The Republic of The Union of Myanmar

TECHNOLOGY NEEDS ASSESSMENT REPORT For Mitigation

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Myanmar Technology Needs Assessment Report – Climate Change Mitigation

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Foreword

Myanmar is extremely vulnerable to the impacts of climate change and highly exposed to severe weather events such as heavy rains, storm surges, droughts, floods, cyclones and landslides which have increased in intensity and frequency over the last 60 years. According to the Global Climate Risk Index 2019, Myanmar was ranked the third most vulnerable country to extreme weather events for the period from 1998 and 2017. As a developing country, the impacts of climate change have already undermined the country's development. These impacts will continue to worsen in the future if these drivers of climate change are not addressed and if the most vulnerable sectors are not supported.

Recognizing these circumstances, Myanmar ratified the historic Paris Agreement in September 2017. In addition, Myanmar submitted the Intended Nationally Determined Contribution (INDC) in 2015 with two main mitigation areas – forestry and energy, to contribute toward achieving the 1.5ºC 2030 Paris Goal. To support implementation of the country's INDC, Myanmar has participated in the third phase of the "Technology Needs Assessment (TNA)" project aimed specifically at identifying priority technology transfer investments and to assess which environmentally sound technologies (EST) are most relevant for meeting the country's climate change adaptation and mitigation targets.

The Ministry of Natural Resources and Environmental Conservation (MONREC) recognizes that the TNA Project, implemented in collaboration with the United Nations Environment Programme (UNEP) and UNEP DTU Partnership (UDP), and with the Asian Institute of Technology (AIT) funded by GEF, as the first comprehensive national exercise undertaken towards assessing our climate change technology needs. The TNA process was coordinated by the MONREC through the Climate Change Division of the Environmental Conservation Department (ECD), with the consultations of relevant stakeholders, local experts and national consultants.

The TNA report then presents an analysis of barriers to the adoption of selected technologies and the potential solutions to overcome them. Finally, the TNA process has defined a Technology Action Plan (TAP) that provides a clear, informative, and a realistic road map for transferring, adopting, and diffusing the technologies in the country. Thus, the report provides an assessment of the priority technology requirements and action plans for climate change mitigation in energy and industry sectors; and adaptation in agriculture and water resource management sectors.

I am convinced that this report represents a robust assessment of the necessary technologies required to realize the vision of Myanmar's Climate Change Policy, which is to promote *a climate-resilient, low-carbon society that is sustainable, prosperous and inclusive, for the wellbeing of present and future generation*. Therefore, it gives me great pleasure to present this report to a wide range of stakeholders such as decision-makers, policymakers, developing fund holders, potential investors, technology developers, scientists, researchers.

H.E. U Ohn Winn
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Acknowledgement

This report was an outcome of the project on Technology Needs Assessment (TNA) on climate change adaptation and mitigation for Myanmar, conducted by the national TNA team of Climate Change Division, Environmental Conservation Department (ECD), Ministry of Natural Resources and Environmental Conservation (MONREC) from June 2018 to November 2020.

The TNA Project was funded by the Global Environment Facility (GEF) and implemented with technical support from the United Nations Environment Programme (UNEP) and UNEP DTU Partnership (UDP) in collaboration with the Asian Institute of Technology (AIT). First and foremost, my appreciation goes to the GEF, UNEP, UDP and AIT for their financial and technical support.

We would like to express our sincere thanks to His Excellency Union Minister of MONREC, U Ohn Winn, for his strong encouragement and leadership, as well as his invaluable suggestions and guidance throughout the period of the project.

On behalf of the government of Myanmar, we are also grateful to Professor S. Kumar (Asian Institute of Technology) and Regional Coordinator Dr. Subash Dhar (UNEP DTU Partnership) for their support, encouragement, and invaluable technical inputs for the project.

The MONREC acknowledges the important guidance made by all members of the National TNA Project Steering Committee of the Myanmar TNA Project.

Following the provided methodology and technical assistance, the national TNA team facilitated a series of the stakeholder consultation meetings, bilateral meetings, and working sessions to implement a stakeholder-led Multi-Criteria Analysis (MCA) for the prioritization of technologies targeting both adaptation and mitigation sectors. Stakeholder inputs and recommendations were taken into account during all steps of the TNA process, including in the assessment of barriers to implementation of prioritized technologies and the preparation of Technology Action Plans (TAPs).

The active participation and contributions by numerous stakeholders from concerned Government Departments of various ministries, local and international non-governmental organizations, universities, research institutes, private sectors and civil society organizations played a key role in the successful completion of the TNA process. I wish to take this opportunity to express my sincere gratitude to all those who contributed to make this project realistic. Without their supports this project would never be a success. Moreover, my special thanks are conveying to the individuals from government departments and private sectors related with the agriculture and water resource management sectors for climate change adaptation; energy and industry sectors for climate change mitigation.

Since TNA is a country-driven participatory process, drawing on the diverse and combined knowledge of local expertise and international experiences, I have great confidence that this report can provide tangible solutions to support the government's achievement of international commitment for addressing the climate change-related, and in turn improve our county’s long-term economic, environmental and social development goals.

Finally, I would like to express my sincere appreciation to the national consultants, the national TNA team and the staff of the Climate Change Division for their continuous efforts to realize the TNA project.

U Hla Maung Thein
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Executive Summary

Myanmar is highly vulnerable to climate change. The country sustainable development is threatened by climate change. One of the commitments of the country is to reduce climate vulnerability and to play the role in the global community to combat climate change. Therefore, Myanmar participates in the third phase of the TNA Project which originated from the Poznan Strategic Program on Technology Transfer which was formed at COP 14 to the UNFCCC. The project is designed as a set of country-driven activities. It helps to identify and determine the priority technologies for reducing the CO_2 emission (mitigation) and decreasing vulnerability to the climate (adaption) as well.

This report presents the technology needs assessment for mitigation, and one major outcome of this report is to prioritize technologies for climate change mitigation in the selected sectors. There are two main steps for technology needs assessment for climate change mitigation. These steps are: first, sector selection from among the various sectors and second, technologies prioritization in selected sectors to mitigate greenhouse gas (GHG) emissions. Due to the rapid development of country economic and industry sector booming, there is a crucial from mitigation technologies from energy and industry sector to reduce the GHG emission. Hence, Energy Sector and Industry Sector are selected for TNA mitigation to control the emission.

Initially, 12 technologies were selected for Energy Sector and 8 technologies were chosen for Industry Sector based on the country decision context such as INDC, NDC, Energy Master Plan, Energy Policy, Myanmar Sustainable Development Plan, Myanmar Climate Change Policy, Myanmar Climate Change Strategy, Industry Policy, Energy Efficiency and Conservation Policy, Strategy and Guidelines, Green Economy Framework. With the use of Multi-criteria Analysis (MCA), stakeholder categorized the criteria for technology prioritization for both sectors. There are two criteria groups - cost and benefits. Costs include capital cost and O&M cost. Benefits include economic, social and environment. These criteria were emphasized on viable outcome of the technology.

To prioritize the technologies, the consensus on assigning scores for each technology against criteria and allocating weight on each criterion were requested from stakeholders to examine the results by combining score and weight. As a final result, three technologies for each sector are selected as priority technologies for climate change mitigation. The priority technologies are mentioned below.

For Energy Sector:

1. Solar Mini-Grid
2. Replacing incandescent lamps and fluorescent lamps with LED
3. Substitution of fuelwood with efficient fuel (LPG) at Household Level for cooking

For Industry Sector:

1. Efficient Electric Motors (Using variable speed driver)
2. Energy Efficient Boilers
3. Solar Driers

To examine these results, a sensitivity analysis was conducted but the results remained unchanged. These selected technologies are consistent with the existing Government policies and strategies such as INDC (2015), National Electrification Plan, Myanmar Sustainable Development Plan, Myanmar Climate Change Policy, Energy Efficiency and Conservation Policy. Hence, mitigation technologies are expected to consolidate Technology Action Plan of the government.

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List of Abbreviation

ADB	Asian Development Bank
AIT	Asian Institute of Technology
BAU	Business-as-usual Scenario
CDM	Clean Development Mechanism
CFC	Chlorofluorocarbon
CFL	Compact Fluorescent Lamp
CH_4	Methane
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COP	Conference of Parties
DC	Direct Current
DICA	Directorate of Investment and Company Administration
DRD	Department of Rural Development
DTU	Denmark Technology University
ECD	Environmental Conservation Department
EE	Energy Efficiency
EIA	Environmental Impact Assessment
EST	Environmentally Sound Technologies
FAO	Food and Agriculture Organization
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GEF	Global Environment Facility
Gg	Giga Gram
GHG	Greenhouse Gas
GW	Giga Watt
GWh	Giga Watt Hour
HCFC	Hydro chlorofluorocarbon
IEE	Initial Environmental Examination
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
Km	Kilometer
Ktoe	Kilo Tons of Oil Equivalent
kW	Kilo Watt
kWh	Kilo Watt Hour
Lb	Pound
LED	Light-emitting Diode
LPG	Liquefied Petroleum Gas
MCA	Multi-criteria Analysis
MOI	Ministry of Industry
MOPFI	Ministry of Planning, Finance and Industry
MONREC	Ministry of Natural Resource and Environmental Conservation
MSW	Municipal Solid Waste
MW	Mega Watt
MWh	Mega Watt Hour
N_2O	Nitrous Oxide
NDA	National Designated Authority
NDC	Nationally Determined Contribution
NEP	National Electrification Plan
NMVOC	Non-Methane Volatile Organic Compound

NOx	A Generic Term for The Nitrogen Oxides
ODS	Ozone-depleting Substances
O&M	Operation and Maintenance
PPP	Public Private Partnership
PV	Photovoltaic
RTAD	Road Transport and Administration Department
R&D	Research and Development
SDG	Sustainable Development Goal
SF_6	Sulfur Hexafluoride
SHS	Solar Home System
SIA	Social Impact Assessment
SME	Small and Medium Enterprise
Sox	Sulphur Oxides
SWD	Solid Waste Disposal
TAP	Technology Action Plan
TNA	Technology Needs Assessment
TWG	Technical Working Group
UDP	UNEP DTU Partnership
UNEP	United Nations Environment Programme
UNFCCC	United Nation Framework Convention on Climate Change
USD	US Dollar
VSD	Variable Speed Drives

Chapter 1: Introduction

1.1 About the TNA project

The Technology Needs Assessment (TNA) Project originated from the Poznan Strategic Program on Technology Transfer which was formed at COP 14 to the UNFCCC, and Myanmar participates in the third phase of the project. There are 23 developing countries in this phase including Myanmar, and sixty-one developing countries participated in first and second phase of project between 2009 and 2018. The project is designed as a set of country driven activities. It helps to identify and determine the priority technologies for reducing the CO_2 emission (mitigation) and decreasing vulnerability to the climate (adaption) as well. The Global Environmental Facility (GEF) provides fund for the project, and the United Nations Environment Programme (UNEP) is implementing the project through the UNEP DTU Partnership (UDP). Also, Asian Institute of Technology (AIT) is providing technical support for the Asian Countries.

The purpose of TNA project is to develop investment in technology transfer and to access environmentally sound technologies (EST) that are the most relevant technologies for country climate change adaptation and mitigation targets. There are three main objectives which are stated below:

1. Through country-driven participatory processes, technologies are identified and prioritized to fulfil the participating countries' adaptation and mitigation goals. Also, these are expected to meet their national SDG and priorities.
2. Barriers analysis is conducted to identify challenges for deployment and diffusion of priority technologies. Also, enabling framework is proposed to overcome these barriers.
3. Technology Action Plan (TAP) is created by indicating activities and enabling frameworks to beat the barriers. Also, TAP simplify for transferring, adopting, and diffusing the technologies which are selected in the participating countries.

1.2 Existing national policies on climate change mitigation and development priorities

Myanmar Sustainable Development Plan 2018-2030: There is a strategy which is "Strategy 5.4: Provide affordable and reliable energy to populations and industries via an appropriate energy generation mix". To achieve Strategic Outcomes which is "Climate-resilient and low-carbon energy, transport and industrial systems promoted", these are the action plans related with climate change mitigation (MOPF, 2018):

- Primary energy fuel supply should be mixed with renewable energy sources to attain the most advantageous level,
- The operation of renewable energy resources such as wind, solar, hydro, geothermal and bio-energy should be increased in partnership and with local populations' agreement. Energy generation and distribution efficiency and conservation need encouragement in the use of industry, commercial, household, and public-sector.

Myanmar Climate Change Policy: The policy was formulated by MONREC in 2019 and its vision is "to be a climate-resilient, low- carbon society that is sustainable, prosperous and inclusive, for the wellbeing of present and future generations." For providing long term direction and guidance, the goals of the policy are:

a) Taking and promoting climate change adaptation and mitigation actions in Myanmar;
b) Integrating climate change adaptation and mitigation deliberation into Myanmar's national priorities and across all levels and sectors in a continuous and innovative manner; and
c) Decision making to create and optimize opportunities for sustainable, low carbon, climate-resilient development, making sure benefits for all (MONREC(a), 2019).

Myanmar Climate Change Strategy (2018-2030): This strategy was formulated based on Myanmar Climate Change Policy, so the vision of the strategy is the same with policy. The strategy has its long-term goal which is aim to the year 2030, and the goal is "Myanmar has achieved climate-resilience and pursued a low-carbon growth pathway to support inclusive and sustainable development." Together with Myanmar Climate Change Strategy, MONREC formulated its related master plan throughout the formulation and adoption process to achieve the goal for 2030. To support sustainable development and economic growth, "Resilient and low-carbon energy, transport and industrial systems for sustainable growth" is one of the sectoral outcomes of Myanmar Climate Change Strategy which is focusing on climate change mitigation for Energy, Transport and Industry Sector. To gain this outcome, below are the action plans:

- Country energy security: achievement from the large share of renewable energy generation and high energy efficiency from end-use such as domestic, industrial and other use.
- Transport systems: better resistant to natural disasters while using higher efficiency and low-carbon technologies.
- Industrial systems: productivity enhancement and highly competitive in order to sustainable and green characteristics (MONREC(b), 2019)

Green Economy Policy Framework (Final Draft): There are two components which are (a) an overarching set of guiding principles and goals to support the development of a green economy in Myanmar (b) a green economy investment plan highlighting investment needed to support the development of a green economy in Myanmar and to attain the goals laid out in the Myanmar Sustainable Development Plan as well as the Sustainable Development Goals (SDGs) (MONREC(d), 2019).

Myanmar National Energy Policy: The common targets of Myanmar National Energy Policy are the requirements for energy security, affordability, energy access, poverty alleviation, welfare and the generation of international revenue (NEMC, 2014). The carbon emissions are considered in the policy so far even though climate change is not dominant in it. Energy efficiency & conservation is mainly targeted in most numbers of national policies because there is significant carbon emission reduction from energy waste and fugitives, expansion of energy access, minimization of natural resources impact, and co-benefits of reducing prices.

National Energy Efficiency & Conservation Policy, Strategy and Roadmap for Myanmar: By the assistance of ADB, the report of Energy Efficiency Policy, Strategy, the proposed activities in the key sectors and the road map for implementation has been developed. The report provides information on the rationale for the policy, identifies linkages to the National Energy Policy and other related policies. There is an approach to estimate the energy saving potential in two areas where are (i) consumption of electricity from all different sectors and (ii) consumption of biomass from only residential sector. To do so, at least 14 percent of energy can be saved expectedly compared to business-as-usual scenario (BAU) and the carbon emission could be mitigated. (MOI, 2015).

Environmental Conservation Law: Environmental Conservation Law (2012) is a significant law for industries to be sustainable, and all investor cannot avoid consenting to this. The development of SME and support for manufacturing and processing are the overall target of this policy. Skills development and exploring much more FDI for economic development are also included in policy focuses (The Pyidaungsu Hluttaw, 2012). The main reason to increase FDI is that Myanmar has the intention to move forward to industry-based economy by 2030 (MONREC(b), 2019). In January 2015, EIA procedures were launched and this is an important step forward for climate change.

Environmental Conservation Rule: The main functions of this rule are data collection and compilation for environmental conservation and enhancement, research and training, preparation of IEE and EIA, and declaration of the environmental situation to the whole country. Environmental Conservation Department (ECD) is identified as a designated department to establish and manage Initial Environmental Examinations (IEE) and the Environmental Impact Assessment (EIA) (MOECAF, 2014)

National Environmental Quality (Emission) Guideline: The guideline is providing performance parameters for the regulation and control of air emissions, noise, vibration, and liquid discharges from various sources in order to prevent pollution and thereby protect human and ecosystem health. Also, it provides the basis regulation including general guidelines for Air Emission, Wastewater, Noise and Odor. Moreover, the emphasis of this guideline is on Industrial specific Guidelines which include seven sectors, namely (i) Energy Sector Development, (ii) Agriculture, Livestock and Forestry Development, (iii) Manufacturing (iv) Waste Management, (v) Infrastructure and Service Development, (vi) Water Supply and (vii) Mining (MOECAF, 2015).

Nationally Determined Contribution (NDC): Prior to COP 21 in December 2015, Myanmar developed its INDC, and was finalized in COP 21 and it has become country NDC. There is concern about mitigation actions and policies in the energy sector which focuses on 4 specific areas (MOECAF, 2012).

- Renewable energy – Hydropower: the goal for year 2030 will be 9.4 GW electricity generation which will increase its share of electricity generation (38%) by hydropower.
- Renewable energy – Rural electrification: At least 30% of renewable energy sources will be utilized for rural electrification such as mini-hydropower, biomass, solar, wind and solar mini-grid technologies.
- Energy efficiency – Industrial process: 20% of potential electricity saving is targeted by 2030 against the baseline year of 2012, and mitigate the GHG emission as well.
- Energy efficiency – Cook-stoves: 260,000 energy efficient cook-stoves are planned to be distributed between 2016 and 2031 in order to reduce the consumption of fuelwood from natural forest.

According to draft NDC by March 2020 which is being updated to submit UNFCCC, relevant ministries are implementing step-by-step to achieves above indicative goals. For renewable energy, the country's very first solar power plant located in Magwe Region, and it started its operation in November 2019 with the installed capacity of 40 MW. This plant has the planned 170 MW capacity after the completion of this site. Moreover, public-private partnership agreement with power companies are signed by Ministry of Electricity and Energy to construct solar PV plants with 150 MW capacity in Mandalay's Wundwin and Myingyan townships and with 990 MW capacity in Sagaing, Mandalay and Nay Pyi Taw areas. Under the National Electrification Project, the Myanmar government took a loan of USD 400 million from the World Bank. The loan has two main elements: (1) Grid extension (USD 310 million) which is for procurement of goods and services to extend the national grid (2) Off-grid component (USD 90 million) which is for off-grid electrification through solar home systems, village-level mini-grids, electrification of health clinics, and public street lights.

For cook-stoves distribution target, Dry Zone Greening Department is taking a leading role to distribute energy efficient cook-stoves especially in Dry Zone Areas of Myanmar, and around 56.34% which is 146,479 stoves are already distributed until the fiscal year 2019-2020 to hit the target. Thus, the total emissions reduced from 2016-2019 is around 152,866 tCO_2e (MONREC(e), 2020).

National Environmental Policy of Myanmar: The policy is built on the core values of Myanmar's 1994 National Environmental Policy which is linked with the 1997 Myanmar Agenda 21 and the 2009 National Sustainable Development Strategy. It also expands upon the 2018 Myanmar Sustainable Development Plan. To pursue the vision "A clean environment, with healthy and functioning ecosystems, that ensures inclusive development and wellbeing for all people in Myanmar", the Government of the Republic of the Union of Myanmar adopts the 23 National Environmental Policy principles as the guiding framework for achieving: (a) a clean environment and healthy, functioning ecosystems; (b) sustainable economic and social development; and (c) the mainstreaming of environmental protection and management (The Republic of the Union of Myanmar, 2019).

The National Waste Management Strategy and Master Plan (2018-2030): This is the first national initiative aimed at institutionalizing waste management. Since key stakeholders have been raising their awareness on achieving a resource-efficient and zero-waste society, this mater plan offers a vision and strategy to address key issues, needs and challenges. Although solid waste management is prioritized presently, it addresses waste in all its forms (solid waste, liquid waste/ wastewater, and gaseous emissions) for pollution control and environmental management. It is structured around the framework of 6 goals which are (a) Extending sound waste collection and eliminate uncontrolled disposal and open burning; (b) Extending sustainable and environmentally sound management of industrial and other hazardous wastes; (c) Prevent waste through 3Rs (reduce, reuse and recycle); (d) Ensure sustainable finance mechanisms; (e) Awareness raising, advocacy and capacity building and (f) Compliance monitoring and enforcement. Also, identification of priority actions is described in the master plan to optimize proper collection and disposal of all solid waste which are municipal, industrial, medical, plastic, hazardous and emerging waste, proper disposal and treatment of liquid waste (wastewater from domestic sector and industry). At the same time, waste management services are ensured to be sustainable over the long term (MONREC, UN Environment, IGES, 2020).

In the transport sector, bioethanol which is mixed with gasoline is assumed to create low CO2 emission and reduce primary fuel demand. Moreover, improvement of vehicle fuel efficiency and vehicle fuel economy can achieve enhancement of efficiency (NEMC, 2015). The following existing policies and programs are set for managing emission from mobile sources (Aung N. H., 2009).

- Under 1964 The Motor Vehicle Law, 1989 The Motor Vehicle Rules
- The practice of setting standard exhaust emission (smoke) from RTAD, 50% Bosh Unit
- Restriction of cars which is old-aged (over 2 decades of manufacturing) to be registered in Yangon City Development Area
- Require yearly license renewal for motor vehicles, and biennially for motorcycles
- Random check inspection by using exhaust emission testers

1.3 Sector selection

1.3.1 An overview of sectors, projected climate change, and GHG emissions status and trends of the different sectors

Since GHG inventory in Myanmar's first Initial National Communication was emphasized on key economic sectors of Myanmar, following three sectors are highlighted for their overview with their economic share on country GDP, main energy generation in the country to visualize the linkage between GHG emission from each sector and their economic activities by extracting GHG inventory and projected GHG emission of each sector from INC. Moreover, these sectors are supporting the national development (MOECAF, 2012).

1.3.1.1 An overview of sectors

Agriculture, fisheries and livestock Sector Overview: Agriculture, fisheries and livestock sector is one of the major sectors of Myanmar to support economic development. Agriculture sector-led country GDP sharing in the year 2013 and this sector employed 61% of labor force (MONREC(b), 2019). The main crop of the agriculture sector is rice and it covers almost two-third of cultivated land. Moreover, other crops including oilseeds, various vegetables, chilies, maize, cotton, rubber, sugarcane and tropical fruits could be seen within the country. Especially small-scale fisheries which play the main role in socio-economic development is a major source of livelihood and income for millions of people. More than 1,900 km coastal line and around 380,000 ha of mangroves are providing rich resources of the marine fishery (MONREC(b), 2019). In the livestock sector, household income mostly came from farming activities including cattle, buffalo, pigs and poultry. Backyard method is applied to raise the livestock even though some commercial productions are near large cities. Fisheries and livestock sector shared 8.2% of country GDP in 2013 (MONREC(b), 2019).

Energy Sector Overview: Myanmar has rich energy resources especially hydropower and natural gas. In term of existing Myanmar electricity generation mix, installed capacity connected to the grid is 5489.9 MW including hydropower (3225 MW), coal-fired thermal plant (120 MW), gas turbine (2137.9 MW) by March 2019 (Oo, 2019). In the first half of the 2014 fiscal year, the country revenue was 2.1 billion USD which came from natural gas export. Additionally, new gas fields generate probably around 2.7 billion USD of the revenue per year (ADB(a), 2016). Moreover, Myanmar has an advantage to export energy resources to neighbor countries like Bangladesh, India, China, Laos and Thailand to fulfill their high energy demand according to their rapid economic growth since the country is strategically located in South East Asia. According to DICA, around 54% of country FDI came from the energy sector with 27.72% from oil and gas sector and 26.8% from power sector (DICA, 2019). Since Energy Sector has an ambitious goal which is 100% electrification in 2030, there are plenty of opportunities in this sector for foreign investors throughout the supply chain. Also, Energy is one of the fundamental sectors for both socioeconomic development and industrial sector development.

Forest Sector Overview: Forest cover area was around 42.11% of the devoted total land in Myanmar which was approximately 110,018 m^2 in 2016-2017. In that year, 0.49% of permanent forest estate was increased (CSO, 2017).
Employment: Forest sector is one of the important sources of employment. 4.1% of the national employment rate was accounted in 2015-2016, and 886,000 jobs were created from this sector. Up to 93.7 million USD was generated from this sector as well (MEIT, 2019).
Economic Contribution: Traditionally, forestry is playing one of the major economic roles of Myanmar. Teak exports dominated the sector economy. Nearly 2.2 billion USD was earned in the year 2011 by the wood exports which is the extreme peak exports in the sector due to overharvesting (World Bank, 2019). Therefore, the enactment of the log export ban was released by the government which was also aim to reduce annual allowable cut. However, teak and hardwood logs were major production of the forest, and the production rate were 50,786 cubic tons of teak and 473,802 cubic tons of hardwood logs which were mentioned in Myanmar Statistical Outlook 2017 (CSO, 2017).
Community forest: Myanmar had 248,967 ha of community forests in February 2019 which were covered by community forest user groups and households with 4,711 and around 119,985 respectively (World Bank, 2019).

1.3.1.2 Projected Climate Change

Myanmar National Adaptation Programme of Action to climate change report was launched in 2012. The report predicted below projected climate change that would be happened in Myanmar.

- Particularly from December-May, the temperature would be generally increased across the whole country, and the Central and Northern Regions of Myanmar would experience the significant change of temperature;
- The number of clear sky day would be increased, and it could exacerbate the drought periods;
- Across the whole country from March – November, the rainfall will increase variability during the rainy season especially in Northern part of Myanmar, and it will decrease within December and February; The flooding risk would be increased from a late onset and early withdrawal of monsoon events;
- The frequency and intensity of extreme weather events would be increased, including cyclones/strong winds, flood/storm surge, intense rains, extremely high temperatures and drought (DMH, 2012)

Over the coming century, Myanmar’s average yearly temperature would be projected to increase with the variation of warming magnitude by region and season. Compared to the baseline period which is between year 1980-2006, the prediction of average rising temperature ranges from 1.3℃ to 2.7℃ in 2050. A smaller amount of temperature change is guessed in the wet season compared to warm and cool-season changes. In the wet season (June to October) of the year 2050, the expected mean temperature rise is 1.1℃ – 2.4℃ while average hot season temperature would increase up to 3℃ (Horton, et al., 2017).

Table 1: Projection for mean annual and seasonal temperature change across Myanmar against the baseline year 1980-2006

	Model Baseline (1980-2006)	Warning by (2011- 2040)	Temperature range (2011 – 2040)	Warning by (2041 – 2070)	Temperature range (2041 – 2070)
Annual	23.6 °C	0.7 – 1.1 °C	24.2 - 24.7 °C	1.3 – 2.7 °C	24.8 – 26.2 °C
Hot Season	25.1 °C	0.8 – 1.2 °C	25.9 – 26.3°C	1.4 – 2.9 °C	26.5 – 27.9 °C
Wet Season	25.1 °C	0.6 – 1.1 °C	25.7 – 26.2 °C	1.1 – 2.4 °C	26.2 – 27.5 °C
Cool Season	20.5 °C	0.7 – 1.2 °C	21.2 – 21.6 °C	1.3 – 2.8 °C	21.8 – 23.2 °C

Source: (Horton, et al., 2017)

Concerning about precipitation, nationwide precipitation pattern is expected to change over the coming century. As usual, more rainfall could be seen expectedly in wet season months. Compared to the baseline period (1980-2005), total rainfall in the wet season is guessed to rise in both near and long term (Horton, et al., 2017). Although precipitation will increase in the wet season, there is an uncertainty in the cool and hot season either increased precipitation or decreased precipitation. The detail is shown in table 2.

Table 2: Projection for mean annual and seasonal rainfall change across Myanmar against the baseline year 1980-2006

	Model baseline (1980 – 2006)	Percent change (2011 – 2040)	Precipitation range (2011 – 2040)	Percent change (2041 – 2070)	Precipitation range (2041 – 2070)
Annual	2029	+1% to +11%	2039 to 2242	+6% to +23%	2146 to 2480
Hot Season	285	-11% to +12%	252 to 319	-7% to +19%	266 to 338
Wet Season	1657	+2% to +12%	319 to 1854	+6% to +27%	1753 to 2084
Cool Season	87	-23% to +11%	69 to 96	-12% to +11%	77 to 99

Source: (Horton, et al., 2017)

For the coastal area of Myanmar especially Ayeyarwaddy Delta Region, one of the most pressing concern is the rise of sea level. This will lead to exposing to increase salinity level in water, erode coastal and inundate coastal area by water. Delta could suffer many impacts due to anthropogenic climate and sea-level change. Therefore, there are likely significant negative impacts on the people who are living in Delta Region. For example, the shoreline on the Ayeyarwaddy Delta could move inland by 10 km when sea level rises by 0.5 meters. This is an undoubted impact on local communities and agriculture. The range of sea-level rise projection for Myanmar is 20-41 cm by the year 2050, 37-83 cm by the year 2080 (MONREC(b), 2019).

1.3.1.3 GHG emissions status

Energy sector: Three major GHGs are covered in the national GHG inventory which are CO_2, CH_4 and N_2O. Fuel combustion activity, especially fossil fuel combustion, leads as a major GHG emission in energy sector followed by the fugitive emission from coal mining and fugitive emissions from oil and gas systems. Though traditional biomass fuel combustion is calculated, it is excluded in national GHG inventory estimations. The calculated total GHG emission is 7, 863. 47 Gg of CO_2e from energy sector in year 2000 (MOECAF, 2012).

Industrial processes and product use sector: Non-energy use relegated emission, GHG emission from different types of industrial processes, are linked to material physical/chemical transformation. Various types of GHG are emitted from this sector such as CO_2, NMVOC, SF_6.

Major GHG emission is from Cement industry followed by refrigeration & air conditioning, electrical equipment, lime, etc. Among different industries, NMVOC emission is calculated from only Food & Drink industries. The estimated total GHG emission from this sector in year 2000 is 463.3 Gg of CO_2e (MOECAF, 2012).

Agriculture sector: Since Myanmar is an agricultural country, the share of GDP from this sector is 34% which is including 23% of total export. The sector recruits 63% of labor in 2000. While 30% of populations stay in the urban area, 70% of the population from rural areas are involved in the business of agriculture, livestock and fishery. The staple food of the country is rice and it can be planted in all agro-ecological area of Myanmar. Major CH_4 emitter is flooded rice fields. Additionally, microbial processes of nitrification and denitrification produce N_2O in agricultural soils. The calculated total GHG emissions from this sector is 13,195.41 Gg of CO_2e in year 2000 (MOECAF, 2012).

Livestock sector: 1.25% of CH_4 emission is increased yearly starting from 1998 to 2002 from this sector but the inventory is based on year 2000. The main source of CH_4 is the enteric fermentation of ruminants. Dairy cattle, non- dairy cattle and others are counted in the groups of ruminants. Enteric fermentation produces 404.43 Gg of CH_4 while 52.07 Gg from manure management. The total CH_4 emission is 456.5 Gg as shown in table 1. Among non-dairy cattle, manure management of swine is the largest share of CH_4 emission with 27.82 Gg (MOECAF, 2012).

Land-use change and forestry sector: Biomass carbon stocks increase annually in the forestry sector. Estimated CO_2 emission is 142,221.19 Gg. Due to wood removal, fuelwood removal and harvested wood products, there is total carbon loss which is 29,113.31 Gg of carbon. The total estimated GHG emission from this sector is 40,404.855 Gg of CO_2e. Hence, the annual net calculated CO_2 removal from this sector is 101,816.38 Gg of CO_2e in the year 2000 (MOECAF, 2012).

Waste sector*:* There are two different sources of CH_4 emission. They are solid waste disposal and domestic and commercial wastewater treatment. In this sector, CH_4 emission is calculated mainly based on population data in urban areas since there is limited information on the quantities of waste and the practice on waste management as like as in most developing countries. Therefore, total methane emission from waste sector is 1345.7 Gg. In this amount, solid waste disposal is accounted as 133.31 Gg which is 99% of total emission from this sector and other 1% which is 1.198 Gg is from wastewater from domestic and commercial (MOECAF, 2012).

GHG emissions in Myanmar for the year 2000: The national GHG inventory is calculated based on year 2000. In term of CO_2 emission, forestry sector is the main emitter of the country with 33,656.51 Gg CO_2 followed by the energy sector (7,658.65 Gg CO_2) and industry sector (248.59 Gg CO_2). The most methane emission come from the agriculture sector which is 963.75 Gg CH_4. Although forestry sector emits large amount of CO_2, there is a huge amount of CO_2 removal from forestry sector with 142,221.2 GgCO_2. Therefore, the estimated total GHG emission in Myanmar is -67,820.1 Gg of CO_2e in 2000 as shown in table 3 (MOECAF, 2012).

Table 3: GHG emissions and removals in Myanmar for the year 2000

Source/ Sink	CO_2 Removal (Gg)	CO_2 Emission (Gg)	CO (Gg)	CH_4 (Gg)	N_2O (Gg)	No_x (Gg)	CO_2e (Gg). Total Emission	CO_2e (Gg) Net Emission
Energy Sector		7,658.65	-	5.62	0.28	-	7,863.47	7,863.47
Industry Sector		248.59	-	-	-	-	463.29*	463.29
Agricult-ure Sector			0.81	963.75	8.4	0.022	22,843.67	22,843.67
(a)Agric-ulture			0.81	507.25	8.2	0.022	13,195.17	13,195.17
(b)Live-stock				456.5	0.2		9648.5	9648.5
Forestry Sector	142,221.2	33,656.51	2,215.37	144.85	4.26	34.08	40,404.73	-101,816.5
Waste Sector				134.57			2,825.97	2825.97
Total	142,221.2	41,563.75	2,216.18	1,248.79	12.94	34.102	74,401.13	-67,820.1

*Note: * Other gases NMVOC, ODS and SF6 amounted to 214.7 Gg CO_2e.*
Source: (MOECAF, 2012)

1.3.1.4 The trend of GHG emissions in Myanmar

From the year 2000 to 2005, the trend analysis of estimated GHG emission in Energy sector which includes industrial process and product use showed many fluctuations. During the year 2000 to 2005, energy and transformation industries and transportation are main responsible for most CO_2 emissions. Therefore, the GHG emissions from energy sector will be largely influenced the development of industries and economy. Table 5 also indicates that NMVOC, ODS, SF_6 emissions also show a considerable amount. However, The Montreal Protocol stated that those ODSs must be deducted from industrial sector. Thus, the trends for those emissions are expected to decrease. In short-term (2000 – 2005), the trend of GHG emissions clearly indicates that agriculture and livestock sector increases sharply. In the livestock sector, the CH_4 and N_2O emissions are probably increased because of the increase in the net sown area and more inputs in agricultural systems and the increased domestic animals. Table 8 shows that CH_4 emissions in waste sector are increased due to the population growth and increased urban population. For both short-term and long-term, the CH_4 emission is likely to drastically increase (MOECAF, 2012). The major GHG emitter in Myanmar was from the land use change and forestry sector and also the major emissions came from deforestation, shifting cultivation and land clearing for forest plantations. Due to deforestation and degradation, the total annual CO_2 removals by natural forests are declining steadily. It is important that the forest should be protected, conserved and managed sustainably as they constitute both a source and a sink of CO_2 (MOECAF, 2012) .

Table 4: GHG emission projection for Energy Sector based on year 2000

	2000	2001	2002	2003	2004	2005
Energy and transformation industries (Gg)						
CO_2	2,323.02	2,118.25	2,430.94	2,756.17	3,734.13	3,050.16
Industry (Gg)						
CO_2	784.83	865.39	889.92	866.07	961.44	695.03
N_2O	0.08	0.06	0.07	0.07	0.06	0.06
Transport (Gg)						
CO_2	2,129.98	1,980.12	2,486.63	2,608.35	2,504.92	2,432.82
CH_4	0.46	0.42	0.48	0.54	0.55	0.67
N_2O	0.1	0.09	0.12	0.12	0.12	0.11
Small combustion (Gg)						
CO_2	1528.30	1428.30	1,417.08	1,406.97	1,177.10	1,333.94
N_2O	0.1	0.08	0.08	0.07	0.07	0.07
Fugitive emission from fuels (Gg)						
CH_4	0.53	0.35	0.42	0.61	0.83	0.73
Oil and natural gas (Gg)						
CH_4	4.63	4.8	5.12	5.41	6.59	6.76
Others (Gg)						
CO_2	895.52	363.82	331.1	425.92	248.53	454.3
Total CO_2e (Gg)	7,863.47	6,994.15	7,765.79	8,281.84	8,870.99	8,212.01

Source: (MOECAF, 2012)

Table 5: GHG emission projection for Industrial Process and Product Use Sector based on year 2000

	2000	2001	2002	2003	2004	2005
Industrial Processes						
CO_2 (Gg)	241.2	225.9	227.17	336.02	302.77	292.01
NMVOC* (Gg)	4.57	4.84	4.29	3.52	3.66	3.17
HCFCs/CFCs (Gg)	0.11	0.08	0.09	0.12	0.18	0.11
SF_6 (Gg)	0.003	0.003	0.003	0.003	0.003	0.003
Solvent Used						
CO_2 (Gg)	7.39	6.26	6.98	7.13	6.52	6.33
Total CO_2e (Gg)	463.3	407.9	422.9	570.9	615	513

Source: (MOECAF, 2012)

Table 6: GHG emission projection for Agriculture Sector based on year 2000

Years	1990	1995	2000	2001	2002	2003	2004	2005
Emissions from Rice Cultivation (Gg)								
CH_4	349.33	485.18	507.23	514.06	511.32	523.69	540.09	589.81
Emission from Agricultural Soils (Gg)								
N_2O	5.53	7.07	8.2	8.53	8.67	9.05	9.49	10.19
Emissions from Field Burning of Agricultural Residues (Gg)								
CH_4	0.0174	0.0214	0.024	0.0249	0.0247	0.0255	0.0264	0.0282
N_2O	0.0004	0.0006	0.0006	0.0006	0.0006	0.0007	0.0007	0.0007
NOx	0.0161	0.0198	0.022	0.0231	0.0229	0.0236	0.0245	0.0262
CO	0.5913	0.729	0.81	0.8488	0.843	0.8696	0.9003	0.9623
Total (Gg CO_2e)	9,051.39	12,381.94	13,195.41	13,441.23	13,427.08	13,804.73	14,285.58	15,546. 81

Source: (MOECAF, 2012)

Table 7: GHG emission projection for Livelihood sector based on year 2000

GHG	1990	1995	2000	2001	2002	2003	2004	2005
CH_4 (Gg)	378.38	404.83	456.5	469.29	484.11	495.49	506.49	519.23
N_2O (Gg)	0.14	0.17	0.2	0.21	0.22	0.23	0.24	0.25
Total CO_2e(Gg)	7990.79	8554.35	9648.31	9919.57	10233.98	10476.59	10709.42	10980.15

Source: (MOECAF, 2012)

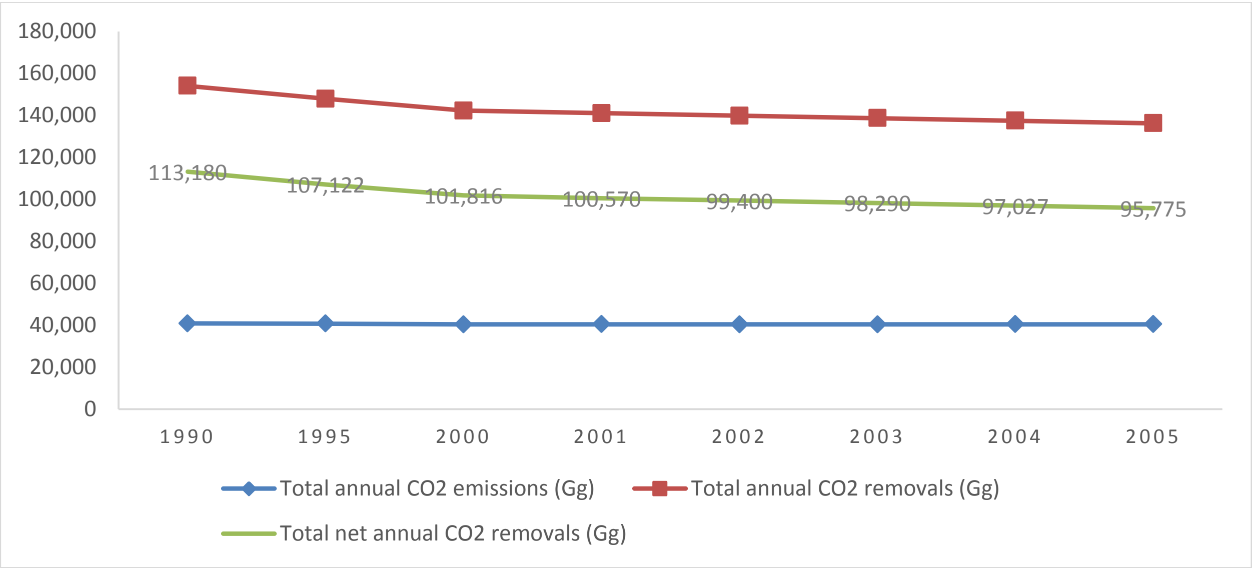

Figure 1: GHG emission/removal projection for Land Use Change and Forestry Sector based on year 2000

Source: (MOECAF, 2012)

Table 8: GHG emission projection for Waste Sector based on year 2000

Year	From SWDs (Gg)	From Domestic & Commercial waste-water (Gg)	From Sludge (Gg)	Total Emissions (Gg)
2000	133.31	1.198	0.059	134.57
2001	136.05	1.222	0.060	137.206
2002	138.01	1.240	0.061	139.311
2003	141.59	1.272	0.063	142.925
2004	144.396	1.297	0.064	145.757
2005	147.32	1.320	0.065	148.70
2010	157.32	1.420	0.070	159.44
2015	172.690	1.550	0.076	174.30
2020	188.650	1.700	0.083	190.40

Source: (MOECAF, 2012)

1.3.2 Process and results of sector selection

Myanmar launched its INDC in 2015 which was finalized in COP 21 to become the country NDC. Forestry and energy sector (hydro, rural electrification, industrial energy efficiency, cookstoves) were listed for mitigation sectors while the adaptation sectors were agriculture, early warning system, public health, water resource management, coastal zone protection, energy and industry, and biodiversity preservation.

Based on country NDC, Myanmar Climate Change Strategy was developing starting from 2014 and it was launched in 2019. According to Myanmar Climate Change Strategy, energy, transport and industry are backbone of development and economic growth. These sectors could generate the country income and create job opportunities in future years (MONREC(b), 2019). For this reason, "Climate-resilient and low-carbon energy, transport and industrial systems" was planned as a sectoral outcome to support inclusive and sustainable development and economic growth. These sectoral outcomes which are relating with climate change mitigation are mentioned in Section 1.2. This strategy was prepared based on country NDC in close consultation with national and local-level stakeholders. These stakeholders were representing a cross-section of the government institution, national NGOs, community representatives, private sector actors, development partners, professionals and academics covering a wide range of sectors. These stakeholders were engaged through bilateral discussions, four national workshops and five sub-national workshops. Also, more than 600 participants who were from local government, civil society organizations, communities and the private sector were engaged in five of Myanmar's climate-vulnerable states/regions (MONREC(b), 2019). Under the guidance of Myanmar Climate Change Alliance, most of the consultation workshops were conducted. The Myanmar Climate Change Strategy is therefore strong, with multiple views and perspectives, effectively capturing this diversity.

What is more, following facts and figures were used to select the sectors. According to the economic development of Myanmar, the country real GDP growth rate was increasing year by year which were 8.4% in 2013, 8% in 2014, 7% in 2015, 5.9% in 2016, and 6.8% in 2017 respectively (IMF, 2016). Based on figure 2, country GDP sectoral composition was changing, and Agricultural Sector led a country GDP sharing with 22.5% followed by Services Sector (21.6%), Process and Manufacturing Sector (21%), Energy Sector (18.8%), etc. (MONREC(b), 2019). Consequently, a larger share of employment and output came from these sectors. Per June 2019 Sectoral FDI which was released by DICA, oil and gas sector took the largest share of FDI with 27.72 % followed by power sector with 26.8%, manufacturing sector with 13.82%, transport and communication sector with 13.41%, and so on (DICA, 2019). McKinsey Global Institute expected that Myanmar Economy size could be growth more than quadruple in year 2030 compared to year 2010 by expending seven sectors including manufacturing, agriculture, infrastructure, energy and mining, tourism, financial services and telecom (Chhor, et al., 2013).

During September 25 to September 28, 2018, the TNA scoping mission to Myanmar was carried out by UDP and AIT for the TNA Project. In this mission, Deputy Director of ECD presented the status of Myanmar's INDC on behalf of TNA Coordinator, Director of ECD, and TNA project was then introduced by Deputy Director of ECD. Continuously, stakeholders who are mentioned in Annex II as the participants of scoping mission workshop selected the four different sectors for TNA project based on the combination of priority sectors from INDC, the strategies of Myanmar Climate Change Strategy and above-mentioned facts and figures under the guidance of the presentation from ECD.

As a result, Energy Sector and Industry Sector are listed to be two priority sectors for mitigation for TNA Project.

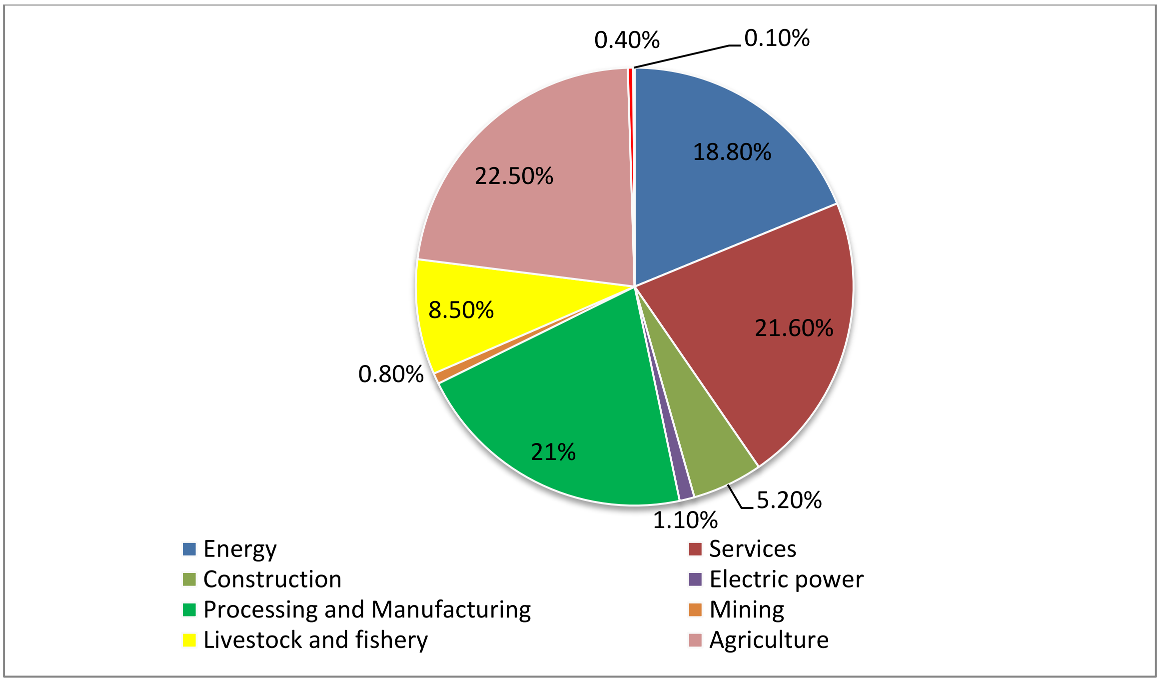

Figure 2: Myanmar GDP Structural Transformation, 2012-2013
Source: (MONREC(b), 2019)

Chapter 2: Institutional arrangement for the TNA and the stakeholder involvement

Climate change is one of the major concerns of environment nowadays, and MONREC is well placed to be a main ministry to coordinate to implement the task relating with climate and environment with other line ministries, and make sure to consolidate the concerns of climate change into the development of National and Sectoral Plans and Programs. The focal point for climate change, MONREC's ECD, communicates with international organization, as the NDA of Myanmar. The main duty is that to negotiate with UNFCCC, to report to UNFCCC, and to implement national level by transforming global-level decision which is including the endorsement of projects from different climate change funds to support the country.

2.1 National TNA team

From the support of GEF through UDP, MONREC's ECD is assigned as a project management unit to prepare TNA. Figure 3 shows the overall TNA structure, and following the step-by-step guide note of TNA, Myanmar TNA Team is set up.

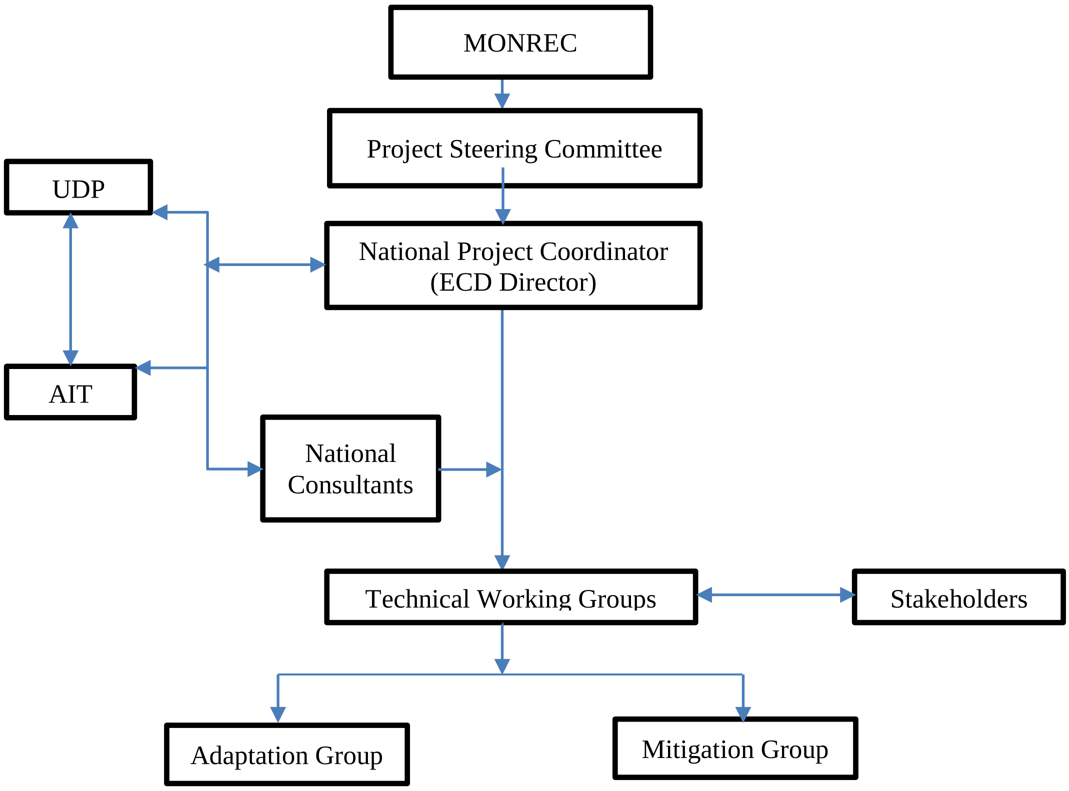

Figure 3: Myanmar TNA Organization Structure

National TNA team comprises of a steering committee, national TNA coordinator, sectoral working groups and two consultants for mitigation and adaptation respectively. Their main roles and responsibilities of the TNA team are presented below.

The steering committee: This steering committee is chaired by Director General of Environmental Conservation Department who is also the country NDA. National Steering Committee plays an important role in making decision of the project, and the committee consists of members who are responsible for policy making of the academia sector and civil society from relevant ministries and key stakeholders. The committee is also responsible to provide political acceptance of the Technological Needs Assessment (TNA) and Technology Action Plan (TAP) process. The members of the steering committee are presented in Annex III.

The national TNA coordinator: The Director of Climate Change Division from Environmental Conservation Department is appointed as the national TNA Project Coordinator who has a strong background of project management and policy formulation for environmental and climate change relating issues. He is the focal person to manage of the overall TNA process such as vision and leadership for the overall effort, facilitating in communication between the National TNA Committee members, National Consultants and stakeholder groups, and also provide formation of networks, information acquisition, and coordination and communication of all work products.

Sectoral working groups: To constitute the workgroups by minister office to provide an active role to the stakeholders in the TNA process, in which stakeholders are central to the TNA process. In order to provide appropriate technologies for a sector, the workgroups are on sectoral basic, and conduct market barrier analysis and recommend an enabling framework for the sector. The working group members are listed in Annex IV.

The Mitigation and adaptation consultant: To identify and prioritize of technologies, barrier analysis and market assessment. It is also responsible for the drafting of project proposals for priority technologies for their respective area of expertise.

2.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

For a successful TNA project, Stakeholder Engagement process is an essential element of the project. Therefore, involving stakeholders in the most important steps or activities, such as, scoping mission workshop, inception workshop, stakeholder consultation workshop for technology prioritization is an efficient and effective way to implement the project. Moreover, involvement of different institutions from the starting point of the process will make sure to achieve the rightful choice of technologies and the ownership by deciding selected and prioritized technologies. To do so, utilization of this TNA at the end will lead to be easier transformation of technology program.

On September 27, 2018, there was a workshop to identify the sector for TNA Project during the scoping mission of UDP and AIT. ECD organized the workshop and the workshop invitation letters were sent to respective ministries relating with environment and climate change such as MOEE, MONREC, MOE, MOI, MOALI to nominate a representative of the ministry to participate in the workshop. Detail stakeholders list who attended the workshop is presented in Annex II. To organize a Sectoral Working Group of the TNA Project, the Project Coordinator Team and Consultants discussed to make a list of key stakeholders for the project, then the selection of key stakeholders was done by Project Coordinator Team. The most relevant government agencies, NGOs, INGOs and private sectors were listed by ECD, and they were requested to nominate a relevant person for sectoral working group. After receiving the nominees, the working group were formed for each sector. According to Notification Number (78/2019) on 28 May 2019, the lists of working groups were approved by the Minister of the Ministry of Natural Resources and Environmental Conservation (MONREC). Detail list of working group members is described in Annex IV.

After working group was formed, organizing Inception Workshop plus Stakeholder Consultation Workshop was started. For stakeholder engagement for this workshop, project coordinator team led to distribute the workshop invitation letter to all sectoral working group members. Moreover, other key stakeholders as like as SNC National GHG Inventory Working Group, local NGO and INGO and other relevant public sectors were invited. The attendances list of the workshop is in Annex V. Moreover, working session for mitigation group was held on August 30, 2019 to review again the list of prioritizing technologies by inviting key stakeholder from each working group before confirming the selected technologies from concern ministries and departments. The attendance list of working session is shown in Annex VI. Then, bilateral meeting with concern ministries and departments took place to finalise the decision from previous meeting and workshop for technology selection. The bilateral meeting was done only with the concern government agencies which are described in Annex VII with pre-selected technologies from Stakeholder Consultation Workshop and Working Session. Finally, the final selection of technologies was reported to The Minister of Ministry of Natural Resources and Environmental Conservation through Chairman of Project Steering Committee for official endorsement of technology prioritization for TNA project.

Below is the overall process of stakeholder engagement:

- Various stakeholders are invited to participate in inception workshops.
- The stakeholder consultation workshop, focus on group discussions, are conducted with related stakeholders for relevant sector.
- Working sessions are also conducted by inviting key stakeholders from each working group and related stakeholders from ministries,
- Bilateral meeting is also taken place with relevant ministries to finalize the decision of technology prioritization.
- Official communications have been done with focal ministry for requesting review and validation.

Although this is a key process, engaging all stakeholders is unachievable because of limited times and resources.

2.3 Consideration of Gender Aspects in the TNA process

Based on different existing inequalities, roles and responsibilities, there are different needs and priorities from women and men, and they suffer the climate impact in different ways. Also, women are the most vulnerable to climate change and hazards compared to men. In Myanmar, there are limitation for women to participate in decision making roles, to access equally to natural resources, to have opportunity to access markets, capital, training and technology because of culturally manners (MONREC(b), 2019). However, women can play an essential role in climate change mitigation because of their primary attention which is to fulfil their family's needs and well-being for their family members while using energy efficient appliances, low-carbon-footprint technologies and influencing the use of ecosystem services by the household.

In Myanmar, doing household activities are mostly led by women. They spend most of their time on these activities instead of doing productive livelihood activities from their times. For example, collecting fuelwood for cooking activities is done by women instead of using most of their time for education for their personal improvement. Due to the emission from traditional cook-stoves which consume fuelwood and charcoal, working time (early and late hours of the day) and working condition (in the dark situation), there is an impact on the women health (ADB(a), 2017). The absence of reliable energy services, women are more vulnerable than men because they may refuse to attend trainings, classes meetings since they have to be done more household activities without electricity after the sunset. Therefore, women may have willingness to prioritize the technologies which can provide reliable energy services with low-carbon technologies and energy-efficient appliances.

There are a lot of co-benefits from mitigation actions from energy and industry for women in terms of economic, social and health and nutrition (Rojas, Prebble, & Siles, 2015). Below perspectives of Myanmar are not comprehensive since many co-benefits can achieve based on technologies, situation, geographic condition, etc. In Myanmar, the employment rate of women could be increased while they are involving in energy and industry sector as engineers, professionals and decision-makers. Since women are involving in these sectors, they could consequently gain new knowledge and skills based on this technology while these sectors are expanding in the country. Therefore, they could have more choice to select their job in the future. To do so, their income generation could be increased and they can access the new economic activities more than before. In term of social benefits, the literacy rate of girls could be increased through the better access to energy services, and women may feel more secure than before while accessing the street lighting in the village. From health and nutrition perspective, reduction of physical labour can lead to increase in the maternity rate and reproductive health. Also, improve nutrition can obtain by using more efficient cooking technologies.

Throughout the implementation of TNA project on a national level, women are focal for the project beneficiaries and this can happen inviting more women stakeholders in composition of working group for the project to identify prioritize technologies. The composition of sectoral working groups in Energy Sector is 6 females plus 9 males while 10 females out of 14 are in Industry Sector Working Group. During the inception workshop plus stakeholders' consultation workshop, 9 female stakeholders out of 17 stakeholders from Energy Sector and 10 female stakeholders out of 17 stakeholders from Industry Sector participated in the focused group discussion throughout the workshop. Firstly, all stakeholders took into consideration of gender issues whether the impacts of technologies were directly affected on women when criteria set was developed in the workshop. For example, reducing drudgery time of the selected mitigation technologies was considered during the criteria development. Then, the technology prioritization and identification were done by emphasizing on women stakeholders' contribution to discussion. The target of consideration of gender aspects in this report is that all population from Myanmar are provided benefits equally from the actions set out in TNA by considering the gender differences throughout the entire process of TNA.

Chapter 3: Technology prioritisation for Energy Sector

3.1 GHG emissions and existing technologies of Energy Sector

According to IPCC 2006 Guidelines, there are three main emission sources from Myanmar energy sector which are fuel combustion, fugitive emission from coal mining and fugitive emission from oil and gas systems. The main CO_2 emitter in energy sector is fossil fuel combustion which is 7,658.65 Gg CO_2. Although traditional biomass fuel combustion emits a large amount of CO_2, it is excluded in calculation of national GHG inventory. Most methane emission comes from fugitive emission from oil and gas systems with 4.63 Gg of CH_4. Therefore, the total estimated GHG emission is 7,863.47 Gg of CO_2e in year 2000.

Table 9: Total GHG emission from Energy Sector in year 2000

No	Emission Sources	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	Total CO_2e (Gg)
1.	Fuel Combustion				
	-Fossil fuel combustion	7,658.65	0.46	0.28	7,755.11
	-Traditional biomass fuel combustion*	27,475.3*	7.36*	0.98*	28,297.82*
2.	Fugitive emissions from coal mining	-	0.53	-	11.13
3.	Fugitive emissions from oil and gas systems	-	4.63	-	97.23
	Total	7,658.65	5.62	0.28	7,863.47

Source: (MOECAF, 2012)

The main existing technologies in the sector are electricity generation mix to meet the electricity demand of the country and production of secondary fuel for transportation and household cooking sector. In Myanmar, electricity generation is mixed with renewable energy such as hydro, solar and wind. At March 2019, the total installed capacity of electricity generation (grid connection) is 5,489.9 MW which is combined with hydropower around 59%, gas around 39% and around 2% of coal (Oo, 2019). Therefore, Myanmar electricity generation is dominant by hydropower and gas. According to Myanmar's National Electrification Plan (NEP), Department of Rural Development (DRD) is implementing both solar home system and mini-grid system in rural area. Within two and a half year of project duration, around 0.23 million of households are electrified by this project with is 38% of electrification rate (DRD, 2019). To share the electricity generation, the installation of 30 MW wind farm project has been planned in Chaungtha, Pathein Area for the purpose of developing more wind power project in the country (Soe, Bhaskaran, Boopathi, & Gomathinayagam, 2017)

In the residential sector, biomass has been playing historically a vital role in end-use energy consumption, since most households use inefficient cook-stove including traditional cookstove and 3 stone for cooking activities. Final energy consumption in rural area is overwhelmed by fuelwood followed by bagasse and charcoal. For instance, around 19,906 kton of fuelwood are consumed for heating and cooking purposes in one year period from 2013 to 2014 (NEMC, 2015). Moreover, some rural areas of Myanmar have applied 190 biogas digesters with various small capacities for the intention of lighting and cooking. Biofuel production has been initiated by various agencies between year 2003 and 2010, and there are 5 biofuel plants which have been constructed. Although there are plants, the operation of biofuel plants has been stopped for several years due to insufficient support, Jatropha cultivation barriers and absence of policy. Biofuel production, transportation, storage and sale permit is notified by the government of Myanmar in 2009 to encourage the substitution of gasoline with biofuel (ADB(a), 2016).

Myanmar transportation system has 4 main categories which are road transport, rail transport, water transport and civil aviation. Among them, road transport is the major transportation system in the country which is leading with long-distance travel, and carrying freight transport (90%) and passenger transport (86%) (ADB(b), 2016). Currently, Petroleum fossil fuels (Gasoline, Diesel, CNG, LPG, Aviation Gasoline, Coal and Fuel Oil) are mainly used for the transportation system.

3.2 Decision context

The decision context is established as a very first step of MCA process to prioritize the technologies. There are several sectoral policies, plans and strategies in country, and establishing decision context for conducting MCA is done by consultant by reviewing existing sectoral policies, plans and strategies relating with Energy Sector. Below contexts are already developed by decision-makers of respective sector.

Myanmar Energy Sector Policy: "The main objective of the Myanmar Energy Sector Policy is to ensure energy security for the sustainable economic development in the country; and to provide affordable and reliable energy supply to all categories of consumers, especially to those living in the remote areas that are currently without electricity" (NEMC, 2014). Under the energy sector development plan, the Government set top priority for rural electrification through using renewable energy sources such as solar, wind, mini-hydro power, and biofuels as well.

The Myanmar National Electrification Plan (NEP): "The Myanmar National Electrification Plan (NEP) aims to electrify 100% of Myanmar's households by 2030" (Castalia Strategic Advisors, 2014).

National Energy Efficiency Policy: There are two main areas of energy-saving potential which are electricity consumption in all sectors and biomass consumption in the residential sector. The main objective of the policy is 12% reduction of national electricity demand in 2020, 16% in 2025 and 20% in 2030 from all energy end used sector (Residential, Commercial, Private and including Industry Sector) against 2012 as the baseline year (8,254 GWh of electricity consumption) by reducing energy use and resulting GHG emissions (MOI, 2015). Based on the calculated energy saving potential, the National Energy Efficiency Policy objective using 2012 as the baseline is as follows:

- Reduction of 12 % national electricity demand in 2020 (from all sectors)
- Reduction of 2.3% of biomass used in 2020 (from the residential sector)
- Reduction of 78,690 tonnes of national CO_2 emission in 2020 (from all sectors) (MOI, 2015)

There are six objectives in Myanmar Climate Change Master Plan to achieve the sector outcome which is "Resilient and low-carbon energy, transport and industrial systems for sustainable growth" with short (3 years), medium (8 years) and long term (10 years) plans. These plans are assigned to relevant line ministries to achieve these outcomes in year 2030. The objectives are following -

1. Integrate climate change into energy, transport and industry policies, plans, research and development, and extension services at national, sectoral and local levels
2. Establish and reinforce institutional arrangements to plan and implement climate change responses
3. Establish financial mechanisms to mobilize and allocate resources for climate-resilient and low-carbon development
4. Increase access to climate-resilient and low-carbon technologies and practices in the energy, transport and industry sectors.
5. Enhance awareness and capacity to promote and implement climate-resilient and low-carbon responses.
6. Promote multi-stakeholder partnerships to support and scale-up climate-resilient and low-carbon responses (MONREC(c), 2019).

According to Green Economy Policy Framework, Clean and Accessible Energy is one of the priority areas of Green
Economy Investment and below areas are desired and required Green economy investments (MONREC(d), 2019).

- Modernization of the public electricity grid

- Solar energy (i.e. photovoltaic and concentrated solar power)
- Waste-to-energy (solid waste and biomass)
- Biomass energy
- Wind energy
- Biofuels
- Electricity from tidal waves
- Geothermal Energy
- Storage Technology (e.g. battery, pump storage)
- Run-of-River hydropower
- Energy efficiency in buildings, industry, transport
- Refurbishment of existing facilities
- Systematic off-grid electrification

Even though each policy and plan have their own objectives, there are challenges to fulfill these objectives. Followings are key examples of challenges within the country:

- End-use issues
    - Most buildings in the commercial sector and residential sector use inefficient fluorescent lighting.
    - Biomass is still playing a major role in household cooking energy in both rural and urban.
    - Low efficient electrical appliances are overwhelming the country market share.
- Source related issues
    - Electricity generation cannot supply to meet the peak load in whole year basic.
    - The consumption of electricity always increases in summer and there are two times a day of peak demand.
- Transmission and distribution issues
    - Most of the current transmission lines are single circuit.
    - Technical and nontechnical losses of the combined transmission and distribution system were high with around 20% in 2013 (ADB(a), 2016).

According to state objectives and challenges above, the main goal of analysis in TNA is to develop the energy sector with low carbon emission by using renewable energy sources, to utilize more efficient energy end-use appliances than before and to provide universal electricity access with clean and low carbon energy solutions.

3.3 An overview of possible mitigation technology options in Energy Sector and their mitigation potential and other co-benefits

Based on the decision context and as the second step of MCA, climate change mitigation options are identified in a particular sector by conducting research on existing national policies, national and local development strategies and low carbon strategies which are relating with Energy Sector. This research work was done by consultant to identify possible technologies with climate change mitigation potential. Also, the consultant reviewed the global databases on technology (climate techwiki), technologies for climate change mitigation guidebook from TNA website and case studies from participant countries in TNA project before. After finishing this kind of desk review, a list of technologies (12 technologies) is established for Energy Sector and this list is circulated to the sectoral working group members before and during the inception workshop plus stakeholder consultation workshop which is held on 2nd July 2019 that is described in Annex V. This list was consented for further discussion for technologies prioritization by stakeholders who attended the workshop. The pre-selected technologies were focused on the technology components - software, hardware, orgware of the technologies to identify them.

Table 10 presents an overview of mitigation technology options in Energy Sector with their benefits on climate change mitigation, applicability and potential. Technology applicability and potential are defined as below.

- Small-scale: household and/or community level;
- Large-scale: larger than household and/or community level;
- Short-term: mature technologies which are already diffuse in current market of Myanmar or which have been developed in Myanmar;
- Medium-term: technologies which are pre-commercial in the current market of Myanmar but it would be available in full market in the next 5 years;
- Long-term: technologies which are needed to do R&D or are still in a phase of R&D or is a prototype;

Table 10: Overview of technologies for Energy Sector and their mitigation benefits

No	Technologies	Climate Change Mitigation Benefits	Applicability and Potential	Capital Costs USD	O&M Costs USD
1.	Traditional Charcoal production to Efficient Charcoal Production (Biomass briquette)	297 tons of CO_2e per year, if 1,200 tons of firewood are not burned in a year (Miriam Otoo, 2018)	Small scale, short term	About 30,000-450,000 USD (medium scale (300- 1,500 tons)) (Miriam Otoo, 2018)	O&M cost of 1500 tons briquette production is 94,875 USD (transportation, labor, utilities, marketing and packaging) (Miriam Otoo, 2018), so 300 tons briquette production should be around 18,975 USD.
2.	Replacing incandescent lamps and fluorescent lamps with LED	It is assumed that 0.5 million households replace five 40 W fluorescent lamps with five 18 W LEDs for 5 daily operation hours, the GHG emissions can be saved around 32,120 ton CO_2e per year. Here, grid emission factor is 0.32 ton CO_2/ MWhr (ADB(b), 2017).	Small-scale, short term	The cost of LED varies with the design features, materials used, application, brands, etc. Average cost of a basic branded LED in Myanmar is less than USD 2.5 for a 8 W bulb (Aung N. , 2019).	N/A
3.	Substitution of Fuelwood with LPG at Household Level for cooking	71,500 tons of CO_2e per year (compared to fuelwood stove from 250,000 households) (Myint, 2018)	Small-scale, short term	10 USD / stove (exchange rate 1 USD = 1500 MMK) average selling price above 13.33 USD for a 16.3 kg LPG	N/A

				tank (Htay, 2019).	
4.	Municipal Solid Waste (MSW) to Electricity Generation	If a landfill gas project were implemented to collect the methane generated at the landfill, and the gas was utilized in gas engines, supplying the national grid with electricity, the potential would be about 4,663 tCO_2e per year (JFE, 2014) under what condition?	Large-scale, long term	115 million USD for 20MW h electricity generation (JFE, 2018)	4.8 million USD (JFE, 2018)
5.	Small Scale Hydropower	By using grid emission factor, 47,900 tons of CO_2e per year which is calculated based on total installed capacity of 36,524 MW and 5,000 annual average operation hours (UNEP RISO, 2013) under what condition?	Small-scale, short term	0.023 USD/ kWh - 0.11 USD/kWh (IRENA(a), 2012)	1% to 6% of capital cost (IRENA(a), 2012)
6.	Wind Energy – Onshore Large Scale	If 1000 MW of wind power replaces about 2,500 GWh of power from grid (based on 2,500 hours of annual operation), 655,750 tons of CO_2 e per year which is calculated with the gird emission factor of 0.2623 (UNEP RISO, 2013) under what condition?	Large scale – long term	1700-2450 USD/kW (IRENA(b), 2012)	0.01-0.025 USD/kWh (IRENA(b), 2012).
7.	Wind Energy – Small Scale	327,870 tons of CO_2 e per year if 125 MWh of grid electricity is replaced by wind.	Small scale – long term	3000-6000 USD/kW which is the purchase price of small turbine with a capacity below 100 kW	0.01 USD to 0.05 USD/kWh (IRENA(b), 2012)
8.	Solar Mini-Grid	6.92 GWh per year which is actual saving in Fiscal year of 2016-2017 and 2018-2019 of electricity generation from mini	Large scale, short term	2300 mini-grid will require 537 million USD investments (Khanna,	N/A

		grid can save 0.495 million tons of CO_2e per year (DRD, 2019).		2019).	
9.	Solar Home system (SHS)	1.4 million SHS can mitigate 0.8 million tons of CO_2e per year (Hoque, Das, & Beg, 2014).	Small scale, short term	The cost of one SHS which is including 80-90 W solar panel with other necessary equipment (battery, controller, cable, etc.), 3 W LED, two 20 W Lamps is 200,000 MMK which is around 130 USD (Greacen, 2015).	N/A
10.	Promote and facilitate the import of low GHG emitting hybrid vehicles	In every 161 km, emission can reduce 10.9 kg of CO_2e compared to one normal car (Roos, n.d.). If 0.1 million hybrid cars s are used for 10,000 km travel, 67,702 tons of CO_2e per year can mitigate.	Small-scale, short term	The cost of hybrid cars could range from 11, 000 USD to 16, 000 USD depending on the type, brand of car, the features of the car and its mileage (San, 2019).	Hybrid cars sold today usually have warranties on the hybrid system that are good for eight years/100,000 miles (160,934 kilometers) or 10 years/ 150,000 miles (241,402 kilometers). The battery price for today is expected around 2, 000 USD. Operation and maintenance costs are estimated at 8.5% of the annual cost of investment (C.Brinson, n.d.)
11.	Full-Scale Bus Rapid Transits	25,000 tons of CO_2e per year (UNEP RISO, 2013)	Large-scale, long term	1-15 million USD per km (IPCC, 2007)	It is assumed that costs will be 20-50% of the annual cost of investment. Accordingly, the costs will be

					500, 000 USD/ year or 0.13 USD/one thousand passenger-km (IPCC, 2007).
12.	Bioethanol for transportation	100,000 tons of CO_2e per year (UNEP RISO, 2013)	Large-scale, short term	Production costs vary from 0.31 USD/l to 0.87 USD/l. For a plant with a production capacity of 6.8 million liters/ year investment with the average production costs which is 0.585 USD/l is 3.978 million USD (ECN, n.d.).	Operation and maintenance costs are estimated at 0.02 USD/liter or, taking into account the plant capacity of 6.8 million liters/year, of 0.136 million USD/year (CCO, 2012).

Table 11: Co-benefits of possible technologies for Energy Sector

No	Technologies	Gender Benefits	Economic Benefits	Social Benefits	Environmental Benefits
1.	Traditional Charcoal production to Efficient Charcoal Production (Biomass briquette)	Income generation, reduce drudgery time, improve health and safety	Increase doing productive activities, increase income, increase skill for SME	Create entrepreneurial opportunities, Job creation and income generation	Reduce toxic indoor air pollutants, Reduce deforestation
2.	Replacing incandescent lamps and fluorescent lamps with LED	Improve living standard, convenient to do livelihood activities	Reduce electricity bills	Improves indoor comfort, reduce consumers spending	Lower GHG emissions, lower environmental impact of electricity generation
3.	Substitution of Fuelwood with efficient fuel (LPG) at Household Level for cooking	Income generation, reduce drudgery time, improve health and safety	Income generation	Convenient to store and transport, time saving for cooking avoid respiratory problems	Produces less air pollutants, reduce the rate of deforestation

4.	Municipal Solid Waste (MSW) to Electricity Generation	Income generation, reduce drudgery time, improve health and safety	Reduce cost of fossil fuel for electricity generation, increase energy security	Reduce land fill usage and land fill expansion, reduce trucking long distance for waster, job creation, Increase electricity access	Reduce air pollution and water pollution, reduce GHG emission
5.	Small Scale Hydropower	Income generation, reduce drudgery time, improve health and safety	Increase income generating activities, improve agricultural production, reduce fossil fuel cost for electricity generation, increase energy security	Improve health, decrease social burdens	Reduce air pollution, reduce GHG emission
6.	Wind Energy – Onshore Large Scale	Income generation, reduce drudgery time, improve health and safety	Ensure Energy Security, increase income generating activities, reduce fossil fuel cost for electricity generation	Job creation, Improvement of health conditions through improved comfort	Reduce air pollution, reduce GHG emission
7.	Wind Energy – Small Scale	Income generation, reduce drudgery time, improve health and safety	Ensure Energy Security, increase income generating activities, reduce fossil fuel cost for electricity generation	Job creation, Improvement of health conditions through improved comfort	Reduce air pollution, reduce GHG emission
8.	Solar Mini-Grid	Income generation, reduce drudgery time, improve health and safety	Increase income generating activities, improve agricultural production, reduce fossil fuel cost for electricity generation,	Job creation, Improvement of health conditions through improved comfort	Reduce air pollution, reduce GHG emission

			increase energy security		
9.	Solar Home system (SHS)	Income generation, reduce drudgery time, improve health and safety	Increase income generating activities, improve agricultural production, reduce fossil fuel cost for electricity generation, increase energy security	Improve air quality, reduce expenditures for energy consumption	Reduce air pollution, reduce GHG emission
10.	Promote and facilitate the import of low GHG emitting hybrid vehicles	Save household income, contribution to household wellbeing	Reduce fuel bill, increase energy security	Reduce health risk	Reduce air pollution, reduce GHG emission
11.	Full-Scale Bus Rapid Transits	Improve health and safety	Reduced travel time, more reliable product deliveries, increased economic productivity, increased employment better work conditions	More equitable accessibility throughout the city, less accidents and illness, increased civic pride and sense of community	Reduce air pollution, reduce noise pollution, reduce GHG emission
12.	Bioethanol for transportation	Save household income, contribution to household wellbeing	Increasing energy security, saving foreign currency, diversifying the industrial sector, increase farm income	Job creation, diversifying the industrial sector, access to energy market	Reduce air pollution, reduce GHG emission

3.4 Criteria and process of technology prioritisation for Energy Sector

According to TNA Guidebook, multi-criteria analysis (MCA) is used as a main analysis tool to identify and prioritize technologies. The participatory approach was adopted in MCA process as a nature of TNA, so stakeholder involvements are crucial for discussion. During the inception workshop plus stakeholder consultation workshop which was held on 2 July 2019, discussion on its relevance and importance in a mitigation context of the pre-selected twelve technologies was done to develop criteria set as a third step of MCA which is necessary based on the nature of MCA. The agenda and participants list of the workshop is given in Annex V. Also, the development of criteria is based on country decision context and the purpose Number C of Myanmar Climate Change Policy which is “Take decisions to create and maximize opportunities for sustainable, low carbon, climate-resilient development, ensuring benefits for all” (MONREC(a), 2019).

After brainstorming discussion, all stakeholders from mitigation group agreed to use the following criteria set as shown in table 12 which has two different groups. One group is cost which includes the technology investment cost/capital cost and O&M cost, and another group is the development aspects and GHG reduction potential, which are called benefits. This group took into consideration economic, social and GHG reduction potential which was assumed the same as an environmental benefit by all stakeholders of the energy sector.

Table 12: The set of criteria

Cost	Capital Cost: including technology fees, land rental cost, facility building cost, etc. to manage the technology. Although there are no general representative values in Myanmar for most technologies from the list, most values which describe in this report are taken from various countries case studies. Technologies with less capital cost are the most preferable.	
	O&M Cost: including annual maintenance cost, operation cost, miscellaneous cost, etc. The higher scores can get from lower cost.	
Benefits	Economic	Energy Saving: based on the consideration of fuel saving when the technologies are utilized compared to the traditional way at the demand side. The more energy saving, the higher scores are results.
		Energy Security: possibility to secure more energy resources at the supply side to utilize again these resources in other places for other economic activities. The higher scores will get from higher energy security.
	Social	Potential to create job: possibility to appear more job opportunities than before when technologies are adopted to deploy. Technologies with higher potential job opportunities will have more scores.
		Effective population: whether or not the technology can give a positive effect on a large number of populations. If technology can give a positive effect on a large number of populations, it will get more scores.
		Gender equity: based on the consideration of positive effect on gender e.g. reduce drudgery time, contribution to household wellbeing, etc. The higher scores can get from higher potential of gender equity.
		Health & Safety improvement: whether or not the technology has a high potential of H&S improvement such as decrease accident rate, increase safety location. The higher H&S improvement will result the higher score.
	Environmental (Reduction in GHG emission): a very important criterion of technology assessment to mitigate the climate change and for future trend of GHG emission. The technology with higher GHG reduction potential will result the higher score.	

The performance matrix is developed according to above mentioned criteria. Although there are no general representative quantitative values (Cost and GHG reduction potential) in Myanmar for almost all of the technology from the list, most values which described in technology fact sheets were taken from international case studies and some were from local case studies. Once stakeholders finished to reviewing the various TFS, the performance was described by them as the score range was from 1(very low) to 5 (very high) for Benefits and Costs based on the information, case studies and data from TFS. According to expert/stakeholder judgement, energy sector performance matrix was created as shown in Table 13.

Table 13: Energy Sector Performance Matrix

Name	Costs		Benefits						
			Economic			Social			Environmental
	Capital Cost (%)	**O&M Cost (%)**	**Energy Saving (%)**	**Energy Security (%)**	**Potential to create job (%)**	**Effective Population (%)**	**Gender Equity (%)**	**Improve health & safety (%)**	**Reduction in GHG emission (%)**
O-1	1	1	2	3	3	4	4	3	1
O-2	3	1	4	4	2	4	1	3	4
O-3	3	1	4	3	3	4	4	4	4
O-4	5	5	3	2	2	1	4	4	2
O-5	4	3	4	4	3	3	3	3	3
O-6	5	5	2	2	2	2	3	4	4
O-7	4	3	2	3	2	2	3	4	3
O-8	5	1	4	4	3	4	4	4	5
O-9	4	1	3	3	2	3	4	3	3
O-10	3	2	4	3	1	3	4	4	3
O-11	5	4	3	2	3	3	4	4	3
O-12	4	4	2	2	2	2	2	3	4
Preferred value	Lower	Lower	Higher	Higher	Higher	Higher	Higher	Higher	Higher
Data Source	Expert judgement based on the TFS		Expert Judgement						Expert judgement based on the TFS

Notes:
O-1: Efficient Charcoal Production (Biomass briquette)
O-2: Replacing incandescent lamps and fluorescent lamps with LED
O-3: Substitution of Fuelwood with efficient fuel (LPG) at Household Level for cooking
O-4: Municipal Solid Waste (MSW) to Electricity Generation
O-5: Small Scale Hydropower
O-6: Wind Energy – Onshore Large Scale
O-7: Wind Energy – Small Scale
O-8: Solar Mini-Grid
O-9: Solar Home system (SHS)
O-10: Promote and facilitate the import of low GHG emitting hybrid vehicles
O-11: Full-Scale Bus Rapid Transits
O-12: Bioethanol for transportation

Once the performance matrix was finished to create, stakeholders of energy sector were requested to give a score for each technology against each criterion as a fourth step of MCA. The preference was considered on a scale range from 0 (the least preferred) to 100 (the most preferred). Table 14 is showing detail information of normalized scores. After scoring, assigning weights to the different criteria were done by stakeholders of the energy sector based on how much criteria were important to each technology option and decision context. To finish this process, the participatory discussion which was facilitated by the national consultant was done and he helped to create a consensus among the experts to allocate the different weights on each criterion for the fifth step of MCA. As a result of this process, all stakeholders agreed that social benefit was the most important criterion which was given 40%, and other criteria were weighted equally. The detail weighted value is shown in below table 15. Once scoring and weighting are completed, these are combined to determine the final result as a step 6 of MCA.

Table 14: Energy Sector Scoring Matrix

Options	Costs		Benefits						
			Economic		Social				Environmental
	Capital Cost (%)	O&M Cost (%)	Energy Saving (%)	Energy Security (%)	Potential to create job (%)	Effective Population (%)	Gender Equity (%)	Improve health & safety (%)	Reduction in GHG emission (%)
O-1	100.00	100.00	33.33	66.67	66.67	100.00	100.00	66.67	0.00
O-2	50.00	100.00	100.00	100.00	33.33	75.00	0.00	66.67	75.00
O-3	50.00	100.00	100.00	66.67	66.67	100.00	100.00	100.00	75.00
O-4	0.00	0.00	66.67	33.33	33.33	0.00	100.00	100.00	25.00
O-5	25.00	50.00	100.00	100.00	66.67	66.67	66.67	66.67	50.00
O-6	0.00	0.00	33.33	33.33	33.33	33.33	66.67	100.00	75.00
O-7	25.00	50.00	33.33	66.67	33.33	33.33	66.67	100.00	50.00
O-8	0.00	100.00	100.00	100.00	66.67	100.00	100.00	100.00	100.00
O-9	25.00	100.00	66.67	66.67	33.33	66.67	100.00	66.67	50.00
O-10	50.00	75.00	100.00	66.67	0.00	66.67	100.00	100.00	50.00
O-11	0.00	25.00	66.67	33.33	66.67	66.67	100.00	100.00	50.00
O-12	25.00	25.00	33.33	33.33	33.33	33.33	33.33	66.67	75.00

Table 15: The value of weights to each criterion for Energy Sector

Category		Criteria	Weight Factor
Cost (20%)		Capital Cost	10
		O&M Cost	10
Benefits	Economic (20%)	Energy Saving	10
		Increase Energy Security	10
	Social (40%)	Potential to create job	10
		Effective population	10
		Gender Equity	10
		Improve health & safety	10
	Environmental (20%)	Reduction in GHG emission	20

3.5 Results of technology prioritisation for Energy Sector

The final result of technology prioritisation was done by using MCA approach as mentioned in Section 3.4. The detail final total score for each technology is mentioned in table 16, and the top three technologies are (1) Solar Mini-Grid, (2) Substitution of Fuelwood with efficient fuel (LPG) at Household Level for cooking and (3) Replacing incandescent lamps and fluorescent lamps with LED. The final ranking of technologies is described in the table 17.

Table 16: Final Total Score for each technology from Energy Sector

Options	Costs		Benefits							Total score
			Economic		Social				Environmental	
	Capital Cost (%)	O&M Cost (%)	Energy Saving (%)	Energy Security (%)	Potential to create job (%)	Effective Population (%)	Gender Equity (%)	Improve health & safety (%)	Reduction in GHG emission (%)	
O-1	10.00	10.00	3.33	6.67	6.67	10.00	10.00	6.67	0.00	63.33
O-2	5.00	10.00	10.00	10.00	3.33	7.50	0.00	6.67	15.00	67.50
O-3	5.00	10.00	10.00	6.67	6.67	10.00	10.00	10.00	15.00	83.33
O-4	0.00	0.00	6.67	3.33	3.33	0.00	10.00	10.00	5.00	38.33
O-5	2.50	5.00	10.00	10.00	6.67	6.67	6.67	6.67	10.00	64.17
O-6	0.00	0.00	3.33	3.33	3.33	3.33	6.67	10.00	15.00	45.00
O-7	2.50	5.00	3.33	6.67	3.33	3.33	6.67	10.00	10.00	50.83
O-8	0.00	10.00	10.00	10.00	6.67	10.00	10.00	10.00	20.00	86.67
O-9	2.50	10.00	6.67	6.67	3.33	6.67	10.00	6.67	10.00	62.50
O-10	5.00	7.50	10.00	6.67	0.00	6.67	10.00	10.00	10.00	65.83
O-11	0.00	2.50	6.67	3.33	6.67	6.67	10.00	10.00	10.00	55.83
O-12	2.50	2.50	3.33	3.33	3.33	3.33	3.33	6.67	15.00	43.33

Table 17: Final Ranking of technologies from Energy Sector

Options	Total Score	Ranking
Solar Mini-Grid	86.67	1
Substitution of Fuelwood with efficient fuel (LPG) at Household Level for cooking	83.33	2
Replacing incandescent lamps and fluorescent lamps with LED	67.50	3
Promote and facilitate the import of low GHG emitting hybrid vehicles	65.83	4
Small Scale Hydropower	64.17	5
Traditional Charcoal production to Efficient Charcoal Production (Biomass briquette)	63.33	6
Solar Home system (SHS)	62.50	7
Full-Scale Bus Rapid Transits	55.83	8
Wind Energy – Small Scale	50.83	9
Wind Energy – Onshore Large Scale	45.00	10
Bioethanol for transportation	43.33	11
Municipal Solid Waste (MSW) to Electricity Generation	38.33	12

As a final step of MCA, the sensitivity analysis is conducted to examine the result since the final scores of top 7 technologies are not much different each other. For sensitivity analysis, national consultant again helped to create a consensus to allocate again the different weight on each criterion to reflect their relative importance in the decision-making process. New allocation of weight is shown in table 18. and the result remains unchanged for top 3 priority technologies. The result of sensitivity analysis is shown in table 19.

Table 18: The value of weight to each criterion on Energy Sector

Category		Criteria	Weight Factor
Cost (20%)		Capital Cost	10
		O&M Cost	10
Benefits	Economic (25%)	Energy Saving	5
		Increase Energy Security	20
	Social (35%)	Potential to create job	5
		Effective population	20
		Gender Equity	5
		Improve health & safety	5
	Environmental (20%)	Reduction in GHG emission	20

Table 19: The results of sensitivity analysis of Energy Sector

Options	Total Score	Ranking
Solar Mini Grid	88.33	1
Substitution of Fuelwood with efficient fuel (LPG) at Household Level for cooking	81.67	2
Replacing incandescent lamps and fluorescent lamps with LED	75.00	3
Traditional Charcoal production to Efficient Charcoal Production (Biomass briquette)	66.67	4
Small Scale Hydropower	65.83	5
Promote and facilitate the import of low GHG emitting hybrid vehicles	64.17	6
Solar Home system (SHS)	62.50	7
Wind Energy – Small Scale	49.17	8
Full-Scale Bus Rapid Transits	49.17	9
Bioethanol for transportation	41.67	10
Wind Energy – Onshore Large Scale	40.00	11
Municipal Solid Waste (MSW) to Electricity Generation	26.67	12

Chapter 4: Technology prioritisation for Industry Sector

4.1 GHG emissions and existing technologies of Industry Sector

Eleven different industrial processes are included in the calculation of national GHG inventory for year 2000. Among these industries, cement industry leads the national GHG emission with 44% which is 203.23 Gg of CO_2e followed by refrigeration and air conditioning, electrical equipment, lime and lubricant use, etc. In the inventory, NMVOC is only calculated from food and drink industry, while ODS is from refrigeration and air condition industry and SF_6 is from electrical equipment industry. Therefore, 463.3 Gg of CO_2e is emitted from industrial processes in 2000.

Table 20: Total GHG emission of Industry Sector in year 2000

Source of category	CO_2 (Gg)	NMVOC (Gg)	ODS (Gg)	SE_6 (Gg)	Total CO_2e (Gg)
Industrial processes					
Cement	203.23				203.23
Lime	30.74				30.74
Glass	1.74				1.74
Urea	0.8				0.8
Iron & Steel	4.34				4.34
Food & Drink		4.57			
Product Use					
Carbide for Acetylene Production	0.35				0.35
Refrigeration & Air Conditioning			0.11		143
Electrical Equipment				0.003	71.7
Lubricant Use	7.39				7.39
Total	248.6	4.57	0.11	0.003	463.3

Source: (MoECAF, 2012)

Below lists of industries are currently in operation in the country (MOI, 2016).

1. Food and Beverages
   i. Food stuff industries
   ii. Beverage industries
   iii. Tobacco and related products industries
   iv. Pharmaceutical, chemical and botanical products for medicinal products industries
2. Clothing and Apparel
   i. Textile industries
   ii. Clothing industries

iii. Production of textiles, cotton and animal by-products for apparels

3. Construction Materials
    i. Furniture industries
    ii. Wood-based industries
    iii. Iron and steel milling
    iv. Construction materials manufacturing industries
    v. Construction and other manufacturing
4. Personal Goods
    i. Leather and related products industries
    ii. Personal and cosmetic industries
5. Consumer Products
    i. Rubber and polymer industries
    ii. Toys production industries
    iii. Paints for building and auto industries
6. Literature and Arts
    i. Paper and paper products industries
    ii. Telecast, broadcast and printing
7. Raw Goods
    i. Coke and refinery industries
    ii. Chemical and chemical products industries
    iii. Production of non-metal mining products
    iv. Basic metal production
    v. Advanced rubber raw material production industry
8. Metal and mineral production
    i. Innovated metal products industries (exclude machineries and tools)
    ii. Metallurgical products production
9. Agriculture machinery
    i. Farm machineries
    ii. Pump
    iii. Hand tools for farming
10. Industrial tools and equipment
    i. Machineries and tools
    ii. Cable and steel wire
11. Automobiles
    i. Vehicles, trailers and semi-trailers
    ii. Others transportation materials
    iii. Tires and tubes
    iv. Auto-parts industries
12. Electrical equipments
    i. Computer, electrical, television and related products
    ii. Electrical and electronic products
    iii. Electrical power generator and related machineries
    iv. Electrical power transmitting and distributing and related items
13. General
    i. Machine and machineries assembling and repairing
    ii. Other Production

4.2 Decision context

Based on National Industry Policy from MOI, the common targets are (a) expansion of value-added agriculture industries and agro-based industries for the purpose of becoming heavy industry from the development of SME, (b) development of industry sector by inviting for investment and cooperation in technology transfer while there is a priority for private sector promotion and PPP development, (c) encouragement to do R&D and elaboration of industrial human resources according to improve industrial products quality and standard, and (d) establishment of green industries through using natural resources, raw materials and energy efficiently with sustainable manners (MOI, 2016).

Green industries processes: To be green industries, there are some processes which are considered for sustainable development in the National Industry Policy. These are wastewater management, recycling from wastes (solid, liquid and vapour), emission control, a requirement of environmental conservation procedures (IEE, EIA and SIA) and environmental management (MOI, 2016).

National Energy Efficiency Policy: Since industries efficiency guideline is under National Energy Efficiency Policy, the main objectives for industries efficiency are the same as mentioned above in Section 3.2 which is 12% of electricity reduction from all sectors and 78,690 tons of CO_2 reduction from all sectors by 2020. (MOI, 2015).

To meet the above-mentioned objectives, there are some significant challenges to overcome. Old and inefficient equipment are currently used in most industries, and these are seriously needed to refurbish. To do so, the investment for energy efficiency is one of the limitations in industry sector. Moreover, the capacity gap from industry owners, managers and engineers are preventing for going forward to the green industries way. Also, EE opportunities which are linked with their business should be learned by industry owners, managers and engineers (MOI, 2015).

As discussed in Section 3.2, the sectoral outcomes from Myanmar Climate Change Master Plan apply for Industry Sector as well since the objectives are integrated for Industry Sector together with Energy and Transport Sector.

For the purpose of climate change mitigation, Myanmar industry sector should be developed to be more sustainable by using natural resources effectively and practicing energy efficiency activities to limit the GHG emission, as the industry sector has a large share in the country's GDP.

4.3 An overview of possible mitigation technology options in Industry Sector and their mitigation potential and other co-benefits

The identification process of options for Industry Sector is same as Section 3.3. Table 21 gives an overview of possible technologies for industry sector and their mitigation benefits. The technology applicability and potential are defined as below;

- Small-scale: technologies which are applied within one industry
- Large-scale: technologies which are applied for more than one industry
- Short-term: mature technologies which are already diffuse in the current market of Myanmar or which have been developed in Myanmar;
- Medium-term: technologies which are pre-commercial in the current market of Myanmar but it would be available in the full market in the next 5 years;
- Long-term: technologies which are needed to do R&D or are still in a phase of R&D or is a prototype

Table 21: An overview of possible technologies for industry sector and their climate change mitigation benefits

No	Technologies	Climate Change Mitigation Benefits	Applicability and Potential	Capital Costs (USD)	O&M Costs (USD)
1.	Natural Gas CHP (O-1)	If 50 million kWh of electricity from thermal power plant was replaced by this CHP, the mitigation potential would be ~10,000 ton of CO_2e per year (CCO, 2012) under what	Small scale, short-term	The investment cost of gas-turbine CHP plants usually ranges from 850 USD/kWe to 1950 USD/ kWe, with a typical figure of about	The operation and maintenance (O&M) costs 200 USD/kWe – 300 USD/kWe per year (IEA

		condition		1150 USD/ kWe (IEA ETSAP(a), 2010).	ETSAP(a), 2010).
2.	Biomass Residue Based CHP (O-2)	If the design capacity factor of the plant was 0.8 while overall efficiency is 34.5% (13.8% electricity and 20.8% thermal), the mitigation potential would be ~ 11,300 ton of CO_2e per year (saw dust is the source of fuel) (MoERE, 2011) under what assumption	Small scale, long-term	The investment costs of biomass-based CHP plants are between 3,000 and 6,000 USD/kWe (typically, some 4000 USD/kWe in 2008) (IEA ETSAP(b), 2010).	Operation and maintenance (O&M) costs are in the order of 100 USD/kWe per year (IEA ETSAP(b), 2010).
3.	Efficient Electric Motors (Using variable speed driver) (O-3)	599,831 ton of CO_2e per year (20% saving by using VSD in 60% of local industries which fixed their motors VSD for 40%) (Detail calculation is shown in Annex I)	Large scale, short term	1900 USD for 25 HP (Lipu & Karim, 2013)	The special operation is not required, since all methods are more or less similar system to currently used motor and some other types of motor (automation) operate automatically based on the set up program. However, the trained operators or supplier may be needed in case of problems.
4.	Substitution of wet process kiln with dry process kiln in cement industry (O-4)	350,536.183 ton of CO_2e per year (if 60% of local industries apply) (Detail calculation is shown in Annex I)	Small scale, long - term	96 USD/ annual ton cement capacity For 2.8 million ton of cement annually, 268.8 million USD (U.S. Environmental	782.2 USD / ton CO_2 (U.S. Environmental Protection Agency, 2010)

				Protection Agency, 2010).	
5.	Clinker substitution in cement production (O-5)	• 0.02-0.51 ton CO_2/ton material (steel slag or 200-860 lb CO_2/ton cement for cement with 30-70% blast furnace slag For 2.8 million ton cement with 30-70% blast furnace slag, 254,011.72 – 1,092,250.43 ton of CO_2e per year • fly ash) (U.S. Environmental Protection Agency, 2010) For 2.8 million ton cement with steel slag or fly ash, 56,000 – 1,428,000 ton of CO_2e per year	Large scale, long - term	- For using blast-furnace slag, retrofitting a facility to allow blending in the finish grinding process may require investment costs ranging from about 7.5-15 million USD (U.S. Environmental Protection Agency, 2010). - For using steel slag or fly ash, retrofitting a facility to allow blending in the finish grinding process may require investment costs ranging from 12-18 million USD (U.S. Environmental Protection Agency, 2010).	Increased by 0.08 USD/ton cement for steel slag fed into kiln without grinding (U.S. Environmental Protection Agency, 2010)
6.	Substitute Fossil fuels with waste or biomass in cement kilns (O-6)	159,200 ton of CO_2e per year (20% of used tires in total coal consumption) (Detail calculation is shown in Annex I)	Small scale, long - term	~ 1.1 USD to 3.34 USD million (IFC, 2017)	~ 5.64 to 11.27 USD per ton (IFC, 2017)
7.	Energy Efficient Boilers (O-7)	Emission preheat output of natural gas is 66.3 kg CO_2/ mm Btu and coal is 117.5 kg CO_2/ mm Btu in the case of 80% boiler thermal efficiency. Therefore, clean technology can reduce CO_2 emission more than 70% in the	Large scale, short term	The cost for replacing a standard gas boiler is about 4,000 USD. A high efficiency model costs about 7,500 USD. This cost estimate usually includes removal and	N/A

		case of complete combustion (MoEFPD, 2013).		disposal of the old unit, as well as all necessary lines, ducts and wiring needed for the new system to run properly (HomeAdvisor Inc., 2019) .	
8.	Solar Driers (O-8)	The mitigation potential is in the range of 110,000–940,000 tones of CO_2e by replacing coal consumption while solar thermal systems are applied in agri-processing industries (WWF, 2017).	Large-scale, short term	Solar tunnel dryer- 10.5 USD/ square feet with the operating temperature range between 60-70 °C (ATR Solar, 2019). Forced convention dryer around 11,300 USD with operating temperature 70 °C for chamber size of Length - 2200 mm, Width - 1200 mm, Height - 1200 mm with two pairs of 1HP blowers (E Solar Shoppe, 2019).	N/A

Table 22: Co-benefits of possible technologies for Industry Sector

No	Technologies	Gender Benefits	Economic Benefits	Social Benefits	Environmental Benefits
1.	Natural Gas CHP	Increase women employment rate, gain new knowledge and skills, Get choice of job, income generation	Improve Energy Security, reduce energy bills	Lower emission, increase efficiency of energy conversion and use	Reduce air pollution, reduce GHG emission
2.	Biomass Residue Based CHP	Increase women employment rate, gain new knowledge and skills, Get choice of job, income generation	Improve Energy Security, reduce energy bills	Lower emission, increase efficiency of energy conversion and use	Reduce air pollution, reduce GHG emission

3.	Efficient Electric Motors -Using variable speed drivers	Increase women employment rate, gain new knowledge and skills, Get choice of job, income generation	Increase productivity of industry sector, reduce electricity bill	Improve air quality, reduce noise pollution	Lower environmental impact of electricity generation, reduce GHG emission
4.	Substitution of wet process kiln with dry process kiln in cement industry	Increase women employment rate, gain new knowledge and skills, Get choice of job, income generation	Reduce energy and water bills, improve energy security	Creation of new jobs, improve air quality	Reduce water consumption, reduce energy consumption, reduce GHG emission
5.	Clinker substitution in cement production	Increase women employment rate, gain new knowledge and skills, Get choice of job, income generation	Reduce energy cost, improve energy security	Improve air quality, enhance energy efficiency	Reduce emission, reduce landfill, reduce industries waste
6.	Substitute Fossil fuels with waste or biomass in cement kilns	Increase women employment rate, gain new knowledge and skills, Get choice of job, income generation	Reduce energy cost, improve energy security	Improve air quality, enhance energy efficiency	Reduce emission, reduce landfill, reduce industries waste
7.	Energy Efficient Boilers	Increase women employment rate, gain new knowledge and skills, Get choice of job, income generation	Reduce energy cost, fuel saving	Reduce health and safety hazard due to heat losses, improve air quality	Reduce GHG emission
8.	Solar Driers	Increase women employment rate, gain new knowledge and skills, Get choice of job, income generation	Reduce energy bill, Increase energy security, Increase market value of product through processing into variety of different products from dry food.	Improve air quality Job creation Food security improvement through longer life time of food storage after drying Better food quality and hygiene compared to traditional sun drying	Reduce air pollution, reduce GHG emission

4.4 Criteria and process of technology prioritisation for Industry Sector

Again, MCA approach is used to prioritize technologies for Industry Sector as like as for Energy Sector. Detail approach is mentioned in Section 3.4 and table 23 presents the criteria set for Industry Sector which is agreed by stakeholders after discussion to develop this based on decision context. Table 24 gives an information of performance matrix and the score matrix is shown in table 25.

Table 23: Criteria set for Industry Sector

Cost	Capital Cost: including technology fees, land rental cost, facility building cost, etc. to manage the technology. Although there are no general representative values in Myanmar for most technologies from the list, most values which describe in this report are taken from various countries case studies. Technologies with less capital cost are the most preferable.	
	O&M Cost: including annual maintenance cost, operation cost, miscellaneous cost, etc. The higher scores can get from lower cost.	
Benefits	Economic	Energy Saving: based on the consideration of fuel saving when the technologies are utilized compared to the traditional way to improve production and capacity utilization. The more energy saving, the higher scores are results.
		Increase Energy Security: possibility to secure more energy resources at the supply side to utilize again these resources in other places for other economic activities. The higher scores will get from higher energy security.
	Social	Potential to create job: possibility to appear more job opportunities than before when technologies are adopted to deploy. Technologies with higher potential job opportunities will have more scores.
		Gender equity: based on the consideration of positive effect on gender e.g. increase women employment rate, gain new knowledges and skills, income generation, get choice of job etc. The higher scores can get from higher potential of gender equity.
		Health & Safety improvement: whether or not the technology has a high potential of H&S improvement such as decrease accident rate, increase safety location. The higher H&S improvement will result the higher score.
	Environmental (Reduction in GHG emission): a very important criterion of technology assessment to mitigate the climate change and for future trend of GHG emission. The technology with higher GHG reduction potential will result the higher score.	

Table 24: Industry Sector Performance Matrix

Name	Costs		Benefits					
			Economic		Social			Environmental
	Capital Cost (%)	**O&M Cost (%)**	**Energy Saving (%)**	**Increase energy security (%)**	**Potential to create job (%)**	**Health & Safety (%)**	**Gender Equity (%)**	**Reduction in GHG emission (%)**
O-1	3	4	4	3	1	3	1	1
O-2	3	3	4	3	3	1	3	1
O-3	2	1	4	4	1	4	1	5
O-4	5	4	5	5	1	2	1	3
O-5	5	2	3	2	1	2	1	4
O-6	3	5	4	3	2	1	2	3
O-7	3	2	5	5	3	4	2	3
O-8	2	1	2	3	2	4	1	5
Preferred Value	Lower	Lower	Higher	Higher	Higher	Higher	Higher	Higher
Data Source	Expert Judgement based on international and local case studies		Expert Judgement					Expert Judgement based on international and local case studies

Table 25: Industry Sector Scoring Matrix

Name	Costs		Benefits					
			Economic		Social			Environmental
	Capital Cost (%)	**O&M Cost (%)**	**Energy Saving (%)**	**Increase energy security (%)**	**Potential to create job (%)**	**Health & Safety (%)**	**Gender Equity (%)**	**Reduction in GHG emission (%)**
O-1	66.67	25.00	66.67	33.33	0.00	66.67	0.00	0.00
O-2	66.67	50.00	66.67	33.33	100.00	0.00	100.00	0.00
O-3	100.00	100.00	66.67	66.67	0.00	100.00	0.00	100.00
O-4	0.00	25.00	100.00	100.00	0.00	33.33	0.00	50.00
O-5	0.00	75.00	33.33	0.00	0.00	33.33	0.00	75.00
O-6	66.67	0.00	66.67	33.33	50.00	0.00	50.00	50.00
O-7	66.67	75.00	100.00	100.00	100.00	100.00	50.00	50.00
O-8	100.00	100.00	0.00	33.33	50.00	100.00	0.00	100.00

The weighting to each criterion has been done by stakeholder as shown in table 26 to reflect their relative importance in the decision-making process.

Table 26: The value of weights to each criterion for Industry Sector

Category		Criteria	Weight Factor
Cost (30%)		Capital Cost	20
		O&M Cost	10
Benefits	Economic (30%)	Energy Saving	20
		Increase Energy Security	10
	Social (20%)	Potential to create job	8
		Improve health & safety	10
		Gender Equity	2
	Environmental (20%)	Reduction in GHG emission	20

4.5 Results of technology prioritisation for Industry Sector

In industry sector, Efficient Electric Motors (Using variable speed driver) technology I s nominated as the 1st priority for this sector followed by energy efficient boilers and solar driers. The detail rankings of technologies are shown in table 27.

Table 27: The final total score and ranking of technologies from Industry Sector

Options	Total Score	Ranking
Efficient Electric Motors (Using variable speed driver)	80.00	1
Energy Efficient Boilers	79.83	2
Solar Driers	67.33	3
Substitution of wet process kiln with dry process kiln in cement industry	45.83	4
Biomass Residue Based CHP	45.00	5
Substitute Fossil fuels with waste or biomass in cement kilns	45.00	6
Natural Gas CHP	39.17	7
Clinker substitution in cement production	32.50	8

To conduct the sensitivity analysis for examining the result, different weight on each criterion were given by stakeholder when national consultant facilitated to conduct participatory approach discussion. Even though sensitivity analysis has been done, the ranking of top 3 technologies has not been changed.

Table 28: Overall scoring matrix with weighted scores of Sensitivity Analysis

Name	Costs		Benefits						Total score
			Economic		Social			Environmental	
	Capital Cost (%)	**O&M Cost (%)**	**Energy Saving (%)**	**Increase energy security (%)**	**Potential to create job (%)**	**Health & Safety (%)**	**Gender Equality (%)**	**Reduction in GHG emission (%)**	
O-1	10.00	2.50	10.00	3.33	0.00	3.33	0.00	0.00	29.17
O-2	10.00	5.00	10.00	3.33	10.00	0.00	5.00	0.00	43.33
O-3	15.00	10.00	10.00	6.67	0.00	5.00	0.00	30.00	76.67
O-4	0.00	2.50	15.00	10.00	0.00	1.67	0.00	15.00	44.17
O-5	0.00	7.50	5.00	0.00	0.00	1.67	0.00	22.50	36.67
O-6	10.00	0.00	10.00	3.33	5.00	0.00	2.50	15.00	45.83
O-7	10.00	7.50	15.00	10.00	10.00	5.00	2.50	15.00	75.00
O-8	15.00	10.00	0.00	3.33	5.00	5.00	0.00	30.00	68.33
Criteria on weight	0.15	0.1	0.15	0.1	0.1	0.05	0.05	0.3	1

Chapter 5: Summary and Conclusions

For TNA project, economic development factor like sectoral GDP share and FDI and INDC are considered as a backbone to determine two priority sectors for climate change mitigation. Therefore, Energy Sector and Industry Sector are selected to be a priority for mitigation technology needs assessment in Myanmar. Moreover, Multi-criteria Analysis (MCA) is the main tool for the whole technology prioritization process. Since TNA is a country-driven project, stakeholders play a vital role to develop relevant criteria to judge each technology based on the country decision context within the stakeholder consultation workshop to prioritize the technologies for selected sectors.

In the Energy Sector, solar mini-grid, replacing incandescent lamps and fluorescent lamps with LED and substitution of fuelwood with efficient fuel (LPG) at household level for cooking are selected for priority technologies through stakeholder consultation workshop, working session and bilateral meeting. These technologies are prioritized based on their GHG reduction potential, energy saving opportunities, suitability to country situations and potential impact on country development priorities.

By using a similar approach, Efficient Electric Motors (Using variable speed driver), energy efficient boilers and solar driers technologies are chosen as priority technologies for Industry Sector.

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Annex I: Technology Fact Sheets

Technology Fact Sheets for Energy Sector

Technology Fact Sheet - 1

Technology Name	Solar Mini-Grid
Subsector GHG emission (Mt CO2-eq)	2,560,691.222 tones (Energy Industries) (MOECAF(a), 2015)
Introduction	At present, 50 percent of the population in Myanmar has access to power supply service (President Office, 2019). The Government is committed to achieve 100 percent electrification by 2030, which will require a roughly double the current pace. Many areas may not receive electricity for at least 10 years, even if Myanmar is able to achieve its ambitious rural electrification grid extension scale-up targets (Greacen, 2015).
Technology Characteristics	Solar photovoltaic systems use sunlight to directly generate electricity. A Solar Mini-Grid consists of three main subsystems: • (i) Generation. This comprises the power sources (solar panels), batteries, charge controllers, and inverters. These determine the amount of electricity that can be produced by the system. • (ii) Distribution. This involves the method of delivering the electricity to the end users through a grid covering the community. Different choices can be made for the grid: DC or AC; single-phase or three-phase; and basic or grid-ready, meaning that it can be connected to the main grid when it arrives in the community. • (iii) Consumption. This includes all the equipment at the site of consumption, including meters, power limiters, electric sockets, and appliances such as lights, fans, and TVs. Rural electrification can be achieved through grid expansion and through off-grid solutions. The government of Myanmar has a plan to expand the grid but grid expansion could not cover all recent off-grid areas. Instead of relying on grid electricity, solar mini grid is one of the possible solution to provide electricity in off-grid areas to fulfill the 100% electrification commitment by government.
Country specific applicability and potential	Large scale, short term
Status of technology in country	Solar PV technology has been popular in Myanmar especially in rural areas where electrification rate is low compared to city areas. There are 6569 villages have been electrified in Myanmar by solar home system, and 88 villages by solar mini-grid system, and therefore a total number of 377688 households have been electrified by using solar PV technology at the end of 2018-2019 (DRD, 2019).

Climate change mitigation benefits	6.92 GWh per year of electricity generation from mini grid can save 0.495 million tons of CO_2e per year (DRD, 2019).
Gender benefits	Potential benefits for women include the reduction of time dedicated to household tasks, income generation, as well as health and safety improvements.
Benefits to economic	Increase income generating activities Improve agricultural production Country reduces the expenditure of fossil fuel for power generation. Increase energy security
Benefits to social	Job creation, Improvement of health conditions through improved comfort
Benefits to environmental development	Decrease in air pollution with no noise during operation and reduced GHG emissions
Costs	
Capital cost	2300 Mini-Grid will require 537 million USD investment (Khanna, 2019).
O & M costs	N/A
Cost of GHG reduction	N/A
Lifetime	25 years
Payback period	5.9 years (ADB(a), 2017)

Technology Fact Sheet - 2

Technology Name	Replacing incandescent lamps and fluorescent lamps with LED
Subsector GHG emission (Mt CO2-eq	1,026,714.801 tones (Commercial and Residential Sector) (MOECAF(a), 2015)
Introduction	According to the IEA, lighting ranks among the major end-uses in global power demand. Lighting represents 650 mtoe of primary energy consumption and 2550 TWh of electricity consumption in 2005.This means that grid-based electric lighting is equivalent to 19% of total global electricity production (IEA, 2006). The statistics supplied by the IEA report (2006) shows that lighting requires as much electricity as is produced by all gas-fired generation or 1265 power plants. Of this amount, the major consumption sector is commercial at 43% followed by residential at 31%, industrial (18%), and outdoor stationary sources at 8%. These statistics refer to on-grid sources. In developing countries, however, off-grid fuel based lighting is the norm, for which, in 2005, 77 billion liters of kerosene and gasoline/diesel were used (Compact Fluorescent Lamp, n.d.).

Technology Characteristics	LED is a two-lead semiconductor light source. There are various types of LED bulbs such as solid-state lighting (SSL), organic light-emitting diodes (OLEDs) and light –emitting polymers (LEPs). Light is emitted by LED in a narrow spectral band but white light can be produced. Therefore, these kinds of bulbs are applicable of daily life of offices and houses. Compared to other types of light bulbs, LED bulbs are more efficient, durable and longer lasting. LED consumes about 90% less energy than incandescent bulb while CFL consumes around 75% less energy than incandescent bulb (Alt, 2019).
Country specific applicability and potential	Small-scale, short term
Status of technology in country	This technology is proven and available in Myanmar. Its market can be considerably increased if enabling environment is in place (awareness, financial incentive, policy and regulation, etc.).
Climate change mitigation benefits	It is assumed that 0.5 million households replace five 40 W fluorescent lamps with five 18 W LEDs for 5 daily operation hours, the GHG emissions can be saved around 32,120 ton CO_2e per year. Here, grid emission factor is 0.32 ton CO_2/ MWhr (ADB(b), 2017).
Gender benefits	Better lighting can provide more comfortable life for the women and children such as women can finish their household tasks quickly and children can study conveniently under the bright and efficient light.
Benefits to economic	If one household replace five 40 W fluorescent lamps with five 18 W LEDs for 5 daily operation hours, this house can save more or less than 200 units in one year. If 0.5 million household replaces these lamps, 275,000 units can be saved. This saving can lead not only to reduce energy bill in household but also to save national grid electricity.
Benefits to social	Improves indoor comfort. Reduce consumers spending. The project directly benefits individual households through the installation of LED which will result in energy savings and lower expenditures, and contribute to national objectives to reduce poverty and increase energy efficiency.
Benefits to environmental development	The major benefit of LEDs lies in the improved energy efficiency, which has socio-economic benefits in terms of increased energy security and environmental benefits, i.e. lower GHG emissions, and lower environmental impact of electricity generation. In addition, LED leads to improve local air quality. All these are in line with the country's environmental development priorities.
Costs	
Capital cost	The cost of LED varies with the design features, materials used, application, brands, etc. Average cost of a basic branded LED in Myanmar is around 7 USD for an 18 W downlight LED lighting

	(Aung N. , 2019).
O & M costs	N/A
Cost of GHG reduction	
Lifetime	Based on the color of LED, LED lamps have very long lifespan approximately between 40,000 and 100,000 operating hours (Cam, Wynn Chi-Nguyen, n.d.).

Technology Fact Sheet - 3

Technology Name	Substitution of Fuelwood with LPG at Household Level for cooking
Subsector GHG emission (Mt CO2-eq	47,256.086 tones (Residential Sector)
Introduction	Currently, the main source of energy for Cooking in Myanmar is fuelwood (Biomass) 69.2%, charcoal 11.8%, electricity 16.4% and LPG, biogas, ethanol gel, etc. 0.6% (Myint, 2018). It is caused vulnerable for environment by wide use of fuel wood. Among the ASEAN countries, electrical tariff in Myanmar is the cheapest because the government subsidies electricity costs. The tariff rate is increased by government. Therefore, cost of using LPG stoves will be cheaper than electric stoves for Household levels. According to the new government economic policy, as a promotion of privatization, license was granted to public by Ministry of Electricity and Energy focusing LPG harmlessly and beneficially in households, industrial and commercial use (Tun, 2016). Widespread use of LPG stoves instead of electrical and traditional firewood stoves are promoted by MPE and private sector. Based on SEAP, MPE considered Environmental and Social Issues of alternatives fuel consumption for cooking. Therefore, LPG for cooking is one of the suitable solutions to address for households cooking energy consumption because LPG is a clean-burning, efficient, portable fuel and produced as a by-product of natural gas extraction and crude oil refining (Myint, 2018).
Technology Characteristics	LPG has a high energy per unit volume and is convenient to use. Its calorific value per unit volume is about 2.5 times larger than that of natural gas (methane). It is used for road transport, cooking, heating, refrigeration, air conditioning and in spray cans. It is a portable source of energy used for remote and leisure applications in the EU and in cooking and transport in developing countries. LPG is manufactured during the refining of crude oil (40%) or from natural gas during extraction (60%). Currently, LPG is widespread used in the county but it is not dominant in cooking sector. Fuel switching from fuel wood to LPG could be clean source of energy for cooking.
Country specific applicability and potential	Small–scale, short term

Status of technology in country	The reliability of LPG cook stoves is generally considered high as the technology is mature and applied widely across the world and even in Myanmar as well. According to LPG plan, Myanmar LPG market has a huge potential for expansion and it provides a clean and cost-effective alternative fuel for cooking purpose, particularly in household levels. Demand for LPG in Myanmar has been growing at 15-20% per annum for the past five years based on the year of 2017 (Myint, 2018). This growth is driven mainly by the population switching from traditional fuel to LPG as their preferred energy source for cooking. Currently, only 12% of Myanmar's population is using LPG and there is still considerable room for the growth in demand to continue for the next five to ten years.
Climate change mitigation benefits	71,500 ton of CO_2e per year (compared to fuelwood stove from 250,000 households) (Myint, 2018)
Gender benefits	Potential benefits for women include the reduction of time dedicated to household tasks, income generation, as well as health and safety improvements.
Benefits to economic	Capital cost at households will decrease in future. Income generation can be happened due to doing productive activities while the time for cooking is reduced.
Benefits to social	• Convenient to store and transport • Time saving for cooking • Avoid respiratory problems caused by smoke and other pollutants
Benefits to environmental development	Produces less air pollutants than kerosene, wood or coal, charcoal. Fuel switching from fuelwood to LPG can reduce the rate of deforestation.
Costs	
Capital cost	10 USD/ stove (exchange rate 1 USD = 1500 MMK) average selling price above 13.33 USD for a 16.3 kg LPG tank (Htay, 2019)
O & M costs	N/A
Cost of GHG reduction	81.5 USD / ton CO_2
Lifetime	N/A

Technology Fact Sheets for Industry Sector
Technology Fact Sheet- 1

Technology Name	Efficient Electric Motor (Using variable speed driver)
Subsector GHG emission (Mt CO2-eq	510, 700.83 tones (Electrical energy saving method is relevant to all industries by applying efficient electric motor) (MOECAF(a), 2015)
Introduction	Myanmar has significant potential in its industrial and commercial activities for substantial savings in energy consumption. The potential savings estimated are 45% for the iron and steel industry, 65% for pulp and paper, and 35% for sugar mills due to their high electrical and thermal demands (ADB(a), 2016). By installing efficient electric motors to provide the needed final use energy, efficient electric motors can greatly increase the facility's operational efficiency and decrease energy costs.
Technology Characteristics	The variable speed control system or an electronic drive can adjust the speed to suit the application not only by adjusting the speed but also torque characteristics of the motor. Since the speed controller is electronic, the energy loss in the controller very much less than that of a mechanical speed controller and also very compact. However, electronic drives should have stable supply for its trouble-free operation. Various manufacturers provide other technologies to achieve fine improvements of motor operation to achieve more energy saving and optimizing the operation. Energy saving can gain by replacing inefficient mechanical speed controlling devices to control the motor speed.
Country specific applicability and potential	Large scale, short term
Status of technology in country	There are several ESCOs who can provide such solutions to save electrical energy in Myanmar.
Climate change mitigation benefits	Estimated CO_2 emission reduction is 599,831 tons of CO_2e per year which is 20% saving by using VSD in 60% of local industries which fixed their motors VSD for 40%.
Gender benefits	The employment rate of women could be increased while they are involved in industry sector as engineers, professionals and decision makers. Consequently, they could gain new knowledge and skills based on this technology. Therefore, they could have a more choice to select their job in the future. Moreover, their income generation could improve based on new skills.
Benefits to economic	Increase productivity of industry sector Reduce electricity bill
Benefits to social	Improve air quality Reduce noise pollution

Benefits to environmental development	Lower environmental impact of electricity generation Reduce GHG emission
Costs	
Capital cost	1900 USD for 25 HP (Lipu & Karim, 2013)
O & M costs	No special operation is required, as all methods are more or less similar to the presently used operations (efficient motors) and the other type (automation) is generally programmed to operate automatically. However, involvement of a trained technical personnel or supplier may be required in case of problems.
Cost of GHG reduction	N/A
Lifetime	20 years

Calculation for climate change mitigation benefits

Industrial electricity consumption in Myanmar (A) (NEMC, 2015)	3,764,000,000 kWh
Electricity used for motors in local industries (60% of A)=(B)	2,258,400,000 kWh
Assume 40% motors are fixed with VSD (40% of B) = (C)	903,360,000 kWh
Expected saving by using VSD (20% of C) = D	180,672,000 kWh
Annual saving based on year 2014 data	180,672,000 kWh
Electricity saving for 10 years period	1,806,720,000 kWh
CO2 reduction due to electricity saving (Grid emission factor = 0.332 t CO2/ MWh) (ADB(b), 2017)	599,831 tCO_2e
Saving for 10 years (based on year 2014)	5,998,310 tCO_2e

Technology Fact Sheet- 2

Technology Name	Energy Efficient Boilers
Subsector GHG emission (Mt CO2-eq)	510, 700.83 tones (Energy saving method from boilers is relevant to all industries by applying energy efficient boilers) (MOECAF(a), 2015)
Introduction	Boilers account for a significant share of industrial energy consumption and are the key components in power generation and industrial plants. Industrial boiler systems are used for heating with hot water or steam in industrial process applications. Over 2,300 boilers are now used in Myanmar Industries (DISI, 2019). The major source of GHG emissions from a boiler system is carbon dioxide (CO_2) from the combustion of fossil fuels in the boiler. Other minor sources of GHGs can include methane (CH_4) from leaks in the natural gas distribution system and CH_4 and nitrous oxide (N_2O) as byproducts of combustion processes.

Technology Characteristics	Improvement of efficiency of industrial boilers can be attained by adding advanced heat recovery and controls measures to the boiler system. These technology-based efficiency improvements can be achieved when retrofitting or replacing an existing boiler with new technology, when purchasing a LPG boiler to meet new demand, and/or when switching from a wood fuel, fuel oil, coal or electricity based boiler to a LPG boiler or a biomass pellet based boiler. Appropriate dual burners system (to LPG or for fuel-oil) should upgrade, and boilers emission reduction bases on boiler efficiency and fuel type (MoEFPD, 2013). Also, proper solid fuel burner system should upgrade in wood fuel boiler to switch to use biomass pellets instead of wood fuel. Moreover, using economizer can improve the efficiency of boiler.
Country specific applicability and potential	Large scale, short term
Status of technology in country	Many energy efficient boilers are available in market. Also, there are several ESCOs who can provide such solution.
Climate change mitigation benefits	CO_2 emissions are based on input fuel emission factors corrected for boiler efficiency. Emission preheat output of natural gas is 66.3 kg CO_2/ mmBtu and coal is 117.5 kg CO_2/ mmBtu in the case of 80% boiler thermal efficiency. Therefore, clean technology can reduce CO_2 emission more than 70% in the case of complete combustion (MoEFPD, 2013).
Gender benefits	The employment rate of women could be increased while they are involving in industry sector as engineers, professionals and decision makers. Consequently, they could gain new knowledge and skills based on this technology. Therefore, they could have a more choice to select their job in the future. Moreover, their income generation could improve based on new skills.
Benefits to economic	Reduce energy cost Fuel saving
Benefits to social	Reduce health and safety hazard due to heat losses Improve air quality
Benefits to environmental development	Reduce GHG emission
Costs	
Capital cost	Most boiler issues come down to weighing the costs and benefits of repair versus replacement. Repairs typically cost between 300 USD and 500 USD, which can involve replacing key elements like heat exchangers, burners, chimneys or lines. Over time, the mix of water and fuel can have an effect on the boiler's components, possibly inducing corrosion. The cost for replacing a standard gas boiler is about 4,000 USD. A high efficiency model costs about 7,500 USD. This

	cost estimate usually includes removal and disposal of the old unit, as well as all necessary lines, ducts and wiring needed for the new system to run properly (HomeAdvisor Inc., 2019) .
O & M costs	N/A
Cost of GHG reduction	N/A
Lifetime	N/A

Technology Fact Sheet- 3

Technology Name	Solar Driers
Subsector GHG emission (Mt CO2-eq	510, 700.83 tones (Electrical energy saving method is relevant to all industries by applying solar thermal energy) (MOECAF, 2012)
Introduction	A major portion of industrial energy consumption is in the form of thermal energy, and primary sources of this thermal energy are fossil fuels like coal, lignite, oil and gas. These fuels release large quantities of pollutants. Industrial process heat is the thermal energy used directly in the preparation or treatment of materials and items manufactured by an industry. In the food industries, around 29% of total energy is consumed for process heating while approximately 16% is for process cooling and refrigeration (GoN, n.d.). Large portion of industrial process heat is at sufficiently low temperatures which can easily be supplied by solar energy.
Technology Characteristics	Traditionally, sun drying method is applied to dry small amount of food in open air in rural area but this method is not convenient for large amount of food since large area of open space is needed to expose to sun directly. Moreover, there is a difficulty for monitoring and overviewing large quantities of food to avoid contamination of the products through rain, dust, insects, rodents, birds, etc. On the other hand, electric dryers are used to take out the moisture from food in SME. To maximize the energy efficiency in agro-food industries, using solar dryer is one of the best solutions to fulfill the industries need thermal energy. The solar dryer is a relatively simple concept. The basic principles are including three functions which are transforming light to heat, heat trapping and heat transfer to the food (JIN, n.d.) There are various solar dryer designs. Solar driers are principally categorized into three groups (1) natural convention driers, (2) forced convention driers, and (3) tunnel driers. The choice of the driers is totally depended on the user specification such as production capacity of the products, the available space to set-up the dryer, etc.
Country specific applicability and potential	Large-scale, short term

Status of technology in country	Solar energy is mature technology in the country.
Climate change mitigation benefits	The emissions savings potential for the uptake of solar thermal in agri-processing is in the broad range of 110,000–940,000 ton of CO_2e per year. The large difference in potential carbon savings is clearly due the inclusion of coal (which is a particularly carbon intense fuel) in the food and beverages (WWF, 2017). The reduction of CO_2 emission can be varied in Myanmar according to the location of industry, type of fuel used for heating process within industry, the necessary amount of thermal energy, etc.
Gender benefits	The employment rate of women could be increased while they are involving in industry sector as engineers, professionals and decision makers. Consequently, they could gain new knowledge and skills based on this technology. Therefore, they could have a more choice to select their job in the future. Moreover, their income generation could improve based on new skills.
Benefits to economic	Reduce energy bill Increase energy security Increase market value of product through processing into variety of different products from dry food.
Benefits to social	Improve air quality Job creation Food security improvement through longer life time of food storage after drying Better food quality and hygiene compared to traditional sun drying
Benefits to environmental development	Reduce air pollution Reduce GHG emission
Costs	
Capital cost	Solar tunnel dryer – 10.5 USD/square feet with the operating temperature range between 60-70 °C (ATR Solar, 2019). Forced convention dryer – around US$ 11,300 with operating temperature 70 °C for chamber size of Length - 2200 mm, Width - 1200 mm, Height - 1200 mm with two pairs of 1HP blowers (E Solar Shoppe, 2019).
O & M costs	N/A
Cost of GHG reduction	N/A
Lifetime	N/A

Annex II: List of stakeholders involved in Scoping Mission Workshop on 27 September 2018

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Academic				
34.	Dr. Hsu Myat Naing	Director	Department of Higher Education, Ministry of Education	hsumyatnaing07@gmail.com
35.	U Thar Htet Phay	Assistant Director	Department of Research and Innovation , Ministry of Education	tharhtetphay83@gmail.com
36.	Dr. Nyo Mar Htwe	Deputy Director	Yezin Agricultural University, Ministry of Agriculture, Livestock and Irrigation	nyomarhtwe@gmail.com
INGO				
37.	U Kyaw Moe Aung	Project Coordinator	SNC Project	kyawmoeaung@nationalcommunication.org
Private Sector				
38.	Daw Ei Ei Kyaw	Staff officer	Thilawa Special Economic Zone	eieikyaw.chemical@ gmail.com

Annex III: List of Steering Committee

No	Name	Designation	Organization
1.	U Hla Maung Thein (Chair)	Director General	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation
2.	U Thant Zaw (Co-chair)	Deputy Director General	Central Statistical Organization, Ministry of Planning, Finance and Industry
3.	Daw Thu Zar Myint	Director	Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation
4.	Daw May Khin Chaw	Director	Department of Meteorology and Hydrology, Ministry of Transport and Communications
5.	Dr. Thaung Naing Oo	Director	Forest Department, Ministry of Natural Resources and Environmental Conservation
6.	U Ohn Lwin	Director	Department of Mines, Ministry of Natural Resources and Environmental Conservation
7.	U Zaw Win	Director	Dry Zone Greening Department, Ministry of Natural Resources and Environmental Conservation
8.	Daw Khin Khin Aye	Director	Oil and Gas Planning Department, Ministry of Electricity and Energy
9.	U Myat Zaw	Director	Directorate of Industrial Collaboration, Ministry of Planning, Finance and Industry
10.	U Thaung Oo	Director	Directorate of Industrial Supervision and Inspection, Ministry of Planning, Finance and Industry
11.	Daw Win Min Phyo	Director	Department of Trade, Ministry of Commerce
12.	Dr. Aung Moe	Director	Department of Research and Innovation, Ministry of Education
13.	U Hla Myo	Director	Department of Cleaning, Mandalay City Development Committee
14.	Dr. Myat Taw Htet	Deputy Director	Engineering Department, Naypyidaw Development Committee
15.	Dr. Win Win Mar	Assistant Director	Thilawa Special Economic Zone Management Committee
16.	Dr. Moe Moe	Head of Department (Staff Officer)	Environmental Conservation and Cleaning Department, Yangon City Development Committee
17.	U Pyae Phyo Aung	Energy Officer	World Wide Fund for Nature (WWF)
18.	U Tun Tun Zaw	Program Officer	Myanmar Environment Rehabilitation – Conservation Network (MERN)
19.	Dr. San Oo (Secretary)	Deputy Director General	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation

Annex IV: List of stakeholders involved in sectoral working group for mitigation

According to Notification Number (78/2019) on 28 May 2019, below working groups are formed by an order from Union Minister Office of MONREC.

For Industry Sector

No	Name	Designation	Organization	Contact
1.	Daw Tin Tin Nyo (Leader)	Deputy Director	Department of Nuclear, Department of Technology Promotion and Coordination. Ministry of Education	tintinnyo68@gmail.com
2.	Daw Htay Htay Kyi (Co-leader)	Assistant Director	Directorate of Industrial Collaboration, Ministry of Planning, Finance and Industry	htayhtaykyi58@gmail.com
3.	Daw Thin Thuzar Win	Deputy Director	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	thithuzar1981@gmail. com
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5.	Daw Swai Thi Htut	Assistant Director	Directorate of Industrial Supervision and Inspection, Ministry of Planning, Finance and Industry	shput2008@gmail.com
6.	U Wai Lin Tun	Assistant Director	State Estate Department, Ministry of Construction	wailinntun.mm@gmail.com
7.	U Zaw Lin Aung	Assistant Director	Engineering Division, Mayor Office, Nay Pyi Taw Development Committee	zlinag1978@gmail.com
8.	U Soe Aung	Assistant Director	Cleaning Department, Mandalay City Development Committee	soeaungmrdac@gmail. com
9.	Daw Thant Zin Maw	Staff Officer	Forest Department, Ministry of Natural Resources and Environmental Conservation	thantzinmaw6689@ gmail.com
10.	Daw Zin Mar Phyu	Staff Officer	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	zinmarphyu123@gmail.com
11.	Daw Yi Yi Cho	Staff Officer	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	yiyicho.env@gmail.com
12.	Daw Ei Ei Kyaw	Staff Officer	Thilawa Special Economic Zone	eieikyaw.chemical@ gmail.com
13.	Daw Aye Aye Htet	Staff Officer	Union of Myanmar Federation of Chambers of Commerce and Industry	tvet.umfcci2014@ gmail.com
14.	U Kyaw Kyaw Myo	Program Officer	Myanmar Environmental Rehabilitation – Conservation Network (MERN)	myokk94@gmail.com

For Energy Sector

No	Name	Designation	Organization	Contact
1.	Dr. Nan Sandar Lwin (Leader)	Director	Department of Research and Innovation, Ministry of Education	sandar.lwin75@gmail. com
2.	Dr. Wunna Swe (Co-leader)	Professor and Head	Department of Electrical Power, Mandalay Technological University, Ministry of Education	myomyintbiot@gmail. com
3.	Daw Thida Sann	Deputy Director	Department of Hydropower Implementation, Ministry of Electricity and Energy	thidasann@gmail.com
4.	Daw Su Su Soe	Deputy Director	Oil and Gas Planning Department, Ministry of Electricity and Energy	suusuusoe@gmail.com
5.	Dr. Ohn Zin Linn	Associate Professor	Department of Electrical Power, Yangon Technological University, Ministry of Education	homzinlinsydu.edu.mm@gmail.com
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7.	U Soe Ko Ko Aung	Assistant Director	Department of Electric Power Planning, Ministry of Electricity and Energy	dazadda@gmail.com
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9.	Daw Aye Myat Theint Kyaw	Assistant Director	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	ayemyattheintkyaw.ecd@gmail.com
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11.	U Khin Maung Lwin	Assistant Engineer	Road Transport Administration Department, Ministry of Transport and Communications	khinlwin335067@gmail.com
12.	Dr. Moe Moe	Staff Officer	Department Head, Yangon City Development Committee	moemoemechanical@gmail.com

13.	Dr. Ei Ei Theint	Deputy Staff Officer	Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation	theint.eiei@gmail. com
14.	U Aung Nanda	Managing Director	Myanmar Sustainable Development Engineering Services Company Limited	nanda@m-sdes.com
15.	U Pyae Phyo Aung	Energy Officer	Climate Change and Training Coordinator, WWF	pyaephyo.aung@wwf.org. mm

Annex V: List of stakeholders involved in Inception Workshop Plus Stakeholders Consultation Workshop, 2 July 2019

For Industry Sector

No	Name	Designation	Organization	Contact
1.	Daw Tin Tin Nyo (Leader)	Deputy Director	Department of Nuclear, Department of Technology Promotion and Coordination. Ministry of Education	tintinnyo68@gmail.com
2.	Daw Htay Htay Kyi (Co-leader)	Assistant Director	Directorate of Industrial Collaboration, Ministry of Planning, Finance and Industry	htayhtaykyi58@gmail.com
3.	Daw Thin Thuzar Win	Deputy Director,	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	thithuzar1981@gmail.com
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7.	Daw Zin Mar Phyu	Staff Officer	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	zinmarphyu123@gmail.com
8.	Daw Yi Yi Cho	Staff Officer	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	yiyicho.env@gmail.com
9.	Daw Ei Ei Kyaw	Staff Officer	Thilawa Special Economic Zone	eieikyaw.chemical@gmail.com
10.	Daw Aye Aye Htet	Staff Officer	Union of Myanmar Federation of Chambers of Commerce and Industry	tvet.umfcci2014@gmail.com
11.	U Kyaw Kyaw Myo	Program Officer	Myanmar Environmental Rehabilitation – Conservation Network (MERN)	myokk94@gmail.com
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14.	U Myint Tun Kyaw	Deputy Director	Department of Industrial Collaboration, Ministry of Planning Finance and Industry	myinttunkyaw81@gmai l. com
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For Energy Sector

No	Name	Designation	Organization	Contact
1.	Dr. Nan Sandar Lwin (Leader)	Director	Department of Research and Innovation, Ministry of Education	sandar.lwin75@gmail. com
2.	Dr. Wunna Swe (Co-leader)	Professor and Head	Department of Electrical Power, Mandalay Technological University, Ministry of Education	myomyintbiot@gmail. com
3.	Daw Thida Sann	Deputy Director	Department of Hydropower Implementation, Ministry of Electricity and Energy	thidasann@gmail.com
4.	Daw Su Su Soe	Deputy Director	Oil and Gas Planning Department, Ministry of Electricity and Energy	suusuusoe@gmail.com
5.	Dr. Ohn Zin Linn	Associate Professor	Department of Electrical Power, Yangon Technology University, Ministry of Education	homzinlinsydu.edu.mm @gmail.com
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8.	U Kyaw Zin Latt	Assistant Director	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	kyawzinlatt@gmail. com

9.	U Pyae Phyo Aung	Energy Officer	Climate Change and Training Coordinator, WWF	pyaephyo.aung@wwf.org.mm
10.	U Tin Htut	Assistant Engineer	Yangon City Development Committee	1988278@gmail.com
11.	U Aung Myat Htun	Assistant Director	Department of Mines, Ministry of Natural Resources and Environmental Conservation	aungmyattun@gmail.com
12.	U Moe Aung	Staff Officer	Dry Zone Greening Department, Ministry of Natural Resources and Environmental Conservation	zmoeaung08@gmail.com
13.	Daw Swe Linn Myint	Assistant Director	Myanmar Petroleum Enterprise, Ministry of Electricity and Energy (SNC – Energy Team Leader)	shwelinmyint@gmail.com
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15.	Daw Thiri Wai Zaw	Deputy Staff Officer	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	thiriwaizaw@gmail.com
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18.	Daw Shwe Sin Win	Deputy Assistant Staff Officer	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	shwesinwin@gmail.com

The agenda of the workshop

Time	Agenda	Responsible Person
9:00-9:30	Registration	
9:30-9:50	Opening Speech	Director General (ECD)
9:50-10:10	Photo Session and Tea Break	
10:10-10:30	The background of the project	Project Coordinator
10:30-12:00	Step-by-step procedures of the project, project plan and discussion on TFS	Consultant
12:00-13:00	Lunch break	
13:00-15:00	Discussion on TFS and multi-criteria analysis	Consultant
15:00-15:15	Tea break	
15:15-17:00	Finalize the results of MCA	All
17:00-17:15	Closing Remark	ECD

Annex VI: Working Session of Mitigation Group on 30th Aug 2019 for reviewing pre-selected technologies from workshop

Energy Sector

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3.	Daw Kyaw Nyein Aye	Assistant Director	Department of Electric Power Planning, Ministry of Electricity and Energy	kyawnyeinaye@gmail.com
4.	Daw Swe Linn Myint	Assistant Director,	Myanmar Petroleum Enterprise, Ministry of Electricity and Energy (SNC – Energy Team Leader)	shwelinmyint@gmail.com
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6.	Daw Thin Thuzar Win	Deputy Director,	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	thithuzar1981@gmail.com
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8.	Daw Kyi Kyi Win	Deputy Staff Officer	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	kyikyiwin.ecd@gmail.com
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Industry Sector

No	Name	Designation	Organization	Contact
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4.	Daw Thin Thuzar Win	Deputy Director,	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	thithuzar1981@gmail.com
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Annex VII: Bilateral Meeting on 13th and 28th Sep 2019 to finalize the technology prioritization for pre-selected technologies from workshop and working session

Department of Rural Development

1. U Maung Win -Deputy director general
2. Dr. Soe Soe Ohn -Director
3. U Myo Myo- Deputy Director
4. U Zaw Nyut Oo -Assistant Director
5. U Han Tin -Staff officer

Oil and Gas Planning Department

1. Daw Khin Khin Aye- Director
2. Daw Su Su Soe- Deputy Director
3. Daw Win Win Kyu- Deputy director
4. Daw Su Mi San - Assistant Director

Myanma Petrochemical Enterprise

1. Daw Khin Cho Oo - Assistant Director (Production)
2. Daw Swe Lin Myint - Assistant Director (Planning)
3. Daw Kyu Kyu Myint - Head of Department (Production)

Myanma Oil and Gas Enterprise

1. U Zarni Oo – Senior Engineering

Myanma Petroleum Product Enterprise

1. U Aung Zaw Myint – Deputy Assistant Director

Road Transport and Administration Department

1. U Thein Han Oo – Chief Engineer
2. U Myo Khaing – Senior Engineer
3. U Lwin Ko Aung- Assistant Engineer
4. U Hein Razar Aung- Assistant Engineer

Energy Efficiency and Conservation Department, Ministry of Industry

1. U Myat Zaw-Director
2. U Myint Htun Kyaw- Deputy Director

Renewable Energy Research Department - Renewable Energy and Electronic Technology Research Center – Department of Research and Innovation

1. Dr. Hla Myo Aung - Director & Head of Renewable Energy Research Department
2. Dr. Nan Sandar Lwin - Director
3. Dr. Ye Min Htut - Deputy Director
4. U Saw Khu Say - Researcher