced polishing, wet-milling (for flour) and colour sorting. Farm inputs and fuel-powered farm activities are intentionally excluded in this analysis to focus the assessment on electrification opportunities. While farm inputs constitute between 30 – 50% of the total wholesale value of rice, they are excluded here due to negligible relevance to energy use within the value chain. Similarly, farm-level activities powered by diesel show limited scope for electrification in the short- and medium-term, even in developed countries.

Figure 7: Stakeholders and value chain dynamics of the rice value chain[27]

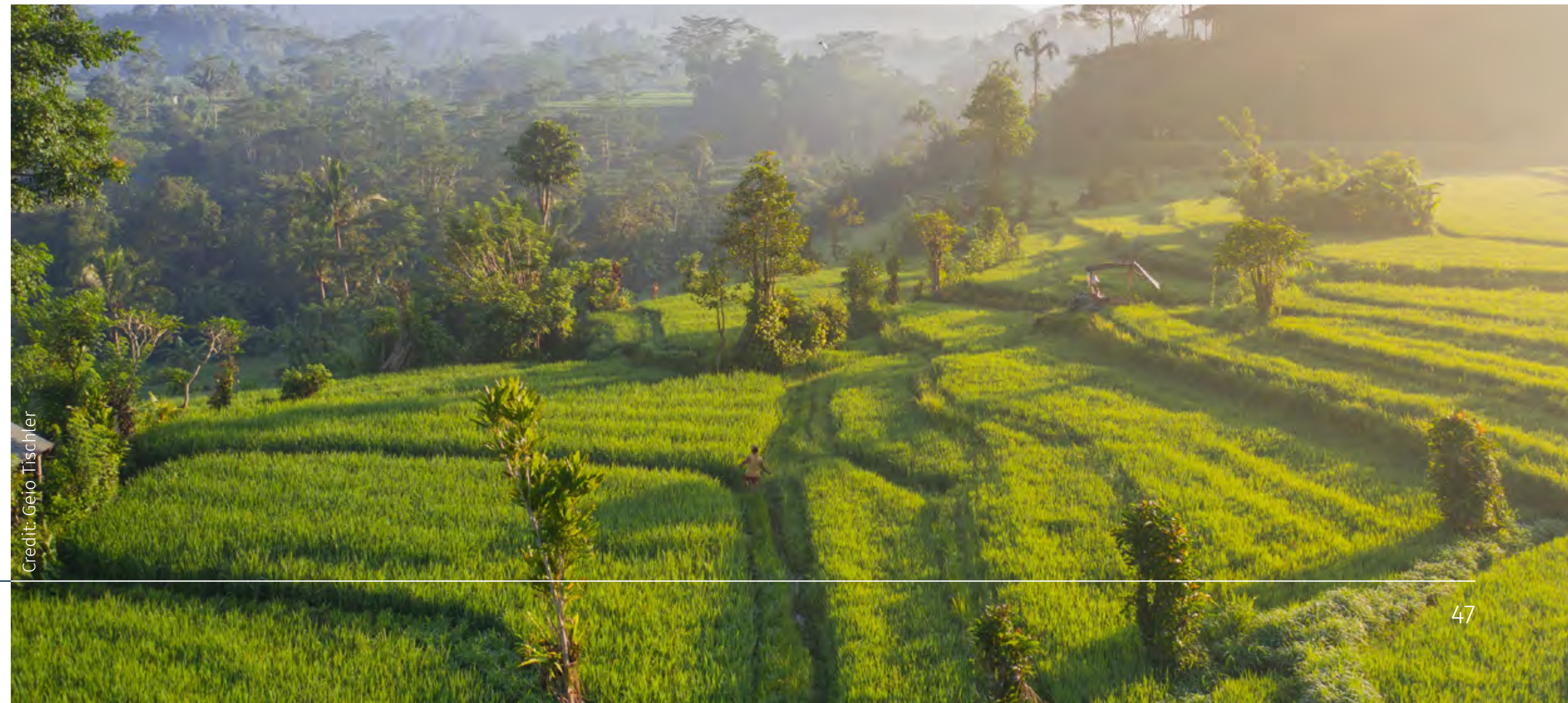


27 The World Bank, Myanmar Rice and Pulses: Farm Production Economics and Value Chain Dynamics, 2019 (*link*)
27A Fertilisers, chemicals, seeds, tractors, pumps, harvesters, etc.

The diagram below presents the results of a qualitative assessment of where best to electrify value chain activities and with which energy systems to do so. The assessment takes into account that upstream activities are likely to take place on farm- or village level, while downstream activities are likely to take place at town level. Standalone solar and mini-grid solutions are best suited for farm- and village level, while captive power grid smoothing solutions are suited for town level, as the main grid is likely to be located here.

Table 2: Rice value chain energy needs and suitable energy solutions

		Suitable Context			Energy System Options		
VC Activity	Power Range (kW)	Farm Level	Village Level	Town Level	Standalone solar	Mini-grids	Captive power
Irrigation	0.2 – 6	☑	☐	☐	☑	☐	☐
Threshing	2 – 20	☑	☑	☐	☑	☑	☑
Drying	0.4 – 9	☑	☑	☐	☑	☑	☑
De-Husking	0.4 – 20	☑	☑	☑	☐	☑	☑
Basic Milling	2 – 40	☑	☑	☑	☐	☑	☑
Grading / Sizing	0.5 – 3	☐	☑	☑	☐	☑	☑
Polishing	10 – 55	☐	☑	☑	☐	☑	☑
Colour Sorting	0.2 – 12	☐	☐	☑	☐	☐	☑
Combined Milling	10 – 100	☐	☐	☑	☐	☐	☑



Case study summary: Rice producing villages in Labutta township, Ayeyarwady[28]

A study mapping the social dynamics of rice farmers and processors in Bi Tut and Kan Bet villages in the lower delta of Ayeyarwady region highlights several key challenges and opportunities in the rice value chain. Many of these challenges are similarly shared by survey respondents.

Poor access to agriculture finance is stifling value added activities
Inefficient and poorly conceived credit processes are promoting pervasive, predatory informal lending. This increases exposure to risks like crop failure and market fluctuations while reducing negotiating power and risk appetite. As a result, farmers and processors are hesitant to explore new opportunities or invest in value added equipment.

Waste value chains can boost economic performance but require greater cooperation
There is an existing market for rice husk with potential for material cost savings and small-scale value-added activities. Rice husk can feasibly be utilised as biomass fuel or to generate electricity through gasification. Husk-to-energy conversion can reduce waste handling costs and reduce energy expenditure. Markets for husk are still poorly developed and require better vertical coordination (longer term contractual trade agreements instead of ad-hoc deals).

A detailed discussion of the case study is presented in Appendix G.

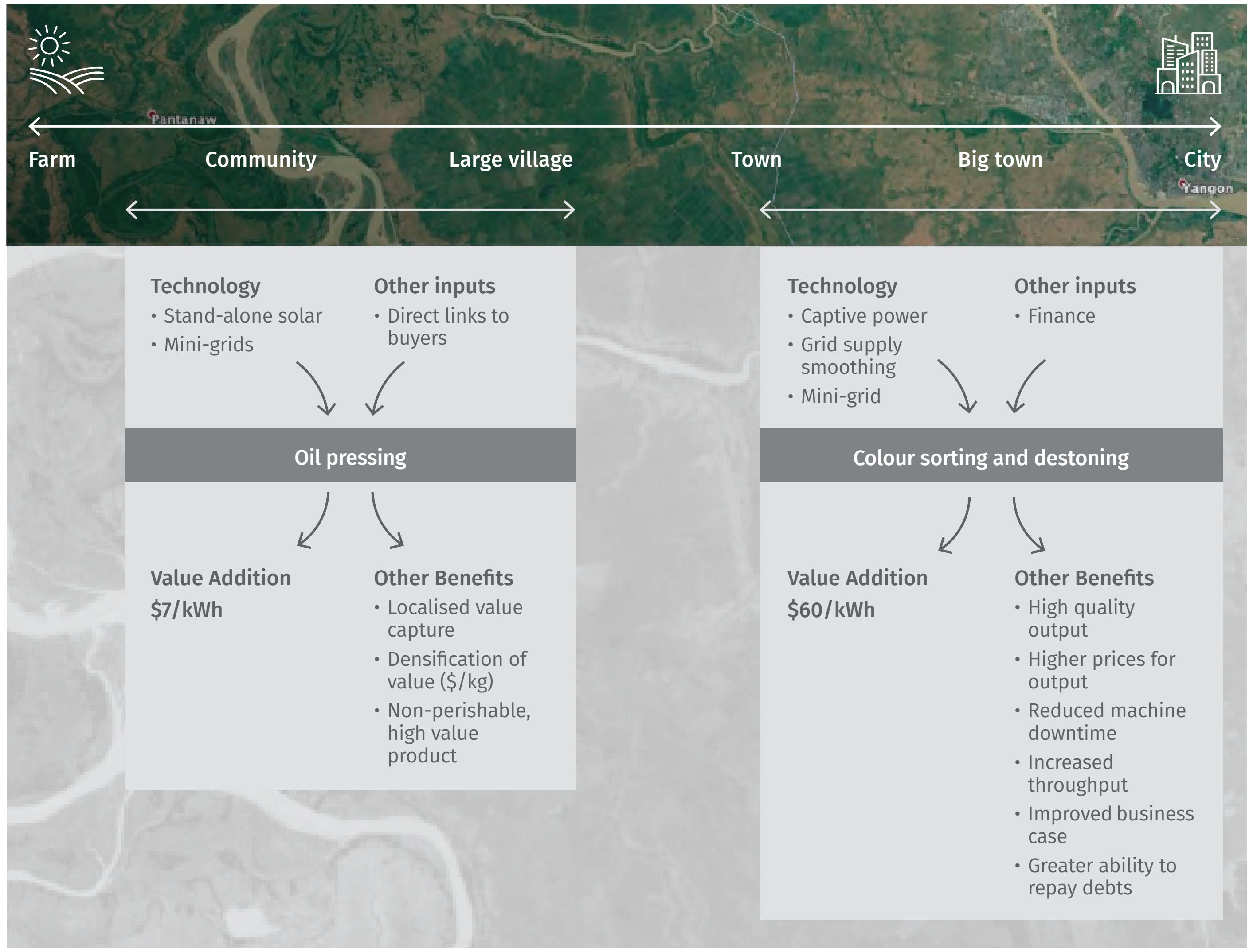
28 Mercy Corps Myanmar, Renewable Energy Association of Myanmar, Biomass Energy Association of Myanmar & University of Manchester, Bridging Agricultural Livelihoods and Energy Access, 2020, (*link*)

2.2 Beans, pulses and oilseeds

2.2.1 Key takeaways

- All equipment used by medium-scale processors except threshing machines are already powered by electricity implying ease of adoption of localised electricity supply such as a captive power system.
- Various pieces of equipment including oil presses can be used to process several different crop types, decreasing the exposure to seasonality and increasing the capacity utilisation of the machine.
- Grading and colour sorting machines have the capability to sort large amounts of produce based on specific quality parameters. This, combined with their low power use, enables them to add significant value per kWh consumed.
- Grading and sorting machines leverage high technological sophistication, which comes at a high price. Downstream processors, with their large-scale operations have better access to the capital required to purchase sophisticated equipment.
- Converting seed directly to high value-density oil at the village scale avoids some of the downstream processes and can be an excellent way to capture value upstream.

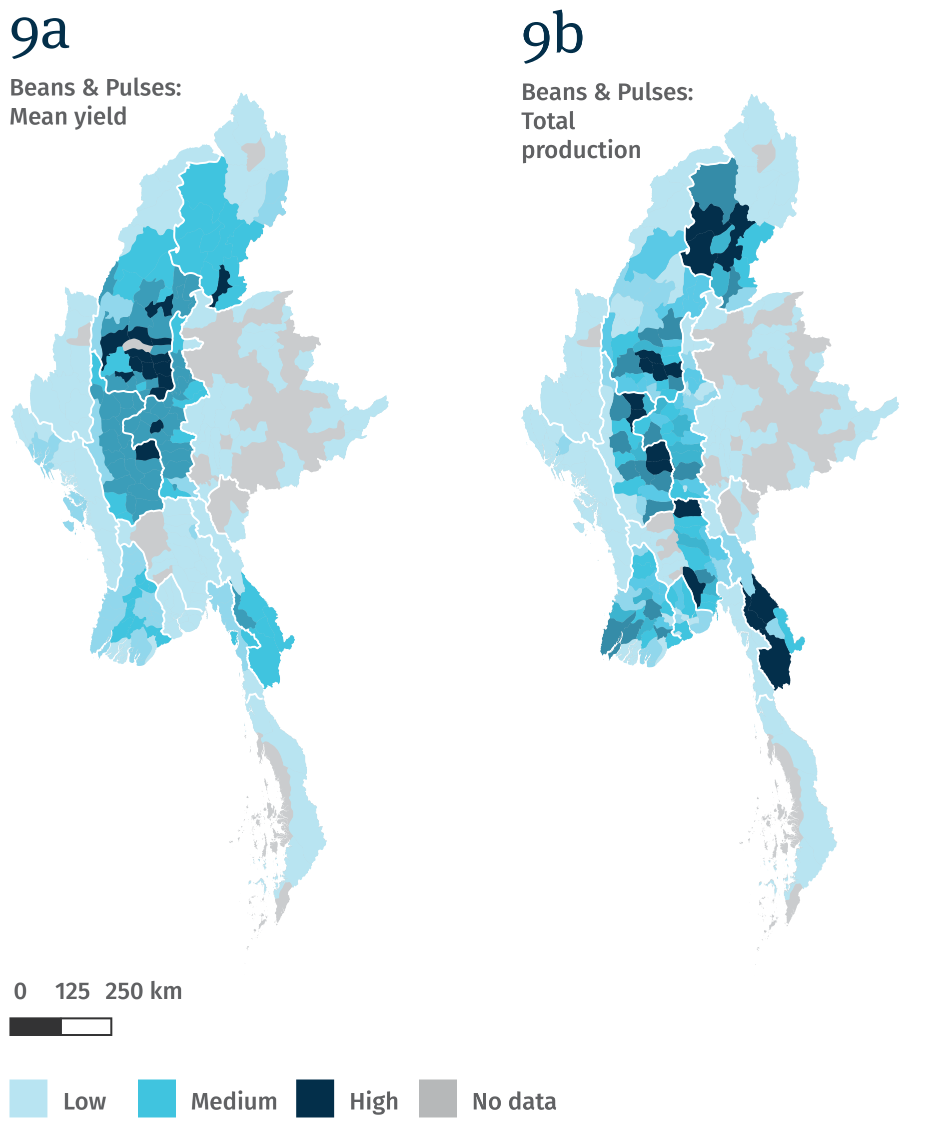
Figure 8: Location, energy source, key inputs and value addition of priority activities on the BPO value chain



Myanmar is one of the world's largest exporters of beans, pulses and oilseeds. In 2019, the country ranked first in the export of black gram and green gram beans, fifth for pigeon peas, fifth for sesame seeds and eleventh for chickpeas.[29] The most important regions for beans and pulses cultivation are Sagaing, Ayeyarwady, and Magway, which together account for over 58% of total production. **The vast majority of oilseeds are grown in the lowland and dry zone region.** An estimated 82% of production occurs in these areas, where sesame and groundnut are the dominant crops.[30]

29 Feed the Future, International Market Opportunities for Myanmar Agricultural Products, 2020 (offline)
30 Myanmar Ministry of Commerce, National Export Strategy – Beans, Pulses and Oilseeds, 2015 (*link*)

Figure 9: Beans and pulses production and yield in Myanmar[31]



2.2.2 Value chain structure and energy needs

The beans, pulses and oilseeds value chain is organised in a **pre-production and production segment** of farmers and input suppliers, a **trading segment**, where traders and brokers collect and aggregate products from farms and dispatch these to processors, and a **processing segment**, where processors convert raw produce to finished products of varying degrees. Full details on the market conditions of the value chain are presented in Appendix B.

31 Production refers to the total production quantity of the relevant township (measured in tonnes). Yield is calculated as total production divided by the total area of the township, which makes it a measure of agricultural productivity.

a. Production

The use of electric-powered equipment is limited in the pre-production and production stages. Equipment used by medium scale farmers include fuel- or electric-powered insecticide spraying machines, diesel-powered water pumps, fuel-powered combine harvesters and diesel-powered tractors. Despite there being less of a need for drying in this value chain as compared to rice, medium-scale farmers have noted that access to a drying machine would make threshing easier. The only fuel-powered equipment identified among small-scale farmers were tractors, water pumps and threshing machines. Surveyed medium-scale farmers did not have main grid access on their farms, despite having access in their villages, while small-scale farmers had no access whatsoever. Farmers typically sell their produce in raw form to processors or traders, often as a collective in order to achieve better negotiation power. Both medium-scale and small-scale farmers only perform basic processing in the form of threshing.

b. Processing

Medium-scale processors operate threshing machines, pre-cleaning machines, grading machines, colour sorters and oil milling machines, most of which are powered by electricity. Only threshing machines were powered by fuel. All of these processors accessed electricity from the main grid. Processors indicated that **different types of beans can be processed by the same equipment,** by changing sieve sizes. Similarly, **different types of oilseeds can be pressed by the same equipment**. Small-scale processors perform considerably less sophisticated processing operations compared to their medium-scale counterparts. They only operate small threshing machines powered by diesel generators. Processors sell their output to wholesalers, located both domestically (mainly Mandalay and Yangon) and abroad (mainly China). In addition to processed products, processors also sell by-products such as oilseed cake and bran as animal feed.

Operators across the value chain are often forced to perform crucial activities at limited capacity, with sub-optimal equipment or without electricity at all. Many of these tasks add considerable value to the finished product if performed optimally (see Figures 10 and 11). Hence, sub-optimal performance of these tasks can often have a severe impact on the quality of the finished product.

Figure 10: Value addition of specific activities along the beans and pulses value chain

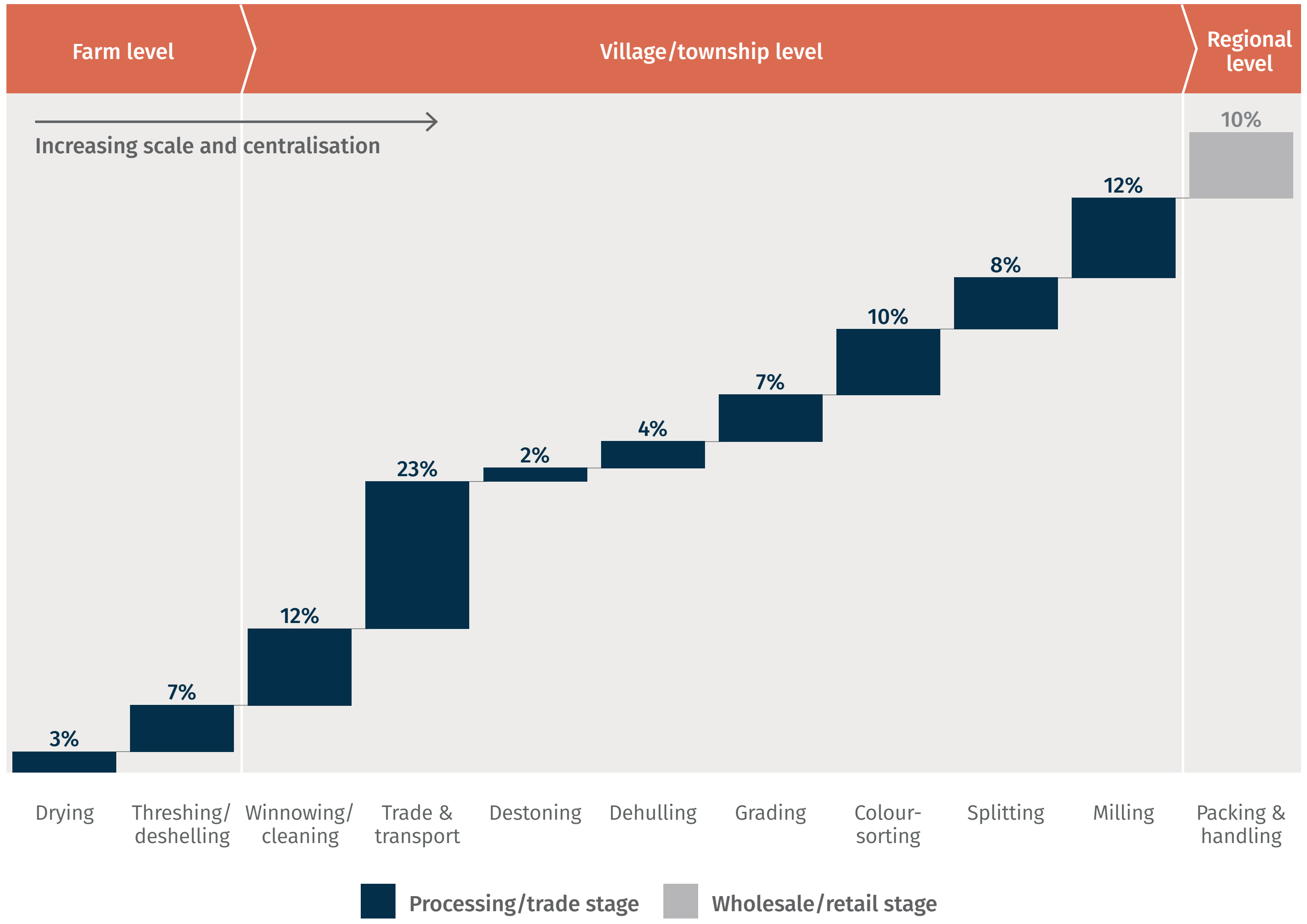
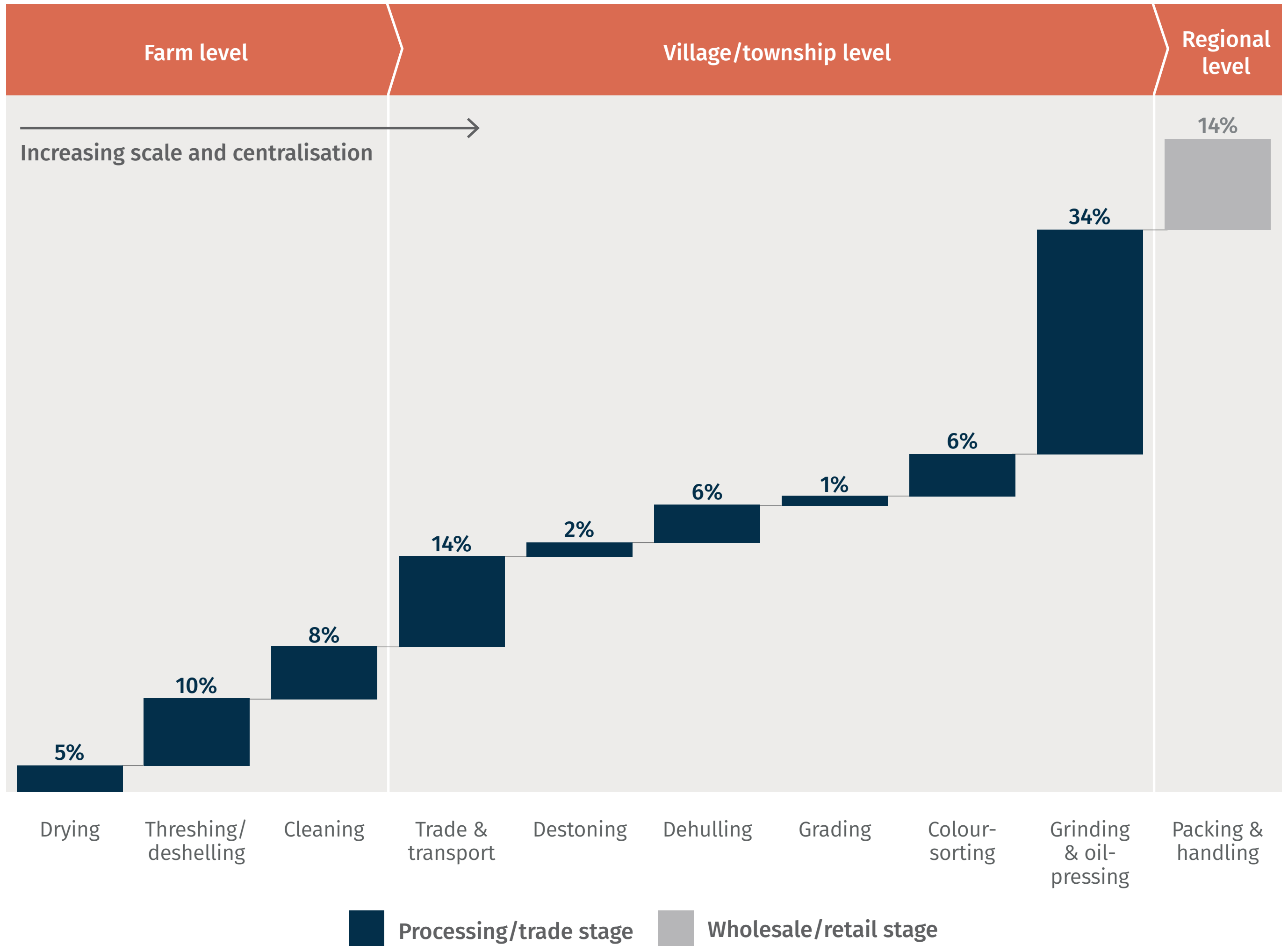


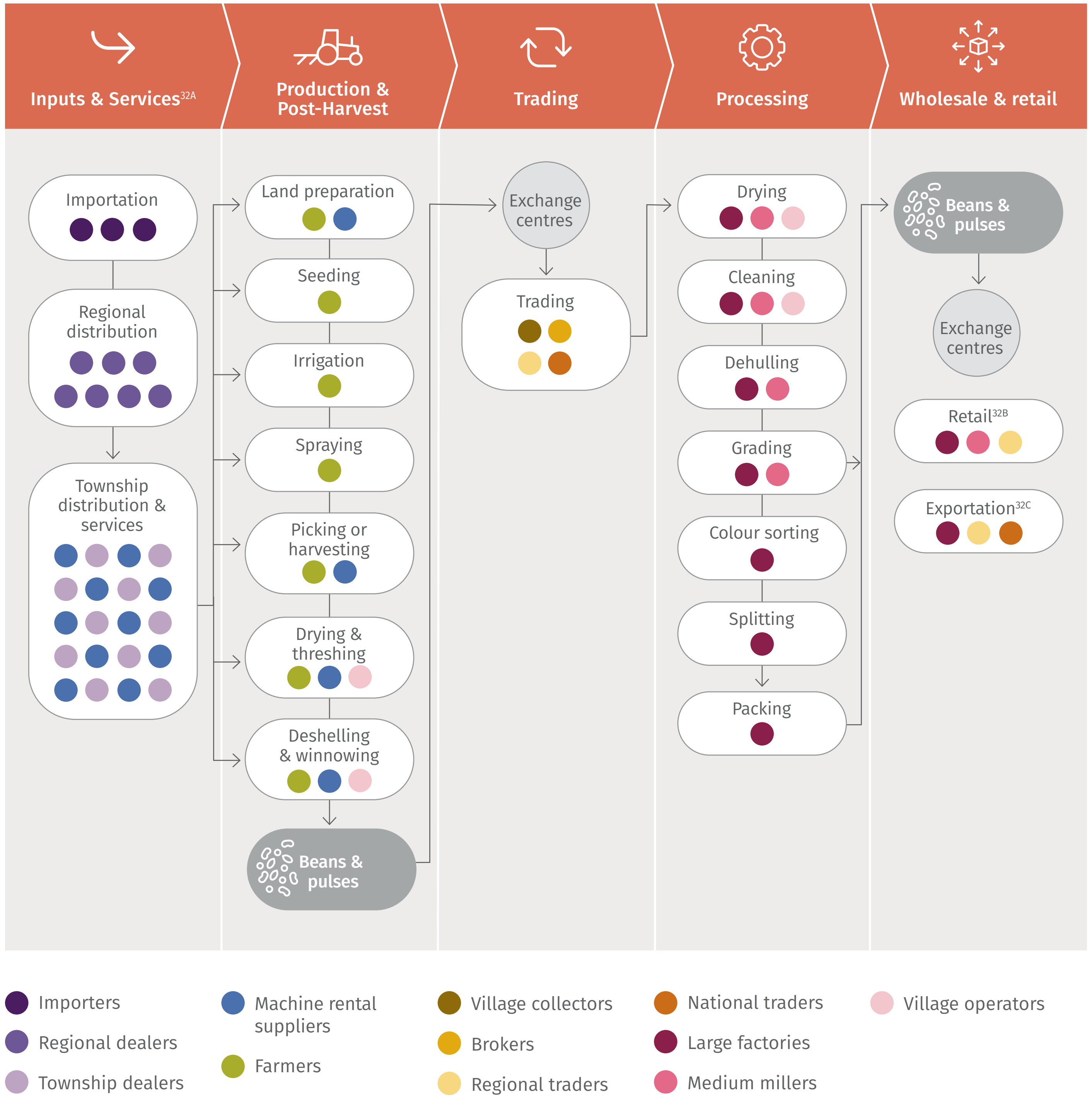
Figure 11: Value addition of specific activities along the oilseeds value chain



c. Wholesale and retail

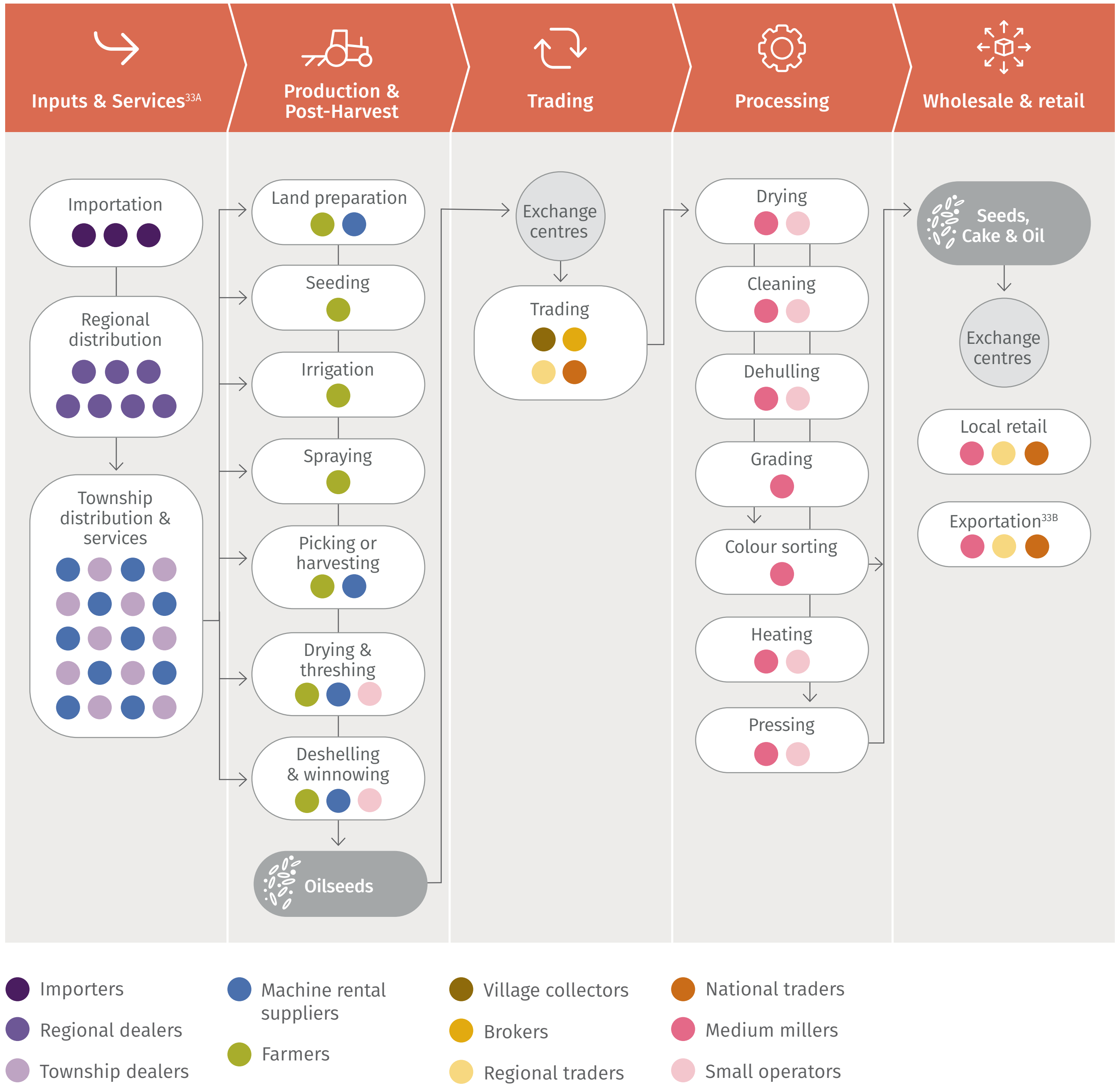
Traders often undertake some processing themselves, typically focusing on destoning and colour-sorting. Traders buy raw produce from farmers and then either on-sell to processors, or process the produce in-house and then sell to local and international buyers.

Figure 12: Stakeholders and value chain dynamics of the beans and pulses value chain[32]



32 AFSIM analysis
32A Fertilisers, chemicals, seeds, tractors, pumps, harvesters, etc.
32B 5–10% to retail markets, including village shops, supermarkets and town markets.
32C 90–95% export to India, China, Bangladesh and Thailand.

Figure 13: Stakeholders and value chain dynamics of the oilseeds value chain[33]



Detailed maps of energy use in the beans, pulses and oilseeds value chain, categorised into medium-scale and small-scale stakeholders, are presented in Appendix C. The diagram below presents the results of a qualitative assessment of where best to electrify value chain activities and with which energy systems to do so.

Table 3: Beans, pulses and oilseeds value chain energy needs and suitable energy solutions

			Suitable Context			Energy System Options		
VC Activity	Power Range (kW)	Max throughput (kg/hour)	Farm Level	Village Level	Township / Peri-Urban Level	Standalone solar	Mini-grids	Captive power
Threshing	2 – 8	150 – 1,000	☑	☑	☐	☑	☑	☑
Dehulling	1.5 – 30	100 – 3,500	☐	☑	☑	☐	☑	☑
Destoning	3 – 16	5,000 – 10,000	☐	☑	☑	☐	☑	☑
Oil pressing	0.75 – 15	15 – 200	☐	☑	☑	☐	☑	☑
Colour sorting/ grading	1 – 5	850 – 3,000	☐	☐	☑	☐	☐	☑

2.3 Cotton

2.3.1 Key takeaways

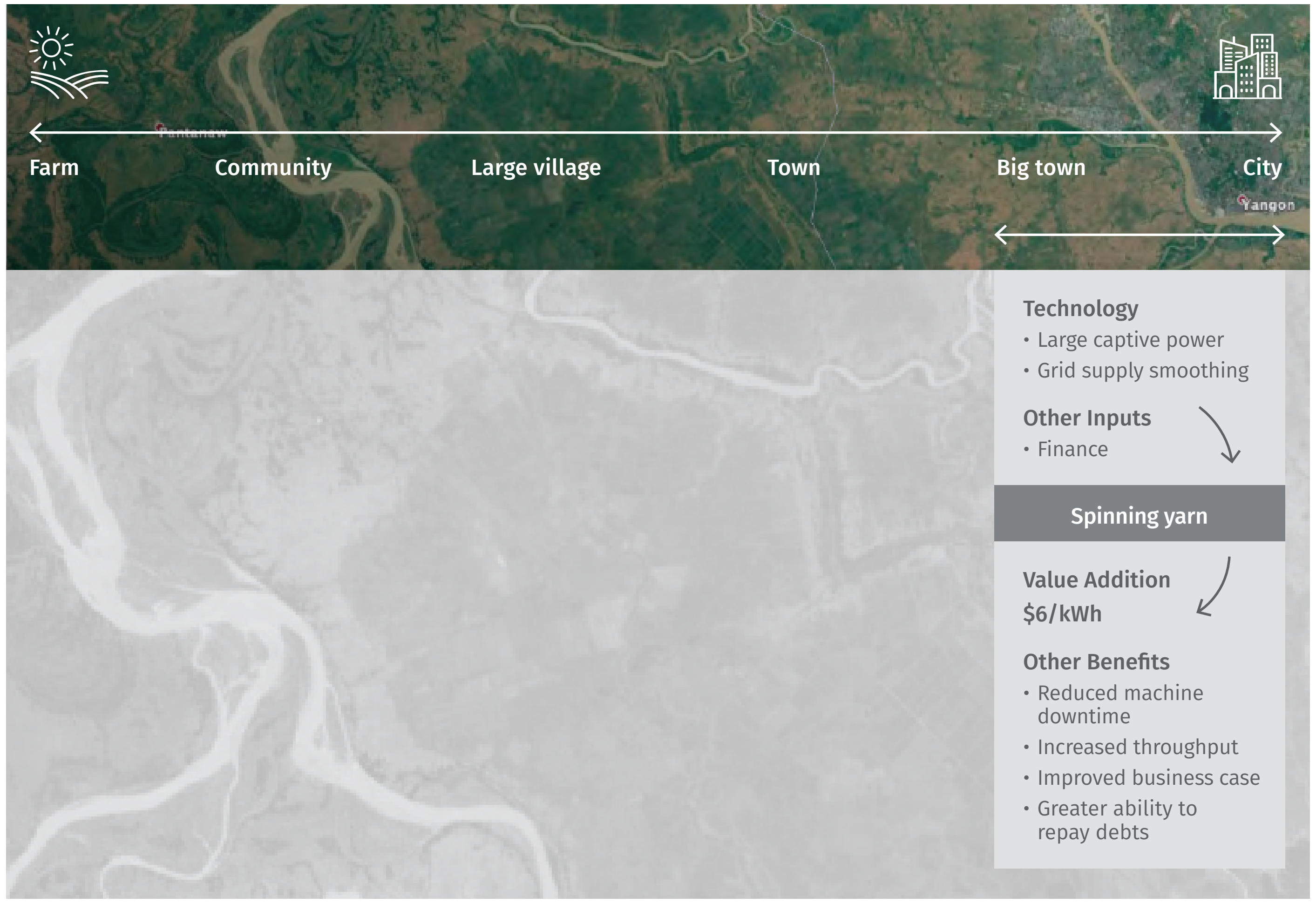
- Cotton in Myanmar is grown in the Central Dry Zone (CDZ).
- Farmers typically do not perform any processing tasks despite having access to electricity.
- Upstream processing (drying, ginning and cleaning) is performed by processors operating at various scales, but generally with inefficient machinery resulting in a low-quality product. Downstream processing is mainly done by largely government-owned industrial-scale facilities.
- Yarn production can add significant value, yet the large capital investment required to purchase machinery may require economies of scale beyond the village level.

33 AFSIM analysis
33A Fertilisers, chemicals, seeds, tractors, pumps, harvesters, etc.
33B Export to Japan, Korea, China

- Manufacturers use more imported yarn than locally produced yarn, as imported yarn is less expensive than local yarn if compared at the same level of quality.
- The costs of spinning machines (to make yarn) and power looms (to weave yarn into fabric) range from several thousand to tens of thousands of dollars. In the absence of extensive financial support, small-scale processors would struggle to afford this machinery. This and the downstream nature of the activity imply that these machines are better suited to more established, large-scale processors.

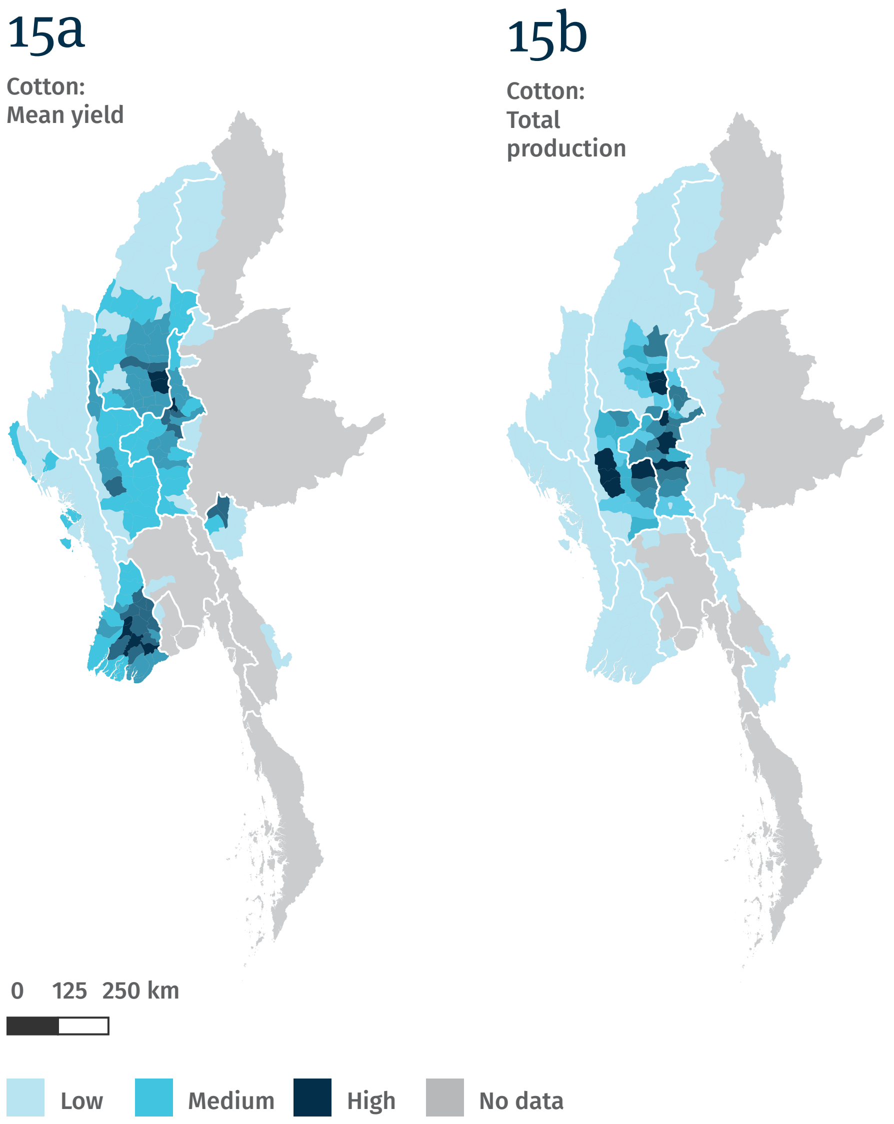
Cotton in Myanmar is predominantly grown in the CDZ and the majority of finished fabrics are sold on the local wholesale and retail markets. Exports of raw cotton fibre have recently increased, notably to China via the land border, but this remains small as compared to local use. All processors and traders surveyed sold to local markets, mostly around Mandalay.

Figure 14: Location, energy source, key inputs and value addition of priority activities on the cotton value chain



2.0 Key agricultural value chains in Myanmar

Figure 15: Cotton production and yield in Myanmar[34]



2.3.2 Value chain structure and energy needs

a. Production

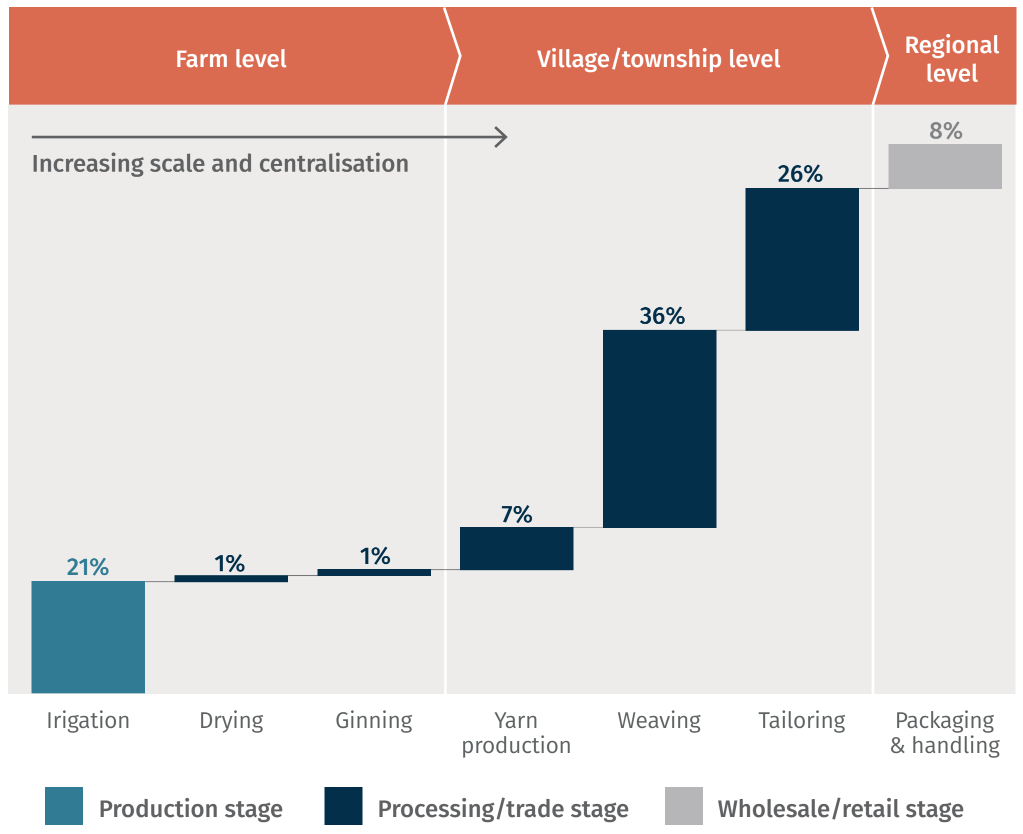
Cotton goes through an extensive process from raw cotton bolls to lint, then to yarn and finally to fabric to be used in clothing. As is the case with other value chains, input suppliers in the cotton industry can be categorised into material suppliers and equipment suppliers. Material suppliers surveyed were offering fertilisers and pesticides to farmers and equipment suppliers were renting out tractors. As is the case with other value chains, the use of electricity in the pre-production and production stages is limited. Input suppliers use fuel for activities such as transport, ploughing and harrowing. Surveyed farmers indicated that ploughing and harrowing are major energy challenges and investment in mechanisation will improve quality.

Cotton farmers tend to have access to grid electricity on-farm but only use it for light residential loads. Oxen and hired tractors are used for ploughing and harrowing and fuel-powered water pumps are used for irrigation. Farmers sell to brokers and traders who come to their villages or to traders located in nearby villages. These traders in turn sell mostly to large government-owned textile mills although a small amount of fibre goes to local workshops. Farmers are not able to negotiate prices, but different brokers usually offer different buying prices, allowing farmers to compare offers.

b. Processing

Contrary to other value chains, cotton farmers do not currently perform any processing whatsoever although survey respondents expressed an interest in doing so. This was echoed by industry associations who noted the importance of promoting the use of cotton processing machines at village level.

Figure 16: Value addition of specific activities along the cotton value chain



34 Production refers to the total production quantity of the relevant township (measured in tonnes). Yield is calculated as total production divided by the total area of the township, which makes it a measure of agricultural productivity.

Yarn is produced through a series of steps including drying, cleaning, ginning, baling, carding, roving and spinning. Yarn is then woven in order to produce fabric to be used in garments. Small- and medium-scale workshops in rural villages still use a significant share of manual labour to carry out yarn spinning, weaving and dyeing. Manual processing and outdated low-tech machines lead to low productivity and quality levels and limit the performance of these small units.

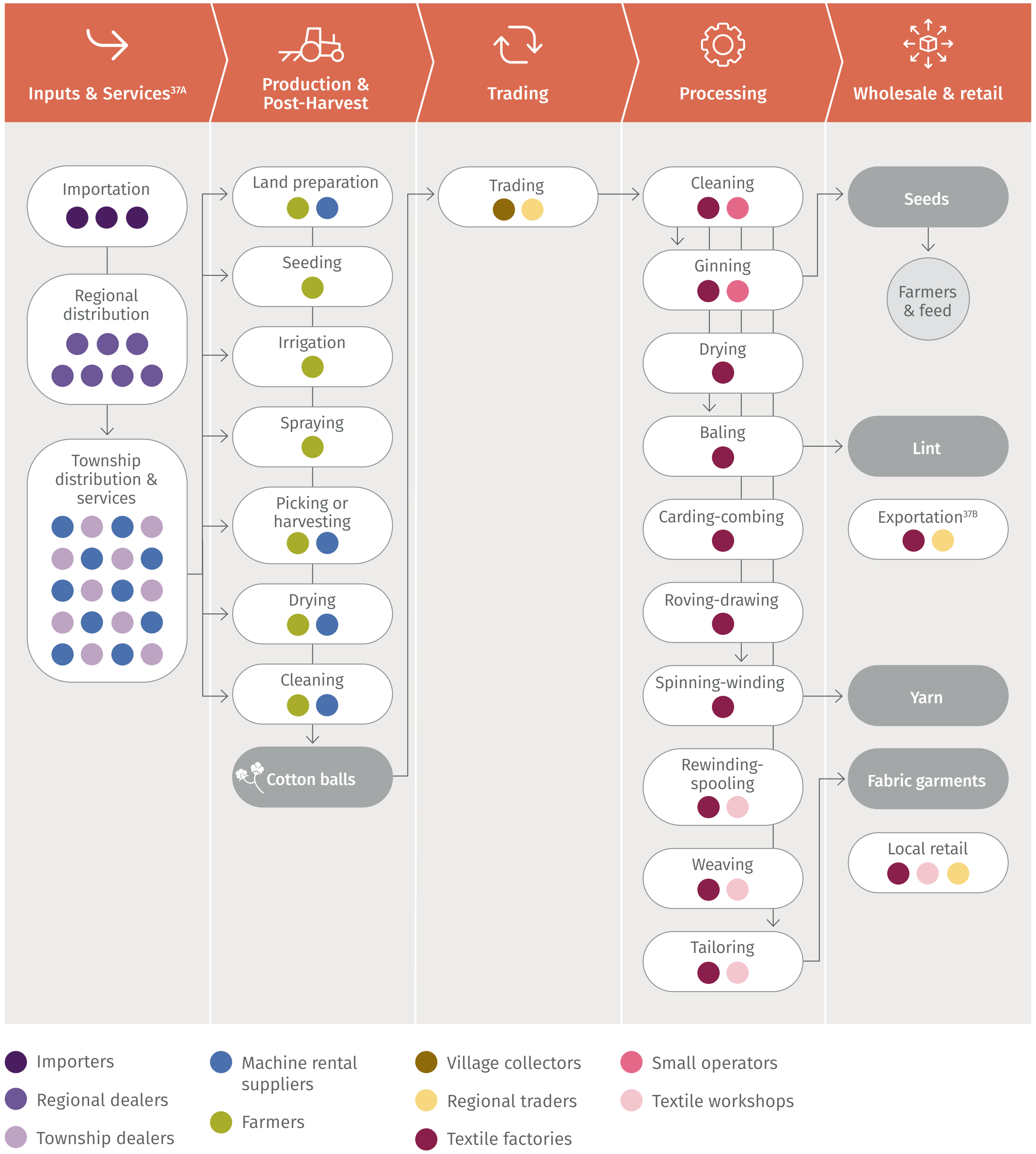
Ginning is a necessary processing step, however it is an energy intensive process and more than half of the input by weight is lost to waste or is a by-product. As such it has limited energy derived value addition. The main by-product of ginning is cotton seed which has low market value and is often returned to farmers or converted into seedcake to feed livestock.

Yarn production is typically done by large, industrial-scale facilities, while smaller facilities are less common. Production of fabric is common among small workshops as well as large textile facilities. **Both large textile mills and smaller workshops use more imported yarn than locally produced yarn, as imported yarn is less expensive than local yarn if compared at the same level of quality.**[35] Manual equipment used among respondents included carding devices, spindles (for cotton spinning) and hand looms (for weaving). Equipment found in larger processing facilities are powered by electricity and include power looms and spinning machines.

Stakeholders across the value chain indicated a significant opportunity to improve the quality of local cotton.[36] Addressing energy challenges can serve as a major catalyst for quality improvements. Detailed maps of energy use in the cotton value chain are presented in Appendix C.

35 The higher quality of imported yarn roughly equates to a price premium of about $230 per tonne.
36 The Department of Agriculture is actively involved in this pursuit by offering quality seeds to farmers and developing new varieties. To date, the department has produced approximately 36 tonnes of seeds.

Figure 17: Stakeholders and value chain dynamics of the cotton value chain[37]



37 AFSIM analysis
37A Fertilisers, chemicals, seeds, tractors, pumps, harvesters, etc.
37B Export to China.

The diagram below presents the results of a qualitative assessment of where best to electrify value chain activities and with which energy systems to do so.

Table 4: Cotton value chain energy needs and suitable energy solution

			Suitable Context			Energy System Options		
VC Activity	**Power Range (kW)**	**Max throughput (kg/hour)**	**Farm Level**	**Village Level**	**Township / Peri-Urban Level**	**Standalone**	**Mini-grids**	**Captive power**
Carding	1.1 – 5.5	15-70	☐	☑	☑	☐	☑	☑
Spinning	0.5 – 25	2-500	☐	☐	☑	☐	☐	☑
Weaving (looms)	1.5 – 2.2	N/A	☐	☑	☑	☐	☑	☑

c. Wholesale and retail

The majority of cotton produced in Myanmar is consumed locally. Both small workshops and large factories sell finished textiles and apparel on the wholesale and retail markets. All traders surveyed also sold to local markets, mostly around Mandalay. Exports have recently increased, notably to China via the land border, but this remains small as compared to local consumption.

2.4 Transport challenges

Underdeveloped transport infrastructure in Myanmar, much like energy infrastructure, is a major barrier to development and is particularly acute in rural areas. Systemic underinvestment and neglect of roads and rail infrastructure over many years have left Myanmar's transport system lagging well behind many of its ASEAN peers. Despite major recent and forthcoming transport projects in Yangon and elsewhere,[38] rural transport systems remain wholly underdeveloped and inaccessible. More than half of the country's rural population, or about 20 million people, lack access to all-season roads. Moreover, an estimated 25 000 villages or 9.2 million people are not connected to any motorable road,[39] requiring them to walk and carry goods themselves or on the backs of animals.

38 Oxford Business Group, Myanmar 2020 (*link*)
39 ADB, Myanmar Transport Sector Policy Note: Rural Roads and Access, 2016 (*link*)

Weak transport infrastructure negatively impacts agricultural competitiveness by increasing transport cost and reducing efficiency and accessibility. Logistical constraints, like those experienced in rural parts of Myanmar, impede rural-urban economic integration and limit access to higher value urban and export markets.

Figure 18: Key figures demonstrating the extent of Myanmar's deficient rural transport infrastructure[40]

20m
People without access to an all-season road
Only 5% of village roads are paved and the majority is earthen, many of which become impassable during the rainy season.

- Estimated 40% of total population
- >50% of rural population

9.2m
People not connected by any motorable road
Without a motorable road, people have to walk; they carry goods themselves, or on the backs of animals.

- Estimated 25,000 villages
- 40% of villages
- 25% of rural population

64%
Of rural population have to travel 2 km+ to reach an all-season road
Based on the internationally used Rural Access Indicator (RAI), which also accounts for a person's location within the village (which may not be the village centre).

Portion of population within 2km range of all-season road:
- Mandalay & Yangon: 60%
- Mon: 73%
- Chin: 11%
- Kachin, Kayin & Rakhine: 15–19%
- Ayeyarwaddy, Sagaing & Shan: 23–29%

100k
Kilometres of new roads needed to connect all villages
In addition to upgrading the existing 75,000km of roads to all-season road, Myanmar needs at least another 100,000km of new roads.

- Myanmar needs a total of 250,000km of roads to connect all villages
- The country currently has about 157,000km of roads
- Only about 75,000km of roads are accessible all-season

40 ADB, Myanmar Transport Sector Policy Note: Rural Roads and Access, 2016 (*link*)

2.5 Gender dynamics in agriculture

Women in general are disproportionately affected by a lack of energy access, especially in rural, agrarian communities.[41] This is due in part to women's labour roles, characterised by multiple and simultaneous activities also known as the '*triple burden*' of home and childcare, farming and community work. Despite conducting a disproportionate amount of farm and household work, rural women often lack the knowledge, support and access to opportunities needed for effective farming. Women constitute about half of the agricultural workforce in Myanmar yet farming conventions are still largely male-orientated.[42] This includes beliefs that certain agricultural tools and tasks (including driving) are more suited to men and that men have the responsibility to seek financing.[43] Samples drawn from Ayeyarwady, Bago, Sagaing and Shan states suggest that approximately 88% of agricultural households in these states are male-headed.[44] A number of studies have found that women in these male-headed households are typically not involved in important decision making processes when it comes to farming and budgeting.[45,46]

Regarding female-headed households, the average production per farm is 5.85 tonnes versus 6.43 tonnes for male-headed households, more than 10% lower. This productivity disparity is primarily the result of gaps in access to improved inputs, extension services and agricultural land ownership.[47] The gap in access to land is due to a convention in which ownership certificates are issued to household heads, which are most commonly men, rather than jointly.[48] As a result, support services are more geared towards men, further widening the gap in knowledge and skills between men and women. Female heads of households are also on average less educated than their male counterparts. Approximately 30% of women in Myanmar agricultural value chains have no formal education compared to 19% of men.[49] Female-headed households typically generate less income than male headed households. For example, in the rice value chain, average profit margins of female-headed households are $175 per hectare as compared to $280 per hectare for male-headed households.[50]

41 UN Treaty Database, Rights of rural women, 2016 (*link*)
42 Dana Facility & UKAid, Women's participation in agricultural value chains, 2019 (*link*)
43 CRS Myanmar, Gender value chain analysis study, 2019 (*link*)
44 The World Bank, Myanmar Farm Production Economics, 2016 (*link*)
45 Dana Facility & UKAid, Women's participation in agricultural value chains, 2019 (*link*)
46 UNCTAD, a gender assessment of Myanmar and of the Inle Lake area with a focus on the agriculture and tourism sectors, 2020 (*link*)
47 The World Bank, Myanmar Food and Agriculture System Project, 2020 (*link*)
48 MOALI, Social Assessment: Peaceful and Prosperous Communities Project, 2019 (*link*)
49 The World Bank, Myanmar Farm Production Economics, 2016 (*link*)
50 The World Bank, Myanmar Farm Production Economics, 2016 (*link*)

Despite this inequality, indicators have slowly improved in recent years. These include labour force participation, non-agricultural wage employment, access to credit, literacy rates, primary and secondary education and maternal mortality rate. Examples of women in male-headed households being increasingly involved in important decision making are also starting to emerge. For example, a study in Chin state found that important decisions such as planning around planting and budgeting are done jointly.[51] In these cases, it is assumed that women are equally involved in directing the course of action of their household's agricultural business.

51 CRS Myanmar, Gender value chain analysis study, 2019 (*link*)

3.0 Evaluating energy interventions along key value chains

Of all steps along the agricultural value chain, **processing provides the most promising opportunity for electrification investment.** This is due to it being the most energy intensive step (compared to production, wholesale and retail) and the significant increases in product value that energy-enabled processing provides. There is also a strong match between the ideal locations of processing activities and decentralised energy technologies as well as a match between the equipment sizes of both.

Agricultural processing, as a subset of entire agricultural value chains, can be conceptualised as a continuum, with upstream agricultural processing activities on the one end and downstream activities on the other, as demonstrated in Figure 19. Each end is characterised by energy, agricultural and contextual features that define the typical operating environment of agricultural processing activities at that end. These features and their dynamics along the continuum provide a useful framework and starting point for evaluating high value agricultural electrification opportunities. Because the operating environment for agricultural processors can vary widely, the operational characteristics outlined below are general and intended to provide a high-level overview of important drivers and constraints that affect viability and therefore decision making. The relevance of different features will also vary depending on the mandate of an organisation and the intended outcomes of electrification efforts. In general, the continuum and associated features are useful for:

1. Characterising a target site, or set of target sites;
2. Identifying and evaluating possible intervention points in the agriculture-energy nexus;
3. Defining project boundaries and energy solution design parameters;
4. Evaluating early-stage viability of electrification efforts.

Figure 19: The agricultural processing continuum showing how certain factors change upstream and downstream along the processing segment

Small-scale, upstream agricultural processing (indicated on the left side of the continuum in Figure 19) typically occurs closer to the farms from which inputs are sourced. In many cases, they also primarily serve consumers from local and surrounding villages. Accordingly, small processors are often located in relatively isolated areas, like rural villages, where transport and energy infrastructure is weak and the costs of transport and energy are high. Reduced product quality due to inefficient processes limit access to high value markets, as do transport constraints. Electrification interventions targeting small-scale processors hold significant potential for social impact, by catalysing and expanding energy access to surrounding households.

Medium- and large-scale agricultural processing (indicated on the right side of the continuum in Figure 19) generally happens in larger economic nodes with better, and therefore more affordable energy and transport systems. Grid access means their energy costs are relatively low, although unreliable supply necessitates backup generation to keep operations running. Agricultural processors operating at medium- and large-scales are better integrated into longer and larger value chains, and as a result they typically serve higher-value markets in larger towns, cities, or for export. **Electrification efforts targeting more integrated agricultural processing operations can help address operational downtime, thereby improving capacity utilisation and affecting primarily economic impact.**

The following sections outline a core set of considerations and associated analyses to help identify and prioritise opportunities along the agricultural processing continuum. Opportunities for intervention, and how these opportunities are assessed can vary widely according to stakeholders, value chains and geographies, among many other variables. Accordingly, discussion of metrics and application of analyses are intended to provide a guide for sector stakeholders on *how to think about* agricultural energy interventions in Myanmar, with a specific focus on agricultural processing as a high value segment.[52]

The methods described below provide a holistic view on key indicators of viability, and integrate various stakeholder perspectives (e.g. profit-driven vs. impact-driven), to help guide decision-making and steer investment. Analytical techniques and the conceptual framework underpinning them are presented and structured to:

1. Highlight major considerations that influence the viability of agricultural processing energy interventions, including their dynamics and how these change depending on an intervention's position on the continuum;

52 Due to significant variability and complexity of both agriculture and energy in Myanmar, the factors outlined in this section are not exhaustive and serve merely as indicative exploration of the most significant factors to consider when developing energy interventions.

2. Explore analytical and methodological techniques to evaluate a subset of these considerations to support informed investment strategy design and decision-making;
3. Demonstrate application of the analyses and their derived metrics along and across key value chains in Myanmar.

3.1 Structural suitability

Structural suitability evaluates mostly qualitative indicators of value chain structure and dynamics. Because agricultural processing is a critical intermediary step in most value chains, linking production to wholesale, it is fundamental to the effective functioning of that value chain while also being highly exposed to its risks. **Understanding the drivers and constraints that govern a value chain is therefore fundamental to identifying and prioritising possible agriculture-energy interventions.** Similarly, understanding the degree to which prospective targets for electrification[53] are integrated into a value chain provides insight into project viability and impact. Major indicators of structural suitability include:

- **Up- and downstream value chain linkages** affect the ability of processors to source inputs and sell outputs. Sourcing inputs directly affects a processor's throughput and in turn capacity utilisation, while access to markets and the ability to offload processing outputs determines revenue, profits and ultimately ability to pay for energy.
- **Agglomeration** (or economies of agglomeration) are the benefits that arise when firms and people, particularly those involved in similar industries, are located near one another, typically in economic clusters. Centralisation of agricultural processing nodes benefit from shared technical expertise, aggregation of produce and cooperative transport, among others.
- **Transport** is a major challenge across agricultural value chains and therefore a significant cost driver which negatively affects achievable processor profits. Processing activities that increase weight density also reduces transportation requirements and so costs.

53 'Electrification targets' in this context is used broadly to refer to beneficiary stakeholders, value chain activities, specific villages, sites or other groupings under consideration for electrification intervention.

3.2 Energy-derived agricultural value addition

Agricultural value addition evaluates the increase in the value of agricultural produce as it moves through the value chain alongside the corresponding energy consumption. Similar to the concept of *energy intensity*, energy-derived agricultural value addition aims to determine **the efficiency of converting energy into economic value.** This technique has several useful applications, particularly for analysing cost and revenue structures and as a tool for comparing or prioritising agricultural activities for electrification efforts. Evaluating energy-derived value addition can highlight several relevant insights, including:

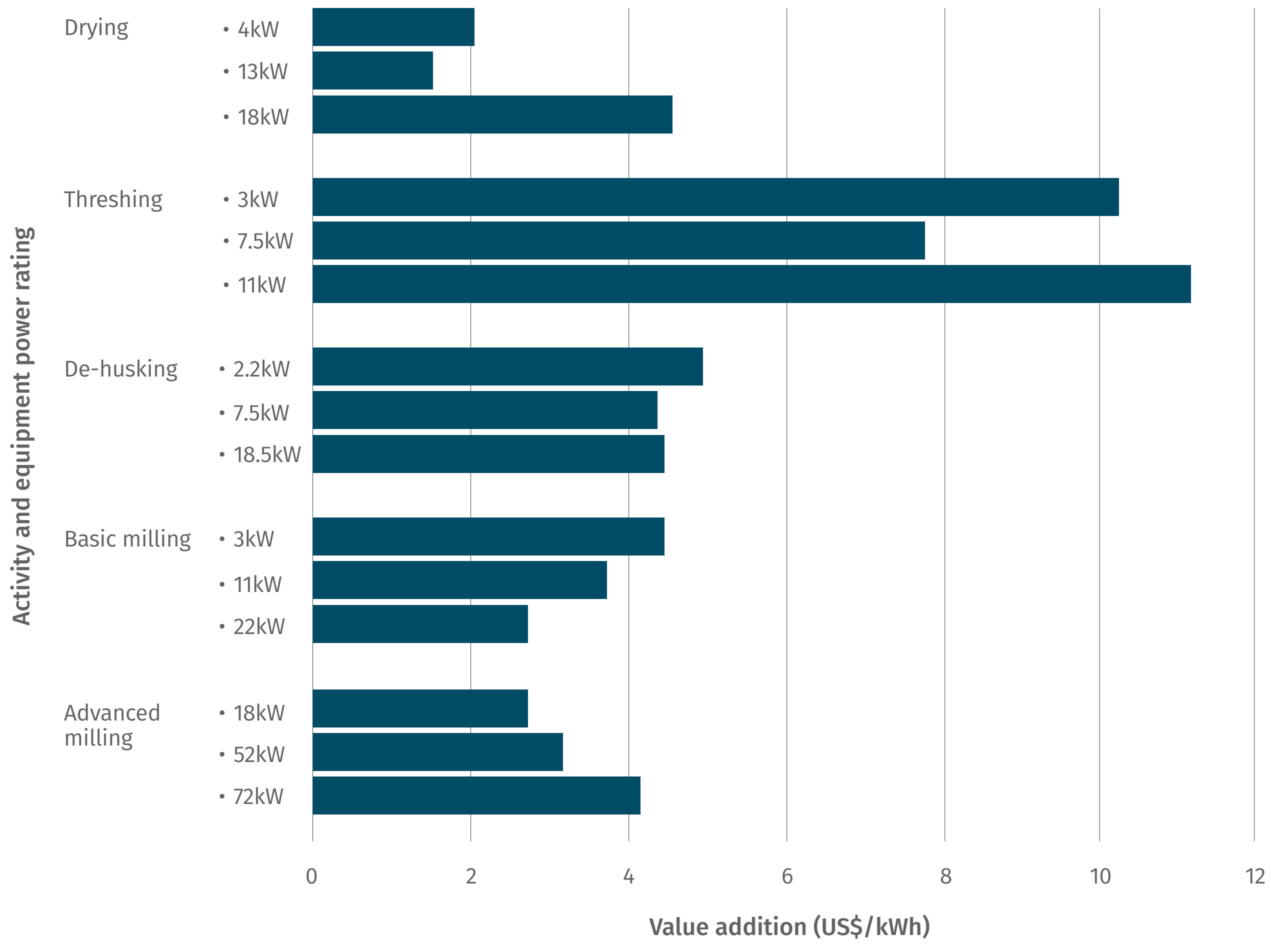
- **The implicit cost of downtime** due to power outages incurs direct losses through lost labour and machine productivity while incurring significant associated opportunity costs from lost sales. Sufficiently large direct and indirect costs can be offset through the provision of alternative, albeit more expensive, energy sources.
- **Energy-driven value added** considers the agricultural value addition resulting from each kWh of energy consumed during a processing activity. Modeled here using the unit US$/kWh, this analysis can be used to compare activities on the continuum at three levels:
  - Across different value chains;
  - Different activities along a single value chain;
  - A single activity at different points or different scales along a single value chain
- **Economies of scale** refers to the decrease in a processor's cost per unit of output as the size of an operation increases. In the case of energy, larger machines and processors are likely to consume less energy for each unit of agricultural output than smaller ones, thereby decreasing energy costs relative to output volumes.
- **Tariff justification** compares the increase in agricultural value resulting from agricultural processing against the tariff charged for the energy to power the process. While in some cases like off-grid mini-grids, tariffs can be high, **sufficient levels of value addition can offset high energy tariffs.**

3.0 Evaluating energy interventions along key value chains

Figure 20 below shows the value addition per kWh of processes along the key value chains (see Appendix E for full details on the methodology and data sources). **The greatest value addition per kWh for rice comes from threshing, an upstream activity, whereas the greatest value addition for beans, pulses and oilseeds comes from colour sorting, a more downstream process. Spinning lint into yarn offers the greatest value addition per kWh in the cotton value chain.**

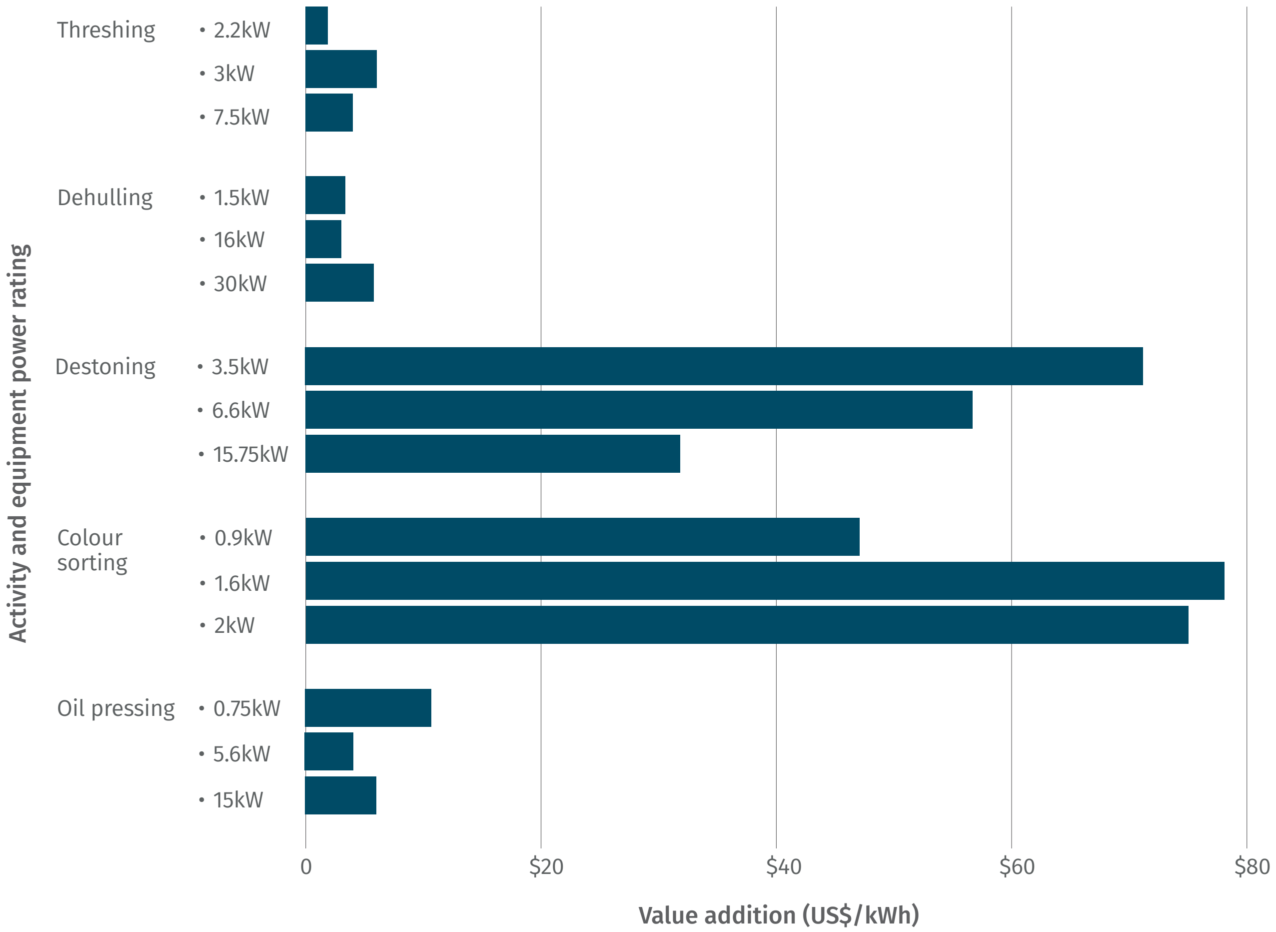
Figure 20: Process value addition as a function of energy consumed and equipment power rating

20a: Rice value addition per kWh

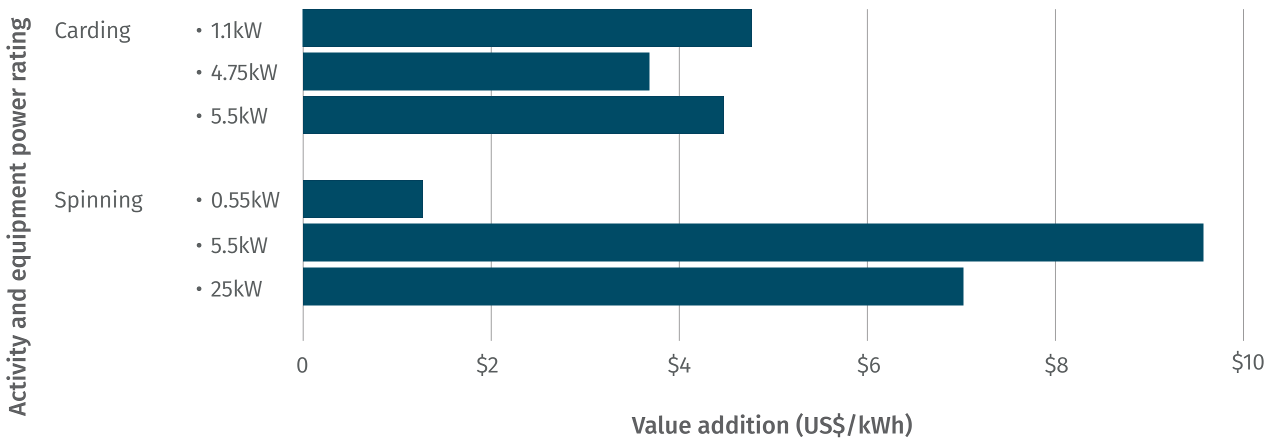


3.0 Evaluating energy interventions along key value chains

20b: BPO value addition per kWh



20c: Cotton value addition per kWh



Of the three key value chains assessed, rice emerged as being the most suitable for scaled, village level energy intervention. This is a result of the high value addition of upstream processing per unit of energy consumption (particularly drying and threshing) and the relatively low capital expenditure (CAPEX) requirements of the equipment required to perform these activities. Another major advantage of threshing rice upstream is that the value density of the rice is greatly increased by removing the significant volume of unwanted parts of the harvested plant, reducing the costs of transportation. As such, the closer to the field this processing step can occur, the better. Every location varies however, and a local assessment of the competitiveness of village level, mini-grid enabled threshing versus in-field, fuel powered threshers would need to be carried out to determine the viability of electrifying threshing in a particular area.

Research and surveys suggest that drying various crops is the single most important processing step to ensure high quality output and reduce post-harvest losses, however the straightforward value addition analysis of the value addition per kWh of electricity does not identify this as a valuable energy intervention. This is because the process of drying rice often requires heating which is generally an inefficient use of electrical energy. However, if waste heat from another process can be harnessed for the drying then the calculation shifts significantly. One such process is the generation of electrical energy through the gasification of rice husks. There are numerous examples both internationally and in Myanmar of rice husk gasification powered mini-grids. This is a good example of the importance of considering value chain activities both collectively and according to their specific characteristics (in this case involving heat).

A similar logic applies to the cotton value chain where analysis from the perspective of value addition as a function of kWh consumed would suggest that spinning offers the greatest opportunity for an energy based intervention, for example supplementing erratic grid supply to a spinning factory using a captive power solar and storage system.[54] However, high volume spinning machines cost tens of thousands of dollars and thus an analysis of the techno-economic profile of this intervention would reveal that in order to achieve commercial viability, a large and guaranteed throughput is required. This pushes the process of cotton spinning down the value chain towards areas that can aggregate produce and processors that have access to the capital required to purchase the machinery.

54 Ginning was not considered in the analysis as it was not identified as an energy-related challenge during the survey. It's worthwhile to note however that should unmet energy needs related to ginning be addressed, this is best done in the upstream stages of the value chain, at the village level. This is because ginning is done before other processing tasks can be done, while it also reduces weight (and in turn transport costs) and improves efficiencies downstream. Further, while not cheap, ginning machinery is relatively affordable (approximately $1,000).

Research indicates that much of the yarn used in Myanmar is imported as the quality of local yarn is low. This would imply that any energy interventions into the cotton value chain be considered alongside interventions to improve the quality of the raw feedstock (for example higher quality seeds).

3.3 Agricultural processing techno-economics

Techno-economic analysis aims to assess and compare the feasibility of various interventions using a range of financial and operating variables. Like value addition analysis, techno-economic analysis can be applied across different value chains, among different activities in a single value chain, or along a single activity at different scales in a value chain. Major parameters for determining techno-economic viability are:

- **CAPEX** evaluates the initial capital outlay required to procure equipment and set up processing facilities. Capital requirements, including access to and affordability of finance, are major determinants of the viability of an operation and influence several key factors including scale, payback periods and profitability.
- **Operating expenditure (OPEX)** evaluates continuous costs associated with operating machinery and includes energy, labour (of operator), maintenance and other running costs. Operating costs are closely correlated to machine uptime and therefore capacity utilisation, which, like CAPEX, affects scale, payback periods and profitability.
- **Capacity utilisation** measures the extent to which productive capacity is employed, or simply, how much of a processing facility's total potential capacity is being used. Higher utilisation rates mean a machine is less idle, delivers more output and increases sales revenue. Utilisation can be sensitive to seasonal variability and upstream linkages (to source process inputs).
- **Levelised cost of energy (LCOE)** measures the average cost of energy, which may be generated from a range of sources, including national grid or mini-grid, diesel backup or other over a specified period of time. LCOE in the form of energy expenditure is an important operating expense due to its considerable influence on feasibility metrics like profit.[55]

55 In cases where the agricultural processor does not take ownership of the energy system (such as being a mini-grid customer), they will pay a retail tariff, which will be composed of LCOE plus the energy system operator's margin.

- **Processing scale** considers the range of scales and operating environments at which a processing activity is practical and viable. Practicality evaluates the often qualitative benefits and costs of conducting an activity at various scales,[56] while viability is closely related to CAPEX, economies of scale and associated energy-derived value addition.

As the discussion above demonstrates, one of the many factors that determine the commercial viability of an agricultural processing activity is the cost of the machinery itself. The analysis in Table 5 presents the business case of investing in different processing machines from the perspective of the user. It incorporates the cost of buying and operating the machine and compares this with the profit made from operating the machine. The model is based on the premise that the higher the net profit of operating the equipment and in turn the shorter the payback period, the better the business case would be from the user's point of view. Hence, the machines are ranked according to the time taken to recoup the initial investment. For the sake of this analysis a standard Myanmar mini-grid tariff has been used, but the same analysis is relevant regardless of the energy source.

56 For example, practicality in the rice value chain recognises that threshing can be done at various scales and value chain nodes, but likely make most sense upstream by reducing product weight and so transport requirements.

Table 5: Indicative techno-economic assessment and payback periods of various processing equipment

Equipment	Rice dryer	Rice thresher	Beans colour sorter	Cotton carding machine
Power rating (kW)	3.75	13	1.4	1.1
Upfront cost (USD)	$1,500	$1,200	$30,000	$1,000
Max throughput (kg/hour)	250	700	1500	10
Estimated throughput (kg/hour)[57]	125	350	750	5
Estimated operational hours per day[58]	5	5	5	5
Annual capacity utilisation[59]	66.67%	66.67%	66.67%	66.67%
Annual energy consumption (kWh)[60]	3258.75	11297	1216.6	955.94
Mini-grid tariff ($/kWh)[61]	$0.40	$0.40	$0.40	$0.40
Energy expenditure per year	$1,303.50	$4,518.80	$486.64	$382.38
Annual OPEX[62]	$1,554.58	$1,554.58	$1,554.58	$1,554.58
Annual gross profit[63]	$3,258.75	$6,611.96	$29,980.50	$3,025.67
Annual net profit[64]	$400.67	$1,020.82	$27,939.28	$1,088.71
Average monthly net profit	$24.15	$32.46	$1,684.10	$65.62
Payback period (working months)[65]	62.11	36.96	17.81	15.24

a. Business case analysis

From the four systems analysed in Table 5, the cotton carding machine has the best productive use potential as it has the best business case, all factors considered. It must be noted that the data that the model was populated with is based on a number of assumptions. These are listed in footnotes to the table. In addition, power ratings, maximum hourly throughput and upfront costs of processing machines vary widely.

57 Assumes 50% of maximum hourly throughput.
58 The five-hour workday is a general average between long workdays in-season and short workdays out of season.
59 Higher capacity utilisation factors are more characteristic of medium- to large scale processors in Myanmar. Smaller processors operate their machinery less frequently. Factors listed here aim to capture an average between larger and smaller processors.
60 Calculated by multiplying power rating with operational hours per year. The latter is a product of operational hours per day, number of working days per year and annual capacity utilisation.
61 Average tariff charged by mini-grid developers in Myanmar in 2019.
62 Assumes one employee earning a $5.42 daily Myanmar wage and annual maintenance of $146.25.
63 The gross profit is calculated by multiplying operational hours per year, throughput per year (in kg) and profit per kg. Profit per kg is the output of an analysis done by TFE Energy, based on multiple data streams, including survey data from this project. Processors' profits were typically reported per viss or basket, and hence conversion to kilogram was necessary.
64 Net profit is calculated by subtracting energy expenditures (determined by consumption and tariff) and operating costs (salaries and maintenance) from gross profit (which is a product of hours of daily operation, annual capacity utilisation, throughput per hour and profit per kg).
65 A working month consists of 22 days

This analysis has been done to demonstrate a methodology. In order to apply it accurately, the user should populate the model with data relevant to their own project. The same analysis would also need to be conducted across multiple machines and activities.

b. The importance of energy prices

The results of this analysis are highly sensitive to the tariff. For example, a tariff reduction from $0.40/kWh to $0.30/kWh reduces the payback period of a rice threshing machine from 37 to 11.9 months, all else being equal. **This vast improvement in the business case can serve as a valuable advocacy tool for continued mini-grid subsidisation in Myanmar.**

c. The importance of throughput

Multiple model runs have shown that results are highly sensitive to throughput. **This highlights the importance of ensuring that a processor has feedstock throughout the year and that the duration of daily operations is maximised.** Compared to smaller processors, larger processors in Myanmar are more successful in this regard. The value chain deep dive sections have shown that this is mainly due to the better access larger processors have to capital and storage facilities. This enables them to buy raw produce from across the country and store excess for months. Conversely, smaller processors are forced to scale operations down outside harvest season when farmgate prices are higher as storage space limited. Hence, from the perspective of mini-grid cash flows, larger processors will likely be a more beneficial customer type. Smaller processors can also improve their throughput, but **better access to finance and increased storage space need to be available. To assist with this rural energy interventions should be located in catchment areas where produce from a large number of smallholder farmers can be aggregated.**

Upgrading existing inefficient machinery or providing capital for processors to purchase higher quality, more expensive equipment can also positively impact throughput and thus revenues in the long term – a machine requiring extensive annual planned maintenance (and thus downtime) will result in lower annual throughput, higher operational costs and reduced net profit compared to a low maintenance machine delivering the same output type. Finally, **throughput can be further increased through machines that are able to process more than one crop type** such as dryers and colour sorters.

Credit: Hakan Nural

3.4 Geographic determinants

Many of the structural suitability indicators described in section 3.1 above vary considerably from place to place. This is particularly true in Myanmar which has significant geographic and environmental variability. Fortunately, many of the factors that underpin these indicators can be determined remotely through analysis of GIS and other data. This makes the process of identifying the most suitable location for a prioritised energy access investment considerably more time and cost effective.

Increases in the availability of data layers relevant to value chain analysis globally continue apace. So too do the innovations in tools to process this data and extract useful insights. MIMU is also an excellent source for data specific to the country. Layering information extracted from all of the available datasets is a powerful tool to map the suitability of different regions in Myanmar for different types of investment.

Table 6 below describes some of the indicators that characterise the upstream and downstream dynamics that affect a value chain as well as some of the site-specific indicators that will govern the viability of a given intervention.

Table 6: Examples of factors that affect value chain dynamics

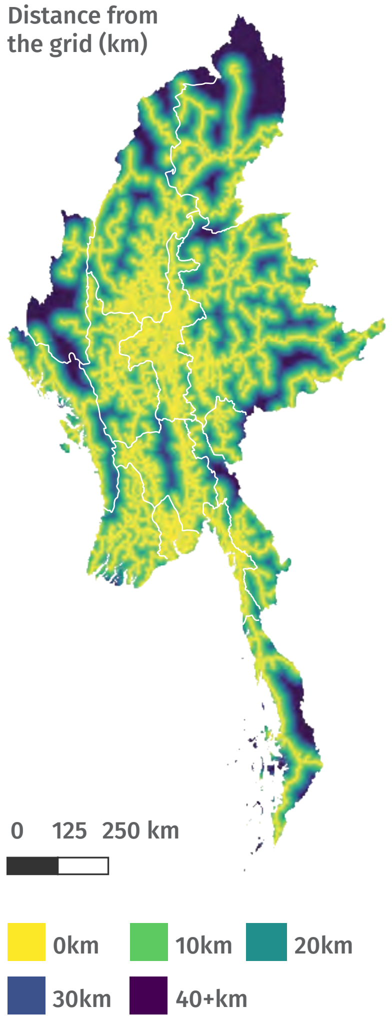
Category	Useful Data layers	Insights
Upstream	• Crop yield and production • Area of land under irrigation • Clustering with other villages and nodes of production • Seasonal variation • Number of yearly harvests	• Indications of the volume and reliability of agricultural input • Potential to aggregate produce from a wide catchment area
Downstream	• Quality of roads and transport infrastructure • Proximity to markets	• Transport costs • Seasonality of access • Ability to offload agricultural outputs
Site level	• Solar irradiation • Quality of grid services • Village density, size and rate of growth • Environmental vulnerability • Community socio-economic profile	• Suitability and sizing of different energy technologies • Diversity of off-takers • Ability to pay for services • Viability gap and risk of commercial investments • Resilience to climate change

Figure 21 below shows the map of Myanmar with some of these data layers overlaid. For a more detailed description of how these layers can be combined to guide the geographic prioritisation of different energy access interventions upstream and downstream, please see Appendix D.

Figure 21: Some examples of the geospatial data layers used in the value chain analysis

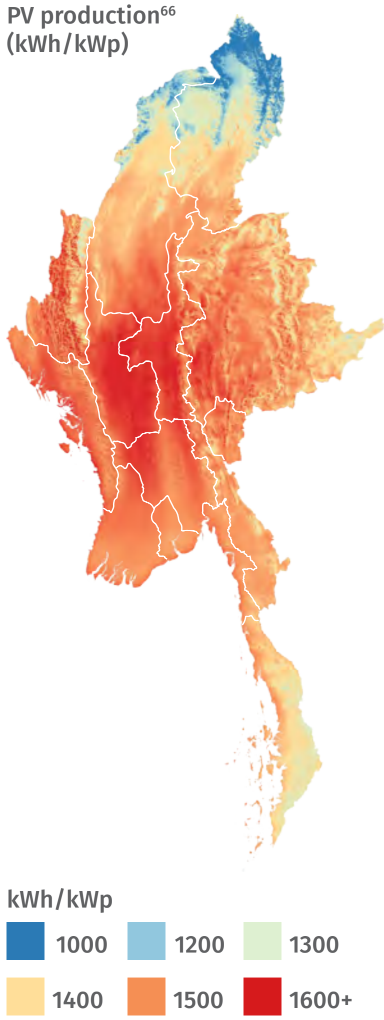
21a

Distance from the grid (km)



21b

PV production[66] (kWh/kWp)

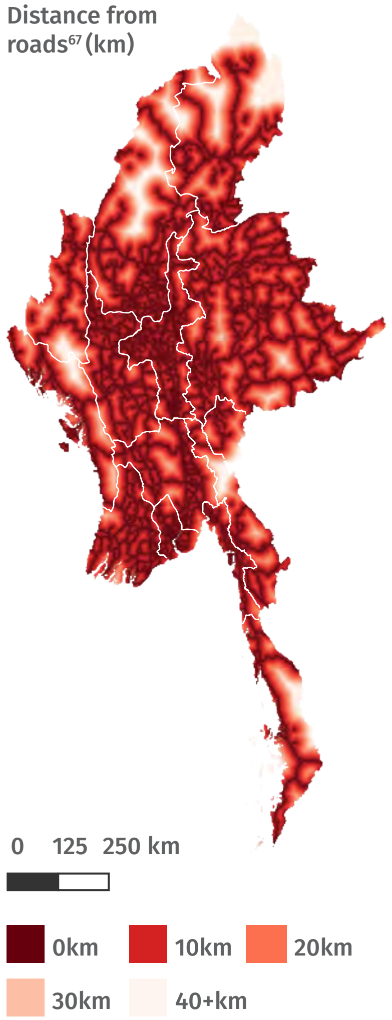


66 Global Solar Atlas (*link*)

3.0 Evaluating energy interventions along key value chains

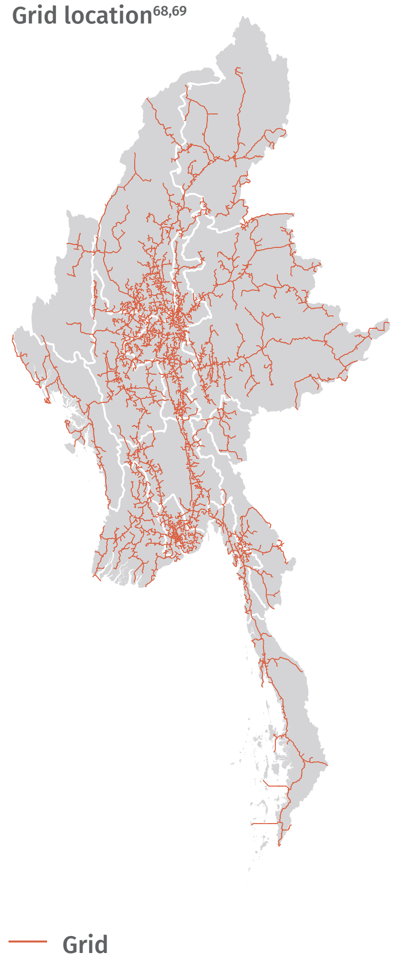
21c

Distance from roads[67] (km)



21d

Grid location[68,69]



67 OpenStreetMap (*link*)

68 This data, extracted using machine-learning based algorithms on night-light satellite imagery, NASA Visible Infrared Imaging Radiometer Suite (VIIRS) imagery and other spatial data, is available online in an interactive and zoomable map on the VIDA platform. (*link*)

69 Village Data Analytics (*link*)

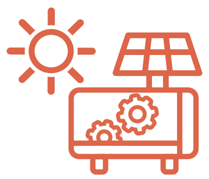
4.0 Delivering improved energy access

4.1 Energy access technologies

Section 2 explored the energy challenges arising in the rice, cotton and beans, pulses and oilseeds value chains in Myanmar. The majority of these are related to **processing**. Section 3 outlined the continuum along which these processing activities can be energised. The range of renewable energy technologies that can be deployed towards this end includes:

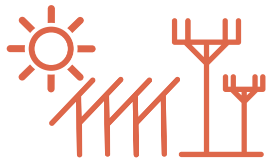
Standalone systems

Dedicated energy source powering a single machine or piece of equipment (e.g. solar thresher), typically in off-grid rural settings. With these systems, kilowatt hours (kWh) are not a useful metric to consider as any generated electricity is converted directly into performing a specific function (e.g. threshing rice).



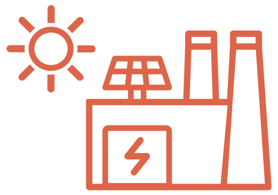
Mini-grids

An energy service consisting of generation (e.g. solar PV, hydro, gasification) and low voltage distribution infrastructure where kWh are consumed by multiple off-takers. Mini-grids can be isolated or interconnected with the main grid.



Captive power systems

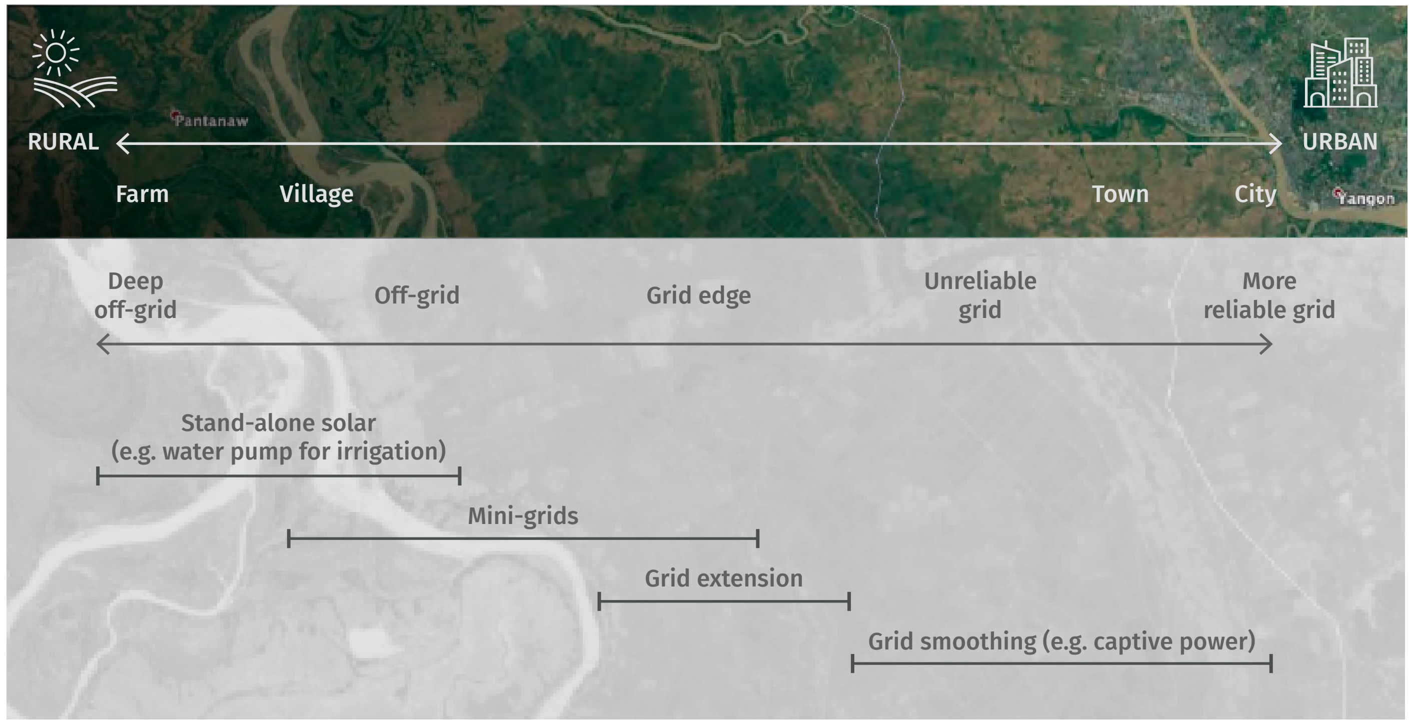
An energy system, typically in the form of rooftop solar, designed for a single off-taker. Captive power systems can be off-grid or grid-connected. In the latter case, the system is designed to provide energy when the grid is not available, either from energy stored in batteries or generated on-site, or both.



The choice between standalone, mini-grid and captive power will be different depending on **whether the processing activity to be energised is performed in an off-grid area or grid-connected area and whether the activity is performed on the farm, village or town level.**

In off-grid areas, standalone solar will likely be the best suited technology in a farm setting, while mini-grids are likely the best suited technology in a village. Yet, as chapter 2 has shown, processing on-farm is uncommon. Furthermore, standalone processing machines on the market are limited to solar threshers, dryers and de-huskers.[70] In grid-connected areas, captive power technologies are likely best suited, but standalone solar and mini-grid technologies could prove to be relevant in less common cases. For example, a grid-connected mini-grid could be required in cases where the processing activity to be energised requires distribution infrastructure additional to that of the main grid.

Figure 22: Different energy supply options are relevant at different points of the continuum



70 This excludes applications beyond agricultural processing, for example solar water pumps.

4.0 Delivering improved energy access

4.1.1 Off-grid technologies

Off-grid decentralised energy technologies, comprising standalone systems, isolated mini-grids and off-grid captive power systems are increasingly becoming a viable rural electrification alternative to on-grid electrification. The case becomes ever stronger as technology costs continue to fall, business models evolve and financing mechanisms improve. In the majority of cases, where solar is the main generation source, these systems are especially suitable to provide affordable and reliable electricity for agriculture activities as the profile of most agricultural processing activities (which take place during the day), are well matched to systems which generate electricity from the sun.

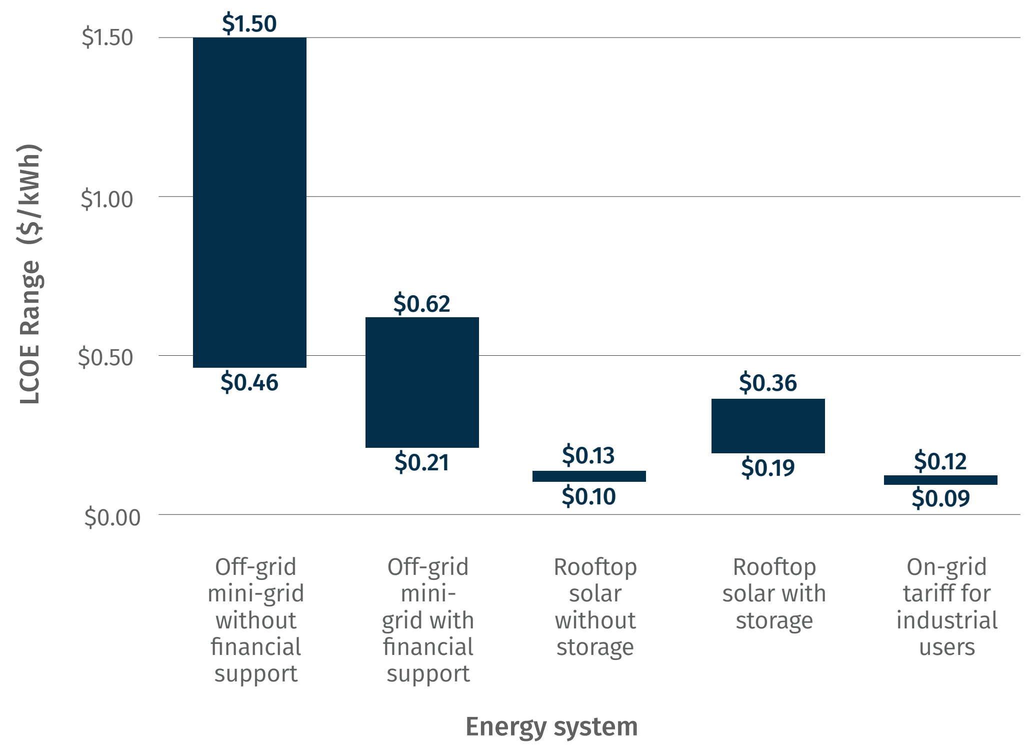
The market for standalone solar agricultural processing machines is in its infancy. Business models are still underdeveloped and the technology struggles to compete with existing diesel-powered machines, both in terms of performance and economics.[71] Compared to standalone systems, isolated mini-grids and off-grid captive power systems energise a wider variety of agricultural processing activities. This is the result of the ability to power higher wattage machinery by virtue of larger peak capacity and the provision of 220-240V AC power. Mini-grids and captive power systems can also leverage other sources of energy, including small hydro and rice husk gasification.

While the LCOE of off-grid mini-grids in Myanmar without financial support is high, ranging between $0.46/kWh and $1.50/kWh,[72] the introduction of the Department of Rural Development (DRD) 60% CAPEX subsidy and 20% community contribution reduces these figures by more than half as shown in Figure 23.[73] Unlike the utility, mini-grid developers cannot sell electricity below the cost of production. Thus, as is the case with LCOE, tariffs charged to customers are high – 2019 tariffs ranged between 350 – 500 Kyat/kWh ($0.25 – $0.36/kWh).[74] These relatively high figures are consistent with the notion that LCOE of energy systems are typically higher in upstream stages of the value chain, which typically take place in off-grid rural areas.

However, the social impact delivered by mini-grids is considerable as they address the energy needs of diverse off-takers beyond agriculture, including households, civic institutions (like schools and clinics) and non-agricultural businesses. This **contributes to poverty alleviation in communities and helps to catalyse rural development.** This is directly in line with the DRD's goals to reduce rural poverty.

71 Lighting Global, GOGLA & ESMAP, Off-Grid Solar Market Trends Report, 2020 (*link*)
72 Smart Power Myanmar, Decentralised Energy Market Assessment in Myanmar, 2019 (*link*)
73 The 60% subsidy is anticipated to be reduced in phase 2 of the NEP.
74 Numata, M., Sugiyama, M. & Mogi, G., Barrier Analysis for the Deployment of Renewable-Based Mini-Grids in Myanmar Using the Analytic Hierarchy Process, 2020 (*link*)

Figure 23: LCOE of decentralised energy systems in Myanmar[75,76,77]



4.1.2 On-grid technologies

Crucially this study is not limited to off-grid areas. A thorough assessment of the potential impact for energy interventions on agricultural value chains would be incomplete without consideration of grid-connected areas. The impact of renewable energy installations on value chains can be significant in so-called 'under-grid' areas where the quality of supply from the national grid is poor and as a result machinery is often idle. These 'weak grid' areas often have connections to large wholesale markets, serve as aggregation nodes for multiple crops and benefit from better access to transport infrastructure, stockpiling facilities and a diverse and better educated workforce. Interventions can be brownfield or greenfield by nature (see Appendix F). Brownfield approaches are characterised as projects which improve the electricity supply for existing processing operations and are therefore less risky. Greenfield projects are those which establish entirely new processing capacity in strategic locations and while more risky, offer a potentially bigger upside.

75 Smart Power Myanmar, Decentralised Energy Market Assessment in Myanmar, 2019 (*link*)
76 Wood Mackenzie, Solar-plus-storage opportunities in the APAC region, 2019 (*link*)
77 IFC, Myanmar Distributed Generation Scoping Study, 2019 (offline)

The cost of investing in a renewable energy system either as a captive power system (solar, storage or solar plus storage) or a grid tied mini-grid has the potential to result in a greater increase in added value per dollar invested in a value chain than in a rural village where the economies of scale are smaller. The techno-economic modelling of the best fit solution however relies on accurate data of energy costs. Grid tariffs paid by commercial and industrial customers in Myanmar do not exceed 175 Kyat/kWh ($0.12/kWh). Despite these low grid tariffs, a grid-connected agricultural processing facility faced with unreliable grid supply may be willing to adopt a solar without storage captive power solution, as grid-connected commercial and industrial solar LCOE without storage is already as low as $0.10/kWh – $0.13/kWh (see Figure 23). Lithium-ion batteries on their own also offer an attractive captive power option in Myanmar, mainly as a result of the low grid tariffs. The battery system can be charged with subsidised electricity when it is available and keep machinery going by discharging when it is not. Given the prevailing grid tariff, a grid-connected lithium-ion storage-only solution in Myanmar has an estimated LCOE of $0.14/kWh.[78]

Even with the addition of sales margins to these LCOE figures, it is likely that costs are within the range of grid-connected agricultural processors' willingness to pay. **Survey data indicate that processors are willing to pay amounts in the range of $0.23/kWh for diesel generators during grid downtime.**[79]

A second critical determinant of the best fit solution is the quality of existing grid supply. Surveys suggest that in many grid-connected areas availability is about 75%, but this varies by region[80] and by season.[81] In a 75% uptime scenario, machinery is sitting idle 25% of the time. This will affect the competitiveness of the processor. Therefore a critical question arises: **When does extra productivity resulting from improved electricity supply justify the investment into the equipment needed to guarantee this supply?** The simplified techno-economic model in Appendix F demonstrates an approach to answer this question, using the example of an existing bean colour sorting processor investing in a storage-only solution to smooth supply. This activity was selected because the ratio of value added to kWh consumed for a colour sorter is high and the high costs of the machinery imply that it is more suited to a downstream, high throughput processor. **As the calculation shows, it takes the processor ten working weeks to recoup the investment of a 2.56kWh lithium-ion battery (brownfield scenario), while it takes them 24 working months to recoup the investment of the storage system and processing machine collectively (greenfield scenario).**

78 TFE Energy analysis

79 One of the larger scale bean processors interviewed noted that a unit of electricity generated from a generator costs MMK 300 ($0.23). The processor indicated that despite the expense, this still makes business sense and there is no other option available.

80 Expert interviews indicate that Ayeyarwaddy, Shan and Rakhine states are some of the worst affected states. Respondents located in Sagaing, Bago and Yangon states also reported downtime during the summer months.

81 Downtime occurs especially during the summer months (rainy season). During downtime, operators that are highly dependent on electricity (typically processors) resort to diesel generators.

4.0 Delivering improved energy access

Renewable energy technologies in Myanmar

Solar photovoltaics (PV) is widely used as a source of renewable energy and is well suited to off-grid rural electrification owing to the fact that it can be used anywhere with suitable solar irradiance. Rapidly declining costs and improving efficiency make it an increasingly cost competitive alternative to conventional sources of energy like diesel in rural settings. In Myanmar, solar energy is estimated to power 190 villages through mini-grid systems and nearly 8,000 others, primarily via solar home systems.[82]

Small hydro is well suited to hilly areas with suitable rainfall and seems to be concentrated in Shan, Mandalay and Sagaing states.[83] It generally offers a low LCOE and is an established and trusted technology. Myanmar has a long history with small hydro, with several local manufacturers of hydropower systems.[84] An estimated 25% of existing mini-grids in the country are powered by small hydro.

Rice husk gasification involves the burning of rice husks and the combustion of the resulting syngas in a generator to create electricity.[85] Gasification also boasts a low LCOE and the byproducts of the process include biochar, an excellent soil conditioner that can be cycled back to the farm and silica which is an industrial feedstock.[86] The specificity of the feedstock however limits any widespread applicability of this generation technology. Myanmar produces around 6 million tonnes of rice husk annually and in 2016 already had more than a thousand rice mills powered by small scale biomass gasifiers using husk as feedstock.[87]

4.1.3 The concept of utility

While the comparison of the LCOE of different energy provision options is useful, it should be noted that it is not the only metric to consider. The value or 'utility' derived from each kWh converted to useful work is different depending on the application. For example, the small fraction of a kWh used to power a light bulb in a low-income household to replace expensive and harmful kerosene lamps will have considerable value to the user. In the same way, using a kWh for an agricultural process that significantly increases the value of the crop will have a value that might justify a higher unit price paid for that kWh. This is particularly true if the opportunity cost (i.e. lost potential revenue) of not having the energy available is taken into account. This equation is the same whether the kWh is being generated, purchased and consumed in an off-grid context where there is no alternative or in a weak grid context when the supply of cheaper, on-grid kilowatt hours is interrupted.

82 SPM, Decentralised Energy Market Assessment in Myanmar, 2019 (*link*)
83 Greacen, C. The role of mini-grids for electrification in Myanmar, 2016 (*link*)
84 Including Sai Htun Hla and Brothers Mini Hydropower Company, Kyaw Soe Win Mini Hydropower Company and Royal Htoo Linn Manufacturing Co. Ltd. From Vaghela, D., Cornerstone of Myanmar's self-financed mini-grids success, 2017 (*link*).
85 Companies like HUSK Power have had commercial success with mini-grids based on this technology across India and East Africa (*link*).
86 Mitsubishi Research Institute and Fujita Corporation, Feasibility Study on Rice Husk Power Generation System for Low-carbon Communities in Ayeyarwady Region, Myanmar, 2015 (*link*)
87 Pode, R.B. & Pode, G., Solution to sustainable rural electrification in Myanmar, 2016 (*link*)

4.2 Delivery models

Decentralised renewable energy (DRE) technologies offer several promising options for the scaled electrification of agricultural processing. However, developing and deploying sustainable DRE systems requires a fundamentally different approach to traditional electrification. The transition from large, centralised, top-down infrastructure projects to small-scale, distributed and bottom-up ones faces several interconnected barriers which can limit effective implementation at scale. Both creating an enabling environment for DRE at the macro scale and delivering a project at the micro scale require consideration of several key factors. These are presented in Figure 24 and discussed in greater depth throughout the remainder of Chapter 4.

Figure 24: DRE implementation barriers in Myanmar

Policy & regulation	Financial & economic constraints	Technical and operational factors
• Tariffs • Subsidies • DRE specific regulations • Institutional capacity • Grid encroachment policy • Duties and taxes	• Political stability • Currency risk • Local finance sector capacity • Access to project developement capital • Access to consumer finance • In-country DFI suport • Mobile money penetration • Ability to pay	• National technical standards • Grid interoperability • Mobile telecoms • DRE private sector capacity • Labour availability • Equipment availability • Revenue collection • Business model innovation • Existing infrastructure

4.0 Delivering improved energy access

4.2.1 Policy and regulation

Decentralised energy systems in Myanmar are categorised as "small electrical businesses" by the Electricity Law of 2014 – systems that are less than 10 MW. Enforcement of small electrical business regulations and all associated licensing processes is the responsibility of the relevant regional and state governments, which includes authorising new small sized energy projects.[88]

There is no dedicated regulatory framework in place for decentralised off-grid energy systems. Extensive work has however been done by GIZ and the DRD to improve the regulatory environment, which culminated in the publishing of the draft Electricity Authority Isolated Small Scale Electric Power Enterprise Regulations of 2018. These regulations address a number of issues including mini-grid tariff setting processes and contingency plans for grid arrival at isolated mini-grid sites (asset transfer or interconnection)[89] among others. At the time of writing, the regulations were still under review by the Ministry of Electricity and Energy (MOEE).

There are also no specific regulations applicable to grid-connected decentralised energy systems. A draft renewable energy policy released in 2014 does encourage private parties to build, own and operate grid-connected renewable energy systems,[90] and the DRD and GIZ published the draft Ministry of Electricity and Energy Grid-Connected Small Scale Electric Power Enterprise Regulations alongside the isolated small scale electricity regulations in 2018. These cover important provisions such as net metering, but at the time of writing are still also under review by MOEE. State/region governments are further hard pressed to buy energy from grid-connected solar operators given that their revenue from energy sales goes to the union government. In turn, state/region governments only receive an allowance to cover their costs of implementing distribution infrastructure.[91]

a. NEP rules and guidelines

Despite the absence of national decentralised energy regulations, a variety of rules and guidelines are applicable to NEP funded mini-grids. Developers are required to sign a tripartite agreement with the DRD and the village electrification committee (VEC), submit a land acquisition certificate and environmental and social safeguard screening forms and comply with technical standards. In addition, service agreements must be signed with customers. Tariff setting processes for NEP-supported mini-grids are clearly specified in the programme's documentation.[92] The NEP mini-grid guidelines indicate that tariffs should consider the community's willingness to pay, while also ensuring a reasonable financial return for the developer. Tariffs are determined in the tripartite agreement between the developer, VEC and the DRD and the agreed tariff is to be reflected in the service agreement between the developer and customers. The DRD also supports developers that respond to calls for proposals with a variety of tools and information documents such as budgeting templates, load profile templates, willingness to pay estimation tools and energy demand estimation questionnaires.

88 IFC, Myanmar Distributed Generation Scoping Study, 2019 (offline)
89 Smart Power Myanmar, Decentralised Energy Market Assessment in Myanmar, 2019 (*link*)
90 Republic of the Union of Myanmar, Draft Myanmar Renewable Energy Policy, 2014 (*link*)
91 The Asia Foundation, Decentralising Power – The Role of State and Region Governments in Myanmar's Energy Sector, 2019 (*link*)

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92 National Electrification Project, Call for proposals for engineering, procurement, construction and operation of mini-grid projects in rural villages, 2018 (*link*)

Establishing enabling mini-grid policy – Lessons from Cambodia[93]

Cambodia, like Myanmar, has over the last few decades experienced an emergence of informal, mostly diesel-powered mini-grids. Transitioning away from the informal laissez-faire conditions of the electricity sector, the government created the Electricity Authority of Cambodia (EAC) which allowed it to:

Regulate
All operators are required to obtain a license from the EAC and adhere to technical standards.

Fund
Licensees are eligible for grants and concessional loans through a Rural Electrification Fund (REF).

Integrate mini-grids with the main grid
Once the main grid arrives at a mini-grid site, the mini-grid is interconnected and generation assets decommissioned. The mini-grid can then source cheaper power from the grid, and resell to their customers at a margin.

Important policy design elements include:

1. A standard customer tariff applies to interconnected mini grids.
2. The standard grid tariff does not apply to isolated mini grids, or mini grids purchasing power from a medium voltage line fed by imports. Instead, each site is evaluated and tariffs individually determined based on cost of supply.
3. License terms are adjusted according to operator performance. EAC grants longer term licenses to operators that comply with service requirements.

Key achievements include:

- Licensees made around one million new connections between 2005 – 2015.
- The number of licensees increased from 85 to more than 300 between 2003 – 2015.
- In 2015, most licensees supplied energy for 24 hours a day, compared to 2003 when only about a third could provide 24-hour supply.
- In the same period, electricity tariffs were halved, from US$0.50/kWh to US$0.25/kWh.

Despite these impressive feats, the push for tariff reduction leads to market consolidation. More established operators can leverage economies of scale and decrease operating margins, which can squeeze out smaller operators.

93 ESMAP, Mini-grids in Cambodia – a case study of a success story, 2017 (*link*)

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d. Duties and taxes

The Myanmar government does not charge value added tax (VAT) on products and services, but import duties are enforced (as per Myanmar Customs Tariffs guidelines). Import duty rates for selected renewable energy components are listed in the table below.

Table 7: Import duty rates of various renewable energy technologies in Myanmar[94]

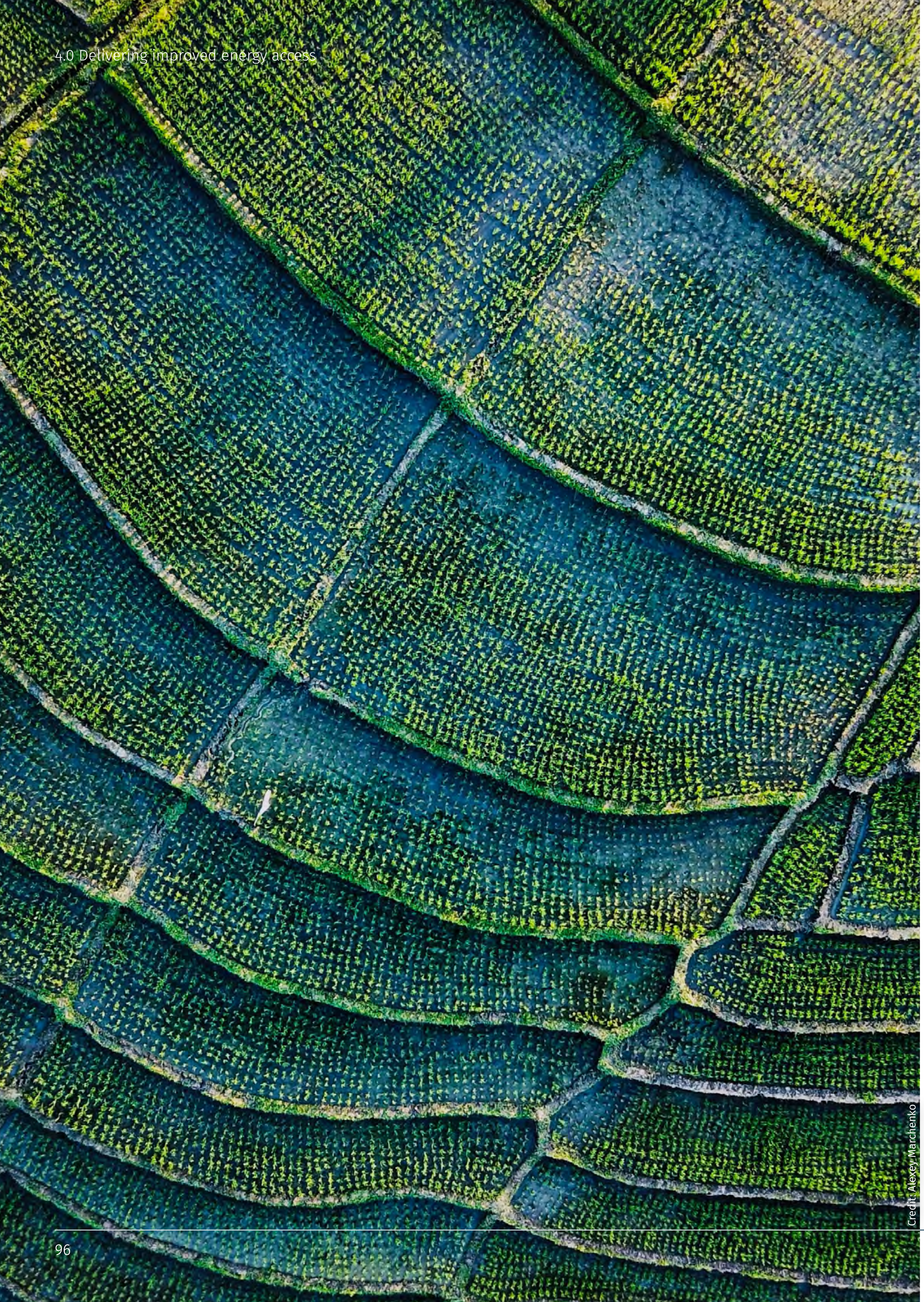
Renewable energy component	Duty rate
Solar panels	7.5%
Inverters	3%
Lithium-ion batteries	3%
Lead acid batteries	3%
Hydro turbines not exceeding 1 MW	3%
Wind turbines not exceeding 5 MW	3%

The positive effects of duty reduction or removal on renewable energy industries are well documented. Many developing countries, especially those without domestic PV manufacturing facilities, have successfully supported renewable energy industries through the removal of all import duties from the main renewable energy components. The application of these best practices in Myanmar can ease operating conditions and specific recommendations are provided in Chapter 5.

4.2.2 Project developer access to finance

The financing landscape for decentralised renewable energy in Myanmar is constrained. Local financial institutions often lack experience evaluating projects and their risks,[95] and receiving international investment as a project developer is challenging.[96] The small scale of most mini-grid and captive power projects relative to the minimum ticket sizes of commercial banks further exacerbate financing challenges.[97]

94 Myanmar National Trade Portal, Commodity Search, 2021 (*link*)
95 On the mini-grid front, Smart Power Myanmar is actively addressing this barrier by training commercial banks' risk departments on mini-grid project economics. This forms part of SPM's Myanmar Equipment Financing Facility.
96 This is due to, in part, exchange rate risk of the Myanmar Kyat and the requirement that all offshore loans must be approved by the Myanmar Central Bank (which takes approximately one month).
97 Commercial banks' transaction costs associated with due diligence and loan origination are fixed irrespective of project size and thus prefer to invest in larger projects.



Credit: Alexey Marchenko

4.0 Delivering improved energy access

Perceptions of risk are compounded by inherent uncertainty in the sector resulting from a combination of factors:

1. Mini-grid developers often struggle to prove their business models to funders due to a lack of consumer data. In Myanmar and further afield, it is difficult to predict the creditworthiness and energy demand of rural, unbanked customers. The same applies to the captive power segment, where credit ratings for C&I solar customers are not in place.[98]
2. Low ability to pay for mini-grid energy services negatively affects the business model. Consumers often compare mini-grid tariffs to highly subsidised main grid tariffs (despite main grid tariffs being below LCOE) and hence find it hard to justify a price premium for mini-grid energy services.
3. The lack of published policies and regulations increases uncertainty around crucial components of mini-grid and captive power business models.
4. NEP-supported mini-grid developers are unable to collateralise mini-grid assets due to ownership issues resulting from the condition that the assets of DRD-subsidised mini-grids must be transferred to the VEC after 8-10 years of operation. This in turn increases investment risk.[99]

To account for risk, interest rates are increased, loan tenors shortened (sometimes as short as one year) and the capital contributions by banks limited, going as low as 20% of project cost.

4.2.3 Off-taker access to financial services

Currently, Myanmar scores among the lowest of its regional peers for financial inclusion with only 26% of adults having an account at a financial institution and less than 1% having a mobile money account.[100] Despite poor relative performance, financial inclusion seems to be steadily increasing, even for rural populations, as demonstrated by Figure 25. Farmers and agricultural micro, small and medium enterprises (MSMEs) are critical segments for greater inclusion efforts given high use of credit, potential for increasing productive capacity and roles in both food security and

98 IFC, Myanmar Distributed Generation Scoping Study, 2019 (offline)

99 Smart Power Myanmar, Closing the Finance Gap – Assessing Options for Decentralised Renewable Energy Mini-Grids in Myanmar, 2019 (*link*)

100 The World Bank, Global Findex Database, 2017 (*link*)

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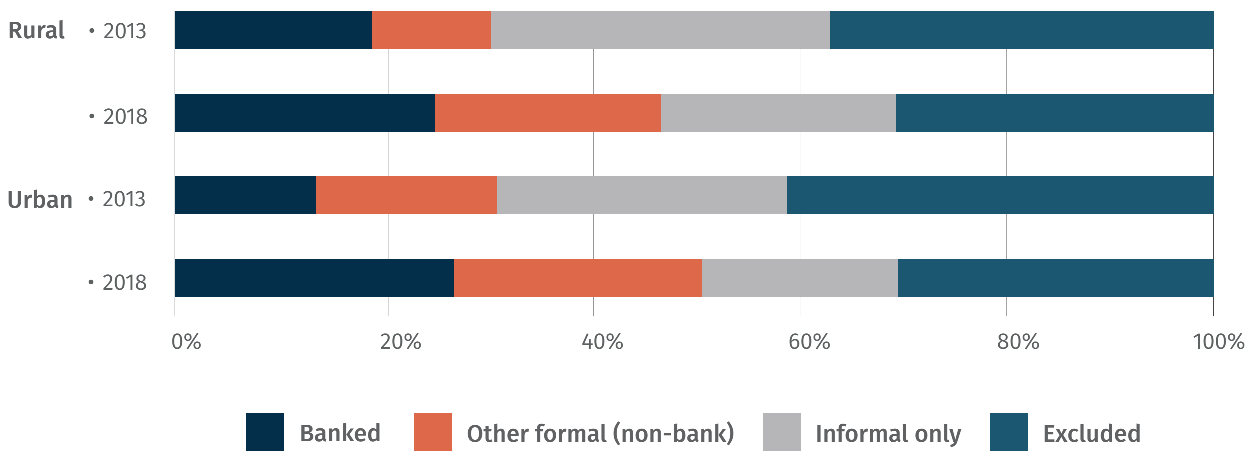
livelihoods. Myanmar's financial landscape is poised for growth to both broaden[101] and deepen[102] financial services, increasing levels of inclusion and sophistication respectively.[103]

Figure 25: Percentage of adults with an account at a financial institution[104]



During surveys, input suppliers, farmers, processors and traders all mentioned that a lack of access to affordable credit is a major barrier to development. Applications of credit, should it be accessed, are similar across surveyed operators. Input suppliers would like to buy additional equipment to be rented to farmers, while farmers mentioned the need for credit in order to buy machinery and inputs such as seeds. Processors would like to buy more processing machinery and traders require credit to buy more produce. Among processors and traders, the need to access storage space is an additional motivation for accessing credit. Larger processors are more likely to have sufficient capital to acquire storage space and fill it up with raw produce. This enables them to spread out their operations far beyond harvest season (when selling prices are higher). Similarly, traders with sufficient storage space have the ability to store large amounts of raw or finished produce and sell to processors or retailers when prices are attractive.

Some survey respondents indicated that they have easy access to agricultural credit through the dedicated Myanma Agricultural Development Bank (MADB). However, delays in the timing of MADB disbursements often force actors along the agricultural value chain to rely on informal loans at high interest rates to cover any time-sensitive shortfall.[105] Although informal loans are repaid once MADB funds are disbursed, the significant difference in interest rates can easily erode limited capital reserves held by farmers. Informal loans also lend themselves to predatory behaviour by traders and other off-takers, often forcing farmers to sell produce below market value or carry a disproportionate amount of risk, as in the case of crop failure. Few private banks offer products or services tailored to the needs of farmers or processors, and even less so to the needs of the nascent private energy sector.

In recent years, innovative financial solutions have emerged to expand financial services and credit to unbanked, often rural populations. From micro-finance institutions (MFIs) and crowdfunding to mobile money and credit scoring based on agri-tech data, companies are finding new ways of reducing transaction costs, streamlining historically onerous processes and engaging customers. Examples of enabling financial innovation in Myanmar include:

1. **Mee Panyar** crowdfunding to train rural electricians to install and maintain solar mini-grids;[106]
2. **Agrosolar** raise debt through crowd lending to finance solar pumps for 100 smallholder farmers;[107]
3. **Maha Agriculture Microfinance** provide loan, savings and insurance products to a range of small-scale agriculture actors, including farmers, vendors and SMEs;[108]
4. **Proximity Finance** leverage alternative credit scoring metrics to extend tailored loan products to rural farmers.[109]

4.2.4 Technical standards and quality assurance

Myanmar currently lacks clear national DRE technical standards,[110] yet the NEP has its own set of standards and quality assurance protocols applicable to mini-grid developers building sites under the programme.[111] These cover standards related to civil works, generation and balance of system components, distribution lines and demand-side infrastructure such as in-house cables and

101 Broadening financial services means to expand financial products and services to a larger user base.
102 Deepening financial services means to increase the sophistication of financial products and services, often for specialised and or dedicated applications like small scale PUE equipment.
103 Making Access Possible, Myanmar Financial Inclusion Roadmap 2019 – 2023, 2019 (*link*)
104 Making Access Possible, Myanmar Financial Inclusion Roadmap 2019 – 2023, 2019 (*link*)

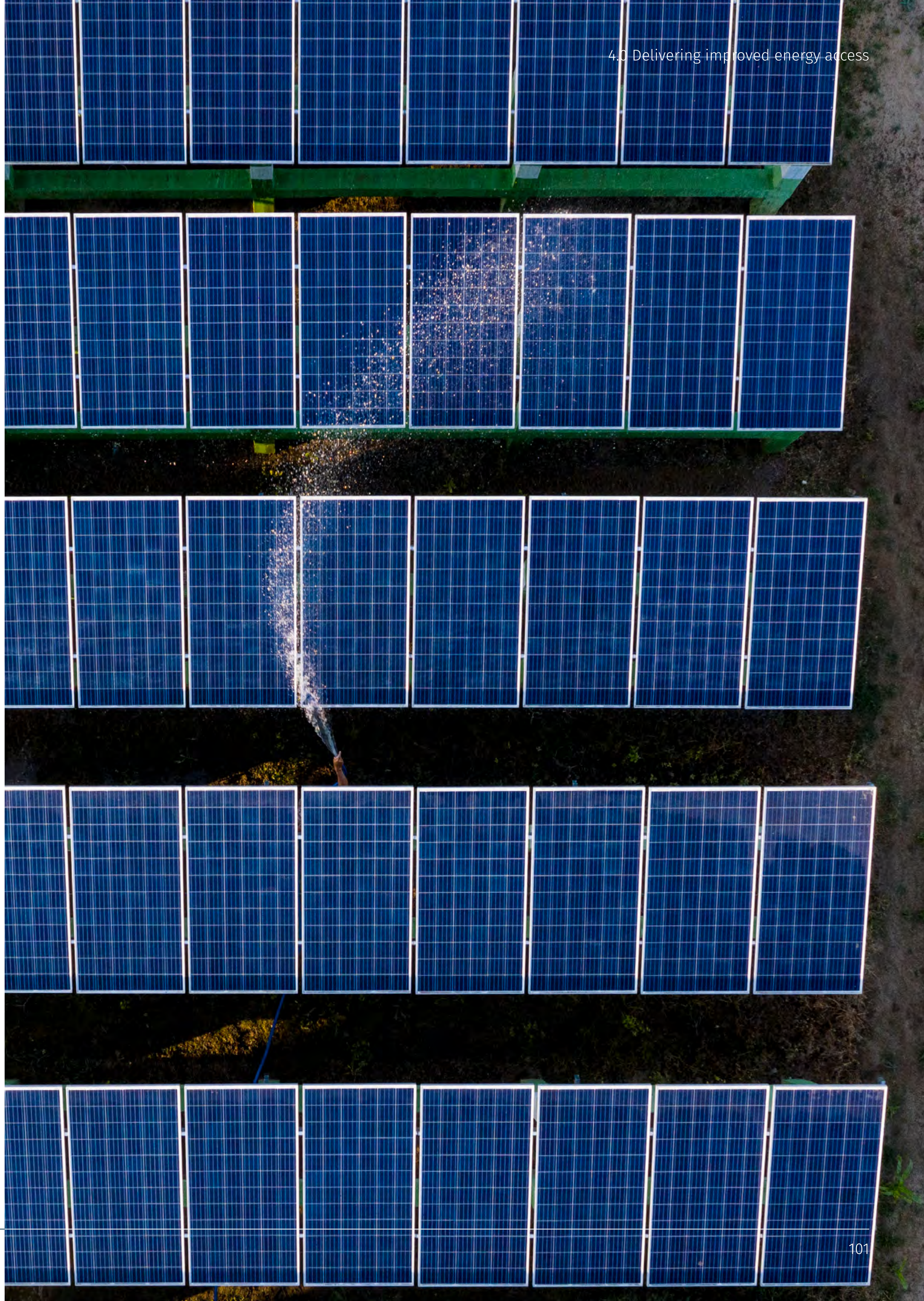
105 Mercy Corps et al., Bridging agricultural livelihoods and energy access, 2020 (*link*)
106 Energy4Impact, News, 2019 (*link*)
107 KIVA, Agrosolar's story, 2021 (*link*)
108 Maha Agriculture Microfinance (*link*)
109 Proximity Farm aFinance (*link*)
110 Draft regulations mentioned earlier in this chapter are expected to elaborate on technical standards.
111 Department of Rural Development, Mini-grid technical guidelines, 2019 (*link*)

meters. The standards are also accompanied by a standardised performance reporting protocol containing indicators from the NREL Quality Assurance Framework (QAF) for mini-grids and IEC reporting protocols. Standardised technical and financial performance reporting is useful in a programme such as the NEP as it allows the DFI and rural electrification agency to monitor a mini-grid programme consisting of projects developed and operated by multiple and diverse developers. NEP developers are required to monitor service interruption events, customer level consumption data, number of customers, load profile, energy generated and energy sold. To collect and share this data, the NEP performance reporting guidelines recommend the use of internet-enabled components (e.g. inverters and smart meters) linked with an online platform.[112] Online data hosting platforms on the market today are typically integrated with most of the monitoring web portals of the common inverter and smart meter manufacturers and data is shared via application programming interfaces (APIs).[113]

While standardised reporting eases programme monitoring, its benefits also extend to individual developers. The ability of project operators to remotely monitor their systems reduces operations and maintenance (O&M) costs by, for example, reducing the need to send technicians to site and improves system uptime thereby increasing the quality of the delivered energy service. For the industry at large, a standardised data pool offers a valuable advocacy tool by providing evidence of the efficacy of mini-grids as a viable electrification route. The Government of Myanmar plans to reach universal electrification through grid extension alone by 2030 but the likelihood of reaching this target is decreasing over time due to the slower than expected progress being made. Large scale data on the efficacy of mini-grids will be an indispensable tool that can be used to convince policymakers to include mini-grids in official electrification planning and in so doing speed up the progress of electrification in Myanmar.

In the future, the operationalised QAF could also assist rural electrification agencies and DFIs such as the DRD and the World Bank to implement results-based financing schemes, as it will enable them to make data-driven decisions on whether mini-grid developers qualify for funding. Operational disbursement triggers such as energy service availability over time can only be verified using data and standardised performance reporting protocols. Smart meter and inverter data can for example be used to determine whether an RBF claimant's operations meet the quality standards prescribed in the QAF. While this can be done manually, platforms like Odyssey can enable automatic, data-based triggers for funds disbursement.

112 If no internet connectivity is available on-site, data must be uploaded manually once a month.
113 For example, Odyssey Energy Solutions (*link*)



4.0 Delivering improved energy access

4.2.5 Emerging private sector delivery models

As the DRE industry evolves and matures worldwide, providers of energy services are increasingly finding innovative ways to increase efficiencies and bring costs down. In off-grid areas, mini-grid operators are increasingly aware of the disproportionate contribution that productive users of energy make to the commercial viability of a project. These ‘high yield’ customers generally make up a small proportion of a mini-grid user base (typically around 20%) yet provide most of the revenues (typically 80%). Thus, **the electrification of rural agricultural processors serves the functions of improving the business case of the energy service provider,** supporting rural entrepreneurship, bringing agricultural value capture upstream, improving community livelihoods and unlocking both direct and indirect rural development.

In the same way that high yield individual customers play a significant role in improving the mini-grid business case, the same can be said for the electrification of high yield,[114] value-adding agricultural processing activities. Furthermore, as is the case with mini-grids, captive power system providers also **improve the business case of a project by focusing efforts on energising and enabling productive uses of electricity in the form of high yield agricultural activities.**

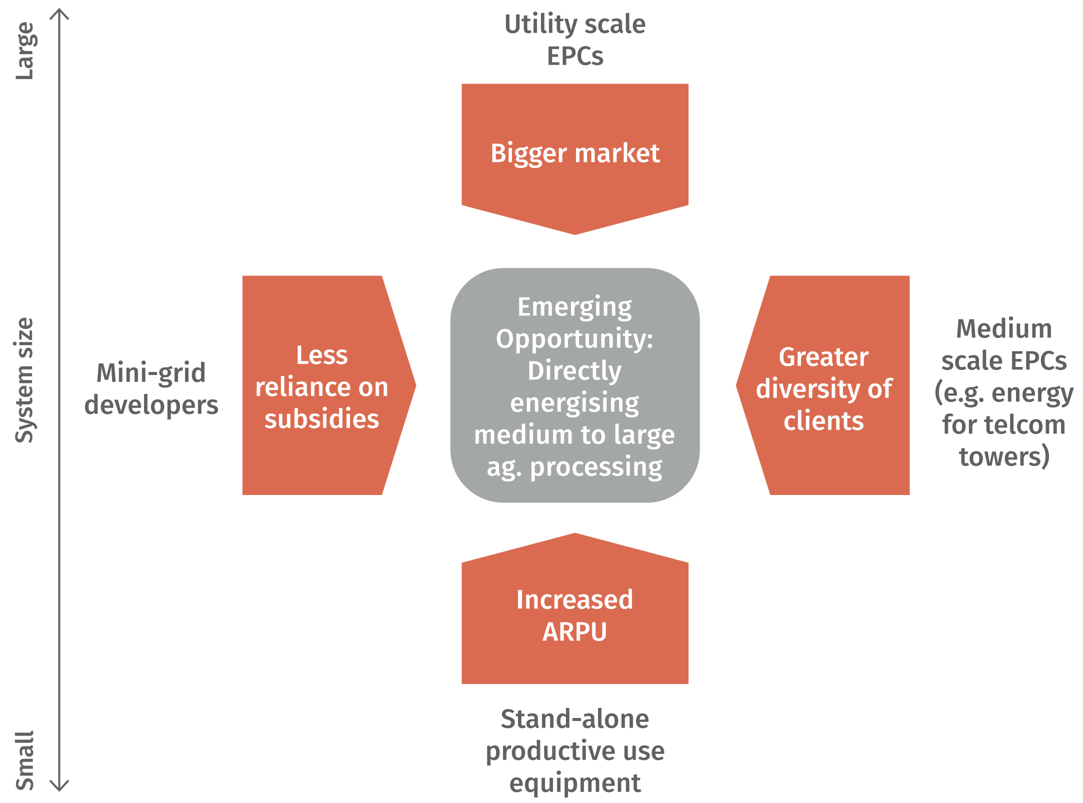
By extension, the same can be said for the providers of capital to finance the installation of these systems. This emerging opportunity is thus a significant driver for scale for any initiative designed to maximise the impact of renewable energy in agricultural value chains and provides a fundamental rationale for the techno-economic modelling of proposed interventions.

a. Productive use focused business models

To date a majority of the productive uses of energy delivery models have focused on the far ends of the spectrum. Located at one end of the spectrum are small-scale productive uses of energy equipment, associated with small project ticket sizes and a small number of users. At the other end are utility scale energy and infrastructure, associated with large ticket sizes and a large number of users. Small scale equipment is attractive as the capital requirements and operational costs generally match the ability-to-pay of individual small-scale operators, while utility scale projects are attractive as capital requirements fit well into the financing models of large financial institutions. There is potential for both subsectors to shift, grow and diversify into large to medium scale productive uses of energy models (see Figure 26). Energising agricultural processing in Myanmar is an ideal case for medium to large productive uses of energy. This subsector has significant growth potential, large social impact combined with reasonable economic return and can help increase the financial viability of DRE.

114 Defined as providing significant revenues or value addition per unit of electricity consumed.

Figure 26: Energy service providers of different scales can benefit from energising agricultural processing



The ability for smaller energy provision companies to shift from small to larger scale is facilitated by the emergence of new innovative captive power delivery models and the increasing awareness of the value proposition of DRE amongst consumers, policy makers and financiers. It is also enabled by improved access to affordable capital for smaller companies, for example the crowd funded capital of companies like Mee Panyar. In the case of a mini-grid operator, translating the experience (e.g. collecting payments) and technology know-how (e.g. remote equipment monitoring) gained from running rural mini-grids to providing energy for a single big off-taker is an attractive proposition. The shift from utility scale to smaller scale is helped by the shrinking minimum economies of scale enabled by increasingly affordable modular DRE technology. There is also an emerging ability (assisted by better data technologies) to aggregate medium scale projects into large portfolios which are more accessible to larger financial institutions and government departments.

This shift can be best supported by the provision of more capital within the currently underserved 3-10 year payback period bracket (outside traditional short term 1-2 year and long term 15+ year payback periods) and widening the access to subsidies earmarked for small scale electrification (such as the 60% mini-grid CAPEX subsidy).

Examples of scalable large to medium scale productive uses of energy

Opportunities within emerging large- to medium-scale productive uses of energy are accessible to a wide range of stakeholders within the energy sector. A number of these models are ready for market and poised for growth.

An example of one of these opportunities is a company which offers solar irrigation pumps which cost $600-$1,000 to individual smallholder farmers on an 18-month pay-as-you-go (PAYG) basis. This company could expand using its existing systems and begin offering solar powered mills to SMEs which cost $6,000-$10,000 on a PAYG basis over a 5-7 year period with the help of a small national subsidy or a first loss pool. Such a model could help scale local agricultural processing across multiple value chains.

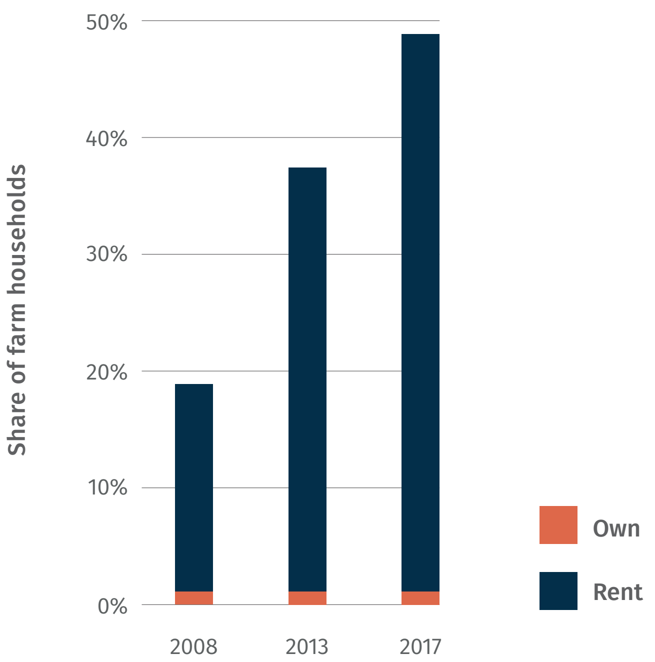
Another example is for a large engineering, procurement and construction (EPC) company to expand into offering energy-as-service to a portfolio of diesel-powered off-grid rice mills owned and operated by cooperatives in villages across Myanmar in partnership with a large off-taker of the processed rice. The business case for the EPC is compelling as the business model displaces expensive diesel generator electricity and an off-taker is guaranteed.

Opportunities are equally present in grid-tied scenarios. A small but growing local EPC can act as a micro-utility and offer grid smoothing services to a large agricultural processor faced with grid outages. This presents an opportunity to rapidly scale the local EPC's business. Simultaneously, displacing backup diesel generator electricity with cheaper and more reliable DRE electricity improves the competitiveness of the agricultural processor. This is particularly true in value chains that are vulnerable to cheaper imports of competing products.

b. Service-based business models

Agricultural processing-as-a-service is common in Myanmar as it is in most developing countries. This trend has been reflected in the survey data, as well as secondary data (see Figure 27).

Figure 27: Share of farmers owning and renting threshing machines in Myanmar's CDZ[115]



In the same way, DRE can also be a service. Mini-grids are well established as an energy-as-a-service model, but the same cannot be said for the providers of captive power systems. Energy-as-a-service in this sub-sector can take the form of a micro-utility. A micro-utility is defined as an organisation owning and operating at least one power system connected to a behind-the-meter network supplying and selling electricity to one or more customers.

The concept of a micro-utility or in other words the selling of kWh to commercial off-takers like medium- or large-scale agricultural processors is not well established in Myanmar. Yet as this report demonstrates, the low-quality grid service and the existence of power shortages in Myanmar which currently hampers industries such as agricultural processing improve the commercial viability of this model.

115 IFPRI, Agricultural Mechanisation in the Dry Zone of Myanmar, 2018 (*link*)

4.0 Delivering improved energy access

There are significant systemic challenges to this approach in Myanmar. These include a lack of local technical capacity, poorly established supply chains for the enabling technology, poor access to affordable finance and a lack of supportive regulation. The national policy landscape has a major influence on the micro-utility model. Without supportive regulation the sophistication of the model is limited to private sector financing for a productive use off-taker to purchase a captive power system (such as rooftop solar panels) for their own use. More advanced legislation unlocks the micro-utility model proper, where a private entrepreneur can install a captive power system on the roof of a commercial off-taker and sign a power purchase agreement locking in a predictable cost of energy and reducing barriers to adoption for the off-taker. Furthermore, by reducing most of the risk to the off-taker, this model can significantly accelerate the deployment of renewable energy systems at the commercial scale.

In the most sophisticated regulatory environments, independent power producers can generate electricity from large, utility scale renewable energy installations and wheel it (at a fee) to customers anywhere in the country. Likewise, time-of-use energy pricing means that owners of DRE systems can play a brokering role, sourcing the cheapest energy in real time to re-selling to their off-taker customers as well as making additional revenue offering grid smoothing services to the national grid.[116] Myanmar is some way away from this being a likely scenario.

c. Building end-to-end value chains

More and more mini-grid companies are acknowledging the importance of stimulating productive uses of energy through, for example, financing the purchase of productive use equipment. This has the dual function of increasing demand for energy as well as diversifying revenue streams and reducing off-taker risk (see the ANKA Agrigrid case study). One of the most extreme examples of this is the KeyMaker model in Tanzania, where Jumume, a mini-grid developer operating mini-grids on the shores of Lake Victoria built an entire value chain. Fish are purchased from local fisherfolk, refrigerated using energy from the mini-grid, transported to the capital city and sold directly to regular customers. This is a resource intensive system to set up, but has numerous advantages including supporting the mini-grid business model, providing predictable and improved incomes for the fisherfolk as well as concentrating value capture to fewer stakeholders.

116 This model is successfully being applied in Germany (*link*).

Case study summary: Agrigrid concept in Madagascar

Agrigrid is an innovative business model concept devised by ANKA Madagascar, a Malagasy small-scale energy company and mini-grid developer. The model responds to several key constraints also prevalent across Myanmar's energy and agriculture sectors, including:

- Unfavourable agribusiness environment
- Inefficient energy and agricultural systems
- Weak infrastructure
- Agriculture focused finance

To overcome these constraints, Agrigrid defines the energy company as an agribusiness company and positions it as an institutional intermediary linking rural, small-scale farming communities with external markets. The intermediary usually undertakes basic processing/value addition activities, effectively serving as its own anchor load. The model has within it three distinctive levels of innovation.

First is the vertical integration of complementary rural agriculture and energy services, serving as a buyer of agricultural goods on one side and as a seller of electricity on the other. Second is a profit-sharing mechanism which gives communities a sense of ownership of projects and provides additional disposable income often recycled into energy sales. Third is the consolidation of multiple services into a single company, centralising assets and increasing potential investment size, thus enhancing attractiveness.

d. Community-centred delivery and management

Myanmar has had unrivalled success in developing small-scale, off-grid energy solutions developed, owned and managed largely by rural communities and in some cases local technology developers. Between 4,000 and 6,000 informal mini-grids have been developed by communities utilising a range of energy sources, including diesel, small-hydro, biomass and solar.[117] While many of these systems are crude, often inefficient and prone to breakdowns, they were designed and implemented without formal technical training, limited government or donor support, technology and material shortages and in an environment with no enabling policies. This achievement demonstrates the tenacity and ingenuity of rural communities and highlights several lessons for developing mini-grids in the intermediate scale between large, highly commercial projects and small, local and informal village mini-grids.

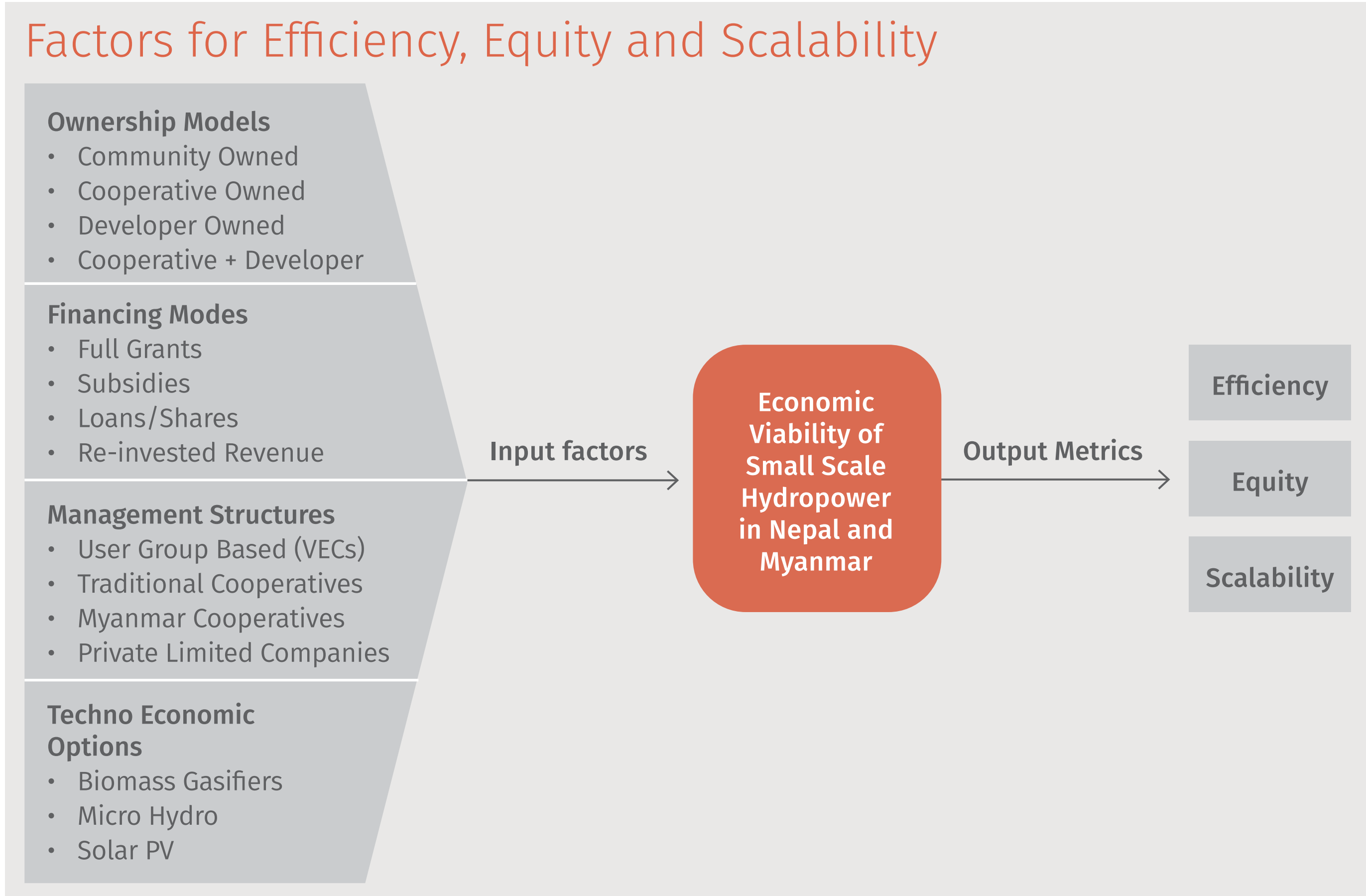
Experience in Myanmar has shown that community-centred energy projects often require a balance of responsibilities between the community and private developer. Embedding mechanisms for shared responsibility and value into business model or project design holds several benefits for both parties.

- Sharing upside benefit and downside risk aligns financial incentives of both parties, thereby encouraging cooperation towards a mutual goal.
- For the developer, on-site presence of local agents or technicians reduces the site visit travel requirements and associated operating costs.
- Local community members receive skills training and can be locally employed in some capacity to conduct paid activities on behalf of the developer.
- Local technical upskilling and increased local incomes improve livelihoods and stimulate local economic activity. Increased economic activity may increase energy demand and improve ability to pay, thereby catalysing a virtuous cycle of rural development.

117 HPNET, Community Enterprise Hydropower Networks, 2019 (*link*)

4.0 Delivering improved energy access

Figure 28: Design factors affecting small-scale community energy enterprise projects[118]



118 HPNET, Community Enterprise Hydropower Networks, 2019 (*link*)

Examples of sharing mechanisms include:

- Profit sharing, where the energy company distributes a portion of their profit to the community, usually to incentivise desired behaviour like on-time payment or as profit in a shared ownership scheme;
- Shared ownership, where business assets are co-owned and profits distributed accordingly between the energy company and the community. This has several benefits:
  - Incentivising communities to support a project's success;
  - Catalysing local economies, providing livelihood opportunities and additional sources of income which can be recirculated via energy sales;
  - Community capital contributions provide a source of co-financing. This reduces external financing requirements and retains value[119] locally.
- Public benefit where an energy company provides street lighting at low or no cost to a community to gain goodwill.[120]

Leveraging Myanmar's strong local capacity can be a key driver for scaling mini-grids while providing capacity development and economic opportunities. Combining the technical and managerial capabilities of rural populations with their intimate knowledge of local dynamics can help overcome many of the challenges developers face when scaling. At the pre-build stage, demand estimation, willingness to pay assessment and customer acquisition can be supported by trained local representatives. Similarly, post-build on-site activities like collection of payments, technical maintenance and customer care can be readily undertaken by local agents. Local agents, by virtue of their familiarity with local conditions, may also be more effective at facilitating engagement between developers and communities. Increases in developer operating costs from agent remuneration could be offset against reduced travel requirements, improved demand estimation and system sizing, better customer risk evaluation, and improved customer acquisition.

119 Value here refers to any gains resulting from community capital contribution and may include profit returned, interest income or similar.

120 HPNET, Community Enterprise Hydropower Networks, 2019 (*link*)

Case study summary: Indigenous mini-grid developers in Myanmar

Myanmar has a unique off-grid energy landscape comprising thousands of village-level generation systems. They were developed with effectively no government or development support. Equally interesting is the community-centric and shared value business model that underpins many of these projects that embed local ownership and skills development into project design. To date this approach has stimulated the local socio-economies of hundreds of villages through employment while ensuring project sustainability.

The 80kW Mae Mauk micro-hydro power plant in the Shan highlands is a case in point. It serves 700 customers across 13 villages and is managed by Lin Yuang Chi Mini-hydro Cooperative (LYCMC) that employs seven people.[121] 50% of shares in the project is owned by Sai Htun Hla and Brothers Mini Hydropower Company ('SHH & Co'), a local company providing hydropower training, development and installation support and the remaining 50% is held by the community and users through a public-private partnership agreement. Technical and financial functions are largely fulfilled by the cooperative, while SHH & Co provide technical backup for repairs and replacements under a build-own-operate (BOO) agreement. The project, established in 2013, provides all 13 villages with free street lighting, and is currently saturated with demand far exceeding supply.

121 Doh Gabar, Mae Mauk waterfall mini hydro electrification project, 2021 (*link*)

5.0 Key findings and recommendations

5.1 Energy technology viability

Key Finding - 1

Decentralized renewable energy technologies have a higher LCOE than the subsidized grid. They also deliver more reliable energy supply, meaning machines can keep running. The resulting increased income can justify the higher unit cost of energy from renewable energy technologies.

Recommendation:

- **Focus electrification efforts on agricultural-processing activities with high utility (those that add significant value to the product).**
- **Facilitate access to efficient machinery to improve the value added per kWh consumed by a process.**

Benefit / Substantiation

- Value addition can be derived from improved product quality, improved process efficiency, loss reduction, or increasing value density (i.e. removing byproducts), which reduces transport requirements.

Key Finding - 2

Agricultural processing can make rural energy provision businesses more viable. Upstream, the addition of new agricultural processing can unlock energy business models by stimulating demand.

Recommendation:

- **Enhance coordination between the public and private sectors to develop, establish and maintain an effective business enabling environment for DRE project developers.**
- **Facilitate dialogue and better linkages between the agriculture and energy sectors.**

Benefit / Substantiation

- There is value in collaboration between government and development partners and private sector developers and financiers toward creating a business enabling environment for DRE. This includes development of financial support mechanisms and efficient regulatory processes, as well as sharing risk and responsibility.

- There is significant accumulated knowledge and experience in the agricultural sector that can be leveraged to the advantage of public and private energy stakeholders alike.

Key Finding - 3

Under-grid is a promising but nascent sub-sector. Downstream energy investments mostly support existing agricultural processing. Deploying technology that smoothes intermittent energy supply for larger, grid-connected processors provides rapid rates of return by maintaining throughput and thereby boosting profitability.

Recommendation:

- **Promote the use of embedded generation and/or storage systems in medium- and large scale, high-value agricultural-processing facilities in weak-grid areas.**
- **Establish energy trading systems between producers, consumers and the national grid.**

  Finalize the work with policy makers on improving regulations for grid-connected independent power providers and the re-selling of grid-sourced energy.

  Build the capacity of local lenders to develop products to finance captive power specifically.

- **Develop local technical and institutional capacity to implement captive power projects.**
- **Improve access to data on grid location and quality at agriculturally significant grid-edge locations. On-ground surveys and sensor networks could help fill these gaps.**

Benefit / Substantiation

- Reliable energy supply from self-generation or storage can help avoid significant direct and indirect losses from equipment downtime due to poor grid availability. This boosts processor productivity.
- Well regulated energy trading improves the business case for local energy generation or storage, catalyzing commercial investment.

  Net metering and energy arbitrage models can reduce energy prices and improve reliability for consumers. Weak centralized infrastructure can benefit from smoothing services provided by distributed energy systems.

  The micro-utility captive power model can remove almost all of the risk for off-takers, removing barriers to entry and catalyzing project roll-out.

- Institutional arrangements for developing, financing and implementing captive power projects can be complex and require robust legal, economic, technical and managerial skills.

- Better data on grid quality and location at the grid edge can assist with centralized planning (e.g grid strengthening) and private sector investment (e.g. captive power systems) alike.

Key Finding - 4

Certain energy generation technologies (such as micro-hydro or biomass gasification) are only appropriate in specific contexts. However, where appropriate, they can offer significantly lower LCOEs than solar and storage based systems.

Recommendation:

- **Improve the process of sourcing sites with significant local resources (e.g. micro-hydro or rice husk gasification).**

- **Develop and implement mechanisms to leverage Myanmar's significant local and informal mini-grid sub-sectors.**

Benefit / Substantiation

- Utilizing local energy resources helps alleviate transport constraints, reduces agri-waste (in the case of rice husk) and can provide much lower LCOEs.

  Diversifying sources of energy reduces reliance on a single source and improves resilience against seasonal and climate variability.

- Creating clear formalization routes and viable opportunities for rural, informal mini-grid operators and technology manufacturers (like micro-hydro turbines) can catalyze formal inclusion and leverage resources present in the mini-grid sector. Support can include promoting technical standards, providing technical assistance, creating licencing systems and outlining grid arrival modalities.

5.2 Finance

Key Finding - 5

Availability of agile and affordable finance would serve as a catalyst for energy enabled economic growth. This is an opportunity for innovative business models.

Recommendation:

- **Build the capacity of local financial organizations to better understand the risks and opportunities in the sector.**

  Develop national support mechanisms to de-risk investment into the sector (e.g. first loss pools).

- **Develop tailored financing mechanisms for PUE equipment, specifically targeted to modern and efficient agricultural-processing.**

- **Leverage existing and emerging businesses (e.g fintech providers) and distribution channels (e.g. mini-grid operators) to extend reach of financial services into rural areas.**

Benefit / Substantiation

- Local currency investments are generally preferable and are more easily supported or underwritten by national agencies.

- Financing productive agricultural-processing assets can be a commercially lucrative opportunity for banks, other financial institutions and even fintech providers.

- MADB can provide asset finance products geared to suit the payment and credit profiles of processors.

  Energy operators can serve as a distribution channel for processing equipment financing. This can also usefully diversify their revenue streams.

  Widespread adoption of mobile phones and digital payment systems unlocks increasingly sophisticated fintech business model innovation.

Key Finding - 6

Off-grid mini-grids can provide significant social impact, but will likely require financial support to be viable.

Recommendation:

- **Design dedicated financial and operational support mechanisms, and suitable investment incentives for high social impact, off-grid electrification projects like mini-grids.**

- **Implement a dedicated public financing facility to streamline transactions and attract developmental funding targeted to mini-grids.**

Benefit / Substantiation

- Well-designed blended or concessional finance can make marginal projects viable and thereby leverage significant private investment.
- Establish a tailored financial vehicle like a Rural Electrification Fund to absorb and channel funding from the government and development community, to bridge private sector shortfall and subsidize expansion of energy services to rural households.

Key Finding - 7

Weak-grid captive power systems for medium and large scale agricultural-processing are likely to be commercially viable and palatable, but may require finance to help overcome high capital costs.

Recommendation:

- **Develop capacity of local developers and financial institutions (banks, dedicated financiers) to implement captive power systems.**
- **Provide dedicated guidelines that outline standard operating procedures between off-takers, system providers, asset owners and financiers.**

Benefit / Substantiation

- Reducing the risk, knowledge gap and other barriers to entry for off-takers of captive power systems can accelerate widespread deployment.
- Like what has been done by MOALI for contract farming, formal, longer-term cooperation governed by standard legal agreements provide business certainty, allowing parties to take a longer term view in decision making and investment. Examples include PPAs or lease agreements.

5.3 Transport and market linkages

Key Finding - 8

Small-scale agricultural-processors fulfil a critical function in linking rural farmers to traders and markets by increasing value density of produce and providing local points for aggregation and logistics.

Recommendation:

- **Prioritize off-grid energy interventions for upstream (on-farm or village-level) agricultural-processing that improve value density, transportability and/or storability of produce.**
- **Explore opportunities for technical assistance for village based production of high-value, non-perishable products (e.g. sesame oil) alongside energy access interventions that enable the activity.**

Benefit / Substantiation

- Improved access to energy and mechanization can improve produce quality. This reduces transport costs making market linkages more efficient. Improved shelf-life can enhance the ability of small-scale processors to absorb and store more local produce.

- Shifting value-added agricultural-processing upstream to more rural areas can help retain value locally and catalyze a virtuous cycle of local socio-economic development.
- Creating direct links between village-based producers and foreign buyers can provide significant opportunity for maximizing local value capture. However this is resource intensive and hard to apply at scale.

5.4 Policy and regulation

Key Finding - 9

Uncertainty resulting from a weak regulatory framework stymies investment into decentralized energy systems.[123]

Recommendation:

- **Establish clear policy on grid arrival at mini-grid sites.**
- **Clarify processes relating to mini-grid licensing and tariffs.**
- **Improve the standard tripartite agreement between mini-grid developers, VECs and the DRD.**

123 This study acknowledges that the draft isolated and grid-connected regulations aim to address regulatory issues raised in these recommendations.

- **Clarify conditions for operation of grid-connected energy systems, including licensing and approval processes, conditions for grid connection and feed-in tariffs.**

- **Remove or reduce import duties on renewable energy components.**

Benefit / Substantiation

- Clear grid encroachment contingencies (asset transfer or mini-grid interconnection) reduces investment risk.

- Clarity around tariffs is an important factor affecting investor confidence in mini-grid projects. A simple, clearly stated process for setting reasonable tariffs such as is laid out in the NEP guidelines is essential. Project developers should be given the freedom to charge tariffs that will lead to a reasonable return on investment within the confines of the off-taker's willingness to pay (willing buyer willing seller). There needs to be regulatory surety that developers will not be required to unexpectedly change the tariffs they charge.

- Currently, roles and responsibilities are not clearly defined in agreements and developers struggle to use the agreement in order to access local debt.

- Absence of grid-connected regulations creates investment uncertainty and limits the potential of captive power projects.

- Removal or reduction of import duties on renewable energy components would allow for more affordable imports of generation and balance of system components.

Key Finding - 10

A lack of technical standards for energy operators hinders investment at scale into decentralized energy projects.

Recommendation:

- **Establish robust technical quality standards for decentralized energy systems at a national level.**

- **Establish appropriate performance reporting mechanisms.**

Benefit / Substantiation

- A clear set of standards prescribing the quality of standalone solar systems and mini-grid and captive power projects can enhance the growth of the small-scale decentralized energy sector.

For mini-grids specifically, a key mitigation strategy for the risk of grid encroachment is to ensure that isolated mini-grids are built to be compatible with the main grid. NEP experience with technical standards can be of use for the finalization of technical standards in the impending national small scale energy regulations.

- Standardized technical and financial performance reporting allows for easy comparison between projects. This enables investors to aggregate projects into portfolios, which means that due diligence efforts and costs can be spread across multiple projects, instead of being spent on a project-by-project basis.

Key Finding - 11

Standardized technical designs can streamline mini-grid project development and reduce upfront costs.

Recommendation:

- **Make available standard mini-grid technical designs in the public domain for developers to use at their discretion.**

- **Aggregate several mini-grid sites into lots for tendering.**
- **Liaise with industry associations to facilitate discussions between developers on the adoption of standardized technical designs.**

Benefit / Substantiation

- Standardized technical designs in the public domain equip inexperienced developers to leverage international best practices and reduce their project development costs.
- Large project pipelines, combined with standard technical designs can help developers to buy more equipment in a single order, reducing unit costs.
- Bulk procurement reduces upfront CAPEX, which can be facilitated by a variety of developers using the same design.

5.5 Integration of energy and agriculture sectors

Key Finding - 12

The agriculture and energy sectors have many shared challenges and characteristics including access to finance, risk factors, infrastructure constraints, rural development, data gaps and small scales.

Recommendation:

- **Improve communication and coordination between stakeholders across energy and agri sectors.**
- **Leverage operational networks to promote adoption of modern energy systems.**

Benefit / Substantiation

- Tools that are useful to actors in both sectors facilitate coordination between them.

  For example, expanding dedicated agricultural services like MADB finance to include energy projects.
- For example, agricultural extension workers can promote productive uses of energy.

5.0 Key findings and recommendations

Key Finding - 13

Effective use of data and GIS tools can significantly improve the planning and prioritization of investments into energy along value chains.

Recommendation:

- **Close the data gaps, particularly those that can facilitate the geographic prioritization of energy investments.**
- **Develop tools to improve access to and usability of existing agricultural and energy datasets and provide an interface to integrate diverse layers.**

Benefit / Substantiation

- Granular data on localized agricultural production and factors such as village size, clustering, location and access to markets can help pinpoint high-value sites.
- Myanmar benefits from unusually high quality national data, but integration with other datasets would greatly assist ag/energy planning and facilitate investment.

5.6 Socio-economic development and gender

Key Finding - 14

Increasing access to energy can improve agricultural land and labour productivity, increase achievable profitability and enhance the livelihoods of rural agricultural communities, but can have unintended consequences.

Recommendation:

- **Embed agricultural and social performance indicators into energy project impact planning and reporting.**
- **Tailor interventions to context-specific conditions by conducting on-ground research to understand local context.**
- **Embed social, environmental and economics afeguards to prevent unintended consequences.**

Benefit / Substantiation

- Tracking non-energy impact metrics provides deeper insights linking the effect of energy access to agriculture, and creates a basis for sustainability and impact reporting.
- Project development should flexibly account for significant variability across social, economic and operational dimensions in Myanmar.

- The mechanisation of a manual process can affect the livelihoods of people (often women) that rely on manual work.

Key Finding - 15

Women are disproportionately affected by a lack of energy access despite being involved in many agricultural activities and increasingly in important decision making.

Recommendation:

- **Women are a prime target group for agriculturally-focused energy interventions, particularly because they are on average more efficient at putting energy to productive use.**

Benefit / Substantiation

- Energy access is therefore a powerful tool to promoting gender equality, and so should be embedded into intervention design.

Appendices

Appendix A
Data collection process

Initial longlist of value chains in Myanmar

Initial data collection focused on generating an updated understanding of all the prominent agricultural activities in Myanmar. From this, a longlist of key agricultural value chains was identified and prioritised according to economic significance, convergence and energy-driven value addition potential. Table A1 below shows the longlist with shortlisted value chains highlighted in green.

Table A1: Long list of agricultural value chains in Myanmar

Value chain	Producers (approx. nr)	Processors & traders (approx. nr)	Crop value (million USD)	Energy needs	Value addition	Mechanisation	Main cultivation zones
Beans, Pulses & Oilseeds	1.4 – 2.7 million	1,350 (only 5-10 large processors)	2,165.6	Medium	Medium	Low. Limited sorting and cleaning	Sagaing, Kachin, Bago, Magway, Ayeyarwaddy, Yangon, Kayin, Rakhine, Shan
Cotton	500,000	60 (ginning)	606	High	High	Medium	Mandalay, Magway, Sagaing, Bago, Shan
Rice	2.15 – 3.4 million	16,000 millers (10% are large sized)	8,422.1	Medium	Medium	High. Diesel powered machines for processing	Ayeyarwaddy, Sagaing, Bago, Yangon, Shan, Rakhine, Mandalay, Kayin, Mon, Tanintharyi, Kachin
Fisheries & Aquaculture	3.3 million	114 (Small-mid sized)	1,104	Medium	Medium	Medium. Typically pumping & filtering, refrigeration/freezing and when relevant, filleting & grinding	Yangon, Bago, Rakhine and Ayeyarwady.
Corn/maize	123,000	Same as beans, pulses	382.5	High	Medium	Low (only high among the 5 large processors)	Shan, Magway, Sagaing
Spices: Chili, turmeric, ginger	30,000 – 50,000	50	100	Medium	Medium	Medium. Mostly during processing	Mandalay, Shan, Kayi, Ayeyarwaddy
Fruits & Vegetables	510,000 – 750,000	1,000	1,100	Medium	Low	Low. No cold chain. Mostly for cleaning, sorting, blanching and drying	Mandalay, Shan, Sagaing, Magway
Coffee & tea	47,500	750 (Small-sized)	100	Medium	High	Medium. Only in processing.	Shan, Mandalay, Kaya, Chin

Value chain	Producers (approx. nr)	Processors & traders (approx. nr)	Crop value (million USD)	Energy needs	Value addition	Mechanisation	Main cultivation zones
Fruits & Vegetables	510,000 – 750,000	1,000	1,100	Medium	Low	Low. No cold chain. Mostly for cleaning, sorting, blanching and drying	Mandalay, Shan, Sagaing, Magway
Coffee & tea	47,500	750 (Small-sized)	100	Medium	High	Medium. Only in processing.	Shan, Mandalay, Kaya, Chin
Dairy	32,000	100	408	Medium	High	High (only at large facilities).	Mandalay, Yangon, Sagaing
Rubber	20,000	5	366	High	High	Low. Only mixing and air drying	Mon, Kayin, Tanintharyi
Livestock	2.9 million	730 – 1,100 (only 3-5 large processors)	3,225	Low	Medium	Low. Cold chains are uncommon.	All country
Oil palm	5,000	5	153	High	High	High – processing.	Mon, Kayin, Taninthariyi

Value chain shortlisting criteria

Based on selection criteria presented in the table below, the final shortlist of value chains was generated from the longlist. The shortlist was composed of rice, cotton and the grouping of beans, pulses and oilseeds.

Table A2: Value chain shortlisting criteria

Criteria	Description & decision impact
Production value, trends and opportunities	Production value ($) indicates significance of the value chain in the country, and higher figures positively affect selection.
Relevance to small-scale rural processing	Small-scale rural processing refers to farm- or village-level processing activities that can be electrified by means of decentralised systems, typically mini-grids. Higher relevance in this regard positively influenced selection.
Level of added value	Value chain activities with higher value addition provide greater economic benefit and indicate large opportunity for productive uses.
Number of producers and actors	Greater amounts of participants, especially relative to production value, indicate more smallholders and greater levels of decentralisation, which are better suited to decentralised energy systems.
Levels of mechanisation at primary and processing stages	Low levels of current mechanisation in Myanmar combined with high potential mechanisation indicate greater potential for improvement via electrification.
Energy requirements	Value chains with high energy requirements, especially in upstream activities, provide greater electrification potential and are prioritised. Conversely, value chains with large, industrial and energy-intensive processing requirements may be poorly suited to decentralised energy, and so are deprioritised.

Surveys

Our survey team conducted two rounds of surveys, the first of which was focused on more established stakeholders with access to relatively good infrastructure. Farm sizes in this category ranged between 8 and 35 acres. In general, value chain actors in this category tended to be located relatively close to urban areas. The processors we interviewed work with large volumes of produce that is sourced not only from the immediate area, but also from across the country.

Upon review of this first round of data, the team identified processing and to a lesser degree production (growing phase) as the steps in the value chains where energy access is most critical. The first survey round focused on farmers and processors that already had some form of connection to an electricity source. The second round of surveys aimed to evaluate how unelectrified farmers and processors in deep rural areas operate. Farm sizes in this category ranged between 3 and 10 acres.

Interviews were fully structured and done in-field and telephonically. Interviews with farmers and processors were mostly done in-field, while industry associations and some processors and traders were interviewed telephonically. In total, 60% of interviews were done face to face and 40% telephonically. The number of respondents in each value chain is listed in the tables below.

Table A3: Number of respondents per value chain in round one survey

	Rice	Beans, pulses, oilseeds	Cotton
Input suppliers	8	6	4
Farmers	11	8	3
Processors	11	6	5
Traders	14	6	4
Industry associations	6	6	2
Total	50	32	18

Table A4: Number of respondents per value chain in follow-up survey

	Rice	Beans, pulses, oilseeds
Farmers	8	8
Processors	5	3
Total	13	11

Appendix B
Market information of key value chains

Rice

Rice constitutes about 73% of dietary intake for the urban population, equating to an average per capita consumption of about 133 kg/year and 80% or 165 kg/year respectively for rural areas. Despite increasing dietary diversification, domestic consumption of milled rice has been steadily increasing since 2010 by about 100,000 t/year.[122]

Demand for rice varied significantly across regions, likely the result of a combination of rice varieties, quality, proximity to different markets and changing consumer preferences linked to urbanisation, increasing incomes and diversified diets. Farmers in Bago reported weak demand with unsatisfactory prices while those in Ayeyarwaddy saw marginal improvements in both demand and pricing. Demand was positive in the CDZ and Sagaing area, and grew significantly in the Shwebo area where the premium quality Shwe Bo Paw San variety is widely cultivated.

In July 2020 the Myanmar Government set a floor price on rice to protect farmers against low prices during harvest time. The floor price was fixed at MMK 520,000 per 100 baskets (one basket is equivalent to 20.86 kg), 4% higher than in 2019, reflecting higher production costs.[123] In practice however, these pricing conventions are not always observed.

Small farms on average deliver higher yields (in tonne/ha) than large farms yet struggle to translate higher yields into higher profits.[124] This can be partially attributed to differences in economies of scale, allowing large farms to adopt modern technology and reduce unit costs. It may also be indicative of the distinct duality of the farm production node of the value chain. On one hand, small-scale farmers tend to operate within a highly localised network, retaining an estimated 30% of production for own use and selling excess to small scale processors for mostly local (i.e. nearby villages and township) consumption. On the other hand, larger scale farms operate in better connected networks and at larger volumes, selling to larger and more sophisticated processors linked to large domestic (i.e. city) and export markets.

Beans, pulses and oilseeds

Demand for beans and pulses is perceived by farmers, processors and traders to be on an upward trend. Oilseeds are however experiencing declining demand, in part due to competing imported oils. The tables below indicate farmgate prices and processing selling prices respectively, identified during the survey.

122 The World Bank, Myanmar Rice and Pulses: Farm Production Economics and Value Chain Dynamics, 2019 (*link*)
123 FAO, Food Price Monitoring and Analysis, 2020 (*link*)
124 The World Bank, Myanmar Farm Production Economics, 2016 (*link*)

Table B1: Beans, pulses and oilseeds farmgate prices[125]

	$/tonne	MMK/basket[126]
Green mung bean	$800 – $884	MMK 38,000 – 42,000
Black gram	$530 – $630	MMK 25,000 – 30,000
Butter bean	$550	MMK 25,000
Chickpea	$660 – $705	MMK 30,000 – 32,000
Black sesame	$1,845 – $2,265	MMK 66,000 – 80,000
White sesame	$1,070 – $1,270	MMK 38,000 – 45,000

Table B2: Processors' selling prices

	$/tonne	Profit margin
Green mung bean	$1,314	15%
Black gram	$1,025	5%
Chickpea splits	$866	2%
Chickpea powder	$929	2%
Peanut oil	$2320	2%

Cotton

Input suppliers are experiencing stable demand for their products and services, yet it must be noted that cotton is not the only value chain that the surveyed suppliers were servicing. Tractor hire costs about MMK 15,000 – MMK 20,000 ($35) per acre. Farmers and traders are experiencing stable demand for raw cotton, with a slight price decrease caused by the COVID-19 pandemic. Further downstream, the demand for finished cotton fabrics is also perceived to be stable by processors. The future outlook also remains positive, as cotton cloth remains widely used in Myanmar. Respondents representing the Department of Agriculture and the Cotton Grower and Production Association echoed the stable cotton demand for both raw produce and finished goods.

Farm gate prices have experienced downward trends over the past five years. Prices for raw cotton bolls identified during the survey are in the range of $0.3 to $0.6 per kg (MMK 700 – MMK 1,300 per viss[127]). Farmers earn an estimated profit of $300 to $350 per hectare (MMK 150,000 to 200,000 per acre). Traders sell the raw produce for approximately $0.7 to $0.8 per kg to processors (MMK 1,500 – MMK 1,800 per viss), earning a profit margin in the range of 5% to 10%. Processors purchase local cotton yarn for approximately $3 per kg (MMK 7,000 per viss) and imported cotton yarn price for about $6.5 to $9 per kg (MMK 17,000 – 21,000 MMK per viss). Further downstream, wholesalers purchase finished fabrics for approximately MMK 2,500 to MMK 3,500 per piece.[128] This is equal to approximately $8.35 per kg of cotton fabric.[129]

125 Note that prices tend to be similar irrespective of whether a trader or processor buys the produce.
126 One basket of beans and pulses vary between 31.3 kg and 32.7 kg, while an oilseed basket is equal to approximately 24.5kg.
127 One viss equals 1.6 kg.
128 One piece is 2 yards long and 1 yard wide.
129 Assuming cotton weight of 4.5 oz per yard.

Appendix C
Value chain energy analysis

The energy maps indicate the energy consuming activities performed by different stakeholders at each step of the value chain, the seasonality of the activities and the type of energy used to perform the activity. It also indicates whether stakeholders already have access, need access or need improved access. In cases where electricity is already used, the source of electricity is also indicated.[130]

Rice

Figure C1: Energy use map for rice value chain (medium-scale operations)

Pre-Production							
Stakeholders		Seasonality (dry season)	Seasonality (monsoon)	Source of Electricity	Equipment Suppliers	Material Suppliers	Farmers
Energy Consuming Activities	Seed storage	All year	All year				
	Packing	All year	All year				
	Pumping fuel	All year	All year				
	Transporting inputs	Jan-Mar	Jan-Mar				
	Ploughing	Oct-Dec	May-Jun				
	Harrowing	Oct-Dec	May-Jun				

Production							
Stakeholders		Seasonality (dry season)	Seasonality (monsoon)	Source of Electricity	Equipment suppliers	Farmers	Traders
Energy Consuming Activities	Seeding	Dec-Jan	Jun				
	Fertiliser application	Jan-Mar	Jul-Aug				
	Irrigation	Dec-May	Aug-Sep				
	Weeding	Feb-Mar	Jul-Aug				
	Transplanting	Dec-Jan	Jul				
	Pesticide spraying	Jan-Jun	Jul-Jan				
	Harvesting	Apr-Jun	Oct-Nov				
	Stubble cutting	Apr-Jun	Dec-Jan				

130 Type of energy used: Labour, Fuel, Electricity, Heat
Status of access: Have access, Want access, Want improved access
Source of electricity: Main grid, Standalone diesel

Processing							
Stakeholders		Seasonality (dry season)	Seasonality (monsoon)	Source of Electricity	Farmers	Processors	Traders
Energy Consuming Activities	Drying	Apr-Jun	Oct-Nov	Main grid	Heat (have access); Electricity (want access)	Heat; Electricity (want improved access)	Heat; Electricity (want improved access)
	Threshing	Apr-Jun	Nov-Jan	Main grid; Standalone diesel	Labour; Fuel (have access)	Fuel; Electricity (want improved access)	Electricity (have access)
	Cleaning/ destoning	All year	All year	Main grid		Electricity (have access)	Electricity (have access)
	Dehusking	Apr-Jun	Nov-Jan	Main grid; Standalone diesel	Labour; Fuel (have access)	Fuel; Electricity (want improved access)	Electricity (have access)
	Length grading	All year	All year	Main grid		Electricity (have access)	Electricity (want improved access)
	Polishing	All year	All year	Main grid		Electricity (want improved access)	Electricity (want improved access)
	Colour sorting	All year	All year	Main grid		Electricity (have access)	Electricity (want improved access)
	Parboiling	All year	All year	Main grid		Electricity (have access)	
	Packing	All year	All year	Main grid		Electricity (want improved access)	Electricity (have access)

Figure C2: Energy use map for rice value chain (small-scale operations)

Pre-production				
Stakeholders		Seasonality (dry season)	Seasonality (monsoon)	Farmers
Energy Consuming Activities	Seed storage	All year	All year	Labour (have access)
	Ploughing	Oct-Dec	May-Jun	Fuel (want improved access); Labour (have access)
	Harrowing	Oct-Dec	May-Jun	Fuel (want access)

Production				
Stakeholders		Seasonality (dry season)	Seasonality (monsoon)	Farmers
Energy Consuming Activities	Seeding	Dec-Jan	Jun	Fuel (want access)
	Fertiliser application	Jan-Mar	Jul-Aug	Labour (have access)
	Irrigation	Dec-May	Aug-Sep	Fuel (want improved access)
	Weeding	Feb-Mar	Jul-Aug	Fuel (want access)
	Transplanting	Dec-Jan	Jul	Labour (have access)
	Pesticide spraying	Jan-Jun	Jul-Jan	Labour (have access)
	Harvesting	Apr-Jun	Oct-Nov	Fuel (want access)
	Stubble cutting	Apr-Jun	Dec-Jan	Labour (have access)

Processing					
Stakeholders		Seasonality (dry season)	Seasonality (monsoon)	Farmers	Processors
Energy Consuming Activities	Drying	Apr-Jun	Oct-Nov	Fuel; Electricity (want access)	Fuel; Electricity (want access)
	Threshing	Apr-Jun	Nov-Jan	Fuel (want improved access)	Fuel (want access)
	Dehusking	Apr-Jun	Nov-Jan	Fuel (want improved access)	Fuel (want access)
	Polishing	All year	All year		Electricity (want access)
	Colour sorting	All year	All year		Electricity (want access)

Appendix C: Value chain energy analysis

Beans, pulses and oilseeds

Figure C3: Energy use in beans and pulses value chain (medium-scale operations)

Pre-production						
Stakeholders		Seasonality (Central dry zone)	Seasonality (Bago & Ayeyarwady)	Source of Electricity	Input suppliers	Farmers
Energy consuming activities	Seed storage	All year	All year		Labour (have access)	Labour (have access)
	Packing	All year	All year	Main grid	Electricity (want improved access)	
	Transporting inputs	Jan-Mar	Feb-Apr		Labour; Fuel (have access)	Fuel; Labour (have access)
	Ploughing	May-Jun	Nov-Dec		Fuel (want improved access)	Labour (have access); Fuel (want improved access)

Production						
Stakeholders		Seasonality (Central dry zone)	Seasonality (Bago & Ayeyarwady)	Source of Electricity	Input Suppliers	Farmers
Energy consuming activities	Seeding	Oct-Nov	Nov-Dec			Labour (have access); Fuel (want improved access)
	Fertiliser application	Nov-Jan	Dec-Feb			Labour (have access)
	Weeding	Nov-Dec	Dec-Jan			Labour (have access)
	Irrigation	Jan-Feb	Feb-Mar			Labour; Fuel (have access)
	Insecticide spraying	Dec-Feb	Jan-Mar	Main grid		Fuel; Electricity (want improved access)
	Harvesting	Feb-Mar	Mar-Apr		Fuel (want improved access)	Labour (have access); Fuel (want improved access)

Processing							
Stakeholders		Seasonality (Central dry zone)	Seasonality (Bago & Ayeyarwady)	Source of Electricity	Farmers	Processors	Traders
Energy consuming activities	Drying	Feb-Mar	Mar-Apr		Heat (have access)	Heat (have access)	
	Threshing	Feb-Mar	Mar-Apr		Fuel (want improved access)	Fuel (want improved access)	
	Winnowing	All year	All year		Labour (have access)	Fuel (have access)	
	Deshelling	All year	All year	Main grid		Electricity (have access)	
	Cleaning/ Destoning	All year	All year	Main grid		Electricity (have access)	Electricity (want improved access)
	Dehulling	All year	All year	Main grid		Electricity (have access)	
	Grading	All year	All year	Main grid	Electricity (want access)	Electricity (have access)	Electricity (want access)
	Colour sorting	All year	All year	Main grid		Electricity (have access)	Electricity (want improved access)
	Splitting	All year	All year	Main grid		Electricity (want improved access)	
	Milling (for flour)	All year	All year	Main grid		Electricity (have access)	
	Packing	All year	All year	Main grid		Labour; Electricity (have access)	

Type of energy used: Labour Fuel Electricity Heat
Status of access: Have access Want access Want improved access
Source of electricity: Main grid Standalone diesel

Figure C4: Energy use in oilseeds value chain (medium-scale operations)

Pre-Production						
Stakeholders		Seasonality (Central dry zone)	Seasonality (Bago & Ayeyarwady)	Source of Electricity	Input suppliers	Farmers
Energy consuming activities	Seed storage	All year	All year		Labour	Labour
	Packing	All year	All year	Main grid	Electricity	
	Transporting inputs	Jan-Mar	Feb-Apr		Labour, Fuel	Fuel, Labour
	Ploughing / Harrowing	May-Jun	Jun-Jul		Fuel	Labour, Fuel

Production						
Stakeholders		Seasonality (Central dry zone)	Seasonality (Bago & Ayeyarwady)	Source of Electricity	Input Suppliers	Farmers
Energy consuming activities	Seeding	Oct-Nov	Nov-Dec			Labour, Fuel
	Fertiliser application	Nov-Jan	Dec-Feb			Labour
	Weeding	Nov-Jan	Dec-Jan			Labour
	Irrigation	Jan-Feb	Feb-Mar			Labour, Fuel
	Insecticide spraying	Nov-Feb	Oct-Mar	Main grid		Fuel, Electricity
	Harvesting	Feb-Mar	Mar-Apr		Fuel	Labour, Fuel

Processing							
Stakeholders		Seasonality (Central dry zone)	Seasonality (Bago & Ayeyarwady)	Source of Electricity	Farmers	Processors	Traders
Energy consuming activities	Drying	Feb-Mar	Mar-Apr			Heat	
	Threshing	Feb-Mar	Mar-Apr		Fuel	Fuel	
	Winnowing	Feb-Mar	Mar-Apr		Labour	Fuel	
	Deshelling	All year	All year	Main grid		Electricity	
	Cleaning/ Destoning	All year	All year	Main grid	Electricity	Electricity	Electricity
	Dehulling	All year	All year	Main grid		Electricity	
	Grading	All year	All year	Main grid	Electricity	Electricity	Electricity
	Colour sorting	All year	All year	Main grid		Electricity	Electricity
	Heating	All year	All year	Main grid		Electricity	
	Oil pressing	Nov-Jun	Dec-Jul	Main grid		Electricity	
	Packing	All year	All year	Main grid		Labour, Electricity	

Figure C5: Energy use in beans, pulses and oilseeds value chain (small-scale operations)

Pre-Production				
Stakeholders		Seasonality (Central dry zone)	Seasonality (Bago & Ayeyarwady)	Farmers
Energy consuming activities	Seed storage	All year	All year	Labour
	Ploughing	May-Jun	Nov-Dec	Fuel, Labour

Production					
Stakeholders		Seasonality (Central dry zone)	Seasonality (Bago & Ayeyarwady)	Farmers	Processors
Energy consuming activities	Seeding	Oct-Nov	Nov-Dec	Labour	
	Fertiliser application	Nov-Jan	Dec-Feb	Labour	
	Weeding	Nov-Dec	Dec-Jan	Labour	
	Irrigation	Jan-Feb	Feb-Mar	Fuel	
	Harvesting	Feb-Mar	Mar-Apr	Fuel	Fuel

Processing						
Stakeholders		Seasonality (Central dry zone)	Seasonality (Bago & Ayeyarwady)	Source of Electricity	Farmers	Processors
Energy consuming activities	Drying	Feb-Mar	Mar-Apr		Fuel, Electricity	Fuel, Electricity
	Threshing	Feb-Mar	Mar-Apr	Standalone diesel	Fuel	Electricity
	Winnowing	Feb-Mar	Mar-Apr		Labour	
	Deshelling	Feb-Mar	Mar-Apr			Fuel
	Cleaning/ Destoning	May-Aug	Jun-Sep		Electricity	Electricity
	Dehulling	May-Aug	Jun-Sep	Standalone diesel		Electricity
	Colour sorting	May-Aug	Jun-Sep		Electricity	
	Heating	May-Aug	Jun-Sep		Electricity	
	Oil pressing	May-Aug	Jun-Sep		Electricity	

Type of energy used: Labour, Fuel, Electricity, Heat
Status of access: Have access, Want access, Want improved access
Source of electricity: Main grid, Standalone diesel

Cotton

Figure C6: Energy use in the cotton value chain (small- and medium-scale operations)[131]

Pre-production						
Stakeholders		Seasonality (Post-monsoon)	Source of Electricity (if applicable)	Equipment Suppliers	Material Suppliers	Farmers
Energy consuming activities	Seed storage	All year			Labour	Labour
	Packing	All year				Labour
	Transporting inputs	Jan-Mar		Labour, Fuel	Labour, Fuel	Labour, Fuel
	Ploughing	May-Jun		Fuel	Fuel	Labour, Fuel
	Harrowing	May-Jun		Fuel	Fuel	Labour, Fuel

Production				
Stakeholders		Seasonality (Post-monsoon)	Source of Electricity (if applicable)	Farmers
Energy consuming activities	Seeding	Jun		Labour, Fuel
	Ferteliser application	Jul-Aug		Labour
	Irrigation	Oct-Nov	Standalone diesel	Electricity, Fuel
	Weeding	Jul-Aug		Labour
	Pesticide spraying	Jun-Oct		Labour, Fuel
	Harvesting	Jul-Sep		Labour, Fuel

Processing					
Stakeholders		Seasonality (Post-monsoon)	Source of Electricity (if applicable)	Processors	Farmers
Energy consuming activities	Drying	Sep-Oct		Heat	
	Ginning	Jul-Sep	Main grid, Standalone diesel	Labour, Electricity	Electricity
	Carding/ roving	All year	Main grid, Standalone diesel	Labour, Electricity	
	Spinning/ winding	All year	Main grid, Standalone diesel	Labour, Electricity	
	Weaving	All year	Main grid, Standalone diesel	Labour, Electricity	
	Dyeing	All year	Main grid	Labour, Electricity	
	Tailoring	All year		Labour	

131 Note that year-round operation of processing activities is characteristic of larger processors only.

Type of energy used: Labour; Fuel; Electricity; Heat
Status of access: Have access; Want access; Want improved access
Source of electricity: Main grid; Standalone diesel

Appendix D
Using geospatial data to prioritise on-grid and off-grid interventions

The team used VIDA's[132] GridLight algorithm to identify the locations of on- and off-grid areas in Myanmar[133] and classify them into three categories of zones. The first was **on-grid areas,** those that VIDA showed had a national grid connection (as evidenced by night light imagery). To reduce potential error, we included in this category a buffer of 5km around the predicted grid lines. **Off-grid areas** were areas with no actual or predicted grid lines. We categorised **weak-grid** areas as the off-grid areas closest to the grid which are likely to have a low voltage grid connection or could have one relatively inexpensively but for which the quality of supply is expected to be low (as evidenced by little or no night light imagery). Using a continuous scale rather than distinct categories also allowed us to model for **deep off-grid** areas which were located far from any predicted grid lines. Once these zones were identified, we combined this information with other data layers to create a number of scenarios that illustrate how these processes can be used to help prioritise upstream, downstream investments with varying degrees of grid access.

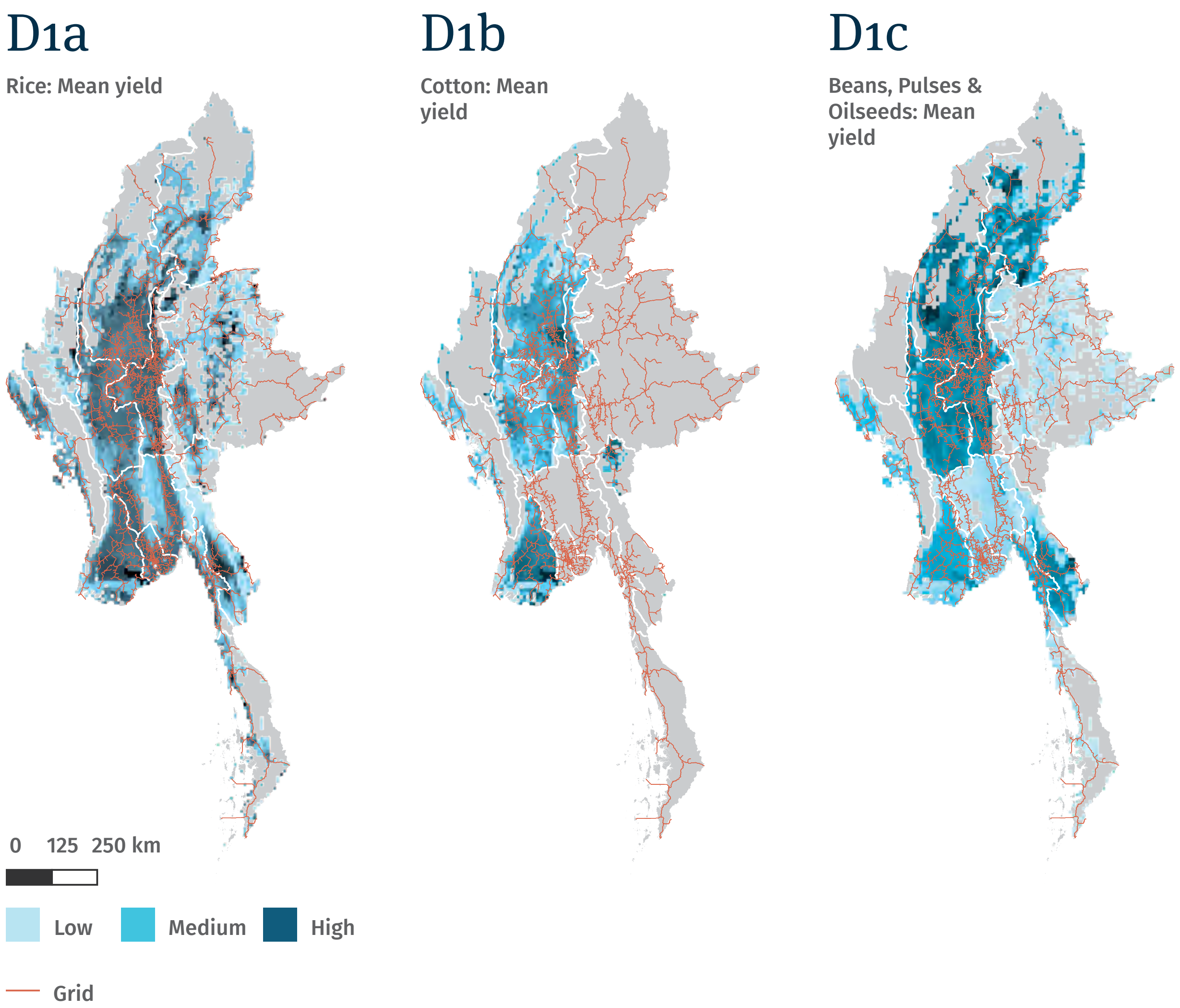
Scenarios

For the sake of demonstrating a process to determine the high-level prioritisation of areas most suitable for the different types of value chain interventions outlined in this report, two broad scenarios are considered and the transitional dynamics between them discussed. Scenarios and their dynamics are primarily underpinned by agricultural production and electric grid access, as demonstrated for each key value chain in the figure below. Other factors like population and proximity to economic corridors are employed to further develop insights into potential energy interventions along key nodes of each value chain.

It is important to understand that these scenarios are by no means distinct, discrete, mutually exclusive or exhaustive. Rather, they should be thought of as two ends of a spectrum, between which lie the majority of settlements and the agricultural value chain nodes they underpin. Therefore, while this analysis provides a starting point for identifying areas suited to agriculturally focused energy interventions and evaluating likely success factors, follow-on work based on these findings should consider the possibility that any area under assessment will likely have characteristics resembling both isolated and integrated scenarios.

132 Village Data Analytics (*link*)
133 This data is available online in an interactive and zoomable map format (*link*).

Figure D1: Evaluating agricultural production and grid access



Isolated scenario

The ‘isolated scenario’ focuses on villages and townships that are, in general, poorly connected to both grid infrastructure and market linkages within agricultural value chains yet have high levels of agricultural production. This environment of relative economic isolation creates unique patterns of production and consumption of both energy and agricultural produce. Activities are characterised by rudimentary agricultural techniques and technologies for small-scale production and processing. Access to high-quality agricultural inputs is limited, as is knowledge on the effective application of inputs due to a dearth of agricultural extension services. Transport infrastructure in isolated areas is typically poor, further eroding achievable prices and weakening access to markets and economic corridors. As a result, value chains are generally short, serving mostly local markets like neighbouring villages and townships with limited outflow of produce to larger urban and export markets.

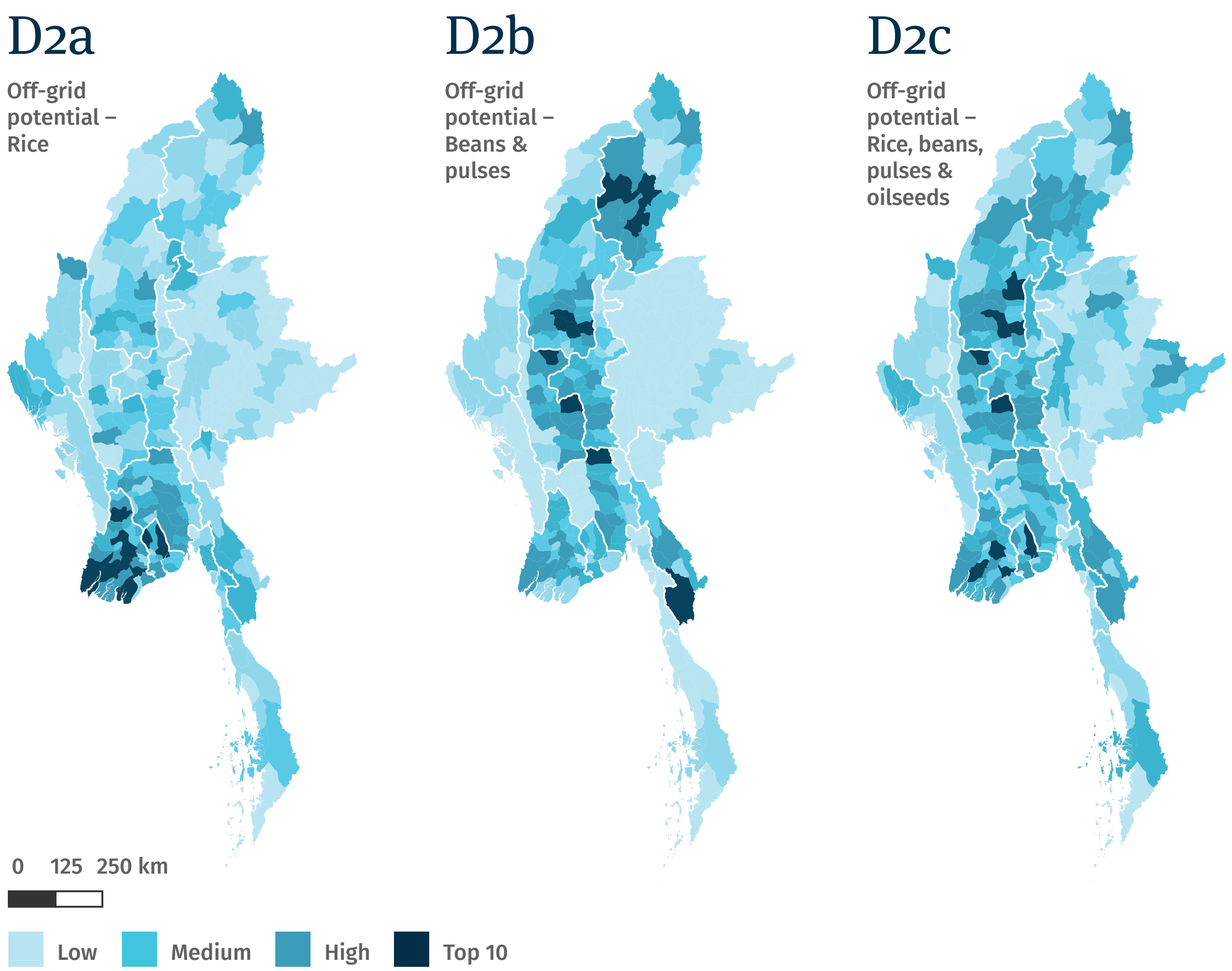
Regional prioritisation of isolated areas

Using a variety of data sources, a number of geospatial analyses have been carried out to outline areas suitable for energy access interventions for different value chains under the isolated scenario. Analyses aim to evaluate areas that are well-suited to off-grid interventions by evaluating three metrics:

1. **Agricultural production:** Areas with higher productivity stand to benefit more from energy related interventions, specifically for processing activities.
2. **Population:** Townships with large populations provide dual benefits for off-grid energy interventions, serving both as local consumers of agricultural products and as potential energy off-takers.
3. **Grid access:** Areas with poor proximity to the national electricity grid are generally preferred for off-grid interventions.[134]

It should be noted that these analyses are very high level and serve only to demonstrate what kind of analysis could be carried out for projects with a more specific mandate, for example to maximise the social impact of rural farmers or to achieve the greatest value chain additional impact per unit of investment.

Figure D2 a - c: Ranking off-grid areas according to total crop production, population and grid proximity



134 With a lack of clear regulatory guidelines on what happens when the main grid encroaches on a mini-grid, areas close to the grid are considered risky for financiers investing in commercial mini-grids.

Figure D2 shows the outputs of a ranking algorithm that identifies townships and clusters of townships likely to be well suited to off-grid agricultural interventions. Each value chain or combination shows a unique distribution profile across various regions, which can be incorporated into programme and project design to meet specific outcomes. For example, because rice production is high and relatively centralised in Ayeyarwaddy, medium- or large-scale rice-specific productive interventions like milling would be appropriate in this region. Conversely, the areas ranked most highly for beans and pulses are dispersed across the country, as seen in Figure D2b. As such, interventions targeting these value chains would differ depending on whether they were focused on remote areas for which much of the consumption would happen locally or areas that were closely located to Mandalay (for example) which might benefit from a sizable offtake market for agricultural produce.

Finally, from Figure D2c, combining rice with BPO value chains demonstrates some clustering of the highest ranked areas with the advantage of crop diversification, which can help overcome seasonality of processing activities. Optimising capacity utilisation of productive use machinery improves the business case for energy interventions by reducing downtime and increasing throughput. Practically, this could mean embedding activities that are transferable across value chains, like drying, into the design of interventions targeted on areas that demonstrate 'crop mix clustering'.

Figure D2 further demonstrates the importance of prioritising geographic areas according to the specific goals of an intervention. The central off-grid regions of Myanmar might have high agricultural production and good market access potential. However, being closer to the national grid, they might also be areas more likely to be electrified via grid extension sooner than the areas that are further off-grid. This will affect the design of the intervention. For example, if these central areas are selected for mini-grid based investment, it would be wise to design them for grid integration both technically and from a business model and policy point of view. In addition, to reduce the risk of private sector financing of these projects it would be useful to be able to provide surety that the mini-grid operator will either be compensated with a purchase of assets or be able to continue to sell energy (albeit with revised cost-reflective tariffs) once the national grid has reached the community. In this case the mini-grid will become an under-grid mini-grid and, with built-in solar and energy storage, would most likely be able to provide end-users with a quality of service (e.g. better system uptime, reduced voltage fluctuations, etc.) better than local, grid-only communities. This could justify a marginally higher tariff and would most likely be the best way of ensuring community buy-in.

Integrated scenario

For the sake of this analysis, 'integrated' refers to areas that are better integrated with national infrastructure including transport networks and centralised grid energy. The integrated scenario is focused on areas with existing or potential medium- and large-scale production and processing facilities, better developed trade networks with urban and export markets and access to the national grid. Typically, these semi-rural areas will suffer from a low level of grid service quality. In this report we refer to these as 'weak grid' areas. Farming operations under this scenario are larger than those targeted in the isolated scenario, typically exceeding ten hectares, and are often located close to more central economic hubs. Better transport infrastructure increases ease of access and, along with a higher presence of traders, creates a more competitive business environment. Processing nodes generally aggregate produce from several farms or even several villages, and often play a critical role in moving goods along the value chain to large urban markets for domestic wholesale or export. Equipment and machinery are more sophisticated and have better economies of scale than those in isolated areas, however many are outdated and so deliver poor energy- and throughput efficiency, and may adversely affect quality.

Appendix D: Using geospatial data to prioritise on-grid and off-grid interventions

Regional prioritisation of integrated areas

Energy access interventions in more integrated areas hold significant potential for strengthening agricultural value chains because they leverage latent energy demand and existing market structures. While these areas can have better energy and agricultural fundamentals, the dearth of data on the quality of national grid services at the grid edge poses a major challenge to identifying the areas most suitable for weak grid interventions. For the sake of this report, we have used the potential for energy enabled agricultural value addition and the possibilities for trade with major domestic and export markets as indicators to characterise prospective areas for intervention. To quantify this, we have used data on:

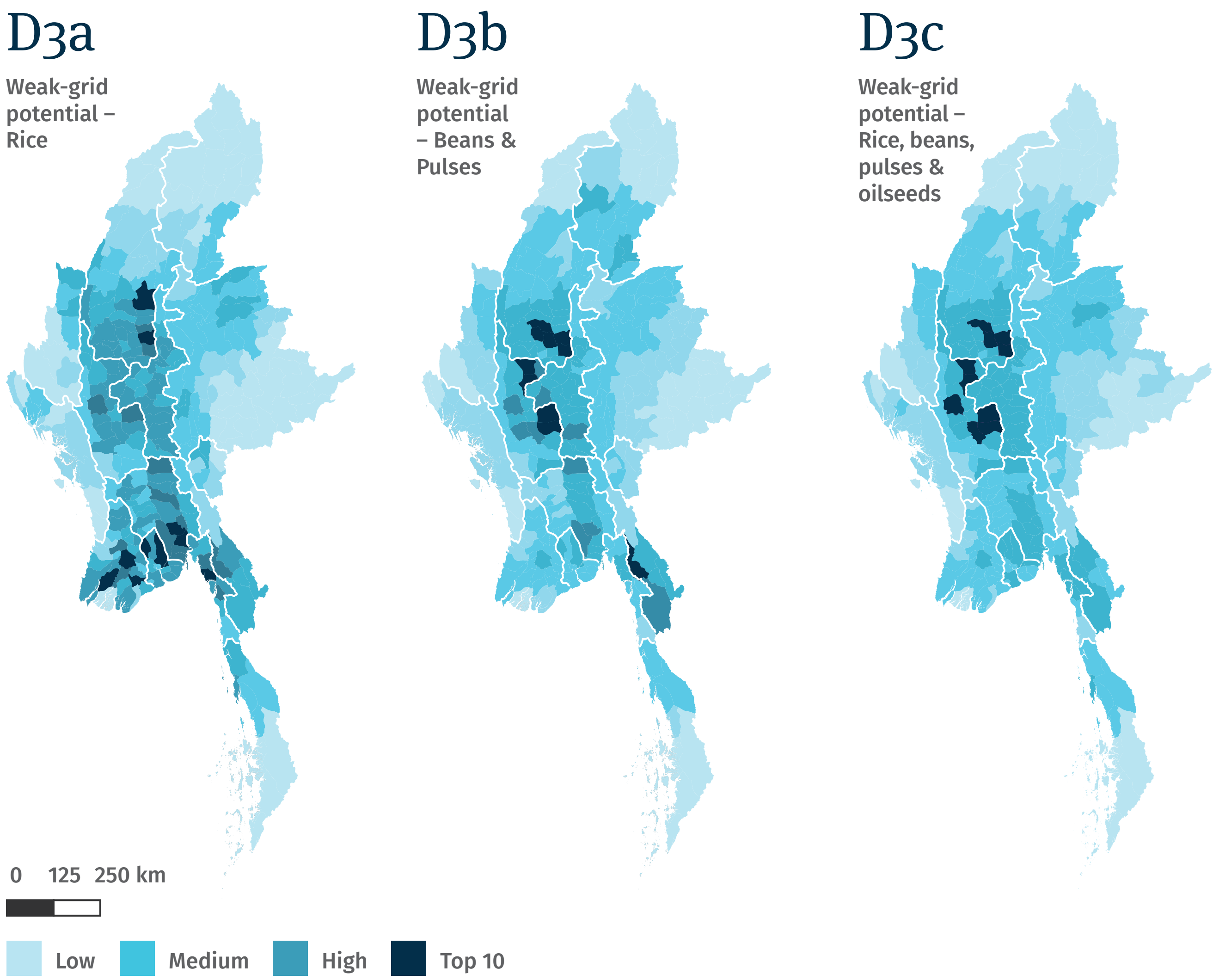
1. **Agricultural production:** Areas with higher productivity stand to benefit more from energy related interventions, specifically for processing activities.
2. **Economic corridors:**[135] Major economic corridors are transport routes that link important aggregation and trade nodes, like cities, border posts and seaports. Agricultural areas located close to these corridors are more likely to be well integrated into large trade networks, and so stand to benefit from energy-enable production and processing gains.
3. **Grid access:** Areas with close proximity to the national electricity grid are generally more integrated and have some level of energy service already.

As before, it should be understood that these analyses and their outputs have inherent limitations. They are not prescriptive and should be complemented by location-specific due diligence. Given the scale and scope of this study, the following maps merely serve as indication of factors that influence energy and agriculture, and how these can be combined to help guide strategic and operational decision-making. The analysis assumes that the quality of the grid is the same across all the weak grid areas in Myanmar. This is not the case in reality.

Figure D3 outlines townships which may be interesting for improving existing energy systems within agricultural value chains. These areas have high levels of agricultural production, good proximity to economic transport routes and likely unreliable grid service. Rice production from Figure D3a is largely centralised in Ayeyarwaddy, with some hotspots in the central interior. There is anecdotal evidence of highly unreliable grid service in Ayeyarwaddy resulting from damage to grid infrastructure caused by monsoons and unstable delta soil structure. Collectively, these factors suggest good potential for medium- or even large-scale processing nodes powered by mini-grids and serving major domestic and export markets through Yangon and coastal trade ports. If for some reason this is deemed infeasible, several alternate areas could be explored around Mandalay, Northern Magway and Southern Sagaing, for example. Figure D3b shows that these areas also host significant bean and pulse production, which is a major export crop. Such an insight can be used to steer and support programmatic interventions like crop-rotation, crop-switching or greater integration of these different value chains. Figure D3c corroborates this hypothesis by combining production of rice and BPO value chains alongside grid and economic access factors. This yields similar results for the highest-ranking townships.

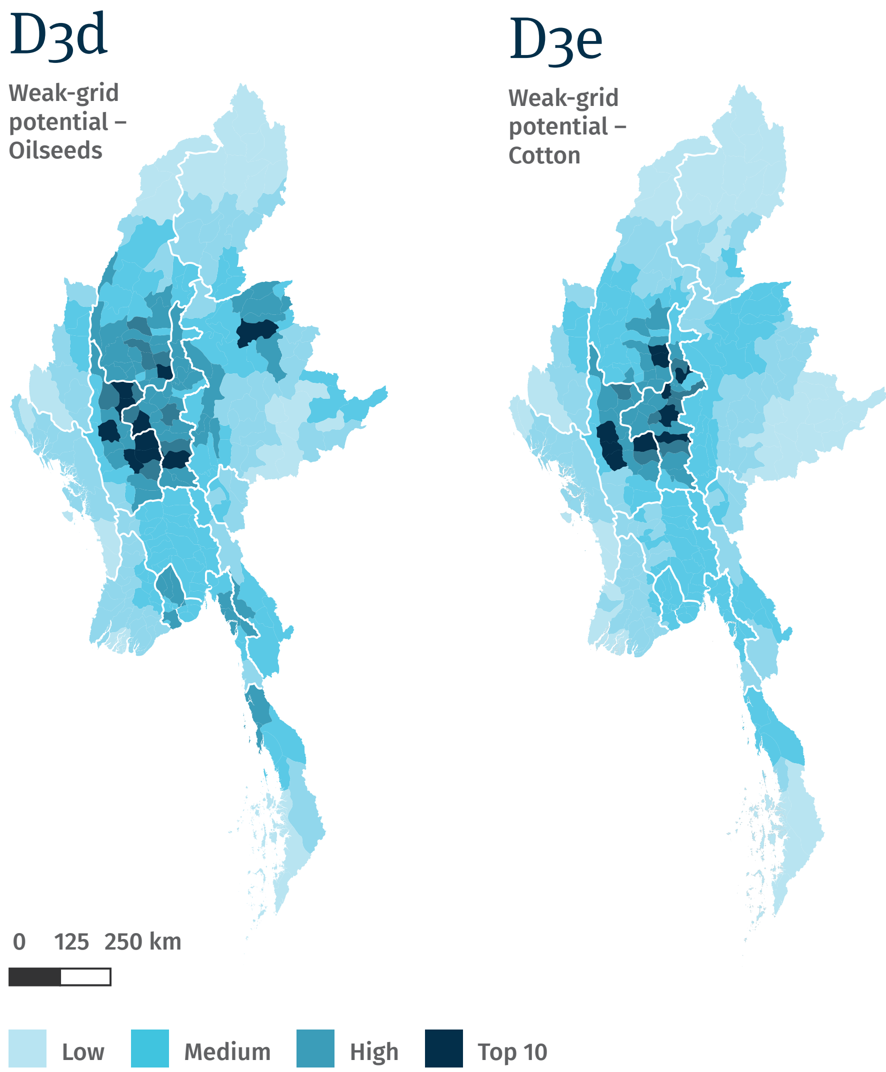
135 MIMU, Economic and Trade Infrastructure in Myanmar Map, 2018 (*link*)

Figure D3 a-c: Ranking weak-grid areas according to total crop production and proximity to grid and economic corridors



Oilseed crops are generally grown alongside beans and pulses. The overlap between highly ranking beans and pulse regions and those for oilseeds (shown in Figure D3d) is further evidence of this. However, because their production processes can differ fundamentally it is also important to highlight areas that are more favourable to oilseeds and less so to beans and pulses, as is the case in Northern Shan. The implication of this is that productive use value chain interventions in this area should prioritise oilseed-specific activities like oil pressing and, where possible, consider the use of byproducts like oilseed cake as fodder to enhance the agricultural business case.

Figure D3 d, e: Ranking weak-grid areas according to total crop production and proximity to grid and economic corridors



Cotton-producing nodes under the integrated scenario are centralised around the Mandalay region, which supports findings that report limited local or small-scale cotton processing. This status quo may well be the result of historic policies in support of large, central processing facilities intended to catalyse the sector, rather than the result of a lack of suitable small-scale processing opportunities. Nonetheless, such facilities would be ideal candidates for under-grid mini-grids or grid-tied captive power systems to supplement weak grid supply due to the major detrimental effect of system downtime on productivity of systems at this scale.

Appendix E
Value addition analysis methodology

A key factor to consider when identifying an unmet energy need to address is the extent to which the activity adds value to the crop per unit of electricity consumed. Towards this end, the team has developed a methodology for calculating monetary value addition of each processing activity per kWh. This is done by dividing value addition per kilogram with energy consumption per kilogram. To illustrate, small-scale oil pressing is used as an example below:

Inputs:

Power use: 0.75 kW
Throughput: 17.5 kg/hour
Value added per kg: $0.46/kg[136]

Calculation:

$0.46 per kg / (0.75 kW / 17.5 kg per hour)
= $0.46 per kg / 0.0429 kWh/kg
= $10.72

From the analysis above we can see that for every kWh used by this oil press $10.72 of value is added to the raw material. What follows below is the same process applied to each of the value chains.

Three equipment sizes are considered for each processing step, along with their maximum throughput per hour.[137] Examples are presented below, followed by a table containing the results for all value chain steps in each value chain, and their comparison to the LCOE of different energy systems.

136 Added value per kilogram is synonymous with the gross profit that a processor earns from processing one kilogram of produce with a specific machine. $/kg thus differs between processing activities. Gross profit for each activity was calculated from survey data and secondary research where necessary.

137 Data on power ratings and throughput per hour was collected from equipment manufacturers' data sheets.

Appendix E: Value addition analysis methodology

Rice

Table E1: Modelling inputs for rice threshing at different scales

Activity	Threshing		
Scale (kW)	3	7.5	11
Max capacity (kg/hour)	500	950	2000
Value addition per kg	$0.06	$0.06	$0.06
Energy consumption per kg (kWh/kg)	0.0060	0.0079	0.0055
Value added per kWh	**$10.29**	**$7.82**	**$11.23**

Table E2: Ratios of value addition of difference rice processing activities at different scales to energy costs from different energy systems

				Value addition relative to cost of kWh					
VC activity	Machine power rating (kW)	Machine cost (USD)	Value addition (USD/kWh)	Mini-grid	Mini-grid with DRD subsidy and comm. contr.	Rooftop solar without storage	Rooftop solar with storage	Grid	Under-grid storage
Indicative Energy Cost ($/kWh)				$1.00	$0.41	$0.12	$0.28	$0.09	$0.14
Threshing	3kW	$400	$10.29	10.29	25.10	85.75	36.75	114.34	73.50
	7.5kW	$1,100	$7.82	7.82	19.07	65.17	27.93	86.90	55.86
	11kW	$2,000	$11.23	11.23	27.38	93.55	40.09	124.73	80.18
Drying	4kW	$4,000	$2.07	2.07	5.04	17.23	7.38	22.97	14.77
	13kW	$10,000	$1.53	1.53	3.72	12.72	5.45	16.96	10.90
	18kW	$45,000	$4.59	4.59	11.20	38.28	16.41	51.04	32.81
De-Husking	2.2kW	$300	$5.01	5.01	12.22	41.76	17.90	55.68	35.80
	7.5kW	$1,250	$4.41	4.41	10.76	36.75	15.75	49.00	31.50
	18.5kW	$3,000	$4.47	4.47	10.90	37.25	15.96	49.66	31.93
Basic Milling	3kW	$250	$3.31	3.31	8.07	27.56	11.81	36.75	23.63
	11kW	$2,000	$3.76	3.76	9.17	31.32	13.42	41.76	26.85
	22kW	$5,000	$2.76	2.76	6.72	22.97	9.84	30.63	19.69
Advanced Milling	18kW	$8,000	$2.09	2.09	5.09	17.40	7.46	23.21	14.92
	52kW	$25,000	$3.18	3.18	7.76	26.51	11.36	35.34	22.72
	22kW	$35,000	$4.18	4.18	10.19	34.81	14.92	46.41	29.84

Beans, pulses and oilseeds

Table E3: Modelling inputs for oilseed pressing at different scales

Activity	Oil pressing		
Scale (kW)	0.75	5.6	15
Max capacity (kg/hour)	17.5	50	200
Value addition per kg	$0.46	$0.46	$0.46
Energy consumption per kg (kWh/kg)	0.0429	0.1120	0.0750
Value added per kWh	$10.73	$4.11	$6.13

Table E4: Ratios of value addition of difference BPO processing activities at different scales to energy costs from different energy systems

				Value addition relative to cost of kWh					
VC activity	Machine power rating (kW)	Machine cost	Value addition (USD/kWh)	Mini-grid	Mini-grid with DRD subsidy and community contr.	Rooftop solar without storage	Rooftop solar with storage	Grid	Under-grid storage
Indicative Energy Cost ($/kWh)				$1.00	$0.41	$0.12	$0.28	$0.09	$0.14
Oil pressing	0.75 kW	$1,000.00	$10.73	10.73	26.18	89.44	38.33	119.26	76.67
	3 kW	$1,600.00	$4.11	4.11	10.02	34.23	14.67	45.63	29.34
	15 kW	$1,200.00	$6.13	6.13	14.96	51.11	21.90	68.15	43.81
Dehulling	1.5 kW	$546.00	$3.33	3.33	8.13	27.78	11.90	37.04	23.81
	16 kW	$2,100.00	$3.13	3.13	7.62	26.04	11.16	34.72	22.32
	30 kW	$7,500.00	$5.83	5.83	14.23	48.61	20.83	64.81	41.67
Threshing	2.2kW	$215.00	$2.05	2.05	4.99	17.05	7.31	22.73	14.61
	3 kW	$1,200.00	$6.00	6.00	14.63	50.00	21.43	66.67	42.86
	7.5 kW	$1,500.00	$4.00	4.00	9.76	33.33	14.29	44.44	28.57
Colour sorting/ grading	0.9 kW	$8,800.00	$47.22	47.22	115.18	393.52	168.65	524.69	337.30
	1.6 kW	$17,800.00	$78.13	78.13	190.55	651.04	279.02	868.06	558.04
	2 kW	$38,000.00	$75.00	75.00	182.93	625.00	267.86	833.33	535.71
Destoning	3.5 kW	$1,700.00	$71.43	71.43	174.22	595.24	255.10	793.65	510.20
	6.6 kW	$7,000.00	$56.82	56.82	138.58	473.48	202.92	631.31	405.84
	15.75 kW	$8,300.00	$31.75	31.75	77.43	264.55	113.38	352.73	226.76

Appendix E: Value addition analysis methodology

Cotton

Table E5: Modelling inputs for cotton carding at different scales

Activity	Carding		
Scale (kW)	1.1	4.75	5.5
Max capacity (kg/hour)	15	50	70
Value addition per kg	$0.35	$0.35	$0.35
Energy consumption per kg (kWh/kg)	0.0733	0.0950	0.0786
Value added per kWh	$4.77	$3.68	$4.45

Table E4: Ratios of value addition of difference cotton processing activities at different scales to energy costs from different energy systems

				Value addition relative to cost of kWh (%)				
VC activity	Machine power rating (kW)	Machine cost	Value addition (USD/kWh)	Mini-grid	Mini-grid with DRD subsidy and community contr.	Rooftop solar without storage	Rooftop solar with storage	Under-grid storage
Indicative Energy Cost ($/kWh)				$1.00	$0.41	$0.12	$0.28	$0.14
Carding	1.1 kW	$1,000.00	$4.77	4.77	11.64	39.77	17.05	34.09
	4.75 kW	$1,000.00	$3.68	3.68	8.99	30.70	13.16	26.32
	5.5 kW	$1,000.00	$4.45	4.45	10.86	37.12	15.91	31.82
Spinning	0.55 kW	$11,000.00	$1.27	1.27	3.10	10.61	4.55	9.09
	5.5 kW	$50,000.00	$9.55	9.55	23.28	79.55	34.09	68.18
	25 kW	$55,000.00	$7.00	7.00	17.07	58.33	25.00	50.00

Appendix F
Brownfield and greenfield energy analyses

Brownfield analysis

In the brownfield scenario, an installed energy storage system recharges when the grid is available and discharges when it is not, thereby smoothing supply for the existing processing facility. The model makes many assumptions including a steady supply of feedstock and predictable grid outages, but shows that with 75% grid availability, the costs of installing the energy storage system would be recouped in approximately ten working weeks.

The starting point of the analysis is a calculation of daily revenue earned by two processors performing the same activity with the same machine. A 900W bean colour sorting machine was considered. Processor A's only energy source is the national grid, while Processor B has installed lithium-ion battery backup to smooth supply during grid downtime. Firstly the difference in daily operating hours between the two processors must be calculated, considering that Processor A cannot operate during grid downtime:

Inputs:

Normal operating hours per day:[138]	5
Grid availability (% of workday):	75%

Table F1: Comparison of processing scenarios

	Processor A	Processor B
Operating hours per day	5 hours x 75% = 3,75 hours	5 hours x 100% = 5 hours

As the calculation shows, Processor A ceases operations for 1.25 hours of the 5-hour workday (assuming a ballpark figure of 25% grid downtime). Next, daily revenue is calculated by multiplying the machine's power rating with hours of daily operation and revenue generated from the use of one unit of electricity. Processor B earns additional revenue of $26.40 by virtue of being able to operate without any energy supply-related interruptions:

Inputs:

Value addition ($/kWh):[139]	$23.61
Grid usage (hours per day):	3.75 hours

138 Typical 8-hour workday is reduced to five hours to account for times when feedstock is not available.
139 See appendix E for a demonstration of how $/kWh is calculated. The original value of $47.22 was halved to reflect 50% of maximum throughput.

Battery operational hours per day:	1.25 hours
Grid tariff:[140]	$0.09
Grid + storage tariff:[141]	$0.14

Calculation:

Table F2: Revenues for different processor scenarios

	Processor A	Processor B
Revenue per day	0.9 kW x 3.75 hrs x $23.61/kWh =$79.68	0.9 kW x 5 hrs x $23.61/kWh =$106.25
Energy expenditure	$0.09 x 0.9 kW x 3.75 hrs =$0.30	($0.09 x 0.9 kW x 3.75 hrs) + ($0.14 x 0.9 kW x 1.25 hrs) =$0.47
Revenue minus energy expenditure	$79.68 – $0.30 =$79.38	$106.25 – $0.47 =$105.78

Finally, an assessment is conducted to determine how long it would take Processor B to pay back the capital expenditure incurred in purchasing the battery system:

Inputs:

Battery CAPEX:[142]	$799
Installation cost:[143,144]	$512
Additional daily revenue:	$26.40

Calculation:

($799 + $512) / $26.40 = 50 days

Greenfield analysis

Our definition of greenfield projects is based on the premise that there are potentially strategic locations for high-volume commercial agricultural processing that have not been exploited due to poor energy supply. The techno-economic modelling would be similar as that applied to brownfield sites above, but include the costs of purchasing and installing the processing machinery as well as the energy technology. Once again, commercial viability of the project will be a function of the processing revenue and the LCOE. This energy could come from a simple battery bank that smooths intermittent grid availability as in the model above, from a grid connected captive power system with a portion of solar generation capacity or from an entirely stand-alone renewable energy system.

140 Tariff for a light commercial user in Myanmar.
141 This tariff represents the cost of charging the battery with grid electricity and the cost of operating the battery.
142 Price of a Bluesun 2.56 kWh lithium-ion battery in Myanmar
143 IRENA, Electricity storage and renewables: Costs and markets to 2030, 2017 (*link*)
144 Pienke, D., Dyasons Klip 5: Battery storage, 2020 (*link*)

To illustrate the model, the same battery system and colour sorting machine analysed in the brownfield scenario was considered in the greenfield scenario. The first step of the analysis is to calculate the number of hours that the machine is operated in a year. At this stage of the analysis only feedstock availability is considered:

Inputs:

Operational hours per day:	5
Operational days per week:	5
Weeks per year:	52.14
Annual capacity utilisation:[145]	66.67%

Calculation:

5 hours x 5 days x 52.14 weeks x 66.67%
= 869 operational hours per year

Annual gross profit can then be calculated by multiplying operational hours per year by estimated throughput per hour and the processor's gross profit margin of colour sorting one kilogram of beans:

Inputs:

Operational hours per year:	869 hours
Estimated throughput per hour:	200 kg/hour
Gross margin:[146]	$0.05/kg

Calculation:

869 hours x 200kg/hour x $0.05/kg
=$7,994.80

Energy expenditure is then calculated:

Inputs:

Equipment power rating:	0.9 kW
Grid usage per year:	651.75 hours
Battery operational hours per year:	217.25 hours
Grid tariff:	$0.09/kWh
Grid + storage tariff:	$0.14/kWh

Calculation:

[(0.9 kW x 651.75 hours) x $0.09/kWh] + [(0.9 kW x 217.25 hours) x $0.14/kWh]
=$52,79 + $27,37
=$80,16

145 This percentage reflects eight operational months per year (12 months). Eight months was the average annual operational period identified among processors in the survey.
146 The gross margin was derived from downstream processors surveyed

Appendix F: Brownfield and greenfield energy analyses

Factoring in energy expenditure and indicative additional OPEX, the net profit can then be calculated:

Inputs:

Gross profit:	$7,994.80
Energy expenditure:	$80,16
Annual OPEX:[147]	$1,229.58

Calculation:

$7,994.80 – $80.16 – $1,228.59
=$6,685.05

Finally the payback period for the colour sorting machine is calculated:

Inputs:

Equipment upfront CAPEX: $8,800
Average net profit per working month:[148] $402.96

Calculation:

$6,685.05 / $402.96
=21.84 months

The total payback period in the greenfield scenario is 24,11 working months (calculated by adding the payback period of the machine to the energy system).

147 Assumes one employee earning a $5.42 daily Myanmar wage and annual maintenance of $146.
148 A working month is defined as 22 days

Appendix G
Detailed case studies

Energy in rice producing villages in Labutta township

During 2019 and 2020, a consortium of energy and climate organisations[149] conducted a collaborative research project exploring the link between agricultural livelihoods and energy access in Myanmar. The case study focused on two primarily rice-producing villages, **Bi Tut and Kan Bet, in Labutta township in the country's Lower Delta region**. Participants included farmers (both members and non-members of Mercy Corps' FPE[150] initiative) and millers (small- and medium-scale).

Mapping the social networks of communities across the rice value chain in these villages, as illustrated in the figure below, **reveals a unique set of challenges and opportunities** for improving agricultural productive uses of energy. It also provides a unique perspective on the **complex local socio-economic dynamics that underpin farming operations**, including their ability to adopt energy-based practices and how these vary across different points in the value chain and at different scales.

Key findings include:

Risks and benefits are unequally distributed across value chain actors

Farmers and labourers are perceived to be the group benefitting the least from value chain activities, despite being the group that arguably carries the most risk. Conversely, traders and processors are perceived as most influential and those deriving most benefit from activities. Interestingly, processors and farmers respectively consider themselves to be responsible for the '*most important activity to reduce risk and increase income*', potentially indicating a poor understanding of up- and downstream activities along the value chain.

Small-scale processors provide critical networks and services to rural value chains

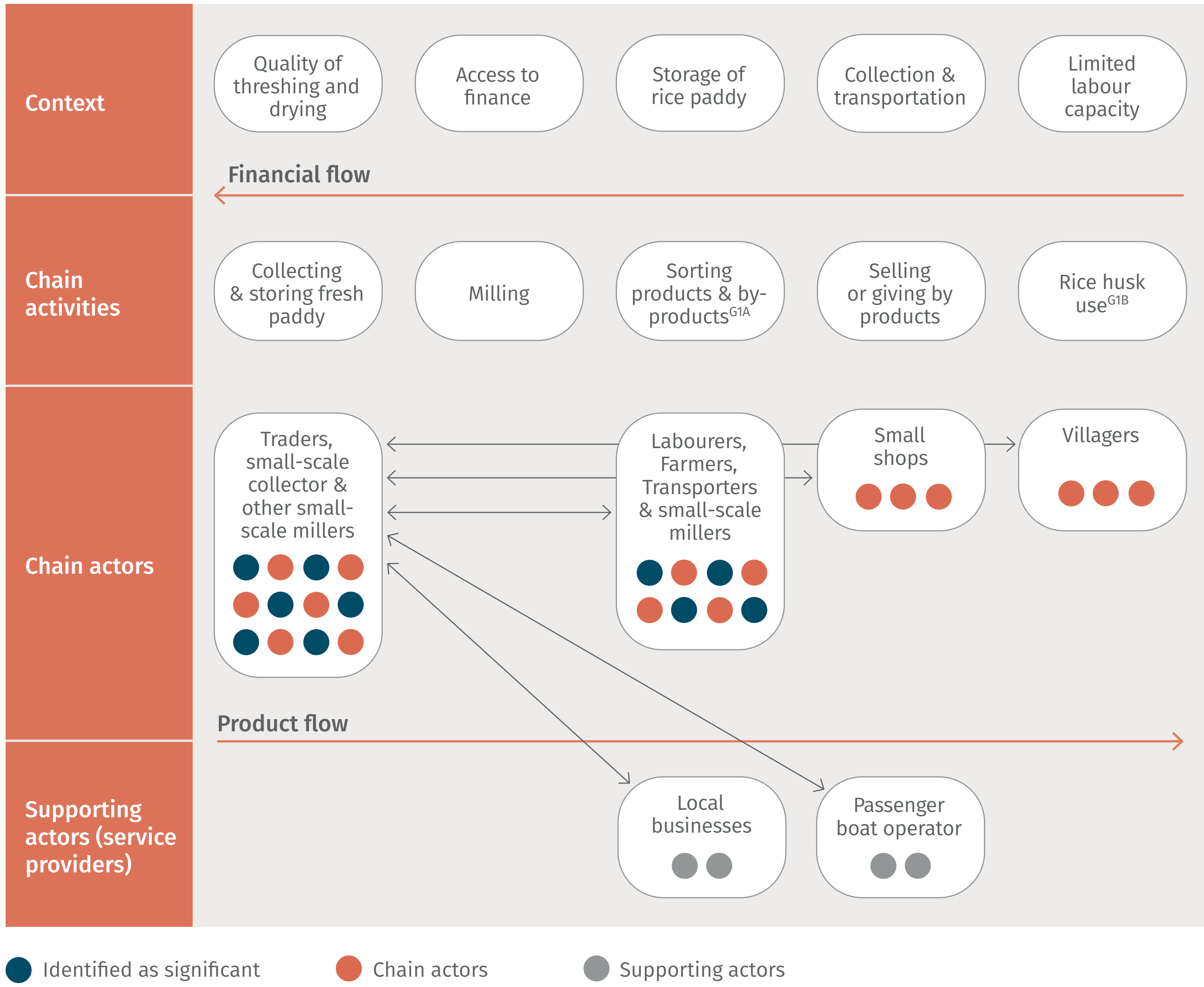
Small-scale processors generally have larger and more interconnected social networks than their medium-scale counterparts. These networks support and facilitate many critical operations, from group-financing to sourcing labour and storage to balancing the supply and demand for processing services. Conversely, larger processors tend to enjoy greater levels of financial and technological support from the government, and are less reliant on informal networks for services like transport, storage and financing that are vertically integrated.

Small-scale processors also play an important role as intermediaries providing critical linkages between rural smallholder farmers and downstream value chain actors like shops, traders and collectors. Given these fundamental differences between millers operating at different levels of centralisation and scales, it is important to differentiate between types of millers and recognise the contribution of small-scale millers beyond simply processing.

149 Mercy Corps Myanmar, Renewable Energy Association of Myanmar (REAM) with Biomass Energy Association of Myanmar (BEAM) and the Tyndall Centre for Climate Change Research at the University of Manchester.

150 Farmer Producer Enterprises (FPE) is part of a Mercy Corps project in Labutta which aims to increase farmers' income by linking farmers to market actors and introducing new agricultural technologies and practices.

Figure G1: Social network map of the value chain for small-scale rice millers



G1A Including rice, rice husk, broken rice, small particles.
G1B Fuel for cooking, briquette, compost, disposed in streams.

Access to effective finance is a major constraint despite several lender groups

While loans from the MADB carry low interest, there can be a considerable delay before funds are disbursed. To acquire the needed inputs, farmers are then forced to take out informal, short-term and often high-interest loans from neighbours or traders which are repaid once MADB funds are released. This creates unique power structures and conditions for exploitation of debtors.

There is an untapped potential market for rice husks and derivative products

Several opportunities exist for enhancing the local beneficiation of rice husks, mostly as a source of energy. Rice husk is typically either sold as traditional fuel (i.e. direct combustion) mostly used for cooking, or is used for modern bioenergy processes like gasification to generate electricity to power mills. The latter lends itself well to small-scale operations and is generally preferred for better efficiency, reduced waste and pollution, and a wider range of applications than simple heat. In addition, some value-added activities for rice husk exist and are largely supported by local businesses, including composting, briquetting and brickmaking. However, vertical coordination[151] needs to be improved to ensure effective utilisation of rice husk.

Agrigrid business model concept in Madagascar

Agrigrid is a pioneering new approach to developing local energy markets by leveraging cross-sectoral innovation in energy and agriculture to *create rural wealth*. The Agrigrid concept redefines a mini-grid business not simply as a provider of energy, but combines this with a community-driven agribusiness to generate long-term agricultural income.

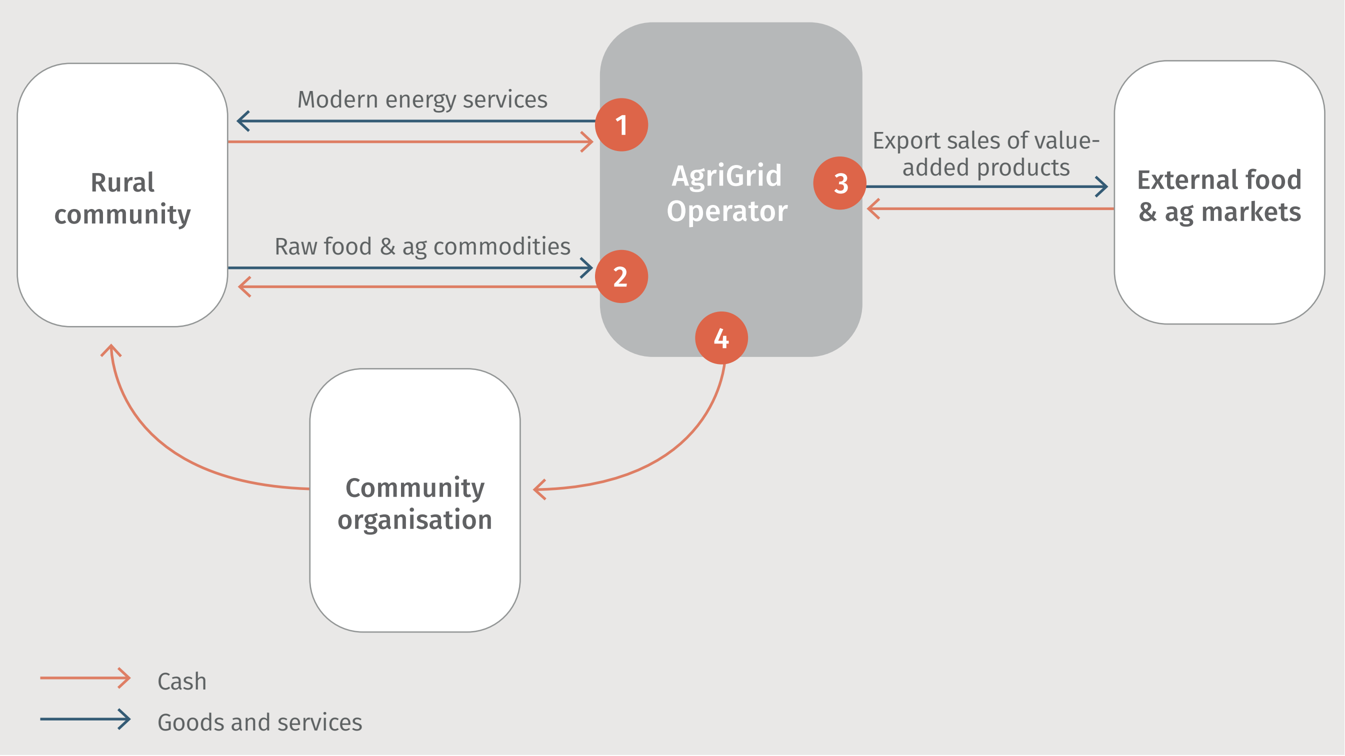
Local mini-grid developer ANKA Madagascar, recognised a common set of challenges facing agricultural commodity value chains and the sustained scaling-up of mini-grids in many African countries. These dual challenges are also pervasive across many developing countries in Asia, including Myanmar, and include:

- Unfavourable agribusiness environment, with rural areas remaining at the mercy of informal traders and middlemen;
- Inefficient energy and agricultural systems with unrealised technical potential and large losses;
- Weak infrastructure, both hard and soft, driving up costs while limiting investment and modernisation;
- Limited inclusivity, sustainability and nutrition;
- Finance is limited to agricultural activities and poorly structured.

Agrigrid was conceived to respond to most of these challenges by positioning the mini-grid company also as an agribusiness company, linking rural economies to domestic and international markets. Similar to the KeyMaker model developed by Inensus, Agrigrid operates as an institutional intermediary between rural, agricultural communities and external markets. As intermediary, some level of localised processing or manufacturing is usually undertaken to both retain value locally and increase the productive use of energy in rural settings, thereby improving the business case for mini-grids. The figure below provides an overview of the Agrigrid model, including profit sharing to foster a sense of community ownership.

151 Improved institutional arrangements such as longer term contractual agreements instead of ad-hoc deals.

Figure G2: AgriGrid business model



1. AgriGrid Operator installs and operates mini-grid and sells energy services to the community.
2. AgriGrid Operator develops an agricultural strategy, and purchases raw food & ag products from the community.
3. AgriGrid Operator refines raw food & agricultural products and sells value-added food & ag products to external markets.
4. AgriGrid Operator and Community Organisation manage a profit-sharing arrangement with the community.

ANKA conducted a case study on the rice value chain to test the Agrigrid model, focusing on rice bran oil (RBO) as a value-added activity. Key lessons that emerged include:

Domestic and export market opportunities exist for product

Current domestic (local rural and urban) demand for cooking oil is largely met by imports that could be competitively displaced by locally produced RBO. High quality RBO could also be exported using market linkages provided by Agrigrid Operator, further enhancing value chain viability.

Seasonality and storage are critical to smoothing energy demand

The change in demand for agricultural processing and therefore energy across different seasons is a critical consideration to ensuring sustained operations throughout the year. Maximising viability requires avoiding demand spikes during harvest time and downtime during cultivation. This can be achieved through a well-designed agricultural strategy that accounts for the number of harvests per year, crop cycling, inter-crop processing and crop-types that can be effectively stored, either raw or processed.

Centralising energy and agriculture investments and assets increases deal size and simplifies operations

Mini-grid and agricultural processing (in this case RBO production) assets and equipment are owned by a single entity, enhancing the institutional processes like due diligence required to raise capital. In addition to adding a significant economically productive user of energy to the mini-grid, a centralised structure also provides a critical market linkage between local and external markets.

Community ownership enhances business model design and can increase energy consumption

Shared ownership fosters a greater sense of community buy-in while creating a single point of (mutually beneficial) contact between the mini-grid developer and the community through pre-determined mechanisms, like agricultural off-taker or community profit-share. Finally, shared benefits increase households' disposable income that in turn increase energy consumption and ultimately mini-grid viability.

Small scale hydro: Indigenous developers, community ownership and local capacity

Myanmar is estimated to have more than 2,000 village-level micro-hydro power plants,[152] most of which have been developed and built by local companies or individual villages without any government or development support. Today many of these plants continue to power local households, businesses and industries, public institutions and farms. Lessons and valuable insights can be drawn from this unprecedented achievement on how to develop sustainable and scalable rural energy projects in Myanmar.

The 80kW Mae Mauk waterfall micro-hydro power plant is located a few hours' drive from Pyin Oo Lwin through the Shan highlands. Operation of the plant and associated business functions are managed by the Lin Yuang Chi Mini-hydro Cooperative, which was established in 2013 and employs seven people. Together, it serves 700 customers spread over 13 villages comprising households and, importantly, public institutions and village-level enterprises. The cooperative also provides free electricity for all the streetlights in the service area in all 13 villages.[153] The system is currently saturated, and not taking on any new connections as demand cannot be met by the current micro-hydro system.

A key characteristic of this model, and a likely driver of its sustained success, is the public-private partnership in which the technology provider, Sai Htun Hla & Brothers (*'SHH & Co'*), hold 50% of the shares in the cooperative and the rest held by community and users. While technical and financial functions are largely fulfilled by the cooperative, SHH & Co provide technical backup support for repairs and replacements under a Build-Own-Operate (BOO) agreement.

Sai Htun Hla and Brothers Mini Hydropower Company (*'SHH & Co'*) is a local company providing hydropower development and installation support through planning, design, feasibility study, turbine fabrication, installation, village-scale transformer production, and energy distribution to rural areas. The company was founded in 2000 and is based in Lashio in Northern Shan, although Sai Htun Hla, the company's founder, has been producing hydroelectric turbines since 1982. To date, SHH & Co has installed more than 200 similar turbines across Myanmar, ranging in capacity from 5 to 300 kW, including 34 pico-hydro plants (<5 kW); 110 micro-hydro plants (<100 kW); and 4 mini-hydro plants (1 MW).

Another important success factor is a strong focus on developing local capacity for O&M of the plant, complemented by the intentional preference for less sophisticated technologies to facilitate this. While prioritising simpler technologies over more sophisticated and likely efficient options is questionable, there is a good case to be made for keeping the system manageable and serviceable, even at the potential cost of lower quality power.

SHH & Co's focus on local skills development and community ownership is shared by a Myanmar-based social enterprise, Mee Panyar, who train local technicians (or '*meesayar*') to build, operate and maintain mini-grids. While their focus is mostly on solar and diesel-hybrid mini-grids, their approach and relative success despite only being founded in 2019 speaks to the need for empowering local stakeholders. The company is also showcasing financial innovation in the sector by leveraging crowdfunding to raise money in support of their goal.

Key insights

Finding a productive user base is crucial to achieving viability, and can include public institutions

Mae Mauk's success is partly attributed to an abundance of village enterprises serving as economically productive users of energy. These include, telecom towers, fabrication workshops, brick making, coffee, poultry, silviculture and more. Importantly, public institutions like healthcare facilities, schools and monasteries are an important group of anchor customers. In general they provide reliable demand, regular payment, and form critical social infrastructure to enable the proliferation of other village enterprises.

Shared value management models drive mini-grid viability through improved socio-economics

Effective cooperation and local ownership, like the equal split in shareholding of the cooperative between SHH & Co and the community, holds several core benefits:

1. **Establishes a common goal**: to generate, sell and utilise energy;
2. **Strengthens connections between developers and energy end-users**: giving the community decision-making power;
3. **Stimulates local economic development:** by developing local skills and creating jobs.

152 Mee Panyar, Position Paper, 2018 (*link*)
153 Doh Gabar, Mae Mauk waterfall mini hydro electrification project (*link*)

Not only do such connections promote customer buy-in, it also enhances their ability-to-pay while creating social and economic incentives to pay. In addition, forging strong partnerships helps to establish mechanisms by which risks, responsibilities and benefits can be fairly yet flexibly shared. For example, the responsibility for O&M of the plant is shared by stakeholders according to capacity and on agreed terms, or the benefit of free public lighting in all 13 villages served.

Village-level knowledge and networks streamline business management processes

In the context of remote management of mini-grids, the ability to leverage village-level knowledge and networks can be pivotal to designing, building and operating a feasible project. The cooperative, composed mostly of local technicians and stakeholders, can likely estimate the required system size with far greater accuracy than some generic and costly *in-situ* evaluation. Similarly, the inherent social networks they have mean that connection extension, tariff collection, dispute resolution and most other technical or business issues can be handled with the appropriate care.

Appendix H
Climate change resilience

Myanmar is highly exposed to the effects of climate change arising from several direct and indirect risks. Myanmar is one of the top three countries most affected by climate change in the 20 years between 1999 and 2018. With more than 7,000 deaths, Myanmar's death toll during this period is more than double that of other countries in the top ten combined.[154] The country's vulnerability to climate change stems from several direct and indirect impacts:

- Direct impacts include loss of life and damage to infrastructure and property as a result of increasing frequency and severity of adverse weather conditions. This was clearly demonstrated by the 2008 Cyclone Nargis, that claimed an estimated 140,000 lives, destroyed the property of approximately 2.4 million people[155] and destroyed rice paddies in the Ayeyarwady Delta, decimating production to half of normal levels.[156]
- Low lying areas are often highly productive and are home to large concentrations of people. However they are also particularly vulnerable. For example, if average sea levels were to rise by half a metre, the rice producing Ayeyarwady Delta shoreline would recede by 10 km.[157]
- Climate risks are exacerbated by high levels of poverty, high exposure to natural hazards – especially for the many subsistence farmers – and low capacity to effectively prepare for or respond to impending climate threats. As threats mount, vulnerable communities are forced to relocate as climate migrants. Between 2009 and 2014, in the period following Cyclone Nargis, more than 800,000 internal migrants arrived in Yangon and settled informally in peripheral, often industrial townships.[158]

Despite climate vulnerabilities, Myanmar is well positioned to grow a climate resilient economy and has taken concerted steps to better respond to climate change. Under the global UNFCCC Paris Agreement, Myanmar in 2017 submitted its Nationally Determined Contributions (NDCs) which outline the country's planned contribution to the fight against climate change. In 2020, a revision was drafted[159] outlining the country's action plan for climate mitigation and adaptation. Mitigation efforts, which focus on curbing greenhouse gas (GHG) emissions, include provisions for:

- Specific GHG emissions reductions targets promoting renewable energy for power generation;
- Reduced deforestation and forest degradation (REDD+);
- GHG emissions reduction targets in the Agriculture sector;
- Mitigation co-benefits from projects related to development of renewable energy based rural mini-grids;

154 Global Climate Risk Index, 2020 (*link*)
155 Global Climate Risk Index, 2020 (*link*)
156 USAID, Country Climate Risk Profile: Burma, 2017 (*link*)
157 USAID, Country Climate Risk Profile: Burma, 2017 (*link*)
158 Khin Khin, E. Climate migrations in Myanmar, 2020 (*link*)
159 GGGI, High-level inter-ministerial consultation brings Myanmar closer to agreement on revised NDC, 2020 (*link*)

- Energy efficiency actions to be taken by a range of urban, industrial and transportation sector actors.[160]

Adaptation efforts are centred around building resilient systems that are able to respond to the inherent uncertainty and increasing frequency and severity of extreme weather events. Because of the country's high degree of vulnerability and status as a least developed country (LDC), it is seeking support for developing its adaptation strategy, expected to be finalised by 2024.[161] The 2020 draft NDC outlines the following priorities:

- Climate-smart agriculture, fisheries, and livestock for food security;
- Sustainable management of natural resources for healthy ecosystem;
- Resilient, inclusive and sustainable cities and towns;
- Climate risk management and education, science and technology for a resilient society.

Energy and agriculture are core to Myanmar's climate, social and economic resilience. In the context of inherent uncertainty and risks associated with climate change, access to energy can provide a basis for improving the ability of farmers, processors and other value chain actors to effectively respond and adapt to changes. A key determinant of energy-enabled climate resilience is strong agricultural value chains and the willingness of different actors to support each other in times of crisis.[162]

160 GGGI, High-level inter-ministerial consultation brings Myanmar closer to agreement on revised NDC, 2020 (*link*)
161 The Irrawaddy, Myanmar Vows to Slash Carbon Emissions by Hundreds of Millions of Tonnes, 2020 (*link*)
162 Kangogo, D., Dentoni, D. & Bijman, J., Determinants of Farm Resilience to Climate Change: The Role of Farmer Entrepreneurship and Value Chain Collaborations, 2020 (*link*)